The paleoenvironmental context of the Early and Middle Pleistocene at Melka Kunture archaeological site (Upper Awash Valley, Ethiopia), as evidenced by stable isotope analysis

Dissertation

der Mathematisch-Naturwissenschaftlichen Fakultät

der Eberhard Karls Universität Tübingen

zur Erlangung des Grades eines

Doktors der Naturwissenschaften

(Dr. rer. nat.)

vorgelegt von

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Cariati (CS) - Italien

Tübingen

2022

Gedruckt mit Genehmigung der Mathematisch-Naturwissenschaftlichen Fakultät der Eberhard Karls Universität Tübingen.

Tag der mündlichen Qualifikation:	26.04.2022
Dekan:	Prof. Dr. Thilo Stehle
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Abstract

Stable isotope analysis is a well-established and powerful tool for determining valid information on paleodiet, paleoenvironment, and paleoecology (Bibi *et al*. 2013; Bocherens *et al*. 1996; Cerling *et al*. 2015; Lee-Thorp *et al*. 2010; Levin *et al*. 2008; Rivals *et al*. 2018). This method has been widely applied to Pleistocene archaeological sites in eastern Africa at medium and low altitudes (Ascari *et al*. 2018; Bedaso *et al*. 2010; Negash *et al*. 2020; Rivals *et al*. 2017; Semaw *et al*. 2020; Uno *et al*. 2018); however, the literature lacks isotopic reconstructions of ecological conditions at high elevations.

Here, are reported the carbon and oxygen stable isotope compositions (^{13}C, ^{18}O) of fossil teeth enamel (carbonates) from the Melka Kunture (MK) prehistoric site, located in the Ethiopian highland (~2000 m a.s.l.), in order to provide paleoenvironmental insights. The $^{13}C/^{12}C$ and $^{18}O/^{16}O$ isotopic ratios were measured on 178 fossil teeth representing a various range of *taxa* (Hippopotamidae, Bovidae, Equidae, Suidae, Giraffidae, and Crocodylidae) to determine the extent of the vegetation types. Collectively, 310 enamel samples (bulk and intra-tooth) were analyzed. The carbon isotopic results of hippopotamids, bovids, equids, suids, and giraffids indicate a range of foraging strategies across the pure C_4 diets to mixed C_3-C_4 diets, with variations between ~1.95 Ma and ~0.6 Ma (Mega annum) (Early and Middle Pleistocene). In contrast, the bulk and intra-tooth carbon isotopic ratios of crocodiles suggest that these Pleistocene reptiles ate herbivores that consumed C_3 plants. The intra-tooth results of hippo, equid, and suid teeth indicated C_4 diets and stable water conditions during the lifetime of the sampled mammals. The isotopic data, which emphasize the presence of open space conditions such as C_4 high-elevation grasslands, are consistent with pollen and phytolith analysis, indicating extended mountain grasslands, with a different abundance of mesophytic grasses, mountain forests, woodlands, and bushlands. However, it should be kept in mind that isotopic results from teeth enamel reflect the feeding strategies and the ecological behaviour of the analyzed *taxa*, while fossil pollen allows describing the plant types present even at a certain distance from the site, and phytolith data allow characterizing the distribution of the “on the spot” plants at the time of deposit formation. These complementary data encourage a combined approach among distinct methods that can yield more detailed paleoenvironmental and ecological insights.

Keywords: Melka Kunture, Ethiopian Highland, Pleistocene, stable isotopes, tooth enamel, paleoenvironment.

Acknowledgments

The funds for the Ph.D. research project were provided by Sapienza University of Rome (Italy) (three-year scholarship, extended for 3 months by "Legge 21 maggio 2021, n. 69"), while the Biogeology Lab of Eberhard Karls University of Tübingen (Germany) covered the costs of the isotopic analyses and hosted me several times at the Institut für Geowissenschaften (Hölderlinstrasse 12, Tübingen). This study was also supported by the Research Grant-Short Term 2021 (57552336) of the DAAD (Deutscher Akademischer Austauschdienst), the Research Grant (decreto n.1605/2020, Prot. n. 0044296) by Sapienza University of Rome, and the Grant of the CFEE (Centre français des études éthiopiennes) in Addis Ababa (Ethiopia). I would like to thank the director (Prof. Margherita Mussi), the co-directors (Dr. Joaquín Panera and Dr. Eduardo Méndez-Quintas), and all the members of the Italo-Spanish Archaeological Mission at Melka Kunture and Balchit (Italy-Spain) for the support in the fieldworks and during the collection of the enamel samples, for allow to conduct the isotopic analyses, but also for the advice, ideas, and any kind of support about the experience in Ethiopia. I am thankful to the Authority for Research and Conservation of Cultural Heritage (ARCCH) of the Ministry of Culture and Tourism for the collection assistance during my visits to Addis Ababa and permission to sample fossil teeth archived at the National Museum of Ethiopia. I would specifically like to thank Dr. Denis Geraads for the short stay at the Muséum National d'Histoire Naturelle (Paris), and Proff. Rita T. Melis and Laura Pioli for the significant help and instructions on the collection and treatment of the sediment samples, at the Department of Geology of the University of Cagliari (Italy). The time spent at the working group Biogeology of the Department of Geosciences (University of Tübingen) was a memorable and enjoyable experience. I am enormously thankful to all the lab members I have met during these years, especially to Dr. Dorothée Drucker for the scientific and nice conversations. Dr. Silvia Santiccioli, my dear psychotherapist, thank you for the best healthy-long relationship we sharing for 6 years: asking for help is not easy, and working on yourself takes effort, but it must be done, isn't it?! Finally, I would like to thank my supervisors, Prof. Margherita Mussi and Prof. Hervé Bocherens for supporting and having faith in me. Thank you, Margherita and Hervé for introducing me to such exciting topics of African archaeology, human evolution, and palaeoenvironmental reconstructions by stable isotope analysis. Thanks for your guidance, encouragement, care, and kindness. All this is the "stratigraphic accumulation" and the "subsequently reworking" of my graduate and post-graduate education, the support, and encouragement of many individuals, such as colleagues, friends, and family.

To Margherita Mussi

“It is our choices, Harry, that show what

we truly are, far more than our abilities.”

(Albus Dumbledore, Harry Potter and the Chamber of Secrets)

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Chapter 1: Introduction

1.1 Research topic and objectives

For decades, stable isotope analysis of mammal teeth from Pleistocene archaeological sites has proven highly informative regarding paleodiet, paleoenvironment, and paleoecology (Bibi *et al*. 2013; Bobe & Behrensmeyer 2004; Bocherens *et al*. 1996; Cerling & Harris 1999; Cerling *et al*. 1997, 2003, 2015; Foley 1994; Kingston & Harrison 2007; Lee-Thorp *et al*. 2003, 2010; Levin *et al*. 2008; Potts 2007; Rivals *et al*. 2018). This powerful and well-established method has been successfully used to assess the paleoenvironment of Pleistocene archaeological sites in East Africa at medium and low altitudes (Ascari *et al*. 2018; Bedaso *et al*. 2010; Negash *et al*. 2020; Rivals *et al*. 2017; Semaw *et al*. 2020; Uno *et al*. 2018). However, the literature lacks isotopic reconstructions of ecological conditions at high elevations.

The present study uses carbon and oxygen stable isotope analyses on teeth enamel (carbonates) to provide paleoenvironmental insights between ~1.96 and ~0.6 Ma (Early and Middle Pleistocene), at Melka Kunture (MK) prehistoric site (Upper Awash Valley, Ethiopia). MK is located in the tropical zone, but at a high altitude (~2000 m a.s.l.) and its Afromontane vegetation complex (Bonnefille *et al*. 2018) represents a unique condition for testing hypotheses on hominin adaptive capabilities in the highlands, contrary to what is known about the phenomena of human evolution at low elevations (Coppens 1994; Dart 1925; Lee-Thorp & Sponheimer 2007; Lee-Thorp *et al*. 2000, 2003, 2010). The goals of this research are 1) to determine the dietary and ecological information of the fossil fauna from MK; 2) to evaluate the impact of climate variations on the vegetation as well as dietary adaptation between ~1.95 Ma and ~0.6 Ma (Early and Middle Pleistocene); 3) to characterize the sampled Early and Middle Pleistocene habitats of the Ethiopian highlands in which humans lived.

1.2 Carbon and oxygen stable isotope analysis

Carbon and oxygen isotopic analyses of tooth enamel have been accepted as valuable tools for the reconstruction of terrestrial paleoenvironments (Bocherens *et al*. 1996; Boisserie *et al.* 2005; Cerling *et al*. 2003; Franz-Odendaal *et al*. 2002; Harrison 2007; Kingston & Koch 1998; Kohn & Cerling 2002; Schoeninger *et al*. 2003; Sponheimer & Lee-Thorp 2003). Tooth enamel is almost entirely inorganic (mineral fraction: ~99% of calcium phosphate and ~3-5% of carbonate; organic fraction: ~1%) (Bocherens & Drucker 2013;

Wang & Cerling 1994) and consists of hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), which is a relatively stable mineral in surface-weathering environments. Thus, because tooth enamel is less susceptible to diagenesis and forms by accretion without remodeling, it is the most suitable fossilized material for preserving stable isotopic signatures (Ayliffe *et al*. 1994; Bryant *et al*. 1994; Lowenstam & Weiner 1989; Wang & Cerling 1994). The carbon and oxygen isotopic abundances in tooth enamel (carbonate) from herbivores are related to the types of plants consumed and ingested water during the formation of the analyzed tissue, respectively (Cerling *et al*. 2008; Clementz & Koch 2001). The stable isotopic results are normally expressed in the following standard δ-notation: $X = [(R_{sample}/R_{standard})-1]*1000$, where X is the $\delta^{13}C$ and $\delta^{18}O$ values, and R represents $^{13}C/^{12}C$ or $^{18}O/^{16}O$, respectively. The interpretation of the carbon isotopic composition of tooth enamel is based on differences in isotope fractionation, which takes place from the diets to teeth enamel when the plants (C_3 and C_4) are eaten by herbivores, and when the herbivores are consumed by the carnivores (Smith & Epstein 1971). Terrestrial plants are generally divided into three categories, C_3 (Calvin), C_4 (Hatch-Slack), and CAM (Crassulacean acid metabolism), according to the different pathways of photosynthesis that cause differences in carbon isotopic fractionation during the processes of fixation. The C_3 pathway is present in trees, shrubs, and cold-tolerant herbs (Deng *et al*. 2001). The C_3 plants have $\delta^{13}C$ values ranging from -35‰ to -22‰ (mean of -27‰) (O'Leary 1988). The C_4 photosynthesis occurs in grasses, sedges, and herbs, and is typical of drier and warmer environments (Raven *et al*. 1999). The C_4 plants have $\delta^{13}C$ values ranging from -19‰ to -9‰ (mean of -13‰) (Cerling *et al*. 1997; Farquhar *et al*. 1989; O'Leary 1988). The CAM pathway occurs in succulent plants adapted to arid climates, which have carbon isotopic values that are intermediate between those of C_3 and C_4 plants (Ehleringer & Monson 1993). Other factors (rainfall, altitude, light intensity, atmospheric carbon dioxide concentration, and canopy effect) affect the carbon isotopic signal of plants (Farquhar *et al*. 1989), which becomes more negative with an increase in rainfall, altitude, and latitude (Bocherens & Drucker 2013; Kohn 2010).

The oxygen isotope composition of mammalian tooth enamel reflects the source and amount of body water derived from drinking water and food (Kohn 1996; Kohn *et al*. 1998). The oxygen isotopic values in plant leaves are higher than those in meteoric water, due to evaporation. This means that herbivores eat leaves with higher oxygen isotopic values than those drinking meteoric water (Pederzani & Britton 2019), enabling the browsers to be distinguished from the grazers. In addition, mammals that are so-called "water-dependent drinkers" (as hippos) usually have lower oxygen isotopic values than "non-obligate drinkers" (as equids), depending on water availability and seasonality of rainfall. The oxygen isotopic composition can also be affected by habitat differences: for semi-aquatic mammals, such as hippos, stable oxygen isotopic signals are depleted compared to terrestrial herbivores (Bocherens *et al*. 1996, 2011; Clementz *et al*. 2008; Harris *et al.* 2008). Finally, many other factors such as altitude, latitude, temperature, and precipitation, play a relevant role in the change of oxygen isotopic composition (Bocherens & Drucker 2013; Levin *et al*. 2008).

1.3 Melka Kunture: an overview

Melka Kunture (MK) is a vast cluster of prehistoric sites known for its extensive geo-archaeological and paleontological records spanning over most of the Early, Middle, and Late Pleistocene. The area is located on the northern Ethiopian plateau, 50 km^2 south of Addis Ababa. Archaeological evidence extends for more than 70 km^2 on the banks of the Upper Awash River, at approximately 2000 m a.s.l. (Fig.1) (Chavaillon & Piperno 2004; Raynal & Kieffer 2004; WoldeGabriel *et al*. 2000). The site, which was discovered in 1963, was investigated from 1965 to 1999 by the French Archaeological Mission led by Jean Chavaillon. Subsequently, this work was conducted by the first Italian Archaeological Mission, directed by Prof. Marcello Piperno. Thereafter, starting in 2011, research activities were conducted by the second Italian Archaeological Mission, directed by Prof. Margherita Mussi. Currently, the Italo-Spanish Archaeological Mission, directed by Prof. Margherita Mussi, and co-directed by Dr. Joaquín Panera and Dr. Eduardo Méndez-Quintas, has taken over fieldwork and lab activities. Since 2012, the Melka Kunture site has been included in UNESCO's Tentative List of World Heritage Sites (https://whc.unesco.org/en/tentativelists/?action=listtentative&pattern=ethiopia&state=&theme=&criteria_restrication=&date_start=&date_end=&order=) (Mussi 2011, 2012).

The geo-archaeological deposits at MK are characterized by gravel, sand, silt, and clay sediments, typical of a fluvial and lacustrine context. Among these deposits, layers of volcanic origin constitute an important stratigraphic reference. The layers mentioned above are the result of the geomorphological evolution of the area, which was mainly influenced by the Wachaca and Furi volcanoes in the north, the Bori and Agoiabi volcanoes in the south, fluvial processes, and cyclically by erosion and re-deposition episodes (Chavaillon & Taieb 1968; Gallotti *et al*. 2010; Raynal & Kieffer 2004; Taieb 1974). The timescale approved by IUGS has been used as a reference for the geo-chronological sequence: the

Early (Lower) Pleistocene is dated from 2.58 Ma to ~770-773 ka; the Middle Pleistocene is dated from ~770-773 ka to ~130 ka; the Late (Upper) Pleistocene is dated from ~130 ka to 11,700 cal. years (Gibbar *et a*l. 2010).

The chronological assessment of MK is a combination of magneto-chronological studies (Perini *et al*. 2021; Tamrat *et al.* 2014; Westphal *et al*. 1979), radiometric dating of tuff/cinerite using $^{40}K/^{40}Ar$ (Chavaillon & Piperno 2004; Schmitt *et al*. 1977), $^{40}Ar/^{39}Ar$ (Morgan *et al*. 2012), and Electron Spin Resonance spectrometry on quartz grains (Sánchez-Dehesa Galán *et al*. 2022), coupled with accurate stratigraphic positioning of the archaeological layers that recorded human remains. The local Paleolithic sequence at MK (Fig.2) is documented with the Oldowan at Garba IV F (~2.02 Ma) (Perini *et al*. 2021), Garba IV E (~2.0 Ma) (Perini *et al*. 2021), Gombore I C, and Karre I. It continues with the Early Acheulean at Garba IV D (~1.95 Ma) (Perini *et al*. 2021), Gombore I B (~1.66 Ma) (Perini *et al*. 2021), Gombore I γ (~1.51 Ma) (Perini *et al*. 2021), Gombore I δ (~1.41 Ma) (Perini *et al*. 2021). Simbiro III, with a $^{40}Ar/^{39}Ar$ date at the top of the sequence of ~1.0 Ma (Morgan *et al*. 2012), comprises the so-called Monumental Section (MS) (~1.3 Ma) (Mussi *et al*. in prep.) and the gully. The middle Acheulean is recorded at Garba XIIJ (~1.13 Ma) (Perini *et al*. 2021), Garba XIII C (~1.0 Ma) (Perini *et al*. 2021), Gombore II-1 (~1.0 Ma) (Perini *et al*. 2021), Gombore II-3, Gombore II-4, Gombore II-5, Gombore OAM (Open Air Museum) (~1.03 Ma) (Perini *et al*. 2021), and Atebella II. The final Acheulean is attested at Gombore II-2 (~0.75 Ma) (Perini *et al*. 2021), Garba III C (~0.68 Ma) (Perini *et al*. 2021), Garba I B (~0.6 Ma) (Sánchez-Dehesa Galán *et al*. 2022), and Gombore III. The Middle Stone Age is documented at Garba III, while the Late Stone Age, so far, has eroded from superficial deposits at Wofi II, Wofi III, and Kella I. Recently, a new Late Stone Age site, Beefa Cave, was discovered in 2019. Finally, the site of Balchit, located 7 km^2 north of the core area of MK, documents the obsidian exploitation from the Oldowan until historical times (Chavaillon & Berthelet 2004; Chavaillon & Coppens 1986; Chavaillon *et al*. 1974, 1979; Gallotti 2013; Gallotti & Mussi 2015, 2017, 2018; Gallotti *et al*. 2010, 2014; Mendez-Quintas *et al*. 2019; Mussi & Gallotti 2014; Mussi *et al*. 2014, 2016, 2021, 2022; Piperno *et al*. 2009). During many years of archaeological investigations, hundreds of thousands of lithic industries, paleontological (Geraads 1979; Geraads *et al*. 2004), and paleoanthropological remains (Fig.3) have been discovered. The oldest human remain is a hemimandible of *Homo erectus* child, found at Garba IV E (Le Cabec *et al.* 2021; Zilberman *et al*. 2004). A humerus attributed to *Homo erectus* was found in level B of Gombore I (Di Vincenzo *et al*. 2015); skull fragments related to the emergence of *Homo heidelbergensis* come from Gombore II-1 (Profico *et al*. 2016).

Finally, cranial fragments of archaic *Homo sapiens* were discovered in Garba III (Mussi *et al*. 2014). Many Pleistocene horizons with animal and hominin fossil footprints (Fig.4) have been identified (Mussi *et al*. 2016; Altamura *et al*. 2017, 2018, 2020). The analysis of fossil pollen at MK recorded the presence of Afroalpine mountain vegetation ("Dry evergreen Afromontane Forest and grassland Complex"), ranging from forests to grasslands and bushlands. The paleovegetation at MK was distinct from plant and tree species of the African savanna, present at low elevations and in drier and warmer environments (Bonnefille *et al*. 2018).

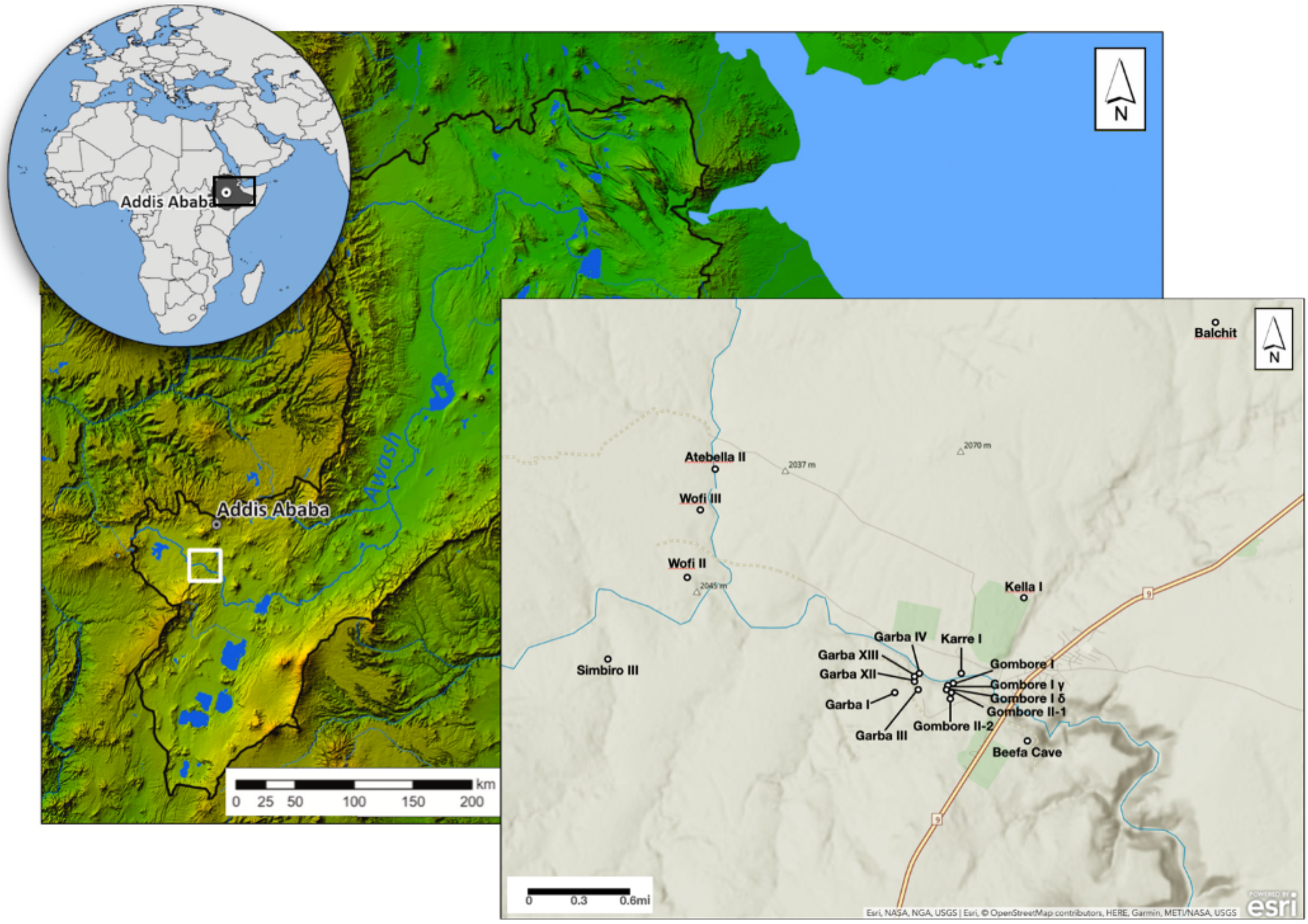


Fig.1. Location map of Melka Kunture and detail of the archaeological sub-sites, in the Upper Awash Valley of Ethiopia.

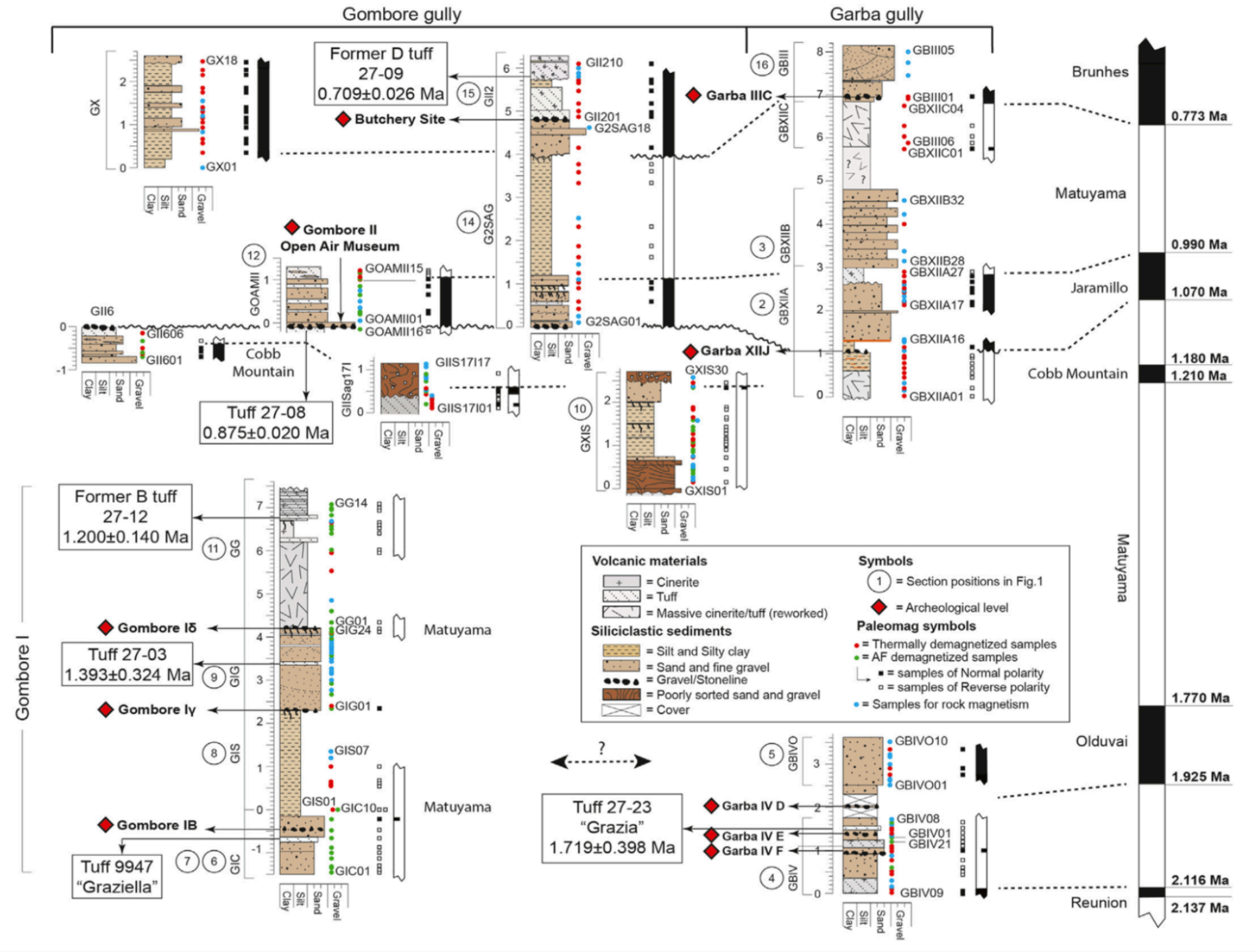


Fig.2. Stratigraphic scheme of the Melka Kunture sedimentary succession, correlated with magnetostratigraphy and available radiometric dating of tuff levels (Perini *et al.* 2021)

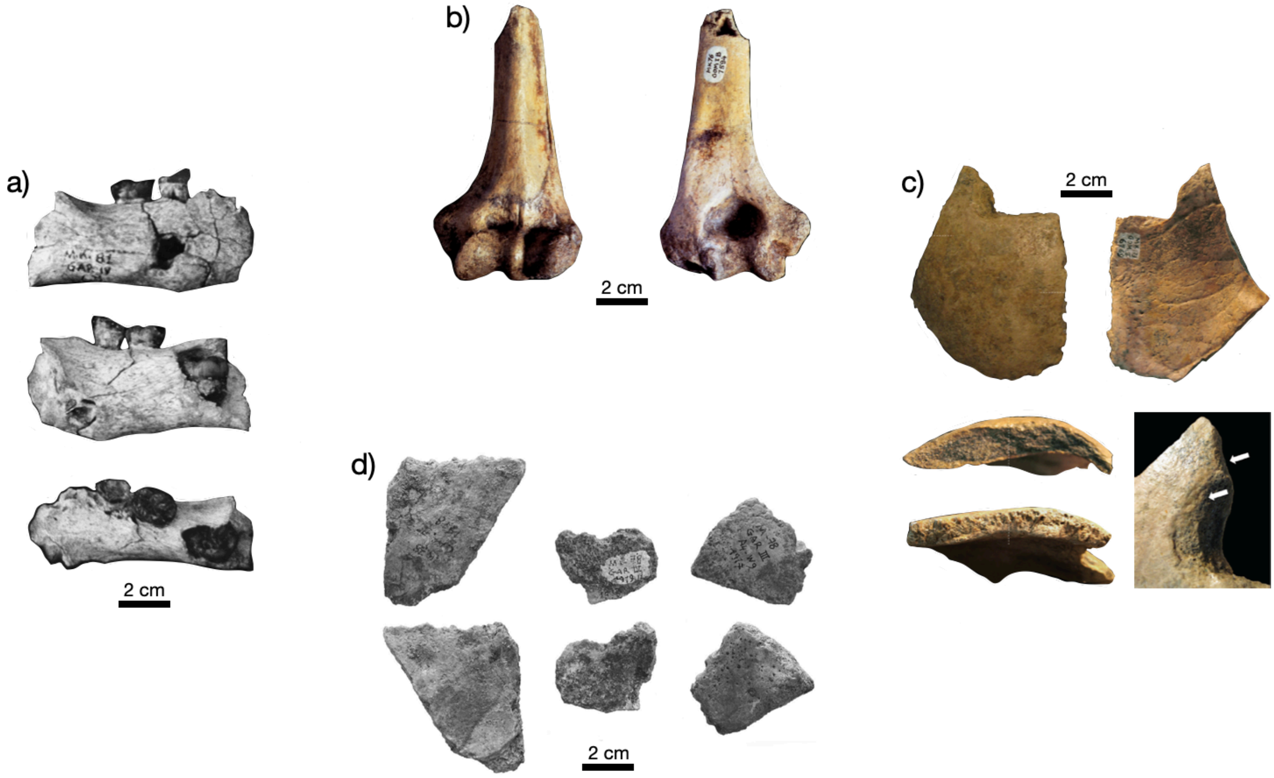


Fig.3. Palaeoantropological remains from Melka Kunture: a) buccal, lingual, and occluso-lingual view of the hemimandible of *Homo erectus* child from Garba IV E; b) anterior and posterior view of the humerus of *Homo erectus* from Gombore I B; c) exocranial and endocranial surface of the skull fragments of *Homo heidelbergensis* from Gombore II-1; d) parietal and occipital fragments of an archaic *Homo sapiens* from Garba III (Di Vincenzo *et al*. 2015; Le Cabec *et al.* 2021; Mussi *et al*. 2014; Profico *et al*. 2016; Zilberman *et al*. 2004).

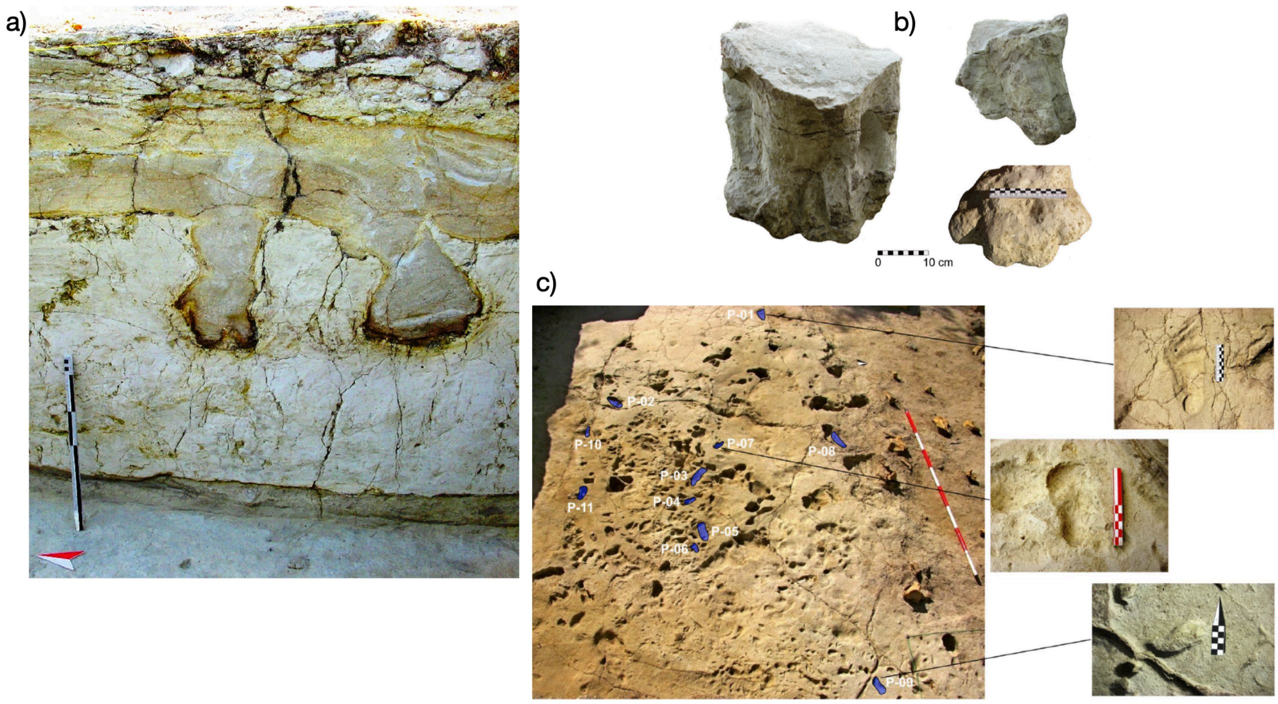


Fig.4. Fossil footprints from Gombore II-2: a) sectioned hippo footprint; b) cast of hippo prints; c) overview of animal and human footprint surface, with detail of human footprints (Altamura *et al.* 2017, 2018).

Chapter 2: Material and Method

2.1 The paleontological specimens

The $^{13}C/^{12}C$ and $^{18}O/^{16}O$ isotopic ratios were measured on 178 fossil teeth representing a various range of *taxa*. The fossil specimens used in this study have been generally identified at the family level, sometimes also in terms of species and genus (Geraads *et al*. 2004) as follows: Hippopotamidae (*Hippopotamus* cf. *amphibius*), Bovidae (bovids *sensu lato*; *Alcelaphini*, *Connochaetes*; *Hippotragini*; *Bovini*; *Reduncini*), Equidae (equids *sensu lato, Hipparion*), Suidae (suids *sensu lato*; *Kolpochoerus*; *Metridiochoerus*), *Giraffidae* (*Sivatherium*), and Crocodylidae (Fig.5).

The specimens included in this study came to light from several archaeological subareas of the Melka Kunture (MK) complex. From the oldest to the youngest, the localities included in this study are Garba IV D (~1.95 Ma), Gombore I B (~1.66 Ma), Karre I (no radiometric date); Gombore I γ, Gombore I δ, Garba XIIJ dated at ~1.51 Ma, ~1.41 Ma, and ~1.13 Ma, respectively; Simbiro III MS (levels A, B, D) (~1.3 Ma), and the gully. The list of the localities diachronically continues with Garba XIII C (~1.0 Ma), Gombore II-1 (~1.0 Ma), Gombore II-2 (~0.75 Ma), and it concludes with Garba III C (~0.68 Ma), Garba I B (~0.6 Ma), and Gombore III (Table 1, 2) (Morgan *et al*. 2012; Mussi *et al*. in prep.; Perini *et al*. 2021; Sánchez-Dehesa Galán *et al*. 2022). The entire paleontological collection is currently stored at the National Museum of Ethiopia (Addis Ababa) for the steady evaluation of the state of conservation of fossil remains. The lists and tables made by paleontologist Dr. Denis Geraads were extremely useful for recognizing and selecting the materials. The samples were collected during 2018 (November) and 2019 (April, November, and December), thanks to several research stays at Addis Ababa, in agreement with the ARCCH (Authority for Research and Conservation of the Cultural Heritage) authorities and Prof. Margherita Mussi, director of the Italo-Spanish archaeological mission at Melka Kunture and Balchit (Italy-Spain). A very limited set of samples have been collected at the Muséum National d'Histoire Naturelle (Paris) (July 2019), under the supervision of Dr. Denis Geraads. Since the end of 2019, sampling activities have been stopped due to the COVID-19 pandemic spreading all over the world. Between the end of 2021 and the beginning of 2022, the political situation in Ethiopia also limited access to the paleontological collection.

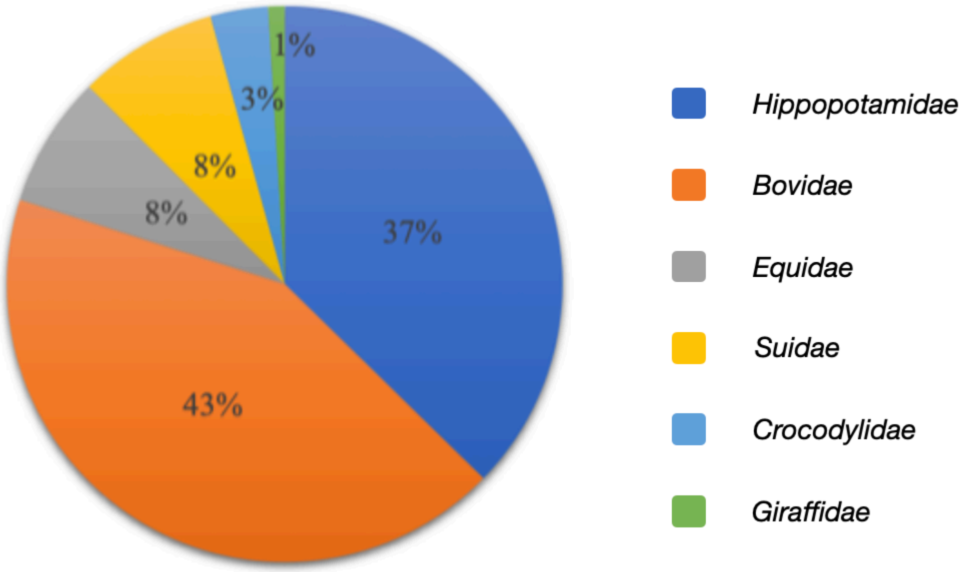


Fig.5. Graph with the percentages of each *taxon* used for sampling and isotopic analysis, from Melka Kunture.

Table 1. List of the sub-sites of Melka Kunture and chronology.

Archaeological site	**Sub-site**	**Magneto-stratigraphy (Perini *et al.* 2021)**	**$^{40}Ar/^{39}Ar$ (Morgan *et al.* 2012)**	**ESR spectrometry (Sánchez-Dehesa Galán *et al.* 2022)**
Melka Kunture	Garba IV D	~1.95 Ma	~1.6 Ma	-
Melka Kunture	Gombore I B	~1.66 Ma	-	-
Melka Kunture	Karre I	-	-	-
Melka Kunture	Gombore I γ	~1.51 Ma	~1.4 Ma	-
Melka Kunture	Gombore I δ	~1.41 Ma	~1.3 Ma	-
Melka Kunture	Simbiro III (MS)	-	~1.3 Ma	-
Melka Kunture	Garba XIIJ	~1.13 Ma	-	-
Melka Kunture	Garba XIII C	-	~1.0 Ma	-
Melka Kunture	Gombore II-1	~1.0 Ma	~0.85 Ma	-
Melka Kunture	Gombore II-2	~0.75 Ma	~0.70 Ma	-
Melka Kunture	Garba III C	~0.68 Ma	-	-
Melka Kunture	Garba I B	-	-	~0.6 Ma
Melka Kunture	Gombore III	-	-	-

Table 2. List of the *taxa* and the number of the specimens from each sub-area of Melka Kunture (Ethiopia).

	Hippopotamidae	Bovidae	Equidae	Suidae	Giraffidae	Crocodylidae	Tot.
Garba IV D	7	0	0	0	0	7	14
Gombore I B	6	5	1	4	0	0	16
Karre I	1	0	0	0	0	0	1
Gombore I γ	14	2	0	1	2	0	19
Gombore I δ	3	5	1	2	0	0	11
Garba XIIJ	2	0	0	1	0	0	3
Simbiro III (MS & gully)	27	23	5	1	0	0	56
Garba XIII C	2	0	0	0	0	0	2
Gombore II-1	5	20	2	0	0	0	27
Gombore II-2	11	2	9	0	0	0	22
Gombore III	0	2	0	0	0	0	2
Garba I B	0	1	0	0	0	0	1
Garba III C	1	9	0	0	0	0	10
Tot.	79	69	18	9	2	7	

2.2 Samples preparation

The practical laboratory activities were carried out following the internal protocol of the working group Biogeology, headed by Prof. Hervé Bocherens (University of Tübingen), for isotopic analyses of carbonates from archaeological teeth (enamel and dentine). As a preliminary step, empty tubes (Eppendorf Reaktionsgefäße) have been prepared for each set of analyses. All the tubes were weighed and labeled. In this case, the Lab-code corresponds to some letters of the Melka Kunture name (MLK) followed by a progressive number (MLK1, MLK2, MLK3, etc.). In addition to the samples to be analyzed for the project, two more samples have been added to each set of pretreatments to check the quality of the pretreatment and isotopic analysis, as the chemical and isotopic compositions of these two specimens are well-known from numerous previous analyses (Elephant and Hippo, both fossil enamel from Chad with different isotopic values). The relevant information was recorded for each sample on an Excel data sheet, and the archaeological teeth were drawn and photographed before and after sampling.

Before sampling, the uppermost surface of the teeth was cleaned using a diamond drill bit (>2.0 mm) to remove exterior and potential contaminants from the tooth surface. Fossil enamel was then sampled using a drilling device equipped with a diamond-tipped bit (<2.0 mm) to obtain 12-15 mg of powder. To avoid contamination, each technical phase was performed using protective masks, and the fossil teeth were always manipulated with gloves. The instruments used have been cleaned with Millipore water at the end of each operation or have been completely replaced for the same purpose.

2.3 Sampling techniques: bulk and intra-tooth methods

The bulk enamel powder was sampled along a wide transect (Fig.6), following the entire length of the tooth in order to obtain an average diet and ecological setting during the period of tooth formation (Feranec & McFadden 2000; Fricke & O'Neil 1996; Rivals *et al*. 2015; Sharp & Cerling 1998). Enamel intra-tooth samples were collected along the tooth growth axis (one sample every 5 mm) (Fig.6) (Reade *et al*. 2015; Souron *et al*. 2012). The stable isotope ratios of serial sections sampled on the tooth enamel thus record the specific foraging behaviour of the individual during the formation time of the different tooth sections. Therefore, the isotopic profile of the serial sections of tooth enamel may reveal the spatiotemporal dietary and environmental changes throughout the development of the tooth (Bagasse 2002; Fox & Fisher 2004; Fox *et al*. 2007; Zazzo *et al*. 2005).

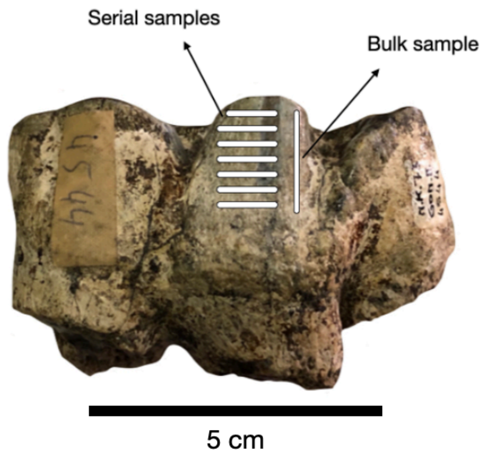


Fig.6. Schematic draw of sampling procedures on a molar of hippopotamid from Melka Kunture. Bulk samples are taken along the growing axis of the crown while serial samples are drilled perpendicularly to the axis of enamel growth (one sample every 5 mm).

2.4 Chemical pretreatment

The enamel powder pretreatment and isotopic analyses were conducted according to the protocol by Bocherens *et al*. (1996) at the Biogeology unit of the Geosciences Department at the University of Tübingen (Germany). Powdered samples were soaked in 1.35 ml of sodium hypochlorite (NaOCl) at a concentration of 2–3% to oxidize organic residues. The solution was mixed using a vortex (IKA MS3 basic) for approximately 30 seconds, and the enamel samples were placed on a shaker (Heidolf Vibramax 100) for 24 hours at 20°C. The NaOCl was replaced twice, and the samples were rinsed three times with Millipore water (Milli-Q H_2O) to remove all of the NaOCl. Between rinses, the samples were centrifuged to separate the solution from the enamel. The remaining samples were treated with 1.35 ml of 0.1 M buffer acetic acid-calcium acetate (CH_3COOH) (pH = 4.66) for 24 hours at 20°C to remove exogenous carbonate. Subsequently, the samples were mixed using a vortex and left to react for 24 hours during which they were shaken constantly. The samples were rinsed three times with Millipore water and centrifuged between each rinse. Finally, the samples were placed in an oven and dried at 40°C for 72 hours (Bocherens *et al*. 1996).

2.5 Isotopic analysis

Only 2.5-3 mg of the structural carbonate proceeded into the IRMS-analysis (Koch *et al*. 1997). The pretreated enamel carbonates were reacted with 99% H_3PO_4 for 4 hours at 70°C, using a MultiFlow-Geo interfaced with the Elementar IsoPrime 100 IRMS at the working group Biogeology Lab University of Tübingen (Germany). Final isotopic ratios are reported per mil (‰) and calibrated with the international standards (IAEA-603: $\delta^{13}C$ = 2.46 / $\delta^{18}O$ = -2.37 and NBS-18: $\delta^{13}C$ = -5.014 / $\delta^{18}O$ = -23.2), as well as three in-house standards. IonOS software (Version 4.3) by Elementar was used to carry out multi-point standard isotope calibration by generating a trend line (y=mx+c) that maps measured versus expected isotopic results, which is then used to calibrate sample results (Bocherens *et al*. 1994; Koch *et al*. 1997; Wright & Schwarcz 1999). Two internal enamel samples (Elephant and Hippo) were processed with every set of samples. 0.1 mg of IAEA-603 (International Atomic Energy Agency), NBS-18 (National Bureau of Standards, now National Institute of Standards and Technology), and the internal LM standard (Laaser Mamor) were used as secondary isotopic reference materials. The international reference standards are Vienna PeeDee Belemnite (VPDB) for carbon and oxygen and Vienna Standard Mean Ocean Water (VSMOW) for oxygen (Bocherens *et al*. 1996).

Chapter 3: Results

This chapter reports the results of carbon and oxygen isotopic ratios from each analyzed *taxon* in order of their abundance (from the most to the least abundant in terms of the number of sampled specimens) with median $\delta^{13}C$ and $\delta^{18}O$ values and ranges provided for each *taxon*. Collectively, 310 carbonate enamel samples were obtained for $^{13}C/^{12}C$ and $^{18}O/^{16}O$ isotopic ratios. This number (310) corresponds to both bulk and intra-tooth samples. However, during the handling of data, some intra-tooth samples have been recognized as insufficient in number to provide numerically useful sets. In these cases, intra-tooth samples have been averaged as one bulk value using the median function in Excel (Table S1 - Supplementary Information). Finally, 281 carbonate enamel samples were considered, consisting

of 176 bulk samples and 105 samples obtained through intra-tooth sampling.

In this paragraph, first, the bulk enamel results grouped for *taxa* were reported, then the bulk and intra-tooth results were divided in chronological order. The bulk and intra-tooth carbon and oxygen isotopic ratios produced in this study are summarized in Tables S2 and S3 (Supplementary Information), respectively.

3.1 $\delta^{13}C$ and $\delta^{18}O$ of bulk enamel samples

Bovidae. The bovids analyzed comprise 68 specimens belonging to five tribes identified: *Alcelaphini*, *Antilopini*, *Reduncini*, *Bovini*, and *Hippotragini*. Other specimens of bovids have been identified only at the family level.

Alcelaphini. Samples from *Alcelaphini* (n = 25) had a median $\delta^{13}C$ value of +1.6‰ with values ranging from -2.1‰ to +4.3‰, while the median $\delta^{18}O$ value was +27.5‰ with values ranging from +23.6‰ to +30.3‰. The $\delta^{13}C$ values indicate that *Alcelaphini* bovids had a predominantly C_4 diet.

Antilopini. A sample of *Antilopini* had a $\delta^{13}C$ value of -2.8‰ and a $\delta^{18}O$ value of +26.5‰.

Reduncini. Two samples of reduncini bovids had $\delta^{13}C$ values of -5.5‰ and +1.4‰, indicating a diet by mixed C_3-C_4 resources and a purely C_4 diet, respectively. The median $\delta^{18}O$ value was +25.3‰ with only two $\delta^{18}O$ values (+24.3‰ and +26.4‰).

Bovini. Bovine samples (n = 3) had a median $\delta^{13}C$ value of -1.9‰ with values ranging from -2.3‰ to -1‰, indicating a C_3-C_4 mixed diet. The median $\delta^{18}O$ value was +26.7‰ with values ranging from +26‰ to +27.8‰.

Hippotragini. Samples of *Hippotragini* (n = 2) had $\delta^{13}C$ values of -2‰ and +2.1‰, indicating a C_3-C_4 mixed diet and a C_4 diet, respectively. The $\delta^{18}O$ values were +24.4‰ and +27.6‰.

Bovidae *sensu lato.* Samples from bovids (n = 35) not identified in terms of tribes had a median $\delta^{13}C$ value of +1.5‰, with values ranging from -4.6‰ to +4.5‰, while the median $\delta^{18}O$ value was +24.9‰ with values ranging from +20.2‰ to +28.8‰. The $\delta^{13}C$ values clearly indicate the consumption of C_4 plants.

Collectively, the $\delta^{13}C$ values of all the analyzed bovids (median $\delta^{13}C$ = +1.2‰) show a prevalent C_4 diet although some carbon isotopic ratios are more depleted than others, pointing to a C_3-C_4 mixed diet (Fig.7). The depleted $\delta^{13}C$ belonged to samples of Bovidae *sensu lato* and *Reduncini*. For the $\delta^{18}O$, the range of values is homogeneous and related to the taxonomic diversity of the samples. In particular, *Alcelaphini* samples exhibited the most positive $\delta^{18}O$ values (median = +27.5‰), when compared with other bovid specimens (Fig.8).

Hippopotamidae. This category comprises 76 samples of *Hippopotamus* cf. *amphibius*. The median $\delta^{13}C$ and $\delta^{18}O$ values were -0.3‰ and +23.2‰, respectively. The $\delta^{13}C$ values of hippopotamids range from -6.6‰ to +2.6‰, indicating the co-presence of a prevalent C_4 diet but also the consumption of C_3 plants (C_3-C_4 mixed diet) (Fig.7). The $\delta^{18}O$ values, ranging from +18.2‰ to +28.7‰, confirm a well-known isotopic feature of hippopotamids as semi-aquatic mammals which show $\delta^{18}O$ values lower than those of terrestrial herbivores (Fig.8) (Bocherens *et al*. 1996, 2011; Cerling *et al*. 2008; Clementz & Koch 2001; Clementz *et al*. 2008; Levin *et al*. 2008; Souron *et al*. 2012; Sponheimer & Cerling 2014).

Equidae. The equids analyzed comprise 16 samples.

Hipparion. A sample of *Hipparion* had a $\delta^{13}C$ value of +0.1‰ and a $\delta^{18}O$ value of +26.5‰.

Equidae *sensu lato.* Samples from equids (n = 35) had a median $\delta^{13}C$ value of 0.6‰, with values ranging from -1.9‰ to +3.1‰, indicating that equids were C_4 plants feeder. The median $\delta^{18}O$ value was +26.2‰ with values ranging from +23.1‰ to +29.7‰.

Collectively, the $\delta^{13}C$ values of all the analyzed equids show a prevalent C_4 diet (Fig.7).

Suidae. This group comprises samples of two genera (*Kolpochoerus* n = 1, *Metridiochoerus* n = 1) and samples (n = 6) identified only at the family level.

Kolpochoerus. A sample of *Kolpochoerus* had a $\delta^{13}C$ value of -2.3‰ and a $\delta^{18}O$ value of +24.7‰.

Metridiochoerus. A sample of *Metridiochoerus* had $\delta^{13}C$ values of -0.6‰, while the $\delta^{18}O$ value was +28.2‰.

Suidae *sensu lato.* Samples from suids (n = 6) not identified in terms of tribes had a median $\delta^{13}C$ value of +0.5‰, with values ranging from -1.6‰ to +1.9‰ (C_4 diet), while the median $\delta^{18}O$ value was +27.8‰ with values ranging from +25.4‰ to +29.4‰.

The $\delta^{13}C$ values of all the analyzed equids show a prevalent C_4 diet, despite *Kolpochoerus* $\delta^{13}C$ value (-2.3‰) could be interpreted as a C_3-C_4 mixed diet (Fig.7).

Giraffidae. This family comprises only two samples. $\delta^{13}C$ values were +2.1‰ and +1.9‰ (C_4 diet) while $\delta^{18}O$ values were +29‰ and +28.8‰ (Fig.7, 8).

Crocodylidae. Six samples of crocodiles had a median $\delta^{13}C$ value of -9.3‰ with values ranging from -7.5‰ to -10.5‰, while the median $\delta^{18}O$ value was +25.5‰ with values ranging from +24.4‰ to +26.4‰ (Fig.7, 8). Crocodiles' $\delta^{13}C$ values are the most depleted among the analyzed *taxa*. In this case, carbon isotopic signals suggest that crocodiles have eaten fish or it may reflect variations within the diets of the herbivores that they ate, with more prey consuming C_3 plants (Ascari *et al*. 2018).

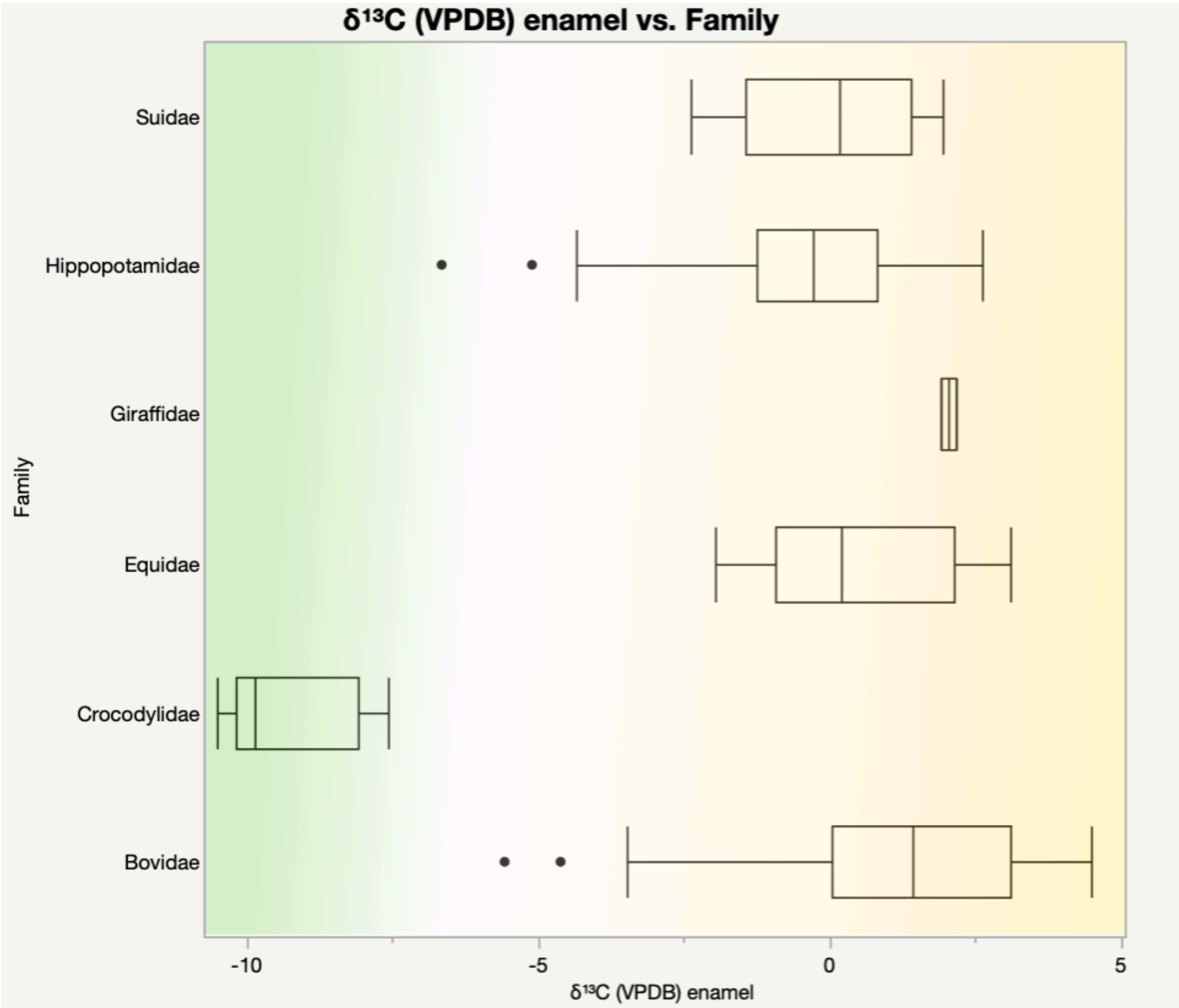


Fig.7. Boxplots of δ^{13}C values (enamel) for the fossil teeth from Melka Kunture (Ethiopia). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

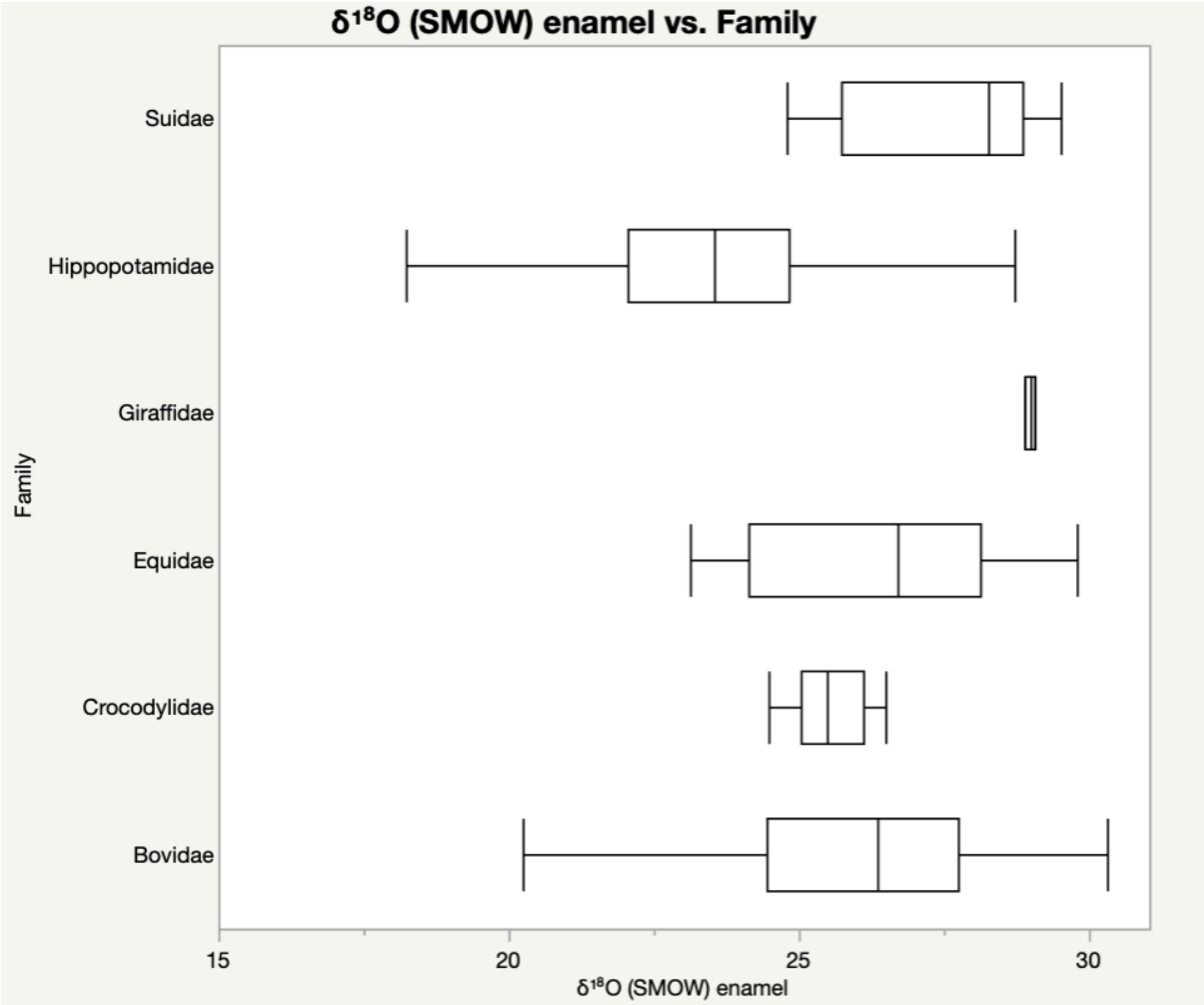


Fig.8. Boxplots of and $\delta^{18}O$ values (enamel) for the fossil teeth from Melka Kunture (Ethiopia).

3.2 Isotopic results associated with chronology

This paragraph is dedicated to the presentation of isotopic results from a chronological perspective. For this purpose, three main chronological windows have been considered: from ~1.95 to ~1.66 Ma (Early Pleistocene), from ~1.51 to ~1.13 Ma (Early Pleistocene), from ~1.0 to ~0.6 Ma (Early and Middle Pleistocene). In addition, samples (n = 16) from Bocherens *et al*. (1996) and unpublished results (n = 8) (produced by Giuseppe Briatico Master thesis, 2018) are included in the presentation of the results, as they referred to Melka Kunture. The Carbon and oxygen isotope abundances produced by this study are summarized in Tables S1, S2, and S3 (Supplementary Information), while Table S4 shows the isotopic values by Bocherens *et al*. (1996) and the Master thesis (Giuseppe Briatico, 2018).

3.2.1 Early Pleistocene isotopic data from ~1.95 to ~1.66 Ma

Bulk samples results*.* The bulk samples analyzed comprise 34 isotopic results belonging to hippopotamids, bovids, equids, suids, and crocodiles. Samples have been collected from three archaeological sites: Garba IV D (~1.95 Ma), Gombore I B (~1.66 Ma), and Karre I (Oldowan - no radiometric date) (Fig.9, 10).

Hippopotamidae. This category comprises 16 samples of *Hippopotamus* cf. *amphibius*. The median δ^{13}C and δ^{18}O values were -0.03‰ and +24.5‰, respectively. The δ^{13}C values of hippopotamids range from -1.2‰ to +2.6‰, indicating a C_4 diet. Only a δ^{13}C value (-4.7‰) was depleted compared to the other values, indicating the consumption of some C_3 plants in addition to C_4 plants. The δ^{18}O values range from +19.2‰ to +29.9‰.

Bovidae. The analyzed bovids (6 samples) belonged to *Alcelaphini* and bovid *sensu lato*.

Alcelaphini. Samples from *Alcelaphini* (n = 5) had a median δ^{13}C value of +1.8‰ with values ranging from -0.6‰ to +3.1‰, while the median δ^{18}O value was +29‰ with values ranging from +23.6‰ to +33.1‰. The data of δ^{13}C indicate that alcelaphin bovids had a predominantly C_4 diet.

Bovidae *sensu lato.* A sample of bovid had a δ^{13}C value of +3.3‰ and a δ^{18}O value of +27.7‰.

Bovid samples, collectively show a prevalent C_4 diet. For the δ^{18}O, the range of values is homogeneous.

Equidae. Only two samples of equid have been analyzed.

Hipparion. A sample of *Hipparion* had a δ^{13}C value of +0.1‰ and a δ^{18}O value of +26.5‰.

Equidae *sensu lato.* A sample of equid (*sensu lato*) had a $\delta^{13}C$ value of +2.7‰ and a $\delta^{18}O$ value of +30.9‰. Both sample results indicate that equids were C_4 plants feeder.

Suidae. This group is represented by 4 samples from *Kolpochoerus* and suids identified only at the family level.

Kolpochoerus. A sample of *Kolpochoerus* had a $\delta^{13}C$ value of -2.3‰ and a $\delta^{18}O$ value of +24.7‰.

Suidae *sensu lato.* Samples from suids (n = 3) not identified in terms of tribes had a median $\delta^{13}C$ value of +0.5‰, with values ranging from -0.7‰ to +1.2‰ (indicating a C_4 diet), while the median $\delta^{18}O$ value was +28‰ with values ranging from +26.5‰ to +28.9‰.

Crocodylidae. Six samples of crocodiles had a median $\delta^{13}C$ value of -9.3‰ with values ranging from -7.5‰ to -10.5‰, while the median $\delta^{18}O$ value is +25.5‰ with values ranging from +24.4‰ to +26.4‰. Crocodiles' $\delta^{13}C$ values were the most depleted among the other analyzed *taxa*, indicating that they have eaten fish or herbivores from C_3 environments (Ascari *et al*. 2018).

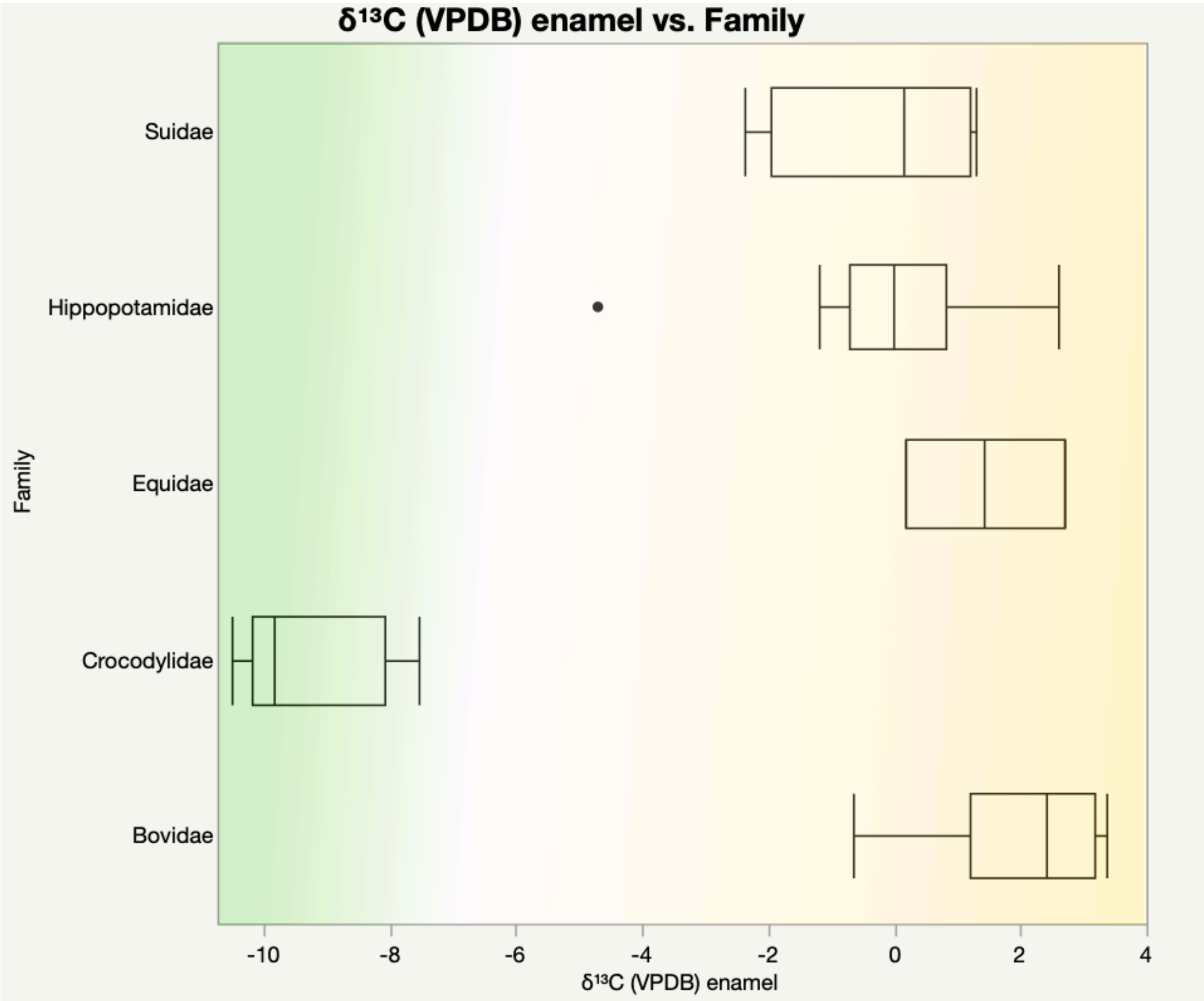


Fig.9. Boxplots of δ^{13}C values (enamel) for the fossil teeth from Garba IV D (~1.95 Ma), Gombore I B (~1.66 Ma), and Karre I (Oldowan). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

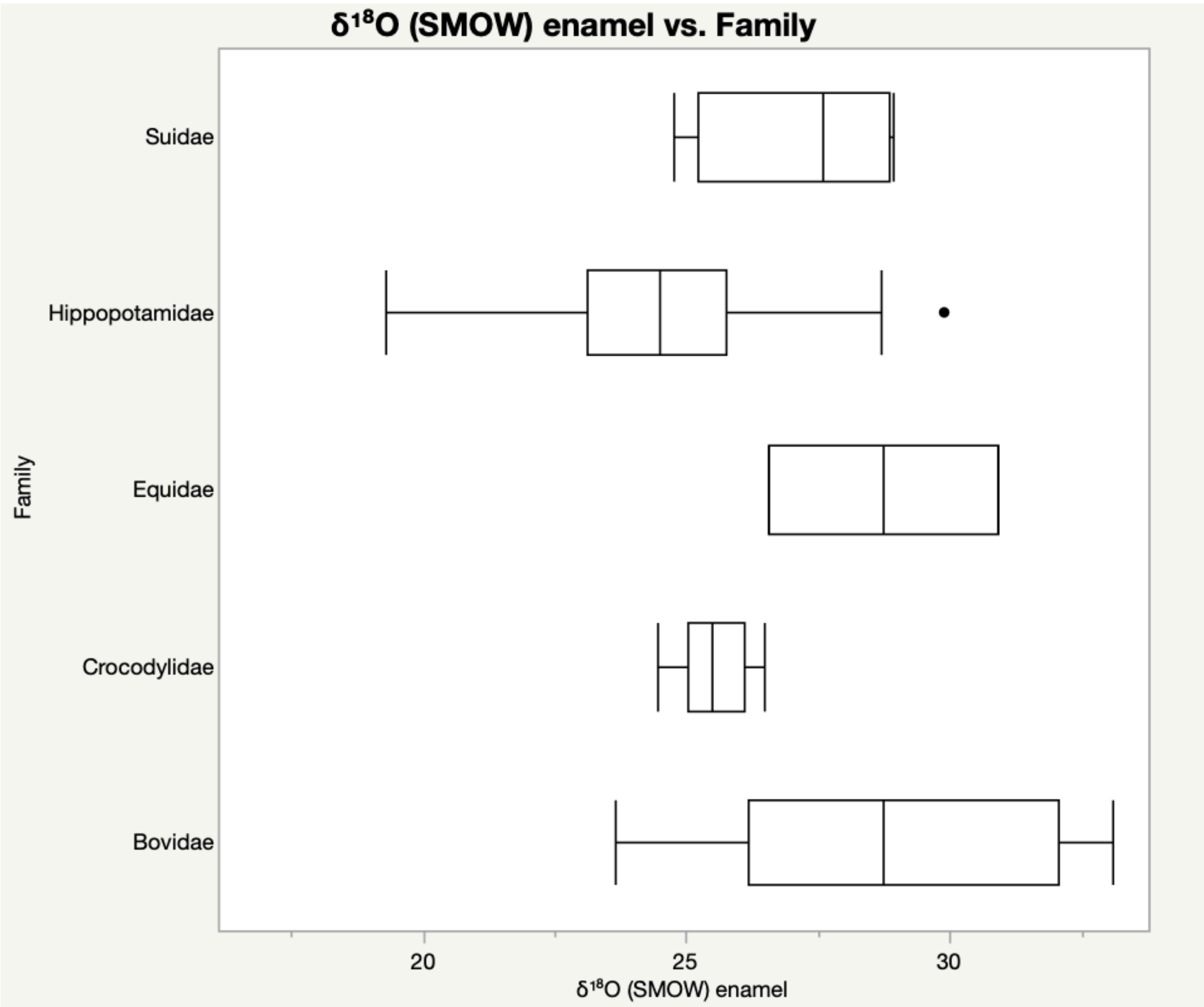


Fig.10. Boxplots of $\delta^{18}O$ values (enamel) for the fossil teeth from Garba IV D (~1.95 Ma), Gombore I B (~1.66 Ma), and Karre I (Oldowan).

3.2.2 Early Pleistocene isotopic data from ~1.51 to ~1.13 Ma

Bulk samples results*.* The analyzed bulk samples comprise 80 specimens belonging to hippopotamids, bovids, equids, suids, and giraffids. Samples have been collected from the following archaeological sites: Gombore I γ (~1.51 Ma), Gombore I δ (~1.41 Ma), Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIIJ (~1.13 Ma) (Fig.11, 12).

Hippopotamidae. This category comprises 40 samples of *Hippopotamus* cf. *amphibius*. The median $\delta^{13}C$ and $\delta^{18}O$ values were -0.1‰ and +22.7‰, respectively. The $\delta^{13}C$ values of hippopotamids range from -4.3‰ to +2.6‰, indicating a C_4 diet. Only a few $\delta^{13}C$ values (-4.7‰ and -4.1‰) were depleted compared to the other values, indicating as well as the consumption of C_3 plants. The $\delta^{18}O$ values range from +18.2‰ to +26.4‰.

Bovidae. The analyzed bovids (30 samples) belonged to *Alcelaphini*, *Bovini*, *Hippotragini*, *Reduncini*, and bovid *sensu lato*.

Alcelaphini. Two samples of *Alcelaphini* had $\delta^{13}C$ values of +4.2‰ and +0.7‰, while $\delta^{18}O$ values were +25.3‰ and +27.1‰.

Bovini. A sample of *Bovini* had a $\delta^{13}C$ value of -2.3‰ and a $\delta^{18}O$ value of +27.8‰.

Hippotragini. Two samples of *Hippotragini* have $\delta^{13}C$ values of +2.2‰ and -2‰, while $\delta^{18}O$ values were +24.4‰ and +27.6‰.

Reduncini. A sample of *Reduncini* had a $\delta^{13}C$ value of -5.5‰ and a $\delta^{18}O$ value of +24.3‰.

Bovidae *sensu lato.* The sample of bovids (n = 24) had a median $\delta^{13}C$ value of +1.5‰, with values ranging from -3.4‰ to +4.5‰, while the median $\delta^{18}O$ value was +24.3‰ with values ranging from +20.2‰ to +27.7‰.

Bovid samples, collectively show a prevalent C_4 diet, despite some $\delta^{13}C$ values indicating the consumption of both C_3 and C_4 plants. For the $\delta^{18}O$, the range of values is homogeneous.

Equidae*.* Five samples of equid *sensu lato* have been analyzed. The median of $\delta^{13}C$ values was +1‰, with values ranging from -1.9‰ to +3.1‰ ‰ (indicating a C_4 diet), while the median of $\delta^{18}O$ values was +24.8‰ with values ranging from +23.1‰ to +28.2‰.

Suidae. This group is represented by 4 samples from *Metridiochoerus* and suids identified only at the family level.

Metridiochoerus. A sample had a $\delta^{13}C$ value of -0.6‰ and a $\delta^{18}O$ value of +28.2‰.

Suidae *sensu lato.* Samples from suids (n = 3) not identified in terms of tribes had a median $\delta^{13}C$ value of +0.5‰, with values ranging from -1.6‰ to +1.9‰ (indicating a C_4 diet), while the median $\delta^{18}O$ value is +27.7‰ with values ranging from +25.4‰ to +29.4‰.

Giraffidae. Only two samples of giraffids had $\delta^{13}C$ values of +2.1‰ and +1.9‰ (C_4 diet) while $\delta^{18}O$ values are +29‰ and +28.8‰.

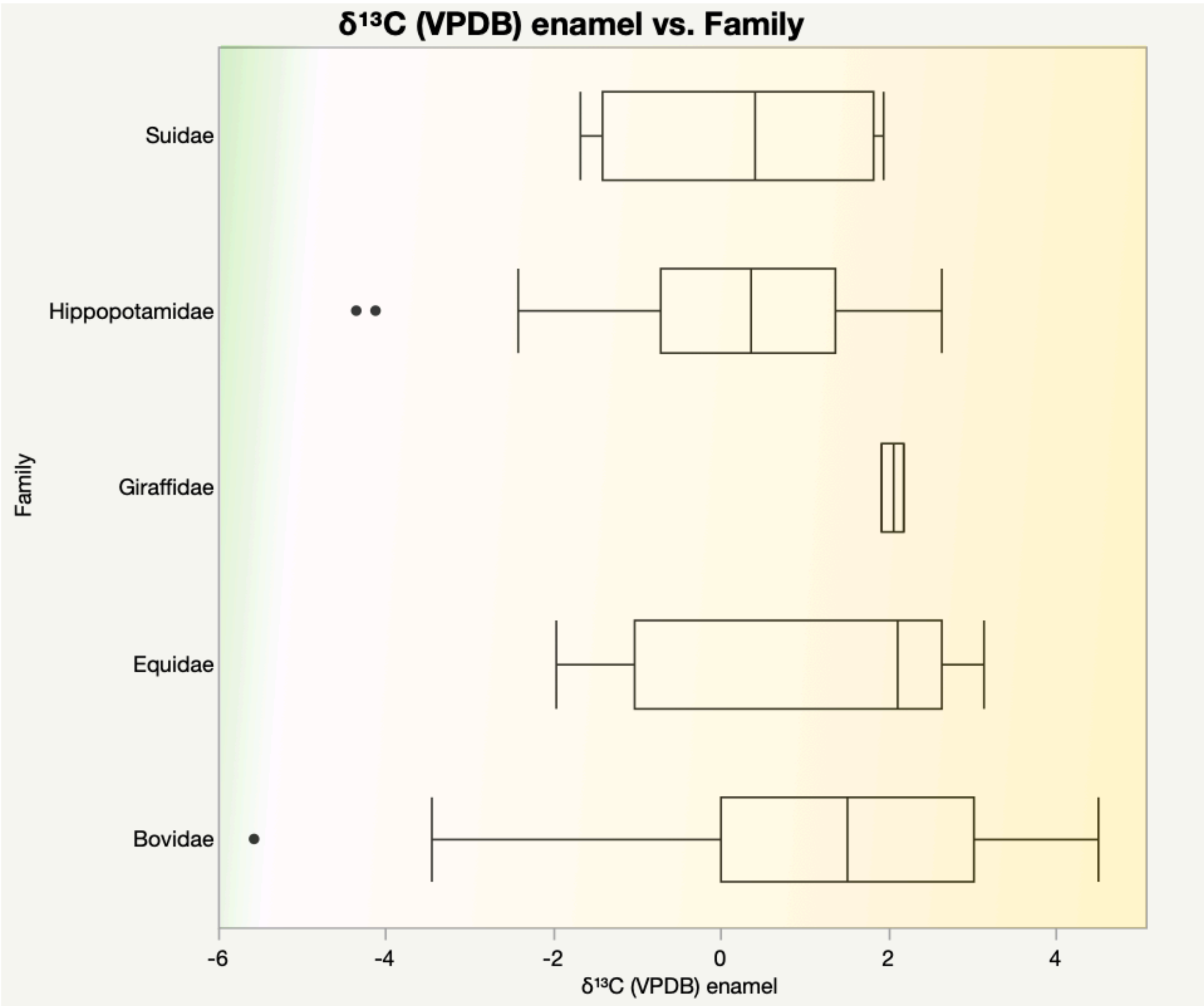


Fig.11. Boxplots of $\delta^{13}C$ values (enamel) for the fossil teeth from Gombore I γ (~1.51 Ma), Gombore I δ (~1.41 Ma), Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIIJ (~1.13 Ma). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

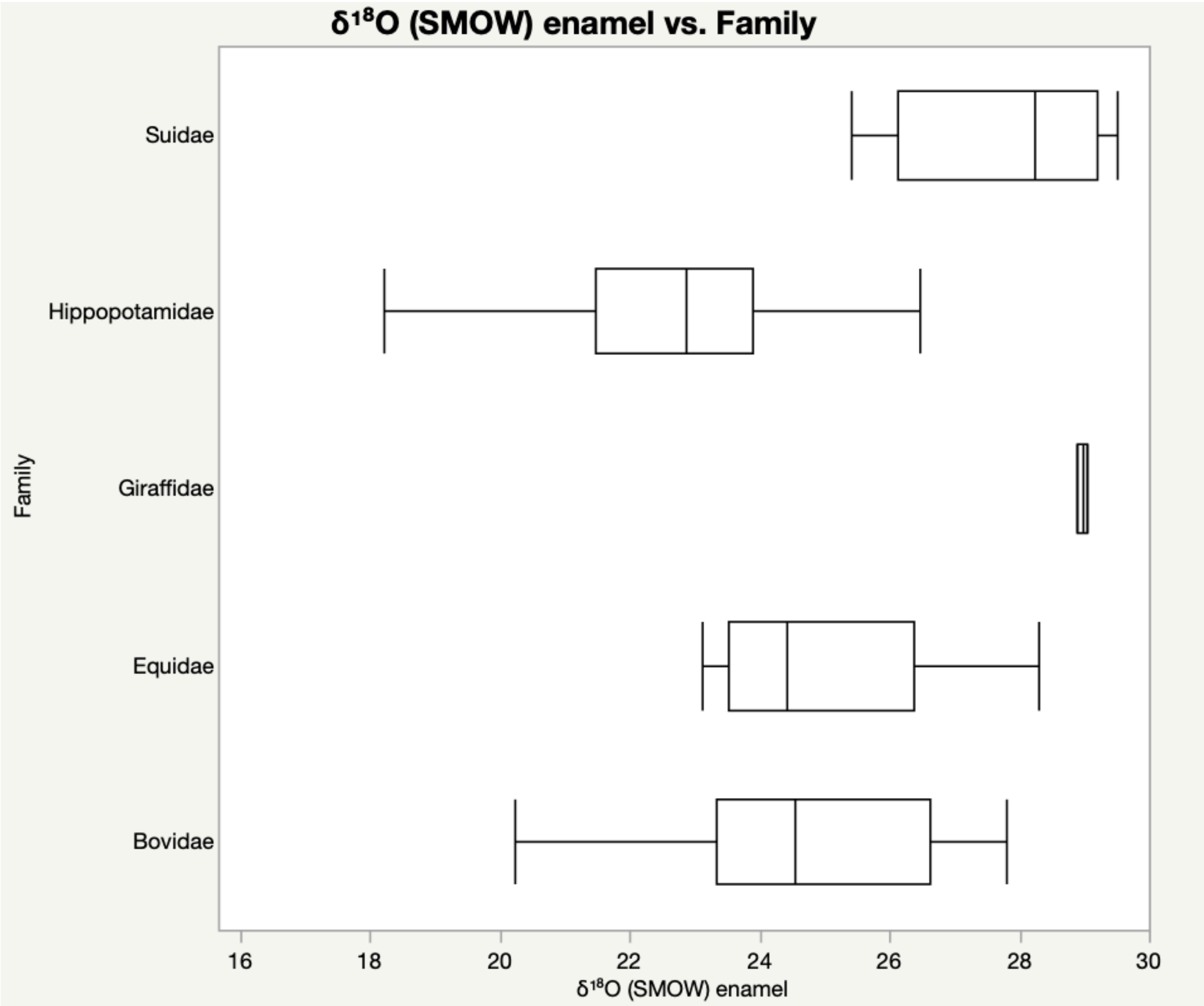


Fig.12. Boxplots of $\delta^{18}O$ values (enamel) for the fossil teeth from Gombore I γ (~1.51 Ma), Gombore I δ (~1.41 Ma), Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIIJ (~1.13 Ma), and Garba XIII C (~1.0 Ma).

3.2.3 Early and Middle Pleistocene isotopic data from ~1.0 to ~0.6 Ma

Bulk samples results*.* The analyzed bulk samples comprise 62 specimens belonging to hippopotamids, bovids, and equids. Samples have been collected from five archaeological areas: Garba XIII C (~1.0 Ma), Gombore II-1 (~1.0 Ma), Gombore II-2 (~0.75 Ma), Garba III C (~0.68 Ma), Garba I B (~0.6 Ma) and Gombore III (Fig.13, 14).

Hippopotamidae. This category comprises 18 samples of *Hippopotamus* cf. *amphibius*. The median $\delta^{13}C$ and $\delta^{18}O$ values were -1.6‰ and +24‰, respectively. The $\delta^{13}C$ values of hippopotamids range from -2.6‰ to +0.6‰, indicating a C_4 diet. Two $\delta^{13}C$ values (-4.3‰ and -5.1‰) were depleted, indicating a C_3-C_4 mixed diet. The $\delta^{18}O$ values range from +20.4‰ to +28.6‰.

Bovidae. The bovids analyzed (36 specimens) belonged to *Alcelaphini*, *Reduncini*, *Antilopini*, *Bovini*, and bovid *sensu lato*.

Alcelaphini. Samples from *Alcelaphini* (n = 22) had a median $\delta^{13}C$ value of +1.6‰ with values ranging from -2.1‰ to +4.3‰, while the median $\delta^{18}O$ value was +27.8‰ with values ranging from +24.6‰ to +31.8‰. The data of $\delta^{13}C$ indicate that alcelaphin bovids had a predominantly C_4 diet.

Antilopini. A sample of *Antilopini* had a $\delta^{13}C$ value of -2.8‰ and a $\delta^{18}O$ value of +26.5‰.

Reduncini. Two reduncini samples had $\delta^{13}C$ values of +0.7‰ and +1.4‰, while $\delta^{18}O$ values were +30.7‰ and +26.4‰.

Bovini. Bovine samples (n = 3) had a median $\delta^{13}C$ value of -1.2‰ with values ranging from -0.6‰ to -1.9‰, while the median $\delta^{18}O$ value was +28.6‰ with values ranging from +26‰ to +31.1‰.

Bovidae *sensu lato.* Five samples of bovid had a median $\delta^{13}C$ value of -0.3‰ with values ranging from -3.4‰ to +3.9‰, while the median $\delta^{18}O$ value is +26.7‰ with values ranging from +23.8‰ to +28.8‰.

Bovid samples, collectively show a prevalent C_4 diet, despite some $\delta^{13}C$ values indicating the consumption of both C_3 and C_4 plants. For the $\delta^{18}O$, the range of values is homogeneous.

Equidae. Eleven samples of equid *sensu lato* have been analyzed. The median $\delta^{13}C$ value was +0.2‰, with values ranging from -1.9‰ to +2.9‰ (C_4 diet). The median $\delta^{18}O$ value was +27‰, with values ranging from +23.7‰ to 29.7‰.

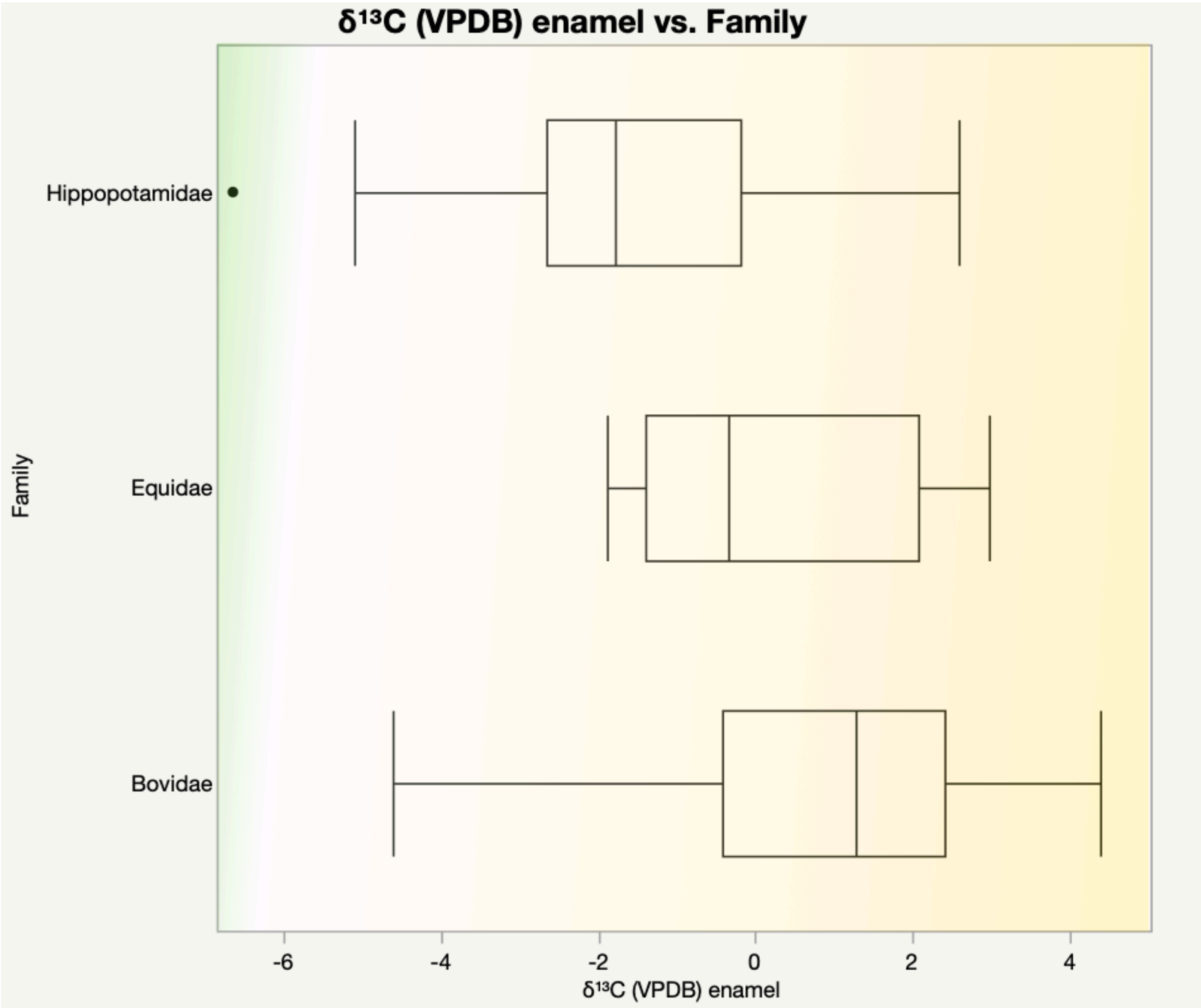


Fig.13. Boxplots of δ^{13}C values (enamel) for the fossil teeth from Garba XIII C (~1.0 Ma), Gombore II-1 (~1.0 Ma), Gombore II-2 (~0.75 Ma), Garba III C (~0.68 Ma), Garba I B (~0.6 Ma), and Gombore III. Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

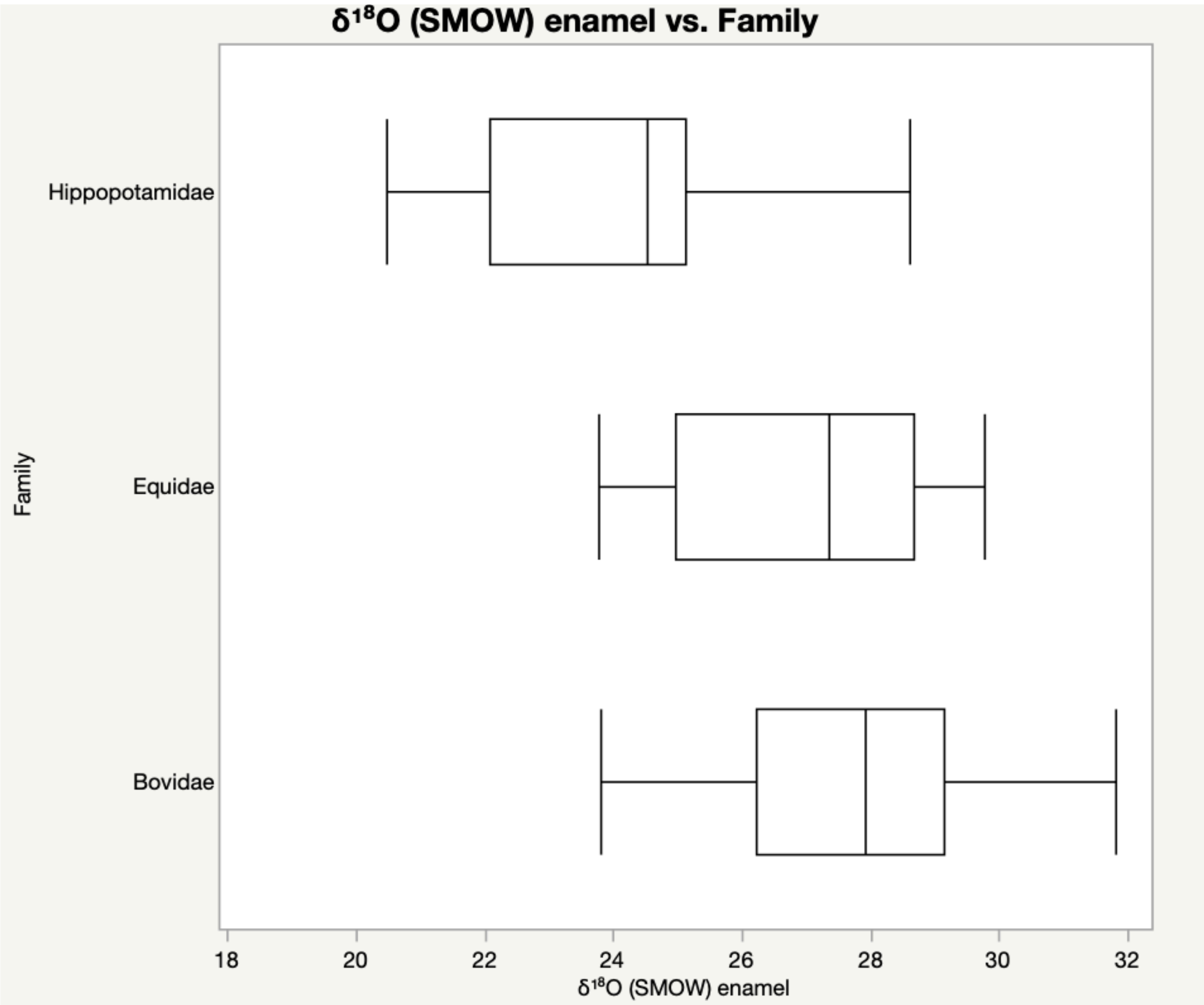


Fig.14. Boxplots of δ^{18}O values (enamel) for the fossil teeth from Garba XIII C (~1.0 Ma), Gombore II-1 (~1.0 Ma), Gombore II-2 (~0.75 Ma), Garba III C (~0.68 Ma), Garba I D (~0.6 Ma), and Gombore III.

3.2.4 Early Pleistocene intra-tooth data from ~1.95 to ~1.0 Ma

Crocodylidae. A serially sampled crocodile tooth (samples = n 9) from Garba IV D (~1.95 Ma) had $\delta^{13}C$ values ranging from -9.6‰ to -9.2‰ while the $\delta^{18}O$ values ranged from +24.9‰ to +25.5‰. The $\delta^{13}C$ values indicate a diet dominated by fish, or it may reflect variations within the diets of the herbivores that they ate (Ascari *et al*. 2018) (Fig.15, 16).

Hippopotamidae. This group comprises 79 samples from 8 tusks of *Hippopotamus* cf. *amphibius* from Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIII C (~1.0 Ma).

Hippo 111. (samples = n 12) $\delta^{13}C$ values vary from -0.3‰ to +1.6‰, while $\delta^{18}O$ values range from +21‰ to +23.7‰.

Hippo 360. (samples = n 10) $\delta^{13}C$ values vary from +0.5‰ to +3.6‰, while $\delta^{18}O$ values range from +21.5‰ to +23.3‰.

Hippo 316. (samples = n 7) $\delta^{13}C$ values vary from -0.3‰ to +2.5‰, while $\delta^{18}O$ values range from +23.7‰ to +26.3‰.

Hippo 103. (samples = n 9) $\delta^{13}C$ values vary from +0.8‰ to +1.4‰, while $\delta^{18}O$ values range from +22.9‰ to +24.2‰.

Hippo 128. (samples = n 13) $\delta^{13}C$ values vary from +0.1‰ to +1.7‰, while $\delta^{18}O$ values range from +23.4‰ to +25.5‰.

Hippo 771. (samples = n 7) $\delta^{13}C$ values vary from +0.1‰ to +0.6‰, while $\delta^{18}O$ values range from +23.4‰ to +23.9‰.

Hippo 200. (samples = n 12) $\delta^{13}C$ values vary from -1.5‰ to +1‰, while $\delta^{18}O$ values range from +18.2‰ to +21.5‰.

Hippo 2056. (samples = n 9) $\delta^{13}C$ values vary from -2.2‰ to +1.8‰, while $\delta^{18}O$ values range from +18‰ to +19.7‰.

Intra-tooth analyses on hippopotamid tusks show uniform isotopic results with no significant variation in either $\delta^{13}C$ or $\delta^{18}O$. These values indicate a stable C_4 diet and water conditions during the growth of the tusks (Fig.15, 16).

Equidae. A molar of equid (ID 325) (samples = n 9) from Simbiro III gully had $\delta^{13}C$ values ranging from +1.7‰ to +2.5‰, and $\delta^{18}O$ values ranging from +21‰ to +24.8‰. The $\delta^{13}C$ values indicate a diet dominated by C_4 resources (Fig.15, 16).

Suidae. The canine of suid (ID 400) (samples = n 9) from Simbiro III gully had $\delta^{13}C$ values ranging from -1.9‰ to -3.1‰, indicating a C_3-C_4 mixed diet, while $\delta^{18}O$ values had a range from +21.7‰ to +23.1‰ (Fig.15, 16).

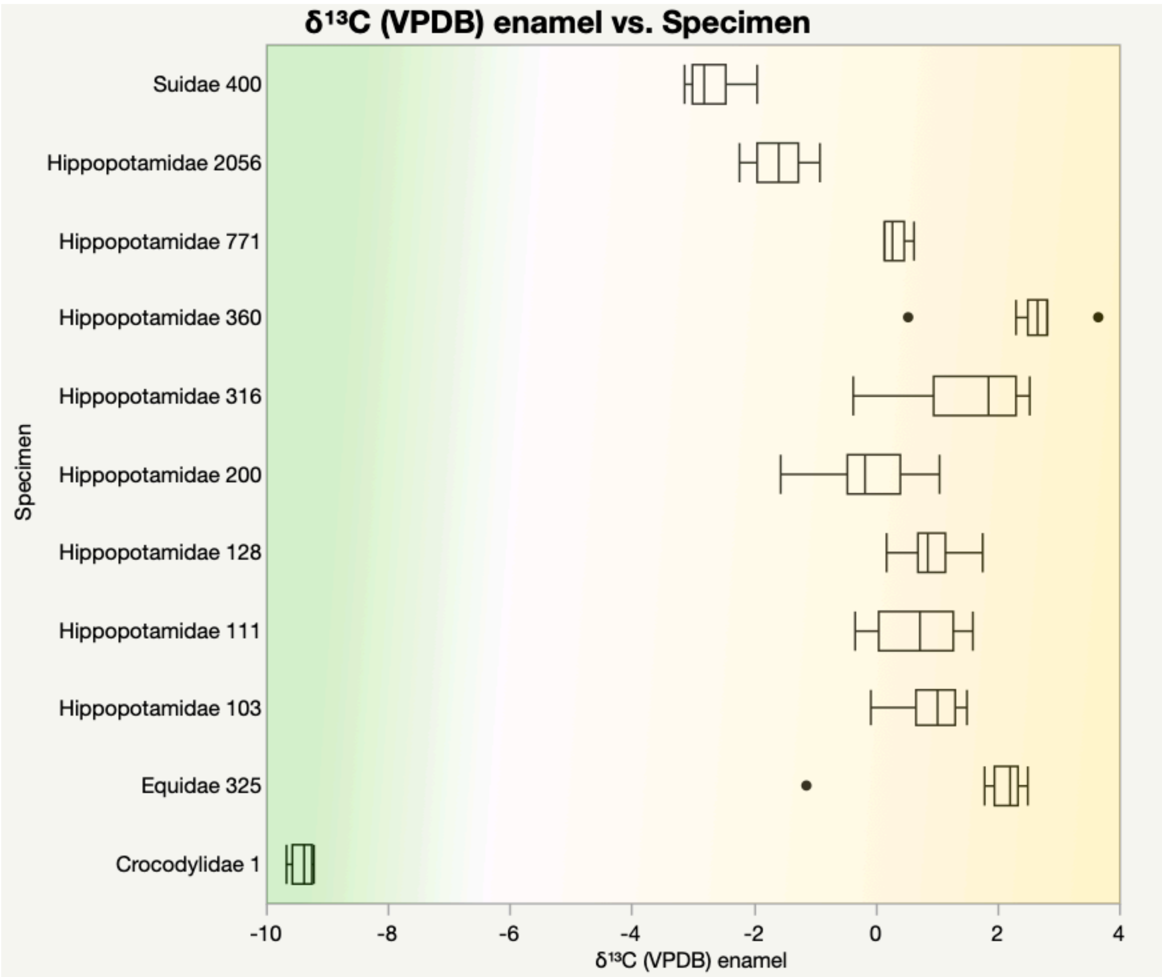


Fig.15. Boxplots of $\delta^{13}C$ values (enamel) for the fossil specimen from Garba IV D (~1.95 Ma), Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIII C (~1.0 Ma). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

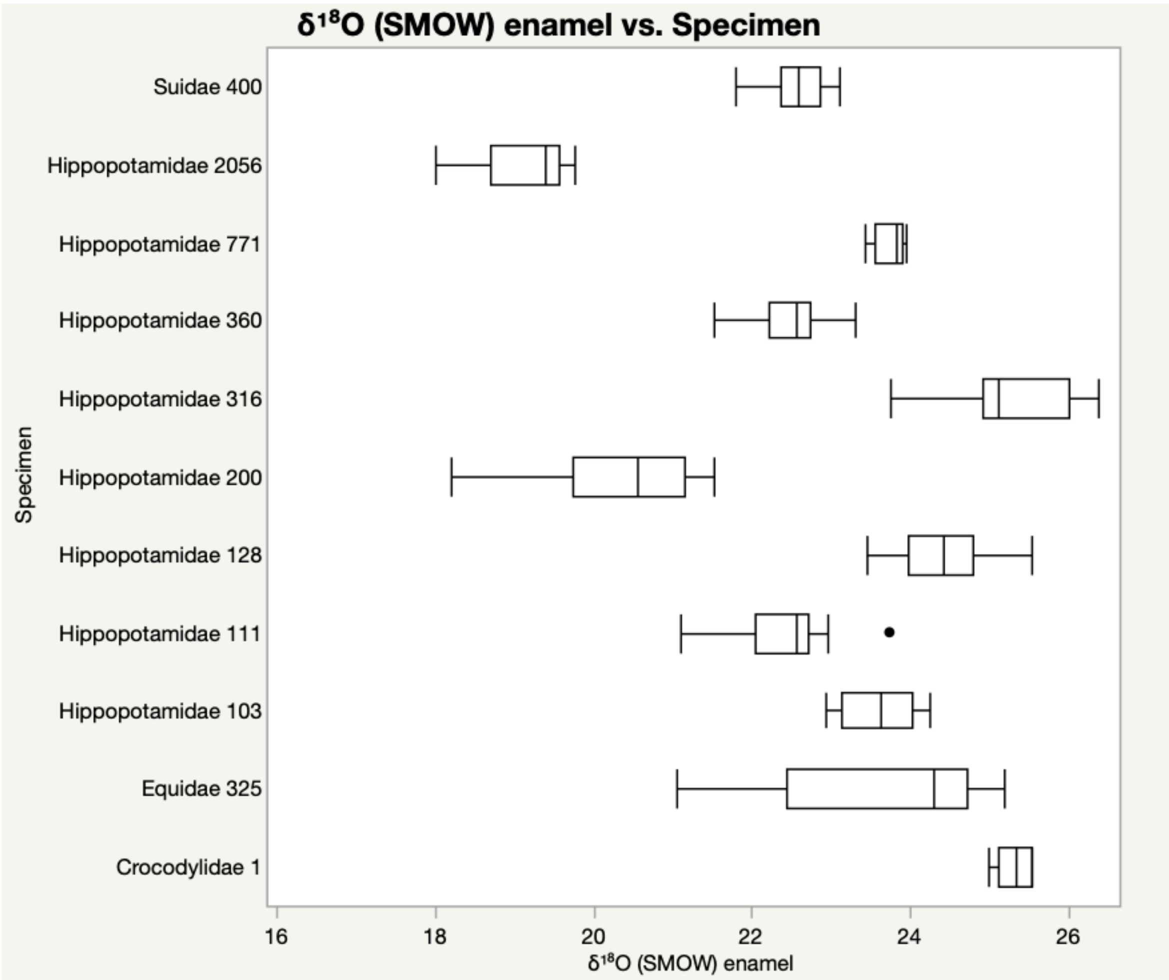


Fig.16. Boxplots of δ^{18}O values (enamel) for the fossil specimen from Garba IV D (~1.95 Ma), Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIII C (~1.0 Ma).

3.3 Statistical analysis

$\delta^{13}C$ and $\delta^{18}O$ values were measured on 187 fossil teeth from the Melka Kunture site (Ethiopia). Isotopic results were classified according to some categorical variables or factors: *taxa* (Hippopotamidae, Bovidae, Equidae, Suidae, Giraffidae, Crocodylidae); habitat (semi-aquatic *vs.* terrestrial); chronology (Early and Middle Pleistocene).

The aim of the statistical analysis is to verify whether $\delta^{13}C$ and $\delta^{18}O$ (continuous response variables) are associated with factors such as *taxa*, habitat, and chronology.

The isotopic results are tested both graphically and by statistical test (Shapiro-Wilk test), to verify whether the data follow the normal distribution. In this case, the Null hypothesis (H_0) implies that "data are normally distributed", while the Alternative hypothesis (H_1) implies that "data are not normally distributed". When the hypothesis of the normal distribution is accepted, parametric tests such as the T-test and the ANOVA test have been used; when the hypothesis of the normal distribution is rejected, non-parametric tests such as the Mann-Whitney U-test (also known as Wilcoxon Rank Sum Test) or the Kruskal-Wallis test have been used. The T-test and the Mann-Whitney U-test are used with two groups or levels, while the ANOVA and the Kruskal-Wallis tests have been used with three or more groups (Fig.17).

The Null hypothesis (H_0) of the ANOVA test states that the normally distributed population means of two or more groups (μ_1, μ_2, etc.) are assumed to be identical to each other (Fig.18, left graph); in contrast, the Alternative hypothesis (H_1) (Fig.18, right graph), which come into plays if the Null hypothesis (H_0) is rejected, asserts that there is almost one group whose mean value is different from the other groups (Levene 1960; Sawyer 2009; Shapiro & Wilk 1965; Wackerly *et al.* 2002).

H_0: $\mu_1 = \mu_2 = \ldots = \mu_k$ *vs.* H_1: almost one mean differs from the others

The Null hypothesis (H_0) of the Kruskal-Wallis test states that "samples in all the groups are drawn from the same population", while the Alternative hypothesis (H_1) states "one or more samples from one or more groups are drawn from different populations".

In the case of two groups, the Null hypothesis (H_0) and the Alternative hypothesis (H_1) of the T-test and the Mann-Whitney U-test are respectively:

T-test: **H_0: $\mu_1 = \mu_2$ *vs.* H_1: $\mu_1 \neq \mu_2$**

U-test: **H_0: both samples are drawn from the same population**

H_1: the two samples are drawn from different populations

The Null hypothesis (*H_0*) is rejected when the *p*-value (probability of an observed or extreme result), yielded by the test is less than a; it is the predetermined upper limit risk for committing a Type 1 error, which is the statistical false positive of incorrectly rejecting the Null hypothesis (*H_0*) and inferring the groups 'means differ when the groups are from the same population. By convention, a is typically set to 0.05. The *p*-value generated by the test statistic is based on numerical analysis of the experimental data and represents the probability of committing a Type 1 error if the Null hypothesis (*H_0*) is rejected. Whether the *p*-value is more than a, we accept the Null hypothesis (*H_0*), while whether *p*-value is less than a, there is a statistically significant result and the values in the two groups are inferred to differ from each other and to represent separate populations. In this case, the Null hypothesis (*H_0*) is rejected, and the Alternative hypothesis (*H_1*) is accepted (Sawyer 2009). JMP software (16 version, license by University of Tübingen) is used.

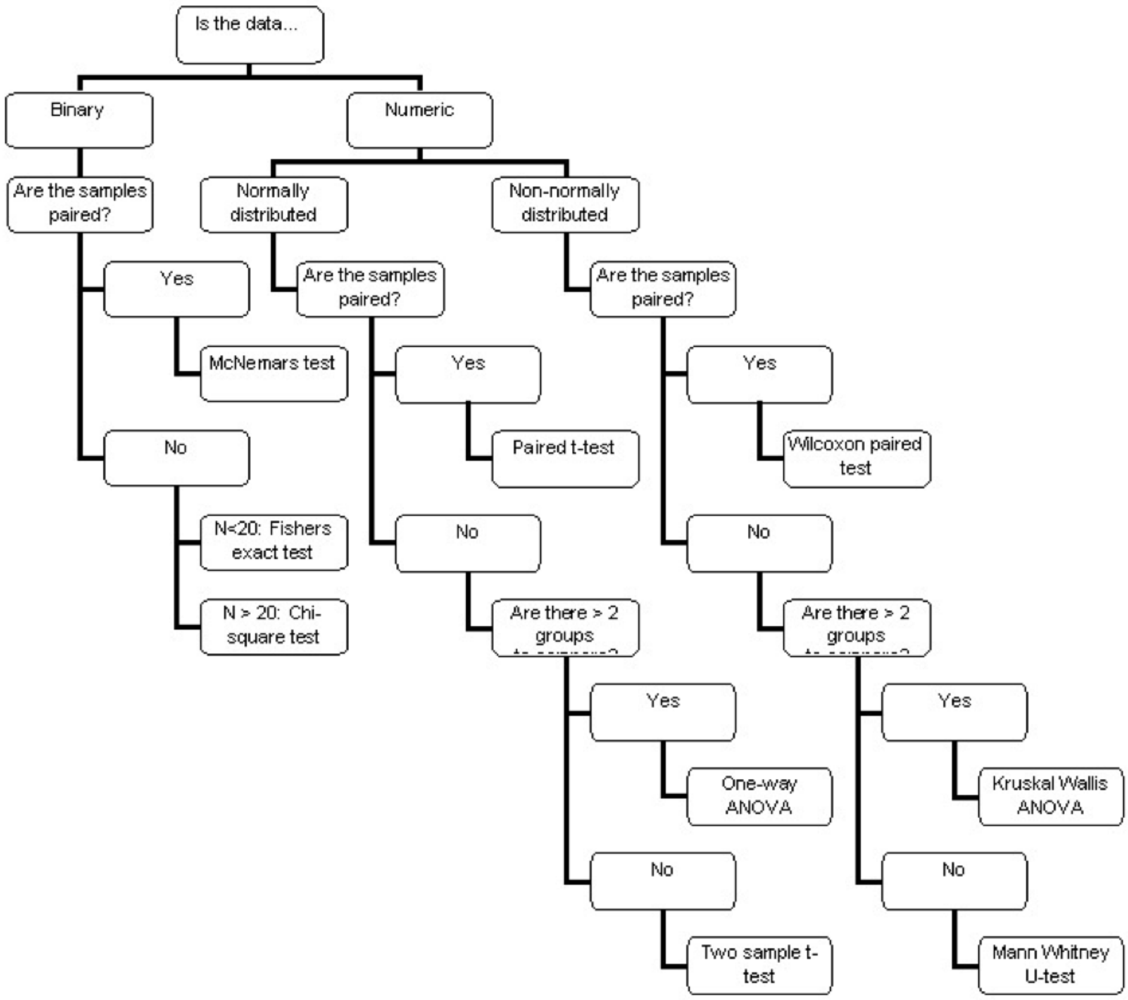


Fig.17. Schematic illustration about "How to choose the right statistical test?" for binary and numeric data (courtesy of Sandro Tomaro).

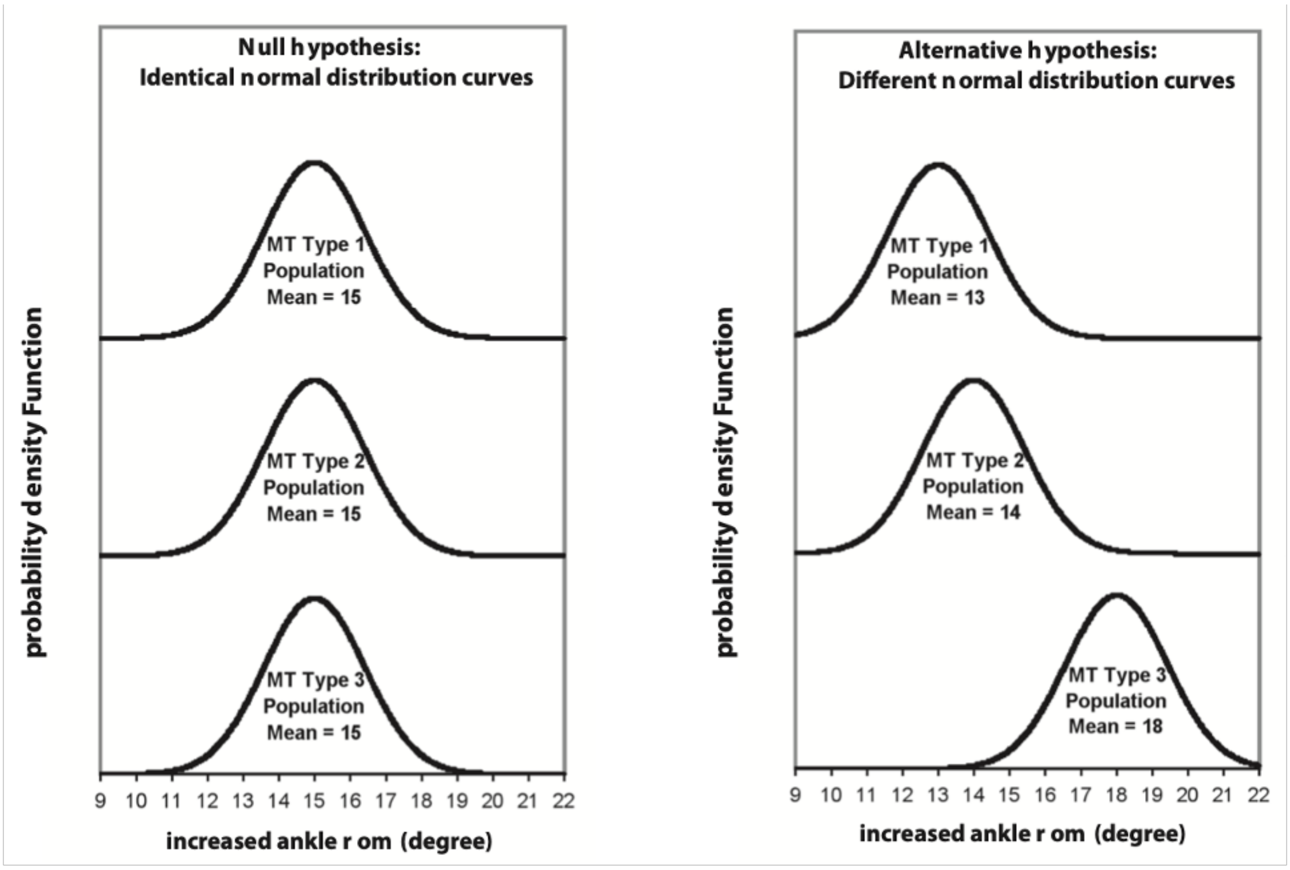


Fig.18. Graphical representation of statistical Null (left graph) and Alternative (right graph) hypotheses for ANOVA test (Sawyer 2009).

First, the isotopic results from all the *taxa* are plotted by Kernel density (histogram style) to determine which mammalian families are well-represented or underrepresented. The graphs (Fig.19, 20), for both $\delta^{13}C$ and $\delta^{18}O$ values, show that only Hippopotamidae (81 samples) and Bovidae (69 samples) groups have bell-shaped distribution, consistent with a normal assumption, while the other groups (19 samples of Equidae, 9 samples of Suidae, 7 samples of Crocodylidae, and 2 samples of Giraffidae) show an ascending or descending distribution (not "bell-shaped").

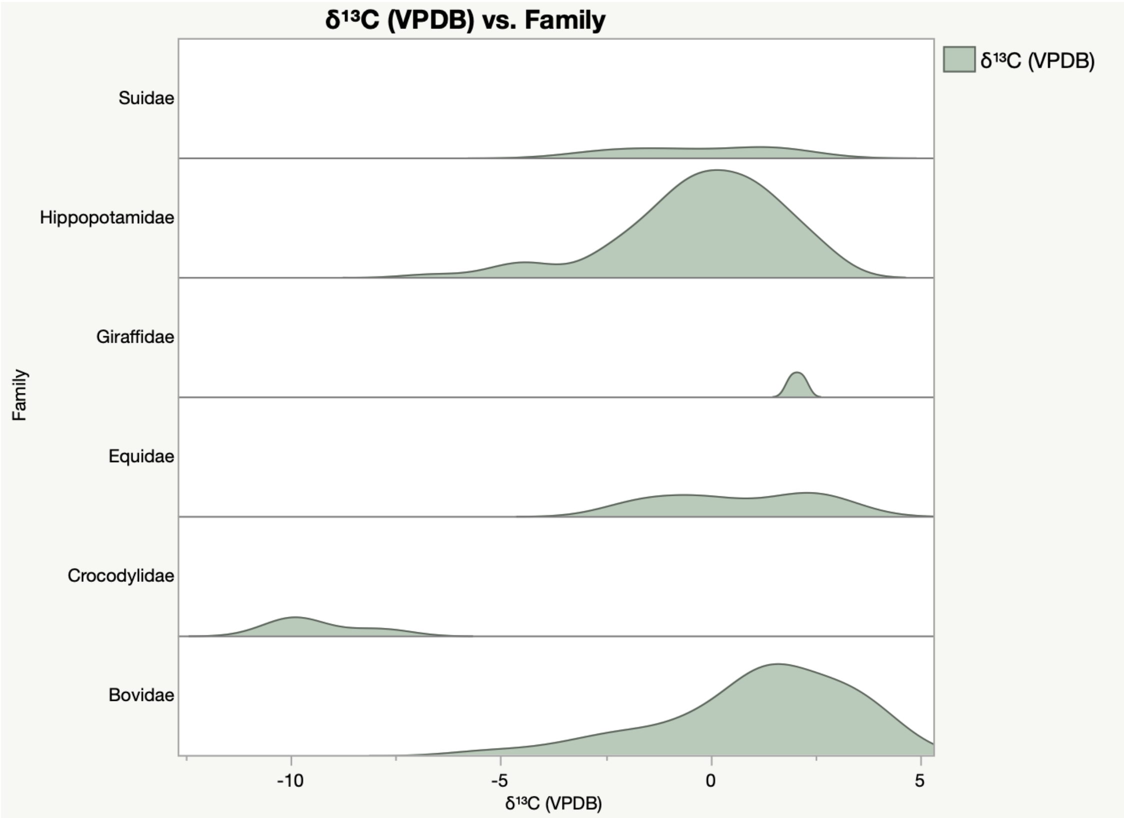


Fig.19. Kernel density plotting $\delta^{13}C$ values of the analyzed *taxa* for isotopic analysis (by JMP 16).

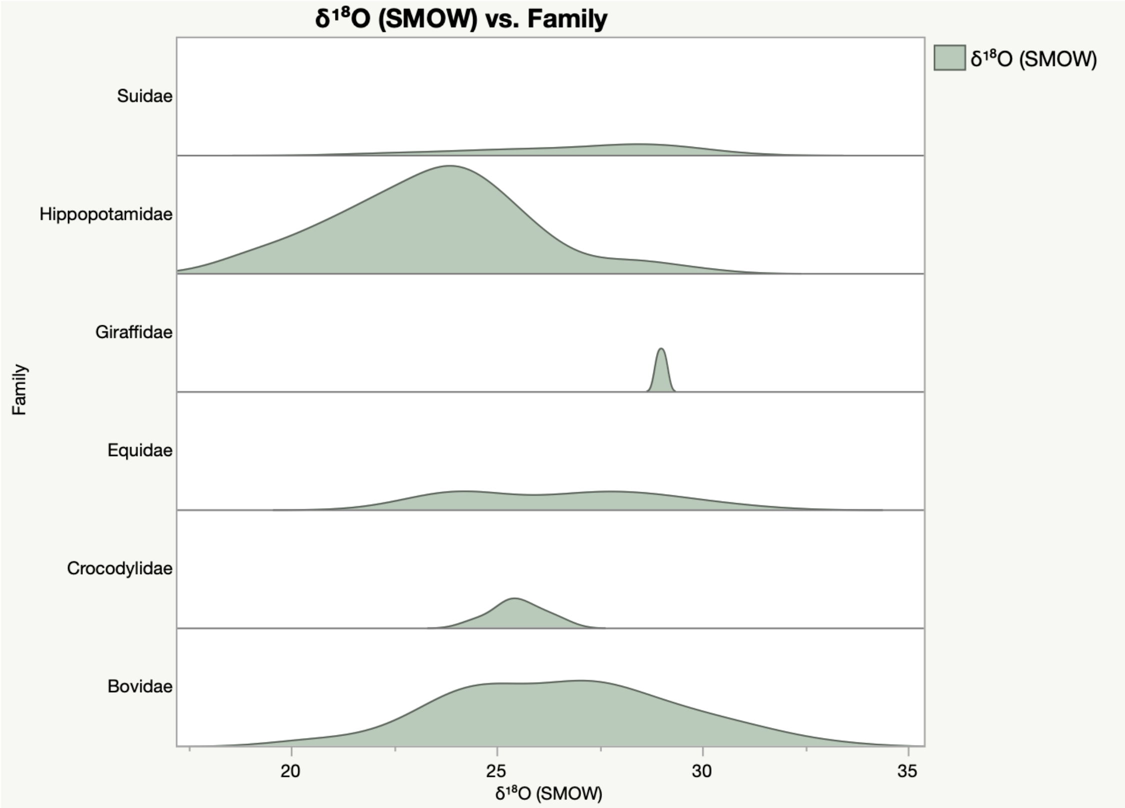


Fig.20. Kernel density plotting $\delta^{18}O$ values of the analyzed *taxa* for isotopic analysis (by JMP 16). The following boxplots (Fig.21, 22) confirm what has been observed by Kernel density. It is concluded that for the groups of Equidae, Suidae, Giraffidae, and Crocodylidae, it would be necessary to expand the sample with further isotopic measurements.

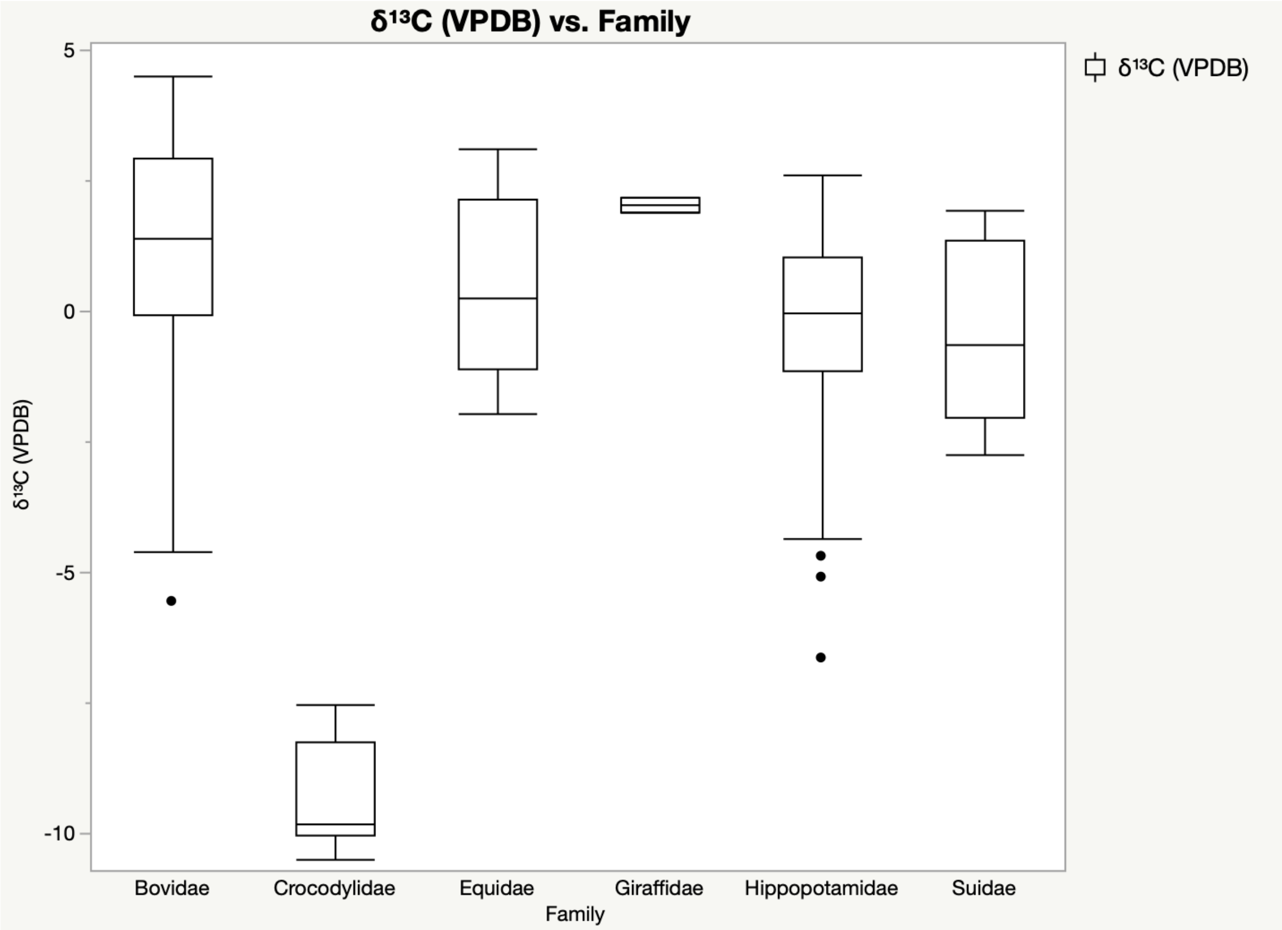


Fig.21. Boxplots with $\delta^{13}C$ values of the analyzed *taxa* for isotopic analysis (by JMP 16).

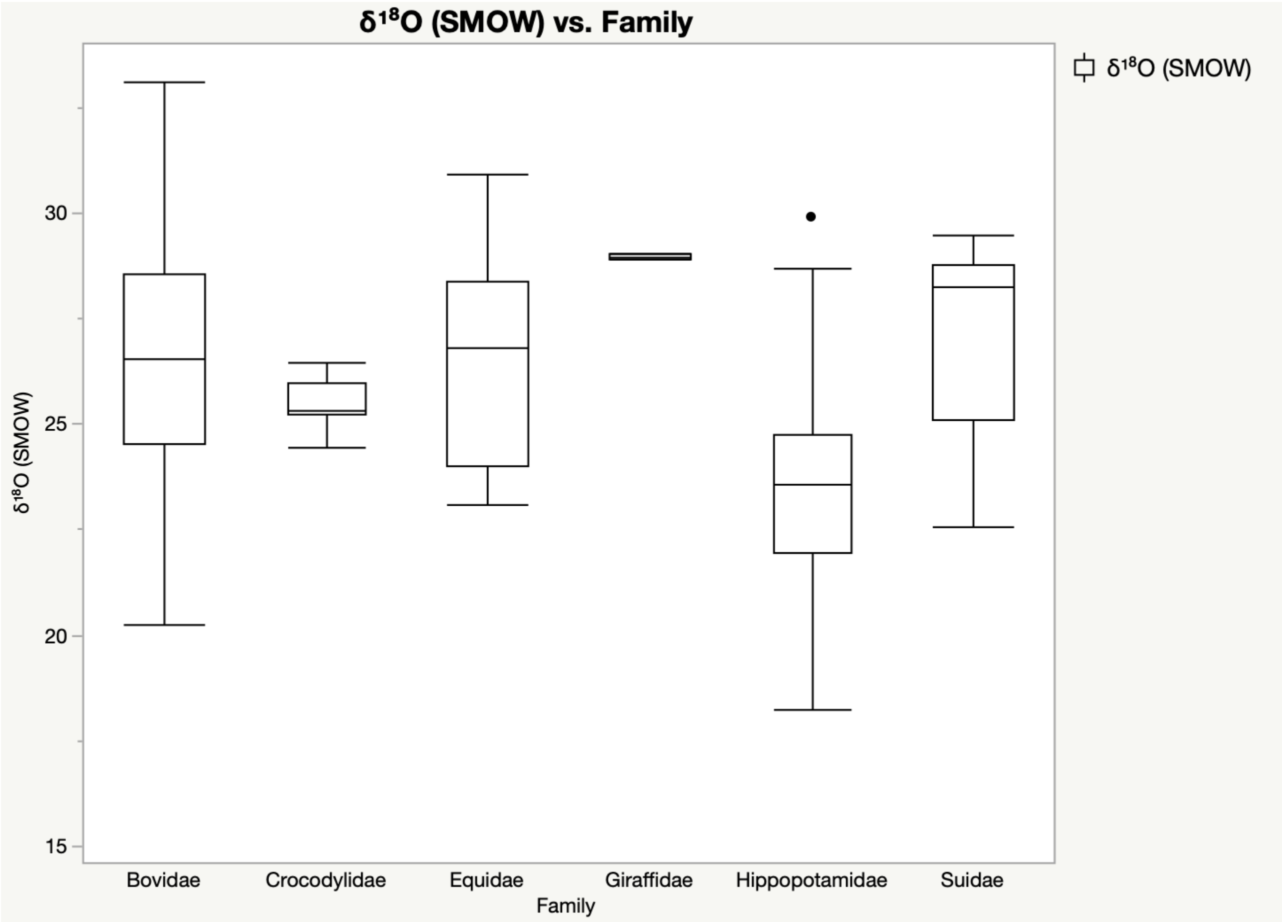


Fig.22. Boxplots with $\delta^{18}O$ values of the analyzed *taxa* for isotopic analysis (by JMP 16).

Therefore, the isotopic results have been grouped into several Tests (1. Semi-aquatic *vs*. terrestrial herbivores; 2. Hippopotamidae vs. Bovidae; 3. Bovids; 3.1. Bovidae (sensu lato) vs. Bovidae (Alcelaphini); 4. Terrestrial herbivores; 5. Hippos (Early and Middle Pleistocene); 6. Bovids (Early and Middle Pleistocene) are discussed in the paragraphs below.

Test 1. Semi-aquatic *vs.* terrestrial herbivores

Test 1 comprises two sample groups, the semi-aquatic and the terrestrial herbivores. The category of semi-aquatic herbivores contains 81 isotopic results from Hippopotamidae. The terrestrial herbivores' category (total = n 99 enamel samples) contains 69 isotopic results from Bovidae, 19 from Equidae, 9 from Suidae, and 2 from Giraffidae.

Fig.23, and 24 (Kernel density and boxplots, respectively) show the plotting of $\delta^{13}C$ in both groups. A long-left tail is observed.

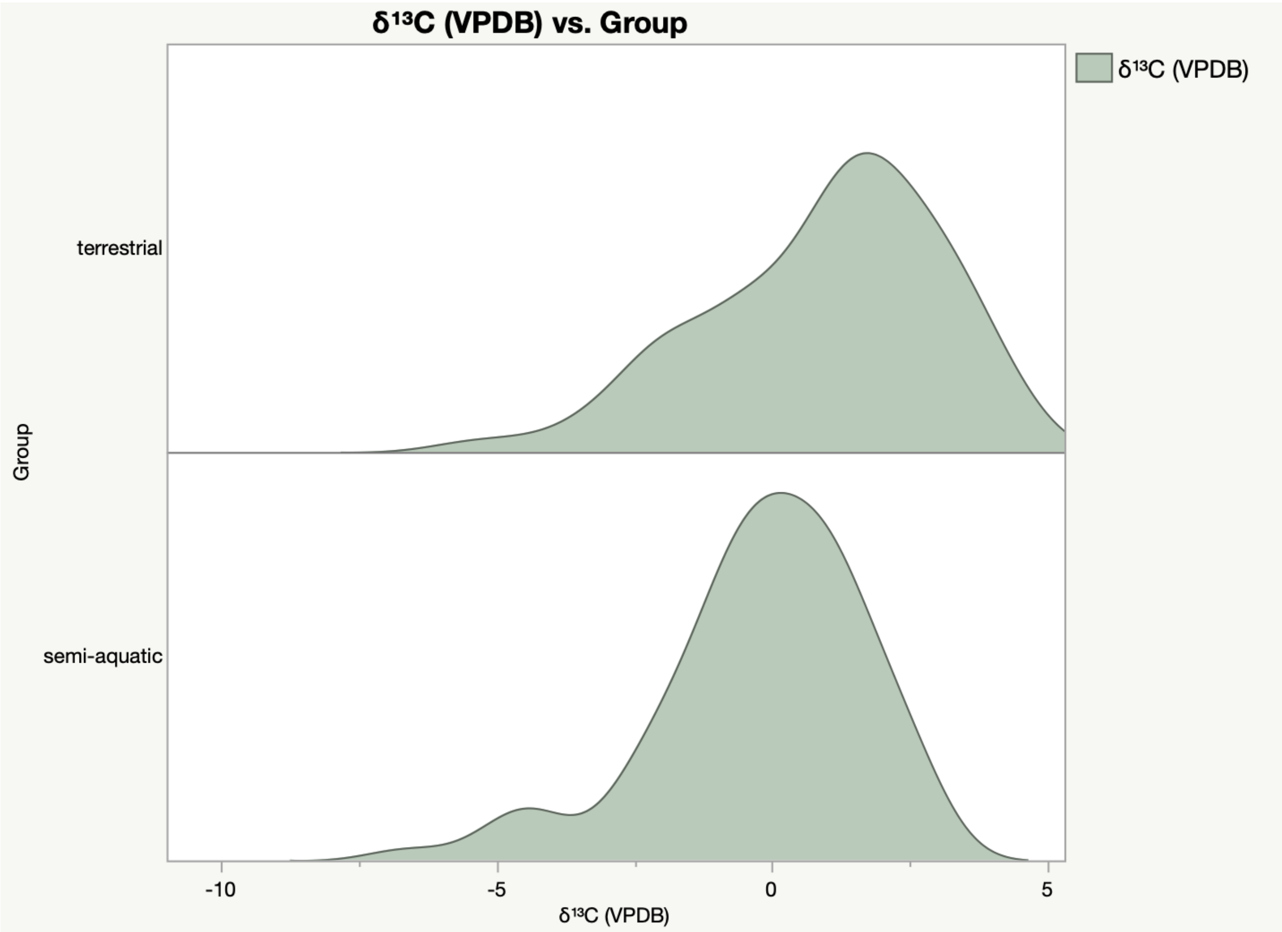


Fig.23. Kernel density plotting $\delta^{13}C$ values of semi-aquatic and terrestrial herbivores (by JMP 16).

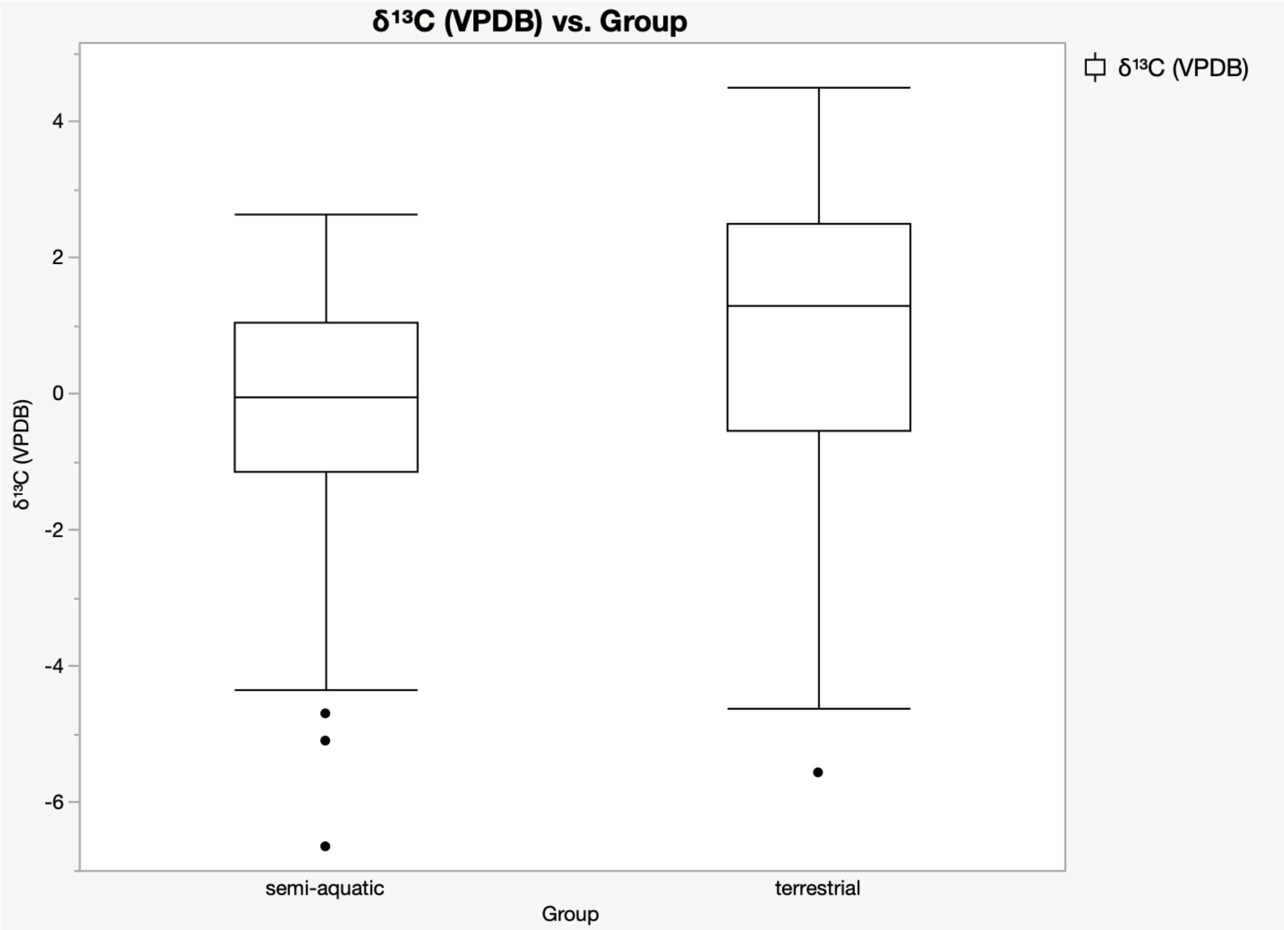


Fig.24. Boxplots with δ^{13}C values of semi-aquatic and terrestrial herbivores (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = semi-aquatic

	W	Prob<W
Shapiro-Wilk	0,9383599	0,0007*

Goodness-of-Fit Test

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

	W	Prob<W
Shapiro-Wilk	0,9631467	0,0072*

Distribution Group = terrestrial

Goodness-of-Fit Test

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

Then, the Mann-Whitney U-test is used, and the Null hypothesis (H_0) implies that "mean values are the same in the two groups" while the Alternative hypothesis (H_1) implies that "mean values are different in the two groups".

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
semi-aquatic	81	5945,50	7330,50	73,401	-3,981
terrestrial	99	10344,5	8959,50	104,490	3,981

Wilcoxon/Krustal-Wallis Tests (Rank Sums):

Sample Test, Normal Approximation:

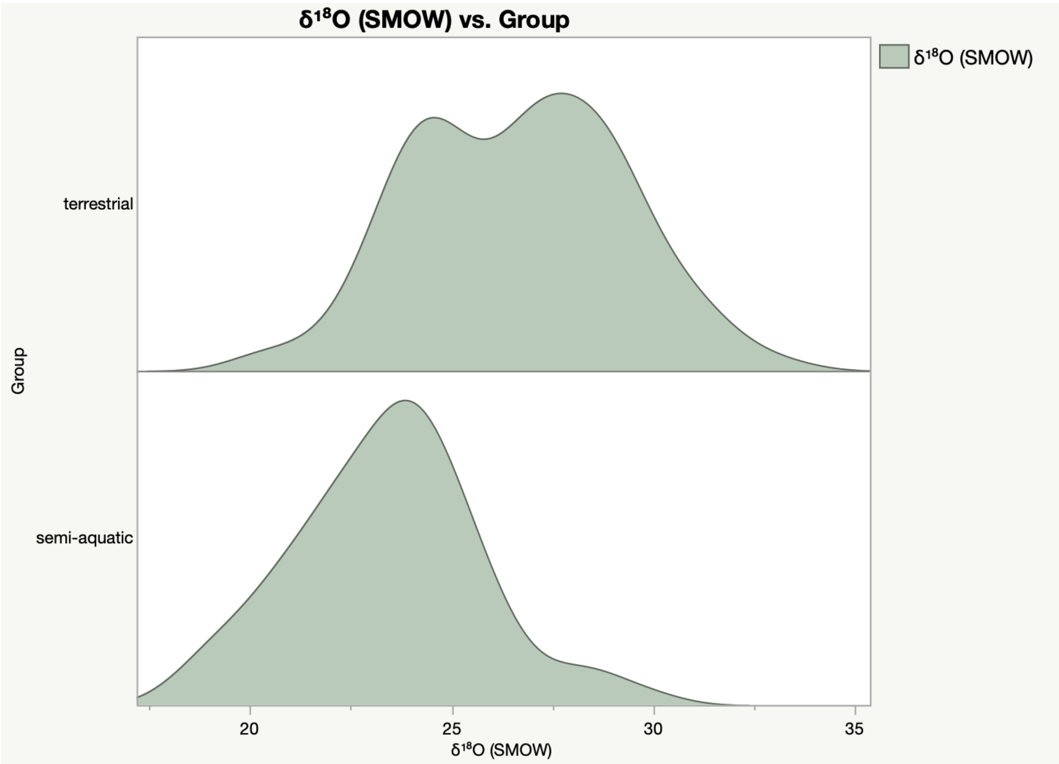
S	Z	Prob>|Z|
5945,5	-3,98093	<,0001*

Way Test, ChiSquare Approximation:

ChiSquare	DF	Prob>ChiSq
15,8593	1	<,0001*

The Mann-Whitney U-test shows a *p*-value <0.0001 and is smaller than 5%. The Null hypothesis (H_0) is rejected at a 5% significance level.
It is concluded that $\delta^{13}C$ on average is different in semi-aquatic and terrestrial herbivores.

Fig.25, and 26 (Kernel density and boxplots, respectively) show the plotting of $\delta^{18}O$ in both



groups. A long right tail is observed for the semi-aquatic data.

Fig.25. Kernel density plotting $\delta^{18}O$ values of semi-aquatic and terrestrial herbivores (by JMP 16).

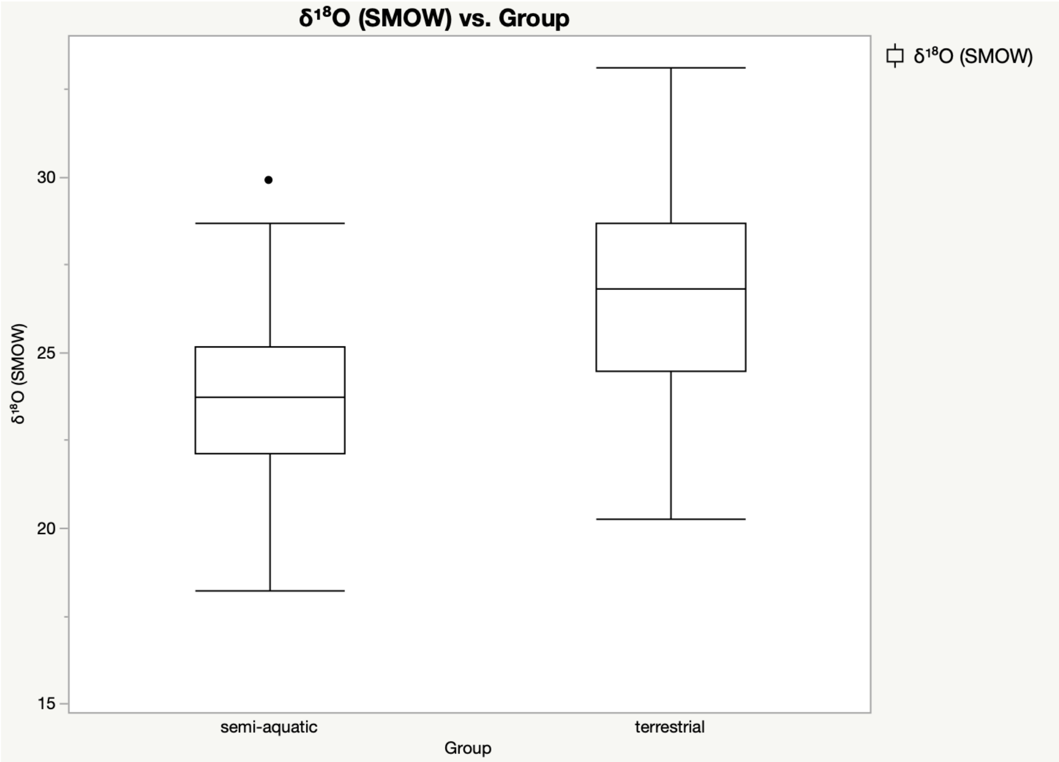


Fig.26. Boxplots with $\delta^{18}O$ values of semi-aquatic and terrestrial herbivores (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = semi-aquatic

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9871711	0,6012

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Distribution Group = terrestrial

Goodness-of-Fit Test

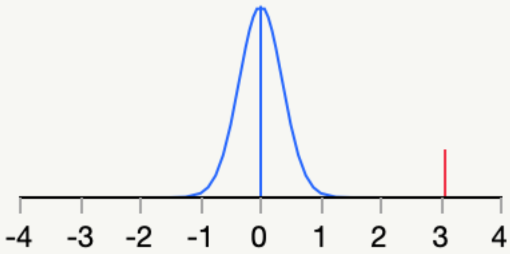
	W	Prob<W
Shapiro-Wilk	0,9897649	0,6524

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

terrestrial-semi-aquatic

Assuming unequal variances

Difference	3,06680	t Ratio	8,532411
Std Err Dif	0,35943	DF	184,9965
Upper CL Dif	3,77590	Prob > |t|	<,0001*
Lower CL Dif	2,35769	Prob > t	<,0001*
Confidence	0,95	Prob < t	1,0000



Then, the T-test is used:

p-value = Prob > |t| = <0.0001

The *p*-value is smaller than 1%, and the Null hypothesis (H_0) has been rejected at a level of significance α = 1% (risk of false positives equal to 1%).

It is concluded that δ^{18}O on average is different in semi-aquatic and terrestrial herbivores with at the level of significance α = 1.

Test 2. Hippopotamidae vs. Bovidae

Test 2 comprises two sample groups: hippopotamids and bovids. The group of hippopotamids contains 81 isotopic results from *Hippopotamus* cf. *amphibius*, while the Bovidae category contains 69 isotopic results, generally grouped but related to several species.

Fig.27, and 28 (Kernel density and boxplots, respectively) show the plotting of δ^{13}C in both groups. A long-left tail is observed.

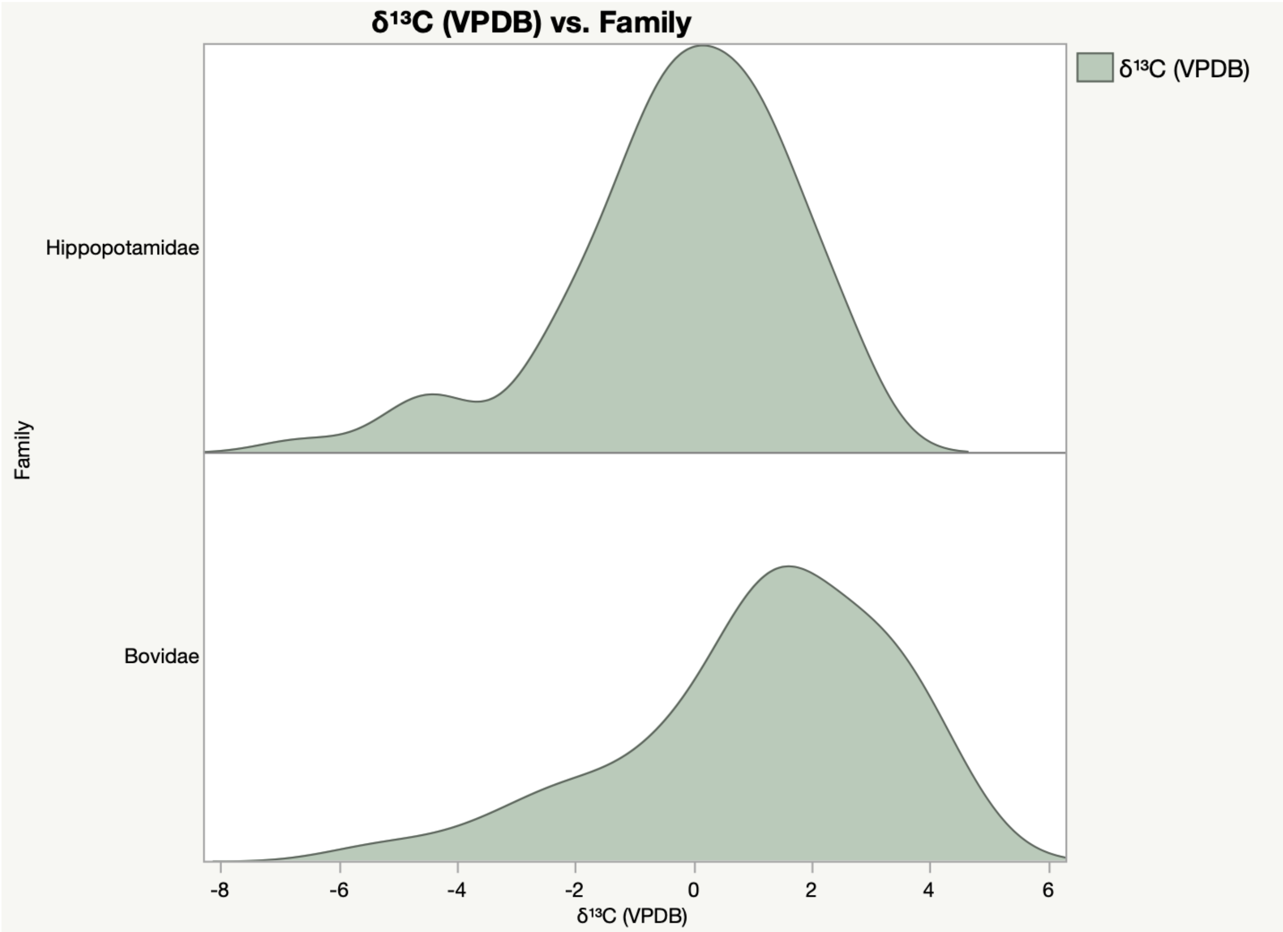


Fig.27. Kernel density plotting $\delta^{13}C$ values of hippopotamids and bovids (by JMP 16).

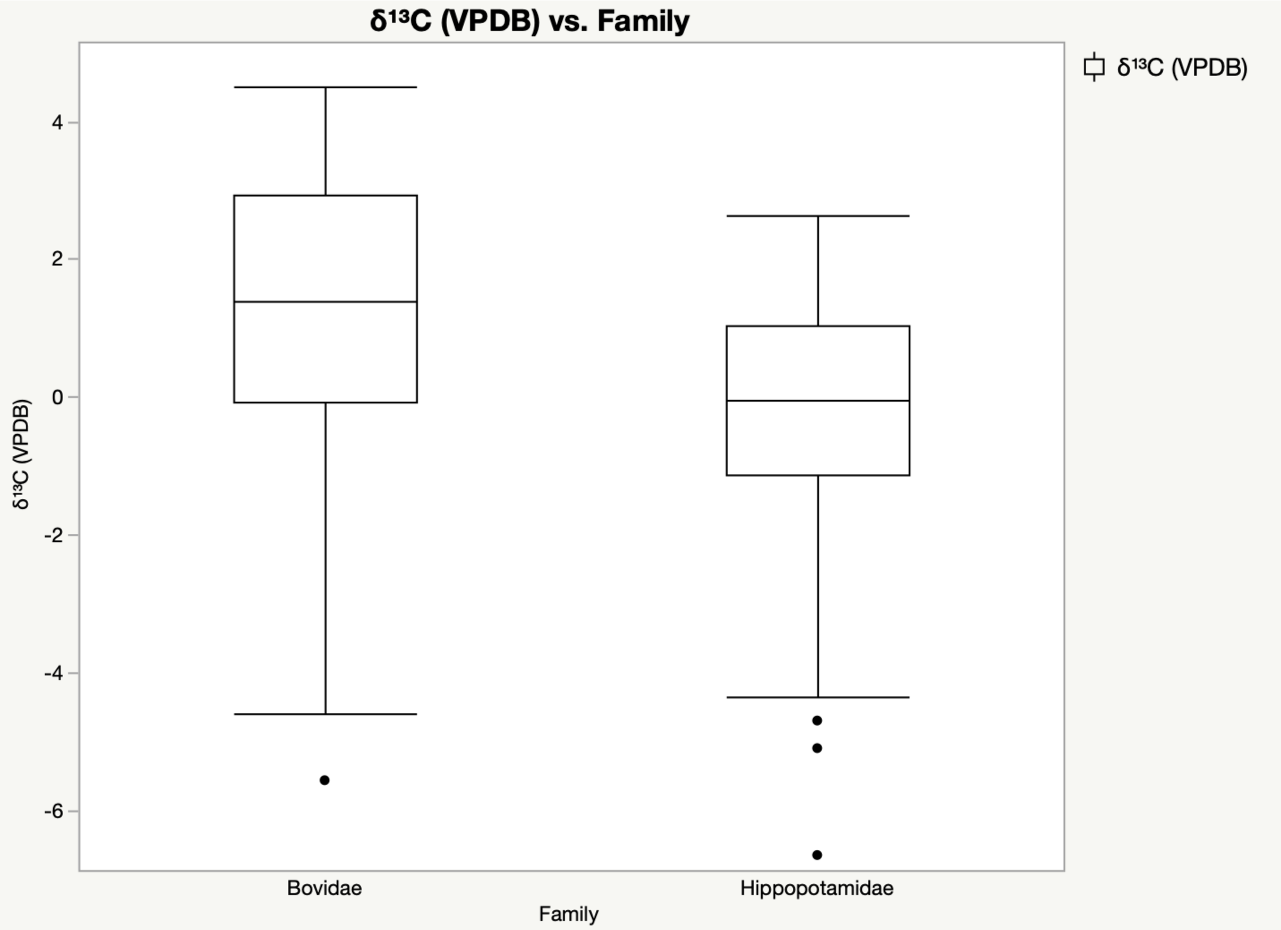


Fig.28. Boxplots with $\delta^{13}C$ values of hippopotamids and bovids (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Bovidae

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9421857	0,0031*

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

Distribution Group = Hippopotamidae

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9383599	0,0007*

The Shapiro-Wilk test has a p-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

Then, the Mann-Whitney U-test is used, and the Null hypothesis (H_0) implies that "mean values are the same in the two groups" while the Alternative hypothesis (H_1) implies that "mean values are different in the two groups".

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Bovidae	69	6362,50	5209,50	92,2101	4,346
Hippopotamidae	81	4962,50	6115,50	61,2654	-4,346

Wilcoxon/Krustal-Wallis Tests (Rank Sums):

S	Z	Prob>|Z|
6362,5	4,34588	<,0001*

Sample Test, Normal Approximation:

ChiSquare	DF	Prob>ChiSq
18,9031	1	<,0001*

Way Test, ChiSquare Approximation:

The Mann-Whitney U-test shows a p-value <0.0001 and is smaller than 5%. The Null hypothesis (H_0) is rejected at a 5% significance level.

It is concluded that $\delta^{13}C$ on average is different in Hippopotamidae and Bovidae.

Fig.29, and 30 (Kernel density and boxplots, respectively) show the plotting of $\delta^{18}O$ in both groups. A long right tail is observed for the Hippopotamidae data.

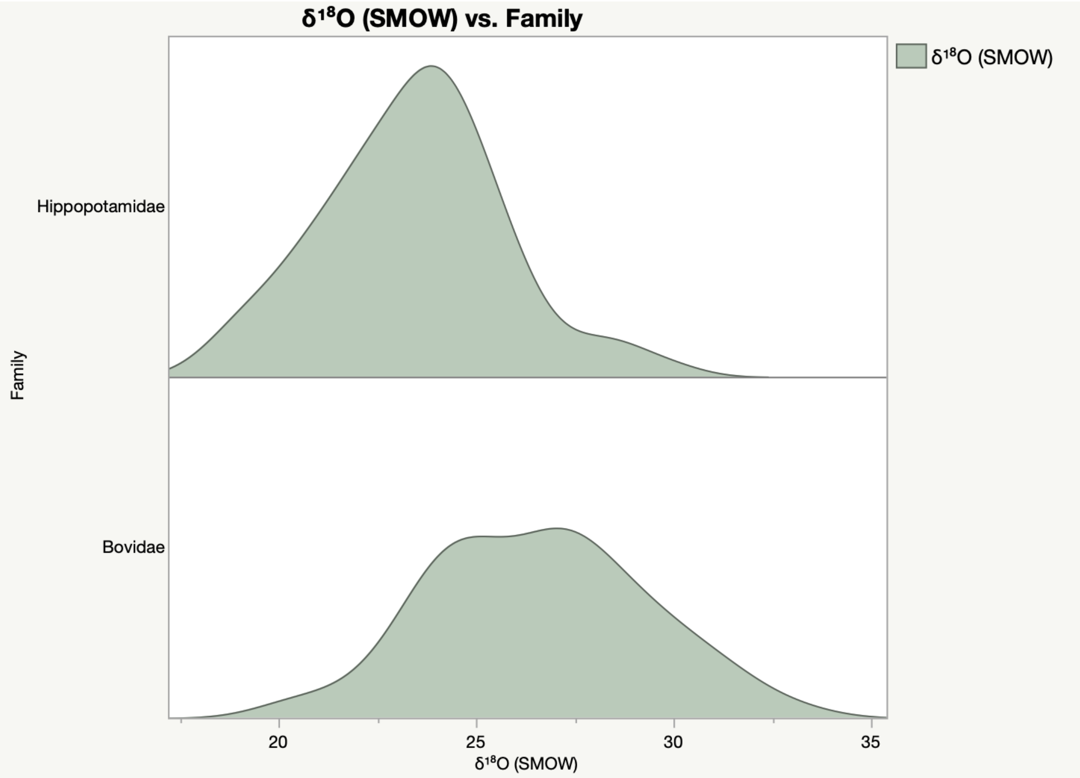


Fig.29. Kernel density plotting $\delta^{18}O$ values of hippopotamids and bovids (by JMP 16).

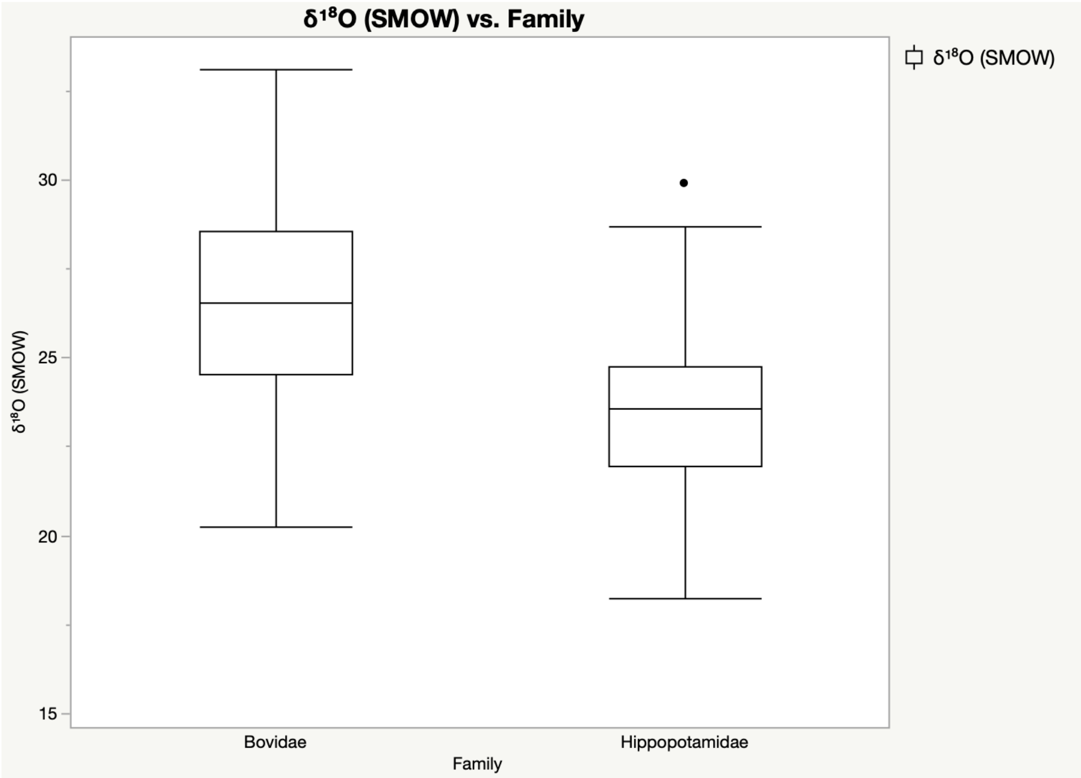


Fig.30. Boxplots with $\delta^{18}O$ values of hippopotamids and bovids (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Bovidae

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9923204	0,9509

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Distribution Group = Hippopotamidae

	W	Prob<W
Shapiro-Wilk	0,9871711	0,6012

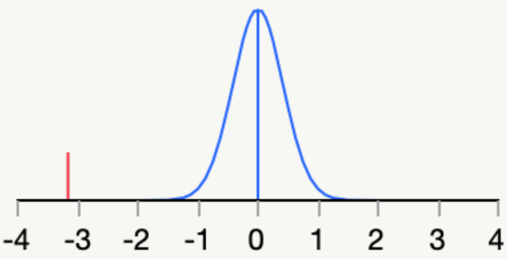
Goodness-of-Fit Test

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Hippopotamidae-Bovidae

Assuming unequal variances

Difference	-3,1632	t Ratio	-7,55872
Std Err Dif	0,4185	DF	134,2323
Upper CL Dif	-2,3355	Prob > |t|	<,0001*
Lower CL Dif	-3,9908	Prob > t	1,0000
Confidence	0,95	Prob < t	<,0001*



Then, the T-test is used:

p-value = Prob > |t| = <0.0001

The *p*-value is smaller than 1%, and the Null hypothesis (H_0) has been rejected at a level of significance α = 1% (risk of false positives equal to 1%).

It is concluded that δ^{18}O on average is different in *Hippopotamidae and Bovidae* with a level of significance α = 1%.

Test 3. Bovids

Test 3 comprises six sample groups, following the specimens identified for the family of Bovidae. In detail, the category contains 30 isotopic results from Bovidae (*sensu lato*), 29 from Bovidae (*Alcelaphini*), 1 from Bovidae (*Antilopini*), 4 from Bovidae (*Bovini*), 2 from Bovidae (*Hippotragini*), and 3 from (*Reduncini*) (total = n 69 enamel samples).

The graphs (Fig.31, 32), for both δ^{13}C and δ^{18}O values, show that only Bovidae (*sensu lato*) and Bovidae (*Alcelaphini*) have bell-shaped distribution, consistent with a normal assumption, while the other groups (*Antilopini*, *Bovini*, *Hippotragini*, and *Reduncini*) show no distribution due to the low number of samples.

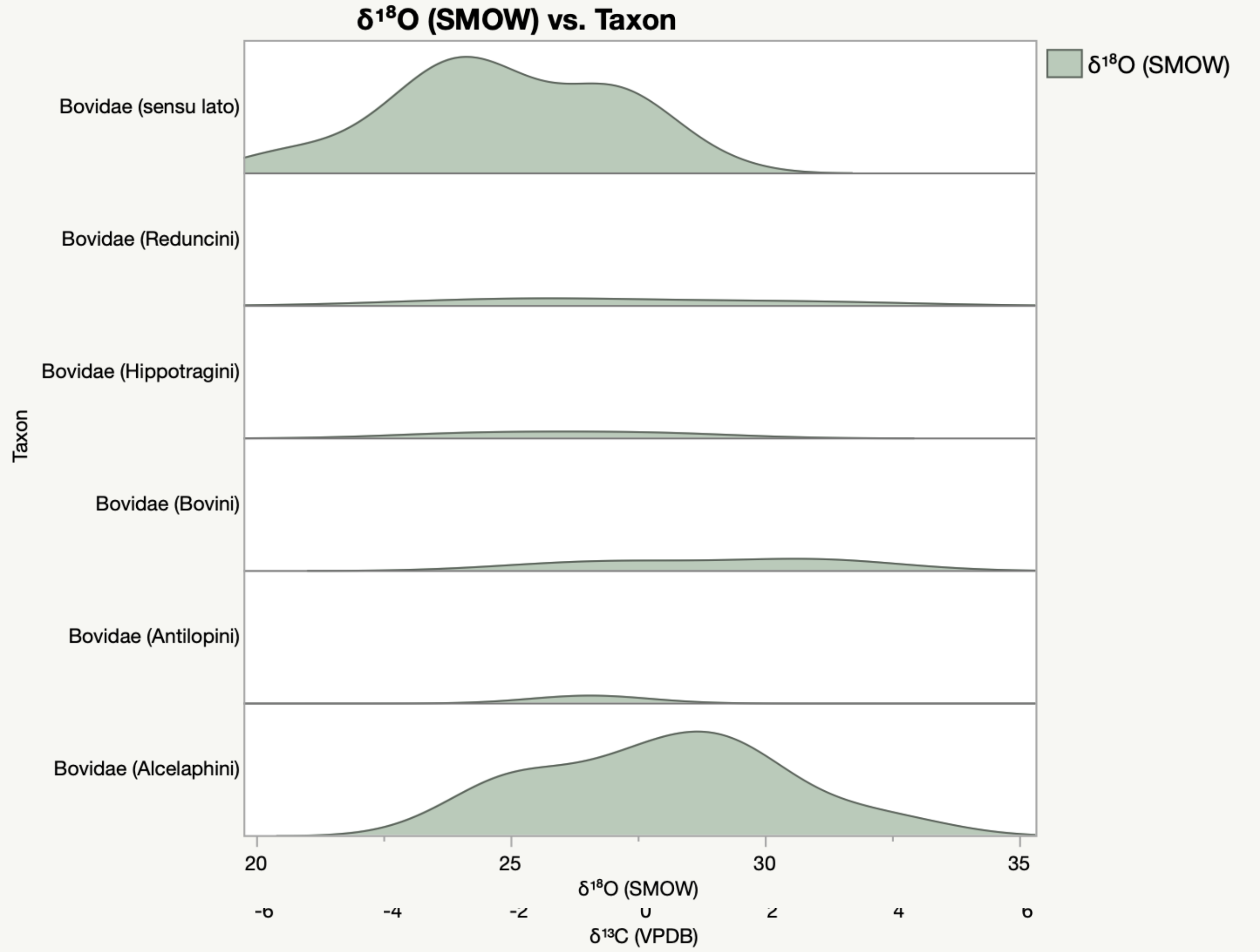


Fig.31. Kernel density plotting $\delta^{13}C$ values of bovid species (by JMP 16).

The following boxplots (Fig.33, 34) confirm what has been observed by Kernel density. It is concluded that for the groups of *Antilopini*, *Bovini*, *Hippotragini*, and *Redunci*, it would be necessary to expand the sample with further isotopic measurements.

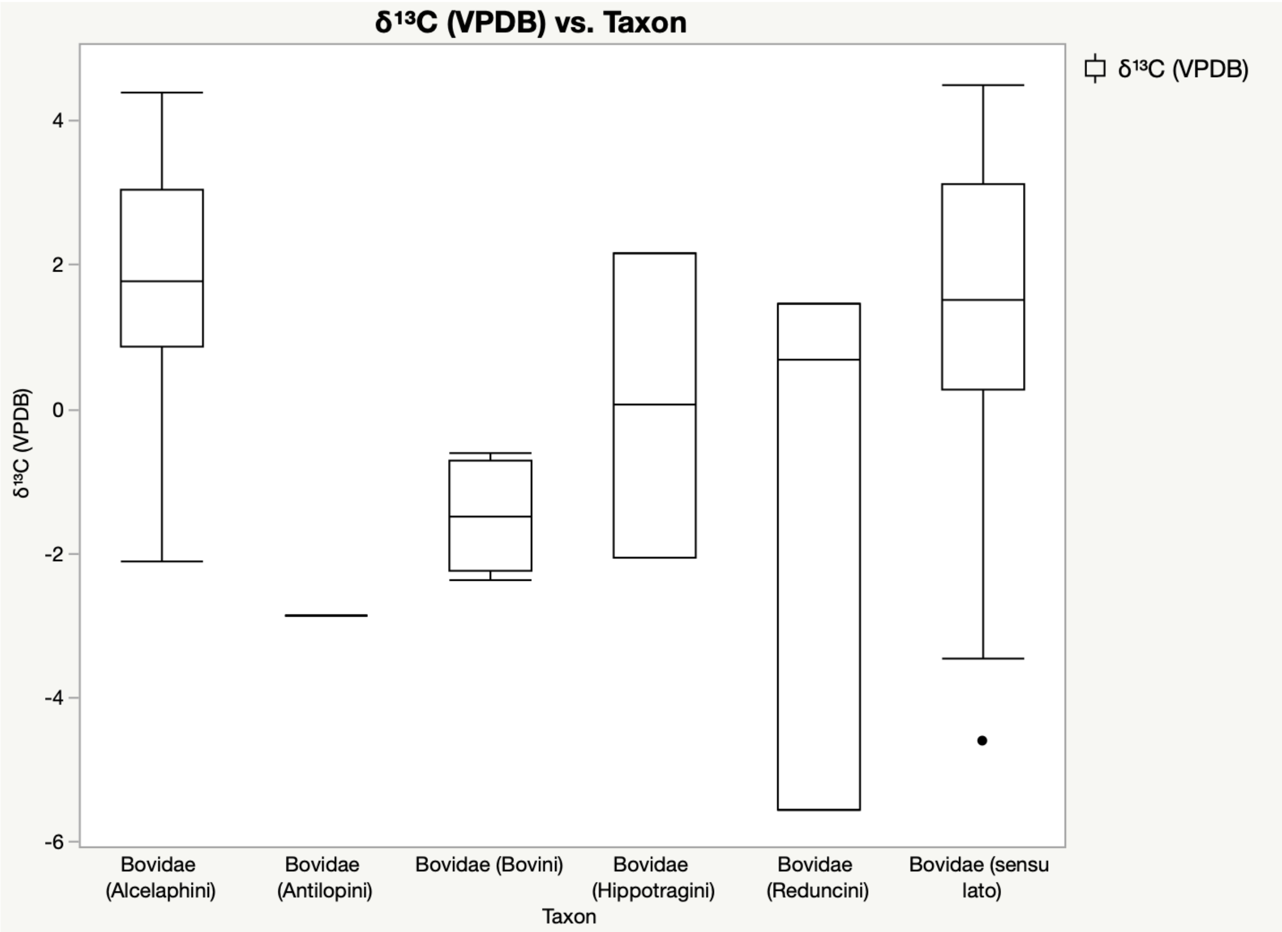


Fig.33. Boxplots with $\delta^{13}C$ values of bovid species (by JMP 16).

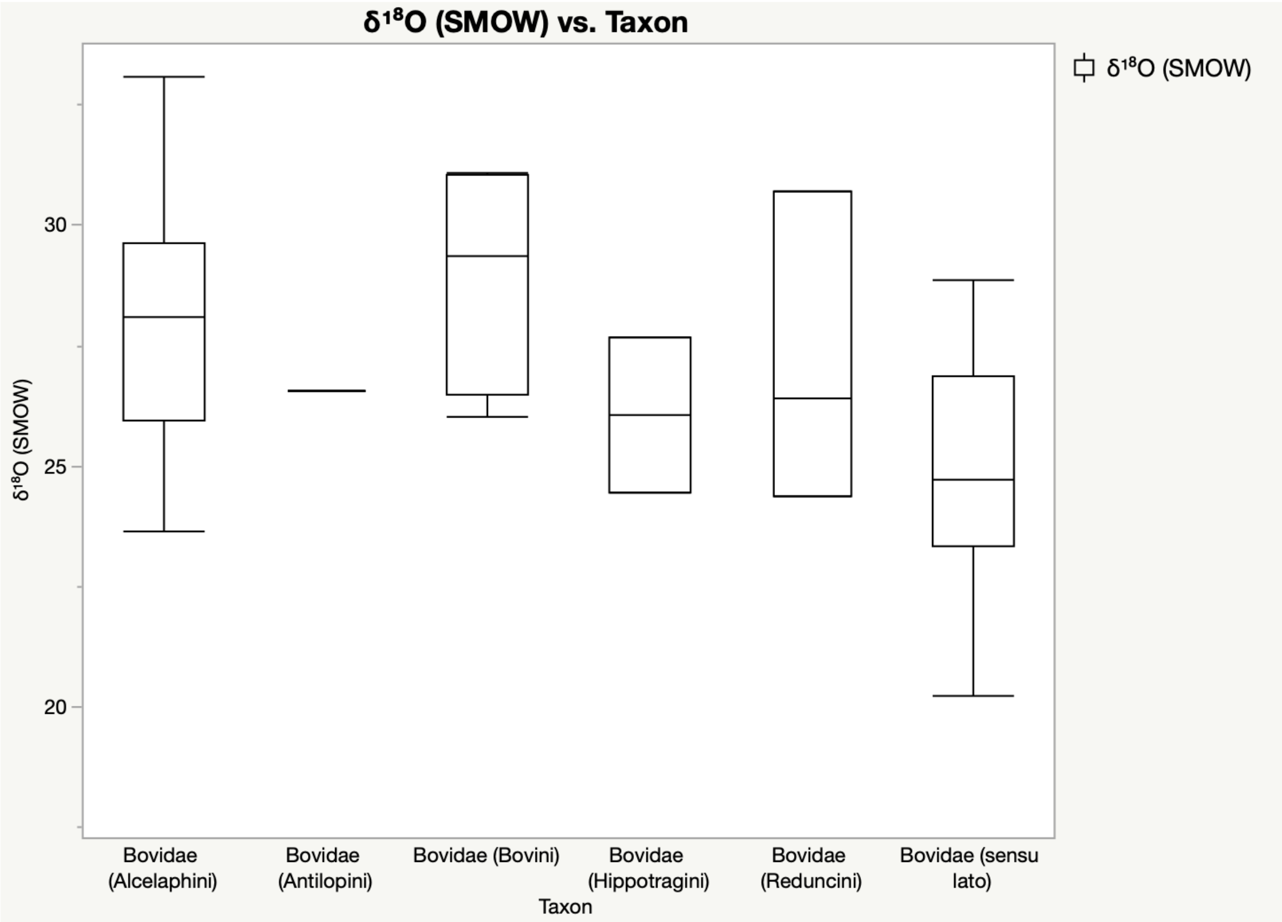


Fig.34. Boxplots with $\delta^{18}O$ values of bovid species (by JMP 16).

Therefore, the isotopic results of bovids have been grouped in just one Test and discussed in the following paragraph 3.1. Bovidae (*sensu lato*) *vs.* Bovidae (*Alcelaphini*).

Test 3.1. Bovidae (*sensu lato*) *vs.* Bovidae (*Alcelaphini*)

Test 3.1 comprises two sample groups: Bovidae *(sensu lato)* and Bovidae (*Alcelaphini*). The category contains 30 isotopic results from Bovidae *(sensu lato)* and 29 from Bovidae (*Alcelaphini*) (total = n 59 enamel samples).

Fig.35, and 36 (Kernel density and boxplots, respectively) show the plotting of $\delta^{13}C$ in both groups. A long-left tail is observed.

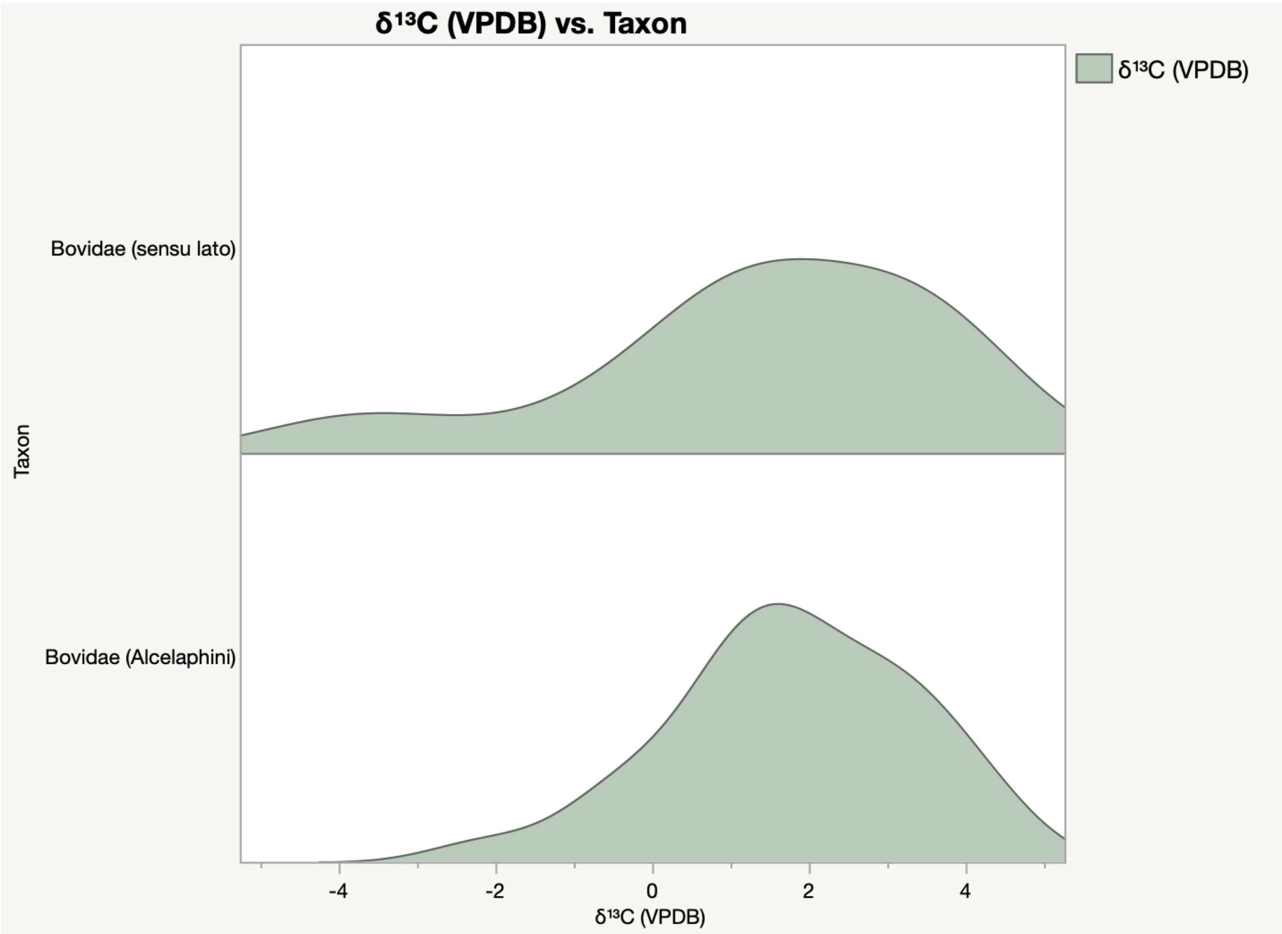


Fig.35. Kernel density plotting $\delta^{13}C$ values of Bovidae *(sensu lato)* and Bovidae (*Alcelaphini*) (by JMP 16).

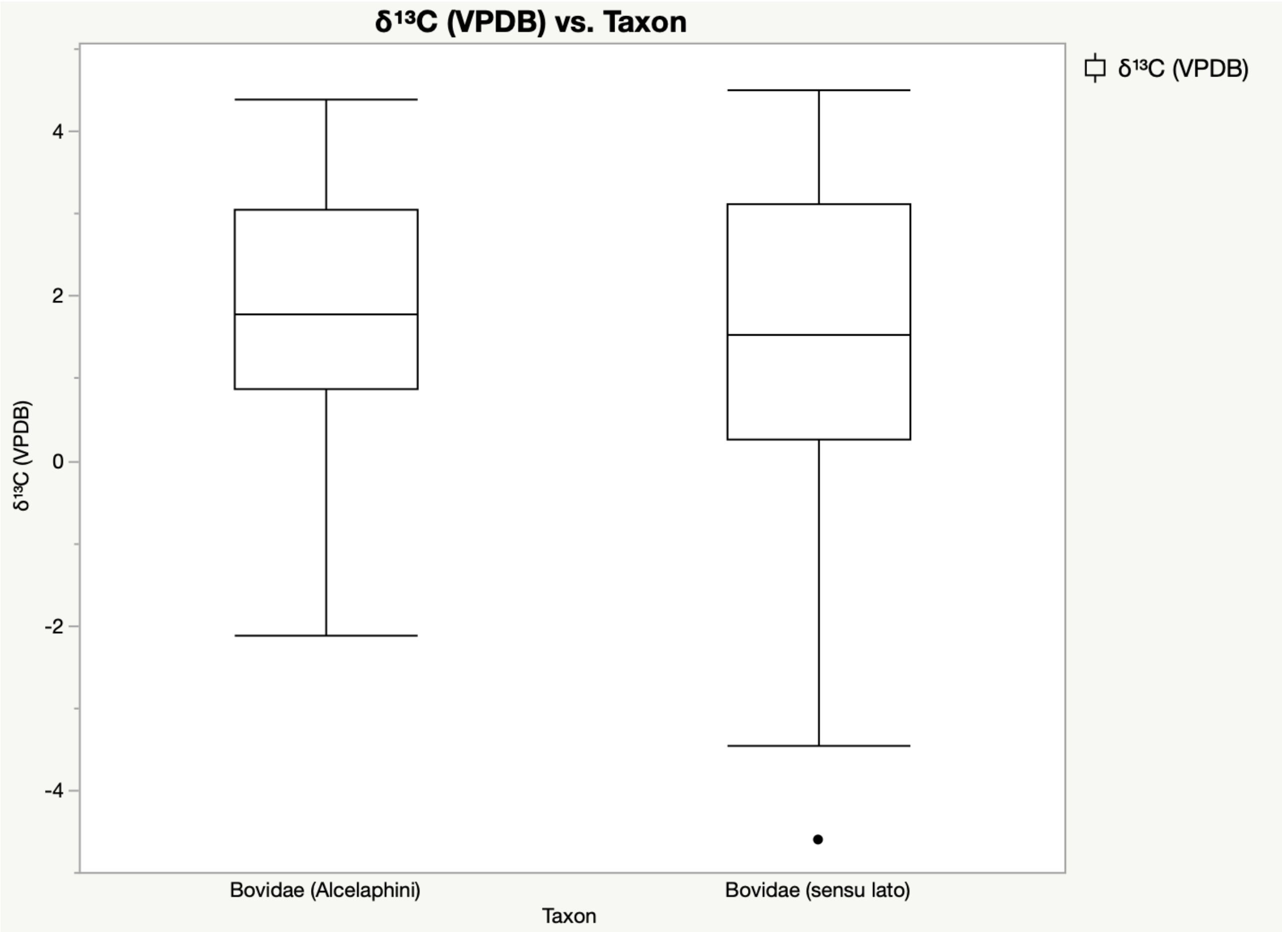


Fig.36. Boxplots with $\delta^{13}C$ values of Bovidae *(sensu lato)* and Bovidae (*Alcelaphini*) (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Bovidae (*Alcelaphini*)

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9785079	0,7991

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Distribution Group = Bovidae (*sensu lato*)

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9172101	0,0227*

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

Then, the Mann-Whitney U-test is used, and the Null hypothesis (H_0) implies that "mean values are the same in the two groups" while the Alternative hypothesis (H_1) implies that "mean values are different in the two groups".

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Bovidae (Alcelaphini)	29	897,000	870,000	30,9310	0,402
Bovidae (sensu lato)	30	873,000	900,000	29,1000	-0,402

Wilcoxon/Krustal-Wallis Tests (Rank Sums):

Sample Test, Normal Approximation:

S	Z	Prob>|Z|
897	0,40180	0,6878

Way Test, ChiSquare Approximation:

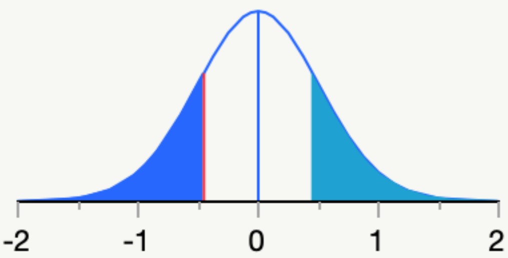
ChiSquare	DF	Prob>ChiSq
0,1676	1	0,6823

The Mann-Whitney U-test shows a *p*-value >5%. The Null hypothesis (H_0) is accepted at a 5% significance level.

It is concluded that $\delta^{13}C$ on average is equal in Bovidae *(sensu lato)* and Bovidae (*Alcelaphini*).

Bovidae (sensu lato)-Bovidae (Alcelaphini)
Assuming unequal variances

<table>
<tr><td>Difference</td><td>-0,4524</td><td>t Ratio</td><td>-0,8815</td></tr>
<tr><td>Std Err Dif</td><td>0,5132</td><td>DF</td><td>50,74164</td></tr>
<tr><td>Upper CL Dif</td><td>0,5780</td><td>Prob > |t|</td><td>0,3822</td></tr>
<tr><td>Lower CL Dif</td><td>-1,4827</td><td>Prob > t</td><td>0,8089</td></tr>
<tr><td>Confidence</td><td>0,95</td><td>Prob < t</td><td>0,1911</td></tr>
</table>



Then, the T-test is used:

p-value = Prob > |t| = <0.3822

The *p*-value is bigger than 1%, and the Null hypothesis (H_0) has been accepted.

It is concluded that $\delta^{13}C$ on average is not different in Bovidae (*sensu lato*) and Bovidae (*Alcelaphini*) with at the level of significance α > 1%.

Fig.37, 38 (Kernel density and boxplots, respectively) shows the plotting of $\delta^{18}O$ in both groups.

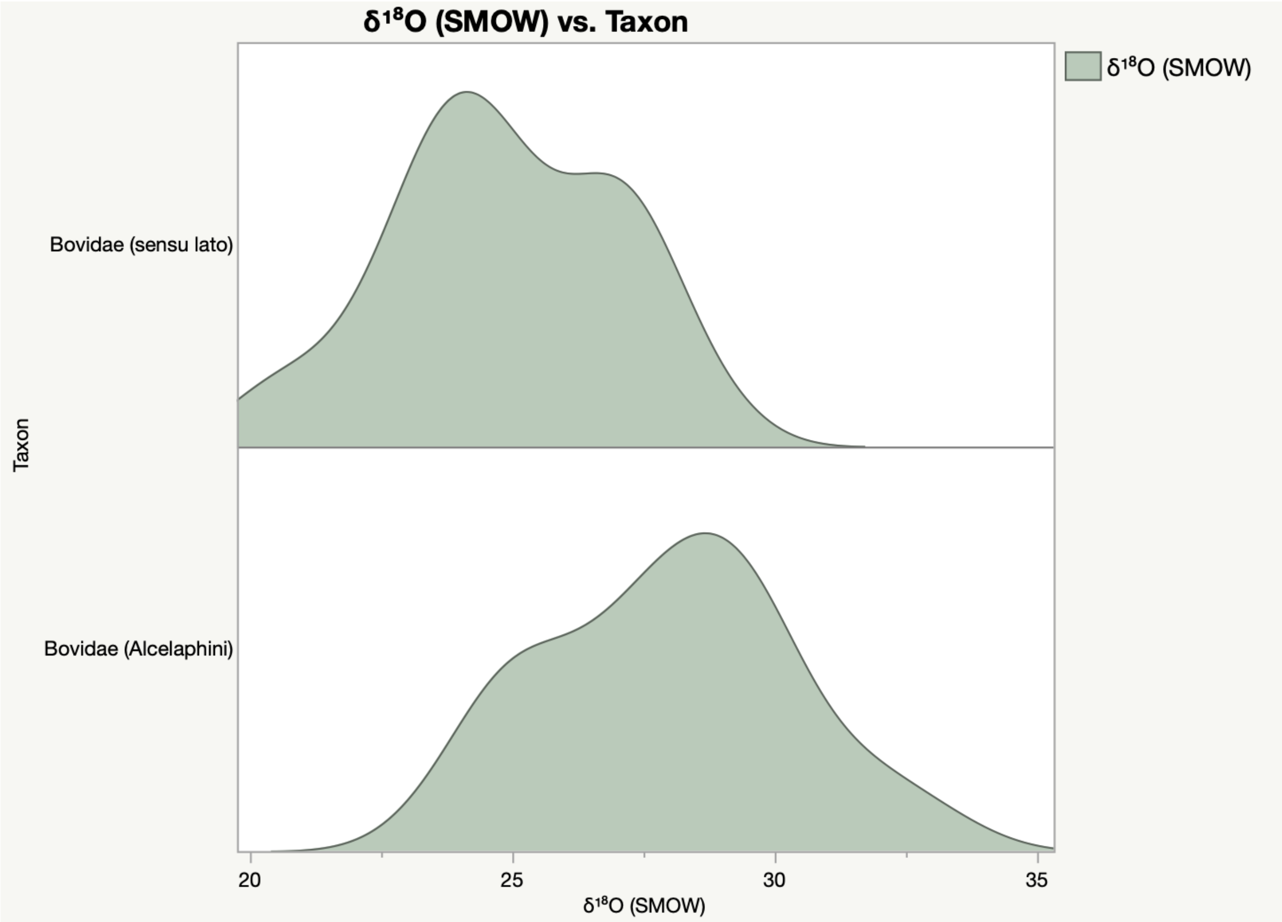


Fig.37. Kernel density plotting $\delta^{18}O$ values of Bovidae *(sensu lato)* and Bovidae (*Alcelaphini*) (by JMP 16).

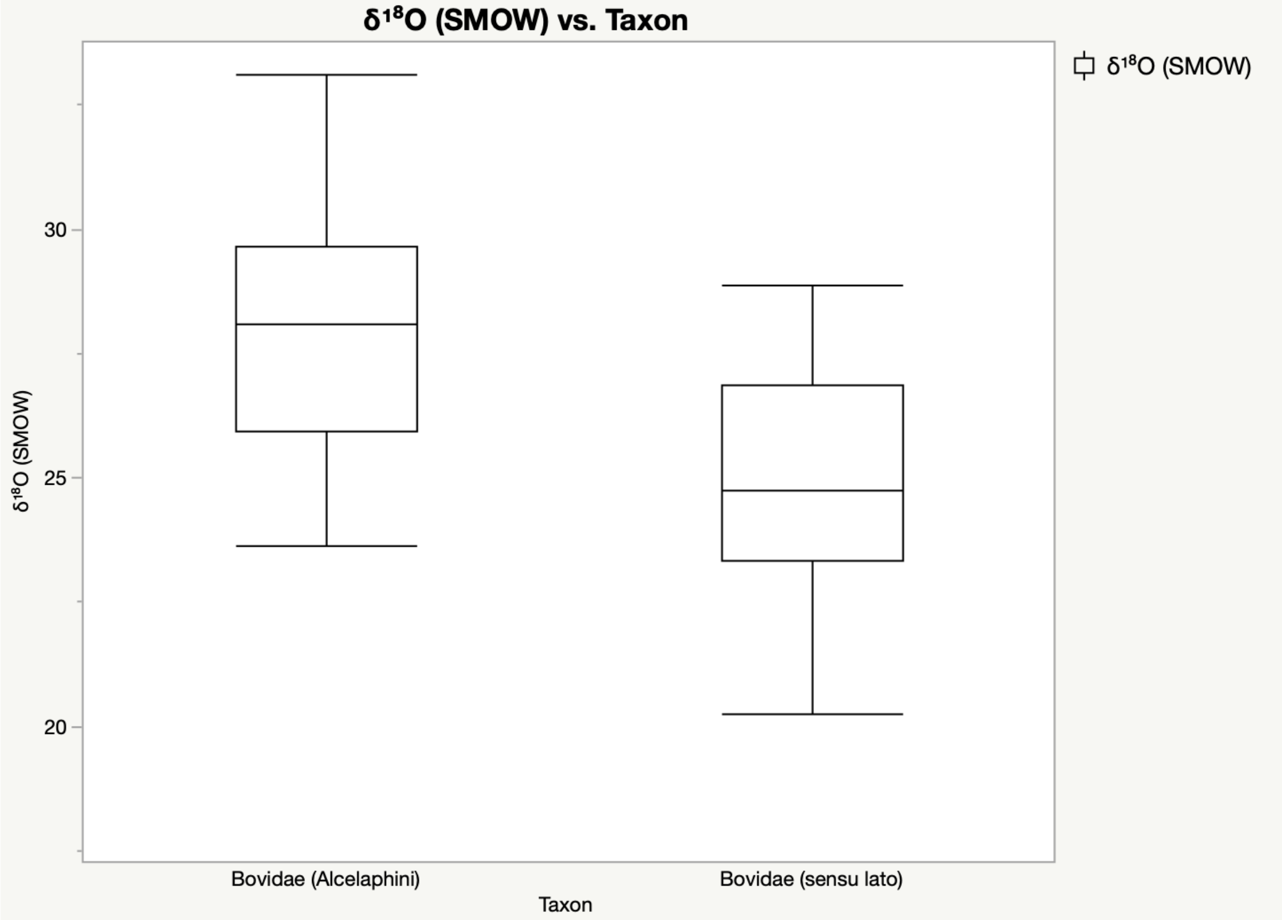


Fig.38. Boxplots with $\delta^{18}O$ values of Bovidae (sensu lato) and Bovidae (Alcelaphini) (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Bovidae (*Alcelaphini*)

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9781275	0,7888

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Distribution Group = Bovidae (*sensu lato*)

Goodness-of-Fit Test

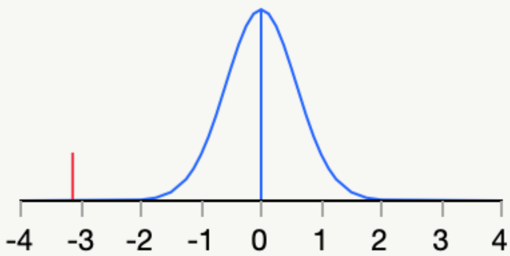
	W	Prob<W
Shapiro-Wilk	0,9754667	0,6965

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Bovidae (sensu lato)-Bovidae (Alcelaphini)

Assuming unequal variances

Difference	-3,1363	t Ratio	-5,30549
Std Err Dif	0,5911	DF	56,14413
Upper CL Dif	-1,9522	Prob > |t|	<,0001*
Lower CL Dif	-4,3204	Prob > t	1,0000
Confidence	0,95	Prob < t	<,0001*



Then, the T-test is used:

p-value = Prob > |t| = <0.0001

The *p*-value is smaller than 1%, and the Null hypothesis (H_0) has been rejected at a level of significance α = 1% (risk of false positives equal to 1%).

It is concluded that $\delta^{18}O$ on average is different in Bovidae (*sensu lato*) and Bovidae (*Alcelaphini*) with at the level of significance α = 1%.

Test 4. Terrestrial herbivores

Test 4 comprises twelve sample groups, following the specimens identified for the terrestrial herbivores (total = n 99 enamel samples). In detail, group 4 contains 30 isotopic results from Bovidae (*sensu lato*), 29 from Bovidae (*Alcelaphini*), 1 from Bovidae (*Antilopini*), 4 from Bovidae (*Bovini*), 2 from Bovidae (*Hippotragini*), and 3 from (*Reduncini*), 17 from Equidae *sensu lato*, 2 from Equidae (*Hipparion*), 2 from Giraffidae (*Sivatherium*), 7 from Suidae *sensu lato*, 1 from Suidae (*Kolpochoerus*), 1 from Suidae (*Metridiochoerus*).

The graphs (Fig.39, 40), for both $\delta^{13}C$ and $\delta^{18}O$ values, show that among all the terrestrial herbivores, only Bovidae (*sensu lato*) and Bovidae (*Alcelaphini*) have bell-shaped distribution, consistent with a normal assumption, while the other groups show no distribution due to the low number of samples.

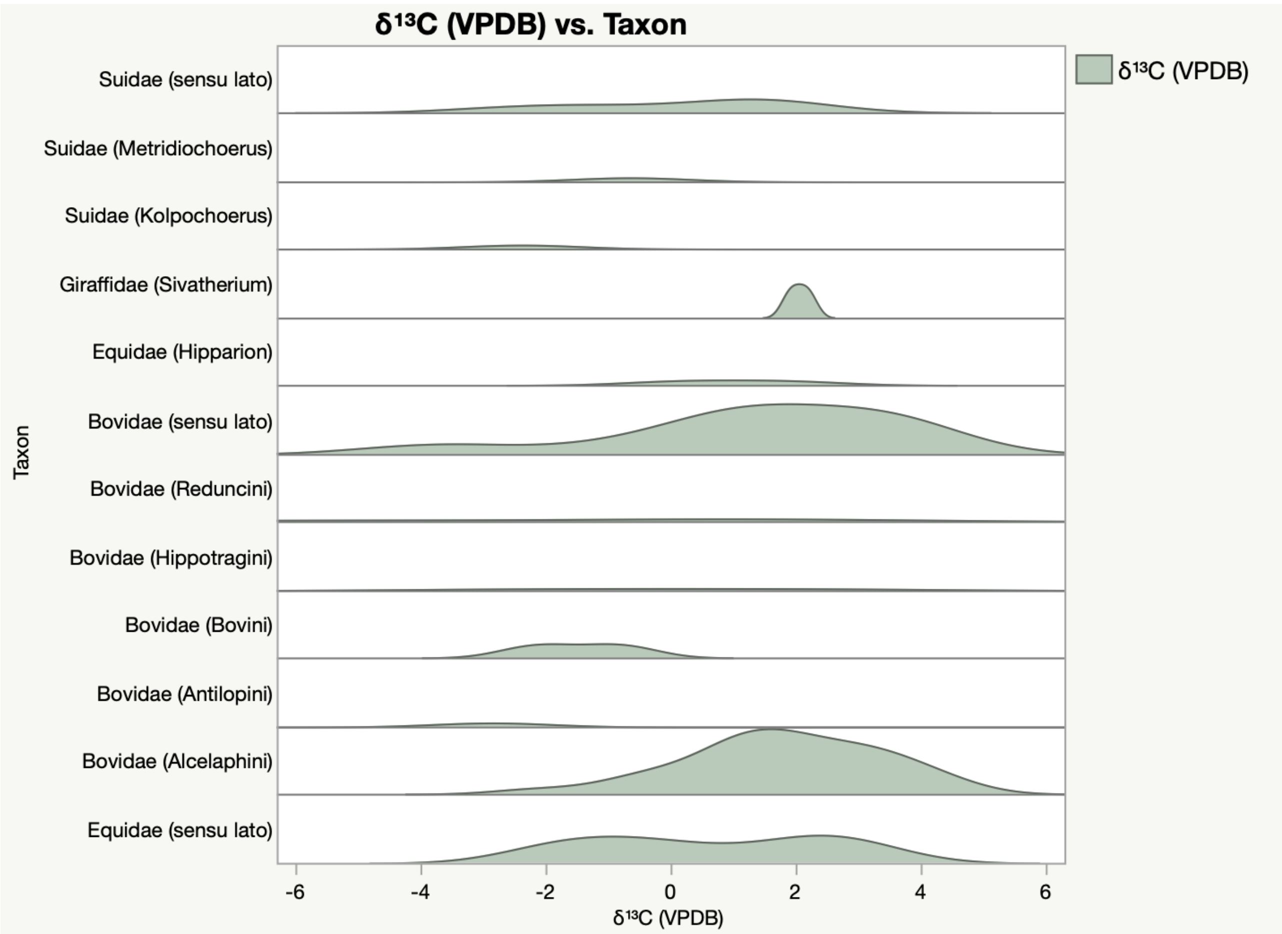


Fig.39. Kernel density plotting $\delta^{13}C$ values of terrestrial herbivores (by JMP 16).

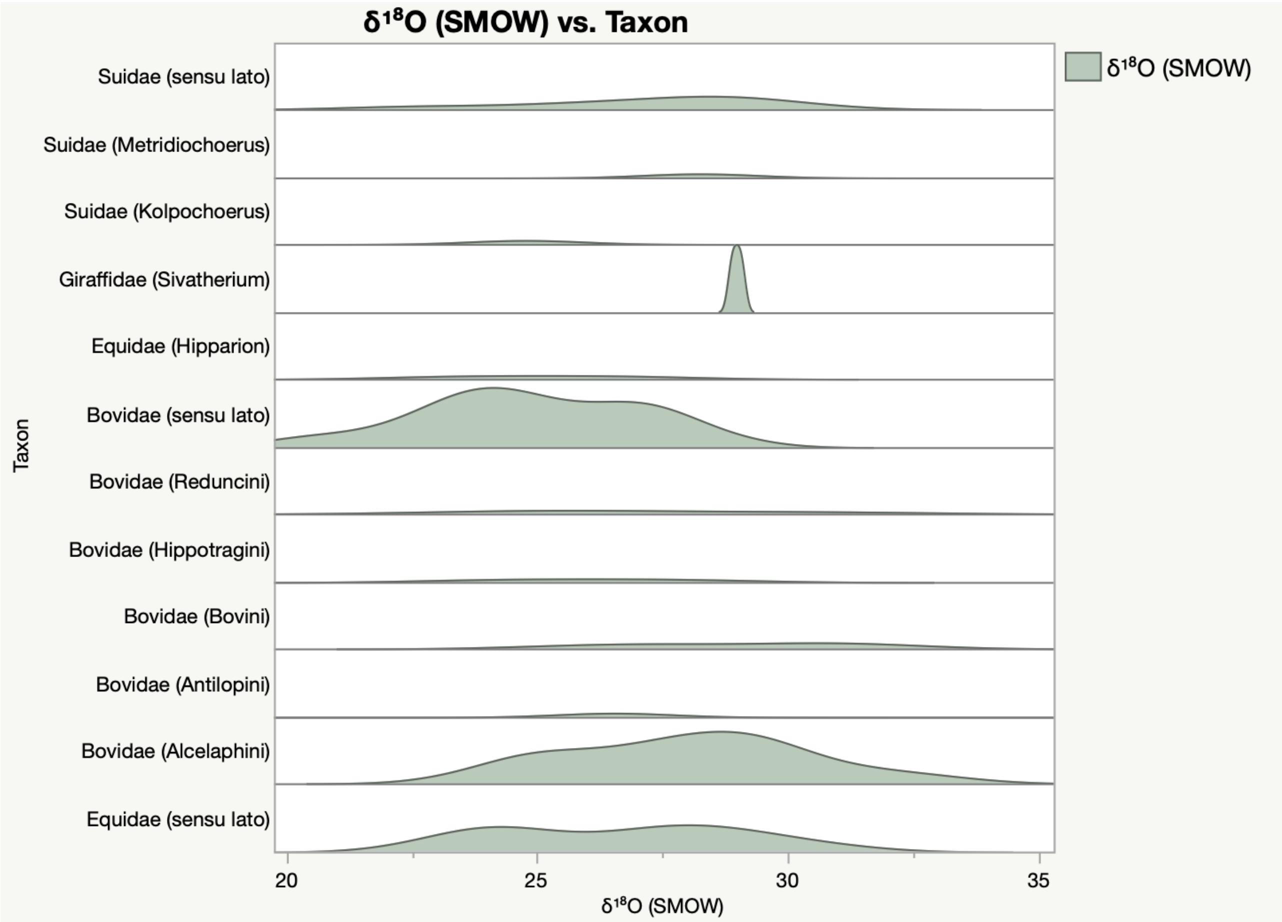


Fig.40. Kernel density plotting $\delta^{18}O$ values of terrestrial herbivores (by JMP 16).

The following boxplots (Fig.41, 42) confirm what has been observed by Kernel density. It is concluded that for the groups of Bovidae (*Antilopini*), Bovidae (*Bovini*), Bovidae (*Hippotragini*), (*Reduncini*), Equidae (*sensu lato*), Equidae (*Hipparion*), Giraffidae (*Sivatherium*), Suidae (*sensu lato*), Suidae (*Kolpochoerus*), Suidae (*Metridiochoerus*), it would be necessary to expand the sample with further isotopic measurements.

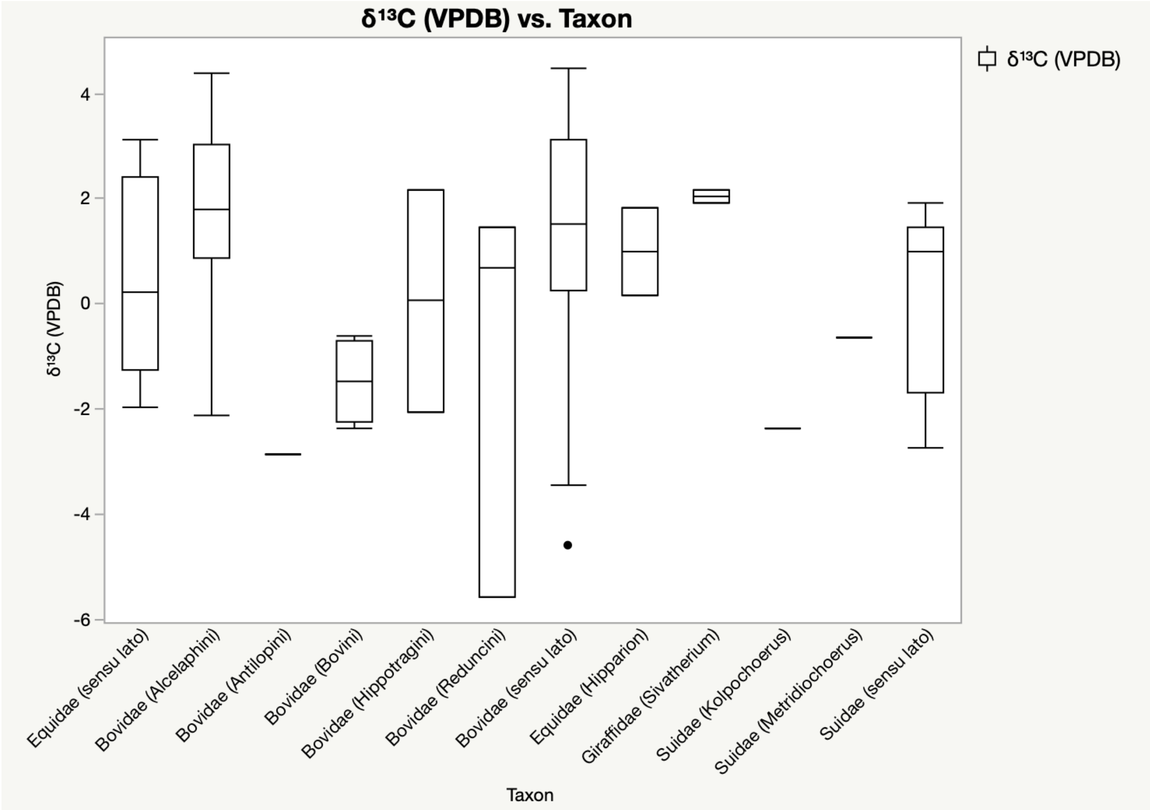


Fig.41. Boxplots with $\delta^{13}C$ values of terrestrial herbivores (by JMP 16).

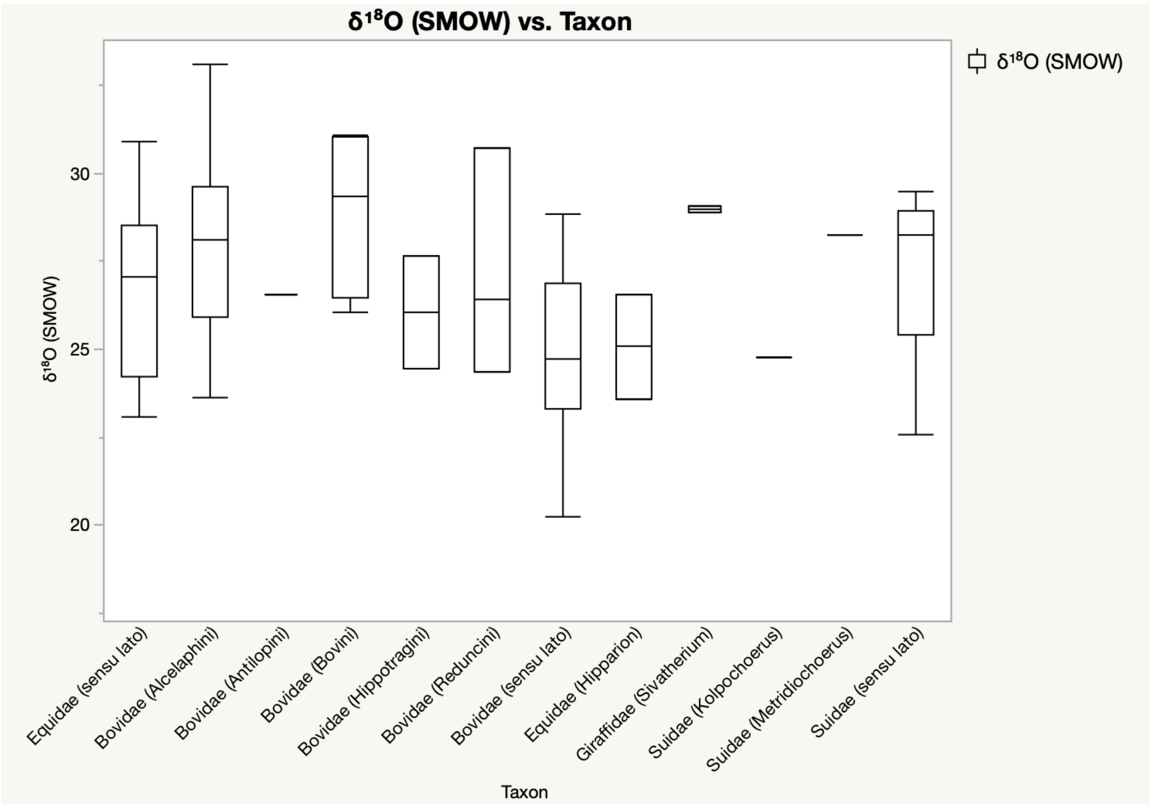


Fig.42. Boxplots with $\delta^{18}O$ values of terrestrial herbivores (by JMP 16).

Test 5. Hippos (Early and Middle Pleistocene)

Test 5 comprises 81 isotopic results of hippos for two sample groups, the Early and Middle Pleistocene. Fig.43, and 44 (Kernel density and boxplots, respectively) shows the plotting of $\delta^{13}C$ in both groups. A long-left tail is observed for the Early Pleistocene data.

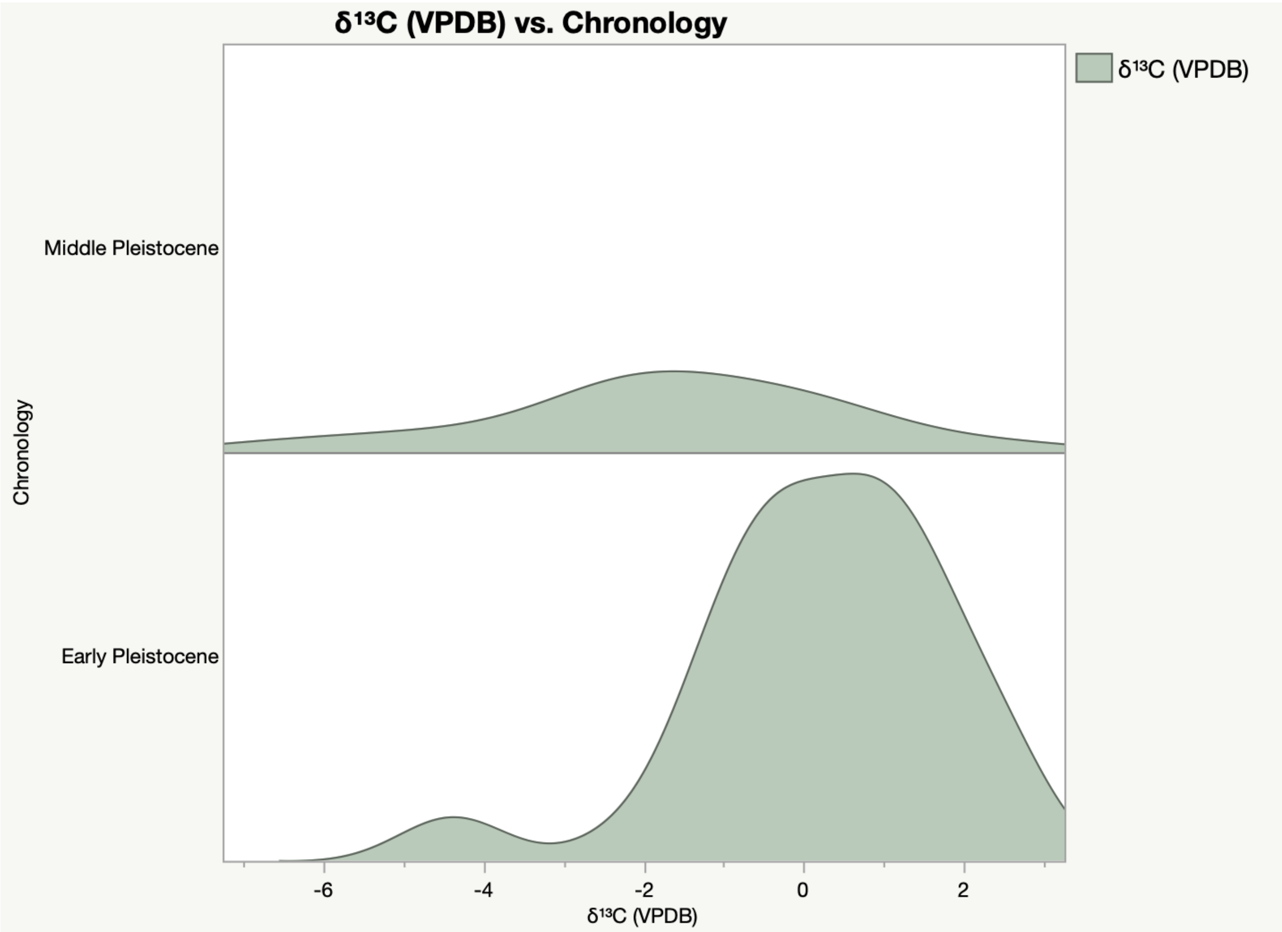


Fig.43. Kernel density plotting $\delta^{13}C$ values of hippos for the Early and Middle Pleistocene (by JMP 16).

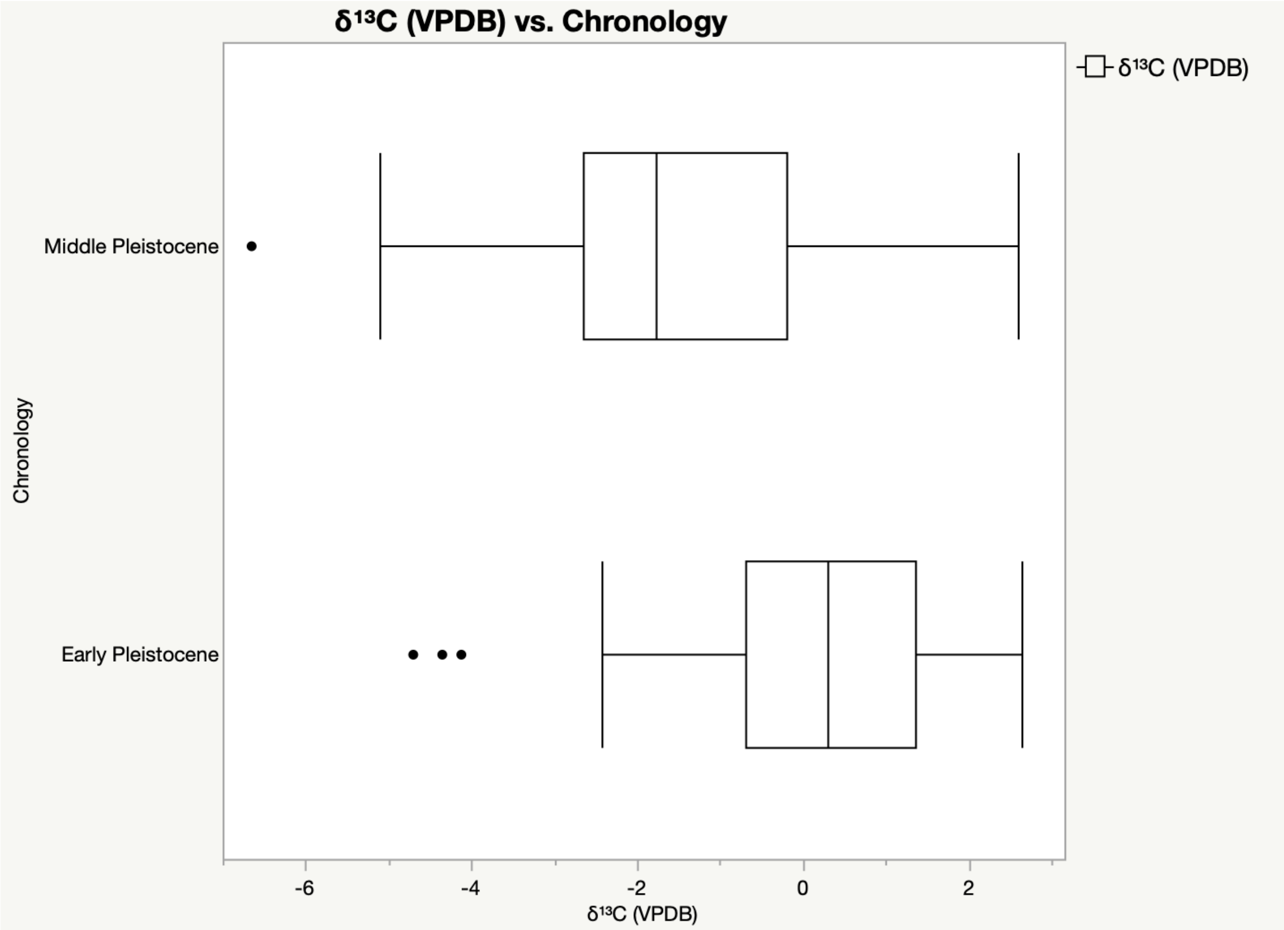


Fig.44. Boxplots with $\delta^{13}C$ values of hippos for the Early and Middle Pleistocene (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Early Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9315843	0,0017*

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

Distribution Group = Middle Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9721527	0,8371

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Then, the Mann-Whitney U-test is used, and the Null hypothesis (H_0) implies that “mean values are the same in the two groups” while the Alternative hypothesis (H_1) implies that “mean values are different in the two groups”.

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Early Pleistocene	63	2903,50	2583,00	46,0873	3,635
Middle Pleistocene	18	417,500	738,000	23,1944	-3,635

Wilcoxon/Krustal-Wallis Tests (Rank Sums):

Sample Test, Normal Approximation:

<table>
<tr><th>S</th><th>Z</th><th>Prob>|Z|</th></tr>
<tr><td>417,5</td><td>-3,63523</td><td>0,0003*</td></tr>
</table>

Way Test, ChiSquare Approximation:

ChiSquare	DF	Prob>ChiSq
13,2562	1	0,0003*

The Mann-Whitney U-test shows a *p*-value <0.0003 and is smaller than 5%. The Null hypothesis (H_0) is rejected at a 5% significance level.

It is concluded that $\delta^{13}C$ on average is different during the Early and Middle Pleistocene.

Mid Pleistocene-Early Pleistocene

Assuming unequal variances

<table>
<tr><td>Difference</td><td>-1,8930</td><td>t Ratio</td><td>-3,3985</td></tr>
<tr><td>Std Err Dif</td><td>0,5570</td><td>DF</td><td>22,1641</td></tr>
<tr><td>Upper CL Dif</td><td>-0,7383</td><td>Prob > |t|</td><td>0,0026*</td></tr>
<tr><td>Lower CL Dif</td><td>-3,0476</td><td>Prob > t</td><td>0,9987</td></tr>
<tr><td>Confidence</td><td>0,95</td><td>Prob < t</td><td>0,0013*</td></tr>
</table>

Then, the T-test is used:

p-value = Prob > |t| = <0.0026

The *p*-value is smaller than 1%, and the Null hypothesis (H_0) has been rejected at a level of significance α = 1% (risk of false positives equal to 1%).

It is concluded that $\delta^{13}C$ of Hippopotamidae on average is different during the Early and Middle Pleistocene with at the level of significance α = 1%.

Fig.45, and 46 (Kernel density and boxplots, respectively) show the plotting of $\delta^{18}O$ in both groups. A long right tail is observed for the Early Pleistocene data.

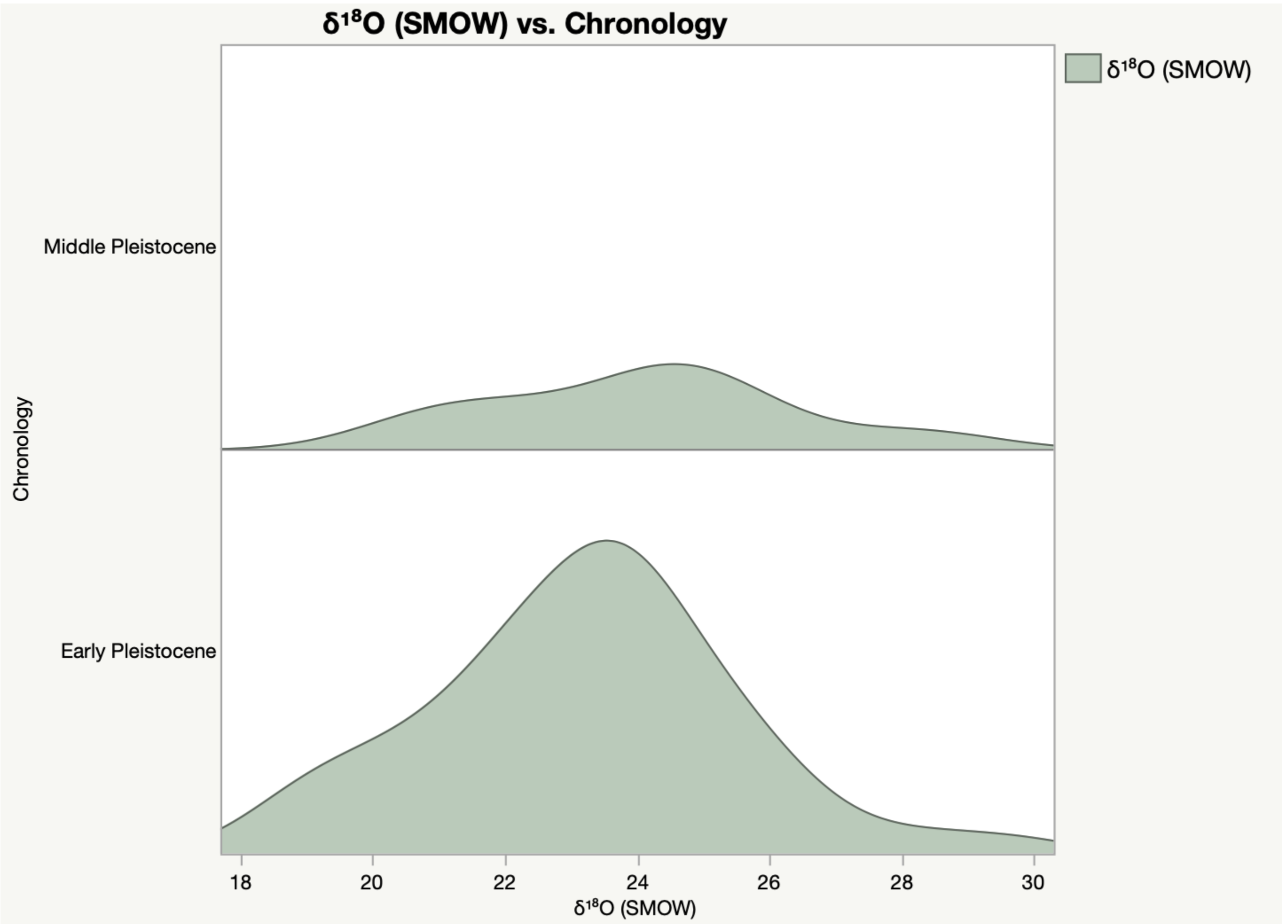


Fig.45. Kernel density plotting $\delta^{18}O$ values of hippos for the Early and Middle Pleistocene (by JMP 16).

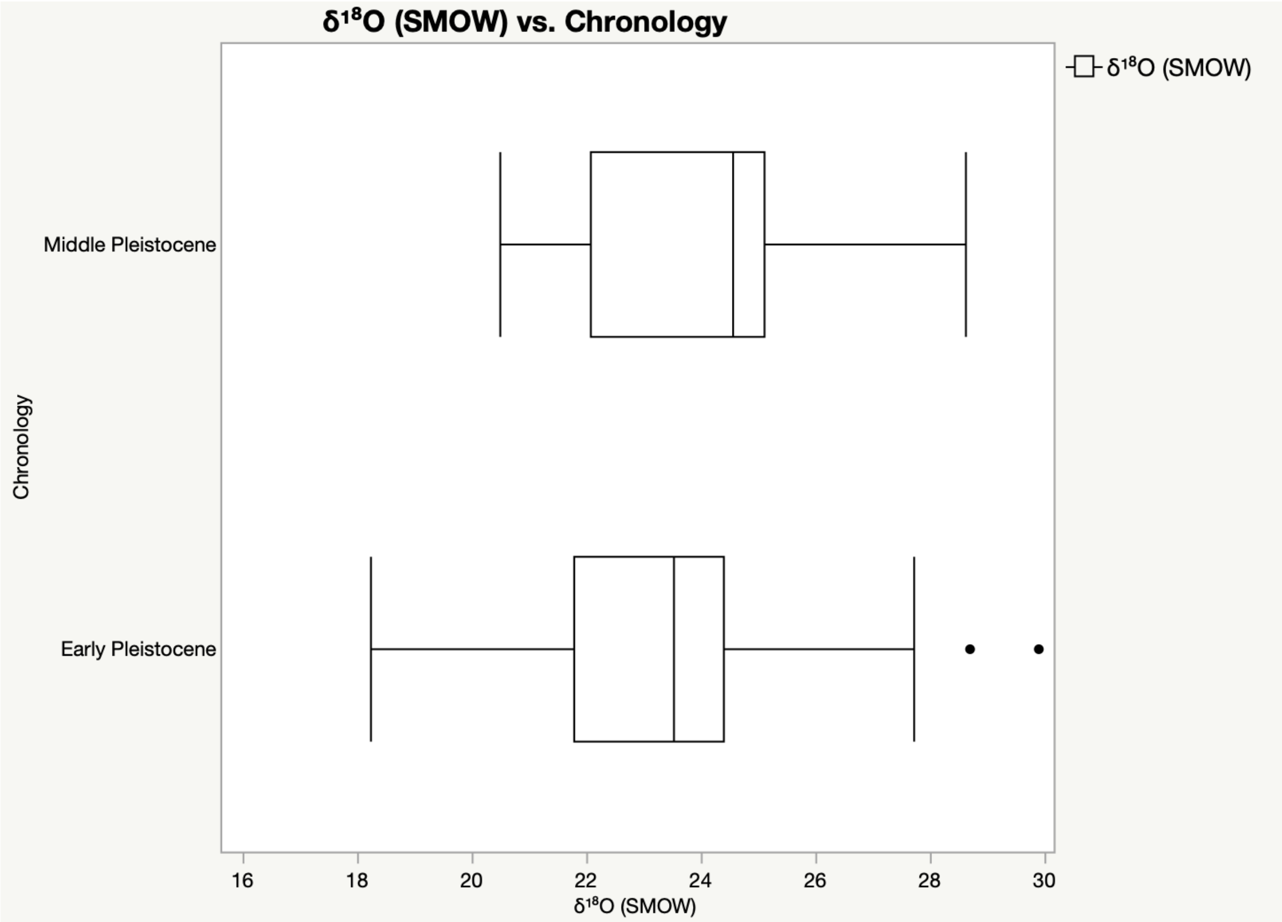


Fig.46. Boxplots with $\delta^{18}O$ values of hippos for the Early and Middle Pleistocene (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Early Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9832528	0,5471

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Distribution Group = Middle Pleistocene

Goodness-of-Fit Test

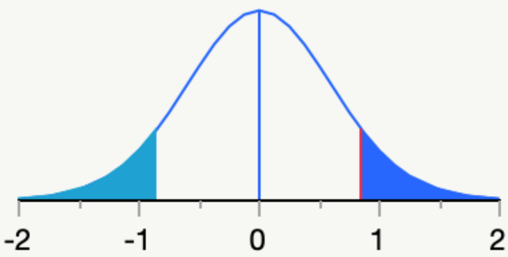
	W	Prob<W
Shapiro-Wilk	0,9547218	0,5038

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Mid Pleistocene-Early Pleistocene

Assuming unequal variances

Difference	0,8454	t Ratio	1,391963
Std Err Dif	0,6074	DF	28,18213
Upper CL Dif	2,0892	Prob > |t|	0,1748
Lower CL Dif	-0,3983	Prob > t	0,0874
Confidence	0,95	Prob < t	0,9126



Then, the T-test is used:

p-value = Prob > |t| = <0.1748

The *p*-value is bigger than 1%, and the Null hypothesis (H_0) has been accepted.

It is concluded that $\delta^{18}O$ of Hippopotamidae on average is not different during the Early and Middle Pleistocene with at the level of significance $\alpha > 1\%$.

Test 6. Bovids (Early and Middle Pleistocene)

Test 6 comprises 69 isotopic results of bovids for two sample groups, the Early and Middle Pleistocene. Fig.47, and 48 (Kernel density and boxplots, respectively) show the plotting of $\delta^{13}C$ in both groups. Long-left tails are observed.

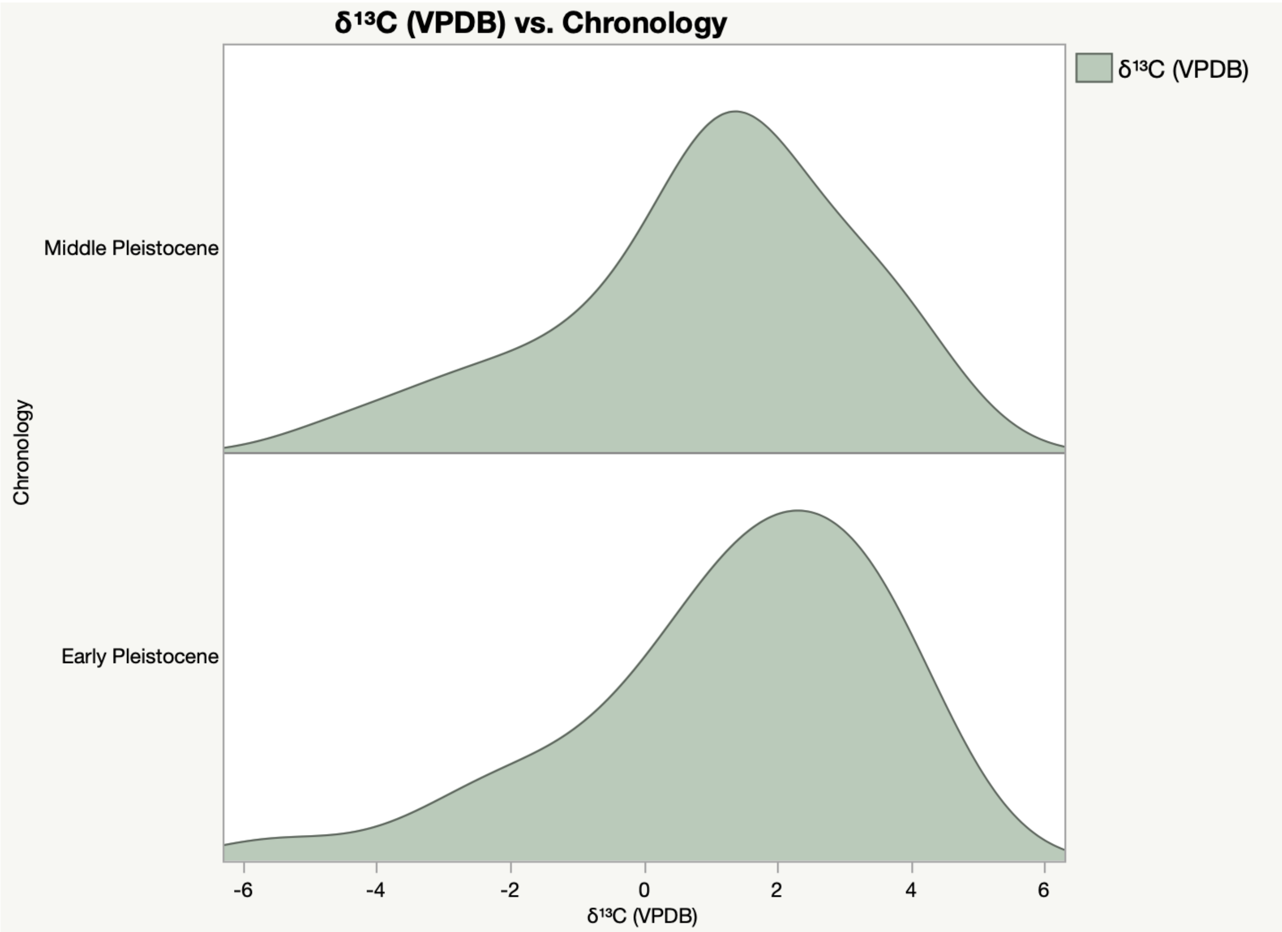


Fig.47. Kernel density plotting $\delta^{13}C$ values of bovids for the Early and Middle Pleistocene (by JMP 16).

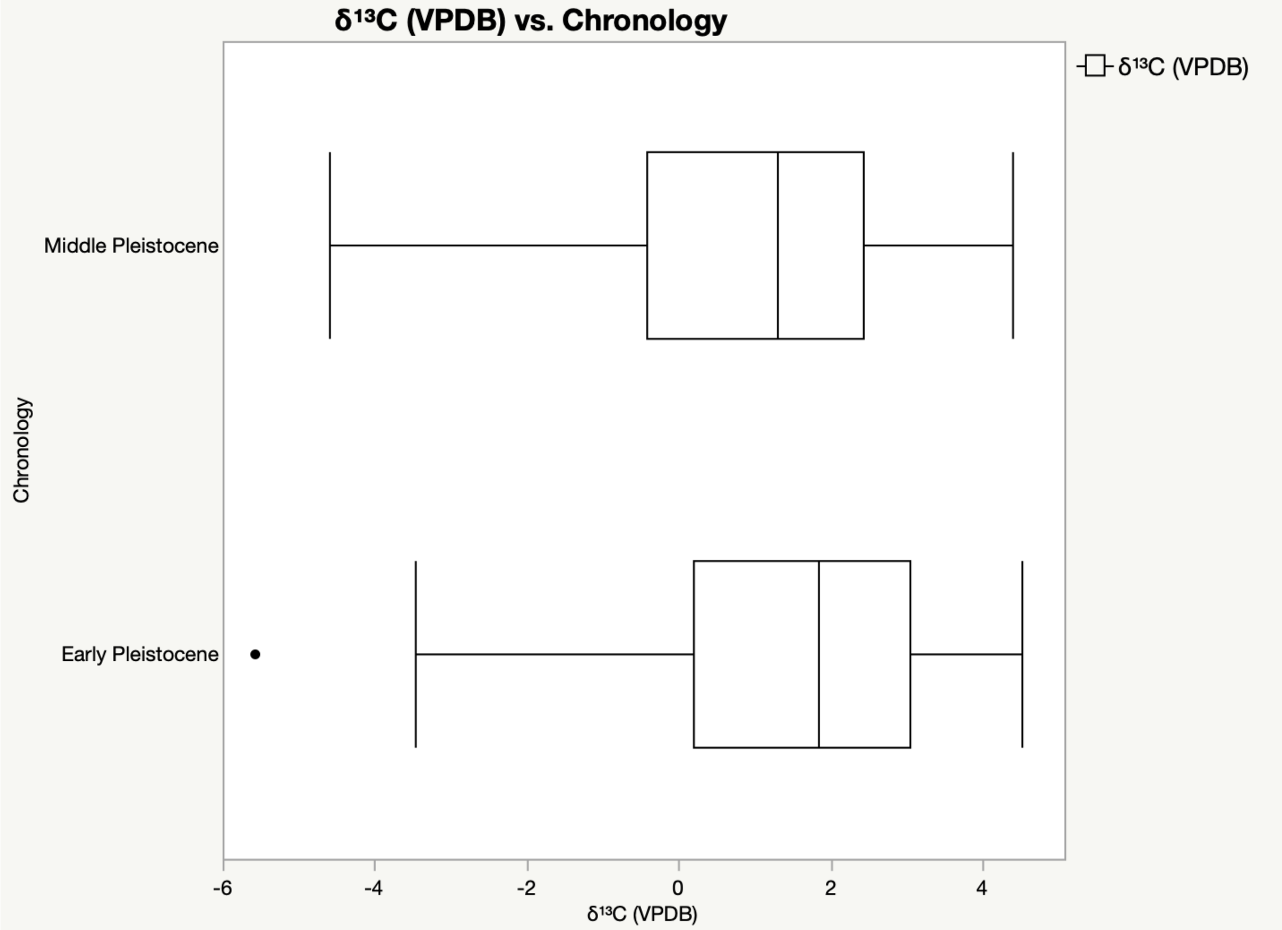


Fig.48. Boxplots with $\delta^{13}C$ values of bovids for the Early and Middle Pleistocene (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Early Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9552409	0,1528

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is rejected at a 5% significance level.

Distribution Group = Middle Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9771343	0,6968

The Shapiro-Wilk test has a *p*-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Early Pleistocene	36	930,000	1260,00	25,8333	-3,958
Mid Pleistocene	33	1485,00	1155,00	45,0000	3,958

Wilcoxon/Krustal-Wallis Tests (Rank Sums):

Sample Test, Normal Approximation:

S	Z	Prob>|Z|
1485	3,95812	<,0001*

Way Test, ChiSquare Approximation:

ChiSquare	DF	Prob>ChiSq
15,7143	1	<,0001*

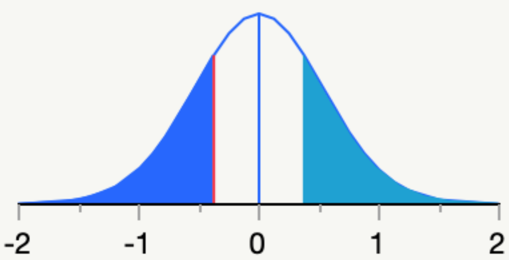
The Mann-Whitney U-test shows a *p*-value <0.0001 and is smaller than 5%. The Null hypothesis (H_0) is rejected at a 5% significance level.

It is concluded that $\delta^{13}C$ on average is different during the Early and Middle Pleistocene.

Mid Pleistocene-Early Pleistocene

Assuming unequal variances

Difference	-0,3763	t Ratio	-0,69865
Std Err Dif	0,5387	DF	66,8995
Upper CL Dif	0,6989	Prob > |t|	0,4872
Lower CL Dif	-1,4516	Prob > t	0,7564
Confidence	0,95	Prob < t	0,2436



Then, the T-test is used:

p-value = Prob > |t| = <0.4872

The *p*-value is bigger than 1%, and the Null hypothesis (H_0) has been accepted.

It is concluded that $\delta^{13}C$ of Bovidae on average is not different during the Early and Middle Pleistocene with a level of significance α = 1%.

Fig.49, and 50 (Kernel density and boxplots, respectively) show the plotting of $\delta^{18}O$ in both groups. A long right tail is observed for the Early Pleistocene data.

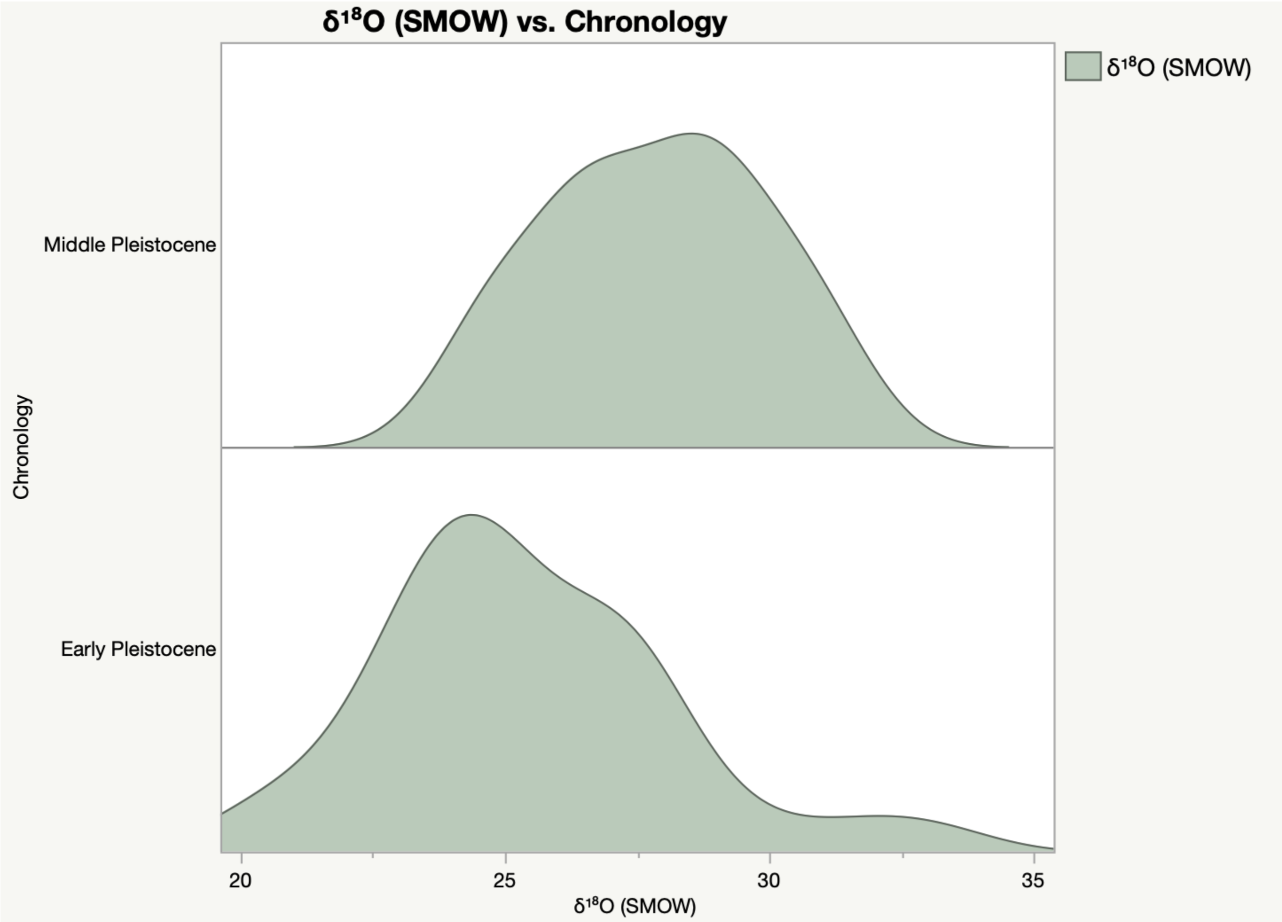


Fig.49. Kernel density with $\delta^{18}O$ values of bovids for the Early and Middle Pleistocene (by JMP 16).

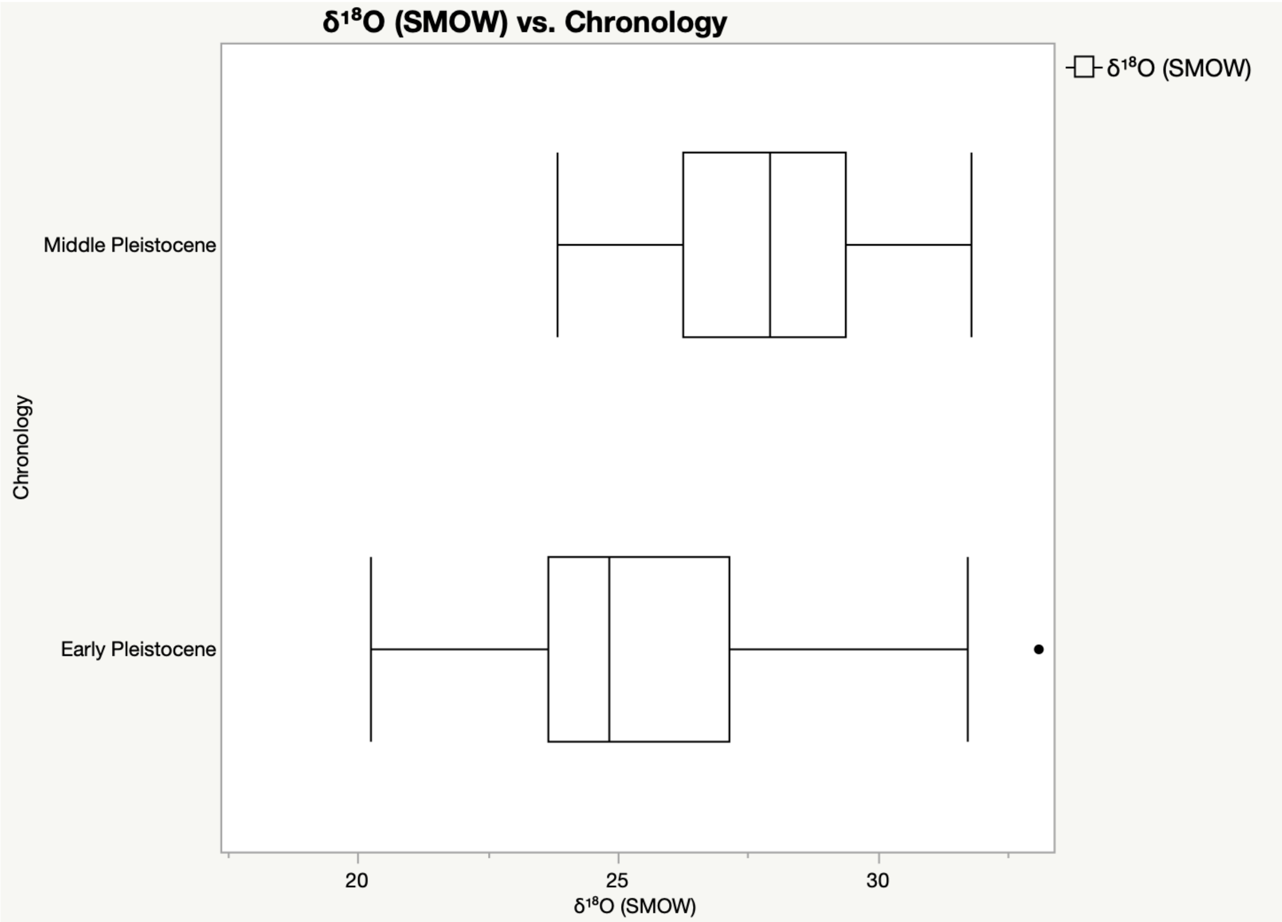


Fig.50. Boxplots with $\delta^{18}O$ values of bovids for the Early and Middle Pleistocene (by JMP 16).

Then, the normal assumption is tested below.

Distribution Group = Early Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9552409	0,1528

The Shapiro-Wilk test has a *p*-value <5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Distribution Group = Middle Pleistocene

Goodness-of-Fit Test

	W	Prob<W
Shapiro-Wilk	0,9771343	0,6968

The Shapiro-Wilk test has a p-value >5%. The Null hypothesis (H_0) of normality is accepted at a 5% significance level.

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Early Pleistocene	36	930,000	1260,00	25,8333	-3,958
Mid Pleistocene	33	1485,00	1155,00	45,0000	3,958

Wilcoxon/Krustal-Wallis Tests (Rank Sums):

Sample Test, Normal Approximation:

S	Z	Prob>|Z|
1485	3,95812	<,0001*

Way Test, ChiSquare Approximation:

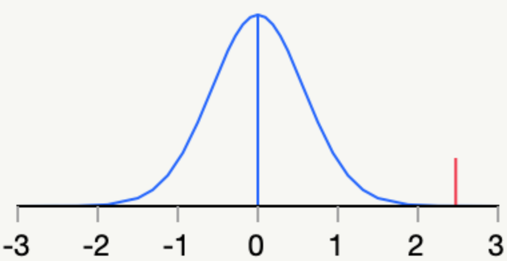
ChiSquare	DF	Prob>ChiSq
15,7143	1	<,0001*

The Mann-Whitney U-test shows a p-value <0.0001 and is smaller than 5%. The Null hypothesis (H_0) is rejected at a 5% significance level.

It is concluded that $\delta^{13}C$ on average is different during the Early and Middle Pleistocene.

Mid Pleistocene-Early Pleistocene
Assuming unequal variances

Difference	2,47233	t Ratio	4,228306
Std Err Dif	0,58471	DF	65,09134
Upper CL Dif	3,64005	Prob > |t|	<,0001*
Lower CL Dif	1,30462	Prob > t	<,0001*
Confidence	0,95	Prob < t	1,0000



Then, the T-test is used:

p-value = Prob > |t| = <0.0001

The p-value is smaller than 1%, and the Null hypothesis (H_0) has been rejected at a level of significance α = 1% (risk of false positives equal to 1%).

It is concluded that $\delta^{18}O$ of Bovidae on average is different during the Early and Middle Pleistocene with at the level of significance α = 1%.

Chapter 4: Discussion

4.1 Dietary reconstruction by stable isotopes

Early Pleistocene from ~1.95 to ~1.66 Ma. The bulk enamel samples (n = 34) from Garba IV D (~1.95 Ma), Gombore I B (~1.66 Ma), and Karre I (Oldowan - no radiometric date) show that $\delta^{13}C$ values of the hippos, bovids, equids, and suids indicate the consumption of C_4 plants ($\delta^{13}C$ median = +0.5‰), pointing to extensive C_4 high-elevation grasslands in the vegetation. Among the grazers, the hippopotamids show some depleted carbon isotopic values (Wilcoxon test, p = 0.0001), indicating a probable opportunistic feeding strategy that included C_3 plants as well. In contrast, the $\delta^{13}C$ values of crocodiles (bulk samples) are more depleted ($\delta^{13}C$ median = -9.8‰) than those of the other analyzed *taxa* due to the type of prey eaten, such as fish and/or herbivores who consumed C_3 plants. The intra-tooth serial samples of a crocodile show no variations in the $\delta^{13}C$ and $\delta^{18}O$ values, indicating a stable diet and water condition throughout the time span. As evidenced by the bulk samples, the $\delta^{13}C$ values suggest that crocodiles mostly browse herbivores (Edmunds 1962). The $\delta^{18}O$ values of hippos and crocodiles are consistent with their semi-aquatic habits, showing $\delta^{18}O$ values more depleted (for hippos: T-test, p = 0.0001) than for fully terrestrial bovids, equids, and suids. The oxygen isotopic signals of bovids, equids, and suids are indicative of diverse water sources and more mobility in the territory of hippos and crocodiles.

Early Pleistocene from ~1.51 to ~1.13 Ma. From Gombore I γ (~1.51 Ma), Gombore I δ (~1.41 Ma), Simbiro III MS (~1.3 Ma), Simbiro III gully, and Garba XIIJ (~1.13 Ma), 80 bulk enamel samples have been analyzed. The $\delta^{13}C$ values of the hippos, bovids, equids, suids and giraffids collectively show a dominant C_4 diet ($\delta^{13}C$ median = +0.6‰), although some $\delta^{13}C$ values of hippos and bovids indicate the consumption of both C_3 and C_4 plants.

As previously shown, the $\delta^{18}O$ values indicate habitat partitioning between semi-aquatic and terrestrial herbivores (T-test, p = 0.0001). Intra-tooth serial sampling (n = 97) of the hippo, equid, and suid teeth indicates a stable diet of C_4 plants and stable water conditions during the lifetime of these mammals. More specimens with high-resolution sampling (enamel serial samples taken each 1-3 mm) are needed to determine if the observed stable trend reflects a general pattern for the diets of the analyzed *taxa*. However, both bulk and intra-tooth isotopic results document an open space in vegetation such as C_4 mountain grassland, while C_3 plants were growing nearby, as shown by the $\delta^{13}C$ values of hippopotamids and bovids.

Early and Middle Pleistocene from ~1.0 to ~0.6 Ma. The bulk enamel samples (n = 64) from Garba XIII C (~1.0 Ma), Gombore II-1 (~1.0 Ma), Gombore II-2 (~0.75 Ma), Garba III C (~0.68 Ma), Garba I B (~0.6 Ma), and Gombore III, show that $\delta^{13}C$ values of hippos, bovids, and equids consumed mostly C_4 plants, but they also included in their diet more C_3 vegetation ($\delta^{13}C$ median = -1.6‰). In particular, hippopotamids and bovids show a wide range of both C_3 and C_4 values, indicating a mixed diet, as evidenced by depleted $\delta^{13}C$ values. The $\delta^{18}O$ values of all analyzed *taxa* confirm their habits in terms of ecology (difference between semi-aquatic and terrestrial herbivores: T-test, $p = 0.0001$). Finally, no intra-tooth samples have been collected for this time frame.

4.2 Palaeovegetation reconstruction by pollen analyses

This paragraph sums up the pollen results from Melka Kunture (MK) sites, published by Bonnefille *et al*. (2018). The palynological data are presented selecting only the archaeological contexts for which the isotopic analysis has been carried out as well. For more details about this study see the paper "Variability in the Mountain Environment at Melka Kunture Archaeological Site, Ethiopia, During the Early Pleistocene (~1.7 Ma) and the Mid-Pleistocene Transition (0.9–0.6 Ma)" (Bonnefille *et al*. 2018).

Early Pleistocene from ~1.95 to ~1.66 Ma. The pollen analysis at Garba IV D indicates the presence of expanded high-elevation grasslands at ~1.95 Ma, considering the high percentage of grass pollen (*Plantago* and various species of *Asteraceae*) and the low arboreal percentage (*Podocarpus*). Pollen results from Gombore I B point to a Juniper-dominated woodland/forest growing near the site at ~1.66 Ma, as evidenced by a greater amount of *Juniperus* pollens and other plant species typical of the highland forest (as *Podocarpus*, *Olea*, *Polyscias*, *Hypericum*, and *Myrica*). Nevertheless, the forest at Gombore I B was broken up by large open spaces in the vegetation (mountain grasslands), probably near the river, as evidenced by the large proportion of the grass pollen of *Poaceae* (Bonnefille *et al*. 2018).

Early Pleistocene at ~1.4 Ma. Pollen results of a sample from Garba gully, stratigraphically close to Garba IV level D, show abundant grass pollen (*Plantago*) pointing to open vegetation. At this time, the vegetation was also characterized by the presence of *Achyrantes*, an herb abundant on riverbanks, and several types of *Pteridophytae*, pointing to local humidity conditions. The presence of a few *Podocarpus*, *Euclea*, *Dodonaea* *angustifolia*, *Syzygium*, and *Acacia* trees suggest a mountain woodland and wooded grassland in the surrounding (Bonnefille *et al*. 2018).

Early and Middle Pleistocene from ~1.0 to ~0.6 Ma. At ~1.0 Ma, pollen samples from Garba gully evidenced that the vegetation surrounding Melka Kunture was dominated by Afromontane grasslands with scattered forest trees. At ~0.85 Ma, despite the high percentage of grasses in the pollen spectrum, the presence of shrubs (*Dodonaea angustifolia*, *Rumex*, *Jasminum*, *Rhus*, and *Myrsine africana*) indicates dense evergreen bushland. Moreover, the numerous and diversified tree *taxa* (*Podocarpus*, *Juniperus, Olea*, and *Rutaceae*) point to a more diverse mountain forest. Another pollen sample from Garba gully, at around the same age (~0.85 Ma), shows an increase in the arboreal pollen in which *Juniperus* becomes more abundant but includes also *Ulmaceae*, *Apocynaceae*, *Pygeum*, and *Celastraceae*. These pollen results indicate a different type of forest/woodland with dominant *Juniperus* had developed near Melka Kunture (Bonnefille *et al*. 2018). Slightly later, the pollen data show different vegetation: the arboreal pollens decreased, *Juniperus* is not present anymore, and other tree species appeared such as *Hagenia abyssinica* and *Caesalpiniaceae*, Acacia, and *Combretum* but also *Anthospermum*, a common herb of high-elevation grasslands. Finally, between ~1.0 Ma and ~0.75 Ma, the pollen composition of Gombore II-1 and Gombore II-2 indicate a diversified forest with a dense canopy of trees (*Ebenaceae*, *Croton*, *Pterolobium*, *Acacia*, and *Carissa edulis*) and shrubs (as *Heteromorpha* of the *Apiaceae* family) (Bonnefille *et al*. 2018).

4.3 Palaeovegetation reconstruction by phytolith analyses

Phytolith analysis, conducted at Simbiro III MS (for levels B, C, D) (~1.3 Ma), shows an abundance of grass phytoliths, indicating that dominant grasses were likely mesophytic *Panicoideae* (which include many C_4 species but also species using the C_3 photosynthetic pathway), and C_3 high-elevation *Pooideae*, while xerophytic C_4 grasses were rare. Seasonally, the area was probably wet, as evidenced by pennate forms diatoms. Forest indicators (conifers and woody dicots phytoliths) recorded the presence of forests or woodlands including broadleaved trees and shrubs, and conifers were likely developed at some distance (Briatico *et al*. 2021, poster; Mussi *et al*. in prep.).

4.4 Comparison of isotopic data (teeth enamel)

In this paragraph are presented 869 isotopic results ($\delta^{13}C$, $\delta^{18}O$), collected from the literature (Ascari *et al*. 2018; Bedaso *et al*. 2010; Bocherens *et al*. 1996; Negash *et al*. 2020; Rivals *et al*. 2018; Semaw *et al*. 2020; Uno *et al*. 2018; van der Merwe 2013), in order to compare the new isotopic results from MK with the published isotopic data from East Africa. For this purpose, the following archaeological sites in East Africa have been selected, at high, medium, and low altitudes: Turkana Basin, Kenya (~336 m a.s.l.); Shungura Formation, Ethiopia (~440 m a.s.l.); Gona, Ethiopia (~540 m a.s.l.); Olduvai Gorge, Tanzania (~1400 m a.s.l.); Busidima Formation, Ethiopia (~1470 m a.s.l.); Melka Kunture, Ethiopia (~2000 m a.s.l.). The isotopic results of the archaeological sites mentioned above have been selected for a chronological frame spanning from ~2.1 Ma to ~0.6 Ma (Early Pleistocene and Middle Pleistocene), using as a parameter the different altitudes. Only the *taxa* present in the faunal assemblage analyzed from MK have been compared. Isotopic data are listed in Supplementary Tables S5-10.

Hippopotamidae. This group comprises 161 isotopic results of hippopotamids (*Hippopotamus karumensis*, *Hippopotamus aethiopicus*, *Hippopotamus* cf. *amphibius*, *Hippopotamus gorgops*, and other hippos) from the Shungura Formation (Ethiopia), Turkana Basin (Kenya), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia), chronologically between ~2.1 Ma and ~0.7 Ma. The $\delta^{13}C$ values of the archaeological sites mentioned above indicate diets dominated by C_4 plants ($\delta^{13}C$ median = -0.6‰). These results suggest that the dietary strategies of the Hippopotamidae were mostly grazing and fed primarily on C_4 grasses, likely reflecting the predominance of C_4 vegetation at low, medium, and high altitudes. Nevertheless, $\delta^{13}C$ values of hippos from Shungura Formation (Ethiopia) and Melka Kunture (Ethiopia) indicate both C_4 and mixed C_3-C_4 diets (Fig.51). These results are consistent with other studies, showing opportunistic feeding for hippos, sampling available vegetation within a long and short distance from their source of aquatic shelter (Bocherens *et al*. 1996; Boisserie *et al*. 2005; Cerling *et al*. 2003; Franz-Odendaal *et al*. 2002; Kingston 1999; Levin *et al*. 2008; Morgan *et al*. 1994; Schoeninger *et al*. 2003; Zazzo *et al*. 2000). The $\delta^{18}O$ values of the analyzed hippos show a wide range of values. As "obligate drinkers", the hippos usually show $\delta^{18}O$ significantly depleted in relation to other herbivores since getting water from rivers or lakes. In this case, the comparison of $\delta^{18}O$ values among archaeological localities at a different altitude, show $\delta^{18}O$ depleted for the site at high elevation (Melka Kunture) if compared with the sites at medium and low altitude (Shungura Formation, Turkana Basin, Olduvai Gorge, Busidima Formation), probably indicating differences in temperature as well (Fig.52, 63) (Bedaso *et al*. 2010; Bocherens *et al*. 1996; Negash *et al*. 2020; Rivals *et al*. 2018; Uno *et al*. 2018; van der Merwe 2013).

Bovidae. The group of the bovids (*Aepycerotini, Alcelaphini*, *Antilopini*, *Bovini*, *Hippotragini, Reduncini*, *Tragelaphini*, and other bovids) comprises 413 isotopic results from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia), chronologically between ~2.1 Ma and ~0.6 Ma. Collectively, the δ^{13}C values (median = +0.2‰) suggest that all the diverse tribes of bovids from the mentioned sites were adapted to a wide range of feeding strategies, including in their diets a significant C_4 component but also feeding by mixed C_3-C_4 resources (Fig.53). Especially the bovids from Shungura Formation (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia) show depleted δ^{13}C values, reflecting the inclusion of C_3 vegetation component in the diet of these herbivores (Ascari *et al*. 2018; Bedaso *et al*. 2010; Bocherens *et al*. 1996; Negash *et al*. 2020; Rivals *et al*. 2018; Semaw *et al*. 2020; Uno *et al*. 2018; van der Merwe 2013). The δ^{18}O values show a wide range of values, reflecting the different drinking habits of these bovid tribes. As for the group of hippos, the oxygen isotopic results from Melka Kunture are more depleted than the other archaeological localities due to the altitude and temperature effect (Fig.54, 63).

Equidae. This group comprises 101 isotopic results of equids (*Equus olduwayensis*, *Eurygnathohippus cornelianus*, *Hipparion* sp., and other equids) from the Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia), chronologically between ~2.1 Ma and ~0.7 Ma. The δ^{13}C values (median = +0.9‰) indicate a dominant C_4 diet (Fig.55), while δ^{18}O values reflect different drinking water sources and the altitudinal effect as well, showing depleted δ^{18}O values for the high elevation context (Melka Kunture) and enriched δ^{18}O values for the archaeological sites at medium and low altitude (Fig.56, 63) (Ascari *et al*. 2018; Bedaso *et al*. 2010; Bocherens *et al*. 1996; Negash *et al*. 2020; Rivals *et al*. 2018; Uno *et al*. 2018; van der Merwe 2013).

Suidae. The group of the suids (*Metridiochoerus, Metridiochoerus compactus*, *Notochoerus*, *Phacochoerus modestus, Kolpochaerus*, *Kolpochoerus afarensis*, *Kolpochaerus limnetes, Kolpochoerus majus*, *Kolpochoerus* cf. *olduvaiensis, Kolpochoerus paiceae*, and other suids) comprises 141 isotopic results from Shungura Formation

(Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia), chronologically between ~2.1 Ma and ~0.7 Ma. All the tribes of suids from the sites mentioned above have δ^{13}C values (median = -0.5‰) that clearly indicate C_4 diets, with only a few depleted carbon isotopic values from Shungura formation (Ethiopia) and Olduvai Gorge that point to a mixed C_3-C_4 feeding strategy (Fig.57, 58, 63) (Ascari *et al*. 2018; Bedaso *et al*. 2010; Bocherens *et al*. 1996; Negash *et al*. 2020; Rivals *et al*. 2018; Uno *et al*. 2018; van der Merwe 2013).

Giraffidae. This group comprises 24 isotopic results of giraffids (*Giraffa* cf. *stillei*, *Giraffa* cf. *jumae, Sivatherium*, *Sivatherium maurusium*, and other giraffids) from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia), chronologically between ~2.1 Ma and ~0.7 Ma. The δ^{13}C values of *Giraffa* specimens from the Shungura and Busidima Formation (Ethiopia) indicate diets dominated by C_3 vegetation (Bedaso *et al*. 2010; Negash *et al*. 2020). In contrast, the two samples of *Sivatherium* from Melka Kunture (Ethiopia) show δ^{13}C values suggesting the consumption of C_4 grasses. The δ^{13}C values of the giraffid specimens from Olduvai Gorge (Tanzania) indicate different dietary patterns, from a C_3 to mixed diets, as well as C_4 diets (Fig.59, 60, 63) (Rivals *et al*. 2018; Uno *et al*. 2018; van der Merwe 2013).

Crocodylidae. The group of the crocodiles (*Crocodylus niloticus* and other crocodiles) comprises 29 isotopic results from Melka Kunture (Ethiopia), and Olduvai Gorge (Tanzania), chronologically between ~1.9 Ma and ~1.5 Ma. The δ^{13}C values of *Crocodylus niloticus* from Olduvai Gorge (Tanzania) suggest that they ate fish and/or grazing herbivores, with carbon isotope results indicating both C_4 and mixed diets (Ascari *et al*. 2018). In contrast, δ^{13}C values from Melka Kunture (Ethiopia) indicate that crocodiles ate fish and/or herbivores who consumed C_3 plants (Fig.61, 62, 63).

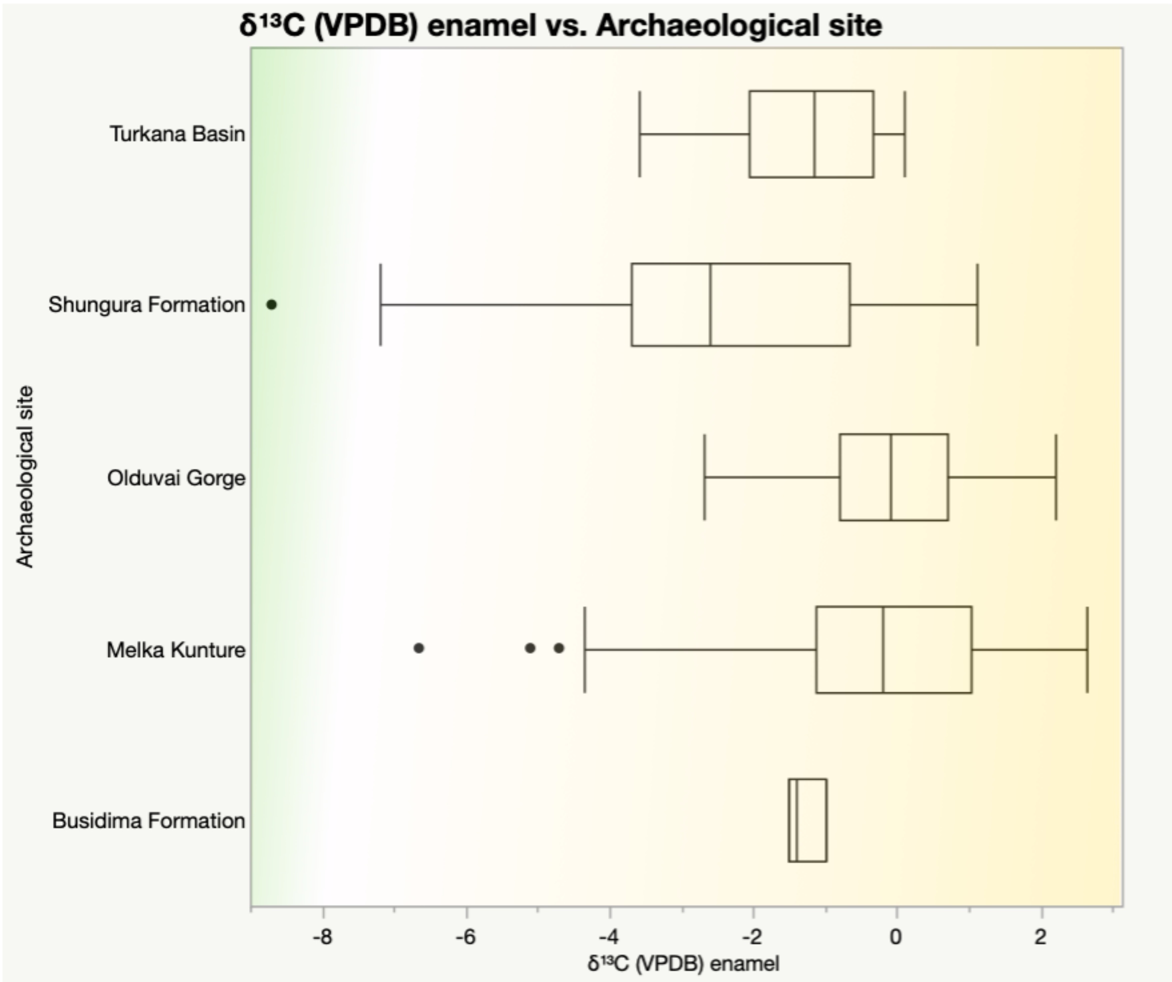


Fig.51. Boxplots of $\delta^{13}C$ values (enamel) for the fossil hippopotamids from Shungura Formation (Ethiopia), Turkana Basin (Kenya), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

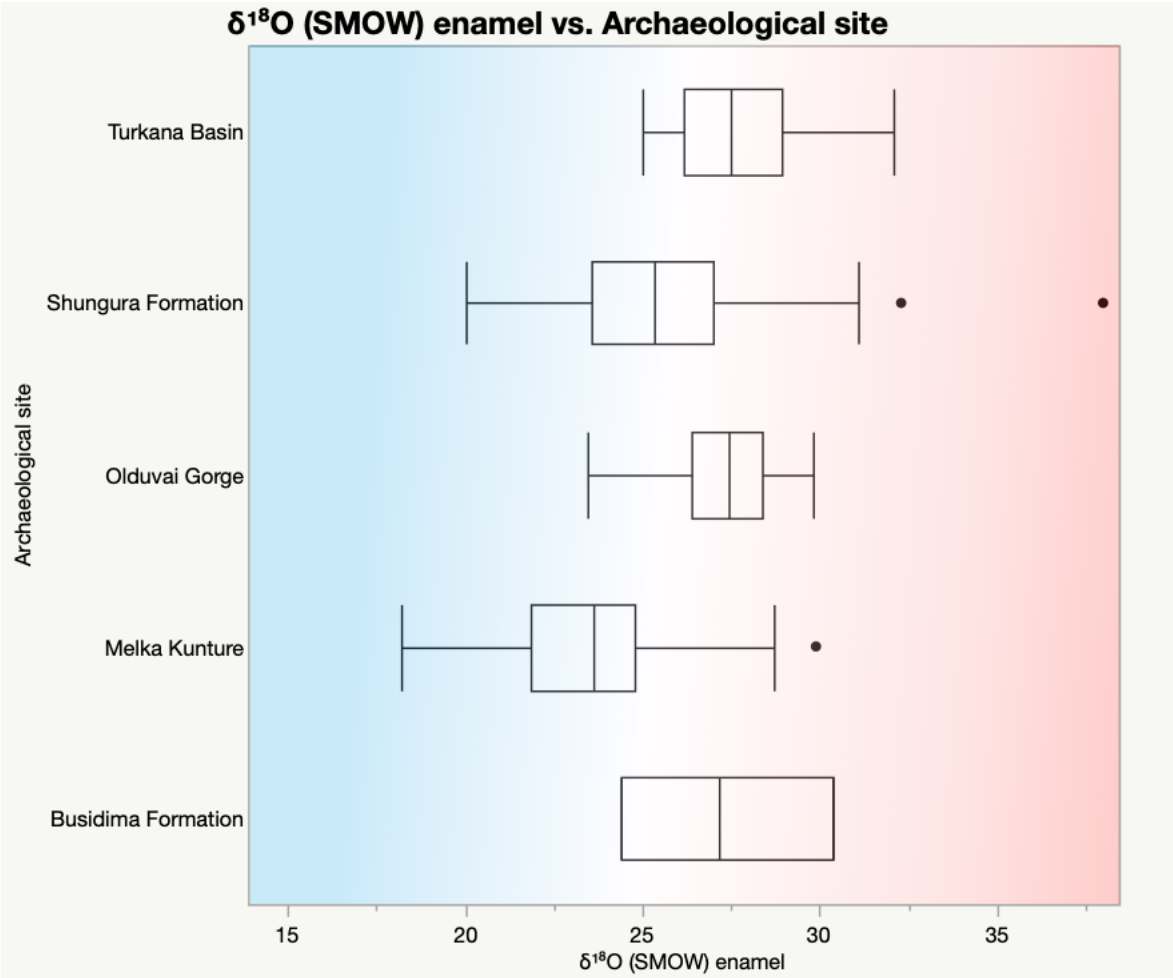


Fig.52. Boxplots of $\delta^{18}O$ values (enamel) for the fossil hippopotamids from Shungura Formation (Ethiopia), Turkana Basin (Kenya), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia). Blue and red shades indicate cold and warm temperatures, respectively.

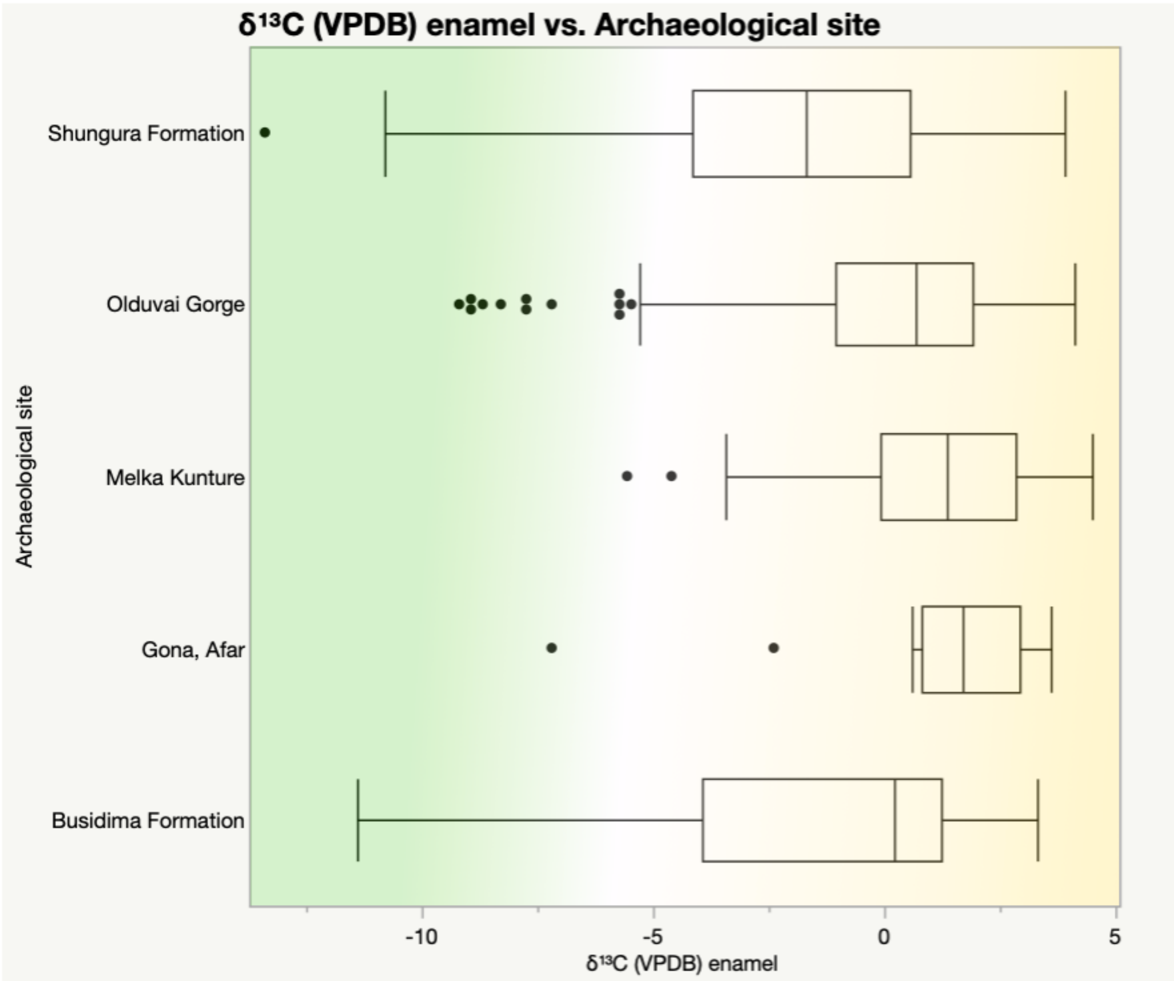


Fig.53. Boxplots of δ^{13}C values (enamel) for the fossil bovids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

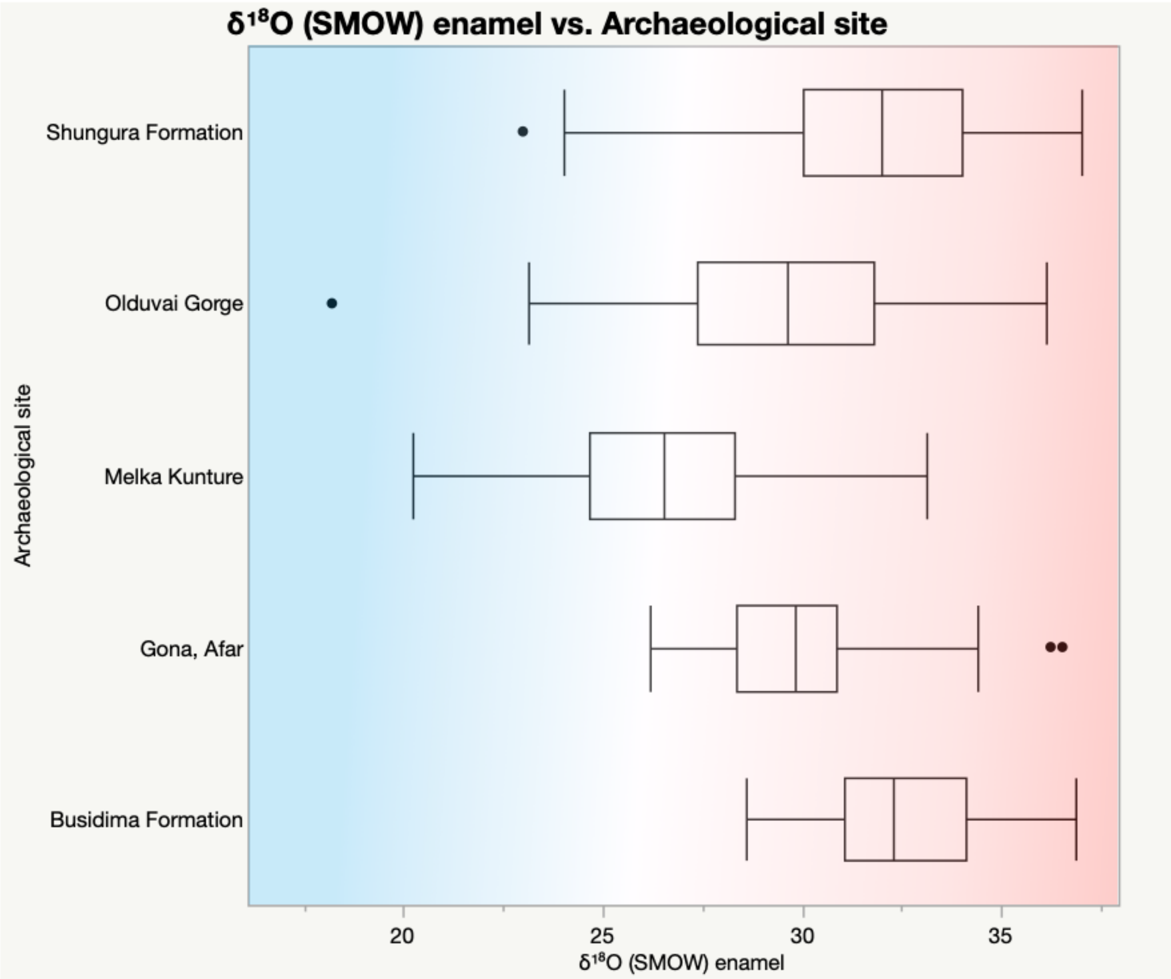


Fig.54. Boxplots of $\delta^{18}O$ values (enamel) for the fossil bovids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia). Blue and red shades indicate cold and warm temperatures, respectively.

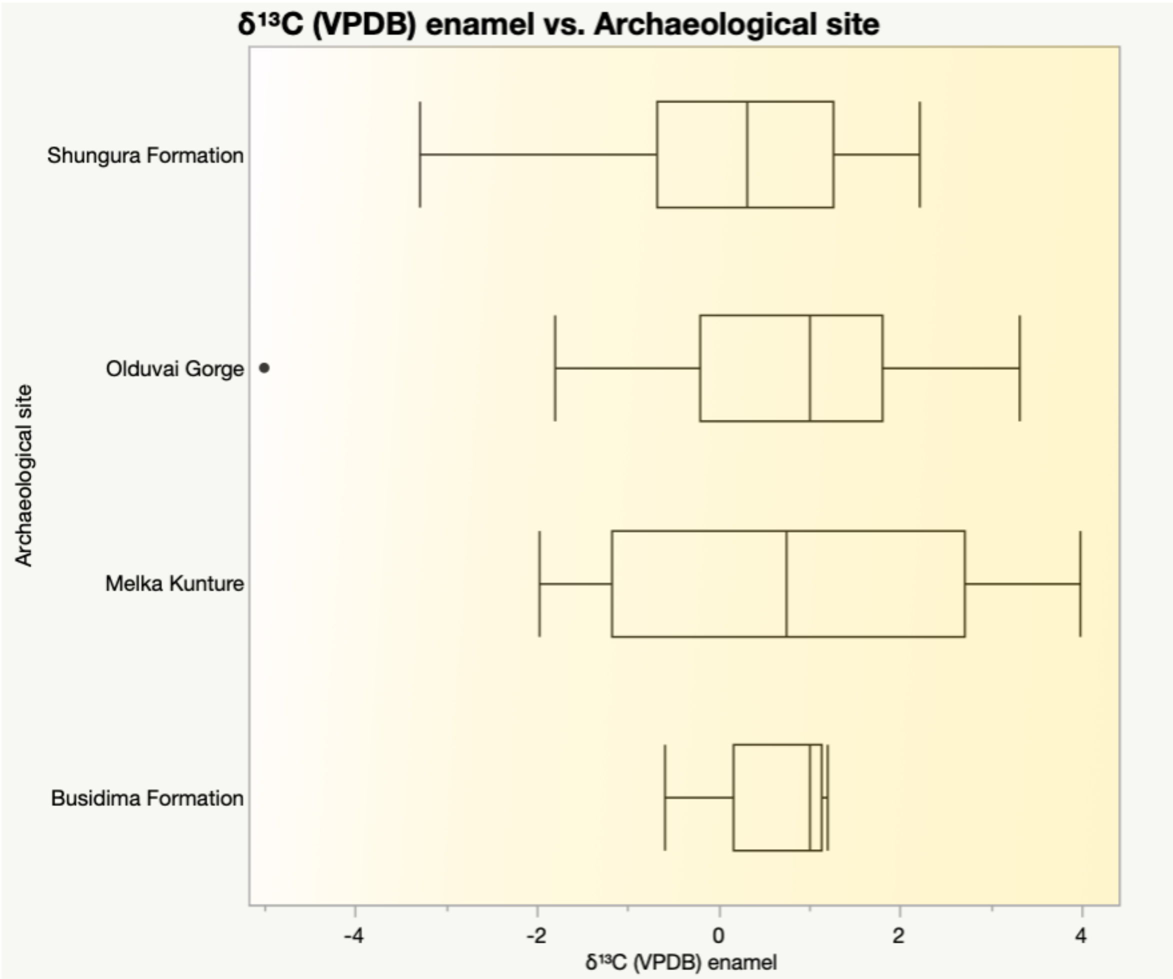


Fig.55. Boxplots of $\delta^{13}C$ values (enamel) for the fossil equids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia). White and yellow shades indicate mixed C_3-C_4 and C_4 diets, respectively.

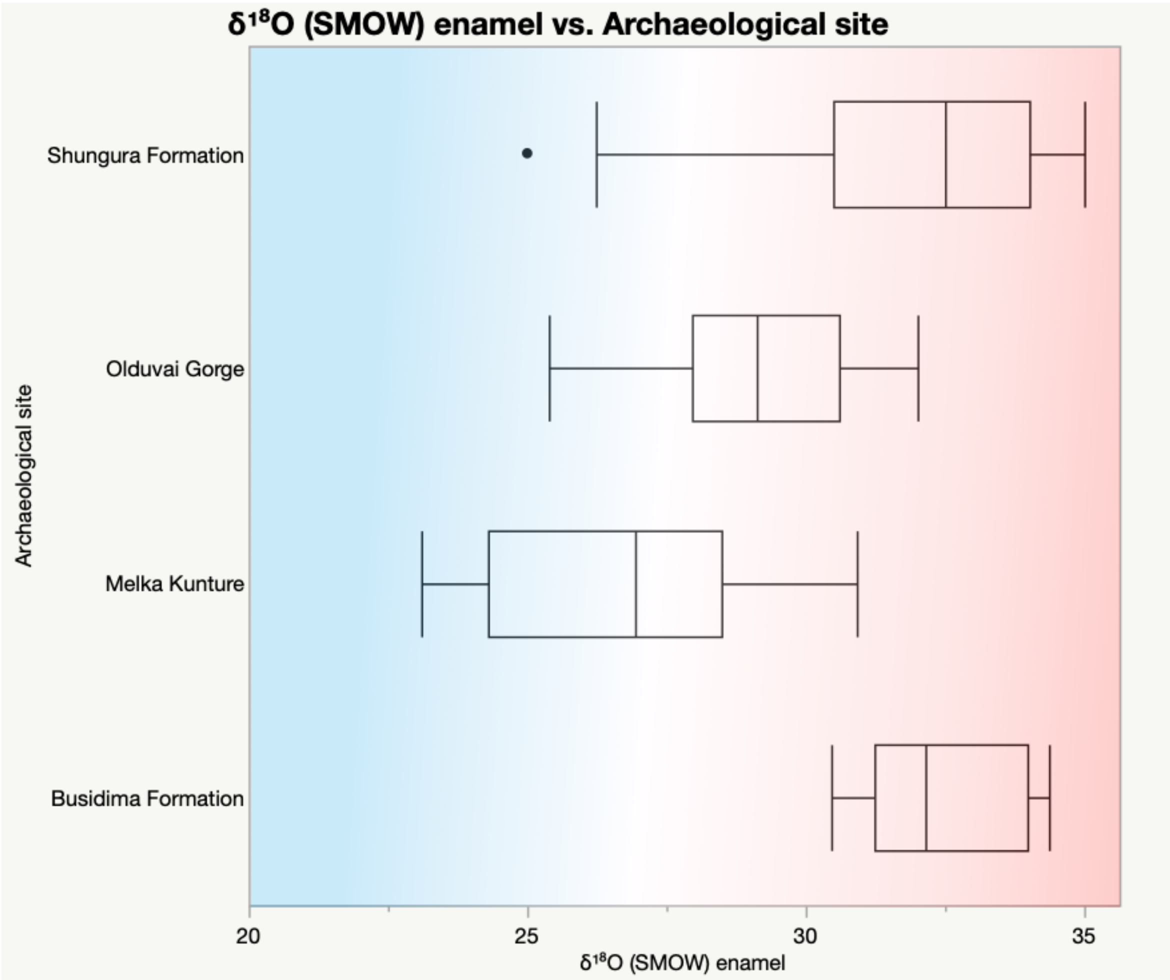


Fig.56. Boxplots of δ^{18}O values (enamel) for the fossil equids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia). Blue and red shades indicate cold and warm temperatures, respectively.

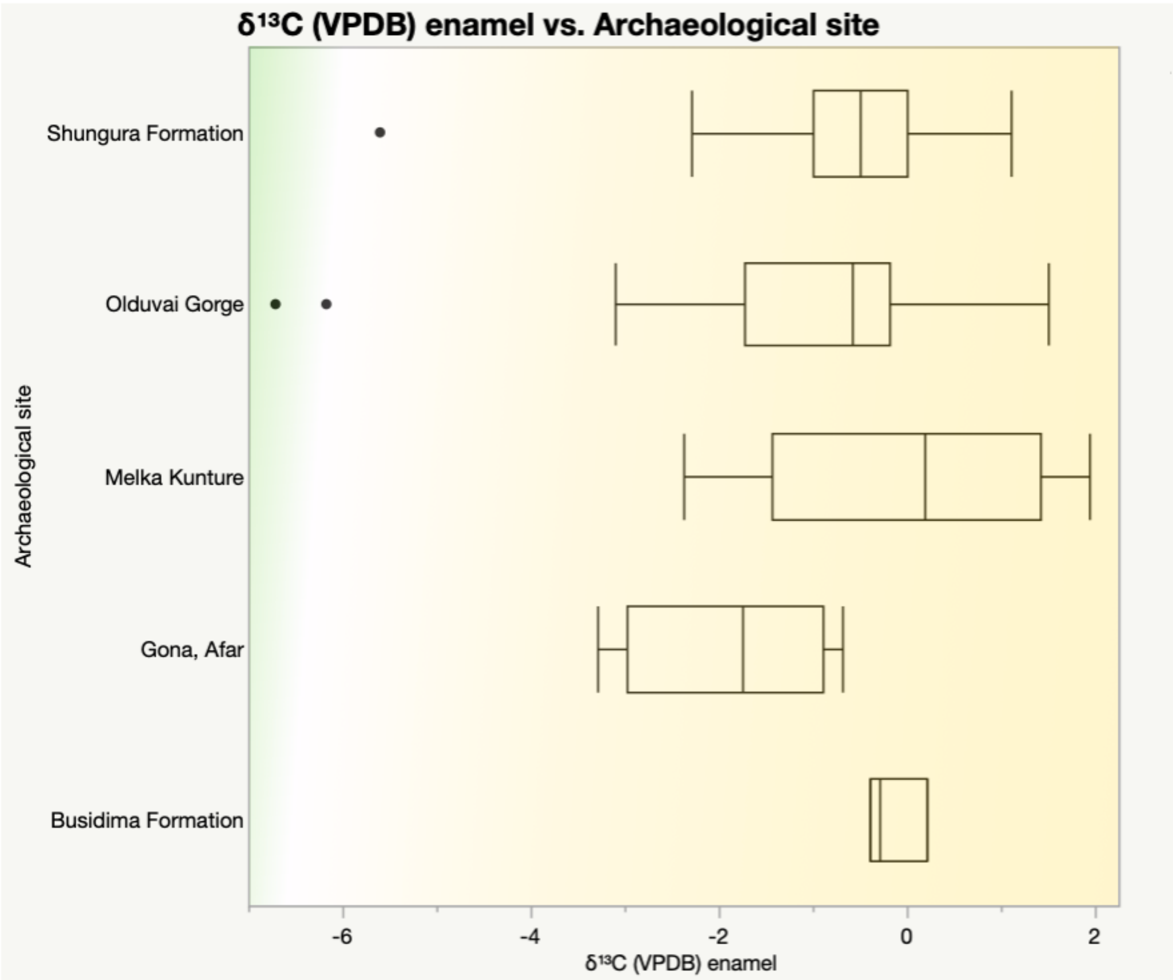


Fig.57. Boxplots of δ^{13}C values (enamel) for the fossil suids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia) and Busidima Formation (Ethiopia). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

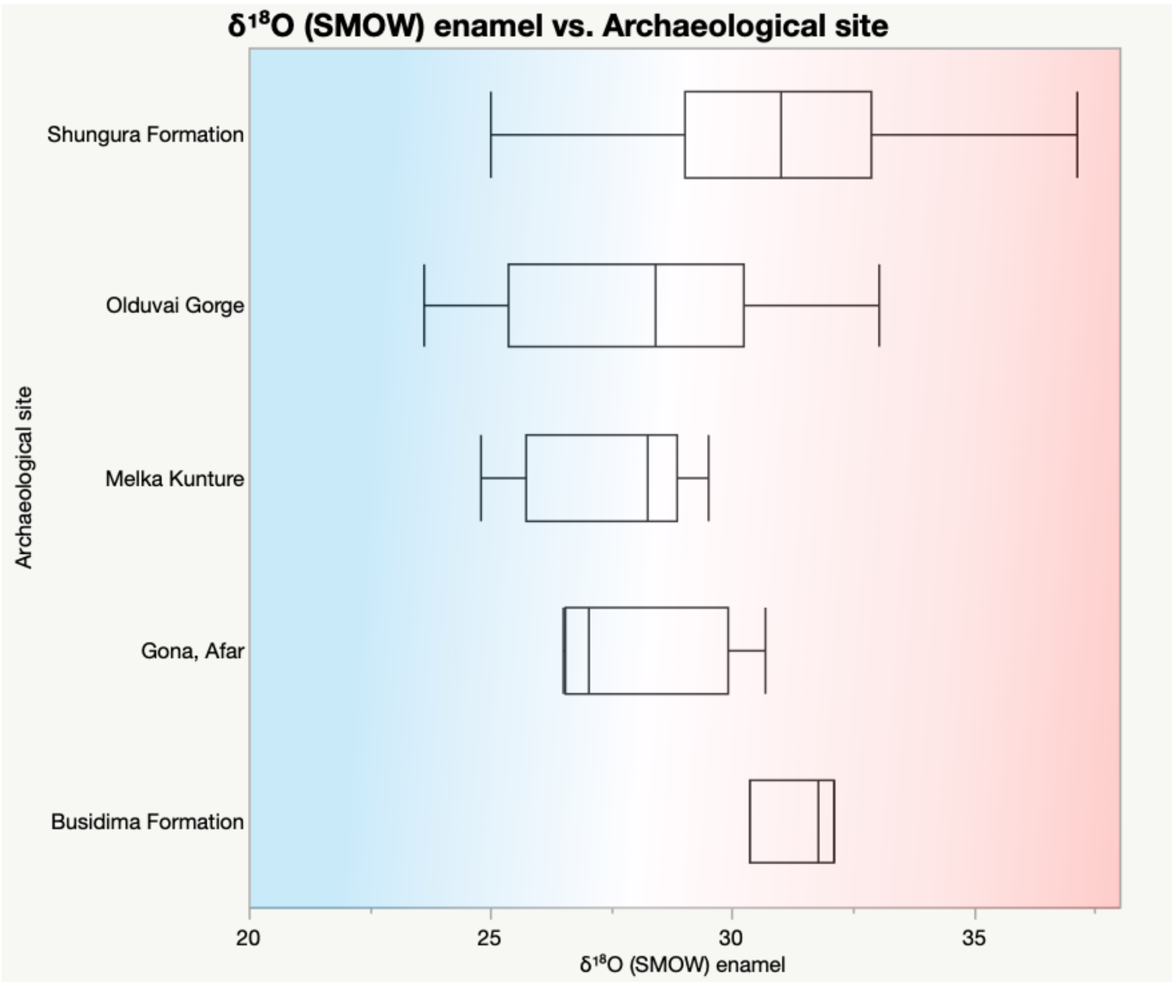


Fig.58. Boxplots of $\delta^{18}O$ values (enamel) for the fossil suids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia). Blue and red shades indicate cold and warm temperatures, respectively.

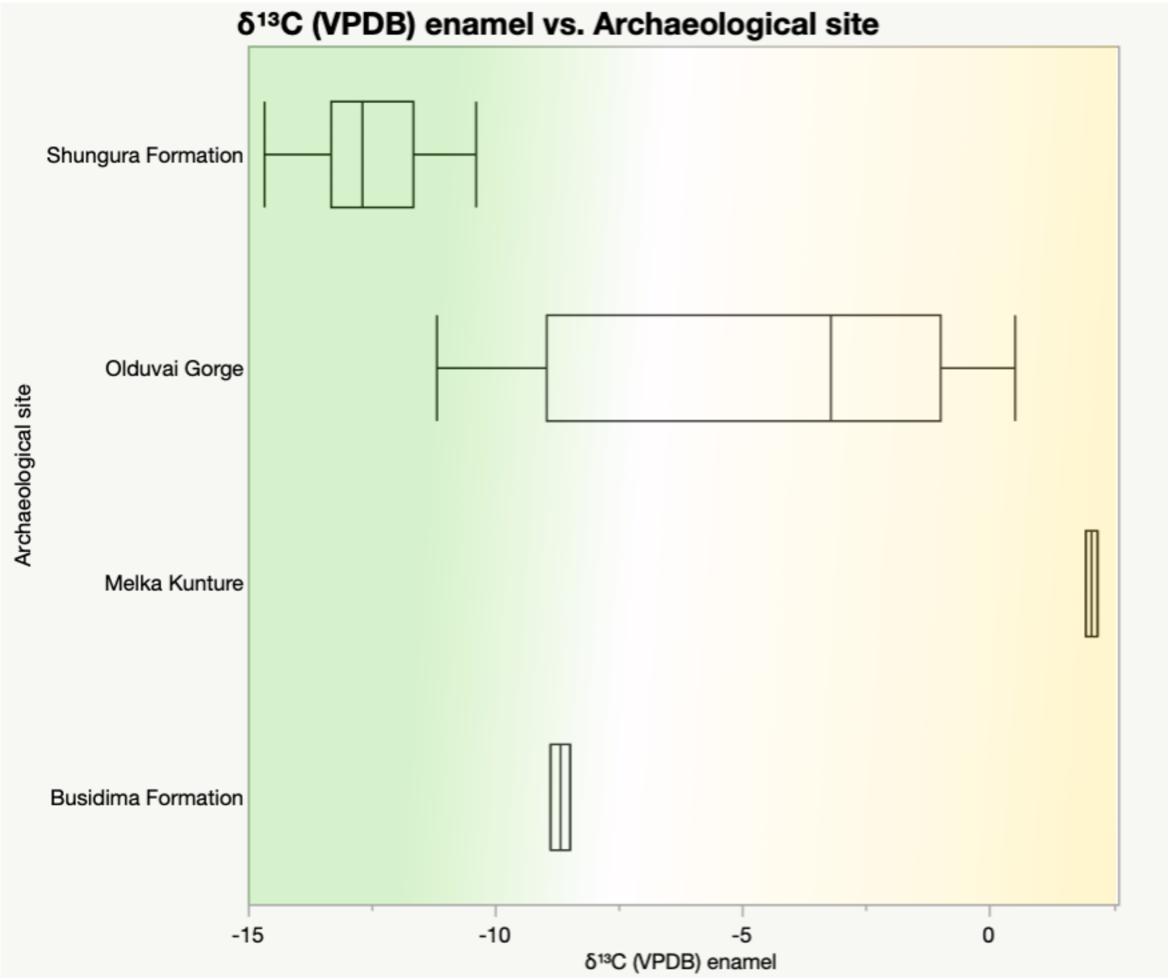


Fig.59. Boxplots of δ^{13}C values (enamel) for the fossil giraffids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

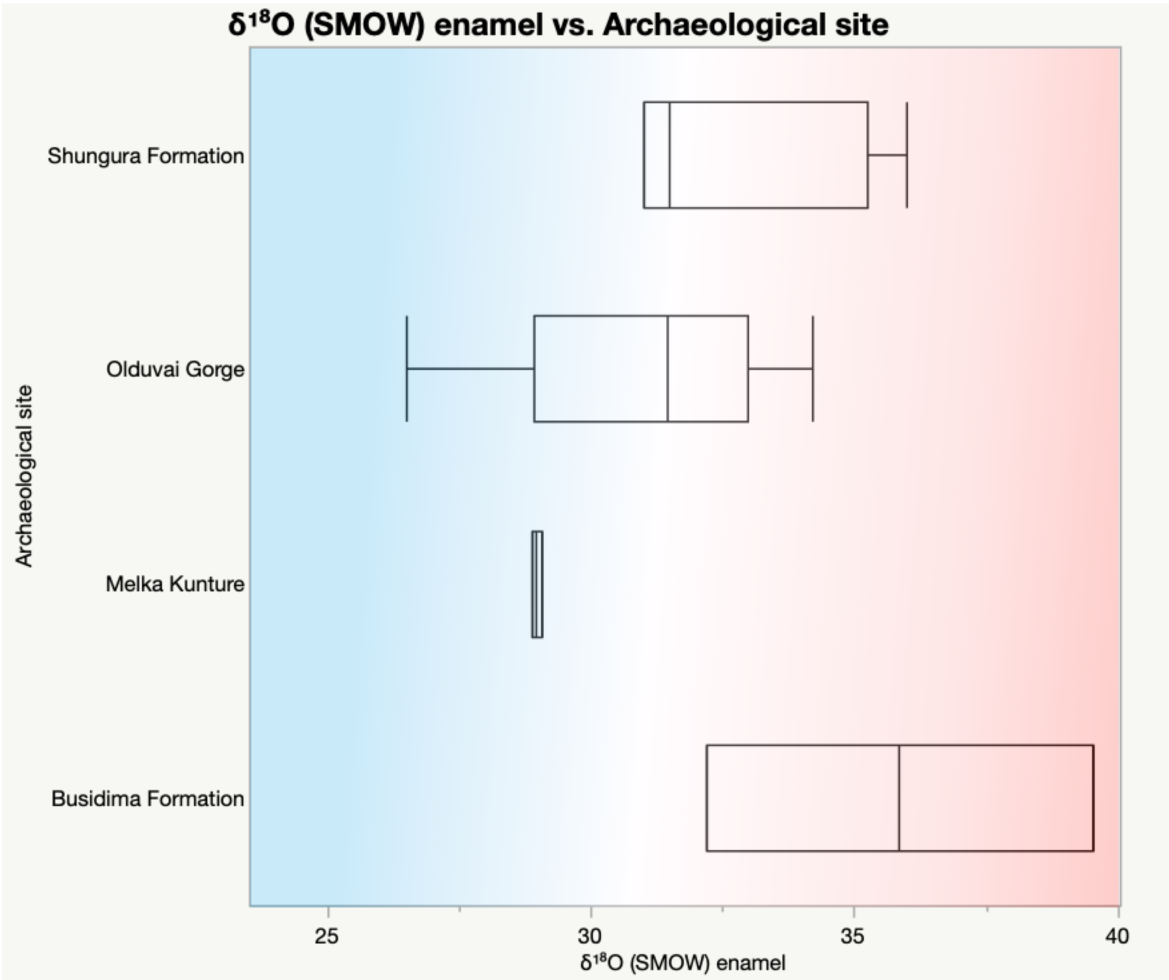


Fig.60. Boxplots of $\delta^{18}O$ values (enamel) for the fossil giraffids from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia). Blue and red shades indicate cold and warm temperatures, respectively.

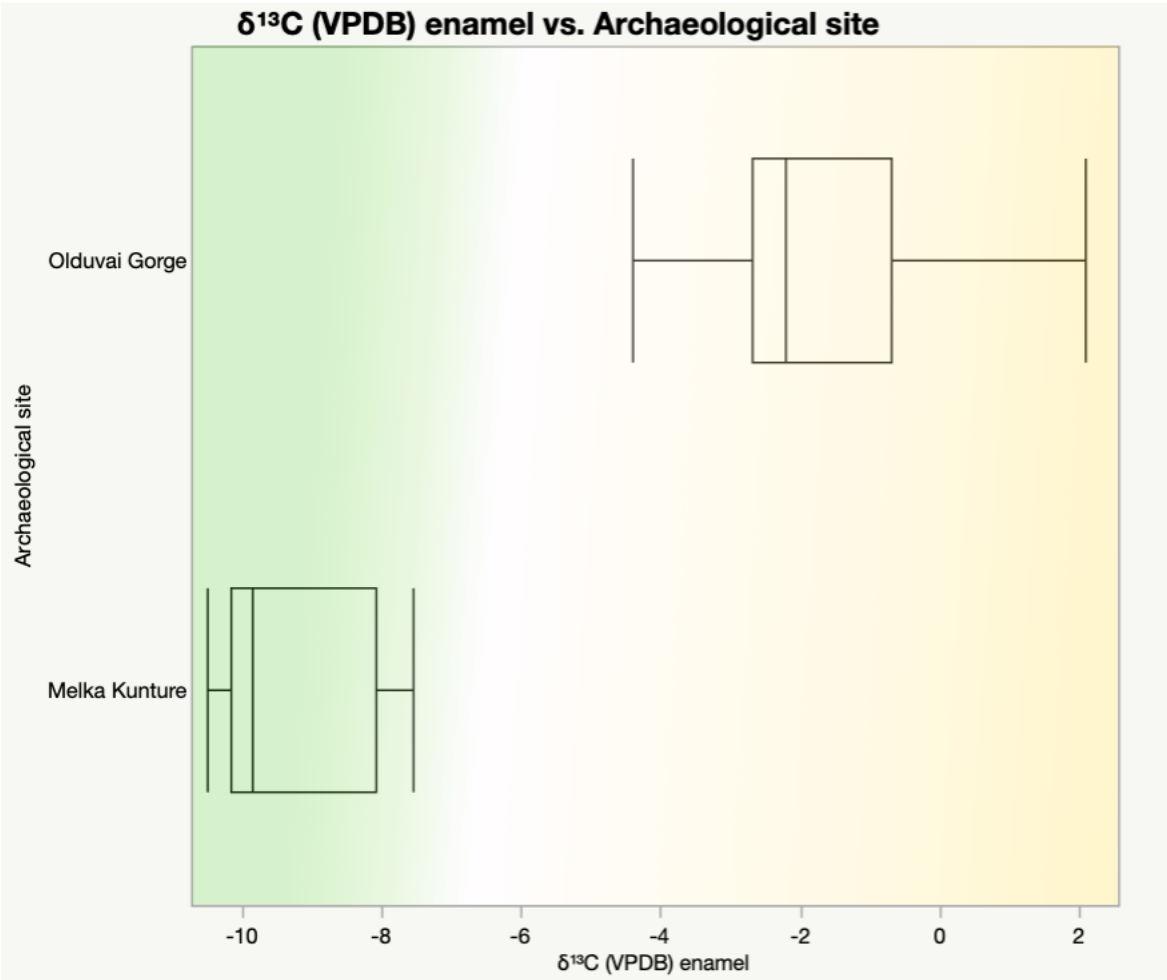


Fig.61. Boxplots of δ^{13}C values (enamel) for the fossil crocodiles from Melka Kunture (Ethiopia), and Olduvai Gorge (Tanzania). Green, white, and yellow shades indicate C_3, mixed C_3-C_4, and C_4 diets, respectively.

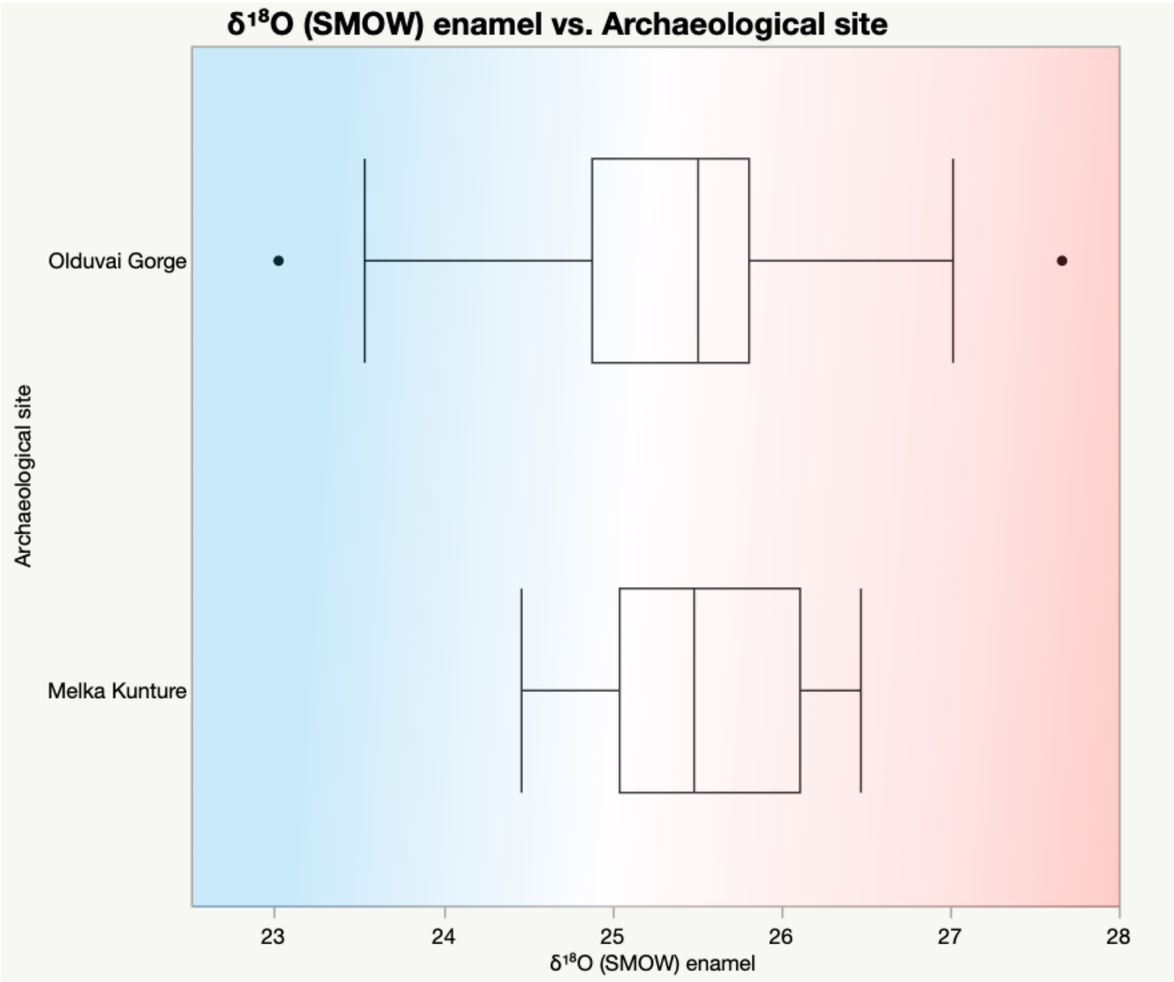


Fig.62. Boxplots of $\delta^{18}O$ values (enamel) for the fossil crocodiles from Melka Kunture (Ethiopia), and Olduvai Gorge (Tanzania). Blue and red shades indicate cold and warm temperatures, respectively.

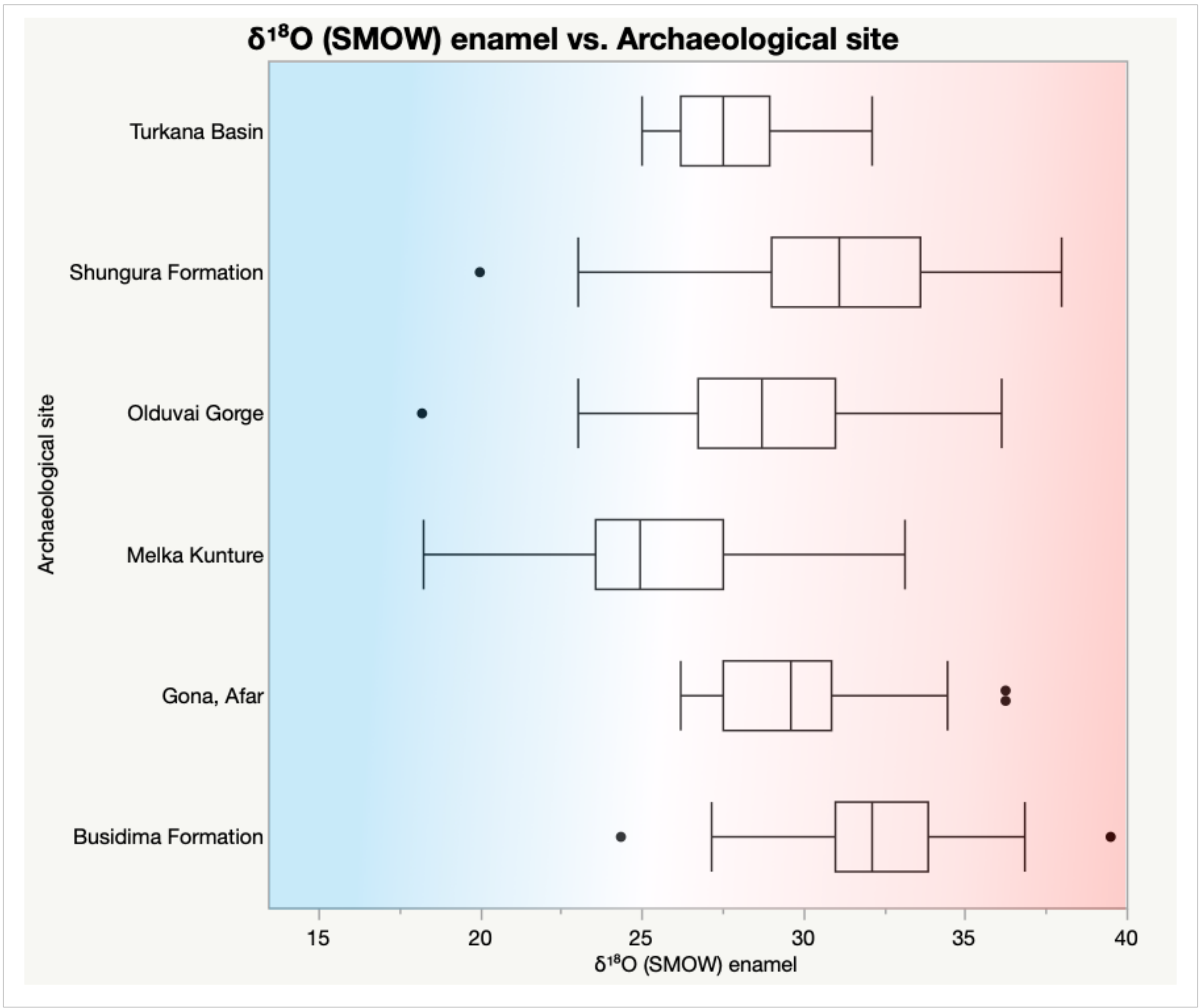


Fig.63. Boxplots of $\delta^{18}O$ values (enamel) for the fossil specimen from Shungura Formation (Ethiopia), Turkana Basin (Kenya), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia) and Busidima Formation (Ethiopia), representing the following *taxa*: Bovidae, Hippopotamidae, Equidae, Suidae, Giraffidae, and Crocodylidae. Blue and red shades indicate cold and warm temperatures, respectively.

Chapter 5: Conclusion

The isotopic analyses at the Melka Kunture (MK) prehistoric site, in the Ethiopian highland (~2000 m a.s.l.), were carried out on tooth enamel samples (carbonate) of fossil *taxa* (Hippopotamidae, Bovidae, Equidae, Suidae, Giraffidae, and Crocodylidae) to analyze the dietary adaptation of the fauna and reconstruct the range of paleoenvironmental conditions in which the fauna lived. Several specimens of the faunal assemblage have been sampled in order to test the extension of the vegetation types at MK, from ~1.95 to ~0.6 Ma (Early and Middle Pleistocene).

The carbon isotopic data from MK indicate a range of foraging strategies across the spectrum of pure C_4 diets to mixed C_3-C_4 diets, with variations between ~1.95 and ~0.6 Ma (Early and the Middle Pleistocene). From ~1.95 to ~1.66 (Early Pleistocene), at MK the hippo, bovid, equid, and suid specimens were mainly grazers, consuming C_4 grasses. In contrast, the bulk and intra-tooth carbon isotopic ratios of crocodiles suggest that Pleistocene crocodiles ate herbivores that consumed C_3 plants. Additionally, for the same sites and chronology, the palynological analyses document and confirm a paleolandscape dominated by extended grasslands at Garba IV D (~1.95 Ma), while Gombore I B (~1.66 Ma) was characterized by a mountain woodland/forest, although locally the open space was covered by herbaceous vegetation and periaquatic plants (Bonnefille *et al*. 2018). From ~1.51 to ~1.13 Ma (Early Pleistocene), the carbon isotopic data of hippos, bovids, equids, suids, and giraffids indicate a dominant C_4 diet, collectively. Only some carbon isotopic values from hippopotamids and bovids indicate a mixed C_3-C_4 feeding strategy. The intra-tooth results of hippo, equid, and suid teeth indicate C_4 diets and stable water conditions during the lifetime of the sampled mammals. Similarly, pollen analysis at Garba gully evidenced the presence of extended grasslands and mountain woodlands at ~1.4 Ma (Bonnefille *et al*. 2018). Conversely, phytolith analyses at the Simbiro III MS (~1.3 Ma.) suggested abundant likely mesophytic grasses (*Panicoideae*, both C_4 and C_3 grass species; *Pooideae*, C_3 high-elevation grass) and rare xerophytic C_4 grasses, whereas forests or woodlands (including broadleaved trees, shrubs, and conifers) likely developed at some distance (Briatico *et al*. 2021, poster; Mussi *et al*. in prep.). From ~1.0 to ~0.6 Ma (Early and Middle Pleistocene), the carbon isotopic evidence from hippos, bovids, and equids still indicate a dominant C_4 diet, but especially hippopotamids and bovids show more depleted carbon isotopic values than the previously Early Pleistocene phases, indicating a more opportunistic feeding strategy and C_3-C_4 mixed diets. This observation is also consistent with statistical tests, showing that hippopotamids and bovids had different mean carbon values (for hippos and bovids, Wilcoxon-test: $p = 0.0003$, $p = 0.0001$, respectively). At ~1.0-0.6 Ma, palynological data suggest more variations in the pollen assemblage, in which mountain grasslands and dense evergreen bushlands were permanently established, as well as forests and Afroalpine vegetation in the background. At ~0.95 Ma the presence of cold mountain grassland is followed by the expansion of the mountain juniper forest related to more humid conditions. At ~0.85 Ma the re-expansion of grasslands is related to cooler conditions. Finally, at ~0.6 Ma, the establishment of a rich and diversified humid forest closer to the site attests to a warmer and more humid climate (Bonnefille *et al*. 2018).

Based on carbon isotopic analysis of the Pleistocene fauna, combined with pollen and phytolith data, the overall environment at MK between ~1.95 and ~0.6 Ma is interpreted as extended C_4 open mountain vegetation, with a different abundance of mesophytic grasses, mountain forests, woodlands, and bushlands which changed locally and diachronically. Apparently, the results from pollen, phytoliths, and stable isotope analyses are in contrast. However, it should be kept in mind that isotopic results from mammalian teeth reflect the animal diet over the period of tooth formation, so the feeding and ecological strategies of the analyzed *taxa*, including the selection of preferred plant species and grazing at distant locations from the site; the study of fossil pollen allows to describe the plant types present even at a certain distance from the site, while phytolith data allow characterizing the distribution of the "on the spot" plants at the time of deposit formation.

Combining the stable isotopes, which emphasize the extensive open space condition as C_4 high-elevation grasslands, with the phytolith and pollen data, which also indicate the presence of mesophytic grasses, mountain forests, and wooded grasslands makes it possible to elaborate a more exhaustive paleoenvironmental and paleoecological reconstruction of the Afromontane context at MK, using all these complementary data instead of a single proxy alone. In this sense, it was also useful to compare the isotopic data (faunal teeth enamel) of some selected East African archaeological sites. The isotopic results from MK have been integrated into a regional and chronological perspective, confirming the predictions of the environment, habitat, and diets of the analyzed specimens. The feeding strategy of Pleistocene hippopotamids, bovids, equids, suids, giraffids, and crocodiles show no difference at high, medium, and low elevations. Therefore, although the vegetation at MK differed from those of the archaeological localities at medium and low altitudes (Bonnefille *et al*. 2018), it did not impact overall feeding strategies. In addition, the oxygen isotopic data from MK probably suggest that from ~1.95 to ~0.6 Ma

(Early and Middle Pleistocene) the temperature in the Ethiopian highland was colder than at lower elevation sites, as expected, considering the high elevation of MK (~2000 m a.s.l.). Finally, the hominins (*H. erectus*, and *H. heidelbergensis*) of MK, who were adapted to mountain climate conditions and experienced the variability in the Ethiopian highland from ~1.95 to ~0.6 Ma (Early and Middle Pleistocene) (as discussed in Bonnefille *et al*. 2018), lived in a diverse mountain composition of vegetation and explored both open (C_4 plants/resources) and forested/wooded (C_3 plants/resources) habitats.

The approach proposed in this dissertation confirms and strengthens a combined methodological perspective that can yield more detailed palaeoenvironmental and ecological insights. To prevent oversimplification, it is recommended to avoid reconstructions based on a single method and consider local features at a regional level.

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Supplementary Information

Testing the carbonates content in sediment samples from Melka Kunture

To verify the presence/absence of carbonate content in the geological sediments from Melka Kunture (MK), the sediment samples were tested using HCl (Hydrochloric acid) at a concentration of 10%. The tests took place at the MK archaeological camp (November 2018, November 2019), at the facilities of Sapienza University of Rome (Via dei Volsci) (March 2019), and at the laboratories of the University of Cagliari (Italy, Sardinia) (June 2019). In total, 186 geological samples were tested and showed no chemical reactions, recording no carbonate content. In January 2020, thanks to the collaboration with Prof. R.T. Melis and Prof. Laura Pioli (University of Cagliari), a new methodological strategy was applied. 64 sediment samples were dried for 24 hours and ground with the use of an agate mortar and pestle. Subsequently, 16 sediment samples were manually split and separated using an electric sieve, equipped with sieves with different mesh sizes (1000 μm, 250 μm, 63 μm, <63 μm), to classify the sediments for their granulometric features (Fig.S1). The material was collected separately, and observed under the microscope and each size group was retested with HCl (10%). Again, no chemical reactions were recorded. Finally, 3 sediment samples were analyzed with Infra-Red Spectrometry at the University of Cagliari (Fig.S2), and 16 sediment samples were analyzed with the Elementar IsoPrime 100 IRMS at the University of Tübingen (Germany). As for the previous tests, the tested samples do not show enough carbonates, probably due to the volcanic origin of the context from which the geological sediments come.

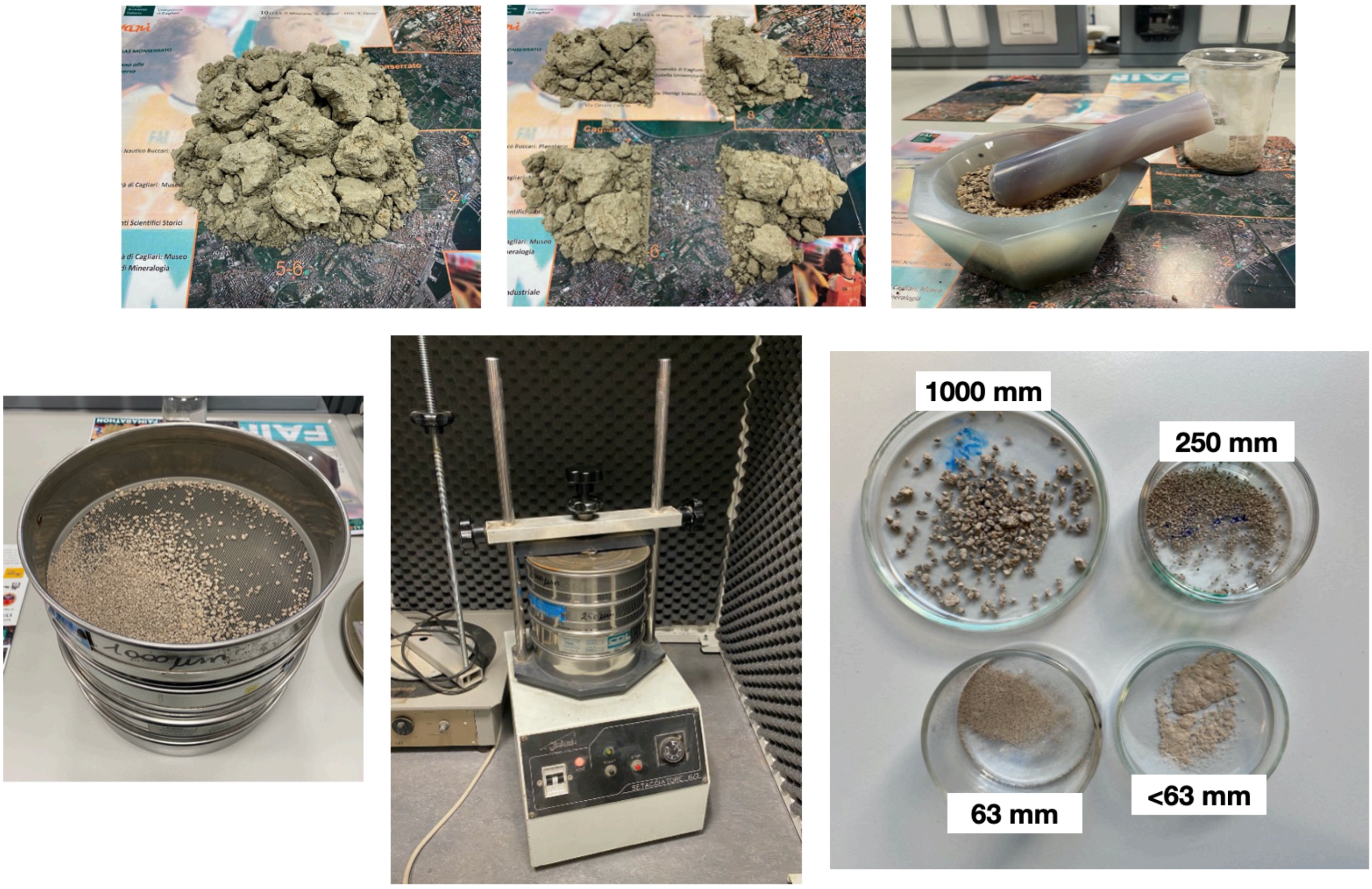

Fig.S1. Lab activities for the preparation of the sediment samples (University of Cagliari).

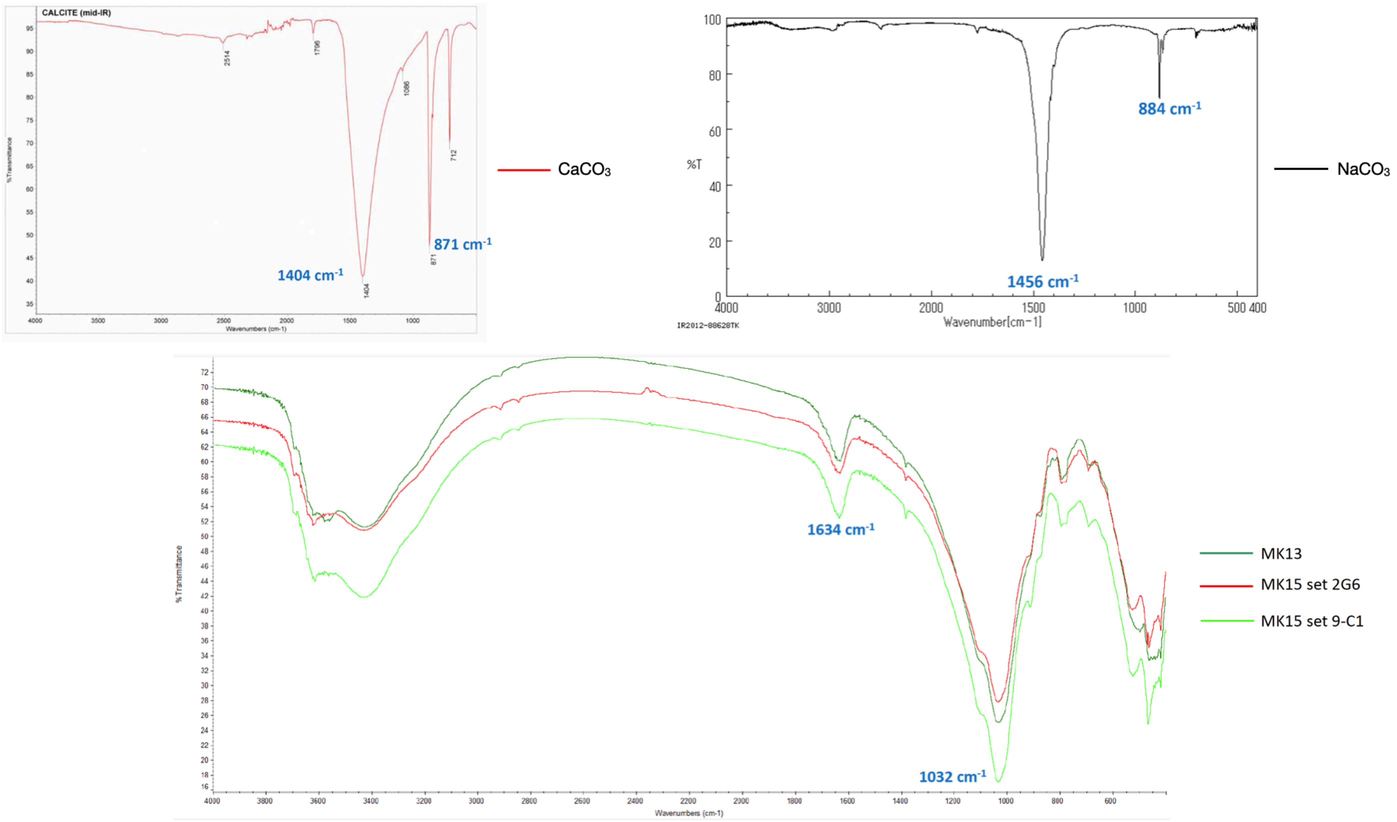

Fig.S2. Infra-Red Spectrometry results from the sediment samples (University of Cagliari).

Table S1. List of the bulk samples and values of carbon and oxygen isotopic ratio, derived from intra-tooth measurements.

	Sample number	Site	*Taxon*	Tecnique	Tissue	$\delta^{13}C$ (VPDB)	$\delta^{18}O$ (SMOW)
1	MLK 204-208	Gombore I δ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.1	+22.3
2	MLK 275-279	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.3	+22.2
3	MLK 52-55	Gombore II-1	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+0.6	+29.1
4	MLK 214-219	Garba III	Bovidae *(Bovini)*	bulk sampling	enamel	-1	+26.1
5	MLK 136-139	Garba I D	Bovidae *(Bovini)*	bulk sampling	enamel	-2.3	+26.2
6	MLK 180-185	Gombore I γ	Bovidae *(Hippotragini)*	bulk sampling	enamel	-2	+27.6
7	MLK 246-251	Simbiro III	Bovidae	bulk sampling	enamel	+3.5	+27.3
8	MLK 97-99	Simbiro III	Bovidae	bulk sampling	enamel	+3.5	+26.5

Table S2. List of the bulk samples and values of carbon and oxygen isotopic ratio.

	Sample number	Site	*Taxon*	Tecnique	Tissue	$\delta^{13}C$ (VPDB)	$\delta^{18}O$ (SMOW)
1	MLK 1	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.6	+25.9
2	MLK 2	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.8	+28.7
3	MLK 3	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.4	+24.4
4	MLK 4	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.6	+23.1
5	MLK 5	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	0	+21.2

6	MLK 6	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.8	+24.9
7	MLK 7	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.6	+24.7
8	MLK 8	Gombore II-1	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-5.1	+27.9
9	MLK 9	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-2.4	+21.1
10	MLK 11	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.7	+26.4
11	MLK 13	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.3	+22.1
12	MLK 14	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.1	+24.4
13	MLK 15	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.1	+21.6
14	MLK 28	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.8	+22.2
15	MLK 29	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.1	+22.9
16	MLK 30	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.7	+18.9
17	MLK 31	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.4	+23.8
18	MLK 32	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-4.35	+19.1
19	MLK 35	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.7	+23.8
20	MLK 67	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-10.6	+19.7
21	MLK 89	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.3	+20.5
22	MLK 92	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.1	+22.2
23	MLK 96	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.4	+23.4

24	MLK 135	Garba XIII B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.26	+18.2
25	MLK 140	Karre I K	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.7	+23.5
26	MLK 141	Garba XII	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.1	+26.3
27	MLK 142	Garba XII	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-2.3	+25.7
28	MLK 144	Gombore II-1	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.6	+24.7
29	MLK 148	Gombore II-1	*Hippopotamus cf. amphibius*	bulk sampling	enamel	-1.4	+21.1
30	MLK 149	Gombore II-1	*Hippopotamus cf. amphibius*	bulk sampling	enamel	-2.6	+28.6
31	MLK 150	Gombore II-1	*Hippopotamus cf. amphibius*	bulk sampling	enamel	-2.4	+20.8
32	MLK 166	Garba XII	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.8	+23.6
33	MLK 167	Garba XII	*Hippopotamus* cf. *amphibius*	bulk sampling	dentine	-1.4	+24.8
34	MLK 168	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.6	+26.4
35	MLK 169	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-4.1	+22.5
36	MLK 170	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1	+26.3
37	MLK 171	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.2	+22.3
38	MLK 172	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.8	+23.9
39	MLK 173	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.7	+23.6
40	MLK 174	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.6	+23.8
41	MLK 175	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	dentine	-1.5	+25.1

42	MLK 176	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.1	+23.6
43	MLK 178	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.3	+23.8
44	MLK 179	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.2	+25.1
45	MLK 186	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1	+24.1
46	MLK 187	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.1	+22.8
47	MLK 188	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.5	+23.5
48	MLK 190	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	0	+25.4
49	MLK 193	Gombore I γ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.5	+22.7
50	MLK 199	Gombore I δ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.3	+24.3
51	MLK 203	Gombore I δ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.9	+21.1
52	MLK 222	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-4.3	+24.8
53	MLK 223	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-2.6	+25.8
54	MLK 224	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-6.6	+22.7
55	MLK 240	Garba III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.6	+24.8
56	MLK 242	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.5	+25.4
57	MLK 243	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.6	+19.9
58	MLK 244	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.2	+20.5
59	MLK 245	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.4	+20.1

60	MLK 263	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.9	+22.1
61	MLK 267	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.2	+21.7
62	MLK 282	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.1	+21.4
63	MLK 284	Gombore II	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.9	+24.5
64	MLK 285	Gombore II	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.5	+20.4
65	MLK 290	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-2.2	+25.8
66	MLK 291	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.9	+23.5
67	MLK 292	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.3	+22.1
68	MLK 293	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.1	+21.8
69	MLK 294	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.6	+23.9
70	MLK 299	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.4	+24.5
71	MLK 303	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.4	+19.2
72	MLK 304	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.1	+23.1
73	MLK 305	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	0	+22.1
74	MLK 306	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.1	+24.4
75	MLK 204-208	Gombore I δ	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.1	+22.3
76	MLK 275-279	Simbiro III	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.3	+22.2
77	MLK 177	Gombore I γ	Giraffidae *(Sivatherium)*	bulk sampling	enamel	+2.1	+29.1

78	MLK 189	Gombore I γ	Giraffidae (Sivatherium)	bulk sampling	enamel	+1.9	+28.8
79	MLK 234	Garba IV D	Crocodylidae	bulk sampling	enamel	-10.5	+25.9
80	MLK 235	Garba IV D	Crocodylidae	bulk sampling	enamel	-8.2	+25.7
81	MLK 236	Garba IV D	Crocodylidae	bulk sampling	enamel	-9.8	+25.2
82	MLK 237	Garba IV D	Crocodylidae	bulk sampling	enamel	-10	+26.4
83	MLK 238	Garba IV D	Crocodylidae	bulk sampling	enamel	-9.8	+24.4
84	MLK 239	Garba IV D	Crocodylidae	bulk sampling	enamel	-7.5	+25.2
85	MLK 10	Simbiro III	Equidae	bulk sampling	enamel	+3.1	+28.2
86	MLK 12	Simbiro III	Equidae	bulk sampling	enamel	+2.1	+23.1
87	MLK 33	Simbiro III	Equidae	bulk sampling	enamel	-1.9	+24.4
88	MLK 36	Simbiro III	Equidae	bulk sampling	enamel	+2.1	+23.9
89	MLK 164	Gombore II-1	Equidae	bulk sampling	enamel	+0.2	+29.2
90	MLK 198	Gombore I δ	Equidae	bulk sampling	enamel	-0.1	+24.4
91	MLK 286	Gombore VI	Equidae	bulk sampling	enamel	-0.3	+23.7
92	MLK 289	Gombore II-2	Equidae	bulk sampling	enamel	+2.1	+24.9
93	MLK 295	Gombore II-2	Equidae	bulk sampling	enamel	-1.1	+27.3
94	MLK 296	Gombore II-2	Equidae	bulk sampling	enamel	-1.6	+29.7
95	MLK 297	Gombore II-2	Equidae	bulk sampling	enamel	-0,40	+27.5

96	MLK 298	Gombore II-2	Equidae	bulk sampling	enamel	-1.9	+24.1
97	MLK 300	Gombore II-2	Equidae	bulk sampling	enamel	+1.2	+28.6
98	MLK 301	Gombore II-2	Equidae	bulk sampling	enamel	+2.7	+27.1
99	MLK 302	Gombore II-2	Equidae	bulk sampling	enamel	+2.9	+26.8
100	MLK 145	Gombore I B	Equidae *(Hipparion)*	bulk sampling	enamel	+0.1	+26.5
101	MLK 143	Garba XII	Suidae	bulk sampling	enamel	-1.6	+29.4
102	MLK 196	Gombore I δ	Suidae	bulk sampling	enamel	+1.9	+28.2
103	MLK 200	Gombore I δ	Suidae	bulk sampling	enamel	+1.4	+25.4
104	MLK 307	Gombore I B	Suidae	bulk sampling	enamel	+1.2	+28.5
105	MLK 308	Gombore I B	Suidae	bulk sampling	enamel	+0.9	+28.9
106	MLK 311	Gombore I B	Suidae	bulk sampling	enamel	-0.7	+26.5
107	MLK 163	Gombore I B	Suidae *(Kolpochoerus)*	bulk sampling	enamel	-2.3	+24.7
108	MLK 191	Gombore I γ	Suidae *(Metridiochoerus)*	bulk sampling	enamel	-0.6	+28.2
109	MLK 47	Gombore II-1	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+3.5	+28.1
110	MLK 48	Gombore II-1	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+4.3	+28.4
111	MLK 49	Gombore II-1	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+3.2	+27.3
112	MLK 159	Gombore II-1	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+1.1	+26.1

113	MLK 212	Garba III	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	-0.5	+24.6
114	MLK 52-55	Gombore II-1	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+0.6	+29.1
115	MLK 51	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	-2.1	+27.9
116	MLK 85	Simbiro III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+4.2	+25.3
117	MLK 87	Simbiro III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+0.7	+27.1
118	MLK 151	Gombore III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+2.4	+28.7
119	MLK 152	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	-0.3	+30.2
120	MLK 153	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+0.4	+29.5
121	MLK 154	Gombore I	Bovidae *(Alcelaphini)*	bulk sampling	enamel	-0.6	+29.6
122	MLK 155	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.2	+28.6
123	MLK 156	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.1	+29.7
124	MLK 158	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.3	+29.1
125	MLK 160	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+2.9	+26.8
126	MLK 161	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.7	+27.6
127	MLK 162	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.1	+28.9
128	MLK 165	Gombore II-1	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+3.3	+30.3
129	MLK 209	Garba III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.4	+25.8
130	MLK 210	Garba III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+2.1	+24.7

131	MLK 211	Garba III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+2.3	+24.9
132	MLK 213	Garba III	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+3.8	+24.8
133	MLK 310	Gombore I B	Bovidae *(Alcelaphini)*	bulk sampling	enamel	+1.7	+23.6
134	MLK 221	Garba III	Bovidae *(Antilopini)*	bulk sampling	enamel	-2.8	+26.5
135	MLK 192	Gombore I γ	Bovidae *(Reduncini)*	bulk sampling	enamel	-5.5	+24.3
136	MLK 220	Garba III	Bovidae *(Reduncini)*	bulk sampling	enamel	+1.4	+26.4
137	MLK 94	Simbiro III	Bovidae *(Bovini)*	bulk sampling	enamel	-2.3	+27.8
138	MLK 214-219	Garba III	Bovidae *(Bovini)*	bulk sampling	enamel	-1	+26.1
139	MLK 136-139	Garba I D	Bovidae *(Bovini)*	bulk sampling	enamel	-2.3	+26.2
140	MLK 95	Simbiro III	Bovidae *(Hippotragini)*	bulk sampling	enamel	+2.1	+24.4
141	MLK 180-185	Gombore I γ	Bovidae *(Hippotragini)*	bulk sampling	enamel	-2	+27.6
142	MLK 34	Simbiro III	Bovidae	bulk sampling	enamel	-1.8	+24.2
143	MLK 246-251	Simbiro III	Bovidae	bulk sampling	enamel	+3.5	+27.3
144	MLK 37	Simbiro III	Bovidae	bulk sampling	enamel	+0.1	+22.2
145	MLK 97-99	Simbiro III	Bovidae	bulk sampling	enamel	+3.5	+26.5
146	MLK 50	Gombore II-1	Bovidae	bulk sampling	enamel	-4.6	+26.8
147	MLK 56	Simbiro III	Bovidae	bulk sampling	enamel	+1.2	+23.9
148	MLK 57	Simbiro III	Bovidae	bulk sampling	enamel	+0.7	+22.8

149	MLK 86	Simbiro III	Bovidae	bulk sampling	enamel	+0.8	+23.6
150	MLK 88	Simbiro III	Bovidae	bulk sampling	enamel	+2.7	+23.3
151	MLK 90	Simbiro III	Bovidae	bulk sampling	enamel	+2.7	+23.2
152	MLK 91	Simbiro III	Bovidae	bulk sampling	enamel	+4.5	+24.8
153	MLK 93	Simbiro III	Bovidae	bulk sampling	enamel	+3.1	+27.7
154	MLK 97	Simbiro III	Bovidae	bulk sampling	enamel	+3.5	+25.9
155	MLK 98	Simbiro III	Bovidae	bulk sampling	enamel	+3.6	+26.8
156	MLK 99	Simbiro III	Bovidae	bulk sampling	enamel	+3.4	+26.7
157	MLK 146	Gombore III	Bovidae	bulk sampling	enamel	-3.4	+28.8
158	MLK 147	Gombore III	Bovidae	bulk sampling	enamel	-14.1	+19.8
159	MLK 157	Gombore II-1	Bovidae	bulk sampling	enamel	-9.5	+28.9
160	MLK 194	Gombore I δ	Bovidae	bulk sampling	enamel	-0.5	+20.6
161	MLK 195	Gombore I δ	Bovidae	bulk sampling	enamel	-3.4	+20.2
162	MLK 197	Gombore I δ	Bovidae	bulk sampling	enamel	+3.6	+26.8
163	MLK 201	Gombore I δ	Bovidae	bulk sampling	enamel	+2.2	+25.8
164	MLK 202	Gombore I δ	Bovidae	bulk sampling	enamel	+0.3	+25.3
165	MLK 241	Garba III	Bovidae	bulk sampling	enamel	+1.3	+27.5
166	MLK 261	Simbiro III	Bovidae	bulk sampling	enamel	+3.1	+25.1

167	MLK 262	Simbiro III	Bovidae	bulk sampling	enamel	+4.1	+26.8
168	MLK 264	Simbiro III	Bovidae	bulk sampling	enamel	+1.8	+24.8
169	MLK 265	Simbiro III	Bovidae	bulk sampling	enamel	+1.1	+24.6
170	MLK 266	Simbiro III	Bovidae	bulk sampling	enamel	-0.5	+21.9
171	MLK 280	Simbiro III	Bovidae	bulk sampling	enamel	+1.6	+23.9
172	MLK 281	Simbiro III	Bovidae	bulk sampling	enamel	+1.8	+23.3
173	MLK 283	Simbiro III	Bovidae	bulk sampling	enamel	+1.3	+24.3
174	MLK 287	Gombore II-2	Bovidae	bulk sampling	enamel	+3.9	+23.8
175	MLK 288	Gombore II-2	Bovidae	bulk sampling	enamel	+0.7	+26.5
176	MLK 309	Gombore I B	Bovidae	bulk sampling	enamel	+3.3	+27.7

Table S3. List of the intra-tooth samples and values of carbon and oxygen isotopic ratio.

	Sample number	**Site**	***Taxon***	**Tecnique**	**Tissue**	**δ^{13}C (VPDB)**	**δ^{18}O (SMOW)**
1	MLK 16	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.6	+21.9
2	MLK 17	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.6	+22.9
3	MLK 18	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.1	+22.7
4	MLK 19	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.3	+22.6

5	MLK 20	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.2	+22.5
6	MLK 21	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.1	+22.4
7	MLK 22	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.6	+22.3
8	MLK 23	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	0	+21.7
9	MLK 24	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.3	+21.1
10	MLK 25	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.4	+22.6
11	MLK 26	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.8	+22.6
12	MLK 27	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.2	+23.7
13	MLK 68	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.7	+22.9
14	MLK 69	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.8	+22.5
15	MLK 70	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.6	+22.2
16	MLK 71	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.3	+22.5
17	MLK 72	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.6	+22.6
18	MLK 73	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.6	+22.6
19	MLK 74	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+3.6	+23.3

20	MLK 75	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.5	+22.5
21	MLK 76	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.5	+21.5
22	MLK 77	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.8	+22.1
23	MLK 78	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.8	+25.1
24	MLK 79	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.3	+26.1
25	MLK 80	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+2.5	+26.3
26	MLK 81	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.6	+25.5
27	MLK 82	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.8	+25.1
28	MLK 83	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.9	+24.9
29	MLK 84	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.3	+23.7
30	MLK 100	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.4	+23.8
31	MLK 101	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.1	+23.4
32	MLK 102	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	0	+23.2
33	MLK 103	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.4	+24.2
34	MLK 104	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.7	+23.1

35	MLK 105	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.8	+22.9
36	MLK 106	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.6	+23.6
37	MLK 107	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.1	+23.6
38	MLK 108	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.1	+24.2
39	MLK 109	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.7	+24.2
40	MLK 110	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-7	+21.5
41	MLK 111	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.2	+23.4
42	MLK 112	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.1	+24.6
43	MLK 113	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.8	+24.7
44	MLK 114	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.1	+23.9
45	MLK 115	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.8	+23.6
46	MLK 116	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.7	+25.2
47	MLK 117	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.8	+24.1
48	MLK 118	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.4	+25.5
49	MLK 119	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.7	+24.8

50	MLK 120	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.6	+24.4
51	MLK 121	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.5	+24.3
52	MLK 268	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.6	+23.9
53	MLK 269	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.4	+23.8
54	MLK 270	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.2	+23.8
55	MLK 271	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.2	+23.8
56	MLK 272	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.2	+23.5
57	MLK 273	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.1	+23.4
58	MLK 274	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.1	+23.7
59	MLK 122	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.4	+18.9
60	MLK123	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.4	+19.7
61	MLK 125	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+1.1	+20.4
62	MLK 126	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.9	+21.1
63	MLK 127	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.5	+20.9
64	MLK 128	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.2	+21.5

65	MLK 129	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.2	+20.9
66	MLK 130	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.1	+21.4
67	MLK 131	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	0	+20.1
68	MLK 132	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	+0.4	+19.7
69	MLK 133	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.3	+18.2
70	MLK 134	Garba XIII B	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.9	+20.6
71	MLK 38	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.8	+18.1
72	MLK 39	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-2.1	+18.2
73	MLK 40	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-2.2	+19.1
74	MLK 41	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.6	+19.3
75	MLK 42	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.5	+19.3
76	MLK 43	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.1	+19.4
77	MLK 44	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-0.9	+19.3
78	MLK 45	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.4	+19.6
79	MLK 46	Simbiro III	*Hippopotamus* cf. *amphibius*	serial sampling	enamel	-1.4	+19.7

80	MLK 58	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.1	+22.9
81	MLK 59	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.5	+24.4
82	MLK 60	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.3	+24.8
83	MLK 61	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.2	+24.5
84	MLK 62	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.2	+23.1
85	MLK 63	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.2	+21.8
86	MLK 64	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+2.3	+21.1
87	MLK 65	Simbiro III	Equidae *(Hipparion)*	serial sampling	enamel	+1.7	+24.2
88	MLK 252	Simbiro III	Suidae	serial sampling	enamel	-1.9	+23.1
89	MLK 253	Simbiro III	Suidae	serial sampling	enamel	-2.3	+22.9
90	MLK 254	Simbiro III	Suidae	serial sampling	enamel	-2.7	+21.7
91	MLK 255	Simbiro III	Suidae	serial sampling	enamel	-2.6	+22.2
92	MLK 256	Simbiro III	Suidae	serial sampling	enamel	-2.8	+22.4
93	MLK 257	Simbiro III	Suidae	serial sampling	enamel	-2.9	+22.7
94	MLK 258	Simbiro III	Suidae	serial sampling	enamel	-2.9	+22.5

95	MLK 259	Simbiro III	Suidae	serial sampling	enamel	-3	+22.6
96	MLK 260	Simbiro III	Suidae	serial sampling	enamel	-3.1	+22.5
97	MLK 225	Garba IV D	Crocodylidae	serial sampling	enamel	-9.6	+25.1
98	MLK 226	Garba IV D	Crocodylidae	serial sampling	enamel	-9.3	+25.2
99	MLK 227	Garba IV D	Crocodylidae	serial sampling	enamel	-9.2	+25.3
100	MLK 228	Garba IV D	Crocodylidae	serial sampling	enamel	-9.3	+24.9
101	MLK 229	Garba IV D	Crocodylidae	serial sampling	enamel	-9.2	+25.3
102	MLK 230	Garba IV D	Crocodylidae	serial sampling	enamel	-9.2	+25.5
103	MLK 231	Garba IV D	Crocodylidae	serial sampling	enamel	-9.4	+25.5
104	MLK 232	Garba IV D	Crocodylidae	serial sampling	enamel	-9.6	+25.4
105	MLK 233	Garba IV D	Crocodylidae	serial sampling	enamel	-9.5	+25.5

Table S4. List of the bulk samples and values of carbon and oxygen isotopic ratio from Garba IV D (~1.9 Ma), Gombore I B (~1.6 Ma), Karre I (Oldowan) (Melka Kunture, Ethiopia) (by Bocherens *et al*. 1996 and Giuseppe Briatico Master thesis, 2018).

	Sample number	**Site**	***Taxon***	**Tecnique**	**Tissue**	**δ^{13}C (VPDB)**	**δ^{18}O (SMOW)**
1	MLK 1 (G.B., 2018)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.6	+25.9

2	MLK 2 (G.B., 2018)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.8	+28.7
3	MLK 3 (G.B., 2018)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.4	+24.4
4	MLK 4 (G.B., 2018)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.6	+23.1
5	MLK 5 (G.B., 2018)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	0	+21.2
6	89000 (Bocherens *et al.* 1996)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-4.7	+25.3
7	98800 (Bocherens *et al.* 1996)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+1.4	+25.2
8	98900 (Bocherens *et al.* 1996)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.5	+24.6
9	88900 (Bocherens *et al.* 1996)	Garba IV D	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-0.8	+29.9
10	MLK 6 (G.B., 2018)	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+0.8	+24.9
11	88700 (Bocherens *et al.* 1996)	Gombore I B	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-1.2	+27.7
12	88600 (Bocherens *et al.* 1996)	Gombore I B	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+3.1	+27.1
13	99000 (Bocherens *et al.* 1996)	Gombore I B	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+2.9	+33.1
14	88800 (Bocherens *et al.* 1996)	Garba IV D	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+1.9	+31.7
15	89400 (Bocherens *et al.* 1996)	Garba IV D	Equidae	bulk sampling	enamel	+2.7	+30.9

16	88600 (Bocherens *et al.* 1996)	Gombore I B	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+3.1	+27.2
17	99000 (Bocherens *et al.* 1996)	Gombore I B	Bovidae *(Alcelaphini, Connochaetes)*	bulk sampling	enamel	+2.9	+33.1
18	88800 (Bocherens *et al.* 1996)	Garba IV D	Bovidae *(Alcelaphini, Damaliscus)*	bulk sampling	enamel	+1.9	+31.7
19	89400 (Bocherens *et al.* 1996)	Garba IV D	Equidae	bulk sampling	enamel	+2.7	+30.9
20	MLK 9 (G.B., 2018)	Gombore II-1	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	-5.1	+27.9
21	MLK 7 (G.B., 2018)	Gombore II-2	*Hippopotamus* cf. *amphibius*	bulk sampling	enamel	+2.6	+24.7
22	89400 (Bocherens *et al.* 1996)	Gombore II-1	Equidae	bulk sampling	enamel	-1.4	+28.4
23	89300 (Bocherens *et al.* 1996)	Gombore II-1	Bovidae *(Reduncini, Kobus)*	bulk sampling	enamel	+0.7	+30.7
24	89500 (Bocherens *et al.* 1996)	Gombore II-1	Bovidae *(Bovini)*	bulk sampling	enamel	-1.9	+31.1

Table S5. List of the bulk samples and values of carbon and oxygen isotopic ratio of hippos teeth enamel, from Shungura Formation (Ethiopia), Turkana Basin (Kenya), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia) (~2.1-0.7 Ma).

	Archaeological site	**m a.s.l.**	**$\delta^{13}C$ (VPDB)**	**$\delta^{18}O$ (SMOW)**	***Taxon***	**Chronology (Ma)**	**Reference**
1	Shungura Formation (Ethiopia)	~440	-1.3	+23.1	Hippopotamidae	2.1	Negash *et al*. 2020
2	Shungura Formation (Ethiopia)	~440	-3.5	+38.2	Hippopotamidae	2.1	Negash *et al*. 2020

3	Shungura Formation (Ethiopia)	~440	-5.5	+27.1	Hippopotamidae	2.1	Negash *et al*. 2020
4	Shungura Formation (Ethiopia)	~440	-2.8	+26.1	Hippopotamidae	2.1	Negash *et al*. 2020
5	Shungura Formation (Ethiopia)	~440	-2.4	+28.1	Hippopotamidae	2.1	Negash *et al*. 2020
6	Shungura Formation (Ethiopia)	~440	-4.3	+24.4	Hippopotamidae	2.1	Negash *et al*. 2020
7	Shungura Formation (Ethiopia)	~440	-4.9	+25.2	Hippopotamidae	2.0	Negash *et al*. 2020
8	Shungura Formation (Ethiopia)	~440	-0.7	+25.1	Hippopotamidae	2.0	Negash *et al*. 2020
9	Shungura Formation (Ethiopia)	~440	0	+26.1	Hippopotamidae	2.0	Negash *et al*. 2020
10	Shungura Formation (Ethiopia)	~440	-0.9	+27.1	Hippopotamidae	2.0	Negash *et al*. 2020
11	Shungura Formation (Ethiopia)	~440	-8.7	+27.2	Hippopotamidae	2.0	Negash *et al*. 2020
12	Shungura Formation (Ethiopia)	~440	-7.2	+20.3	Hippopotamidae	1.9	Negash *et al*. 2020
13	Shungura Formation (Ethiopia)	~440	-0.5	+23.9	Hippopotamidae	1.8	Negash *et al*. 2020
14	Shungura Formation (Ethiopia)	~440	-1	+25.2	Hippopotamidae	1.8	Negash *et al*. 2020
15	Shungura Formation (Ethiopia)	~440	+0.4	+23.2	Hippopotamidae	1.8	Negash *et al*. 2020

16	Shungura Formation (Ethiopia)	~440	-3.3	+23.6	Hippopotamidae	1.8	Negash *et al*. 2020
17	Shungura Formation (Ethiopia)	~440	-3	+23.1	Hippopotamidae	1.8	Negash *et al*. 2020
18	Shungura Formation (Ethiopia)	~440	+1.1	+25.6	Hippopotamidae	1.5	Negash *et al*. 2020
19	Shungura Formation (Ethiopia)	~440	-0.6	+26.9	Hippopotamidae	1.3	Negash *et al*. 2020
20	Shungura Formation (Ethiopia)	~440	-3.5	+23.2	Hippopotamidae	1.3	Negash *et al*. 2020
21	Shungura Formation (Ethiopia)	~440	-2.8	+32.1	Hippopotamidae	1.3	Negash *et al*. 2020
22	Shungura Formation (Ethiopia)	~440	-1.8	+31.1	Hippopotamidae	1.3	Negash *et al*. 2020
23	Turkana Basin (Kenya)	~336	-0.1	+26.1	*aff. Hippopotamus karumensis*	2.0	Harris *et al*. 2008
24	Turkana Basin (Kenya)	~336	-1.8	+27.1	*aff. Hippopotamus karumensis*	1.9	Harris *et al*. 2008
25	Turkana Basin (Kenya)	~336	-2.4	+27.1	*aff. Hippopotamus karumensis*	1.9	Harris *et al*. 2008
26	Turkana Basin (Kenya)	~336	-1.2	+27.1	*aff. Hippopotamus karumensis*	1.9	Harris *et al*. 2008
27	Turkana Basin (Kenya)	~336	+0.1	+26.1	*Hippopotamus gorgops*	1.9	Harris *et al*. 2008
28	Turkana Basin (Kenya)	~336	0	+29.1	*Hippopotamus gorgops*	1.9	Harris *et al*. 2008
29	Turkana Basin (Kenya)	~336	-3.1	+31.2	*Hippopotamus gorgops*	1.9	Harris *et al*. 2008

30	Turkana Basin (Kenya)	~336	-0.8	+29.2	*aff. Hippopotamus aethiopicus*	1.85	Harris *et al*. 2008
31	Turkana Basin (Kenya)	~336	-0.4	+26.8	*Hippopotamus gorgops*	1.85	Harris *et al*. 2008
32	Turkana Basin (Kenya)	~368	-3.6	+24.9	*aff. Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
33	Turkana Basin (Kenya)	~368	-2.7	+32.1	*aff. Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
34	Turkana Basin (Kenya)	~368	-1.3	+26.1	*aff. Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
35	Turkana Basin (Kenya)	~368	-1	+28.6	*aff. Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
36	Turkana Basin (Kenya)	~368	-0.6	+25.7	*aff. Hippopotamus karumensis*	1.4	Harris *et al*. 2008
37	Turkana Basin (Kenya)	~368	-2.1	+27.2	*aff. Hippopotamus karumensis*	1.4	Harris *et al*. 2008
38	Turkana Basin (Kenya)	~368	-0.6	+28.1	*aff. Hippopotamus karumensis*	1.4	Harris *et al*. 2008
39	Turkana Basin (Kenya)	~368	-0.7	+28.1	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
40	Turkana Basin (Kenya)	~368	+0.1	+24.9	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
41	Turkana Basin (Kenya)	~368	-1.6	+26.8	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
42	Turkana Basin (Kenya)	~368	-1.4	+25.9	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
43	Turkana Basin (Kenya)	~336	-2.9	+30.6	*Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
44	Turkana Basin (Kenya)	~336	-1.5	+27.7	*Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008

45	Turkana Basin (Kenya)	~336	-0.3	+28.1	*Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
46	Turkana Basin (Kenya)	~336	-1.9	+28.4	*Hippopotamus aethiopicus*	1.4	Harris *et al*. 2008
47	Turkana Basin (Kenya)	~336	-2.7	+24.9	*Hippopotamus karumensis*	1.4	Harris *et al*. 2008
48	Turkana Basin (Kenya)	~336	0	+28.1	*Hippopotamus karumensis*	1.4	Harris *et al*. 2008
49	Turkana Basin (Kenya)	~336	-1.8	+26.6	*Hippopotamus karumensis*	1.4	Harris *et al*. 2008
50	Turkana Basin (Kenya)	~336	-0.5	+26.9	*Hippopotamus karumensis*	1.4	Harris *et al*. 2008
51	Turkana Basin (Kenya)	~336	-0.1	+29.1	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
52	Turkana Basin (Kenya)	~336	-3	+30.1	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
53	Turkana Basin (Kenya)	~336	-0.2	+27.7	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
54	Turkana Basin (Kenya)	~336	-1.1	+30.3	*Hippopotamus gorgops*	1.4	Harris *et al*. 2008
55	Melka Kunture (Ethiopia)	~2000	+0.6	+25.9	*Hippopotamus* cf. *amphibius*	1.9	G.B. Master 2018
56	Melka Kunture (Ethiopia)	~2000	+0.8	+28.7	*Hippopotamus* cf. *amphibius*	1.9	G.B. Master 2018
57	Melka Kunture (Ethiopia)	~2000	-0.4	+24.4	*Hippopotamus* cf. *amphibius*	1.9	G.B. Master 2018
58	Melka Kunture (Ethiopia)	~2000	+2.6	+23.1	*Hippopotamus* cf. *amphibius*	1.9	G.B. Master 2018
59	Melka Kunture (Ethiopia)	~2000	0	+21.2	*Hippopotamus* cf. *amphibius*	1.9	G.B. Master 2018
60	Melka Kunture (Ethiopia)	~2000	-4.7	+25.3	*Hippopotamus* cf. *amphibius*	1.9	Bocherens *et al*. 1996
61	Melka Kunture (Ethiopia)	~2000	+1.4	+25.2	*Hippopotamus* cf. *amphibius*	1.9	Bocherens *et al*. 1996

62	Melka Kunture (Ethiopia)	~2000	+2.5	+24.6	*Hippopotamus* cf. *amphibius*	1.9	Bocherens *et al*. 1996
63	Melka Kunture (Ethiopia)	~2000	-0.8	+29.9	*Hippopotamus* cf. *amphibius*	1.9	Bocherens *et al*. 1996
64	Melka Kunture (Ethiopia)	~2000	+0.7	+23.5	*Hippopotamus* cf. *amphibius*	1.9	this study
65	Melka Kunture (Ethiopia)	~2000	+0.8	+24.9	*Hippopotamus* cf. *amphibius*	1.6	G.B. Master 2018
66	Melka Kunture (Ethiopia)	~2000	-1.2	+27.7	*Hippopotamus* cf. *amphibius*	1.6	Bocherens *et al*. 1996
67	Melka Kunture (Ethiopia)	~2000	-0.4	+19.2	*Hippopotamus* cf. *amphibius*	1.6	this study
68	Melka Kunture (Ethiopia)	~2000	-1.1	+23.1	*Hippopotamus* cf. *amphibius*	1.6	this study
69	Melka Kunture (Ethiopia)	~2000	-0.04	+22.1	*Hippopotamus* cf. *amphibius*	1.6	this study
70	Melka Kunture (Ethiopia)	~2000	-0.1	+24.4	*Hippopotamus* cf. *amphibius*	1.6	this study
71	Melka Kunture (Ethiopia)	~2000	-0.6	+26.4	*Hippopotamus* cf. *amphibius*	1.4	this study
72	Melka Kunture (Ethiopia)	~2000	-4.1	+22.5	*Hippopotamus* cf. *amphibius*	1.4	this study
73	Melka Kunture (Ethiopia)	~2000	-1	+26.3	*Hippopotamus* cf. *amphibius*	1.4	this study
74	Melka Kunture (Ethiopia)	~2000	+1.2	+22.3	*Hippopotamus* cf. *amphibius*	1.4	this study
75	Melka Kunture (Ethiopia)	~2000	+1.8	+23.9	*Hippopotamus* cf. *amphibius*	1.4	this study
76	Melka Kunture (Ethiopia)	~2000	+0.7	+23.6	*Hippopotamus* cf. *amphibius*	1.4	this study
77	Melka Kunture (Ethiopia)	~2000	-0.6	+23.8	*Hippopotamus* cf. *amphibius*	1.4	this study
78	Melka Kunture (Ethiopia)	~2000	+1.1	+23.6	*Hippopotamus* cf. *amphibius*	1.4	this study
79	Melka Kunture (Ethiopia)	~2000	+1.3	+23.8	*Hippopotamus* cf. *amphibius*	1.4	this study
80	Melka Kunture (Ethiopia)	~2000	-0.2	+25.1	*Hippopotamus* cf. *amphibius*	1.4	this study

81	Melka Kunture (Ethiopia)	~2000	-1	+24.1	*Hippopotamus* cf. *amphibius*	1.4	this study
82	Melka Kunture (Ethiopia)	~2000	+2.1	+22.8	*Hippopotamus* cf. *amphibius*	1.4	this study
83	Melka Kunture (Ethiopia)	~2000	+1.5	+23.5	*Hippopotamus* cf. *amphibius*	1.4	this study
84	Melka Kunture (Ethiopia)	~2000	0	+25.4	*Hippopotamus* cf. *amphibius*	1.4	this study
85	Melka Kunture (Ethiopia)	~2000	+0.5	+22.7	*Hippopotamus* cf. *amphibius*	1.4	this study
86	Melka Kunture (Ethiopia)	~2000	+1.1	+21.6	*Hippopotamus* cf. *amphibius*	1.4	this study
87	Melka Kunture (Ethiopia)	~2000	+0.3	+20.5	*Hippopotamus* cf. *amphibius*	1.4	this study
88	Melka Kunture (Ethiopia)	~2000	+0.1	+22.2	*Hippopotamus* cf. *amphibius*	1.4	this study
89	Melka Kunture (Ethiopia)	~2000	-0.4	+23.4	*Hippopotamus* cf. *amphibius*	1.4	this study
90	Melka Kunture (Ethiopia)	~2000	+1.9	+22.1	*Hippopotamus* cf. *amphibius*	1.4	this study
91	Melka Kunture (Ethiopia)	~2000	-0.2	+21.7	*Hippopotamus* cf. *amphibius*	1.4	this study
92	Melka Kunture (Ethiopia)	~2000	+1.2	+21.4	*Hippopotamus* cf. *amphibius*	1.4	this study
93	Melka Kunture (Ethiopia)	~2000	+1.5	+25.4	*Hippopotamus* cf. *amphibius*	1.4	this study
94	Melka Kunture (Ethiopia)	~2000	+2.6	+19.9	*Hippopotamus* cf. *amphibius*	1.4	this study
95	Melka Kunture (Ethiopia)	~2000	-0.2	+20.5	*Hippopotamus* cf. *amphibius*	1.4	this study
96	Melka Kunture (Ethiopia)	~2000	+2.4	+20.1	*Hippopotamus* cf. *amphibius*	1.4	this study
97	Melka Kunture (Ethiopia)	~2000	+1.5	+21.4	*Hippopotamus* cf. *amphibius*	1.4	this study
98	Melka Kunture (Ethiopia)	~2000	+1.3	+24.3	*Hippopotamus* cf. *amphibius*	1.3	this study
99	Melka Kunture (Ethiopia)	~2000	+0.9	+21.1	*Hippopotamus* cf. *amphibius*	1.3	this study

100	Melka Kunture (Ethiopia)	~2000	+1.6	+23.2	*Hippopotamus* cf. *amphibius*	1.3	this study
101	Melka Kunture (Ethiopia)	~2000	-1,11	+26.3	*Hippopotamus* cf. *amphibius*	1.3	this study
102	Melka Kunture (Ethiopia)	~2000	+1.8	+23.6	*Hippopotamus* cf. *amphibius*	1.3	this study
103	Melka Kunture (Ethiopia)	~2000	-0.8	+22.2	*Hippopotamus* cf. *amphibius*	1.3	this study
104	Melka Kunture (Ethiopia)	~2000	-1.7	+18.9	*Hippopotamus* cf. *amphibius*	1.3	this study
105	Melka Kunture (Ethiopia)	~2000	-0.4	+23.8	*Hippopotamus* cf. *amphibius*	1.3	this study
106	Melka Kunture (Ethiopia)	~2000	-4.3	+19.1	*Hippopotamus* cf. *amphibius*	1.3	this study
107	Melka Kunture (Ethiopia)	~2000	-0.7	+23.8	*Hippopotamus* cf. *amphibius*	1.3	this study
108	Melka Kunture (Ethiopia)	~2000	-2.4	+21.1	*Hippopotamus* cf. *amphibius*	1.3	this study
109	Melka Kunture (Ethiopia)	~2000	-1.2	+18.2	*Hippopotamus* cf. *amphibius*	1.0	this study
110	Melka Kunture (Ethiopia)	~2000	-5.1	+27.9	*Hippopotamus* cf. *amphibius*	0.85	G.B. Master 2018
111	Melka Kunture (Ethiopia)	~2000	-0.6	+24.7	*Hippopotamus* cf. *amphibius*	0.85	this study
112	Melka Kunture (Ethiopia)	~2000	-1.4	+21.1	*Hippopotamus cf. amphibius*	0.85	this study

113	Melka Kunture (Ethiopia)	~2000	-2.6	+28.6	*Hippopotamus cf. amphibius*	0.85	this study
114	Melka Kunture (Ethiopia)	~2000	-2.4	+20.8	*Hippopotamus cf. amphibius*	0.85	this study
115	Melka Kunture (Ethiopia)	~2000	-4.3	+24.8	*Hippopotamus* cf. *amphibius*	0.7	G.B. Master 2018
116	Melka Kunture (Ethiopia)	~2000	-2.6	+25.8	*Hippopotamus* cf. *amphibius*	0.7	this study
117	Melka Kunture (Ethiopia)	~2000	-6.6	+22.7	*Hippopotamus* cf. *amphibius*	0.7	this study
118	Melka Kunture (Ethiopia)	~2000	-1.9	+24.5	*Hippopotamus* cf. *amphibius*	0.7	this study
119	Melka Kunture (Ethiopia)	~2000	-0.5	+20.4	*Hippopotamus* cf. *amphibius*	0.7	this study
120	Melka Kunture (Ethiopia)	~2000	-2.2	+25.8	*Hippopotamus* cf. *amphibius*	0.7	this study
121	Melka Kunture (Ethiopia)	~2000	-1.9	+23.5	*Hippopotamus* cf. *amphibius*	0.7	this study
122	Melka Kunture (Ethiopia)	~2000	-0.3	+22.1	*Hippopotamus* cf. *amphibius*	0.7	this study
123	Melka Kunture (Ethiopia)	~2000	+0.1	+21.8	*Hippopotamus* cf. *amphibius*	0.7	this study
124	Melka Kunture (Ethiopia)	~2000	+0.6	+23.9	*Hippopotamus* cf. *amphibius*	0.7	this study
125	Melka Kunture (Ethiopia)	~2000	+0.4	+24.5	*Hippopotamus* cf. *amphibius*	0.7	this study

126	Melka Kunture (Ethiopia)	~2000	-0.3	+23.7	*Hippopotamus* cf. *amphibius*	0.7	this study
127	Melka Kunture (Ethiopia)	~2000	+2.6	+24.7	*Hippopotamus* cf. *amphibius*	0.6	this study
128	Olduvai Gorge (Tanzania)	~1400	-0.7	+24.6	Hippopotamidae	1.7	Ascari *et al*. 2018
129	Olduvai Gorge (Tanzania)	~1400	-0.5	+26.5	Hippopotamidae	1.7	Ascari *et al*. 2018
130	Olduvai Gorge (Tanzania)	~1400	+1.8	+24.4	*Hippopotamus gorgops*	1.7	van der Merwe 2013
131	Olduvai Gorge (Tanzania)	~1400	+1.4	+24.6	*Hippopotamus gorgops*	1.7	van der Merwe 2013
132	Olduvai Gorge (Tanzania)	~1400	+0.9	+26.4	*Hippopotamus gorgops*	1.7	van der Merwe 2013
133	Olduvai Gorge (Tanzania)	~1400	-0.8	+25.2	*Hippopotamus gorgops*	1.7	van der Merwe 2013
134	Olduvai Gorge (Tanzania)	~1400	+1.7	+26.9	*Hippopotamus gorgops*	1.7	van der Merwe 2013
135	Olduvai Gorge (Tanzania)	~1400	+0.6	+28.3	*Hippopotamus gorgops*	1.7	van der Merwe 2013
136	Olduvai Gorge (Tanzania)	~1400	-0.8	+26.5	*Hippopotamus gorgops*	1.7	van der Merwe 2013
137	Olduvai Gorge (Tanzania)	~1400	+0.5	+25.6	*Hippopotamus gorgops*	1.7	van der Merwe 2013
138	Olduvai Gorge (Tanzania)	~1400	+2.2	+23.4	*Hippopotamus gorgops*	1.7	van der Merwe 2013

139	Olduvai Gorge (Tanzania)	~1400	+0.6	+24.9	*Hippopotamus gorgops*	1.7	van der Merwe 2013
140	Olduvai Gorge (Tanzania)	~1400	-0.9	+27.1	*Hippopotamus gorgops*	1.7	van der Merwe 2013
141	Olduvai Gorge (Tanzania)	~1400	-2.4	+26.9	Hippopotamidae	1.7	Rivals *et al*. 2018
142	Olduvai Gorge (Tanzania)	~1400	-1.9	+27.1	Hippopotamidae	1.7	Rivals *et al*. 2018
143	Olduvai Gorge (Tanzania)	~1400	-2.7	+28.5	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
144	Olduvai Gorge (Tanzania)	~1400	-0.8	+27.7	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
145	Olduvai Gorge (Tanzania)	~1400	-0.3	+28.6	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
146	Olduvai Gorge (Tanzania)	~1400	+0.8	+28.6	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
147	Olduvai Gorge (Tanzania)	~1400	+1.1	+27.8	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
148	Olduvai Gorge (Tanzania)	~1400	-0.6	+27.4	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
149	Olduvai Gorge (Tanzania)	~1400	-0.1	+28.6	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
150	Olduvai Gorge (Tanzania)	~1400	-0.1	+29.8	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
151	Olduvai Gorge (Tanzania)	~1400	+0.2	+27.8	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018

152	Olduvai Gorge (Tanzania)	~1400	+0.4	+28.3	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
153	Olduvai Gorge (Tanzania)	~1400	+0.4	+28.6	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
154	Olduvai Gorge (Tanzania)	~1400	+0.7	+27.4	*Hippopotamus gorgops*	1.6	Uno *et al*. 2018
155	Olduvai Gorge (Tanzania)	~1400	-2.6	+26.3	*Hippopotamus gorgops*	1.5	Uno *et al*. 2018
156	Olduvai Gorge (Tanzania)	~1400	-1.7	+28.5	*Hippopotamus gorgops*	1.5	Uno *et al*. 2018
157	Olduvai Gorge (Tanzania)	~1400	-1.1	+27.4	*Hippopotamus gorgops*	1.5	Uno *et al*. 2018
158	Olduvai Gorge (Tanzania)	~1400	-0.1	+28.1	*Hippopotamus gorgops*	1.5	Uno *et al*. 2018
159	Busidima Formation (Ethiopia)	~1470	-1	+30.4	Hippopotamidae	0.7	Bedaso *et al.* 2010
160	Busidima Formation (Ethiopia)	~1470	-1.5	+27.1	Hippopotamidae	0.7	Bedaso *et al.* 2010
161	Busidima Formation (Ethiopia)	~1470	-1.4	+24.3	Hippopotamidae	0.7	Bedaso *et al.* 2010

Table S6. List of the bulk samples and values of carbon and oxygen isotopic ratio of bovids teeth enamel, from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia) (~2.1-0.6 Ma).

	Archaeological site	**m a.s.l.**	**$\delta^{13}C$ (VPDB)**	**$\delta^{18}O$ (SMOW)**	***Taxon***	**Chronology (Ma)**	**Reference**

1	Shungura Formation (Ethiopia)	~440	-3.4	+36.1	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
2	Shungura Formation (Ethiopia)	~440	-1	+30.3	Bovidae *(Bovini)*	2.1	Negash *et al*. 2020
3	Shungura Formation (Ethiopia)	~440	+0.2	+32.4	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
4	Shungura Formation (Ethiopia)	~440	-1.8	+33.1	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
5	Shungura Formation (Ethiopia)	~440	-0.6	+30.2	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
6	Shungura Formation (Ethiopia)	~440	+0.8	+34.1	Bovidae *(Bovini)*	2.1	Negash *et al*. 2020
7	Shungura Formation (Ethiopia)	~440	-0.3	+34.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
8	Shungura Formation (Ethiopia)	~440	-4	+30.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
9	Shungura Formation (Ethiopia)	~440	+0.1	+36.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
10	Shungura Formation (Ethiopia)	~440	-2.5	+27.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
11	Shungura Formation (Ethiopia)	~440	-3.5	+32.3	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
12	Shungura Formation (Ethiopia)	~440	-5.2	+32.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
13	Shungura Formation (Ethiopia)	~440	-6.2	+29.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020

14	Shungura Formation (Ethiopia)	~440	-5.2	+31.5	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
15	Shungura Formation (Ethiopia)	~440	+2.2	+36.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
16	Shungura Formation (Ethiopia)	~440	+1.4	+32.3	Bovidae *(Bovini)*	2.1	Negash *et al*. 2020
17	Shungura Formation (Ethiopia)	~440	+0.5	+31.3	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
18	Shungura Formation (Ethiopia)	~440	+0.6	+33.1	Bovidae *(Bovini)*	2.1	Negash *et al*. 2020
19	Shungura Formation (Ethiopia)	~440	-3.3	+30.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
20	Shungura Formation (Ethiopia)	~440	-3.2	+31.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
21	Shungura Formation (Ethiopia)	~440	-1.5	+29.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
22	Shungura Formation (Ethiopia)	~440	-4.4	+33.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
23	Shungura Formation (Ethiopia)	~440	-4.8	+33.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
24	Shungura Formation (Ethiopia)	~440	-1.9	+31.2	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
25	Shungura Formation (Ethiopia)	~440	-3.5	+31.2	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020
26	Shungura Formation (Ethiopia)	~440	-1.1	+32.1	Bovidae *(Aepycerotini)*	2.1	Negash *et al*. 2020

27	Shungura Formation (Ethiopia)	~440	+2.1	+32.1	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
28	Shungura Formation (Ethiopia)	~440	+0.8	+37.2	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
29	Shungura Formation (Ethiopia)	~440	+0.7	+32.4	Bovidae *(Alcelaphini)*	2.1	Negash *et al*. 2020
30	Shungura Formation (Ethiopia)	~440	+0.7	+37.1	Bovidae *(Bovini)*	2.1	Negash *et al*. 2020
31	Shungura Formation (Ethiopia)	~440	+0.6	+33.1	Bovidae *(Bovini)*	2.1	Negash *et al*. 2020
32	Shungura Formation (Ethiopia)	~440	-1.2	+31.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
33	Shungura Formation (Ethiopia)	~440	-0.1	+33.2	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
34	Shungura Formation (Ethiopia)	~440	-1.9	+31.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
35	Shungura Formation (Ethiopia)	~440	-0.1	+30.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
36	Shungura Formation (Ethiopia)	~440	-0.3	+35.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
37	Shungura Formation (Ethiopia)	~440	-0.4	+34.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
38	Shungura Formation (Ethiopia)	~440	+0.1	+34.1	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020
39	Shungura Formation (Ethiopia)	~440	+0.5	+33.2	Bovidae *(Reduncini)*	2.1	Negash *et al*. 2020

40	Shungura Formation (Ethiopia)	~440	-5.3	+30.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
41	Shungura Formation (Ethiopia)	~440	-9.8	+31.2	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
42	Shungura Formation (Ethiopia)	~440	-6	+33.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
43	Shungura Formation (Ethiopia)	~440	-5	+33.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
44	Shungura Formation (Ethiopia)	~440	-5.1	+31.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
45	Shungura Formation (Ethiopia)	~440	-10.8	+33.2	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
46	Shungura Formation (Ethiopia)	~440	-5.7	+30.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
47	Shungura Formation (Ethiopia)	~440	-6.6	+29.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
48	Shungura Formation (Ethiopia)	~440	-7.6	+29.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
49	Shungura Formation (Ethiopia)	~440	-8.1	+33.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
50	Shungura Formation (Ethiopia)	~440	-4.4	+36.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
51	Shungura Formation (Ethiopia)	~440	-7.3	+30.1	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020
52	Shungura Formation (Ethiopia)	~440	-7.8	+31.3	Bovidae *(Tragelaphini)*	2.1	Negash *et al*. 2020

53	Shungura Formation (Ethiopia)	~440	+1.9	+31.1	Bovidae *(Alcelaphini)*	2.0	Negash *et al*. 2020
54	Shungura Formation (Ethiopia)	~440	-9.3	+29.1	Bovidae *(Tragelaphini)*	2.0	Negash *et al*. 2020
55	Shungura Formation (Ethiopia)	~440	-7.7	+30.1	Bovidae *(Tragelaphini)*	2.0	Negash *et al*. 2020
56	Shungura Formation (Ethiopia)	~440	+0.6	+34.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
57	Shungura Formation (Ethiopia)	~440	+1.5	+36.1	Bovidae *(Bovini)*	2.0	Negash *et al*. 2020
58	Shungura Formation (Ethiopia)	~440	-3.9	+26.2	Bovidae *(Tragelaphini)*	2.0	Negash *et al*. 2020
59	Shungura Formation (Ethiopia)	~440	+0.3	+33.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
60	Shungura Formation (Ethiopia)	~440	+1.3	+29.1	Bovidae *(Alcelaphini)*	2.0	Negash *et al*. 2020
61	Shungura Formation (Ethiopia)	~440	+3.9	+33.1	Bovidae *(Alcelaphini)*	2.0	Negash *et al*. 2020
62	Shungura Formation (Ethiopia)	~440	+1.7	+33.1	Bovidae *(Alcelaphini)*	2.0	Negash *et al*. 2020
63	Shungura Formation (Ethiopia)	~440	+2.8	+25.1	Bovidae *(Alcelaphini)*	2.0	Negash *et al*. 2020
64	Shungura Formation (Ethiopia)	~440	-1.3	+37.1	Bovidae *(Bovini)*	2.0	Negash *et al*. 2020
65	Shungura Formation (Ethiopia)	~440	-6.7	+26.1	Bovidae *(Tragelaphini)*	2.0	Negash *et al*. 2020

66	Shungura Formation (Ethiopia)	~440	-2.3	+27.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
67	Shungura Formation (Ethiopia)	~440	-1.8	+30.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
68	Shungura Formation (Ethiopia)	~440	-6.5	+26.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
69	Shungura Formation (Ethiopia)	~440	-2.2	+27.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
70	Shungura Formation (Ethiopia)	~440	-0.8	+27.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
71	Shungura Formation (Ethiopia)	~440	-1.9	+26.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
72	Shungura Formation (Ethiopia)	~440	-7.9	+28.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
73	Shungura Formation (Ethiopia)	~440	-2.9	+25.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
74	Shungura Formation (Ethiopia)	~440	-2.9	+23.1	Bovidae *(Aepycerotini)*	2.0	Negash *et al*. 2020
75	Shungura Formation (Ethiopia)	~440	+2.5	+36.1	Bovidae *(Alcelaphini)*	2.0	Negash *et al*. 2020
76	Shungura Formation (Ethiopia)	~440	+1.6	+36.1	*Bovidae (Alcelaphini)*	2.0	Negash *et al*. 2020
77	Shungura Formation (Ethiopia)	~440	-0.7	+30.1	*Bovidae (Alcelaphini)*	2.0	Negash *et al*. 2020
78	Shungura Formation (Ethiopia)	~440	+1.4	+35.1	*Bovidae (Alcelaphini)*	2.0	Negash *et al*. 2020

79	Shungura Formation (Ethiopia)	~440	+2.1	+34.1	*Bovidae (Alcelaphini)*	2.0	Negash *et al*. 2020
80	Shungura Formation (Ethiopia)	~440	+2.5	+35.1	*Bovidae (Alcelaphini)*	2.0	Negash *et al*. 2020
81	Shungura Formation (Ethiopia)	~440	-1.3	+28.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
82	Shungura Formation (Ethiopia)	~440	-6.3	+26.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
83	Shungura Formation (Ethiopia)	~440	-6.9	+24.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
84	Shungura Formation (Ethiopia)	~440	-4.5	+25.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
85	Shungura Formation (Ethiopia)	~440	-8.5	+25.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
86	Shungura Formation (Ethiopia)	~440	-6.4	+28.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
87	Shungura Formation (Ethiopia)	~440	-8.7	+24.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
88	Shungura Formation (Ethiopia)	~440	-0.8	+26.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
89	Shungura Formation (Ethiopia)	~440	-6.6	+27.1	*Bovidae (Tragelaphini)*	2.0	Negash *et al*. 2020
90	Shungura Formation (Ethiopia)	~440	-3.6	+28.1	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
91	Shungura Formation (Ethiopia)	~440	+1.6	+36.9	*Bovidae (Aepycerotini)*	1.8	Negash *et al*. 2020

92	Shungura Formation (Ethiopia)	~440	+1.1	+31.9	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
93	Shungura Formation (Ethiopia)	~440	-0.5	+30.5	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
94	Shungura Formation (Ethiopia)	~440	-2	+31.4	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
95	Shungura Formation (Ethiopia)	~440	+1.4	+33.6	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
96	Shungura Formation (Ethiopia)	~440	-5	+31.3	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
97	Shungura Formation (Ethiopia)	~440	-3.8	+33.2	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
98	Shungura Formation (Ethiopia)	~440	-0.8	+30.7	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
99	Shungura Formation (Ethiopia)	~440	-0.3	+29.2	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
100	Shungura Formation (Ethiopia)	~440	+0.7	+31.1	*Bovidae (Reduncini)*	1.8	Negash *et al*. 2020
101	Shungura Formation (Ethiopia)	~440	-13.4	+29.6	*Bovidae (Reduncini)*	1.6	Negash *et al*. 2020
102	Shungura Formation (Ethiopia)	~440	+0.7	+31.2	*Bovidae (Reduncini)*	1.6	Negash *et al*. 2020
103	Shungura Formation (Ethiopia)	~440	-1.7	+27.2	*Bovidae (Reduncini)*	1.6	Negash *et al*. 2020
104	Shungura Formation (Ethiopia)	~440	-0.7	+33.8	*Bovidae (Reduncini)*	1.6	Negash *et al*. 2020

105	Shungura Formation (Ethiopia)	~440	+0.8	+29.7	*Bovidae (Reduncini)*	1.6	Negash *et al*. 2020
106	Shungura Formation (Ethiopia)	~440	-0.6	+33.3	*Bovidae (Bovini)*	1.6	Negash *et al*. 2020
107	Shungura Formation (Ethiopia)	~440	-2.4	+31.1	*Bovidae (Reduncini)*	1.6	Negash *et al*. 2020
108	Shungura Formation (Ethiopia)	~440	-3.8	+34.4	*Bovidae (Aepycerotini)*	1.5	Negash *et al*. 2020
109	Shungura Formation (Ethiopia)	~440	-3.2	+34.1	*Bovidae (Aepycerotini)*	1.5	Negash *et al*. 2020
110	Shungura Formation (Ethiopia)	~440	-1.6	+30.5	*Bovidae (Aepycerotini)*	1.5	Negash *et al*. 2020
111	Shungura Formation (Ethiopia)	~440	-4.1	+34.7	*Bovidae (Aepycerotini)*	1.5	Negash *et al*. 2020
112	Shungura Formation (Ethiopia)	~440	-1.4	+36.7	*Bovidae (Alcelaphini)*	1.5	Negash *et al*. 2020
113	Shungura Formation (Ethiopia)	~440	-1.8	+30.1	*Bovidae (Reduncini)*	1.5	Negash *et al*. 2020
114	Shungura Formation (Ethiopia)	~440	-2.8	+36.3	*Bovidae (Reduncini)*	1.5	Negash *et al*. 2020
115	Shungura Formation (Ethiopia)	~440	-4.9	+34.2	*Bovidae (Reduncini)*	1.5	Negash *et al*. 2020
116	Shungura Formation (Ethiopia)	~440	-3.3	+36.8	*Bovidae (Aepycerotini)*	1.3	Negash *et al*. 2020
117	Shungura Formation (Ethiopia)	~440	-2.1	+33.3	*Bovidae (Aepycerotini)*	1.3	Negash *et al*. 2020

118	Shungura Formation (Ethiopia)	~440	+0.1	+35.6	*Bovidae (Reduncini)*	1.3	Negash *et al*. 2020
119	Shungura Formation (Ethiopia)	~440	-0.4	+32.6	*Bovidae (Reduncini)*	1.3	Negash *et al*. 2020
120	Shungura Formation (Ethiopia)	~440	-4.2	+36.9	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
121	Shungura Formation (Ethiopia)	~440	+2.4	+34.9	*Bovidae (Alcelaphini)*	1.2	Negash *et al*. 2020
122	Shungura Formation (Ethiopia)	~440	-6	+33.9	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
123	Shungura Formation (Ethiopia)	~440	-2.2	+33.5	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
124	Shungura Formation (Ethiopia)	~440	-1.4	+34.6	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
125	Shungura Formation (Ethiopia)	~440	-3.3	+34.2	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
126	Shungura Formation (Ethiopia)	~440	-4.1	+34.6	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
127	Shungura Formation (Ethiopia)	~440	-2.3	+34.6	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
128	Shungura Formation (Ethiopia)	~440	-3.9	+33.7	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
129	Shungura Formation (Ethiopia)	~440	-2.6	+34.9	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
130	Shungura Formation (Ethiopia)	~440	-5	+35.1	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020

131	Shungura Formation (Ethiopia)	~440	-2.9	+27.6	*Bovidae (Aepycerotini)*	1.2	Negash *et al*. 2020
132	Shungura Formation (Ethiopia)	~440	+1.1	+33.1	*Bovidae (Alcelaphini)*	1.2	Negash *et al*. 2020
133	Shungura Formation (Ethiopia)	~440	+0.5	+35.1	*Bovidae (Alcelaphini)*	1.2	Negash *et al*. 2020
134	Shungura Formation (Ethiopia)	~440	+3.4	+30.7	*Bovidae (Alcelaphini)*	1.2	Negash *et al*. 2020
135	Shungura Formation (Ethiopia)	~440	+0.6	+36.3	*Bovidae (Alcelaphini)*	1.2	Negash *et al*. 2020
136	Shungura Formation (Ethiopia)	~440	+1.1	+32.8	*Bovidae (Alcelaphini)*	1.2	Negash *et al*. 2020
137	Shungura Formation (Ethiopia)	~440	+0.9	+33.4	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
138	Shungura Formation (Ethiopia)	~440	+1.5	+32.2	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
139	Shungura Formation (Ethiopia)	~440	+0.6	+33.7	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
140	Shungura Formation (Ethiopia)	~440	+0.3	+30.1	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
141	Shungura Formation (Ethiopia)	~440	+0.3	+34.1	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
142	Shungura Formation (Ethiopia)	~440	-1.4	+31.6	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
143	Shungura Formation (Ethiopia)	~440	+0.1	+34.7	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020

144	Shungura Formation (Ethiopia)	~440	-2	+31.7	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
145	Shungura Formation (Ethiopia)	~440	+0.7	+36.1	*Bovidae (Reduncini)*	1.2	Negash *et al*. 2020
146	Melka Kunture (Ethiopia)	~2000	+1.9	+31.7	*Bovidae (Alcelaphini), Damaliscus*	1.9	Bocherens *et al*. 1996
147	Melka Kunture (Ethiopia)	~2000	+3.3	+27.7	*Bovidae*	1.6	this study
148	Melka Kunture (Ethiopia)	~2000	+1.7	+23.6	*Bovidae (Alcelaphini)*	1.6	this study
149	Melka Kunture (Ethiopia)	~2000	-0.6	+29.6	*Bovidae (Alcelaphini)*	1.6	this study
150	Melka Kunture (Ethiopia)	~2000	+3.1	+27.1	*Bovidae (Alcelaphini, Connochaetes)*	1.6	Bocherens *et al*. 1996
151	Melka Kunture (Ethiopia)	~2000	+2.9	+33.1	*Bovidae (Alcelaphini, Connochaetes)*	1.6	Bocherens *et al*. 1996
152	Melka Kunture (Ethiopia)	~2000	-5.5	+24.3	*Bovidae (Reduncini)*	1.4	this study
153	Melka Kunture (Ethiopia)	~2000	-2.1	+27.6	*Bovidae (Hippotragini)*	1.4	this study
154	Melka Kunture (Ethiopia)	~2000	-1.8	+24.2	*Bovidae*	1.4	this study
155	Melka Kunture (Ethiopia)	~2000	+1.2	+23.9	*Bovidae*	1.4	this study
156	Melka Kunture (Ethiopia)	~2000	+0.7	+22.8	*Bovidae*	1.4	this study
157	Melka Kunture (Ethiopia)	~2000	+2.7	+23.2	*Bovidae*	1.4	this study
158	Melka Kunture (Ethiopia)	~2000	+4.5	+24.8	*Bovidae*	1.4	this study
159	Melka Kunture (Ethiopia)	~2000	+3.1	+27.7	*Bovidae*	1.4	this study
160	Melka Kunture (Ethiopia)	~2000	+3.1	+25.1	*Bovidae*	1.4	this study
161	Melka Kunture (Ethiopia)	~2000	+4.1	+26.8	*Bovidae*	1.4	this study

162	Melka Kunture (Ethiopia)	~2000	+1.8	+24.8	*Bovidae*	1.4	this study
163	Melka Kunture (Ethiopia)	~2000	+1.2	+24.6	*Bovidae*	1.4	this study
164	Melka Kunture (Ethiopia)	~2000	-0.5	+21.9	*Bovidae*	1.4	this study
165	Melka Kunture (Ethiopia)	~2000	+1.6	+23.9	*Bovidae*	1.4	this study
166	Melka Kunture (Ethiopia)	~2000	+3.5	+27.3	*Bovidae*	1.4	this study
167	Melka Kunture (Ethiopia)	~2000	+1.8	+23.3	*Bovidae*	1.4	this study
168	Melka Kunture (Ethiopia)	~2000	+1.3	+24.3	*Bovidae*	1.4	this study
169	Melka Kunture (Ethiopia)	~2000	+4.2	+25.3	*Bovidae (Alcelaphini)*	1.3	this study
170	Melka Kunture (Ethiopia)	~2000	+0.7	+27.1	*Bovidae (Alcelaphini)*	1.3	this study
171	Melka Kunture (Ethiopia)	~2000	-2.3	+27.8	*Bovidae (Bovini)*	1.3	this study
172	Melka Kunture (Ethiopia)	~2000	+2.2	+24.4	*Bovidae (Hippotragini)*	1.3	this study
173	Melka Kunture (Ethiopia)	~2000	-0.6	+20.6	*Bovidae*	1.3	this study
174	Melka Kunture (Ethiopia)	~2000	-3.4	+20.2	*Bovidae*	1.3	this study
175	Melka Kunture (Ethiopia)	~2000	+3.6	+26.8	*Bovidae*	1.3	this study
176	Melka Kunture (Ethiopia)	~2000	+2.2	+25.8	*Bovidae*	1.3	this study
177	Melka Kunture (Ethiopia)	~2000	+0.3	+25.3	*Bovidae*	1.3	this study
178	Melka Kunture (Ethiopia)	~2000	+0.2	+22.2	*Bovidae*	1.3	this study
179	Melka Kunture (Ethiopia)	~2000	+3.5	+26.5	*Bovidae*	1.3	this study
180	Melka Kunture (Ethiopia)	~2000	+0.8	+23.6	*Bovidae*	1.3	this study

181	Melka Kunture (Ethiopia)	~2000	+2.7	+23.3	*Bovidae*	1.3	this study
182	Melka Kunture (Ethiopia)	~2000	+1.9	+31.8	*Bovidae (Alcelaphini, Connochaetes)*	0.85	Bocherens *et al*. 1996
183	Melka Kunture (Ethiopia)	~2000	+3.6	+28.1	*Bovidae (Alcelaphini, Connochaetes)*	0.85	this study
184	Melka Kunture (Ethiopia)	~2000	+4.4	+28.5	*Bovidae (Alcelaphini, Connochaetes)*	0.85	this study
185	Melka Kunture (Ethiopia)	~2000	+3.2	+27.4	*Bovidae (Alcelaphini, Connochaetes)*	0.85	this study
186	Melka Kunture (Ethiopia)	~2000	+1.1	+26.1	*Bovidae (Alcelaphini, Connochaetes)*	0.85	this study
187	Melka Kunture (Ethiopia)	~2000	+0.6	+29.2	*Bovidae (Alcelaphini, Connochaetes)*	0.85	this study
188	Melka Kunture (Ethiopia)	~2000	-2.1	+27.9	*Bovidae (Alcelaphini)*	0.85	this study
189	Melka Kunture (Ethiopia)	~2000	-0.3	+30.2	*Bovidae (Alcelaphini)*	0.85	this study
190	Melka Kunture (Ethiopia)	~2000	+0.4	+29.6	*Bovidae (Alcelaphini)*	0.85	this study
191	Melka Kunture (Ethiopia)	~2000	+1.3	+28.6	*Bovidae (Alcelaphini)*	0.85	this study
192	Melka Kunture (Ethiopia)	~2000	+1.2	+29.7	*Bovidae (Alcelaphini)*	0.85	this study
193	Melka Kunture (Ethiopia)	~2000	+1.3	+29.2	*Bovidae (Alcelaphini)*	0.85	this study
194	Melka Kunture (Ethiopia)	~2000	+2.9	+26.8	*Bovidae (Alcelaphini)*	0.85	this study
195	Melka Kunture (Ethiopia)	~2000	+1.7	+27.7	*Bovidae (Alcelaphini)*	0.85	this study
196	Melka Kunture (Ethiopia)	~2000	+1.1	+28.9	*Bovidae (Alcelaphini)*	0.85	this study
197	Melka Kunture (Ethiopia)	~2000	+3.3	+30.3	*Bovidae (Alcelaphini)*	0.85	this study
198	Melka Kunture (Ethiopia)	~2000	+0.7	+30.7	*Bovidae (Reduncini, Kobus)*	0.85	Bocherens *et al*. 1996
199	Melka Kunture (Ethiopia)	~2000	-1.9	+31.1	*Bovidae (Bovini)*	0.85	Bocherens *et al*. 1996

200	Melka Kunture (Ethiopia)	~2000	-4.6	+26.8	*Bovidae*	0.85	this study
201	Melka Kunture (Ethiopia)	~2000	+0.8	+26.5	*Bovidae*	0.7	this study
202	Melka Kunture (Ethiopia)	~2000	-1.6	+24.8	*Bovidae (Alcelaphini, Connochaetes)*	0.6	this study
203	Melka Kunture (Ethiopia)	~2000	-0.5	+24.6	*Bovidae (Alcelaphini)*	0.6	this study
204	Melka Kunture (Ethiopia)	~2000	+2.5	+28.7	*Bovidae (Alcelaphini)*	0.6	this study
205	Melka Kunture (Ethiopia)	~2000	+1.4	+25.8	*Bovidae (Alcelaphini)*	0.6	this study
206	Melka Kunture (Ethiopia)	~2000	+2.1	+24.7	*Bovidae (Alcelaphini)*	0.6	this study
207	Melka Kunture (Ethiopia)	~2000	+2.3	+24.9	*Bovidae (Alcelaphini)*	0.6	this study
208	Melka Kunture (Ethiopia)	~2000	+3.8	+24.8	*Bovidae (Reduncini)*	0.6	this study
209	Melka Kunture (Ethiopia)	~2000	+1.4	+26.4	*Bovidae (Antilopini)*	0.6	this study
210	Melka Kunture (Ethiopia)	~2000	-2.8	+26.5	*Bovidae (Bovini)*	0.6	this study
211	Melka Kunture (Ethiopia)	~2000	-1.2	+26.1	*Bovidae (Bovini)*	0.6	this study
212	Melka Kunture (Ethiopia)	~2000	+1.2	+25.6	*Bovidae*	0.6	this study
213	Melka Kunture (Ethiopia)	~2000	-3.4	+28.8	*Bovidae*	0.6	this study
214	Melka Kunture (Ethiopia)	~2000	+1.4	+27.5	*Bovidae*	0.6	this study
215	Olduvai Gorge (Tanzania)	~1400	-2	+29.4	*Bovidae (Reduncini, Kobus)*	1.8	van der Merwe 2013
216	Olduvai Gorge (Tanzania)	~1400	-5	+23.3	*Bovidae (Reduncini, Kobus)*	1.8	van der Merwe 2013
217	Olduvai Gorge (Tanzania)	~1400	-3.8	+26.9	*Bovidae (Reduncini, Kobus)*	1.8	van der Merwe 2013

218	Olduvai Gorge (Tanzania)	~1400	-0.3	+27.7	*Bovidae (Hippotragini, Hippotragus gigas)*	1.8	van der Merwe 2013
219	Olduvai Gorge (Tanzania)	~1400	+0.1	+26.3	*Bovidae (Antelopinae, Gazella/Aepyceros)*	1.8	van der Merwe 2013
220	Olduvai Gorge (Tanzania)	~1400	-2	+26.6	*Bovidae (Antelopinae, Gazella/Aepyceros)*	1.8	van der Merwe 2013
221	Olduvai Gorge (Tanzania)	~1400	-3.5	+27.6	*Bovidae (Antelopinae, Gazella/Antidorcas)*	1.8	van der Merwe 2013
222	Olduvai Gorge (Tanzania)	~1400	+0.7	+27.7	*Bovidae (Antelopinae, Gazella/Antidorcas)*	1.8	van der Merwe 2013
223	Olduvai Gorge (Tanzania)	~1400	-4.1	+26.1	*Bovidae (Antelopinae, Gazella/Antidorcas)*	1.8	van der Merwe 2013
224	Olduvai Gorge (Tanzania)	~1400	-1.9	+28.5	*Bovidae (Antelopinae, Gazella/Antidorcas)*	1.8	van der Merwe 2013
225	Olduvai Gorge (Tanzania)	~1400	-1.6	+27.1	*Bovidae (Alcelaphinae, Megalotragus)*	1.8	van der Merwe 2013
226	Olduvai Gorge (Tanzania)	~1400	-0.6	+25.9	*Bovidae (Alcelaphinae, Megalotragus)*	1.8	van der Merwe 2013
227	Olduvai Gorge (Tanzania)	~1400	+1.7	+26.7	*Bovidae (Alcelaphinae, Megalotragus)*	1.8	van der Merwe 2013
228	Olduvai Gorge (Tanzania)	~1400	+0.2	+25.9	*Bovidae (Alcelaphinae, Megalotragus)*	1.8	van der Merwe 2013
229	Olduvai Gorge (Tanzania)	~1400	+0.3	+24.9	*Bovidae (Alcelaphinae, Beatragus/Connochaetes)*	1.8	van der Merwe 2013
230	Olduvai Gorge (Tanzania)	~1400	-1.1	+27.3	*Bovidae (Alcelaphinae, Beatragus/Connochaetes)*	1.8	van der Merwe 2013

231	Olduvai Gorge (Tanzania)	~1400	+0.2	+23.7	*Bovidae (Alcelaphinae, Beatragus/Connochaetes)*	1.8	van der Merwe 2013
232	Olduvai Gorge (Tanzania)	~1400	+0.2	+26.7	*Bovidae (Alcelaphinae, Beatragus/Connochaetes)*	1.8	van der Merwe 2013
233	Olduvai Gorge (Tanzania)	~1400	+1.2	+28.2	*Bovidae (Alcelaphinae, Parmularius)*	1.8	van der Merwe 2013
234	Olduvai Gorge (Tanzania)	~1400	+1.1	+29.1	*Bovidae (Alcelaphinae, Parmularius)*	1.8	van der Merwe 2013
235	Olduvai Gorge (Tanzania)	~1400	+0.1	+27.1	*Bovidae*	1.7	Ascari *et al.* 2018
236	Olduvai Gorge (Tanzania)	~1400	-0.4	+26.5	*Bovidae*	1.7	Ascari *et al.* 2018
237	Olduvai Gorge (Tanzania)	~1400	-3.2	+28.4	*Bovidae*	1.7	Ascari *et al.* 2018
238	Olduvai Gorge (Tanzania)	~1400	-3.6	+29.1	*Bovidae (Bovini, Tragelaphus)*	1.7	Ascari *et al.* 2018
239	Olduvai Gorge (Tanzania)	~1400	-0.3	+28.9	*Bovidae (Bovini, Tragelaphus)*	1.7	Ascari *et al.* 2018
240	Olduvai Gorge (Tanzania)	~1400	+2.8	+26.3	*Bovidae (Bovini, Tragelaphus)*	1.7	Ascari *et al.* 2018
241	Olduvai Gorge (Tanzania)	~1400	+1.8	+27.7	*Bovidae (Antilopini, Hippotragus gigas)*	1.7	Ascari *et al.* 2018
242	Olduvai Gorge (Tanzania)	~1400	-0.4	+29.3	*Bovidae (Antilopini, Hippotragus gigas)*	1.7	Ascari *et al.* 2018
243	Olduvai Gorge (Tanzania)	~1400	+0.2	+28.9	*Bovidae (Antilopini, Hippotragus gigas)*	1.7	Ascari *et al.* 2018
244	Olduvai Gorge (Tanzania)	~1400	-0.3	+26.4	*Bovidae (Antilopini, Hippotragus gigas)*	1.7	Ascari *et al.* 2018
245	Olduvai Gorge (Tanzania)	~1400	-1.2	+26.2	*Bovidae (Antilopini, Hippotragus gigas)*	1.7	Ascari *et al.* 2018
246	Olduvai Gorge (Tanzania)	~1400	+0.7	+25.7	*Bovidae (Antilopini, Hippotragus gigas)*	1.7	Ascari *et al.* 2018
247	Olduvai Gorge (Tanzania)	~1400	-0.1	+31.1	*Bovidae (Antilopini)*	1.7	Ascari *et al.* 2018

248	Olduvai Gorge (Tanzania)	~1400	-1.8	+27.7	*Bovidae (Reduncini)*	1.7	Ascari *et al*. 2018
249	Olduvai Gorge (Tanzania)	~1400	-1.9	+27.2	*Bovidae (Reduncini)*	1.7	Ascari *et al*. 2018
250	Olduvai Gorge (Tanzania)	~1400	-4.1	+18.2	*Bovidae (Alcelaphini)*	1.7	Ascari *et al*. 2018
251	Olduvai Gorge (Tanzania)	~1400	+0.6	+28.2	*Bovidae (Alcelaphini)*	1.7	Ascari *et al*. 2018
252	Olduvai Gorge (Tanzania)	~1400	-2.8	+25.5	*Bovidae (Alcelaphini)*	1.7	Ascari *et al*. 2018
253	Olduvai Gorge (Tanzania)	~1400	+1.1	+27.1	*Bovidae (Alcelaphini)*	1.7	Ascari *et al*. 2018
254	Olduvai Gorge (Tanzania)	~1400	+0.5	+26.9	*Bovidae (Alcelaphini)*	1.7	Ascari *et al*. 2018
255	Olduvai Gorge (Tanzania)	~1400	+2.1	+27.9	*Bovidae (Alcelaphini)*	1.7	Ascari *et al*. 2018
256	Olduvai Gorge (Tanzania)	~1400	-0.6	+26.3	*Bovidae (Reduncini)*	1.7	van der Merwe 2013
257	Olduvai Gorge (Tanzania)	~1400	-2.4	+30.5	*Bovidae (Tragelaphinae, Tragelaphus strepsiceros)*	1.7	van der Merwe 2013
258	Olduvai Gorge (Tanzania)	~1400	-5.7	+30.7	*Bovidae (Tragelaphinae, Tragelaphus strepsiceros)*	1.7	van der Merwe 2013
259	Olduvai Gorge (Tanzania)	~1400	-5.7	+31.4	*Bovidae (Tragelaphinae, Tragelaphus scriptus)*	1.7	van der Merwe 2013
260	Olduvai Gorge (Tanzania)	~ 1400	-4.2	+28.5	*Bovidae (Tragelaphinae, Tragelaphus oryx)*	1.7	van der Merwe 2013
261	Olduvai Gorge (Tanzania)	~1400	-2.9	+26.9	*Bovidae (Tragelaphinae, Tragelaphus)*	1.7	van der Merwe 2013
262	Olduvai Gorge (Tanzania)	~1400	-9.2	+31.1	*Bovidae (Tragelaphinae, Tragelaphus)*	1.7	van der Merwe 2013
263	Olduvai Gorge (Tanzania)	~1400	+3.3	+28.6	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013

264	Olduvai Gorge (Tanzania)	~1400	+2.3	+28.2	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
265	Olduvai Gorge (Tanzania)	~1400	+2.1	+29.6	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
266	Olduvai Gorge (Tanzania)	~1400	+1.2	+27.3	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
267	Olduvai Gorge (Tanzania)	~1400	+2.4	+29.4	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
268	Olduvai Gorge (Tanzania)	~1400	+4.1	+26.9	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
269	Olduvai Gorge (Tanzania)	~1400	+3.5	+30.7	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
270	Olduvai Gorge (Tanzania)	~1400	+0.2	+23.7	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
271	Olduvai Gorge (Tanzania)	~1400	+0.2	+26.7	*Bovidae (Alcelaphinae, Connochaetes/Beatragus)*	1.7	van der Merwe 2013
272	Olduvai Gorge (Tanzania)	~1400	+2.1	+28.4	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
273	Olduvai Gorge (Tanzania)	~1400	+2.1	+29.5	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
274	Olduvai Gorge (Tanzania)	~1400	+2.5	+26.5	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
275	Olduvai Gorge (Tanzania)	~1400	+3.8	+29.7	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
276	Olduvai Gorge (Tanzania)	~1400	+0.9	+29.2	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013

277	Olduvai Gorge (Tanzania)	~1400	+1.3	+29.5	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
278	Olduvai Gorge (Tanzania)	~1400	+1.1	+29.7	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
279	Olduvai Gorge (Tanzania)	~1400	+1.7	+26.2	*Bovidae (Alcelaphinae, Parmularius)*	1.7	van der Merwe 2013
280	Olduvai Gorge (Tanzania)	~1400	+0.7	+26.8	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
281	Olduvai Gorge (Tanzania)	~1400	-0.7	+28.2	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
282	Olduvai Gorge (Tanzania)	~1400	+0.5	+31.1	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
283	Olduvai Gorge (Tanzania)	~1400	+1.3	+31.8	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
284	Olduvai Gorge (Tanzania)	~1400	+0.2	+30.7	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
285	Olduvai Gorge (Tanzania)	~1400	+0.5	+30.7	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
286	Olduvai Gorge (Tanzania)	~1400	+1.1	+31.8	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
287	Olduvai Gorge (Tanzania)	~1400	+1.2	+30.9	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
288	Olduvai Gorge (Tanzania)	~1400	+0.8	+31.6	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	van der Merwe 2013
289	Olduvai Gorge (Tanzania)	~1400	+0.2	+24.4	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013

290	Olduvai Gorge (Tanzania)	~1400	-7.7	+28.9	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
291	Olduvai Gorge (Tanzania)	~1400	-9	+23.1	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
292	Olduvai Gorge (Tanzania)	~1400	+1.2	+32.5	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
293	Olduvai Gorge (Tanzania)	~1400	+0.3	+26.1	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
294	Olduvai Gorge (Tanzania)	~1400	0	+27.8	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
295	Olduvai Gorge (Tanzania)	~1400	-5.2	+27.3	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
296	Olduvai Gorge (Tanzania)	~1400	-5.6	+31.9	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
297	Olduvai Gorge (Tanzania)	~1400	-9.1	+25.1	*Bovidae (Antelopinae, Gazella)*	1.7	van der Merwe 2013
298	Olduvai Gorge (Tanzania)	~1400	+0.5	+31.1	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
299	Olduvai Gorge (Tanzania)	~1400	+2.1	+32.7	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
300	Olduvai Gorge (Tanzania)	~1400	+2.4	+31.7	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
301	Olduvai Gorge (Tanzania)	~1400	+2.6	+29.5	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
302	Olduvai Gorge (Tanzania)	~1400	-5.3	+32.2	*Bovidae (Antilopini/Aepyceros)*	1.7	Rivals *et al*. 2018
303	Olduvai Gorge (Tanzania)	~1400	-7.2	+33.7	*Bovidae (Antilopini/ cf. Antidorcas recki)*	1.7	Rivals *et al*. 2018
304	Olduvai Gorge (Tanzania)	~1400	+2.6	+31.9	*Bovidae (Antilopini/ cf. Antidorcas recki)*	1.7	Rivals *et al*. 2018

305	Olduvai Gorge (Tanzania)	~1400	+0.5	+32.1	*Bovidae (Bovini)*	1.7	Rivals *et al*. 2018
306	Olduvai Gorge (Tanzania)	~1400	+1.7	+34.9	*Bovidae (Hippotragini)*	1.7	Rivals *et al*. 2018
307	Olduvai Gorge (Tanzania)	~1400	-0.5	+33.1	*Bovidae (Hippotragini, Oryx)*	1.7	Rivals *et al*. 2018
308	Olduvai Gorge (Tanzania)	~1400	+2.2	+32.6	*Bovidae (Reduncini, Kobus cf. ellipsiprymnus)*	1.7	Rivals *et al*. 2018
309	Olduvai Gorge (Tanzania)	~1400	-7.8	+31.5	*Bovidae (Tragelaphini)*	1.7	Rivals *et al*. 2018
310	Olduvai Gorge (Tanzania)	~1400	+2.8	+32.1	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
311	Olduvai Gorge (Tanzania)	~1400	-1.1	+30.9	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
312	Olduvai Gorge (Tanzania)	~1400	-0.1	+32.1	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
313	Olduvai Gorge (Tanzania)	~1400	+0.7	+28.9	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
314	Olduvai Gorge (Tanzania)	~1400	+0.7	+32.7	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
315	Olduvai Gorge (Tanzania)	~1400	+1.3	+29.8	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
316	Olduvai Gorge (Tanzania)	~1400	+3.3	+34.1	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
317	Olduvai Gorge (Tanzania)	~1400	+1.8	+31.5	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
318	Olduvai Gorge (Tanzania)	~1400	+1.9	+30.9	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
319	Olduvai Gorge (Tanzania)	~1400	+3.2	+30.6	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
320	Olduvai Gorge (Tanzania)	~1400	+3.2	+30.1	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
321	Olduvai Gorge (Tanzania)	~1400	+2.6	+30.5	*Bovidae (Alcelaphini)*	1.7	Rivals *et al*. 2018
322	Olduvai Gorge (Tanzania)	~1400	-8.9	+34.2	*Bovidae (Antilopini/Aepyceros)*	1.7	Rivals *et al*. 2018

323	Olduvai Gorge (Tanzania)	~1400	-5.8	+31.1	*Bovidae (Antilopini/Aepyceros)*	1.7	Rivals *et al*. 2018
324	Olduvai Gorge (Tanzania)	~1400	+1.9	+33.9	*Bovidae (Antilopini cf. Antidorcas recki)*	1.7	Rivals *et al*. 2018
325	Olduvai Gorge (Tanzania)	~1400	-0.7	+29.3	*Bovidae (Hippotragini, Hippotragus gigas)*	1.7	Rivals *et al*. 2018
326	Olduvai Gorge (Tanzania)	~1400	+2.7	+33.8	*Bovidae (Hippotragini, Oryx)*	1.7	Rivals *et al*. 2018
327	Olduvai Gorge (Tanzania)	~1400	+1.1	+33.3	*Bovidae (Reduncini, Kobus)*	1.7	Rivals *et al*. 2018
328	Olduvai Gorge (Tanzania)	~1400	+2.8	+33.7	*Bovidae (Reduncini, Kobus cf. ellipsiprymnus)*	1.7	Rivals *et al*. 2018
329	Olduvai Gorge (Tanzania)	~1400	-8.3	+31.1	*Bovidae (Tragelaphini)*	1.7	Rivals *et al*. 2018
330	Olduvai Gorge (Tanzania)	~1400	+1.2	+36.1	*Bovidae*	1.7	Rivals *et al*. 2018
331	Olduvai Gorge (Tanzania)	~1400	-0.7	+32.8	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
332	Olduvai Gorge (Tanzania)	~1400	+0.1	+31.2	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
333	Olduvai Gorge (Tanzania)	~1400	+0.5	+32.3	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
334	Olduvai Gorge (Tanzania)	~1400	+1.4	+31.2	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
335	Olduvai Gorge (Tanzania)	~1400	+1.4	+30.1	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
336	Olduvai Gorge (Tanzania)	~1400	+2.1	+32.5	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
337	Olduvai Gorge (Tanzania)	~1400	+2.7	+32.9	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
338	Olduvai Gorge (Tanzania)	~1400	+3.1	+31.6	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
339	Olduvai Gorge (Tanzania)	~1400	+2.4	+32.9	*Bovidae (Alcelaphini, Megalotragus isaaci)*	1.6	Uno *et al*. 2018
340	Olduvai Gorge (Tanzania)	~1400	+3.6	+31.6	*Bovidae (Alcelaphini, Megalotragus isaaci)*	1.6	Uno *et al*. 2018

341	Olduvai Gorge (Tanzania)	~1400	+1.1	+32.5	*Bovidae (Hippotragini, Hippotragus gigas)*	1.6	Uno *et al*. 2018
342	Olduvai Gorge (Tanzania)	~1400	+4.1	+33.1	*Bovidae (Reduncini, Kobus sigmoidalis/ellipsiprymnus)*	1.6	Uno *et al*. 2018
343	Olduvai Gorge (Tanzania)	~1400	+1.5	+31.1	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
344	Olduvai Gorge (Tanzania)	~1400	+1.9	+29.1	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
345	Olduvai Gorge (Tanzania)	~1400	+2.1	+32.6	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
346	Olduvai Gorge (Tanzania)	~1400	+2.1	+32.3	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
347	Olduvai Gorge (Tanzania)	~1400	+2.8	+32.3	*Bovidae (Alcelaphini)*	1.6	Uno *et al*. 2018
348	Olduvai Gorge (Tanzania)	~1400	+0.7	+30.1	*Bovidae (Alcelaphini, Megalotragus isaaci)*	1.6	Uno *et al*. 2018
349	Olduvai Gorge (Tanzania)	~1400	-1.3	+31.7	*Bovidae (Antilopini)*	1.6	Uno *et al*. 2018
350	Olduvai Gorge (Tanzania)	~1400	-2.8	+31.8	*Bovidae (Tragelaphini, Taurotragus)*	1.6	Uno *et al*. 2018
351	Olduvai Gorge (Tanzania)	~1400	+0.2	+34.6	*Bovidae (Tragelaphini, Tragelaphus strepsiceros)*	1.6	Uno *et al*. 2018
352	Olduvai Gorge (Tanzania)	~1400	-0.1	+27.5	*Bovidae (Bovini)*	1.5	Ascari *et al*. 2018
353	Olduvai Gorge (Tanzania)	~1400	+1.5	+25.4	*Bovidae (Hippotragus)*	1.5	Ascari et al. 2018
354	Olduvai Gorge (Tanzania)	~1400	+1.1	+30.7	*Bovidae (Alcelaphini, Megalotragus isaaci)*	1.5	Uno *et al*. 2018
355	Olduvai Gorge (Tanzania)	~1400	+2.8	+30.5	*Bovidae (Alcelaphini, Megalotragus isaaci)*	1.5	Uno *et al*. 2018
356	Olduvai Gorge (Tanzania)	~1400	+3.1	+30.4	*Bovidae (Hippotragini, Hippotragus gigas)*	1.5	Uno *et al*. 2018
357	Olduvai Gorge (Tanzania)	~1400	+1.3	+31.1	*Bovidae (Antilopini cf. Antidorcas recki)*	1.3	Uno *et al*. 2018
358	Gona (Ethiopia)	~540	+2.6	+30.8	*Bovidae (Alcelaphini)*	1.2	Semaw *et al*. 2020

359	Gona (Ethiopia)	~540	+3.6	+36.2	*Bovidae (Alcelaphini)*	1.2	Semaw *et al*. 2020
360	Gona (Ethiopia)	~540	+0.8	+27.4	*Bovidae (Alcelaphini)*	1.2	Semaw *et al*. 2020
361	Gona (Ethiopia)	~540	+2.9	+28.6	*Bovidae (Alcelaphini)*	1.2	Semaw *et al*. 2020
362	Gona (Ethiopia)	~540	+1.7	+29.3	*Bovidae (Hippotraginae, cf. Hippotragus)*	1.2	Semaw *et al*. 2020
363	Gona (Ethiopia)	~540	+2.9	+29.5	*Bovidae (Hippotraginae, cf. Hippotragus)*	1.2	Semaw *et al*. 2020
364	Gona (Ethiopia)	~540	+1.4	+29.8	*Bovidae (Hippotraginae, cf. Hippotragus)*	1.2	Semaw *et al*. 2020
365	Gona (Ethiopia)	~540	+1.7	+30.7	*Bovidae (Reduncini, cf. Kobus)*	1.2	Semaw *et al*. 2020
366	Gona (Ethiopia)	~540	+0.6	+26.1	*Bovidae (Reduncini, cf. Kobus)*	1.2	Semaw *et al*. 2020
367	Gona (Ethiopia)	~540	+2.6	+36.3	*Bovidae (Bovini)*	1.2	Semaw *et al*. 2020
368	Gona (Ethiopia)	~540	+3.2	+34.4	*Bovidae (Bovini)*	1.2	Semaw *et al*. 2020
369	Gona (Ethiopia)	~540	+2.7	+30.7	*Bovidae (Bovini)*	1.2	Semaw *et al*. 2020
370	Gona (Ethiopia)	~540	+1.7	+28.3	*Bovidae (Bovini)*	1.2	Semaw *et al*. 2020
371	Gona (Ethiopia)	~540	-7.2	+30.8	*Bovidae (Tragelaphini)*	1.2	Semaw *et al*. 2020
372	Gona (Ethiopia)	~540	-2.4	+26.4	*Bovidae (Tragelaphini)*	1.2	Semaw *et al*. 2020
373	Busidima Formation (Ethiopia)	~1470	+0.4	+30.3	*Bovidae (Alcelaphini, Connochaetes)*	0.7	Bedaso *et al*. 2010
374	Busidima Formation (Ethiopia)	~1470	+0.9	+32.1	*Bovidae (Alcelaphini, Damaliscus)*	0.7	Bedaso *et al*. 2010
375	Busidima Formation (Ethiopia)	~1470	+2.5	+30.7	*Bovidae (Alcelaphini, Megalotragus)*	0.7	Bedaso *et al*. 2010

376	Busidima Formation (Ethiopia)	~1470	-5.7	+30.1	*Bovidae (Antilopini, Gazella granti)*	0.7	Bedaso *et al.* 2010
377	Busidima Formation (Ethiopia)	~1470	-4.7	+35.6	*Bovidae (Antilopini, Gazella)*	0.7	Bedaso *et al.* 2010
378	Busidima Formation (Ethiopia)	~1470	-7.7	+35.1	*Bovidae (Antilopini, Gazella)*	0.7	Bedaso *et al.* 2010
379	Busidima Formation (Ethiopia)	~1470	-5.5	+36.2	*Bovidae (Antilopini, Gazella)*	0.7	Bedaso *et al.* 2010
380	Busidima Formation (Ethiopia)	~1470	-3.3	+34.1	*Bovidae (Antilopini, Gazella granti)*	0.7	Bedaso *et al.* 2010
381	Busidima Formation (Ethiopia)	~1470	-8	+34.1	*Bovidae (Antilopini, Gazella)*	0.7	Bedaso *et al.* 2010
382	Busidima Formation (Ethiopia)	~1470	-6.4	+28.7	*Bovidae (Antilopini, Gazella)*	0.7	Bedaso *et al.* 2010
383	Busidima Formation (Ethiopia)	~1470	-4.2	+33.2	*Bovidae (Antilopini, Gazella)*	0.7	Bedaso *et al.* 2010
384	Busidima Formation (Ethiopia)	~1470	+0.7	+31.1	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
385	Busidima Formation (Ethiopia)	~1470	+1.8	+28.5	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
386	Busidima Formation (Ethiopia)	~1470	-2.3	+30.9	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
387	Busidima Formation (Ethiopia)	~1470	+2.5	+33.1	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
388	Busidima Formation (Ethiopia)	~1470	-0.9	+30.9	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010

389	Busidima Formation (Ethiopia)	~1470	+0.9	+32.6	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
390	Busidima Formation (Ethiopia)	~1470	-0.1	+36.8	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
391	Busidima Formation (Ethiopia)	~1470	+0.8	+30.9	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
392	Busidima Formation (Ethiopia)	~1470	+2.7	+34.1	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
393	Busidima Formation (Ethiopia)	~1470	+1.2	+32.2	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
394	Busidima Formation (Ethiopia)	~1470	+3.3	+31.2	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
395	Busidima Formation (Ethiopia)	~1470	0	+31.1	*Bovidae (Bovini)*	0.7	Bedaso *et al.* 2010
396	Busidima Formation (Ethiopia)	~1470	+1.1	+34.7	*Bovidae (Hippotragini)*	0.7	Bedaso *et al.* 2010
397	Busidima Formation (Ethiopia)	~1470	+0.1	+31.6	*Bovidae (Hippotragini)*	0.7	Bedaso *et al.* 2010
398	Busidima Formation (Ethiopia)	~1470	+2.3	+32.6	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
399	Busidima Formation (Ethiopia)	~1470	+1.9	+33.1	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
400	Busidima Formation (Ethiopia)	~1470	-3	+28.7	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
401	Busidima Formation (Ethiopia)	~1470	+1.2	+31.4	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010

402	Busidima Formation (Ethiopia)	~1470	+0.3	+31.4	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
403	Busidima Formation (Ethiopia)	~1470	+0.2	+30.9	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
404	Busidima Formation (Ethiopia)	~1470	+1.1	+32.7	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
405	Busidima Formation (Ethiopia)	~1470	+0.3	+31.1	*Bovidae (Reduncini)*	0.7	Bedaso *et al.* 2010
406	Busidima Formation (Ethiopia)	~1470	-5.7	+34.6	*Bovidae (Reduncini)*	0.7	Bedaso *et al.* 2010
407	Busidima Formation (Ethiopia)	~1470	+1.8	+32.1	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
408	Busidima Formation (Ethiopia)	~1470	-2.6	+33.4	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
409	Busidima Formation (Ethiopia)	~1470	+3.1	+32.3	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
410	Busidima Formation (Ethiopia)	~1470	-0.2	+32.9	*Bovidae (Reduncini, Kobus)*	0.7	Bedaso *et al.* 2010
411	Busidima Formation (Ethiopia)	~1470	-6.5	+32.4	*Bovidae (Tragelaphini, Taurotragus)*	0.7	Bedaso *et al.* 2010
412	Busidima Formation (Ethiopia)	~1470	-11.4	+35.7	*Bovidae (Tragelaphini, Taurotragus)*	0.7	Bedaso *et al.* 2010
413	Busidima Formation (Ethiopia)	~1470	-3.7	+34.6	*Bovidae (Tragelaphini, Taurotragus)*	0.7	Bedaso *et al.* 2010

Table S7. List of the bulk samples and values of carbon and oxygen isotopic ratio of equids teeth enamel, from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia) (~2.1-0.7 Ma).

	Archaeological site	**m a.s.l.**	**$\delta^{13}C$ (VPDB)**	**$\delta^{18}O$ (SMOW)**	***Taxon***	**Chronology (Ma)**	**Notes**
1	Shungura Formation (Ethiopia)	~440	+2.1	+35.1	*Equidae*	2.1	Negash *et al*. 2020
2	Shungura Formation (Ethiopia)	~440	+2.2	+34.1	*Equidae*	2.1	Negash *et al*. 2020
3	Shungura Formation (Ethiopia)	~440	+0.8	+32.1	*Equidae*	2.1	Negash *et al*. 2020
4	Shungura Formation (Ethiopia)	~440	+1.8	+31.1	*Equidae*	2.1	Negash *et al*. 2020
5	Shungura Formation (Ethiopia)	~440	+0.9	+35.1	*Equidae*	2.1	Negash *et al*. 2020
6	Shungura Formation (Ethiopia)	~440	-0.9	+30.1	*Equidae*	2.1	Negash *et al*. 2020
7	Shungura Formation (Ethiopia)	~440	-0.1	+31.1	*Equidae*	2.1	Negash *et al*. 2020
8	Shungura Formation (Ethiopia)	~440	+1.2	+28.1	*Equidae*	2.1	Negash *et al*. 2020
9	Shungura Formation (Ethiopia)	~440	+1.2	+33.1	*Equidae*	2.1	Negash *et al*. 2020
10	Shungura Formation (Ethiopia)	~440	+1.8	+25.1	*Equidae*	2.1	Negash *et al*. 2020
11	Shungura Formation (Ethiopia)	~440	-1.3	+28.1	*Equidae*	2.1	Negash *et al*. 2020
12	Shungura Formation (Ethiopia)	~440	+1.4	+33.2	*Equidae*	2.1	Negash *et al*. 2020
13	Shungura Formation (Ethiopia)	~440	+1.4	+33.1	*Equidae*	2.1	Negash *et al*. 2020
14	Shungura Formation (Ethiopia)	~440	-0.6	+31.1	*Equidae*	2.1	Negash *et al*. 2020
15	Shungura Formation (Ethiopia)	~440	-1.1	+33.1	*Equidae*	2.1	Negash *et al*. 2020
16	Shungura Formation (Ethiopia)	~440	+0.3	+35.1	*Equidae*	2.1	Negash *et al*. 2020
17	Shungura Formation (Ethiopia)	~440	-0.4	+31.1	*Equidae*	2.1	Negash *et al*. 2020

18	Shungura Formation (Ethiopia)	~440	-1.5	+30.1	*Equidae*	2.1	Negash *et al*. 2020
19	Shungura Formation (Ethiopia)	~440	+0.9	+33.1	*Equidae*	2.0	Negash *et al*. 2020
20	Shungura Formation (Ethiopia)	~440	+0.3	+30.1	*Equidae*	2.0	Negash *et al*. 2020
21	Shungura Formation (Ethiopia)	~440	+1.8	+35.1	*Equidae*	2.0	Negash *et al*. 2020
22	Shungura Formation (Ethiopia)	~440	+1.2	+31.1	*Equidae*	2.0	Negash *et al*. 2020
23	Shungura Formation (Ethiopia)	~440	-0.6	+28.1	*Equidae*	2.0	Negash *et al*. 2020
24	Shungura Formation (Ethiopia)	~440	-1.2	+31.1	*Equidae*	2.0	Negash *et al*. 2020
25	Shungura Formation (Ethiopia)	~440	-0.2	+31.1	*Equidae*	2.0	Negash *et al*. 2020
26	Shungura Formation (Ethiopia)	~440	+0.5	+35.1	*Equidae*	2.0	Negash *et al*. 2020
27	Shungura Formation (Ethiopia)	~440	+1.4	+30.6	*Equidae*	1.2	Negash *et al*. 2020
28	Shungura Formation (Ethiopia)	~440	+0.1	+34.1	*Equidae*	1.2	Negash *et al*. 2020
29	Shungura Formation (Ethiopia)	~440	-0.5	+34.1	*Equidae*	1.2	Negash *et al*. 2020
30	Shungura Formation (Ethiopia)	~440	-3.3	+26.2	*Equidae*	1.2	Negash *et al*. 2020
31	Shungura Formation (Ethiopia)	~440	-1	+34.7	*Equidae*	1.2	Negash *et al*. 2020
32	Shungura Formation (Ethiopia)	~440	+0.3	+33.9	*Equidae*	1.2	Negash *et al*. 2020
33	Shungura Formation (Ethiopia)	~440	+0.1	+33.5	*Equidae*	1.2	Negash *et al*. 2020
34	Shungura Formation (Ethiopia)	~440	-1.5	+33.5	*Equidae*	1.2	Negash *et al*. 2020
35	Melka Kunture (Ethiopia)	~2000	+2.7	+30.9	*Equidae*	1.9	Bocherens *et al*. 1996
36	Melka Kunture (Ethiopia)	~2000	+0.1	+26.5	*Equidae (Hipparion)*	1.6	this study
37	Melka Kunture (Ethiopia)	~2000	-1.9	+24.4	*Equidae*	1.4	this study

38	Melka Kunture (Ethiopia)	~2000	+2.1	+23.9	*Equidae*	1.3	this study
39	Melka Kunture (Ethiopia)	~2000	+3.1	+28.3	*Equidae*	1.3	this study
40	Melka Kunture (Ethiopia)	~2000	+2.2	+23.1	*Equidae*	1.3	this study
41	Melka Kunture (Ethiopia)	~2000	-0.1	+24.5	*Equidae*	1.3	this study
42	Melka Kunture (Ethiopia)	~2000	-1.4	+28.4	*Equidae*	0.85	Bocherens *et al*. 1996
43	Melka Kunture (Ethiopia)	~2000	+0.2	+29.3	*Equidae*	0.85	this study
44	Melka Kunture (Ethiopia)	~2000	+2.1	+24.9	*Equidae*	0.7	this study
45	Melka Kunture (Ethiopia)	~2000	-1.1	+27.3	*Equidae*	0.7	this study
46	Melka Kunture (Ethiopia)	~2000	-1.6	+29.7	*Equidae*	0.7	this study
47	Melka Kunture (Ethiopia)	~2000	-0.4	+27.5	*Equidae*	0.7	this study
48	Melka Kunture (Ethiopia)	~2000	-1.9	+24.1	*Equidae*	0.7	this study
49	Melka Kunture (Ethiopia)	~2000	+1.2	+28.6	*Equidae*	0.7	this study
50	Melka Kunture (Ethiopia)	~2000	+2.7	+27.1	*Equidae*	0.7	this study
51	Melka Kunture (Ethiopia)	~2000	+2.9	+26.8	*Equidae*	0.7	this study
52	Melka Kunture (Ethiopia)	~2000	+3.9	+23.8	*Equidae*	0.7	this study
53	Olduvai Gorge (Tanzania)	~1400	+1.5	+29.1	*Equidae*	1.7	Ascari *et al*. 2018
54	Olduvai Gorge (Tanzania)	~1400	+0.5	+28.7	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
55	Olduvai Gorge (Tanzania)	~1400	-0.4	+28.1	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
56	Olduvai Gorge (Tanzania)	~1400	-0.2	+28.2	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
57	Olduvai Gorge (Tanzania)	~1400	+1.4	+28.9	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013

58	Olduvai Gorge (Tanzania)	~1400	+1.1	+29.1	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
59	Olduvai Gorge (Tanzania)	~1400	-0.8	+27.1	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
60	Olduvai Gorge (Tanzania)	~1400	+0.7	+27.4	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
61	Olduvai Gorge (Tanzania)	~1400	-1.7	+27.7	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
62	Olduvai Gorge (Tanzania)	~1400	+2.7	+27.6	*Equidae (Equus olduwayensis)*	1.7	van der Merwe 2013
63	Olduvai Gorge (Tanzania)	~1400	+3.1	+31.9	*Equidae*	1.7	van der Merwe 2013
64	Olduvai Gorge (Tanzania)	~1400	+1.1	+25.3	*Equidae (Hipparion)*	1.7	van der Merwe 2013
65	Olduvai Gorge (Tanzania)	~1400	-1.8	+26.2	*Equidae (Hipparion)*	1.7	van der Merwe 2013
66	Olduvai Gorge (Tanzania)	~1400	-1.2	+27.9	*Equidae (Ambiguous)*	1.7	van der Merwe 2013
67	Olduvai Gorge (Tanzania)	~1400	+0.9	+28.6	*Equidae (Ambiguous)*	1.7	van der Merwe 2013
68	Olduvai Gorge (Tanzania)	~1400	-0.4	+26.9	*Equidae (Ambiguous)*	1.7	van der Merwe 2013
69	Olduvai Gorge (Tanzania)	~1400	+1.9	+29.1	*Equidae (Ambiguous)*	1.7	van der Merwe 2013
70	Olduvai Gorge (Tanzania)	~1400	+1.2	+26.7	*Equidae (Ambiguous)*	1.7	van der Merwe 2013
71	Olduvai Gorge (Tanzania)	~1400	-0.2	+27.9	*Equidae (Ambiguous)*	1.7	van der Merwe 2013
72	Olduvai Gorge (Tanzania)	~1400	+0.3	+30.9	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018
73	Olduvai Gorge (Tanzania)	~1400	+0.9	+31.7	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018
74	Olduvai Gorge (Tanzania)	~1400	-1.1	+30.8	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018
75	Olduvai Gorge (Tanzania)	~1400	+1.2	+30.3	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018
76	Olduvai Gorge (Tanzania)	~1400	+1.6	+30.5	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018
77	Olduvai Gorge (Tanzania)	~1400	+2.1	+31.1	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018

78	Olduvai Gorge (Tanzania)	~1400	-0.1	+30.1	*Equidae (Equus cf. oldowayensis)*	1.7	Rivals *et al*. 2018
79	Olduvai Gorge (Tanzania)	~1400	-1.4	+30.7	*Equidae (Equus oldowayensis)*	1.6	Uno *et al*. 2018
80	Olduvai Gorge (Tanzania)	~1400	+1.3	+30.1	*Equidae (Equus oldowayensis)*	1.6	Uno *et al*. 2018
81	Olduvai Gorge (Tanzania)	~1400	+0.9	+30.8	*Equidae (Equus oldowayensis)*	1.6	Uno *et al*. 2018
82	Olduvai Gorge (Tanzania)	~1400	+1.2	+28.8	*Equidae (Equus oldowayensis)*	1.6	Uno *et al*. 2018
83	Olduvai Gorge (Tanzania)	~1400	-0.2	+30.2	*Equidae (Equus oldowayensis)*	1.6	Uno *et al*. 2018
84	Olduvai Gorge (Tanzania)	~1400	+1.3	+31.3	*Equidae (Equus oldowayensis)*	1.5	Uno *et al*. 2018
85	Olduvai Gorge (Tanzania)	~1400	+1.4	+29.4	*Equidae (Equus oldowayensis)*	1.5	Uno *et al*. 2018
86	Olduvai Gorge (Tanzania)	~1400	+2.1	+30.5	*Equidae (Equus oldowayensis)*	1.5	Uno *et al*. 2018
87	Olduvai Gorge (Tanzania)	~1400	+1.9	+30.4	*Equidae (Equus oldowayensis)*	1.5	Uno *et al*. 2018
88	Olduvai Gorge (Tanzania)	~1400	+1.9	+30.9	*Equidae (Eurygnathohippus cornelianus)*	1.5	Uno *et al*. 2018
89	Olduvai Gorge (Tanzania)	~1400	+1.6	+29.5	*Equidae*	1.5	Uno *et al*. 2018
90	Olduvai Gorge (Tanzania)	~1400	-0.7	+26.7	*Equidae*	1.5	Ascari *et al*. 2018
91	Olduvai Gorge (Tanzania)	~1400	+2.1	+29.4	*Equidae (Eurygnathohippus cornelianus)*	1.3	Uno *et al*. 2018
92	Olduvai Gorge (Tanzania)	~1400	+2.4	+31.2	*Equidae (Equus oldowayensis)*	1.3	Uno *et al*. 2018
93	Olduvai Gorge (Tanzania)	~1400	+1.8	+28.8	*Equidae (Equus oldowayensis)*	1.3	Uno *et al*. 2018
94	Olduvai Gorge (Tanzania)	~1400	-5.1	+30.6	*Equidae (Equus oldowayensis)*	1.3	Uno *et al*. 2018
95	Olduvai Gorge (Tanzania)	~1400	+3.3	+29.1	*Equidae (Eurygnathohippus cornelianus)*	1.3	Uno *et al*. 2018
96	Busidima Formation (Ethiopia)	~1470	+1.2	+32.1	*Equidae (Equus)*	0.7	Bedaso *et al.* 2010
97	Busidima Formation (Ethiopia)	~1470	+0.4	+33.8	*Equidae (Equus)*	0.7	Bedaso *et al.* 2010
98	Busidima Formation (Ethiopia)	~1470	+1.1	+34.3	*Equidae (Equus)*	0.7	Bedaso *et al.* 2010
99	Busidima Formation (Ethiopia)	~1470	+1.1	+31.4	*Equidae (Equus)*	0.7	Bedaso *et al.* 2010
100	Busidima Formation (Ethiopia)	~1470	-0.6	+30.4	*Equidae (Equus)*	0.7	Bedaso *et al.* 2010
101	Busidima Formation (Ethiopia)	~1470	+1.1	+32.2	*Equidae (Equus)*	0.7	Bedaso *et al.* 2010

Table S8. List of the bulk samples and values of carbon and oxygen isotopic ratio of suids teeth enamel, from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), Gona (Ethiopia), and Busidima Formation (Ethiopia) (~2.1-0.7 Ma).

	Archaeological site	**m a.s.l.**	**$\delta^{13}C$ (VPDB)**	**$\delta^{18}O$ (SMOW)**	***Taxon***	**Chronology (Ma)**	**Notes**
1	Shungura Formation (Ethiopia)	~440	-0.8	+28.1	*Suidae (Notochoerus)*	2.1	Negash *et al.* 2020
2	Shungura Formation (Ethiopia)	~440	-2.3	+32.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al.* 2020
3	Shungura Formation (Ethiopia)	~440	-5.6	+31.1	*Suidae (Notochoerus)*	2.1	Negash *et al.* 2020
4	Shungura Formation (Ethiopia)	~440	-1	+30.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al.* 2020
5	Shungura Formation (Ethiopia)	~440	0	+30.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al.* 2020
6	Shungura Formation (Ethiopia)	~440	-1.1	+32.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al.* 2020
7	Shungura Formation (Ethiopia)	~440	-1.9	+34.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al.* 2020
8	Shungura Formation (Ethiopia)	~440	-1.2	+32.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al.* 2020
9	Shungura Formation (Ethiopia)	~440	-1.3	+29.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al.* 2020
10	Shungura Formation (Ethiopia)	~440	-1.1	+32.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al.* 2020
11	Shungura Formation (Ethiopia)	~440	-1.5	+32.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al.* 2020

12	Shungura Formation (Ethiopia)	~440	-0.5	+26.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
13	Shungura Formation (Ethiopia)	~440	-0.9	+32.1	*Suidae (Notochoerus)*	2.1	Negash *et al*. 2020
14	Shungura Formation (Ethiopia)	~440	-0.7	+32.1	*Suidae (Notochoerus)*	2.1	Negash *et al*. 2020
15	Shungura Formation (Ethiopia)	~440	-1.7	+33.1	*Suidae (Notochoerus)*	2.1	Negash *et al*. 2020
16	Shungura Formation (Ethiopia)	~440	-1.1	+34.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
17	Shungura Formation (Ethiopia)	~440	-0.2	+32.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
18	Shungura Formation (Ethiopia)	~440	+0.2	+31.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
19	Shungura Formation (Ethiopia)	~440	-1.2	+26.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
20	Shungura Formation (Ethiopia)	~440	-0.5	+25.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
21	Shungura Formation (Ethiopia)	~440	-1.3	+26.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
22	Shungura Formation (Ethiopia)	~440	-0.3	+28.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
23	Shungura Formation (Ethiopia)	~440	-1.9	+28.1	*Suidae (Kolpochaerus)*	2.1	Negash *et al*. 2020
24	Shungura Formation (Ethiopia)	~440	-0.7	+32.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al*. 2020

25	Shungura Formation (Ethiopia)	~440	-0.7	+30.1	*Suidae (Metridiochoerus)*	2.1	Negash *et al*. 2020
26	Shungura Formation (Ethiopia)	~440	+0.7	+31.1	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020
27	Shungura Formation (Ethiopia)	~440	+0.4	+29.1	*Suidae (Kolpochaerus)*	2.0	Negash *et al*. 2020
28	Shungura Formation (Ethiopia)	~440	-0.9	+31.1	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020
29	Shungura Formation (Ethiopia)	~440	-0.6	+32.1	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020
30	Shungura Formation (Ethiopia)	~440	-0.8	+32.1	*Suidae (Notochoerus)*	2.0	Negash *et al*. 2020
31	Shungura Formation (Ethiopia)	~440	-1.2	+29.1	*Suidae (Notochoerus)*	2.0	Negash *et al*. 2020
32	Shungura Formation (Ethiopia)	~440	+0.3	+26.1	*Suidae (Notochoerus)*	2.0	Negash *et al*. 2020
33	Shungura Formation (Ethiopia)	~ 440	-1.4	+29.1	*Suidae (Notochoerus)*	2.0	Negash *et al*. 2020
34	Shungura Formation (Ethiopia)	~440	-0.8	+29.1	*Suidae (Notochoerus)*	2.0	Negash *et al*. 2020
35	Shungura Formation (Ethiopia)	~440	-2	+26.1	*Suidae (Kolpochaerus)*	2.0	Negash *et al*. 2020
36	Shungura Formation (Ethiopia)	~440	-1.7	+30.2	*Suidae (Kolpochaerus)*	2.0	Negash *et al*. 2020
37	Shungura Formation (Ethiopia)	~440	-0.4	+31.3	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020

38	Shungura Formation (Ethiopia)	~440	-0.5	+36.1	*Suidae (Notochoerus)*	2.0	Negash *et al*. 2020
39	Shungura Formation (Ethiopia)	~440	-0.9	+31.1	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020
40	Shungura Formation (Ethiopia)	~440	+0.6	+28.1	*Suidae (Kolpochaerus)*	2.0	Negash *et al*. 2020
41	Shungura Formation (Ethiopia)	~440	-0.2	+29.1	*Suidae (Kolpochaerus)*	2.0	Negash *et al*. 2020
42	Shungura Formation (Ethiopia)	~440	-0.3	+29.1	*Suidae (Kolpochaerus)*	2.0	Negash *et al*. 2020
43	Shungura Formation (Ethiopia)	~440	-1.9	+31.2	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020
44	Shungura Formation (Ethiopia)	~440	-1	+31.1	*Suidae (Metridiochoerus)*	2.0	Negash *et al*. 2020
45	Shungura Formation (Ethiopia)	~440	-0.1	+32.9	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
46	Shungura Formation (Ethiopia)	~440	+0.7	+31.2	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
47	Shungura Formation (Ethiopia)	~440	-0.1	+29.3	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
48	Shungura Formation (Ethiopia)	~440	+0.5	+35.2	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
49	Shungura Formation (Ethiopia)	~440	+0.4	+29.2	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
50	Shungura Formation (Ethiopia)	~440	-0.5	+26.4	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020

51	Shungura Formation (Ethiopia)	~440	+0.3	+27.1	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
52	Shungura Formation (Ethiopia)	~440	-0.4	+29.9	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
53	Shungura Formation (Ethiopia)	~440	-1.2	+30.5	*Suidae (Notochoerus)*	1.8	Negash *et al*. 2020
54	Shungura Formation (Ethiopia)	~440	0	+30.5	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
55	Shungura Formation (Ethiopia)	~440	+0.2	+30.2	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
56	Shungura Formation (Ethiopia)	~440	+0.6	+30.1	*Suidae (Kolpochaerus)*	1.8	Negash *et al*. 2020
57	Shungura Formation (Ethiopia)	~440	-0.3	+33.3	*Suidae (Metridiochoerus)*	1.8	Negash *et al*. 2020
58	Shungura Formation (Ethiopia)	~440	+0.3	+33.7	*Suidae (Metridiochoerus)*	1.8	Negash *et al*. 2020
59	Shungura Formation (Ethiopia)	~440	-0.3	+26.1	*Suidae (Metridiochoerus)*	1.8	Negash *et al*. 2020
60	Shungura Formation (Ethiopia)	~440	-0.2	+32.6	*Suidae (Notochoerus)*	1.8	Negash *et al*. 2020
61	Shungura Formation (Ethiopia)	~440	-0.1	+34.5	*Suidae (Notochoerus)*	1.8	Negash *et al*. 2020
62	Shungura Formation (Ethiopia)	~440	-0.1	+33.4	*Suidae (Notochoerus)*	1.8	Negash *et al*. 2020
63	Shungura Formation (Ethiopia)	~440	-0.1	+35.3	*Suidae (Notochoerus)*	1.8	Negash *et al*. 2020

64	Shungura Formation (Ethiopia)	~440	+0.1	+31.9	*Suidae (Notochoerus)*	1.8	Negash *et al.* 2020
65	Shungura Formation (Ethiopia)	~440	-0.5	+34.1	*Suidae (Notochoerus)*	1.8	Negash *et al.* 2020
66	Shungura Formation (Ethiopia)	~440	-0.5	+33.7	*Suidae (Notochoerus)*	1.8	Negash *et al.* 2020
67	Shungura Formation (Ethiopia)	~440	-0.8	+33.9	*Suidae (Notochoerus)*	1.8	Negash *et al.* 2020
68	Shungura Formation (Ethiopia)	~440	-0.1	+37.1	*Suidae (Metridiochoerus)*	1.6	Negash *et al.* 2020
69	Shungura Formation (Ethiopia)	~440	+0.2	+31.3	*Suidae (Kolpochaerus)*	1.5	Negash *et al.* 2020
70	Shungura Formation (Ethiopia)	~440	0	+29.3	*Suidae (Kolpochaerus)*	1.5	Negash *et al.* 2020
71	Shungura Formation (Ethiopia)	~440	+0.9	+29.3	*Suidae (Kolpochaerus)*	1.5	Negash *et al.* 2020
72	Shungura Formation (Ethiopia)	~440	+0.2	+31.5	*Suidae (Kolpochaerus)*	1.5	Negash *et al.* 2020
73	Shungura Formation (Ethiopia)	~440	+0.9	+29.3	*Suidae (Kolpochaerus)*	1.5	Negash *et al.* 2020
74	Shungura Formation (Ethiopia)	~440	-0.3	+33.7	*Suidae (Metridiochoerus)*	1.5	Negash *et al.* 2020
75	Shungura Formation (Ethiopia)	~440	-0.6	+32.7	*Suidae (Metridiochoerus)*	1.5	Negash *et al.* 2020
76	Shungura Formation (Ethiopia)	~440	-0.1	+32.3	*Suidae (Kolpochaerus)*	1.3	Negash *et al.* 2020

77	Shungura Formation (Ethiopia)	~440	-0.6	+29.7	*Suidae (Kolpochaerus)*	1.3	Negash *et al*. 2020
78	Shungura Formation (Ethiopia)	~440	-0.1	+33.1	*Suidae (Metridiochoerus)*	1.3	Negash *et al*. 2020
79	Shungura Formation (Ethiopia)	~440	-0.2	+28.3	*Suidae (Metridiochoerus)*	1.3	Negash *et al*. 2020
80	Shungura Formation (Ethiopia)	~440	-1.2	+35.6	*Suidae (Kolpochaerus)*	1.3	Negash *et al*. 2020
81	Shungura Formation (Ethiopia)	~440	-0.8	+34.4	*Suidae (Metridiochoerus)*	1.3	Negash *et al*. 2020
82	Shungura Formation (Ethiopia)	~440	+0.3	+27.4	*Suidae (Metridiochoerus)*	1.3	Negash *et al*. 2020
83	Shungura Formation (Ethiopia)	~440	0	+32.8	*Suidae (Metridiochoerus)*	1.3	Negash *et al*. 2020
84	Shungura Formation (Ethiopia)	~440	+0.9	+30.3	*Suidae (Kolpochaerus)*	1.2	Negash *et al*. 2020
85	Shungura Formation (Ethiopia)	~440	+1.1	+34.8	*Suidae (Metridiochoerus)*	1.2	Negash *et al*. 2020
86	Shungura Formation (Ethiopia)	~440	-0.9	+28.2	*Suidae (Metridiochoerus)*	1.2	Negash *et al*. 2020
87	Shungura Formation (Ethiopia)	~440	+0.6	+33.2	*Suidae (Metridiochoerus)*	1.2	Negash *et al*. 2020
88	Shungura Formation (Ethiopia)	~440	-0.8	+33.2	*Suidae (Metridiochoerus)*	1.2	Negash *et al*. 2020
89	Shungura Formation (Ethiopia)	~440	-2.3	+32.8	*Suidae (Metridiochoerus)*	1.2	Negash *et al*. 2020

90	Olduvai Gorge (Tanzania)	~1400	-0.7	+24.6	*Suidae*	1.7	Ascari *et al*. 2018
91	Olduvai Gorge (Tanzania)	~1400	-0.9	+26.2	*Suidae (Kolpochaerus)*	1.7	Ascari *et al*. 2018
92	Olduvai Gorge (Tanzania)	~1400	+0.1	+29.4	*Suidae (Phacochoerus modestus)*	1.8	van der Merwe 2013
93	Olduvai Gorge (Tanzania)	~1400	-0.3	+30.9	*Suidae (Phacochoerus modestus)*	1.8	van der Merwe 2013
94	Olduvai Gorge (Tanzania)	~1400	-1.5	+27.1	*Suidae (Phacochoerus modestus)*	1.7	van der Merwe 2013
95	Olduvai Gorge (Tanzania)	~1400	-2	+27.8	*Suidae (Phacochoerus modestus)*	1.7	van der Merwe 2013
96	Olduvai Gorge (Tanzania)	~1400	-1.1	+26.1	*Suidae (Phacochoerus modestus)*	1.7	van der Merwe 2013
97	Olduvai Gorge (Tanzania)	~1400	-1.1	+28.3	*Suidae (Phacochoerus modestus)*	1.7	van der Merwe 2013
98	Olduvai Gorge (Tanzania)	~1400	-0.9	+28.3	*Suidae (Phacochoerus modestus)*	1.7	van der Merwe 2013
99	Olduvai Gorge (Tanzania)	~1400	-1.4	+28.4	*Suidae (Kolpochaerus limnetes)*	1.7	van der Merwe 2013
100	Olduvai Gorge (Tanzania)	~1400	-0.9	+27.9	*Suidae (Kolpochaerus limnetes)*	1.7	van der Merwe 2013
101	Olduvai Gorge (Tanzania)	~1400	-0.6	+27.6	*Suidae (Kolpochaerus limnetes)*	1.7	van der Merwe 2013
102	Olduvai Gorge (Tanzania)	~1400	-0.5	+27.6	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
103	Olduvai Gorge (Tanzania)	~1400	-1.9	+27.5	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013

104	Olduvai Gorge (Tanzania)	~1400	-2.5	+23.6	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
105	Olduvai Gorge (Tanzania)	~1400	-3.1	+24.1	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
106	Olduvai Gorge (Tanzania)	~1400	-3.1	+24.6	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
107	Olduvai Gorge (Tanzania)	~1400	-2.2	+23.6	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
108	Olduvai Gorge (Tanzania)	~1400	-0.5	+25.2	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
109	Olduvai Gorge (Tanzania)	~1400	-2.2	+25.3	*Suidae (Kolpochoerus afarensis)*	1.7	van der Merwe 2013
110	Olduvai Gorge (Tanzania)	~1400	-0.2	+29.1	*Suidae (Kolpochoerus cf. olduvaiensis)*	1.7	Rivals *et al*. 2018
111	Olduvai Gorge (Tanzania)	~1400	0	+30.3	*Suidae (Kolpochoerus cf. olduvaiensis)*	1.7	Rivals *et al*. 2018
112	Olduvai Gorge (Tanzania)	~1400	-0.2	+32.2	*Suidae (Metridiochoerus cf. compactus)*	1.7	Rivals *et al*. 2018
113	Olduvai Gorge (Tanzania)	~1400	-0.6	+29.8	*Suidae (Kolpochoerus cf. olduvaiensis)*	1.7	Rivals *et al*. 2018
114	Olduvai Gorge (Tanzania)	~1400	-0.6	+28.6	*Suidae (Kolpochoerus limnetes)*	1.6	Uno *et al*. 2018
115	Olduvai Gorge (Tanzania)	~1400	-0.5	+28.8	*Suidae (Kolpochoerus paiceae)*	1.6	Uno *et al*. 2018
116	Olduvai Gorge (Tanzania)	~1400	0	+31.1	*Suidae (Kolpochoerus)*	1.6	Uno *et al*. 2018

117	Olduvai Gorge (Tanzania)	~1400	+0.8	+31.2	*Suidae (Kolpochoerus majus)*	1.6	Uno *et al*. 2018
118	Olduvai Gorge (Tanzania)	~1400	+1.5	+29.7	*Suidae (Kolpochoerus limnetes)*	1.6	Uno *et al*. 2018
119	Olduvai Gorge (Tanzania)	~1400	-0.2	+30.1	*Suidae (Metridiochoerus)*	1.6	Uno *et al*. 2018
120	Olduvai Gorge (Tanzania)	~1400	-0.1	+33.1	*Suidae (Metridiochoerus cf. compactus)*	1.6	Uno *et al*. 2018
121	Olduvai Gorge (Tanzania)	~1400	+0.9	+31.8	*Suidae (Metridiochoerus compactus)*	1.6	Uno *et al*. 2018
122	Olduvai Gorge (Tanzania)	~1400	+1.1	+31.3	*Suidae (Metridiochoerus)*	1.6	Uno *et al*. 2018
123	Olduvai Gorge (Tanzania)	~1400	-6.2	+23.5	*Suidae*	1.5	Ascari *et al*. 2018
124	Olduvai Gorge (Tanzania)	~1400	-6.2	+23.6	*Suidae*	1.5	Ascari *et al*. 2018
125	Olduvai Gorge (Tanzania)	~1400	-1.5	+25.1	*Suidae*	1.5	Ascari *et al*. 2018
126	Olduvai Gorge (Tanzania)	~1400	-0.6	+31.8	*Suidae (Kolpochoerus paiceae)*	1.5	Uno *et al*. 2018
127	Melka Kunture (Ethiopia)	~2000	-2.4	+24.7	*Suidae (Kolpochoerus)*	1.6	this study
128	Melka Kunture (Ethiopia)	~2000	+1.3	+28.6	*Suidae*	1.6	this study
129	Melka Kunture (Ethiopia)	~2000	+1.1	+28.9	*Suidae*	1.6	this study
130	Melka Kunture (Ethiopia)	~2000	-0.7	+26.6	*Suidae*	1.6	this study
131	Melka Kunture (Ethiopia)	~2000	-0.6	+28.2	*Suidae (Metridiochoerus)*	1.4	this study
132	Melka Kunture (Ethiopia)	~2000	+1.9	+28.2	*Suidae*	1.3	this study
133	Melka Kunture (Ethiopia)	~2000	+1.4	+25.4	*Suidae*	1.3	this study

134	Melka Kunture (Ethiopia)	~2000	-1.6	+29.5	*Suidae*	1.2	this study
135	Gona (Ethiopia)	~540	-1.5	+30.6	*Suidae (Metridiochoerus compactus)*	1.2	Semaw *et al.* 2020
136	Gona (Ethiopia)	~540	-2.1	+27.5	*Suidae (Metridiochoerus compactus)*	1.2	Semaw *et al.* 2020
137	Gona (Ethiopia)	~540	-3.3	+26.5	*Suidae (Kolpochoerus majus)*	1.2	Semaw *et al.* 2020
138	Gona (Ethiopia)	~540	-0.7	+26.5	*Suidae (Kolpochoerus majus)*	1.2	Semaw *et al.* 2020
139	Busidima Formation (Ethiopia)	~1470	-0.4	32.1	*Suidae (Phacochoerus)*	0.7	Bedaso *et al.* 2010
140	Busidima Formation (Ethiopia)	~1470	-0.3	+30.3	*Suidae (Kolpochoerus majus)*	0.7	Bedaso *et al.* 2010
141	Busidima Formation (Ethiopia)	~1470	+0.2	+31.7	*Suidae (Kolpochoerus majus)*	0.7	Bedaso *et al.* 2010

Table S9. List of the bulk samples and values of carbon and oxygen isotopic ratio of giraffids teeth enamel, from Shungura Formation (Ethiopia), Melka Kunture (Ethiopia), Olduvai Gorge (Tanzania), and Busidima Formation (Ethiopia) (~2.1-0.7 Ma).

	Archaeological site	**m a.s.l.**	**$\delta^{13}C$ (VPDB)**	**$\delta^{18}O$ (SMOW)**	***Taxon***	**Chronology (Ma)**	**Notes**
1	Shungura Formation (Ethiopia)	~440	-10.4	+35.1	*Giraffidae*	2.1	Negash *et al.* 2020
2	Shungura Formation (Ethiopia)	~440	-12.8	+32.1	*Giraffidae*	2.1	Negash *et al.* 2020
3	Shungura Formation (Ethiopia)	~440	-14.7	+31.2	*Giraffidae*	2.1	Negash *et al.* 2020
4	Shungura Formation (Ethiopia)	~440	-12.9	+31.4	*Giraffidae*	2.1	Negash *et al.* 2020
5	Shungura Formation (Ethiopia)	~440	-12.1	+31.2	*Giraffidae*	2.0	Negash *et al.* 2020
6	Shungura Formation (Ethiopia)	~440	-12.6	+36.1	*Giraffidae*	2.0	Negash *et al.* 2020

7	Olduvai Gorge (Tanzania)	~1400	-8.7	+26.4	*Giraffidae*	1.7	Ascari *et al*. 2018
8	Olduvai Gorge (Tanzania)	~1400	-8.1	+29.6	*Giraffidae (Giraffa)*	1.7	van der Merwe 2013
9	Olduvai Gorge (Tanzania)	~1400	-8.1	+27.1	*Giraffidae (Giraffa)*	1.7	van der Merwe 2013
10	Olduvai Gorge (Tanzania)	~1400	-11.2	+29.1	*Giraffidae (Giraffa)*	1.7	van der Merwe 2013
11	Olduvai Gorge (Tanzania)	~1400	-1.3	+31.1	*Giraffidae (Sivatherium)*	1.7	van der Merwe 2013
12	Olduvai Gorge (Tanzania)	~1400	-3.7	+33.1	*Giraffidae (Sivatherium)*	1.7	van der Merwe 2013
13	Olduvai Gorge (Tanzania)	~1400	-0.5	+28.1	*Giraffidae (Sivatherium)*	1.7	van der Merwe 2013
14	Olduvai Gorge (Tanzania)	~1400	-10.5	+34.2	*Giraffidae (Giraffa cf. stillei)*	1.7	Rivals *et al*. 2018
15	Olduvai Gorge (Tanzania)	~1400	+0.2	+29.9	*Giraffidae (Sivatherium cf. maurusium)*	1.7	Rivals *et al*. 2018
16	Olduvai Gorge (Tanzania)	~1400	-2.8	+32.8	*Giraffidae*	1.7	Rivals *et al*. 2018
17	Olduvai Gorge (Tanzania)	~1400	-1.2	+31.8	*Giraffidae (cf. Sivatherium)*	1.6	Uno *et al*. 2018
18	Olduvai Gorge (Tanzania)	~1400	-1.1	+32.1	*Giraffidae (Sivatherium maurusium)*	1.6	Uno *et al*. 2018
19	Olduvai Gorge (Tanzania)	~1400	-0.8	+32.9	*Giraffidae (Sivatherium maurusium)*	1.6	Uno *et al*. 2018
20	Olduvai Gorge (Tanzania)	~1400	-9.7	+33.1	*Giraffidae (Giraffa cf. jumae)*	1.3	Uno *et al*. 2018
21	Melka Kunture (Ethiopia)	~2000	+2.2	+29.1	*Giraffidae (Sivatherium)*	1.4	this study
22	Melka Kunture (Ethiopia)	~2000	+1.9	+28.8	*Giraffidae (Sivatherium)*	1.4	this study
23	Busidima Formation (Ethiopia)	~1470	-8.5	+32.2	*Giraffidae (Giraffa)*	0.7	Bedaso *et al.* 2010
24	Busidima Formation (Ethiopia)	~1470	-8.9	+39.5	*Giraffidae (Giraffa)*	0.7	Bedaso *et al.* 2010

Table S10. List of the bulk samples and values of carbon and oxygen isotopic ratio of crocodile teeth enamel, from Melka Kunture (Ethiopia), and Olduvai Gorge (Tanzania) (~1.9-1.5 Ma).

	Archaeological site	**m a.s.l.**	**$\delta^{13}C$ (VPDB)**	**$\delta^{18}O$ (SMOW)**	***Taxon***	**Chronology (Ma)**	**Notes**

1	Melka Kunture (Ethiopia)	~2000	-10.5	+25.9	*Crocodylidae*	1.9	this study
2	Melka Kunture (Ethiopia)	~2000	-8.3	+25.7	*Crocodylidae*	1.9	this study
3	Melka Kunture (Ethiopia)	~2000	-9.8	+25.2	*Crocodylidae*	1.9	this study
4	Melka Kunture (Ethiopia)	~2000	-10.1	+26.4	*Crocodylidae*	1.9	this study
5	Melka Kunture (Ethiopia)	~2000	-9.8	+24.4	*Crocodylidae*	1.9	this study
6	Melka Kunture (Ethiopia)	~2000	-7.5	+25.2	*Crocodylidae*	1.9	this study
7	Olduvai Gorge (Tanzania)	~1400	-1.5	+24.3	*Crocodylidae*	1.8	Ascari *et al.* 2018
8	Olduvai Gorge (Tanzania)	~1400	-0.5	+25.4	*Crocodylidae*	1.8	Ascari *et al.* 2018
9	Olduvai Gorge (Tanzania)	~1400	-2.6	+25.2	*Crocodylidae*	1.8	Ascari *et al.* 2018
10	Olduvai Gorge (Tanzania)	~1400	-2	+24.8	*Crocodylidae*	1.8	Ascari *et al.* 2018
11	Olduvai Gorge (Tanzania)	~1400	-2.9	+25.8	*Crocodylidae*	1.8	Ascari *et al.* 2018
12	Olduvai Gorge (Tanzania)	~1400	-1.1	+25.4	*Crocodylidae*	1.8	Ascari *et al.* 2018
13	Olduvai Gorge (Tanzania)	~1400	-2.7	+25.6	*Crocodylidae (Crocodylus niloticus)*	1.8	van der Merwe 2013
14	Olduvai Gorge (Tanzania)	~1400	-3.1	+25.7	*Crocodylidae (Crocodylus niloticus)*	1.8	van der Merwe 2013
15	Olduvai Gorge (Tanzania)	~1400	-2.2	+25.7	*Crocodylidae (Crocodylus niloticus)*	1.8	van der Merwe 2013
16	Olduvai Gorge (Tanzania)	~1400	-3.3	+24.3	*Crocodylidae (Crocodylus niloticus)*	1.8	van der Merwe 2013
17	Olduvai Gorge (Tanzania)	~1400	-4.4	+23.1	*Crocodylidae (Crocodylus niloticus)*	1.8	van der Merwe 2013

18	Olduvai Gorge (Tanzania)	~1400	-1.6	+23.5	*Crocodylidae*	1.7	Ascari *et al*. 2018
19	Olduvai Gorge (Tanzania)	~1400	-0.7	+25.6	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
20	Olduvai Gorge (Tanzania)	~1400	-3.3	+26.5	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
21	Olduvai Gorge (Tanzania)	~1400	-2.3	+25.6	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
22	Olduvai Gorge (Tanzania)	~1400	+0.2	+26.9	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
23	Olduvai Gorge (Tanzania)	~1400	-2.5	+24.9	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
24	Olduvai Gorge (Tanzania)	~1400	-0.5	+26.4	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
25	Olduvai Gorge (Tanzania)	~1400	-2.2	+25.3	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
26	Olduvai Gorge (Tanzania)	~1400	-2.3	+24.8	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
27	Olduvai Gorge (Tanzania)	~1400	+2.1	+27.6	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
28	Olduvai Gorge (Tanzania)	~1400	+1.1	+27.1	*Crocodylidae (Crocodylus niloticus)*	1.7	van der Merwe 2013
29	Olduvai Gorge (Tanzania)	~1400	-1.1	+24.4	*Crocodylidae*	1.5	Ascari *et al*. 2018