**African farmers, not Stone Age foragers: Reassessment of human remains from the Mumbwa Caves, Zambia**

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**Abstract**

In this article, we reassess the human remains from the Mumbwa Caves housed in the Raymond A. Dart Archaeological Human Remains Collection at the University of the Witwatersrand, South Africa. Based on new radiocarbon dates from human bone collagen and stable isotope analysis, our results revealed that the poorly preserved remains, comprising mostly crania and teeth, represent at least 16 individuals. Some of them have culturally-modified anterior teeth. Enamel hypoplastic lesions were seen in a few individuals, which indicates disease and malnutrition during childhood. Radiocarbon dating revealed that all the individuals were buried at Mumbwa sometime between the late tenth and early twentieth century CE, with most dates clustering between the early sixteenth and the late nineteenth century. With the exception of a single individual who seems to have had a hunter-gatherer/forager diet, the carbon and nitrogen isotope values of others are consistent with what would be expected from a low-trophic farmer diet based on foodplants with C4 photosynthetic pathways. It is, therefore, our contention that, rather than being associated with the Stone Age as previously suggested, these individuals lived in more recent agricultural communities around the Mumbwa Caves.

**Résumé**

Dans cette étude, nous réexaminons les restes humains des grottes de Mumbwa conservés dans la collection archéologique Raymond A. Dart à l'Université Witwatersrand, en Afrique du Sud. Nous présentons de nouvelles datations au radiocarbone à partir du collagène osseux humain ainsi que des mesures des isotopes stables du carbone et de l'azote. Nos résultats ont révélé que les restes humains, composés majoritairement de crânes et de dents, appartiennent à au moins 16 individus. Certains d'entre eux présentent des modifications des dents antérieures dues à des pratiques culturelles. Des lésions hypoplasiques de l'émail ont été observées sur quelques individus, ce qui indique l'occurrence de maladies et/ou de malnutrition pendant l'enfance. La datation au radiocarbone a également révélé que tous les individus ont été enterrés à Mumbwa entre la fin des années 900 AD et le début du 20e siècle, la plupart des dates se regroupant du début du 16e siècle à la fin du 19e siècle. À l'exception d'un seul individu qui semble avoir eu un régime alimentaire de chasseur-cueilleur, les valeurs isotopiques du carbone et de l'azote sont toutes cohérentes avec ce que l'on pourrait attendre d'un régime alimentaire basé sur la consommation de plantes cultivées caractérisées par des mécanismes de photosynthèse en C4. Nous soutenons donc que, plutôt que d'être associés à l'âge de pierre comme suggéré précédemment, ces individus vivaient probablement dans des communautés d'agriculteurs autour des grottes de Mumbwa au moment de leur disparition.

## Introduction

The Mumbwa Caves site, located in the central Zambezian *miombo* woodlands of Zambia (Fig. 1), is a rare archaeological site in south-central Africa because it preserves human skeletal remains in stratified dated deposits from the late Middle Pleistocene (>172ka) to the present (Barham, 2000). Five investigations were undertaken between 1925 and 1996, of which two expeditions recovered skeletal materials. The largest collection was made by the Italian Scientific Expedition in 1930 (Dart & Del Grande, 1931), of which some of the human remains are curated in the Raymond A. Dart Archaeological Human Remains Collection at the School of Anatomical Sciences of the University of the Witwatersrand, South Africa (henceforth the Dart Collection). We focus on these remains in this study. Dart and Del Grande (1931, p. 388-390, 425-426) found the fragmentary remains of 16 individuals, some from deliberate burials, in deposits they attributed to a general 'Late Stone Age' stratum, which is now recognized to have encompassed a succession of Middle Stone Age, Later Stone Age, and Iron Age contexts (Barham, 2000). Later excavations between 1993 and 1996 produced a small sample of isolated teeth and post-cranial fragments (Pearson et al., 2000).

The primary legacy of the Dart and Del Grande investigation at Mumbwa was the culture-stratigraphic sequence they established for the region based on the exposure of an eight-meter deposit in the main cave. They recognized seven strata from the base to the top using a mix of archaeological and geomorphological criteria: Ancient Palaeolithic, Sterile Clay, Mousterian, Furnace Stratum, Solidified Ash, Pure Stone Culture, and Iron Arrow Heads (Dart & Del Grande, 1931, figs. 4-6). All the materials found above the Mousterian stratum belong to the three-meter thick 'Late Stone Age' unit, which included all the human remains. The remains were found in five sequential layers (also called strata, Table 1), presumably spanning a depth range of 40-200 mm below the main entrance surface based on the authors' stratigraphic drawings (Dart & Del Grande 1931, p. 425-426, figs. 4-6). Bone preservation varied according to depth, with the best-preserved materials coming from strata III-V within and just below the Furnace Stratum. Three stone-built features or 'tombs' were recorded. Two of these (Tomb A, Tomb B) were in stratum III, containing cranial materials, and the third tomb (Tomb C) was in stratum V and consisted of fragments of a humerus. The remains in tombs A and B were too fragmentary, and the body orientation cannot be reconstructed with certainty but was assumed to have been buried in a fetal sitting position based on the orientation of the calvaria (Dart & Del Grande, 1931, p. 390). A nearly complete skull and the remains of two other individuals were recovered from stratum 4.

Dart and Del Grande (1931, p. 426) concluded that of the 15 identifiable individuals, "it is apparent that 10 represent frankly Bushmen and the other 5 portray admixture with ancient and primitive types." Jones (1941, p. 318) also identified the Tomb A and Tomb B remains as "Bushmen." Clark (1942, p. 179) considered the burials to be intrusive from Later Stone Age (Wilton) levels higher in the sequence based on his excavations at the entrance to the main cave in 1938. He observed that the burials intruded into Middle Stone Age deposits, and their depth and use of stone resembled burial practices recorded among foragers in the Namib Desert. A Stone Age origin of the burials appeared to be confirmed by Protsch (1977), who reported a radiocarbon date of 22181-21396 cal BC, 95% probability (UCLA-1750C, 19780±130 BP) on bone collagen from several bone fragments including a fibula attributed to Tomb C (A345). Based on this unexpectedly early date, Clark (1989, p. 577) speculated that the Mumbwa tombs were rare examples of Middle Stone Age burials.

A later attempt by Reiner R. R. Protsch at dating bone fragments from the same Tomb C collection indicated insufficient carbon for dating (Barham, 2000, p. 148). A discrepancy was also noted between Protsch's dated sample, which included a fibula, and Dart and Del Grande's description of the Tomb C contents as containing only fragments of a humerus. This discrepancy undermined confidence in the stratigraphic attribution by Protsch, and it has since been shown that the ages suggested by Protsch are untrustworthy (Breyer & Kausch, 2004; Line, 2005; Schwanebeck, 2014). A sample of bone from one of the upper tombs gave a result ranging from 905 to 1150 cal CE, 95% probability (OxA-8879, 1060±35 BP, $\delta^{13}C$=-8.3). Thus, the upper tombs appear to belong to the Late Holocene. The age of the remains in the lower tomb is unknown, but they are unlikely to be coeval with the surrounding sediments, which have been dated by luminescence to the Last Interglacial age ([MIS 5e] Barham 2000). Inconsistencies in labeling (Gabel, 1963) and the subsequent loss of skeletal material (Rightmire, 1984) add to contextual uncertainties, as does the anomalous preservation of shell-nacre in tombs A and B (Dart & Del Grande, 1931, p. 426). In the recent excavations, shells were not found beyond 70 cm depth, whereas the tombs are estimated to have been at a depth of 220 cm below the datum (Barham, 2000, p. 147). This difference supports Clark's (1942) original interpretation of the burials as intrusive features.

The excavations in 1993-1996 focused on the earlier deposits identified by Dart and Del Grande and the entrance area sampled by Clark. Decades of section collapse had obscured the outlines of the Dart and Del Grande's central pit, including the locality of the tombs. The only surviving feature was a furnace hearth (Furnace Stratum) at a depth of 177 cm below the datum, which forms part of what is now recognized as the Last Interglacial deposit (Barham, 1996; 2000). Fourteen units or stratigraphic horizons were described with a chronology based on optically stimulated luminescence (OSL), electron spin resonance dating (ESR) of tooth enamel (faunal), and AMS radiocarbon dating. The results are a discontinuous record of five phases of human use of the main cave, from bottom to top: >170 ka; 130-105 ka; 40 ka; 15/12-6 ka; and 2 ka to the present. These stratigraphic units cannot be linked directly to Dart and Del Grande's sequence. However, based on the estimated depth of the tombs, they would have been dug into Middle Stone Age deposits dating to 130-105 ka.

In this paper, we report on a systematic re-analysis of the skeletal remains from the Mumbwa Caves in the Dart Collection. The materials curated in Zambia (Livingstone Museum) from the 1993-1996 excavations have been reported by Pearson et al. (2000) and are not included here. We provide a detailed analysis of the skeletal remains and their context (inferred as far as possible from the archaeological records) and report the new radiocarbon dates and stable isotopes of carbon and nitrogen for several remains.

**Materials and Methods**

Eleven catalog numbers/entries from Mumbwa Caves are curated in the Dart Collection (Table 1). The entries are listed by strata, and we assume that remains from Tombs A and B are those from stratum III since no other human remains were recorded from this context (Dart & Del Grande, 1931). The fragments from stratum V (A345) cannot be attributed to Tomb C based on the contents described by Dart and Del Grande (1931, p. 426). Many bones show extensive mineralization, and as suchwere at some point stored at the Evolutionary Studies Institute, University of the Witwatersrand, as part of their hominin collection. These remains were, however, returned to the Dart Collection in 2017. We used standard biological anthropological methods to assess the remains (e.g., Buikstra & Ubelaker, 1994; İşcan & Steyn, 2013). The remains are poorly preserved with some commingling, so the analysis involved sorting and identifying individuals based on their teeth(De Villiers, 1968), Many individuals were represented by teeth only .

The ages at death were mostly estimated based on dentition. In the case of juveniles, the dental development chart of AlQahtani, et al. (2010) was used, while for adults, a very general assessment was made based on the degree of dental wear. Cranial sutures, where available, were assessed only as open or closed, whereas all skeletons were screened for signs of degenerative changes. None of the individuals had pubic symphyses or sternal ends of ribs available for analysis. These are usually the more reliable skeletal parts to use for age assessment. Sex, when possible, was assessed using features of the skull (Buikstra & Ubelaker, 1994; Iscan & Steyn, 2013) and measurements of long bones (Steyn, 2013). None of the individuals had intact pelvii, and no attempt was made to assess the sex of juveniles.

We analyzed all the teeth for signs of decay (caries) and dental modification and noted enamel hypoplastic lesions. Where present, postcranial elements were measured using the guidelines of Buikstra and Ubelaker (1994). Cranial remains were measured according to Howells (1973), and only measurements that could be done with standard sliding and spreading calipers were included. Using a stepwise Forward Wilk analysis, these measurements were then assessed against the Howells measurements in FORDISC, which included Teita, Dogon, and Khoe-San groups (Ousley & Jantz, 2020). Here the Teita represent East African Bantu speakers and Dogon represent West Africans. The databases of African samples in FORDISC are limited, and these results should be interpreted cautiously.

The materials for radiocarbon (14C) measurements and ancient DNA analyses (future publication) were collected simultaneously at the University of the Witwatersrand using a portable hand-held drill and cleaned circular diamond blades. For each individual, a minimum of 100 mg of bone was collected. The bones were cleaned before the samples were collected. The first step consisted of scraping the surface of the bone with a hand-held Dremel. The bone surface was then gently wiped with bleach diluted 1/5, then rinsed with ultra-pure milli-Q water. Last, the bones were submitted to UV treatment for 20 min. The cleaned bones were stored in clean plastic bags until sampling. Bone samples were transported to Uppsala University (Sweden) to be processed. Carbon dating and isotope analysis were performed at the Tandem Laboratory, Department of Physics and Astronomy, Uppsala University, Sweden (Ua-number).

Then All 14C measurements presented in this study are calibrated with OxCal 4.4 (Bronk Ramsey, 2009) using the atmospheric curve SHCal20 (Hogg et al., 2020). Calendar ages are reported as “cal CE” (calibrated, Common Era). All calibrated ranges are given at 95.4% probability. Because of the recent date range of the measurements, we used 1930 in the chronological model as the terminus ante quem (i.e., the latest possible date) corresponding to the year of excavation of the bone remains in this study.

Stable isotopes of carbon (13C) and nitrogen (15N) were measured independently by isotope-ratio mass spectrometry (IRMS) at the Tandem Laboratory, Uppsala University. To discuss the possible dietary implications of the isotope data, we compare the stable isotope values of carbon and nitrogen obtained from the Mumbwa individuals to those of several other African groups, including farmers, foragers, and pastoralists from different bioregional contexts, for whom such data are available (Ambrose & DiNero, 1986; Lee-Thorp et al., 1993; Ribot et al., 2010; Lewis & Sealy, 2018; Meyer et al., 2022). We also plot the Mumbwa individuals’ stable isotope values of carbon and nitrogen against the general ranges for bona fide marine and terrestrial C3-plant and C4-plant diets (following Mays, 1998) and a few other control groups.

**Results**

The analysis shows that several Dart accession numbers included more than one individual, often in a commingled state. A summary of the remains from the Mumbwa Caves housed in the Dart Collection is shown in Table 1, with new radiocarbon dates and isotope results where available. Numbers starting with ‘A’ in the first column refer to the accession numbers of the University of the Witwatersrand. We also include the stratum/layer to which each individual presumably belongs (Table 1). As mentioned, the remains are poorly preserved and often comprise teeth only. Some of these have been sorted into individuals by previous researchers. However, some remains are not associated with any specific individual, and the teeth present per individual may not always be assigned correctly. Some very worn and unworn teeth, for example, were sometimes included as one individual, which seems unlikely. In such cases, we made a judgment call about the majority of teeth present, and other (possibly unrelated) teeth were excluded. Different individuals accessioned under one Wits accession number are now labeled as Individuals A, B, C, etc. WUD refers to the sample number.

A337

Three individuals were accessioned under A337. They are now labeled as A, B, and C (Table 1) and originated from Stratum I. Individual A comprised five permanent and one deciduous tooth only. The permanent teeth included four premolars and a molar, and the apices of two of the premolars were open. The deciduous tooth was a lower second molar. Thus, the individual was a juvenile of 10.5-12.5 years old at death (AlQahtani et al., 2010). The presence of a deciduous molar along with premolars with closed roots seemed incongruous, and the possibility of commingling should be considered.

The remains accessioned under Individual B comprised only six worn teeth of an adult. The teeth included an upper premolar, the two lower central incisors, one lower premolar, one lower molar, and a peg-shaped tooth modified by filing both lateral edges (Fig. 2). This tooth was most probably an upper, lateral incisor as they are known to be the teeth most commonly reduced to a peg shape (Turner, 1911).

Individual C was an adult comprising a few small cranial fragments, a radius shaft, a distal phalanx, and 11 worn teeth (Fig. 3A). The teeth included seven upper (central incisor, lateral incisor, one canine, one premolar, and three molars) and four lower (one premolar and three molars) teeth. The crown of the right upper central incisor was filed on the mesial and distal surfaces so that it was rounded (Fig. 3B & C). One of the upper molars had a large carious lesion (interproximal), and the canine had at least three enamel hypoplastic lines (Fig. 3D). Individual C was dated to 1664-1884 cal CE (Ua-61970) and presented stable isotope values of -9.8 ‰ for $\delta^{13}C$ and 7.5 ‰ for $\delta^{15}N$.

A338

There were also three individuals from Stratum I accessioned under this number, with two partial long bones (femur and radius), a cranial fragment, and a tooth not associated with either individuals A, B, or C (Table 1). Individual A included small cranial fragments and a partial mandible of an adult individual. The partial left mandible showed signs of rodent gnawing and included a second and third molar. These teeth were worn to a degree where the cusps were flattened and did not show signs of caries or enamel hypoplasia.

The remains of individual B comprised a partial, weathered, reconstructed skull without a mandible. The teeth (maxillary right second molar, left central incisor, left premolars, and the first and second left molars) were worn to a degree where the cusps were flattened (but without dentine patches). No antemortem losses or signs of dental disease were observed. A midline diastema was evident. The sagittal suture of the skull was completely obliterated, suggesting a middle-aged or older adult. This skull was robust, with a sloped forehead, large glabella, and rounded orbital margins (Fig.

4). The individual was flat-faced with some subnasal prognathism and a large nasal aperture. Measurements that were possible are shown in Table 2. The FORDISC results were generally uninformative and showed the closest association with the Teita but with very low typicalities (all below 0.01). Dental and petrous bone samples of this individual yielded a date of 1668-1895 cal CE (Ua-61834), and the stable isotope values were -16.6‰ for $\delta^{13}C$ and 12.6‰ for $\delta^{15}N$.

A339

A339 was a single adult attributed to Stratum III. It consisted of cranial fragments, a partial left mandible (with both premolars and all molars), one proximal phalanx of a toe, and ten loose teeth. The relatively unworn teeth suggested a young adult. A loose upper first premolar showed signs of enamel hypoplasia. The differential wear on some loose teeth may suggest commingling from another grave. Also included with this accession were some faunal remains representing a right distal humerus possibly associated with a Galagidae (bush baby), possibly *Otolemur crassicaudatus* (Fig. 5A), some Achatina shell fragments (Fig. 5B), a possible freshwater mussel shell fragment (Fig. 5C, e.g., *Cafferia caffra*), along with a stone tool. The relationship between the fauna and human remains is not known. One of the loose human molars was dated to 1673-1913 cal CE (Ua-61835) with stable isotope measurements of -7.4‰ 8.0‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively.

A340

A340 represented a single middle- or old-aged adult of indeterminate sex ascribed to Stratum III. It comprised a neurocranium (skull cap), a mandible fragment, a humeral fragment, and six teeth. The cranial sutures were partly obliterated. The teeth were worn, and some were fragmentary, making them difficult to identify. The left upper lateral incisor showed evidence of modification by the filing of both the mesial and distal sides (Fig. 6). Unfortunately, this was the only anterior tooth available, as the others were all premolars and molars, and the full modification pattern could therefore not be established. The first left mandibular molar was dated to 1675-1916 cal CE (Ua-61973) with stable isotope values of -8.1‰ for $\delta^{13}C$ and 9.2‰ for $\delta^{15}N$.

A341

The remains of this individual from Stratum III were also very incomplete. They comprised a fragmentary central portion of a mandible, five teeth, shafts of both humeri, and vertebral fragments only. The heavily worn teeth indicated an adult individual. The humeral measurements of this individual (midshaft circumference 66 mm, minimum midshaft diameter 19 mm, maximum midshaft diameter 22 mm) suggested a male (Steyn & İşcan, 1999). Extensive rodent gnawing was evident on both humeri. The teeth included an upper and lower first molar, a maxillary second premolar, a mandibular central incisor, and a mandibular canine. Other than for the extensive wear, no pathology or modifications were noted. The premolar yielded a date of 994-1155 cal CE (Ua-61971), and the stable isotope values were -10.3‰ for $\delta^{13}C$ and 9.0‰ for $\delta^{15}N$.

A342

The remains from Stratum IV included a partial calvarium only. The visible sutures were completely obliterated, suggesting an older adult individual. The nuchal area seemed fairly robust, possibly suggesting a male individual. The individual was not dated as it was incomplete.

A343

At least two individuals from Stratum IV were accessioned under A343. Individual A comprised a heavily mineralized femur shaft, fibular shaft, some other long bone fragments, and a lower canine possibly associated with a class 4 Bovidae (Fig. 7; possibly *Bos taurus*). The number A346 is written on this tooth, so it is unclear exactly which skeleton it was found with. The human bones showed signs of rodent gnawing. Based on the size of the remains, this individual was an adult. The only bones of Individual B were the shaft of a fibula and two other fragments. In addition to the two individuals marked as A and B, a reconstructed, varnished skull with an incomplete mandible was present. Another right-sided petrous bone of a different individual was also present. It could not be established whether these skulls were associated with Individuals A or B or with none of them. The petrous bone was dated to 1025-1178 cal CE (Ua-61837), with stable isotope measurements of -12.0‰ and 9.4‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively.

The more complete, heavily reconstructed skull included bones from the frontal, parietal, occipital, and temporal regions, as well as fragments from the maxilla with the right second premolar and first and second molars (Fig. 8). The mandible was near complete except for the right ramus and included the left second molar, as well as the right second premolar, and first and second molars. The teeth of this individual were all permanent and were worn to a degree where only enamel rims remained for many of the teeth. This suggested a middle-aged or older individual. The skull was gracile, with a smooth, vertical forehead, sharp supra-orbital margins, and a smooth occipital area. The mandible was also gracile with a pointed chin. These characteristics suggested a female individual. No signs of trauma or disease could be observed. Some infection was noted around the root of the right lower first molar. There were no antemortem tooth losses and no evidence of caries or enamel hypoplasia. However, it should be kept in mind that the teeth were varnished along with the skull, making assessment difficult.

A344

A344, associated with Stratum IV, comprised a single adult's reconstructed skull (calvarium). No facial bones were present except a fragment of the maxilla with three left-sided molars. A loose left-sided molar of another individual was also present but was more heavily worn and did not belong to this individual.  The three permanent maxillary molars were unworn, suggesting that this was a young adult. The mastoids were large, and there was a prominent glabella, rounded supra-orbital margins, and prominent inion, suggesting a male individual. Some cranial measurements were possible and are shown in Table 2. The individual had very unusual forward-projecting nasal bones (Fig. 9), but it should be kept in mind that the remains were reconstructed, and this may possibly have been an artifact of reconstruction. The FORDISC analysis of this individual also showed the closest alignment with Teita (representing East African Bantu-speakers), but with relatively low typicalities (Typ F 0.030; Typ Chi 0.012). No signs of disease or trauma were evident. There was no cribra orbitalia, and the three molars did not show signs of dental disease. The remains were dated (using the first, upper left molar) to 1506-1880 cal CE (Ua-61974), with stable isotope values of -16.1‰ for $\delta^{13}C$ and 7.8‰ for $\delta^{15}N$.

A345

It was reported that this individual's remains originated from stratum V. The remains comprised an adult's cranial fragments and the shaft fragment of a long bone. No other information could be obtained from this skeleton, and no suitable material was available for dating.

A346

A note with these remains indicated it as "Additional human material, recovered from the sieves, near the ash stratum"; "Superficial furnace ash stratum." The only elements available for this individual are 17 permanent teeth, cranial fragments, and part of a distal right humerus. There is also an animal vertebra. The teeth showed different degrees of wear, and the presence of  seven upper molars suggested some commingling. One of the lower premolars showed signs of enamel hypoplasia. The distal humerus could not be measured. The remains, therefore, represented at least one, and possibly two adult individuals. An upper first molar was dated to 1505-1668 cal CE (Ua-61972), and the stable isotope values were -5.6‰ for $\delta^{13}C$ and 9.0‰ for $\delta^{15}N$.

A347

Remains accessioned under this number represented at least two individuals and are commingled. They are not associated with any of the strata. Instead, a hand-written note in the box read, "Kawena, 80 foot fissure in … (unreadable) ground in Mumbwa valley. People were thrown into this fissure as capital penalty according to local tradition." The first skull (Individual A) comprised part of the frontal bone, both parietals, part of the occipital, and part of the right temporal bone. The observable mastoid process was relatively small, possibly suggesting a female individual. The open cranial sutures suggested a young or middle-aged adult individual. The skull of individual B was represented by only a partial, left temporal bone. A large mastoid process was evident, tentatively suggesting an adult individual.

In addition to the abovementioned two partial skulls, fragments of two scapulae, two humeri, and other unidentifiable smaller fragments were present. The measurements of one of the humeri (minimum midshaft diameter 16 mm; maximum midshaft diameter 23 mm; and deltoid circumference 66 mm) very tentatively suggest a male individual (Steyn & İşcan, 1999). This implies that these bones were associated with individual B, although this could not be confirmed. Individual B was dated to 1451-1629 cal CE (Ua-61829), and the stable isotope values were -10.1‰ for $\delta^{13}C$ and 9.2‰ for $\delta^{15}N$.

**Implications of the New Radiocarbon Dates for the Mumbwa Caves Site**

At least seven or eight of the individuals from the Mumbwa Caves currently curated in the Dart Collection were once thought to date to Later Stone Age contexts (A339, A340, A341, A342, A343, A344), and perhaps from a late Middle Stone Age tomb (Stratum V). The contexts and dating of these remains have been challenged (Barham, 2000; Clark, 1942). It has since been established that Reiner R. R. Protsch falsified dates of the human remains, and the full extent of his swindle remains unknown (e.g., Line 2005). Our $^{14}C$ measurements on human bone (Table 1, Fig. 9) range between 994-1155 cal CE and 1675-1916 cal CE, further demonstrating that none of the human remains from Mumbwa housed in South Africa can be confidently assigned to Stone Age foraging communities of great antiquity. Thus, unless other direct dates on human remains from Mumbwa confirm their Stone Age context, we suggest that it is most parsimonious to consider the human remains as dating to within the last millennium (Fig. 10).

The archaeological record of this region of southcentral Africa indicates that farming communities arrived ~50 CE, followed by a complex history of interaction with local forager communities (Philipson, 1976; Robertson, 2000). On the central plateau, which includes Mumbwa, foragers co-existed with farming communities until the early 19th century AD (Musonda, 1987). A similar pattern of recent coexistence is evident in northern Zambia (Miller, 1969; Musonda, 1987). In the immediate area of Mumbwa, local tradition places the Ila-Tonga as the first agropastoralists to settle, followed in the 19th century by the Kaonde. Both communities retain an oral tradition of hunter-gatherers living in and around the caves (Barham, 2000). The cave remains a place of offerings to ancestral spirits and to commemorate the unification of Kaonde-Ila, but no tradition of burial in the cave is recorded. The dated Iron Age site nearest to Mumbwa is Sebanzi Hill, located 160 km to the south and with a single charcoal date of ~1525 cal CE (98.9% probability) (750 ± 135 BP, GX 109) (Fagan & Phillipson, 1965). This date falls within the range of the radiocarbon measurements for the Mumbwa human remains. The regional record of the coexistence of foragers and farmers in the last millennium raises the possibility that the Mumbwa Caves remains may represent both communities. Genetic studies on BaTwa forager and fishing communities from the Kafue flats 65 km to the south, show a greater contribution from ancestral foraging groups, related to current-day San groups from Namibia, compared to their Bantu-speaking neighbors (Breton et al., in prep.).

**Dietary Assessment from Stable Isotopes of Carbon and Nitrogen**

Most dietary studies focus on the stable isotope ratios of carbon (13C to 12C, expressed as $\delta^{13}C$) and nitrogen (15N to 14N, expressed as $\delta^{15}N$). The $\delta^{13}C$ values are especially useful in that they indicate carbon sources of the primary producers capturing energy from the sun by using different photosynthetic processes. Terrestrial plants that make use of $C_3$ and $C_4$ photosynthetic processes have very different $\delta^{13}C$ signatures, while marine sources also have unique ranges. $\delta^{13}C$ signatures persist through the trophic levels. The value of $\delta^{15}N$ lies in that this ratio is an effective tagging mechanism for the trophic level. Through each subsequent trophic level, 14N is lost through waste products and 15N increases. Although factors such as metabolism and environment may influence stable isotopic signatures, the correlation between certain stable isotope signatures and diet has been well established (Correia et al., 2019).

The $\delta^{13}C$ values in bone collagen may reflect the contribution of different dietary macronutrients, such as proteins, carbohydrates, and lipids, to individual diets, whereas $\delta^{15}N$ values only reflect the sources of dietary proteins and the position of the consumer in the food chain (e.g., Ambrose and Norr, 1993; Jim et al., 2006; O'Connell et al., 2012; Webb et al., 2017). To assess such dietary aspects in the Mumbwa population, compared to those of other African groups, we collated stable isotope carbon and nitrogen data from farmers, foragers, and pastoralists from different bioregional contexts in eastern and southern Africa (Table 3).

The human bone collagen samples (n=9) from the Mumbwa Caves displayed stable isotope values ranging between -16.6‰ and -5.6‰ (mean±SD: -10.6±3.7%) for carbon and 7.5‰ and 12.6‰ (mean±SD: 9.1±1.5‰) for nitrogen, with chronological and intra-individual variations. In terms of $\delta^{13}C$ values (Table 3), the Mumbwa individuals as a group were most similar to the sub-escarpment, Karoo, dry savanna, and montane grassland farming communities (Fig. 10). The Drakensberg Grassland farmers lived there at about 622-1646 cal CE and based on the interpretation of their carbon and nitrogen isotopes, they are thought to have subsisted predominantly on a diet of $C_4$ plants (e.g., millets and sorghum), with limited access to dairy products or meat (Meyer et al., 2022). A similar profile has been described for the farmers from the sub-escarpment Savanna of KwaZulu-Natal. For example, Ribot et al. (2010) suggested a mostly $C_4$ diet but pointed out that it is difficult to infer the importance of $C_4$ crops from bone collagen alone because animal products such as milk and meat from domesticated animals that ate $C_4$ grasses may contribute to the signature.

Also, the $\delta^{15}N$ values for the Mumbwa individuals from the Dart Collection grouped them most closely with farming communities such as those from the montane grassland, savanna woodland, and early Iron Age in Botswana (Table 3, Fig. 10). The group from the Botswanan Kalahari/savanna biotope (dating to ~1200-1300 AD) has been interpreted as having a variable diet of which most individuals show a $C_4$ portion accounting for between 80% and 100% of their total dietary protein, and some display a relatively low trophic level diet (Mosothwane, 2010). Mosothwane (2010) found that the mean $\delta^{15}N$ value is similar to those reported for relatively wet climatic conditions and that although these communities were known to have sizeable herds of cattle and small stock, they had a mostly plant-based diet. This reflects that cattle were not seen as meat resource. Rather, they were more valued in terms of the status (wealth and power) they bestow on their owners and served as bridal-price currency, as still practiced in southern Africa (Mosothwane, 2010). These dietary outcomes are consistent with the interpretation of Lee-Thorp et al. (1993) for the savanna woodland farmer group from South Africa that also has a $\delta^{15}N$ median value, close to that of the Mumbwa individuals from the Dart Collection.

Collectively, the diet of the people who were buried at Mumbwa over the last millennium was similar to those of recent farmers who depended largely on $C_4$ crops and/or plant foods with relatively limited dairy and meat supplements (Fig. 11). It is therefore reasonable to suggest that most of them followed a farmer existence, despite variability in the values of their carbon and nitrogen stable isotopes (Table 3).

The bone collagen stable isotopes of carbon and nitrogen for each individual from the Mumbwa Caves provided a more detailed understanding of the population who lived around the caves in terms of dietary variation. In Figure 12 we plotted the values of the respective individuals from the Mumbwa Caves against the hypothetical ranges for a pure $C_3$ terrestrial diet, a pure $C_4$ terrestrial diet, and a pure marine diet (e.g., Mays, 1998). As archaeological reference points, we plotted them against ranges obtained for inland hunter-gatherers/foragers from South Africa, Savanna farmers from South Africa, and Savanna Pastoral Neolithic herders from Kenya (data collated from Table 3). We also used the European *Homo sapiens* sample dating to 40-25 ka as a control for *bona fide* hunter-gatherer/forager populations from relatively wetter regions (Richards & Trinkhaus, 2009), and a hunter-fisher-gatherer profile from Lake Baikal, Siberia (Katzenberg & Weber, 1999), as a control for a fresh-water diet (Fig. 10).

From the plot analysis (Fig. 12), it became clear that eight of the nine individuals may have had almost purely plant-based diets, falling outside expected ranges for relatively high meat, milk, and/or fish intake. While one of them (individual A344) may have included relatively high volumes of $C_3$ foodplants, most (n=7) subsisted on foodplants with only or mostly $C_4$ photosynthetic pathways (e.g., individuals in the orange/right circle of Fig. 12). All these individuals also had lower trophic levels compared to the savanna farmers from South Africa, who seemed to have followed a relatively balanced meat/milk *vs.* plant food diet. Only one individual (A338B) buried at Mumbwa seemed to have followed a *bona fide* hunter-gatherer/forager diet, relying mostly on meat and plant food with $C_3$ photosynthetic pathways. This individual lived in the area sometime between 1668-1895 cal CE and based on the diet, may be a hunter-gatherer descendant from Later Stone Age populations who lived in and around the caves.

## Discussion and Conclusion

The human remains from the Mumbwa Caves housed in the Dart Collection represent at least 16 individuals, including males, females, and older children. The bones are fragmentary and commingled, restricting their analytical value and making assessment difficult. For example, the incomplete nature of the remains limits our ability to comment on aspects such as health status and diet. We observed no signs of trauma or specific diseases. A few teeth showed enamel hypoplastic lesions that may suggest hardships such as acute infectious disease or malnutrition during childhood (Goodman & Rose, 1990). However, these remain hard to interpret due to the small sample size and incomplete nature of the remains. The teeth generally had very few carious lesions or abscesses, suggesting a diet that was probably not high in refined carbohydrates. Overall, the results of the FORDISC were uninformative. In the two cases where results were possible, the closest alignment was with the Teita, representing East Africans. However, the typicalities were low, suggesting that these individuals are not closely related to any of the groups currently available in the FORDISC database.

The dental modification of several adult individuals excavated from the main Mumbwa site is of sociocultural interest. Although it is difficult to deduce the pattern because many teeth were isolated and commingled, it seems that only the upper incisors were modified to form a V-shape. The dental modification was a common practice among many cultures (Van Reenen, 1964, 1986; Handler, 1994). However, this type of modification is most commonly found in African Iron Age populations. For instance, in their study of skeletal remains from the Zambian sites of Isamu Pati and Ingombe Ilede, Gibbon and Grimoud (2014) found that 29% of the adults in their sample (7/24) had dental modifications. They described three modification styles, including the V-shape of upper incisors – as observed in this study. The V-shaped modification of the central and lateral maxillary incisors was noted in one adult female from the Isamu Pati mound sample, associated with the Kalomo Culture (eleventh through the fourteenth century; Gibbon & Grimoud, 2014) and a young adult male individual recovered from Twickenham Road, Zambia, possibly post-dating the Kalomo Culture (Phillipson, 1970). Dental modifications of the Iron Age peoples from Zambia are thus well described in the literature, and this should have been an indication of the recent age of the individuals from Mumbwa Caves.

The excavation methods used in the 1920s, and the subsequent collapse of the deposits, obscured the relationship between the burials and the stratigraphic sequence of the Mumbwa Caves site. Subsequent excavations and the radiometric dating of the deposits highlighted this discrepancy so we cannot assume that the burials are coeval with the deposits in which they were found. This interpretation is reinforced by the direct dating of some of the human remains in this study ranging between the late 900s CE and the early twentieth century (Fig. 9). These dates are considerably more recent than previously thought, indicating that the burials represent activities that took place in the cave long after the deposition of the major Stone Age archaeological strata. Most dates cluster between the early sixteenth century and the late 1800s, suggesting these caves were more frequently used for human burials during this time. This points to a long and continuous use of the caves, with the burials intrusive into much earlier deposits.

The bone collagen stable isotope values of carbon and nitrogen for most individuals from the Mumbwa Caves suggest a diet rich in $C_4$ plants with little animal-derived proteins. At Isamu Pati and Ingombe Ilede, isotopic values suggested a similar diet based mainly on cultivated crops (Murphy, 1996, as cited in Gibbon et al., 2014). This seems to correspond to the recently identified macro-botanical signature of the Kalundu Mound site, also associated with the Kalomo Culture, which suggested the cultivation of $C_4$ crops such as finger millet, sorghum, and possibly pearl millet (Goldstein et al., 2021). However, Gibbon et al. (2014) noted that these archaeological communities typically had a mixed economy, including domesticated crop farming, herding, and some foraging. Goldstein et al. (2021) confirmed the continued reliance on hunting as a subsistence strategy for the Kalomo Cultures, with relatively high frequencies of non-domesticated faunal remains found in the assemblages at the Kalundu and Isamu Pati sites. This practice may account for the slightly higher $\delta^{15}N$ values in the Mumbwa individuals compared to the Drakensberg farmers (Meyer et al., 2022).

Despite the limitations of the early excavations and poor preservation of the remains, the Mumbwa Caves material highlights the importance of the direct dating of human remains rather than inferring an age from associated deposits. The Mumbwa material also highlights how much information can be extracted from older museum collections. The dating and dietary analyses of the Dart Collection remains contribute to an understanding of the region's later prehistory and early history derived from multiple sources. The oral history of the recent coexistence of foragers and farmers at Mumbwa now has additional support from the dietary evidence.

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TABLES

**Table 1** Summary of the individuals analyzed in this study and the new $^{14}C$ and stable isotope ($^{13}C$, $^{15}N$) measurements on bone collagen

**Table 2** Cranial measurements (Howells, 1970). All measurements in mm

**Table 3** Comparative isotope data for several groups of farmers, foragers, and one group of pastoralists from sub-Saharan African contexts

FIGURES

**Fig. 1** Map showing the location of Mumbwa as well as other well-known archaeological sites in the region

**Fig. 2** Labial (A) and lingual (B) views of the culturally modified upper lateral incisor associated with A377 individual B (note the mesiodistal filing of the crown)

**Fig. 3** Individual A337C's dentition. A: Occlusal wear on the upper second molar; B & C: Labial (B) and lingual (C) surfaces of the culturally modified right upper central incisor (note the mesio-distal filing of the crown); D: Linear enamel hypoplasia (indicated by the red arrows) observable on the lower canine

**Fig. 4** Anterior (A) and left lateral (B) views of the cranium of A338 individual B

**Fig. 5** Faunal remains associated with A339. A: Right distal humerus possibly associated with a Galagidae (possibly *Otolemur crassicaudatus*); B: Achatina shell fragments; C: Freshwater mussel shell fragment (possibly *Cafferia caffra*)

**Fig. 6** Labial (A) and lingual (B) surfaces of the culturally-modified left upper lateral incisor associated with A340 (note the mesio-distal filing of the crown)

**Fig. 7** Bovidae lower incisor in labial and lingual views (possibly associated with *Bos taurus*)

**Fig. 8** Anterior (A) and left lateral (B) view of the skull of A343

**Fig. 9** Anterior (A) and left lateral (B) view of the skull of A344

**Fig. 10** Radiocarbon measurements obtained in the scope of this study from human remains excavated in 1930 in the Mumbwa Caves. Calibrated by OxCal 4.4 (Bronk Ramsey, 2009) using ShCal20 (Hogg et al., 2020)

**Fig. 11** Comparative analysis of the $\delta^{13}C$ and $\delta^{15}N$ values obtained for the Mumbwa individuals from the Dart Collection, and other groups from sub-Saharan Africa (also see Table 3)

**Fig. 12** Isotope dietary plots of the Mumbwa individuals (orange dots with accession numbers) from the Dart Collection, compared to several control groups (colored and outlined blocks).

**Table 1** Summary of the individuals analysed in this study and the new $^{14}C$ and stable isotope ($^{13}C$, $^{15}N$) measurements on bone collagen

| Wits number | Origin | Description | Element sampled | $^{14}C$ Lab number | $^{14}C$ Age BP | $\delta^{13}C$ (‰) VPDB | $\delta^{15}N$ (‰) AIR | C:N | Calibrated date range (95.4% probability) |
|---|---|---|---|---|---|---|---|---|---|
| A337 | Mumbwa stratum I | Individual A | - | - | - | - | - | - | - |
| | | Individual B | - | - | - | - | - | - | - |
| | | Individual C | Petrous bone (WUD001) | Ua-61970 | 195 ± 32 | -9.8 | 7.5 | 3.2 | 1664-1884 |
| A338 | Mumbwa stratum I | Individual A | - | - | - | - | - | - | - |
| | | Individual B | Molar tooth & petrous bone (WUD002) | Ua-61834 | 168 ± 39 | -16.6 | 12.6 | 3.2 | 1668-1895 |
| | | Individual C | - | - | - | - | - | - | - |
| A339 | Mumbwa stratum III | One adult individual | Molar tooth (WUD003) | Ua-61835 | 147 ± 35 | -7.4 | 8.0 | 3.2 | 1673-1913 |
| A340 | Mumbwa stratum III | One adult individual | Molar tooth (WUD004) | Ua-61973 | 134 ± 36 | -8.1 | 9.2 | 3.2 | 1675-1916 |
| A341 | Mumbwa stratum III | One adult individual | Premolar tooth (WUD005) | Ua-61971 | 1 030 ± 33 | -10.3 | 9.0 | 3.3 | 994-1155 |
| A342 | Mumbwa stratum IV | One adult individual | N/A | - | - | - | - | - | - |
| A343 | Mumbwa stratum IV | Two skulls*<br>Individual A<br>Individual B | Petrous bone (WUD007) | Ua-61837 | 995 ± 35 | -12.0 | 9.4 | 3.4 | 1025-1178 |
| A344 | Mumbwa stratum IV | One adult individual | Molar tooth (WUD008) | Ua-61974 | 253 ± 57 | -16.1 | 7.8 | 3.2 | 1506-1880 |
| A345 | Mumbwa stratum V | One adult individual | N/A | - | - | - | - | - | - |
| A346 | Mumbwa no stratum | Possibly two adult individuals** | Molar (WUD010) | Ua-61972 | 311 ± 29 | -5.6 | 9.0 | 3.3 | 1505-1668 |
| A347 | Fissure Mumbwa area | Individual A | - | - | - | - | - | - | - |
| | | Individual B | Petrous bone (WUD011) | Ua-61829 | 409 ± 43 | -10.1 | 9.2 | 3.3 | 1451-1629 |

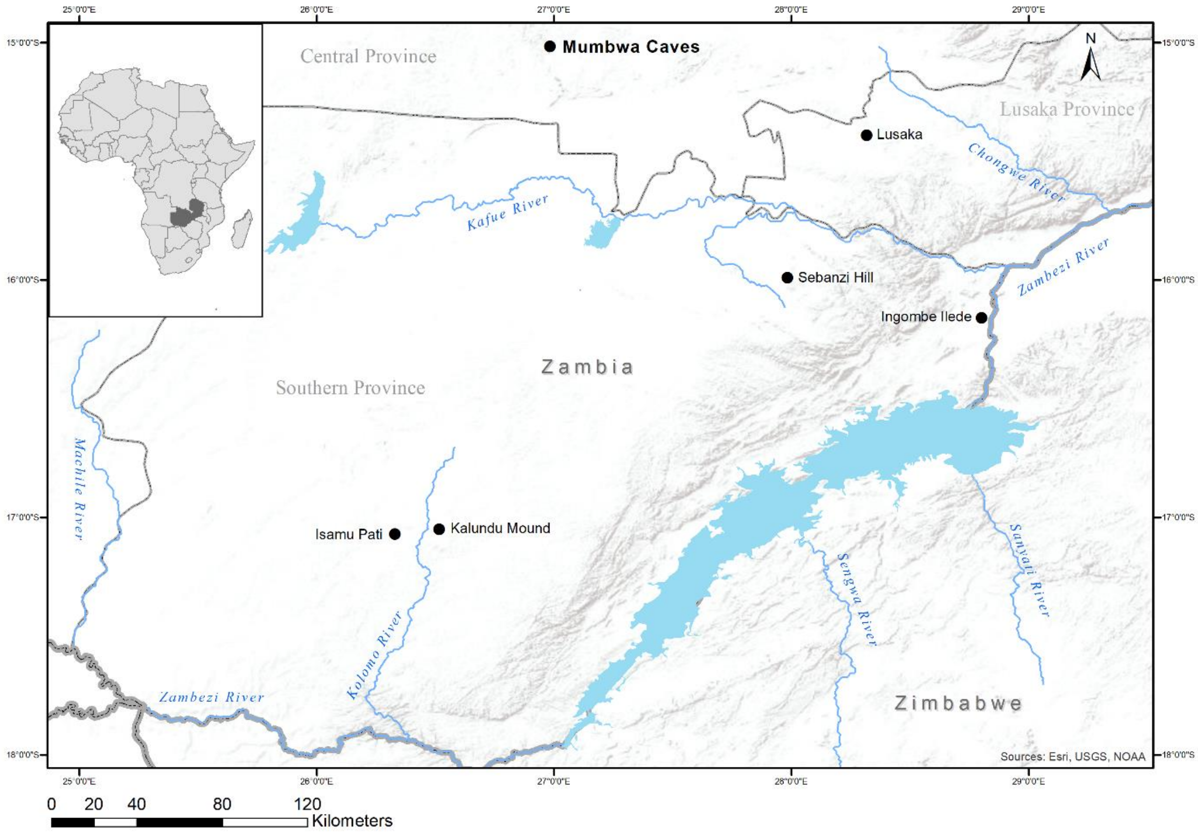
*These skulls may belong to either Individual A or B, or to none of them. Sample WUD007 was collected from the incomplete skull with exposed temporal bone. **Commingled teeth of which one molar was sampled.

**Table 2** Cranial measurements (Howells, 1970). All measurements in mm

| MEASUREMENT | A338 B | A344 |
|---|---|---|
| Glabello-Occipital Length GOL | - | 199 |
| Nasio-Occipital Length NOL | - | 198 |
| Maximum Cranial Breadth XCB | - | 126 |
| Maximum Frontal Breadth XFB | 115 | - |
| Bistephanic Breadth STB | 111 | 102 |
| Biauricular Breadth AUB | 93 (est)* | 114 |
| Minimum Cranial Breadth WCB | 60 | - |
| Nasion-Prosthion Height NPH | 61 (est) | - |
| Nasal Height NLH | 46 | - |
| Orbit Height Left OBH | 29 | - |
| Orbit Breadth Left OBB | 39 | - |
| Nasal Breadth NLB | 32 | - |
| Palate Breadth MAB | 66 | - |
| Bifrontal Breadth FMB | 103 | 105 |
| Biorbital Breadth EKB | 104 | - |
| Interorbital Breadth DKB | 32 | - |
| Simotic Chord WNB | 13 | 12 |
| Cheek Height WMH | 24 | - |
| Nasion-Bregma Chord FRC | 118 | 116 |
| Bregma-Lambda Chord PAC | 105 | 125 |
| Lambda-Opisthion Chord OCC | - | 96 |

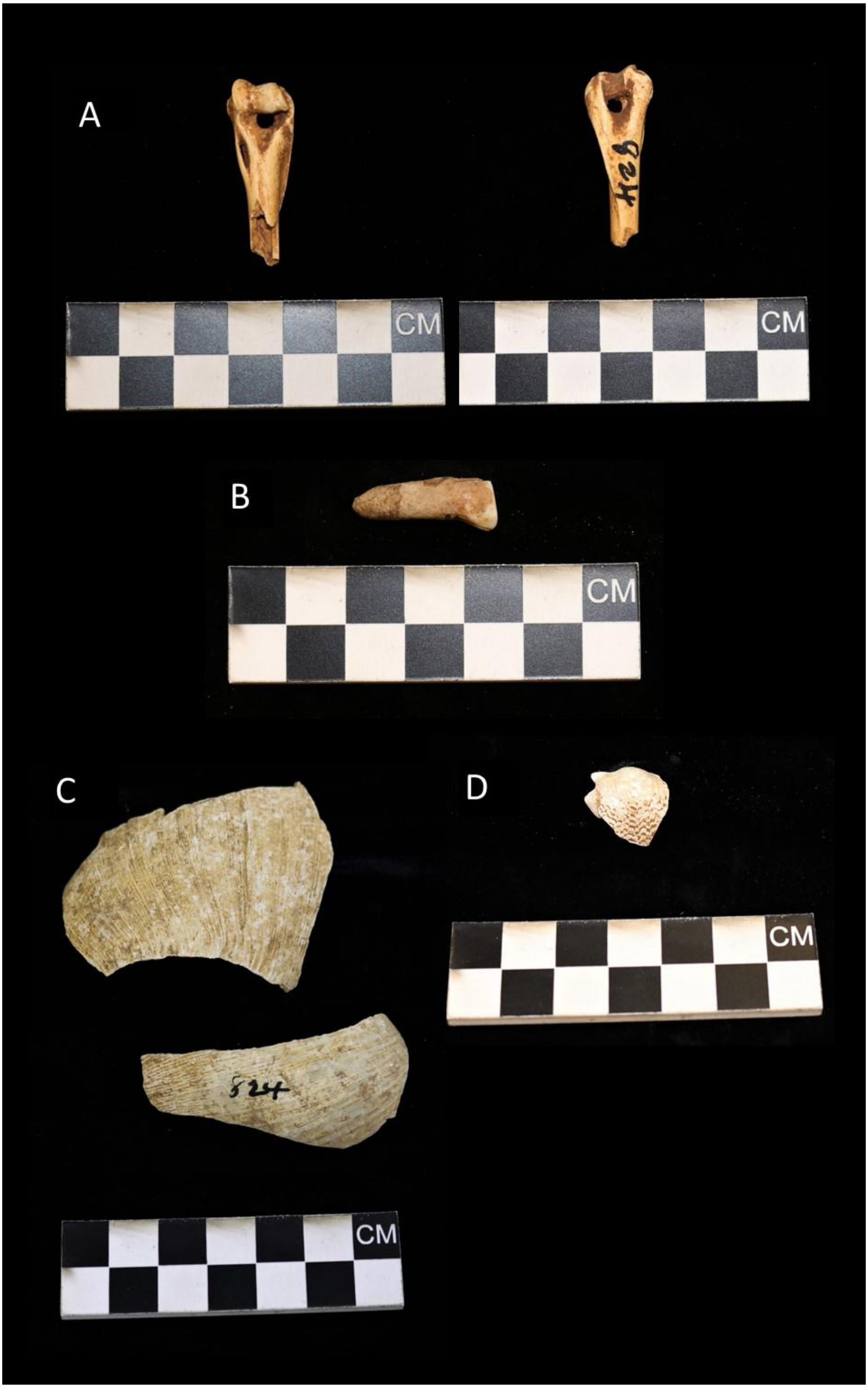
**Table 3** Comparative isotope data for several groups of farmers, foragers and one group of pastoralists from sub-Saharan African contexts

| Population | $\delta^{13}C$ | | | $\delta^{15}N$ | | | Source |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | Mean | SD | Median | |
| Mumbwa Dart Collection (n=9) | -10.6 | 3.7 | -10.1 | 9.1 | 1.5 | 9 | This study |
| Pastoralists, Neolithic, savanna, Kenya (n=10) | -7.3 | 0.8 | -5.9 | 12.6 | 0.8 | 12.8 | Ambrose & DeNiro, 1986 |
| Farmers, Neolithic/Iron Age, Kenya (n=10) | -5.8 | 0.7 | -5.8 | 11 | 1 | 11.1 | Ambrose & DeNiro, 1986 |
| Farmers, Early Iron Age, Kalahari Basin/Savanna biotope, Botswana (n = 25) | -9.5 | 1.5 | -9.2 | 9.4 | 1.3 | 8.9 | Mosothwane, 2010 |
| Farmers, savanna woodland/Magaliesberg Savanna-Grassland Biotope, SA (n=7) | -7.3 | 0.6 | -7.3 | 9.5 | 0.8 | 9.3 | Lee-Thorp, 1993 |
| Farmers, savanna/Central Bushveld Bioregion, SA (n=12) | -8.1 | 1.3 | -8.1 | 10.6 | 0.8 | 10.4 | Lee-Thorp, 1993 |
| Farmers, dry savanna/ Mopane Bioregion, SA (n=17) | -10.6 | 1.3 | -10.7 | 11.8 | 1.4 | 11.6 | Lee-Thorp, 1993 |
| Farmers, sub-escarpment Savanna, SA farmer (n=9) | -10.6 | 2.4 | -10.4 | 10.1 | 2.1 | 10.1 | Ribot et al., 2010 |
| Farmers, western mesic grassland, SA (n-11) | -7.5 | 1.8 | -7 | 10.3 | 0.9 | 10.4 | Lee-Thorp, 1993 |
| Farmers, Montane/Drakensberg Grassland, SA (n=5) | -10.2 | 1.7 | -10.3 | 8.4 | 0.4 | 8.2 | Meyer et al., 2022 |
| Farmers, Karoo-Arid Karoo, SA (n=14) | -10.7 | 2 | -10.7 | 13 | 2 | 13 | Lee-Thorp, 1993 |
| Foragers, dry grassland, SA (n=9) | -12.1 | 3.2 | -11.8 | 9 | 2.7 | 15 | Unpublished data |
| Foragers, eastern mesic grassland, SA (n=7) | -14.1 | 0.5 | -13.9 | 12.5 | 1 | 12.5 | Ribot et al., 2010 |
| Foragers, Fynbos, SA (n=6) | -17.5 | 1.2 | -17.7 | 13 | 2.5 | 13.4 | Sealy et al., 2000 |
| Foragers, southern Cape, SA (n=34) | -12.8 | 1.4 | -12.5 | 14.9 | 1.6 | 15.3 | Lewis & Sealy, 2018 |
| Foragers, southern Cape coastal, SA (n=12) | -13.7 | 2.4 | -13.4 | 12.9 | 1.4 | 13.1 | Ambrose & DeNiro, 1986 |


Mumbwa Caves
Central Province
Lusaka Province
Lusaka
Chongwe River
Kafue River
Sebanzi Hill
Zambezi River
Ingombe Ilede
Zambia
Southern Province
Machile River
Isamu Pati
Kalundu Mound
Kalomo River
Sengwa River
Sanyati River
Zambezi River
Zimbabwe
Sources: Esri, USGS, NOAA
N
0 20 40 80 120
Kilometers


A
B
C
D

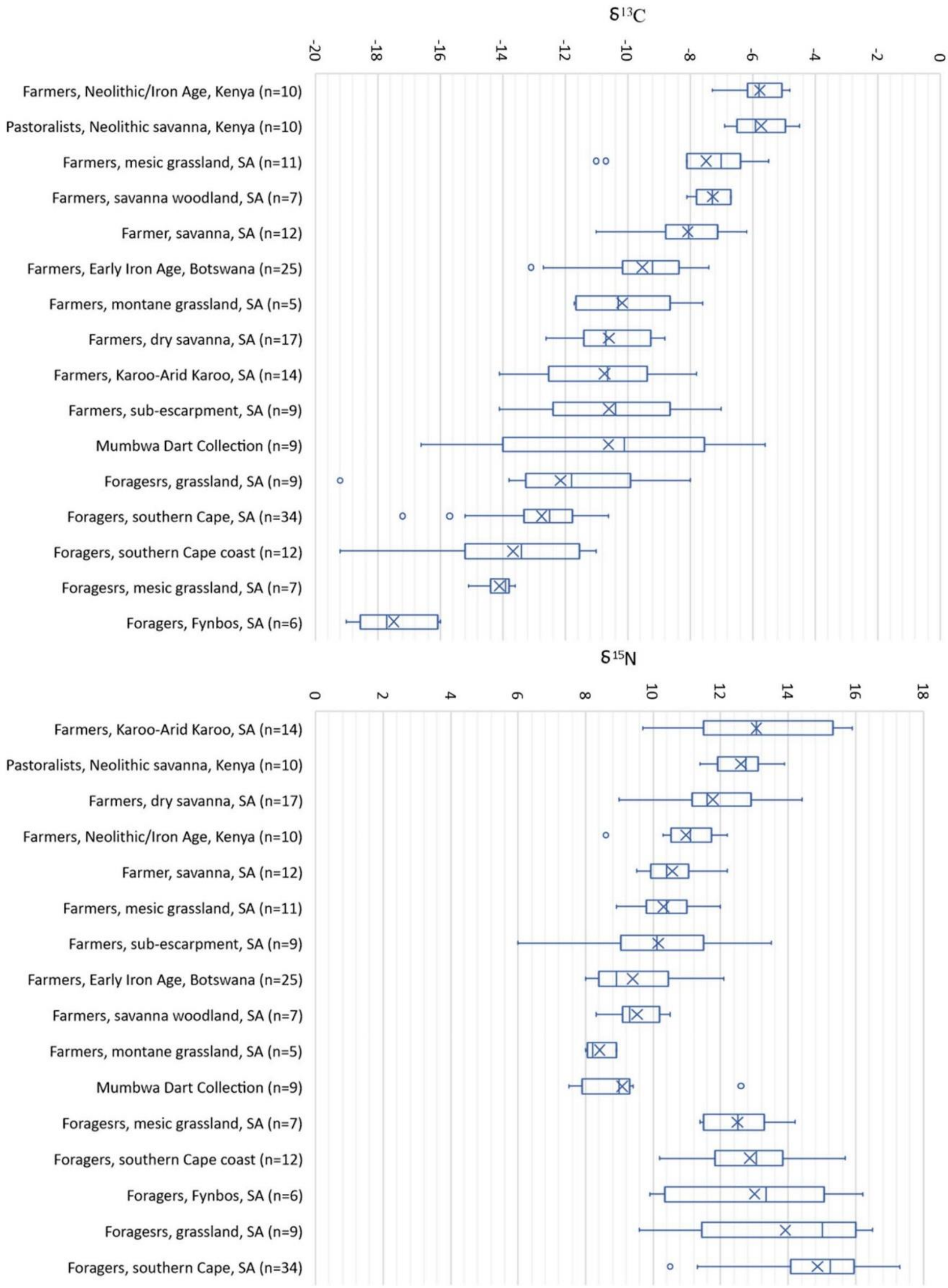

A338
A338
A
B

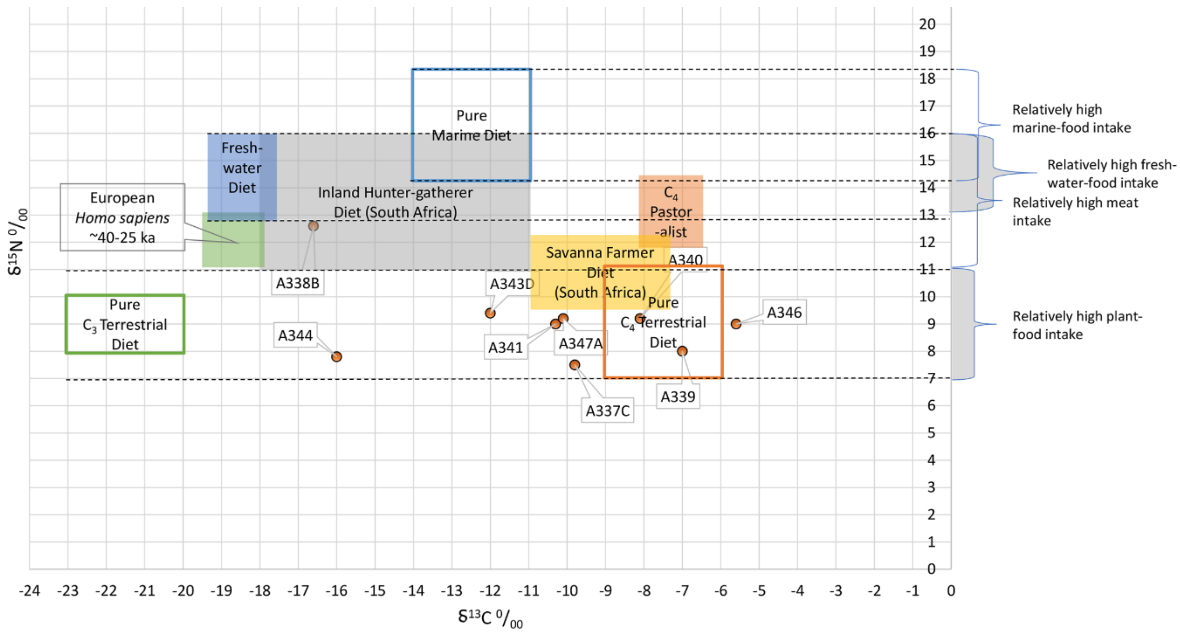

A
CM
CM
B
CM
C
CM
D
CM


A
B


CM
CM


A344
MUMBWA IV
Dart & del Grande 1931
Wells 1950
A
B


δ13C
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
Farmers, Neolithic/Iron Age, Kenya (n=10)
Pastoralists, Neolithic savanna, Kenya (n=10)
Farmers, mesic grassland, SA (n=11)
Farmers, savanna woodland, SA (n=7)
Farmer, savanna, SA (n=12)
Farmers, Early Iron Age, Botswana (n=25)
Farmers, montane grassland, SA (n=5)
Farmers, dry savanna, SA (n=17)
Farmers, Karoo-Arid Karoo, SA (n=14)
Farmers, sub-escarpment, SA (n=9)
Mumbwa Dart Collection (n=9)
Foragesrs, grassland, SA (n=9)
Foragers, southern Cape, SA (n=34)
Foragers, southern Cape coast (n=12)
Foragesrs, mesic grassland, SA (n=7)
Foragers, Fynbos, SA (n=6)
δ15N
0
2
4
6
8
10
12
14
16
18
Farmers, Karoo-Arid Karoo, SA (n=14)
Pastoralists, Neolithic savanna, Kenya (n=10)
Farmers, dry savanna, SA (n=17)
Farmers, Neolithic/Iron Age, Kenya (n=10)
Farmer, savanna, SA (n=12)
Farmers, mesic grassland, SA (n=11)
Farmers, sub-escarpment, SA (n=9)
Farmers, Early Iron Age, Botswana (n=25)
Farmers, savanna woodland, SA (n=7)
Farmers, montane grassland, SA (n=5)
Mumbwa Dart Collection (n=9)
Foragesrs, mesic grassland, SA (n=7)
Foragers, southern Cape coast (n=12)
Foragers, Fynbos, SA (n=6)
Foragesrs, grassland, SA (n=9)
Foragers, southern Cape, SA (n=34)



Pure
Marine Diet
Fresh-
water
Diet
European
Homo sapiens
~40-25 ka
Inland Hunter-gatherer
Diet (South Africa)
C4
Pastor
-alist
Savanna Farmer
Diet
(South Africa)
Pure
C4 Terrestrial
Diet
Pure
C3 Terrestrial
Diet
A338B
A343D
A340
A346
A344
A341
A347A
A337C
A339
Relatively high
marine-food intake
Relatively high fresh-
water-food intake
Relatively high meat
intake
Relatively high plant-
food intake
δ15N 0/00
δ13C 0/00