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Laffoon, J.E.; Espersen, R.; Mickleburgh, H.L.

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THE LIFE HISTORY OF AN ENSLAVED AFRICAN: MULTIPLE ISOTOPE EVIDENCE FOR FORCED CHILDHOOD MIGRATION FROM AFRICA TO THE CARIBBEAN AND ASSOCIATED DIETARY CHANGE *

J. E. LAFFOON,^{1,2,†}  R. ESPERSEN^{1,3} and H. L. MICKLEBURGH¹

¹Faculty of Archaeology, Leiden University, 2300 RA Leiden, The Netherlands

²Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam, 1081 HV Amsterdam, The Netherlands

³Saba Archaeological Center (SABARC), Windward Side, Saba, The Netherlands Antilles

Archaeological excavations of an enslaved African domestic area at the Spring Bay Flat plantation on the island of Saba, Dutch Caribbean, uncovered a small concentration of artefacts (shell, metal nails, animal bones and five human teeth) overlaid with a lock hinge, interpreted as a lockbox and its contents. Dental anthropological and multi-isotope (strontium, oxygen, carbon and nitrogen) analyses of the teeth revealed that they belonged to a single individual who originated from Africa and survived a period of pronounced nutritional stress as a juvenile. The results provide rare insights into the life history of an individual who probably experienced enslavement, (forced) migration from Africa and adaptation to plantation life in the colonial-era Caribbean.

KEYWORDS: CARIBBEAN, ISOTOPES, ENAMEL, DENTINE, MIGRATION, DIET, JUVENILE

INTRODUCTION

The transatlantic slave trade often dominates the discourse on the historical trajectory of the Atlantic World (Thornton 1998; Rawley and Behrendt 2005). It has been estimated that from c. AD 1500 to 1850, approximately 10 million enslaved Africans were forcibly transported from Africa to the New World (Eltis n.d.). Despite broad similarities, many factors associated with the enslavement and forced migrations of Africans were highly variable throughout the colonial period. These factors include variations within or between places of origins (cultural, linguistic, religious and dietary), modes of transshipment, European colonial powers, purposes of enslaved labour and destinations in the Americas. Therefore, as to be expected from processes spanning several centuries and involving numerous and varied actors from a vast array of geographical, national and cultural contexts, the life histories of enslaved individuals were not uniform but highly diverse.

Traditionally, historical and archaeological studies of slavery and the slave trade in the colonial period of the Americas in general, and of the West Indies in particular, have focused on large-scale processes, patterns and trends. Conversely, more recent research on these topics has stressed regional and local diversity and variability in lived experiences. Various bioarchaeological and biomolecular studies published in recent years have begun to shed light on various aspects of slavery and enslavement at ever finer scales of analysis (Schroeder *et al.* 2015). For example, strontium isotope analysis of dental enamel is one of the most common and successful approaches for studying

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†Corresponding author: email j.e.laffoon@arch.leidenuniv.nl

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human (and animal) migration and mobility in archaeological research, while carbon and nitrogen isotope analyses of collagen are the most established methods for palaeodietary reconstruction. Recently, several studies have employed multiple isotope analyses of skeletal remains to investigate slavery, forced migrations (Leach *et al.* 2010; Kootker *et al.* 2016), and specifically the life histories of African-born individuals in the colonial-era Americas (Schroeder *et al.* 2009, 2014; Price *et al.* 2012; Laffoon *et al.* 2013; Bastos *et al.* 2016).

This study focuses on a small collection of human teeth recovered from a buried cache in an African domestic area at the Spring Bay Flat sugar and indigo plantation on the island of Saba, Dutch Caribbean (Fig. 1). The disarticulated human teeth were buried in a wooden lockbox with several iron nails, a shell and assorted isolated animal bones. We employ an innovative sampling design and multi-isotope proxy approach involving: strontium ($^{87}\text{Sr}/^{86}\text{Sr}$), carbon ($\delta^{13}\text{C}$) and oxygen ($\delta^{18}\text{O}$) isotope analyses of enamel from dental elements forming at different ages, to identify changes in geographical residence throughout the sub-adult period; and carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope analyses of incrementally sampled dentine collagen, to track dietary changes at high temporal resolution. The combined results provide new perspectives on the life history of an individual who experienced long-distance forced migration from Africa to Saba and subsequent distinct changes in diet as a child.

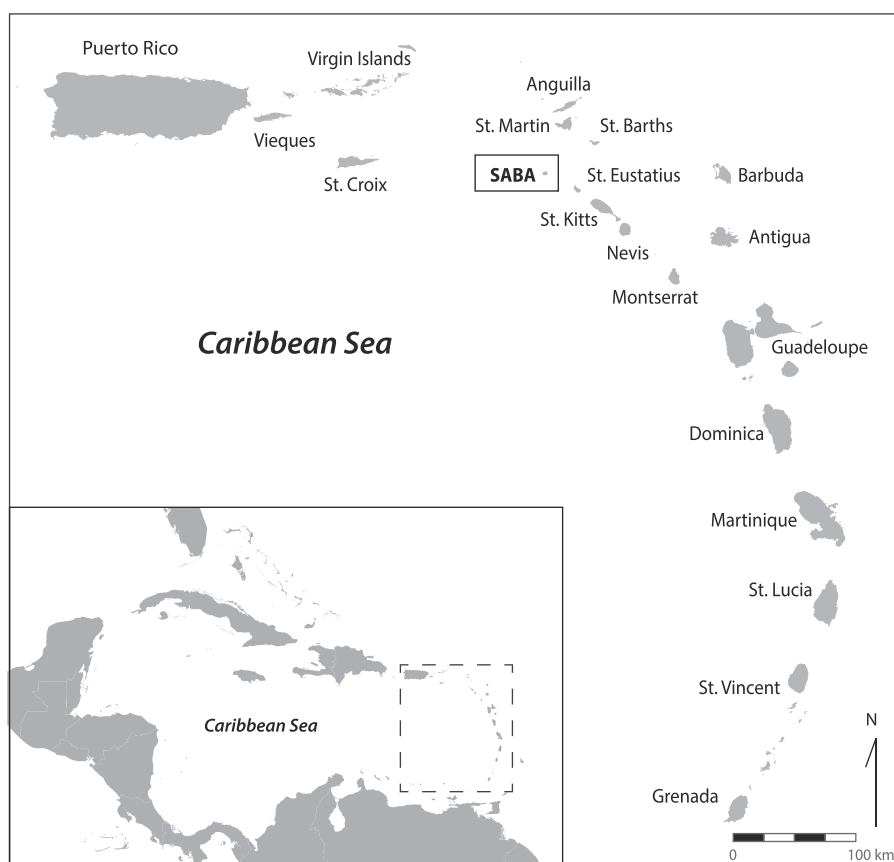


Figure 1 A map of the Caribbean, showing the location of the island of Saba.

The archaeological context

Saba is the northernmost volcanic island in the active arc of the Lesser Antilles group, measuring around 13 km² in area, and about 890 m in elevation. The island was an atypical Caribbean colony, as it never developed a full plantation-based economy. The island's population never exceeded 1800 free and enslaved residents prior to the 19th century, and the island's geological history resulted in a very steep topography, thereby fostering a social premium upon flat or moderately sloped landscapes, and limiting plantations to small-scale enterprises.

Sugar production began on the island during the 1650s, just above sea level at Spring Bay, but there are only four known sugar plantations in operation during the colonial period (Espersen 2016). Other small-scale plantation enterprises included coffee, indigo and cotton (*ibid.*). Sugar production at Spring Bay Flat (Fig. 2), located on a ridge about 300 m above Spring Bay, occurred from the early 18th century to around 1815. The estate featured a small, two- or three-pot sugar works located within the approximately 120 ha Spring Bay estate. The estate also includes the ruins of an earlier 17th-century boiling house, and two indigo production areas, close to the coast at Spring Bay and Cove Bay respectively.

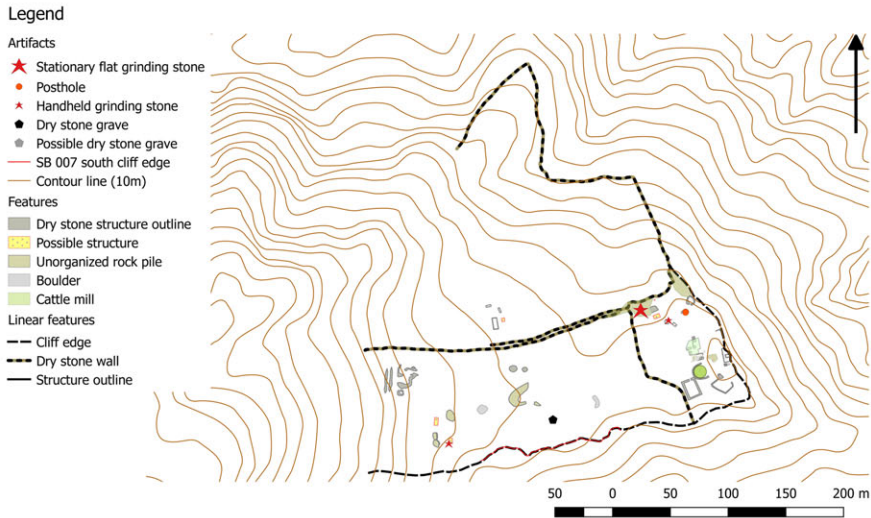
At Spring Bay Flat, Structures C, E and G were identified as enslaved African huts based on their location relative to the Big House, boiling house and cane field; shared architectural elements; the presence of identical structures at Spring Bay and Hell's Gate; evidence of food processing areas nearby; and the preponderance of domestic-oriented artefacts from archaeological excavations (Armstrong and Kelly 2000; Espersen 2016). The northern enslaved African domestic area features at least three identified houses with two types of construction. Structure C was a wattle hut with an interior floor of small, rounded cobblestones, while Structures E and G were constructed of two dry stone walls built into the back of a boulder (Espersen 2016). Structure D consists of a 2 × 3 m excavated unit, divided into six 1-m² units, which encompassed the house-yard of a nearby structure. The assemblage of concern in this paper was found almost at the centre juncture of the northernmost four 1 × 1 m units associated with Structure D.

Within the centre of this feature, a ferrous, hinged latch with a loop to accept a lock was found on top of a small, compacted assemblage consisting of five small wrought nails (less than 20 cm in length), two large wrought nails (over 20 cm in length), a *Cittarium pica* shell with a diameter of 45 mm, a tong-smoothed clay pipe stem, various animal bones and five human teeth (Fig. 3). The position of the latch over the assemblage indicates that this is probably the remnant of a wooden lockbox that contained these remains.

Samples

Five permanent teeth were recovered from the lockbox and were submitted for isotopic analysis. Based on the identification of these dental elements, their consistency in size and morphology, degree of occlusal wear and matching interproximal wear facets, we consider them to belong to a single individual. All teeth were in functional occlusion at some time prior to death, as evidenced by occlusal wear facets. The presence of the upper left third molar (2.8), as well as indirect evidence of the eruption of the lower right third molar (4.8) through the presence of a distal wear facet on the lower right second molar (4.7), indicates an estimated age at death of at least 18–20 years (AlQahtani *et al.* 2010). The upper left third molar (2.8) shows occlusal calculus deposition on the lingual half of the occlusal surface, suggesting that this tooth may have been misaligned, or its opposite (3.8) was absent. Considering the estimated eruption time of each dental element, the degree of occlusal wear is consistent with the teeth belonging to a single individual.

(a) Spring Bay Flat Sugar and Indigo Plantation



(b) Spring Bay Flat, Northern Enslaved African Domestic Area

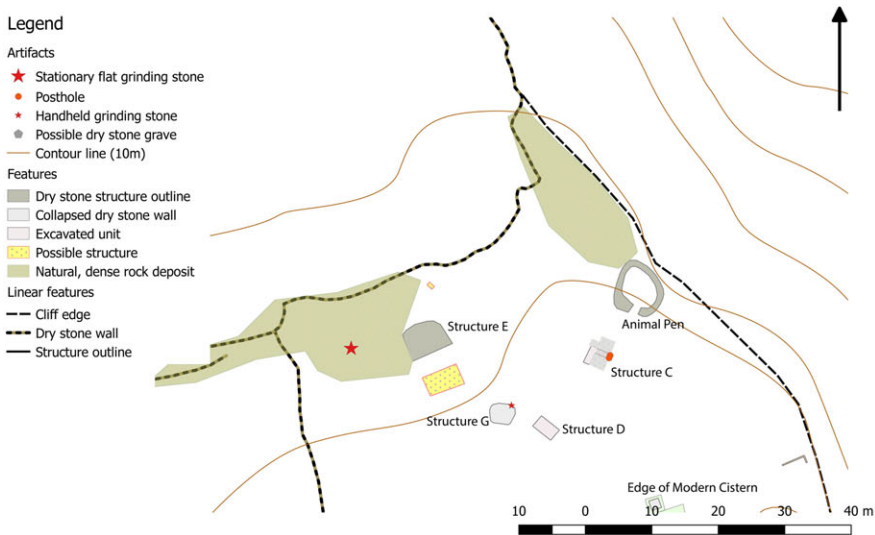


Figure 2 A map of the Spring Bay Flat site on Saba, indicating (a) the sugar and indigo plantation and (b) the enslaved African domestic area. [Colour figure can be viewed at wileyonlinelibrary.com]

Estimation of the age of migration of this individual relies on the identification of the dental elements and the corresponding estimated age of crown enamel mineralization and root formation. An overview of the identified elements and the corresponding characteristics that

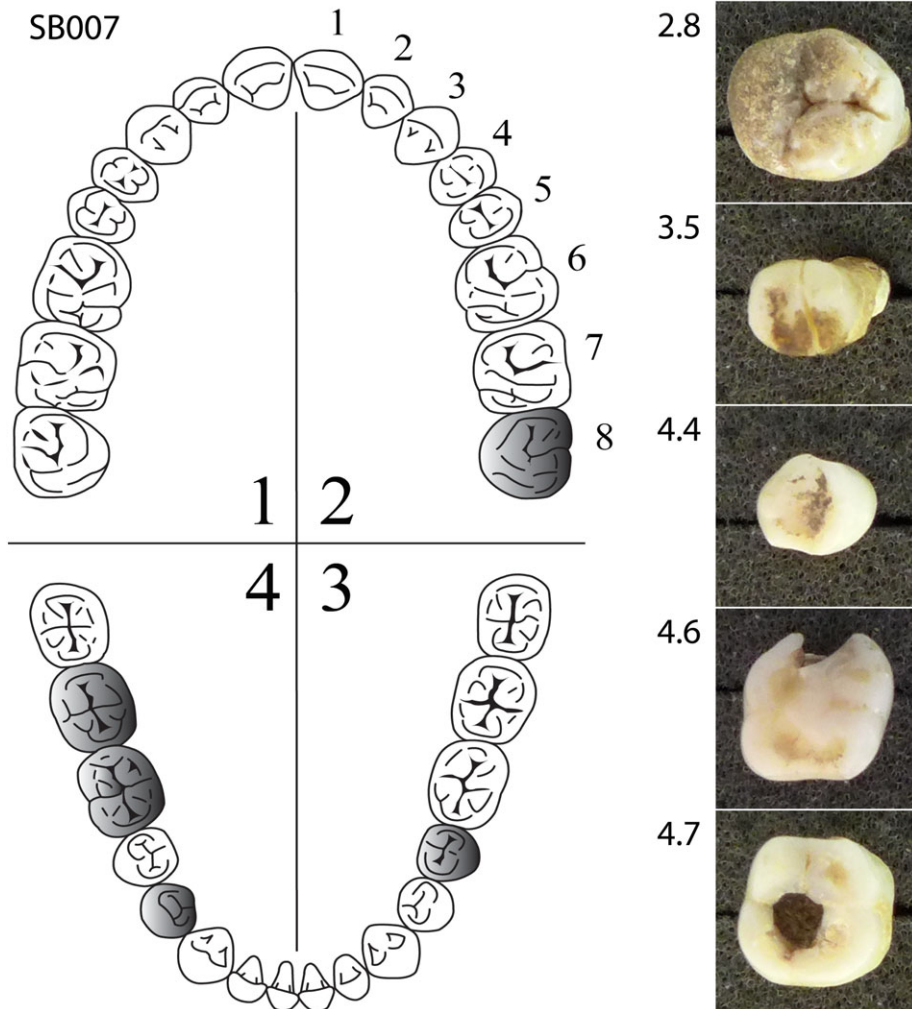


Figure 3 Diagram and photographs of the human teeth from the lockbox associated with Structure D. [Colour figure can be viewed at wileyonlinelibrary.com]

support the dental identifications can be found in Appendix S1. This individual is represented by the following dental elements: 4.4, 3.5, 4.6, 4.7 and 2.8.

METHODS

Sampling strategy

Strontium ($^{87}\text{Sr}/^{86}\text{Sr}$), carbon ($\delta^{13}\text{C}_{\text{enamel}}$) and oxygen ($\delta^{18}\text{O}_{\text{enamel}}$) isotope analyses of dental enamel were carried out on all five teeth (P1, P2, M1, M2 and M3). Enamel crowns were mechanically cleaned and ~2 mg of inner enamel was extracted using a pre-cleaned drill bit. Powdered enamel was pre-treated using a modified version of the protocol of Bocherens *et al.* (2011) to remove possible diagenetic contaminants. Samples were soaked in a 2.5% bleach

solution (NaOCl) for 20 h, rinsed thoroughly with ultra-pure water (Milli-Q H₂O), leached for 4 h in 1 M Ca acetate buffered (pH 4.7) acetic acid (CH₃CO₂H) and rinsed to neutral. Strontium was isolated via ion exchange chromatography on columns loaded with Sr-spec resin (Eichrom®) after dissolution of pre-treated enamel samples in 3 M HNO₃.

Carbon (¹³C_{dent}) and nitrogen (¹⁵N_{dent}) isotope analyses of dentine collagen were conducted using a modified version of the serial sampling protocol (sectioning method 2) of Beaumont *et al.* (2013). Roots were separated from the dental crown using a pre-cleaned circular cutting disc attached to a handheld drill (Dremel). Roots were demineralized in 0.6 M HCl at 4 °C for 4–6 days, with the acid refreshed every 48 h, and then were rinsed three times in ultra-pure water. Incremental samples of demineralized dentine were taken at 1 mm intervals, starting from the cemento-enamel junction (CEJ) to the apex of each root, for three dental elements (M1, M2 and M3). This sampling method generated 26 serial dentine collagen samples (eight each from the M1 and M3, and 10 from the M2). Owing to the overlap in root formation ages between molars, it is expected that these serial samples will reflect most of the sub-adult period of this individual's life (Eerkens *et al.* 2011). Collagen samples were processed using a modified version (Brown *et al.* 1988; Ambrose 1990) of the Longin (1971) method. Subsequent to demineralization and sectioning, samples were treated with 0.125 M sodium hydroxide (NaOH) for ~20 h at 20 °C, rinsed to neutral and gelatinized in 0.001 M (pH 3) hydrochloric acid (HCl) at 80 °C for 24–48 h. Collagen extracts were then purified with Ezee filters (Elkay®), frozen, lyophilized and packed into tin capsules (0.5 mg) for stable isotope analyses.

Analytical procedures

Strontium isotope measurements were conducted on a MAT-Finnigan262 RPQ-Plus TIMS in static mode. ⁸⁷Sr/⁸⁶Sr ratios were corrected for mass fractionation, and were normalized to the NBS987 standard, with a mean long-term ⁸⁷Sr/⁸⁶Sr value of 0.71024 ± 0.00002 (1σ). Total procedural blanks had negligible Sr (< 100 pg). Typical internal precision of samples is < 0.00001 (2SE). For carbon and oxygen isotope analyses of enamel, pre-leached powder (0.7 mg) was weighed into glass vials and placed in a hot block at 45 °C for 24 h after the addition of 100% orthophosphoric acid (H₃PO₄). Carbon and oxygen measurements of dental enamel were carried out on a Delta-Plus IRMS with a GasBench II, and both stable isotope values are reported in the delta notation (δ) in parts per mil (‰), normalized to the VPDB scale using an in-house carbonate reference material (VICS) calibrated against certified reference materials (NBS19), with IAEA-CO1 used as a control standard to monitor instrument performance. Collagen samples were analysed on a ThermoQuest IRMS Delta XP plus interfaced with a Flash EA after combustion to produce CO₂ and N₂ gases purified via GC columns using He as the carrier gas. International standards USGS40 and USGS 41, and IAEA-310(A) and IAEA-NO3, were used for sample calibration, and isotope values are presented relative to VPDB and AIR for δ¹³C and δ¹⁵N respectively. Analytical uncertainty for collagen δ¹³C and δ¹⁵N is typically < 0.2‰. All samples yielded sufficient collagen for isotope measurement and possessed C:N ratios within the accepted range (2.9–3.6) for unaltered collagen (Ambrose 1990).

RESULTS AND DISCUSSION

Enamel isotope results (Table 1) are presented first (Fig. 4), followed by the dentine collagen isotope results. Both sets of data are analysed relative to approximate ages of crown and root formation based on age ranges reported in the dental literature (Hillson 1996; White and Folkens

Table 1 Sampling information and isotope results for enamel

Laboratory ID	Sample	Type	Element	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}_{\text{enamel}}$ (‰) VPDB	$\delta^{18}\text{O}_{\text{enamel}}$ (‰) VPDB
U356	SB007.C	M1	4.6	0.71227	-3.7	-4.5
U358	SB007.E	P1	4.4	0.71255	-3.3	-4.4
U357	SB007.D	P2	3.5	0.71364	-2.6	-3.8
U518	SB007.A	M2	4.7	0.71325	-3.0	-4.7
U519	SB007.B	M3	2.8	0.70986	-8.6	-4.8

2005; AlQahtani *et al.* 2010). There is a high degree of inter-individual and population variation in crown and root formation times (Moorrees *et al.* 1963) and there are non-trivial differences in reported age estimates; thus those reported here should be considered approximate. Enamel data indicate distinct and highly enriched $^{87}\text{Sr}/^{86}\text{Sr}$ ($M = 0.71293$) and $\delta^{13}\text{C}_{\text{enamel}}$ values ($M = -3.1\text{‰}$) for the four earlier-forming teeth (M1, P1, P2 and M2), while the third molar (M3) has much lower $^{87}\text{Sr}/^{86}\text{Sr}$ (0.70986) and $\delta^{13}\text{C}_{\text{enamel}}$ (-8.6‰) values. In contrast, the $\delta^{18}\text{O}_{\text{enamel}}$ values of all five teeth were broadly similar (range -4.8‰ to -3.8‰) and showed no systematic changes between the different teeth.

The $^{87}\text{Sr}/^{86}\text{Sr}$ values of all five teeth are much higher than the range of prehistoric human or bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ for not only the island of Saba (Laffoon and Hoogland 2012) but also the insular Caribbean more broadly (Bataille *et al.* 2012; Laffoon 2012; Laffoon *et al.* 2012), with the possible exception of Trinidad. The strontium isotope results clearly indicate non-local origins, exclude the Antilles as a possible place of childhood origin, and thus indicate long-distance migration between natal origin(s) and the location of final deposition on Saba. The elevated $^{87}\text{Sr}/^{86}\text{Sr}$ values of the four earlier-forming teeth are characteristic of regions underlain by older, more radiogenic, continental geological deposits, and are consistent with an African origin for this individual, as suggested on the basis of the archaeological and chronological contexts. The variation in $^{87}\text{Sr}/^{86}\text{Sr}$ between the four earlier-forming teeth could be interpreted as indicating that, contrary to our initial assessment, the teeth derive from different individuals. However, if these teeth derive from a single individual, the variable $^{87}\text{Sr}/^{86}\text{Sr}$ ratios could indicate mobility between different geochemical environments during early childhood (e.g., transhumance).

The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the third molar is somewhat anomalous in that it is not only clearly distinct from the other four teeth but also does not match the $^{87}\text{Sr}/^{86}\text{Sr}$ range of Saba or the Antilles. Assuming that all five teeth do indeed come from the same individual, two main mechanisms could account for this pattern. One is that this individual migrated at least twice, first from the place of origin characterized by higher $^{87}\text{Sr}/^{86}\text{Sr}$ (natal origin) to a place of residence with intermediate $^{87}\text{Sr}/^{86}\text{Sr}$ during later childhood/adolescence (when the M3 was mineralizing), and subsequently to the island of Saba. Although admittedly speculative, such a scenario is historically plausible if the individual first 'migrated' from the interior to the coast (which would be expected to have broadly similar $^{87}\text{Sr}/^{86}\text{Sr}$ values similar to modern seawater), and then subsequently at an older age to the Caribbean. Another possibility is that there was single migration from the natal location to Saba that occurred while the M3 crown was forming and that owing to the bulk nature of the sampling strategy, the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the M3 reflects a combination of Sr incorporated from two isotopically distinct places; that is, higher $^{87}\text{Sr}/^{86}\text{Sr}$ ($\sim 0.712\text{--}0.713$) as reflected in the other teeth and the lower $^{87}\text{Sr}/^{86}\text{Sr}$ characteristic of Saba

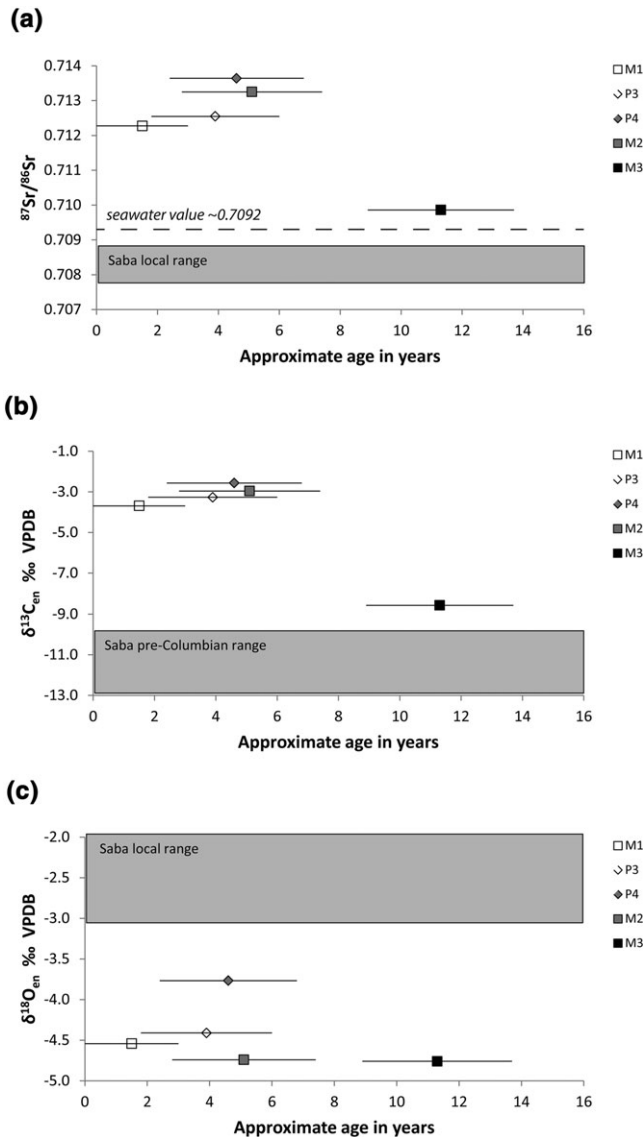


Figure 4 The results of multiple isotope analyses of dental enamel samples plotted relative to approximate age of formation for (a) $^{87}\text{Sr}/^{86}\text{Sr}$; (b) $\delta^{13}\text{C}_{\text{en}}$ and (c) $\delta^{18}\text{O}_{\text{en}}$. Isotope ranges for Saba from Laffoon et al. (2012) for $^{87}\text{Sr}/^{86}\text{Sr}$; and from Laffoon et al. (2013) for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$.

(~0.707–0.709). Owing to the prolonged period of mineralization of human teeth, especially of M3s, and the residence time of Sr in the body, migration between isotopically distinct regions during late childhood/adolescence is likely to produce such a mixed signal, and in fact the $^{87}\text{Sr}/^{86}\text{Sr}$ value of individual SB007's M3 falls on a mixing line between the values of the earlier-forming teeth and the local range for Saba.

These higher $^{87}\text{Sr}/^{86}\text{Sr}$ values are also very comparable to some of the reported $^{87}\text{Sr}/^{86}\text{Sr}$ values of presumably African-born migrants at various colonial-era sites in the Americas, such

as: the African Burial Ground National Monument, New York, USA (Goodman *et al.* 2004); Colonial Campeche, Campeche, Mexico (Price *et al.* 2012); Pretos Novos cemetery, Rio de Janeiro, and Sé de Salvador cathedral, Salvador, Brazil (Bastos *et al.* 2016); and including sites in the Caribbean—Newton Plantation, Christ Church, Barbados (Schroeder *et al.* 2009) and Zoutsteeg, Philipsburg, St Maarten (Schroeder *et al.* 2014). The interpretation of African origins for many individuals at these sites is supported not just by strontium isotope data but in most cases also by other isotope proxy data, the presence of African-style dental modifications, skeletal morphology, the archaeological context or a combination thereof. For the three African-born individuals excavated from Zoutsteeg, St Maarten (neighbouring Saba) this complementary evidence also includes genomic data that unequivocally indicates African ancestry (Schroeder *et al.* 2015).

As previously mentioned, the pattern of $\delta^{13}\text{C}_{\text{enamel}}$ values mirrors that of the $^{87}\text{Sr}/^{86}\text{Sr}$ results, with very similar and high values for the four earlier-forming teeth and a much lower value for the later-forming M3. The higher $\delta^{13}\text{C}_{\text{enamel}}$ values of the earlier-forming teeth are much less negative than published $\delta^{13}\text{C}_{\text{enamel}}$ values for prehistoric Amerindian populations of the Caribbean (Laffoon *et al.* 2013, 2016) or reported bone apatite $\delta^{13}\text{C}_{\text{apatite}}$ values of colonial-period slaves from the Antilles (Varney 2003). Similar to the pattern noted in the $^{87}\text{Sr}/^{86}\text{Sr}$ results, relatively high $\delta^{13}\text{C}_{\text{enamel}}$ values have also been recorded for presumed first-generation African migrants at Mexican (Price *et al.* 2012) and Brazilian colonial sites (Bastos *et al.* 2016), and for a single African-born individual from an early colonial context at the site of El Chorro de Maíta, Cuba (Valcárcel Rojas *et al.* 2011; Laffoon *et al.* 2013). It should be noted that $\delta^{13}\text{C}$ of (bone and enamel) bio-apatite is reflective of average whole diets, whereas $\delta^{13}\text{C}$ of (bone and dentine) collagen primarily reflects the protein component of diet (e.g., Ambrose and Norr 1993). As $\delta^{13}\text{C}_{\text{enamel}}$ is expected to primarily reflect dietary energy sources (during childhood), it has been proposed that high $\delta^{13}\text{C}$ amongst African-born individuals indicates origins from the C_4 crop zone of the African Sahel (Schroeder *et al.* 2009; Valcárcel *et al.* 2011; Price *et al.* 2012; Bastos *et al.* 2016), where sorghum and millet (both C_4 plants) have traditionally been staple crops (Harris 1976). The $\delta^{13}\text{C}_{\text{enamel}}$ of the M3, however, is intermediate, somewhat more similar to the $\delta^{13}\text{C}_{\text{enamel}}$ of local indigenous Caribbean populations (Laffoon *et al.* 2013, 2016) and is indicative of a mixed diet of both C_3 and C_4 /marine resources.

It is noteworthy that the $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{13}\text{C}_{\text{enamel}}$ results display identical patterns of clustering of earlier-forming teeth and then a profound change in these values in the later-forming M3 (Fig. 5). This pattern is not evident in the $\delta^{18}\text{O}_{\text{enamel}}$ results, which display much less overall variation (range 1‰) and no clear age-related shift. The $\delta^{18}\text{O}_{\text{enamel}}$ values are lower than those reported for prehistoric Sabans but fall within the range of $\delta^{18}\text{O}_{\text{enamel}}$ for both prehistoric (Laffoon *et al.* 2013, 2016) and historical-period Caribbean populations (Schroeder *et al.* 2009). One possible explanation for this anomaly is the possible influence of a breastfeeding effect on the $\delta^{18}\text{O}_{\text{enamel}}$ value of the M1 (Wright and Schwarcz 1998; Britton *et al.* 2015). As breast milk is enriched in $\delta^{18}\text{O}$, enamel that forms in infancy (e.g., M1) should possess higher $\delta^{18}\text{O}_{\text{enamel}}$ values relative to other teeth in the same dentition (assuming stationary residence). Given that our enamel samples were taken closer to the outer surface than to the enamel–dentine junction and the fact that weaning ages can vary considerably cross-culturally, it is unclear if (or to what extent) the sampled enamel reflects a breastfeeding input. In any case, even if we correct for this effect by subtracting 1.5‰ from the measured value, we obtain a $\delta^{18}\text{O}$ estimate of about –6.0‰ for the M1, which is much lower than the measured values for the other teeth, but does not mirror the overall temporal trend observed in the $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{13}\text{C}_{\text{enamel}}$ data. It should also be noted that the provenance information provided by $\delta^{18}\text{O}$ tends to be generally coarser than that

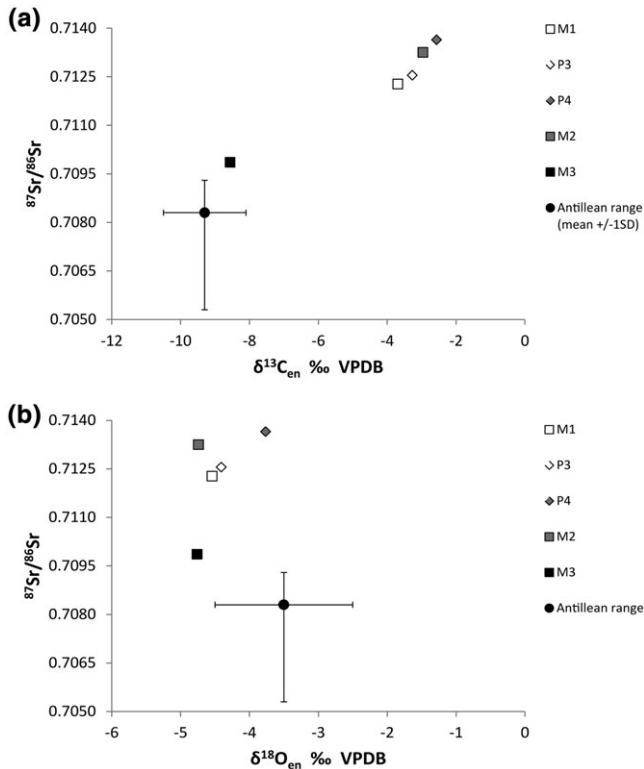


Figure 5 Scatterplots of (a) $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{13}\text{C}_{\text{enamel}}$ and (b) $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}_{\text{enamel}}$ values compared to the reported ranges for the Antilles. Local isotope ranges for the Antilles from Laffoon *et al.* (2012) for $^{87}\text{Sr}/^{86}\text{Sr}$, and from Laffoon *et al.* (2013, 2016) for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$.

provided by $^{87}\text{Sr}/^{86}\text{Sr}$ (Lightfoot and O'Connell 2016), and doubts have been expressed concerning the utility of $\delta^{18}\text{O}$ analysis for human provenance research especially within and between tropical regions (Price *et al.* 2012).

The dentine collagen $\delta^{13}\text{C}_{\text{dent}}$ and $\delta^{15}\text{N}_{\text{dent}}$ results (Table 2) display a high degree of variation overall, but most of the variation can be accounted for by the M1 dentine sections (Fig. 6). The $\delta^{13}\text{C}_{\text{dent}}$ and $\delta^{15}\text{N}_{\text{dent}}$ values of dentine sections from the M2 and M3 are much more clustered relative to the overall data set, with the exception of the first (coronal) dentine sample of the M2, which overlaps temporally with the M1 root formation period. The overall trend is a net decrease in $\delta^{13}\text{C}_{\text{dent}}$ and a net increase in $\delta^{15}\text{N}_{\text{dent}}$ over time, and large ranges in both $\delta^{13}\text{C}_{\text{dent}}$ (~7‰) and $\delta^{15}\text{N}_{\text{dent}}$ (~5‰) values are observed across the dentine profiles. These differences are much greater than would be expected simply on the basis of age-related dietary change throughout childhood and suggest that the proposed migration for this individual was linked to dramatic shifts in diet and foodways.

The high $\delta^{13}\text{C}_{\text{dent}}$ values obtained from earliest-forming dentine collagen samples of the M1 are higher than measured bone or dentine collagen $\delta^{13}\text{C}$ values from indigenous populations of the Caribbean (Laffoon *et al.* 2016 and references therein), which provides further indication of non-local dietary practices for this individual. Similar $\delta^{13}\text{C}_{\text{dent}}$ and $\delta^{15}\text{N}_{\text{dent}}$ values have, however, been observed for dentine collagen from African-born individuals at colonial sites in Brazil (Bastos *et al.* 2016), Barbados (Schroeder *et al.* 2009) and Cuba (Laffoon unpublished data). The

Table 2 Sampling information and isotope results for dentine collagen

Laboratory ID	Type	Element	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	C:N ratio
SB007C	M1	4.6	-9.6	10.1	3.4
SB007C	M1	4.6	-10.4	9.9	3.4
SB007C	M1	4.6	-13.3	10.2	3.4
SB007C	M1	4.6	-16.6	11.8	3.4
SB007C	M1	4.6	-14.6	12.1	3.4
SB007C	M1	4.6	-12.6	12.3	3.3
SB007C	M1	4.6	-15.7	13.7	3.4
SB007C	M1	4.6	-15.1	14.2	3.4
SB007A	M2	4.7	-12.8	11.5	3.3
SB007A	M2	4.7	-14.4	13.4	3.2
SB007A	M2	4.7	-14.5	14.1	3.3
SB007A	M2	4.7	-15.1	14.4	3.3
SB007A	M2	4.7	-15.9	14.9	3.4
SB007A	M2	4.7	-15.3	14.7	3.3
SB007A	M2	4.7	-15.3	14.4	3.3
SB007A	M2	4.7	-14.9	14.3	3.2
SB007A	M2	4.7	-13.8	14.6	3.2
SB007A	M2	4.7	-13.8	14.0	3.3
SB007B	M3	2.8	-15.0	14.6	3.4
SB007B	M3	2.8	-13.9	14.7	3.4
SB007B	M3	2.8	-14.5	14.8	3.4
SB007B	M3	2.8	-15.3	14.6	3.4
SB007B	M3	2.8	-15.7	14.2	3.4
SB007B	M3	2.8	-15.2	14.4	3.5
SB007B	M3	2.8	-15.7	14.4	3.6
SB007B	M3	2.8	-16.2	14.3	3.6

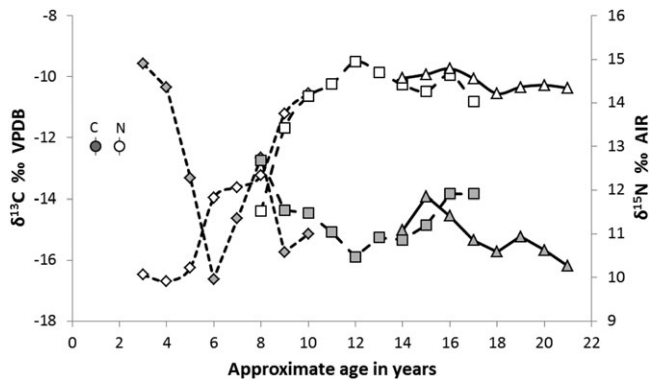


Figure 6 $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of serially sampled dentine collagen sections plotted against approximate age of formation: filled symbols, $\delta^{13}\text{C}$ values; open symbols, $\delta^{15}\text{N}$ values; \diamond , M1; \square , M2; \triangle , M3.

main cluster of $\delta^{13}\text{C}_{\text{dent}}$ (about -16% to -14%) and $\delta^{15}\text{N}_{\text{dent}}$ ($\sim 13.5\text{--}15\%$) from the later-forming M2 and M3 samples display substantial overlap in $\delta^{13}\text{C}$ but are more elevated in $\delta^{15}\text{N}$ than indigenous Caribbean populations (Laffoon *et al.* 2016). Compared to later enslaved Caribbean

populations, this main cluster has similar $\delta^{15}\text{N}$ but lower $\delta^{13}\text{C}$ than Barbados (Schroeder *et al.* 2009); somewhat higher $\delta^{15}\text{N}$ than enslaved individuals from Antigua (Varney 2003) and Montserrat (Sparkes *et al.* 2012); and is most similar to the population from Ste Marguerite, Guadeloupe (Sparkes *et al.* 2012). Overall, these patterns seem to indicate that there was substantial geographical, chronological and cultural variation in the diets of African slaves, both in their African homelands but also within colonial Caribbean contexts.

Given the collagen results and the highly elevated $\delta^{13}\text{C}_{\text{enamel}}$ values of the earlier-forming teeth, we suggest that during early childhood (represented by the first few M1 dentine samples) this individual's diet was dominated by C_4 carbohydrates as the primary energy source and that dietary protein was derived from a mix of plant and terrestrial animal protein sources. As reflected in the other dentine sections of the apical M1, M2 and M3, there was an apparent dramatic shift that occurred during childhood to a diet with much greater contributions from C_3 plants and a much higher reliance on marine protein sources.

When correlating these isotopic profiles to the estimated time of tissue formation, it is important to note that because the sampling of the root collagen followed the CEJ, the intra-coronal dentine was not sampled and therefore the serial profile does not capture the very beginning of the root formation age (Burt and Garvie-Lok 2013). Fairly large changes (as high as 3‰ in $\delta^{13}\text{C}$ and 1.8‰ in $\delta^{15}\text{N}$) in isotope values between adjacent dentine sections indicate that dietary change was fairly pronounced and rapid. The dentine isotope profiles plotted by approximate age indicate that the largest change in dentine collagen isotope values (and thus diet) seems to occur approximately between the ages of 4 and 12 years and thereafter both the $\delta^{13}\text{C}_{\text{dent}}$ and $\delta^{15}\text{N}_{\text{dent}}$ profiles become more stable. These age estimates agree well with the estimated age of transatlantic migration inferred from the enamel isotope results (~8–15 years), if we assume that this occurred during the formation of the M3 enamel. Where the dentine profiles overlap in developmental age, the isotope ratios are very similar, usually within error of each other, a fact that provides the strongest evidence to date in support of the initial conclusion that the teeth (or at least the three molars) derive from the same individual.

Recent research has demonstrated that short-term dietary changes are reflected in carbon and nitrogen isotope values of various tissues (Hulsemann *et al.* 2009; Beaumont *et al.* 2013, 2015; D'Ortenzio *et al.* 2015; Lehn *et al.* 2015; Beaumont and Montgomery 2016). To date, several archaeological applications using stable isotope analyses of serially sampled dentine collagen have focused on questions concerning childhood dietary patterns, including the timing of weaning processes in the past (Eerkens *et al.* 2011; Beaumont *et al.* 2013, 2015; Montgomery *et al.* 2013). Forensic isotope analyses of incrementally growing hair tissue samples indicate that such data can be used to identify periods of malnutrition, undernutrition and starvation, in addition to recovery from these conditions (Hatch *et al.* 2006; Mekota *et al.* 2006; Neuberger *et al.* 2013). More specifically, a pattern of divergent carbon and nitrogen isotope values (opposing covariance; Beaumont and Montgomery 2016) has been observed with $\delta^{13}\text{C}$ values positively correlated with body mass index (BMI) and $\delta^{15}\text{N}$ values negatively correlated during bouts of nutritional stress (Hatch *et al.* 2006; Mekota *et al.* 2006; Neuberger *et al.* 2013). The opposite pattern has been observed when individuals recover from these periods of stress as BMI increases (Mekota *et al.* 2006). A comparable pattern has been documented by stable isotope analyses of incremental dentine collagen (utilizing a similar approach to this study) amongst individuals suffering from famine (Beaumont and Montgomery 2016).

In light of these patterns and the observed association between the estimated age at migration and the age of abrupt dietary change for the individual (SB007) in this study, an alternative but not mutually exclusive interpretation of the combined results is that the increase in $\delta^{15}\text{N}$ values

and decrease in $\delta^{13}\text{C}$ between the earlier- and later-forming tissues reflects an acute episode of nutritional and/or physiological stress. It is perhaps not overly surprising that forced migration during childhood, especially in the context of the transatlantic slave trade, could profoundly impact dietary intake, including leading to both acute bouts of under- or malnutrition. However, in consideration of the observation that the dentine collagen isotope profile shows no sign of recovery (i.e., persistent opposing covariance) in that the $\delta^{15}\text{N}$ values remain high and the $\delta^{13}\text{C}$ remain low until the end of the dentine sequence corresponding to early adulthood (~20–24 years of age), it is possible that the condition of undernutrition was followed by adaptation to 'local' dietary patterns and permanent dietary change as demonstrated by the seemingly stable dentine stable isotope profile for the M3.

CONCLUSIONS

In summary, the enamel and dentine collagen multiple isotope data, in conjunction with the cultural, spatial and chronological contexts of the remains and associated materials, are highly suggestive of African origins and migration from Africa to Saba. Based on estimates of the timing and age of crown enamel mineralization and root formation, we estimate that the forced migration occurred during childhood and may have involved more than one migration. These results provide direct empirical evidence substantiating documentary records indicating the targeting of children for enslavement and trans-oceanic transport to the New World. Based on the combined isotope results, we propose that individual SB007 may have originated from the C₄ crop zone associated with north-central Africa, but we acknowledge that more research is required to further constrain this individual's natal origins.

Importantly, this individual's (forced) migration corresponded with a distinct and rapid change in dentine collagen isotope values possibly reflecting the stress of the forced migration process, adaptations to Caribbean enslaved African dietary regimes or both. The long-term dietary changes would have involved not only alterations in the relative proportions of different food groups but also the likely absence of accustomed foods and introduction of a wide range of new food items. These patterns highlight the resilience of this individual to the stresses of long-distance migration, enslavement and adaptation to new environmental, cultural and culinary conditions during childhood, based on the observation that he/she survived these experiences into adulthood. Although this is not the first study to link childhood changes in diet and foodways to migration (Beaumont *et al.* 2013), it is to the best of our knowledge the first to do so by combining multiple isotope analyses of dental enamel with stable isotope analyses of serially sampled dentine collagen and to explicitly identify a potential marker for the stress of forced migration in the bioarchaeological record.

This study demonstrates the abundance and diversity of relevant information that can be obtained from utilizing a contextualized multi-isotope approach, and we note that even skeletal remains with incomplete and limited element representation can still yield valuable information concerning various aspects of individual lifeways. This research is partly inspired by earlier isotopic life history approaches (e.g., Sealy *et al.* 1995; Cox and Sealy 1997) and represents an example of the increasing application of innovative bioarchaeological advances to studies of the slave trade, diasporas, migrations and individual life histories (Goodman *et al.* 2004; Schroeder *et al.* 2009; Nystrom *et al.* 2011; Price *et al.* 2012; Laffoon 2013; Bastos *et al.* 2016; Kootker *et al.* 2016). Future research will focus on obtaining more relevant information concerning this individual (e.g., radiocarbon dating, aDNA analyses) as well as revising and expanding the approach to other similar diasporic contexts. Lastly, it should be noted that the

phenomena of burial caches within enslaved African contexts in the New World and the social and cultural implications of these findings are the focus of another paper.

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