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1 **Chemical evidence of dairying by hunter-gatherers in highland Lesotho in the**
2 **late 1st millennium AD**

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16 **Abstract**

17 The recovery of Early Iron Age (EIA) artefacts and domestic animal remains from hunter-gatherer
18 contexts at Likoaeng, Lesotho, has been argued to indicate contact between highland hunter-gatherers
19 and EIA agropastoralist communities settled in lowland areas of south-eastern Africa during the second
20 half of the first millennium AD. However, disagreement between archaeozoological studies and ancient
21 DNA means that the possibility that those hunter-gatherers kept livestock themselves remains
22 controversial. Here we report analyses of pottery-absorbed organic residues from two hunter-gatherer
23 and one agriculturalist sites in highland Lesotho to reconstruct prehistoric subsistence practices. Our
24 results demonstrate the exploitation of secondary products from domestic livestock by hunter-gatherers
25 in Lesotho, directly dated to the seventh century AD at Likoaeng and the tenth century AD at the nearby
26 site of Sehonghong. The data provide compelling evidence for the keeping of livestock by hunter-
27 gatherer groups and their likely incorporation as ancillary resources into their subsistence strategies.

28

29 Introduction

30 Early Iron Age (EIA) populations who combined cereal and legume cultivation with livestock-keeping and
31 almost certainly spoke Bantu languages began settling in southernmost Africa from the third century AD,
32 initially focusing on the Woodland Savanna Biome of the region's summer rainfall zone¹⁻³. Only in the
33 early centuries of the second millennium AD did they begin to penetrate the grassland areas of Gauteng
34 or northern KwaZulu-Natal, and effective occupation of the Highveld of the Free State and western
35 Lesotho was not established until the seventeenth century. In contrast, the Maloti-Drakensberg
36 Mountains of the remainder of Lesotho and the upland areas to its east along the uKhahlamba-
37 Drakensberg Escarpment remained the domain of hunter-gatherer groups until the nineteenth century
38 and the earliest farming villages along the upper portions of Lesotho's Senqu River (Fig. 1a) were not
39 established until 1878⁴. Despite their geographical separation, rock art and historical accounts have long
40 been cited as evidence of prolonged contact between Maloti-Drakensberg hunter-gatherers and
41 agricultural populations in neighbouring areas⁵⁻¹⁰. On the farmer side of this equation, linguistic and
42 cultural borrowings among both Nguni and South Sotho speakers attest to such contacts¹¹⁻¹³, as do more
43 recent genetic studies that point to considerable admixture between hunter-gatherers and Bantu-
44 speaking agropastoralist groups in south-eastern Africa¹⁴⁻¹⁷.

45 At Likoaeng in the highlands of Lesotho (Fig. 1), excavations in the 1990s uncovered remains in Layer 1
46 of domestic sheep and cattle, a few fragments of iron and a single decorated EIA potsherd from a
47 context securely radiocarbon dated (on bone, charcoal and iron) to the second half of the first
48 millennium AD (Table 1)¹⁸. Other aspects of the assemblage suggest that this was otherwise an
49 exclusively hunter-gatherer site, comparable to others known in the region. The rest of the pottery, for
50 example, falls into a class of thin-walled (mean thickness ~6–8 mm), almost invariably grey to black, grit-
51 tempered and undecorated ceramics found in multiple hunter-gatherer contexts elsewhere in highland
52 Lesotho and across the uKhahlamba-Drakensberg Escarpment in KwaZulu-Natal and the Eastern Cape

53 Province^{19,20}. Associated stone and bone artefacts, which include scrapers, adzes and
54 arrowpoint/linkshaft fragments, are also typical of such sites and fall within the well-known Final Later
55 Stone Age (post-classic Wilton) complex²¹⁻²⁴. Contemporary EIA pottery, on the other hand, is thick-
56 walled (mean thickness >10 mm), often decorated, and generally oxidised, rather than reduced,
57 characteristics only matched by the one EIA sherd already mentioned³. Collectively, this evidence
58 suggested contact between highland hunter-gatherers and agropastoralists in the lowlands of KwaZulu-
59 Natal on a scale sufficient to account for the presence of domestic livestock within the Senqu Valley, a
60 millennium or more before they are otherwise attested there. Isolated events such as raiding, trade or
61 even hunter-gatherer care for agropastoralists' livestock were deemed unlikely given the distance to the
62 nearest known EIA village (>150 km over rugged terrain), the ready availability of pasture within
63 KwaZulu-Natal and the 3000-m high barrier of the uKhahlamba-Drakensberg Escarpment that intervenes
64 between it and Likoaeng (Fig. 1a)^{21,23}. It was therefore suggested that the Layer 1 assemblage might
65 support the 'hunters-with-sheep' hypothesis previously proposed by Sadr^{25,26} with respect to the
66 Western Cape Province of southern Africa whereby some hunter-gatherer groups successfully acquired
67 livestock from food-producers and incorporated them as ancillary resources into their own subsistence
68 strategies.

69 Likoaeng is not alone in its evidence for contact between Maloti-Drakensberg hunter-gatherers and
70 agropastoralists. A domestic sheep mandible excavated from Melikane, 40 km south of Likoaeng (Fig.
71 1a), is stratigraphically associated with a date of cal AD 545 – 656 (95.4% probability: Pta-1364: 1450 ±
72 40 BP)³². Much closer to Likoaeng (Fig. 1b), two rockshelters — Sehonghong³³ and the nearby site of
73 Pitsaneng³⁴ — have both produced faunal remains identified as domestic sheep and cattle in layers
74 dating to the first and second millennia AD, implying that hunter-gatherer possession of livestock may
75 have been a recurrent, rather than a temporally isolated, phenomenon³⁵. The story remains contentious
76 however, with recently published archaeogenetic studies arguing that the presence of domestic species

77 in hunter-gatherer contexts in southern Africa has been over-estimated^{27,36,37}. At both Blydefontein in
78 South Africa's Eastern Cape Province and at Sehonghong in Lesotho, analysis of the ancient DNA of
79 faunal remains morphologically identified as domestic species has instead identified the genetic
80 signatures of wild species, leading to the conclusion that previous morphological analyses are
81 incorrect^{27,36,37}. Although these claims have been refuted by the zooarchaeologist involved in the original
82 analysis³⁸, debate over the relative merits of morphological analysis *versus* molecular analysis
83 continues³⁹⁻⁴². Thus far, however, there has been no biochemical evidence to support the long-term
84 exploitation of domestic species by hunter-gatherer groups in the Lesotho highlands.

85 In recent decades, lipid residue analysis of archaeological pottery has become a core tool for exploring
86 ancient diet. Gas chromatography (GC), GC-mass spectrometry (GC-MS) and compound-specific stable
87 carbon isotope analysis allow differentiation between ruminant (e.g. cattle, sheep and goats) and non-
88 ruminant (e.g. pigs) adipose fats. Crucially, using this approach, ruminant dairy fats can be distinguished
89 from the carcass fats due to biosynthetic differences between the major fatty acids⁴³⁻⁴⁷. This technique
90 has proven pivotal for tracing the spread of dairying practices across Europe^{44,48-55}, the Levant^{56,57},
91 Central Asia⁵⁸ and northern^{59,60} and eastern^{61,62} Africa. Increasingly high sensitivity mass spectrometry
92 has further allowed the identification of a suite of diagnostic aquatic biomarkers which may be
93 preserved in absorbed lipid residues, including dihydroxy acids (DHYA), ω -(*o*-alkylphenyl)alkanoic acids
94 (APAAs) and isoprenoid fatty acids (IFAs)⁶³. Recent advances in the direct radiocarbon dating of
95 individual lipid compounds extracted from archaeological pottery now provide the potential to gain
96 crucial chronological context for the interpretation of ancient diet^{62,64,65}.

97 Lipid residue analysis of hunter-gatherer pottery excavated from Likoaeng and Sehonghong and
98 agropastoralist ceramics from the surface of a nearby abandoned Basotho village was undertaken to
99 explore the diet of these groups after the arrival of agropastoralists in adjacent parts of southern Africa

100 from the early centuries AD. The specific aim was to determine if there was any evidence for contact
101 with agropastoralist groups through the subsistence strategies of highland hunter-gatherers. The results
102 hold important implications for understanding the interactions between, and practices of, indigenous
103 and incoming groups since the arrival of agriculture in south-eastern Africa in the first millennium AD.

104

105 **Results**

106 *Lipid preservation and distribution*

107 Thirty potsherds from Likoaeng (Layer 1), 17 from Sehonghong (eight from Layer GAP, nine from Layer
108 DC) and 27 from the Basotho village Mokatlpoli were analysed in the study (Extended Data Fig. 1). Lipid
109 preservation was excellent at all three sites. Likoaeng had an average yield of 0.4 mg lipid per gram of
110 potsherd (g^{-1}) with 87% of sherds ($n=27$) yielding sufficiently high lipid concentrations for analysis via gas
111 chromatography – combustion – isotope ratio mass spectrometry (GC-C-IRMS) (Supplementary Table 1).
112 The high rate of preservation at Likoaeng is comparable with sites in the hyper-arid conditions of North
113 Africa⁵⁹. At Sehonghong, 41% of potsherds ($n=7$) contained sufficient lipids for isotopic analysis (five
114 from Layer DC, two from Layer GAP; Supplementary Table 2), while at Mokatlpoli 41% ($n=11$) did so
115 (Supplementary Table 3). One exceptional sherd from Sehonghong Layer DC contained $> 10\text{mg g}^{-1}$.
116 Excluding this outlier, the average lipid yield from Sehonghong was 0.5 mg g^{-1} , whereas that from
117 Mokatlpoli was 0.3 mg g^{-1} . The composition of the majority of lipid extracts resembled degraded animal
118 fats (Fig. 2), dominated by $\text{C}_{16:0}$ and $\text{C}_{18:0}$ fatty acids although five residues from the historic site of
119 Mokatlpoli and one from Layer GAP at Sehonghong contained high intensities of unsaturated fatty
120 acids, possibly deriving from plant-based oils⁶⁶. Only the animal-derived fats are considered further here.

121

122 *Compound specific stable isotopic values*

123 The compound-specific stable carbon isotope values of lipid residues extracted from pottery from
124 Likoeng, Sehonghong and Mokatlapoli are shown in Fig. 3 (Supplementary Tables 1-3). The $C_{16:0}$ and
125 $C_{18:0}$ fatty acids exhibited a wide range of $\delta^{13}C$ values, from -30‰ to -13‰ (Fig. 3a). To allow comparison
126 of lipid residues derived from mixed C_3/C_4 sources the results are compared using the globally applicable
127 $\Delta^{13}C$ proxy ($\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$ plotted against $\delta^{13}C_{16:0}$; Fig. 3b), which emphasises metabolic origins of fats
128 over environmental variability^{48,59,67,68}. From Layer 1 at Likoeng, 10 of the lipid extracts exhibited $\delta^{13}C_{18:0}$
129 and $\delta^{13}C_{16:0}$ values characteristic of ruminant dairy fats, 10 those of ruminant adipose fats and seven
130 those of non-ruminant adipose fats. The single animal fat residue from Layer GAP at Sehonghong had an
131 isotopic composition characteristic of ruminant adipose fat whereas two of the lipid extracts from Layer
132 DC had $\delta^{13}C_{18:0}$ and $\delta^{13}C_{16:0}$ values characteristic of dairy fats and three of ruminant adipose fats. At
133 Mokatlapoli, five of the degraded animal fats derived from dairy products and one sits on the border
134 between dairy and ruminant adipose fat. Due to the low content of $C_{18:0}$ fatty acids in aquatic fats, the
135 mixing of these with terrestrial adipose fats can lead to more negative $\Delta^{13}C$ values⁶⁹. A theoretical mixing
136 model based on the data obtained in this study indicates that such mixtures would not produce $\Delta^{13}C$
137 values reaching the range of ruminant dairy fats and would be far removed from the very negative $\Delta^{13}C$
138 values obtained for the dairy residues at all three sites (Supplementary Fig. 1). Moreover, biomarkers for
139 aquatic fats were infrequent amongst those residues classified as dairy fats.

140 *Aquatic biomarkers*

141 An aquatic contribution was determined in 10 potsherds from Likoeng, based upon the presence of
142 long chain ($C_{20:0}$ and $C_{22:0}$) APAAs (Fig. 2b) and two or more isoprenoid fatty acids (IFAs; Fig. 3;
143 Supplementary Table 1). In a further six residues, the identification of only $C_{18:0} - C_{20:0}$ APAAs and one IFA
144 means that an aquatic contribution is likely but not certain (Supplementary Table 1; marked as 'Likoeng
145 - aquatic?' in Fig. 3). The aquatic biomarkers were identified in residues characterised isotopically as

146 deriving predominantly from ruminant adipose products (n = 6), as well as non-ruminants (which would
147 include fish) (n = 2) and dairy (n = 2), implying that the pots were used for processing both aquatic and
148 terrestrial fats. The relatively low proportion of C_{18:0} fatty acid in aquatic fats means that the stable
149 isotopic values obtained from such mixtures will be strongly biased towards the terrestrial species⁶⁹. In
150 contrast, at Sehonghong aquatic biomarkers were recovered from possibly only one residue (SHH41),
151 classified as predominantly of dairy origin, and no aquatic biomarkers at all were recovered from
152 residues from Mokatlapoli (Supplementary Tables 2; 3).

153 *Direct dating of dairy residues in pottery*

154 To confirm the antiquity of the pottery and its dairy contents, we conducted compound-specific
155 radiocarbon dating of the absorbed fatty acids from two sherds^{62,64,65,71,72}. Sherds LIK10 and SHH42
156 (Extended Data Fig. 1), containing high concentrations of saturated C_{16:0} and C_{18:0} fatty acids and shown
157 through compound-specific stable carbon isotope analysis to derive from a dairy origin, were selected
158 and individual fatty acids collected using preparative-GC and radiocarbon dated (Supplementary Table
159 4). The radiocarbon dates from these residues calibrate to cal AD 579 – 654 (95% probability; BRAMS-
160 2613: 1481 ± 27 BP) for LIK10 (combined date) and cal AD 885 – 990 (95% probability; BRAMS-2612:
161 1161 ± 28 BP) for SHH42 (combined date). They confirm that the dairy residues, and thus the pottery
162 vessels from which they derive, date to the mid- and late-first millennium AD at Likoaeng and
163 Sehonghong respectively (Fig. 4).

164

165 **Discussion**

166 The biomolecular analysis of residues extracted from potsherds from Likoaeng and Sehonghong, which
167 include two directly dated examples, provides strong evidence for the exploitation of domesticated
168 secondary products by hunter-gatherer groups in the highlands of Lesotho in the mid-/late-first

169 millennium AD, with dairy residues comprising *ca.* 35% of residues characterised (n=12). The direct date
170 from the dairy residue LIK10 from Likoaeng (cal AD 579-654 at 95.4% probability; BRAMS-2613: 1481 ±
171 27 BP) is within 2σ of the dated charcoal from the same layer (cal AD 641–969 at 95.4% probability; Pta-
172 7877: 1310 ± 80 BP) although the precision of the charcoal date is rather low. The dairy residue dates
173 slightly older than the bone (cal AD 681–884 at 95.4% probability; GrA-23237: 1285 ± 40 BP) and iron
174 (cal AD 682–879 at 95.4% probability; GrA-26831: 1290 ± 30 BP) dates from Layer 1, possibly indicating a
175 longer span of occupation represented in the layer than the existing dates suggested. Based upon
176 archaeological interpretation and five existing radiocarbon dates (Table 1), Layer DC at Sehonghong was
177 thought to have accumulated during occupation of the site during both the first and second millennia
178 AD, but the clustering of radiocarbon dates indicates that the bulk of material originates from the late
179 first millennium AD. The direct date we obtained from the dairy residue SHH42 (cal AD 885-990 at 95.4%
180 probability; BRAMS-2612: 1161 ± 28 BP) is consistent with this earlier cluster, confirming that dairying
181 was practised here from the earliest phase of this occupation layer. In the late nineteenth/early
182 twentieth centuries at nearby Mokatlapoli nearly all of the animal-derived pottery lipid residues derive
183 from dairy products ($\Delta C_{18}-C_{16} \leq -3.1\text{‰}$; one is on the border between ruminant dairy and ruminant
184 adipose indicating mixing). This indicates that dairy products formed an important part of the
185 subsistence strategies of both precolonial hunter-gatherers and nineteenth-/twentieth-century Basotho
186 agriculturalists (Fig. 4). When taken in conjunction with the osteoarchaeological identification of
187 domestic livestock in the faunal assemblages at Likoaeng²² and Sehonghong⁷³, the evidence for
188 maintenance and exploitation of domestic animals and their secondary products in the Lesotho
189 highlands by hunter-gatherer groups is compelling.

190 The exploitation of dairy products confers an important adaptive advantage onto humans, providing a
191 predictable source of carbohydrate, fat, protein and calcium, as well as liquid during times of drought,
192 and greatly increases the degree of nutrition represented by one animal. The distinct advantages of milk

193 consumption led to a rapid increase in the frequency of adult humans able to digest lactose (lactase
194 persistence), representing one of the strongest signals of positive selection observed in recent *Homo*
195 *sapiens* populations, and one that occurs at highest frequencies in traditionally pastoralist populations⁷⁴⁻
196 ⁷⁷. Lactase persistence was likely present only in low frequencies in the hunter-gatherer groups
197 inhabiting Likoaeng and Sehonghong in the mid-late first millennium AD. However, fermented dairy
198 products, facilitated by the use of pottery, retain their nutritional value⁷⁸ and are much more palatable
199 for lactose intolerant individuals compared to fresh milk, largely due to the hydrolysis of lactose to
200 its component sugars during the fermentation process⁷⁹. It is probable that the dairy residues recovered
201 during this study originate from fermented milk products, which permit the consumption of secondary
202 products by lactose intolerant individuals without detrimental health effects. Fermented milk is still
203 widely consumed in Lesotho ('mafi') and South Africa ('amasi') today⁸⁰.

204 The high variety of animal taxa present at Likoaeng and Sehonghong indicates that a wide range of
205 resources was exploited by the hunter-gatherer groups who occupied these sites in the first and second
206 millennia AD^{22,33,73}. Whereas dairy residues most likely derive from domestic species, such as sheep,
207 goats or cattle, the ruminant carcass fats could originate from either domesticates or hunted antelope
208 including common duiker (*Sylvicapra grimmia*), grey rhebuck (*Pelea capreolus*), mountain reedbeek
209 (*Redunca fulvorofula*), red hartebeest (*Alcelaphus buselaphus*) and eland (*Taurotragus oryx*). The non-
210 ruminant carcass residues, on the other hand, most likely derive from fish (at both sites), or, at
211 Sehonghong in particular, mammals such as rock hyrax (*Procavia capensis*), scrub hare (*Lepus saxatilis*),
212 warthog (*Phacochoerus africanus*) and baboon (*Papio hamadryas*).

213 Whilst the stable carbon isotopic composition of wild animals reflects their preferred pasture, that of
214 domestic species will reflect an average of the different pastures they are exposed to by the groups
215 managing them. Although the environmental composition of Layer 1 at Likoaeng predominantly

216 consisted of C₄ grassland (*ca.* 70%)⁸¹, both aspect and elevation significantly affect the C₃/C₄
217 composition. Only relatively short-distance movements of no more than 5–15 km from both Likoaeng
218 and Sehonghong (readily achieved by following rivers upstream from these sites) would reach elevations
219 where the vegetation cover becomes predominantly C₃ (2100–2700 m a.s.l. depending on aspect)⁸².

220 The $\delta^{13}\text{C}_{16:0}$ and $\delta^{13}\text{C}_{18:0}$ values of the dairy residues from Likoaeng are lower than the ruminant/non-
221 ruminant carcass fats from the same site (Fig. 3), indicating a greater C₃ contribution to the dairy fats.
222 This could reflect the preferential grazing of domesticates (predominantly exploited for milk) at elevated
223 C₃ pastures whereas the mixed C₃/C₄ signal of the carcass fats could represent the preferred pastures of
224 hunted wild game or be a reflection of the integrated signature of carcass tissues from domestic animals
225 moved seasonally between C₃ and C₄ pastures. The practice of vertical transhumance is well attested in
226 Lesotho historically⁸³ and continues today. Traditionally, livestock would be kept in the village environs
227 throughout winter and moved to better grazing at higher elevations for the summer months⁸⁴, a period
228 when milk production is highest. The isotopic patterning of the dairy residues observed at Likoaeng,
229 directly dated to the first millennium AD, suggests that a mobile system of animal management was also
230 practised by the population occupying that site during that time.

231 A striking isotopic separation (*ca.* 5 - 6‰) can also be observed in the dairy residues between the late
232 first-millennium hunter-gatherer sites and the historic Basotho agropastoralist village (Fig. 3), which is
233 located in close proximity to the site of Sehonghong. The dairy residues from Mokatlapoli have a clear C₄
234 isotopic signal. Considering the 1000 year time gap between these observations, the wide isotopic
235 separation in the dairy residues likely reflects differences in animal husbandry practices. Historically and
236 today, cattle are grazed on maize stubble after crops are harvested⁸⁴ (P. Mitchell, pers. obs.), which
237 would increase the C₄ signal in the diet of domesticates after its introduction in the nineteenth century
238 and explain the shift in the isotopic composition of domesticate tissues.

239 Fish remains represent just under 20% of the faunal collection of Layer 1 at Likoaeng²². Due to the site's
240 location on the bank of the Senqu River, the presence of aquatic fats in potsherds from Likoaeng is
241 unsurprising. Indeed, a rock art scene immediately adjacent to the site depicts the use of what are
242 probably basket traps and fences to catch fish migrating up the Senqu, although its age is unknown⁸⁵.
243 The Sehonghong sequence likewise documents a long history of exploitation of fish, with fish forming a
244 large portion of the faunal assemblage from Layers GAP and DC⁷³. The presence of partial suites of
245 aquatic biomarkers in potsherds from Likoaeng further attests to the exploitation of aquatic resources
246 by people inhabiting the sites. Consistent with the fact that Basotho largely ignored fish as a source of
247 food in precolonial times^{86,87}, aquatic biomarkers are absent from the potsherds from Mokatlapoli.

248 The decoration on the single EIA potsherd from Likoaeng indicates that it belongs to either the Msuluzi
249 (AD 650–750), or Ndongonwane (AD 750–950), phase of the Kalundu Tradition of the Early Iron Age²¹,
250 both of which are well-represented at farming villages in KwaZulu-Natal³. Work by Maggs⁸⁸ and Mazel⁸⁹
251 in KwaZulu-Natal's Thukela Basin region immediately northeast of the uKhahlamba-Drakensberg
252 Escarpment has uncovered extensive evidence for contact between hunter-gatherers and incoming
253 agricultural populations in the first millennium AD. The agricultural settlement of Msuluzi Confluence,
254 for example, appears to have produced iron in excess of local demand, leading Maggs⁸⁸ to suggest that
255 this was likely for exchange with non-iron-producing hunter-gatherer groups. The iron fragments
256 recovered at Likoaeng must also come from this kind of source.

257 Existing networks of exchange between hunter-gatherer groups living on both sides of the uKhahlamba-
258 Drakensberg Escarpment may have facilitated the easy spread of such commodities, but the presence of
259 dairy residues in potsherds at both Likoaeng and Sehonghong suggests that those making and using the
260 ceramics from which they came had sufficient knowledge of animal husbandry to exploit the secondary
261 products of cattle and/or caprines. Moreover, the fact that – except for the single decorated EIA sherd

262 from Likoaeng – all the pottery analysed there and from Layers DC and GAP at Sehonghong is of hunter-
263 gatherer type^{19,20} strongly suggests that those dairy residues derive from livestock living in or very close
264 to the Senqu Valley. Although these animals, or their ancestors, must originally have been obtained
265 from an agropastoralist source, there is absolutely no archaeological or historical evidence to indicate
266 that agropastoralists were living in highland Lesotho prior to 1878. Had they been, they would, for
267 example, undoubtedly have been recognised when Joseph Orpen and James Murray Grant led a British
268 military expedition through the region, stopping off at Sehonghong, in 1873^{90,91}. The absence of
269 agropastoralists and the otherwise entirely Later Stone Age context of the pottery from both Likoaeng
270 and Sehonghong reinforces the argument that the ceramics we have analysed are indeed of hunter-
271 gatherer origin.

272 Although the numbers of livestock identified as being present at Sehonghong⁷³ have been questioned,
273 Horsburgh, et al.²⁷ confirmed the presence of one *Bos taurus* specimen (SHH-7358) in Layer DC at
274 Sehonghong. Unfortunately, the 1.8 g bone fragment was consumed during aDNA analysis so direct
275 dating of the specimen was not possible. The bone came from the same square and context as a distal
276 phalanx (SHH-7356) that Horsburgh, et al.²⁷ identified as eland (rather than cattle) and directly dated to
277 cal AD 775–983 (95% probability; Wk-34784: 1200 ± 30 BP). This may indicate that it is of similar age but
278 associated dates must be treated with caution. Although this result does provide molecular support for
279 the small-scale presence of domestic livestock at Sehonghong, the presence of a single donkey (*Equus*
280 *asinus*) specimen in Layer GAP and of several pig (*Sus scrofa*) and chicken (*Gallus gallus*) specimens in
281 Layer DC shows that some disturbance of the uppermost levels of Sehonghong's stratigraphy has taken
282 place; none of these species can have been available locally before the onset of Basotho settlement in
283 1878⁷³. However, the direct dating of a dairy residue from Sehonghong now confirms the antiquity of
284 domesticates at this site.

285 Although molecular analysis of the Likoaeng domestic assemblage has not yet been undertaken, the
286 reliability of the identification of sheep remains at Likoaeng has specifically been questioned based on
287 the aDNA results obtained at Sehonghong³⁷. From the faunal collection at Likoaeng, nine specimens
288 were morphologically attributed to sheep/goat, two to sheep (*Ovis aries*) and eight to cattle (*Bos*
289 *taurus*)²³. Most of these were recovered from Layer 1, with just a few small elements displaced
290 downwards below this²³. Although collagen from the cattle bones was insufficiently preserved for
291 dating, direct AMS dating of one sheep/goat bone confirms the antiquity of this specimen and produced
292 a result (cal AD 681–884 at 95% probability; GrA-23237: 1285 ± 40 BP) consistent with the remainder of
293 the chronological evidence for Layer 1²³. The directly dated dairy residue from Likoaeng (cal AD 600-644
294 at 95% probability; BRAMS-2613: 1481 ± 27 BP) clearly attests to the presence of domestic livestock at
295 the site in the first millennium AD. It does not, however, tell us the number of animals that were
296 present. The high calorific value of milk means that dairy products could have formed an important
297 supplement to the diet even at very low numbers of livestock or in situations where few such animals
298 were killed and the rest kept as socio-political capital and/or for dairy production⁹².

299

300 **Conclusion**

301 The results reported here provide further evidence that by the late first millennium AD hunter-gatherer
302 communities living in the highlands of eastern Lesotho had established contact with agropastoralist
303 communities, most likely ones located in lowland areas of KwaZulu-Natal over 150 km away. The
304 presence of dairy residues in otherwise Later Stone Age contexts at both Sehonghong and, more
305 compellingly, Likoaeng supports the notion of hunter-gatherer people practising a ‘hunters-with-sheep’
306 form of subsistence²⁵. This directly dated evidence lends support to the argument that such contacts,
307 and the incorporation of caprines and cattle, were a feature of people living in highland Lesotho during

308 the late first millennium AD. This suggests that only a few centuries after the establishment of EIA
309 agropastoralist communities in KwaZulu-Natal, such contacts were sufficiently close to allow for the
310 successful transfer to Maloti-Drakensberg hunter-gatherers of both domestic livestock and of the
311 knowledge required to look after them. Patterning in the isotopic values of the residues reveals likely
312 differences in animal management strategies between then and recent times, as evidenced by the C₄
313 animal signatures from the late nineteenth-/early twentieth-century agropastoralist settlement at
314 Mokatlapoli, likely deriving from foddering on more recently-introduced crops including maize and
315 sorghum.

316 The ongoing debate surrounding the relative merits of osteoarchaeological versus molecular analyses
317 for correctly identifying the presence of domestic livestock in faunal assemblages from archaeological
318 sites^{27,36-41} attests to the importance of investigating such wide-reaching questions via multiple lines of
319 enquiry. Considering the high level of lipid residue preservation at these southern African sites, this type
320 of analysis has an important part to play in the ongoing debate surrounding the introduction of
321 livestock-keeping into the region. Since direct dating of faunal remains from the area has been
322 hampered by poor collagen preservation^{23,27}, the direct dating of fatty acids of dairy origin extracted
323 from the potsherds provides an important alternative approach^{62,64,65}. Osteoarchaeological identification
324 is clearly a practice that may at times deliver faulty results (for example, the proximal radius from
325 Sehonghong morphologically identified as sheep⁷³, but directly dated to 5870 ± 30 BP (Wk-34787),
326 several millennia before any domestic livestock were present in southern Africa²⁷). However, it cannot
327 be assumed that ancient DNA identifications are without difficulties of their own, especially where, as in
328 highland Lesotho²⁷, organic preservation is poor. Both approaches would likely benefit from blind-
329 testing and comparative analysis by more than a single specialist or laboratory, following the examples
330 of radiocarbon dating or microwear and residue analyses of stone tools. In the meantime, our
331 biomolecular analysis and direct dating of fatty acid residues from hunter-gatherer ceramics at

332 Sehonghong and Likoaeng not only provide an independent line of evidence to address this debate, but
333 also suggest that, on the whole, the osteoarchaeological identifications previously reported there^{22,73} are
334 likely to be correct.

335

336 **Materials and methods**

337 *Sites and samples*

338 Likoaeng (29°44"S, 28°45"E; 1725 metres above sea level (m a.s.l.)) is located in the Senqu Valley in the
339 Thaba Tseka District of Lesotho. It is an open-air campsite on the southern side of the confluence of a
340 stream (of the same name) with the western bank of the Senqu (Orange) River (Fig. 1b; Extended Data
341 Fig. 2). Eighteen radiocarbon dates set the duration of human activity from 3700–1100 BP. The
342 uppermost occupation horizon (Layer 1) (located under approximately 0.2–1.5 m of culturally sterile
343 sediment; Extended Data Fig. 3) is dated by three radiocarbon determinations to cal AD 641–969 (Table
344 1), consistent with the age of the one decorated sherd recovered which belongs to the Msuluzi or, more
345 likely, Ndongonwane phase of the Early Iron Age³. Layer 1 was the only excavated context at Likoaeng to
346 contain pottery. In their thin walls (mean = 7.6 ± 9.5 mm thick, $n=80$), grit temper, largely grey colour
347 and lack of decoration, 77 of the remaining 79 potsherds recovered are typical of the ceramics found at
348 other hunter-gatherer sites in highland Lesotho^{28,32,34}, KwaZulu-Natal¹⁹ and the Eastern Cape Province⁹³.
349 Such pottery continued to be made locally into the late nineteenth century⁹⁴⁻⁹⁶, while sources of clay
350 were exploited by Basotho residents of the area into the early 1900s (Chris Wingfield, pers. comm.).
351 Thirty of these sherds, along with the decorated EIA sherd, were selected for analysis (Extended Data
352 Fig. 1). Two conjoining red-coloured sherds with exceptionally thin walls and highly burnished exteriors
353 complete the ceramic assemblage from Likoaeng Layer 1, but cannot readily be paralleled elsewhere in

354 the region, except perhaps at Good Hope Shelter in the uKhahlamba-Drakensberg Escarpment of
355 KwaZulu-Natal⁹⁷. Neither was analysed in this study.

356 Sehonghong rockshelter (29°46''S, 28°47''E, 1750 m a.s.l.; Extended Data Fig. 4) lies 3 km south-east of
357 Likoaeng, on the south-eastern bank of the Sehonghong River, which meets the Senqu River 3 km
358 further downstream (Fig. 1b). Sehonghong was first occupied in the Middle Stone Age and preserves a
359 series of occupation pulses across Marine Isotope Stages 3 and 2 as well as the Holocene^{98,99}. Oral
360 histories indicate that it was an important hunter-gatherer base as late as *ca.* 1870 and that the last San
361 individuals to live there did so as recently as *ca.* 1902^{96,100}. Pottery attributable to Maloti-Drakensberg
362 hunter-gatherers by virtue of its thin walls (mean thickness = 7.8 ± 1.6 mm, $n=268$), overwhelmingly
363 reduced condition (grey/black colour), grit temper and lack of decoration (except for rare instances of
364 burnishing) was recovered from the uppermost three layers (Extended Data Fig. 5)²⁸. Layer SS (Surface
365 Scrapings) is a loose grey brown dust that forms the modern surface of the site. Underneath this, Layer
366 DC (Dung Crust) is a hard friable layer rich in bovine and equine dung that becomes finer and ashier
367 towards the bottom. This layer includes the material culture of the hunter-gatherers who made use of
368 the site in the late first and second millennia AD²⁸, but the consistency of radiocarbon dates from it
369 recently obtained by Horsburgh et al.²⁷ raises the possibility that much of its content dates to the late
370 first millennium AD and might therefore be close in age to Layer 1 at Likoaeng. Underlying DC, Layer GAP
371 accumulated in the first half of the first millennium AD and is a soft, loose, grey charcoal-rich ashy layer.
372 In total, eight sherds were analysed from GAP and nine from DC.

373 During field survey of the area around Sehonghong in 1992 an open-air stone artefact scatter
374 (2928DB38) was identified 2 km upstream of the site close to a small cluster of abandoned stone-walled
375 houses with adjacent stock enclosures (29°44''S, 28°48''E). Although no enquiries were made at the time
376 regarding the history of this site or of the nearby village of Masakoane, a settlement by the name of

377 Mokatlapudi (Mokatlapoli in correct Sesotho spelling) appears just to the west of Masakoane on the
378 map of Lesotho prepared by Captain M.C. Dobson¹⁰¹ between 1904 and 1909. This village was described
379 as “now stated in ruins” in 1950 in Webb’s¹⁰² *Gazetteer of Basutoland*. It seems very plausible that the
380 ruins near 2928DB38 therefore belong to Mokatlapoli (Fig. 1b). Webb’s observation, coupled with the
381 fact that there was no Basotho settlement anywhere in the Sehonghong or broader Upper Senqu region
382 before 1878, narrows the age of the ceramics retrieved from the surface of Mokatlapoli to the last two
383 decades of the nineteenth and first four decades of the twentieth centuries. This pottery differs from
384 that recovered from Likoang and Sehonghong in being thicker (mean thickness = 10.5 ± 3.7 mm, $n=69$),
385 predominantly orange or buff (rather than grey to black) in colour and not infrequently burnished²⁸.
386 Twenty-seven of these sherds were analysed in order to obtain a set of residue results for comparison
387 with the hunter-gatherer pottery from Sehonghong and Likoang.

388 *Lipid extraction*

389 Potsherds were cleaned of exogenous lipids by removing the outer surface (*ca.* 2 mm) using a Dremel
390 drill. 1-3 g of potsherd was sampled and ground to a fine powder in a solvent-washed glass mortar and
391 pestle. Lipids were simultaneously extracted and methylated using established methods (4% v/v
392 $\text{H}_2\text{SO}_4/\text{MeOH}$, 5 mL, 70 °C, 1h)¹⁰³. Analytical blanks were prepared alongside each batch of 10 sherds to
393 monitor laboratory-based contamination. The same extraction method repeated three times on new
394 powdered clay (up to 5 g) was followed for the radiocarbon analyses of lipid residues.

395 *Instrumental analysis*

396 Samples were analysed on an Agilent 7890A GC fitted with an on-column injector, flame ionisation
397 detector and a non-polar high temperature DB1-HT column (stationary phase 100%
398 dimethylpolysiloxane, 0.32 mm internal diameter, 0.1 μm film thickness) using helium as a carrier gas (1

399 μl injection volume). The temperature program consisted of a 1 min isothermal at 50 °C, increasing to
400 350 °C (5 min isothermal) at 25 °C min⁻¹.

401 For analysis via GC-MS, fatty acid methyl esters (FAMES) were initially analysed using a ThermoFinnigan
402 Trace mass spectrometer fitted with a non-polar column (100% dimethylpolysiloxane, length 50 m,
403 internal diameter of 0.32 mm and film thickness of 0.17 μm) in EI mode, scanning from m/z 50 – 650
404 (electron energy 70 eV, scan time of 0.6 s). The temperature program commenced at 50 °C (1 min)
405 increasing at 10 °C min⁻¹ until 300°C (10 min isothermal). The FAMES were re-analysed using a
406 ThermoFinnigan single quadrupole TraceMS in EI mode (electron energy 70 eV) fitted with a fused silica
407 capillary column with a high cyano-modified cyanopropyl polysilphenylenesiloxane stationary phase
408 (Agilent J & W, VF-23ms, 60 m x 0.32 mm i.d., 0.15 μm film thickness). The oven temperature
409 programme comprised an isothermal at 70 °C, ramping to 100 °C at 10 °C min⁻¹ and a second ramp to
410 250 °C at 4 °C min⁻¹. The GC/MS was operated in both full scan (m/z 50 – 650) and selected ion
411 monitoring (m/z 105, 262, 290, 318 and 346) mode for the identification of aquatic biomarkers (APAAs
412 and IFAs). Data were collected and analysed using Xcalibur software (v. 2.0) and a NIST spectral
413 database.

414 The $\delta^{13}\text{C}$ values of the C_{16:0} and C_{18:0} fatty acids were obtained using an Agilent 7890A GC fitted to an
415 Isoprime isotope ratio mass spectrometer (IRMS). The temperature program began at 40 °C (2 min),
416 increasing by 10 °C min⁻¹ to reach 300 °C (10 min isothermal). Samples were run in duplicate; final
417 results are an average taken of the two values. Analytical reproducibility was $\pm 0.4\%$. Instrumental error
418 was $\pm 0.2\%$. The isotopic values were corrected to account for the carbon atoms added during the
419 methanolic extraction according to Rieley¹⁰⁴. The $\delta^{13}\text{C}$ values were derived according to the equation:
420 $\delta^{13}\text{C}\text{‰} = ((R_{\text{sample}} - R_{\text{standard}}) / R_{\text{standard}}) \times 1000$ (relative to the international standard Pee Dee Belemnite
421 (PDB) and where $R = {}^{13}\text{C}/{}^{12}\text{C}$).

422 For ^{14}C dating, the $\text{C}_{16:0}$ and $\text{C}_{18:0}$ fatty acids were isolated by preparative capillary GC (pcGC) on an
423 Hewlett-Packard 5890 series II GC coupled to a Gerstel preparative fraction collector (PFC) following
424 recently established procedures^{64,65,105}. Total lipid extracts (TLEs) concentrated at *ca.* $5 \mu\text{g} \cdot \mu\text{L}^{-1}$ were
425 injected 40 times into a Rxi-1ms (DB1, 30mx 0.53 mm i.d., 1.5 μm film thickness) column and the fatty
426 acids were collected in a solvent-less trapping system (STS). He (10 psi) was used as carrier gas. The GC
427 oven started with an isothermal hold at 50 °C for 2 min, increased to 200 °C at 40 °C.min⁻¹, then
428 increased to 270 °C at 10 °C.min⁻¹ and finally increased to 300 °C at 20 °C.min⁻¹ and held for 8.75 min.
429 Procedural blanks and standard consisted of trapping sequences of *n*-hexane mirroring the one of
430 FAMES, then addition of the radiocarbon standards (IAEA C7, Phtalic anhydride) to the traps content.
431 The isolated compounds were combusted and graphitised in a Vario Microcube Elemental Analyser
432 coupled with an Automated Graphitization Equipment (EA-AGE3)¹⁰⁶. Graphite targets were pressed
433 using a Pneumatic Sample Press and analysed on the BRIS-MICADAS accelerator mass spectrometer of
434 the Bristol Radiocarbon Accelerator Mass Spectrometry (BRAMS) facility alongside radiocarbon and
435 processed standards (OXA II, IAEA C7, phthalic anhydride). Correction of the measurements for the
436 methyl group added during the derivatization was performed using a mass balance⁷¹. Combination of
437 the measurements was performed as described in Casanova, et al.⁶⁵. Radiocarbon ages were calibrated
438 in OxCal 4.3³¹ against the southern hemisphere, SHCal13, calibration curve³⁰.

439

440

441 **Data availability**

442 All data generated or analysed during this study are included in this published article and its
443 supplementary information files.

444

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702

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716

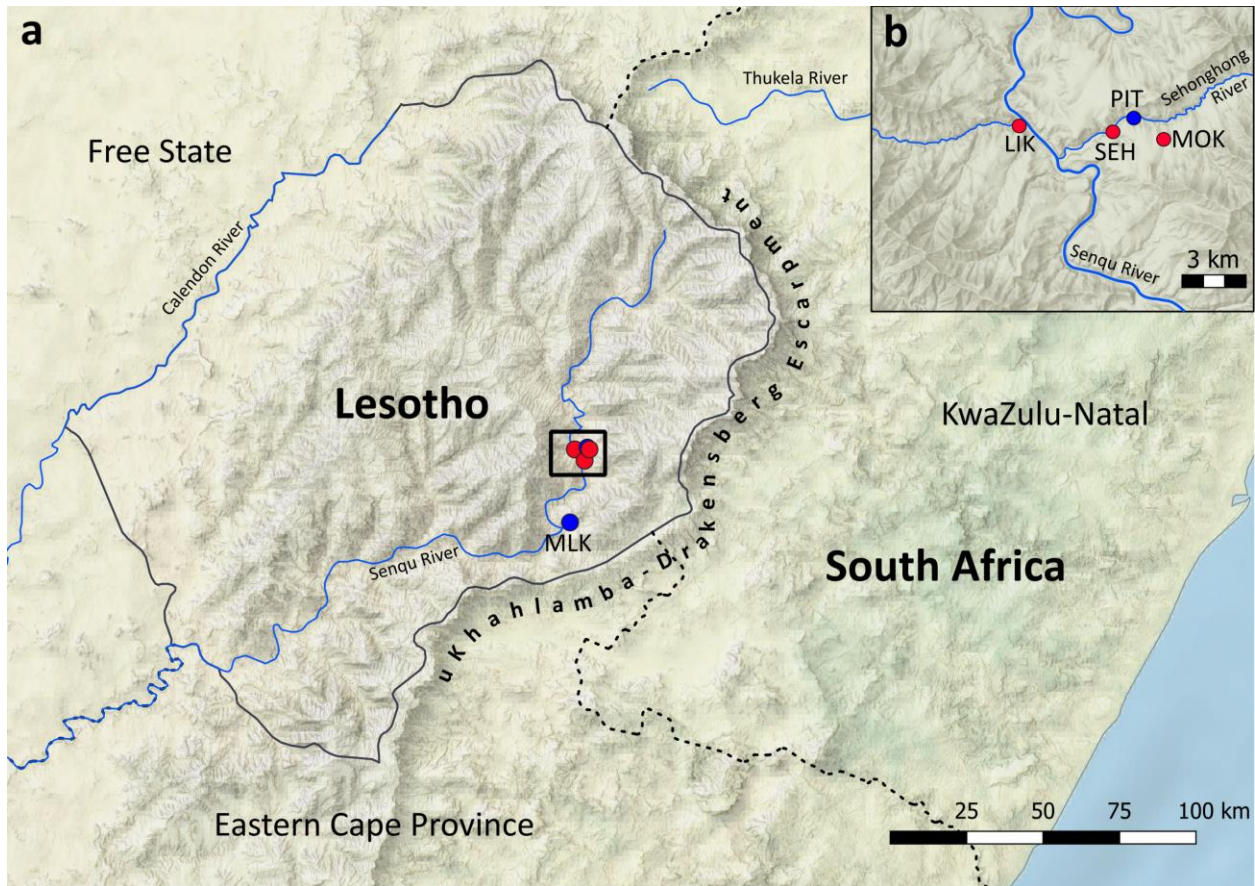
717 **Author contributions**

718 L.J.E.C. and P.J.M. devised the study. H.F. carried out lipid extraction and GC, GC-MS and GC-C-IRMS
719 analyses under the supervision of L.J.E.C. E.C. carried out compound specific ¹⁴C dating. All authors
720 contributed to data analysis and interpretation. H.F. wrote the manuscript with input from all authors.

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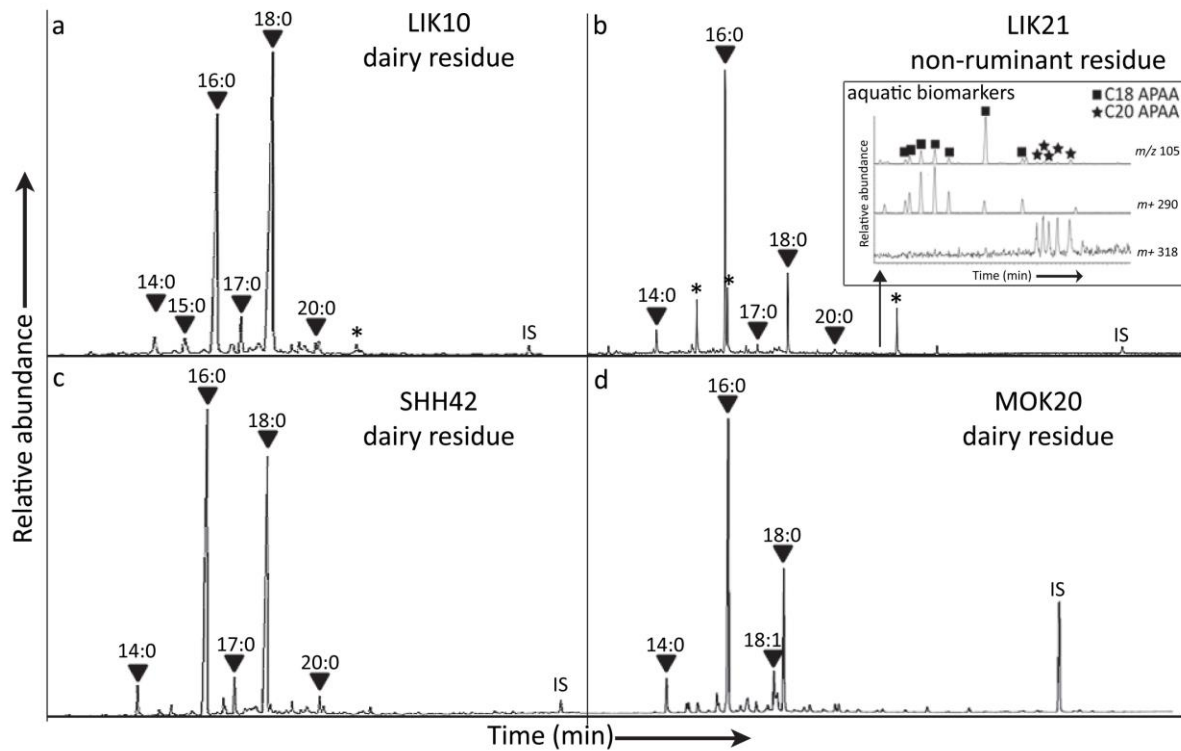
722 **Competing interests**

723 The authors declare no competing interests.



725

726 **Figure 1. Map of Lesotho.** a) Location of sites included in the study (red) and mentioned in the text
727 (blue) within Lesotho, including Melikane (MLK). b) Close-up of the locality of Likoang (LIK),
728 Sehonghong (SEH), Pitsaneng (PIT) and Mokatlpoli (MOK). (Base map downloaded from Natural Earth,
729 free vector and raster map data available at naturalearthdata.com).



730

731 **Figure 2. Partial gas chromatograms from four extracted lipid residues with compositions**

732 **characteristic of degraded animal fats. a)** dairy residue from Likoang which was directly radiocarbon

733 dated; **b)** non-ruminant adipose residue from Likoang; inset shows mass chromatogram from same

734 residue run in SIM mode (M/z 105, $M+290$, $M+318$) identifying aquatic biomarkers $C_{18:0}$ and $C_{20:0}$

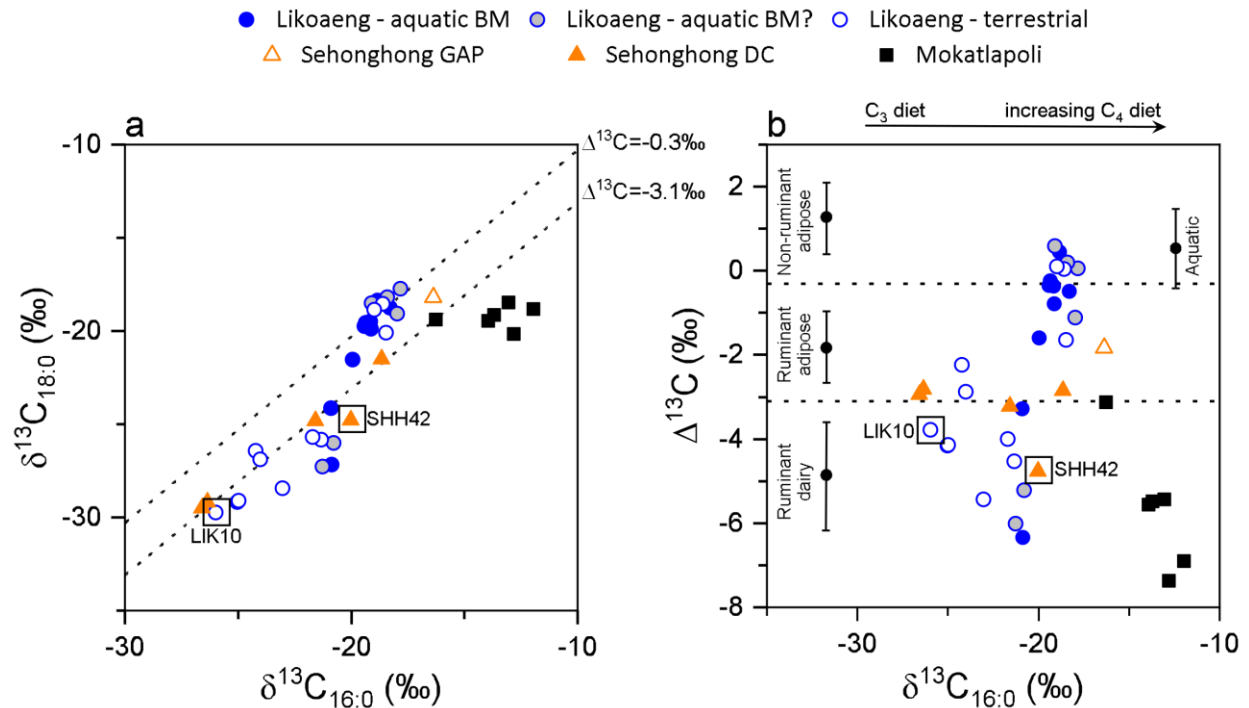
735 APAs; **c)** dairy residue from Layer DC at Sehonghong rock shelter which was also directly radiocarbon

736 dated and **d)** dairy residue from Mokatlpoli. Peaks marked with black triangles represent individual

737 fatty acids labelled (x:y) with carbon chain length x and degree of unsaturation y. IS is the internal

738 standard (*n*-tetratriacontane). Asterisks mark phthalate peaks. Further information on the lipid

739 compositions of the remaining extracts is provided in Supplementary Tables 1-3.



740

741 **Figure 3. Compound specific stable isotopic values of degraded animal fats analysed in the study. a)**

742 $\delta^{13}\text{C}_{18:0}$ values plotted against $\delta^{13}\text{C}_{16:0}$ values and **b)** $\delta^{13}\text{C}_{18:0} - \delta^{13}\text{C}_{16:0}$ ($\Delta^{13}\text{C}$) values plotted against the

743 $\delta^{13}\text{C}_{16:0}$ values obtained from pottery organic residues with biomolecular compositions characteristic of

744 degraded animal fats from Likoeng Layer 1, Sehonghong rock shelter from Layer GAP and Layer DC and

745 from the late nineteenth-/early twentieth-century agricultural village Mokatlapoli. The dashed lines

746 delimit the $\Delta^{13}\text{C}$ values ranges typical of dairy ($\Delta^{13}\text{C} < -3.1\text{‰}$), ruminant adipose ($\Delta^{13}\text{C} = -3.1\text{‰} - -0.3\text{‰}$)

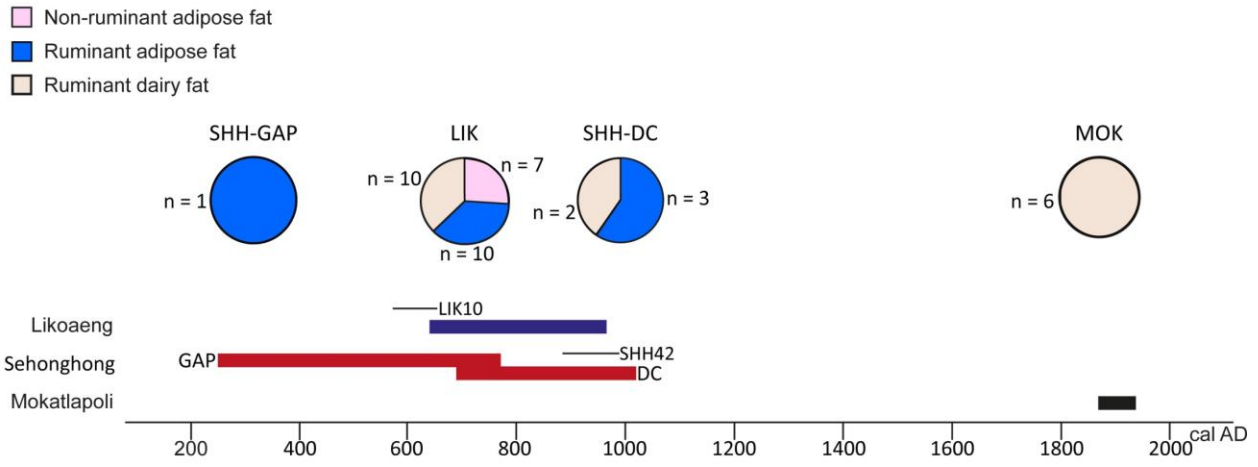
747 and non-ruminant adipose ($\Delta^{13}\text{C} > -0.3\text{‰}$) products. Dairy residues LIK10 and SHH42 (boxed) were

748 directly dated. Residues with evidence for aquatic biomarkers (BM) are indicated. The ranges in **b** show

749 the mean ± 1 s.d. from a database of modern terrestrial reference values published in ⁵⁹ and aquatic

750 reference values published in ^{48,58,63,69}. The modern reference ranges have been corrected for post-

751 industrial carbon contribution $+1.3\text{‰}$ ⁷⁰. Analytical precision is $\pm 0.4\text{‰}$.



752

753 **Figure 4. Timeline showing span of the layers from the three sites that were analysed in the study: the**

754 two Later Stone Age sites, Likaeng Layer 1 (dark blue) and Sehonghong Layer GAP and Layer DC (red)

755 (95.4% calibrated ranges of dates shown in Table 1) and the probable range of the late nineteenth-/early

756 twentieth-century agricultural village, Mokatlapoli (see ‘Sites and samples’ for details). The calibrated

757 (95%) date ranges for the combined compound-specific radiocarbon dating of fatty acids from two

758 terrestrial dairy fats LIK10 and SHH42 are shown as black lines. The pie charts show the proportions of

759 different animal-derived products identified from each assemblage through compound-specific stable

760 isotope analysis.

761 **Tables**

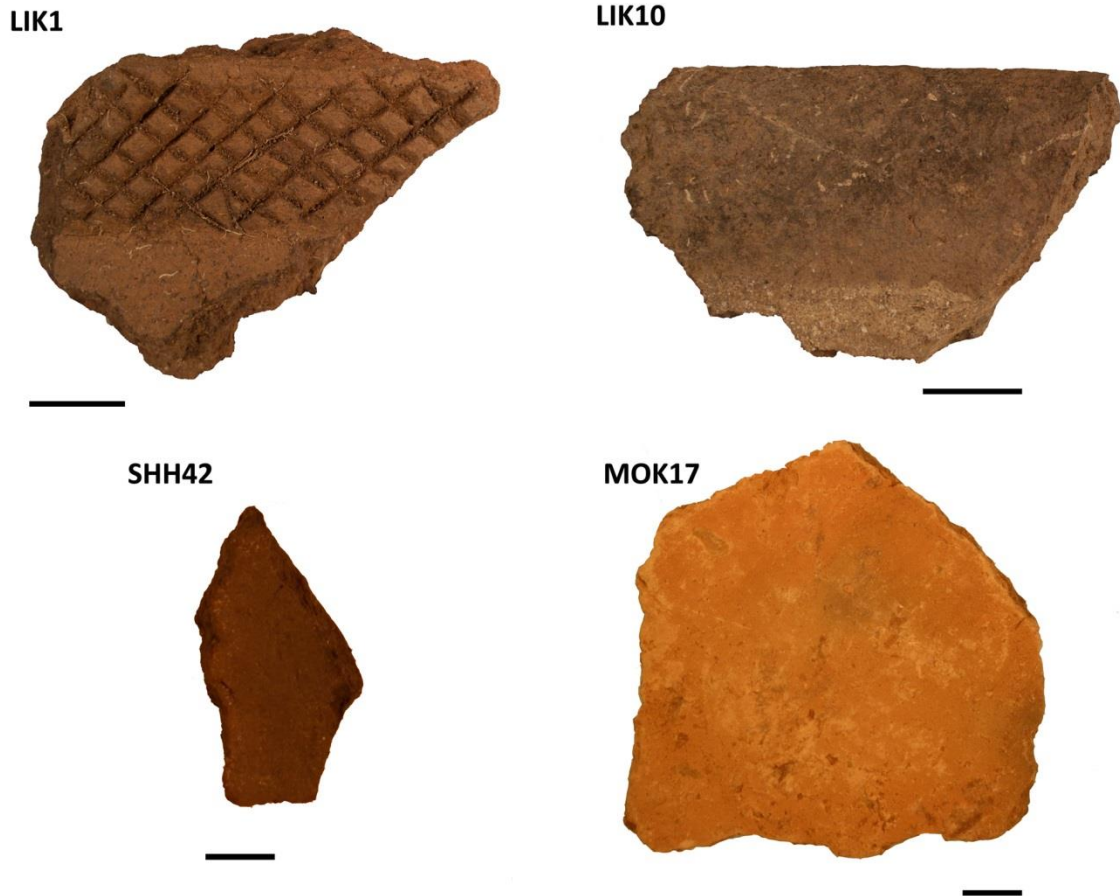
Site	Layer	Laboratory number	Material	¹⁴ C age (BP)	Calibrated age range (2σ)	Notes	Reference
Likoaeng	1	GrA-23237	Bone	1285 ± 40	AD 681–884	Morphological ID: sheep/goat (ulna)	Mitchell, et al. ²¹
Likoaeng	1	GrA-26831	Iron	1290 ± 30	AD 682–879		Mitchell, et al. ²¹
Likoaeng	1	Pta-7877	Charcoal	1310 ± 80	AD 641–969		Mitchell, et al. ²¹
Sehonghong	DC	Wk-34786	Bone – distal metapodial fragment (SHH_7355)	1130 ± 30	AD 892–1018	Morphological ID: <i>Ovis aries</i> (sheep) aDNA ID: <i>Redunca fulvorufula</i> (reedbuck)	Horsburgh, et al. ²⁷
Sehonghong	DC	Wk-34785	Bone – tarsal fragment (SHH_7449)	1130 ± 30	AD 892–1018	Morphological ID: <i>Bos taurus</i> (cattle) aDNA ID: <i>Tragelaphus oryx</i> (oryx)	Horsburgh, et al. ²⁷
Sehonghong	DC	Wk-34784	Bone – distal first phalanx fragment (SHH_7356)	1200 ± 30	AD 775–983	Morphological ID: <i>Bos taurus</i> (cattle) aDNA ID: <i>Tragelaphus oryx</i> (oryx)	Horsburgh, et al. ²⁷
Sehonghong	DC	Pta-6084	Charcoal	1240 ± 50	AD 685–971	This sample was published and previously attributed to Layer GAP. The new Horsburgh et al. ²³ dates from Layer DC and re-assessment of the sample's stratigraphic provenance suggest that it in fact comes from DC.	Mitchell ²⁸
Sehonghong	DC	Wk-34787	Bone – proximal radius (SHH_7459)	5870 ± 30	4787–4581 BC	Morphological ID: <i>Ovis aries</i> (sheep). No DNA recovered. The date indicates that this cannot be from a domestic animal and that the bone must have moved upward from the underlying mid-Holocene Layer GWA.	Horsburgh, et al. ²⁷
Sehonghong	GAP	Pta-885	Charcoal	1400 ± 50	AD 594–771	From the original 1971 excavation of the site.	Carter, et al. ²⁹
Sehonghong	GAP	Pta-6063	Charcoal	1710 ± 50	AD 247–520	Associated with pressure-flaked stone projectile points.	Mitchell ²⁸

762 **Table 1.** Published radiocarbon dates from pottery-containing horizons at Likoaeng and Sehonghong,
763 Lesotho. BP = radiocarbon years before 1950. All dates have been recalibrated using the 2013 southern
764 hemisphere calibration curve³⁰ in OxCal 4.3³¹.

765

766

767 **Extended Data**



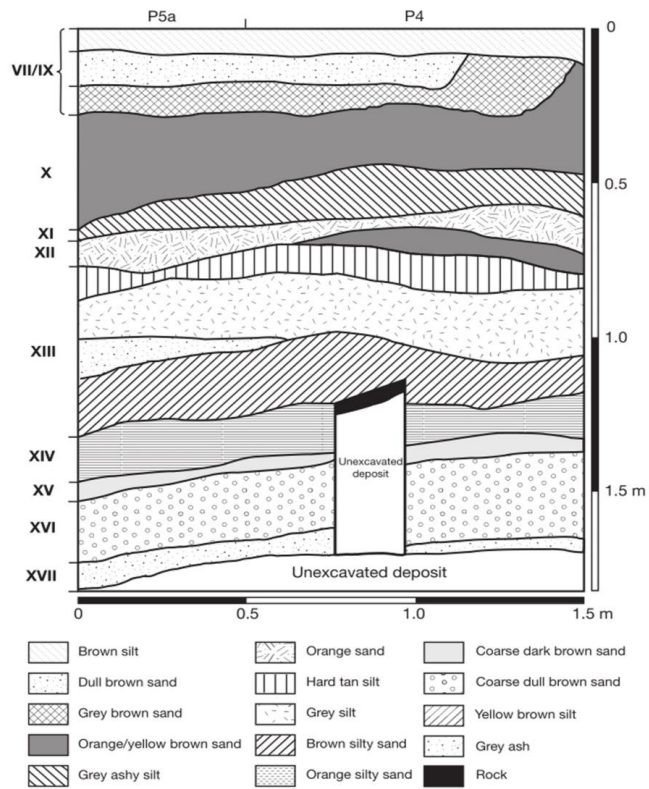
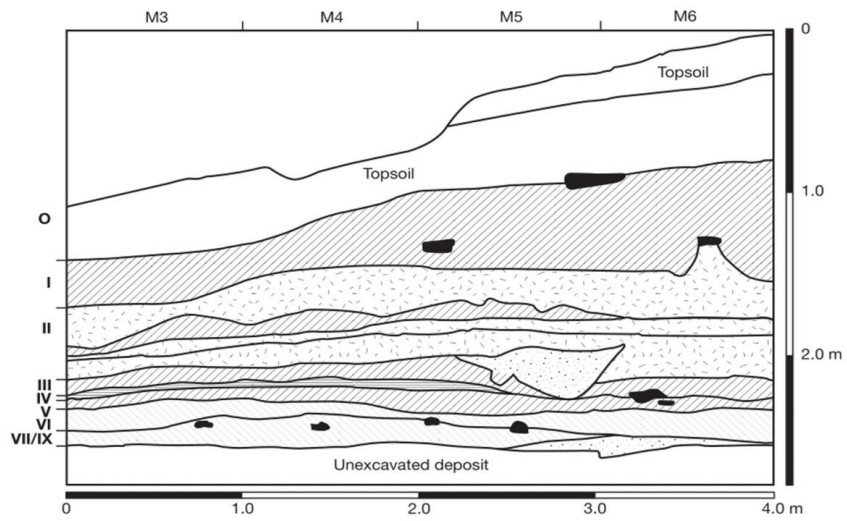
768

769 **Extended Data Fig. 1 | Photographs of four potsherds containing dairy residues analysed in**
770 **the study.** LIK1 is the EIA potsherd recovered from Layer 1 of Likoeng. Lipids extracted from
771 LIK10 and SHH42 were directly dated as part of the study. Scale bar is 1 cm.



772

773 **Extended Data Fig. 2 | View of Likoeng excavation looking upstream of the Senqu River**
774 **(pictured in the background).** The north section of the excavation is shown, and Layer 1 is
775 marked.



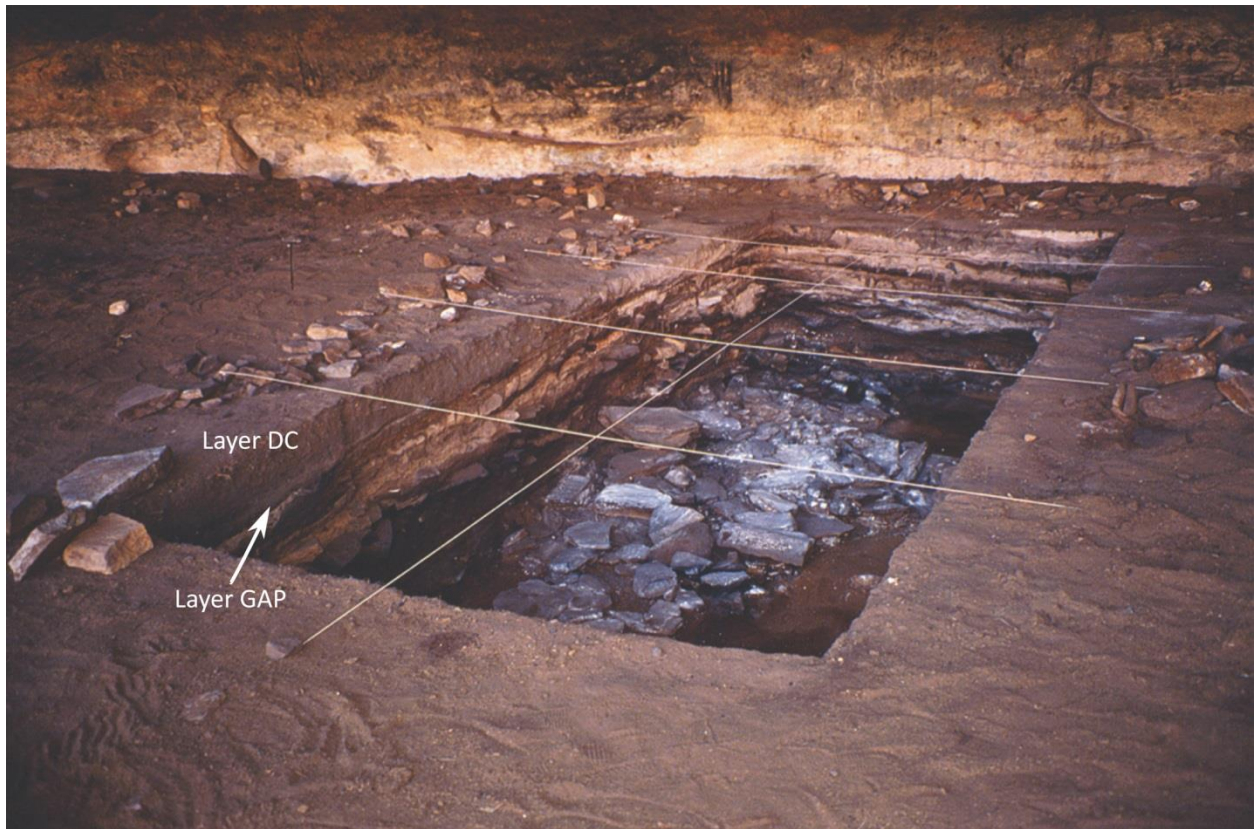
776

777 **Extended Data Fig. 3 | Section drawings of Likoang.** Layers are shown on the left side and grid
 778 square references along the top. Figure modified from a previous publication²³ (reprinted with
 779 permission).



780

781 **Extended Data Fig. 4** | View of Sehonghong rock shelter.



782

783 **Extended Data Fig. 5** | Photograph of the excavation of Sehonghong rock shelter with Layers
784 DC and GAP seen in the section.

785 **Supplementary Information**

786

787 **Supplementary information**

788 *Supplementary Figures*

- 789 • Supplementary Figure 1 - Theoretical mixing model of aquatic and terrestrial fats

790 *Supplementary Tables*

- 791 • Supplementary Table 1 – Information on pottery lipid extracts from Likoaeng
792 • Supplementary Table 2 – Information on pottery lipid extracts from Sehonghong
793 • Supplementary Table 3 – Information on pottery lipid extracts from Mokatlapoli
794 • Supplementary Table 4 – Radiocarbon dates on pottery lipids from Lesotho

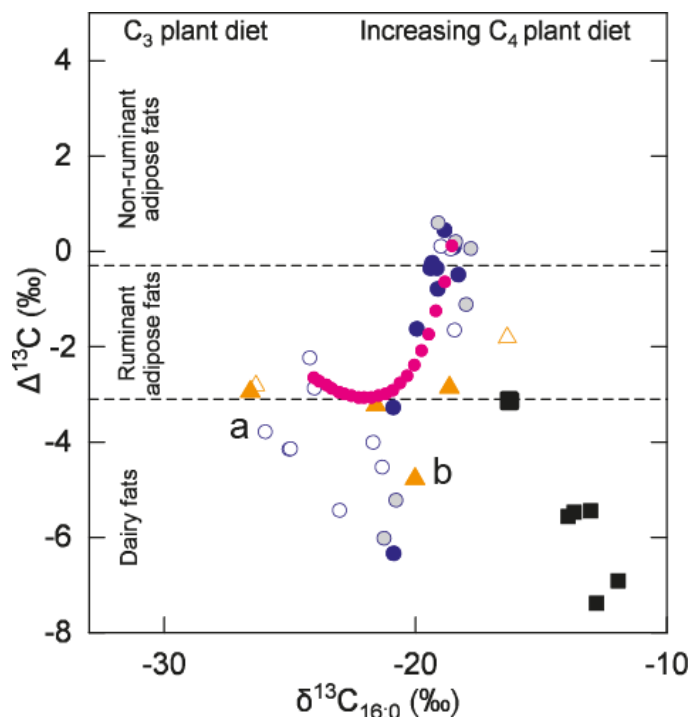
795

796 **Supplementary Figures**

797

798

● Likoang - aquatic BM ○ Likoang - aquatic BM? ○ Likoang - terrestrial
 △ Sehonghong GAP ▲ Sehonghong DC ■ Mokatlapoli



799

800 **Supplementary Figure 1.** Plot of the $\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$ ($\Delta^{13}C$) values against the $\delta^{13}C_{16:0}$ values from potsherds from the three
 801 sites in the study (Fig. 3b in main text; a and b mark the two dairy residues directly dated in the study) with a theoretical mixing
 802 line (bright pink) superimposed over the isotopic values. Modelling was based on averages of the isotopic values obtained from
 803 non-ruminants fats ($\delta^{13}C_{16:0} = -18.6\text{‰}$, $\delta^{13}C_{18:0} = -18.4\text{‰}$) and from the more depleted group of ruminant carcass fats (as these
 804 would most greatly exaggerate any 'dairy' signal arising from mixing; $\delta^{13}C_{16:0} = -24.1\text{‰}$, $\delta^{13}C_{18:0} = -26.7\text{‰}$) and the published
 805 fatty acid % weight averages from 20 freshwater fish species from southern Africa ($C_{16} = 24.2\%$, $C_{18} = 7\%$)^{1,2}. This demonstrates
 806 that the hypothetical mixing of aquatic fats with terrestrial carcass fats based on averages of the data obtained in the study
 807 would not enter the range of ruminant dairy fats, and lie very far from the very negative $\Delta^{13}C$ values of dairy residues obtained.

808

809 **References**

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Supplementary Table 1. Information of extracted potsherds from Likoaeng (Y = yes, N = no, TR = ?).

Sample	Sample weight (g)	Lipid yield (mg g ⁻¹)	$\delta^{13}\text{C}_{16:0}$	$\delta^{13}\text{C}_{18:0}$	$\Delta^{13}\text{C}$	Residue classification	C _{18:0} APAA SIM	C _{20:0} APAA SIM	C _{22:0} APAA SIM	Phytanic acid	Pristanic acid	TMTD	Aquatic contribution?
LIK1	2.62	0.65	-20.9	-24.2	-3.3	dairy	Y	TR	N	Y	TR		Yes
LIK2	1.20	0.10											
LIK3	1.23	0.15	-18.0	-19.1	-1.1	ruminant adipose	Y	TR	N	Y	N	N	?
LIK4	2.40	1.11	-24.2	-26.4	-2.2	ruminant adipose	Y	N	N	Y	N	N	
LIK5	1.66	0.48	-20.8	-26.0	-5.2	dairy	Y	Y	N	Y	N	N	?
LIK6	0.98	1.04	-19.9	-21.5	-1.6	ruminant adipose	Y	Y	N	Y	N	Y	Yes
LIK7	1.79	0.43	-20.9	-27.2	-6.3	dairy	Y	Y	TR	Y	N	Y	Yes
LIK8	2.21	0.45											
LIK9	3.04	0.45	-25.0	-29.2	-4.2	dairy	Y	N	N	Y	N	N	
LIK10	1.74	1.50	-26.0	-29.8	-3.8	dairy	Y	N	N	Y	N	N	
LIK11	2.27	0.05	-21.3	-25.8	-4.5	dairy	N	N	N	N	N	N	
LIK12	2.26	0.13											
LIK13	2.05	0.40	-18.8	-18.4	0.4	non-ruminant adipose	Y	Y	N	Y	N	Y	Yes
LIK14	3.26	0.07	-21.7	-25.7	-4.0	dairy	N	N	N	N	N	N	
LIK15	2.74	0.62	-21.2	-27.3	-6.0	dairy	Y	Y	N	Y	N	N	?
LIK16	3.37	0.26	-24.0	-26.9	-2.9	ruminant adipose	Y	N	N	Y	N	N	
LIK18	2.16	0.62	-23.0	-28.5	-5.4	dairy	Y	N	N	Y	N	N	
LIK19	1.97	0.22	-18.5	-20.1	-1.7	ruminant adipose	N	N	N	Y	N	N	
LIK20	1.36	0.51	-19.1	-18.5	0.6	non-ruminant adipose	Y	Y	N	Y	N	N	?
LIK21	3.34	0.26	-18.5	-18.4	0.1	non-ruminant adipose	Y	Y	Y	Y	N	N	Yes
LIK23	3.46	0.41	-17.8	-17.8	0.1	non-ruminant adipose	Y	Y	N	Y	N	N	?
LIK24	3.19	na	-18.6	-18.6	0.0	non-ruminant adipose	Y	N	N	Y	N	N	
LIK25	2.91	na	-19.0	-18.9	0.1	non-ruminant adipose	Y	N	N	Y	N	N	
LIK26	3.55	na	-19.4	-19.8	-0.4	ruminant adipose	Y	Y	TR	Y	N	N	Yes
LIK27	3.53	na											
LIK28	3.61	na	-25.0	-29.1	-4.2	dairy	Y	N	N	Y	N	N	
LIK29	1.21	0.21	-18.4	-18.2	0.2	non-ruminant adipose	Y	TR	N	Y	N	N	?
LIK30	3.70	0.05	-19.3	-19.6	-0.3	ruminant adipose	Y	Y	TR	Y	N	TR	Yes
LIK31	2.42	0.19	-18.3	-18.8	-0.5	ruminant adipose	Y	Y	TR	Y	N	N	Yes
LIK32	3.01	na	-19.1	-19.9	-0.8	ruminant adipose	Y	Y	Y	Y	N	N	Yes
LIK33	1.23	na	-19.1	-19.5	-0.4	ruminant adipose	Y	Y	TR	Y	N	Y	Yes

Supplementary Table 2. Information of extracted potsherds from Sehonghong rock shelter.

Sample	Layer	Sample weight (g)	Lipid yield (mg g ⁻¹)	$\delta^{13}\text{C}_{16:0}$	$\delta^{13}\text{C}_{18:0}$	$\Delta^{13}\text{C}$	Residue classification	C _{18:0} APAA SIM	C _{20:0} APAA SIM	C _{22:0} APAA SIM	Phytanic acid	Pristanic acid	TMTD	Aquatic contribution?
SHH28	GAP	1.78	0.05	-24.8	-24.0	0.8	Not predominantly animal derived	N	N	N	N	N	N	
SHH29	GAP	1.94	0.03											
SHH30	GAP	2.77	0.94	-16.4	-18.2	-1.8	ruminant adipose	N	N	N	N	N	N	
SHH31	GAP	2.99	0.06											
SHH32	DC	2.49	0.06											
SHH33	DC	2.15	10.33	-26.4	-29.2	-2.8	ruminant adipose	N	N	N	N	N	N	
SHH34	DC	2.12	0.19	-18.7	-21.5	-2.9	ruminant adipose	Y	N	N	Y	N	N	
SHH35	DC	2.15	0.03											
SHH36	GAP	2.19	0.11											
SHH37	GAP	1.42	0.17											
SHH38	GAP	1.16	0.05											
SHH39	GAP	2.63	0.01											
SHH40	DC	3.30	0.04											
SHH41	DC	2.08	2.99	-21.6	-24.8	-3.2	dairy	Y	TR	N	Y	N	N	?
SHH42	DC	1.58	1.24	-20.0	-24.8	-4.8	dairy	Y	Y	TR	Y	N	N	
SHH44	DC	3.03	0											
SHH45	DC	1.67	2.60	-26.6	-29.5	-2.9	ruminant adipose	Y	N	N	Y	n	n	

Supplementary Table 3. Information for extracted potsherds from Mokatlapoli.

Sample	Sample weight (g)	Lipid yield (mg g ⁻¹)	$\delta^{13}\text{C}_{16:0}$	$\delta^{13}\text{C}_{18:0}$	$\Delta^{13}\text{C}$	Residue classification	C _{18:0} APAA SIM	C _{20:0} APAA SIM	C _{22:0} APAA SIM	Phytanic acid	Pristanic acid	TMTD	Aquatic contribution?
MOK1	2.04	0.01	-24.4	-21.1	3.3	Not predominantly animal derived	N	N	N	N	N	N	
MOK2	3.56	0											
MOK3	3.39	0.01											
MOK4	2.67	0.02											
MOK5	3.38	0.21	-13.0	-18.5	-5.4	dairy	N	N	N	Y	N	N	
MOK6	2.96	0											
MOK7	3.61	0.01											
MOK8	2.11	0											
MOK9	1.85	1.92	-13.9	-19.5	-5.6	dairy	Y	?N	N	Y	N	N	
MOK10	3.66	0.02											
MOK11	2.79	0.01											
MOK12	1.99	0.94	-11.9	-18.8	-6.9	dairy	N	N	N	Y	N	N	
MOK13	3.74	0											
MOK14	1.92	3.69	-12.8	-20.2	-7.4	dairy	N	N	N	Y	N	N	
MOK15	2.56	0.01	-23.8	-22.6	1.2	Not predominantly animal derived	N	N	N	N	N	N	
MOK16	3.07	0					N	N	N	N	N	N	
MOK17	3.33	0.04	-16.3	-19.4	-3.1	dairy	N	N	N	N	N	N	
MOK18	2.30	0.04	-13.5	-14.5	-1.1	Not predominantly animal derived	N	N	N	N	N	N	
MOK19	3.56	0.01	-15.0	-16.2	-1.2	Not predominantly animal derived	N	N	N	N	N	N	
MOK20	2.21	0.05	-13.7	-19.2	-5.5	dairy	N	N	N	N	N	N	
MOK21	2.02	0.03											
MOK22	3.34	0.01											
MOK23	2.65	0.01											
MOK24	2.51	0.02											
MOK25	3.82	0.01											
MOK26	2.52	0.12											
MOK27	3.24	0.03	-18.6	-18.8	-0.2	Not predominantly animal derived	Y	N	N	N	N	N	

Supplementary Table 4. Radiocarbon dates on pottery lipids from Lesotho.

Laboratory nr.	sample label	¹⁴ C age (y) BP	Replicate agreement (σ range)	Combined age (y) BP	Calibrated range (68.2 % probability)	Calibrated range (95.4 % probability)
BRAMS-2612.1.1	SHH42-C _{16:0}	1155 ± 34	1 σ	BRAMS-2612: 1161 ± 28	AD 895-935 (41.8 %)	AD 885-990
BRAMS-2612.1.2	SHH42-C _{18:0}	1169 ± 36			AD 955-980 (26.4 %)	
BRAMS-2613.1.1	LIK10-C _{16:0}	1504 ± 29	X	-	-	-
BRAMS-2613.1.2	LIK10-C _{18:0}	1734 ± 28				
BRAMS-2613.2.1	LIK10-C _{16:0}	1438 ± 30	2 σ	BRAMS-2613: 1481 ± 27	AD 600-644	AD 579-654
BRAMS-2613.2.2	LIK10-C _{18:0}	1516 ± 30				