

1 **Title:**

2 Stable isotopic composition of fossil mammal teeth and environmental change in
3 southwestern South Africa during the Pliocene and Pleistocene

4

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46 Grazing herbivores in southwestern South Africa ate substantial amounts of C₃ grasses

47 and minor amounts of C₄ grasses

48

49 Winter rainfall has persisted in southwestern South Africa since at least 5 Ma

50

51 Elandsfontein was likely buffered from regional aridity during the mid-Pleistocene

52 **Abstract**

53 The past 5 million years mark a global change from the warmer, more stable
54 climate of the Pliocene to the initiation of glacial-interglacial cycles during the
55 Pleistocene. Marine core sediment records located off the coast of southwestern Africa
56 indicate aridification and intensified upwelling in the Benguela Current over the Pliocene
57 and Pleistocene. However, few terrestrial records document environmental change in
58 southwestern Africa over this time interval. Here we synthesize new and published
59 carbon and oxygen isotope data of the teeth from large mammals (>6 kg) at
60 Langebaanweg (~5 million years ago, Ma), Elandsfontein (1.0 – 0.6 Ma), and
61 Hoedjiespunt (0.35 – 0.20 Ma), to evaluate environmental change in southwestern Africa
62 between the Pliocene and Pleistocene. The majority of browsing and grazing herbivores
63 from these sites yield enamel $\delta^{13}\text{C}$ values within the range expected for animals with a
64 pure C_3 diet, however some taxa have enamel $\delta^{13}\text{C}$ values that suggest the presence of
65 small amounts C_4 grasses at times during the Pleistocene. Considering that significant
66 amounts of C_4 grasses require a warm growing season, these results indicate that the
67 winter rainfall zone, characteristic of the region today, could have been in place for the
68 past 5 million years. The average $\delta^{18}\text{O}$ value of the herbivore teeth increases ~4.4‰
69 between Langebaanweg and Elandsfontein for all taxa except suids. This increase may
70 solely be a function of a change in hydrology between the fluvial system at
71 Langebaanweg and the spring-fed environments at Elandsfontein, or a combination of
72 factors that include depositional context, regional circulation and global climate.
73 However, an increase in regional aridity or global cooling between the early Pliocene and
74 mid-Pleistocene cannot explain the entire increase in enamel $\delta^{18}\text{O}$ values. Spring-fed

75 environments like those at Elandsfontein may have provided critical resources for
76 mammalian fauna in the mid-Pleistocene within an increasingly arid southwestern Africa
77 ecosystem.

78

79

80 **Introduction**

81 The Pliocene-Pleistocene climatic transition is marked by a global shift from
82 relatively warm and stable climate conditions in the Pliocene to colder and more variable
83 conditions in the Pleistocene (Imbrie et al., 1992; Zachos et al., 2001). Over the course of
84 this transition African landscapes are considered to have become more arid (e.g.,
85 deMenocal, 2004; Dupont et al., 2013). In southwestern Africa, intensified upwelling of
86 cold bottom waters in the Benguela Current System has been linked with increased
87 regional aridity and the onset, expansion and speciation of the endemic Cape flora since
88 the Miocene (Marlow et al., 2000; Dupont et al., 2005; 2011; Etourneau et al., 2009).
89 While marine-based records indicate major changes in vegetation and climate in southern
90 Africa, terrestrial-based records could provide a more local perspective of the
91 hydrological setting, vegetation and climate of southwestern South Africa since the
92 Pliocene; currently there are few archives of environmental change in this region during
93 the last 5 million years (myr) (Roberts et al., 2011; Eze and Meadows, 2014).

94 Sedimentary strata from known Pliocene and Pleistocene fossil sites in
95 southwestern South Africa have the potential to provide direct evidence for the local
96 environmental response to climate change (Table 1). Sedimentary records indicate a
97 transition from fluvial to spring-fed and eolian deposition in southwestern South Africa

98 (Roberts et al., 2011; Eze and Meadows, 2014). Data from pre-Holocene mammalian
99 fossils suggest the presence of significant amounts of surface water and a vegetated
100 landscape composed of a fynbos shrubland and grassland mosaic, interspersed with trees
101 and broad-leafed bush, which contrasts the dry, eolian landscapes that are prevalent in
102 southwestern South Africa today (e.g., Luyt et al., 2000; Franz-Odenaal et al., 2002;
103 Stynder, 2009; 2011; Braun et al., 2013).

104 Here we use the carbon and oxygen isotopic composition of fossil herbivore tooth
105 enamel obtained from paleontological and archaeological sites in southwestern South
106 Africa to investigate trends in regional climate and hydrology, vegetation and animal diet
107 between the Pliocene and Pleistocene. Together with marine archives off the coast of
108 southern Africa that record broader, regional-scale climate and vegetation, we use these
109 terrestrial-based data to improve upon the understanding of how environments in
110 southwestern South Africa responded to global climatic changes during the Pliocene and
111 Pleistocene.

112

113

114 **Background**

115 *2.1 South African climate and vegetation*

116 South Africa is predominantly semiarid with three distinct rainfall zones and
117 corresponding vegetation zones (Fig. 1; Cowling et al., 2002). The winter rainfall zone of
118 western South Africa encompasses an area of ~200-km² where ~65% of mean annual
119 precipitation (MAP) occurs between April and September. The summer rainfall zone is
120 affected by the warm Agulhas Current that flows along the eastern coast of South Africa.

121 At the intersection of these two major meteorological zones, situated along the South
122 Coast of South Africa, there is a region that receives rainfall during both the summer and
123 winter. This annual rainfall zone spans from the southern coast of the Eastern Cape
124 Province of South Africa into the Western Cape Province (e.g., Chase and Meadows,
125 2007).

126 Rainfall zones in South Africa partition zones of vegetation, which can be seen
127 through the spatial distribution of the frequency of the three main photosynthetic
128 pathways: C₃, C₄, and Crassulacean Acid Metabolism (CAM). The distribution of these
129 pathways is largely determined by environmental factors (Farquhar et al., 1989). C₄
130 plants thrive in environments with a warm growing season while C₃ plants grow primarily
131 in cool growing seasons. CAM plants, such as cacti and succulents, are often found in
132 semiarid to arid environments. The distribution of grass type is related to the seasonality
133 of rainfall in South Africa; C₄ grasses mostly grow in regions with summer rainfall, C₃
134 grasses grow where there is winter rainfall, and both C₃ and C₄ grasses grow in the
135 annual rainfall zone (Vogel et al., 1978; Cowling et al., 2002; Bar-Matthews et al., 2010).
136 Increased upwelling and the latitudinal movement of the Benguela Current may modify
137 the movement of warm waters along the coast of South Africa and this could impact the
138 distribution of the rainfall zones (Chase and Meadows, 2007). The positions of the
139 rainfall and vegetation zones are hypothesized to have shifted during the late Quaternary
140 in response to the position and upwelling intensity of the Benguela Current (Lee-Thorp
141 and Beaumont, 1995), however it is unclear whether they were stable in the Pliocene and
142 mid-Pleistocene.

143 The paleontological and archaeological sites that are the focus of this paper are
144 within southwestern South Africa, west of the Cape Fold Mountains and stretch across 40
145 kms of the coastal plain. These sites, Langebaanweg (~5 million years ago (Ma), early
146 Pliocene), Elandsfontein (1.0 – 0.6 Ma, mid-Pleistocene) and Hoedjiespunt (0.35 – 0.20
147 Ma, late Pleistocene), are within the winter rainfall zone (Fig. 1). Regionally the area is
148 known as Strandveld (literally ‘beach vegetation’) and geomorphologically is dominated
149 by a coastal plain variably covered by marine sands (Mabbutt, 1955; Roberts et al., 2012).
150 Limited outcrops of granite to the south and west interrupt Cenozoic-aged eolian deposits
151 that blanket much of the region. The western portion of the area is underlain by shales of
152 the Malmesbury Group leading up to the Palaeozoic sandstones of the Cape Supergroup
153 (Besaans, 1972; Roberts et al., 2009). The contemporary vegetation in the study area is
154 primarily composed of small-leafed, nutrient-poor taxa of the strandveld and fynbos
155 families. C₃ grasses and trees are scarce in this area because of the nutrient-poor soils. It
156 has generally been presumed that C₄ grasses are limited in the southwestern Cape by the
157 long, hot and dry summers, however C₄ grasses are able to grow in areas that are well
158 watered throughout the year (e.g., Cowling et al., 2002; 2005).

159

160 ***2.2 Pliocene and Pleistocene climate and vegetation in western South Africa***

161 *2.2.1 Marine records*

162 Marine sediment records from cores off the coast of southwestern Africa span the
163 past 4.5 myr and provide information about terrestrial responses to global climate change
164 and the degree of ocean upwelling (Marlow et al., 2000; Dupont, 2005; Etourneau et al.,
165 2009). Charcoal and plant waxes preserved offshore show that there was an increase in

166 aridity, seasonality and fires to the north of the study area during the Miocene and
167 Pliocene (Hoetzel et al., 2013). The drying trend continued across the
168 Pliocene-Pleistocene climatic transition; offshore pollen records indicate a reduction in
169 grass and an increased occurrence of fynbos and semi-desert vegetation (e.g., Dupont et
170 al., 2005).

171

172 *2.2.2 Terrestrial records*

173 In contrast to the high-resolution, marine-based proxy records that extend into the
174 Miocene, there are no terrestrial-based proxy records with a similar time span or
175 resolution. However the numerous archives of eolian and riverine sedimentary sequences
176 on the coastal plains of southwestern South Africa provide some details of late Cenozoic
177 environments. There have been numerous studies of ancient environments in this region
178 based on these records (e.g., Klein, 1978; 1982; 1983; 1991; Klein and Cruz-Uribe, 1991;
179 February, 1992; Meadows et al., 1996). However, the vast majority of these studies have
180 focused on environments since the Last Interglacial (0.125 Ma). Langebaanweg,
181 Elandsfontein and Hoedjiespunt are paleontological and archeological sites within the
182 study area that date to within the last ~5 myr. These sites are well known for their
183 contribution to our understanding of faunal change and human evolution in South Africa
184 (e.g., Hendey, 1976; Klein, 1978; Berger and Parkington, 1995; Stynder, 1997; Stynder et
185 al., 2001; Klein et al., 2007; Braun et al., 2013). The flora, fauna and sediment records at
186 these sites provide a record of environmental change in the area from the Pliocene and
187 Pleistocene (Luyt et al., 2000; Franz-Odendaal et al., 2002; Stynder, 2009; Roberts et al.,
188 2011; Stynder, 2011; Braun et al., 2013; Hare and Sealy, 2013; Eze and Meadows, 2014).

189 While these sites have been the focus of a variety of paleoecological studies (Table 1),
190 currently there is no detailed, integrated record of the hydrological, ecological and
191 climatic changes in southwestern South Africa over the past 5 myr.

192

193 *2.3 Carbon and oxygen isotope composition of herbivore tooth enamel*

194 C₃, C₄ and CAM plants have distinct stable carbon isotope values primarily due to
195 different physiologies of the different photosynthetic pathways (e.g., Farquhar et al.,
196 1989). Carbon isotope data of plants are traditionally presented using δ -notation, where

197
$$\delta = \left(\frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right) * 1000$$
 in per mil (‰) units and R_{sample} and R_{standard} are the ratios of heavy

198 to light isotopes (in this case, ¹³C and ¹²C) of the sample and standard, respectively. $\delta^{13}\text{C}$
199 values are reported relative to Vienna Pee Dee Belemnite (VPDB). The $\delta^{13}\text{C}$ values of C₃
200 plants globally range from $\sim -31.7\text{‰}$ to $\sim -23.1\text{‰}$ (Kohn et al., 2010). The $\delta^{13}\text{C}$ values C₄
201 plants range from $\sim -14.0\text{‰}$ and $\sim -10.0\text{‰}$ (Hattersley, 1982). In southwestern South
202 Africa the average $\delta^{13}\text{C}$ value of C₄ plants is $-12.8 \pm 1.3\text{‰}$ (Radloff, 2008), whereas $\delta^{13}\text{C}$
203 values of CAM plants range from $\sim -24\text{‰}$ to $\sim -16\text{‰}$ (Boom et al., 2014).

204 The $\delta^{13}\text{C}_{\text{enamel}}$ value reflects the proportion of C₃ and C₄ plants in an animal's diet
205 such that the $\delta^{13}\text{C}_{\text{enamel}}$ values of fossil herbivore teeth can be used to determine the
206 presence or absence of C₃ and C₄ grasses in the past. There is a $+14.1\text{‰}$ dietary
207 enrichment of $\delta^{13}\text{C}$ values between the diet of large herbivorous mammals (> 6 kg) and
208 their enamel (Cerling et al., 1999) and as such the $\delta^{13}\text{C}$ value of tooth enamel ($\delta^{13}\text{C}_{\text{enamel}}$)
209 reflects the isotopic composition of an animal's diet (see Kohn and Cerling, 2002 for
210 review). Here we define large mammals as > 6 kg because the smallest mammal included

211 in this category is the grysbok, which is ~10 kg, whereas we refer to the mammals from
212 Elandsfontein with body weights < 6 kg as small mammals, which includes the rodent
213 genera *Bathyergus* and *Otomys*. For fossil sites, in southern Africa, the presence or
214 absence of C₃ and C₄ grasses in mammalian diet has been presumed to reflect the
215 presence or absence of winter and summer rainfall (Luyt et al., 2000; Franz-Odenaal et
216 al., 2002; Hare and Sealy, 2013). Within a C₃-dominated ecosystem, the isotopic
217 composition of tooth enamel from large herbivores can be used to tease apart subtleties in
218 the distribution of vegetation (e.g., Luyt et al., 2000; Franz-Odenaal et al., 2002; Hare
219 and Sealy, 2013). For example, Hare and Sealy (2013) suggest that there was some C₄
220 grass in C₃-dominated grasslands in southwestern South Africa during the late
221 Pleistocene because the $\delta^{13}\text{C}_{\text{enamel}}$ values of grazers were more enriched in $\delta^{13}\text{C}_{\text{enamel}}$
222 values than what is expected for a grazer consuming purely C₃ vegetation. CAM plants
223 are not considered to have greatly influenced the $\delta^{13}\text{C}_{\text{enamel}}$ values because they do not
224 comprise a major proportion of large mammalian herbivore diets (Cerling et al., 2003)
225 and therefore they will not be further considered in this study.

226 The stable oxygen isotope composition of the carbonate component of herbivore
227 tooth enamel is affected by a number of factors including the $\delta^{18}\text{O}$ value of ingested
228 water, which is influenced by the $\delta^{18}\text{O}$ values of precipitation, surface and plant water, as
229 well as animal physiology and behavior (as reviewed in Kohn and Cerling, 2002). All of
230 these factors generally contribute to higher $\delta^{18}\text{O}$ values of enamel in more arid
231 environments. The comparison of enamel $\delta^{18}\text{O}$ values between obligate drinkers and non-
232 obligate drinkers has been specifically used for evaluating relative aridity in terrestrial
233 ecosystems (e.g., Levin et al., 2006).

234 The oxygen isotopic composition of enamel phosphate has also been used as a
235 proxy for paleoclimate and is considered to be less susceptible to alteration than the
236 oxygen isotope composition of the carbonate component of enamel because oxygen in the
237 phosphate component is more tightly bound than in the carbonate component of enamel
238 (Chenery et al., 2012). The offset between $\delta^{18}\text{O}$ values of the carbonate and phosphate
239 components of enamel ranges from 7.2‰ to 10.6‰ in well-preserved teeth and has been
240 used as a means to evaluate diagenetic modification of the $\delta^{18}\text{O}$ values of fossil teeth
241 (e.g., Iacumin et al., 1996).

242

243

244 **3. Materials and Methods**

245 ***3.1 Fossil enamel samples***

246 We sampled mid-Pleistocene fossil teeth from two separate faunal collections at
247 Elandsfontein. The first collection is housed at the Iziko South African Museums in Cape
248 Town, South Africa. This faunal sample, known as Elandsfontein Main (EFTM), was
249 predominantly collected from surface deposits over the course of several decades as
250 described in Klein et al. (2007). The second collection derives from recent fieldwork
251 conducted by the West Coast Research Project (WCRP) between 2008 and 2014. These
252 materials are archived at the Archaeology Department, University of Cape Town and
253 include both surface samples and excavated teeth. All fossils that we sampled from the
254 WCRP collection derive from the Upper Pedogenic Sand lithological unit that is part of
255 the Langebaan Formation (Braun et al., 2013). We also sampled Pliocene teeth ($n = 10$)
256 from the Varswater Formation at the Langebaanweg paleontological locality, which were

257 obtained from the West Coast Fossil Park (Roberts et al., 2011). The teeth from
258 Langebaanweg were sampled to provide a point of comparison in the evaluation of the
259 diagenetic alteration of oxygen isotopes in tooth enamel from Elandsfontein. All tooth
260 enamel was sampled with a diamond drill bit along the tooth growth axis. When possible,
261 third molars were sampled. New data were compiled with previously published carbon
262 and oxygen isotope tooth enamel data from the region, including 64 teeth from
263 Langebaanweg (Franz-Odendaal et al., 2002), 18 teeth from Elandsfontein (Luyt et al.,
264 2000), and 39 teeth from Hoedjiespunt (Hare and Sealy, 2013). This compilation does not
265 include the isotope data of the fossil teeth from the “Bone Circle” at Elandsfontein that
266 Luyt et al. (2000) published because we are uncertain of their context and relationship to
267 the other fossils from Elandsfontein (Braun et al., 2013).

268

269 *3.2 Isotopic measurements*

270 We measured $\delta^{13}\text{C}_{\text{enamel}}$ values and $\delta^{18}\text{O}$ values of both the carbonate and
271 phosphate components of fossil tooth enamel. We also measured $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values of
272 surface and ground waters in the immediate vicinity of Elandsfontein and in the general
273 Langebaan-Hopefield region.

274

275 *3.2.1 Analysis of the enamel carbonate component*

276 Fossil enamel was powdered, treated with 3% H_2O_2 to remove organic material
277 and rinsed three times with deionized water. The resultant powder was rinsed with 0.1 M
278 buffered acetic acid to remove secondary carbonate, rinsed three times with deionized
279 water and dried overnight at 60°C. Approximately 500 to 800 μg of each powdered

280 sample were placed in a silver capsule then digested under vacuum in a common bath of
281 100% phosphoric acid at 90°C and the resultant CO₂ was purified using a custom-built
282 automated device (Passey et al., 2010). The CO₂ was analyzed for ¹³C/¹²C and ¹⁸O/¹⁶O
283 ratios using a dual inlet system on a Thermo MAT253 isotope ratio mass spectrometer in
284 the Department of Earth and Planetary Sciences, Johns Hopkins University. The isotopic
285 composition of the resultant CO₂ was determined with respect to a working CO₂
286 reference, calibrated using NBS-19, and monitored using working references of calcite
287 and enamel. The precision of the working carbonate enamel standards over the course of
288 the analyses made for this study was 0.4‰ and 0.2‰ for δ¹³C and δ¹⁸O, respectively. An
289 acid fractionation factor of 1.00725 was used for determining δ¹⁸O values of the
290 carbonate component of fossil enamel digested at 90°C (Passey et al., 2007). All δ¹³C
291 values are reported relative to VPDB (Vienna Pee Dee Belemnite) and δ¹⁸O values are
292 reported relative to VSMOW (Vienna Standard Mean Ocean Water).

293

294 *3.2.2 Analysis of the δ¹⁸O values of enamel phosphate*

295 Forty-eight fossil teeth from Langebaanweg and Elandsfontein were analyzed for
296 the δ¹⁸O values of enamel phosphate, in addition to carbon and oxygen isotope analyses
297 of enamel carbonate mentioned above. Samples were drilled and pretreated in the manner
298 described above (Section 3.2.1). Phosphate-bound oxygen was isolated and extracted
299 from enamel using a modified version of the batch Ag₃PO₄ precipitation method of
300 O’Neil et al. (1994) followed by δ¹⁸O analysis of approximately 400 μg of Ag₃PO₄ via
301 high temperature pyrolysis to CO (TC/EA) on a continuous flow Delta Plus XL isotope
302 ratio mass spectrometer at the Department of Geosciences, Princeton University.

303 Long-term performance (precision of the isotope ratio mass spectroscopy
304 measurement and wet chemistry conversion from hydroxyapatite to Ag_3PO_4) was
305 confirmed by repeat analysis of NBS120c, a phosphate rock with certified metal oxide
306 abundances and distributed by the National Institute of Standards and Technology and the
307 *de facto* standard for $\delta^{18}\text{O}$ in phosphate, with $\delta^{18}\text{O}$ values ranging from 21.3 to 22.6‰
308 VSMOW (e.g., Vennemann et al., 2002; Halas et al., 2011). Although precipitation yield
309 varied using the modified O'Neil et al. (1994) batch precipitation method ($52\pm 22\%$),
310 repeat analysis of the NBS120c phosphate standard over 18 months averaged
311 $22.36\pm 0.48\%$ and showed no dependence of measured $\delta^{18}\text{O}$ values on precipitation yield,
312 with the average value aligning well with published $\delta^{18}\text{O}$ values.

313

314 *3.2.3 Analysis of the $\delta^{18}\text{O}$ values of water*

315 Samples of standing water and ground water ($n = 3$) were collected from a series
316 of active springs in the vicinity (within a ~ 3 km to ~ 17 km radius) of the Quaternary
317 deposits at Elandsfontein where fossil teeth were collected. Tap water from The Western
318 Cape Fossil Park (which is in the general proximity of the study area) was also collected
319 ($n = 1$). Samples were passed through a $0.45\text{-}\mu\text{m}$ filter in the field and sealed in a glass
320 bottles with polycone seal lids and wrapped in parafilm to prevent evaporation. Samples
321 were cleaned with activated charcoal to remove organics, filtered again and then analyzed
322 by laser absorption spectroscopy on a Los Gatos Research Liquid-Water Isotope
323 Analyzer at the Department of Earth and Planetary Sciences, Johns Hopkins University.
324 The precision of the working water standard USGS48 over the course of the water
325 analyses was 0.03% and 0.1% for $\delta^{18}\text{O}$ and $\delta^2\text{H}$ respectively. The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values of

326 water samples are reported relative to the VSMOW-SLAP scale, where SLAP is Standard
327 Light Antarctic Precipitation.

328

329 ***3.3 Interpretation of stable isotope results***

330 *3.3.1 Influence of $\delta^{13}\text{C}$ values of atmospheric CO_2*

331 The $\delta^{13}\text{C}$ value of atmospheric CO_2 has decreased over the past 5 myr (Tipple et
332 al., 2010) and this decrease needs to be considered when using $\delta^{13}\text{C}_{\text{enamel}}$ values to
333 determine the proportion of C_3 and C_4 plants in an animal's diet. The $\delta^{13}\text{C}$ value of
334 atmospheric CO_2 will influence the $\delta^{13}\text{C}$ values of C_3 and C_4 plants and as a consequence
335 will influence $\delta^{13}\text{C}_{\text{enamel}}$ values of the tissues of the animals that eat these plants. We
336 calculated the ranges in $\delta^{13}\text{C}$ values that we expect for C_3 and C_4 plants at the time
337 periods representative of Langebaanweg (~5 Ma), Elandsfontein (1.0 – 0.6 Ma) and
338 Hoedjiespunt (0.35 – 0.20 Ma) to better determine what herbivore $\delta^{13}\text{C}_{\text{enamel}}$ values may
339 indicate about the distribution of C_3 and C_4 plants in the study area, considering the $\delta^{13}\text{C}$
340 values of atmospheric CO_2 reconstructed from benthic foraminifera (Tipple et al., 2010;
341 see Table S1 for details). Given changes in the $\delta^{13}\text{C}$ value of atmospheric CO_2 , the
342 maximum $\delta^{13}\text{C}_{\text{enamel}}$ values for large mammals with a pure C_3 diet are -7.6‰ for
343 Langebaanweg and -8.4‰ for both Elandsfontein and Hoedjiespunt (Table S1). If the
344 $\delta^{13}\text{C}_{\text{enamel}}$ value of a grazer is higher than the reconstructed maximum $\delta^{13}\text{C}_{\text{enamel}}$ value for
345 an animal eating a pure C_3 diet, then it implies the presence of C_4 grass in the animal's
346 diet and, in turn, the growth of C_4 plants in the otherwise dry summer months in
347 southwestern South Africa. As mentioned earlier, the presence of C_4 grass in
348 southwestern South Africa is interpreted as the inclusion of rainfall during the summer

349 months in this ecosystem. Alternatively, large mammals may be feeding around
350 permanent water sources such as springs and rivers where C₄ plants may have grown.

351

352 *3.3.2 Analysis of the δ¹⁸O values of enamel phosphate*

353 Low carbonate content of fossils, bones and sediments at Elandsfontein have led
354 to hypotheses that carbonate has been leached from the fossil deposits at the
355 Elandsfontein archeological site since initial deposition and burial (Luyt et al., 2000).

356 This is in contrast to fossils from the sites Langebaanweg and Hoedjiespunt, which have
357 been recovered from carbonate-rich sediments (Stynder, 1997; Roberts et al., 2013). To
358 evaluate the potential influence of leaching on the δ¹⁸O values of the carbonate

359 component of tooth enamel at Elandsfontein and whether or not these δ¹⁸O values can be
360 used as indicators of paleoclimate, we compared the offsets in δ¹⁸O values of the
361 carbonate and phosphate of fossil teeth from Elandsfontein to those from Langebaanweg.

362 Oxygen in enamel phosphate is more strongly bound and more resistant to
363 diagenetic alteration than in enamel carbonate. There is a consistent enrichment between
364 the δ¹⁸O value in enamel phosphate and carbonate and as such δ¹⁸O values of the oxygen
365 in the phosphate and carbonate component of tooth enamel are strongly correlated for
366 modern and unaltered fossil enamel (Bryant et al., 1996; Iacumin et al., 1996; Martin et
367 al., 2008). This enrichment, or epsilon

368 (i.e., εδ¹⁸O_{A-B} where $\epsilon\delta^{18}\text{O}_{A-B} = \left[\frac{1000 + \delta^{18}\text{O}_A}{1000 + \delta^{18}\text{O}_B} \right] \times 1000$ and where in this case A = CO₃

369 and B = PO₄), ranges from 7.2 to 10.6‰ for enamel that has not experienced significant
370 diagenesis (Bryant et al., 1996; Iacumin et al., 1996; Martin et al., 2008). The

371 εδ¹⁸O_{CO₃-PO₄} has been used to determine if the oxygen isotopic composition of the

372 carbonate in bioapatite has been diagenetically altered (Iacumin et al., 1996). We
373 compared $\epsilon\delta^{18}\text{O}_{\text{CO}_3\text{-PO}_4}$ values of teeth at Elandsfontein to those from Langebaanweg and
374 from compilations of modern teeth to evaluate the integrity of the $\delta^{18}\text{O}$ values of the
375 carbonate component of teeth from Elandsfontein. If the $\epsilon\delta^{18}\text{O}_{\text{CO}_3\text{-PO}_4}$ values at
376 Langebaanweg and Elandsfontein are similar to one another and within the range
377 expected for unaltered teeth, then the $\delta^{18}\text{O}$ values of the carbonate component of enamel
378 from Elandsfontein can be used to reconstruct paleoenvironment.

379

380 *3.3.3 Statistical comparison of isotopic values*

381 All comparisons of isotope data from fossil teeth were performed using the JMP
382 11, a statistical analytical software program developed by the SAS Institute and evaluated
383 using the Tukey-Kramer HSD test. The \pm symbol is used throughout this paper to
384 represent one standard deviation from the mean.

385

386

387 **4. Results**

388 *4.1 Isotopic composition of fossil enamel carbonate from Elandsfontein*

389 The compiled dataset for carbon and oxygen isotope data (carbonate component
390 only) for large mammalian teeth from Elandsfontein is comprised of two collections that
391 represent the mid-Pleistocene, EFTM ($n = 71$; Luyt et al., 2000; this study) and WCRP
392 ($n = 123$; this study). The EFTM and WCRP collections include fossil teeth from seven
393 herbivore families: Bovidae, Elephantidae, Equidae, Giraffidae, Hippopotamidae,
394 Rhinocerotidae and Suidae, in addition to a single tooth from the primate family,

395 Cercopithecidae (see Table 2 and Table S2). These samples likely all belong to the same
396 stratigraphic unit, the mid-Pleistocene Upper Pedogenic Sand in the Langebaan
397 Formation (Braun et al., 2013). The main difference between these collections is that
398 fossils in the EFTM collection were collected from surface finds over decades (Klein et
399 al., 2007), whereas the WCRP collection includes a combination of fossils recovered
400 from surface surveys and excavations made with careful attention to stratigraphic context
401 (Braun et al., 2013).

402 There are no differences in either the $\delta^{13}\text{C}$ values ($p > 0.9$) or $\delta^{18}\text{O}$ values
403 ($p > 0.2$) of enamel carbonate, grouped by taxonomic family, from the EFTM collection
404 data reported by Luyt et al. (2000) and the new EFTM data that we report in this study.
405 When the isotopic data from teeth in the combined EFTM dataset (Luyt et al., 2000; this
406 study) are compared to the isotopic data from fossils in the WCRP collection (this study
407 only), we do not find any differences in $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of fossil teeth from like
408 families except for $\delta^{18}\text{O}$ values (enamel carbonate) of the suids (EFTM, $n = 5$,
409 $26.3 \pm 2.6\text{‰}$; WCRP, $n = 3$, $32.1 \pm 0.6\text{‰}$, $p = 0.004$). We note that the sample size is small
410 for several of the families analyzed at Elandsfontein (see Table 2 and Table S2). From
411 here on out, we discuss the isotope data from both the EFTM and WCRP collections
412 together and refer to them as all from Elandsfontein, unless otherwise noted.

413 We classified the dietary behavior (i.e., grazer, browser or mixed feeder) of 104
414 teeth from the compiled collections for Elandsfontein using a combination of approaches,
415 including mesowear, microwear and taxonomic analogy (Fig. 2; Table S2; Stynder, 2009;
416 2011). The individual teeth fall into three groups: browsers ($n = 20$), mixed feeders ($n =$
417 4) and grazers ($n = 71$). *Theropithecus* at Elandsfontein has not yet been analyzed using

418 mesowear or microwear to determine diet so we do not place it in one of these categories.
419 We consider hippopotamids apart from the other taxa that we sampled and classify it as
420 semi-aquatic because in modern African ecosystems *Hippopotamus amphibious* spends a
421 significant amount of time immersed in water, unlike the other taxa in this dataset (e.g.,
422 Bocherens et al., 1996; Cerling et al., 2008). The $\delta^{13}\text{C}_{\text{enamel}}$ values of browsers, mixed
423 feeders and grazers average $-11.6 \pm 0.8\text{‰}$ ($n = 20$), $-10.3 \pm 1.1\text{‰}$ ($n = 4$) and $-10.1 \pm 1.0\text{‰}$ (n
424 $= 71$), respectively. The average $\delta^{13}\text{C}_{\text{enamel}}$ value of hippopotamids from Elandsfontein
425 is $-12.3 \pm 1.1\text{‰}$ ($n = 9$). The $\delta^{18}\text{O}$ values of the carbonate component of enamel of
426 browsers, mixed feeders, grazers and hippopotamids are $33.1 \pm 1.9\text{‰}$, $31.3 \pm 1.6\text{‰}$,
427 $32.4 \pm 2.5\text{‰}$ and $29.7 \pm 1.5\text{‰}$, respectively. Hippopotamid $\delta^{18}\text{O}$ values of enamel carbonate
428 are significantly lower than $\delta^{18}\text{O}$ values of browsers ($p = 0.002$) and grazers ($p = 0.005$).

429

430 ***4.2 Comparison of oxygen isotopic values between enamel carbonate and enamel*** 431 ***phosphate***

432 We analyzed the oxygen isotope composition of both the carbonate and phosphate
433 components of a subset of tooth enamel from Elandsfontein and Langebaanweg to
434 evaluate whether the $\delta^{18}\text{O}$ value of the carbonate component of enamel from fossil teeth
435 at Elandsfontein is well enough preserved that it can be used as a proxy for conditions
436 during the animal's life. The average $\epsilon\delta^{18}\text{O}_{\text{CO}_3\text{-PO}_4}$ values of enamel are $9.2 \pm 0.7\text{‰}$
437 ($n = 38$) and $8.2 \pm 0.7\text{‰}$ ($n = 10$) for Elandsfontein and Langebaanweg, respectively; these
438 values fit within the range observed for well-preserved teeth ($7.2 - 10.6\text{‰}$) (Bryant et al.,
439 1996; Iacumin et al., 1996 and Martin et al., 2008; Fig. 3; Table S3). Based on the
440 similarities in these offsets to what has been measured in well-preserved enamel, we

441 consider the $\delta^{18}\text{O}$ values of the carbonate component of tooth enamel from Elandsfontein
442 to be unaltered and to reflect the environmental and physiological conditions experienced
443 by an animal during tooth formation.

444 Further data to support this conclusion comes from interspecific comparisons of
445 $\delta^{18}\text{O}$ values of enamel carbonate. Numerous fossil and modern localities have
446 documented that $\delta^{18}\text{O}$ values of hippopotamid enamel carbonate are lower than the $\delta^{18}\text{O}$
447 values of coeval taxa because they would be eating plants close to water and drinking
448 water (e.g., Bocherens et al., 1996; Levin et al., 2006). Similar taxonomic distinctions
449 found between ancient taxa in the Elandsfontein collection indicate that the unaltered
450 biogenic signal of isotopic values is preserved in these specimens (Fig. 2b). Henceforth,
451 we only discuss the $\delta^{18}\text{O}$ values from the carbonate component of tooth enamel and refer
452 to them as $\delta^{18}\text{O}_{\text{enamel}}$ values.

453

454 ***4.3 Trends in $\delta^{13}\text{C}_{\text{enamel}}$ and $\delta^{18}\text{O}_{\text{enamel}}$ values from southwestern South Africa since 5***

455 ***Ma***

456 We compiled the new carbon and oxygen isotope data from tooth enamel
457 produced in this study from Elandsfontein and Langebaanweg with the published data
458 from Langebaanweg (Franz-Odendaal et al., 2002), Elandsfontein (Luyt et al., 2000) and
459 Hoedjiespunt (Hare and Sealy, 2013) to examine environmental and climatic changes in
460 southwestern South Africa over the past ~5 myr. We used mesowear, microwear and
461 taxonomic analogy to classify the dietary behavior of taxa for samples from
462 Langebaanweg and Elandsfontein (Sponheimer et al., 2001; Franz-Odendaal et al., 2004;

463 Stynder, 2009; 2011). Dietary behaviors of Hoedjiespunt bovids are discussed in Hare
464 and Sealy (2013). These data are compiled in Table S2.

465 The $\delta^{13}\text{C}_{\text{enamel}}$ values of fossil teeth average $-11.3\pm 1.3\text{‰}$ ($n = 74$) at
466 Langebaanweg, $-10.6\pm 1.3\text{‰}$ ($n = 194$) at Elandsfontein and $-9.5\pm 1.5\text{‰}$ ($n = 39$) at
467 Hoedjiespunt. The average $\delta^{13}\text{C}_{\text{enamel}}$ value of large mammals (> 6 kg) at each site fall
468 within the range of the $\delta^{13}\text{C}_{\text{enamel}}$ values expected for animals with diets comprised of
469 purely C_3 vegetation (Fig. 4).

470 Comparisons of $\delta^{18}\text{O}_{\text{enamel}}$ values from each family from Langebaanweg and
471 Elandsfontein indicate significant differences for like taxa ($p < 0.001$), where the
472 $\delta^{18}\text{O}_{\text{enamel}}$ values for teeth from Elandsfontein are typically $\sim 4.5\text{‰}$ more positive than
473 those from Langebaanweg (Table 2; Table S2, Fig. 4b). This distinction holds for
474 $\delta^{18}\text{O}_{\text{enamel}}$ values of all taxa sampled from the two sites except for suids for which there is
475 no difference in $\delta^{18}\text{O}_{\text{enamel}}$ values for Elandsfontein ($28.0\pm 3.1\text{‰}$) and Langebaanweg
476 ($27.7\pm 0.9\text{‰}$) (Fig. 4b). However, we do observe a $\sim 4.4\text{‰}$ increase in suid $\delta^{18}\text{O}_{\text{enamel}}$
477 values between Langebaanweg and Elandsfontein when we only consider the suid
478 $\delta^{18}\text{O}_{\text{enamel}}$ values from the WCRP collection at Elandsfontein ($32.1\pm 0.6\text{‰}$, $n = 3$) and
479 exclude the suid $\delta^{18}\text{O}_{\text{enamel}}$ values from EFTM from Luyt et al. (2000). The Hoedjiespunt
480 enamel samples are limited to bovids and the comparison of $\delta^{18}\text{O}_{\text{enamel}}$ values for fossil
481 bovids from the three fossil sites are distinct from one another ($p < 0.001$). Bovid
482 $\delta^{18}\text{O}_{\text{enamel}}$ values average $28.7\pm 2.8\text{‰}$ at Langebaanweg, $33.2\pm 2.0\text{‰}$ at Elandsfontein, and
483 $31.4\pm 1.5\text{‰}$ at Hoedjiespunt.

484

485

486 **5. Discussion**

487 **5.1 Vegetation trends in southwestern South Africa**

488 Mammalian faunal and offshore pollen records indicate that the ecosystem of
489 southwestern South Africa was different in the Pliocene and Pleistocene from today and
490 that C₃ grasses were an important component of the physiognomic structure of these
491 ecosystems at times during the last 5 myr (e.g., Dupont et al., 2005; Faith, 2011; Hare and
492 Sealy, 2013). Today the vegetation community is composed of mostly woody, fynbos
493 shrubs. Although rare in southwestern South Africa, grasses are more common inland
494 where they grow on shale substrate, than they are on the marine sands typically found in
495 the study area (Cowling, 1992).

496 The $\delta^{13}\text{C}_{\text{enamel}}$ values of large mammals from Langebaanweg, Elandsfontein and
497 Hoedjiespunt show that herbivores had diets composed largely of C₃ vegetation (Luyt et
498 al., 2000; Franz-Odenaal et al., 2002; Hare and Sealy, 2013; this study). Specifically, the
499 $\delta^{13}\text{C}_{\text{enamel}}$ values of grazers indicate that the majority of the grasses consumed were C₃
500 grasses. Although the presence of C₄ vegetation cannot be totally discounted at
501 Elandsfontein and Hoedjiespunt (Luyt et al., 2000; Hare and Sealy, 2013; Patterson et al.,
502 *in revision*), the $\delta^{13}\text{C}_{\text{enamel}}$ data presented here indicate that it was a relatively small
503 component of the diets of large herbivores (Fig. 4).

504 The bovids at Elandsfontein are diverse and have a range of dietary behaviors
505 such that the variation in the isotopic composition of bovid teeth may be used to develop
506 a more detailed understanding of the nature of vegetation in the C₃-dominated ecosystem
507 of southwestern South Africa. For this reason, we compared the $\delta^{13}\text{C}_{\text{enamel}}$ and $\delta^{18}\text{O}_{\text{enamel}}$

508 values among different bovid tribes, classifying them as browsers, grazers or mixed
509 feeders (see Table 2 and Fig. 4).

510 When split by tribe there are no distinctions among the $\delta^{13}\text{C}_{\text{enamel}}$ values of bovids
511 from the other grazing and browsing taxa at Langebaanweg ($p > 0.8$). The $\delta^{13}\text{C}_{\text{enamel}}$
512 values of all fossil teeth at Langebaanweg (browsers, grazers and mixed feeders) are
513 $> 2\text{‰}$ more negative than the cutoff value for animals with a diet that includes any C_4
514 vegetation (-7.6‰ , refer to Section 3.3.1), indicating that all of the animals we sampled
515 had diets composed of solely C_3 vegetation. At Elandsfontein, the $\delta^{13}\text{C}_{\text{enamel}}$ values of
516 browsing taxa (Tragelaphini, Neotragini and giraffid) are significantly more negative
517 than those of grazing taxa (Alcelaphini, Bovini, Reduncini and equid) ($p = 0.005$). In
518 comparison, at Hoedjiespunt the $\delta^{13}\text{C}_{\text{enamel}}$ values of browsing and grazing bovids are not
519 statistically different from one another ($p = 0.97$). In addition, we find that $\delta^{13}\text{C}_{\text{enamel}}$
520 values of browsing bovid tribes at Hoedjiespunt are $\sim 4\text{‰}$ more positive than those of the
521 browsers at Elandsfontein (Fig. 4), whereas the $\delta^{13}\text{C}_{\text{enamel}}$ values of grazing bovids at
522 Elandsfontein and Hoedjiespunt are not significantly different from one another in
523 ($p = 0.2$). This might indicate that the browse vegetation at Elandsfontein was different
524 from that at Hoedjiespunt, which could be related to a drier or less dense mosaic
525 landscape (Kohn, 2010) at Hoedjiespunt compared with Elandsfontein. There are no clear
526 trends that distinguish the $\delta^{18}\text{O}_{\text{enamel}}$ values among different bovid tribes at either
527 Elandsfontein or Hoedjiespunt. There are some indications of C_4 vegetation in the diets of
528 both browsers and grazers at Hoedjiespunt and of grazers at Elandsfontein, however there
529 are no indications of C_4 in the diet among browsers at Elandsfontein and any of the
530 herbivores at Langebaanweg. There are no distinctions in $\delta^{13}\text{C}_{\text{enamel}}$ or $\delta^{18}\text{O}_{\text{enamel}}$ values

531 among the bovids that were sampled and identified to tribe (Acelaphini and Reduncini) at
532 Langebaanweg ($p = 1.0$).

533 The $\delta^{13}\text{C}_{\text{enamel}}$ values of grazers at Elandsfontein and Hoedjiespunt that are more
534 positive than what is expected for a pure C_3 diet (-8.4‰, refer to Section 3.3.1) could
535 indicate the presence of some C_4 grasses, either in some seasons or on specific points on
536 the landscape, like well-watered areas such as springs which is consistent with results
537 from Patterson et al. (*in revision*). Hare and Sealy (2013) also suggest that the presence of
538 some C_4 vegetation in the diets of grazing bovids from Hoedjiespunt might reflect the
539 ability for C_4 plants to grow within a winter rainfall zone during low $p\text{CO}_2$ conditions
540 that are characteristic of glacial intervals. Although low $p\text{CO}_2$ conditions might account
541 for the presence of some C_4 vegetation in the diets of grazers at Elandsfontein, the dating
542 of the deposits at Elandsfontein precludes us from assigning it to either a glacial or
543 interglacial period (Braun et al., 2013).

544 The survival of large herbivores in southwestern South Africa would have
545 required access to resources throughout the year. It is possible that there was an extended
546 rainy season and that abundant food resources grew on nutrient-rich calcareous soils,
547 which are no longer present at the fossil sites (Luyt et al., 2000). A year-round supply of
548 palatable browse and graze would have required sufficient surface water and at
549 Elansfontein, this likely included springs (Braun et al., 2013).

550

551 ***5.2 Oxygen isotope record***

552 The ~4.5‰ increase in $\delta^{18}\text{O}_{\text{enamel}}$ values between the Langebaanweg and
553 Elandsfontein fossil localities (from ~5 to 1.0 – 0.6 Ma) occurs across a time of global

554 cooling and aridification (Marlow et al., 2000; Etourneau et al., 2009). $\delta^{18}\text{O}_{\text{enamel}}$ values
555 can be influenced by a combination of factors including the $\delta^{18}\text{O}$ value of surface water,
556 aridity and animal physiology (Kohn and Cerling, 2002). We do not think that
557 physiological changes are responsible for the increase in $\delta^{18}\text{O}_{\text{enamel}}$ values as we observe
558 it among multiple herbivore families and consider it unlikely that multiple disparately
559 related herbivore families would converge upon identical physiological changes across
560 this time span. Consequently, we must consider the influence of changes in the $\delta^{18}\text{O}$
561 value of surface water and changes in aridity on the observed increase in $\delta^{18}\text{O}_{\text{enamel}}$ values
562 between the fossil teeth at Langebaanweg and Elandsfontein.

563

564 *5.2.1 Oxygen isotopic composition of reconstructed surface water*

565 In modern ecosystems $\delta^{18}\text{O}_{\text{enamel}}$ values of hippopotamids closely track the $\delta^{18}\text{O}$
566 values of meteoric water (Bocherens et al., 1996) and as such, fossil hippopotamid
567 $\delta^{18}\text{O}_{\text{enamel}}$ values can be used to reconstruct the $\delta^{18}\text{O}$ values of meteoric waters (Levin et
568 al., 2006). We used hippopotamid $\delta^{18}\text{O}_{\text{enamel}}$ values from Langebaanweg ($n = 18$) and
569 Elandsfontein ($n = 9$) to estimate the $\delta^{18}\text{O}$ values of the surface waters in which these
570 hippopotamids lived, which would reflect a combination of the $\delta^{18}\text{O}$ value of regional
571 precipitation and the hydrological condition of the local surface waters. We were not able
572 to estimate the $\delta^{18}\text{O}$ values of the surface waters at Hoedjiespunt because there are no
573 hippopotamid teeth preserved at the site (Stynder, 1997). We estimated $\delta^{18}\text{O}$ values of
574 local surface waters from the hippopotamid $\delta^{18}\text{O}_{\text{enamel}}$ values by considering both the
575 $5.4 \pm 1.3\text{‰}$ enrichment in $\delta^{18}\text{O}$ between local surface water and hippopotamid body water
576 reported by Levin et al. (2006) for modern hippopotamids and the carbonate-water

577 $^{18}\text{O}/^{16}\text{O}$ fractionation relationship reported by Kim and O'Neil (2005), assuming that
578 tooth formation formed at typical mammalian body temperatures of 37°C.

579 Using this approach, we reconstruct the average $\delta^{18}\text{O}$ values of local surface
580 water to $-3.9\pm 1.6\text{‰}$ at Langebaanweg and $-0.3\pm 1.5\text{‰}$ at Elandsfontein. For comparison,
581 spring, tap and standing water nearby modern springs exhibit a mean $\delta^{18}\text{O}$ value
582 of $-1.7\pm 2.2\text{‰}$ ($n = 4$) (Table S4). The similarity between the $\delta^{18}\text{O}$ values of the
583 reconstructed mid-Pleistocene water and that of modern waters within the Elandsfontein
584 vicinity indicate that hydrological conditions of waters near spring systems in the region
585 may not have not changed greatly since the mid-Pleistocene. However, the $3.6\pm 1.8\text{‰}$
586 increase in reconstructed surface water $\delta^{18}\text{O}$ values between Langebaanweg and
587 Elandsfontein requires further explanation. The possible explanations for this $\sim 4\text{‰}$
588 increase include 1) a change in regional precipitation patterns as a result of changes in
589 global climatic patterns that would affect precipitation $\delta^{18}\text{O}$ values and 2) a change in the
590 type of surface waters (rivers vs. springs) that the hippopotamids were living in during
591 the early Pliocene vs. the mid-Pleistocene. Here we review the potential roles of climate
592 change and hydrological setting on the increase in $\delta^{18}\text{O}$ values of surface waters in
593 southwestern South African between the early Pliocene and the mid-Pleistocene.

594

595 5.2.2 *Global cooling*

596 Decreased global temperatures and increased ice volume affected $\delta^{18}\text{O}$ values of
597 precipitation globally between the Pliocene and Pleistocene with the onset of glacial and
598 interglacial cycles (Zachos et al., 2001) but it is not clear how these oscillations affected
599 $\delta^{18}\text{O}$ values of precipitation in southern Africa. A study of $\delta^{18}\text{O}$ values from speleothem

600 carbonate from Buffalo Cave in South Africa (Hopley et al., 2007) that dates to the
601 Pliocene/early Pleistocene (1.99 to 1.52 Ma) can provide perspective on the amplitude of
602 change in the $\delta^{18}\text{O}$ values of meteoric water that we would expect between glacial and
603 interglacial periods in southern Africa. Hopley et al. (2007) determine that there may be a
604 $\sim 2\text{‰}$ increase in $\delta^{18}\text{O}$ values of regional precipitation between interglacials and glacials
605 based on a combination of temperature and ice-volume effects. Despite some work that
606 attributes the fossils at Elandsfontein to an interglacial interval based on the size of fossil
607 carnivores (Klein et al., 2007), this assignment is less certain from more recent work at
608 Elandsfontein (Braun et al., 2013). Regardless of whether the Elandsfontein fossils
609 represent an interglacial or glacial interval, the maximum amount of change in $\delta^{18}\text{O}$
610 values of precipitation that we would expect between glacials and interglacials is $\sim 2\text{‰}$,
611 which is not enough to explain a $\sim 4\text{‰}$ difference in $\delta^{18}\text{O}$ values of surface water between
612 the early Pliocene and mid-Pleistocene.

613

614 *5.2.3 Rainfall amount*

615 The negative correlation between rainfall amount and the $\delta^{18}\text{O}$ value of rain is
616 termed the “amount effect” (Dansgaard, 1964). This effect must be considered in the
617 interpretation of the $\sim 4\text{‰}$ increase in $\delta^{18}\text{O}$ values of reconstructed surface waters. If
618 southwestern South Africa became more arid between the early Pliocene and the
619 mid-Pleistocene, as indicated by offshore archives (e.g., Marlow et al., 2010; Dupont et
620 al., 2013), then we might expect to see indications of less rainfall in the reconstructed
621 surface water $\delta^{18}\text{O}$ values. Modern precipitation data from Cape Town indicate that the
622 “amount effect” is limited in southwestern South Africa (Midgley and Scott, 2004; Harris

623 et al., 2010; West et al., 2014); it is equivalent to -10mm/1‰ $\delta^{18}\text{O}$ for monthly winter
624 rainfall (based on $\delta^{18}\text{O}$ values of monthly rainfall reported in Harris et al. (2010)) and
625 thus very little of the variation in $\delta^{18}\text{O}$ values of precipitation in modern southwestern
626 South Africa can be explained by amount rainfall. In comparison, Panama (WGS-84
627 Lat/Long: 9.00970, -79.60324) has a strong “amount effect” with -35 mm rainfall for
628 every 1‰ increase in the $\delta^{18}\text{O}$ value of rainfall (Higgins and MacFadden, 2004).

629 In addition, we do not expect to observe an “amount effect” in southwestern
630 South Africa because this oxygen isotopic effect mostly occurs where temperatures are
631 $> 20^\circ\text{C}$ and where there is high humidity or significant rainfall (e.g., Rozanski et al.,
632 1993), a pattern seen at collection sites globally (IAEA/WMO, 2001). The majority of
633 rain in this region falls in the winter and it is associated with cold, westerly fronts; it is
634 unlikely that average winter temperatures were $> 20^\circ\text{C}$. If temperatures during the rainy
635 season were $> 20^\circ\text{C}$ during the Pliocene and Pleistocene, then it could have been warm
636 enough for the growth of C_4 grass. The $\delta^{13}\text{C}$ values of fossil enamel from grazers,
637 however, suggest that there was little C_4 grass in this region.

638 Although a change in the $\delta^{18}\text{O}$ values of rainfall related to moisture source may
639 contribute to the increase in the $\delta^{18}\text{O}$ values of rainfall, it is unlikely that this would
640 represent a substantial contribution to the full $\sim 4\%$ increase documented between the
641 Pliocene and mid-Pleistocene. If there had been a change in the rainfall related moisture
642 source from the east (i.e., contribution of summer rainfall), then we would expect to see
643 the $\delta^{13}\text{C}_{\text{enamel}}$ values of some large mammalian herbivores to be more positive than what
644 is calculated for a pure C_3 diet because they would be incorporating C_4 grasses that grow
645 during the summer months into their diet. We find that the majority of $\delta^{13}\text{C}_{\text{enamel}}$ values

646 are within the range expected for animals with pure C₃ diets and no change in $\delta^{13}\text{C}_{\text{enamel}}$
647 values between the fossil herbivores at Langebaaweg and Elandsfontein (Fig. 4).
648 Furthermore, models of regional climate indicate that the source of atmospheric moisture,
649 Atlantic water off the coast of southwestern South Africa, would have been constrained
650 by relatively stable regional meteorological factors (e.g. ICTZ, Agulhas Current,
651 Subtropical convergence zone and Benguela Current; McClymont et al., 2005) and thus
652 would not have drastically changed between the early Pliocene and mid-Pleistocene.

653

654 *5.2.4 Depositional mode and surface water*

655 A change in the local hydrology and $\delta^{18}\text{O}$ value of surface water might be
656 responsible for the increase $\delta^{18}\text{O}_{\text{enamel}}$ values between Langebaanweg and Elandsfontein.
657 Today much of the coastal plain of southwestern South Africa is fed by ground water and
658 many areas have standing water associated with artesian wells. The depositional
659 environments of the Varswater Formation (i.e., the Langebaanweg fossil site) indicate the
660 presence of fluvial and estuarine waters (Roberts et al., 2011). Various sedimentological
661 studies indicate that the paleo-Berg River in the early Pliocene had a southerly trajectory
662 and emptied into the embayment which is today the Saldanha Bay as opposed to
663 emptying into the Atlantic Ocean in St. Helena Bay as the Berg River does today (e.g.,
664 Roberts et al., 2011; Fig.1). Although a previous study of Elandsfontein suggested the
665 presence of fluvial activity (Butzer, 1973), recent investigations document the complete
666 lack of any sedimentary structures that would support a fluvial explanation for the
667 sediments in which fossils at Elandsfontein have been found (Braun et al., 2013).
668 Geomorphological reviews emphasize that large Cenozoic eolianites as well as granite

669 outcrops act as barriers for any fluvial systems west of the Salt River and south of the
670 Berg River (Mabbutt, 1952). As a result the main source of surface water in the region is
671 provided by springs fed by the large underground Elandsfontyn and Langebaan Road
672 aquifers (Brumfitt et al., 2013). Thus the $\delta^{18}\text{O}$ values of the enamel from large, mid-
673 Pleistocene mammals at Elandsfontein likely reflect the $\delta^{18}\text{O}$ values of isolated springs
674 distributed around the landscape. The waters from the Berg River headwaters have $\delta^{18}\text{O}$
675 values today that range from -6.0‰ to -4.0‰ (Weaver and Telma, 2005; West et al.,
676 2014), whereas $\delta^{18}\text{O}$ values of spring and tap waters surrounding the Elandsfontein
677 vicinity today range from -3.6 to -1.9‰ (Table S4; Midgley and Scott, 1994; West et al.,
678 2014; this study). There is a 0.4 to 4.1‰ difference in $\delta^{18}\text{O}$ values between surface
679 waters sourced from the Berg River compared with waters from springs near
680 Elandsfontein. Standing spring water at Elandsfontein has been evaporated and yields
681 $\delta^{18}\text{O}$ value of 1.5‰. Furthermore, the average $\delta^{18}\text{O}$ value of reconstructed surface water
682 at Elandsfontein (-0.3 ± 1.5 ‰) sits within the expected range of water near the
683 Elandsfontein locality today. If offsets between $\delta^{18}\text{O}$ values of waters from the Berg
684 River and from springs in the study area were consistent over the last 5 myr, then the
685 ~ 4 ‰ increase in reconstructed surface water $\delta^{18}\text{O}$ values from tooth enamel between
686 Langebaanweg and Elandsfontein fossil sites can be explained solely by a difference in
687 local hydrology. At Langebaanweg, hippopotamids likely spent much of their time in
688 waters that derived from the paleo-Berg River, whereas some four million years later, the
689 hippopotamids from the Elandsfontein fossil deposits likely spent much of their time in
690 water bodies that were fed by springs. The differences in the enamel $\delta^{18}\text{O}$ values of these

691 two hippopotamid populations may be best explained by these local differences types of
692 water bodies in which they wallowed.

693

694 *5.2.5 Aridity*

695 Aridity can have an effect on $\delta^{18}\text{O}_{\text{enamel}}$ values in multiple ways. Aridity can be
696 the result of decreased rainfall amount which will affect $\delta^{18}\text{O}_{\text{enamel}}$ values due to a change
697 in $\delta^{18}\text{O}$ values of precipitation that then contributes to the water that animals ingest.
698 However, the degree of aridity may influence $\delta^{18}\text{O}_{\text{enamel}}$ values independent of any
699 changes in the $\delta^{18}\text{O}$ values of precipitation via the ingestion of leaf water, which becomes
700 greatly enriched in ^{18}O relative to ^{16}O in arid climates (Levin et al., 2006). The $\delta^{18}\text{O}_{\text{enamel}}$
701 values of animals that are not obligate drinkers (e.g., giraffes and oryx) are sensitive to
702 aridity in part because a large fraction of their body water may come from leaf water. The
703 strong relationship between aridity and $\delta^{18}\text{O}_{\text{enamel}}$ values of these Evaporation Sensitive
704 (ES) animals, taxa whose body water is derived largely from leaf water, today can be
705 used to evaluate aridity in the past by comparing $\delta^{18}\text{O}_{\text{enamel}}$ values of ES animals to those
706 from Evaporation Insensitive (EI) animals, taxa whose body water is derived largely from
707 ingested surface water (e.g., hippopotamids and elephantids). The $\delta^{18}\text{O}_{\text{enamel}}$ values of EI
708 taxa do not vary with aridity and can be used to control for changes in meteoric water
709 $\delta^{18}\text{O}$ values (Levin et al., 2006). The $\epsilon_{\text{ES-EI}}$ between $\delta^{18}\text{O}_{\text{enamel}}$ values of ES and EI taxa is
710 greater in more arid environments than in less arid environments (Levin et al., 2006).

711 We evaluated whether increased aridity could explain the $\sim 4\%$ increase in enamel
712 $\delta^{18}\text{O}$ values between the early Pliocene and mid-Pleistocene by comparing the $\epsilon_{\text{ES-EI}}$ of
713 $\delta^{18}\text{O}_{\text{enamel}}$ values of individual teeth from Langebaanweg ($n = 47$) and Elandsfontein

714 ($n = 16$), where hippopotamids (i.e., *Hippopotamus*) are the representative EI taxa and
715 giraffids (i.e., *Sivatherium*) are the representative ES taxa. Calculated $\epsilon_{\text{ES-EI}}$ values are
716 $+3.0 \pm 1.9\text{‰}$ and $+2.7 \pm 1.9\text{‰}$ for Langebaanweg and Elandsfontein, respectively. There is
717 no large difference between the $\epsilon_{\text{ES-EI}}$ values for the two populations, suggesting no
718 change in aridity between the Pliocene and mid-Pleistocene environments in
719 southwestern South Africa. However, we cannot simply evaluate aridity as outlined
720 above if 1) there were changes in $\delta^{18}\text{O}$ values of surface water due to the differences in
721 depositional setting between Langebaanweg and Elandsfontein and 2) if the behavior of
722 EI and ES taxa was different during the Pleistocene and the Pliocene. First, $\delta^{18}\text{O}_{\text{enamel}}$
723 values from hippopotamids might not be closely tracking precipitation $\delta^{18}\text{O}$ values during
724 the mid-Pleistocene in the same way as in the early Pliocene if hippopotamids from
725 Elandsfontein wallowed in pools of evaporated spring water, whereas hippopotamids
726 from the Langebaanweg collection spent time immersed in river waters. Our compilation
727 of $\delta^{18}\text{O}$ values from modern waters in the region indicates that spring-based water
728 sources have more positive $\delta^{18}\text{O}$ values than that of river waters (Table S4). Second, it is
729 important to note that in this analysis we use the genus *Sivatherium* rather than *Giraffa* as
730 the ES taxon. Although these two taxa are within the family Giraffidae, isotopic studies
731 from eastern Africa indicate that *Sivatherium* underwent a major transition during the
732 Pliocene and Pleistocene to incorporate more graze into their diet, while *Giraffa* did not
733 (Cerling et al., 2015). Thus, it is feasible that sensitivity to aridity was different between
734 these two taxa such that *Sivatherium* might not be an appropriate ES taxon to use in the
735 $\delta^{18}\text{O}_{\text{enamel}}$ -based aridity index proposed by Levin et al. (2006).

736 While we cannot rule out the effects of evaporation on surface water $\delta^{18}\text{O}$ values,
737 we do not think that aridity is the primary driver of the $\sim 4\text{‰}$ increase in reconstructed
738 surface water $\delta^{18}\text{O}$ values between the early Pliocene and the mid-Pleistocene. It is
739 unlikely that we would observe a uniform increase in the average $\delta^{18}\text{O}_{\text{enamel}}$ values of
740 herbivore families from Langebaanweg and Elandsfontein because hippopotamids would
741 have remained in the water, somewhat buffered from increased aridity, resulting in a
742 smaller shift for hippopotamids than for other herbivore families. Furthermore, the $\sim 4\text{‰}$
743 increase in reconstructed surface water $\delta^{18}\text{O}$ values between fossil sites can be explained
744 solely by a shift from riverine water to groundwater-fed springs as discussed in Section
745 5.2.4. Given the present data, we view this as the simplest way to explain the trends in the
746 fossil $\delta^{18}\text{O}_{\text{enamel}}$ values we observe.

747

748 ***5.3 Theropithecus diet at Elandsfontein***

749 The diet of fossil *Theropithecus* species from southern and eastern Africa have
750 been evaluated to determine the partitioning of resources between primates and other
751 mammalian species as well as to better define the influences that contributed to the
752 success of *Homo* (e.g., Lee-Thorp et al., 1989; Codron et al., 2005; Cerling et al., 2013;
753 Levin et al., 2015). A single *Theropithecus* mandible was excavated from Elandsfontein
754 (WCRP collection) and this specimen has a $\delta^{13}\text{C}_{\text{enamel}}$ value of -10.2‰ , which is
755 indicative of a diet composed of C_3 vegetation (Fig. 4; Table S2). This is the only
756 $\delta^{13}\text{C}_{\text{enamel}}$ value of *Theropithecus* from Pleistocene southwestern South Africa.
757 Contemporaneous *Theropithecus* $\delta^{13}\text{C}_{\text{enamel}}$ values from eastern Africa and in other
758 locations in South Africa indicate that *Theropithecus* consumed C_4 graze (e.g., Codron et

759 al., 2005; Cerling et al., 2013). The addition of carbon isotope data from *Theropithecus* at
760 Elandsfontein shows that *Theropithecus* was able to survive on diets composed C₃
761 vegetation during the Pleistocene (whether it was browse or graze) if it lived in
762 environments where C₃ vegetation was dominant, as with the modern gelada baboon
763 (Levin et al., 2008).

764

765 ***5.4 Hominin paleoenvironment at mid-Pleistocene Elandsfontein***

766 The sedimentary record at Elandsfontein provides unique insights into the ecology
767 of southwestern South Africa during the mid-Pleistocene, which is not well documented
768 elsewhere in southern Africa (Klein et al., 2007; Braun et al., 2013). The archives at
769 Elandsfontein also provide evidence for some of the earliest hominin behavior in a winter
770 rainfall zone in southern Africa. The association of the fossil fauna with Acheulean stone
771 tools (i.e., hominin technology that indicate behavioral advances intersecting with the
772 biological change) in an excavated context at Elandsfontein allows us to use inferences
773 about paleoclimate from $\delta^{13}\text{C}_{\text{enamel}}$ and $\delta^{18}\text{O}_{\text{enamel}}$ values to develop an understanding of
774 hominin ecology. This is especially important because of the age of this locality (1.0 –
775 0.6 Ma) situates the site around the time of the mid-Pleistocene transition in climate
776 dynamics (McClymont et al., 2005). Large mammalian remains at Elandsfontein indicate
777 that there were both large browsing and grazing herbivore communities, suggesting that
778 the landscape would have had sufficient resources to assure the survival of these animals,
779 in stark contrast to the modern ecosystems in this area. This ancient landscape clearly
780 was a draw for hominins, as indicated by the thousands of stone tools recovered from this
781 locality (Singer and Wymer, 1968; Klein, 1983; Braun et al., 2013) as well as fossil

782 remains of early humans (Drennan, 1953). The springs at Elandsfontein (Braun et al.,
783 2013) would have been a resource-rich environment for early humans, if Elandsfontein
784 had been buffered from the regional aridification during the mid-Pleistocene. This is
785 consistent with studies of Pleistocene archaeological sites where springs and
786 groundwater-fed areas have been considered to be important resource for hominins (e.g.,
787 Cuthbert and Ashley, 2014).

788

789

790 **6. Conclusions**

791 The results of this study add to a growing body of work, from both terrestrial- and
792 marine-based archives, on how climate and vegetation in southwestern South Africa have
793 changed over the last 5 myr (Fig. 5). The main conclusions from this study are:

794 1) The $\delta^{13}\text{C}_{\text{enamel}}$ values of fossil teeth from southwestern South Africa indicate
795 that both browsing and grazing herbivores had diets dominated by C_3
796 vegetation, which suggests the dominance of the winter rainfall season during
797 the time intervals of fossil deposition at Langebaanweg, Elandsfontein and
798 Hoedjiespunt. We can not, however, totally discount the presence of C_4 grasses
799 during the mid-Pleistocene and late Pleistocene.

800 2) There is an increase in reconstructed surface water $\delta^{18}\text{O}$ values from
801 southwestern South Africa between the early Pliocene and mid-Pleistocene of
802 $\sim 4\text{‰}$. We attribute the increase in $\delta^{18}\text{O}$ values of surface waters primarily to a
803 shift in hydrology and depositional environments along the coastal plain of
804 southwestern South Africa. The major source of water for animals during the

805 Pliocene appears to have been a fluvial system whereas springs were likely the
806 dominant surface waters in the mid-Pleistocene.

807 3) While increased aridity in southwestern Africa is indicated both by the marine-
808 and terrestrial-based proxy records compiled in this study, it is not clearly
809 evident in the isotopic record of large mammals presented here. The
810 Elandsfontein archaeological site may have been buffered from regional mid-
811 Pleistocene aridification as a result of the available surface water indicated by
812 ancient spring deposits. If springs were annually active, then water and other
813 resources associated with springs would have been available to mammals, such
814 that the area may have served as an oasis of sorts within a relatively drier
815 landscape.

816 4) This study highlights the importance of considering depositional environment
817 and the local environmental setting when understanding how specific terrestrial
818 environments responded to regional climate and environmental change.

819

820

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842

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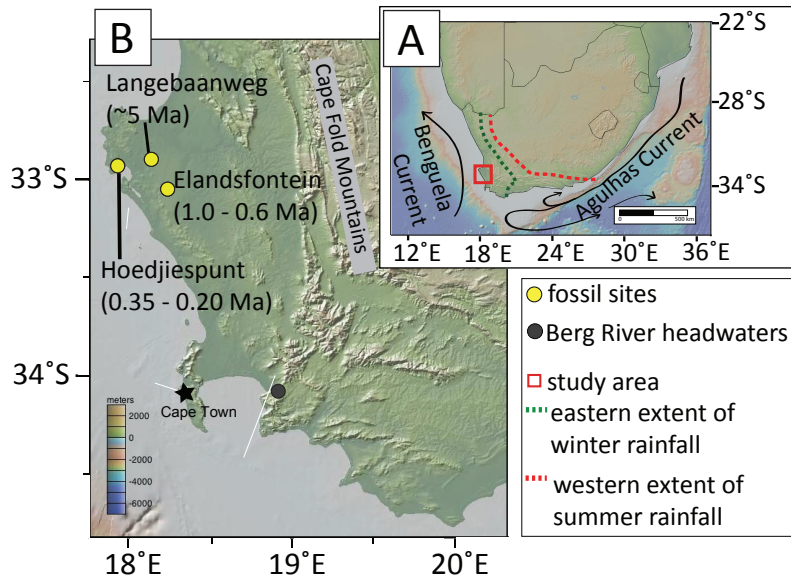
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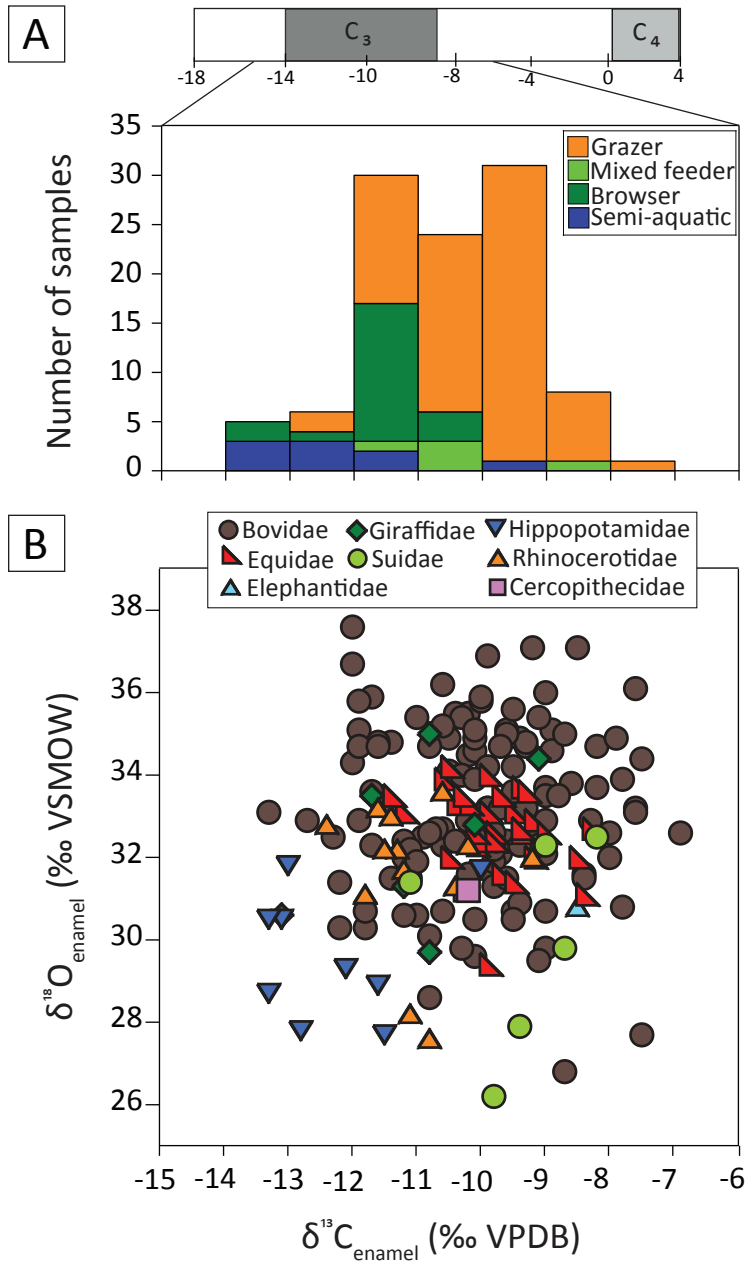
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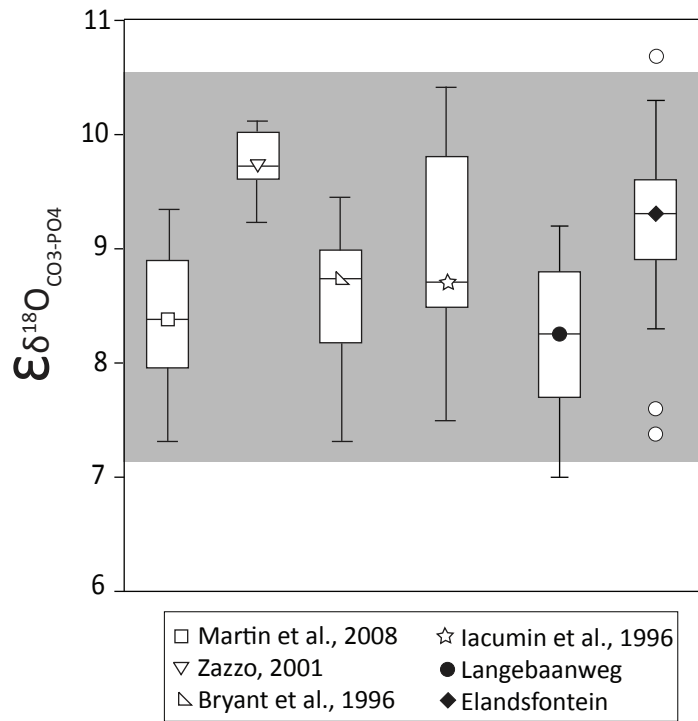
Lehmann et al., Figure 1 (single column)



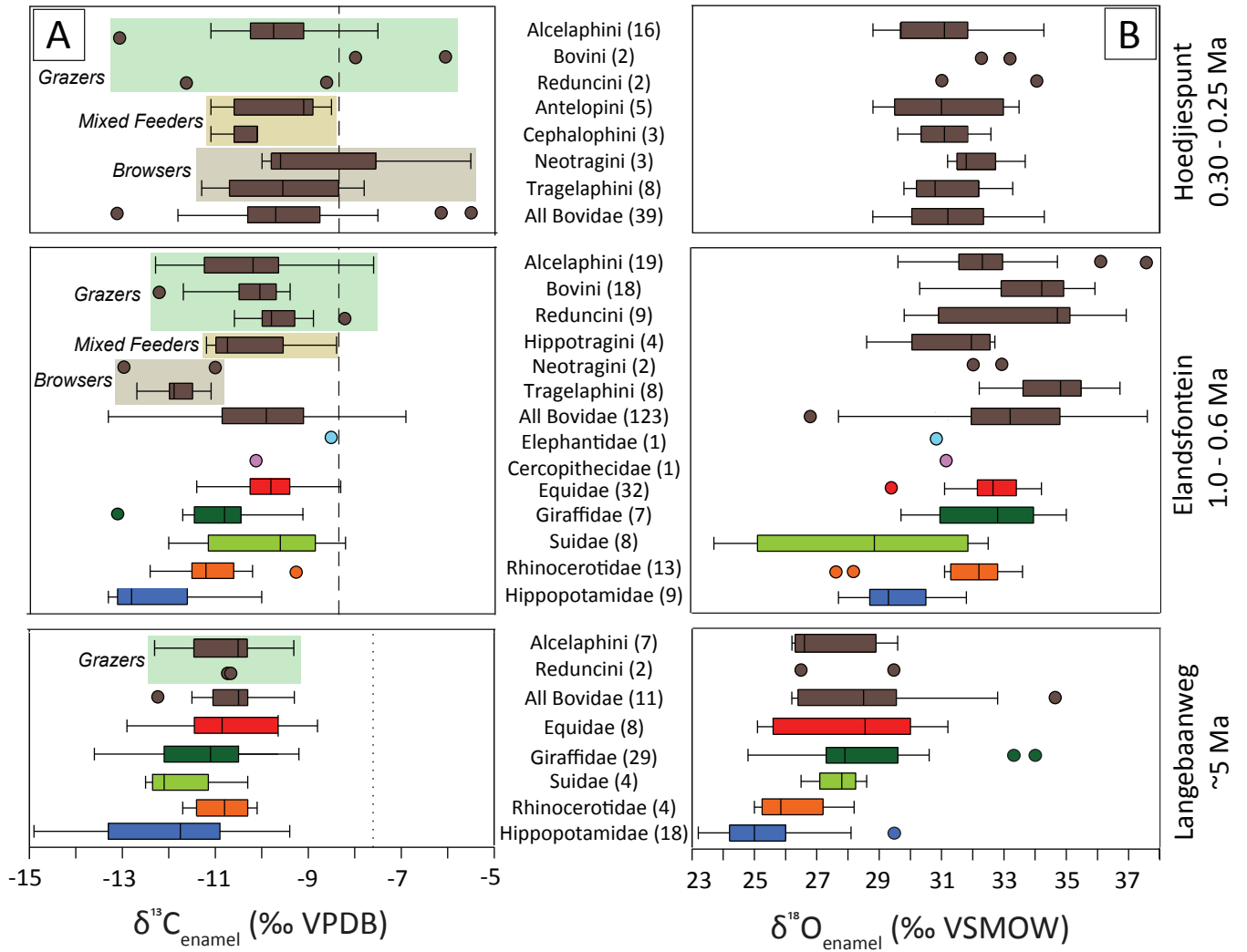
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Lehmann et al., Figure 3 (single column)



Lehmann et al., Figure 4 (double column)



Lehmann et al., Figure 5 (double column)

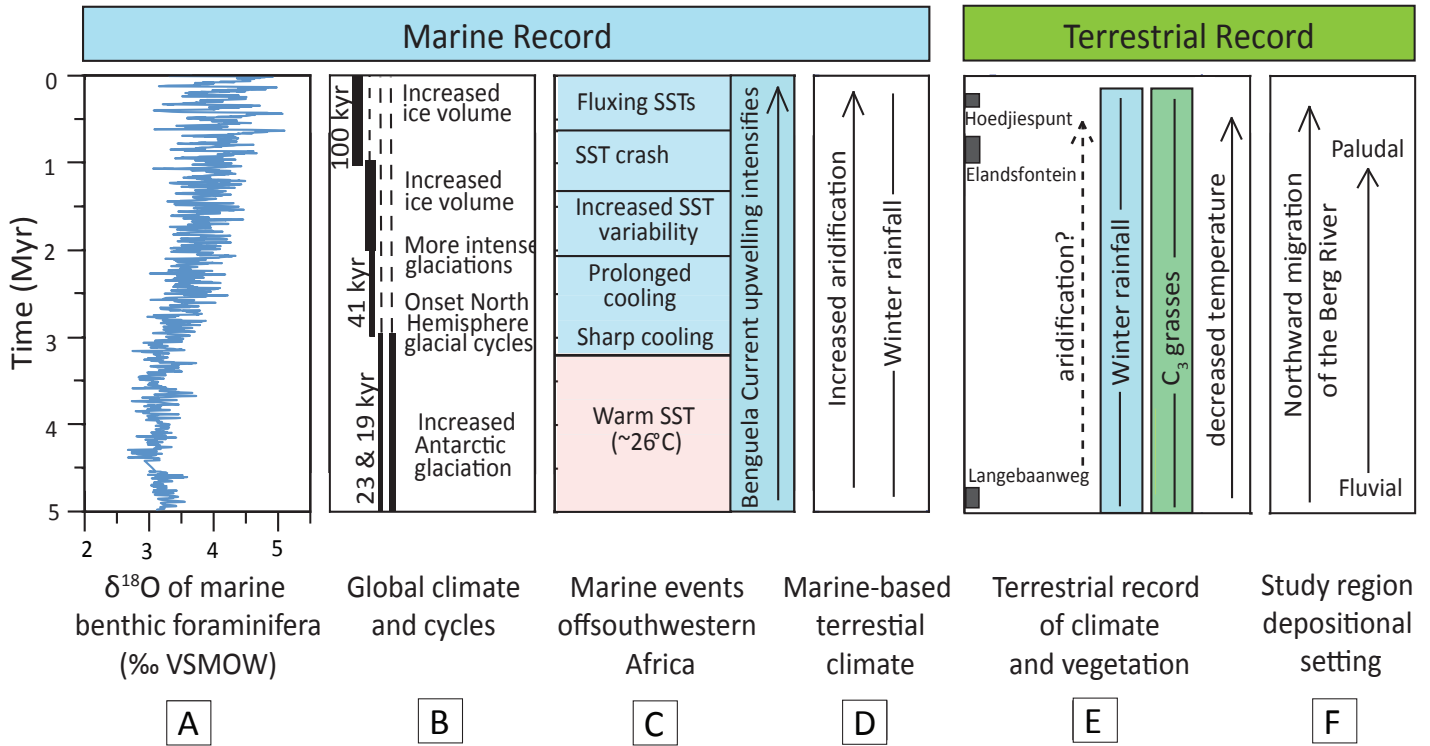


Table 1: A summary of the terrestrial records of climate, vegetation and depositional environment from southwestern South Africa.

Age	Locality	Depositional environment	Substrate	Vegetation	Climate	Data sets	References
late Pleistocene (0.35 - 0.25 Ma)	Hoedjiespunt	Coastal	Sands	Shrubs and widespread grasslands	Glacial	Taxonomy ^a Stable isotopes ^a	Klein, 1983 Stynder, 1997 Hare and Sealy, 2013
mid-Pleistocene (~1.0 - 0.6 Ma)	Elandsfontein	Spring-fed and eolian	Eolian and marine sands, carbonate-leached sediments, pedogenically modified sands	Trees, shrubs, and seasonal grasses	Glacial and/or Interglacial	Taxonomy ^a Stable isotopes ^a Microwear ^a Sedimentology	Butzer, 1973 Klein, 1978 Luyt et al., 2000 Stynder, 2009 Braun et al., 2013
Pliocene (~5 Ma)	Langebaanweg	Fluvial and deltaic	Floodplain, marsh, and river channel deposits	Trees, shrubs, and seasonal grasses	Warm and wet	Taxonomy ^a Stable isotopes ^a Mesowear ^a Microwear ^a	Franz-Odendaal et al., 2002 Roberts et al., 2011 Stynder, 2011

^a Datasets that apply to teeth.

Table 2: $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of fossil tooth enamel from sites in southwestern South Africa, averaged by family and bovid tribe.

Taxon (family or tribe)	Dietary behavior^b	$\delta^{13}\text{C}_{\text{enamel}}$ (‰ VPDB$\pm 1\sigma$)	$\delta^{18}\text{O}_{\text{enamel}}$ (‰ VSMOW$\pm 1\sigma$)	Number of samples
<i>Hoedjiespunt (0.35 - 0.25 Ma)</i>				
Alcelaphini	grazer	-9.8 \pm 1.3	31 \pm 1.5	16
Bovini	grazer	-7.1 \pm 1.3	32.9 \pm 0.6	2
Reduncini	grazer	-10.2 \pm 2.3	32.7 \pm 2.0	2
Antelopini	mixed feeder	-9.6 \pm 1.1	31.2 \pm 2.1	5
Neotragini	mixed feeder	-8.4 \pm 2.5	32.2 \pm 1.3	3
Cephalophini	browser	-10.4 \pm 0.6	31.1 \pm 1.5	3
Tragelaphini	browser	-9.5 \pm 1.3	31.2 \pm 1.2	8
All Bovidae	-	-9.5 \pm 1.5	31.4 \pm 1.5	39
<i>Elandsfontein (~1.0 - 0.6 Ma)</i>				
Alcelaphini	grazer	-10.3 \pm 1.2	32.6 \pm 1.9	19
Bovini	grazer	-10.3 \pm 0.8	33.8 \pm 1.6	18
Reduncini	grazer	-9.6 \pm 0.7	33.3 \pm 2.7	9
Hippotragini	mixed feeder	-10.3 \pm 1.3	31.3 \pm 1.9	4
Neotragini	browser	-12.3 \pm 1.4	32.6 \pm 0.7	2
Tragelaphini	browser	-11.8 \pm 0.5	34.6 \pm 1.4	8
All Bovidae	-	-10.0 \pm 1.3	33.2 \pm 2.0	123
Elephantidae	grazer	-8.5	30.8	1
Cercopithecidae	-	-10.2	31.2	1
Equidae	grazer	-9.8 \pm 0.7	32.7 \pm 1.0	32
Giraffidae	browser	-11.0 \pm 1.3	32.5 \pm 2.0	7
Hippopotamidae	semi-aquatic	-12.3 \pm 1.1	29.7 \pm 1.5	9
Suidae	grazer	-9.9 \pm 1.4	28.0 \pm 3.1	8
Rhinocerotidae	grazer and browser	-11.0 \pm 0.8	31.6 \pm 1.8	13
<i>Langebaanweg (~5 Ma)</i>				
Alcelaphini	browser to grazer	-10.8 \pm 1.0	27.5 \pm 1.5	7
Reduncini	-	-10.7 \pm 0.0	28.0 \pm 2.1	2
All Bovidae	-	-10.7 \pm 0.8	28.7 \pm 2.8	11
Equidae	grazer	-10.7 \pm 1.4	28.1 \pm 2.4	8
Giraffidae	browser	-11.4 \pm 1.2	28.4 \pm 2.0	29
Suidae	-	-11.8 \pm 1.0	27.7 \pm 0.9	4
Rhinocerotidae	grazer	-10.9 \pm 0.7	26.2 \pm 1.4	4
Hippopotamidae	semi-aquatic	-11.9 \pm 1.5	25.4 \pm 1.7	18

^a In addition to the new isotopic data, the isotopic data from previously published papers are included to determine the average $\delta^{13}\text{C}_{\text{enamel}}$ and $\delta^{18}\text{O}_{\text{enamel}}$ data for mammalian families and bovid tribes at each fossil site (Luyt et al., 2000; Franz-Odenaal et al., 2002; Hare and Sealy, 2013). See Table S2 for the compilation of data from individual teeth and the corresponding references.

^b References for the classification of dietary behavior are provided in Table S2.

Table S1: Estimated $\delta^{13}\text{C}$ values for atmospheric CO_2 , vegetation and herbivore tooth enamel for the time intervals discussed in the text.

	Time Interval (Ma)			
	Present $\delta^{13}\text{C}$ (‰ VPDB)	Hoedjiespunt $\delta^{13}\text{C}$ (‰ VPDB) (0.35 - 0.25 Ma)	Elandsfontein $\delta^{13}\text{C}$ (‰ VPDB) (~1.0 - 0.6 Ma)	Langebaanweg $\delta^{13}\text{C}$ (‰ VPDB) (~5 Ma) ^a
Time span from benthic foraminifera record (Ma)	n/a	0.35 - 0.25	1.0 - 0.6	5.7 - 3.33
$\delta^{13}\text{C}$ CO_2 ^b	-8.0	-7.1	-7.1	-6.3
$\delta^{13}\text{C}$ of vegetation (‰ VPDB) ^c				
C ₃ (average)	-26.1	-25.3	-25.3	-24.5
C ₃ minimum	-31.7	-30.8	-30.8	-30.0
C ₃ maximum	-23.1	-22.2	-22.2	-21.4
C ₄ (average)	-11.0	-10.1	-10.1	-9.3
C ₄ minimum (mesic)	-10.0	-9.1	-9.1	-8.3
C ₄ maximum (xeric)	-14.0	-13.2	-13.2	-12.4
$\delta^{13}\text{C}_{\text{enamel}}$ (‰ VPDB) ^d				
C ₃ diet (average)	-12.6	-11.5	-11.5	-10.7
C ₃ diet minimum	-18.2	-17.1	-17.1	-16.4
C ₃ diet maximum	-9.5	-8.4	-8.4	-7.6
C ₄ diet (average)	2.9	3.8	3.8	4.6
C ₄ diet minimum (mesic)	3.9	4.9	4.9	5.7
C ₄ diet maximum (xeric)	-0.2	0.8	0.8	1.6

^a Paleo- CO_2 record is based on the mean benthic foraminifera record with two data points for the Langebaanweg time period that date to 5.7 Ma and 3.33 Ma (-6.19‰ and -6.35‰, respectively).

^b Foraminifera isotopic data are used to estimate the $\delta^{13}\text{C}$ value of atmospheric CO_2 (Tippie et al., 2010).

^c The $\epsilon_{\text{atmosphere-plant}}$ values were calculated from the modern $\delta^{13}\text{C}$ values of CO_2 and the average, minimum and maximum $\delta^{13}\text{C}$ values of C₄ (Hattersley, 1982) and C₃ plants (Kohn, 2010). The $\epsilon_{\text{atmosphere-plant}}$ values and the average reconstructed $\delta^{13}\text{C}$ values of CO_2 for each time period (Tippie et al., 2010) were used to estimate the $\delta^{13}\text{C}$ values of C₃ and C₄ vegetation in the past.

^d The $\delta^{13}\text{C}$ values of enamel for herbivores with a diet of C₃ and C₄ vegetation were calculated using an $\epsilon_{\text{plant-enamel}}$ of +14.1‰ (Cerling et al., 1999) and the calculated plant $\delta^{13}\text{C}$ values at each time period denoted in this table.

Table S2: Compilation of new and published $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the carbonate component of tooth enamel from Pliocene and Pleistocene sites in southwestern South Africa.

Sample ID	Family	Tribe	Genus	Species	Locality	Collection, horizon ^b	Bay ^c	Behavior ^d	$\delta^{13}\text{C}_{\text{enamel}}$		$\delta^{18}\text{O}_{\text{enamel}}$		Tooth element ^e	Reference
									(‰ VPDB) 1 σ	(‰ VSMOW) 1 σ	n ^f	n ^f		
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-9.2	- 31.2	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-9.8	- 31.9	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-10.0	- 32.0	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-9.7	- 29.5	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-9.6	- 31.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-8.1	- 31.0	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-10.2	- 31.7	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-10.3	- 29.7	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-9.0	- 30.4	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-9.0	- 29.7	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-10.2	- 30.1	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes/Alcelaphus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-7.5	- 29.7	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Damaliscus</i>	<i>pygargus pygargus</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-9.3	- 28.8	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Damaliscus</i>	<i>pygargus pygargus</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-13.1	- 31.8	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Damaliscus</i>	<i>pygargus pygargus</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Grazer	-11.1	- 34.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Damaliscus</i>	<i>pygargus pygargus</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-10.4	- 33.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Antelopini	<i>Antidorcas</i>	<i>australis</i>	Hoedjiespunt	Hoedjiespunt 1, ROOF	-	Mixed feeder	-8.9	- 29.5	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Antelopini	<i>Antidorcas</i>	<i>australis</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Mixed feeder	-11.1	- 28.8	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Antelopini	<i>Antidorcas</i>	<i>australis</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Mixed feeder	-10.6	- 31.0	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Antelopini	<i>Antidorcas</i>	<i>australis</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Mixed feeder	-8.5	- 33.5	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Antelopini	<i>Antidorcas</i>	<i>australis</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Mixed feeder	-9.1	- 33.0	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Bovini	-	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-8.0	- 33.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Bovini	-	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Grazer	-6.1	- 32.4	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Cephalophini	<i>Sylvicapra</i>	<i>grimmia</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Browser	-10.1	- 31.1	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Cephalophini	<i>Sylvicapra</i>	<i>grimmia</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Browser	-10.1	- 32.6	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Cephalophini	<i>Sylvicapra</i>	<i>grimmia</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Browser	-11.1	- 29.6	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Neotragini	<i>Raphicerus</i>	-	Hoedjiespunt	Hoedjiespunt 1, ROOF	-	Mixed feeder	-10.0	- 33.7	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Neotragini	<i>Raphicerus</i>	-	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Mixed feeder	-9.6	- 31.2	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Neotragini	<i>Raphicerus</i>	-	Hoedjiespunt	Old Hoedjiespunt	-	Mixed feeder	-5.5	- 31.8	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Hoedjiespunt	Hoedjiespunt 1, LCSS	-	Grazer	-11.8	- 34.1	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Hoedjiespunt	Old Hoedjiespunt	-	Grazer	-8.6	- 31.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Browser	-11.3	- 32.1	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Old Hoedjiespunt	-	Browser	-9.0	- 29.8	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Hoedjiespunt 1, GUF1	-	Browser	-10.3	- 30.9	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Browser	-10.1	- 33.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Old Hoedjiespunt	-	Browser	-8.5	- 30.7	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Old Hoedjiespunt	-	Browser	-11.1	- 30.0	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Hoedjiespunt	Hoedjiespunt 1, ROOF	-	Browser	-8.2	- 30.4	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>oryx</i>	Hoedjiespunt	Hoedjiespunt 1, HOMS	-	Mixed feeder	-7.8	- 32.3	-	-	Third molar when possible	Hare and Sealy, 2013
-	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-11.8	- 30.3	-	-	Second or third molar when possible	Luyt et al., 2000
EFTM 11281	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-12.0	- 37.6	-	-	M2 or M3	This study
EFTM 1656	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-9.9	- 33.2	-	-	rm2	This study
EFTM 20858	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-10.1	- 29.6	-	-	lm3 or lmM2	This study
EFTM 20996	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-11.1	- 31.5	-	-	lm3	This study
EFTM 6177*	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-9.7	1.0 32.1	1.0 8	-	rm3	This study
EFTM 8953	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-10.2	- 31.6	-	-	rm2	This study
EFTM 8958A	Bovidae	Alcelaphini	<i>Connochaetes</i>	<i>gnou</i>	Elandsfontein	EFTM	-	Grazer	-10.6	- 32.7	-	-	rm3	This study
WCRP 1669	Bovidae	Alcelaphini	<i>Megalotragus</i>	-	Elandsfontein	WCRP	0609	Grazer	-10.5	- 34.1	-	-	Molar fragment	This study
WCRP 2168	Bovidae	Alcelaphini	<i>Megalotragus</i>	-	Elandsfontein	WCRP	0609	Grazer	-12.3	- 32.5	-	-	Molar fragment	This study
WCRP 1352	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0209	Grazer	-7.6	- 36.1	-	-	Molar	This study
WCRP 17324	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0609	Grazer	-8.4	- 31.6	-	-	Molar or premolar fragment	This study
WCRP 18010	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0609	Grazer	-9.2	- 32.5	-	-	Molar or premolar fragment	This study
WCRP 32340	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0313	Grazer	-11.4	- 31.5	-	-	Molar fragment	This study
WCRP 36612	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0909	Grazer	-9.3	- 34.7	-	-	Molar or premolar fragment	This study
WCRP 3698	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0209	Grazer	-9.6	- 32.4	-	-	Molar	This study
WCRP 46257	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0313	Grazer	-11.8	- 30.7	-	-	Fragment	This study
WCRP 7505	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0609	Grazer	-9.9	- 31.7	-	-	Second or third molar	This study
WCRP 9060	Bovidae	Acelaphini	genus indet.	-	Elandsfontein	WCRP	0610	Grazer	-10.6	- 32.3	-	-	Molar fragment	This study
EFTM 11908	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-9.5	- 30.7	-	-	lm3	This study
EFTM 1694	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-10.2	- 35.5	-	-	lm3	This study
EFTM 1746	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-9.8	- 31.9	-	-	lm3	This study
EFTM 1755	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-9.9	- 33.2	-	-	lm3	This study
EFTM 1759+1742	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-10.9	- 32.5	-	-	lm3	This study
EFTM 5063	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-9.7	- 33.2	-	-	lm3	This study
EFTM 5113 [†]	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-9.4	0.5 34.9	0.5 12	-	lm3	This study
EFTM IZ 7892	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	EFTM	-	Grazer	-10.21	- 32.9	-	-	lm3	This study
WCRP 32064	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-10.2	- 34.5	-	-	Premolar or first molar	This study
WCRP 32119	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-10.1	- 34.6	-	-	Third molar	This study
WCRP 32265	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-9.6	- 35.1	-	-	Molar or premolar fragment	This study

Table S2: Compilation of new and published $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the carbonate component of tooth enamel from Pliocene and Pleistocene sites in southwestern South Africa.

Sample ID	Family	Tribe	Genus	Species	Locality	Collection, horizon ^b	Bay ^c	Behavior ^d	$\delta^{13}\text{C}_{\text{enamel}}$		$\delta^{18}\text{O}_{\text{enamel}}$		Tooth element ^e	Reference
									(‰ VPDB) 1 σ	(‰ VSMOW) 1 σ	n ^f			
WCRP 32289	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-9.5	- 34.2	-	-	Molar fragment	This study
WCRP 32386	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-9.9	- 34.2	-	-	Molar	This study
WCRP 34441	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0710	Grazer	-10.0	- 35.8	-	-	Fragment	This study
WCRP 46245	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-11.7	- 35.9	-	-	Molar fragment	This study
WCRP 46251	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-10.5	- 34.9	-	-	Fragment	This study
WCRP 46256	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0313	Grazer	-12.2	- 30.3	-	-	Fragment	This study
WCRP 9380	Bovidae	Bovini	<i>Syncerus</i>	<i>antiquus</i>	Elandsfontein	WCRP	0309	Grazer	-11.7	0.0 33.6	0.5	2	Molar fragment	This study
-	Bovidae	Hippotragini	<i>Hippotragus</i>	<i>gigas</i>	Elandsfontein	EFTM	-	Mixed feeder	-10.8	- 28.6	-	-	Second or third molar when possible	Luyt et al., 2000
-	Bovidae	Hippotragini	<i>Hippotragus</i>	<i>gigas</i>	Elandsfontein	EFTM	-	Mixed feeder	-8.4	- 31.5	-	-	Second or third molar when possible	Luyt et al., 2000
WCRP 1666	Bovidae	Hippotragini	<i>Hippotragus</i>	<i>gigas</i>	Elandsfontein	WCRP	0609	Mixed feeder	-10.7	- 32.7	-	-	rm3	This study
WCRP 5387	Bovidae	Hippotragini	<i>Hippotragus</i>	<i>gigas</i>	Elandsfontein	WCRP	0609	Mixed feeder	-11.2	- 32.4	-	-	Molar fragment	This study
WCRP 5656	Bovidae	Neotragini	<i>Raphicerus</i>	<i>melanotis</i>	Elandsfontein	WCRP	0609	Browser	-13.3	0.5 33.1	0.5	4	rm1	This study
WCRP 5675	Bovidae	Neotragini	<i>Raphicerus</i>	<i>melanotis</i>	Elandsfontein	WCRP	0609	Browser	-11.2	2.2 32.0	1.3	2	rm1	This study
EFTM 1575	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-8.9	0.5 35.1	1.2	2	lm3	This study
EFTM 1587	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-8.2	- 34.7	-	-	lm3	This study
EFTM 2834	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-9.8	- 31.3	-	-	lm3	This study
EFTM 3514	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-9.9	- 36.9	-	-	Molar fragment	This study
EFTM 6700	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-10.6	- 30.7	-	-	rm3	This study
EFTM 8568	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-10.0	- 35.9	-	-	lm2 and lm3	This study
EFTM 8657	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-9.3	- 34.8	-	-	lm3	This study
EFTM 1585	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	EFTM	-	Grazer	-10.3	- 29.8	-	-	Molar fragment	This study
WCRP 8399	Bovidae	Reduncini	<i>Redunca</i>	<i>arundinum</i>	Elandsfontein	WCRP	0909	Grazer	-9.4	- 30.9	-	-	RM3	This study
EFTM 2296	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-11.4	- 34.8	-	-	rm3	This study
EFTM 2719	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-11.9	- 35.1	-	-	rm3	This study
EFTM 2728	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-12.0	- 36.7	-	-	rm3	This study
EFTM 2733	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-11.9	- 35.8	-	-	rm3	This study
EFTM 2736 ^g	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-11.1	1.4 32.2	2.8	2	rm3	This study
EFTM 2738	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-11.6	0.3 34.8	0.8	2	rm3	This study
EFTM 8273	Bovidae	Tragelaphini	<i>Tragelaphus</i>	<i>strepsiceros</i>	Elandsfontein	EFTM	-	Browser	-12.7	0.4 32.9	1.4	2	rm3	This study
WCRP 5043	Bovidae	Tragelaphini	<i>Taurotragus</i>	<i>oryx</i>	Elandsfontein	WCRP	0609	Browser	-12.0	- 34.3	-	-	Second molar	This study
WCRP 13288	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0209	-	-9.0	- 33.7	-	-	Fragment	This study
WCRP 13461	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.9	- 34.6	-	-	Fragment	This study
WCRP 13642	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.0	- 32.1	-	-	Fragment	This study
WCRP 1467	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0509	-	-9.0	- 33.5	-	-	Fragment	This study
WCRP 1468	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0509	-	-10.6	- 36.2	-	-	Lower Molar	This study
WCRP 1654	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.6	- 35.0	-	-	Fragment	This study
WCRP 17201 ^h	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.0	0.1 29.8	0.3	2	Molar or premolar fragment	This study
WCRP 18432	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.6	- 31.5	-	-	Fragment	This study
WCRP 18838	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.8	- 32.6	-	-	Fragment	This study
WCRP 19349	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-11.4	- 33.2	-	-	Molar	This study
WCRP 19429	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0209	-	-9.8	- 32.6	-	-	Fragment	This study
WCRP 20443	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0710	-	-10.3	- 34.0	-	-	rm3	This study
WCRP 2105	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.1	- 32.3	-	-	Fragment	This study
WCRP 2158	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.1	- 32.5	-	-	Fragment	This study
WCRP 2189	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.8	- 34.7	-	-	Molar	This study
WCRP 23212	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0209	-	-10.1	- 30.5	-	-	Fragment	This study
WCRP 2395	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.2	- 37.1	-	-	Fragment	This study
WCRP 2689	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.7	- 26.8	-	-	Third molar	This study
WCRP 27624	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0110	-	-11.0	- 35.4	-	-	Fragment	This study
WCRP 2891	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.2	- 33.7	-	-	Premolar or incisor	This study
WCRP 29026	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0910	-	-9.1	- 29.5	-	-	Molar	This study
WCRP 32213	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0313	-	-10.1	- 33.9	-	-	Molar	This study
WCRP 32391	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0313	-	-11.9	- 34.7	-	-	Fragment	This study
WCRP 34057	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0110	-	-9.1	- 35.4	-	-	Fragment	This study
WCRP 34690	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609 or 0710	-	-9.7	- 34.7	-	-	Molar	This study
WCRP 34695	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609 or 0710	-	-8.6	- 33.8	-	-	Molar	This study
WCRP 39321 ⁱ	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0112	-	-7.5	0.8 34.4	0.1	2	Fragment	This study
WCRP 39322	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0112	-	-8.0	- 32.6	-	-	Fragment	This study
WCRP 46258	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0313	-	-12.2	- 31.4	-	-	Fragment	This study
WCRP 46259	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0313	-	-11.0	- 30.6	-	-	Fragment	This study
WCRP 46260	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0313	-	-9.8	- 32.2	-	-	Fragment	This study
WCRP 5266	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.0	- 36.0	-	-	Fragment	This study
WCRP 5565	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-7.6	- 33.2	-	-	Fragment	This study
WCRP 5636	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.4	- 35.5	-	-	First molar	This study
WCRP 5654	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.4	- 32.3	-	-	rm3	This study
WCRP 5655	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-6.9	- 32.6	-	-	Molar	This study
WCRP 5659	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-7.6	- 33.1	-	-	Second molar	This study
WCRP 5660	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.7	- 35.0	-	-	First molar	This study
WCRP 5823	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.3	- 35.4	-	-	M2 or M3	This study
WCRP 5825	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.6	- 35.2	-	-	Molar	This study

Table S2: Compilation of new and published $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the carbonate component of tooth enamel from Pliocene and Pleistocene sites in southwestern South Africa.

Sample ID	Family	Tribe	Genus	Species	Locality	Collection, horizon ^b	Bay ^c	Behavior ^d	$\delta^{13}\text{C}_{\text{enamel}}$		$\delta^{18}\text{O}_{\text{enamel}}$		Tooth element ^e	Reference	
									(‰ VPDB)	1 σ	(‰ VSMOW)	1 σ			n ^f
WCRP 5843 ³	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-11.0	0.2	31.9	0.5	2	Fragment	This study
WCRP 6185	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0309	-	-7.8	-	33.9	-	-	Molar fragment	This study
WCRP 6243	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0309	-	-9.3	-	33.2	-	-	Molar fragment	This study
WCRP 6695	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0610	-	-10.1	-	34.9	-	-	Molar	This study
WCRP 6703	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0610	-	-11.7	-	32.3	-	-	Premolar	This study
WCRP 6717	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0610	-	-11.2	-	30.6	-	-	Premolar or first molar	This study
WCRP 6802	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0610	-	-7.8	-	30.8	-	-	Molar	This study
WCRP 6806	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0610	-	-9.5	-	35.6	-	-	Second molar	This study
WCRP 6975 ⁴	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0109	-	-9.5	0.2	33.6	0.2	2	Second molar	This study
WCRP 7169	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0109	-	-7.5	0.2	27.7	0.5	2	Fragment	This study
WCRP 7589	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0109	-	-10.8	-	30.1	-	-	Molar	This study
WCRP 7611	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0109	-	-9.0	-	30.7	-	-	Molar or premolar fragment	This study
WCRP 7639	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0109	-	-9.5	-	30.5	-	-	Molar	This study
WCRP 7832	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0109	-	-11.9	-	32.9	-	-	Molar	This study
WCRP 9043 ⁵	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.1	1.1	35.1	0.3	2	Fragment	This study
WCRP 9050	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.5	-	37.1	-	-	Molar fragment	This study
WCRP 9053	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	West Site	-	-8.3	-	32.9	-	-	Fragment	This study
WCRP 9079	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0510	-	-8.0	-	32.0	-	-	Molar	This study
WCRP 9085	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0610	-	-9.0	-	32.9	-	-	Molar	This study
WCRP 9377	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0809	-	-10.4	-	32.4	-	-	Fragment	This study
WCRP 9378	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	ND	-	-7.9	-	34.9	-	-	Third molar	This study
WCRP 9386	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.8	-	33.5	-	-	Third molar	This study
WCRP 9944	Bovidae	Bovidae indet.	-	-	Elandsfontein	WCRP	0609	-	-11.6	-	34.7	-	-	Molar fragment	This study
WCRP 32232	Cercopithecidae	-	<i>Theropithecus</i>	-	Elandsfontein	WCRP	0313	-	-10.2	0.3	31.2	1.9	2	lm3	This study
WCRP 17199	Elephantidae	Elephantidae indet.	-	-	Elandsfontein	WCRP	0609	Grazer	-8.5	-	30.8	-	-	Fragment	This study
-	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-10.3	-	31.2	-	-	Second or third molar when possible	Luyt et al., 2000
-	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-9.9	-	29.4	-	-	Second or third molar when possible	Luyt et al., 2000
-	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-9.4	-	32.6	-	-	Second or third molar when possible	Luyt et al., 2000
EFTM 2619	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-9.7	-	31.6	-	-	rm3	This study
EFTM 13873 ⁶	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-9.9	0.6	33.1	0.6	13	rm3	This study
EFTM 16660	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-9.2	-	32.0	-	-	rm3	This study
EFTM 1952	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-11.2	-	33.1	-	-	rm3	This study
EFTM 2112	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-10.6	-	33.9	-	-	rm3	This study
EFTM 5065	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-9.5	-	33.1	-	-	rm3	This study
EFTM 6727 ⁷	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	EFTM	-	Grazer	-8.5	0.4	32.0	0.1	2	rm3	This study
WCRP 2103	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	WCRP	0609	Grazer	-10.1	-	32.3	-	-	lm3	This study
WCRP 6242	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	WCRP	0309	Grazer	-10.0	-	32.4	-	-	RM3	This study
WCRP 9384	Equidae	-	<i>Equus</i>	<i>capensis</i>	Elandsfontein	WCRP	0609	Grazer	-9.8	0.3	32.6	0.3	3	Fragment	This study
WCRP 1007	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0109	-	-9.2	-	32.9	-	-	Fragment	This study
WCRP 12965	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.3	-	32.7	-	-	Fragment	This study
WCRP 13314	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0109	-	-9.8	-	32.6	-	-	Fragment	This study
WCRP 17333	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.4	-	33.7	-	-	Fragment	This study
WCRP 2049	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.4	-	33.3	-	-	Molar	This study
WCRP 2101	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.2	-	33.3	-	-	Molar	This study
WCRP 2102	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.5	-	32.0	-	-	Molar	This study
WCRP 2106	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.3	-	33.6	-	-	Fragment	This study
WCRP 2110	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-8.4	-	31.1	-	-	Molar	This study
WCRP 2182	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.5	-	34.2	-	-	Fragment	This study
WCRP 29223	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0110	-	-11.4	-	33.5	-	-	Fragment	This study
WCRP 36806	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0909	-	-9.4	-	32.7	-	-	Fragment	This study
WCRP 3815	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0209	-	-9.0	-	32.6	-	-	Fragment	This study
WCRP 5056	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.7	-	33.5	-	-	Fragment	This study
WCRP 9041 ⁸	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	ND	-	-9.9	0.5	34.0	0.3	2	Fragment	This study
WCRP 9045	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0610	-	-9.8	-	32.4	-	-	Molar	This study
WCRP 9054	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	West Site	-	-10.3	-	33.5	-	-	Molar	This study
WCRP 9140	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-10.1	-	32.6	-	-	Molar	This study
WCRP 9357 ⁹	Equidae	Equidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.5	0.1	31.4	0.2	2	Fragment	This study
-	Giraffidae	-	<i>Sivatherium</i>	<i>maurusium</i>	Elandsfontein	EFTM	-	Browser	-11.2	-	31.3	-	-	Second or third molar when possible	Luyt et al., 2000
-	Giraffidae	-	<i>Sivatherium</i>	<i>maurusium</i>	Elandsfontein	EFTM	-	Browser	-13.1	-	30.6	-	-	Second or third molar when possible	Luyt et al., 2000
-	Giraffidae	-	<i>Sivatherium</i>	<i>maurusium</i>	Elandsfontein	EFTM	-	Browser	-10.8	-	29.7	-	-	Second or third molar when possible	Luyt et al., 2000
EFTM 4028	Giraffidae	-	<i>Sivatherium</i>	<i>maurusium</i>	Elandsfontein	EFTM	-	Browser	-10.8	-	35.0	-	-	Second molar?	This study
EFTM 4031	Giraffidae	-	<i>Sivatherium</i>	<i>maurusium</i>	Elandsfontein	EFTM	-	Browser	-11.7	0.5	33.5	0.6	2	lm3	This study
WCRP 8031	Giraffidae	-	<i>Sivatherium</i>	<i>maurusium</i>	Elandsfontein	WCRP	0709	Browser	-10.1	-	32.8	-	-	rm3	This study
WCRP 8682	Giraffidae	Giraffidae indet.	-	-	Elandsfontein	WCRP	1009	-	-9.1	-	34.4	-	-	Fragment	This study
-	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-12.8	-	27.8	-	-	Second or third molar when possible	Luyt et al., 2000
-	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-11.5	-	27.7	-	-	Second or third molar when possible	Luyt et al., 2000
EFTM 4030	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-13.1	-	30.5	-	-	Molar fragment	This study
EFTM 4042	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-13.0	-	31.8	-	-	Tusk fragment	This study
EFTM 4088	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-12.1	-	29.3	-	-	Molar	This study

Table S2: Compilation of new and published $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the carbonate component of tooth enamel from Pliocene and Pleistocene sites in southwestern South Africa.

Sample ID	Family	Tribe	Genus	Species	Locality	Collection, horizon ^b	Bay ^c	Behavior ^d	$\delta^{13}\text{C}_{\text{enamel}}$		$\delta^{18}\text{O}_{\text{enamel}}$		Tooth element ^e	Reference	
									(‰ VPDB) 1 σ	(‰ VSMOW) 1 σ	n ^f	n ^f			
EFTM 5015	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-13.3	-	30.5	-	Molar	This study	
EFTM 66908	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-11.6	-	28.9	-	Tusk fragment	This study	
EFTM MS121094	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	EFTM	-	Semi-aquatic	-13.3	-	28.7	-	Molar fragment	This study	
WCRP 49364	Hippopotamidae	-	<i>Hippopotamus</i>	<i>amphibius</i>	Elandsfontein	WCRP	0909	Semi-aquatic	-10.0	1.6	31.7	1.6	2	Canine	This study
EFTM 3410	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>simum</i>	Elandsfontein	EFTM	-	Grazer	-10.2	-	32.3	-	Molar	This study	
EFTM 3440	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>simum</i>	Elandsfontein	EFTM	-	Grazer	-11.6	-	33.2	-	Fragment	This study	
EFTM 8610B	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>simum</i>	Elandsfontein	EFTM	-	Grazer	-11.3	-	32.2	-	Fragment	This study	
EFTM 93998	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>simum</i>	Elandsfontein	EFTM	-	Grazer	-10.4	-	31.3	-	Molar	This study	
EFTM 16617	Rhinocerotidae	-	<i>Diceros</i>	<i>bicornis</i>	Elandsfontein	EFTM	-	Browser	-11.2	-	31.7	-	RM3	This study	
EFTM 20939	Rhinocerotidae	-	<i>Diceros</i>	<i>bicornis</i>	Elandsfontein	EFTM	-	Browser	-11.5	-	32.2	-	Fragment	This study	
EFTM 20982	Rhinocerotidae	-	<i>Diceros</i>	<i>bicornis</i>	Elandsfontein	EFTM	-	Browser	-11.4	-	33.0	-	Molar fragment	This study	
EFTM 8700K ⁴	Rhinocerotidae	-	<i>Diceros</i>	<i>bicornis</i>	Elandsfontein	EFTM	-	Browser	-11.8	0.1	31.1	0.3	2	Molar	This study
-	Rhinocerotidae	Rhinocerotidae indet.	-	-	Elandsfontein	EFTM	-	-	-10.8	-	27.6	-	Second or third molar when possible	Luyt et al., 2000	
-	Rhinocerotidae	Rhinocerotidae indet.	-	-	Elandsfontein	EFTM	-	-	-11.1	-	28.2	-	Second or third molar when possible	Luyt et al., 2000	
0313 Rhino-Lot 2744	Rhinocerotidae	Rhinocerotidae indet.	-	-	Elandsfontein	WCRP	0313	-	-12.4	0.3	32.8	0.7	3	Premolar	This study
WCRP 18531	Rhinocerotidae	Rhinocerotidae indet.	-	-	Elandsfontein	WCRP	0609	-	-9.2	-	32.0	-	Fragment	This study	
WCRP 9055	Rhinocerotidae	Rhinocerotidae indet.	-	-	Elandsfontein	WCRP	West Site	-	-10.6	-	33.6	-	Fragment	This study	
-	Suidae	-	<i>Kolpochoerus</i>	<i>paiceae</i>	Elandsfontein	EFTM	-	Grazer	-8.7	-	29.8	-	Second or third molar when possible	Luyt et al., 2000	
-	Suidae	-	<i>Kolpochoerus</i>	<i>paiceae</i>	Elandsfontein	EFTM	-	Grazer	-9.8	-	26.2	-	Second or third molar when possible	Luyt et al., 2000	
-	Suidae	-	<i>Kolpochoerus</i>	<i>paiceae</i>	Elandsfontein	EFTM	-	Grazer	-12.0	-	23.7	-	Second or third molar when possible	Luyt et al., 2000	
WCRP 12156	Suidae	-	<i>Kolpochoerus</i>	<i>paiceae</i>	Elandsfontein	WCRP	0209	Grazer	-9.0	-	32.3	-	rm3	This study	
WCRP 12284	Suidae	-	<i>Kolpochoerus</i>	<i>paiceae</i>	Elandsfontein	WCRP	0209	Grazer	-8.2	-	32.5	-	lm3	This study	
WCRP 6438	Suidae	-	<i>Kolpochoerus</i>	<i>paiceae</i>	Elandsfontein	WCRP	0610	Grazer	-11.1	-	31.4	-	lm3	This study	
-	Suidae	-	<i>Metridiochoerus</i>	<i>andrewsi</i>	Elandsfontein	EFTM	-	Grazer	-11.2	-	24.0	-	Second or third molar when possible	Luyt et al., 2000	
-	Suidae	-	<i>Metridiochoerus</i>	<i>andrewsi</i>	Elandsfontein	EFTM	-	Grazer	-9.4	-	27.9	-	Second or third molar when possible	Luyt et al., 2000	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer to Browser	-11.4	-	26.3	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer to Browser	-12.3	-	26.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer to Browser	-9.3	-	28.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer to Browser	-10.5	-	29.3	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer to Browser	-10.3	-	26.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer to Browser	-10.3	-	29.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Alcelaphini	<i>Damalacra</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM	-	Grazer to Browser	-11.5	-	26.3	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Reduncini	<i>Kobus</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM	-	-	-10.7	-	26.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Reduncini	<i>Kobus</i>	<i>sp.</i>	Langebaanweg	Varswater Formation, PPM	-	-	-10.7	-	29.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Bovidae	Bovidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-10.0	-	34.6	-	Molar	This study	
-	Bovidae	Bovidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-10.4	-	32.8	-	Molar	This study	
LBW13G-001	Equidae	-	<i>Hipparion</i>	<i>cf. baardi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer	-11.7	-	25.1	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
LBW13G-002	Equidae	-	<i>Hipparion</i>	<i>cf. baardi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer	-12.9	-	25.1	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Equidae	-	<i>Hipparion</i>	<i>cf. baardi</i>	Langebaanweg	Varswater Formation, PPM	-	Grazer	-11.0	-	26.1	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Equidae	-	<i>Hipparion</i>	<i>cf. baardi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer	-11.2	-	28.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Equidae	-	<i>Hipparion</i>	<i>cf. baardi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Grazer	-10.7	-	29.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Equidae	-	<i>Hipparion</i>	<i>cf. baardi</i>	Langebaanweg	Varswater Formation, PPM	-	Grazer	-10.4	-	28.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
LBW13G-003	Equidae	Equidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-8.9	-	30.4	-	Molar	This study	
LBW13G-004	Equidae	Equidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-8.8	-	31.2	-	Incisor	This study	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-12.0	-	27.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-13.5	-	24.8	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-13.2	-	28.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-13.6	-	26.8	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.5	-	29.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM	-	Mixed feeder	-10.4	-	28.8	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.7	-	27.9	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.5	-	27.9	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.7	-	30.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.3	-	27.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-11.1	-	27.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-9.9	-	29.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-11.1	-	30.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-12.0	-	27.8	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-11.9	-	27.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-11.6	-	27.4	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-12.1	-	26.8	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.3	-	27.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-12.5	-	29.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.4	-	27.9	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-10.8	-	28.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-11.1	-	27.3	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-12.3	-	29.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-11.1	-	27.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Giraffidae	-	<i>Svatharium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-13.5	-	27.4	-	Molar fragments when possible	Franz-Odenaal et al., 2002	

Table S2: Compilation of new and published $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the carbonate component of tooth enamel from Pliocene and Pleistocene sites in southwestern South Africa.

Sample ID	Family	Tribe	Genus	Species	Locality	Collection, horizon ^b	Bay ^c	Behavior ^d	$\delta^{13}\text{C}_{\text{enamel}}$		$\delta^{18}\text{O}_{\text{enamel}}$		Tooth element ^e	Reference	
									(‰ VPDB)	1 σ	(‰ VSMOW)	1 σ			
-	Giraffidae	-	<i>Sivatherium</i>	<i>hendeyi</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Mixed feeder	-13.0	-	25.4	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
LBW13G-009	Giraffidae	Giraffidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-12.0	-	34.0	-	Molar	This study	
LBW13G-010	Giraffidae	Giraffidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-9.3	-	33.3	-	Fragment	This study	
LBW13G-011	Giraffidae	Giraffidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	-	-9.2	-	30.3	-	Molar	This study	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-10.9	-	27.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-13.3	-	23.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-11.6	-	26.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-12.7	-	25.3	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-14.9	-	24.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-12.0	-	23.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-11.8	-	24.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-9.4	-	24.4	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-12.1	-	25.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-11.5	-	25.9	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-13.6	-	24.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-10.0	-	25.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-13.8	-	24.3	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-11.7	-	23.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
LBW13G-006	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	Semi-aquatic	-10.3	-	25.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
LBW13G-007	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	Semi-aquatic	-13.3	-	28.1	-	Tusk fragment	This study	
LBW13G-008 ^a	Hippopotamidae	Hippopotamidae indet.	-	-	Langebaanweg	Varswater Formation, PPM	-	Semi-aquatic	-10.9	-	27.1	-	Molar	This study	
-	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>praecox</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Semi-aquatic	-10.2	0.2	29.5	0.9	2	Premolar	This study
-	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>praecox</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Browser	-11.1	-	25.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>praecox</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Browser	-10.1	-	28.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>praecox</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Browser	-10.5	-	25.0	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Rhinocerotidae	-	<i>Ceratotherium</i>	<i>praecox</i>	Langebaanweg	Varswater Formation, PPM, Bed 3aN	-	Browser	-11.7	-	26.2	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Suidae	-	<i>Nyanzachoerus cf.</i>	<i>jaegeri</i>	Langebaanweg	Varswater Formation, PPM	-	-	-12.2	-	27.9	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Suidae	-	<i>Nyanzachoerus cf.</i>	<i>jaegeri</i>	Langebaanweg	Varswater Formation, PPM	-	-	-10.3	-	26.5	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Suidae	-	<i>Nyanzachoerus cf.</i>	<i>jaegeri</i>	Langebaanweg	Varswater Formation, PPM	-	-	-12.5	-	27.7	-	Molar fragments when possible	Franz-Odenaal et al., 2002	
-	Suidae	-	<i>Nyanzachoerus cf.</i>	<i>jaegeri</i>	Langebaanweg	Varswater Formation, PPM	-	-	-12.0	-	28.6	-	Molar fragments when possible	Franz-Odenaal et al., 2002	

^a Averaged enamel samples from one specimen.

^b Teeth are from EFTM (Elandsfontein Main) or WCRP (West Coast Research Project, collected as part of this study). Information for Langebaanweg and Hoedjiespunt are about the collections and geological context.

^c Location of teeth of WCRP collection is given by bay number (see Braun et al., 2013).

^d Taxa were considered semi-aquatic, grazer, mixed feeder and browser when possible (Sponheimer et al., 2001; Franz-Odenaal et al., 2004; Stynder 2009; 2011; Hare and Sealy, 2013).

^e Original data were reported relative to VPDB and were converted to the VSMOW notation using the equation $\delta^{18}\text{O}_{\text{VSMOW}} = 1.3086 \times \delta^{18}\text{O}_{\text{VPDB}} + 30.86$.

^f Number of analyses averaged.

^g Abbreviations for tooth position and elements are as follows: R, right; L, left; M, molar. Uppercase and lowercase letters refer to the maxillary and mandibular teeth, respectively. Molar position is indicated by 1, 2 or 3, when known. Tooth element and position information for previously published samples are reported from the original studies.

Table S3: The $\delta^{18}\text{O}$ values of the phosphate and carbonate component of tooth enamel from Elandsfontein and Langebaanweg.

Sample ID	Family	$\delta^{18}\text{O}_{\text{enamel-phosphate}}$			$\delta^{18}\text{O}_{\text{enamel-carbonate}}$			$\epsilon_{\text{CO}_3\text{-PO}_4}$	
		(‰ VSMOW)	1σ	n	(‰ VSMOW)	1σ	n	avg (‰ VSMOW)	$1\sigma^a$
Elandsfontein									
WCRP-1669	Bovidae	23.7	0.3	3	34.1	0.6	1	10.2	1.0
EFTM-6177.8	Bovidae	23.5	0.5	2	32.6	0.6	1	8.9	1.1
EFTM-8953	Bovidae	23.0	0.3	4	31.6	0.6	1	8.4	0.9
WCRP-5043	Bovidae	24.1	0.2	4	34.3	0.6	1	10.0	0.9
EFTM-11908	Bovidae	21.6	0.2	4	30.7	0.6	1	8.9	0.9
EFTM-5063	Bovidae	24.0	0.3	4	33.2	0.6	1	9.0	1.0
IZ-7892E	Bovidae	23.2	0.1	4	32.9	0.6	1	9.5	0.9
EFTM-5113.6	Bovidae	24.2	0.4	7	34.4	0.6	1	10.0	1.0
EFTM-1746	Bovidae	22.6	0.2	3	31.9	0.6	1	9.2	0.9
EFTM-1694	Bovidae	25.6	0.2	4	35.5	0.6	1	9.6	0.9
EFTM-8657	Bovidae	24.4	0.3	3	34.8	0.6	1	10.1	0.9
EFTM-2728	Bovidae	25.7	0.2	4	36.7	0.6	1	10.7	0.9
EFTM-2738	Bovidae	25.1	0.4	4	34.8	0.6	1	9.4	1.0
WCRP-1666	Bovidae	23.0	0.1	3	32.7	0.6	1	9.5	0.8
EFTM-4088	Hippopotamidae	20.3	0.2	4	29.3	0.6	1	8.8	0.9
EFTM-4030	Hippopotamidae	21.2	0.2	3	30.5	0.6	1	9.1	0.9
EFTM-MSI2699	Hippopotamidae	19.9	0.4	4	28.7	0.6	1	8.6	1.0
EFTM-6727	Equidae	22.1	0.2	4	32.0	0.6	1	9.7	0.9
EFTM-16660	Equidae	22.8	0.4	6	32.0	0.6	1	9.0	1.0
EFTM-2112	Equidae	23.5	0.1	3	33.9	0.6	1	10.2	0.9
EFTM-5065	Equidae	23.7	0.1	4	33.1	0.6	1	9.1	0.9
EFTM-8958A	Equidae	22.8	0.3	3	32.7	0.6	1	9.7	1.0
WCRP-2103	Equidae	23.1	0.4	6	32.3	0.6	1	8.9	1.0
EFTM-2619	Equidae	22.3	0.2	2	31.6	0.6	1	9.0	0.9
EFTM-1952	Equidae	23.3	0.3	4	33.1	0.6	1	9.6	0.9
EFTM-4028A	Giraffidae	24.4	0.0	3	35.0	0.6	1	10.3	0.8
EFTM-4031	Giraffidae	23.6	0.3	2	33.5	0.6	2	9.6	0.9
WCRP-8031	Giraffidae	23.1	0.3	4	32.8	0.6	1	9.5	0.9
EFTM-20939	Rhinocerotidae	23.6	0.2	2	32.2	0.6	1	8.5	0.9
EFTM-20982D	Rhinocerotidae	23.3	0.2	4	33.0	0.6	1	9.4	0.9
EFTM-16617A	Rhinocerotidae	24.0	0.4	4	31.7	0.6	1	7.4	1.0
EFTM-8700K	Rhinocerotidae	23.3	0.2	4	31.1	0.3	2	7.6	0.7
EFTM-3410A	Rhinocerotidae	23.8	0.1	2	32.3	0.6	1	8.3	0.9
EFTM-8610B	Rhinocerotidae	22.9	0.2	3	32.2	0.6	1	9.0	0.9
EFTM-93998	Rhinocerotidae	22.5	0.2	3	31.3	0.6	1	8.6	0.9
WCRP-12156	Suidae	22.5	0.3	3	32.3	0.6	1	9.6	1.0
WCRP-12284	Suidae	22.7	0.3	4	32.5	0.6	1	9.6	1.0
WCRP-6438	Suidae	22.8	0.3	1	31.4	0.6	1	8.4	1.0
Langebaanweg									
LBW13G-001	Bovidae	25.2	0.2	4	34.6	0.6	1	9.2	0.9
LBW13G-004	Equidae	22.8	0.4	6	31.2	0.6	1	8.2	1.0
LBW13G-006	Hippopotamidae	20.3	0.1	4	28.1	0.6	1	7.7	0.9
LBW13G-007	Hippopotamidae	19.9	0.2	4	27.1	0.6	1	7.0	0.9
LBW13G-008A	Hippopotamidae	21.3	0.7	2	30.3	0.6	1	8.8	1.2
LBW13G-008B	Hippopotamidae	21.2	0.6	2	28.7	0.6	1	7.4	1.1
LBW13G-008 (A & B)	Hippopotamidae	21.3	0.6	4	29.5	1.1	2	8.1	1.3
LBW13G-009	Giraffidae	25.2	0.1	4	34.0	0.6	1	8.6	0.9
LBW13G-010	Giraffidae	24.0	0.4	4	33.3	0.6	1	9.1	1.0
LBW13G-011	Giraffidae	21.9	0.2	4	30.3	0.6	1	8.3	0.9

^a propagated error

$$\epsilon_{\text{carbonate-phosphate}} = \sqrt{(\text{standard deviation } \delta^{18}\text{O}_{\text{enamel-phosphate}})^2 + (\text{standard deviation } \delta^{18}\text{O}_{\text{enamel-carbonate}})^2}$$

Table S4: Oxygen and hydrogen isotope composition of waters from southwestern South Africa.

Location	Sample source	Year(s) of collection ^a	$\delta^{18}\text{O}$ of water avg ^b ‰ VSMOW	$\delta^2\text{H}$ of water avg ^b ‰ VSMOW	Rainfall zone	References
Cape Town	Springs	1996, 1997, 2010 - 2012	-3.3±0.5 (<i>n</i> = 87)	-10.7±2.0 (<i>n</i> = 69)	Winter	Harris et al., 2000; Harris and Diamond, 2013
Cape Town	Water treatment plants	1996, 1997	-3.0±1.5 (<i>n</i> = 16)	-10.3±8.5 (<i>n</i> = 16)	Winter	Harris et al., 1999
Cape Town	Aquifers	1996, 1997	-3.0±0.6 (<i>n</i> = 29)	-12.1±4.7 (<i>n</i> = 29)	Winter	Harris et al., 1999
Western Cape (primarily surrounding Cape Town)	Rivers	1996, 1997, 2010 - 2012	-3.5±1.2 (<i>n</i> = 68)	-16.1±10.0 (<i>n</i> = 70)	Winter	Harris et al., 1999; Harris and Diamond, 2013
University of Cape Town	Precipitation (monthly)	1996 - 2008	-2.8±1.7 (<i>n</i> = 163)	-9.5±2.8 (<i>n</i> = 163)	Winter	Harris et al., 2010
University of Cape Town	Precipitation (daily)	1996 - 2008	-2.67±2.1 (<i>n</i> = 109)	-7.1±14.2 (<i>n</i> = 109)	Winter	Harris et al., 2010
Western Cape (primarily surrounding Cape Town)	Precipitation	2010 - 2012	-2.9 (<i>n</i> = ND) ^c	-9.2 (<i>n</i> = ND) ^c	Winter	Harris and Diamond, 2013
Table Mountain Cableway, Cape Town	Precipitation	2010 - 2012	-3.6±1.1, -3.7 (<i>n</i> = 18) ^c	-12.4±5.8, 14.4 (<i>n</i> = 17) ^c	Winter	Harris and Diamond, 2013
Jonkershoek Valley (closest major city is Western Cape, West Coast)	Catchment waters	1992	-4.0±0.2 (<i>n</i> = 24)	ND	Winter	Midgley and Scott, 1994
Western Cape, South Coast	Groundwater and precipitation	1999 - 2000	-3.9±1.4 (<i>n</i> = 19)	ND	Winter	Weaver and Telma, 2005
Western Cape, South Coast	Groundwater and precipitation	1999 - 2000	-5.2±1.3 (<i>n</i> = 5)	ND	Annual	Weaver and Telma, 2005
Hopefield, Western Cape	Precipitation (annually cumulative)	1999 - 2000	-3.2 (<i>n</i> = 1)	ND	Winter	Weaver and Telma, 2005
Langebaan Road Wellfield, Western Cape	Precipitation (annually cumulative)	1999 - 2000	-2.8 (<i>n</i> = 1)	ND	Winter	Weaver and Telma, 2005
Langebaan Road Wellfield, Western Cape	Aquifer	1999 - 2000	-3.6±0.1 (<i>n</i> = 4)	ND	Winter	Weaver and Telma, 2005
Cape Fold Belt	Precipitation	2010 - 2012	-4.3±1.8 (<i>n</i> = 226)	-17.1±9.8 (<i>n</i> = 232)	Winter and Annual	Harris and Diamond, 2013
Jonkershoek Valley area	Groundwater, tapwater, modeled isoscape	2006, 2007, 2009, 2010	-5.2 to -2.9 (model based on 770 water samples)	-29.0 to -10.0	Winter	West et al., 2014

Table S4: Oxygen and hydrogen isotope composition of waters from southwestern South Africa.

Location	Sample source	Year(s) of collection ^a	$\delta^{18}\text{O}$ of water avg ^b ‰ VSMOW	$\delta^2\text{H}$ of water avg ^b ‰ VSMOW	Rainfall zone	References
Elandsfontein area	Groundwater, tapwater, modeled isoscape	2006, 2007, 2009, 2010	-2.8 to -0.5 (model based on 770 water samples)	-19.0 to 0.0	Winter	West et al., 2014
Elandsfontein ^d	Standing water	2010	1.5 ($n = 1$)	6.2 ($n = 1$)	Winter	This study (sample SA10W400) WGS-84 Lat/Long: -33.1250, 18.23667
Elandsfontein ^d	Spring water	2010	-3.2 ($n = 1$)	-13.8 ($n = 1$)	Winter	This study (sample SA10W401) WGS-84 Lat/Long: -33.10744, 18.20932
Western Cape Fossil Park ^d	Tap water	2010	-1.9 ($n = 1$)	-9.2 ($n = 1$)	Winter	This study (sample SA10W402) WGS-84 Lat/Long: -32.95659, 18.11633
Brakfontein, near Elandsfontein ^d	Spring water	2010	-3.3 ($n = 1$)	-14.4 ($n = 1$)	Winter	This study (sample SA10W403) WGS-84 Lat/Long: -32.95215, 18.24296

^a Only months with both precipitation amount and $\delta^{18}\text{O}$ of precipitation were used for this study. Samples were not collected over continuous time periods for every site.

^b Isotope data are reported as averages with their standard deviation (1σ). The number of samples are given in parentheses.

^c Weighted mean of rainfall as reported in Harris and Diamond (2013).

^d GPS coordinates for the samples collected and their sample ID are provided in the reference column. 'ND' is used to indicate no data.