

# *Colonialism, slavery and 'The Great Experiment': carbon, nitrogen and oxygen isotope analysis of Le Morne and Bois Marchand cemeteries, Mauritius*

Article

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1           **Colonialism, Slavery and 'The Great Experiment': Carbon, Nitrogen and**  
2           **Oxygen Isotope Analysis of Le Morne and Bois Marchand Cemeteries, Mauritius**

3  
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22  
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24  
25           **Highlights**

- 26           • Isotopic analyses of two 19<sup>th</sup> century cemeteries give insights into Mauritian  
27           diets
- 28           • A wide range of diets was consumed, particularly in terms of C<sub>4</sub> consumption
- 29           • People buried at Le Morne consumed more C<sub>4</sub> foods than those at Bois  
30           Marchand
- 31           • The individuals from Le Morne had different childhood diets but similar adult  
32           diets
- 33           • This is consistent with Le Morne's interpretation as a post-emancipation  
34           cemetery

35  
36           **Abstract**

37  
38           Slavery, colonialism and emancipation are important aspects of archaeological  
39           research in the Atlantic region, but the lifeways of colonial populations remain  
40           understudied in the Indian Ocean World. Here, we help to redress this imbalance by  
41           undertaking stable isotope analysis (C, N and O) on human remains from Mauritius, a  
42           location which played an important role in the movement of people across the Indian  
43           Ocean and beyond. The results indicate that a wide range of diets was consumed in  
44           Mauritius during the nineteenth century, varying with location and circumstances of  
45           birth such that while a range of resources would have been available on the island, the  
46           proportions of the different resources consumed was different for different people.  
47           Most people consumed some C<sub>4</sub> resources, likely maize, although the proportion of  
48           the diet that this represented varied widely. There is some evidence for the use of  
49           marine resources, with one individual consuming a very high proportion of marine  
50           foods. In general, the people buried at the post-emancipation cemetery Le Morne

51 consumed a higher proportion of C<sub>4</sub> foodstuffs and a lower proportion of animal  
52 protein and/or marine resources than those individuals buried at the formal public  
53 cemetery Bois Marchand. The data from La Morne are consistent with a population  
54 that lived separately as children and then came to live, and eat, together during  
55 adulthood. This study has shown a much more nuanced picture of diet in Mauritius at  
56 this time than was previously known. The research complements and enriches the  
57 historic narrative, adding dimensions to small islands that would otherwise remain  
58 obscure in the absence of rigorous scientific assessment of archaeological finds.  
59

60  
61 **Key words:** Indian Ocean, indentured labour, palaeodiet, collagen, enamel carbonate  
62

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73  
74

## 75 1. Introduction 76

77 Archaeological aspects of slavery, colonialism and emancipation have been well-  
78 studied in the Atlantic region, but comparatively little research has been undertaken in  
79 the Indian Ocean area (Seetah, 2016). In particular, the lifeways of colonial  
80 populations, especially bondmen and women, freed slaves and indentured labourers  
81 remains under-studied. Mauritius formed an important node in the movement of  
82 people in the Indian Ocean and beyond, and was the home of the 'Great Experiment',  
83 when the British replaced slavery with 'free', indentured, labour. This research  
84 examines the diet of various groups residing in Mauritius in the years following  
85 emancipation. Using carbon, nitrogen and oxygen isotopic evidence from dentine  
86 collagen, enamel carbonate and bone collagen, we assess the diet and life histories of  
87 individuals buried in two cemetery sites in Mauritius (Fig. 1).  
88



89  
 90 *Figure 1: Map of Mauritius with analysed sites (generated with ArcGIS version*  
 91 *10.2.2).*

92  
 93 Le Morne 'Old Cemetery' is thought to be a post-emancipation cemetery and is  
 94 located within the buffer zone of a UNESCO World Heritage site that commemorates  
 95 slave resistance. At the time of writing, it appears to be the only post-emancipation  
 96 cemetery excavated from the Southwestern Indian Ocean (Seetah, 2015a). Bois  
 97 Marchand is a formal cemetery dating from 1867 with extensive burial records  
 98 indicating that a cross-section of society was buried there (Pike 1873; Seetah 2015a).  
 99 By comparing the individuals buried at these two sites, this study ~~will acquire represents~~  
 100 a better understanding of what life was like for nineteenth century Mauritians and  
 101 how this varied with circumstances of birth and life history.

102  
 103 **2. Background**

104  
 105 **2.1. Historical Background**

106  
 107 Detailed accounts of the history of Mauritius are provided by Allen (1999, 2003,  
 108 Teelock (2009) and Vaughan (2005), and only a brief outline will be  
 109 presented here. Mauritius was colonised by the French in AD 1721, although the  
 110 Dutch had made two short-lived previous attempts, and runaway enslaved people  
 111 most likely stayed on the island following the latter attempt. The island was under  
 112 French jurisdiction until 1810 when the British seized it for its strategic significance,  
 113 and it remained a British colony until 1968 when it ~~was granted gained~~ independence.  
 114

115 Between the late seventeenth and mid-nineteenth centuries c. 280,000 to 322,000  
116 enslaved people were brought to Mauritius and neighbouring Réunion (Allen, 2004).  
117 Although the British Empire banned the slave trade in 1807, the practice continued  
118 well into the 1820s. Most enslaved people were from Madagascar (45%) and  
119 Mozambique (40%), with smaller numbers from India (13%) and West Africa (2%;  
120 Allen, 1999, Filliot, 1974). Resistance was a significant problem for the French and  
121 British colonists (Peerthum, 2006); during the first half of the 1820s approximately  
122 11% of the enslaved population absconded (Allen, 1999). In 1835, a Proclamation  
123 was issued that gave all slaves their freedom after a four to six-year apprenticeship  
124 (Nwulia, 1978).

125  
126 The rapid expansion of the Mascarene sugar industries in the late 1820s, coupled with  
127 the decline and eventual demise of the slave trade, led to shortages of agricultural  
128 labour. Attempts were made in the 1820s to take free indentured labourers from China  
129 and India to Réunion, but ~~there was heavy resistance from the the scheme ultimately~~  
130 ~~failed due to resistance of the~~ labourers to the poor conditions, ~~and the scheme~~  
131 ~~eventually failed~~. The indentured labour system began in earnest in 1835 and  
132 continued until 1910 (Allen, 2014b). By 1861 there were 193,000 South Asian  
133 people, mainly from Indian subcontinent, in Mauritius, representing 62% of the  
134 island's population at that time (Allen, 1999). The indentured labourers were subject  
135 to many of the same harsh treatments as slaves: recruitment through deception and  
136 tracking, diseased ship-board passage, travel restrictions within Mauritius and poor  
137 treatment, including corporal punishment and imprisonment on estates. They also  
138 resisted this oppression using many of the same tactics the enslaved people had,  
139 including absconding (Allen, 1999). Even so, the indentured labours were legally free  
140 and the small salary that they received set them apart from slaves; they were part of  
141 labour commodification in the post-slavery colonial empire system. Genetic analysis  
142 of the modern population of Mauritius has evidenced the multicultural nature of this  
143 region (Fregel et al., 2014). Today, most mtDNA lineages in Mauritius are of Indian  
144 origin (58.76%), with also significant contributions from Madagascar (16.60%),  
145 East/Southeast Asia (11.34%) and Sub-Saharan Africa (10.21%).

146  
147 Historical evidence suggests that the diets of enslaved people were based upon maize  
148 and manioc. Baron Grant, a French planter who lived in Mauritius from 1740 to 1758,  
149 reports that enslaved people consumed ground maize boiled in water, or manioc  
150 loaves, and that owners were required to give enslaved people meat once a week,  
151 although this law was not observed (Grant, 1801). In 1825, Governor Sir Lowry Cole  
152 notes that daily slave food rations were no more than 1.25lb of maize or 3lb of manioc  
153 (Allen, 1999). There is evidence, however, that enslaved people owned pigs, goats  
154 and chickens and produced enough fruits, vegetables and other products to sell the  
155 surplus (Allen, 1999). After abolition, the vast majority of ~~ex-Previously enslaved~~  
156 ~~individuals~~ left the plantations. They worked instead in a variety of occupations,  
157 including craft production, trade, agriculture and domestic service. Many ~~Previously~~  
158 ~~ex-slaved individuals~~ became smallholders, acquiring plots of land which they  
159 used to grow bananas, maize, manioc, sweet potatoes and other fruits and vegetables,  
160 and to raise poultry or swine (Allen, 1999). According to their contracts, indentured  
161 labourers had to receive rations of rice, dal, oil, chilli, salt, salt fish, and so on which  
162 were often poor and inadequate. Through time, both in the camps and in newly  
163 acquired plots of land, labourers could supplement their modest diets by growing food  
164 (Sain, 1980).

165  
166 Historical records also indicate that food shortages were a problem throughout the  
167 eighteenth century, which increased in the early nineteenth century when more land  
168 was given over to sugar production, and again with Indian immigration (Allen, 1999,  
169 Ly-Tio-Fane, 1968). Rice and cattle had to be imported to Mauritius from India and  
170 Madagascar in order to prevent famines (Allen, 1999).  
171  
172 **2.2. Le Morne Cemetery**  
173  
174 This study examines two sites, Le Morne and Bois Marchand cemeteries. Le Morne is  
175 located on a peninsular on the south-western tip of Mauritius. The area is isolated  
176 from the rest of the island by a 545m high inselberg with only a single, precarious  
177 access point. Oral history describes this region as a last resort for runaway slaves  
178 (Seetah, 2016). The cemetery itself lies at the foothill of the inselberg and is thought  
179 to be a post-emancipation cemetery. It has become a symbol of slave resistance,  
180 recognized by its inscription on the UNESCO World Heritage List in 2008 as Le  
181 Morne Cultural Landscape (<http://whc.unesco.org/en/list/1259>).  
182  
183 Archaeological investigations of the area, undertaken by the Mauritian Archaeology  
184 and Cultural Heritage (MACH) project and in close association with the Le Morne  
185 Heritage Trust Fund, commenced in 2009. The initial survey revealed 45 surface  
186 features thought to be burial structures, eight of which were excavated in 2010. The  
187 human remains found in these eight graves are included in this analysis (Seetah,  
188 2010). The graves were delineated by basalt rocks, with the size of the graves  
189 proportional to the size of the interred. All graves contained evidence for well-  
190 constructed coffins but very few additional objects were found, although notable  
191 exceptions include a series of mother-of-pearl buttons, a small number of French  
192 coins dating from 1812 to 1828 (grave 7, Fig. 2) and seven clay tobacco pipes,  
193 manufactured in Britain in the first half of the nineteenth century (graves 23, 24 and  
194 42). Radiocarbon dating has proved problematic; however, the evidence from coins  
195 and pipes suggests that the cemetery dates to the mid 1830s, around the period of  
196 emancipation (Seetah, 2015b, Seetah, 2015a). The burial traditions do not reflect  
197 Christian religious practices; the absence of any kind of religious building or any  
198 other sign of 'delimited sacred space', the orientation of the bodies to the west, the  
199 burial of neonatal and newborn individuals (i.e. individuals unlikely to have been  
200 baptized), and the inclusion of grave goods would suggest African traditions were  
201 being followed (Seetah, 2010). In particular, the tobacco pipes could be interpreted as  
202 'slave material culture' as they are often found in slave cemetery graves in the  
203 Atlantic region but are not documented in cemeteries associated with people of  
204 European descent (Katz-Hyman and Rice, 2011). The burials themselves appear to  
205 reflect a population of some means, at least to the extent to which they could  
206 provision their deceased: the dead were buried in well-constructed coffins; the  
207 mother-of-pearl buttons suggests that they were dressed in relatively fine clothes; and  
208 they were placed in clearly delineated graves, which were maintained and cared for.  
209 This would seem to indicate that they were free people, but whether they had  
210 previously been enslaved remains unclear (Seetah, 2010).  
211



212  
213 *Figure 2: Le Morne Cemetery: skeletal remains of an individual in the grave 7, with*  
214 *bronze coins in-situ; 2010 excavation (MACH archive).*  
215

216 Eleven skeletons were recovered from eight graves and were available for analysis.  
217 All were primary inhumations, with six juveniles (three perinatal and three under 5  
218 years at death), four females or possible females and one male individual (Appleby et  
219 al., 2014, Appleby in Seetah, 2010). The presence and the position of a foetus  
220 between the legs of the female in grave 1 suggests that she may have died in  
221 childbirth. There were few osteological indications of dietary stress suggesting that  
222 nutrition was adequate, however the stature of the individuals was relatively small,  
223 fitting with the documentary evidence for slaves' heights recorded in the 1817 census  
224 (Allen pers. comm.). The presence of caries and abscesses in the mouth suggest that  
225 the diet was highly cariogenic and that dental hygiene was poor; 12% of teeth had  
226 caries and antemortem tooth loss is observed in 18% of alveoli (Santana pers. com.).  
227 Pathological conditions present include periosteal bone lesions which are frequent in  
228 individuals with compromised immunity and chronic illnesses, such as malnutrition  
229 and immune-deficiency diseases. Preliminary genetic analyses on the same  
230 [archaeological material](#)individuals using mitochondrial DNA, suggests that nine of  
231 the individuals were most probably of East African (possibly Mozambican) descent  
232 while two were Madagascan (Seetah, 2015a), but it does not necessarily follow that  
233 these individuals had themselves been enslaved. Given the available evidence, Seetah  
234 (2015a) has tentatively concluded that the cemetery contains the remains of the first  
235 generation of freeborn Mauritians.  
236

237 **2.3. Bois Marchand Cemetery**  
238

239 Bois Marchand is a formal, public cemetery located in the northern part of the island,  
240 approximately 50 km from Le Morne. It was inscribed in 1867 in response to the tens  
241 of thousands of people who died from malaria (Pike, 1873). The cemetery was  
242 divided into large parcels, with different religious ascriptions including Christian,  
243 Hindu and Muslim, and occupational plots for police, firefighters, soldiers, criminals,  
244 and so on. Our research focuses on one such parcel (section "R") which was in use  
245 from 1867 to 1868. The parcel has 42 rows of graves, with c. 500 individuals buried  
246 here. We anticipated finding the remains of indentured laborers, however the public  
247 cemetery was open to all and the excavated individuals represent a cross-section of  
248 the Mauritian population, including many indentured workers. The extensive burial  
249 records indicate that the individuals buried here were from as far as England, Jamaica,  
250 'Arabia' and 'America' (Bois Marchand Cemetery Archive, burial registers (BR) No.  
251 2: June 6<sup>th</sup> to July 26<sup>th</sup> 1898; BR no number: August 23<sup>rd</sup> to October 1<sup>st</sup> 1903; BR No.  
252 19: May 6<sup>th</sup> to July 9<sup>th</sup> 1901).

253

254 The archaeological research of the MACH project in Bois Marchand commenced in  
255 2011. Here we are presenting the data from the seasons 2011 when we excavated six  
256 graves with eight individuals, and from 2015, when we excavated eight graves with  
257 fourteen individuals. The red ferrallitic soil in the area causes all organic material to  
258 decompose extremely quickly, thus the human remains and other organic materials  
259 are very poorly preserved, preventing an in-depth osteological study of the skeletons  
260 (Fig. 3).

261



262

263 *Figure 3: Bois Marchand cemetery: an individual buried in a corrugated iron coffin,*  
264 *grave 1, 2011 excavation (MACH archive).*

265  
266 All the graves in Bois Marchand cemetery follow an established protocol: NE-SW  
267 orientation; similar size (c. 1.80 x 0.90m) and depth (c. 1.60–1.70m); and c. 0.90m  
268 spacing between the graves. Out of 14 graves uncovered, nine were double and four  
269 single skeletal burials, with one grave empty; in total 22 interments with 17 adults,  
270 two adolescents and three infants. All 22 burials were interred in coffins made out of  
271 wood, corrugated iron or in corrugated iron lined wooden coffins, with two wooden  
272 coffins also lined with lead. Infants were buried wrapped in a shroud: the fabric  
273 decomposed, while silver pins that held the textile, remained as testimony. The burials  
274 contained various personal objects such as rings, toe-rings, earrings, and belt buckles.  
275 The double burials are intriguing, as they are not recorded in the cemetery's burial  
276 registers, except a few cases of mother dying with a new-born child. Seven  
277 individuals (three infants and four adults, representing four graves) were buried in  
278 atypical positions, mostly with the opposite orientation, that is SW-NE. The presence  
279 of these 'deviant' burials is highly unusual and calls for further research.  
280

281 Due to the poor preservation of remains osteological analysis is limited and likely  
282 biased. However, the preserved remains showed evidence for osteoarthritis of the  
283 axial skeleton, hip and knee, and a high prevalence of dental caries and calculus. This  
284 poor preservation also has implications for collagen isotope analysis, as diagenesis  
285 could cause changes in the stable isotope ratios of bone and dentine collagen. Indeed,  
286 dentine samples were taken, in part, as a precaution against poor collagen  
287 preservation, because teeth tend to show better preservation than bone. Nevertheless,  
288 Dobberstein and colleagues (2009) have shown that the collagen triple helix and  
289 polypeptide chains remain intact until 99% of collagen is lost. Therefore, bone  
290 samples with collagen yields greater than 1% can reliably be used for stable isotope  
291 analysis. This and other collagen preservation criteria – a ratio of carbon to nitrogen  
292 atoms between 2.9–3.6 (De Niro, 1985), and final carbon and nitrogen yields of at  
293 least 13% and 4.8%, respectively (Ambrose, 1990) – are applied to our samples,  
294 below.  
295

296 Ancient DNA analyses on the Bois Marchand individuals are ongoing. Preliminary  
297 results indicate a demographic shift compared with Le Morne, with some individuals  
298 having clear South Asian mtDNA lineages, which is congruent with archaeological  
299 findings and historical record. However, some individuals have an African/Malagasy  
300 origin, indicating that the population buried at Bois Marchand was admixed (Fregel et  
301 al., 2015).

## 302 **2.4. Scientific Background**

303 The individuals excavated from Le Morne and Bois Marchand were sampled for  
304 carbon, nitrogen and oxygen stable isotope analysis. Carbon and nitrogen stable  
305 isotope analysis is a quantitative method for studying palaeodiet. When foods vary in  
306 their isotopic composition individuals consuming these different diets can be  
307 identified via their body chemistry. Stable isotope ratios in adult bone protein  
308 (collagen) reflect diet over a period of years, the precise period varying between  
309 different skeletal elements (Hedges et al., 2007). Collagen extracted from tooth  
310 dentine reflects the diet at the time of tooth formation, that is from a number of years  
311  
312

313 during childhood (Gage et al., 1989). As body protein is primarily constructed from  
314 the dietary protein intake, the stable isotope ratios of collagen reflect mainly the  
315 protein portion of the diet (Ambrose and Norr, 1993, Howland et al., 2003, Jim et al.,  
316 2006, Tieszen and Fagre, 1993). Stable carbon isotopic values in tooth enamel also  
317 reflect the diet at the time of tooth formation but reflect the whole diet (Ambrose and  
318 Norr, 1993, Tieszen and Fagre, 1993).

319  
320 Carbon isotopic ratios can be used to distinguish between marine and terrestrial  
321 protein (Schoeninger and DeNiro, 1984) and between C<sub>3</sub> and C<sub>4</sub> plants (Vogel and  
322 van der Merwe, 1977). These two plant groups use different methods to take in  
323 carbon dioxide from the atmosphere during photosynthesis, resulting in different  
324 carbon isotopic ratios in the plant (Vogel and van der Merwe, 1977, Smith and S,  
325 1971, O'Leary, 1988). Most staple plants are C<sub>3</sub>, including wheat, barley and rice,  
326 while maize, sugar cane, millet and sorghum are C<sub>4</sub>. Nitrogen isotope ratios provide  
327 an indication of trophic position, as there is an increase in  $\delta^{15}\text{N}$  of between 3 to 5‰  
328 per trophic level (Bocherens and Drucker, 2003, Hedges and Reynard, 2007). As  
329 marine and freshwater foodchains tend to be longer than terrestrial ones, nitrogen  
330 isotopes can be used to identify fish and aquatic predator consumption, and  
331 distinguish between C<sub>4</sub> and marine consumption (Schoeninger and DeNiro, 1984).

332  
333 Oxygen isotopic analysis ~~is a can be utilised as a~~ method for the identification of non-  
334 local individuals. Oxygen isotope ratios in precipitation reflect the local climate and  
335 vary mainly with temperature and distance from the source of the water (Dansgaard,  
336 1964, Rozanski et al., 1993, Rozanski et al., 1992). The oxygen isotope signal in tooth  
337 enamel carbonate is derived mainly from ingested water and thus reflects the local  
338 climate (Allen, 1999, Longinelli, 1984, Luz and Kolodny, 1985). As tooth enamel  
339 does not remodel during life, the isotopic ratios in the carbonate reflect the water  
340 drunk at the time of tooth formation. Individuals whose oxygen isotope ~~values-ratios~~  
341 are notably different from that of the local precipitation are identified as migrants.  
342 The identification of migrants using this method is not straightforward; the reader is  
343 referred to Lightfoot and O'Connell (2016), Pollard et al. (2011) and Pryor et al.  
344 (2014) for a full discussion.

345  
346 Both nitrogen and oxygen isotope values are affected by breastfeeding. Infants tend to  
347 have higher  $\delta^{15}\text{N}$  values than adults as breastfeeding effectively increases the trophic  
348 level of the infant (Mays et al., 2002, Fuller et al., 2006, Fogel et al., 1989). Oxygen  
349 isotope values are affected as the breastmilk is enriched in <sup>18</sup>O relative to local water  
350 due to the producer's higher body temperature (Wright and Schwarcz, 1989, Roberts  
351 et al., 1988, Lin et al., 2003). Food deprivation can also affect human isotope values,  
352 with  $\delta^{15}\text{N}$  values increasing and  $\delta^{13}\text{C}$  ~~values~~ decreasing ~~as with~~ body mass ~~decreases~~  
353 in modern studies (Mekota et al., 2006, Neuberger et al., 2013). This has been seen  
354 archaeologically in incremental samples of human hair and dentine (Beaumont et al.,  
355 2013, Beaumont and Montgomery, 2016). With bulk collagen samples, which  
356 represent an average diet over many years, however, the influence of food deprivation  
357 is most likely seen through lower  $\delta^{15}\text{N}$  values, related to low animal protein  
358 consumption, and potentially through the use of famine foods where these are  
359 isotopically distinct (Beaumont et al., 2013).

360  
361  
362

### 3. Methodology

363

### 364 3.1. Collagen Isotopic Analysis

365

366 Bone and dentine samples were taken from eight human skeletons from Le Morne.  
367 Bone samples only were also taken from the two peri-natal individuals in grave 6.  
368 From Bois Marchand, bone samples were taken from six individuals excavated in  
369 2011, with dentine samples also taken from three of these individuals. No bone was  
370 available for sampling from the 2015 excavation; however, dentine samples were  
371 taken from 11 individuals. Ribs and molars were preferentially sampled, where  
372 possible; full sample details are given in Appendix 1.

373

374 The sample preparation was carried out in the Dorothy Garrod Laboratory for  
375 Isotopic Analysis, University of Cambridge using the standard laboratory protocol  
376 based upon Richards and Hedges (1999). *c.* 0.5g of bone was sampled using a drill  
377 and cleaned via sand-blasting. Samples were demineralized in c. 10mL 0.5M aq. HCl  
378 at 4°C for up to two weeks and then gelatinized at 75°C for 48 hours in pH 3 water.  
379 The 'collagen' was then lyophilized before weighing for isotopic analysis.

380

381 Each sample was run in triplicate using a Costech elemental analyser coupled in  
382 continuous flow to a Finnigan isotope ratio mass spectrometer at the University of  
383 Cambridge. Stable carbon and nitrogen isotopic compositions were calibrated relative  
384 to the VPDB and AIR scales using international standards. Repeated measurements  
385 on international and in-house standards (L-alanine, IAEA-600, USGS-40, Protein 2  
386 and EMC) showed that the analytical error was  $\pm 0.2\%$  for both carbon and nitrogen  
387 (see Appendix 2).

388

389 Measured collagen is deemed to be of good quality if it fulfills the following criteria:  
390 an atomic C:N ratio of 2.9–3.6 (De Niro, 1985); a 'collagen' yield of 1% by mass;  
391 final carbon yields of 13%; and final nitrogen yields of 4.8% (Ambrose, 1990). All  
392 collagen data fulfilled these criteria, despite the poor bone preservation observed at  
393 Bois Marchand.

394

### 395 3.2. Tooth Enamel Carbonate Isotope Analysis

396

397 Enamel samples were taken from all individuals analysed for dentine, described  
398 above, plus two extra individuals from the 2011 Bois Marchand excavation  
399 (Appendix 1).

400

401 The teeth were cleaned with a tooth brush to remove adhering dirt and the surface  
402 abraded with a carbide drill bit. *c.* 6-8mg of tooth enamel powder was then taken  
403 using a diamond drill bit. The pretreatment method was based on Balasse et al.  
404 (2002). 0.1mL of 2–3% aqueous sodium hypochlorite was added per mg of sample  
405 and left for 24 hours at 4 °C. They were then rinsed five times with distilled water.  
406 0.1mg of acetic acid was added per mg of sample and left for four hours at room  
407 temperature. The samples were then rinsed with distilled water. The samples were  
408 freeze-dried to remove any remaining liquid and transferred to a vial with a screw cap  
409 holding a septa and PCTFE washer to make a vacuum seal. The samples were reacted  
410 with 100% orthophosphoric acid at 90 °C using a Micromass Multicarb Sample  
411 Preparation System and the carbon dioxide produced was dried and transferred  
412 cryogenically into a VG SIRA mass spectrometer for isotopic analysis. Carbon and

413 oxygen isotopic ratios were measured on the delta scale, in comparison to the  
414 international standard VPDB calibrated using the NBS19 standard (Coplen, 1995,  
415 Craig, 1957). Repeated measurements on international and in-house standards show  
416 that the analytical error is better than  $\pm 0.08\text{\textperthousand}$  for carbon and  $\pm 0.10\text{\textperthousand}$  for oxygen.  
417

### 418 **3.3. Statistical Analyses**

419  
420 Statistical analyses were performed using SPSS version 23 for Mac. Samples were  
421 tested for normality using histograms, Kolmogorov-Smirnoff and Shapiro-Wilks tests  
422 and for equality of variance using Levene's tests. For parametric data independent  
423 samples t-tests were used, while Kolmogorov Smirnov Z tests were used for non-  
424 parametric data. Outliers are identified as samples that lie more than 1.5 times the  
425 interquartile range (IQR) below quartile 1 (Q1) or above quartile 3 (Q3) (following  
426 Lightfoot and O'Connell, 2016).  
427

## 428 **4. Results**

429  
430 The results are summarized in Table 1 and given in full in Appendix 1. The dentine  
431 results are shown in Figure 4, the enamel carbonate results in Figure 5 and the bone  
432 collagen data in Figure 6. The difference between the dentine and bone collagen  
433 results for individuals where both samples were analysed are shown in Figure 7.  
434

			$\delta^{13}\text{C}$ (VPD) (‰)						$\delta^{15}\text{N}$ (AIR) (‰)						$\delta^{18}\text{O}$ (VPD) (‰)					
		n	Mean	St Dev	Maximum	Minimum	Range	Mean	St Dev	Maximum	Minimum	Range	Mean	St Dev	Maximum	Minimum	Range			
Le Morne	Bone collagen	10	-13.9	1.2	-11.4	-14.8	3.4	11.0	0.6	11.8	10.1	1.7								
	Dentine Collagen	8	-14.0	2.4	-10.9	-17.7	6.8	11.0	2.0	13.1	6.4	6.8								
	Enamel Apatite	7	-8.1	2.7	-3.7	-10.9	7.2						-4.2	0.4	-3.7	-4.9	1.2			
Bois Marchand	Bone collagen	6	-17.3	0.6	-16.6	-18.3	1.8	11.9	0.5	12.3	10.8	1.4								
	Dentine Collagen	14	-16.3	2.4	-9.1	-18.3	9.2	12.1	1.5	15.7	9.4	6.2								
	Enamel Apatite	16	-10.8	3.0	-0.7	-13.6	13.0						-4.3	0.7	-2.9	-5.1	2.2			

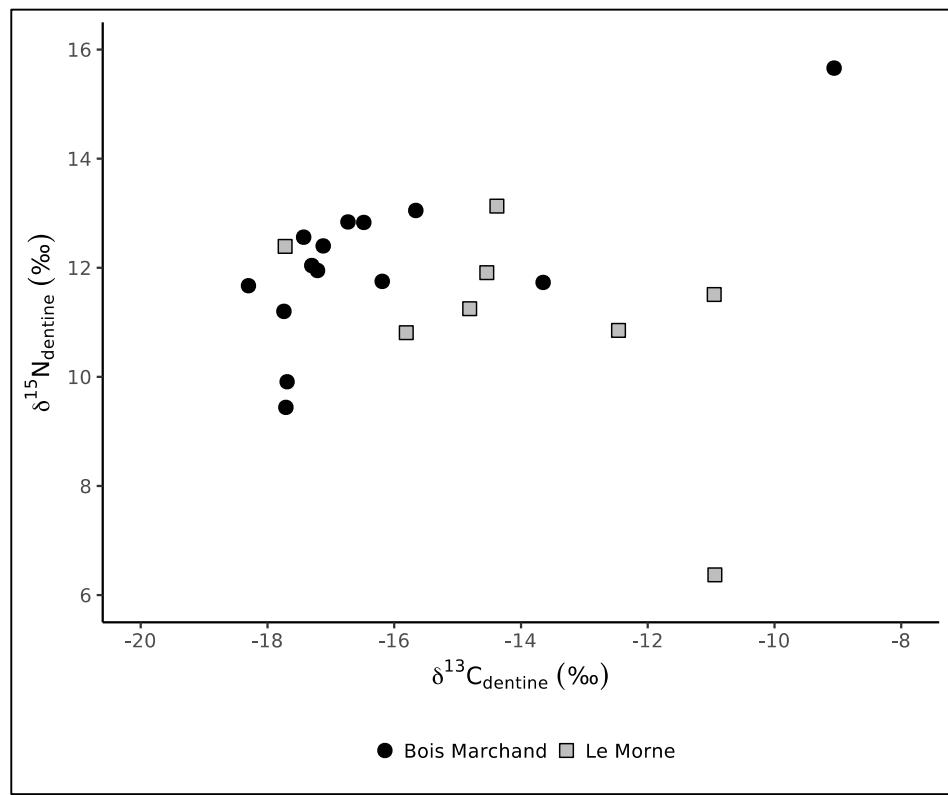
Table 1: Summary of stable isotope results from Le Morne and Bois Marchand

1

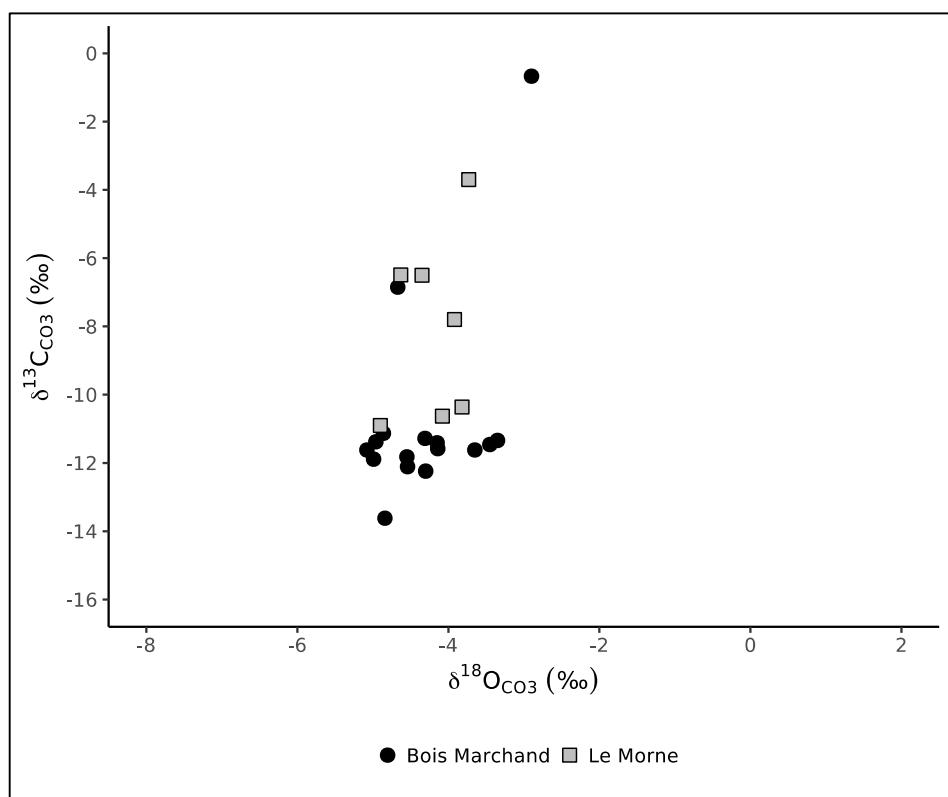
2

3

4

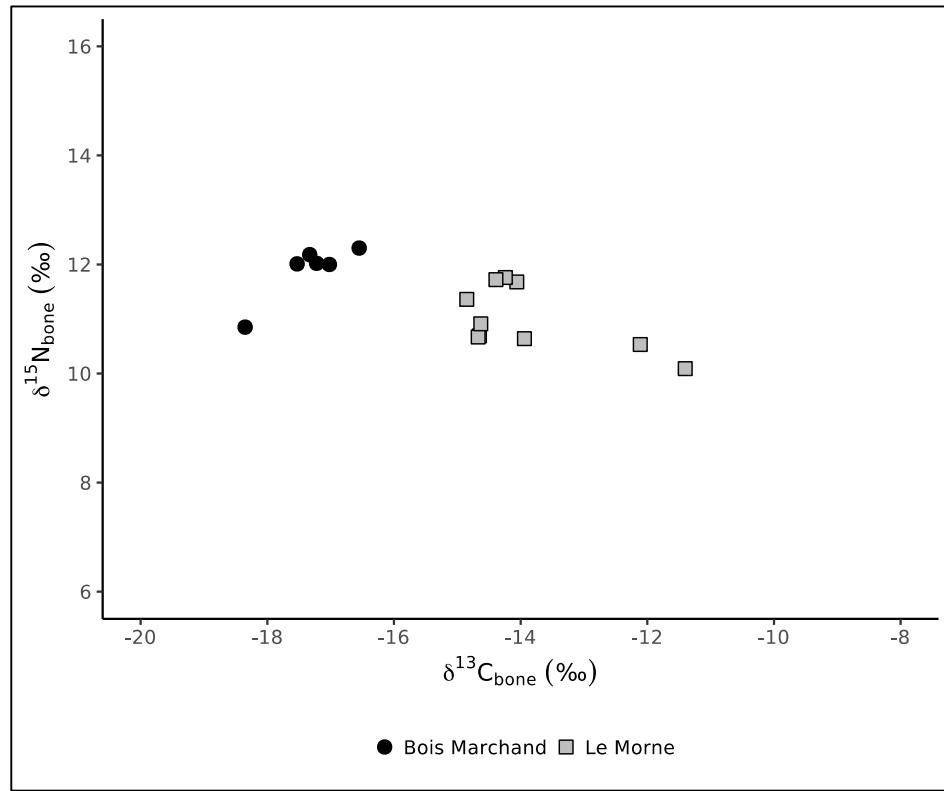


5 *Figure 4: Scatter plot of human dentine collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values from Le Morne*  
6 *and Bois Marchand*



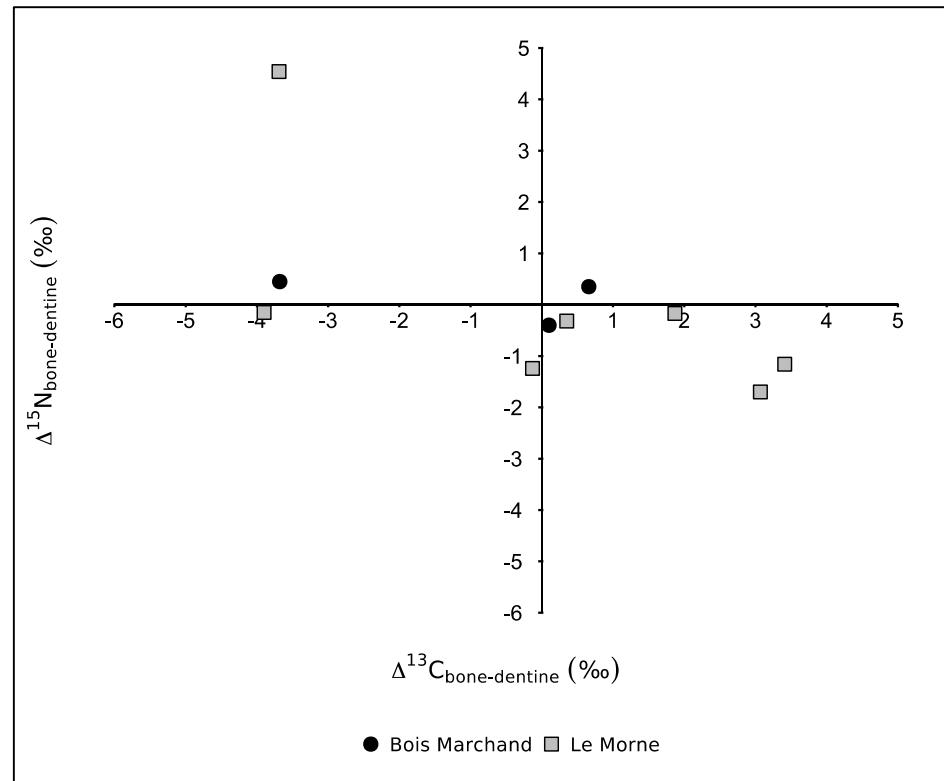
9 *Figure 5: Scatter plot of human tooth enamel carbonate  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values from Le*  
10 *Morne and Bois Marchand*

14



15  
16 *Figure 6: Scatter plot of human bone collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values from Le Morne*  
17 *and Bois Marchand*

18



19  
20 *Figure 7: Scatter plot of the difference between human dentine and bone collagen*  
21 *isotope data from Le Morne and Bois Marchand*

22

23 **4.1. Le Morne**

24  
25 The dentine collagen  $\delta^{13}\text{C}$  results from Le Morne range from -17.7 to -10.9‰, while  
26 the  $\delta^{15}\text{N}$  results range from 6.4 to 13.1‰ (n = 8). One outlier can be identified  
27 (STR33/L) with a very low  $\delta^{15}\text{N}_{\text{dentine}}$  value, despite this sample being taken from a  
28 canine and thus likely to have been affected by breastfeeding which should increase  
29 their  $\delta^{15}\text{N}$  value. When this individual is excluded, the  $\delta^{15}\text{N}_{\text{dentine}}$  results range from  
30 10.8 to 13.1‰, with a mean of  $11.7 \pm 0.9\text{‰}$  (range = 2.3‰, n = 7). There is no  
31 correlation between  $\delta^{13}\text{C}_{\text{dentine}}$  and  $\delta^{15}\text{N}_{\text{dentine}}$  ( $r = -0.568$ ,  $p = 0.142$ ).

32  
33 The enamel  $\delta^{13}\text{C}_{\text{CO}_3}$  results from Le Morne range from -10.9 to -3.7‰ (n = 7). No  
34 outliers were identified.

35  
36 The bone collagen  $\delta^{13}\text{C}$  results range from -14.8 to -11.4‰, while the  $\delta^{15}\text{N}_{\text{bone}}$  results  
37 range from 10.1 to 11.8‰ (n = 10). Two outliers can be identified (STR33/U and  
38 STR25) who have high  $\delta^{13}\text{C}_{\text{bone}}$  values. When these outliers are excluded, the  $\delta^{13}\text{C}_{\text{bone}}$   
39 results range from -14.8 to -13.9‰ with a mean of -14.4‰ (range = 0.9‰, n = 8). There  
40 is no correlation between  $\delta^{13}\text{C}_{\text{bone}}$  and  $\delta^{15}\text{N}_{\text{bone}}$  ( $r = -0.584$ ,  $p = 0.076$ ).

41  
42 The difference between dentine and bone collagen results from individuals where  
43 both samples were analysed (n = 8, including 3 children), range from -3.9 to 3.4‰ in  
44  $\delta^{13}\text{C}$  and -1.7 to 4.6‰ in  $\delta^{15}\text{N}$ . Seven individuals have a difference of at least 1‰ in  
45 carbon and/or nitrogen isotope values, with one individual (STR025, 3-5 years old)  
46 having differences of c. 0.3‰ in both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ .

47  
48 The enamel  $\delta^{18}\text{O}_{\text{CO}_3}$  results from Le Morne range from -4.9 to -3.7‰ (n = 7). No  
49 outliers were identified.

50  
51 **4.2. Bois Marchand**

52  
53 The dentine collagen  $\delta^{13}\text{C}$  results range from -18.3 to -9.1‰, while the  $\delta^{15}\text{N}$  results  
54 range from 9.4 to 15.7‰ (n = 14). Four outliers have been identified. BM35/L is an  
55 outlier with high  $\delta^{13}\text{C}_{\text{dentine}}$  and  $\delta^{15}\text{N}_{\text{dentine}}$  values (from a premolar, and thus unlikely  
56 to have been affected by breastfeeding). BM04 is an outlier with a high  $\delta^{13}\text{C}_{\text{dentine}}$   
57 value. BM33/L and BM36/L are outliers with low  $\delta^{15}\text{N}_{\text{dentine}}$  values. When the four  
58 outlying individuals are excluded the  $\delta^{13}\text{C}_{\text{dentine}}$  results range from -18.3 to -15.7‰,  
59 with a mean of  $-17.0 \pm 0.8\text{‰}$  (range = 2.6‰, n = 10) while the  $\delta^{15}\text{N}_{\text{dentine}}$  results range  
60 from 11.2 to 13.1‰, with a mean of  $12.2 \pm 0.6\text{‰}$  (range = 1.9‰, n = 10). While there  
61 is a correlation between  $\delta^{13}\text{C}_{\text{dentine}}$  and  $\delta^{15}\text{N}_{\text{dentine}}$  ( $r = 0.731$ ,  $p = 0.003$ ), there is no  
62 correlation between  $\delta^{13}\text{C}_{\text{dentine}}$  and  $\delta^{15}\text{N}_{\text{dentine}}$  when the outlying individuals are  
63 excluded ( $r = 0.629$ ,  $p = 0.051$ ).

64  
65 The enamel  $\delta^{13}\text{C}_{\text{CO}_3}$  results range from -13.6 to -0.7‰ (n = 16). There are two outliers  
66 (BM35/L and BM04) with high  $\delta^{13}\text{C}_{\text{CO}_3}$  values. BM38 is also an outlier, with a low  
67  $\delta^{13}\text{C}_{\text{CO}_3}$  value. When these individuals are excluded the  $\delta^{13}\text{C}_{\text{CO}_3}$  results range from -  
68 13.6 to -11.1‰, with a mean of  $-11.8 \pm 0.6\text{‰}$  (range = 2.5‰, n = 14).

69  
70 The bone collagen  $\delta^{13}\text{C}$  results range from -18.4 to -16.6‰, while the  $\delta^{15}\text{N}_{\text{bone}}$  results  
71 range from 10.9 to 12.3‰ (n = 6). There is one outlier with low values for both

72  $\delta^{13}\text{C}_{\text{bone}}$  and  $\delta^{15}\text{N}_{\text{bone}}$ . While there is a correlation between  $\delta^{13}\text{C}_{\text{bone}}$  and  $\delta^{15}\text{N}_{\text{bone}}$  ( $r = 0.893$ ,  $p = 0.017$ ), when the outlier is removed there is no correlation ( $r = 0.666$ ,  $p = 0.220$ ). This, combined with the small sample size, suggests that the correlation should be treated with caution.

76

77 The enamel  $\delta^{18}\text{O}_{\text{CO}_3}$  results from Bois Marchand range from -5.1 to -2.9‰ (n = 16).  
78 No outliers were identified.

79

#### 80 **4.3. Comparison between the sites**

81

82 The dentine results show a wide variation at both sites, and they overlap substantially  
83 in  $\delta^{15}\text{N}_{\text{dentine}}$  values (there is no statistical difference in  $\delta^{15}\text{N}_{\text{dentine}}$ :  $D(21) = 0.411$ ,  $Z = 0.927$ , *n.s.*). In  $\delta^{13}\text{C}_{\text{dentine}}$ , there is notable overlap, but this mainly relates to an outlier  
84 from each site. In general, there is a tendency for the individuals buried at Le Morne  
85 to have higher  $\delta^{13}\text{C}_{\text{dentine}}$  than those from Bois Marchand, with a statistically  
86 significant difference between the two sites ( $D(21) = 0.661$ ,  $Z = 1.491$ ,  $p = 0.023$ ,  
87 outliers included).

88

89 With the exception of the two high  $\delta^{13}\text{C}_{\text{CO}_3}$  outliers from Bois Marchand, the results  
90 from the two sites show no overlap in enamel  $\delta^{13}\text{C}_{\text{CO}_3}$  values and the means of the  
91 two sites are statistically different ( $D(22) = 0.875$ ,  $Z = 1.931$ ,  $p = 0.001$ , outliers  
92 included).

93

94 The bone collagen results from the two sites are clearly and statistically different in  
95 both  $\delta^{13}\text{C}_{\text{bone}}$  ( $D(15) = 1.00$ ,  $Z = 1.936$ ,  $p = 0.001$ ) and  $\delta^{15}\text{N}_{\text{bone}}$  ( $D(15) = 0.833$ ,  $Z = 1.614$ ,  $p = 0.011$ ).

96

97 The enamel  $\delta^{18}\text{O}_{\text{CO}_3}$  data from the two sites are very similar and there is no statistical  
98 difference between them ( $t(21) = -0.337$ , *n.s.*). While there is a larger range in values  
99 at Bois Marchand than Le Morne (2.2‰ as compared to 1.2‰), this is likely related  
100 to the differences in sample size.

101

### 102 **5. Discussion**

103

#### 104 **5.1. Le Morne**

105

106 The dentine and enamel  $\delta^{13}\text{C}$  results indicate that during childhood the people buried  
107 at Le Morne ate a wide range of diets in terms of the proportion of  $\text{C}_3$  and  $\text{C}_4$   
108 resources; some individuals (e.g. STR008) consumed a diet primarily based on  $\text{C}_3$   
109 resources, while others (e.g. STR033/L) consumed large proportions of  $\text{C}_4$  or marine  
110 foodstuffs – although individuals that died as children are included in these analyses,  
111 we note that none of these individuals have either the highest or lowest values in  
112 terms of  $\delta^{13}\text{C}_{\text{dentine}}$  or  $\delta^{13}\text{C}_{\text{CO}_3}$ . Given that the  $\delta^{13}\text{C}_{\text{CO}_3}$  data suggests the consumption  
113 of  $\text{C}_4$  carbohydrate, it is reasonable to conclude that these individuals were consuming  
114  $\text{C}_4$  plants, as opposed to consuming primarily animals fed upon  $\text{C}_4$  plants or marine  
115 foods. Given the historical evidence it is likely that this reflects maize consumption  
116 (Grant, 1801; Allen 1999). It is also possible, however, that some or all of the  $\text{C}_4$   
117 consumption reflects sugar cane both directly consumed and animals fed on waste  
118 products from sugar production. Indeed the high prevalence of caries and abscesses,  
119

120

121 noted above, may support the human consumption of sugar cane, as high sugar use  
122 may be connected to poor dental health. The  $\delta^{15}\text{N}_{\text{dentine}}$  data also shows a wide range  
123 of values; one individual's (STR33/L)  $\delta^{15}\text{N}_{\text{dentine}}$  values were sufficiently low  
124 ( $\delta^{15}\text{N}_{\text{dentine}} = 6.4\text{\textperthousand}$ ), and indeed, substantially lower than the other individuals (4.6%  
125 lower than the mean), that they must have consumed little or no animal protein during  
126 childhood (note that no animals were ~~sampled or~~ included in the batch during  
127 processing) (Bocherens and Drucker, 2003, Hedges and Reynard, 2007, O'Connell et  
128 al., 2012). While the remaining individuals certainly did consume animal protein  
129 during childhood, there is variation in the proportion they consumed, although some  
130 of this variation likely relates to the trophic effect of breastfeeding.

131  
132 The bone collagen stable isotope data shows a different pattern, with a main group of  
133 individuals who consumed similar diets that included a significant proportion of C<sub>4</sub>  
134 resources and less variation in the proportion of animal protein in the adult diet. This  
135 group includes four out of the five children. Two outlying individuals (STR025, 3–5  
136 years, and STR33/U, an adult) consumed diets that were predominantly based on C<sub>4</sub>  
137 resources.

138  
139 These results, combined with the generally large differences between dentine and  
140 bone isotope results from the same individuals, are consistent with a population that  
141 lived separately as children and then came to live, and eat, together during life. When  
142 one considers the life histories of the adult individuals, we can see that there are some  
143 individuals who ate a higher proportion of C<sub>4</sub> foods during childhood than later in life  
144 (STR007, STR033/L), while others who consumed little C<sub>4</sub> during childhood but a  
145 higher proportion later in life (STR001, STR008). Individual STR33/U also shows an  
146 increase in the proportion of C<sub>4</sub> foods they consumed during life, and during  
147 adulthood their diet contained more C<sub>4</sub> than most of the other individuals. It is  
148 possible that this individual was a recent arrival to Le Morne who died before their  
149 bone had had enough time to remodel and reflect the new dietary conditions in this  
150 region.

151  
152 Individual STR33/L (mid to old adult, female; biological sex confirmed by aDNA  
153 analysis: Fregel, unpublished results) stands out as having had the most pronounced  
154 change in diet during life; during childhood they ate a diet very low in animal protein  
155 but very high in C<sub>4</sub> plants (presumably maize), while during adulthood the proportion  
156 of animal protein in their diet increased, and their consumption of C<sub>4</sub> plants  
157 decreased. The aDNA results from this individual suggest that they are most probably  
158 of Mozambican ancestry (Fregel et al 2014; Seetah 2015b). It is tempting to speculate  
159 that this individual was enslaved during childhood, but came to live at Le Morne  
160 some years before death.

161  
162 In general, the children's  $\delta^{13}\text{C}$  results show consistency in the proportion of C<sub>4</sub>  
163 consumed between dentine and bone collagen, as would be expected. The individual  
164 with outlying  $\delta^{13}\text{C}_{\text{bone}}$  data (STR025), also showed relatively high  $\delta^{13}\text{C}$  enamel and  
165 dentine results. This suggests either that they were born and lived locally but  
166 consumed a diet different from that of the rest of the population, or that they were  
167 brought to Le Morne close to or after death. The latter scenario fits with the oral  
168 history tradition that Le Morne was a safe location for burial (Seetah 2016). There is  
169 some intra-individual variation in the children's  $\delta^{15}\text{N}_{\text{dentine}}$  and  $\delta^{15}\text{N}_{\text{bone}}$  values, likely  
170 related to the varying timing of tissue formation, different amounts of turnover and

171 differences in breast-feeding practices. The peri-natal twins buried in STR006 show  
172 indistinguishable isotope results (bone only) that reflect the diet of their mother  
173 during her pregnancy, which was typical of the population buried at Le Morne.  
174

175 The  $\delta^{18}\text{O}_{\text{CO}_3}$  results provide no evidence for migrants within this group, however we  
176 note that there is significant overlap in  $\delta^{18}\text{O}$  values of rainfall in Mauritius and  
177 Madagascar (IAEA/WMO 2019). It is therefore not possible to distinguish between  
178 these individuals being enslaved people born in Madagascar, and these individuals  
179 being free-born Mauritians.  
180

## 181 **5.2. Bois Marchand**

182

183 The dentine and enamel  $\delta^{13}\text{C}$  results indicate that during childhood the people buried  
184 at Bois Marchand ate a fairly wide range of diets. The  $\delta^{13}\text{C}_{\text{CO}_3}$  results form a tighter  
185 main cluster of data than the  $\delta^{13}\text{C}_{\text{dentine}}$  dataset. This suggests that while this main  
186  $\delta^{13}\text{C}_{\text{CO}_3}$  group consumed relatively little C<sub>4</sub> carbohydrate, they also ate varying  
187 proportions of C<sub>4</sub> protein (i.e. animals fed on C<sub>4</sub> foods) or marine resources. This  
188 main group also shows a fairly large range in  $\delta^{15}\text{N}_{\text{dentine}}$  results, with some individuals  
189 consuming more animal or marine protein than others (note that the teeth analysed  
190 here are unlikely to have a trophic effect from breastfeeding). It is therefore likely that  
191 a combination of C<sub>4</sub> protein and marine resources were consumed, with individuals  
192 consuming different proportions of these two resource types.  
193

194 There are four individuals who consumed different diets to this main group.

195 Individuals BM33/L and BM36/L have outlying  $\delta^{15}\text{N}_{\text{dentine}}$  results, suggesting that they  
196 consumed a lower proportion of animal and marine protein than the other  
197 analysed individuals. Both of these individuals were the lower individuals in double  
198 burials and both buried in corrugated iron coffins. BM04 has high and statistically  
199 outlying  $\delta^{13}\text{C}_{\text{enamel}}$  and  $\delta^{13}\text{C}_{\text{dentine}}$  values but typical  $\delta^{15}\text{N}_{\text{dentine}}$  values indicating that  
200 during childhood they consumed a higher proportion of C<sub>4</sub> resources than the other  
201 individuals analysed from Bois Marchand. Individual BM35/L has extremely high  
202  $\delta^{13}\text{C}_{\text{CO}_3}$ ,  $\delta^{13}\text{C}_{\text{dentine}}$  and  $\delta^{15}\text{N}_{\text{dentine}}$  values (all of which are statistical outliers),  
203 suggesting that they consumed a diet largely based on marine resources combined  
204 with C<sub>4</sub> or marine carbohydrate, presumably maize. We note that high  $\delta^{15}\text{N}$  values  
205 can also be caused by prolonged starvation (Mekota et al., 2006), however given that  
206 the enrichment is seen in both collagen carbon and nitrogen and therefore likely  
207 reflects the protein component of the diet, and that the magnitude of the enrichment is  
208 large, a marine diet is a more parsimonious explanation. This individual was buried in  
209 a manner inconsistent with the other excavated individuals. The body was orientated  
210 with the head towards the west, rather than the east; furthermore, the head was  
211 separated from the rest of the body and placed in the south-western corner of the  
212 grave, with the mandible and teeth scattered over the upper part of the skeleton. While  
213 it is difficult to form a conclusion about what this represents, it is clear that this  
214 individual was different in life and in death (cf. Parker Pearson, 1999, Reynolds,  
215 Gregoricka et al., 2017).  
216

217 Very few bone samples were available for analysis due to the poor preservation  
218 conditions. In general, the analysed bone isotope results are consistent with the  
219 dentine data in that most individuals consumed a small proportion of C<sub>4</sub> protein, and

220 one individual (BM03/L, adult, unknown sex, bone collagen data only) consumed a  
221 diet that had less C<sub>4</sub> than the other analysed individuals. It is likely that the  
222 differences in ranges between dentine and bone  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  relates to the difference  
223 in sample size.

224  
225 As with Le Morne, the  $\delta^{18}\text{O}_{\text{CO}_3}$  results provide no evidence for migrants within this  
226 group. This is surprising given the historical evidence for the wide range of origins for  
227 the people buried in the cemetery. When one compares the modern precipitation  
228 oxygen isotope values from Mauritius to those from India and South Asia, these data  
229 indicate that, although there is overlap, the range of values found in South Asia is  
230 notably greater than would be expected for Mauritius (IAEA/WMO 2019). One  
231 would not therefore expect to be able to identify all migrants, but migrants from some  
232 areas of South Asia should in theory be identifiable, if present.

233  
234 **5.3. Comparison between Le Morne and Bois Marchand**

235 The isotopic data from Le Morne and Bois Marchand show that a wide range of diets  
236 were consumed on Mauritius in the nineteenth century. Most people consumed some  
237 C<sub>4</sub> resources, although the proportion of the diet that this represented varied widely.  
238 There is some evidence for the use of marine resources at Bois Marchand, but there is  
239 only one individual (BM35/L) from either site who consumed significant quantities of  
240 marine resources, despite the historical evidence for fishing. The historical evidence  
241 discussed above indicates that the diet was likely quite poor and subject to shortages.  
242 The isotopic evidence for the consumption of a range of isotopically distinct diets on  
243 Mauritius, fits well with the idea that people had differential access to the limited  
244 available resources based upon, presumably, where and when they lived, their  
245 occupation and their social status.

246  
247 The people buried at the two sites clearly consumed different diets during life – the  
248 sites are statistically different in  $\delta^{13}\text{C}_{\text{dentine}}$ ,  $\delta^{13}\text{C}_{\text{CO}_3}$ ,  $\delta^{13}\text{C}_{\text{bone}}$  and  $\delta^{15}\text{N}_{\text{bone}}$ . While there  
249 are exceptions, the people buried at Le Morne generally consumed a higher  
250 proportion of C<sub>4</sub> foods during childhood and adulthood than the people at Bois  
251 Marchand. The two sites also differ in the proportion of animal protein consumed,  
252 with the people buried at Bois Marchand tending to have a higher proportion of  
253 animal protein and/or marine resources in their diet than individuals buried at Le  
254 Morne. We note, however, that due to the lack of faunal samples it is not possible to  
255 exclude the possibility that isotopic baselines varied through time and space.  
256 Nevertheless, the isotopic difference is consistent with the osteological evidence  
257 noted above that the individuals buried at Le Morne had compromised immunity and  
258 chronic illnesses, and were relatively short in stature.

259  
260 The Le Morne cemetery is approximately 30 years earlier in date than Bois  
261 Marchand, so it may be that the Mauritian diet changed through time with decreasing  
262 maize (or other C<sub>4</sub>) consumption and increased access to animal protein and/or marine  
263 resources. It is likely that with the end of slavery the consumption of maize would  
264 have declined, as former enslaved people had more time and land available post-  
265 emancipation to grow a range of crops and raise animals, rather than being forced to  
266 rely on maize for sustenance. The isotopic data also fit with the historical evidence for  
267 increased use of animals for traction as sugar production expanded, as these animals  
268 would eventually have been consumed as meat (Joglekar et al., 2013).

270 Nevertheless, given the archaeological context of the sites, issues of time and identity  
271 cannot be clearly separated; it also seems likely that these dietary differences reflect  
272 the social circumstances of the buried individuals. Le Morne is a community cemetery  
273 representing people who lived at or near the site, although it remains possible that  
274 other former enslaved people or their descendants were buried here if it was seen as a  
275 haven for burial. The stable isotope results from Le Morne are consistent with a  
276 population including individuals who spent their childhoods in different groups,  
277 consuming different foods and who later came together and consumed similar diets  
278 (see above). Bois Marchand, on the other hand, was used as a burial ground for a  
279 much wider area of the island and for a cross-section of the population. Although  
280 hampered by the lack of bone samples available for analysis, this dataset is consistent  
281 with a burial population drawn from different social groups with access to the same  
282 suite of resources but utilizing them in different ways.  
283

284 It is likely that a combination of both chronology and circumstances of birth explains  
285 the differences between the two sites. Further research is needed, particularly in terms  
286 of numbers of individuals available for analysis, before more firm conclusions can be  
287 drawn. Nevertheless, it is clear that the subsistence strategies undertaken by  
288 nineteenth century Mauritians varied through time, with location and with  
289 circumstances of birth, such that although a range of resources were, in theory,  
290 available to people on the island, the proportions of the different resources actually  
291 consumed was different for different people.  
292

## 293 6. Conclusion

294

295 Isotopic analyses of people buried in two Mauritian cemeteries have revealed  
296 interesting insights into lifeways in nineteenth century Mauritius. Although sample  
297 size is small, it is clear that the people buried at Le Morne consumed different diets  
298 during childhood and adulthood to the people buried at Bois Marchand. It is likely  
299 that these differences relate both to the date of the cemeteries and to the circumstance  
300 of birth of the people buried in them. This study has shown a much more nuanced  
301 picture of diet in Mauritius at this time. The research complements and enriches the  
302 historic narrative, adding dimensions to small islands that would otherwise remain  
303 obscure in the absence of rigorous scientific assessment of archaeological finds.  
304

## 305 Acknowledgements

306

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321

322 **Bibliography**

323

324 ALLEN, R. B. 1999. *Slaves, Freedmen, and Indentured Laborers in Colonial*  
325 *Mauritius* Cambridge, Cambridge University Press.

326 ALLEN, R. B. 2003. The Mascarene slave-trade and labour migration in the Indian  
327 Ocean during the Eighteenth and Nineteenth Centuries *Slavery & Abolition*  
328 24, 33-50.

329 ALLEN, R. B. 2004. The Mascarene Slave-Trade and Labour Migration in the Indian  
330 Ocean during the Eighteenth and Nineteenth Centuries. In: CAMPBELL, G.  
331 (ed.) *The Structure of Slavery in Indian Ocean Africa and Asia*. London:  
332 Frank Cass.

333 ALLEN, R. B. 2014a. *European Slave Trading in the Indian Ocean, 1500-1850*  
334 Athens, Ohio, Ohio University Press.

335 ALLEN, R. B. 2014b. Slaves, Convicts, Abolitionism and the Global Origins of the  
336 Post-Emancipation Indentured Labor System,. *Slavery and Abolition*, 35, 328-  
337 348.

338 AMBROSE, S. H. 1990. Preparation and Characterization of Bone and Tooth  
339 Collagen for Isotopic Analysis. *Journal of Archaeological Science*, 17, 431-  
340 451.

341 AMBROSE, S. H. & NORR, L. 1993. Isotopic composition of dietary protein and  
342 energy versus bone collagen andapatite: Purified diet growth experiments. In:  
343 LAMBERT, J. & GRUPE, G. (eds.) *Prehistoric Human Bone: Archaeology at*  
344 *the Molecular Level*. New York: Springer-Verlag.

345 APPLEBY, J., SEETAH, K., CALAON, D., CAVAL, S., JANOO, A. & TEELOCK,  
346 V. 2014. The juvenile cohort from Le Morne cemetery: A snapshot of early  
347 life and death after abolition *International Journal of Osteoarchaeology* 24,  
348 737-746.

349 BALASSE, M., AMBROSE, S. H., SMITH, A. B. & RPICE, T. D. 2002. The  
350 seasonal mobility model for prehistoric herders in the South-western Cape of  
351 South Africa assessed by isotopic analysis of sheep tooth enamel. *Journal of*  
352 *Archaeological Science*, 29, 917-932.

353 BEAUMONT, J., GEBER, J., POWERS, N., WILSON, A., LEE-THORP, J. A. &  
354 MONTGOMERY, J. 2013. Victims and survivors: Stable isotopes used to  
355 identify migrants from the great Irish famine to 19th century London.  
356 *American Journal of Physical Anthropology*, 150, 87-98.

357 BEAUMONT, J. & MONTGOMERY, J. 2016. The great Irish famine: Identifying  
358 starvation in the tissues of victims using stable isotope analysis of bone and  
359 incremental dentine collagen. *PLoS ONE*, 11, e0160065.

360 BOCHERENS, H. & DRUCKER, D. 2003. Trophic level isotopic enrichment of  
361 carbon and nitrogen in bone collagen: Case studies from recent and ancient  
362 terrestrial ecosystems. *International Journal of Osteoarchaeology*, 13, 46-53.

363 COPLEN, T. B. 1995. New IUPAC guidelines for the reporting of stable hydrogen,  
364 carbon and oxygen isotope-ratio data. *Journal of Research of the National*  
365 *Institute of Standards and Technology*, 100, 285.

366 CRAIG, H. 1957. Isotopic standards for carbon and oxygen and correction factors for  
367 mass-spectromic analysis of carbon dioxide. *Geochimica et Cosmochimica*  
368 *Acta*, 12, 133-149.

369 DANSGAARD, W. 1964. Stable isotopes in precipitation. *Tellus*, 16, 436-468.

370 DE NIRO, M. J. 1985. Postmortem Preservation and Alteration of in Vivo Bone

371 Collagen Isotope Ratios in Relation to Paleodietary Reconstruction. *Nature*,

372 317, 806-809.

373 DOBBERSTEIN, R. C., COLLINS, M. J., CRAIG, O. E., TAYLOR, G.,

374 PENKMAN, K. E. H. & RITZ-TIMME, S. 2009. Archaeological collagen:

375 Why worry about collagen diagenesis? *Archaeological and Anthropological*

376 *Sciences*, 1, 31-42.

377 FILLIOT, J.-M. 1974. *La traite des esclaves vers les Mascareignes au XVIII<sup>e</sup> siècle*

378 Paris, Office de la Recherche Scientifique et Technique Outre-Mer.

379 FOGEL, M. L., TUROSS, N. & OWSLEY, D. 1989. Nitrogen isotope tracers of

380 human lactation in modern and archaeological populations. *Carnegie Institute*

381 *of Washington Yearbook*.

382 FREGEL, R., SEETAH, K., BETANCOR, E., SUÁREZ, N., CALAON, D., ČAVAL,

383 S., JANOO, A. & PESTANO, J. 2014. Multiple ethnic origins of

384 mitochondrial DNA lineages for the population of Mauritius. *PLoS ONE* 9,

385 e93294.

386 FREGEL, R., SIKORA, M., SEETAH, K. & BUSTAMANTE, C. 2015. Genetic

387 impact of slavery abolition in Mauritius: Ancient DNA data from Le Morne

388 and Bois Marchand cemeteries [abstract]. *Proceedings of the 80th Annual*

389 *Meeting of the Society for American Archaeology*. San Francisco, California.

390 FULLER, B. T., FULLER, J. L., HARRIS, D. A. & HEDGES, R. E. M. 2006.

391 Detection of breastfeeding and weaning in modern human infants with carbon

392 and nitrogen stable isotope ratios. *American Journal of Physical*

393 *Anthropology*, 129, 279-293.

394 GAGE, J., FRANCIS, M. & TRIFFITT, J. 1989. *Collagen and dental matrices*,

395 London, Wright.

396 GRANT, C. 1801. *The History of Mauritius or the Isle of France and the*

397 *Neighbouring Islands from their First Discovery to the Present Time*, London,

398 W. Bulmer.

399 GREGORICKA, L. A., SCOTT, A. B., BETSINGER, T. K. & POLCUN, M. 2017.

400 Deviant burials and social identity in a postmedieval Polish cemetery: An

401 analysis of stable oxygen and carbon isotopes from the 'vampires' of

402 Drawsko. *American Journal of Physical Anthropology*, 163, 741-758.

403 HEDGES, R. E. M., CLEMENT, J. G., THOMAS, D. L. & O'CONNELL, T. C.

404 2007. Collagen Turnover in the Adult Femoral Mid-shaft: Modeled from

405 Anthropogenic Radiocarbon Tracer Measurements. *American Journal of*

406 *Physical Anthropology*, 133, 808-816.

407 HEDGES, R. E. M. & REYNARD, L. 2007. Nitrogen isotopes and the trophic level

408 of humans in archaeology. *Journal of Archaeological Science*, 34, 1240-1251.

409 HOWLAND, M. R., CORR, L. T., YOUNG, S. M. M., JONES, V., JIM, S., VAN

410 DER MERWE, N. J., MITCHELL, A. D. & EVERSHED, R. P. 2003.

411 Expression of the dietary isotope signal in the compound-specific delta(13)C

412 values of pig bone lipids and amino acids. *International Journal of*

413 *Osteoarchaeology*, 13, 54-65.

414 JIM, S., JONES, V., AMBROSE, S. H. & EVERSHED, R. P. 2006. Quantifying

415 dietary macronutrient sources of carbon for bone collagen biosynthesis using

416 natural abundance stable carbon isotope analysis. *British Journal of Nutrition*,

417 95, 1055-1062.

418 JOGLEKAR, P. P., CHOWDHURY, A. & MUNGUR-MEDHI, J. 2013. Faunal  
 419 remains from Aapravasi ghat, Nineteenth century immigration depot, Port  
 420 Louis, Mauritius. *Journal of Indian Ocean Archaeology*, 9, 142-165.

421 KATZ-HYMAN, M. B. & RICE, K. S. 2011. *World of a Slave : Encyclopedia of the*  
 422 *Material Life of Slaves in the United States*, Santa Barbara, Calif., Greenwood.

423 LIGHTFOOT, E. & O'CONNELL, T. C. 2016. On the use of biomineral oxygen  
 424 isotope data to identify human migrants in the archaeological record: Sample  
 425 variation, statistical methods and geographical considerations *PLoS ONE* 11,  
 426 e0153850.

427 LIN, G. P., RAU, Y. H., CHEN, Y. F., CHOU, C. C. & FU, W. G. 2003.  
 428 Measurements of  $\delta D$  and  $\delta^{18}O$  stable isotope ratios in milk. *Journal of Food*  
 429 *Science*, 68, 2192-2195.

430 LONGINELLI, A. 1984. Oxygen Isotopes in Mammal Bone Phosphate - a New Tool  
 431 for Paleohydrological and Paleoclimatological Research. *Geochimica Et*  
 432 *Cosmochimica Acta*, 48, 385-390.

433 LUZ, B. & KOLODNY, Y. 1985. Oxygen Isotope Variations in Phosphate of  
 434 Biogenic Apatites: 4. Mammal Teeth and Bones. *Earth and Planetary Science*  
 435 *Letters*, 75, 29-36.

436 LY-TIO-FANE, M. 1968. Problemes d'approvisionnement de l'ile de france au temps  
 437 de l'intendant poivre. *Proceedings of the Royal Society of Arts and Sciences of*  
 438 *Mauritius*, 3, 104-5.

439 MAYS, S., A., RICHARDS, M. P. & FULLER, B. T. 2002. Bone stable isotope  
 440 evidence for infant feeding in Mediaeval England. *Antiquity*, 76, 654-656.

441 MEKOTA, A. M., GRUPE, G., UFER, S. & CUNTZ, U. 2006. Serial Analysis of  
 442 Stable Nitrogen and Carbon Isotopes in Hair: Monitoring Starvation and  
 443 Recovery Phases of Patients Suffering from Anorexia Nervosa *Rapid*  
 444 *Communications in Mass Spectrometry*, 20, 1604-1610.

445 NEUBERGER, F. M., JOPP, E., GRAW, M., PUSHCEL, K. & GRUPE, G. 2013.  
 446 Signs of malnutrition and starvation: Reconstruction of nutritional life  
 447 histories by serial isotopic analyses of hair. *Forensic Science International*,  
 448 226, 22-32.

449 NWULIA, M. D. E. 1978. "Apprenticeship" system in Mauritius: Its character and its  
 450 impact on race relations in the immediate post-emancipation period, 1839-  
 451 1879. *African Studies Review*, 21, 89-101.

452 O'CONNELL, T. C., KNEALE, C., TASEVSKA, N. & GGC, K. 2012. The diet-  
 453 body offset in human nitrogen isotopic values: A controlled dietary study.  
 454 *American Journal of Physical Anthropology*, 149, 426-434.

455 O'LEARY, M. 1988. Carbon isotopes in photosynthesis. *Bioscience*, 38, 328-336.

456 PARKER PEARSON, M. 1999. *The archaeology of death and burial*, Thrupp, Sutton  
 457 Publishing Ltd.

458 PEERTHUM, S. 2006. Forbidden freedom: Prison life for captured Maroons colonial  
 459 Mauritius, 1766-1839. In: AGORSAH, E. K. & CHILDS, G. T. (eds.) *Africa*  
 460 *and the African Diaspora* Bloomington, IN: Authorhouse.

461 PIKE, P. 1873. *Sub-tropical rambles in the land of Aphanapteryx*, New York, Harper  
 462 & Brothers.

463 POLLARD, A. M., PELLEGRINI, M. & LEE-THORP, J. A. 2011. Some  
 464 observations on the conversion of dental enamel  $\delta^{18}Op$  values to  $\delta^{18}Ow$  to  
 465 determine human mobility. *American Journal of Physical Anthropology*, 145,  
 466 499-504.

467 PRYOR, A. J. E., STEVENS, R. E., O'CONNELL, T. C. & LISTER, J. R. 2014.  
 468 Quantification and propagation of errors when converting vertebrate  
 469 biomineral oxygen isotope data to temperature for palaeoclimate  
 470 reconstruction. *Palaeogeography Palaeoclimatology Palaeoecology* 412, 99-  
 471 107.

472 REYNOLDS, A. 2009. *Anglo-Saxon deviant burial customs*, Oxford, Oxford  
 473 University Press.

474 RICHARDS, M. P. & HEDGES, R. E. M. 1999. Stable isotope evidence for  
 475 similarities in the types of marine foods used by late mesolithic humans at  
 476 sites along the Atlantic coast of Europe. *Journal of Archaeological Science*,  
 477 26, 717-722.

478 ROBERTS, S. B., COWARD, W. A., EWING, G., SAVAGE, J., COLE, T. J. &  
 479 LUCAS, A. 1988. Effect of weaning on accuracy of doubly labeled water  
 480 method in infants. *American Journal of Physical Anthropology*, 254, R622-  
 481 R627.

482 ROZANSKI, K., ARAGUAS-ARAGUAS, L. & GONFIANTINI, R. 1993. Isotope  
 483 Patterns in Modern Global Precipitation. In: SWART, P. K. & AL, E. (eds.)  
 484 *Climate Change in Continental Records*. Washington DC: American  
 485 Geophysical Union.

486 ROZANSKI, K., ARAGUASARAGUAS, L. & GONFIANTINI, R. 1992. Relation  
 487 between long-term trends of o-18 isotope composition of precipitation and  
 488 climate. *Science*, 258, 981-985.

489 SAIN, P. B. 1980. A study of the problems faced by Indian indentured labour in  
 490 Mauritius due to violation of contract 1834-1878. *Proceedings of the Indian  
 491 History Congress*, 41, 813-822.

492 SCHOENINGER, M. J. & DENIRO, M. J. 1984. Nitrogen and Carbon Isotopic  
 493 Composition of Bone Collagen from Marine and Terrestrial Animals  
 494 *Geochimica et Cosmochimica Acta*, 48, 625-639

495 SEETAH, K. 2010. Le Morne Cemetery: Archaeological investigations. Report  
 496 commissioned by and prepared for the Truth and Justice Commission,  
 497 Port Louis, Mauritius. From reports by D. Calaon, S. Caval, J. Appleby and E.  
 498 Lightfoot. Unpublished report.

499 SEETAH, K. 2015a. The archaeology of Mauritius *Antiquity*, 89, 922-939.

500 SEETAH, K. 2015b. Objects past, objects present: Materials, resistance and memory  
 501 from the Le Morne Old Cemetery, Mauritius. *Journal of Social Archaeology*,  
 502 15, 233-253.

503 SEETAH, K. 2016. Contextualizing Complex Social Contact:Mauritius, a Microcosm  
 504 of Global Diaspora. *Cambridge Archaeological Journal*, 26, 265-283.

505 SMITH, B. & S, E. 1971. Two categories of C-13/C-12 ratios for higher plants. *Plant  
 506 Physiology*, 47, 380-384.

507 TEELOCK, V. 2009. *Mauritian History* Moka, Mahatma Gandhi Institute.

508 TIESZEN, L. L. & FAGRE, T. 1993. Effect of Diet Quality on the Isotopic  
 509 Composition of Respiratory CO<sub>2</sub>, Bone Collagen, Bioapatite and Soft Tissues.  
 510 In: LAMBERT, J. B. & GRUPE, G. (eds.) *Prehistoric Human Bone:  
 511 Archaeology at the Molecular Level*. Berlin: Springer-Verlag.

512 VAUGHAN, M. 2005. *Creating the Creole Island: Slavery in Eighteenth Century  
 513 Mauritius*, Durham, Duke University Press.

514 VOGEL, J. C. & VAN DER MERWE, N. J. 1977. Isotopic Evidence for Early Maize  
 515 Cultivation in New-York State. *American Antiquity*, 42, 238-242.

516 WRIGHT, L. E. & SCHWARCZ, H. P. 1989. Stable carbon and oxygen isotopes in  
517 human tooth enamel: Identifying breastfeeding and weaning in prehistory.  
518 *American Journal of Physical Anthropology*, 106, 1-18.  
519

## Appendix 2

Carbon and nitrogen isotopic and elemental compositions were determined using Costech elemental analyser coupled in continuous flow to a Finnigan isotope ratio mass spectrometer in the Godwin Laboratory (University of Cambridge). Stable carbon and nitrogen isotope compositions were calibrated relative to VPDB ( $\delta^{13}\text{C}$ ) and AIR ( $\delta^{15}\text{N}$ ) using the standards listed in Table S1.

**Table S1.** Standard reference materials.

Standard	Material	Mean $\delta^{13}\text{C}$ (‰, VPDB)	Mean $\delta^{15}\text{N}$ (‰, AIR)
L-alanine	Alanine	-26.9	-1.4
IAEA-600	Caffeine	-27.5	+1.05
USGS-40	Amino acid	-26.2	-4.5
Protein 2	Protein standard OAS	-26.95	6.0
EMC	Caffeine	-35.85	-2.5

Table S2 presents the means and standard deviations of the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for standards as well as the number of standards included in each analytical session.

**Table S2.** Mean and standard deviation of all check and calibration standards for all analytical sessions containing data presented in this paper.

Session ID	Standard	n	$\delta^{13}\text{C}$ (‰, VPDB)	$\delta^{15}\text{N}$ (‰, AIR)
Session 1	Alanine	3	-26.90 $\pm$ 0.06	-1.50 $\pm$ 0.06
Session 2	Alanine	3	-26.89 $\pm$ 0.00	-1.48 $\pm$ 0.03
Session 3	Alanine	3	-26.96 $\pm$ 0.05	-1.43 $\pm$ 0.02
Session 4	Alanine	10	-26.91 $\pm$ 0.05	-1.47 $\pm$ 0.03
Session 5	Alanine	10	-26.93 $\pm$ 0.06	-1.46 $\pm$ 0.05
Session 6	Alanine	7	-26.89 $\pm$ 0.11	-1.44 $\pm$ 0.04
Session 7	Alanine	6	-26.89 $\pm$ 0.04	-1.47 $\pm$ 0.03
Session 8	Alanine	9	-26.90 $\pm$ 0.04	-1.44 $\pm$ 0.04
Session 9	Alanine	6	-26.88 $\pm$ 0.04	-1.42 $\pm$ 0.13
Session 1	Caffeine	3	-27.48 $\pm$ 0.05	1.11 $\pm$ 0.03
Session 2	Caffeine	3	-27.48 $\pm$ 0.05	1.13 $\pm$ 0.02

Session 3	Caffeine	3	-27.48 ± 0.03	1.19 ± 0.01
Session 4	Caffeine	6	-27.62 ± 0.07	1.13 ± 0.07
Session 5	Caffeine	6	-27.59 ± 0.07	1.12 ± 0.07
Session 6	Caffeine	6	-27.55 ± 0.05	1.08 ± 0.08
Session 7	Caffeine	6	-27.54 ± 0.05	1.06 ± 0.07
Session 8	Caffeine	6	-27.53 ± 0.04	1.06 ± 0.03
Session 9	Caffeine	3	-27.55 ± 0.08	1.02 ± 0.18
Session 1	USGS-40	3	-26.12 ± 0.04	-4.56 ± 0.01
Session 2	USGS-40	1	-26.13	-4.49
Session 3	USGS-40	3	-26.14 ± 0.03	-4.43 ± 0.06
Session 4	USGS-40	6	-26.17 ± 0.07	-4.43 ± 0.08
Session 5	USGS-40	5	-26.10 ± 0.07	-4.43 ± 0.13
Session 6	USGS-40	6	-26.12 ± 0.03	-4.51 ± 0.05
Session 7	EMC	3	-35.87 ± 0.04	-2.54 ± 0.01
Session 8	EMC	3	-35.87 ± 0.03	-2.58 ± 0.05
Session 9	EMC	3	-35.94 ± 0.05	-2.57 ± 0.14
Session 7	Protein 2	7	-26.98 ± 0.04	6.05 ± 0.04
Session 8	Protein 2	7	-26.98 ± 0.03	6.08 ± 0.06
Session 9	Protein 2	4	-26.94 ± 0.06	6.08 ± 0.28

All of the samples were analyzed in triplicate, the results of which are presented in Table S3.

**Table S3.** Triplicate stable carbon and nitrogen isotopic compositions for all samples.

Sample	$\delta^{13}\text{C}_a$	$\delta^{13}\text{C}_b$	$\delta^{13}\text{C}_c$	$\delta^{15}\text{N}_a$	$\delta^{15}\text{N}_b$	$\delta^{15}\text{N}_c$
BM05	-17.01	-16.94	-17.10	12.00	11.95	12.04
BM04	-17.35	-17.33	-17.31	12.14	12.16	12.23
BM03L	-18.32	-18.34	-18.38	10.84	10.83	10.87
BM03U	-17.12	-17.22	-17.33	12.03	12.00	12.02
BM02U	-16.52	-16.44	-16.70	12.25	12.33	12.31

BM01	-17.58	-17.43	-17.57	11.96	12.01	12.08
BMD02	-17.28	-17.14	-17.21	11.92	12.06	11.89
BMD04	-13.71	-13.61	-13.62	11.66	11.79	11.74
BMD05	-17.13	-17.15	-17.09	12.39	12.42	12.40
BMD33	-17.77	-17.74	-17.73	11.20	11.29	11.11
BMD33L	-17.73	-17.64	-17.71	9.94	9.98	9.81
BMD34L	-16.22	-16.15	-16.21	11.79	11.80	11.66
BMD35	-17.52	-17.50	-17.28	12.57	12.58	12.52
BMD35L	-9.05	-9.01	-9.12	15.70	15.76	15.53
BMD36	-16.52	-16.43	-16.49	12.96	12.98	12.57
BMD36L	-17.73	-17.68	-17.72	9.46	9.53	9.34
BMD37	-17.37	-17.20	-17.32	12.07	12.05	11.98
BMD37L	-15.72	-15.65	-15.62	13.04	13.13	12.99
BMD38	-18.30	-18.29	-18.32	11.67	11.74	11.59
BMD39	-16.78	-16.71	-16.70	12.84	12.94	12.74
STR001	-13.94	-13.90	-13.99	10.68	10.57	10.66
STR006_7	-14.05	-14.02	-14.10	11.60	11.71	11.73
STR006_8	-14.38	-14.13	-14.21	11.70	11.75	11.82
STR007	-14.89	-14.82	-14.83	11.33	11.32	11.43
STR008	-14.66	-14.64	-14.65	10.68	10.60	10.79
STR025	-12.10	-12.12	-12.10	10.47	10.56	10.58
STR029	-14.41	-14.40	-14.35	11.71	11.71	11.73
STR030	-14.69	-14.66	-14.66	10.62	10.69	10.71
STR033_U	-11.43	-11.39	-11.40	10.13	10.00	10.13
STR033_L	-14.65	-14.66	-14.57	10.89	10.93	10.92
STRD01	-15.90	-15.78	-15.76	10.72	10.79	10.90
STRD07	-11.02	-10.91	-10.91	11.40	11.48	11.66
STRD08	-17.70	-17.75	-17.70	12.37	12.52	12.28
STRD25	-12.51	-12.51	-12.36	10.83	10.91	10.79
STRD29	-14.44	-14.34	-14.35	13.11	13.16	13.12
STRD30	-14.53	-14.53	-14.57	11.98	11.90	11.84
STRD33_U	-14.92	-14.77	-14.75	11.31	11.25	11.19
STRD33_L	-10.99	-10.96	-10.88	6.60	6.57	5.93

Figure 1

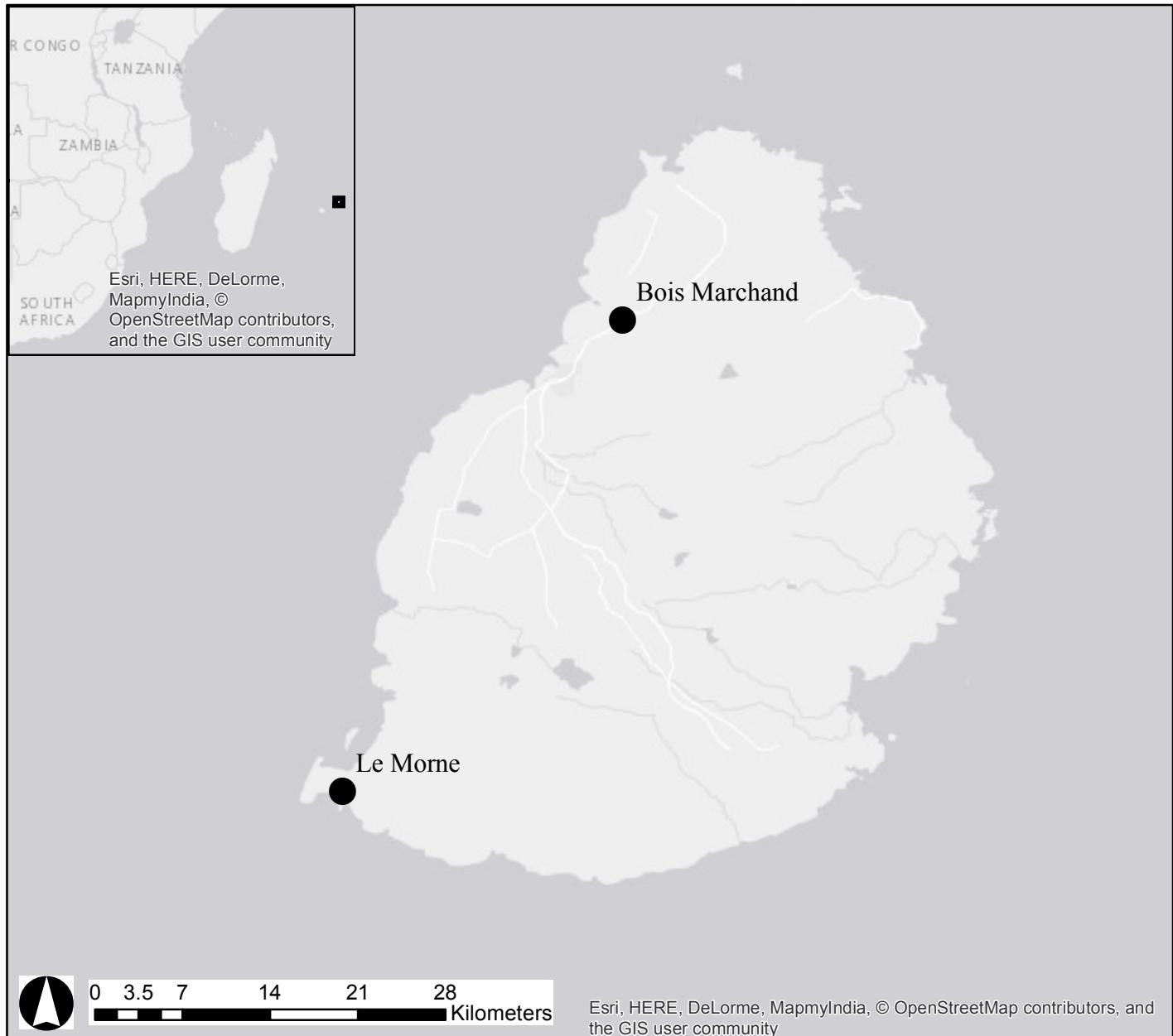






Figure 4

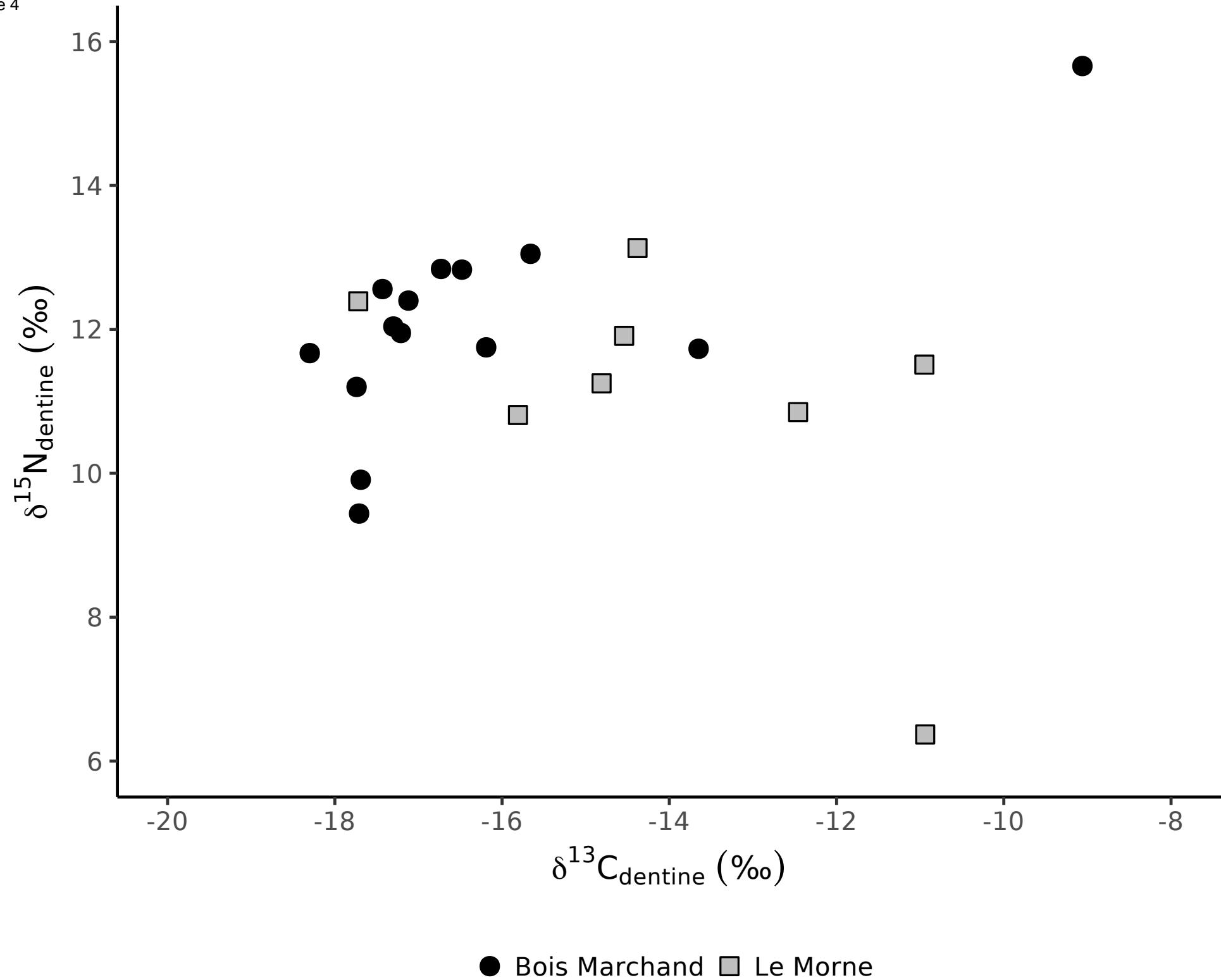


Figure 5

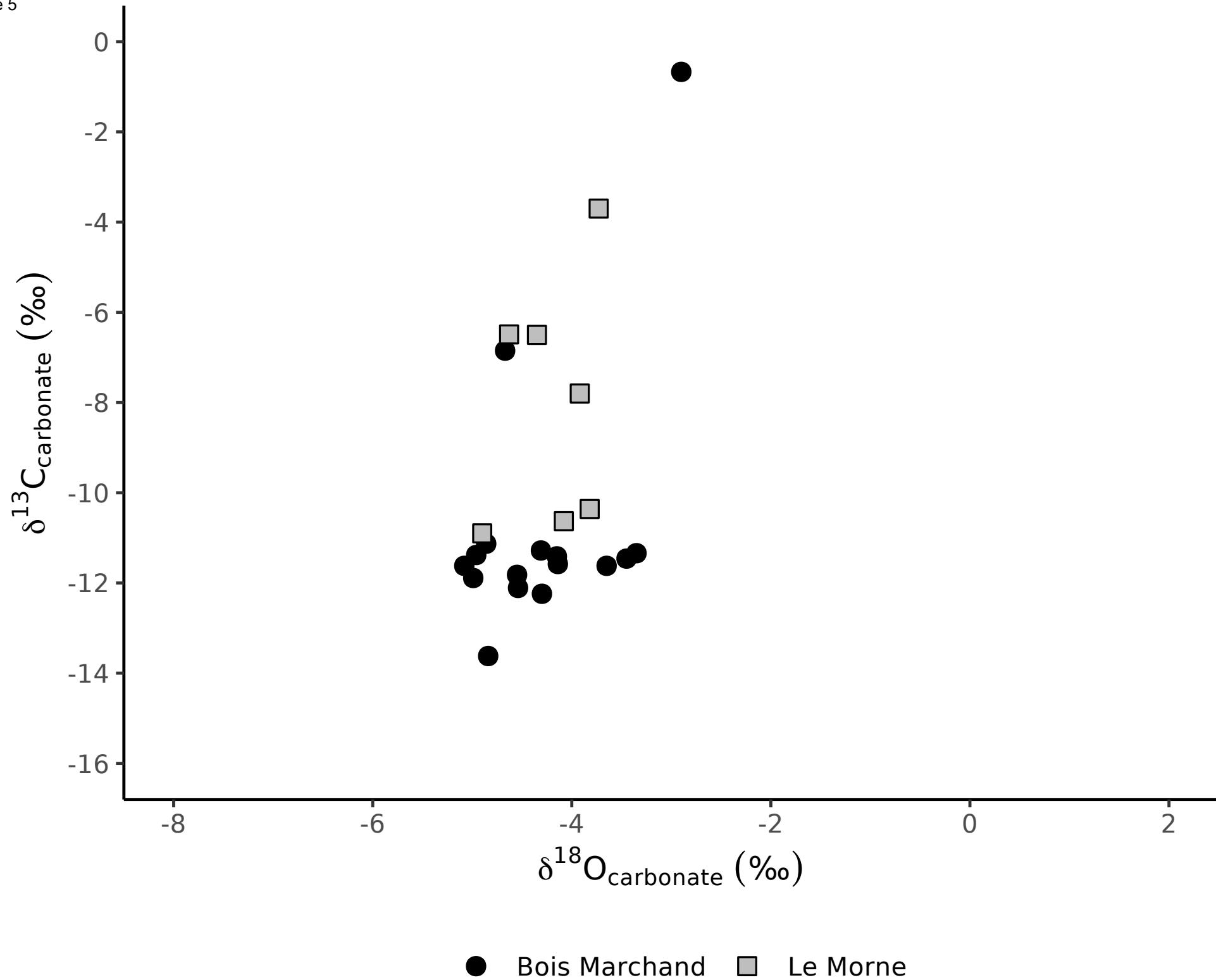


Figure 6

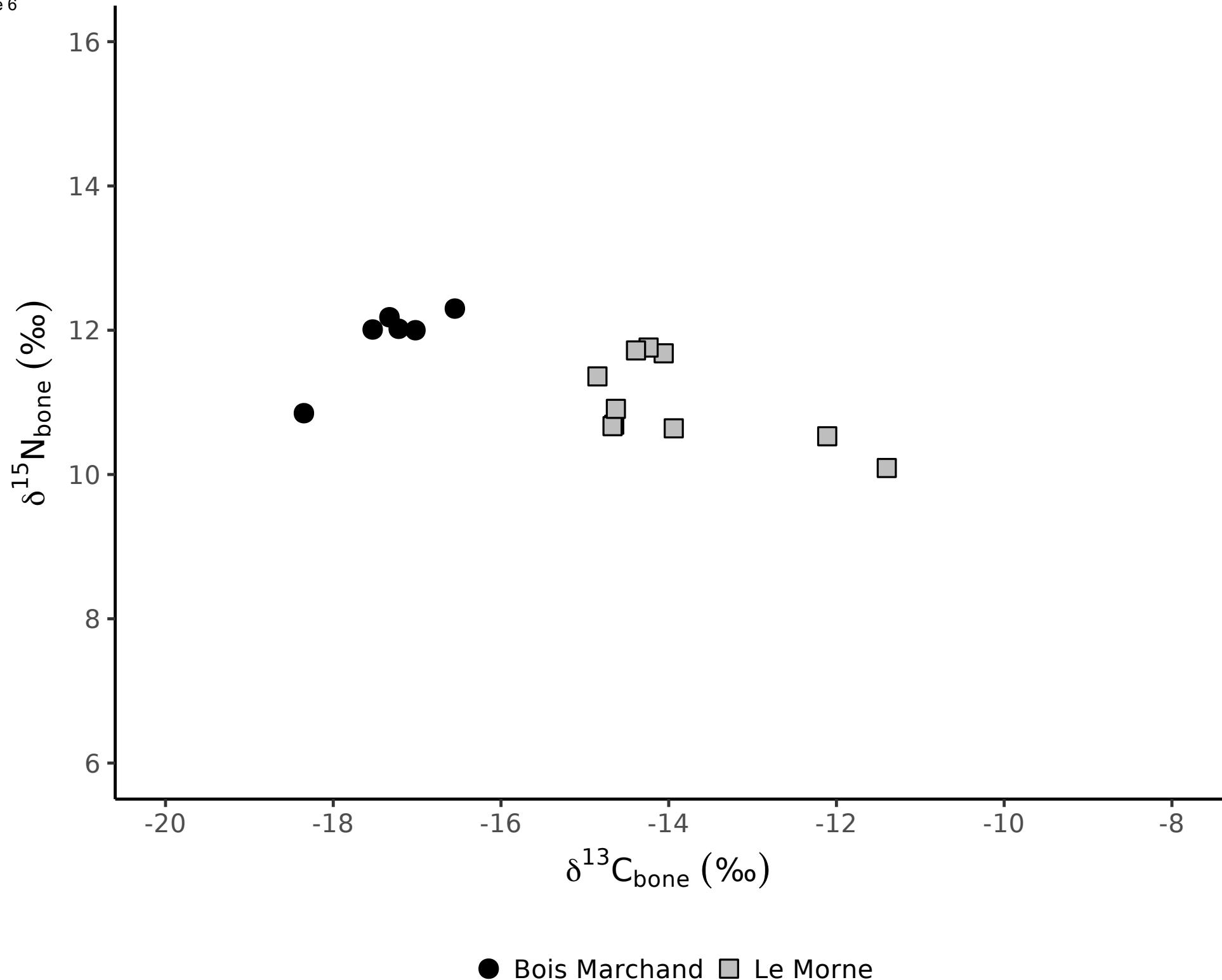
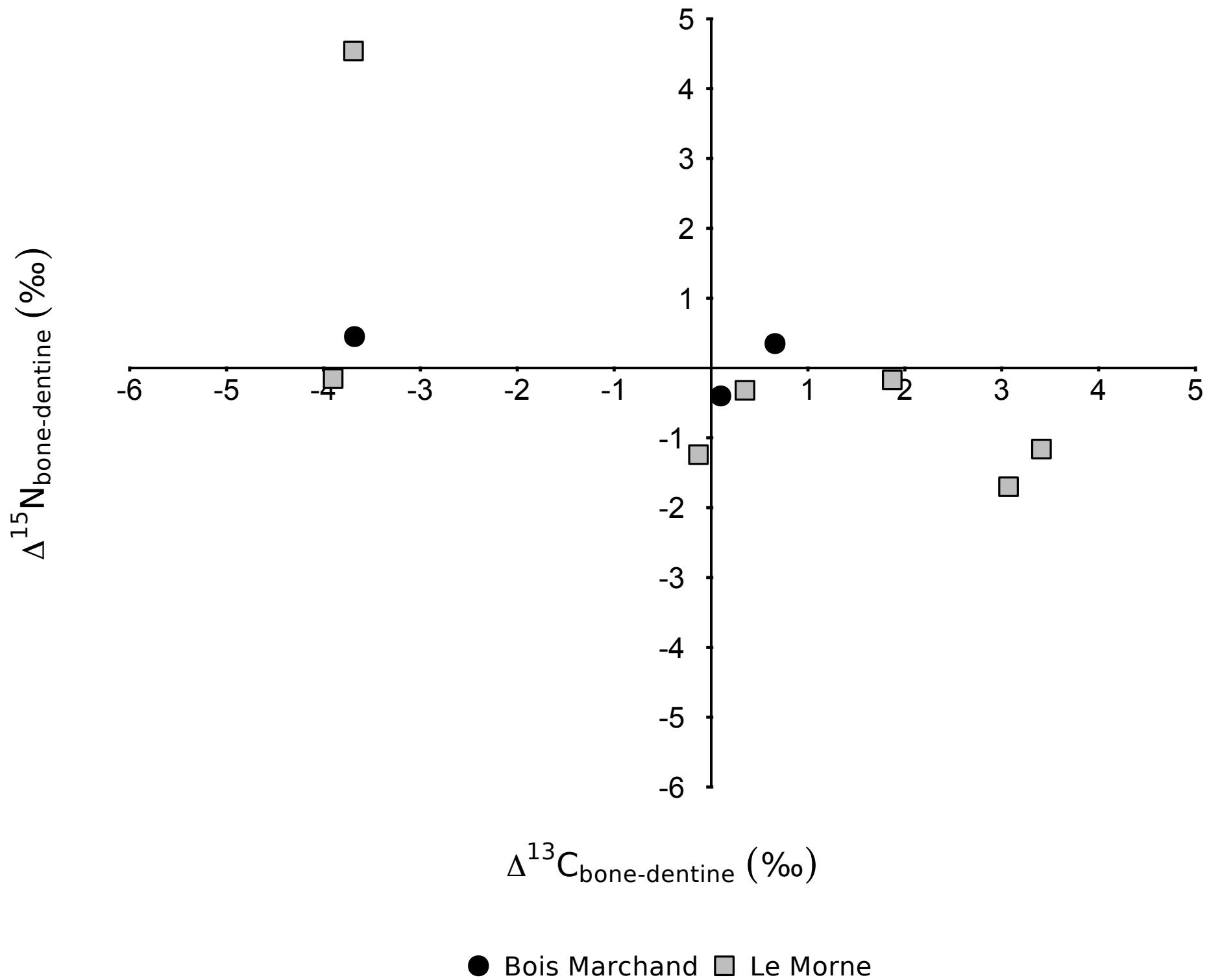


Figure 7





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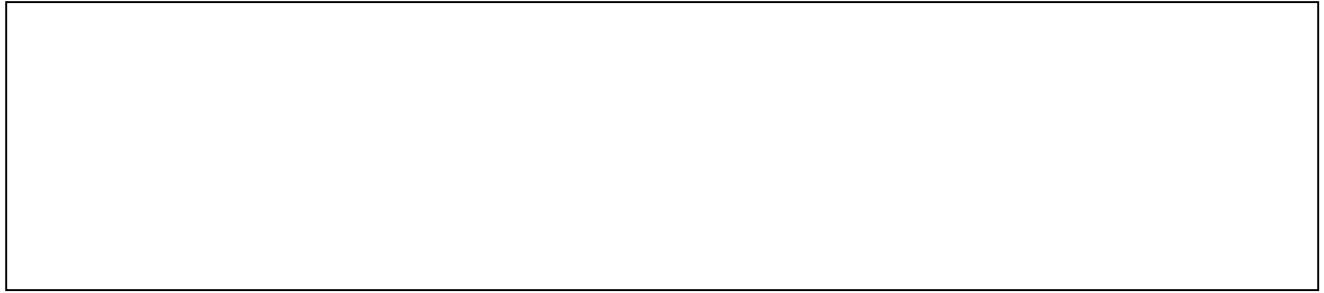
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**Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

A large, empty rectangular box with a thin black border, occupying the lower half of the page. It is intended for authors to provide any necessary declarations of interests.