Isotopic Studies of Human Skeletal Remains from a Sixteenth to Seventeenth Century AD Churchyard in Campeche, Mexico

Diet, Place of Origin, and Age

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CA+ Online-Only Material: Supplement A PDF, Supplement B PDF, and Supplement C

In AD 2000, construction activities in the central plaza of the city of Campeche, Mexico, led to the discovery of an early colonial church and an associated burial ground dating from the sixteenth and seventeenth centuries AD. During the subsequent rescue excavations, the remains of at least 180 individuals were unearthed from the churchyard. We have concluded a series of isotopic studies of these remains to obtain information on diet, status, place of origin, and date of burial. This work involves the application of both light and heavy isotope analyses to both tooth enamel and human bone. Carbon and oxygen isotope ratios were measured in tooth enamel and bone. Carbon and nitrogen isotope ratios were measured on bone collagen. Strontium and lead isotopes were measured in tooth enamel, and the ratios were compared to a large database for the Maya region. Radiocarbon dates were obtained for 10 of the skeletons to evaluate the date of burial and the period of use of the cemetery. The results of our study, interpreted jointly with mortuary information and conventional skeletal examination, provide detailed information on the overall burial population, a sort of collective life history of the deceased individuals. In the context of the historical background, new insights on living conditions, mobility, and diet of the founding generations in the colonial New World are obtained. A new and direct appreciation on life and death in an early multiethnic colonial Spanish town, including its historically invisible sectors—children, women, servants, and slaves—becomes possible.

In the study described here, we examine the isotopic composition of bone and tooth enamel from a number of the individuals buried in an early colonial cemetery in the modern city of Campeche, on the west coast of the Yucatán Peninsula in Mexico. We are interested in questions about diet, status, place of birth, and date of burial. We employ isotopes of carbon, oxygen, nitrogen, lead, and strontium in this study. Carbon isotopes in bone collagen, bone mineral, and tooth mineral have been measured in some of the skeletal remains. We have also measured radiocarbon isotopes in bone collagen for age determinations. Oxygen isotopes have been measured in bone mineral and tooth enamel. Nitrogen isotopes have been measured in bone collagen. Strontium and lead isotope ratios have been assayed in tooth enamel and strontium isotopes in bone mineral. Lead isotope ratios have been measured in a few enamel samples. The isotopic results are examined in light of the contextual evidence of discovery and the biological and biocultural information provided by the analyses of the human remains.

The first sections of this article provide some historical background on the early town of Campeche and the early church that was the focus of religious ceremony and sacred burial. A description of the excavations provides the archaeological and taphonomic context of the human burials in the Campeche plaza cemetery. These and conventional bioarchaeological studies provide the basic attributes of the burial

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population. Previous studies of this skeletal series (Cucina 2010; Cucina, Neff, and Tiesler Blos 2005; Rodríguez 2010; Tiesler 2002; Tiesler and Oliva 2010; Tiesler and Zabala 2001, 2010) shed light on diet, demography, pathological conditions, biological affinity, and body modifications of the burial population. In this paper, these studies have been further detailed and updated to anchor the isotopic data. Discussion of the isotopic studies initially provides some background on the materials sampled and an introduction to the principles and methods employed, followed by presentation of the population's chronology, biological affinities, geographic origins, migration patterns, diet, and living conditions in general. A consideration of the combined data set and interpretation of the results concludes our study. This information adds a human component to an era that today still is understood almost exclusively through historical accounts and particularly underscores the benefits of multiple biogeochemical analyses in bioarchaeological investigations.

A History of Campeche and the Early Colonial Church

San Francisco de Campeche was the first town established by the Spaniards in the Yucatán Peninsula. Its foundation at the end of 1540 or the beginning of 1541 was the first step toward the consolidation of Spanish control over Yucatán and the lands beyond. One year later, the advance of the conquest in the north of the Yucatán culminated with the founding of the new town of Mérida, which would become the administrative capital of Yucatán. The Spanish conquest then continued to the east on the peninsula, and in 1543 the town of Valladolid was established. Finally, in 1544 Salamanca de Bacalar, in the present state of Quintana Roo, became the fourth and last colonial town of the region to be founded during the early decades of the colonization of the New World.[1]

Each of the four towns evolved in a different direction in the years that followed. Mérida became the administrative capital, while Campeche flourished as the major port of the province. Conceived as a center for sea trade and shipyards, Campeche displayed its distinctive urban development from the very start. Within its walled borders, the small population of natives, recruited by the Spaniards from the surrounding environs, coupled with the increasing migrant population from other parts of the Americas, Europe, and Africa meant that the Maya were outnumbered by the Spanish within Campeche's urban core (Lutz and Restall 2005:204–211). As a consequence, local urban customs and lifestyles were distinct from those of the other colonial towns. European assimilation with the Maya was not as common. Instead, relatively more interaction took place with the African portion of the population. In addition, among the different subordinate sectors of urban colonial society—mainly natives, mestizos, and people of African descent—there was ample communication, which soon lead to cultural assimilation and miscegenation (Lutz and Restall 2005; Restall 2010; Zabala 2010). Although always a minority in the Yucatán Peninsula, blacks especially made their presence heavily felt inside Campeche, where they served mostly as enslaved construction and port workers and as servants of the Spaniards (Antochiw 2010:28–30; Rubio Mañé 1938:21). As in other major towns in New Spain, a small but growing number of freed blacks and mulattos also lived and worked in urban Campeche (Lutz and Restall 2005: 194).

Like other new urban centers in the Hispanic New World, Campeche was laid out on a grid that expanded from its main plaza. This square contained the principle church and was lined with its important public buildings and private residences of the founders. Campeche's first church administered to "Spaniards, *mestizos*, *mulattos*, blacks, Indian *naboríos* and seven other Indian tribes" (López de Cogolludo 1954 [1688]: 386–387). This parish church was attended by all people not living in a specific *barrio* (neighborhood), especially in its later years of use, as the population of Campeche expanded in the *barrios* surrounding the original walled town (fig. 1).

The mortal remains of the early generations of Campeche slowly filled the small churchyard, regardless of biological ancestry. Residents of the surrounding neighborhoods were interred in their respective district church cemeteries. The churchyard of San Román, for example, received the bodies of parishioners from the Central Highlands of Mexico living in Campeche (Antochiw 2010). Campeche grew rapidly during the sixteenth and seventeenth centuries, according to the census. Founded by only 30 European conquerors, 40 years later it housed 80 Spaniards and 1,500 natives according to an early listing, in which the mestizo and African inhabitants were not distinguished (Gerhard 1993:81). By 1639, the town incorporated 1,500 Spanish and 5,600 natives, mestizos, and mulattos (Cárdenas Valencia 1937:89). The Hermitage of Our Lady of Guadalupe, later called the Church of the Saintly Name of Jesus, became the primary church and burial place for the black (*morenos*) population. The outlying Franciscan convent administered the sacraments largely to the local Maya natives (fig. 1).

Whereas the blocks around the central plaza of Campeche were reserved for Spanish residents, living spaces for the servant sectors (*barrios*) were created to ensure both segregation and control and to guarantee immediate and permanent services within the urban boundaries (Cárdenas Valencia 1937:89; Contreras Acereto 1983:51–53). Soon, the new *barrios* were inhabited by the native *naboríos*, who had been moved into the town as a labor force for the Spaniards. In addition, the descendants of the Tlaxcaltecans from the Mexican Highlands, who served as auxiliary troops of the army that accompanied Montejo, settled in the city. The segregation of living space also involved the Africans who had obtained their freedom. "Free blacks and *mulattos*," as the sources describe them, were the descendants

1. Archivo General de Indias (Sevilla, España), México, legajo 2999.

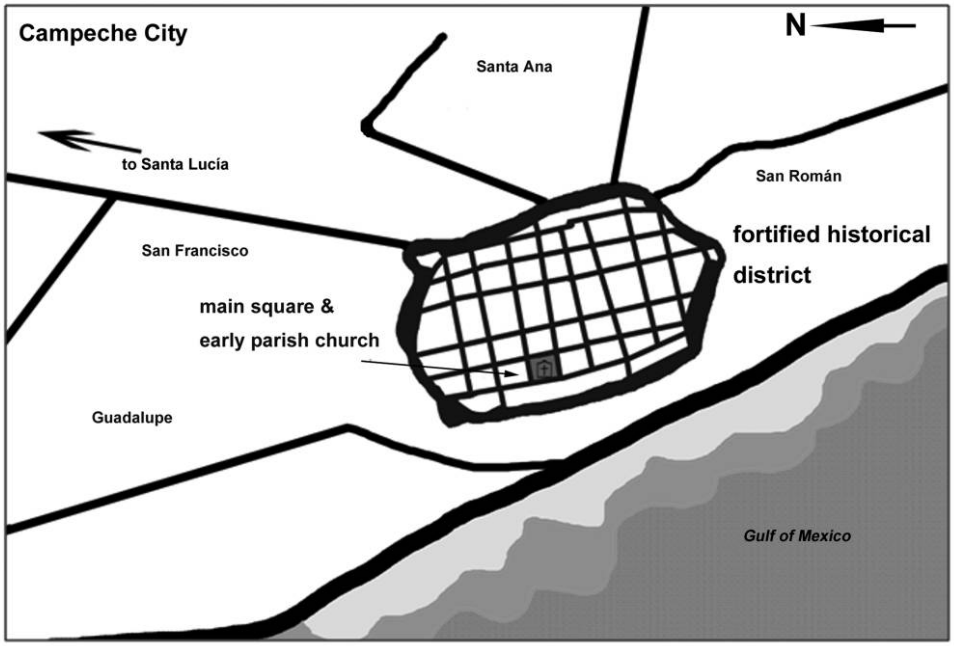

Figure 1. Location of old Campeche, the plaza, and the early parish church in modern Campeche City. The various names refer to early churches or *barrios* in the town (drawing by S. Suzuki).

of the African slaves who had participated in the conquest and, for this reason, were granted their freedom.[2] The Campeche plaza cemetery was the final resting place for many of these individuals, and their story enhances our understanding of life and death in early colonial Campeche.

Excavation of the Campeche Plaza Cemetery

Following the demolition of the early church in the late seventeenth century, Campeche's first central graveyard fell into oblivion, along with the exact location of the church itself. Archaeologists were surprised in the year 2000 when they brought to light the foundations of the early church and the physical remains of those who had been interred in its sanctified ground. This discovery, which turned out to be of great importance for the colonial history of Campeche and for that of the New World in general, was made at a time when the city's historic center was to be officially declared a World Heritage Site by the United Nations Educational, Scientific, and Cultural Organization. The discovery took place during the reconstruction of the old *cabildo* palace that had been torn down decades earlier as part of radical urban renovation efforts. Examination of early city maps revealed that the foundations of the buried structure discovered as part of the reconstruction matched the location of Campeche's pioneer church. This building had been in use during the first century of colonial life in the town, as documented by historical sources as well as a pre–AD 1650 medallion found with one of the burials. This church was the first public structure in Campeche built of limestone (Cárdenas Valencia 1937:89–93). The church remained in place longer than many other buildings. Its existence is documented from the middle of the sixteenth century until almost the last decade of the seventeenth century (Antochiw 1994; Calderón Quijano 1984; Ojeda Mas and Huitz Baqueiro 2010).

During the initial excavations, a series of burials were uncovered within and especially to the southwest of the church itself. The discovery led to an extensive rescue excavation, which lasted 5 months from January to June 2000 and was coordinated by the Mexican National Institute of Anthropology and History under the direction of Heber Ojeda Mas, Carlos Huitz Baqueiro, and Vera Tiesler.

The excavations covered three areas: the stelae fountain next to the bastion known as Our Lady of the Solitude, the remains of the town wall, and the northwest side of the present-day plaza, known as Independence Square (Ojeda Mas and Huitz Baqueiro 2010). Previous excavations had revealed the foundation walls of the church nave, running parallel to the sea at the northern edge of the plaza. Further explorations along the southwestern facade of this structure soon revealed human burials immediately beneath the plaza garden and concrete pavement. Here, trenches were extended to uncover more burials.

During the course of the archaeological work, some 147 burial contexts were recorded, pertaining to at least 180 complete or semicomplete skeletons (Coronel et al. 2001; Tiesler and Zabala 2001, 2010). Most of these ($n = 139$) are located

2. Archivo General de Indias (Sevilla, España), México, legajo 2999.

within the main excavation area of 168 m^2 (fig. 2). According to the burial customs and laws of the Catholic conquerors, the dead had generally been interred within sanctified ground in a supine position with their feet toward the altar of the church (Zabala 2000:193). This is the pattern seen in Campeche's colonial churchyard and in many other coeval circum-Caribbean Hispanic cemeteries (Jacobi 2000; Larsen 1990; Márquez Morfín, Jaén, and Concepción Jiménez 2002; Ojeda Mas and Huitz Baqueiro 2010; Tiesler and Zabala 2010). Notably, coeval slave cemeteries differ from this pattern. The deceased slaves were buried in areas separated from Europeans, and the slave contexts often show evidence of non-Christian burial practices reminiscent of African traditions (Armstrong and Fleischman 2003; Armstrong-Fumero 2010; Handler 1978; Handler and Corruccini 1983).

Old maps and archaeological excavations confirmed that the cemetery belonged to the early inhabitants of this Hispanic town. Its layout corresponds to the norms imposed by the conquerors, who ordered that the deceased be laid to rest in sanctified ground, aligned with the church, and placed in a horizontal, extended position, regardless of sex, age, or place of origin. Such a disposition had been established by Emperor Charles V in the Compilation of the Laws of Indies at the beginning of the conquest. The practice was still prescribed in the Synodal Constitution of 1722, but it was eventually abolished after Mexico gained independence in 1821 (Tiesler and Zabala 2001).

Archaeological, bioarchaeological, and historical research confirms that the burial ground was in use for at least 150 years, from the mid-sixteenth century to the late seventeenth century (Tiesler and Zabala 2010). The overlapping distribution and severe disturbances of many of the graves reflect overcrowding and a general lack of organization in the disposal of the dead. Most of the deceased seem to have been wrapped in a shroud and buried in simple earthen pits. Their burial plots apparently lacked any formal markers. Many of the primary burials have missing parts and were disturbed by subsequent interments. Older graves were frequently disturbed by more recent ones, with parts of the skeletons pushed aside.

The graves in the churchyard at Campeche also stand out because of their early urban and multiethnic quality. The group of burials includes people of European descent, native Mayans, *criollos* (a social class in the caste system of the overseas Spanish colonies, an American-born European, usually of Spanish heritage), and Africans. All shared in the same small churchyard where they were buried indiscriminately of sex, age, or biological ancestry. The cemetery's early date and its central location within the settlement help explain why it was occupied by all segments of Campeche's population, including those subordinated at the service of the Spaniards, both natives and Africans. These individuals must have been baptized, a practice that granted them access to the sanctified ground of the church. Complete religious and ideological assimilation of the colonies was a central goal of the Spanish crown in an effort to implant Iberian society under the watch of the Catholic Church. Already from the beginning of the Spanish Conquest, the Emperor Charles V had proclaimed this practice in the *Recopilación de las Leyes de Indias* (Zabala 2000:195).

After the conclusion of the excavations, an extensive study of the human remains was organized by a team of researchers from the Autonomous University of Yucatán, Mérida, Mexico. To provide a detailed, comprehensive, and integrated account of the findings, an international group of experts in archaeology, taphonomy, biological anthropology, molecular studies, and colonial history was assembled. This multidisciplinary approach has already produced a unique panorama of early colonial life and death in Campeche, the Yucatán Peninsula, and the early colonial New World in general (Tiesler, Zabala, and Cucina 2010). Anchored in different isotopic data sets from the burial population of Campeche's main square, this article sets out to provide a nuanced portrait of life and death in the different segments of early colonial society.

Dating

Radiocarbon dates were obtained from human bone for 10 of the burials from the Campeche cemetery. The information pertinent to these determinations is provided in table 1. Some discussion of these dates is required since there are problems with calibration in this period during the sixteenth and seventeenth centuries AD.

The calibration of ^{14}C dates refers to the conversion of radiocarbon years to calendar years. There is not a 1 : 1 relationship between these two scales because of variation in cosmic radiation and the production of ^{14}C in the atmosphere in the past. Thus, the mathematical curve that describes the relationship between radiocarbon and calendar years is not smooth and linear but is less regular with numerous wiggles. In some parts of the curve, the relationship between ^{14}C and calendar years is almost flat, and thus the same radiocarbon age can be equivalent to several different calendar years. Figure 3 illustrates this using the date Beta 218092 from table 1. The date of 340 in radiocarbon years intercepts the curve at three calendar dates between 1520 and 1620.

The curve is relatively flat in the sixteenth century AD, and for that reason calibration of radiocarbon dates to calendar years is particularly difficult (Buck, Litton, and Scott 1994; Donahue, Olin, and Harbottle 2002). Calibration of the Campeche dates was done using the computer program CALIB 5.1β to produce the cal BC date ranges (at 2σ) shown in table 1 (Blackwell, Buck, and Reimer 2006; Stuiver et al. 1998). Correction for $\delta^{13}C$ values (marine reservoir and/or C_4 plant consumption) has been made in the BP determinations at the radiocarbon laboratories. For most of the dates, the calibration program provided two ranges of dates with a probability of correctness.

In almost every case, the range with higher probability provided an unacceptable date in calendar years prior to the

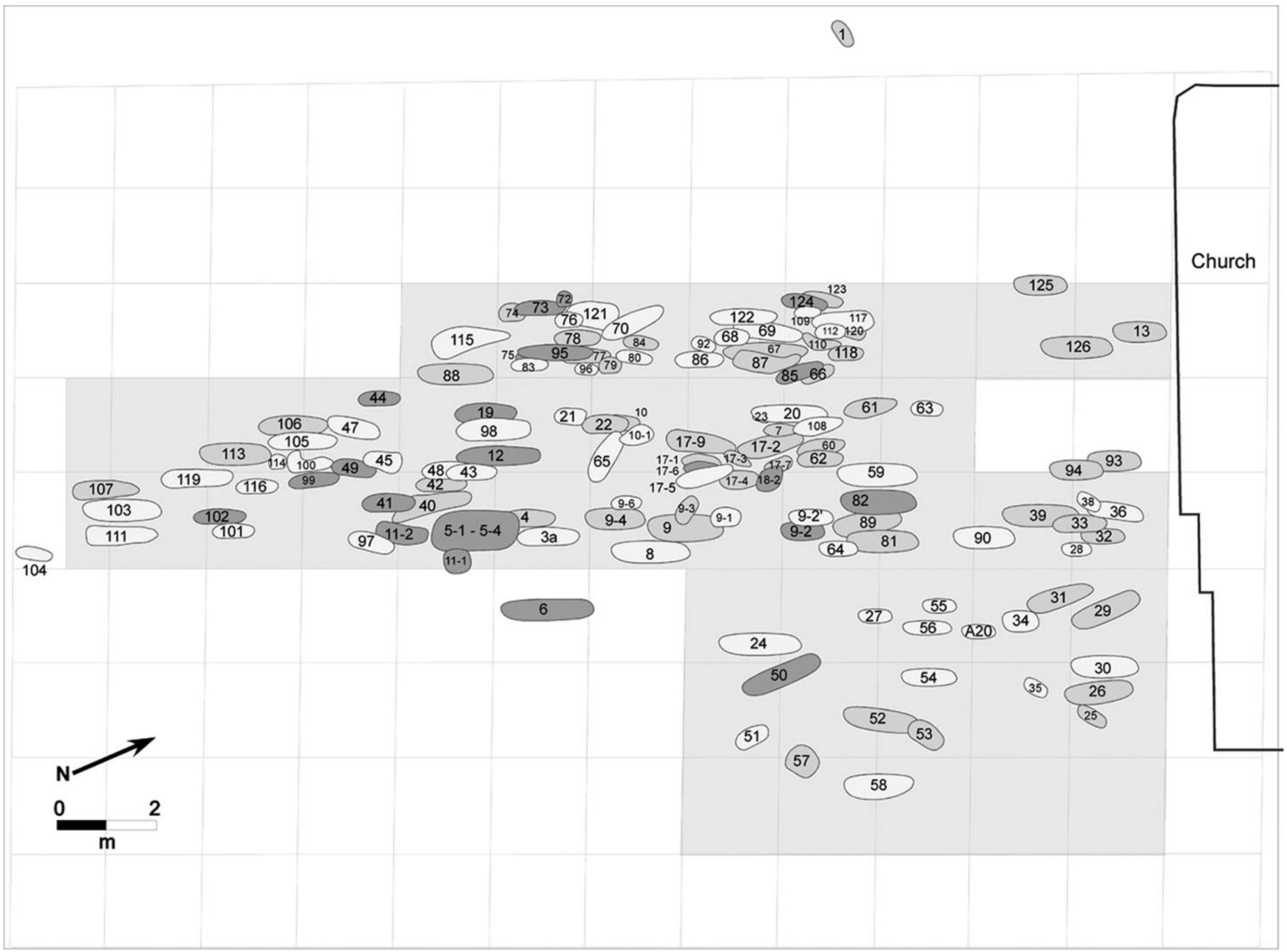

Figure 2. Schematic plan of the location of the graves outside the southwestern facade of the original Campeche church. The shaded graves were sampled for strontium isotope analysis; the darker shading indicates individuals with a nonlocal isotope ratio. The shaded rectilinear area marks the excavation boundary. More of the cemetery lies unexcavated outside this boundary. Disturbances and several of the graves do not appear on this plan. Sampled graves 30, 44, 71, and 128 are not shown. A color version of this figure is available in the online edition of *Current Anthropology*.

Table 1. Radiocarbon measurements, carbon isotope ratios, and cal BC ranges for Campeche burials

Lab no.	Sample ID	Burial no.	Material	$\delta^{13}C$	^{14}C age BP	cal BC (2σ)	% probability
AA74487	F4076	5.3	Bone	−11.5	408 ± 41	1557–1631	.26
AA74488	F4077	9.2	Bone	−9.3	483 ± 41	1393–1474	.96
AA74489	F4078	18.2	Bone	−9.9	383 ± 40	1543–1634	.40
AA74490	F4079	22	Bone	−8.5	400 ± 42	1553–1633	.32
AA74491	F4080	95	Bone	−10.0	376 ± 40	1542–1634	.44
AA74492	F4081	31	Bone	−9.7	379 ± 41	1542–1634	.43
AA74493	F4083	44	Bone	−10.8	414 ± 42	1558–1631	.24
AA74494	F4086	52	Bone	−17.1	383 ± 41	1543–1634	.41
AA74495	F4087	123	Bone	−7.9	319 ± 41	1468–1649	1.0
AA74496	F4177	5.4	Bone	−15.0	426 ± 41	1573–1627	.16
Beta 218092	F4081	31	Bone	−10.5	340 ± 40	1462–1642	1.0

Note. AA74492 and Beta 218092 are duplicate measurements of burial 31.

establishment of the Spanish town of Campeche. The dates for the lower probability range have been listed here (table 1) in all but three cases. Two dates (AA74495 and Beta 218092) were reported with 100% probability that they covered the entire expected span of the cemetery. The date for burial 9.2 (AA74488) does not provide a date range within the historically known period of cemetery use and is either incorrect or may be from a burial dating prior to the establishment of the primitive church and the graveyard. The high strontium isotope ratio (0.7126) for this individual, however, is nonlocal, unknown from Mexico, and suggests that the date is incorrect.

The Spanish town of Campeche was founded near the site of the former Maya town of Ah Kin Pech by Francisco de Montejo in 1541 (Clendinnen 2003; Gerhard 1993). The first Franciscan missionaries arrived in Campeche perhaps as early as 1537, and their first mission was founded 3 years later. Thus, the churchyard was likely not established until 1540 at the earliest. Radiocarbon date ranges prior to that year have been ignored in our study, and the second date range with lower probability, which falls within the historically known period of cemetery use, is provided in table 1. At the same time, as a result of the calibration problems for this period, these date ranges are very wide and cover almost the complete span of time during which the cemetery was in use.

Table 2. Age and sex estimates for the determinable remains of African and non-African segments of the burials from the Campeche cemetery

	African born			Local		
Age group	Total	Male	Female	Total	Male	Female
0–9.9 years	1	. . .	. . .	15	1	. . .
10–19.9 years	5	. . .	2	16	. . .	3
20–29.9 years	5	1	2	20	3	6
30–39.9 years	7	4	2	13	5	2
40–49.9 years	2	1	1	13	6	1
50–59.9 years	0	. . .	. . .	1	1	. . .
Total	20	6	7	78	16	12

Note. The totals differ for age and sex determination because of varying preservation of diagnostic information.

We examined the relationship between radiocarbon age and the distance of the burial from the church walls and found no correlation. The radiocarbon dates from this flat area of the calibration curve are not sufficiently accurate to show a relationship between date of burial and distance from church.

In sum, the radiocarbon determinations (of secondary probability!) largely confirm the use of the cemetery during the latter half of the sixteenth and the first half of the seventeenth century AD. Unfortunately, because of the nature of the radiocarbon calibration curve during this period, more precise dates for the burials that were assessed cannot be determined.

Bioarchaeology of the Burial Population

Conventional skeletal analysis was undertaken to provide information on demography, living conditions, health, nutrition, and artificial body modification. Studies of dental morphology were done specifically to answer questions regarding the origin, ethnogenesis, and biological ancestry of those who shared this small graveyard in death. The following information is summarized from a more detailed study that appears in Tiesler, Zabala, and Cucina (2010).

For skeletal assessment, we followed standard procedures and classifications, as described in Steele and Bramblett (1988) and Buikstra and Ubelaker (1994). To determine the age of adult remains, the individuals were seriated additionally according to the degree of dental wear, and ages were adjusted with those estimated from the auricular surface. Age and sex estimates for the population are provided in table 2. This information is listed for the African and non-African portions of the population on the basis of the isotopic determination of place of origin, presented in a subsequent section. It must be reiterated that the age and sex data are only approximate because of the very poor preservation of the skeletal materials.

CA+ online supplement A, available as a PDF, contains the catalog and bioarchaeological information recorded for these remains from the Campeche cemetery. The information is listed by burial number along with assigned laboratory number; sex; age estimates and range; evidence of cranial or

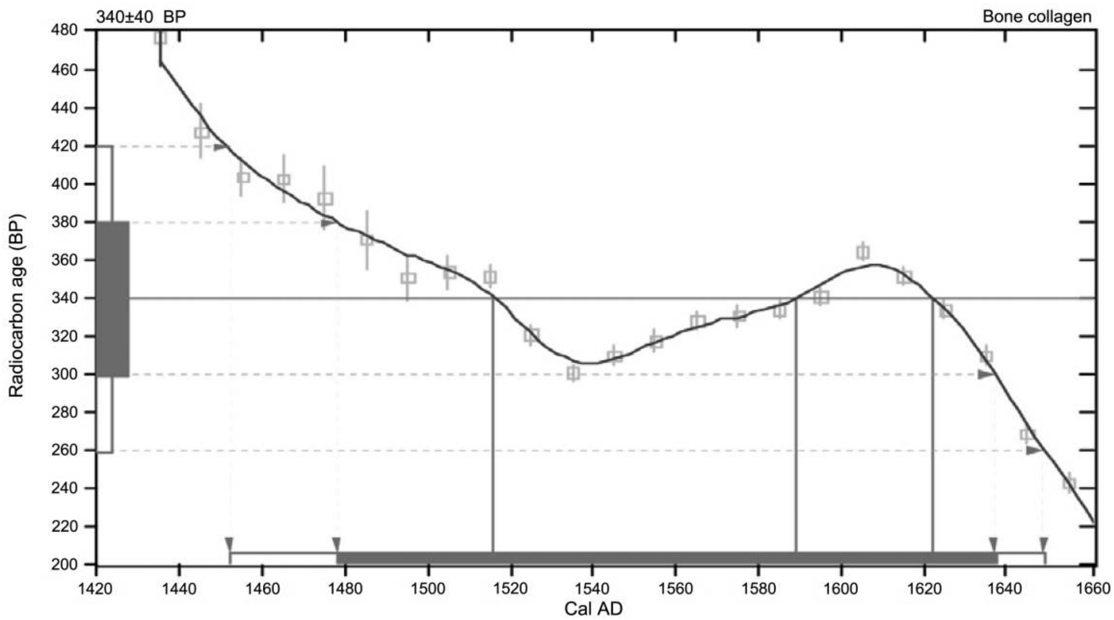

Figure 3. Calibration curve for radiocarbon dates from AD 1440 to 1640. This part of the curve is relatively flat and has a large wiggle. The ^{14}C date illustrated in this figure is 350 years BP. The solid bars mark 1 standard deviation, the open bars encompass 2 standard deviations. Figure courtesy of Darden Hood of Beta Analytic.

dental modification; type of burial (whether primary or secondary); evidence for disturbance; position, orientation, and depth of the burial; and distance in meters from the church. Only two of the burials had associated personal items. Burial numbers with a subdesignation (e.g., 18.2, 49B) refer to the presence of more than one individual in a single grave.

The origins of the individuals unearthed from the cemetery were assessed on the basis of the dental morphological traits scored on the permanent dentition, according to the frequencies reported for African populations by Scott and Turner (1997) and for native Mayas by Cucina and colleagues (Cucina, Tiesler, and Wrobel 2005; Cucina, Ortega, and Tiesler 2008). Major groups were defined as African, natives, mestizos, and Europeans, characterized by specific dental traits that occur at much higher frequencies than in other groups.

Unfortunately, no traits are exclusively and fully representative of a single group. Rather, the relative frequencies of multiple traits allow a tentative assessment of origins. For this reason, we employed a series of traits that tend to distinguish native Maya from African and European populations. Probability was calculated on the basis of the frequencies for each trait reported by Scott and Turner (1997) and by Cucina and colleagues (Cucina, Neff, and Tiesler Blos 2005; Cucina, Ortega, and Tiesler 2008).

These traits could be recorded for a total of 92 individuals from the Campeche cemetery (CA+ online supplement A). The results indicate approximately 25 individuals of African origin, 43 natives, 19 mestizos, and 5 Europeans. The individuals assigned to the "mestizo" category exhibit a mix of traits from among the groups. However, this designation must be used with great caution because the genetic controls—and consequently the pattern of genetic inheritance—for dental traits is not known (Scott and Turner 1997). The spatial distribution of the different groups within the churchyard is surprisingly homogeneous (Rodríguez 2010). It appears that different groups were buried in all parts of the cemetery, with no evidence of segregation.

We must stress the fact that within-group variation is always higher than between-group variation. Moreover, not all individuals were represented by the same number and type of teeth, which limited the consistent application of this approach. Thus, the probability values obtained in this study provide only tentative evidence of origins. We could not use other skeletal markers of biological affiliation (such as facial prognathism or cranial index) because of the very poor and fragmentary preservation of the skeletal remains. In a similar manner, we could not rely on taphonomic and mortuary context because no objects were found in the graves that could help determine affiliation. For a few individuals, information on dental modification was used to assign Maya or African affiliation (Tiesler 2002), as described below. In the majority of cases, the biological (dental traits) and biocultural (dental modification) determinations coincided.

To document dental alteration in the skeletal population from the cemetery, tooth samples were inspected systematically. In the classification of the modifications, we followed the typology established by Romero Molina (1958), after the specifications set forth by Dembo and Imbelloni (1938) and

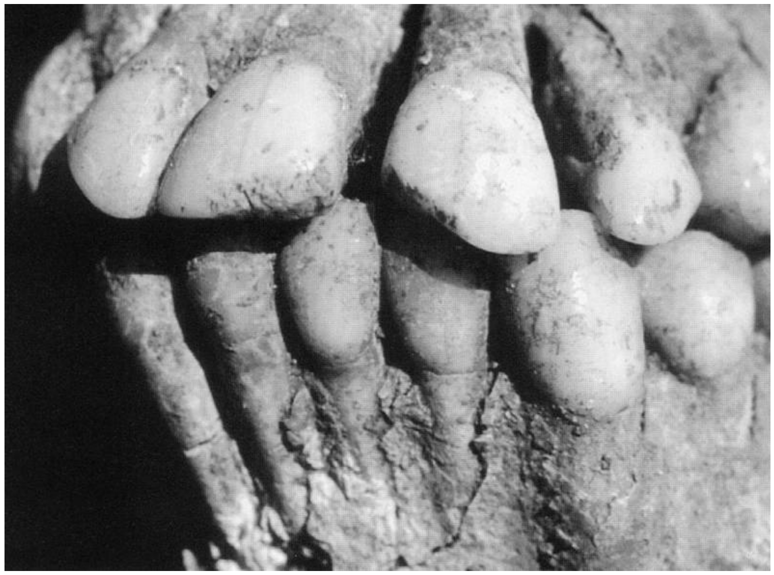

Figure 4. Dental modification of four upper front incisors from burial 19, an individual with a strontium isotope ratio of 0.72128. Photograph by Vera Tiesler.

by Handler, Corruccini, and Mutaw (1982). Some of the altered teeth were examined using scanning electron microscopy (Ramírez Salomón et al. 2003; Tiesler and Oliva 2010).

Five of 54 complete frontal dentitions presented artificial modification. In the case of burial 71, two incisors showed traces of filing. The modification consists of three and four grooves, respectively, on the incisor edge of each tooth (A3 and A5 in Romer's taxonomy). While incisor grooves are common in pre-Hispanic Maya dentitions, the metal instrument that inflicted them is probably a colonial innovation used in place of the stone implements employed prior to European contact (Tiesler 2000; Tiesler and Oliva 2010). This was likely a native individual, given the strongly expressed shovel-shape characteristic of Amerindian populations. This individual also exhibited a typically local strontium isotope ratio in tooth enamel, as discussed below.

The other four altered dentitions belong to burials 19, 41, 102, and 124. Some common patterns are noticeable. All reductions produce a symmetric design, resulting in oblique, pointed tips formed by adjacent teeth or generating mesial diastemas (fig. 4). The artificially produced edges are straight or slightly convex, while the surfaces of the modifications appear either smooth or rugged. Chiseling, in particular, has been described by several authors writing about tooth modification methods related to African customs. This technique has also been documented in dentition from colonial slave burial grounds elsewhere (Dembo and Imbelloni 1938; Handler, Corruccini, and Mutaw 1982; Milner and Larsen 1991; Paúl and Fragoso 1938; Rivero de la Calle 1974; Stewart and Groome 1968). Taken together, these patterns, along with the techniques used to produce them, differ decidedly from the filings and incrustations practiced by the pre-Hispanic Maya. All four of these individuals have very high strontium isotope ratios in tooth enamel, indicative of origins in West Africa. We have argued elsewhere that these individuals were brought from Africa to the New World (Price, Tiesler, and Burton 2006; Tiesler 2002; Tiesler and Oliva 2010).

Additional foci of the skeletal studies were life expectancy, living conditions, nutrition, and health. Generally speaking, our results draw a sober picture of the life of Campeche's first generations, with precarious living conditions and the prospect of an early death (Cucina 2010; Rodríguez 2010). The poor health profile provides a human dimension to the historical accounts of the heavy pressure for assimilation and forced integration that prevailed during the early colonial years (Tiesler and Zabala 2001). This is when epidemics, violent confrontations, and general hardship constituted the status quo. López de Cogolludo (1954 [1688]) writes of an epidemic outbreak that afflicted Campeche in 1648: "the pestilence appeared in the town of Campeche, the evil brought devastation to all ages and social groups and it affected more men than women, except for those who were pregnant" (369).

While not completely representative of all the citizens of colonial Campeche, the burial population clearly reflects the harsh living conditions. The age classes of juveniles and young adults are most common, with a slight prevalence of males over females; infants and mature adults are underrepresented (Tiesler and Zabala 2001). Among the stress-related conditions, high frequencies of porotic hyperostosis, enamel hypoplasia, and periosteal reactions stand out, particularly among the natives and mestizos, which reflect the difficult living endured by the urban population (Cucina 2010; Rodríguez 2010). Developmental stress seemed to be a common feature for those born in Campeche, while African-born individuals show comparatively less evidence of developmental stress (i.e., physiological perturbations during the early years of life). It is also noteworthy that caries afflicted the native segment much more than others, suggesting poor oral hygiene, high carbohydrate intake, and/or dietary changes among the urbanized Maya (Cucina 2010).

Isotopic Studies of the Human Remains

The major focus of this study concerns the results of the isotopic investigations of the inhabitants of the Campeche plaza cemetery. One example, the ^{14}C analyses of bone collagen for radiocarbon dates, has already been discussed. In this section, we consider the materials to be analyzed—bone collagen, bone apatite, and tooth enamel apatite—and the principles of the methods that are used. We then discuss results of the analyses of the isotopic ratios of strontium, lead, carbon, nitrogen, and oxygen.

Isotopic data from the Campeche cemetery are presented in CA+ online supplement B, available as a PDF, by burial number. The columns in this table provide additional information on the material analyzed—tooth or bone—and the isotopic values recorded in these materials. Strontium isotope analysis was conducted on 121 dental samples from 99 individuals and 16 bone samples from 16 individuals. Two or more molars were sampled in a several of the individuals. M1 molars were measured in 92 of the 99 individuals; the seven remaining individual samples were M2 or indeterminate molars. These 99 measurements are the primary data for the strontium isotope discussion; additional M2 and M3 data are listed in the table but are not discussed further because of the small sample size. The primary samples include all individuals presenting at least one molar. The samples for enamel strontium isotope data include more than half of the burial population and are representative of the overall burial population. Some 34 of the 99 sampled individuals were males or probable males, and 24 were females or probable females.

Limitations of time and money prevented all isotopic analyses being applied to all individuals in the cemetery population. Lead isotopes were measured in 10 enamel samples. Bone samples from 51 individuals were analyzed, and there are four bone samples from individuals without associated tooth samples. Bone samples are cortical bone from midlength of femur in every case. Carbon isotope ratios were measured in 41 samples of bone collagen, 51 samples of bone apatite, and 64 samples of enamel apatite. Nitrogen isotope ratios were recorded in 41 samples of bone collagen. Oxygen isotopes were measured in 51 samples of bone apatite and 64 samples of enamel apatite. Each of these samples represents one individual.

In addition, we measured strontium, carbon, and oxygen isotopes in tooth enamel from nine individuals from two other colonial churches in Campeche for comparison. Strontium, carbon, and oxygen isotopes were measured in human tooth enamel, and strontium isotopes were measured in six animal bones from archaeological sites in Andalucía, Spain, for baseline information from one of the potential homelands of the inhabitants of Campeche. The results of these investigations are presented in the following sections.

Strontium, lead, and oxygen have the potential to inform place of origin; carbon isotopes in enamel apatite tell us about childhood diet and can be very useful for the study of mobility by providing supplemental information on individual differences. Carbon and nitrogen isotopes in bone collagen contain information on diet and trophic position. We begin our discussion with strontium and lead isotopes to examine questions of place of birth and then turn to light isotopes to look at diet and geography in the context of the strontium and lead results. We provide more methodological details on strontium, lead, and carbon and oxygen in enamel. Carbon and nitrogen isotopes in bone collagen are in more common use and are well described in the literature (Katzenberg and Harrison 1997; Tykot 2004).

Tooth Enamel and Bone

The sample materials for our investigations, then, are the bones and teeth of the buried inhabitants of the Campeche cemetery. We are interested in both kinds of material from these skeletal remains because each holds different kinds of information. Bone and tooth enamel incorporate chemical signals from different periods in an individual's life.

Enamel forms during early childhood and is constructed from nutrients eaten by the mother and the young child (Hillson 2005). Calcification of the enamel crown of the first molar is normally completed by the age of 5 years (ElNesr and Avery 1994; Ten Cate 1998). Because tooth enamel, composed primarily of the mineral hydroxyapatite, does not change during one's lifetime, it retains the chemistry of the place of birth (Ericson 1985; Krueger 1985; Price et al. 1994). A variety of studies have demonstrated that enamel is highly resistant to postmortem contamination (e.g., Budd et al. 2000; Kohn, Schoeninger, and Barker 1999; Lee-Thorp and Sponheimer 2003).

Bone is a relatively plastic material, containing both an organic (mostly collagen) and inorganic (hydroxyapatite) phase. Because bone is a dynamic tissue, it is constantly remodeling, adding new material and losing old. Thus, the chemical composition of bone reflects the chemistry of diet and place of residence of the later years of life. Because of these differences, we have available in human skeletal remains the means to examine some of the conditions in the life history of a single individual.

Samples of tooth enamel were collected by removing a small amount of enamel, approximately 30 mg, from the whole tooth using dental equipment. Bone samples were taken from cortical bone (midlength sections of femur where possible). Because bone is highly susceptible to diagenesis, this material was pretreated more thoroughly than enamel for analysis to remove potential contaminants. A more complete discussion

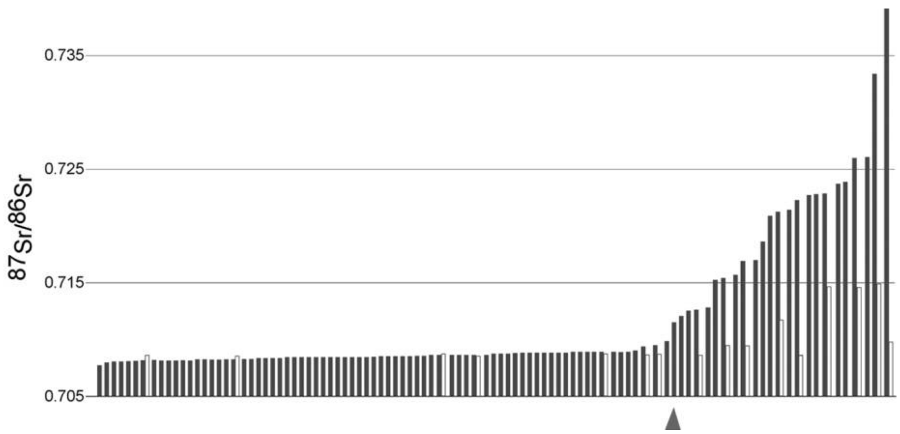

Figure 5. Enamel (shaded) and bone (white) $^{87}Sr/^{86}Sr$ values in rank order for 99 Campeche cemetery samples. Bone values are placed adjacent to the enamel value from the same individual. The triangle marks the inflection point mentioned in the text.

of the methods of preparation and analysis for the different isotopes appears in CA+ online supplement C.

We begin our discussion with strontium and lead isotopes to examine questions of place of birth, and we then turn to light isotopes to examine questions of diet and geography in the context of the strontium and lead results.

Heavy Isotopes: Strontium in Tooth Enamel

The use of strontium isotopes for proveniencing human remains has been ongoing in archaeology for approximately 20 years. The basic principles are straightforward and involve the comparison of isotope ratios in human tooth enamel with local levels in bone or other materials from the place of burial. Geological formations have distinctive strontium isotope ratios, depending on their age and the original rubidium content of the rock or sediments. The isotope rubidium 87 radioactively decays into the isotope strontium 87 over time, changing the strontium isotope ratio of the rock (Faure and Mensing 2005). Geologists have used this principle for years to date rock units.

These isotopes move from rock into humans through the food chain. Thus, the strontium isotope ratio of plants and animals reflects the ratio of the place where they live. Strontium 87 occurs as approximately 7% of total strontium in nature; strontium 86 is roughly 10%, meaning that the theoretical value will be approximately 0.7000. Since ^{87}Sr accumulates over time, more so in rocks with more original rubidium, there are differences in $^{87}Sr/^{86}Sr$ among different kinds of rock. Values for $^{87}Sr/^{86}Sr$ in human tissue generally range from 0.7030 to approximately 0.740. Values for $^{87}Sr/^{86}Sr$ can be measured to six or seven decimal places with scientific instruments, and differences are meaningful for migration studies to the fourth decimal place. Strontium isotope ratios in this study are discussed at four decimal places; measured values in CA+ online supplement B are given to six decimal places for those who are interested.

Virtually all of the strontium in the human body is deposited in the skeleton. Strontium is incorporated into skeletal tissue as a substitute for calcium in the mineral hydroxyapatite. Bone is continually remodeled during the life of an individual, so the chemical composition of the bone reflects the later years of life. The enamel in teeth, on the other hand, forms during infancy and early childhood and undergoes relatively little subsequent change. The strontium isotope ratio fixed in enamel provides a signature of the place of birth, while the chemical turnover of bone results in the introduction of strontium isotopes from new places of residence. Because strontium isotope ratios vary among geological substrates, ratios in teeth that do not match those of the place of burial indicate immigrants to an area.

The city of Campeche sits in an area of Eocene limestone with a geological strontium isotope ratio of approximately 0.7077. Local marine sediments in this coastal region might have higher isotope ratios approaching 0.7092, the value for modern seawater. Thus, from the geology alone we would predict strontium isotope ratios for Campeche to lie somewhere between 0.7077 and 0.7092. The site of Champotón, 65 km southwest of Campeche along the Gulf Coast, is the closest locality from which we have other baseline data and should be similar to Campeche; it has an average $^{87}Sr/^{86}Sr$ value of 0.7083.

Estimates of local $^{87}Sr/^{86}Sr$ values based on geology alone can sometimes be misleading for various reasons. It is important, therefore, to obtain isotope ratios from the bioavailable strontium in the area (Price, Burton, and Bentley 2002). Samples from two *barrio* churches from colonial Campeche were analyzed for comparison to the plaza cemetery. These individuals are thought to be locally born inhabitants of Campeche. Five human enamel samples from the Iglesia

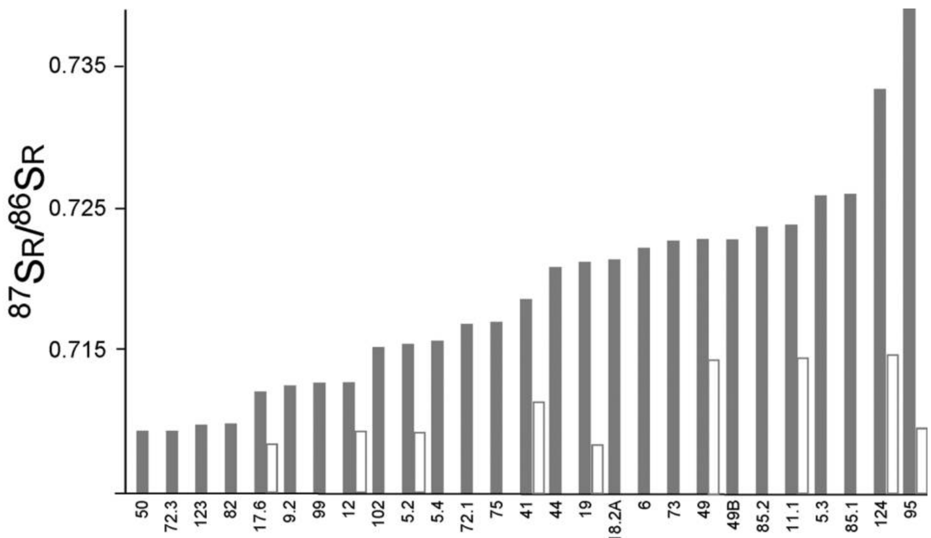

Figure 6. Detail of $^{87}Sr/^{86}Sr$ values greater than 0.7092 in tooth enamel in the Campeche cemetery, with burial numbers. $n = 27$. The white bars are bone.

de San Roman on the south side of the town averaged 0.7083; four human enamel samples from the Rescate San Francisco on the north side of Campeche averaged 0.7085. Both sets of samples were highly homogeneous (CA+ online supplement B). These values likely provide a good estimate of the baseline strontium isotope ratio for local individuals born in or near Campeche.

There is some historical information on the composition of the local population of Campeche. The town was founded at the sea front, just outside a coastal Maya settlement called Ah Kin Pech (Piña Chan 1987:152). It is likely that the indigenous segment of Campeche's early colonial population came largely from the local area. The historical records assert that natives were employed by the Spaniards in agricultural tasks, in construction of domestic and religious buildings, and in road work. Some of the men and women were also employed as domestic servants in Spanish households, especially among the clerics. Apart from mention that a number of Tlaxcaltecans from the Central Highlands of Mexico were among the group that the founder Montejo brought to Campeche, the historical records are silent about the geographic origin and identity of the autochthonous settlers of colonial Campeche. Nonlocal natives were indiscriminately called *naboríos* by the Spaniards, and the term appears only sporadically in the taxation documents of the town (Cook and Borah 1998:86–87).

Samples of enamel and bone carbonate from the Campeche cemetery were analyzed using a multiple-collector thermal ionization mass spectrometer (TIMS). Details of the sample preparation and analysis can be found in CA+ online supplement C. A graph of the results of the strontium isotope analysis of 99 enamel samples and 16 bone samples from the Campeche cemetery is shown in figure 5. Enamel samples are shaded; bone samples are white in this graph. These data are ordered from lowest to highest value and are presented as a bar graph. The values range from 0.7078 to 0.7391, and the mean value for the 99 enamel samples is 0.7104. Enamel results are discussed below; bone data are considered in the subsequent section.

Interpretation of these data is of import with regard to the place of origin of the inhabitants of the Campeche cemetery. There are several patterns visible in this graph. The very first value (0.7078) is noticeably lower than the remainder of the ratios, which begin at 0.7081. This distinctly low value suggests that this individual is not local but is probably from the area south of Campeche.

There is a very clear continuum from the second value (0.7081) to the point where the inflection of the curve begins to change at 0.7092. This continuum of values is typical for a local population eating a varied menu and has been reported in other contexts (e.g., Price and Gestsdóttir 2006). The individuals in this range are likely largely native to the Campeche region. In the case of Campeche, these values may reflect diets ranging from terrestrial (largely maize, beans, and squash) to largely marine (fish and shellfish). More marine diets are at the higher end of this range of values, closer to the isotopic ratio of seawater. Consumption of substantial amounts of salt would also raise $^{87}Sr/^{86}Sr$ values toward the value of seawater (e.g., McKillop 2008; Wright 2005). Diet is discussed in more detail below in the sections on carbon and nitrogen isotopes.

The 27 values above 0.7092 in the Campeche strontium isotope data are also above the value of 0.7092 for modern seawater (Hess, Bender, and Schilling 1986). These individuals in all likelihood were not born in the Yucatán Peninsula, as there are no strontium isotope sources with a ratio above that

Figure 7. Baseline map of strontium isotope ratios in the Maya region in modern Mexico, Belize, Guatemala, and Honduras.

of seawater in the entire region. Figure 6 provides more detail on these samples with high strontium isotope ratios and lists the individual burial numbers. These higher values appear to fall into several plateaus or groups, and there is one distinctively high value at 0.7391. This information suggests that the nonlocal individuals in the Campeche cemetery came from several different places.

All of these values greater than 0.7092 are higher than any we have recorded in humans from Mesoamerica except for three individuals, each of whom is clearly not of local origin (one each from the sites of Copan, Tikal, and Kaminaljuyu) but is from a small region in southern Belize known as the Maya Mountains (Hodell et al. 2004; Price et al. 2008), where values as high as 0.7133 are reported. We consider it very unlikely that individuals in the Campeche cemetery came from the Maya Mountains. This was a relatively uninhabited region at a distance of approximately 400 km from the city of Campeche.

It is possible to put the strontium data from the Campeche cemetery in a larger geographic context by consideration of $^{87}Sr/^{86}Sr$ values across the Maya region, shown in figure 7. Most of the measurements on this map were obtained by the Laboratory for Archaeological Chemistry in Madison, Wisconsin. Our laboratory has been assembling baseline bioavailable strontium isotope ratios for Mesoamerica for some years (Price, Burton, and Bentley 2002; Price et al. 2008), as part of a series of studies of human migration in the region (e.g., Price, Manzanilla, and Middleton 2000; Price, Tiesler, and Burton 2006; Price et al. 2007). A few additional measurements on the map were reported by Hodell et al. (2004) and by Krueger (1985). Several materials have been used for these measurements. We have measured ancient human bone and teeth, both ancient and modern animal bones and teeth, and modern snail shells, along with a few samples of plant material. Materials measured by Hodell et al. (2004) included soil and water samples; Krueger (1985) measured bone.

The geology of the Maya region of Mesoamerica provides the background for these strontium isotope studies. The bed-

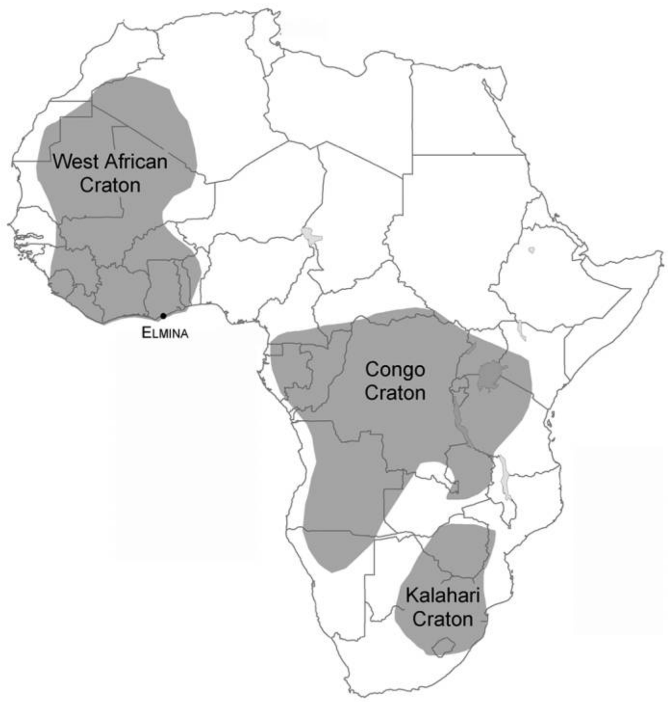

Figure 8. Major cratons of Africa. The West African Craton is the likely source of the high strontium isotope ratios found in tooth enamel in Campeche. A color version of this figure is available in the online edition of *Current Anthropology*.

rock of the Yucatán Peninsula is dominated geologically by the carbonate shelf of the Peten and the Yucatán Peninsula. The oldest carbonates of Cretaceous age are found in the southernmost part of the peninsula and trend in a gradual cline northward to the youngest Quaternary carbonates on the northern coast (Hess, Bender, and Schilling 1986; Hodell et al. 2004). Geologists have documented and dated changes in marine strontium isotope ratios over time (e.g., Hess, Bender, and Schilling 1986). Because of this gradual, age-dependent trend in marine carbonates, the strontium isotopic characteristics of the region can also be inferred, tracking the well-established Tertiary/Quaternary seawater $^{87}Sr/^{86}Sr$ values, which should be approximately 0.7075 in the southern Cretaceous carbonates and trend gradually higher to 0.7092 in Quaternary deposits of the northern coasts. Hodell et al. (2004) documented some of this variation across the Maya area using environmental samples of water, plants, soil, and rock.

Farther south, the carbonate-dominated lowlands are bounded to the south by the young volcanic rocks of the highlands Guatemala. This region has much lower $^{87}Sr/^{86}Sr$ ratios, approximating 0.705–0.706, which are characteristic of young Cordilleran volcanic rocks throughout Mesoamerica. Thus, the general pattern is a north-south trend from approximately 0.704 in the southern highlands to a maximum of 0.709 along the northern coast. The one exception, as we noted earlier, lies in the granitic rocks of the Maya Mountains in southern Belize, where ratios higher than 0.7092 have been reported.

These baseline isotope data from the Maya region and the low probability that individuals in the Campeche cemetery came from the Maya Mountains mean that we must look outside the Yucatán and all of Mesoamerica for the origin of nonlocal individuals with higher strontium isotope values. The question, of course, is from where do these unusual values come?

These higher strontium isotope ratios would require a source that is high in ^{87}Sr—that is, a terrain that is both ancient (>1 billion years) and high in rubidium, such as a granitic terrain in one of the ancient continental cratonic areas. Cratons are large regions of old crust that have been tectonically dormant for more than a thousand million years. The most parsimonious source for the higher Campeche values is the granitic terrain of the West African Craton (Wright et al. 1985). The major cratons of Africa are shown in figure 8. With the exception of a small remnant of the West African Craton in northeastern South America, Africa is the region closest to Campeche with such high ratios.

The West African Craton coincides with a large area extending from the coasts of modern day Liberia, Côte d'Ivoire, and Ghana to the West African interior. Modern-day Ghana, referred to as Mina by the Portugese and as the Gold Coast in later European accounts, was infamous as the center of the African slave trade in the seventeenth century. During that period, the Portuguese supplied slaves to the Spanish from their forts along the Gold Coast, principally from a place known as Elmina, at the southeastern edge of the West African Craton in modern Ghana (DeCorse 2001). This is also the area of West Africa where many of the sailing routes from Africa to the Caribbean originated. It is very likely that most of the individuals from the Campeche plaza with the higher values (greater than 0.7092) came from different places in the larger region of West Africa. Another option would be the Congo Craton in Central Africa (fig. 8), which was also a source region for slaves shipped to the New World. Strontium isotopes cannot discriminate between these two regions. Our discussion tends to focus on West Africa as the closest and perhaps most parsimonious homeland for these individuals, but it is important to remember that Central Africa may be an equally viable alternative.

Some information is available from earlier studies of Africans in the New World. The New York African Burial Ground project began in 1991 when, during construction work for a new federal office building, workers discovered the skeletal remains of the first of more than 400 men, women, and children. Further investigation revealed that during the seventeenth and eighteenth centuries free and enslaved Africans had been buried in this 2.6-ha burial ground in lower Manhattan. A few of the individuals in this cemetery also presented dental modifications similar to those seen at Campeche (Blakey 2001; Blakey and Rankin-Hill 2004).

Strontium isotope analysis of some of the remains from the African burial ground was conducted, and several individuals exhibited high nonlocal $^{87}Sr/^{86}Sr$ in the range of 0.715 to 0.728 (Goodman et al. 2004). The study also reported $^{87}Sr/^{86}Sr$ for two human teeth and a water sample from Ghana in West Africa. The water sample had a value more than 0.735. The dentin and enamel in both teeth were measured. Enamel values ranged between approximately 0.7225 and 0.729; dentin values were approximately 0.721 and 0.716 in the same teeth. In another study from West Africa, Pye (2004) reported a wide range for 40 values in extracts from Nigerian soils, averaging 0.7303 (fig. 9).

Table 3. $^{87}Sr/^{86}Sr$ values for six samples of human tooth enamel from the Ossuary of San Juan de Dios in Cadiz, Spain

Sample	$^{87}Sr/^{86}Sr$
1	.708709
2	.713490
3	.713659
4	.715948
5	.712090
6	.709543

Schroeder et al. (2009) employed isotopes of carbon, nitrogen, oxygen, and strontium to investigate the geographical origin of 25 enslaved Africans who were buried at the Newton plantation, Barbados, sometime between the late seventeenth and early nineteenth centuries. Seven samples yielded enamel oxygen and strontium ratios that were inconsistent with a Barbadian origin and strongly suggested that these individuals were first-generation captives brought to the island in the slave trade. The nonlocal $^{87}Sr/^{86}Sr$ ratios ranged between 0.7109 and 0.7187 and clearly demonstrated that not all of the slaves came from the same part of Africa but from several different areas, possibly including modern Ghana and the Senegambia. These seven individuals also exhibited a dramatic dietary shift between childhood and later life, as recorded in $\delta^{13}C$ values.

These data from other published studies of African origins strongly support our conclusions regarding the high $^{87}Sr/^{86}Sr$ values at Campeche. We suspect that there are other places of origin represented in the Campeche data set as well. It is not unlikely that individuals of European origin were also buried in this early colonial churchyard. The place of origin

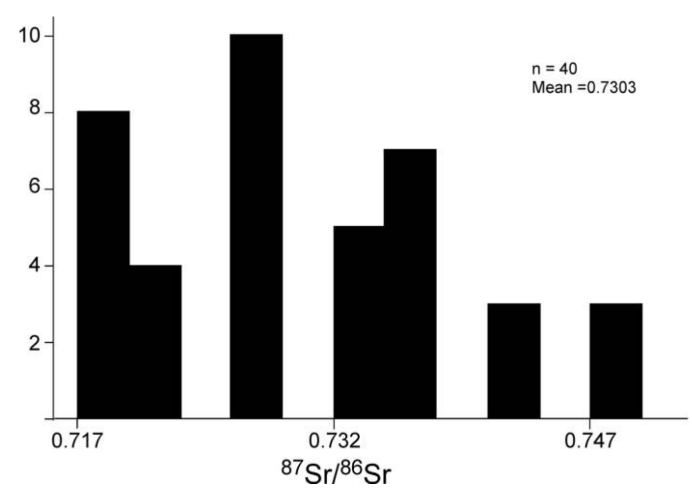

Figure 9. Histogram of $^{87}Sr/^{86}Sr$ in soil extracts from Nigeria (Pye 2004).

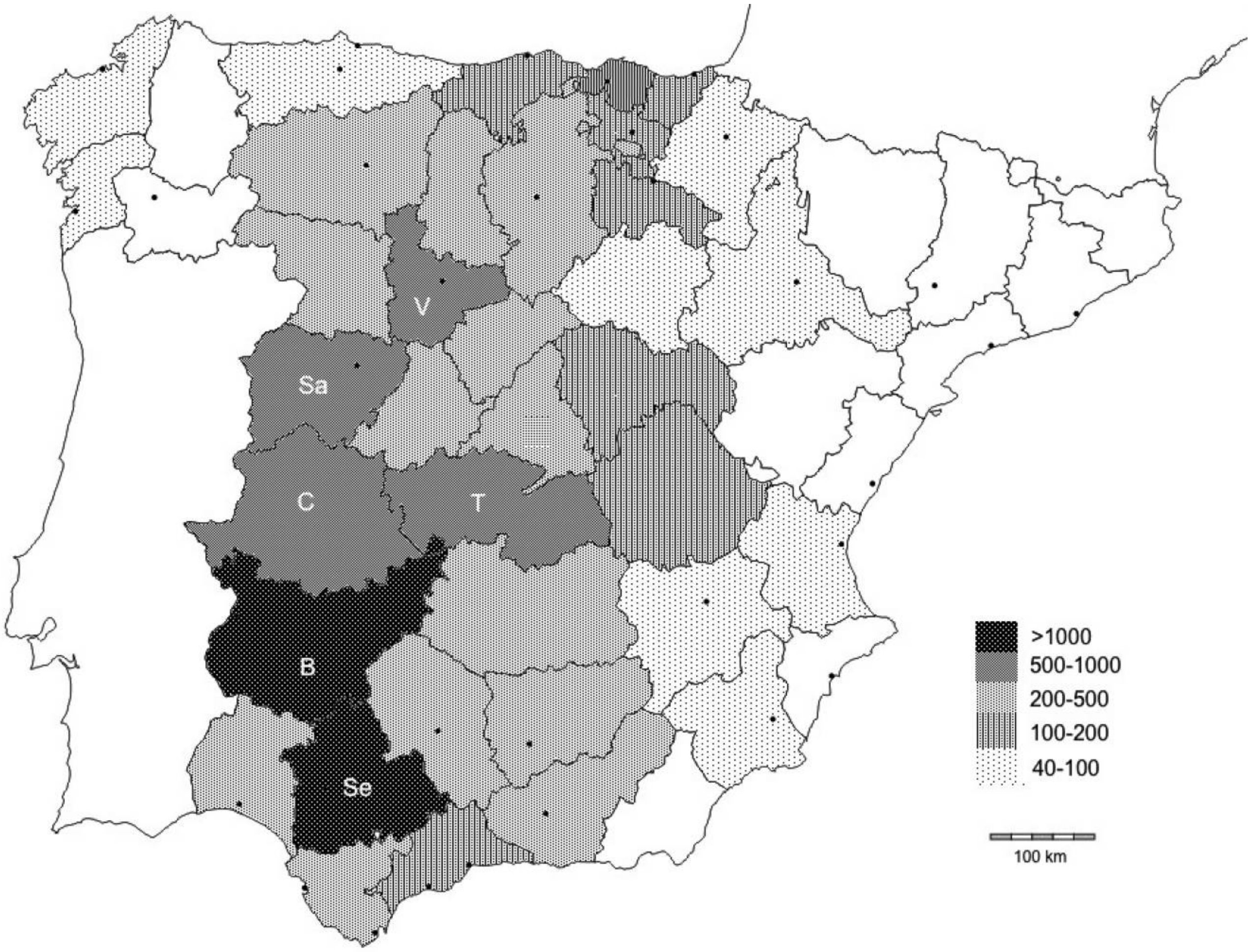

Figure 10. Home provinces of the identified Spanish passengers to the New World in the 2 decades between AD 1520 and 1539 (after Boyd-Bowman 1973). The six provinces that contributed the majority of colonists are labeled. V = Valladolid, Sa = Salamanca, C= Cáceres, T = Toledo, B = Badajoz, Se = Sevilla.

for the Spanish colonists is relatively well documented from the passenger lists of the ships that carried them to the New World (e.g., Archivo General de Indias 1946). These lists have provided the raw data for a number of important studies that quantify the homelands of the immigrants (e.g., Altman 1989; Boyd-Bowman 1956, 1964, 1973, 1976; Jacobs 1995).

Boyd-Bowman provides a chronological view of the sources of the migrants. Prior to AD 1520, the largest single group (40% of the total passengers) came from the region of Andalucía, of whom 78% came from the provinces of Sevilla and Huelva. Between AD 1520 and 1539 (the 2 decades before the establishment of Campeche), the homelands of the emigrants expanded to include more individuals from other provinces, but Andalucía continued to supply more than 30% of the total. Figure 10 shows the numbers of emigrants from the provinces of Spain in this period. In the next 2 decades (1540–1559), of the 9,044 passengers identified on the ships' lists, more than half came from six provinces (Seville, Badajoz, Cáceres, Toldeo, Salamanca, and Valladolid). For the sixteenth century AD as a whole there were more Andalucíans than any other group of emigrants. One-third of all the settlers in Mexico and Panama came from either Seville or Badajoz.

A wide range of values in the distribution of strontium isotope ratios are of potential interest in the search for Europeans in the Campeche cemetery. We have measured several sets of samples from southern Spain as part of the Campeche project. Six teeth from the Ossuary of San Juan de Dios in Cadiz, Spain, showed a broad range of variation in $^{87}Sr/^{86}Sr$ values (table 3) and suggest diverse origins for the inhabitants of the ossuary. Two rabbit bones from the Cueva de Nerja in a limestone geology on the south coast of the eastern corner of Málaga in Andalucía averaged 0.7091. Two pig teeth from the site of El Palomar Los Molares in Sevilla produced values of 0.7085 and 0.7138, comparable to the range observed in the ossuary in Cadiz. Two faunal samples from the site of Reales Atarazanas in Seville were measured at 0.7085 and 0.7089.

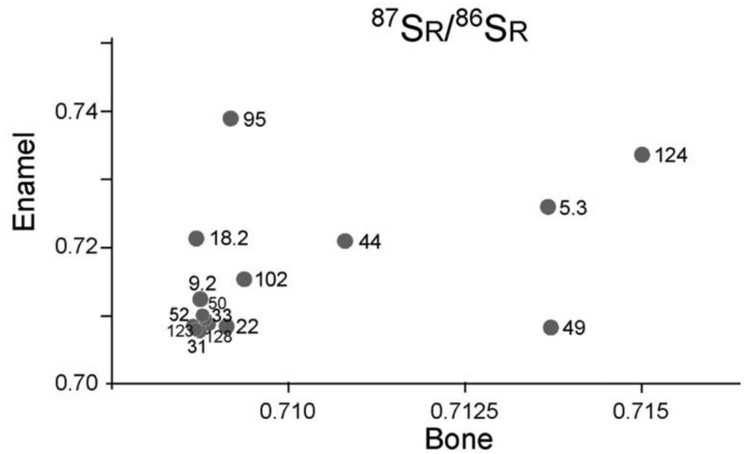

Figure 11. Strontium isotope ratios in enamel and bone from 15 individuals in the Campeche cemetery with burial numbers.

Additional values for Spain have been reported in other studies. Zakrzewski (2010) reported strontium isotope ratios from a medieval Islamic cemetery in Ecija, Spain (80 km northeast of Seville on the Guadalquiver River), where excavations uncovered more than 4,500 burials. Initial analysis of 20 individuals from the cemetery resulted in a narrow range of $^{87}Sr/^{86}Sr$ values between 0.7082 and 0.7089. Prevedorou et al. (2009) measured human and faunal material at the site of Gatas along the eastern coast of Andalucía and reported an average $^{87}Sr/^{86}Sr$ of 0.7098 for the faunal remains.

Although the number of samples and locations is small, these measured and reported ratios from southern Spain suggest that a broad range of $^{87}Sr/^{86}Sr$ values is present in the area, from approximately 0.708 to 0.716. These values suggest that the strontium isotopic landscape of southern Spain may be quite varied. Some of these ratios are high and comparable to some of the higher values from Campeche.

In sum, strontium isotopes in tooth enamel from the Campeche burials suggest that a segment of the population (at least 27 of 99 individuals) were born elsewhere—not in Mexico but most likely in West Africa. Most of these individuals were probably brought as slaves to the Spanish colony. There may also be Europeans present in the cemetery, in addition to the local natives and the Africans. However, strontium isotope values in Spain overlap the local and nonlocal ranges at Campeche. European burials at Campeche may be difficult to distinguish using strontium isotopes in enamel. In this context, lead, carbon, nitrogen, and oxygen isotopes may provide additional information and are discussed in subsequent sections, following a discussion of $^{87}Sr/^{86}Sr$ in bone apatite.

Strontium Isotopes in Bone Apatite

Strontium isotopes were measured in 16 samples of bone and enamel from the same individual. Bone chemically represents the last decade or two of life; enamel, as we have described, represents the place of birth. Figure 5 illustrates the position and value of the bone samples in the larger set of enamel values from the Campeche cemetery. The white bars in this graph are bone values. The only noticeable differences between bone and enamel $^{87}Sr/^{86}Sr$ values are to be seen in the higher, nonlocal individuals. Differences between bone and enamel can be due to diagenesis or to differences between childhood and adult diets. The patterning observed in this graph, with variation in the bone values of the nonlocal individuals, suggests that these differences are more related to diet. This suggestion is confirmed by examination of carbon isotopes in collagen and apatite (below), which also show a diet shift from childhood to adulthood in a number of the nonlocal individuals.

Figure 11 shows a scatterplot of strontium isotope ratios in tooth enamel (childhood diet) and bone apatite (adult diet) with burial numbers. Several patterns are noted. First, there is a cluster of 7 individuals (22, 31, 33, 50, 52, 123, and 128) in the lower left corner of the distribution. This group contains those individuals who were born and died with similar isotopic values, below 0.7092 (except for burial 50), in bone and enamel. These individuals are likely local to Campeche (again except for burial 50). Second, there are five points (5.3, 9.2, 44, 102, and 124) in a linear relationship from the lower left to the upper right. These individuals show a positive correlation between bone and enamel strontium indicating that both values increase similarly. Bone strontium values are lower than enamel, a result of either diet differences between childhood and adulthood or diagenesis. Third, there are three individuals (18.2, 49, and 95) who do not fall into the other two groups. Individuals 18.2 and 95 have enamel values higher than bone, as would be expected for persons who moved from places with higher strontium isotope geology to places with lower strontium isotope ratios. Individual 49 has a higher bone value than enamel and would seem to be a person who was born in a place with strontium isotope values similar to those of Campeche (perhaps in Europe) but who spent much of his or her adulthood in a higher isotope ratio area. This would also appear to be an individual who has moved recently to Campeche from outside Mexico.

Heavy Isotopes: Lead Isotopes in Tooth Enamel

Lead behaves like strontium in terms of provenience studies—both elements substitute for calcium in hydroxyapatite in skeletal tissue. Virtually the entire body burden of both elements is in the skeleton. Bone abundances of both elements are proportionate to dietary (and hence environmental) abundance, and both elements undergo trophic-level biopurification (Elias, Hirao, and Patterson 1982). Most importantly, both elements have both stable and radiogenic isotopes, such that the ratios of these isotopes depend on the local geology and are thus geographically variable.

Lead, in addition to nonradiogenic ^{204}Pb, has three radiogenic isotopes: ^{206}Pb from ^{238}U, ^{207}Pb from ^{235}U, and ^{208}Pb from ^{232}Th (Faure and Mensing 2005). Measurable differences in stable lead isotopic compositions are caused by the differential radioactive decay of ^{238}U ($t_{1/2} = 4.5 \times 10^9$ years), ^{235}U ($t_{1/2} = 0.70 \times 10^9$ years), and ^{232}Th ($t_{1/2} = 1.4 \times 10^{10}$ years). The stable lead isotope, ^{204}Pb, has no long-lived radioactive parent, analogous to ^{86}Sr. These lead isotopes and their ratios locally vary according to both the geologic age of the terrain and the original amounts of parent uranium and thorium isotopes. Importantly, lead isotope ratios, like strontium isotope ratios, are not changed substantially by biological or other low-temperature chemical or physical processes. The ratios present in dental enamel reflect those of diet and, in the New World prior to the modern industrial era, that of the local geology. Although there is evidence for diagenesis of lead in buried bone (Kyle 1986), this contamination does not appear to be present in most cases in tooth enamel (Montgomery, Budd, and Evans 2000; Waldron 1983). More recent increased use of lead in many materials, but especially gasoline, has largely polluted natural levels of these isotopes.

Because of their variability, lead isotopes have had a successful history in archaeometric research for artifact provenience studies. More pertinent here, lead isotopes have been used in recent years to identify prehistoric human immigrants (e.g., Augustine 2002; Barreiro et al. 1997; Budd et al. 1999, 2000; Carlson 1996; Corruccini et al. 1987; Gulson, Jameson, and Gillings 1997; Molleson, Eldridge, and Gale 1986; Montgomery, Budd, and Evans 2000; Montgomery et al. 1999; Reinhard and Ghazi 1992).

Because of this potential for lead isotope ratios to distinguish lead sources, a number of recent studies have begun to apply this tool specifically in Mexico, not only to identify sources of lead exposure (Chaudhary-Webb et al. 1998, 2003) but also to track the origin of archaeological artifacts (e.g., Hosler and Macfarlane 1996). These studies are adding to the existing geologic databases of lead isotopes relevant to humans in ancient Mesoamerica (e.g., Cumming, Kesler, and Krstic 1979, 1981; Sangster, Outridge, and Davis 2000; Torres-Alvarado, Verma, and Carrasco-Nuñez 2000). At the same time, there is still not much information on geographic variation in lead isotopes ratios across Mesoamerica. We also know, on the basis of samples analyzed to date, that there is very little lead in the sedimentary rocks of the lowland Maya area or in the teeth of the local inhabitants of Campeche.

Ratios for various lead isotopes measured for eight tooth samples from the Campeche burials are provided in CA+ online supplement B. Much of this information is redundant or shows little pattern. We will focus on a single ratio in this discussion. Values for ^{208}Pb/^{206}Pb plotted against ^{207}Pb/^{206}Pb in tooth enamel are shown in figure 12. Several observations can be made. Burials 52 and 128 (local strontium isotope ratios) fall very close together with regard to these two lead isotope ratios and very close to a cluster of points (indicated by the shaded cloud) that marks lead isotope ratios in southwestern Spain (Santos Zalduegui et al. 2004; Stos-Gale et al. 1995). This evidence supports our suspicion that these two individuals are of European origin. This question is discussed in more detail in subsequent sections on light isotopes. The nonlocal strontium isotope individuals show a spread of values suggesting different points of origin. The single other local value (burial 9.3) may exhibit the local lead isotope ratio for the Campeche region. More data points are needed to better understand these values.

The individuals with nonlocal strontium isotope signatures also show a spread of values in Pb isotope space. Similar to

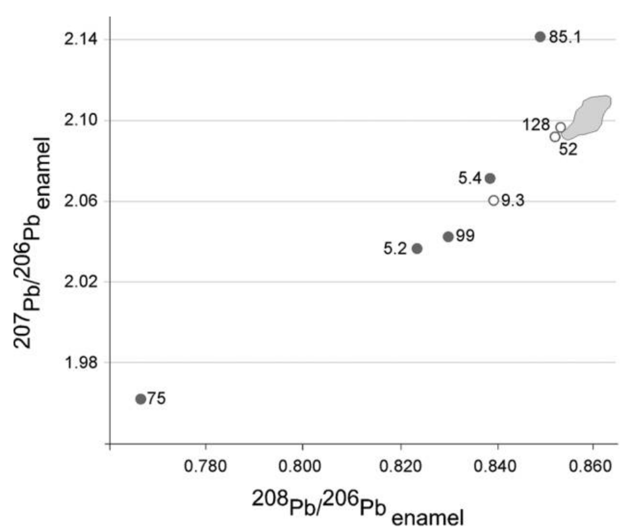

Figure 12. ^{207}Pb/^{206}Pb plotted against ^{208}Pb/^{206}Pb for eight individuals from the Campeche cemetery. The solid circles indicate individuals with ^{87}Sr/^{86}Sr above 0.7092 (nonlocal); open circles have a local strontium isotope signal. The shaded region in the upper right marks the range of values for southwestern Spain (from Santos Zalduegui et al. 2004).

the observed plateaus in Sr isotopic distributions (fig. 5), Pb isotopes also seem to form distinctive signatures suggestive of areas of origin with subtle differences in their Pb-Sr isotope character. The only other individual with a "local" Sr isotope signature (burial 9.3) has a Pb isotope signature that could potentially characterize the local lead isotope composition for the Campeche region. The common Pb isotopic signature of this individual ($^{206}Pb/^{204}Pb = 18.53$; $^{207}Pb/^{204}Pb = 15.60$; $^{208}Pb/^{204}Pb = 38.32$) corresponds to a model (Stacey and Kramers 1975) with a continental crustal Pb isotope composition of approximately 50 Ma, compatible with the predominantly Eocene age of the limestone platform on Yucatán. The Pb isotope composition of individuals 75 and 85.1 are particularly of interest, as they are characterized by extraordinarily high $^{207}Pb/^{204}Pb$ ratios compared with their $^{206}Pb/^{204}Pb$ ratios (CA+ online supplement B).

The composition of these leads indicates sources with a high U/Pb ratio relative to average continental-derived leads and at the same time requires that these sources experienced their U/Pb fractionation relatively early in Earth's history. Such conditions are typically represented by leads from ancient cratonic areas, and therefore we believe that these two individuals must have grown up in regions dominated by Proterozoic to Archean sialic lithologies, as they occur in the West African Craton. This is corroborated and supported also by the elevated $^{87}Sr/^{86}Sr$ ratios measured in enamel samples of these individuals (CA+ online supplement B). More data points are needed to better characterize the Sr versus Pb isotope relationships of the Campeche individuals and to better define the different possible geographic provenance regions.

Light Isotopes: Carbon, Nitrogen, and Oxygen

The measurement of carbon isotope ratios in bone collagen is well known in the study of marine resources and C_4 plants in human diets (e.g., Schoeninger and DeNiro 1984; Tauber 1981; van der Merwe and Vogel 1978). The method has been in use for a number of years and is well established. A variety of applications have been developed (e.g., Katzenberg and Harrison 1997; Koch, Fogel, and Tuross 1994). Carbon is also present in the mineral, or carbonate, portion of bone and tooth enamel and also contains information on diet (Cerling and Harris 1999; Sullivan and Krueger 1981; Tieszen and Fagre 1993). Although there are potential problems with contamination in apatite, this carbon isotope ratio can provide substantial insight into questions regarding diet and place of origin. Apatite carbon is discussed more thoroughly in a subsequent section. Nitrogen isotope ratios can tell us about the importance of meat in the diet, the role of freshwater fish, and the trophic level of human diets.

The isotopes of carbon and nitrogen are expressed as the ratios $^{13}C/^{12}C$ and $^{15}N/^{14}N$. These ratios are then compared with the ratio of a standard and reported as a δ value, which is the ratio of the difference between the sample ratio and the standard ratio compared with that of the standard, given in parts per thousand, or per mil (‰). These δ values are not absolute isotope abundances but express the relative difference between a sample reading and a standard reference material. The standard reference material for nitrogen is air, and for carbon it is the calcite from a mineral deposit known as Pee Dee Belemnite (PDB).

Carbon is reported as $\delta^{13}C$‰ and nitrogen as $\delta^{15}N$‰. Naturally occurring $\delta^{13}C$ numbers for biologically interesting carbon compounds are negative in value and range from roughly 0‰ to −30‰ (e.g., Ambrose 1993; Pate 1994). The numbers are negative because observed ratios are lower than the standard. The ratio of the carbon isotopes in bone reflects the ratio in the diet. Values for $\delta^{13}C$ in human bone collagen range between approximately −5‰ and −25‰. There are two primary sources of variation in ^{13}C in human diet and bone collagen—different kinds of plants that are eaten and terrestrial versus marine foods. ^{13}C is more abundant in certain kinds of tropical plants, such as corn, and in the oceans. Carbon isotopes can tell us about the types of plants we eat and the importance of seafood in the diet. Thus, less negative values for collagen in bone mean that either marine foods or C_4 plants (or both) are in the diet.

Nitrogen is also measured in bone collagen and reported as $\delta^{15}N$, and values in human bone range from approximately 0‰ to more than 10‰. A more positive nitrogen isotope ratio generally reflects a higher trophic position (e.g., DeNiro and Epstein 1981; Hedges and Reynard 2007). There are other factors involved in the variation in nitrogen isotope as well. Consumers of terrestrial foods generally have bone collagen $\delta^{15}N$ values of 10‰ or less, while people who eat a great deal of seafood may have values up to 20‰ (Schoeninger and Deniro 1984). In arid regions, where rainfall is less than about 400 mm per annum, terrestrial systems may yield elevated $\delta^{15}N$, greater than 10‰ (Ambrose 1991; Bocherens and

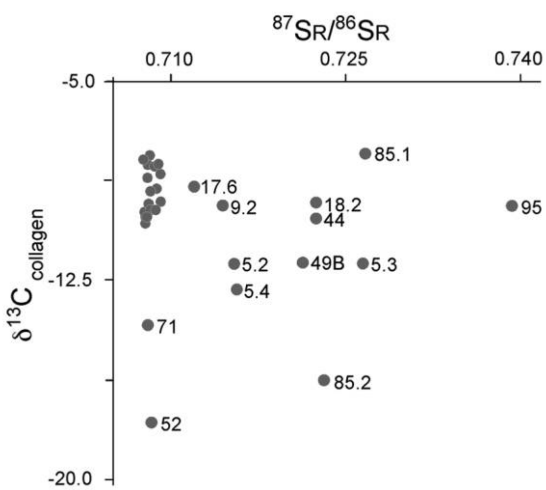

Figure 13. Scatterplot of collagen $\delta^{13}C$ versus enamel $^{87}Sr/^{86}Sr$ in 29 individuals from the Campeche cemetery, with burial numbers given for outliers.

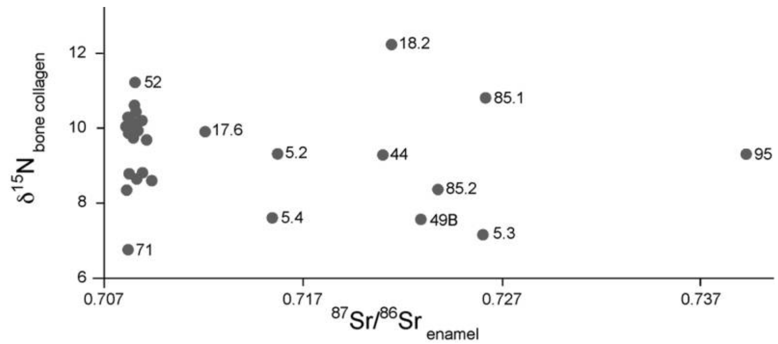

Figure 14. Scatterplot of bone collagen δ^{15}N versus tooth enamel ^{87}Sr/^{86}Sr. Burial numbers are provided for the individuals outside the primary cluster. $n = 28$.

Drucker 2003). Nitrogen isotope ratios can also vary widely in different plant species in the same area (e.g., Dawson et al. 2002; Dijkstra et al. 2003).

Oxygen has three isotopes, ^{16}O (99.762%), ^{17}O (0.038%), and ^{18}O (0.2%), all of which are stable and nonradiogenic. Oxygen isotopes are much lighter and have a much greater relative mass difference than strontium isotopes (^{18}O is 12% heavier than ^{16}O; ^{87}Sr is 1% heavier than ^{86}Sr), making them, in sharp contrast to strontium, highly sensitive to environmental and biological processes. Oxygen isotopes, which are commonly reported as the per mil difference in ^{18}O/^{16}O between a sample and a reference material, can be measured in either the carbonate (CO_3^{-2}) or phosphate (PO_4^{-3}) ions of bioapatite. This value is designated as δ^{18}O. Two different reference materials have been used, one for water (Vienna Standard Mean Ocean Water [VSMOW]) and one for solids (PDB). These values can be equilibrated using a formula from Longinelli (1984) and Iacumin et al. (1996), as illustrated in the next paragraph.

In bones and teeth, isotope variation in δ^{18}O due to physiological factors (e.g., perspiration, metabolic rate, and urine) is averaged, with variation among local populations generally less than 2‰ (White, Spence, and Longstaffe 2002). Oxygen isotopes in the skeleton reflect that of body water (Luz and Kolodny 1985; Luz, Kolodny, and Horowitz 1984), which in turn predominantly reflects that of local rainfall. Isotopes in rainfall are greatly affected by enrichment or depletion of the heavy ^{18}O isotope relative to ^{16}O in water due to evaporation and precipitation. Major factors affecting rainfall oxygen isotope ratios are latitude, elevation, and distance from the evaporation source (e.g., an ocean)—that is, geographic factors. Lachniet and Patterson (2009) analyzed δ^{18}O in surface waters collected from Guatemala and Belize. Their data show that temporally there is also an inverse correlation between rainfall amount and δ^{18}O. Spatially, two variables—distance from the coast and mean catchment altitude—explain 84% of the surface water δ^{18}O variability. Additional information is available from Wassenaar et al. (2009) on oxygen isotopes in groundwater across Mexico. They report $\delta^{18}O_{VSMOW}$ values of −4‰ to −5‰ for the entire Yucatán Peninsula. Using the equation $\delta^{18}O_{ap(PDB)} = 0.653 \times \delta^{18}O_{W(VSMOW)} + 0.09$, derived from Longinelli (1984) and Iacumin et al. (1996), this corresponds to an apatite (PDB) value of approximately −3‰.

Like strontium, oxygen is incorporated into dental enamel—into both carbonate and phosphate ions—during the early life of an individual, where it remains unchanged through adulthood. Oxygen isotopes are also present in bone apatite and are exchanged through the life of the individual by bone turnover, thus reflecting place of residence in the later years of life. Thus, oxygen isotopes, although nonradiogenic, have the potential to be used like strontium to investigate human mobility and provenience. Oxygen isotopes have been employed in a number of studies in Mesoamerica (e.g., Spence et al. 2005; White, Longstaffe, and Law 2001; White, Spence, and Longstaffe 2002, 2004; White et al. 1998, 2000; Wright and Schwarcz 1998).

Carbon and Nitrogen in Bone Collagen

A total of 30 samples were analyzed for carbon and nitrogen isotopes. The average δ^{13}C collagen values (−9.3‰) are quite positive relative to the accepted range between pure C_3 diets of approximately −21.5‰ and primary consumption of C_4 plants such as maize and/or marine foods, with values of −14.0‰ or less negative. The average δ^{15}N values for the bone collagen samples (+9.3‰) are not significantly elevated, implying that seafood was at most a minor component of the diet, despite the location of Campeche, an important fishing harbor today, on the western coast of the Yucatán Peninsula. More details on the nature of the diets represented in the Campeche cemetery appear in subsequent sections.

A plot of strontium isotope ratios in tooth enamel versus carbon isotope ratios in bone collagen (fig. 13) shows the relationship between adult diet and place of birth. In the 24 individuals for whom we have both measurements, there is a clear differentiation between local born, local diet, and foreign born. The cluster of individuals in the upper left of the graph represent low ^{87}Sr/^{86}Sr values, representative of Cam-

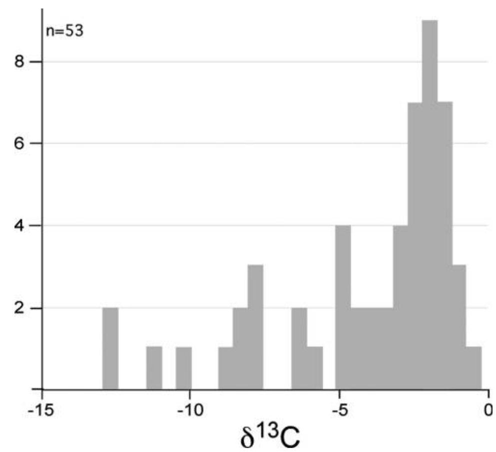

Figure 15. Carbon isotope ratio values in tooth enamel from 64 Campeche burials.

peche, and less negative $\delta^{13}C$ values that point to a diet of largely C_4 plants and perhaps seafood, which is to be expected in a coastal town of colonial Yucatán (Emery 2003; Mansell et al. 2006). Maya diet in the pre-Hispanic and early colonial period consisted predominantly of maize (e.g., White 1999). Recent information also suggests that manioc may have been an important crop in some parts of the Maya region. Salt was a prized additive to food and was traded and consumed in large quantities (McKillop 2008; Wright 2005).

The outliers from this local cluster are also of interest. Individuals with $^{87}Sr/^{86}Sr$ values above 0.7092 are foreigners. The diets of these individuals are highly varied, as indicated by the $\delta^{13}C$ values ranging from being similar to the local values at Campeche to much more negative values suggestive of terrestrial diets and an absence of C_4 plant species. Intermediate values for $\delta^{13}C$, approximately −12.5‰, reflect an intermediate diet between the two extremes.

There are several individuals we suspect to be European in origin. It is important to remember for this discussion that strontium isotope ratios are not unique to a specific location; a number of different places may have similar $^{87}Sr/^{86}Sr$ values. As noted above, $^{87}Sr/^{86}Sr$ values from southern Spain vary at least from 0.7085 to 0.7159, across the 0.7092 boundary we have used for local/nonlocal individuals in Campeche. Because of the very light carbon values in collagen and apatite and the low strontium isotope ratios, we suggest that burials 52 and 128 were European in origin. Burials 95 and 5.4 also have more negative carbon isotopes in enamel and bone apatite. Their higher strontium isotope ratios, however, suggest an African origin. The carbon suggests that these individuals grew up in an area where C_3 plants dominated the diet.

The relationship between nitrogen isotopes in bone collagen and strontium isotopes in tooth enamel is shown in figure 14. This information concerns adult trophic position and place of birth. In general terms, more positive nitrogen isotope values indicate a higher trophic position (more carnivory). The nitrogen isotope values from Campeche range from 6.8‰ to 12.2‰ and average 9.4‰. The nitrogen values cluster in two groups, around 10 and 8.8. Values below this range include those for burials 71, 5.4, 49B, and 5.3. Values above this range include those for 18.2, 52, and 85.1. All of these individuals, with the exception of 71 and 52, have strontium isotope values outside the local range at Campeche and in most cases were likely born in West Africa. The differences in nitrogen isotope ratios among these outliers suggest that highly varied diets were present among the Africans brought to Campeche. This information fits well with the data from carbon isotope ratios and the several peaks in the strontium isotope data that suggest several different places of origin in Africa.

Carbon Isotopes in Enamel Apatite

Krueger and Sullivan (1984) initially documented the difference in stable carbon isotope ratios between the apatite and collagen compartments of bone in the same individual. They proposed that consumer collagen carbon was derived from dietary protein and that apatite carbon came from dietary energy sources. They used this model to explain systematic differences in the isotopic composition of collagen and apatite of nonhuman herbivores versus carnivores and omnivores and marine versus terrestrial human diets.

Controlled diet experiments with rodents confirmed fundamental aspects of their model by demonstrating that carbon isotopes in collagen preferentially reflected that of the protein portion of the diet, while apatite carbon reflected the isotopic composition of the total diet (Ambrose and Norr 1993; Jim, Ambrose, and Evershed 2004; Tieszen and Fagre 1993). These experiments showed that when the protein and bulk diet have the same $\delta^{13}C$ values, collagen is enriched by 5.0‰ and apatite is enriched by 9.4‰ relative to the total diet, and the apatite-collagen spacing is 4.4‰. Evaluation of human apatite and

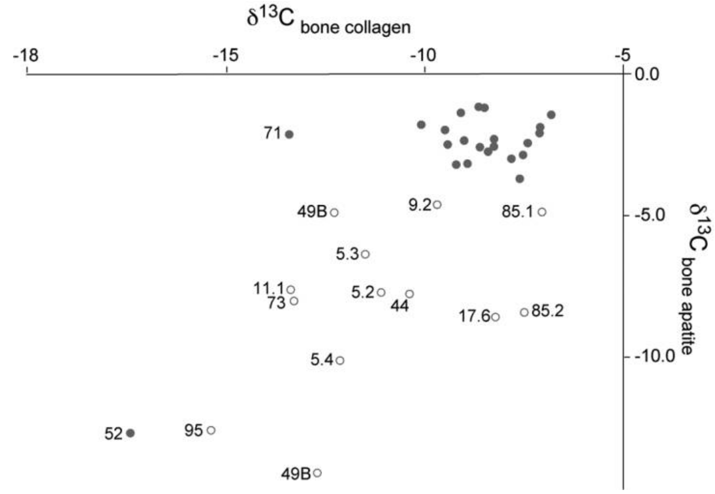

Figure 16. Scatterplot of bone collagen $\delta^{13}C$ versus bone apatite $\delta^{13}C$. Bone collagen $\delta^{13}C$ measures protein carbon intake; bone apatite $\delta^{13}C$ measures whole-diet carbon intake. Burial numbers are shown for outliers from the main cluster. Open circles indicate individuals with $^{87}Sr/^{86}Sr$ above 0.7092. $n = 35$.

enamel values, however, argue for an enrichment of about 12‰ (Tykot et al. 2009). Overall, the results of these experiments permit more detailed reconstruction of the isotopic composition of prehistoric human diets. The bulk diet $\delta^{13}C$ value can be reconstructed from the apatite $\delta^{13}C$ value minus 12.0‰, and that of dietary protein can be reconstructed from the apatite-collagen difference ($\delta^{13}C_{ap\text{-}coll}$). Specifically, a difference of 4.4‰ is found when the protein and bulk diet have the same $\delta^{13}C$ value. A spacing of less than 4.4‰ indicates that dietary protein is isotopically enriched relative to the whole diet. If the spacing is greater than 4.4‰, then dietary protein is isotopically lighter than the whole diet (Ambrose, Buikstra, and Krueger 2003; Ambrose and Norr 1993; Ambrose et al. 1997; Harrison and Katzenberg 2003; Jim, Ambrose, and Evershed 2004).

Marine foods, being rich in protein, will contribute disproportionately to the amino acids in collagen compared with terrestrial plants. Moreover, being enriched in ^{13}C, marine proteins will disproportionately increase the collagen $\delta^{13}C$ values relative to the bulk diet and relative to apatite $\delta^{13}C$. In marine contexts with no C_4 plants, protein comes mainly from ^{13}C-enriched marine animal resources, while carbohydrates and some proteins come from ^{13}C-depleted C_3 plants and C_3-feeding animals. Because the marine protein source is more enriched in the heavy carbon isotope, the diet to collagen spacing ($\Delta^{13}C_{diet\text{-}coll}$) should be greater than 5‰, and the collagen to carbonate spacing ($\Delta^{13}C_{ap\text{-}coll}$) should be less than 4.4‰.

Because the marine protein source is more enriched in ^{15}N, collagen $\delta^{15}N$ values should also be high. In a coastal environment lacking C_4 plants, a positive correlation should exist between collagen $\delta^{13}C$ and $\delta^{15}N$, and a negative correlation should occur between $\delta^{15}N$ and $\delta^{13}C_{ap\text{-}coll}$ (Ambrose et al. 1997). In terrestrial high-latitude diets, the entire food web is based on ^{13}C-depleted C_3 plants, so the bulk diet and dietary protein should have very similar $\delta^{13}C$ values. The diet-collagen spacing should be 5‰, and the apatite-collagen spacing should be at least 4.4‰.

Stable carbon isotope ratios were measured in the apatite of the Campeche samples. The histogram of 64 $\delta^{13}C$ values from tooth enamel (fig. 15) shows a bimodal or trimodal distribution, with a primary mode between -3.0 and -2.0 and secondary modes at -9.0 to -8.0 and -13.0 to -10.0. Enamel values reflect childhood diets when the enamel was forming, and more negative values indicate more terrestrial and/or C_3 diets. The primary mode marks the group of local individuals at Campeche and a diet likely dominated by maize and perhaps fish. Most of the individuals with $\delta^{13}C$ values more negative than -6.0 have nonlocal $^{87}Sr/^{86}Sr$ values, as discussed above.

A total of 35 samples were measured for carbon isotopes in both bone collagen and bone apatite (CA+ online supplement B) and are plotted in figure 16. For Campeche, the average difference between the collagen and apatite values (5.2‰) suggests that C_4 consumption had a greater impact on the apatite than the collagen, most likely from consumption of C_4 plants rather than C_4-fed animals and/or seafood. Overall, the human bone isotope data suggest a very high dependence on C_4 plants, most likely maize. In the case of individuals from Africa, this C_4 contribution may come from millet and sorghum, if those persons came to Mexico from Africa a decade or less before their deaths.

Most of the individuals in this set of 35 who were identified by $^{87}Sr/^{86}Sr$ as being nonlocal also have carbon isotope ratios in collagen or enamel that are significantly lower than those that have $^{87}Sr/^{86}Sr$ ratios within the local range. The more

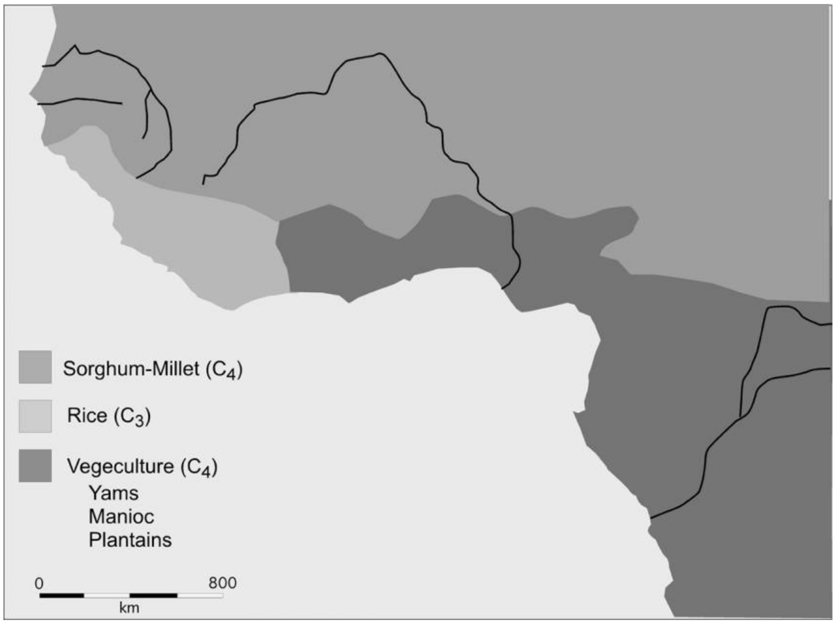

Figure 17. Major crop zones in West Africa, showing the distribution of sorghum-millet, rice, and vegeculture (yams, manioc, and plantains). After Schroeder et al. (2009).

negative collagen carbon in seven of the outliers indicates far less dependence on C_4 crops such as maize. Moreover, since this value is for bone and represents adult diet, the absence of evidence for a maize diet may suggest a relatively short residence in Mexico. These individuals also exhibit greater variation in carbon isotope values, suggesting different homelands and diets in Africa. The low ^{15}N values for this set (8.38‰ ± 0.71‰; $n = 12$) point to a higher dependence on plants and lower consumption of meat.

For a few individuals (burials 17.6, 85.2, and 23), the collagen values are similar to those of people thought to be long-term residents at Campeche, while the apatite values suggest movement from elsewhere. One possible interpretation is that these individuals came from a different part of Africa, perhaps a region dependent on millet and/or sorghum and the consumption of seafood (all resulting in the more positive C and N collagen values than observed in other foreigners). West Africa produces a variety of staple crops that include both C_3 and C_4 plants (fig. 17). Sorghum and millet (both C_4 species) are grown predominantly in the Sahel region and interior, while rice is grown most commonly today in the Senegambia, south and east through the forest and savannah areas of Sierra Leone and Liberia and into Côte d'Ivoire (Harris 1976; Schroeder et al. 2009). South of the Sahel sorghum-millet belt, yams, manioc, and plantains provide a staple food source (C_3) for the southern coastal zone of West Africa.

Additional interesting relationships are apparent in a plot of carbon isotope ratios in enamel apatite versus bone apatite (fig. 18). Enamel apatite records early childhood diet, while bone apatite contains carbon isotopes from the later years of life. A clear cluster of individuals of local origin and similar diets appears in the upper right-hand corner of the graph. Open circles denote nonlocal $^{87}Sr/^{86}Sr$, above 0.7092. Nonlocal individuals exhibit quite varied levels in both bone and enamel apatite, reflecting varied childhood and adult diets. Four individuals stand out in this graph. Burials 23 and 71 have local strontium isotope signals and a very different adult diet from the other local individuals. The more negative carbon isotope ratios in these two individuals suggests a diet with less maize, less fish, or both.

The most striking aberrant points in the scatterplot belong to burials 52 and 128. Both of these individuals exhibit a local strontium isotope signal, but at the same time they are the most different from the local cluster shown in the upper right-hand corner of the graph. Their $\delta^{13}C$ values are the most negative in both enamel and bone apatite in the entire sample, implying a largely terrestrial diet and an absence of C_4 plants. We believe that these two individuals are the best candidates in the burial population for European colonists.

As we have discussed, strontium isotope ratios in southern Spain cover a wide range of values and overlap with the local values in Campeche. At the same time, the carbon isotope values are quite different from the local population and point to a distinctly different diet. Grave location provides an additional clue in the case of burial 128, one of two individuals found during the excavations inside the church. We believe that the placement within the church points to the special status of this adult male individual and may well relate to his European origins. The similarity of values between burials 128 and 52 suggests that both originally came from Europe.

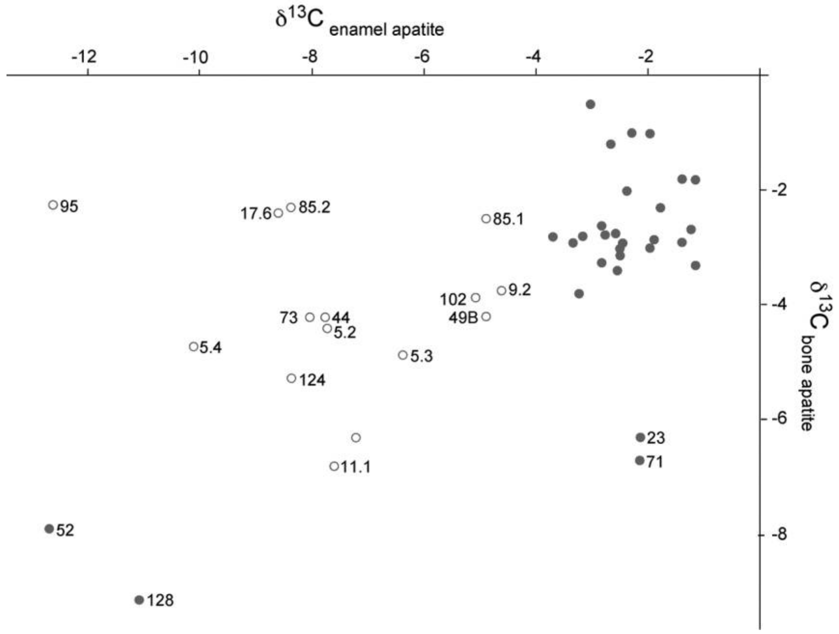

Figure 18. Scatterplot of enamel apatite $\delta^{13}C$ versus bone apatite $\delta^{13}C$. Enamel apatite $\delta^{13}C$ measures childhood diet; bone apatite $\delta^{13}C$ measures adult diet. Burial numbers are shown for outliers from the main cluster. Open circles indicate individuals with $^{87}Sr/^{86}Sr$ above 0.7092. $n = 43$.

Other light isotope studies have been conducted in the Yucatán and Belize at sites dating from the Preclassic through the late Classic period (e.g., Mansell et al. 2006; Tykot 2002). The later (Postclassic and Historic) occupation of Lamanai in Belize is the closest contemporary with Campeche (White and Schwarcz 1989). As seen in figure 19, the individuals from Campeche with the most positive collagen carbon and nitrogen isotope values, who are interpreted to have adapted to local dietary patterns highly dependent on maize, overlap considerably with the later Lamanai residents. Interestingly, the Campeche individuals thought to have been recent migrants prior to their death have lower isotope values and overlap with data for the earlier, late-terminal classic sites of Yaxuna and Chunchucmil. This overlap, however, appears to be coincidental, due to similar levels of millet/sorghum consumption while in Africa, not maize consumption in Mexico. It should also be noted that the adopted dietary patterns at Campeche are similar to those of other regions in Mesoamerica, including the Peten and highland Guatemala in the late Postclassic period (e.g., S. L. Whittington, R. H. Tykot, and D. M. Reed, unpublished manuscript).

Oxygen Isotopes in Apatite

Histograms of $\delta^{18}O$ values in enamel and bone apatite from the Campeche burials were used to explore the variation present in these ratios and to see if we could distinguish individuals from different homelands. The shape of the distributions suggests that there is little significant variation present. A histogram of the oxygen isotope ratios in the apatite fraction of 64 Campeche burials (fig. 20) shows a unimodal distribution and a mean $\delta^{18}O$ of $-2.8‰ \pm 0.7‰$, with no obvious outliers exceeding 3 standard deviations. The standard deviation does not greatly exceed the two per mil variation that we commonly see in populations believed to be local.

Because immigrants, whether African or European, are likely to have changes in their oxygen isotope ratios in bone when moving to the New World, we also measured these data in the bones of 51 individuals to see if there was a shift in the oxygen isotopes (fig. 21). We did not observe significant differences among the individuals or among geographic places of origin. The mean value for bone $\delta^{18}O$ is $-3.1‰ \pm 0.7‰$, only 0.3 per mil different from the enamel data.

Only one individual of the 29 for whom both measurements were made, likely an African, has a bone-enamel $\delta^{18}O$ shift greater than 2.5‰. This individual also has a significant bone-enamel $^{87}Sr/^{86}Sr$ shift from 0.7126 to the local ratio of 0.7087, suggesting arrival in the New World as a young individual. Oxygen isotopes in this study generally failed to provide diagnostic information for determining geographic origin.

Although this was at first surprising to us, it is important to remember that Campeche is at a similar semitropical latitude as West Africa and is of similarly low elevation, such that mean precipitation ratios probably have the same $\delta^{18}O$ range of $-2‰$ to $-6‰$ (Bowen and Wilkinson 2002). Be-

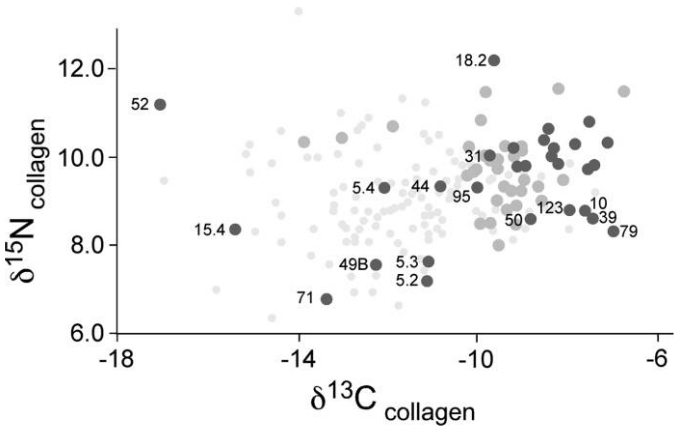

Figure 19. Collagen carbon versus nitrogen isotope values for Campeche (black dots) and other sites in the Yucatán and Belize. The large gray dots are samples from Postclassic and historical sites of Lamanai, Belize, and the small gray dots include a number of Preclassic to Classic sites in the Maya region. For the sources of data other than Campeche, see Tykot (2002).

cause of the insensitivity of δ^{18}O variation within latitudes below 45°, similar ratios also characterize southern Spain. A box plot of the values sorted by place of origin estimated from ^{87}Sr/^{86}Sr (fig. 22) shows no significant differences among the three geographic regions. Even when we sort individuals by geographic origins based on ^{87}Sr/^{86}Sr and δ^{13}C, the δ^{18}O data do not show significant differences except for a slightly greater range among the probable Africas with both the highest and lowest ratios, likely reflecting the huge geographic area from which these individuals came.

Discussion and Conclusions

Recent laboratory methods involving isotopes and ancient DNA are greatly enhancing the study of human remains and providing much new information and insight about groups and individuals in the past. In combination with conventional studies of skeletal evidence, a much richer and more humane picture of our ancestors is possible. That view also encompasses those portions of society that are traditionally underrepresented in the official historical records, including children and women, the underprivileged, the poor, and servants and slaves. Archaeologists no longer need to think of people as pots or arrowheads; the person in the past is becoming more visible.

This last sentence acquires more significance as a tangible reminder for the modern population of Campeche, which barely recalls its important African heritage. This omission is truly astounding given that at least one-third of Campeche's municipality was comprised of African descendants by the end of the colonial period, a legacy that is still perceptible in the local urban population and culture (Redondo 1995; Restall 2010).

In our study, we have utilized a range of isotopes in both bone and tooth from the cemetery in Campeche to learn about the inhabitants of the first colonial town in Mexico. Radiocarbon dates, while generally vague because of the flatness of the calibration curve during the sixteenth century AD, nevertheless confirmed the general age of the cemetery. We employed strontium isotopes in enamel to learn about the African origin of some of the deceased. Carbon isotopes in bone and enamel apatite and lead in enamel helped us to distinguish at least two Europeans in the cemetery. One of these Europeans was buried inside the church, while the other was placed in the graveyard with the majority of the interred individuals. Carbon and nitrogen isotopes in bone collagen provided a signal of adult protein intake and helped us to recognize different diets in the population. Comparison with carbon isotopes in tooth enamel documented potential changes in diet from childhood. Oxygen isotopes in enamel were investigated, but variability was high, and not much information was obtained from these data.

The isotopic analysis of these remains allows us to make inferences about both groups and individuals in the cemetery. The local natives appear to have been the most numerous group in the churchyard. These individuals must have been converted to Christianity to be buried in that sacred place. Carbon and nitrogen isotopes confirm an adult diet that would have been rich in maize. The nitrogen values from Campeche are comparable to other inland Maya sites, suggesting that fish may not have been particularly important in the local diet during colonial times or that most natives migrated to Campeche from the rural inland hinterlands only shortly before death, driven by European recruitment measures or simply compelled by rural hunger and hardship, as the historical records indicate (Farriss 1984:199–124). In Campeche, at the urban seat of power of the newly implanted Ibero-Mexican society, they were treated as "foreigners" in their own land, as they had to assimilate in a culture and society that was decidedly not their own.

That those identified as natives presented a higher level of

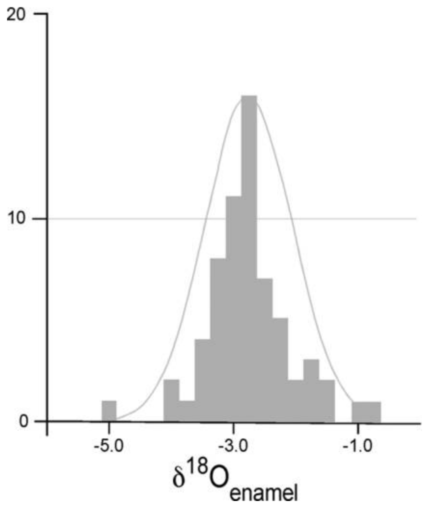

Figure 20. Histogram of oxygen isotopes in the dental enamel of 64 individuals interred in the Campeche burial ground. The estimated normal curve for these values is shown.

carious lesions is consistent with a diet rich in carbohydrates (Cucina 2010). In particular, we have to consider first that they might have come from nearby inland sites, where access to cariostatic protein and marine resources was limited, and second that they were likely not members of the wealthier segment of the indigenous society. In such cases, they might have been exposed to highly cariogenic foods not available to everyone (honey and honey-sweetened cacao, for example) that would have increased the rate of carious lesions (Cucina et al. 2011). However, given the overall biocultural context we tend to believe that this was not the case for the population buried in the Campeche cemetery.

Conventional osteological studies indicate that life was not easy for any of these ethnic groups but weighed most heavily on the natives. The individuals documented from this burial ground generally died at an early age, often in their teens and twenties (average age estimate is 23.2 years). Their bones exhibited the vestiges of hardship and illnesses in the form of periostal reaction and developmental stress as well as, for example, venereal syphilis, whose deforming effects did not spare the first generations of Campecheans (Rodríguez 2010). Developmental stress as manifest in linear enamel hypoplasia was more pronounced in natives, mestizos, and Campeche-born African individuals, while those born in Africa showed considerably fewer examples. The overall biological conditions do not describe a strong population that managed to survive difficult developmental circumstances, as suggested by the osteological paradox (Wood et al. 1992). On the contrary, their living conditions exposed them to a range of short-term and long-term stressors that eventually would lead them to an early death, as the age profile indicates.

Burials of natives and mestizos were scattered throughout the churchyard and intermingled with the Africans and Europeans. This distribution stands in sharp contrast to New World cemeteries in British colonies, for example, where segregation prevailed. At least in Campeche's central early churchyard, segregation does not appear to have been practiced in death, a custom that finds its surprising explanation in the strategies for colonization designed by the Spanish crown, which included forced cultural and religious assimilation.

The placement of the African graves at some distance from the wall of the church suggests that these individuals may have been interred in the churchyard slightly later than the first graves of local individuals, which we assume lie closer to the building. This suggestion is supported by observations during the excavations that the burials closer to the church were slightly deeper in the ground, having been covered by layers of earth and sand added in colonial times to level and raise the surface of the area. Thus, the earlier graves became deeper below the surface over time. This interpretation is also consistent with the mass of Africans arriving relatively late in time after the founding of the town and thus being buried further from the church foundation.

The data suggest that most of those individuals buried in the cemetery with traits of African biological affinity originally came from Africa. There are only a few examples that may represent Africans born in Campeche (burials 23 and 71), where local strontium isotope ratios are correlated with diets distinct from the local Maya population. The first-generation African inhabitants of the cemetery also died young; an average age of death of 24.8 years is estimated. Such estimates are tenuous because of the very fragmentary nature of the skeletal remains, the demographic nonrepresentativeness of the burial population, and the difficulties involved in estimating the age of death.

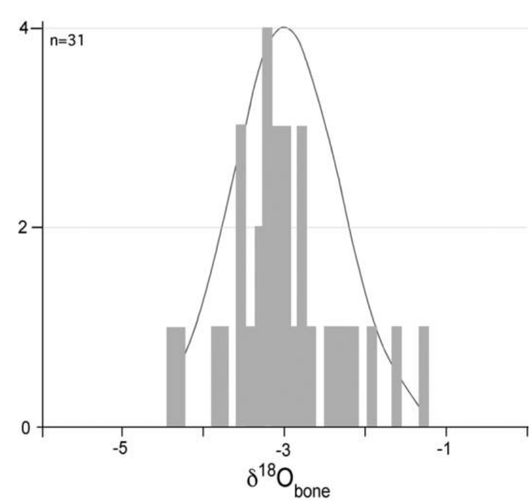

Figure 21. Histogram of oxygen isotopes in the bone apatite of 31 individuals interred in the Campeche burial ground. The estimated normal curve for these values is shown.

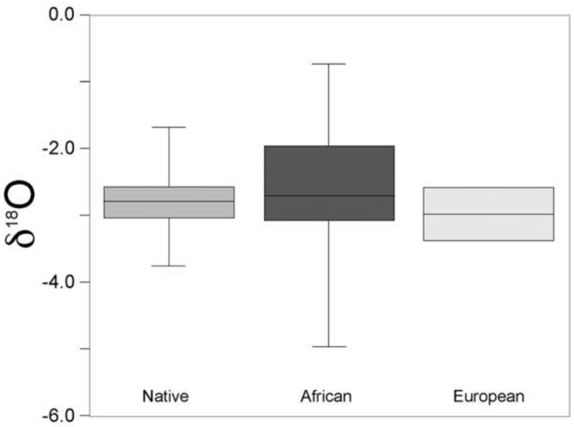

Figure 22. Box plot showing median and interquartile ranges for $\delta^{18}O$ data for 64 individuals from the Campeche burial ground, sorted by geographic origin based on strontium and carbon isotopes. Note the similar median values and overlap of interquartile ranges.

In any case, provided that most of the Africans were youngsters when they were shipped to Campeche,[3] the above average age dramatically underlines the short life expectancy of those who were forced to cross the Atlantic. The slave contracts signed by the Spanish monarchy sometimes specify age groups, for example, between 15 and 18 years; others just mention youngsters as the slave shipment. It was believed that people in their teens were better suited to withstand the hardship of the workload slaves were generally destined to endure.[4] In this context, it is noteworthy that the youngest foreigner in the burial ground, individual 85.1, a first-generation migrant from Africa, died during his or her late childhood or early adolescence (8–11 years) and must have crossed the Atlantic as a child.

This evidence and other data from the cemetery at the Campeche plaza provide dramatic snapshots of the lives and deaths of the inhabitants. For example, burial 124 was a 13–17-year-old female with filed teeth, likely born in Africa, carrying the visible signs of her identity in her dentition. She consumed a diet in early childhood that did not include C_4 plants or marine foods. Such a diet might have been consumed in the rice or vegeculture regions of southern West Africa rather than the interior regions of the continent, where millet and sorghum dominate the crops (fig. 17). This young woman likely died not long after reaching Campeche, given her age and her high bone strontium ratio. That she is buried in the cemetery suggests that she converted to Christianity before her death, probably very soon after arrival, as was common in the Hispanic colonies. Burial 5 is another example—that dramatically highlights the harsh life of the sea voyage and the colonies—with four individuals interred together. These persons may have died from disease or mistreatment on the voyage and were buried in a single grave. The group includes a probable female 35–55 years of age, a probable male 20–50 years of age, and a female of 25–35 years of age. The hasty accommodation of several corpses in the mass grave suggests death from epidemic disease or collective violence.

Burial 128 was an adult male, characterized by a low strontium isotope ratio that matched local values. Nevertheless, the carbon isotope ratios in his bone and enamel point to a very different diet and strongly suggest a European origin. His burial inside the church nave suggests a distinct and higher status for this person who may have been a first-generation Spaniard and possibly a cleric.

Burial 52, an adult middle-aged male, bears a similar European signature as described for burial 128. However, his case and social insertion should have been much different. This individual was buried adjacent to the church wall, probably one of the first generations of dead to integrate the growing rows of death lots in this rapidly expanding cemetery. Although his isotopic signature does not indicate a geographic origin in Africa for reasons stated above, combined dental morphological traits indicate that his biological ancestry might have been African. He shows well-defined, polished, concave wear between the right canine and first premolar (Tiesler and Oliva 2010, fig. 7.12). The contralateral, left pieces show a similar but less pronounced morphology compared with that of the right side.

Such modification indicates that a round abrasive object was habitually kept at the same spot between the two arches (Milner and Larsen 1991). Khudabux (1999:310–311) found similar wear facets in a colonial series of male and female slaves from the Waterloo plantation in Suriname. In addition, Handler (1978) identified grooves in an African slave cemetery from Barbados and interpreted them as the product of clay pipes. The high frequency of the wear facets confirms the popularity of tobacco pipes among the plantation slaves, a pastime that may have been shared by the male from burial 52.

The apparently contradictory evidence (African biological affiliation vs. European geographic origin) may not be contradictory at all, since the African presence in the Indies goes back to the arrival of the first conquerors, who brought African slaves with them from Spain and Portugal as servants and expedition companions (Mallafé 1973:19), a practice that explains why the first legislation for the Americas regarding African slaves (the "Instructions" given by the crown in 1502) dates back as early as 9 years after the conquest. Many slaves had been brought up in the Iberian peninsula to serve the growing numbers of conquerors and colonizers of the New World.

There are more biographies of the people buried and long forgotten in the early colonial graveyard of Campeche, which itself fell into complete oblivion until being unearthed in the year 2000. Our interdisciplinary study, anchored in multiple

3. Archivo General de Indias (Sevilla, España), Contaduría, legajo 261.
4. Archivo General de Indias (Sevilla, España), Contaduría, legajo 261.

isotopic data sets and complementary historical, archaeological, and bioarchaeological information, has helped to write part of this remarkable story of the lives and deaths of early European and African inhabitants in the New World and of those native Mayas who were to join them in death in the town churchyard. The individual life trajectories we have unveiled in this study provide a human side to a crucial epoch in the history of the New World and at the same time grant a nuanced view on the origins of today's diversified social and biological tapestry in the Americas. History, biology, bioarchaeology, and isotopes each elaborate a part of this tale of vastly diverse groups of people who came from very different places, lived hard lives, and often died young yet were joined together in a shared place of death in the colonial town of Campeche.

Acknowledgments

We thank the regional Mexican National Institute of Anthropology and History Center and the Campeche state government for institutional support. Our thanks go to our colleagues from Campeche, Carlos Huitz and Heber Ojeda, for support and sharing information. The U.S. National Science Foundation provided funding for the Laboratory for Archaeological Chemistry to conduct this research. Stephanie Jung was a tremendous help in sample preparation in the laboratory, and we also thank Paul Fullager at the University of North Carolina for the thermal ionization mass spectrometer analysis of the strontium isotope samples. David Dettman of the University of Arizona was responsible for many of the carbon and oxygen isotope measurements in enamel and bone apatite, and his care and attention is much appreciated. Darden Hood of Beta Analytic was a big help in discussions of the radiocarbon calibration curve in the sixteenth and seventeenth centuries AD. Discussions with Greg Hodgins were useful, and he arranged for the missing nitrogen isotope measurements for the Arizona ^{14}C samples. Kitty Emery of the University of Florida is to be particularly acknowledged for her assistance in providing faunal remains for the construction of the strontium isotope baseline map for the Yucatán Peninsula and for her patience. A number of other individuals helped with the creation of the baseline map for the region, including Susan Kepecs and Carolyn Freiwald. Samples and data from Spain were kindly provided by Rosario Cabrero Garcia, Salvador Dominguez-Bella, Arturo Morales, Maria Saña, Carlos Tornero, and Sonia Zakrzewski. Hannes Schroeder helped with useful comments on the manuscript. Thanks also to Stan Ambrose, Alan Goodman, and Kelly Knudson for information and assistance with various aspects of this project. The *Current Anthropology* reviewers did an excellent job, and their help and suggestions improved our manuscript. Special thanks from T. D. Price to the Alexander von Humboldt Foundation for its support in 2010.

Comments

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The authors are to be congratulated for presenting a substantive interdisciplinary study that captures the wide-ranging, interconnected nature of the emerging Atlantic World, as well as its complexity. The Atlantic past is often painted in broad strokes, as numbers on manifests or as arrows on a map. In the Campeche plaza cemetery, you have the breadth of the Atlantic World: Europeans, Africans, and Native Americans of varied origin who were brought together in a complex interethnic setting with the founding of colonial America. The study wonderfully illustrates how it is truly possible to think in terms of a holistic archaeology of the Atlantic World (e.g., Ogundiran and Falola 2007).

While the work by Price and his coauthors has direct relevance to the understanding of Campeche's past, it affords both conceptual and methodological insights that are worldwide in relevance. The indications of the living conditions, dietary stress, and brief life expectancy represented in the Campeche study provide a useful contrast with skeletal remains from other areas of the world. The isotopic studies and the methodologies presented afford a model for approaches that I would like to apply in my own research on burials from West African contexts (DeCorse 2001; Renschler and DeCorse 2012). The isotopic studies detailed are at present largely unexplored in West African settings (cf. Goodman et al. 2004). Yet such research would afford insight into the complex interethnic nature of historic sites such as Elmina in coastal Ghana, as well as provide comparative data with African diaspora populations in the Americas. The discrete lines of evidence provided by the varied nitrogen isotope ratios and the diversity in the strontium isotope data seen in burials 52 and 71 at Campeche underscore the complexity of the process that brought enslaved Africans to the Americas and point out productive avenues for future research into places of origin. The seemingly contradictory data seen in burial 52, possibly a person of African descent brought to Mexico from Europe, further hints at the complex movement of people throughout the nascent Atlantic World. Further analyses in these directions will refine our understanding of the intricacies of the African diaspora and move studies of the Atlantic World away from the generalizations that sometimes characterize research (DeCorse 1999; Hauser and DeCorse 2003).

Areas of the study that could be explored more fully in future research is potential change in the stable carbon isotopic signatures of regional populations through time and the implications these have with regard to dietary change. The diets of many world populations were dramatically transformed with the advent of transatlantic exchanges. While it is true that C_4 plants such as sorghum and millet traditionally predominated in the West African savanna and Sahel, maize was an early introduction from the Americas that became a staple in areas such as coastal Ghana by the seventeenth century (DeCorse 2001:111–112). Consequently, dietary C_4 in some African populations—and related populations in the diaspora—might be expected to be different depending on the time periods represented. Further research on the varied isotopic signatures of historic American, African, and European populations and the documentation of change in these signatures through time provide a unique opportunity to evaluate the dietary impacts of Columbian exchanges.

This article deals with isotopic studies of skeletal remains from Campeche, and this is the primary focus. Yet the research offers compelling insight into the story of the human past, with the authors noting that "archaeologists no longer need to think of people as pots or arrowheads; the person in the past is becoming more visible." Recognizing the constraints of space and the paper's focus, I nevertheless would have liked this aspect of the research to be explored more fully. The various isotopic studies conducted take the forefront; the individuals—and what we have learned about them—are left somewhat overshadowed by the scientific methodologies employed. What further clues do the skeletal data, associated archaeological finds, and historical sources provide about the "person in the past"? Can any more information be gleaned regarding the deaths of the individuals in burial 5 and why they might have shared a grave? What further clues do the isotopic data and the dental modifications seen in burials 19, 41, 102, and 124 together hold for determining the specific African ethnic and cultural affiliations of the individuals? What are the other "biographies" that are left to be told? The discussions of individual burial contexts, associations, and their possible origins felt too brief and, like the first book in a good trilogy, left me longing for more. These stories will undoubtedly be told in future publications.

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There are very few collections of human remains from historical cemeteries that have been subject to isotopic analysis, especially dating from the first 2 centuries after the contact. This certainly makes the contribution here very important for those who are involved in investigation of those colonial periods. Without bioarchaeological studies, people from burial grounds like Campeche could remain obscure concerning ethnic identity, geographical origins, and some of their daily life aspects, such as diet. Isotopic analysis of bones and teeth came here as a special contribution, helping with cross confirmation of hypothesis, including to contrast previous historical interpretation.

The interesting thing about the results presented for San Francisco de Campeche cemetery in Yucatán, Mexico, is that besides bringing a new interpretation to the site, they contribute to the elucidation of individual bioarcheological profiles for the people buried there. Past human remains in tropical areas can be badly preserved, even after some decades or a few centuries, especially in open urban areas. The complementary use of isotopic analysis in bioarchaeology has been shedding light on materials that otherwise would not be very elucidative for archaeology. Macroanalysis of what is "visible" anthropological evidence was here improved by chemical and physical analysis of "nonvisible" evidence. In spite of the frustration in precisely dating the human remains, isotopes led to other interesting results, such as strontium ratios for both teeth and bone, as well as oxygen, nitrogen, and carbon results, clarifying geographical origins and diet. Their use here is a good example of how physical/chemical analyses help to improve interpretation of human remains, especially when the historical context is documented, as in Campeche. Documents related to the European as well as Maya and African groups involved in the foundation of Campeche and following decades were important, of course, to refine the results, giving them historical, biological, and cultural significance.

But isotopic analysis is not applied to many cemeteries. Limitations to the application of isotopic analysis remain the costs and laboratory expertise required, both big challenges to less supported projects. Most of the historical cemeteries already excavated (they are not so many!) were never subjected to detailed isotopic studies. In countries like Brazil, the colonial history has plenty of questions to be answered, but most of the skeletal series exposed in rural/urban areas and historical buildings have been reburied before detailed analysis could be done. In the present decade, people have renewed interest in bioarchaeological studies in historical series, a strategy to reduce lost information. Recent analysis of the Sr ratio for two human series of teeth from the New Blacks (Pretos Novos) burial ground in Rio de Janeiro (Bastos et al. 2010) and the partisans cemetery at the churchyard of the first Cathedral of Brazil in Salvador (still unpublished) are two examples.

Elevated Sr ratios for nonlocals (above 0.7092) at Campeche is contrasted with the low signature for coastal people or locals from Yucatán. The values were similar to what has been previously found for other cemeteries, including from Brazil. Human remains from the New Blacks cemetery, used for the slaves who died in the Valongo slave market in Rio de Janeiro, and the Sé of Salvador cemetery, used for the partisans (slaves and free people) living in Salvador, were studied for anthropological and isotopic analysis. Both are coastal cities, and the cemeteries were used during the seventeenth, eighteenth, and nineteenth centuries (Salvador) and the eighteenth and nineteenth centuries (Rio de Janeiro). Although the total Sr range found for Campeche (0.7081–

0.7391) was close to Salvador's results as well as to those of other Central and North American cemeteries (Goodman et al. 2004; Schroeder et al. 2009), it was not as wide as the Sr ratio published by Bastos et al. (2010) for the New Blacks cemetery in Rio de Janeiro. Enamel Sr ratios from 30 individuals from the New Blacks cemetery resulted in a range from 0.70589 to 0.74985 (95% above the baseline proposed for Campeche nonlocals). Although other isotopes are still under analysis for the Brazilian series, the results are consistent with the historical records for the African slave trade bringing people from different African ports to Rio de Janeiro, while the slave traffic to Salvador was more restricted to the Mina coast, as is also confirmed by dental modifications in those series, some of them similar to what is described for Campeche.

Finally, in this paper Price and colleagues call attention to the unexpected amount of African-born people in that burial ground, discussing that modern representation had apparently reduced their representativeness, both cultural and biological, in Mexican heritage. Except for some eventual cultural traces on their bodies, such as dental modification, ethnicity should not be easy to ascertain in poorly preserved skeletons and partially disturbed graves. Here once more the isotopes played their important role, answering the question "Who?" by signaling geographical and dietary patterns.

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Price and colleagues are to be congratulated on the achievement of their Campeche project and on their commitment to making their findings available (see also Tiesler, Zabala, and Cucina 2010). Their skillful analysis of skeletal and dental remains sheds bright light on a little-studied town in its first colonial century, showing how Spaniards, their African slaves and servants, and native peoples (mostly local Mayas) lived tough lives together, often died from the same grim afflictions, and were buried in close proximity. Yet at the same time these groups were different from each other—with the differences identified and detailed through scientific methods reflecting the different ranks, functions, and experiences of each group within colonial society. This dialectic between commonality and difference is a core issue with which historians wrestle as we study multiracial and multiethnic colonial societies in the Americas.

The work presented here is therefore invaluable to historians. The training and experience of historians is far removed from that of the scientists involved in the Campeche project, and the kinds of source materials that we use cannot possibly replace or render redundant the bones that scientists are able to read—even if written sources confirm, complement, or problematize scientific conclusions. The point is relevant to historians of various fields, whether we zoom in close or far out.

Zooming in close reveals those scholars studying colonial-era Afro-Yucatecans (as I have called them; see Restall 2009); such scholars are relatively small in number, and the field of Afro-Yucatán is relatively new, making contributions such as that of Price and colleagues' Campeche project (see also Tiesler, Zabala, and Cucina 2010) even more important. A close zoom also reveals the field of conquest studies, which is currently experiencing a renaissance, particularly with respect to Mexico and Guatemala (dubbed the New Conquest History; see Restall 2012 for a summary of the field and its contributors). But as yet few new studies focus on Yucatán during the conquest decades of the 1520s–1540s, let alone Campeche (see Chuchiak 2007); thus, the revelation by archaeologists in 2000 of the very existence of the early church in the plaza—aside from the adjacent burials they later unearthed—was new and significant to historians as well.

If we zoom out, we catch the larger fields of ethnohistory in the Americas, of African diaspora studies, of the history of colonial Latin America, and even of Atlantic World history. Despite the breadth of such fields, many scholars within them will find the findings of Price and colleagues' Campeche project to be illuminating and stimulating.

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The Making of a New World

Until recently, our knowledge of life in the Spanish colonies during the sixteenth and seventeenth centuries was largely based on historical accounts. This has begun to change as archaeologists start to unearth the physical remains of colonial life at sites such as Campeche on the Yucatán Peninsula (Tiesler, Zabala, and Cucina 2010). Some of the most fascinating insights of these new studies stem from the analysis of human remains as they shed light on the ethnic composition, demography, social structure, and health status of the colonial population (Cucina 2010; Rodríguez 2010; Tiesler and Oliva 2010; Tiesler and Zabala 2010). Price and colleagues' isotopic study of the human remains from the plaza cemetery in Campeche adds to this growing body of data by providing new information on the geographic origins, migration patterns, diet, and living conditions of the town's population. While the radiocarbon dates are largely disappointing and really only serve to illustrate the problems we face with radiocarbon dating in the early modern period because of the nature of the calibration curve, the other isotopic data provide fascinating insights into the origins and lives of Campeche's residents.

Most isotopic studies in archaeology to date have used only one or two isotopic species to address questions relating to people's movements and migrations in the past, the most common of which are probably strontium and oxygen isotopes. In their study of diet and origins at Campeche, Price and colleagues use a combination of carbon, nitrogen, oxygen, strontium, and lead isotope measurements in what is probably the most comprehensive isotopic study of archaeological human remains to date. The advantage of using several isotopic measurements is that they provide different kinds of information that can help to gain a more nuanced understanding of peoples' movements in the past (Schroeder et al. 2009). While strontium and lead isotope ratios vary spatially with the local geology, oxygen isotope ratios vary according to climatic and geographical variables, including altitude, latitude, and distance from the sea as the source of atmospheric water (Faure and Mensing 2005). In addition, carbon and nitrogen isotopes provide dietary information that can also help in identifying geographic origins (see Sealy, Armstrong, and Schrire 1995; Schroeder et al. 2009).

Using these various isotopic indicators, Price and colleagues are able to distinguish between different groups among the burials from Campeche. On the one hand there are the locals, a large fraction of whom were probably natives who had been moved into the town by the Spaniards. On the other hand there are the European and African immigrants, who are distinguishable on the basis of their nonlocal isotope ratios. The Africans who were probably brought as slaves to the colony stand out on the basis of their elevated strontium ratios, while the Europeans (although indistinguishable in terms of strontium) could be identified on the basis of their lead isotope ratios, which fell very close to a range of values from southwestern Spain, and their carbon and nitrogen isotope values, which suggested that they had subsisted on a C_3 as opposed to a C_4 diet before moving to Campeche. Overall, the strontium isotope measurements appear to be more useful in identifying African-born individuals, while the lead isotope ratios help in identifying Europeans. Carbon and nitrogen isotope ratios provide additional information relating to diet that can also help in identifying origins. This leaves the oxygen isotopes, which appear to be less useful in this context because of a lack of variation in the lower latitudes (Bowen and Wilkinson 2002).

Apart from the lack of variation that affects oxygen isotope ratios, another limitation of using isotopes in archaeology in general is that while they can be used quite effectively to identify nonlocals in a burial population, they cannot be used to pinpoint origins. This is because isotope ratios are not unique to a specific location, as Price and colleagues rightly point out. One possible avenue to explore in this respect involves the use of ancient DNA (aDNA). Although the Caribbean climate poses serious challenges to aDNA studies, previous research has shown that DNA does survive in these unfavorable conditions (Lalueza-Fox et al. 2001). While studies based on mitochondrial or Y-chromosome DNA might not hold sufficient geographical resolution to identify the ancestral origins of Campeche's colonial population down to any more than the crudest level, studies at the genomic level involving so-called autosomal ancestry-informative markers might well hold enough resolution to go further (e.g., Novembre et al. 2008). So far the costs of these analyses, especially when dealing with aDNA, have been prohibitively expensive. However, with the ever-decreasing costs in sequencing this situation is rapidly changing, and it is hoped that future studies involving aDNA will shed more light on the origins and relationships of America's early colonial populations in their making of a new world.

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Price and colleagues provide a detailed biogeochemical study that conclusively shows the diverse origins of those buried in the colonial cemetery of Campeche, Mexico. This study is a significant contribution on both methodological and historical fronts. The colonial period has received little bioarchaeological study in Mexico, and the role that African populations played in the emergence of colonial Mexican culture, society, and identity is undoubtedly underappreciated. Here, Price and colleagues reveal the foreign identities of these early colonists through an interdisciplinary analysis of skeletal, geochemical, and archaeological data.

Comparing the stable isotopic compositions of both first molar enamel (which forms in the first 2 years of life) and bone (which is biased by adolescent growth but remodels throughout life) provides a way to identify migrants. Price and colleagues' study nicely shows the interpretive process that follows collection of the geochemical data. Of the varied data they measured, the strontium isotope data are most easily interpreted, providing a clear identification of African-born individuals in this Campeche cemetery. More exploratory study and interpretation is required to make sense of the oxygen, lead, and paleodietary data. Many foodstuffs have overlapping carbon and nitrogen isotopic signatures, and interpretation of these data become more complicated when both New and Old World crops must be considered, as in this case. I wondered whether the use of pewter serving vessels by immigrants to Campeche (or elites?) might also influence the lead isotope ratios, assuming that the local Maya population continued to use ceramic vessels.

Price and colleagues are skeptical of the utility of stable oxygen isotopes to identify migrants because of the largely overlapping results that they obtained for individuals who differ in $^{87}Sr/^{86}Sr$, which they logically identify to Campechean, Spanish, and African origins. As they note, the $\delta^{18}O$ of rain does not differ dramatically among these semitropical homelands. I agree that $\delta^{18}O$ values are more challenging data for the study of paleomigration because they are shaped by many more variables than strontium or lead isotopes. In addition

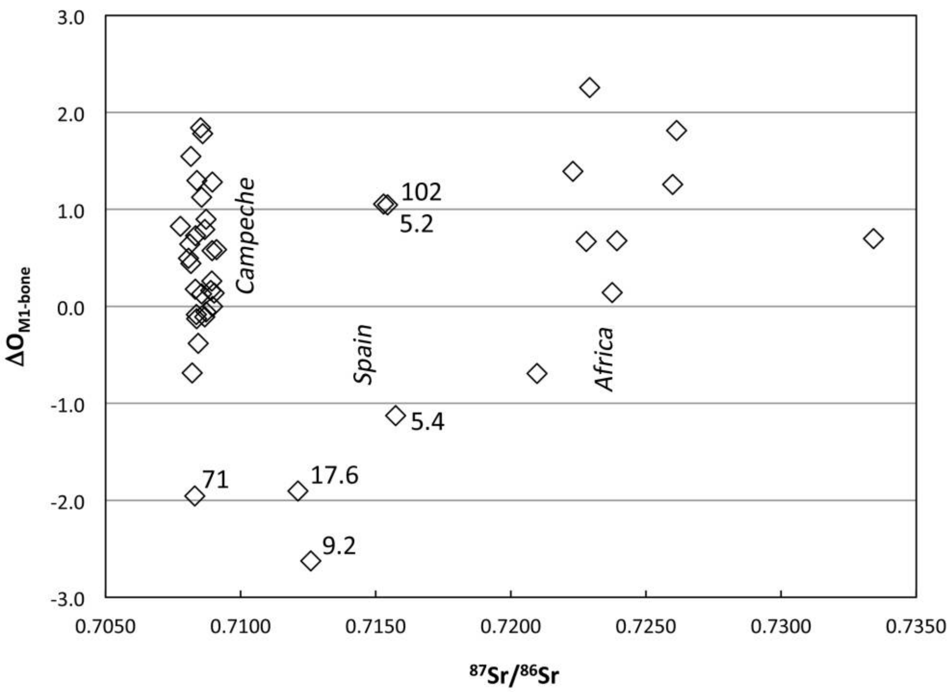

Figure 23. Difference in stable oxygen isotope ratios of first molars and bone ($\Delta O_{M1\text{-}bone}$) plotted against stable strontium isotope ratios ($^{87}Sr/^{86}Sr$). Skeletons with higher $\delta^{18}O_{bone}$ than $\delta^{18}O_{M1}$ show negative ΔO values and may have migrated after childhood. Possible migrants are identified by burial numbers.

to considerable seasonal fluctuation (7‰ in the Maya area), there may be considerable interannual fluctuation, and community water supplies may vary among storage facilities because of dry season evaporative enrichment. This variation within a single site catchment plays out in fairly variable $\delta^{18}O$ even among portions of a single tooth that mineralized at different ages. Accordingly, $\delta^{18}O$ ratios are best compared among teeth sampled in exactly the same manner, such as with a cuspal-cervical section of enamel that spans and averages such variations over the developmental history of the tooth. It is not clear to me from Price and colleagues' sampling protocol whether their enamel apatite samples would consistently capture the same developmental periods in each tooth sampled. Bone shows a longer-term adolescent/adult value, attenuating seasonal and interannual variation. In theory, homogenized large enamel samples or bone should show more narrow location-specific ratios than small enamel samples.

The average $\delta^{18}O$ value of Price and colleagues' M1 enamel and bone samples differ by 0.3‰ in $\delta^{18}O$, likely because of enrichment in ^{18}O due to nursing. Variability in this pattern provides a further cue that may identify migrants. Ordinarily, one would not expect a large difference between bone and averaged M1 enamel, generally less than 2‰. As the authors note, few of their paired enamel and bone data differ by more than 2‰, but it is the direction of this difference that is important. Here, most show a first molar sample that is ^{18}O enriched by comparison with the bone value for the same skeleton, a pattern consistent with a nursing effect and residence in a single location. However, a small number of skeletons show a higher $\delta^{18}O$ value in bone than enamel, which is best explained by movement to a new location. Using Price and colleagues' data, figure 23 shows a plot of the difference between M1 and bone apatite $\delta^{18}O$, $\Delta O_{M1\text{-}bone}$, against $^{87}Sr/^{86}Sr$. Three of five skeletons with $^{87}Sr/^{86}Sr$ consistent with an origin in Spain (9.2, 17.6, and 5.4) have positive $\Delta O_{M1\text{-}bone}$ values, indicating the incorporation of ^{18}O-enriched mineral into bone after migration. They are also among the lowest $\delta^{18}O_{M1}$ in the data set. Two other Spaniards may have died soon after migrating (5.2 and 102).

Burial 71 also has a higher $\delta^{18}O_{bone}$ than $\delta^{18}O_{M1}$. Price and colleagues at first interpret burial 71 as a native Maya in view of the person's shovel-shaped incisors, dental decoration, and local strontium isotope ratio. Later in the paper, they infer that he was an African born in Campeche, on the basis of low $\delta^{13}C$ and $\delta^{15}N$ ratios that imply less maize and/or seafood consumed by this individual, an inconsistency of the sort common to multiple-authored papers. The absolutely low $\delta^{18}O_{M1}$, relatively higher $\delta^{18}O_{bone}$, and distinct diet together raise a further possibility, that this individual might be a Native American migrant from a different colony located on a similar geological substrate. The rich multivariate data contained in this paper make possible such nuanced interpretation and underscore both the interpretive strengths and the challenges of this growing field of biogeochemical archaeological science.

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The research thus far conducted on the Colonial cemetery from the central plaza of Campeche provides a fascinating window into the construction of an early Spanish community in the New World. Like many researchers focusing on pre-Hispanic contexts, I am always profoundly impressed by the interpretive power derived from firsthand historic accounts. While admittedly these accounts are often intentionally or unintentionally biased by the observers, they offer unique perspectives and provide basic descriptive data on a wide assortment of variables related to social, economic, and political organization—factors that are often frustratingly elusive in precolonial contexts. Thus, the central role taken by historic accounts of colonial Mexico is important for providing the detailed social context in which the biological data are understood and interpreted. Perhaps in no other cultural context are such data so politically relevant and important than in those demonstrating the transformative processes of colonization and empire building that has shaped current society. This study presents an especially elegant narrative in which these many sources are woven together.

From an archaeological perspective, what is particularly striking is the juxtaposition of the inclusive and exclusive elements of colonial Campeche society. For instance, the diverse composition of the early church and its associated cemetery, the lack of mortuary differentiation (including signals of resistance to assimilation), the generally universal affliction with disease, the presence of freed slaves, and the multiethnic nature of the population may at first glance paint a picture of a heterogeneous yet united community. However, the segregation of neighborhoods, the differential access to resources, and the enslavement and domination of both native and African groups suggests a strikingly different situation. For archaeologists, this type of study illustrates seemingly contradictory data that would likely be misleading without the historic record.

While the cultural and genetic variability of the cemetery are fascinating and have a number of important ramifications relating to the church's strategy for integration, they also present a very significant limitation for discriminating the variables related to social and ethnic distinctions. Mortuary practices in this case intentionally mask social and ethnic variation in death, although no doubt these were important determinants of an individual's quality of life. Cucina's efforts to determine ancestry using dental morphology is certainly a major step toward this end, and future improvements to ancient DNA methodologies may overcome the limitations currently imposed by the site's poor preservation. An important future contribution this study will have is to facilitate studies focusing on the nature of that variability. For instance, by discriminating between locally born individuals and recent immigrants, we have the opportunity to explore the nature of power in the early colonial period and how well new arrivals were integrated into the uniquely diverse Campeche society.

While documentation of significant dietary change concurrent with relocation from the Old World to the New World is interesting, one would expect a dramatic shift for all groups related to the local availability of specific foods regardless of socioeconomc status. In this way, the variability of carbon isotope ratios of nonlocal Africans documented in this study is attributed to the differential diets among groups living in Africa, rather than intragroup variation of immigrant groups in the New World. However, the unique dietary indicators from the two Mexican-born Europeans may imply intragroup distinctions reflecting status and/or ethnicity. In this case, it potentially demonstrates what must have been an intentional and no doubt difficult-to-manage effort by those of European descent to distinguish themselves from other groups in the community by perhaps adhering to a European menu. In addition to determining differences between the experiences of the ethnic groups, it would be equally important to explore the variations within these groups. As implied in the historical review, the "blacks" in Campeche were represented by both freemen and slaves, while Europeans seem to have varied in socioeconomic status as well as in whether they were living in established households. Such data have the opportunity to tell us about the process of enculturation within colonial society from a number of different perspectives and the effects of institutional and economic controls. For instance, a study by Rose (1985) in Arkansas demonstrated that "general quality of life for southwest Arkansas Blacks had deteriorated significantly since emancipation due to the fall of cotton prices and legalized discrimination" (5).

Unfortunately, the division of individuals into subgroups based on so many variables may not be feasible for the current study sample, because resulting subgroups would be too small for statistically meaningful comparisons. Perhaps for this reason, the authors have taken a life-history approach using specific examples from the multitude of individuals to illustrate the variety of individuals who made up the cemetery and the community. The authors should be commended for integrating such a variety of data sources and providing a framework for future investigations of colonial society.

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Although the authors do not say it, and they are almost hidden within the work, Price and colleagues provide a series of osteobiographies for individuals buried in the churchyard at Campeche. This work is important as it integrates bioarchaeological evidence with a series of isotopic studies to provide a richer picture of society during the early colonial period. Price and colleagues link these varied data sets, thereby making the individual person more visible within the archaeological past. This kind of study is to be commended and encouraged, as it enables less visible aspects of heritage to be highlighted and brought into the overall early colonial history of Campeche.

Strontium, lead, and oxygen were used to inform the place of origin for individuals, with carbon and nitrogen isotopes in enamel apatite, bone apatite, and bone collagen used to look at aspects of diet and then lifetime movement. It is this interlinking of these varying isotopic studies that is, despite repeated calls (e.g., Burton 2008; Katzenberg 2008), sadly relatively unusual.

There are aspects of the strontium ratio analyses that merit further consideration. Price and colleagues have made excellent use of both geological baseline and comparative enamel samples to ascertain the bioavailable strontium within the local area. The inhabitants of the Campeche cemetery exhibit a huge range of $^{87}Sr/^{86}Sr$ values. They argue that the very first value (0.7078) is distinctly low relative to the others, which start at 0.7081. It is true that this is low, but the range for those argued to be local and consuming a varied diet is itself large (0.7081–0.7092). Indeed, some of those individuals who were not born locally have bone $^{87}Sr/^{86}Sr$ values that are higher than might be expected for living locally prior to death or may be affected by some degree of diagenetic change (Bentley 2006; Nelson et al. 1986; Tütken and Vennemann 2011 and papers therein). The comparison with Africans buried in other North American contexts is excellent and provides a dynamic appraisal of the slave trade and the link with Spanish colonists. This research therefore sheds light on the movement of individuals brought as slaves to the Spanish colony, most likely from West Africa. It is also important to critique the overlap in $^{87}Sr/^{86}Sr$ values with individuals of potentially European origin, as the comparative literature studied indicates a relatively broad range of strontium values from southern Spain. This means that the bioarchaeology, such as the dental modification described for burial 19, needs to be fully integrated to elucidate potential individual osteobiographies.

Burials 52 and 128 have strontium isotope ratios within the range considered to be local to Campeche but have enamel lead isotope ratios similar to lead isotope ratios from southwestern Spain. Burial 52 has very low collagen $\delta^{13}C$ and apatite $\delta^{13}C$ values, suggesting a different diet from others in the cemetery, mostly a largely terrestrial diet with an absence of C_4 plants. This individual also has a relatively high $\delta^{15}N$ value, implying a higher-tropic-level diet. Burial 128 has no collagen $\delta^{13}C$ value but has an even lower apatite $\delta^{13}C$ value. Burial 52 was placed adjacent to the church wall, whereas burial 128 was located inside the church nave. In addition, burial 52 exhibited dental wear that the authors associated with the use of clay pipes (commonly used by slaves). Price and colleagues suggest that these two individuals derive from Spain and argue that burial 128 may have been a high-ranking Spaniard, potentially a cleric, whereas burial 52 may have been a slave who was born in Spain of African ancestry. This latter hypothesis is the more contentious, as it relies on the assumption that nonslaves did not use clay pipes, and it would be beneficial to have further investigation of other isotopic signals for this individual.

The relationship between strontium ratios and carbon and nitrogen values in collagen is of particular interest. Distinct patterns can be seen, as the authors note, such as native-born individuals and foreign-born individuals consuming the same diet based on C_4 plants and seafood. Individual 95 is a clear outlier, but the authors also focus specifically on individual 5.4. The other burials from this grave, individuals 5.2 and 5.3, also have nonlocal strontium signatures and low $\delta^{13}C$ values in both their collagen and bone apatite (individual 5.1 is not presented).

A key portion of the argument made by Price and colleagues is a discussion of apatite-collagen spacing. This paper clarifies the importance of this spacing for dietary reconstruction and demonstrates how the food web may be reconstructed from the isotopic signals. This paper reminds us that we need to think about how foods are actually consumed, such as the recognition that, for Campeche, the people consumed C_4 plants themselves rather than C_4-fed animals and/or seafood. This aspect of dietary reconstruction deserves further recognition and discussion and has the potential to enable us to identify differences in food-processing techniques and cuisine between migrants and indigenes or between slaves and their masters.

Reply

We would like very much to express our appreciation to the commentators for their thoughtful and kind remarks regarding our study of the colonial Campeche cemetery. DeCorse's suggestions for future research on contemporary human remains from West Africa certainly highlights an essential next step in the continuing investigation of the African diaspora. His comment on the very early introduction of maize is intriguing and sparks interest in the two-directional consequences of contact and migration. His desire for more information about the "person in the past" is one we share, and more of this information has been published in a volume on the Campeche cemetery (Tiesler, Zabala, and Cucina 2010). More detailed information on the burials and their living histories can be found in the chapters by Tiesler et al., Rodríguez, Cucina, and Tiesler and Oliva, together with a collective history of the town population (Tiesler et al., Tiesler and Zabala) and early colonial society (Antochiw, Witz and Ojeda, Zabala, Restall).

Souza writes from the perspective of Brazilian bioarchaeology and a region where early African cemeteries are also known. One of the most striking aspects of the Campeche churchyard to us was the sharing of space by the remains of local Maya and immigrant Europeans and Africans, a practice in contrast with the frequently segregated burial grounds reported from Brazil, New York, and elsewhere. It was interesting also to learn of the similarity in $^{87}Sr/^{86}Sr$ values between Campeche and the Brazilian sites, particularly the extremely high value of 0.7499 reported from the New Blacks cemetery. As Souza notes, these wide-ranging ratios, almost certainly from Africa, point to different places of origin on that continent. One of the important next steps in such research will be the characterization of bioavailable strontium isotope ratios in West and Central Africa. It is also important to emphasize that the proportion of deceased nonlocals in colonial cemeteries does not necessarily reflect the true proportion of migrant foreigners in the population but simply those who by choice or mandate remained in Campeche. Many others passed through Campeche on their way to other parts of Mexico.

Restall writes from the perspective of a historian and provides several important insights on the Campeche study. He notes the dialectic between commonality and difference as a core issue in colonial societies in the Americas, one made visible in the churchyard at Campeche. Restall reminds us of the importance of new studies in the relatively poorly known colonial history of the Yucatán. Certainly, the involvement of the historian Pilar Zabala was an essential part of our project.

Schroeder, author of a study of an African burial ground in Barbados (Schroeder et al. 2009), correctly notes that while isotopic studies can be used to identify nonlocals, the assignment of a specific place of origin remains problematic. He recommends the use of ancient DNA (aDNA) for the investigation of such skeletal collections, specifically genomic studies involving autosomal ancestry markers to provide additional information on places of origin (e.g., Novembre et al. 2008). The point is well taken, and in fact aDNA studies of the Campeche remains have begun. We might also point out here that the ^{14}C dates were also undertaken to rule out any pre-Hispanic burials that might have been found in the cemetery.

Wright's background in bioarchaeology and her wide-ranging isotopic studies in the Maya region inform her evaluation of our Campeche investigations. Her comment on the underappreciated role of Africans in the emergence of colonial Mexico is certainly on target and hopefully is one of the lessons of this study of the Campeche cemetery. The use of pewter in colonial Campeche is not well documented, but presumably such items would initially have come from the homeland of those who used them. Perhaps these objects served to provide a source for nonlocal lead isotopes. The potential impact of such containers is impossible to know, but we suspect it to be minor. With regard to Wright's query as to whether teeth for oxygen isotope analysis were sampled in the same manner: that was not the case and in fact is rarely possible in studies of archaeological human teeth for a variety of reasons. Neither have we seen any demonstration that such sampling produces less variable results. Wright's observation that the 0.3‰ difference in $\delta^{18}O$ between bone and enamel is due to enrichment of ^{18}O during nursing is certainly a possibility. Her observation that three of five individuals (perhaps from Spain) have bone $\delta^{18}O$ values higher than enamel values suggests to her that bone was enriched with ^{18}O after migration to the Yucatán. Her further note regarding burial 71 suggesting that this individual may be from another location in Mesoamerica is intriguing but difficult to evaluate. We reported that 71 was local but exhibited certain nonlocal characteristics. It is certainly the case that native allies of the Spanish are known to have traveled with them from the Central Highlands of Mexico. We remain cautious in the interpretation of isotopic results, however, when so much variation remains poorly understood.

Wrobel seconds Restall in noting the seeming contradictions between archaeological and historical perspectives and between commonality and difference that are revealed in a study such as ours. He evokes the importance of the historical record in colonial contexts to counter the biases of archaeological evidence. Certainly this process works both ways—the sum is greater than the parts. Wrobel also points in the direction of aDNA studies to provide more detail on the ancestral histories of the churchyard's inhabitants, noting that mortuary practices at Campeche intentionally mask social and ethnic variation. Wrobel also observes the potential for future investigations of the groups identified our study to detail dietary, status, and ethnic differences operating in colonial Campeche.

Zakrzewski's comments point to the biographical nature of such analyses and the focus on the individual. The ability to begin to identify individual life histories is one of the very exciting aspects of the isotopic analyses of human bones and teeth. We believe that burial 128 is European, probably Spanish, on the basis of both the isotopic analyses and the location of the grave inside the early colonial church. Burial 52, the pipe smoker, practiced a habit common among the African slaves; however, we never suggested he was a slave but did suggest he was European. Individuals of African ancestry were not uncommon in fifteenth-century Spain and were in some cases brought to the New World as servants or expedition companions.

The interplay of observation and critique in the context of the CA☆ Comments section provides an important and almost unique forum for studies in anthropology and archaeology. For us, the experience has been beneficial and provides inspiration to continue such research. Again, our thanks are extended to the folks who took the time to comment.

—T. Douglas Price, James H. Burton, Andrea Cucina, Pilar Zabala, Robert Frei, Robert H. Tykot, and Vera Tiesler

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Supplement Table A1

Burial	Sex	AGE ID	Min. ag	Max. a	Agver	Cran.	Dental (	Dent	Burial type	disturbance	position	Orient.	Depth	Distanc	Ass. Personal items
1.1	M?	mature to old adult	45	70	57.5		NID		Primary direct	disturbed	Flexed on the right side	W	1.2	9	0
4A		adult (>20)					NO		Secondary					6	0
4B		adult (>20)					NID		Secondary					6	0
5.2	F?	young middle adult	35	55	45	NO	NO		Primary direct multiple	disturbed	Extended dorsal decubitus	SW	1.1	14	0
5.3	M?	adult (>20)	30	50	40	NO	NO		Primary direct multiple	complete?	Extended dorsal decubitus	NE	1.18	14	0
5.4	F	young adult	25	35	30	NO	NO		Primary direct multiple	complete?	Extended dorsal decubitus	NE	1.16	14	0
6	M	adult (>20)				NO	NO		Primary direct	complete?	Extended dorsal decubitus	SW	1.28	13	0
7		3 INF	7	11	9		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.31	7	0
9	F	young adult	20	30	25		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.24	9	0
9.2	M	adult (>20)					NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.47	6	0
9.3	M	young adult	25	35	30		NO		Primary direct	disturbed	Extended dorsal decubitus	S	1.55	9	0
9.4	M?	young adult	20	30	25	SI	NO		Primary direct	disturbed		SW	1.17	10	0
10	M?	young adult	20	30	25	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.16	11	0
11.1	F?	young adult	20	25	22.5	NO	NID		Secundario?				1.12	15	0
11.2	M?	adult (>20)					NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.1	15	0
12 prim	M?	young adult	25	35	30	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.15	13	0
13A		3 INF	7	9	8		NID		Secondary				1.14	1	0
13B		adolescent?	10	15	12.5		NID		Secondary				1.14	1	0
13C		young adult?	15	25	20		NID		Secondary				1.14	1	0
13D		adult (>20)					NID		Secondary				1.14	1	0
17.1		adolescent	10	15	12.5	NO	NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.1	9	0
17.2	M?	young-middle adult	25	40	32.5		NID		Primary direct	complete?	Extended dorsal decubitus	SW	1.05	6	0
17.3		3 INF	8	10	9		NO		Primary direct	disturbed	Extended dorsal decubitus	W	1.05	6	0
17.4	F?	young adult	25	35	30	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.12	6	0
17.5	F?	young adult	20	35	27.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.18	8	0
17.6	M?	young-middle adult	25	40	32.5	SI	NID		Primary direct	disturbed	Extended dorsal decubitus	SW		8	0
17.7	M?	young-middle adult	30	45	37.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.21	7	0
17.9	F?	young adult	15	20	17.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.24	8	0
18 sec	M	young adult	20	30	25	NO	NID		Secondary				1.1	7	0
18.2	M?	adolescent-young adult	13	20	16.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.34	7	0
19	M	adult (>20)					SI	C	Secondary					13	0
22	F?	middle-mature adult	35	50	42.5	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.06	11	0
23		adult (>20)					NID		Secondary	incomplete (dren.)			1.09	9	0
25		1 INF	0	2	1		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.19	2	0
26	F?	adolescent-young adult	14	18	16		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.45	1	0
29	F?	young adult	17	23	20	NO	NID		Primary direct	complete?	Extended dorsal decubitus	S	1.42	1	0
30		adolescent-young adult	13	17	15		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.36	2	0
31	F	young adult	20	30	25		NID		Primary direct	complete?	Extended dorsal decubitus	SW	1.35	2	0
32	M?	middle-mature adult	35	55	45	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.16	0.5	0
33	M?	adult (>20)					NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.32	2	0
39	F?	young adult	15	25	20		NO		Primary direct	incomplete (dren.)	Extended dorsal decubitus	SW	1.38	1	0
40	M	middle-mature adult	35	50	42.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.1	15	0
41	M?	young-middle adult	25	40	32.5	NO	SI	C	Primary direct	disturbed	Extended dorsal decubitus	SW	1.03	15	0
44		adolescent	10	13	11.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.03	15	0
49		young adult					NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.19	16	0

49.1		adult (>20)					NID		Secondary?				1.19	16	0
49.2		adult (>20)					NO		Secondary?				1.19	16	0
50		young adult	18	28	23		NO		Primary direct	disturbed	Extended dorsal decubitus	S	1.15	7	0
52.1	M	middle-mature adult	35	50	42.5	NO	NO		Primary direct	complete?	Extended dorsal decubitus	SW	1.29	5	0
53	M	young to mature adult	30	50	40		NID		Primary direct	disturbed	Flexed irregular		1.2	6	0
57	F?	young-middle adult	30	40	35	NO	NO		Primary direct	disturbed	irregular	SE	0.89	8	0
59	F	young adult	20	30	25		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.35	5	0
60		adult (>20)				NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.34	6	0
61		adult (>20)					NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.51	5	0
62	F?	young adult	15	25	20		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.48	6	0
66		INF	0	10	5		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	0.86	6	0
67	M?	young to mature adult	30	50	40		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	0.62	8	0
71	M	adult (>20)				NO	NID		Secondary					13	0
72.1		adult (>20)					NO		Secondary				0.82	12	0
72.3		adult (>20)					NID		Secondary				0.82	12	0
72.4		2 INF	2	5	3.5		NO		Secondary				0.82	12	0
73	F?	young-middle adult	25	45	35	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	0.87	12	0
74.1		3 INF	6	10	8		NO		Secondary				0.97	12	0
74.2		young adult	15	25	20		NO		Secondary				0.97	12	0
75		adolescent	10	15	12.5		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	0.85	13	0
77	M?	adult (>20)					NO		Primary direct	complete?	Extended dorsal decubitus	SW	1.08	11	0
78	F?	adult (>20)				NO	NO		Secondary				0.96	12	0
79.1		1/2 INF	2	3	2.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	0.73	11	0
79.2		adult (>20)					NO		Secondary?				0.73	11	0
81		2/3 INF	5	8	6.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.32	5	0
81.1		3 INF	6	10	8		NID		Secondary?				1.32	5	0
81.12		adolescent	10	15	12.5		NID		Secondary?				1.32	5	0
82		young adult	15	30	22.5	NO	NO		Primary direct	complete?	Extended dorsal decubitus	SW	1.14	5	0
84.1		2/3 INF	2	10	6		NID		Secondary?					8	0
85.1		3 INF/adolescent	8	11	9.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.17	7	0
85.2	M	adult (>20)					NID		Secondary?				1.17	7	0
87	F?	middle-mature adult	35	55	45		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.12	8	0
88	M?	young-middle adult	25	40	32.5	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	0.72	14	0
89	M?	middle-mature adult	35	55	45	NO	NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.28	5	0
93.1		adult (>20)					NID		Secondary				0.79	1	0
93.2X	M	3 INF (7-9 a.)	7	9	8	SI	NID		Secondary				0.79	1	0
93.3X	M	adult (>20)				NO	NID		Secondary				0.79	1	0
94.1	M?	young-middle adult	25	45	35		NO		Primary direct	disturbed	Extended dorsal decubitus	SW		1	0
94.2	F?	young adult	15	20	17.5		NID		Secondary?					1	0
95	M	young-middle adult	25	40	32.5		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.22	12	0
99	F?	adolescent	10	15	12.5	NO	NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.2	17	0
102	F?	young adult	18	23	20.5		SI	C	Primary direct	disturbed	Extended dorsal decubitus	SW	1.16	19	0
106		middle-mature adult	35	50	42.5	NO	NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.24	17	0
107		young adult	15	25	20		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.12	21	0
110.1		3 INF	8	9	8.5		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	0.97	6	0
110.2		3 INF/adolescent	9	12	10.5		NID		Secondary?				0.97	6	0

113		young adult	15	25	20		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.18	18	0
118		3 INF/adolescent	8	12	10		NO		Primary direct	disturbed	Extended dorsal decubitus	SW	1.23	7	1
120		3 INF	7	9	8		NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.2	7	0
123		adolescent	10	15	12.5		NID		Primary direct	incomplete	Extended dorsal decubitus	SW	1.23	6	0
124	F?	adolescent-young adult	13	17	15		SI	C	Primary direct	disturbed	Extended dorsal decubitus	SW	1.29	7	1
125		young adult	15	20	17.5	NO	NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.06	2	0
126		middle-mature adult	35	50	42.5	NO	NID		Primary direct	complete?	Extended dorsal decubitus	SW	1.22	1	0
128.1	M	adult (>20)				NO	NID		Primary direct	disturbed	Extended dorsal decubitus	SW	1.41	NAVE	0

Supplement Table B1

Burial	Sample	M1 87/86	M3 87/86	Bone 87/86	Enam C	Enam O	Coll C	Coll N	BONE AP C	BONE AP O	PB 206/204	Pb 207/204	Pb 208/204	Pb 207/206	Pb 206/207	Pb207/208	Pb 208/206
1	M1	0.708522															
4	BONE						-9.6	8.8	-2.4	-3.0							
4.1	M1	0.708779															
4.2	M1	0.708654															
5.2	M1	0.715434			-7.72	-2.25	-11.1	7.6	-4.4	-3.3	19.0434489	15.67897	38.7827903	0.82332792	1.21458159	0.404	2.03655097
5.3	M1	0.725986		0.713646	-6.38	-0.95	-11.5	7.5	-4.9	-2.2							
5.4	M1	0.715732		0.710074	-10.11	-3.44	-12.1	9.3	-4.7	-2.3	18.6939303	15.6689767	38.7400766	0.83818702	1.19304989	0.404	2.07234325
6	M1	0.722293			-7.19	-1.71			-6.3	-3.1							
7	M1	0.708710					-8.3	10.0	-3.0	-3.1							
9	M1	0.708425			-1.97	-3.18			-3.0	-2.8							
9.2	M1	0.712592		0.708740	-4.64	-3.90	-9.7	9.4	-3.8	-1.3							
9.3	M1	0.708372			-1.39	-2.93	-9.1	9.8	-2.9	-2.8	18.587712	15.5969903	38.3227323	0.83910399	1.19174614	0.407	2.06173274
9.4	M1	0.708890	0.708725		-2.56	-3.34	-8.3	10.2	-3.4	-3.5							
10	M1	0.709020			-3.72	-3.06	-7.6	8.8	-2.8	-3.2							
11.1	M1	0.723924			-7.62	-2.82	-13.4	6.9	-6.8	-3.5							
11.2	M1	0.711585			-4.50	-1.47											
12	M1	0.712841															
13A	M1	0.708382			-1.38	-2.98											
13B	M1	0.708246															
13C	M1	0.708609															
13D	M1	0.708943			-1.72	-3.22											
17.1	M2	0.709015															
17.2	M1	0.708552	0.708595		-3.15	-1.98	-8.9	9.8	-2.8	-3.1							
17.3	M1	0.708989			-1.49	-2.81											
17.4	M1	0.708160	0.708281		-3.21	-2.76	-9.2	10.2	-3.8	-3.2							
17.5	M1	0.708961	0.708997		-2.84	-2.70			-2.6	-2.7							
17.6	M1	0.712121			-8.61	-5.00	-8.2	9.9	-2.4	-3.1							
17.7	M1	0.708612	0.708339		-2.08	-2.77											
17.9	M1	0.708856															
18.2	M1	0.721449		0.708699			-9.9	11.5	-5.7	-4.2							
19	M1	0.721277			-2.10	-2.76											
22	M1	0.708671		0.709124	-2.59	-2.39	-8.6	10.0	-2.7	-2.3							
23	M1	0.708515			-2.14	-2.56	-7.1	10.3	-6.3	-4.4							
25	M1	0.708797			-2.16	-3.78											
26	M1	0.708554			-2.50	-2.67	-7.4	9.8	-3.0	-2.8							
29	M1	0.708555			-1.72	-2.95											
30	M1	0.708813															
31	M1	0.708205		0.708785	-2.50	-2.60	-9.4	9.4	-3.2	-1.9							
32	M1	0.708494															
33	M1	0.709102	0.708997	0.708830	-2.86	-2.70	-7.5	9.7	-3.2	-3.3							
39	M1	0.708716			-2.47	-3.46	-7.4	8.6	-2.9	-3.4							
40	M1	0.708932			-1.05	-2.57											
41	M1	0.718690			-4.45	-2.94											
44	M1	0.720967	0.719071	0.710790	-7.77	-3.06	-10.4	7.9	-4.2	-2.4							
49	M1	0.722835		0.713671					-5.4	-3.2							

49A	M1	0.708210	0.708276		-1.67	-2.15											
49B	M1	0.722915			-4.91	-0.74	-12.3	7.6	-4.2	-3.0							
50	M1	0.709467		0.708852			-8.8	8.6	-4.9	-3.6							
52	M1	0.708715		0.708716	-12.68	-3.37	-17.4	10.9	-7.9	-4.3	18.329	15.608	38.344	0.8515	1.1744	0.407	2.0920
53	M1	0.708873															
55	BONE						-7.8	10.3	-3.3	-2.8							
57	M1	0.708437															
59	M1	0.708064			-1.18	-3.30	-8.5	10.8	-3.3	-3.8							
60	M1	0.708481			-2.59	-2.66											
61	M1	0.708380			-2.38	-2.90	-9.0	8.2	-2.0	-4.2							
62	M1	0.708674			-3.03	-3.11	-7.8	10.5	-0.5	-3.9							
66	M1	0.707771			-2.28	-3.08	-8.3	9.5	-1.0	-3.9							
67	M1	0.708324			-1.98	-3.02	-9.5	9.0	-1.0	-3.2							
71	M1	0.708305	0.708341		-2.15	-3.55	-13.4	6.8	-6.7	-1.6							
72	BONE						-11.6	9.3	-2.7	-3.7							
72.1	M1	0.716900															
72.2	BONE								-2.4	-2.8							
72.3	M1	0.709510															
72.4	M1	0.708719															
73	M1	0.722792			-8.04	-2.73	-13.3	7.0	-4.2	-3.4							
74A	M	0.708505															
74B	M1	0.708530															
75	M1	0.717017			-6.30	-2.97					21.4545054	16.439324	42.1030364	0.76624273	1.30506809	0.390	1.96244162
77	M1	0.708588			-2.76	-1.72	-8.4	10.6	-2.8	-3.5							
78	M1	0.708558															
79	M1	0.708181			-0.80	-2.68											
79.2	M1	0.708844															
81	M1	0.708251	0.708157		-2.53	-2.86											
81Bii	M	0.708374			-1.96	-3.21											
81Bi	M	0.708260															
82	M1	0.709881															
84.1	M1	0.708567															
85.1	M1	0.726134			-4.88	-1.99	-7.0	8.3	-2.5	-3.8	18.6108596	15.7982321	39.8502061	0.8488735	1.17803058	0.396	2.14124309
85.2	M	0.723747			-8.38	-3.36	-7.5	10.8	-2.3	-3.5							
87	M1	0.708875															
88.1	M1	0.708562															
89	M1	0.708895															
93	M1	0.708643															
93.2	M	0.708705			-1.81	-3.92											
93A	M1	0.708311			-1.70	-2.70											
94.1	M1	0.708654															
94.2	M1	0.708377			-2.10	-2.79											
95	M1	0.739124	0.727806	0.709180	-12.61	-2.86	-15.4	8.4	-2.2	-2.9							
99	M1	0.712708			-6.09	-2.18					18.9310177	15.7072825	38.6690107	0.82971322	1.20523443	0.406	2.04263578
102	M1	0.715285		0.709383	-5.10	-1.41			-3.9	-2.5							
106	M1	0.708156			-1.41	-1.65	-6.8	9.7	-1.8	-3.2							

107	M1	0.708943			-2.67	-3.13			-1.2	-3.7							
110.1	M	0.708234															
110.2	M	0.708282			-1.63	-3.55											
113	M1	0.708927			-1.26	-2.74			-2.7	-3.0							
118	M1	0.708329			-1.79	-2.57	-10.1	10.2	-2.3	-3.3							
120	M1	0.708516															
123	M1	0.708357	0.709774	0.708703	-1.90	-2.19	-7.1	8.7	-2.9	-2.1							
124	M1	0.733420		0.714974	-8.37	-2.29			-5.3	-3.0							
125	M1	0.708478															
126	M1	0.708119			-1.16	-2.46	-8.6	10.1	-1.8	-3.1							
128	M1	0.708950	0.708912	0.708899	-11.08	-2.57			-9.1	-3.9	18.288	15.595	38.344	0.8527	1.1727	0.407	2.0967
128.2	M2	0.708944															

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Supplement C from Price et al., "Isotopic Studies of Human Skeletal Remains from a Sixteenth to Seventeenth Century AD Churchyard in Campeche, Mexico"

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Sample Preparation and Measurement

Initial Preparation

Tooth Enamel

The permanent first molar is the preferred tooth for isotopic analyses, both for consistency and because the enamel of this tooth forms during late gestation and very early childhood. For each dental sample, we initially abrade the surface of a single cusp of a molar using a dental drill fitted with a diamond burr to remove surface contamination. We then cut a small flake from either the top or the bottom of this cusp with a crosscut blade attached to the drill and remove dentine if any remains with the burr. We try to obtain about 20 mg, approximately 10 mg for strontium isotopes and 2 mg of fine enamel powder for enamel apatite carbon and oxygen isotopes; the remainder in reserved for possible subsequent analysis. For samples for lead isotopes, an additional 30 mg of enamel is obtained. Samples are then sent to collaborators at the University of Arizona for apatite carbon and oxygen, the University of North Carolina for strontium isotopes, and the University of Copenhagen for lead.

Bone

For bone apatite samples for strontium and lead, we heavily abrade the exterior and interior surfaces of cortical bone, weighing from about half a gram to a few grams, then break the sample into several small pieces (<1 cm). These are placed into a 20-mL glass vial filled with deionized water and sonicated in a ultrasonic water bath. They are repeatedly sonicated, with any cloudy water replaced with clean deionized water until the water remains clear after sonication. We then sonicate the samples with 5% acetic acid and again rinse with ultrapure deionized water. These chips are then ashed in a muffle furnace at 750°–800°C for 8 hours, and the resulting ash is used for strontium and lead isotopes.

Strontium Isotopes in Enamel Apatite

$^{87}Sr/^{86}Sr$ was measured by Paul Fullagar at the University of North Carolina using a thermal ionization mass spectrometer (TIMS). For $^{87}Sr/^{86}Sr$, samples weighing approximately 3 mg are dissolved in 5 M nitric acid. The strontium fraction is purified using EiChrom Sr-Spec resin and eluted with nitric acid followed by water. The eluent is dried, and the Sr residue is placed on a tantalum filament. Isotopic compositions are obtained on this strontium fraction using a VG (Micromass) Sector 54 TIMS in the Department of Geological Sciences, University of North Carolina, Chapel Hill. Regular and repeated $^{87}Sr/^{86}Sr$ analyses of the NIST 987 (National Institute of Standards, Standard Reference Material) strontium carbonate yielded a value of 0.710259 ± 0.0003 (2 standard errors). Internal precision (standard error) for the samples is typically 0.000006 to 0.000010, based on 100 dynamic cycles of data collection. Total procedural blanks for strontium typically are below 100 pg, which is insignificant relative to the amounts of strontium in the samples.

Carbon and Oxygen in Enamel Apatite

Enamel apatite carbonate isotopic analysis (sample weight of approximately 700 μg) was performed by David Dettman at the University of Arizona by reacting the finely powdered enamel with 100% phosphoric acid at 70°C in a Kiel III automated carbonate reaction device coupled to the MAT 252. Carbon and oxygen isotope ratios were simultaneously determined on the CO_2 generated by this reaction. Replicate analyses of apatite were not performed. Analytical error on this instrument is $\pm 0.05‰$ for $\delta^{13}C$ and $\pm 1.0‰$ for $\delta^{18}O$ (Balasse et al. 2002).

Carbon and Oxygen in Bone Apatite

Bone apatite samples prepared at the University of South Florida were treated as follows. Whole and fragmented bone (about 1 g) was first cleaned using ultrasonic vibration and distilled water, and 10 mg of bone powder was extracted using a dental drill for apatite analysis. Carbonate from apatite samples was extracted using established techniques (Koch, Tuross, and Fogel 1997), specifically the removal of organic components using bleach (24 hours for enamel, 72 hours for apatite) and of nonbiogenic carbonates using buffered 1 M acetic acid (24 hours). Carbonate samples were analyzed using a similar Finnegan MAT Delta Plus XL mass spectrometer, coupled with a Kiel III device that produces CO_2 gas using 100% phosphoric acid injected into individual sample containers.

For enamel apatite samples analyzed at the University of Arizona by David Dettman, $\delta^{18}O$ and $\delta^{13}C$ of tooth enamel carbonate were measured using an automated carbonate preparation device (Kiel III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). Powdered enamel samples were reacted with dehydrated phosphoric acid under vacuum at 70°C in the presence of silver foil. The isotope ratio measurement is calibrated based on repeated measurements of NBS-19 and NBS-18, and precision is $\pm 0.1‰$ for $\delta^{18}O$ and $\pm 0.06‰$ for $\delta^{13}C$ (1 δ). The carbonate-CO_2 fractionation for the acid extraction is assumed to be identical to calcite.

Carbon and Nitrogen in Collagen

Sample preparation at the University of South Florida was conducted as follows. About 1 g of already-cleaned bone was initially treated with 0.1 M NaOH to remove humic acids. Bone collagen was extracted using 2% HCl for 72 hours. Following a second 24-hour treatment with NaOH, residual lipids were separated with a mixture of methanol, chloroform, and water. After drying, the collagen was weighed to determine percent yield, with 1% or more considered reliable for isotope analyses. Duplicate 1-mg samples were then weighed into tin cups and analyzed using a CHN analyzer coupled with a Finnigan MAT Delta Plus XL stable isotope ratio mass spectrometer set up with a continuous flow. The reliability of isotope measurements was also validated by C and N gas yields and C : N ratios during processing on the mass spectrometer, with values between 2.9 and 3.6 considered equivalent to those found in collagen. The precision of the University of South Florida analyses is about $\pm 0.1‰$ for carbon and $\pm 0.2‰$ for nitrogen. Results are reported relative to the Pee Dee Belemnite and AIR standards, respectively.

Lead Isotopes

Teeth are mechanically precleaned by hand and subsequently repeatedly washed ultrasonically in ultrapure (MilliQ) water until the water remains visually clear. After drying, small pieces of enamel are removed by means of a small diamond blade saw and/or with chromium steel pliers. Extreme care is taken not to separate dentin material from enamel. Amounts of 15–30 mg are weighted into 7-mL Teflon beakers (Savillex). The samples are dissolved in a 1 : 1 mixture of 0.5 mL of 6 N HCl (Seastar) and 0.5 mL of 30% H_2O_2 (Seastar). The samples are typically decomposed within 5–10 minutes, after which the solutions are dried down on a hotplate at 80°C.

Enamel samples were taken up in a few drops of a 3 : 1 mixture of 1.5 N HBr and 2 N HCl and then loaded on disposable miniextraction columns (1-mL pipette tips with a fitted frit at the bottom) charged with 0.1 mL of intensively precleaned mesh 100 anion resin (BioRad AG 1 × 8). The elution recipe essentially followed that described by Frei and Kamber (1995), tailored to the small size of the herein-used extraction columns. Lead samples were dissolved in 2.5 μL of 1 M H_3PO_4 and loaded together with a silica gel activator onto previously outgassed 99.98% single rhenium filaments. Samples were measured at 1,100°–1,200°C in static multicollection mode on a VG Sector 54 IT mass spectrometer equipped with eight Faraday detectors (Institute of Geography and Geology, University of Copenhagen). Repeated analyses of 10-ng loads of the NBS 981 Pb standard were used to control the mass bias of the sample analyses. Mass fractionation amounted to 0.103%/AMU (atomic mass unit) relative to the values for this standard reported by Todt et al. (1996). Total lead procedure blanks were in the order of 50 pg. These amounts are insignificant relative to the total amounts of lead in a sample, and blank corrections therefore were not undertaken.

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