

New insights on feeding habits of *Kolpochoerus* van Hoepen & van Hoepen, 1932 from the Shungura Formation (Lower Omo Valley, Ethiopia) using dental microwear texture analysis

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ABSTRACT

During the Neogene and the Quaternary, African suids show dental morphological changes considered to reflect adaptations to increasing specialization on graminivorous diets, notably in the genus *Kolpochoerus* van Hoepen & van Hoepen, 1932. They tend to exhibit elongated third molars and some degree of hypsodonty, suggesting increasing consumption of abrasive grasses. However, the most significant morphological changes are observed more than 1 million years after the increased consumption of C₄ plants, such as graminoids. To date, only a few studies have applied dental microwear texture analysis (DMTA) to specimens of *Kolpochoerus*, which provides information on the mechanical properties of the diet, and therefore bring fundamental insights on the mechanical stresses exerted on dental morphologies. In addition, none has yet focused on specimens from the

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MOTS CLÉS
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Shungura Formation (Lower Omo Valley, Ethiopia), which is the most complete Late Pliocene to Early Pleistocene record in eastern Africa. To better interpret the dental microwear textures (DMT) of *Kolpochoerus*, we built a modern referential using four genera of extant suids with contrasting diets: the herbivores *Phacochoerus* F.Cuvier, 1826 and *Hylochoerus* Thomas, 1904, and the omnivores *Potamochoerus* Gray, 1854 and *Sus* Linnaeus, 1758. Our results show that their DMT reflect their different feeding habits. In light of these results, we then studied the DMT of 68 *Kolpochoerus* specimens from the Shungura Formation and dating from about 2.8 Ma to 1.0 Ma. Their DMT differ from extant suids, but some similarities with *Phacochoerus* are observed. In line with previous studies, we propose that their DMT reflect a high consumption of herbaceous plants (graminoids and non-graminoids), with preferences for young, low-abrasive grasses. Yet, while a high intake of such grasses is consistent with both the shift toward increased C₄ feeding and morphological changes, more studies are needed to further understand the temporal offset between the two.

RÉSUMÉ

Habitudes alimentaires des Kolpochoerus van Hoepen, 1932 de la formation de Shungura (basse vallée de l'Omo, Éthiopie) : apports de l'analyse des textures de micro-usure dentaire.

Au Néogène et au Quaternaire, les suidés africains présentent des changements morphologiques dentaires considérés comme des adaptations à des alimentations de plus en plus spécialisées sur les graminées, notamment dans le genre *Kolpochoerus* van Hoepen & van Hoepen, 1932. Ils tendent à présenter des troisièmes molaires allongées et un certain degré d'hypsodontie, suggérant une consommation croissante d'herbes abrasives. Toutefois, les changements morphologiques les plus importants sont observés plus d'un million d'années après le changement vers une consommation accrue de plantes en C₄, telles que les graminées. À ce jour, seules quelques études ont appliqué l'analyse des textures de micro-usure dentaire (DMTA) à des spécimens de *Kolpochoerus*, qui renseigne sur les propriétés mécaniques de l'alimentation et fournit des informations essentielles sur les pressions mécaniques exercées sur les morphologies dentaires. En outre, aucune ne s'est intéressée à des spécimens de la formation de Shungura (basse vallée de l'Omo, Éthiopie), qui constitue l'enregistrement le plus complet du Pliocène récent au Pléistocène ancien en Afrique orientale. Pour affiner nos interprétations des textures de micro-usure dentaire (DMT) des *Kolpochoerus*, nous avons développé un référentiel sur quatre genres de suidés actuels ayant des régimes alimentaires contrastés : les herbivores *Phacochoerus* F.Cuvier, 1826 et *Hylochoerus* Thomas, 1904, et les omnivores *Potamochoerus* Gray, 1854 et *Sus* Linnaeus, 1758. Nos résultats montrent que leurs DMT reflètent leurs différentes habitudes alimentaires. À la lumière de ces résultats, nous avons ensuite étudié les DMT de 68 spécimens de *Kolpochoerus* de la formation de Shungura et datant d'environ 2,8 Ma à 1,0 Ma. Leurs DMT diffèrent des suidés actuels, mais certaines similitudes avec *Phacochoerus* sont observées. En lien avec les études précédentes, nous proposons que leurs DMT reflètent une consommation importante de plantes herbacées (graminées ou non), avec des préférences pour les herbacées jeunes et peu abrasives. Néanmoins, si une consommation élevée de telles herbacées est cohérente avec le passage à une alimentation riche en C₄ et avec les changements morphologiques, d'autres études sont nécessaires pour mieux comprendre le décalage temporel entre les deux.

INTRODUCTION

Reconstructing past dietary habits among mammals is crucial for a better understanding of the environmental conditions in which extinct species lived, and how they shared ecological resources (Andrews *et al.* 1979; Fortelius *et al.* 2002). It also helps understanding the potential selective pressures that drove the evolution of dental morphologies. Indeed, mammals generally exhibit teeth that are adapted to their diet, optimizing not only efficient processing of food items but also durability against wear (Hiimae 2000). With the expansion of grasslands during the Neogene and the Quaternary, mammals with dental morphologies adapted to the consumption of large amount of abrasive grasses,

such as high-crowned molars in ruminants or equids, have become more and more abundant (Janis 2008). The evolutionary history of African suids, a rapidly evolving group, also shows this trend towards dental morphologies that are assumed to be adapted to increasing graminivory (i.e., main consumption of abrasive graminoids, or grasses and sedges). These characteristics appear in several suid genera, most likely through convergence, most likely resulting from convergent evolution (Harris & White 1979; Souron *et al.* 2015a). This is particularly observed during the Late Pliocene and the Pleistocene in two suine clades, *Metridiochoerus* Hopwood, 1926 – *Phacochoerus* F. Cuvier, 1826 and *Kolpochoerus* van Hoepen & van Hoepen, 1932 – *Hylochoerus* Thomas, 1904, which are commonly represented

in faunal assemblages from eastern Africa (Rannikko *et al.* 2017; Lazagabaster *et al.* 2018). Thus, in addition to their relevance for biostratigraphic correlations (White & Harris 1977; Cooke 2007), suids also have a potential for paleoenvironmental reconstructions (Harris & Cerling 2002; Bishop *et al.* 2006; Lazagabaster 2019). However, the elongated third molars displayed by African suids, with extra cusps in the distal part, contrast with the ones observed among graminivorous ruminants, which rather exhibit hypsodont molars that are relatively short mesio-distally (e.g. Janis 2008; Madden 2014). Although both dental innovations have been linked to increasing graminivory, elongated molars are probably associated with improved efficiency for fragmenting small foods whereas hypsodont molars are rather linked to increased tooth durability against wear (Lucas 2004; Souron 2017; Yang *et al.* 2022).

In addition, changes in third molar length and height are not similar in the different suid clades. In *Kolpochoerus*, we mostly observe an increase in molar length rather than in molar height, whereas in *Metridiochoerus*, molar height increases significantly with length (Harris & White 1979; Cooke 2007). This suggests that different mechanisms influenced the selection of dental morphologies in *Kolpochoerus* and in *Metridiochoerus*, probably due to different ecologies. Moreover, the most significant changes in dental morphologies, notably in *Kolpochoerus*, are observed substantially after the shift in stable carbon isotope compositions reflecting increasing graminivorous diets (Harris & Cerling 2002; Bibi *et al.* 2013; Souron 2017). In the lineage *Kolpochoerus limnetes* (Hopwood, 1926) – *Kolpochoerus* aff. *paiceae* (Broom, 1931), while the progressive lengthening of third molars from about 2.7 Ma, along with an increasing complexity, has been related to a specialization toward graminivory (Harris & White 1979; Cooke 1985; Kullmer 1999), the shift toward much more derived species with more elongated and hypsodont third molars is described at about 1.5 Ma (Souron 2012). This contrast with the inferred diets that are already strongly dominated by C₄ plants (i.e., mostly graminoids, such as grasses and sedges, and amaranths), since about 3 Ma for most specimens (Harris & Cerling 2002; Bibi *et al.* 2013; Souron 2017; Negash *et al.* 2020). Because there is a temporal offset between the most drastic changes in dental morphologies and the strong dietary shift (as inferred from stable carbon isotopes), further investigation of the paleoecology of *Kolpochoerus* using a multi-proxy approach is needed for better understanding which factors favored the selection of such morphology, and by which mechanisms.

Most commonly used dietary proxies record different aspects of the diet and over different timescales. Therefore, it is not surprising that dental morphology and enamel stable carbon composition do not reflect similar dietary habits (Davis & Pineda Munoz 2016). As already pointed out for extinct African suids (Souron 2017), it is crucial to have a more integrative approach combining different and complementary paleoecological proxies to improve inferences of past diets, and then to better understand the relationships between feeding habits, morphology, and environmental constraints.

Among paleoecological proxies, dental microwear is highly dependent on the physical properties of masticated food items and thus provides insights on mechanical pressures exerted on the feeding system (e.g. Lucas *et al.* 2013, 2014; Daegling *et al.* 2016; Merceron *et al.* 2016). It records the diet over a short timescale, few weeks or months before death (Teaford & Oyen 1989; Teaford *et al.* 2017, 2021; Winkler *et al.* 2020). In recent years, dental microwear texture analysis (DMTA) has proved its efficiency in detecting dietary differences between species (e.g. R. S. Scott *et al.* 2006, 2012; J. R. Scott 2012; Schulz *et al.* 2013; Hullot *et al.* 2021; Merceron *et al.* 2021a), as well as small variations within species or populations (Merceron *et al.* 2010, 2014; Berlioz *et al.* 2017; Percher *et al.* 2017). Thus, this methodology has been widely employed to infer past dietary habits (e.g. Ungar *et al.* 2008, 2017; Berlioz *et al.* 2018; Blondel *et al.* 2018, 2022; Martin *et al.* 2018; Merceron *et al.* 2018, 2021b; Hullot *et al.* 2021). Nevertheless, to date, only few studies have applied DMTA on extant or extinct suids (Souron *et al.* 2015b; Ungar *et al.* 2017; Yamada *et al.* 2018, 2021; Lazagabaster 2019; Louail *et al.* 2021, 2022) and none has yet focused on DMT of *Kolpochoerus* from the Shungura Formation.

The extinct genus *Kolpochoerus* has a promising potential to contribute to a better understanding of the relationships between morphological evolution, dietary changes, and environmental changes. Indeed, it is one of the most abundant suid taxa in Plio-Pleistocene localities and with a wide geographic distribution, suggesting an adaptability to a variety of environmental conditions. Widespread in eastern Africa (e.g. Harris & White 1979; White 1995; Suwa *et al.* 2003, 2014; Bishop 2011; Haile-Selassie & Simpson 2013; Souron *et al.* 2015a), specimens of *Kolpochoerus* have been recovered from northern to southern Africa, including central Africa (e.g. Broom 1931; Hendeby & Cooke 1985; Brunet & White 2001; Geraads *et al.* 2004). Some specimens have even been described from the Middle East (Geraads *et al.* 1986) and possibly from the Siwaliks in eastern Himalaya (Chavasseau 2008; Pickford 2012). The genus *Kolpochoerus* is also one of the most diverse, notably in terms of dental morphologies and feeding habits (Harris & White 1979; Brunet & White 2001; Bishop *et al.* 2006; Souron 2012; Haile-Selassie & Simpson 2013). Fossils from the Shungura Formation have played an important role in our understanding of African environments in the Omo Valley during the Plio-Pleistocene. The Shungura Formation is located in the Lower Omo Valley in southwestern Ethiopia. It is the most complete stratigraphic and paleontological record from the Late Pliocene to Early Pleistocene in eastern Africa, with sediments deposited almost continuously from *c.* 3.75 Ma to *c.* 1.0 Ma. It is subdivided into 12 members of sedimentary deposits: Basal, A to H and J to L, whose ages were determined by using radiochronology of interspersed volcanic tuffs and magnetostratigraphy (Heinzelin 1983; Feibel *et al.* 1989; McDougall & Brown 2006, 2008; McDougall *et al.* 2012; Kidane *et al.* 2014). Since the early 1930s, the Shungura Formation has been intensively surveyed through several research expeditions by C. Arambourg (Arambourg 1934, 1943), the International

Omo Research Expedition (IORE: Howell 1968; Coppens 1975), and the Omo Group Research Expedition (OGRE: Boisserie *et al.* 2008). It has yielded *c.* 57 000 fossil vertebrate specimens, as well as numerous lithic assemblages. On average, suids represent 10.2 % of the Shungura faunal remains (Omo Database – fossil specimen database for Shungura and Usno formations including full IORE and OGRE collections, maintained by OGRE), including about 32 % of *Kolpochoerus*, almost all attributed to the lineage *K. limnetes*/*K. aff. paiceae* (following the same taxonomic framework as described in Bibi *et al.* 2018; Brink *et al.* 2022) and to *Kolpochoerus afarensis* Cooke, 1978 at the base of the sequence (Souron 2012).

To fill the gap regarding inferences on the mechanical properties of food materials consumed by *Kolpochoerus* from the Shungura Formation, we propose here the first study that measures the DMT variations on specimens of *Kolpochoerus* from Member C to Member L (about *c.* 2.76 Ma to 1.0 Ma). As such, our study also complements two recent ones, focusing on relative abundances within the family Suidae (Rannikko *et al.* 2020) and on functional occlusal traits (Yang *et al.* 2022), which have suggested that *Kolpochoerus* might have had a less abrasive diet than typical graminivorous suids. To better interpret the DMT of *Kolpochoerus*, we expand the baseline developed by Souron *et al.* (2015b) and Lazagabaster (2019) by including larger samples of African suids (particularly *Hylochoerus*) with different dietary habits encompassing the full spectrum from herbivorous to omnivorous. We also discussed inter-specific differences within *Phacochoerus* and *Potamochoerus* Gray, 1854 genera, as well as intra-specific differences in Eurasian wild *Sus scrofa* Linnaeus, 1758. Then, considering the patterns observed on extant suids, we explored DMT variations in specimens attributed to the lineage *K. limnetes*/*K. aff. paiceae* through the Shungura sequence to propose inferences regarding their past dietary habits.

MATERIAL AND METHODS

SAMPLE AND DIETARY HABITS OF EXTANT SUIDS

We considered a total of 102 extant wild specimens, belonging to four suid genera and six species: *Hylochoerus* (*Hylochoerus meinertzhageni* Thomas, 1904 or giant forest hog, *n* = 21), *Phacochoerus* (*n* = 23; *n* = 9 for *Phacochoerus africanus* (Gmelin, 1788) or common warthog, and *n* = 14 for *Phacochoerus aethiopicus* (Pallas, 1766) or desert warthog), *Potamochoerus* (*n* = 33; *n* = 15 for *Potamochoerus porcus* (Linnaeus, 1758) or red river hog, and *n* = 18 for *Potamochoerus larvatus* (F. Cuvier, 1822) or bushpig) and *Sus* Linnaeus, 1758 (*Sus scrofa* or wild boar, *n* = 25). For *Sus*, we used two wild boar populations from France (*n* = 6) and from the Białowieża Forest in Poland (*n* = 19). Both areas are closed mixed forest but the former is characterized by an oceanic climate whereas the latter has a much more continental climate with limited human impact. The specimens are housed in the following institutions: Musée Royal de l’Afrique Centrale, Tervuren, Belgium (MRAC); Polish Academy of Sciences in Białowieża, Poland (MRI PAS); The Ethiopian Heritage Authority, collections of

comparative anatomy, Addis Ababa, Ethiopia (MCA); Museo Zoologico dell’Università di Firenze, Italy (MZUF); Naturhistorisches Museum Basel, Switzerland (NMB); Laboratory Paleontology Evolution Paleoecosystems Paleoprimatology (PALEVOPRIM) and Institut National de Recherche pour l’Agriculture, l’Alimentation et l’Environnement, France (INRAE Occitanie-Toulouse).

Taxonomic identifications at the specific level were verified for extant taxa both based on the craniomandibular and dental morphology of the specimens and on their geographical origin. This step is all the more crucial that museum labels frequently indicate incorrect identifications at the specific level, resulting from previous taxonomic practices. Indeed, the extant species of *Phacochoerus* and of *Potamochoerus* were long lumped into single species, respectively called *Ph. aethiopicus* and *Po. porcus* (Oliver 1993; Grubb & d’Huart 2010) and the confusion remains pervasive in the current literature and museum collections. The two extant species of *Phacochoerus* are sympatric in some parts of Ethiopia, Somalia, and especially in Kenya (de Jong *et al.* 2023) but they are easily distinguished from each other by several discrete and continuous morphological characters of the cranium, mandible, and dentition (e.g. d’Huart & Grubb 2005; Groves & Grubb 2011; Souron 2012, 2015, 2016). The two extant *Potamochoerus* species are overall geographically well separated but possibly sympatric in some parts of Democratic Republic of Congo, Burundi, and Rwanda (Leslie Jr. & Huffman 2015). They are morphologically more similar to each other than the two species of warthogs and are mostly distinguished based on shape and size differences of the skull and differences in first upper premolar prevalence (Souron 2012; Boisserie *et al.* 2014). Specimen numbers, tooth positions, and their geographic proveniences are provided in the Supplementary Material (Appendix 1).

None of the extant suid specimens are associated to individual dietary data (such as stomach contents or field observations), but the dietary habits of these extant taxa have been largely investigated – although the giant forest hog (*H. meinertzhageni*) and the desert warthog (*Ph. aethiopicus*) are less known. Extant wild *Sus scrofa* and the two species of *Potamochoerus* are generalized omnivores that eat a wide array of food items such as fruits, seeds, leaves, grasses, barks, underground storage organs (USOs), fungi, animal matter, agricultural crops, feces, as well as human garbage or inorganic matter. Their dietary habits vary greatly depending on the geographic area, the seasonality and food availability (*Sus scrofa*: Giménez-Anaya *et al.* 2008; Keuling *et al.* 2017; *Potamochoerus porcus* and *Po. larvatus*: Skinner *et al.* 1976; Breytenbach & Skinner 1982; Seydack 1990, 2017; Harris & Cerling 2002; Melletti *et al.* 2017). These omnivorous species display molars that are bunodont and brachyodont, in contrast to the two species of *Phacochoerus* and *Hylochoerus meinertzhageni*. The former has very elongated and hypsodont third molars with numerous cusps or pillars, and the latter displays a bunolophodont pattern and moderately hypsodont molars (e.g. Owen 1850; Harris & White 1979; Souron *et al.* 2015a; Souron 2017; Lazagabaster *et al.* 2021; see also Figure 1).

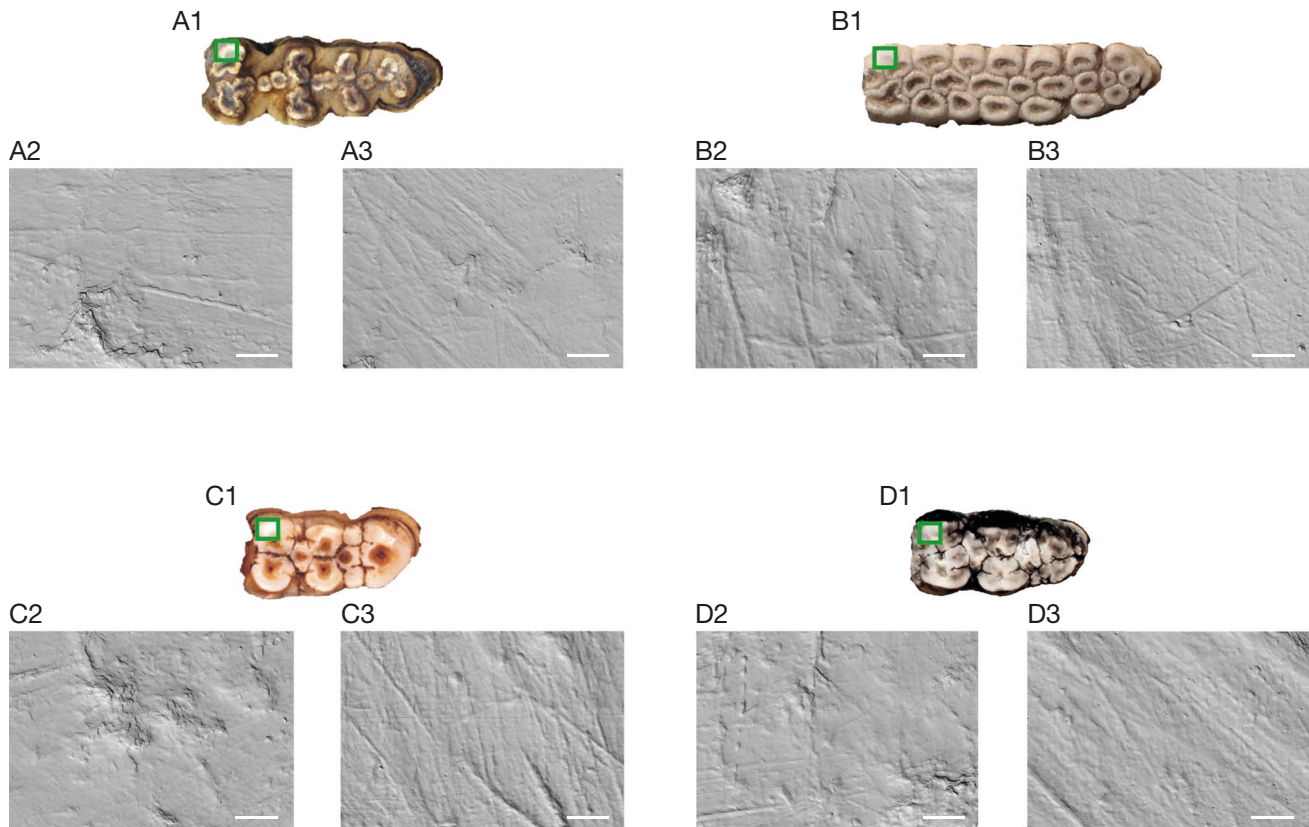


FIG. 1. — Photosimulations of shearing facets on extant suid genera illustrating the diversity within taxa in terms of complexity (**Asfc**) and anisotropy (**epLsar**). The **green squares** on molars of each taxon indicate the location of a shearing facet on a right lower third molar: **A1**, *Hylochoerus* Thomas, 1904: **A2**, MRAC 87.009-M-0001, Asfc = 3.88, epLsar (10^{-3}) = 1.54; **A3**, MRAC 14108, Asfc = 2.71, epLsar (10^{-3}) = 2.12; **B1**, *Phacochoerus* F.Cuvier, 1826: **B2**, MZUF 13303, Asfc = 1.51, epLsar (10^{-3}) = 4.06; **B3**, MZUF 2443, Asfc = 1.10, epLsar (10^{-3}) = 4.38; **C1**, *Potamochoerus* Gray, 1854: **C2**, MZUF C.3000, Asfc = 2.37, epLsar (10^{-3}) = 1.38; **C3**, MZUF C.3279, Asfc = 1.03, epLsar (10^{-3}) = 6.75; **D**, *Sus* Linnaeus, 1758: **D2**, MRI PAS 39, Asfc = 2.09, epLsar (10^{-3}) = 1.44; **D3**, MRI PAS Czerlon-470D-1, Asfc = 1.37, epLsar (10^{-3}) = 6.00. Scale bars: 20 μ m.

Few extant wild suid species are considered as herbivorous: the two species of *Phacochoerus* and, to a lesser extent, *H. meinertzhageni*. These taxa mainly feed on fibrous vegetal matter, such as grasses (graminoids) and forbs (non-graminoids), and incorporate fruits and roots in their diet to a lesser extent (*Ph. africanus* and *Ph. aethiopicus*: Harris & Cerling 2002; Treydte *et al.* 2006; Butynski & de Jong 2017; de Jong & Butynski 2017; Edossa *et al.* 2021; *H. meinertzhageni*: d’Huart 1978; Harris & Cerling 2002; Cerling & Viehl 2004; d’Huart & Kingdon 2013; Reyna-Hurtado *et al.* 2017). Species of *Phacochoerus* are the most specialized, feeding mostly on short, green, tropical grasses and consuming all plant parts, including underground storage organs. *Hylochoerus meinertzhageni* has been less studied than the three other genera, but previous work suggests it is more likely an herbivorous mixed feeder (e.g. d’Huart & Kingdon 2013; Souron *et al.* 2015b; Mekonnen *et al.* 2018). In contrast to other suids, the rooting behavior in this species is strongly reduced and the portion of subterranean foods in its diet is low.

SAMPLE OF *KOLPOCHOERUS* FROM SHUNGURA

We analyzed a total of 68 specimens from the Shungura Formation that belong to the extinct genus *Kolpochoerus* and that do not show any apparent alteration (see section “Procedure

for selecting wear surfaces of fossil specimens”). All specimens represent different individuals and are attributed to the lineage *K. limnetes*/*K. aff. paiceae*. The sample includes specimens from members C (n = 12), E (n = 13), F (n = 8), G (n = 15), H (n = 4), J (n = 4), and L (n = 12), representing a time period from c. 2.76 to 1.0 Ma. We discarded members B, D, and the upper sequence of Member G for which only one or two specimens were available for the study. Specimen numbers, studied teeth, and their stratigraphic provenance are provided in the Supplementary Material (Appendix 2). All specimens are housed in the paleontological collections of the Ethiopian Heritage Authority, Department of Paleontology and Paleoanthropology.

SURFACE ACQUISITION AND PROCESSING

We considered wear facets associated with the shearing phase I of mastication, which are located on the lingual and labial enamel bands (facets 1 to 8, contrary to crushing facets 9 to 13 located on the labial and lingual sides of the occlusal basin on lower and upper molars, respectively; see Miyamoto *et al.* 2022 and Figure 2 in their study; see also Tausch *et al.* 2015). We did not consider crushing facets because they are reduced in some taxa (such as *Phacochoerus*) and are no longer apparent on molars with heavily worn occlusal basin. All suitable worn

TABLE 1. — Descriptive statistics (mean, **SD**, standard deviation, median; **Q1**, first quartile; **Q3**, third quartile, range) of dental microwear texture parameters for extant suid taxa and *Kolpochoerus* van Hoepen & van Hoepen, 1932 through the Shungura sequence (members C, E, F, lower part of G, H, J and L). Abbreviations: **Asfc**, complexity, or area-scale fractal complexity; **epLsar**, anisotropy, or exact proportion of length-scale anisotropy of relief; **HAsfc36**, heterogeneity of area-scale fractal complexity.

	Extant genera				<i>Kolpochoerus</i>							
	<i>Hylochoerus</i> (N = 21)	<i>Phacochoerus</i> (N = 23)	<i>Potamochoerus</i> (N = 33)	<i>Sus</i> (N = 25)	Total (N = 68)	Member C (N = 12)	Member E (N = 13)	Member F (N = 8)	Member G (N = 15)	Member H (N = 4)	Member J (N = 4)	Member L (N = 12)
Asfc												
Mean	2.26	2.20	2.34	3.46	1.78	2.10	1.37	1.46	1.70	2.48	1.75	2.00
(SD)	(1.95)	(1.37)	(1.45)	(2.48)	(1.00)	(1.05)	(0.63)	(0.93)	(0.85)	(2.04)	(0.71)	(1.09)
Median	1.61	1.76	2.06	2.69	1.66	1.83	1.36	1.26	1.82	1.70	1.84	1.82
(Q1, Q3)	(1.13, 2.51)	(1.65, 2.34)	(1.23, 2.60)	(1.67, 4.04)	(1.07, 2.13)	(1.54, 2.55)	(0.87, 1.63)	(0.84, 1.67)	(1.05, 2.08)	(1.12, 3.06)	(1.48, 2.11)	(1.36, 2.20)
Range	0.55-8.55	0.85-6.50	0.82-5.77	1.08-10.48	0.63-5.42	0.78-4.68	0.69-2.84	0.66-3.51	0.63-3.43	1.07-5.43	0.82-2.52	0.90-5.00
epLsar (x10⁻³)												
Mean	3.60	4.39	3.17	3.12	2.45	2.41	2.12	2.35	3.19	2.15	2.48	2.07
(SD)	(1.21)	(1.77)	(1.42)	(1.20)	(1.25)	(1.26)	(1.07)	(1.23)	(1.49)	(0.10)	(1.70)	(0.90)
Median	3.27	4.41	2.96	3.06	2.04	2.14	2.05	2.19	2.81	1.79	1.83	1.89
(Q1, Q3)	(2.81, 3.98)	(2.71, 6.10)	(2.17, 4.06)	(2.54, 3.93)	(1.65, 3.14)	(1.35, 3.27)	(1.26, 2.43)	(1.67, 3.06)	(2.29, 3.99)	(1.68, 2.26)	(1.63, 2.69)	(1.74, 2.57)
Range	1.61-6.61	1.83-7.28	0.76-5.94	1.19-5.89	0.51-6.10	0.88-4.69	0.90-4.56	0.56-4.05	0.67-6.10	1.41-3.63	1.26-4.98	0.51-3.99
HAsfc36												
Mean	0.65	0.46	0.63	0.75	0.53	0.46	0.49	0.65	0.64	0.42	0.42	0.53
(SD)	(0.21)	(0.13)	(0.21)	(0.30)	(0.19)	(0.22)	(0.15)	(0.19)	(0.20)	(0.09)	(0.15)	(0.13)
Median	0.61	0.45	0.58	0.71	0.48	0.41	0.45	0.67	0.57	0.41	0.37	0.49
(Q1, Q3)	(0.53, 0.81)	(0.38, 0.52)	(0.50, 0.70)	(0.54, 0.85)	(0.41, 0.64)	(0.35, 0.47)	(0.43, 0.49)	(0.46, 0.77)	(0.50, 0.78)	(0.35, 0.48)	(0.34, 0.44)	(0.46, 0.57)
Range	0.33-1.13	0.28-0.79	0.33-1.17	0.36-1.67	0.25-1.09	0.25-1.09	0.27-0.84	0.44-0.95	0.37-1.07	0.33-0.51	0.31-0.63	0.38-0.80

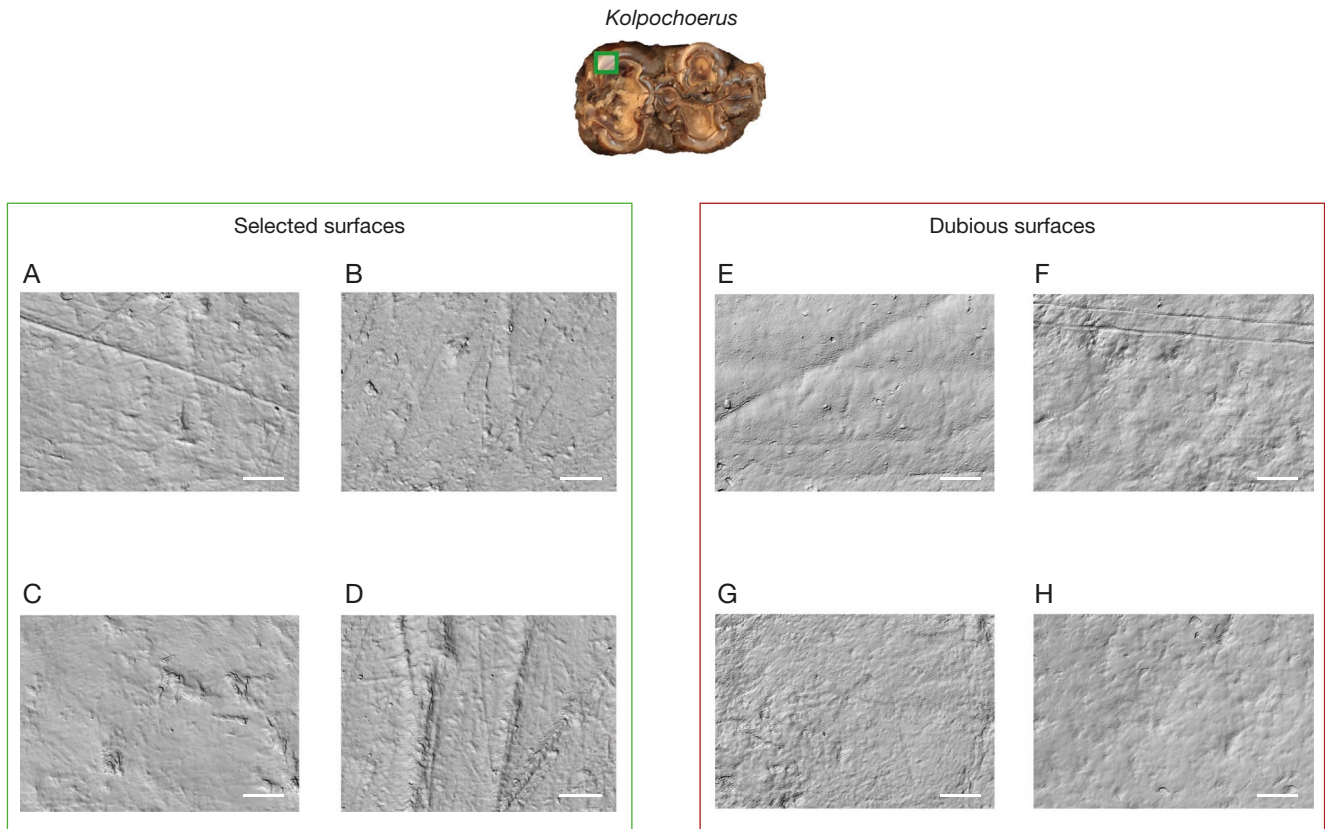


FIG. 2. — Photosimulations of shearing facets on *Kolpochoerus* van Hoepen & van Hoepen, 1932: **A-D**, selected surfaces show relatively heterogeneous texture with pits and scratches of different sizes and different orientations: **A**, OMO 349-10006, $Asfc = 2.83$, $epLsar (10^{-3}) = 1.38$; **B**, OMO 56-10015, $Asfc = 1.02$, $epLsar (10^{-3}) = 6.73$; **C**, OMO 346-10028, $Asfc = 3.55$, $epLsar (10^{-3}) = 3.16$; **D**, L627-384c, $Asfc = 1.77$, $epLsar (10^{-3}) = 8.20$; **E-H**, dubious surfaces were discarded when they show: **E**, OMO 33-1969-329, a thin film over the surface that masks the dietary marks; **F**, OMO 33-J3-1973-3356, long and parallel scratches that run over the surface and with sharp squared edges; **G**, OMO 1B-1969-4693, a homogeneous texture with pits of similar size and an absence of scratch; **H**, L 5-6-25a, a texture showing a “cauliflower-like” aspect and an absence of scratch. The **green square** on the molar of *Kolpochoerus* indicates the location of a shearing facet. Scale bars: 20 μm .

upper and lower first, second and third molars were included in this study (Appendices 1; 2). While it might increase the variability in microwear patterns, studies by Schulz *et al.* (2010) and Ramdarshan *et al.* (2016) showed non-significant variations in microwear textures between cheek teeth along the tooth row, and between upper and lower cheek teeth, when considering homologous wear facets (see also Appendix 3 showing no significant difference between tooth positions within taxon). Each facet was molded with polyvinylsiloxane (Regular Body President, ref. 6015 - ISO 4823, medium consistency, polyvinylsiloxane addition-type, Coltene Whaledent). For each specimen, all suitable non-overlapping worn areas on shearing facets were scanned in order to encompass intra-facet variations. We scanned one to fourteen surfaces for each specimen (Appendices 1; 2). Each surface was scanned as flat as possible using “TRIDENT”, a white-light confocal profilometer Leica DCM8 with a 100 \times objective housed at the PALEVOPRIM lab, CNRS and University of Poitiers, France (Numerical aperture = 0.90; Working distance = 0.9 mm; Leica Microsystems). Each scanned surface was pre-processed using LeicaMap v8.0 (Leica Microsystems; MountainsMap, Digital Surf). Non-measured points (< 3 %) were filled with a smooth shape (Laplacian filter) calculated from neighboring

points. We applied a morphological filter to remove artifacts such as aberrant peaks (Merceron *et al.* 2016) and surfaces were then leveled. A 140 \times 100 μm (1086 \times 776 pixels) leveled area was automatically generated at the center of each surface. In case of adhering dirt particles, the extracted area was shifted aside to get the particles out of the field of selection. In the worst cases (9 % of surfaces in extant suids and 2 % in *Kolpochoerus*), we manually erased the particles using a user-defined contour and replaced with a smooth shape calculated from neighboring points.

PROCEDURE FOR SELECTING WEAR SURFACES OF FOSSIL SPECIMENS

We explored the diversity of surface textures among extant suid taxa as a baseline for selecting wear surfaces of specimens of *Kolpochoerus* without apparent, or potential, taphonomic alterations. Figure 1 shows the variations in surface textures within extant suid taxa, being more or less complex and more or less anisotropic (see “Acquisition of textural parameters” for details on texture parameters).

Moreover, potentially altered surfaces of *Kolpochoerus* were identified, and discarded, using the following characteristics (see also Weber *et al.* 2021): 1) presence of a thin film over

the surface that masks the microwear marks; 2) long and parallel scratches that run over the surface and with sharp squared edges; 3) textures with homogeneous small pits and no visible scratch; and/or 4) homogeneous texture with a “cauliflower-like” appearance and no visible scratch. Figure 2 shows an example of each of these characteristics, as well as the variations in unaltered surfaces within *Kolpochoerus*. Photosimulations and false color elevation maps of all the surfaces included in this study are provided in the Supplementary Material (Appendices 4; 5).

ACQUISITION OF TEXTURAL PARAMETERS

Prior to the acquisition of textural parameters, a second-order least square polynomial surface (PS2) was subtracted from each surface to remove the concavity or convexity of dental facets. We considered three scale sensitive fractal analysis (SSFA) parameters for this study (calculated using LeicaMap v8.0): area-scale fractal complexity (Asfc), exact proportion of length-scale anisotropy of relief (epLsar (Sfrac) in LeicaMap v8.0), and heterogeneity of area-scale fractal complexity (HASfc36, calculated through 6 × 6 blocks in this study). We also computed HASfc9 and HASfc81 (calculated through 3 × 3 and 9 × 9 blocks, respectively) for each surface, but they were discarded because less discriminative than HASfc36 (Appendices 6; 7). Complexity (Asfc) measures the surface roughness at a given scale. Anisotropy (epLsar) quantifies the orientation concentration of surface roughness. Heterogeneity of complexity (HASfc36) measures the variation of complexity of subsampled parts of the surface. Detailed descriptions of these parameters can be found in Scott *et al.* (2006). For each parameter, we considered the mean value of all scanned surfaces per individual (Appendices 1; 2). As a complement to the figures presented in the main text, we provide biplots showing individual data points (Appendix 8), as well as boxplots of SSFA parameters for each sample of extant suids and *Kolpochoerus* as Supplementary Material (Appendices 9-11).

STABLE CARBON ISOTOPE VALUES OF EXTANT SUIDS AND *KOLPOCHOERUS* FROM SHUNGURA

All stable carbon isotopic values on enamel bioapatite of extant African suids and extinct *Kolpochoerus* from the Shungura Formation were compiled from the literature. We used the recently published compilation on extant African suids from Lazagabaster *et al.* (2021), which is available online as supplementary material (see references herein). To our knowledge, no data on enamel bioapatite is available on modern wild and/or free-ranging *Sus scrofa* (but see Hu *et al.* 2009; Russo *et al.* 2017; Balasse *et al.* 2018; Vedel 2022 on other biological tissues and/or on archeological specimens). All data on *Kolpochoerus* from the Shungura Formation were compiled using two recent studies by Bibi *et al.* (2013) and Negash *et al.* (2020). From this latter study, we only included stable carbon isotopic values of specimens for which element identification is documented in the Omo Database, and attributed to a M2 or a M3.

STATISTICAL ANALYSES

All statistical analyses were conducted in the R statistical environment (R Core Team 2020, v4.0.3). We performed analyses of variance (one-way ANOVAs) on each SSFA parameter to detect significant differences between extant taxa and *Kolpochoerus* by members (Appendix 6). The data were Box-Cox transformed prior to the analyses to meet the assumptions of homoscedasticity and normal distributions of the residual errors. Then, we conducted two post-hoc tests for multiple comparisons (package “agricolae”) to determine the sources of significant variations: Tukey’s honest significant difference (HSD) and Fisher’s least significant difference (LSD, less conservative than HSD) tests (Appendices 12; 13). An alternative non-parametric Kruskal-Wallis test was run for one parameter (epLsar) that did not meet the assumptions of normality of residuals (Appendix 14), and followed with a post-hoc Dunn’s test (package “dunn.test”; Appendix 15). We also conducted an ANOVA to detect significant differences between extant *H. meinertzhageni*, *Ph. africanus*, *Ph. aethiopicus*, *Po. larvatus*, *Po. porcus* and the two populations of *Sus scrofa* (see Appendix 7 for descriptive statistics and Appendix 16 for ANOVA results), followed with both HSD and LSD post-hoc tests (Appendices 17; 18).

ABBREVIATIONS

Institutional abbreviations

INRAE	Institut National de Recherche pour l’Agriculture, l’Alimentation et l’Environnement, Occitanie-Toulouse;
MCA	the Ethiopian Heritage Authority, collections of comparative anatomy, Addis Ababa;
MRAC	Musée Royal de l’Afrique Centrale, Tervuren;
MRI PAS	Polish Academy of Sciences in Białowieża;
MZUF	Museo Zoologico dell’Università di Firenze;
NMB	Naturhistorisches Museum Basel;
PALEVOPRIM	laboratory Paleontology Evolution Paleoecosystems Paleoprimatology.

Other abbreviations

ANOVA	analysis of variance;
Asfc	complexity, or area-scale fractal complexity;
DMT	dental microwear textures;
DMTA	dental microwear texture analysis;
epLsar	anisotropy, or exact proportion of length-scale anisotropy of relief;
HAsfc	heterogeneity of area-scale fractal complexity;
HSD	honest significant difference, or Tukey’s posthoc test;
LSD	least-significant difference, or Fisher’s posthoc test;
OGRE	Omo Group Research Expedition;
PS2	2 nd -order polynomial surface;
Si	silicon;
SSFA	scale-sensitive fractal analysis;
USO	underground storage organ.

RESULTS

DMTA OF EXTANT SUID TAXA

At generic level, *Phacochoerus* exhibits the most anisotropic surfaces when compared to other extant suid taxa (Fig. 3A; Tables 1; 2; Appendix 15). Its mean and median epLsar values are significantly higher than in omnivorous *Potamochoerus*

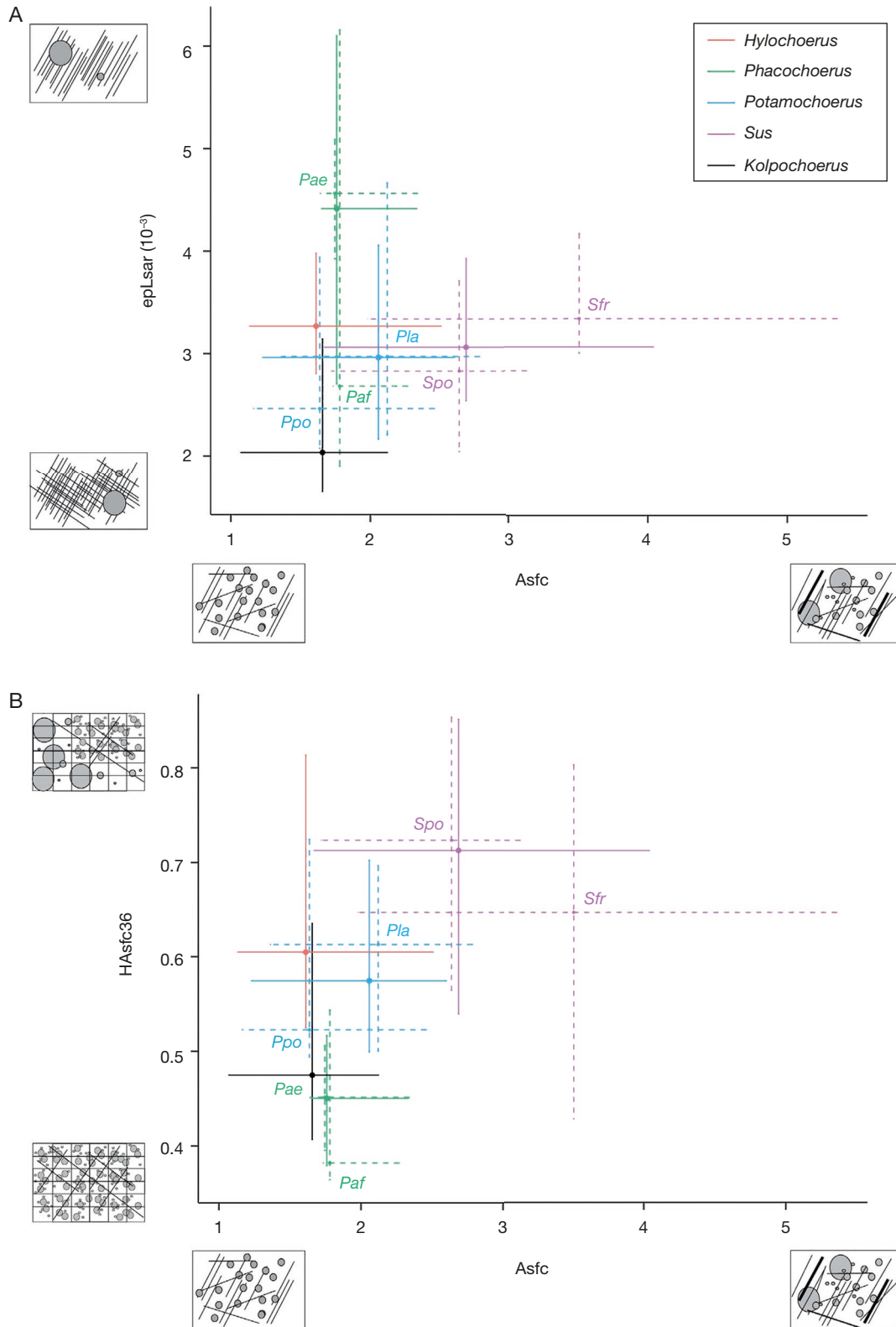


FIG. 3. — Biplots of SSFA parameters on extant *Phacochoerus* F.Cuvier, 1826 (n = 23, green), *Hylochoerus* Thomas, 1904 (n = 21, orange), *Potamochoerus* Gray, 1854 (n = 33, blue), *Sus* Linnaeus, 1758 (n = 25, pink) and *Kolpochoerus* Van Hoepen & Van Hoepen, 1932 (n = 68, black). Inter- and intra-specific variations within extant genera are shown (dotted lines): *Ph. aethiopicus* (Pallas, 1766) (*Pae*, n = 14), *Ph. africanus* (Gmelin, 1788) (*Paf*, n = 9), *Po. larvatus* (F.Cuvier, 1822) (*Pla*, n = 18), *Po. porcus* (Linnaeus, 1758) (*Ppo*, n = 15), *S. scrofa* Linnaeus, 1758 from Poland (*Spo*, n = 19), *S. scrofa* from France (*Sfr*, n = 6). **A**. Biplot of complexity (**Asfc**) and anisotropy (**epLsar**); **B**, biplot of complexity (**Asfc**) and heterogeneity of complexity (**HAsfc36**). Median values are indicated and bars represent the inter-quartile ranges.

and *Sus* ($p < 0.02$, Table 2; Appendix 15), but *Phacochoerus* does not significantly differ from *Hylochoerus*. *Potamochoerus* and *Sus* are similar in anisotropy and include the lowest values. In terms of complexity, we observe that *Sus* shows the highest values among our sample of extant suids. However, significant differences with the three other taxa are identified with LSD post-hoc tests ($p < 0.03$, Table 2; Appendix 12), not HSD tests. *Potamochoerus* tends to exhibit shearing surfaces that are slightly more complex than *Hylochoerus* and *Phacochoerus*. When looking at the heterogeneity of complexity (here, HAsfc36; Fig. 3), we observe that *Phacochoerus* is significantly lower than all other taxa ($p < 0.03$, Table 2; Appendix 13), and strongly differs from *Sus* ($p < 0.001$, Table 2; Appendix 13). *Hylochoerus* and *Potamochoerus* tend to show intermediate HAsfc36 values between *Sus* and *Phacochoerus*, but do not significantly differ from our *Sus* sample. Summary statistics for the extant suid genera analyzed in this study are presented in Table 1.

We also observe differences within the genera *Potamochoerus* and *Phacochoerus*, as well as intra-specific differences within *Sus scrofa* (Fig. 3A). These differences concern the anisotropy (epLsar) and the heterogeneity (HAsfc36) of surface textures, not the complexity (Asfc; Appendices 12; 13; 15). Notably, common warthogs (*Ph. africanus*) exhibit wear surfaces less anisotropic than those of desert warthogs (*Ph. aethiopicus*), as shown by the median value of the former being 1.5 times lower than for the latter (Fig. 3; Appendix 7). However, the two samples of warthogs do not significantly differ (Appendix 17). Common warthogs even exhibit a median epLsar value below the ones measured for the two populations of *Sus scrofa* and the one of *Po. larvatus*. Still, they show the highest inter-quartile range with specimens that present more anisotropic surfaces than all other omnivores, and no significant difference is identified between them and the other suid samples (Appendix 17). Regarding HAsfc36, although desert warthogs tend to show higher values than common warthogs, they do not significantly differ, and both species tend to display more homogeneous wear surfaces than omnivorous and less-specialized suids ($p < 0.04$ with LSD test only; Appendix 18). Species of *Potamochoerus* slightly differ, *Po. larvatus* showing more anisotropic, more complex and more heterogeneous surfaces than *Po. porcus* (Fig. 3), but differences are not significant (Appendices 17; 18). At last, the two wild boar populations also slightly differ (though not significantly; Appendices 17; 18), the boars from France showing more complex, more anisotropic and less heterogeneous wear surfaces than boars from the Białowieża Forest in Poland (Fig. 3).

COMPARISONS BETWEEN *KOLPOCHOERUS* FROM SHUNGURA AND EXTANT SUIDS

Specimens of *Kolpochoerus* from Shungura show low values of complexity, being more similar to herbivorous genera *Phacochoerus* and *Hylochoerus*, and clearly distinct from *Sus* (Fig. 3, Table 2; Appendix 12). Regarding anisotropy, specimens of *Kolpochoerus* show the lowest values and only partly overlap with the values observed on extant suids (Fig. 3A;

Tables 1; 2). Indeed, about half of the specimens of *Kolpochoerus* show anisotropy values that are lower than the first quartile of each extant suid samples (Fig. 3A). They are well distinct from *Phacochoerus* (Fig. 3A; Table 2; Appendix 15). When looking at the heterogeneity of complexity, *Kolpochoerus* also tend to show low mean and median values and are similar to *Phacochoerus* (Fig. 3B; Table 1). However, while *Phacochoerus* strongly differs from the three other extant genera, *Kolpochoerus* show some surfaces that are more heterogeneous than *Phacochoerus* and overlap with the three other taxa. Still, *Kolpochoerus* differs from *Sus*, which has the highest values (Fig. 3B; Table 2; Appendix 13). Summary statistics of the total sample of *Kolpochoerus* are provided in Table 1.

DMTA AMONG *KOLPOCHOERUS* THROUGH THE SHUNGURA SEQUENCE

Through the sequence, no significant difference in the complexity of wear surfaces of *Kolpochoerus* is detected between members with both post-hoc tests, as well as in the heterogeneity of complexity. The complexity seems stable, except for specimens from members E and F that tend to display less complex surfaces (Fig. 4; Tables 1; 2). Compared to extant suids, specimens from members E, F and G show significantly less complex surfaces than *Sus* ($p < 0.03$ with both post-hoc tests, Table 2; Appendix 12). When looking at HAsfc36, we observe increasing values from Member C to Member F, then a decrease from Member F to Member J, and again higher values in Member L. The most heterogeneous surfaces are found in members F and G (Fig. 4; Tables 1; 2). When compared to extant suids, *Kolpochoerus* are generally more similar to *Phacochoerus* in HAsfc36. Nonetheless, it is worth noting that specimens of *Kolpochoerus* from members F and G have less homogeneous surfaces than those of *Phacochoerus*, even though significant differences are only identified with LSD post-hoc test. In Member C, specimens of *Kolpochoerus* significantly differ from the three other extant genera ($p < 0.03$ with both post-hoc tests, Table 2; Appendix 13). In members E and J, they significantly differ from *Sus* only ($p < 0.05$ with both post-hoc tests, Table 2; Appendix 13). Regarding the anisotropy, mean and median values are stable within the sequence. Specimens from the lower part of Member G are slightly more anisotropic (Fig. 4; Tables 1; 2), but they significantly differ from members E and L only ($p < 0.02$, Appendix 15). Compared to extant taxa, *Kolpochoerus* from all members except G strongly differ from herbivorous *Phacochoerus* ($p < 0.02$, Table 2; Appendix 15). They also show less anisotropic surfaces than *Hylochoerus*, except in members G and J ($p < 0.02$, Table 2; Appendix 15). Only specimens from members E and L show significantly less anisotropic surfaces than omnivorous genera *Sus* and *Potamochoerus* ($p < 0.02$, Table 2; Appendix 15). Altogether, even though DMTA parameters do not reveal substantial changes between members, our results highlight some variations in dental microwear textures of *Kolpochoerus* within the sequence.

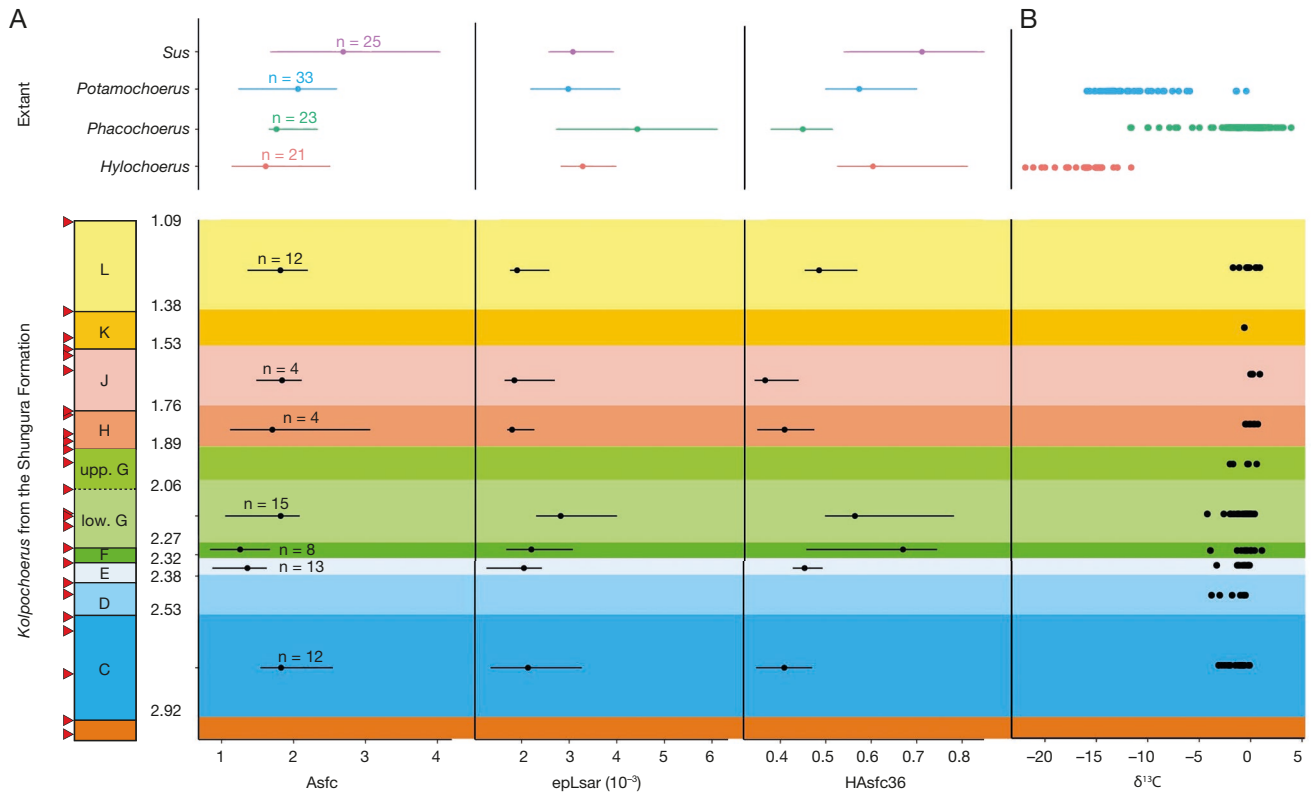


Fig. 4. — **A**, Dental microwear texture parameters on extinct *Kolpochoerus* van Hoepen & van Hoepen, 1932 (**black**) through the different members (C-L) of the Shungura Formation (**Asfc**, complexity; **epLsar**, anisotropy; **HAsfc36**, heterogeneity of complexity). Median values are indicated and bars represent inter-quartile ranges. Data on extant suid genera *Phacochoerus* F.Cuvier, 1826 (**green**), *Hylochoerus* Thomas, 1904 (**orange**), *Potamochoerus* Gray, 1854 (**blue**) and *Sus* Linnaeus, 1758 (**pink**) are indicated for comparison; **B**, enamel stable carbon isotopic compositions on *Kolpochoerus* through the same members of the Shungura Formation and on modern African suids ($\delta^{13}C$ ‰ VPDB; data compiled from Bibi *et al.* 2013 and Negash *et al.* 2020 for *Kolpochoerus* and from the compilation available in Lazagabaster *et al.* 2021 for extant suids).

DISCUSSION

DENTAL MICROWEAR TEXTURES AND DIETARY HABITS IN EXTANT SUID TAXA

This study shows that DMT variations among extant suid taxa, despite overlapping data, reflect differences in dietary habits. These differences are mirrored in three commonly used SSFA parameters that describe the heterogeneity of orientation of wear scratches, the surface roughness and the heterogeneity of surface roughness: anisotropy (epLsar), complexity (Asfc) and heterogeneity of complexity (HAsfc36), respectively. Omnivorous wild boars show the most complex and heterogeneous wear surfaces, and dissimilarities with omnivorous *Potamochoerus* might reflect least variable diet in the latter taxon than in *Sus*. Graminivorous warthogs show the most anisotropic surfaces, as expected for a taxon mainly feeding on abrasive grasses, and the least heterogeneous ones. Microwear patterns of *Hylochoerus* likely reflect their mixed diet including much less abrasive foods than in *Phacochoerus*. These findings are congruent with observations from field studies and previous ecological studies based on dental microwear or stable isotopes (Skinner *et al.* 1976; d’Huart 1978; Breytenbach & Skinner 1982; Seydack 1990, 2017; Harris & Cerling 2002; Cerling & Viehl 2004; Treydte *et al.* 2006; Giménez-Anaya *et al.* 2008; d’Huart & Kingdon 2013; Souron *et al.* 2015b;

Butynski & de Jong 2017; de Jong & Butynski 2017; Keuling *et al.* 2017; Melletti *et al.* 2017; Reyna-Hurtado *et al.* 2017; Mekonnen *et al.* 2018; Lazagabaster 2019; Edossa *et al.* 2021; Lazagabaster *et al.* 2021). Overall, we not only expand the extant DMT baseline developed by Souron *et al.* (2015b) and Lazagabaster (2019), but also highlight inter- and intra-specific differences in extant suids, which most likely reflect variations in food mechanical properties.

In our analysis, the herbivorous taxon *Phacochoerus* strongly differs from the omnivorous *Sus*, showing the highest anisotropy values, and the lowest in heterogeneity of complexity, along with low surface complexity (Fig. 3; Tables 1; 2; Appendices 6; 7; 12; 18). High anisotropy values and low complexity have been documented among graminivorous mammals in previous studies (Ungar *et al.* 2007; J. R. Scott 2012; Merceron *et al.* 2014). Thus, the DMT patterns observed on *Phacochoerus* likely reflect the large amount of fibrous items in its diet, mainly herbaceous monocots (Cumming 1975, 2013; Harris & Cerling 2002; Treydte *et al.* 2006; Butynski & de Jong 2017; de Jong & Butynski 2017). In addition, both common and desert warthogs show homogeneous surfaces compared to other suids, which might reflect their rather monotypic diets on herbaceous plants. These results are congruent with previous dental microwear studies (Souron *et al.* 2015b; Lazagabaster 2019). In the common warthogs, the

	Extant genera											
	<i>Hylochoerus</i>	<i>Phacochoerus</i>	<i>Potamochoerus</i>	<i>Sus</i>	<i>C</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>H</i>	<i>J</i>	<i>L</i>	
Extant	<i>Hylochoerus</i>	<i>Phacochoerus</i>	<i>Potamochoerus</i>	<i>Sus</i>	<i>C</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>H</i>	<i>J</i>	<i>L</i>	
<i>Hylochoerus</i>	HAsfc36											
<i>Phacochoerus</i>		epl.sar; HAsfc36										
<i>Potamochoerus</i>		Asfc; epl.sar; HAsfc36	Asfc									
<i>Sus</i>	Asfc			Asfc								
<i>Kolpochoerus</i>												
C	epl.sar; HAsfc36	epl.sar	HAsfc36	Asfc; HAsfc36	HAsfc36							
E	epl.sar; HAsfc36	Asfc; epl.sar	Asfc; epl.sar; HAsfc36	Asfc; epl.sar; HAsfc36	Asfc							
F	epl.sar	Asfc; epl.sar; HAsfc36	Asfc	HAsfc36	HAsfc36	HAsfc36						
G		HAsfc36		Asfc	HAsfc36	epl.sar; HAsfc36						
H	HAsfc36	epl.sar	HAsfc36	Asfc	HAsfc36	epl.sar; HAsfc36						
J	HAsfc36	epl.sar	HAsfc36	HAsfc36	HAsfc36	HAsfc36	HAsfc36					
L	epl.sar	epl.sar	epl.sar	Asfc; epl.sar; HAsfc36	HAsfc36	HAsfc36	HAsfc36	HAsfc36	HAsfc36	HAsfc36	HAsfc36	

TABLE 2. — Significantly different dental microwear parameters between extant suid genera and *Kolpochoerus* van Hoepen, 1932 from the Shungura Formation using combined Tukey's HSD and Fisher's LSD post-hoc tests following one-way ANOVAs (for Asfc and HAsfc36) and Dunn's test (for epl.sar). Parameters in bold are significant ($p < 0.05$) with both post-hoc tests. The parameter epl.sar is given in italic when significant with a Dunn's test. Abbreviations: Asfc, complexity, or area-scale fractal complexity; epl.sar, anisotropy, or exact proportion of length-scale anisotropy of relief; HAsfc, heterogeneity of area-scale fractal complexity.

large dispersion of anisotropy values (see 1st and 3rd quartiles on Figure 3) could reflect the seasonality of the diet, as it has been suggested that *Ph. africanus* may feed more on roots, barks and rhizomes during the dry season (Cumming 1975, 2013; Souron *et al.* 2015b; but see Treydte *et al.* 2006 showing little evidence for such seasonal variations). Even though *Ph. africanus* show highly dispersed anisotropy values, the median value is much lower than the one of desert warthogs (*Ph. aethiopicus*; Fig. 3). Although the ecology of the desert warthog is largely unknown, these dissimilarities in DMT patterns likely reflect subtle differences in feeding habits and/or habitat between the two species. A different timing of third molar root development in desert warthogs (i.e., late-forming roots allowing enamel columns to continue growing, thus extending tooth durability) might reflect an adaptation to a more abrasive diet and/or more exogenous particles than common warthogs (Grubb & d'Huart 2013). Such a diet could explain the higher values of anisotropy in *Ph. aethiopicus*. In *Ph. africanus*, the low epl.sar median value could reflect feeding preferences on young, fresh (i.e., less abrasive) graminoid and non-graminoid herbs (Butynski & de Jong 2017; see also Francisco *et al.* 2018).

In contrast, the omnivorous *Sus scrofa* shows low anisotropy values and high values of complexity and heterogeneity of complexity (Fig. 3; Tables 1; 2; Appendices 6, 7; 12; 18). This probably reflects the lesser amount of fibrous plants in its diet and greater proportion of fruits, USOs, animal matter, and fungi. Wild boars show significantly higher values in heterogeneity of complexity than *Phacochoerus*. Although the impact of diet on HAsfc remains poorly understood, previous studies have suggested that a more diversified diet leads to heterogeneous wear surfaces (Scott *et al.* 2012; Souron *et al.* 2015b; Ramdarshan *et al.* 2016; Merceron *et al.* 2018). Here, our results tend to support this hypothesis, but there is no doubt that the link between dietary diversity and surface heterogeneity is not that straightforward, notably considering the similarity between *Potamochoerus* and *Hylochoerus*. Differences in heterogeneity could also partly relate to other factors, such as grit ingestion and/or seasonal variations (Souron *et al.* 2015b; Louail *et al.* 2022). Highly dispersed complexity values, along with high values of heterogeneity, might reflect the intra-specific dietary variations among *Sus scrofa*, as well as seasonal variations in the diet (e.g. Keuling *et al.* 2017). Moreover, highly dispersed values most likely reflect the fact that our sample includes specimens from two different geographic areas in Poland and France, with different climates (continental and oceanic, respectively) and slaughtering periods (spring and winter, respectively), as well as differences in the access to agricultural crops or other anthropogenic food supplies. The Białowieża Forest in Poland is one of the best-preserved forest in Europe with limited human impact, and the Polish specimens contrast with the few individuals from France. Notably, the latter tend to show more complex surfaces compared to specimens from Poland (Fig. 3). This could be explained by a higher consumption of acorns,

nuts, roots and tubers in winter than in spring (Keuling *et al.* 2017). A greater consumption of agricultural crops or other by-products of human activities (notably due to hunter-provided supplemental foods in autumn and winter; Keuling *et al.* 2017) might also explain this pattern, as previously observed in wild/free-ranging and stall-fed populations of *Sus* (Yamada *et al.* 2018; Louail *et al.* 2021, 2022). However, we cannot further test this due to the lack of precise data on feeding habits and habitat.

The other omnivorous taxon *Potamochoerus* is similar to *Sus* in terms of anisotropy, but intermediate between *Phacochoerus* and *Sus* when looking at complexity and heterogeneity of complexity. Although a previous study observed more similar DMT patterns between *Potamochoerus* and *Sus scrofa* (Souron *et al.* 2015b; Appendix 19), our results are not directly comparable because these authors used an interferometry-based microscope with a 50× objective whereas we used a confocal profilometer with a 100× objective. Moreover, some of the specimens of *Potamochoerus* and *Sus scrofa* that we studied were not included in Souron *et al.* (2015b). In the present study, some specimens of *Po. larvatus* come from a more open environment (specimens from MZUF; Appendix 1) than the various ones characterizing this genus. Some of them show low complexity values, which might contribute to the differences between Souron *et al.* (2015b) and the present study at the generic level. Moreover, the use of different modules for extracting SSFA parameters might also contribute to differences between the two previous DMTA studies on extant suids (Souron *et al.* 2015b; Lazagabaster 2019; Appendix 19) and the present one (i.e., use of Toothfrax module and, here, use of MountainsMap module; see Calandra *et al.* 2022). In his study, Lazagabaster (2019) observed different DMT patterns between *Po. larvatus* and *Po. porcus*, the former showing more anisotropic, less complex and less heterogeneous wear surfaces than the latter (Appendix 19). The author suggested this could relate to differences in habitats, *Po. larvatus* inhabiting in general more open areas than *Po. porcus* (see also the compilation of isotopic data in Lazagabaster *et al.* 2021 suggesting higher intake of C₄ foods in *Po. larvatus*). Here, we observe that *Po. larvatus* tend to show more anisotropic but more complex and more heterogeneous wear surfaces than *Po. porcus*. These disparities between Lazagabaster's study (2019) and the present one could also be due to differences in geographic provenance or slaughtering periods of specimens sampled. In addition, two specimens identified as *Po. porcus* in Lazagabaster's study come from localities where only *Po. larvatus* is known and one specimen is impossible to identify to specific level without further study of its morphology as it comes from a region where both species occur. This implies a reduction of the sample size of *Po. porcus* in Lazagabaster (2019) from six to three specimens (and an increase of the sample size of *Po. larvatus* from 23 to 25 specimens), which makes robust statistical comparisons between the two species difficult. More studies are needed to further investigate variations in dietary habits within and between the two species. Overall, our results show

that the DMT patterns of *Potamochoerus* reflect the distinct dietary habits between them and herbivorous *Phacochoerus*. Dissimilarities with wild boars could reflect a less versatile diet in terms of physical and mechanical properties than in wild boars, which might face greater seasonal variation in food availability in mid-latitudes than *Potamochoerus* (see also differences in dental topographies documented by Rannikko *et al.* 2020). Observed similarities with *Hylochoerus* (notably in anisotropy and heterogeneity of complexity) could partly relate to their common preference for forested or ecotone areas (Reyna-Hurtado *et al.* 2017), although *Potamochoerus* probably have a more diversified diet than *Hylochoerus* in terms of physical and mechanical properties.

Our results on DMT patterns of *Hylochoerus* are quite surprising because they do not reflect the strong herbivory component in their diet, as observed in previous dental microwear studies (Souron *et al.* 2015b; Lazagabaster 2019; Appendix 19). Nonetheless, in addition to differences in methodological approaches (see above and Appendix 19) that could explain these incongruities, it is worth noting that Souron *et al.* (2015b) and Lazagabaster (2019) only included five and three specimens (respectively) of *Hylochoerus*, whereas 21 specimens were included in the present study. Here, specimens of *Hylochoerus* exhibit low complexity surfaces similarly to herbivorous *Phacochoerus*, but they show in average less anisotropic surfaces. They also exhibit more heterogeneous surfaces than *Phacochoerus*, but the difference between them is reduced compared to previous observations in Souron *et al.* (2015b) and Lazagabaster (2019) (HAsfc9 and HAsfc81; Appendix 19). Our results on a larger sample of *Hylochoerus* are congruent with a lower amount of abrasive grasses in its diet than *Phacochoerus*, as documented by field studies. Less anisotropic surfaces could also be partly explained by differences in mastication biomechanics between the two species, with less extensive transverse movements in *Hylochoerus* (Ewer 1970; Herring 1980). As suggested by Souron *et al.* (2015b), the more heterogeneous surfaces could also be related to less frequent rooting behaviors (see also Louail *et al.* 2022) than in *Phacochoerus*. Even though the feeding ecology of *Hylochoerus* remains largely unknown, several studies have highlighted that this taxon does not feed predominantly on grasses and should rather be considered as an herbivorous mixed feeder (Harris & Cerling 2002; d'Huart & Kingdon 2013; Souron *et al.* 2015b). Notably, a previous work on stable carbon isotope composition of forest hog hair has shown that they consume very little C₄ grasses during the year, reaching only up to 20 % grass in the diet at the beginning of the rainy season (Cerling & Viehl 2004). Although it is unclear why DMT patterns of *Hylochoerus* are that similar to those of the omnivorous *Potamochoerus*, it is likely that they reflect a diet consisting of various herbaceous vegetation in closed, forested habitats, probably including soft browse along with low-abrasive herbaceous plants (grasses and forbs), as reflected by low complexity and low anisotropy. Overall, this microwear pattern is coherent with much less abrasive foods in *Hylochoerus* diet than in *Phacochoerus*.

We need further investigations for a better understanding of the relationships between feeding ecology and dental microwear textures among extant suids. This implies the development of more precise comparative frame, with detailed data that are directly related to each population. Nonetheless, our study shows that microwear patterns among extant suids reflect differences in dietary habits, which validates their use as an extant dental microwear baseline for comparisons with fossil data.

DENTAL MICROWEAR TEXTURES OF *KOLPOCHOERUS* FROM SHUNGURA: DIETARY PERSPECTIVES

We investigated dental microwear texture variations on extinct *Kolpochoerus* from the Shungura Formation. The total sample of *Kolpochoerus* shows DMT characterized by relatively low values of complexity, anisotropy and heterogeneity of complexity compared to most extant taxa. Thus, they tend to differ from all extant taxa. Although they resemble *Phacochoerus* in Asfc and HASfc, more specimens have lower Asfc and higher HASfc values than in the warthog sample. More particularly, they strongly differ from *Phacochoerus* having the lowest anisotropy values. These differences between *Phacochoerus* and *Kolpochoerus* are expected considering that the former is highly specialized. Still, our results appear to contrast with previous studies on dental morphology and stable carbon isotopic compositions of *Kolpochoerus*, which have related dental morphological changes, mainly molar enlargement, to increasing consumption of abrasive grasses. The following paragraphs will discuss: 1) the unlikeness that our dental microwear results on *Kolpochoerus* reflect a taphonomic alteration; and 2) the likelihood that DMT preserved a dietary signal reflecting a significant proportion of low-abrasive herbaceous plants (grasses and forbs).

The question of potential taphonomic alterations in our sample of *Kolpochoerus* arises because their DMT patterns differ from all extant suid taxa in their very isotropic wear surfaces. Notably, samples from members E (n = 13) and L (n = 12) significantly differ from all other extant taxa in this parameter (Tables 1; 2; Fig. 4). Unfortunately, the impact of taphonomic alterations (mechanical or chemical) on dental microwear remains largely unknown, as only few studies have investigated this issue (Gordon 1983, 1984; King *et al.* 1999; Böhm *et al.* 2019; Uzunidis *et al.* 2021; Weber *et al.* 2022). Only three of them have been conducted on non-human mammal teeth (Böhm *et al.* 2019; Uzunidis *et al.* 2021; Weber *et al.* 2022), and only two have considered standard and commonly used DMTA parameters (Böhm *et al.* 2019; Weber *et al.* 2022). Overall, all these studies observed slightly polished wear surfaces following tumbling experiments, but showed that the dietary signal is still preserved. One recent study pointed out that new abrasion marks following a tumbling experiment have a more isotropic distribution (Uzunidis *et al.* 2021). However, these authors used 2D low-magnification microwear analysis and not standard 3D textural parameters, and this trend is not confirmed by the other studies (Böhm *et al.* 2019; Weber *et al.* 2022). Further studies are needed to better understand how texture parameters, notably epLsar, might be influenced by post-mortem alterations, particularly

fluvial transport in sediments. To date, none of these works can be used to validate or invalidate the hypothesis of potential taphonomic alterations in our sample. In contrast, although some specimens excluded from the analyses might have been altered by fluvial transport, several elements strengthen our assumption that wear surfaces used in this study have preserved their dietary signal. Indeed, we first conducted a meticulous selection of fossil surfaces and discarded all specimens with evident post-mortem alterations, as well as dubious ones (see Figure 2 and Weber *et al.* 2021). We also calculated the mean values of several scanned microwear areas on the same (or similar) facet, which avoids including extreme values in our analysis. Overall, DMT parameters measured on *Kolpochoerus* specimens are still within the range of our extant suid baseline. At last, although Lazagabaster (2019) focused on Pliocene specimens, his published DMT data on *Kolpochoerus* from the Hadar Formation also show this trend towards lower anisotropy than in his extant sample, except for *Po. porcus*, a situation nearly similar to our observations. Knowing that fossil preservation and depositional conditions (predominantly lacustrine) are quite different between Shungura and the Hadar Formation, this parallel situation in DMT signals reinforces our assumption that these low anisotropy values in Shungura *Kolpochoerus* are not the results of a taphonomic process, but reflect dietary habits.

The DMT patterns of *Kolpochoerus* analyzed in this study suggest substantial differences in dietary habits from extant suid taxa. They do not reflect the consumption of fibrous, abrasive plants as in herbivorous *Phacochoerus*, neither the consumption of hard or brittle foods as among omnivorous taxa. Although we observe a notable increase in anisotropy from Member E to Member G (both differ significantly; Fig. 4; Appendix 15), values are still much lower than among *Phacochoerus* through all the sequence (except in Lower G). As such, DMT patterns of *Kolpochoerus* do not reflect a major change in the physical and mechanical properties of the diet through time that would reflect an increasing consumption of grasses, as suggested by dental morphological changes. Nonetheless, regarding the heterogeneity of complexity (which is the only texture parameter that strongly distinguish the highly specialized species from the other suids), *Kolpochoerus* appear similar to *Phacochoerus*, having on average low values (Fig. 3). Although *Kolpochoerus* display more heterogeneous surfaces in members F and G (and L to a lesser extent; Fig. 3; Appendix 13), these similarities with extant *Phacochoerus* could reflect a rather monotypic diet. At the species level, *Kolpochoerus* spp. from Shungura appear more similar to some specimens of common warthogs (*Ph. africanus*) that show low anisotropy values (Fig. 3). Differences in dietary habits between the two warthogs species need to be further investigated, but these resemblances between *Kolpochoerus* and common warthogs might reflect a less abrasive and specialized diet than in desert warthogs. Thus, we suggest their overall DMT patterns likely reflect the consumption of herbaceous plants, but rather low-abrasive than fibrous ones. It could explain the overall isotropic wear surfaces in *Kolpochoerus*, conversely to the highly specialized *Phacochoerus*. Indeed,

we have highlighted that the more isotropic wear surfaces in numerous specimens of common warthogs (Fig. 4) might reflect their dietary preference for fresh, short, low-abrasive grasses. Moreover, preliminary observations by M.L. on controlled-fed pigs suggest that increasing consumption of low-abrasive herbaceous plants leads to decreasing anisotropy. Thus, our results appear in line with the hypothesis of *Kolpochoerus* having feeding preferences for fresh grass shoots, probably in more mesic habitats compared to other extinct suid taxa (Harris & Cerling 2002; Rannikko *et al.* 2017, 2020; Yang *et al.* 2022). We propose that this dietary niche is reflected, at Shungura, in the combination of a progressive enlargement and complexity of third molars, a strong C_4 signal, together with DMT patterns reflecting low-abrasive foods (Fig. 4).

In *Kolpochoerus*, as previously pointed out, the elongation of third molars might be related to increasing chewing efficiency as it multiplies the number of chewing sites (Souron 2017; Yang *et al.* 2022). Whereas hypsodonty would be more associated to the abrasiveness of the grasses, molar enlargement would be more related to the size of food items and mouthfuls. It would give an advantage, among herbivorous suids that do not have a specialized digestive physiology such as *Kolpochoerus*, for reducing as much as possible short, young grasses (Lucas 2004; Souron 2017). Thus, dental morphological changes are still in line with feeding preferences on short, young, low-abrasive grasses, as reflected by their DMT patterns. In addition, even if the strong C_4 signal observed in *Kolpochoerus* resemble that of extant warthogs (Fig. 4), it does not necessarily reflect the consumption of abrasive grasses. It is largely assumed that grasses possessing the C_4 photosynthetic pathway are high accumulators of silicon (Si), and consequently are more abrasive than C_3 grasses or browse. However, a recent study has shown that Si concentrations in C_3 and C_4 grasses are also related to growth conditions (hot and dry conditions promoting higher Si accumulation), not only the photosynthetic pathway (Brightly *et al.* 2020). Other studies have investigated the factors of Si accumulation in grasses, and they all highlight a substantial role of growth conditions (e.g. Katz *et al.* 2014, 2018; Quigley *et al.* 2017). Thus, while a strong C_4 signal likely reflects the consumption of herbaceous plants (mostly graminoids), it does not indicate the abrasiveness of the diet, whereas DMT does. Past environmental conditions, such as humidity and insolation, might have more impacted the physical properties of the vegetation. Several studies have highlighted that while Pliocene and Pleistocene eastern African sites show a general trend toward more open landscapes dominated by C_4 resources, the Lower Omo Valley was composed of a mosaic of closed and wooded habitats, riverine forests and open grasslands (e.g. Levin *et al.* 2011; Barr 2015; Negash *et al.* 2015, 2020). This implies that the Lower Omo Valley would have provided a diversity of habitats to exploit, with the persistence of mesic conditions. All studies that analyzed stable oxygen isotopes in *Kolpochoerus* in eastern African sites have shown low $\delta^{18}O$ values compared to other extinct suid taxa, notably at Shungura (Harris & Cerling 2002; Bedaso *et al.* 2010, 2013; Bibi *et al.* 2013; Negash *et al.* 2020). Moreover,

Kolpochoerus tend to show lower values than contemporaneous *Metridiochoerus* from the same sites (Harris & Cerling 2002; Patterson *et al.* 2019; see also Negash *et al.* 2020), which might indicate they were more water dependent. This is supported by other studies that focused on relative abundances and dental topography of Plio-Pleistocene suids in the Turkana basin (Rannikko *et al.* 2017, 2020). Altogether, the combination of these different paleoecological proxies tend to support the hypothesis that *Kolpochoerus* favored more mesic and/or woody habitats, such as at Shungura, with significant consumption of herbaceous plants but dietary preferences for short, soft and low-abrasive ones.

This study focused on specimens of the *K. limnetes/K. aff. paiceae* lineage from the Shungura Formation. As stated in the introduction, *Kolpochoerus* was ubiquitous in the Plio-Pleistocene Africa (Broom 1931; Harris & White 1979; Hendeby & Cooke 1985; White 1995; Brunet & White 2001; Suwa *et al.* 2003; Bishop 2011; Haile-Selassie & Simpson 2013; Souron *et al.* 2015a), and was highly diversified notably in terms of dental morphologies (Harris & White 1979; Brunet & White 2001; Bishop *et al.* 2006; Souron 2012, 2017; Haile-Selassie & Simpson 2013). It most likely exploited a variety of habitats and had various feeding habits depending on the species considered and on local environmental and ecological conditions. As such, we do not pretend here to reconstruct the diet on the generic scale, nor on the Plio-Pleistocene Africa as a whole. Rather, we provide new insights on the paleoecology of this specific lineage and at a local scale. It is possible that specimens attributed to other species, such as *Kolpochoerus majus* (Hopwood, 1934) that overall retained a more conservative dental morphology (Souron *et al.* 2015a), had different dietary habits despite similarly displaying high $\delta^{13}C$ values. In addition, given the apparent ecological flexibility of *Kolpochoerus*, one might expect that specimens from other sites than the Shungura Formation had different feeding habits, reflecting different local environmental dynamics. This underlines the potential of this taxon to contribute to the reconstruction of past environments throughout Plio-Pleistocene Africa, as well as for understanding the relationships between environmental, dietary, and morphological changes in omnivorous-to-herbivorous taxa.

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Conflict of interest

The authors declare no competing interests.

Author contributions

ML, AS, GM and JRB designed the study. GM, AS and JRB provided supervision. AS and ML were responsible for data curation. JRB supervised fieldwork, curated collections, and managed specimen database. ML was responsible for formal analysis and visualization. ML wrote the article with contributions from all the co-authors.

Data availability

Supplementary information accompanies this paper at <https://osf.io/ept6r/>.

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APPENDICES

APPENDIX 1. — List of extant specimens used in this study, as well as their geographic provenance, studied tooth, values of DMT parameters: complexity (**Asfc**), heterogeneity of complexity through 36 cells (**HAsfc36**) and anisotropy (**epLsar**) and number of scanned surfaces per specimen. Abbreviation: **DRC**, Democratic Republic of Congo.

Specimen	Taxon	Geographic provenance	Tooth position	Asfc	HAsfc36	epLsar (10 ⁻³)	Number of scans
MRAC 10460	<i>Hylochoerus meinertzhageni</i>	Buta, DRC	Lower M2	0.951	0.329	5.258	14
MRAC 14108	<i>Hylochoerus meinertzhageni</i>	Nizi, DRC	Lower M2	2.432	0.576	1.606	5
MRAC 14264	<i>Hylochoerus meinertzhageni</i>	Rutshuru, DRC	Lower M2	1.582	0.337	2.983	4
MRAC 2228	<i>Hylochoerus meinertzhageni</i>	Mawambi, DRC	Lower M3	1.818	0.844	3.671	4
MRAC 2229	<i>Hylochoerus meinertzhageni</i>	Mawambi, DRC	Lower M3	1.612	1.134	2.806	2
MRAC 2537	<i>Hylochoerus meinertzhageni</i>	Moto, DRC	Lower M2	1.101	0.651	2.260	3
MRAC 25526	<i>Hylochoerus meinertzhageni</i>	Epulu, DRC	Lower M2	1.363	0.813	4.355	4
MRAC 25678	<i>Hylochoerus meinertzhageni</i>	Gangala Na Bodio, DRC	Lower M2	6.732	0.824	2.669	3
MRAC 25680	<i>Hylochoerus meinertzhageni</i>	Gangala Na Bodio, DRC	Lower M2	0.836	0.559	3.638	8
MRAC 2908	<i>Hylochoerus meinertzhageni</i>	Kilo, DRC	Lower M2	1.683	0.410	3.979	8
MRAC 3418	<i>Hylochoerus meinertzhageni</i>	Penghe, DRC	Lower M3	2.618	0.682	3.269	7
MRAC 37446	<i>Hylochoerus meinertzhageni</i>	Bauelende, DRC	Lower M2	3.510	0.870	5.491	4
MRAC 37447	<i>Hylochoerus meinertzhageni</i>	Kandioka, DRC	Lower M2	0.553	0.605	6.614	6
MRAC 3869	<i>Hylochoerus meinertzhageni</i>	Poko, DRC	Lower M2	1.134	0.506	3.657	4
MRAC 4290	<i>Hylochoerus meinertzhageni</i>	Mawambi, DRC	Lower M2	1.323	0.642	5.137	4
MRAC 7864	<i>Hylochoerus meinertzhageni</i>	Kivu, DRC	Lower M2	1.596	0.585	3.042	3
MRAC 83.006-M-0544	<i>Hylochoerus meinertzhageni</i>	Lulimbi, DRC	Lower M3	2.509	0.615	2.727	3
MRAC 83.006-M-0545	<i>Hylochoerus meinertzhageni</i>	Lulimbi, DRC	Lower M3	2.043	0.574	2.984	4
MRAC 8359	<i>Hylochoerus meinertzhageni</i>	Koteli, DRC	Lower M2	0.988	0.472	3.150	4
MRAC 87.009-M-0001	<i>Hylochoerus meinertzhageni</i>	DRC	Lower M3	8.549	1.042	2.400	8
NMB 12065	<i>Hylochoerus meinertzhageni</i>	Lulimbi, DRC	Upper M3	2.531	0.525	3.783	4
MZUF 13303	<i>Phacochoerus aethiopicus</i>	Mogadiscio, Somalia	Upper M3	1.763	0.511	3.414	4
MZUF 1666	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Upper/Lower M3	1.731	0.395	5.168	11
MZUF 1747	<i>Phacochoerus aethiopicus</i>	Dafet, Somalia	Lower M3	0.966	0.459	6.277	4
MZUF 1822	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Lower M2	1.062	0.394	3.924	2
MZUF 1857	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Lower M3	6.499	0.492	6.485	4
MZUF 1914	<i>Phacochoerus aethiopicus</i>	Brava, Somalia	Lower M3	1.402	0.344	4.711	4
MZUF 2008	<i>Phacochoerus aethiopicus</i>	Afgoi, Somalia	Lower M3	5.951	0.650	2.728	8
MZUF 2443	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Lower M3	2.400	0.416	4.797	4
MZUF 2445	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Lower M3	1.634	0.451	2.371	4
MZUF 2446	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Lower M3	1.667	0.453	4.842	5
MZUF 2447	<i>Phacochoerus aethiopicus</i>	Balad, Somalia	Lower M3	2.629	0.790	7.282	5
MZUF 2458	<i>Phacochoerus aethiopicus</i>	Basso Uebi Shebeli, Somalia	Lower M2	1.760	0.398	4.106	4
MZUF 2459	<i>Phacochoerus aethiopicus</i>	Afgoi, Somalia	Lower M3	2.163	0.276	4.413	3
MZUF 3041	<i>Phacochoerus aethiopicus</i>	Villabruzzi, Somalia	Upper M3	1.728	0.523	3.928	3
MRAC 35622	<i>Phacochoerus africanus</i>	Rugwero, Burundi	Lower M3	2.043	0.561	1.866	3
MRAC 35811	<i>Phacochoerus africanus</i>	Rugwero, Burundi	Lower M2/M3	1.735	0.544	6.982	6
MZUF 1133	<i>Phacochoerus africanus</i>	Setit, Eritrea	Upper M2	2.721	0.382	6.040	2
MCA PH17	<i>Phacochoerus africanus</i>	Ethiopia	Lower M3	1.742	0.365	2.426	2
MCA PH22	<i>Phacochoerus africanus</i>	Ethiopia	Upper M3	2.518	0.715	1.904	2
MCA PH28	<i>Phacochoerus africanus</i>	Ethiopia	Upper M3	1.782	0.474	6.638	3
MCA PH30	<i>Phacochoerus africanus</i>	Ethiopia	Upper M3	2.270	0.335	2.684	2
MCA PH33	<i>Phacochoerus africanus</i>	Ethiopia	Lower M3	1.483	0.377	1.831	4
MCA PH4	<i>Phacochoerus africanus</i>	Bouri, Afar, Ethiopia	Unknown	0.852	0.312	6.156	2
MZUF 1667	<i>Potamochoerus larvatus</i>	Tarda Margherita, Somalia	Upper M3	5.389	0.855	2.964	4
MZUF C.1862	<i>Potamochoerus larvatus</i>	Balad, Somalia	Lower M2	3.288	0.667	2.604	4
MZUF C.1916	<i>Potamochoerus larvatus</i>	Eggi, Somalia	Lower M2	1.377	0.627	5.457	4
MZUF C.2728	<i>Potamochoerus larvatus</i>	Villabruzzi, Somalia	Lower M3	1.092	0.575	2.193	4
MZUF C.3000	<i>Potamochoerus larvatus</i>	Gelib, Somalia	Lower M2	2.065	0.680	2.406	4
MZUF C.3019	<i>Potamochoerus larvatus</i>	Gelib, Somalia	Lower M2	0.866	0.336	2.151	4
MZUF C.3274	<i>Potamochoerus larvatus</i>	Villabruzzi, Somalia	Lower M2	4.974	0.525	1.701	3
MZUF C.3278	<i>Potamochoerus larvatus</i>	Gelib, Somalia	Lower M2	1.055	0.654	3.498	3
MZUF C.3279	<i>Potamochoerus larvatus</i>	Gelib, Somalia	Lower M3	1.361	0.333	4.835	4
MRAC 10193	<i>Potamochoerus larvatus</i>	Lomami, DRC	Lower M2/M3	2.451	1.038	3.248	7
MRAC 14735	<i>Potamochoerus larvatus</i>	Rutshuru, DRC	Lower M2	2.179	1.166	5.204	4
MRAC 18649	<i>Potamochoerus larvatus</i>	Lula river, DRC	Lower M3	2.006	0.345	0.759	4
MRAC 22266	<i>Potamochoerus larvatus</i>	Luiza Territory, DRC	Lower M3	2.059	0.503	2.258	4
MRAC 2699	<i>Potamochoerus larvatus</i>	Zambia	Lower M2	2.224	0.598	2.980	4
MRAC 35414	<i>Potamochoerus larvatus</i>	Kariba, Zimbabwe	Lower M3	4.111	1.096	5.846	8
MRAC 35603	<i>Potamochoerus larvatus</i>	Rugwero, Burundi	Lower M2	1.056	0.469	4.149	4
MRAC 35727	<i>Potamochoerus larvatus</i>	Burundi	Lower M2	2.896	0.702	5.877	4

APPENDIX 1. — Continuation.

Specimen	Taxon	Geographic provenance	Tooth position	Asfc	HAsfc36	epLsar (10 ⁻³)	Number of scans
MRAC 83.006-M-552	<i>Potamochoerus larvatus</i>	Katanga, DRC	Lower M3	2.448	0.500	1.552	3
NMB 12067	<i>Potamochoerus porcus</i>	Ekom, Cameroon	Upper M3	2.602	0.438	5.942	1
NMB 12068	<i>Potamochoerus porcus</i>	Diba, DRC	Upper M2	2.318	0.782	2.452	4
MRAC 13293	<i>Potamochoerus porcus</i>	Malela, DRC	Lower M2	2.074	0.857	2.397	8
MRAC 13294	<i>Potamochoerus porcus</i>	Malela, DRC	Lower M2	1.036	0.859	2.167	4
MRAC 14514	<i>Potamochoerus porcus</i>	Bas Congo, DRC	Lower M2	0.873	0.666	1.588	4
MRAC 14932	<i>Potamochoerus porcus</i>	Lisala, DRC	Lower M2	0.815	0.537	3.368	3
MRAC 15973	<i>Potamochoerus porcus</i>	Manzadi, DRC	Lower M3	1.479	0.506	1.459	8
MRAC 16091	<i>Potamochoerus porcus</i>	Kifuka, DRC	Lower M2	4.421	0.522	3.920	8
MRAC 17388	<i>Potamochoerus porcus</i>	Keseki, DRC	Lower M2	1.860	0.817	3.959	4
MRAC 21342	<i>Potamochoerus porcus</i>	Yokamba, DRC	Lower M2/M3	1.638	0.523	3.334	8
MRAC 5803	<i>Potamochoerus porcus</i>	Mongende, DRC	Lower M3	1.230	0.612	1.991	4
MRAC 83.006-M-0549	<i>Potamochoerus porcus</i>	Tshopo, DRC	Lower M3	1.626	0.480	4.082	7
NMB 12069	<i>Potamochoerus porcus</i>	Batiakuya, DRC	Upper M3	5.772	0.447	1.689	4
NMB 12074	<i>Potamochoerus porcus</i>	Batiakuya, DRC	Upper M2	5.597	0.523	2.466	4
NMB 12073	<i>Potamochoerus porcus</i>	Batiakuya, DRC	Upper M3	1.102	0.483	4.058	2
PALEVOPRIM C-5	<i>Sus scrofa</i>	Paimpont, France	Lower M2	5.777	0.582	4.354	3
PALEVOPRIM C-7A	<i>Sus scrofa</i>	Paimpont, France	Upper M3	1.669	0.377	5.892	5
INRA12	<i>Sus scrofa</i>	Haute-Garonne, France	Lower M3	4.099	0.833	3.616	3
INRA24	<i>Sus scrofa</i>	Haute-Garonne, France	Lower M3	1.637	0.357	2.981	2
INRA28	<i>Sus scrofa</i>	Haute-Garonne, France	Lower M3	10.477	0.713	2.415	4
INRA42B	<i>Sus scrofa</i>	Haute-Garonne, France	Lower M2	2.914	1.669	3.063	3
MRI PAS 1	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	6.930	1.200	1.192	4
MRI PAS 1196	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	9.521	1.270	2.802	3
MRI PAS 1197	<i>Sus scrofa</i>	Białowieża, Poland	Upper M2	3.035	0.539	2.830	4
MRI PAS 12	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	1.930	0.855	3.929	7
MRI PAS 1255	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	1.639	0.499	3.494	4
MRI PAS 1285	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	2.576	0.872	3.173	7
MRI PAS 1287	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	1.474	0.828	1.550	1
MRI PAS 1288	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	2.687	0.711	2.734	4
MRI PAS 16	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	2.210	0.653	4.257	3
MRI PAS 35	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	3.225	0.723	1.409	3
MRI PAS 38	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	1.777	0.630	4.258	4
MRI PAS 39	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	2.711	0.790	3.105	4
MRI PAS 5	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	3.038	0.590	3.413	4
MRI PAS Bor 1 ry	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	2.637	0.851	2.542	3
MRI PAS Bor 2 ry	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	1.079	0.432	1.349	4
MRI PAS Czerlon 470D-1	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	4.041	0.789	4.763	4
MRI PAS Czerlon 470D-2	<i>Sus scrofa</i>	Białowieża, Poland	Lower M2	1.550	0.467	4.725	8
MRI PAS Pod y1	<i>Sus scrofa</i>	Białowieża, Poland	Lower M1	1.667	0.455	1.523	4
MRI PAS Pod y2	<i>Sus scrofa</i>	Białowieża, Poland	Lower M3	6.073	0.946	2.651	4

APPENDIX 2. — List of specimens of *Kolpochoerus* van Hoepen & van Hoepen, 1932 from the Shungura Formation, Lower Omo Valley, Ethiopia, used in this study, as well as their stratigraphic provenance, studied tooth, values of DMT parameters: complexity (**Asfc**), heterogeneity of complexity through 36 cells and anisotropy (**epLsar**), and number of scanned surfaces per specimen.

Specimen	Taxon	Member	Tooth position	Asfc	HAsfc36	epLsar (10 ⁻³)	Number of scans
L 655-2f	<i>Kolpochoerus limnetes</i>	C	Lower M1	0.779	0.429	2.317	8
L 655-2g	<i>K. limnetes</i>	C	Lower M2	1.177	1.087	3.377	4
OMO 349-10014	<i>K. limnetes</i>	C	Upper M2	3.018	0.388	0.877	4
OMO 120-10007	<i>K. limnetes</i>	C	Lower M2	1.701	0.297	1.953	4
OMO 56-10015	<i>K. limnetes</i>	C	Lower M3	1.094	0.532	4.694	8
L 806-10001	<i>K. limnetes</i>	C	Lower M2	1.760	0.561	1.432	4
L 823-10004	<i>K. limnetes</i>	C	Lower M1	2.476	0.449	2.703	8
OMO 156-10005	<i>K. limnetes</i>	C	Upper M3	1.661	0.254	4.240	4
OMO 18/sup-10017	<i>K. limnetes</i>	C	Upper M2	1.894	0.305	1.038	8
OMO 18/sup-10085	<i>K. limnetes</i>	C	Lower M2	4.683	0.360	1.105	8
OMO 349-10006	<i>K. limnetes</i>	C	Upper M3	2.151	0.401	1.951	8
OMO 56-10021	<i>K. limnetes</i>	C	Upper M2	2.763	0.416	3.227	3
L 146-136a	<i>K. limnetes</i>	E	Lower M3	0.687	0.274	1.151	4
L 128-14	<i>K. limnetes</i>	E	Upper M3	0.794	0.513	3.762	2
L 146-46	<i>K. limnetes</i>	E	Lower M3	2.836	0.493	2.231	4
L 185-8	<i>K. limnetes</i>	E	Upper M1	1.629	0.411	0.900	4
L 338/A-1	<i>K. limnetes</i>	E	Upper M3	1.421	0.437	2.429	4
L 5/6-7	<i>K. limnetes</i>	E	Lower M3	0.871	0.467	1.077	8
OMO 166-1973-777	<i>K. limnetes</i>	E	Lower M3	0.705	0.467	4.558	4
OMO 166-1973-778	<i>K. limnetes</i>	E	Upper M2	2.262	0.747	2.541	7
OMO 58-1968-3580	<i>K. limnetes</i>	E	Upper M2	1.681	0.841	2.288	8
OMO 71-1969-215	<i>K. limnetes</i>	E	Lower M3	1.359	0.396	1.261	4
OMO 71-1969-216	<i>K. limnetes</i>	E	Lower M3	1.164	0.451	2.050	4
OMO 71-1969-217	<i>K. limnetes</i>	E	Lower M3	1.362	0.453	1.792	4
OMO 71-1969-218	<i>K. limnetes</i>	E	Lower M3	1.079	0.427	1.502	3
L 398-2260	<i>K. limnetes</i>	F	Upper M2	1.472	0.871	3.979	3
L 747-4	<i>K. limnetes</i>	F	Upper M3	1.655	0.649	1.804	4
OMO 33-1969-326	<i>K. limnetes</i>	F	Lower M3	3.506	0.704	2.026	4
OMO 33-1969-329	<i>K. limnetes</i>	F	Upper M3	1.041	0.439	2.356	2
OMO 33-1974-6603	<i>K. limnetes</i>	F	Lower M2	1.716	0.463	1.248	3
OMO 33-J3-1973-3356	<i>K. limnetes</i>	F	Upper M3	0.705	0.444	0.563	2
OMO 76-1969-248	<i>K. limnetes</i>	F	Upper M3	0.659	0.946	4.054	7
OMO 76-1969-249	<i>K. limnetes</i>	F	Upper M2	0.883	0.692	2.754	4
L 622-14	<i>K. limnetes</i>	Lower G	Lower M2	1.819	0.783	2.609	4
L 627-226	<i>K. limnetes</i>	Lower G	Lower M3	1.131	0.731	3.115	3
L 627-384b	<i>K. limnetes</i>	Lower G	Lower M2	1.069	0.526	3.780	12
L 627-384c	<i>K. limnetes</i>	Lower G	Lower M3	1.965	0.496	6.096	8
OMO 50-1970-1530	<i>K. limnetes</i>	Lower G	Upper M2	1.872	0.560	1.797	7
OMO 114-1972-31	<i>K. limnetes</i>	Lower G	Lower M1	1.088	0.365	1.969	4
OMO 323-10013	<i>K. limnetes</i>	Lower G	Lower M2	2.058	0.409	2.805	8
OMO 323-1976-923	<i>K. limnetes</i>	Lower G	Lower M3	0.826	0.565	2.691	4
OMO 323-1976-943	<i>K. limnetes</i>	Lower G	Upper M2	2.806	0.835	2.701	4
OMO 47-1968-2121	<i>K. limnetes</i>	Lower G	Lower M3	0.879	0.782	5.234	2
OMO 47-1968-2123	<i>K. limnetes</i>	Lower G	Upper M3	2.854	1.072	1.693	3
OMO 47-1968-3553	<i>K. limnetes</i>	Lower G	Lower M2	3.427	0.702	3.274	4
OMO 50/4-10006	<i>K. limnetes</i>	Lower G	Upper M3	2.107	0.383	0.665	4
OMO 75-1969-277	<i>K. limnetes</i>	Lower G	Lower M3	1.027	0.502	5.183	3
OMO 75-1969-284	<i>K. limnetes</i>	Lower G	Upper M1	0.633	0.815	4.194	5
OMO 278-10001	<i>K. limnetes</i>	H	Lower M1	1.072	0.358	1.774	4
OMO 65-1974-1479	<i>K. limnetes</i>	H	Lower M3	1.131	0.514	3.625	4
OMO VE 3-10051	<i>K. limnetes</i>	H	Upper M3	5.425	0.463	1.408	4
OMO VE 3-10093	<i>K. limnetes</i>	H	Lower M3	2.275	0.329	1.799	4
OMO 354-10004	<i>K. limnetes</i>	J	Lower M3	1.701	0.357	4.979	4
OMO 361-10020	<i>K. limnetes</i> or <i>K. aff. paiceae</i>	J	Lower M2	2.517	0.378	1.750	8
P 994-11c	<i>K. aff. paiceae</i>	J	Lower M2	0.816	0.631	1.919	3
P 994-87	<i>K. aff. paiceae</i>	J	Lower M2	1.976	0.306	1.261	4
OMO 340-10066	<i>K. aff. paiceae</i>	L	Upper M3	1.897	0.376	0.512	2
OMO 341-10003	<i>K. aff. paiceae</i>	L	Lower M3	0.898	0.504	1.858	4
OMO 341-10021	<i>K. aff. paiceae</i>	L	Lower M1	1.031	0.383	1.873	7
OMO 342-10045	<i>K. aff. paiceae</i>	L	Lower M2	1.371	0.463	1.933	4
OMO 342-10170	<i>K. aff. paiceae</i>	L	Lower M2	5.003	0.621	1.912	4
OMO 342-10400	<i>K. aff. paiceae</i>	L	Lower M2	1.393	0.429	2.521	8
OMO 346-10019	<i>K. aff. paiceae</i>	L	Upper M3	2.435	0.487	1.419	4
OMO 346-10028	<i>K. aff. paiceae</i>	L	Lower M3	2.669	0.732	1.850	4
OMO 346-10037	<i>K. aff. paiceae</i>	L	Upper M2	1.734	0.554	2.712	4
OMO 355-10134	<i>K. aff. paiceae</i>	L	Lower M3	2.117	0.483	3.992	4
OMO 376-10010	<i>K. aff. paiceae</i>	L	Upper M3	1.319	0.798	3.017	4
OMO 377-10114	<i>K. aff. paiceae</i>	L	Upper M3	2.116	0.486	1.223	4

APPENDIX 3. — Non-parametric Kruskal-Wallis tests for each SSFA parameter between studied tooth position within extant suid taxa.

	Df	χ^2	p
<i>Hylochoerus</i>			
Asfc	2	6.11	0.05
epLsar	2	2.40	0.30
HAsfc36	2	5.03	0.08
<i>Phacochoerus</i>			
Asfc	3	3.01	0.39
epLsar	3	2.06	0.56
HAsfc36	3	0.92	0.82
<i>Potamochoerus</i>			
Asfc	3	5.34	0.15
epLsar	3	2.33	0.51
HAsfc36	3	6.13	0.11
<i>Sus</i>			
Asfc	4	2.05	0.73
epLsar	4	4.37	0.36
HAsfc36	4	5.81	0.21

APPENDIX 4. — Photosimulations and false color elevation maps on dental wear facets of extant suids. Available at: https://doi.org/10.5852/cr-palevol2025v24a7_s1

APPENDIX 5. — Photosimulations and false color elevation maps on dental wear facets of *Kolpochoerus* van Hoepen & van Hoepen, 1932. Available at: https://doi.org/10.5852/cr-palevol2025v24a7_s2

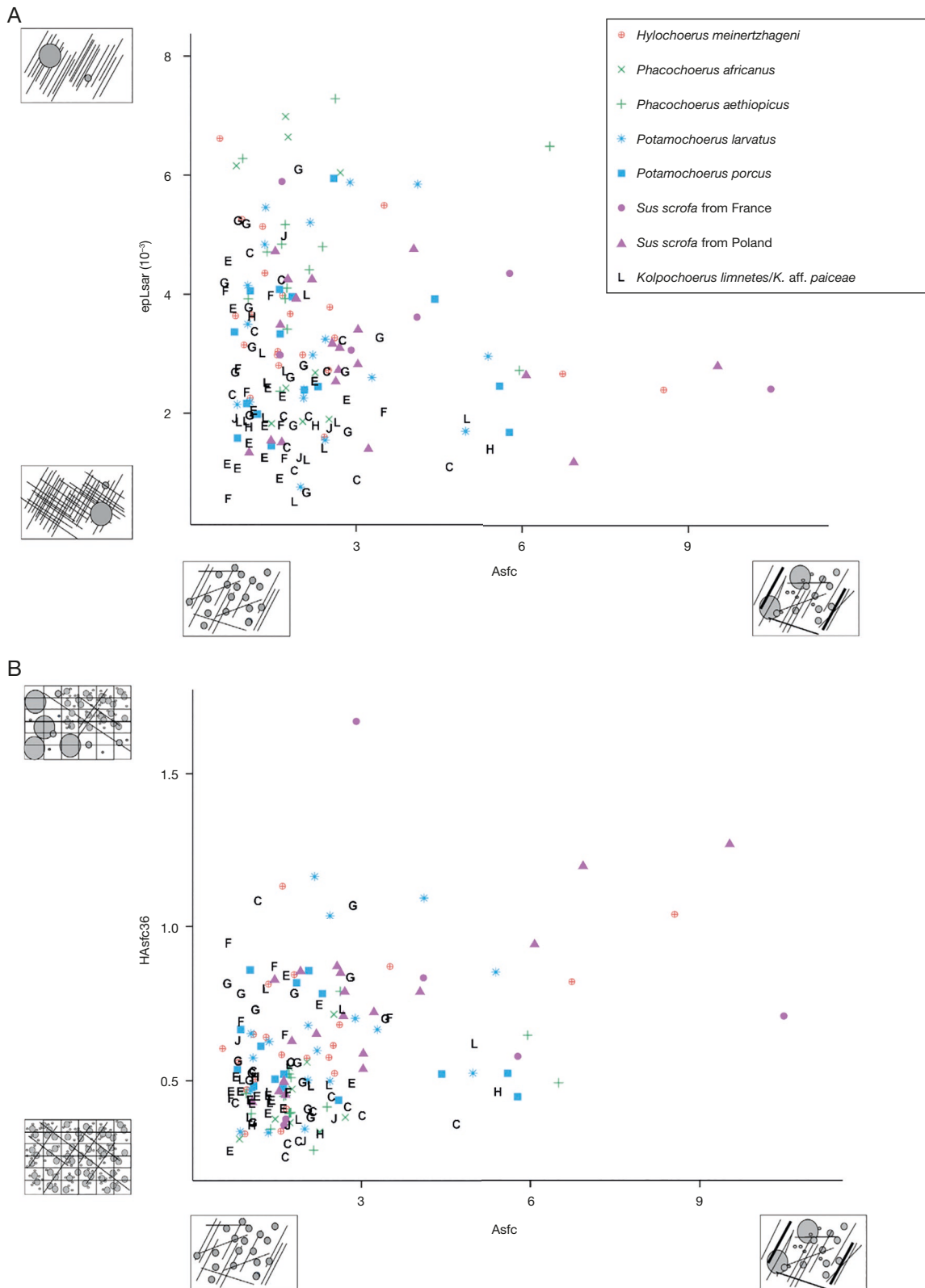
APPENDIX 6. — Analyses of variance (one-ways ANOVAs) on SSFA parameters Asfc (complexity), HAsfc9 (heterogeneity of complexity through 9 cells), HAsfc36 (heterogeneity of complexity through 36 cells) and HAsfc81 (heterogeneity of complexity through 81 cells) measured on shearing facets of molars of extant suids and *Kolpochoerus* from the Shungura Formation by members. Abbreviations: **Df**, degrees of freedom; **F**, F statistic; **MS**, mean sum of squares due to the source; **p**, p-value; **SS**, sum of squares.

		Df	SS	MS	F	p
Asfc	Effect	10	1.872	0.187	2.937	2.080e-3
	Residuals	159	10.136	0.064		
HAsfc9	Effect	10	0.104	0.010	4.471	1.460e-5
	Residuals	159	0.368	0.002		
HAsfc36	Effect	10	0.271	0.027	5.309	9.740e-7
	Residuals	159	0.813	0.005		
HAsfc81	Effect	10	0.446	0.045	5.283	1.060e-6
	Residuals	159	1.341	0.008		

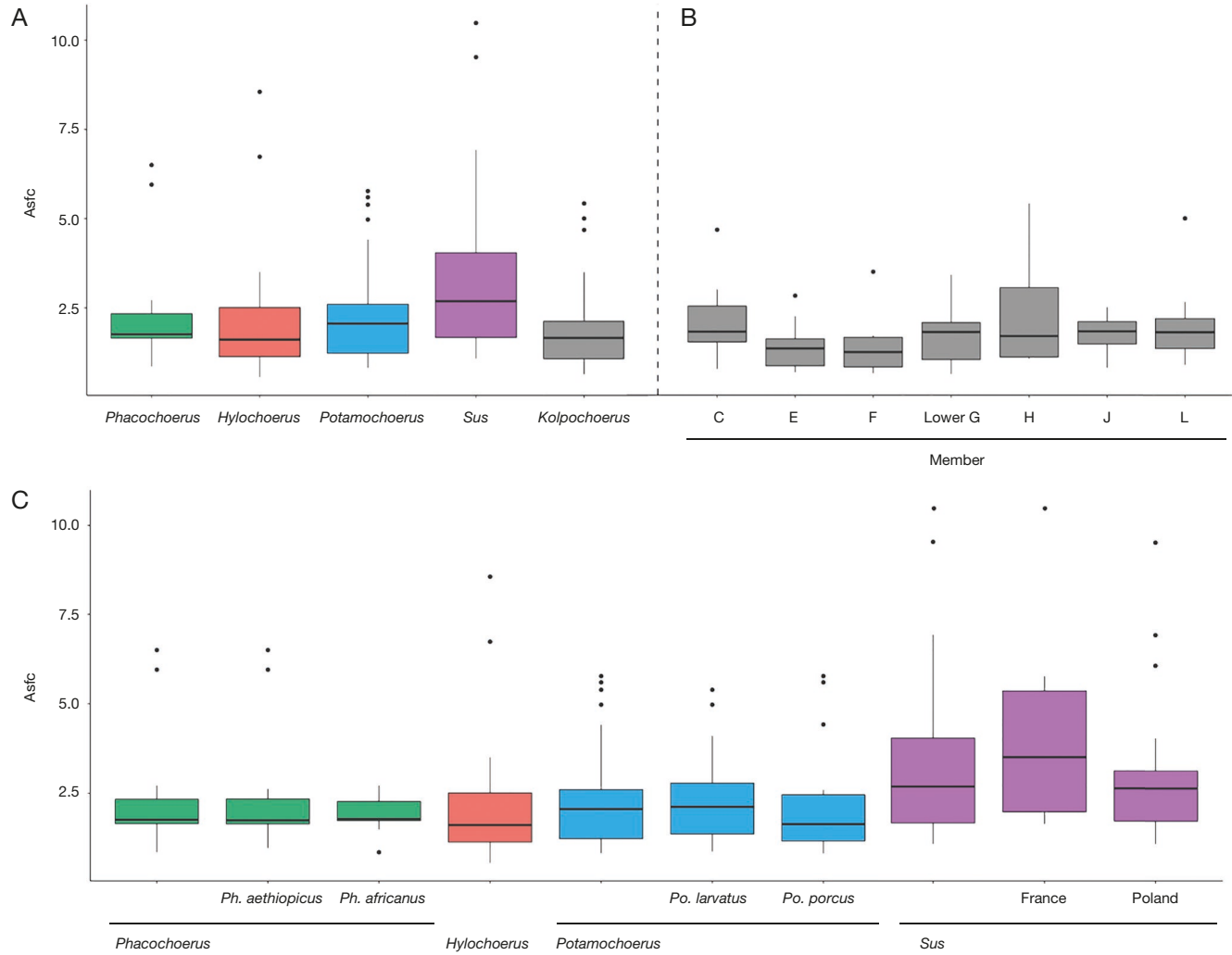
APPENDIX 7. — Descriptive statistics (mean; **SD**, standard deviation; median; **Q1**, first quartile; **Q3**, third quartile, range) on extant suid species.

	Extant									
	<i>Hylochoerus</i> (N = 21)	<i>Phacochoerus</i> (N = 23)	<i>Ph. africanus</i> (N = 9)	<i>Ph. aethiopicus</i> (N = 14)	<i>Potamochoerus</i> (N = 33)	<i>Po. porcus</i> (N = 15)	<i>Po. larvatus</i> (N = 18)	<i>Sus</i> (N = 25)	<i>Sus</i> from France (N = 6)	<i>Sus</i> from Poland (N = 19)
Asfc										
Mean	2.260	2.196	1.905	2.383	2.344	2.296	2.383	3.455	4.429	3.147
(SD)	(1.948)	(1.365)	(0.565)	(1.692)	(1.453)	(1.642)	(1.324)	(2.478)	(3.353)	(2.156)
Median	1.612	1.760	1.782	1.746	2.059	1.638	2.122	2.687	3.507	2.637
(Q1, Q3)	(1.134, 2.509)	(1.651, 2.335)	(1.735, 2.270)	(1.643, 2.341)	(1.230, 2.602)	(1.166, 2.460)	(1.365, 2.785)	(1.669, 4.041)	(1.981, 5.357)	(1.722, 3.132)
Range	0.553-8.549	0.852-6.499	0.852-2.721	0.966-6.499	0.815-5.772	0.815-5.772	0.866-5.389	1.079-10.477	1.637-10.477	1.079-9.521
epLsar (x10⁻³)										
Mean	3.594	4.390	4.059	4.603	3.168	2.992	3.316	3.121	3.720	2.932
(SD)	(1.212)	(1.773)	(2.305)	(1.388)	(1.417)	(1.245)	(1.567)	(1.197)	(1.250)	(1.149)
Median	3.269	4.414	2.684	4.562	2.964	2.466	2.972	3.063	3.340	2.830
(Q1, Q3)	(2.806, 3.979)	(2.707, 6.098)	(1.904, 6.156)	(3.925, 5.087)	(2.167, 4.058)	(2.079, 3.940)	(2.210, 4.664)	(2.542, 3.929)	(3.001, 4.170)	(2.046, 3.712)
Range	1.606-6.614	1.832-7.282	1.832-6.982	2.372-7.282	0.759-5.942	1.459-5.942	0.759-5.877	1.192-5.892	2.415-5.892	1.192-4.763
HAsfc36										
Mean	0.647	0.462	0.452	0.468	0.628	0.604	0.648	0.745	0.755	0.742
(SD)	(0.210)	(0.127)	(0.133)	(0.128)	(0.209)	(0.153)	(0.249)	(0.300)	(0.485)	(0.234)
Median	0.605	0.451	0.382	0.452	0.575	0.523	0.613	0.713	0.647	0.723
(Q1, Q3)	(0.525, 0.813)	(0.379, 0.517)	(0.365, 0.544)	(0.396, 0.506)	(0.500, 0.702)	(0.494, 0.724)	(0.500, 0.697)	(0.539, 0.851)	(0.428, 0.803)	(0.565, 0.853)
Range	0.329-1.134	0.276-0.790	0.312-0.715	0.276-0.790	0.333-1.166	0.438-0.859	0.333-1.166	0.357-1.669	0.357-1.669	0.432-1.270
HAsfc9										
Mean	0.477	0.352	0.0.319	0.0.374	0.453	0.444	0.461	0.546	0.559	0.543
(SD)	(0.132)	(0.128)	(0.102)	(0.142)	(0.168)	(0.131)	(0.197)	(0.280)	(0.422)	(0.234)
Median	0.455	0.306	0.285	0.348	0.407	0.402	0.421	0.483	0.438	0.505
(Q1, Q3)	(0.422, 0.515)	(0.282, 0.415)	(0.245, 0.421)	(0.300, 0.402)	(0.343, 0.523)	(0.370, 0.545)	(0.332, 0.500)	(0.362, 0.617)	(0.297, 0.583)	(0.368, 0.611)
Range	0.246-0.724	0.201-0.768	0.201-0.470	0.203-0.768	0.240-0.864	0.240-0.678	0.240-0.864	0.224-1.369	0.224-1.369	0.316-1.227
HAsfc81										
Mean	0.813	0.576	0.557	0.588	0.576	0.789	0.834	0.958	0.951	0.960
(SD)	(0.269)	(0.153)	(0.172)	(0.145)	(0.285)	(0.217)	(0.336)	(0.378)	(0.576)	(0.314)
Median	0.744	0.530	0.496	0.565	0.719	0.684	0.756	0.901	0.825	0.972
(Q1, Q3)	(0.690, 0.977)	(0.471, 0.629)	(0.434, 0.612)	(0.490, 0.630)	(0.641, 0.999)	(0.645, 0.909)	(0.633, 0.981)	(0.693, 1.121)	(0.569, 1.031)	(0.744, 1.132)
Range	0.400-1.386	0.371-0.907	0.374-0.875	0.371-0.907	0.387-1.499	0.529-1.279	0.387-1.499	0.451-2.024	0.451-2.024	0.481-1.598

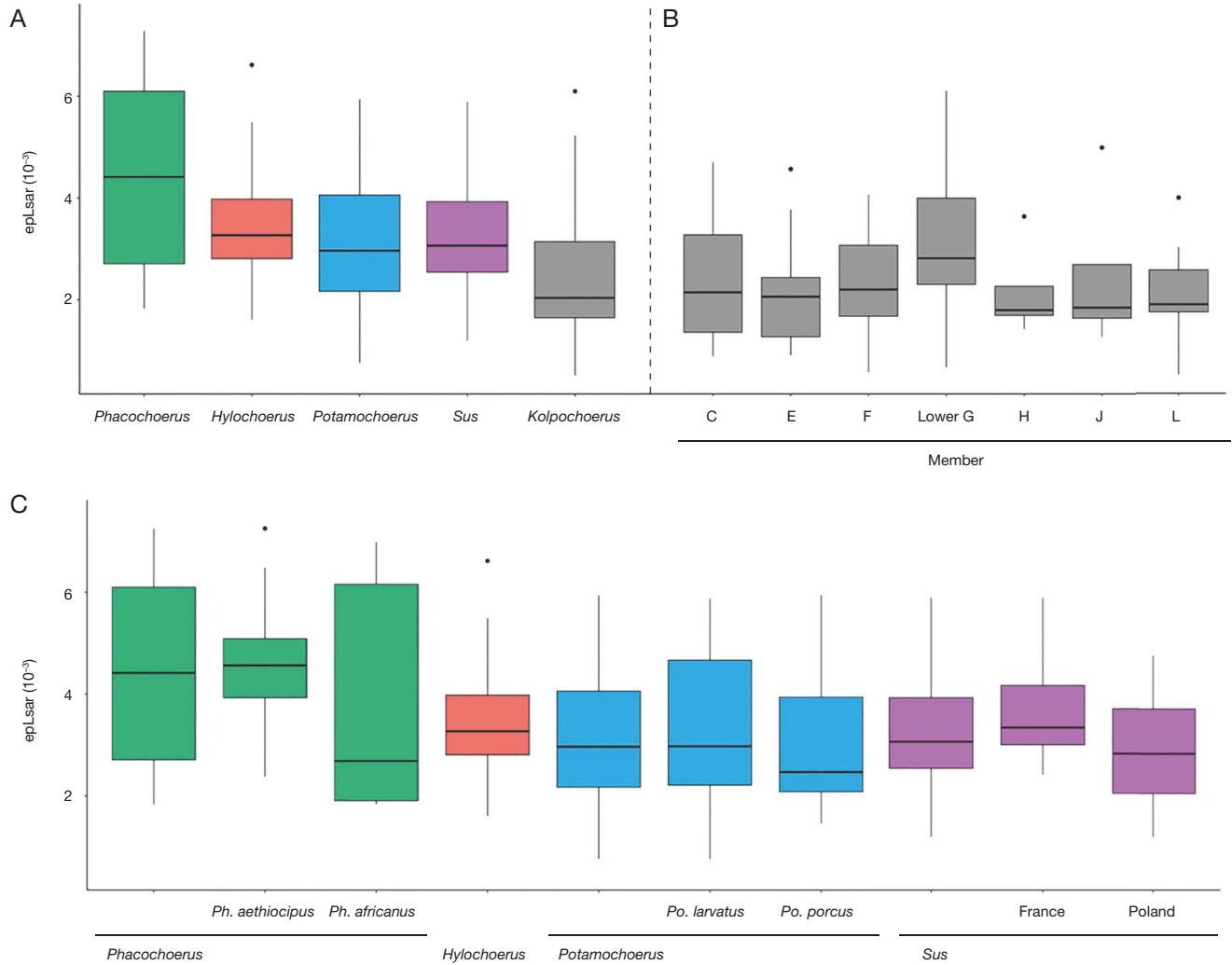
APPENDIX 8. — Biplots of SSFA parameters on extant *Phacochoerus* F.Cuvier, 1826 (green), *Hylochoerus* Thomas, 1904 (orange circle plus), *Potamochoerus* Gray, 1854 (blue), *Sus* Linnaeus, 1758 (pink) and *Kolpochoerus* van Hoepen & van Hoepen, 1932 (black) showing individual data points. Different shapes represent inter- and intra-specific variations within extant genera: *Ph. aethiopicus* (Pallas, 1766) (plus), *Ph. africanus* (Gmelin, 1788) (cross), *Po. larvatus* (F.Cuvier, 1822) (asterisk), *Po. porcus* (Linnaeus, 1758) (square), *S. scrofa* Linnaeus, 1758 from Poland (triangle), *S. scrofa* Linnaeus, 1758 from France (circle). Letters indicate specimens of *Kolpochoerus* by Member: **A**, biplot of complexity (Asfc) and anisotropy (epLsar); **B**, biplot of complexity (Asfc) and heterogeneity of complexity (HAsfc36).



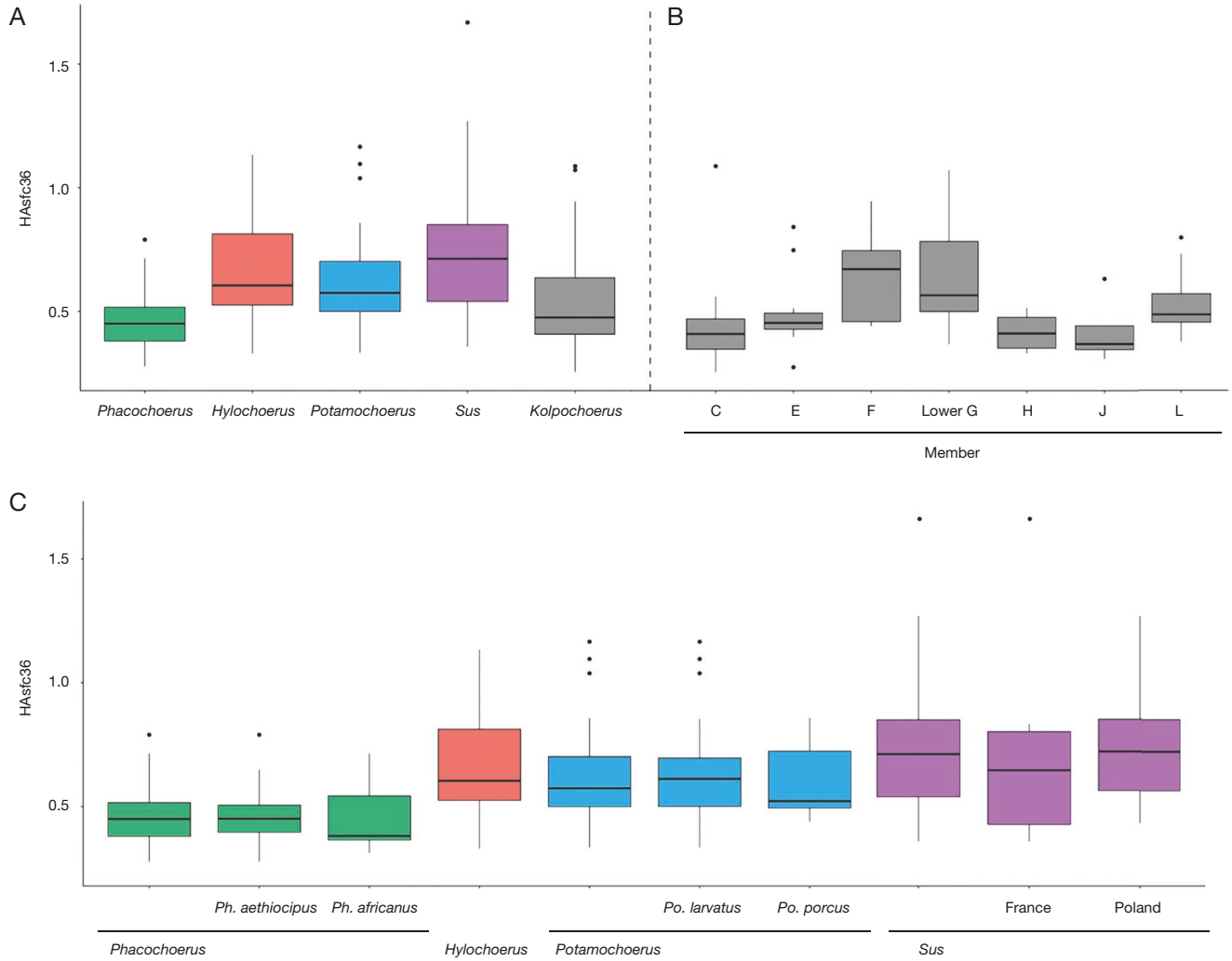
APPENDIX 9. — Boxplots of complexity (**Asfc**) for: **A**, extant suid genera *Phacochoerus* F.Cuvier, 1826, *Hylochoerus* Thomas, 1904, *Potamochoerus* Gray, 1854, *Sus* Linnaeus, 1758 and *Kolpochoerus* van Hoepen & van Hoepen, 1932 from the Shungura Formation (all members); **B**, *Kolpochoerus* from the different members of the Shungura Formation; **C**, extant suid genera and species or populations: *Phacochoerus* F.Cuvier, 1826 (both species), *Ph. aethiopicus* (Pallas, 1766), *Ph. africanus* (Gmelin, 1788), *Hylochoerus* Thomas, 1904, *Potamochoerus* (both species), *Po. larvatus* (F.Cuvier, 1822), *Po. porcus* (Linnaeus, 1758), *Sus* Linnaeus, 1758 (both populations), *Sus* from France and *Sus* from Poland. Boxplots indicate the median value, first and third quartiles, minimum and maximum values (if less than 1.5 times the interquartile range under the first quartile/above the third quartile) and outliers (if more than 1.5 times the interquartile range under the first quartile/above the third quartile).



APPENDIX 10. — Boxplots of anisotropy (epLsar) for: **A**, extant suid genera *Phacochoerus* F.Cuvier, 1826, *Hylochoerus* Thomas, 1904, *Potamochoerus* Gray, 1854, *Sus* Linnaeus, 1758 and *Kolpochoerus* van Hoepen & van Hoepen, 1932 from the Shungura Formation (all members); **B**, *Kolpochoerus* from the different members of the Shungura Formation; **C**, extant suid genera and species or populations: *Phacochoerus* F.Cuvier, 1826 (both species), *Ph. aethiopicus* (Pallas, 1766), *Ph. africanus* (Gmelin, 1788), *Hylochoerus* Thomas, 1904, *Potamochoerus* Gray, 1854 (both species), *Po. larvatus* (F.Cuvier, 1822), *Po. porcus* (Linnaeus, 1758), *Sus* Linnaeus, 1758 (both populations), *Sus* from France and *Sus* from Poland. Boxplots indicate the median value, first and third quartiles, minimum and maximum values (if less than 1.5 times the interquartile range under the first quartile/above the third quartile) and outliers (if more than 1.5 times the interquartile range under the first quartile/above the third quartile).



APPENDIX 11. — Boxplots of heterogeneity of complexity (HAsfc36) for: **A**, extant suid genera *Phacochoerus* F.Cuvier, 1826, *Hylochoerus* Thomas, 1904, *Potamochoerus* Gray, 1854, *Sus* Linnaeus, 1758 and *Kolpochoerus* van Hoepen & van Hoepen, 1932 from the Shungura Formation (all members); **B**, *Kolpochoerus* from the different members of the Shungura Formation; **C**, extant suid genera and species or populations: *Phacochoerus* (both species), *Ph. aethiopicus* (Pallas, 1766), *Ph. africanus* (Gmelin, 1788), *Hylochoerus* Thomas, 1904, *Potamochoerus* Gray, 1854 (both species), *Po. larvatus* (F.Cuvier, 1822), *Po. porcus* (Linnaeus, 1758), *Sus* (both populations), *Sus* from France and *Sus* from Poland. Boxplots indicate the median value, first and third quartiles, minimum and maximum values (if less than 1.5 times the interquartile range under the first quartile/above the third quartile) and outliers (if more than 1.5 times the interquartile range under the first quartile/above the third quartile).



APPENDIX 12. — Combined HSD (above diagonal) and LSD (below diagonal) post-hoc tests following one-way ANOVAs on SSFA parameter Asfc (complexity). P-values below a 10 % level of significance are given for HSD and LSD tests.

Asfc	Extant				Kolpochoerus						
	Hylochoerus	Phacochoerus	Potamochoerus	Sus	C	E	F	Lower G	H	J	L
Extant											
Hylochoerus											
Phacochoerus											
Potamochoerus											
Sus	0.0048	0.0270	0.0186			0.0011	0.0117	0.0273			
Kolpochoerus											
C				0.0475							
E	0.0678			0.0000	0.0487						
F		0.0356		0.0003	0.0766						
Lower G			0.0090	0.0007							
H			0.0262								
J				0.0719							
L				0.0261		0.0790					

APPENDIX 13. — Combined HSD (above diagonal) and LSD (below diagonal) post-hoc tests following one-way ANOVAs on SSFA parameter HAsfc36 (heterogeneity of complexity through 36 cells). P-values below a 10 % level of significance are given.

HAsfc36	Extant				Kolpochoerus						
	Hylochoerus	Phacochoerus	Potamochoerus	Sus	C	E	F	Lower G	H	J	L
Extant											
Hylochoerus											
Phacochoerus											
Potamochoerus											
Sus	0.0006	0.0262	0.0239	0.0002	0.0246			0.0984			
Kolpochoerus											
C				0.0007				0.0702			
E	0.0006			0.0006							
F		0.0074			0.0041	0.0426					
Lower G		0.0030			0.0020	0.0346					
H	0.0145		0.0193	0.0021			0.0226	0.0222			
J	0.0098		0.0131	0.0013			0.0162	0.0155			
L				0.0106	0.0891						

APPENDIX 14. — Alternative non-parametric Kruskal-Wallis test for the SSFA parameter epLsar (anisotropy) measured on shearing facets of molars of extant suids and *Kolpochoerus* from the Shungura Formation by members.

	Df	χ^2	p
epLsar	10	36.444	7.060e-5

APPENDIX 15. — Alternative Dunn's test on the SSFA parameter epLsar (anisotropy) following the Kruskal-Wallis test.

epLsar	Extant				Kolpochoerus						
	Hylochoerus	Phacochoerus	Potamochoerus	Sus	C	E	F	Lower G	H	J	L
Extant											
Hylochoerus											
Phacochoerus											
Potamochoerus		0.007									
Sus		0.016									
Kolpochoerus											
C	0.007	0.001									
E	0.001	0.000	0.009	0.008							
F	0.015	0.002									
Lower G						0.016					
H	0.016	0.004									
J		0.011									
L	0.001	0.000	0.012	0.011				0.019			

APPENDIX 16. — Analyses of variance (one-ways ANOVAs) on SSFA parameters Asfc (complexity), epLsar (anisotropy) and HAsfc36 (heterogeneity of complexity through 36 cells) measured on shearing facets of molars of extant suid samples *Hylochoerus* Thomas, 1904, *Ph africanus* (Gmelin, 1788), *Ph aethiopicus* (Pallas, 1766), *Po. larvatus* (F.Cuvier, 1822), *Po. porcus* (Linnaeus, 1758), and the two populations of boars from Poland and France.

		Df	SS	MS	F	p
Asfc	Effect	6	0.705	0.118	1.787	0.110
	Residuals	95	6.250	0.066		
epLsar	Effect	6	3.072e-5	5.120e-6	2.550	0.025
	Residuals	95	1.907e-4	2.008e-6		
HAsfc36	Effect	6	0.164	0.027	4.142	9.700e-4
	Residuals	95	0.626	0.007		

APPENDIX 17. — Combined HSD (above diagonal) and LSD (below diagonal) post-hoc tests following one-way ANOVAs on SSFA parameter epLsar (anisotropy) measured on extant suid samples *Hylochoerus* Thomas, 1904, *Phacochoerus africanus* (Gmelin, 1788), *Ph. aethiopicus* (Pallas, 1766), *Potamochoerus larvatus* (F. Cuvier, 1822), *Po. porcus* (Linnaeus, 1758), and the two populations of boars from Poland and France. P-values below a 10 % level of significance are given for HSD and LSD tests.

epLsar	<i>Hylochoerus meinertzhageni</i>	<i>Ph. africanus</i>	<i>Ph. aethiopicus</i>	<i>Po. larvatus</i>	<i>Po. porcus</i>	<i>Sus scrofa</i> from Poland	<i>Sus scrofa</i> from France
<i>Hylochoerus meinertzhageni</i>							
<i>Ph. africanus</i>							
<i>Ph. aethiopicus</i>	0.042						
<i>Po. larvatus</i>			0.013				
<i>Po. porcus</i>		0.079	0.003				
<i>Sus scrofa</i> from Poland		0.053	0.001		0.045		
<i>Sus scrofa</i> from France						0.020	

APPENDIX 18. — Combined HSD (above diagonal) and LSD (below diagonal) post-hoc tests following one-way ANOVAs on SSFA parameter HAsfc36 (heterogeneity of complexity through 36 cells) measured on extant suid samples *Hylochoerus* Thomas, 1904, *Phacochoerus africanus* (Gmelin, 1788), *Ph. aethiopicus* (Pallas, 1766), *Potamochoerus larvatus* (F. Cuvier, 1822), *Po. porcus* (Linnaeus, 1758), and the two populations of boars from Poland and France. P-values below a 10 % level of significance are given.

HAsfc36	<i>Hylochoerus meinertzhageni</i>	<i>Ph. africanus</i>	<i>Ph. aethiopicus</i>	<i>Po. larvatus</i>	<i>Po. porcus</i>	<i>Sus scrofa</i> from Poland	<i>Sus scrofa</i> from France
<i>Hylochoerus meinertzhageni</i>		0.090	0.082				
<i>Ph. africanus</i>	0.007					0.005	
<i>Ph. aethiopicus</i>	0.006					0.003	
<i>Po. larvatus</i>		0.013	0.013				
<i>Po. porcus</i>		0.022	0.025				
<i>Sus scrofa</i> from Poland		0.029	0.037				
<i>Sus scrofa</i> from France		0.000	0.000				

APPENDIX 19. — Comparison of summary statistics (number of specimens “n”, mean, median, standard deviation “SD”) of DMTA parameters complexity (Asfc), anisotropy (epLsar) and heterogeneity (HAsfc9, HAsfc36 and HAsfc81) on extant suids between (1) Souron *et al.* (2015), (2) Lazagabaster (2019) and this study. Methodological approaches: (1) interferometry-based microscope, 50× objective, Toothfrax module; (2) confocal profilometer, 100× objective, Toothfrax module; this study used confocal profilometer, 100× objective, MountainsMap module.

		Asfc			epLsar			HAsfc9			HAsfc36		HAsfc81		
		(1)	(2)	This study	(1)	(2)	This study	(1)	(2)	This study	This study	(1)	(2)	This study	
<i>Hylochoerus meinertzhageni</i>	<i>n</i>	5	3	21	–	–	–	–	–	–	–	–	–	–	
	Median	1.76	1.33	1.61	4.09	6.5	3.27	0.84	0.71	0.46	0.61	1.00	2.34	0.74	
	Mean	1.71	1.40	2.26	4.81	6.4	3.59	0.83	0.66	0.48	0.65	1.34	4.31	0.81	
	SD	0.89	0.24	1.95	2.97	0.6	1.21	0.49	0.41	0.13	0.21	0.72	4.14	0.27	
<i>Phacochoerus spp.</i>	<i>n</i>	–	18	23	–	–	–	–	–	–	–	–	–	–	
	Median	–	1.73	1.76	–	4.4	4.41	–	0.44	0.31	0.45	–	0.58	0.53	
	Mean	–	1.73	2.2	–	4.6	4.39	–	0.62	0.35	0.46	–	1.33	0.58	
	SD	–	0.57	1.37	–	1.4	1.77	–	0.49	0.13	0.13	–	1.50	0.15	
<i>Phacochoerus africanus</i>	<i>n</i>	14	–	9	–	–	–	–	–	–	–	–	–	–	
	Median	1.80	–	1.78	3.82	–	2.68	0.22	–	0.29	0.38	0.46	–	0.50	
	Mean	2.12	–	1.91	4.09	–	4.06	0.44	–	0.32	0.45	0.72	–	0.56	
	SD	1.55	–	0.57	2.39	–	2.31	0.66	–	0.01	0.13	1.03	–	0.17	
<i>Phacochoerus aethiopicus</i>	<i>n</i>	–	–	14	–	–	–	–	–	–	–	–	–	–	
	Median	–	–	1.75	–	–	4.56	–	–	0.35	0.45	–	–	0.56	
	Mean	–	–	2.38	–	–	4.06	–	–	0.37	0.47	–	–	0.59	
	SD	–	–	1.69	–	–	1.39	–	–	0.14	0.13	–	–	0.15	
<i>Potamochoerus spp.</i>	<i>n</i>	18	–	33	–	–	–	–	–	–	–	–	–	–	
	Median	3.18	–	2.06	2.64	–	2.96	0.32	–	0.41	0.58	0.53	–	0.72	
	Mean	3.03	–	2.34	3.34	–	3.17	0.71	–	0.45	0.63	0.98	–	0.81	
	SD	1.18	–	1.45	1.84	–	1.42	0.89	–	0.17	0.21	1.04	–	0.28	
<i>Potamochoerus larvatus</i>	<i>n</i>	–	23	18	–	–	–	–	–	–	–	–	–	–	
	Median	–	4.04	2.12	–	2.3	2.97	–	0.21	0.42	0.61	–	0.43	0.76	
	Mean	–	5.24	2.38	–	2.6	3.32	–	0.43	0.46	0.65	–	1.79	0.83	
	SD	–	3.93	1.32	–	1.1	1.57	–	0.45	0.02	0.25	–	2.68	0.34	
<i>Potamochoerus porcus</i>	<i>n</i>	–	6	15	–	–	–	–	–	–	–	–	–	–	
	Median	–	8.46	1.64	–	1.1	2.47	–	0.98	0.04	0.52	–	2.88	0.68	
	Mean	–	9.07	2.3	–	1.2	2.99	–	1.28	0.44	0.06	–	4.08	0.79	
	SD	–	3.35	1.64	–	0.6	1.25	–	0.88	0.13	0.15	–	2.80	0.22	
<i>Sus scrofa</i>	<i>n</i>	27	–	25	–	–	–	–	–	–	–	–	–	–	
	Median	2.84	–	2.69	2.74	–	3.06	0.38	–	0.48	0.71	0.58	–	0.90	
	Mean	3.57	–	3.46	2.81	–	3.12	0.52	–	0.55	0.75	0.97	–	0.96	
	SD	2.49	–	2.48	1.33	–	1.2	0.50	–	0.28	0.03	0.86	–	0.38	