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Earliest evidence of sedentism in the Antilles: Multiple isotope data from Canímar Abajo, Cuba

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The early populations that inhabited the Antilles were traditionally understood as highly mobile groups of hunters/fishers and gatherers. Although more recent data have demonstrated that some populations engaged in the production of domestic plants and cultivars, questions remain about other aspects of their lifeways, including whether the adoption of domesticates was accompanied by a decrease in residential mobility. The level of sedentism in a population is an instrumental variable to understand community social relations and complexity, adaptations, and lifeways. Here, we combined enamel strontium ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O_{en}$), and carbon ($\delta^{13}C_{en}$) isotopes of 44 human teeth from the site of Canímar Abajo—where the oldest human remains from the insular Caribbean have been reported—to examine the mobility patterns of early Antillean groups. In contrast with traditional narratives, the homogeneous strontium isotope values observed in most individuals from the older funerary area of the site (cal. BC 2237–790) were consistent with the pattern expected for a sedentary population subsisting primarily on local resources obtained close to the coast. The isotopic evidence reveals that between cal. AD 403–1282, the mound was reused for funerary practices by both local communities and nonlocal individuals. The evidence suggests that this period saw higher population mobility, with influxes of individuals from more distant locations and diverse dietary and burial traditions. The isotope results from Canímar Abajo provide the earliest isotopic evidence of populations with low-level residential mobility in the Antilles.

Caribbean archaeology | archaic age lifeways | isotope analysis | mobility

Significance

The first peoples of the insular Caribbean were traditionally depicted as hunter/fisher–gatherer societies with high residential mobility. In this study, isotope analysis of 44 human teeth from the Canímar Abajo site provided the earliest direct evidence of a greater degree of sedentism in the Antilles. In contrast to previous accounts, the combination of enamel strontium, oxygen, and carbon isotopes indicated that between cal. BC 2237–790, the individuals buried at the site had a mixed C_3/C_4 diet and spent their lives exploiting and cultivating local resources near the locality. These results suggest that at least some of the first groups to settle the Antilles were more sedentary than previously recognized.

The early settlers of the insular Caribbean were traditionally understood as small bands of highly mobile groups that based their subsistence on readily available natural resources obtained through gathering, hunting, and/or fishing, without agriculture or ceramic production (1–3). New theoretical and methodological approaches to reconstruct human ecodynamics have promoted a general model shift that has substantially modified traditional views about these early societies (4). Ceramics, for instance—previously thought to be brought to the islands by later ceramic groups—are now considered to have been a widespread phenomenon in the early archaeological horizons of the area since at least cal. 550 BC (5). Additionally, while earlier accounts characterized these populations as non-agricultural food foragers (1, 3, 6), more recent paleobotanical data have demonstrated that some populations engaged in the production and consumption of non-native species originating from the continental mainland, such as *Zea mays* (maize), *Ipomoea batatas* (sweet potatoes), *Phaseolus vulgaris* (common beans), and *Manihot esculenta* (manioc) (7–11). Whether selected elements of a farming economy were used for those communities while retaining the mobile lifeway considered to be characteristic of hunter-gatherers, or whether the adoption of horticultural practices was accompanied by a decrease in residential mobility, is currently unknown. Some authors have suggested reduced mobility based on the large size of some shell middens (1) and the assumption or identification of horticultural practices in some early groups (12). However, the size of shell middens is not a direct indicator of long-term residential stability since shells can be accumulated in relatively short periods of time (13). In addition, ethnographic studies support the idea that subsistence strategies do not determine mobility and that horticulturalists are not exclusively sedentary (13, 14). Recently, a study of five individuals of the Ortiz site in Puerto Rico suggested that early groups from the island may have been less mobile than previously thought based on the observation of moderate variability in strontium isotope values and the repeated use of a mortuary space over centuries (15).

Nomadism and sedentism represent the extremes of a mobility continuum, mobility being the movement of a group through space (14). According to Rice (16: 97), "Sedentary settlement systems are those in which at least part of the population remains at the same

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location throughout the entire year." Movement exerts strong influences on population culture and society (13). The level of sedentism in a population is an instrumental variable to understand community social relations and complexity, adaptations, and lifeways. Long-term residential stability creates new potential for interpersonal conflicts, changes in food storage, trade, territoriality, disposal patterns, dwellings, social and gender inequality, sex division of labor, changes in demography, and increased transmission of communicable diseases; it also influences cultural notions of privacy, individuality, and cooperation (13, 14, 17). Although isotopic and paleoethnobotanical analysis has allowed the reevaluation of subsistence strategies of early Antillean groups, the traditional assumptions about their assumed high mobility have not been examined in a representative sample. In this paper, we combine enamel strontium ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O_{en}$), and carbon ($\delta^{13}C_{en}$) isotope values to evaluate the mobility patterns and lifeways of individuals from the site of Canímar Abajo, where the earliest radiocarbon-dated human remains from the insular Caribbean have been reported [cal. BC 2232–1898 (2σ)] (18). The site is a symbolic space that was used for mortuary practices over thousands of years, which indicates that human groups maintained a link with the territory and the site as a persistent place (19). The early occupation and the density of burials at Canímar Abajo provide archaeologists the unique opportunity to examine the mobility and lifeways of early groups that populated the Antilles.

The Canímar Abajo Site

Isotope analyses of 44 human teeth from 26 individuals from the site of Canímar Abajo in Cuba were conducted to assess the mobility of early populations from the Antilles. The site has the earliest and longest occupation of any known funerary site from the insular Caribbean (20). It is in the north coastal area of Matanzas Province in Cuba, approximately 40 m from the southwestern bank of the Canímar River (23°02'16" N and 81°29'47" W) (Fig. 1). The site has two funerary areas, separated by a shell midden, with distinct contextual features (*SI Appendix*, Fig. S1). The older cemetery (OC), under the shell midden, formed at least between cal. BC 2237–790 (2σ), and the younger cemetery (YC) formed from cal. AD 403–1282 (2σ) (18). A carbon sample found in the shell midden (UNAM-0715) yielded a date of cal. BC 5480–5380 (2σ), which placed Canímar Abajo as one the oldest archaeological sites from the Antilles (17, 20). Based on the material culture and context, the site would be classified as *Preagroalfareros* (preagricultural pottery makers) (21), *Ciboney* (1), or *Apropiadores* (appropriators) (12) under the traditional framework of Cuban archaeology, which is roughly equivalent to what is considered the Archaic Age in the rest of the Antilles.

Isotope Analysis and Mobility in the Precolonial Antilles

The Antilles is an ideal region for the application of isotope analyses owing to its geological and ecological diversity (22). The analysis of strontium isotopes to identify people's mobility is based on the principle that strontium isotope values in terrestrial ecosystems are predominantly conditioned by geolithology (23). The ratios of $^{87}Sr/^{86}Sr$ do not fractionate as the element is transferred from the source rock to the biosphere in low-temperature biogeochemical processes (24). Thus, the soil and groundwater strontium isotope ratios are transferred to plants and to animals that consume them. Given the inputs of marine-derived strontium (e.g., from sea spray, precipitation) into terrestrial ecosystems in islands and coastal settings, bioavailable $^{87}Sr/^{86}Sr$ is not simply reflective of geological $^{87}Sr/^{86}Sr$ (25). In most near-coastal settings, local bioavailable $^{87}Sr/^{86}Sr$ reflects a mixture of the two major sources of strontium: bedrock, which is locally variable, and marine, with a uniform $^{87}Sr/^{86}Sr$ of ~0.7092 (22). Large-scale datasets of baseline $^{87}Sr/^{86}Sr$ values derived from diverse sample types (e.g., modern flora, modern and archaeological fauna, soil, water) indicate that the insular Antillean is characterized by bioavailable $^{87}Sr/^{86}Sr$ values from around 0.7055 to 0.7095, except for some areas of the continental islands of Trinidad and Tobago, where $^{87}Sr/^{86}Sr$ is slightly higher (25). The larger and more geologically complex islands of the Greater Antilles, such as Cuba, have bioavailable $^{87}Sr/^{86}Sr$ ranges that overlap most of the entire Antillean range (22, 25).

The lithology hosting the three sites within the Canímar Valley is generally composed of Pliocene–Miocene sedimentary units (26). The Canímar Abajo site is underlain by the Jaimanitas Formation, a fossiliferous/biodetritic limestone that includes a calcareous sandstone unit with marl interbeds (Fig. 1). The Canímar Formation forms the bedrock for the Solapa Cristales site. It is an organic limestone with lenses of calcareous sandstone, conglomeratic marls, and clays. The Carolinas II site is situated within the Guines Formation, a fossiliferous/biodetritic limestone interbedded with calcareous sandstones (27). Strontium isotope ratios near the three sites are generally expected to range between 0.708 and 0.709 (25, 28). The upland areas immediately surrounding the Canímar Valley sites (west, south, and east) are composed of Cretaceous–Tertiary volcanic arc and ophiolite complex rocks (29) (Fig. 1). These older upland rocks are anticipated to have lower $^{87}Sr/^{86}Sr$ values in the range of 0.705 to 0.708, like the values previously reported for much of the interior Greater Antillean islands (22, 25).

Oxygen isotopes represent a complementary paleomobility proxy in many regions (30). Oxygen isotope ($\delta^{18}O$) values in human skeletal remains generally reflect variation of $\delta^{18}O$ in consumed water sources, which is dominated by local water sources for most archaeological contexts, while $\delta^{18}O$ values in precipitation are primarily conditioned by climatic (temperature) and geographic (e.g., latitude, altitude, distance from coast) factors (31). The use of oxygen isotopes as a paleomobility proxy is complicated by the wide range of other biological and cultural processes that can potentially impact skeletal $\delta^{18}O$ values, including seasonality, breastfeeding, and cooking (31). In general, oxygen isotopes are better suited for identifying long-distance migrations to the Caribbean, as opposed to short-distance movements, and are best viewed as a complementary proxy when combined with strontium isotopes and other lines of independent evidence (32).

Carbon isotope ($\delta^{13}C$) analysis is one of the most employed methods for reconstructing paleodietary patterns in bioarcheological research and has been extensively applied in Caribbean archaeology (e.g., 11, 33–37). Previous research has demonstrated a clear spatial structure in the patterning of stable isotope values (carbon and nitrogen) based on biogeographic principles (34). For example, analyzed populations on smaller islands, especially in the Lesser Antilles and Bahamian archipelago, have generally possessed higher collagen carbon and nitrogen isotope values than those from the larger islands of the Greater Antilles (34). Considerable variation in stable carbon isotope values—and, hence, dietary practices—has also been observed within and between different islands and archipelagoes, which has been attributed to both cultural and ecological considerations (34–38). This spatial patterning thereby permits stable carbon isotope values, often used for dietary studies, to also be used as a supplementary proxy for human mobility studies in the Caribbean region (36, 39).

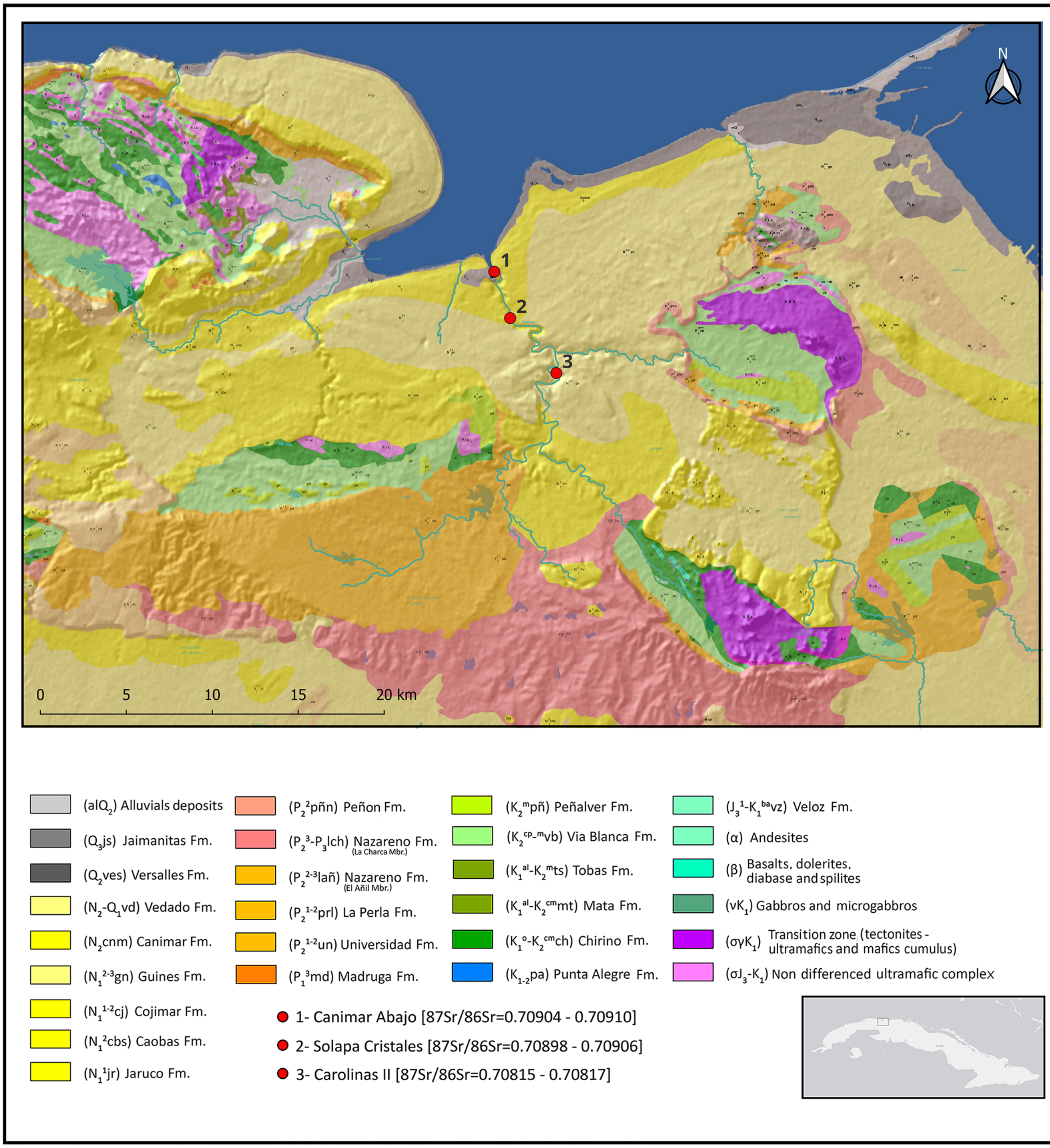

Fig. 1. Geological map of Matanzas, Cuba. Location of the Canímar Abajo, Solapa Cristales, and Carolinas II sites with the bioavailable range. Fm: Formation; Q: Quaternary; N: Neogene; P: Paleogene; K: Cretaceous; J: Jurassic. Elaborated by L.M. Viera Sanfiel.

If Canímar Abajo populations were as mobile as described by traditional Caribbean archaeology, then we would expect the individuals' teeth to have $^{87}Sr/^{86}Sr$ values covering the range between 0.705 and 0.709, in combination with high variability in both $\delta^{18}O$ and $\delta^{13}C$ enamel values.

Results

The isotope results are summarized in Table 1 and detailed in *SI Appendix*, Table S1. The local range of bioavailable $^{87}Sr/^{86}Sr$ in the Canímar Valley was found to be between 0.70816 and 0.70909 (Ave: 0.70887 ± 0.00040) (Table 1). Hutia samples (native rodent) collected at the archaeological site of Canímar Abajo (CA) (Ave: 0.70907 ± 0.00003) and Solapa Cristales (SC) (Ave: 0.70902 ± 0.00004) had a higher strontium ratio than the sample collected in Carolinas II (0.70816), a site from the higher part of the valley.

Notably, 85% of the older cemetery (OC) individuals' tissues had $^{87}Sr/^{86}Sr$ ratios between 0.70891 and 0.70908. Two individuals, E-117 and E-105, were found to be outliers (*SI Appendix*, Fig. S2), but only E-105 (0.70794) had values outside of the area's range of bioavailable $^{87}Sr/^{86}Sr$ (Fig. 2*A*). Molar teeth of the same individuals that formed at different growth periods had similar $^{87}Sr/^{86}Sr$ values (variation between 0.00001 and 0.00005, *SI Appendix*, Table S1).

A higher variation in strontium isotope ratios was found among samples from the younger cemetery (YC) (range 0.70748 to 0.70917, Table 1). One individual, E-77, was identified as an outlier, with an $^{87}Sr/^{86}Sr$ ratio notably out (0.70748) of the $^{87}Sr/^{86}Sr$ bioavailable range (Fig. 2*A* and *SI Appendix*, Fig. S2). Except for E-94, all individuals had similar $^{87}Sr/^{86}Sr$ values in tissues formed

Table 1. Summary of $^{87}Sr/^{86}Sr$, $\delta^{18}O$, and $\delta^{13}C_{en}$ values from Canímar Abajo individuals and the hutia samples from the Canímar Valley

Summary	$^{87}Sr/^{86}Sr$	$\delta^{18}O$ (‰)	$\delta^{13}C_{en}$ (‰)
Older cemetery (N = 23, 13 individuals)			
Total ave (SD)*	0.70895 (0.00027)	−4.44 (0.68)	−10.17 (1.60)
Infants (I, M1), N = 10			
Ave (SD)	0.70892 (0.00035)	−4.11 (0.90)	−10.36 (1.23)
Max/Min	0.70908/0.70794	−2.33/−4.92	−9.30/−13.63
Children (C, M2), N = 7 (2 for Sr)			
Ave (SD)	0.70905 (0.00004)	−4.77 ± (0.27)	−10.34 (2.39)
Max/Min	0.70908/0.70902	−4.40/−5.21	−7.46/−13.64
Juveniles (M3), N = 6			
Ave (SD)	0.70898 (0.00014)	−4.60 (0.17)	−9.56 (0.96)
Max/Min	0.70908/0.70870	−4.37/−4.81	−8.37/−10.77
Younger cemetery (N = 21, 13 individuals)			
Total Ave (SD)*	0.70869 (0.00044)	−4.17 (0.68)	−10.60 (2.64)
Infants (I/M1), N = 9			
Ave (SD)	0.70884 (0.00024)	−3.93 (0.42)	−10.14 (2.70)
Max/Min	0.70917/0.70846	−3.15/−4.55	−4.01/−13.35
Children (C/M2), N = 7 (5 for Sr)			
Ave (SD)	0.70857 (0.00070)	−4.33 (0.92)	−11.14 (2.97)
Max/Min	0.70911/0.70748	−3.01/−5.76	−7.41/−14.36
Juveniles (M3), N = 5			
Ave (SD)	0.70855 (0.00044)	−4.54 (0.57)	−10.72 (2.24)
Max/Min	0.70905/0.70807	−3.91/−5.01	−8.99/−13.25
Hutias (N = 5, 5 hutias)			
Total ave (SD)	0.70887 (0.00040)	−4.04 (1.65)	−14.48 (0.86)
Max/Min	0.70909/0.70816	−2.69/−6.75	−13.20/−15.20

*Outliers included.
I: Incisor, C: Canine, M1, M2, and M3: Permanent first, second, and third molars.

at different periods of growth (variation between 0.00003 and 0.00016) (Fig. 2*A* and *SI Appendix*, Table S1). In the case of E-94, the canine had $^{87}Sr/^{86}Sr$ values consistent with the bioavailable range of the Canímar Abajo fauna, while the M3 is slightly out of the bioavailable $^{87}Sr/^{86}Sr$ range nearby the site (Δ 0.00093; Fig. 2*A* and *SI Appendix*, Table S1). Statistically significant variation in $^{87}Sr/^{86}Sr$ was found among individuals from the OC, those from the YC, and the hutias from Canímar Abajo and Solapa Cristales ($H = 7.75$, df = 2, $P = 0.02$). Post hoc comparisons showed statistically significant differences between YC individuals and both OC ($P = 0.02$) and the hutia samples ($P = 0.05$). No statistically significant differences were observed between OC individuals and the hutia samples ($P = 0.39$).

Samples from the OC and YC showed low variation in oxygen isotope ($\delta^{18}O$) values (OC: Min: –5.21‰; Max: –2.33‰; YC: Min: –5.76‰; Max: –3.01‰). When $\delta^{18}O$ values are controlled by type of tooth in the OC, more variation is explained by the higher $\delta^{18}O$ values observed in some tissues formed during infancy (first molar and incisor) that were identified as outliers (E-105, E-120, and E-131) (Fig. 2*B* and *SI Appendix*, Fig. S2). Teeth from those individuals that formed later in life (second and third molars) had $\delta^{18}O$ values within a more restricted range (Fig. 2*B*). The individual from the YC who had $^{87}Sr/^{86}Sr$ notably out of the local range (E-77) had $\delta^{18}O$ values within the population's range of variation (Fig. 2*B*).

Most individuals from the OC had $\delta^{13}C_{en}$ values between –10.77‰ and –7.90‰ (Fig. 2*C*). Teeth from E-105, one of the individuals whose $^{87}Sr/^{86}Sr$ value was out of the local range, also showed more negative $\delta^{13}C_{en}$ values (first molar –13.63‰, second molar–13.64‰) than other individuals from the OC (Fig. 2 *C* and *D*). The $\delta^{13}C_{en}$ values of E-105, along with that of E-118's third molar, were identified as outliers (*SI Appendix*, Fig. S2). Most OC individuals showed low variation in $\delta^{13}C_{en}$ values among tissues formed at different growth periods (Fig. 2*D*).

Higher dispersion in $\delta^{13}C_{en}$ was observed among individuals from the YC, with values ranging from –14.36‰ to –4.01‰ (Fig. 2*C*). Five individuals had $\delta^{13}C_{en}$ that were notably far from the population mean (E-2, N1, E-9, E-94, and E-77) but were not detected as outliers (e.g., E-2: $W = 0.18$, $P = 0.69$). Two of these individuals had $^{87}Sr/^{86}Sr$ ratios outside of the bioavailable range of the valley. As was the case with the $^{87}Sr/^{86}Sr$ values, E-94's canine had $\delta^{13}C_{en}$ values consistent with the population mean. Compared with other individuals from the YC, E-2 showed the highest $^{87}Sr/^{86}Sr$ ratios of the sample (0.70917) and had a much higher $\delta^{13}C_{en}$ value (–4.01‰) (Fig. 2 *C* and *D* and *SI Appendix*, Table S1). Most YC individuals had similar $\delta^{13}C_{en}$ values between tissues formed at different ages, but some exhibited more variation (e.g., E-10, E-94; *SI Appendix*, Table S1).

Discussion

Individuals from the Older Funerary Area [cal. BC 2237–790 (2σ)]. The clustering of $^{87}Sr/^{86}Sr$ ratios between 0.70891 and 0.70908, observed in most OC individuals, suggests that they obtained their

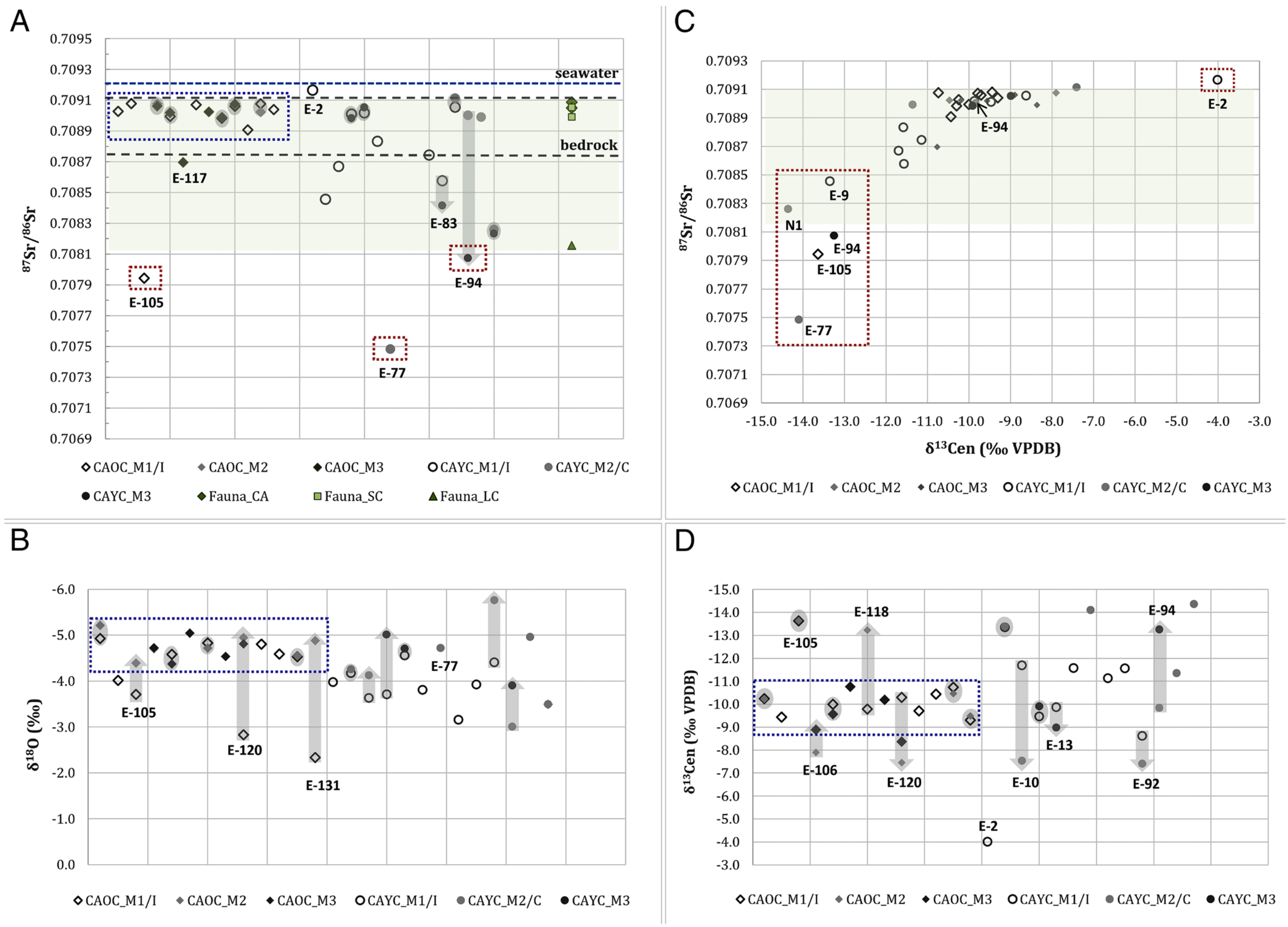

Fig. 2. Isotopic values of individuals from Canímar Abajo. A: $^{87}Sr/^{86}Sr$; B: $\delta^{18}O$; C: $^{87}Sr/^{86}Sr$ vs. δ^{12}Cen; D: δ^{12}Cen values. Shadowed areas represent the range of bioavailable $^{87}Sr/^{86}Sr$ as estimated from the local hutias. The blue discontinued line in A represents the $^{87}Sr/^{86}Sr$ values of seawater. Gray discontinued lines in A represent the average and lower range of local bedrock according to Laffoon et al. (25). Red rectangles represent possible outsiders.

dietary resources from a homogeneous lithological unit, with values consistent with areas of primarily marine carbonate bedrock such as the limestone hills and coastal areas (22). In contrast with the assumed high mobility traditionally associated with early indigenous groups in the Antilles (3, 6), the very homogeneous strontium isotope values observed in most OC individuals are consistent with the pattern expected for a sedentary population subsisting primarily on local resources obtained close to the coast (40). Given the isotopic complexity of the Canímar Valley (Fig. 1), the low variability found in $^{87}Sr/^{86}Sr$ values between teeth formed at different time periods of an individual's life strongly supports that OC people spent their lives obtaining resources from a similar lithological unit. Although the sample size may be considered small, the fact that their values are homogeneous and consistent with each other suggests that the sample is representative of the group.

A sedentary, self-sufficient population (*i.e.*, producing their own food) would be expected to have strontium isotope ratios between two dietary end members - those available in the lithological unit and rainwater - incorporated in different proportions during tooth mineralization (40). The bedrock around the Canímar Abajo site is composed of geologically recent limestone deposits dating from the Pliocene to Quaternary (26), with expected bioavailable $^{87}Sr/^{86}Sr$ values of around 0.70913 ± 00039 (25). These values are consistent with the range of bioavailable $^{87}Sr/^{86}Sr$ obtained from hutia samples collected at the site of Canímar Abajo (1.5 km from the coast) and Solapa Cristales (5 km from the coast) in the Canímar lithological unit (Fig. 1). Strontium isotope ratios of rainwater in coastal ecosystems are very similar to seawater (~ 0.7092) (41). The similarities in $^{87}Sr/^{86}Sr$ between the bedrock around the Canímar Abajo area and the strontium isotopic composition of rainwater indicate a simple two-source mixing and may explain the homogeneity of bioavailable $^{87}Sr/^{86}Sr$ and the restricted range of strontium isotope values observed among OC individuals. In addition to the strontium from the sea deposited in rain, soils in coastal areas may also receive significant contributions of marine-derived strontium from sea splash and sea spray (42). Previous zooarchaeological and isotopic analysis of $\delta^{13}C$ and $\delta^{15}N$ in bone collagen indicate that Canímar Abajo's individuals had a mixed protein diet with substantial contributions of marine resources (10). In contrast to traditional narratives that described the early inhabitants of Cuba as solely food foragers, starch grain analysis revealed that OC individuals engaged in the production and consumption of cultivars including *Z. mays*, *I. batatas*, and *P. vulgaris* among other local and exogenous cultigens and wild plants (10). The amount of strontium that is deposited in an organism's tissues is not simply representative of the proportions of food consumed, but rather is biased by strontium-rich foods, with plants generally contributing the most to strontium isotope ratios recorded in the skeletal tissues of omnivores (43). Although marine resources, including the use of sea salt (44), could contribute to the strontium isotope ratios observed in Canímar Abajo populations, biogenic strontium isotope ratios derived from mixed diets of terrestrial plant and marine protein sources are likely dominated by bioavailable strontium from terrestrial plants. If so, this suggests that OC individuals at Canímar Abajo were consistently obtaining terrestrial strontium from the consumption of locally procured foods, including from farming on soils underlain by carbonate bedrock near the coast.

The type of lithology at Canímar Abajo is also found in other coastal areas of Cuba, which raises the possibility that the homogeneity observed in $^{87}Sr/^{86}Sr$ ratios is the result of groups that moved exclusively along the coast without exploring nearby lithological units. However, the use of the site for mortuary purpose over several centuries [cal. BC 2237–790 (2σ)]—or even millennia, if the YC is included—supports the notion that the individuals had strong ties to the territory and the site as a symbolic place that was used by the community over numerous generations. This makes it unlikely that Canímar Abajo individuals were coastal nomads on a long island like Cuba. The OC individuals are homogeneous in several biological and cultural traits. Recent genomic studies confirmed that they shared a similar ancestry (45), and two individuals (E-108 and E-119) were found to belong to the same family with a third degree of relatedness. In addition, funerary practices of most individuals included in this study were homogeneous, with most interred in an extended position, covered by rocks, and in association with superior layers of charcoal and faunal remains. The low $\delta^{13}C_{en}$ variability of most of the individuals also supports that OC individuals had similar dietary traditions related to a shared identity and to local ecological availability.

Another element that supports that OC individuals resided within the region near the Canímar Abajo site is the low variability observed in oxygen values. Most teeth with $^{87}Sr/^{86}Sr$ values in the range of the local biosphere had $\delta^{18}O$ signatures restricted to the range between −3.5 and −5.0‰ (Fig. 2*B*), which suggests that they obtained their water from a source with similar oxygen isotope values. A range of 2% or less has been proposed to represent a local resident population (46). The consistency of strontium isotope values among most individuals and between different teeth from the same individuals, along with the similarities found between them and the hutias from Canímar Abajo and Solapa Cristales, suggests that they did not rely heavily on exploiting resources, especially plants, from adjacent lithological units, including those characterizing more inland areas (e.g., the higher part of the Canímar Valley), where the bioavailable $^{87}Sr/^{86}Sr$ range was estimated to be considerably lower (Fig. 1). This suggests that although a wider territory could have been exploited for other activities (e.g., sourcing lithic materials), most OC individuals had a low-level residential mobility circumscribed to coastal areas near Canímar Abajo or the areas around the Buey Vaca, San Juan, or Yumurí rivers. This region is very rich in marine, riverine, and terrestrial natural resources, which was probably sufficient to support small- to medium-sized populations.

Two individuals were found to have strontium ratios under 0.7089. One of them, E-117, had an $^{87}Sr/^{86}Sr$ ratio that was still consistent with regional values (Fig. 1*A*). In contrast, the value found in E-105's first permanent molar suggests that during infancy, this individual lived in a location with significantly lower $^{87}Sr/^{86}Sr$ ratios. In addition, this individual's lower $\delta^{13}C_{en}$ value showed that their diet was more dependent on C_3-based resources (C_3 plants, terrestrial animals) than the rest of the population, at least during infancy and childhood (similar to values from the hutias, that are predominantly C_3 plant consumers, Table 1). A previous paleodietary study also found atypical lower $\delta^{13}C_{co}$ values in the femur of E-105 (10), which supports consistent differences in dietary traditions compared with the average population, even in adulthood. Notably, E-105 was one of the last known individuals buried at the OC (cal. BC 1018–807) and was buried in an unusual burial position. An intentional dental modification was identified in their incisors (47). Given the strong ties between the OC community and the Canímar Abajo mound for burial practices, the fact that the individual is buried alongside local members of the community may indicate that despite being a migrant from a different locality, this individual was assimilated into the local community. This suggests that by cal. BC 1018–807, new members were adopted by means of marriage or other social mechanisms.

Individuals from the Younger Funerary Area [cal. AD 403–1282 (2σ)]. The higher variation found in strontium isotope ratios among YC individuals suggests several possibilities: 1) the YC population had a higher level of mobility for foraging and/or farming, covering the territory between the coast and the higher portions of the valley (or other areas with similar isotopic values); 2) individuals from different sedentary communities settled along the Canímar Valley and other areas were burying their dead at the Canímar Abajo mound; and/or 3) the YC individuals belonged to a population comprising locals and individuals from other territories. The reduced variability found in $^{87}Sr/^{86}Sr$ values of teeth formed at different growth periods indicates that most individuals spent their infancy/childhood and adolescence in similar lithological units. This suggests that they did not spend significant amounts of time in lithologically different territories, which could potentially increase the possibility of incorporating isotopically distinct sources of strontium into their dental tissues, which may rule out the possibility of high-residential mobility at least for those individuals.

The $\delta^{13}C_{en}$ values were highly variable among YC individuals (Fig. 2*C*), which suggests that people with different dietary traditions were buried at the site. Some individuals had $\delta^{13}C_{en}$ values consistent with the pattern of mixed diet observed among most OC individuals, while others had much lower $\delta^{13}C_{en}$ values, typical of a diet more dependent on terrestrial C_3 resources. Notably, individuals with more negative $\delta^{13}C_{en}$ values had lower $^{87}Sr/^{86}Sr$ values, which further supports the conclusion that nonlocally born individuals with diverse dietary traditions were buried at the Canímar Abajo YC site. This is also supported by the statistically significant differences in $^{87}Sr/^{86}Sr$ between the YC individuals and both the OC samples and the hutias from lithological units around the site (Jaimanitas and Canímar Formations, Fig. 1). Burial practices also showed higher variability among YC individuals, indicating further diversity. Although most individuals were buried in lateral decubitus position, their hands and feet (including degrees of flexions) and orientations were highly diverse.

Two YC individuals, E-94 and E-77, had $^{87}Sr/^{86}Sr$ values out of the bioavailable range of the Canímar valley and diets more dependent on C_3-based resources. E-77 is one of the last known individuals buried at the site, deposited in a flexed position. This female individual had very low $^{87}Sr/^{86}Sr$ values in comparison with all the other Canímar Abajo burials, indicating that she spent her childhood outside of the locality. According to Chinique de Armas et al. (10), her adult diet was characterized by high $\delta^{13}C_{co}$ values, suggesting a change toward a mixed protein diet more consistent with the average of the YC population. In the case of E-94, the $^{87}Sr/^{86}Sr$ values of this male individual's canine suggest that he was born as a local or spent his childhood in the locality (or similar lithological unit). This is further supported by the oxygen and $\delta^{13}C_{en}$ values of the canine. However, the third molar revealed that by the time of its crown formation (age ~16 y), the individual was exploiting resources from a different lithological unit. He also had lower $\delta^{13}C_{en}$ which is typical of more terrestrial-based diets and C_3 plants. However, high $\delta^{13}C$ collagen values were observed previously, indicating that marine resources gained importance in later periods of this individual's life (10). This individual was buried at the site despite spending at least part of his adolescence in a different location, showing the strong ties between individuals and the burial mound.

One individual, E-2, showed $\delta^{13}C_{en}$ values typical of a diet where C_4 plants and marine resources were predominant. This male individual also showed the highest $^{87}Sr/^{86}Sr$ values of the entire sample set suggesting that he may have been a migrant who was born (and spent his infancy) in a locality with higher strontium isotope ratios and very different dietary traditions (e.g., Mesoamerica). The starches identified in the individual's dental calculus (e.g., maize) (10) further support the connection with this area, although by AD 601–686 AD (date of E-2), plants such as maize, sweet potatoes, and beans were available in other parts of the circum-Caribbean region (8). The presence of several potential migrants and the variability among individuals, not only in their strontium ratios but also their dietary and mortuary traditions, suggest that in contrast with the older component of the cemetery, the more recent funerary area may have been used as a mortuary place for several communities (including nonlocals).

Conclusions

The isotope results of the Canímar Abajo Old Cemetery individuals provide the earliest isotopic evidence of populations with low residential mobility in the Antilles. In contrast to the traditional narratives that characterized early Antillean populations as highly mobile foraging groups that moved over vast territories, the result of this study suggests that between cal. BC 2237–790 (2σ), the individuals buried at the Canímar Abajo shell midden were a relatively homogeneous population in terms of their dietary and burial traditions, spending their lives exploiting and farming local resources nearby the Canímar Abajo site. Contrary to the rigid unilinear evolutionary classification systems operating in Caribbean archaeology, these results suggest that at least some of the first groups that settled Cuba (and possibly the Antilles more broadly) had a higher degree of sedentism than previously recognized. By BC 1018–807, the population had assimilated individuals born in other localities, which may indicate that other groups were moving to the area or that individuals from other localities were accepted into the local population.

The isotopic evidence reveals that between cal. AD 403–1282 (2σ), the mound was reused for funerary practices by both local communities and nonlocal individuals. Higher mobility was present during this period, with influxes of individuals from more distant locations and with much more diverse dietary and burial traditions than in the older cemetery. The greater heterogeneity found during this period makes it difficult to ascertain the patterns of mobility of these communities, but the isotopic results obtained from multiple teeth from the same individuals suggest that most of them spent several years in the same lithological units. The continued use of the funerary area over centuries suggests that the Canímar Abajo mound was a symbolically important persistent place for local and, later, regional communities.

Materials and Methods

Human Sample. Human teeth enamel of 26 individuals from the Canímar Abajo site (OC: 13; YC: 13) was processed for $^{87}Sr/^{86}Sr$, $\delta^{18}O_{en}$, and $\delta^{13}C_{en}$ isotope analysis (Table 1). Seventeen individuals (OC: 9; YC: 8) had more than one tooth available for sampling, allowing a longitudinal study of their mobility and/or diet. The total sample included 44 teeth ($^{87}Sr/^{86}Sr$ was measured in 37 teeth) (Table 1). Sample sizes are always an issue in old sites, which is why they are so valuable. Notably, here, we present results of 13 independent individuals (21 teeth) from cal. BC 2232–800 (2σ) from the oldest known cemetery in the region. Permits to study the sample were granted by the Comisión Nacional de Monumentos de Cuba (PEA 9/19).

Human tooth enamel is not subject to turnover once it is fully formed, retaining the isotopic signals of the period of crown formation (48). Most samples were taken from the first permanent molars (17 teeth), or incisors (2 teeth), for which crown formation occurs during infancy (0 to 3 y) (48). The period of childhood (3 to 7 y) is better represented by second molars (9 teeth) and canines (5 teeth), while the third permanent molars (11 teeth) represent the period of adolescence (48).

Spatial Variation of $^{87}Sr/^{86}Sr$ and Nonlocals. Bioavailable $^{87}Sr/^{86}Sr$ at Canímar Valley was assessed by measuring $^{87}Sr/^{86}Sr$ in the tooth enamel of five hutias from the Canímar Valley (Table 1), a rodent-like mammal from the Antilles, since this approach was found to be a better strategy when studying Caribbean islands settings (25). Archaeological samples were preferred over modern ones to avoid potential recent inputs due to pollutants and the use of fertilizers (23). Hutias from three different sites were included in this study, including two from the Canímar Abajo site (1.5 km from the coast, Jaimanitas Formation), two from Solapa Cristales (3.5 km from the coast, Canímar Formation), and one from Carolinas II (12 km from the coast, Guines Formation) (Fig. 1). In addition, bioavailable, and bedrock, $^{87}Sr/^{86}Sr$ values (predicted and calculated) from the region were used as a baseline (25). Individuals were considered nonlocals when they met three criteria: $^{87}Sr/^{86}Sr$ values were out of the bioavailable range established for the site, they were out of the geoavailable $^{87}Sr/^{86}Sr$ range (seawater - bedrock: Jaimanitas and Canímar Formations), and they were statistically detected as outliers.

Statistics. The Shapiro–Wilk test (W) was used to test normality. When samples were normally distributed, outliers were detected using the Dixon test (Q) (i.e., $\delta^{18}O$, YC: $W = 0.96$, $P = 0.55$; $\delta^{13}C$, YC: $W = 0.94$, $P = 0.28$). For non-normally distributed samples, outliers were identified using boxplots (i.e., $^{87}Sr/^{86}Sr$, OC: $W = 0.48$, $P = 0.00$, YC: $W = 0.89$, $P = 0.03$; $\delta^{18}O$, OC: $W = 0.75$, $P = 0.00$; $\delta^{13}C$, OC: $W = 0.89$, $P = 0.02$). The Kruskal–Wallis (H) test with a Dunn test was used to compare $^{87}Sr/^{86}Sr$ values between individuals and the hutias from the Canímar and Jaimanitas lithological units. The outliers were excluded from the comparison of means.

Isotope Analysis. Samples were processed at Leiden University and measured at the Vrije Universiteit Amsterdam using standard procedures for isotope analyses of archaeological enamel. Dental crowns were mechanically cleaned by removing the outer surface, which is the most susceptible to diagenetic alteration (49). Sample processing included a chemical pretreatment procedure (50), including a wash in 2.5% bleach (NaOCl), and then leaching in calcium acetate–buffered acetic acid (CH_3COOH, pH = 4.75).

Carbon and oxygen isotopes were measured on a Finnigan DeltaPlus IRMS interfaced with a Gasbench II online gas preparation and introduction system. Long-term reproducibility of the international reference material (NBS19) is ±0.1‰ (1σ) for $\delta^{13}C$ and ±0.2‰ (1σ) for $\delta^{18}O$. Results are reported in the δ notation, in parts per thousand (‰) relative to the international VPDB standard. For analysis of strontium isotope ratios ($^{87}Sr/^{86}Sr$), 2 to 3 mg of powdered enamel was dissolved in 3 M nitric acid (HNO_3). The strontium fraction was separated from the matrix via ion-exchange column chromatography using Sr-spec resin (Eichrom). Strontium isotope ratios were analyzed on a ThermoScientific Triton Series multicollector TIMS. $^{87}Sr/^{86}Sr$ ratios were corrected for mass fractionation using an exponential law and an $^{86}Sr/^{88}Sr$ ratio of 0.1194. Analysis of the international standard NBS987 produced a long-term average $^{87}Sr/^{86}Sr$ ratio of 0.71024 ± 0.00004 (2σ) and total procedural blanks (<100 pg Sr) were negligible relative to the strontium content of the samples.

Data, Materials, and Software Availability. All study data are included in the article and/or *SI Appendix*.

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