

## URANIUM-SERIES DATING OF THE HUMAN REMAINS

In order to get a qualitative estimate of the uranium content of the fossils, the Tabon frontal and the left mandibular fragment were measured by means of non-destructive gamma-ray spectrometry. The mass of the fossils and the relatively low uranium content (about 2 ppm) prevented any attempt at direct dating. However, the detection of a small amount of uranium allowed the use of alpha-ray spectrometry and the calculation of the  $^{230}\text{Th}/^{234}\text{U}$  ratio by chemical separation of uranium and thorium isotopes. Such treatment classically includes (Bischoff et al. 1988) dissolution by  $\text{HNO}_3$  and  $\text{H}_2\text{O}_2$ , separation of uranium and thorium using anionic exchange resin, and extraction and deposition before spectrometric counting. A 0.47-g sample of nasal bone was used for this purpose and counted for a week. The sample proved to have a  $0.142 \pm 0.016$   $^{230}\text{Th}/^{234}\text{U}$  ratio. Its 2.88-ppm uranium content is quite consistent with the gamma-ray rough estimate, suggesting a homogeneous distribution of that element in the fossil. The  $^{230}\text{Th}/^{232}\text{Th}$  ratio ( $> 100$ ) shows that no detrital thorium entered the bone after its burial. Following the early-uranium-uptake hypothesis (Bischoff and Rosenbauer 1981), this ratio would imply an age of  $16,500 \pm 2,000$  B.P. for the fossil.

## CONCLUSION

Although the precise geochemical history of the fossil is not fully known, the isotopic  $^{230}\text{Th}/^{234}\text{U}$  ratio directly measured on the Tabon fragmentary cranium strongly suggests a late Pleistocene age. It therefore confirms to some extent Fox's (1970) suggestion of the antiquity of that fossil without being any more precise about its stratigraphic position within the published scheme. It does provide more precision about Palawan Island human settlement well before the Holocene by *H. sapiens*, most probably via the very narrow, several-kilometre-long strait which still separated the island from Borneo during the Upper Pleistocene eustatic declines of sea level. The late Pleistocene declines of sea level (especially during oxygen-isotope stage 2) left the cave far inland, and according to Fox this would account for the conspicuous lack of marine shells in the anthropic Pleistocene layers of Tabon Cave.

The surprising morphology and problematic taxonomic attribution of the fragmentary left mandibular fragment raise the question of a possible colonization of Palawan by Pongidae during the Upper Pleistocene, but doubts concerning the origin of the  $M_3$  and the morphology of the  $P_4$  socket make any conclusion impossible at this stage.

It is hoped that the present fieldwork undertaken by the Archaeology Division of the National Museum of the Philippines will provide us with more archaeological data through a new excavation grid and a better stratigraphic control of Fox's published observations and open the way for new isotopic datings on speleothems and fossil bones and teeth.

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## The Importance of Early Maize Agriculture in Coastal Ecuador: New Data from La Emerenciana<sup>1</sup>

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Maize has often been described as "the grain that civilized the New World." This characterization, however, relies too much on the ethnohistorical evidence indicating that maize was the preeminent crop at the time

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1. [Supplementary material appears in the electronic edition of this issue on the journal's website (<http://www.journals.uchicago.edu/CA/home.html>).]

of Spanish contact in the early 16th century A.D. (Reichel-Dolmatoff 1961, Salomon 1986). Since modern agricultural practices are largely based upon cereals, there has been a tendency by Western scholars to overemphasize its dietary importance. In South America at least, where maize was used more as a vegetable than as a cereal, many other crops were equally important, if not greater, contributors to indigenous human diets (Sauer 1950, Piperno and Pearsall 1998).

In the New World, there is growing evidence that at least some plants (e.g., *Cucurbita* spp.) were domesticated by 10,000 years ago (Smith 1997), about the same time that early domesticates appeared in the Near East, although domesticated beans (*Phaseolus* spp.) are perhaps no earlier than 2,100 B.P. (Kaplan and Lynch 1999). Other plants, especially root crops, were also probably cultivated several thousand years prior to the introduction of ceramics and village settlements in several regions of Central and South America (Piperno et al. 2000). This sequence, however, contrasts with that of the Near East, where village settlements appeared first, followed by agriculture and, even later, ceramics. The origins of maize and its subsequent importance to early American cultures still remain the subject of considerable debate.

It has become evident that even in fairly certain archaeological circumstances, the context and dating of archaeobotanical specimens may be problematic (e.g., Rossen, Dillehay, and Ugent 1996). For example, the contextual associations and chronology of some South American discoveries of maize macrofossils have upon closer examination been challenged (see Bonavía and Grobman 1989, Pearsall 1992). For maize microfossils, critics have focused on two issues. First, the chronology and number of maize microfossils in core samples taken from lake sediments (e.g., Bush, Piperno, and Colinvaux 1989) have been questioned by some as unconvincing evidence of early maize consumption (Fritz 1994a). Second, the actual identification of maize phytoliths (e.g., Piperno and Pearsall 1993) has been argued by others to be problematic on methodological and theoretical grounds (Doolittle and Frederick 1991, Rovner 1999, Russ and Rovner 1989). While most scholars believe that maize was probably domesticated by or before ca. 7,000 B.P., our understanding of the phylogeny, origins, chronology, and routes of dispersal of maize remains incomplete (see Pearsall 1992, 1994, 2002; Piperno 1994; Piperno and Pearsall 1998; Smith 1998).

The Río Balsas region of western Mexico is now widely accepted as the locus of origin of domesticated maize (cf. MacNeish and Eubanks 2000). In the Tehuacán Valley AMS dates on a dozen maize cobs produced dates no older than  $4,700 \pm 110$  B.P. (Long et al. 1989); cf. MacNeish 2001, Long and Fritz 2001). The oldest directly dated macrofossils are now two cobs from Guilá Naquitz at  $5,410 \pm 40$  and  $5,420 \pm 60$  B.P. (Piperno and Flannery 2001), which from an evolutionary standpoint are "transitional," having morphological characteristics that define maize (*Zea mays* L.) while retaining some characteristics of teosinte (*Zea mays* ssp. *parviglumis*) (Benz

2001). In Central America, maize pollen has been identified even earlier at San Andrés near the Gulf Coast of Tabasco (6,000 B.P. [Pope et al. 2001]), as have phytoliths of a primitive maize with teosinte (hard) glume architecture at the Aguadulce rock shelter in Panama ( $5,560 \pm 80$  B.P. [Piperno et al. 1985, 2001]). **[(See CA+ App. A).]**

More important, most scholars would agree that even after domesticated maize became available outside of highland Mexico there was considerable temporal and spatial variability in pre-Columbian subsistence patterns, especially when terrestrial, marine, or riverine fauna were regularly available for exploitation. In general, it appears that domesticated crops were adopted along the coasts of Ecuador and Peru in a patchy manner, suggesting different selective cultural strategies at different sites (Hastorf 1999). It has been extremely difficult, however, to quantify the varied dietary components consumed, since there is no way to balance the uneven representation and preservation of botanical and faunal remains in the archaeological record. While phytoliths, pollen, and starch grains can document the presence of maize and certain other plants, only coprolites (or the contents of the digestive tracts of mummies) are direct indicators of actual consumption. Yet these are the by-product of a few meals at best and thus may not be representative of the typical diet. As Roosevelt (1984:8) has previously noted, "it is not the same thing to establish the presence of certain species archaeologically as it is to determine the role of the plant in the ancient economy."

The consumption of particular food resources can truly be *quantified* only through studies of bone chemistry, in particular the analysis of the stable isotopes of carbon and nitrogen (Katzenberg 2000). At present, stable-isotope data do not provide evidence of maize consumption prior to 5,000 B.P., even in western Mexico, although maize appears to have been a significant component of Panamanian diets by 4,500 B.P. at preceramic coastal sites such as Cerro Mangote (Norr 1995).

We report here stable isotope and other evidence for human diets at the Early Formative site of La Emerenciana in coastal Ecuador, where the precocious construction of ceremonial mounds and use of ceramics by the Valdivia culture has been linked to a subsistence economy centered on maize farming (e.g., Lathrap, Marcos, and Zeidler 1977). Maize phytoliths identified from carbon residues inside Jeli-phase Valdivia pots from La Emerenciana are also derived from archaeological contexts ranging between 4,150 and 3,900 B.P. (Staller 2001). The chronological and contextual evidence from La Emerenciana is consistent with that from other regions of the neotropics.

#### SITE BACKGROUND AND ECOLOGICAL SETTING

La Emerenciana (OOSrSr-42) is one of 11 Early Formative sites identified between the lower Arenillas and Buenavista Rivers in southern El Oro Province, Ecuador, near the Gulf of Guayaquil (Staller 1994) (fig. 1). Valdivia sites are situated on the most inland dune beach ridge or on



FIG. 1. Coastal Ecuador and Peru, showing sites mentioned in the text.

knoll tops beside the coastal streams, suggesting a mixed subsistence economy involving both intensive exploitation of maritime resources by coastal societies and estuarine resource exploitation, plant cultivation, and hunting by more inland populations. La Emerenciana, situated on the landward edge of the intertidal salt flats along the western bank of the Buenavista River, is located within immediate access of mud flats, lagoons, ponds, mangrove forest, freshwater swamps, and salt marshes. While the site is about 2 km south of the modern shoreline, the Early Formative shoreline is represented by a fossil beach ridge under the prehistoric midden at La Emerenciana, the earliest and highest of a series of such topographic features identified in this area of southern Ecuador. The close proximity of the river also makes this a favorable location for seasonal cultivation, although the setting implies an economic focus upon resources from the estuary and the mangrove forest. The dry-tropical-forest vegetation around the site primarily consists of moderately dense xerophytic thorn brush, clusters of carob trees, and a variety of columnar cactus (*Cereus* spp.). **[See CA+ Appendix B and fig. A].**

The investigations carried out at La Emerenciana by Staller (1994) represent the first systematic archaeological study at this locality. Excavations uncovered an earthen mound with oval clay platforms on its summit and artificial retaining walls forming descending terraces

on the northwestern edges of the site. Prehistoric occupation measures 12.4 hectares, making it one of the largest Valdivia sites on the Ecuadorian coast. Excavations, concentrated on the platform mound, included a series of cuts (1–6), as well as trenches (A–D) and profile A, a 29-m-long cut of exposed sediment (fig. 2). Two occupation periods at La Emerenciana were apparent on the basis of stratigraphic evidence, diagnostic ceramics, and associated radiocarbon dates. These correspond to an initial Valdivia IV–VI occupation (ca. 2200–2000 B.C.) associated with stratum 3 and a Valdivia VII–VIII occupation associated with stratum 5 (ca. 1850–1650 B.C.) (table 1). **[See CA+ Appendix C and table A].**

Four Valdivia VII–VIII burials were found at the site, including three complete interments in trench D and a partial skeleton in disturbed contexts along profile A (Staller 1994: 304–12; Ubelaker and Bubniak Jones 2002). All were stratigraphically associated with stratum 5 (floor 2) and when initially reported represented the only skeletons from this late in the Valdivia cultural sequence. Burial 1 was partially disturbed and the cranium and upper torso were missing, while burials 2–4 were fully articulated primary interments (figs. 3 and 4). Each individual was placed in an upright and tightly flexed position in a circular burial pit, along with ritual offerings consisting primarily of marine fauna even though birds and terrestrial mammals constitute about 30% of

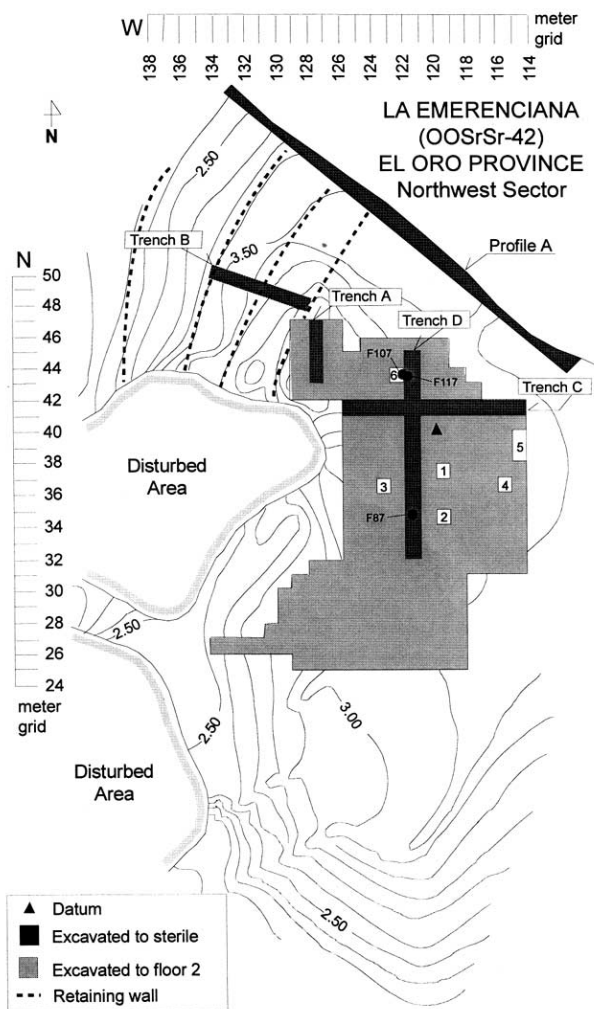


FIG. 2. Plan of the La Emerenciana site, showing excavation areas and burial locations.

the faunal remains recovered at La Emerenciana. The adults were probably wrapped in funerary bundles, although no traces of the wrapping material have survived.

#### PHYTOLITH ANALYSIS

Organic residues on ten potsherds from La Emerenciana were tested for the presence of phytoliths. Maize was absent in two samples from domestic pots on the stratum 3 floor (Valdivia IV–VI), while three of seven samples from stratum 5 (Valdivia VII–VIII) each contained an assemblage of over 100 rondel forms characteristic of maize opal phytoliths (Thompson and Staller 2000, Staller and Thompson 2002). Smaller assemblages of rondel-form phytoliths consistent with maize were also identified in dental calculus from burials 2 and 4 in stratum 5. The phytoliths studied are specifically diagnostic of the cob cupules and chaff portions of the domesticated maize plant rather than the leaves, for which the differ-

ences between maize and teosinte have been debated. Pearsall and Piperno (1990) have long maintained that two varieties of maize, an eight-row popcorn and a flint corn, entered Central and South America 8,000–7,000 years ago. Although it is widely accepted that the eight-row popcorn is very primitive, plant geneticists have identified neither of these varieties as characteristic of canguil, a popcorn variety identified on the basis of ear and kernel morphology as representative of traditional modern Ecuadorian maize. Significantly, the earliest existence of canguil has been genetically traced by Thompson (personal communication) to La Emerenciana and, moreover, was also present almost a millennium later in the southern highlands of Ecuador at Pirincay in contexts dated to ca. 2,700–2,300 B.P. (Bruhns, Burton, and Miller 1990). Such punctuated equilibrium in maize evolution is consistent with the model recently described by Benz (2001). **(See CA+ Appendix D).**

The presence of cob phytoliths in food residues and on human teeth obviates the concerns of contextual integrity and identification methodology raised by Fritz (1994a, b) and other scholars. While these data demonstrate the presence and consumption of maize during Late Valdivia times, they do not allow us to estimate the cultural and economic significance of this important domesticate.

#### STABLE ISOTOPE ANALYSIS

Carbon and nitrogen isotope ratios in human bone may be used to reconstruct prehistoric diet because of differential fractionation of atmospheric carbon dioxide during photosynthesis and of nitrogen during fixation or absorption (Katzenberg 2000). Isotope ratio measurements are reported using the delta notation ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ) relative to international standards and are expressed in parts per mil (‰). Typically, grasses originally native to hot, arid environments follow the  $\text{C}_4$  (Hatch-Slack) photosynthetic pathway and have  $\delta^{13}\text{C}$  values averaging about  $-12\text{‰}$ ; trees, shrubs, and grasses from temperate regions, which follow the  $\text{C}_3$  (Calvin-Benson) photosynthetic pathway, have  $\delta^{13}\text{C}$  values averaging about  $-26\text{‰}$ . Metabolic fractionation in plant consumers results in bone collagen  $\delta^{13}\text{C}$  values of about  $-7\text{‰}$  and  $-21\text{‰}$ , respectively, for pure  $\text{C}_4$  and pure  $\text{C}_3$  diets. A fractionation of  $+9.5\text{‰}$  between diet and bone apatite has been measured in controlled-diet studies, but empirical studies suggest shifts closer to  $+12\text{‰}$ . Nitrogen isotope ratios for plants depend primarily on whether they obtain their nitrogen by symbiotic bacterial fixation or directly from soil nitrates. These values are passed along through the food chain accompanied by an approximately 2–3‰ positive shift for each trophic level. Human consumers of terrestrial plants and animals typically have  $\delta^{15}\text{N}$  values in bone collagen of about 6–10‰ whereas consumers of freshwater or marine fish and sea mammals may have  $\delta^{15}\text{N}$  values of 15–20‰.

In general, bone collagen is produced primarily from the protein portion of the diet, while the carbonate fractions of bone apatite and tooth enamel are produced from

TABLE 1  
Radiocarbon Dates from La Emerenciana (OOSrSr-42)

Lab. No.	Context	Conventional <sup>14</sup> C Age (B.P.)	Calibrated Ages (B.C.) (Intercepts)	Calibrated Age-Range (B.C.) (2σ)
SMU-2241	Trench A	3,361 ± 246	1681, 1669, 1660, 1649, 1639	2300–1010
SMU-2226	Trench D, burial 2 pit	3,400 ± 220	1726, 1724, 1689	2290–1130
Beta-125106	Trench D, sample 5480	3,700 ± 40	2129, 2082, 2043	2200–1950
SMU-2225	Trench D	3,707 ± 148	2133, 2080, 2047	2550–1690
Beta-125107	Trench D, feature 65, sample 5623	3,860 ± 50	2305	2470–2140
SMU-2563	Trench D, feature 65	3,775 ± 165	2199, 2156, 2154	2830–1740

NOTE: SMU dates are conventional radiocarbon determinations on wood charcoal. Beta dates are AMS on organic pottery residues corrected for <sup>14</sup>C/<sup>12</sup>C fractionation and pretreated with acid washes. All results are calibrated using Calib 4.1.2 with a minus 24-year Southern Hemisphere atmospheric sample adjustment and are reported here at the two-sigma range. Staller (1994: fig. 5, 55, 393–94, 306) has provided more detailed information on the SMU dates. All dates are from stratum 5 except SMU-2241, which is from stratum 6.

a mixture of dietary protein, carbohydrates, and fats. Stable isotope analysis of both bone collagen and apatite thus permits quantitative estimates of several dietary components. Both bone collagen and apatite are constantly being resorbed and replenished, with the result that their isotopic composition reflects dietary averages over at least the last several years of an individual's life. The carbonate in tooth enamel, however, is not turned over and represents diet at the time of tooth formation, in some cases from a preweaning age. Stable carbon isotope analysis is particularly useful in New World dietary studies because maize is often the only C<sub>4</sub> plant contributing significantly to human diets; its contribution to bone collagen and to bone apatite may be estimated by interpolation.

The carbon isotope ratios of marine and freshwater organisms are more variable, depending on local ecological circumstances, and often overlap with those of terrestrial plants and their consumers. These foods typically have much higher nitrogen isotope values, however, and their high protein content will contribute much more C<sub>4</sub> carbon to bone collagen than will maize, which is only about 10% protein. Earlier statements regarding the limitations of stable isotope bone chemistry for revealing low levels of maize consumption were based on the fact that the contribution to bone collagen of C<sub>4</sub> carbon from protein-poor maize is overshadowed in diets which include significant amounts of animal protein (see Riley et al. 1994:495–96). The analysis of bone apatite or tooth enamel, which is derived from all food groups, should allow the identification of just a few percent maize in an otherwise C<sub>3</sub>-based diet. (See CA+ Appendix E).

Bone collagen was extracted using well-established laboratory procedures. No collagen was obtained from one sample, and the small amount obtained from a second sample was outside the acceptable 2.9–3.6 ratio of elemental C : N measured during combustion. One tooth enamel and three bone apatite samples were also prepared using procedures that remove nonbiogenic carbonate without altering the biogenic carbon isotope ratios

(Koch, Tuross, and Fogel 1997). Duplicate bone apatite samples were prepared and analyzed to demonstrate that the isotopic results obtained were not affected by the preparation procedures. The identical values obtained for both a bone apatite and a tooth enamel sample from burial 4 are further confirmation of the viability of bone and tooth carbonate analysis. All results are reported in table 2. The carbon isotope ratios of solid organic residues from the same five potsherds that produced phytolith assemblages were also measured (table 3).

(See CA+ Appendix F).

#### RESULTS AND DISCUSSION

The first stable isotope study of prehistoric diets in coastal Ecuador (van der Merwe, Lee-Thorp, and Raymond 1993) used human bone collagen to document subsistence change over several millennia. Unfortunately, none of the late Las Vegas-phase samples tested produced any collagen, and data are available only for the first three phases of the long-lived Valdivia culture. Furthermore, the consumption of marine foods makes it difficult to measure the initial importance of maize from bone collagen data alone. The collagen data do, however, leave little doubt that by the following Machalilla phase (1700–1100 B.C.) maize was a significant dietary component in coastal Ecuador. In highland Ecuador, however, while maize is clearly important during the first half of the 1st millennium B.C. even at sites above 3,000 m such as La Chimba, with average collagen δ<sup>13</sup>C values of –17‰, it becomes a staple only in the 1st millennium A.D., when collagen carbon isotope ratios of –15‰ to –9‰ are found (Tykot, van der Merwe, and Athens 1996, Ubelaker, Katzenberg, and Doyon 1995). While the later development of maize dependence in the highlands may be due to the difficulties in growing maize at extreme altitudes and the availability of alternative subsistence resources, it does support the hypothesis that maize was introduced to South America via a coastal route.

Farther south, in Peru, collagen carbon isotope ratios of –20‰ to –18‰ obtained from Huaricoto and Chavín

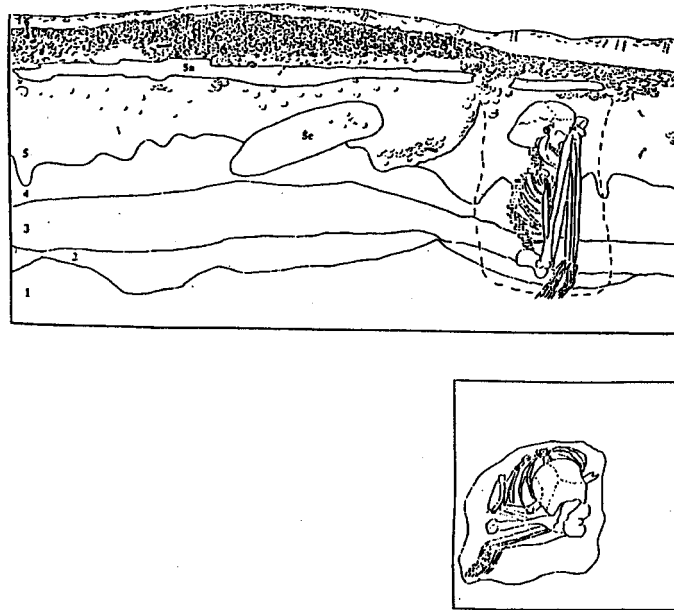


FIG. 3. East profile and plan views of burial 2 (feature 87), trench D, La Emerenciana.

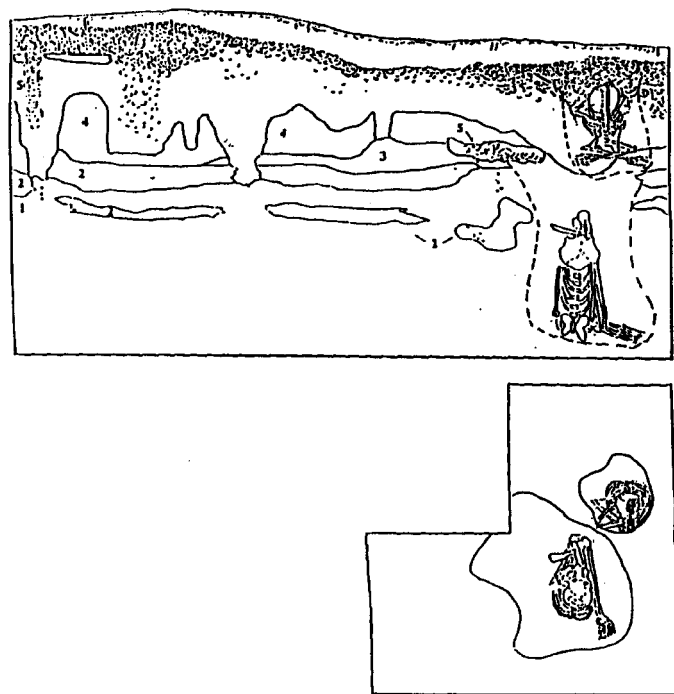


FIG. 4. West profile and plan views of burials 3 (feature 107) and 4 (feature 117), trench D, La Emerenciana.

TABLE 2  
*Stable Isotope Results for Human Skeletal Remains from La Emerenciana*

Description	Sex and Est. Age	$\delta^{13}\text{C}$ (Collagen)	$\delta^{15}\text{N}$ (Collagen)	C:N (Collagen)	$\delta^{13}\text{C}$ (Apatite)	$\delta^{13}\text{C}$ (Enamel)
Feature 84, burial 2	F 40-45	-16.7	14.5	3.5	-14.6 -14.9	-
Feature 107, burial 3	J 5-7	-15.8	14.7	3.6	-10.3 -10.6	-
Feature 117, burial 4	F 36-41	-	-	4.2	-12.5 -12.7	-12.7 -

de Huantar (Burger and van der Merwe 1990) and Pa-copampa (Tykot, van der Merwe, and Burger 1996) suggests that maize was not important in the highlands prior to the late 1st millennium B.C. Along the coast, however, maize consumption is noticeable in the early 1st millennium B.C. from the enriched carbon isotope values ( $-18.1 \pm 1.1\%$ ) in hair samples from Mina Perdida (Tykot, van der Merwe, and Burger 1996) and had become a dietary staple in the Viru and Lurín Valleys by the last centuries B.C. (Ericson et al. 1989; Tykot, van der Merwe, and Burger 1996) with carbon isotope values ( $-12\%$  to  $-9\%$ ) similar to those for the Inca period (Verano and DeNiro 1993).

Our data for La Emerenciana (Valdivia Phases VII and VIII) fill an important chronological gap in the Ecuador sequence while the combination of bone collagen, bone apatite, and tooth enamel data clarifies the importance of maize and marine foods (figs. 5 and 6). Although results were obtained on a very small number of individuals, they are significant for interpreting the significance of maize and other foods in the prehistoric Valdivia diet. The  $\delta^{15}\text{N}$  values for two individuals (burials 2 and 3, a female adult and a juvenile, respectively), both above  $14\%$ , are considerably more enriched than for individuals from highland Ecuador and Peru, indicating that freshwater and/or marine fish (average  $\delta^{15}\text{N}$  of  $+20\%$  and  $+14\%$ , respectively) contributed significantly to the La Emerenciana diet. Since terrestrial fauna average only about  $7\%$  and shellfish (mollusks and crustaceans) about  $11\%$  (van der Merwe, Lee-Thorp, and Raymond 1993), it is likely that at least half of the protein consumed by these two individuals came from fish and possibly sea mammals (although the latter are very rare in coastal

Ecuador except during intense El Niño Southern Oscillation events).

The  $\delta^{13}\text{C}$  values in bone collagen for the same two individuals from La Emerenciana average about  $-16\%$ , suggesting that dietary protein averaged about  $-21\%$  in  $\delta^{13}\text{C}$  and  $+12\%$  in  $\delta^{15}\text{N}$ . Because freshwater and/or marine foods were consumed, we cannot simply interpolate between  $\text{C}_3$  and  $\text{C}_4$  endpoints to estimate the contribution of maize to the diet. With the  $\delta^{13}\text{C}$  values of both  $\text{C}_3$  plants and freshwater fish averaging about  $-26\%$ , however, considerable consumption of marine resources, maize or other  $\text{C}_4$  plants, and/or CAM (crassulacean acid metabolism) plants is indicated. While maize consumption has the effect of increasing  $\delta^{13}\text{C}$  values, the consumption of mollusks and marine fish, with average  $\delta^{13}\text{C}$  values of  $-15\%$  (van der Merwe, Lee-Thorp, and Raymond 1993), will also result in significantly enriched values. Freshwater fish are not, however, rich in  $\delta^{13}\text{C}$  (average about  $-24\%$ ) but have even higher nitrogen isotope ratios than marine fish from coastal Ecuador (van der Merwe, Lee-Thorp, and Raymond 1993). These collagen data show that, hypothetically, maize could have been quite important but isotopically balanced by freshwater fish, which would also have contributed to the elevated nitrogen isotope ratios. Likewise, marine resources could have been quite important but isotopically balanced by  $\text{C}_3$  plants and terrestrial fauna, without any maize in the diet. This problem of equifinality using only bone collagen data may be addressed through analyses of bone apatite and tooth enamel, as well as with evidence from faunal and archaeobotanical remains, ecological analysis, and ethnohistoric records.

Carbon isotope ratios in bone apatite were also ob-

TABLE 3  
*Stable Isotope Results for Organic Pottery Residues from La Emerenciana*

Cat. No.	Context	Description	$\delta^{13}\text{C}$
5480	Stratum 5, feature 1	Cambered jar	-26.2, -25.8
5485	Stratum 5, feature 70	Neckless olla filled with shell, faunal, and organic remains	-26.2
5623	Stratum 5, feature 65	Bottle form with wide neck	-23.8, -21.9
5430	Stratum 3, feature 47	Cambered jar	-26.1
5618	Stratum 3, feature 137	Cambered jar	-26.7

NOTE: Data from Beta Analytic.

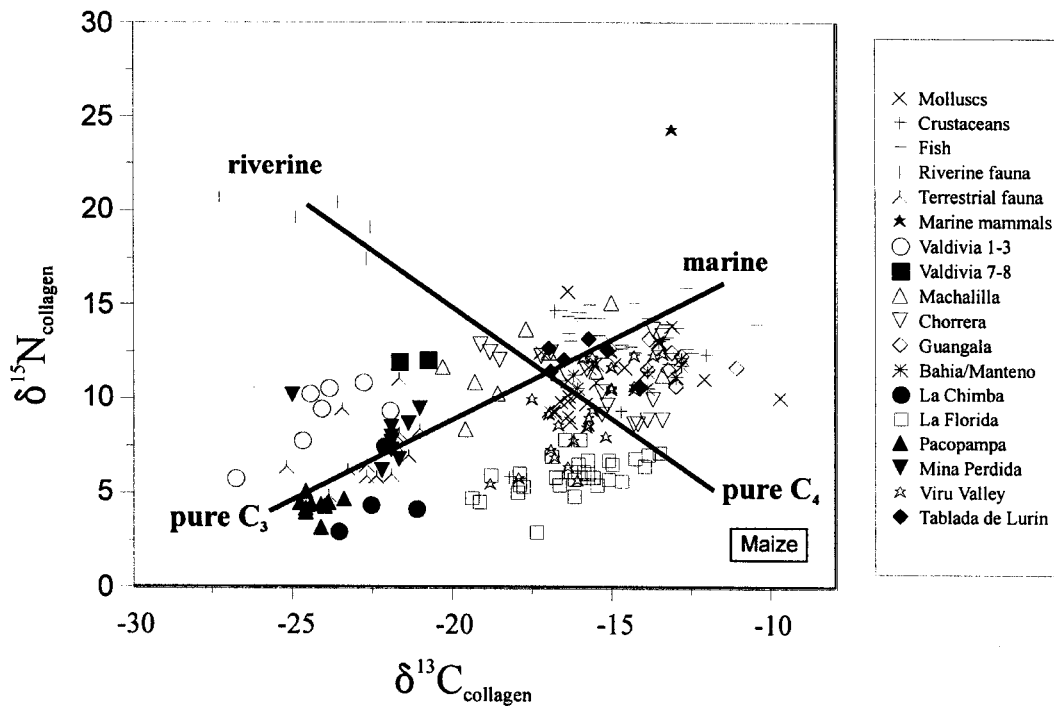


FIG. 5. Reconstruction of dietary protein sources based on stable isotope data for coastal Ecuador. To simulate diet,  $\delta^{13}\text{C}$  values from bone collagen are corrected  $-5.0\text{‰}$  and  $\delta^{15}\text{N}$  values are corrected  $-2.5\text{‰}$ . Faunal data for Ecuador from van der Merwe, Lee-Thorp, and Raymond (1993): modern riverine and terrestrial samples corrected  $+1.5$  in  $\delta^{13}\text{C}$  to account for industrial depletion; bone collagen from all faunal samples corrected  $-2.0$  in  $\delta^{13}\text{C}$  to simulate flesh. Human data from van der Merwe, Lee-Thorp, and Raymond (1993), Tykot, van der Merwe, and Athens (1996), Tykot, van der Merwe, and Burger (1996), and the present study (Valdivia 7–8).

tained for the individuals in burials 2 and 3, while both bone apatite and tooth enamel from a third molar were tested for the individual in burial 4. For this female adult, it is not surprising that bone apatite and tooth enamel produced the same result, since third molar enamel would represent diet at a time of formation (9.5–12 years of age) long after weaning. The 5–7-year-old from burial 3, however, is enriched 3‰ in apatite  $\delta^{13}\text{C}$  relative to the average of the two adults, which is a greater difference than can easily be explained by the higher trophic position of nursing juveniles and the potentially incomplete replacement of preweaning skeletal tissue by the time of this individual's death. The juvenile is also about 1‰ more enriched in collagen  $\delta^{13}\text{C}$  than the older female from burial 2, although their nitrogen isotope ratios are similar. If the carbon isotope differences in our small set of samples are representative of adults and juveniles in the La Emerenciana area, they could be attributed to relatively greater consumption by juveniles of maize as a solid supplement to and replacement for breast milk.

Using a fractionation value of  $+9.5\text{‰}$  relative to diet, the bone apatite and tooth enamel data suggest that the average  $\delta^{13}\text{C}$  value of the whole diet was about  $-22\text{‰}$  (range  $-24$  to  $-20\text{‰}$ ) and therefore at least 1‰ more negative than the average dietary contributor (presum-

ably protein) to collagen carbon. Terrestrial plants other than maize and both terrestrial and freshwater fauna have isotope ratios very similar to this whole-diet average. While the collagen data allowed the possibility that significant quantities of low-protein maize were consumed but isotopically balanced by freshwater fish, the apatite data make it clear that the bulk of the La Emerenciana diet was made up neither of maize nor of any other isotopically enriched terrestrial or marine resources.

Furthermore, residues from only one of the five pottery sherds tested produced a  $\delta^{13}\text{C}$  value suggesting the presence of anything other than  $\text{C}_3$  plant foods, even though two others also contained an assemblage of maize phytoliths (Thompson and Staller 2000, Staller and Thompson 2002). The mean value of  $-26.2\text{‰}$  obtained for four of five sherds tested is notably more negative than any of the 71 samples tested by Hastorf and DeNiro (1985) from the Mantaro Valley, while the average value of  $-22.8\text{‰}$  obtained for sherd 5623 is very similar to their findings for the Early Intermediate and Huanca II periods. For our sherds 5480 and 5485, we must conclude that while maize contributed the bulk of the phytoliths identified in the residue samples,  $\text{C}_4$  plants (including maize) and marine foods were negligible portions by weight of



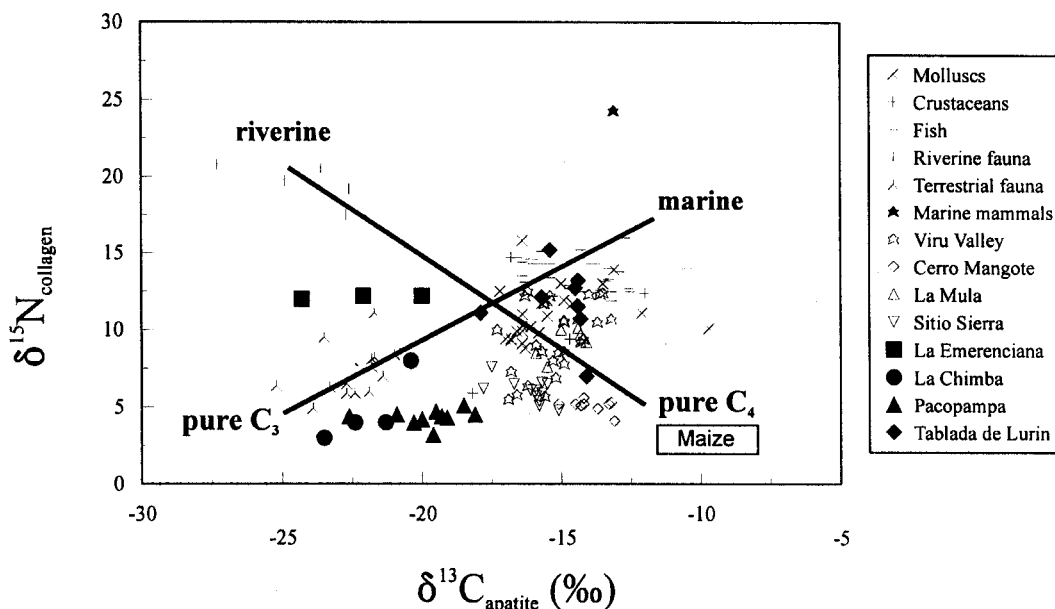


FIG. 6. Reconstruction of whole diet based on stable isotope data. To simulate diet,  $\delta^{13}\text{C}$  values from bone apatite are corrected  $-9.5\text{‰}$  to represent dietary carbon from all sources and  $\delta^{15}\text{N}$  values are corrected  $-2.5\text{‰}$  to simulate dietary protein. Faunal data are the same as for figure 5. Mixing lines are only approximate and do not necessarily reflect complex diets, for example, where protein and nonprotein dietary components have very different isotopic values. Viru Valley data from Ericson et al. (1989); data for three Panamanian sites from Norr (1995).

at least these two organic samples, which must have been composed primarily of  $\text{C}_3$  plants and/or freshwater fish. The modestly enriched  $\delta^{13}\text{C}$  values of  $-23.8\text{‰}$  and  $-21.9\text{‰}$  for two residue samples from sherd 5623 could be due to the presence of maize, as suggested by the phytolith assemblage; meat from animals consuming a strictly  $\text{C}_3$  diet; or  $\text{C}_4$  or CAM plants that have slightly enriched carbon isotope ratios but are not evident in the phytolith assemblage. The bottle form of this particular vessel, however, strongly implies that it was used to store and consume liquids, perhaps including fermented maize (Cutler and Cardenas 1947), which could very well have contributed significantly to the phytolith assemblages in the residues while contributing little to the overall mass of the residue and therefore to its isotopic composition. Unfortunately, it was impossible to obtain nitrogen isotope ratios or a precise determination of the amino-acid content of the residue samples, either of which could have differentiated between terrestrial and aquatic foods. It is worth noting that occasional feasting on fermented maize beverages would be very difficult to identify through isotopic analysis of bone or teeth, although it might be possible with hair samples.

#### CONCLUSIONS

While the average isotopic ratios for the La Emerenciana individuals could result from a variety of dietary combinations, it appears that terrestrial and freshwater fauna

and flora were much greater contributors to the diet than marine fauna, maize, or any other  $\text{C}_4$  or CAM plant with enriched carbon isotope values. Most important, maize clearly was *not* a staple crop in coastal Ecuador during the Valdivia period, when settled villages, ceremonial mounds, and ceramics first appeared. In fact, the stable isotope evidence from the La Emerenciana skeletal remains do not by themselves even prove its consumption at all in the later Valdivia culture, since the isotopic results could be explained by a plausible combination of  $\text{C}_3$  plants and terrestrial, freshwater, and marine fauna.

When compared, however, with the isotopic results obtained from the earlier Valdivia sites of Loma Alta and Real Alto and the later Machalilla- and Chorrera-phase samples (van der Merwe, Lee-Thorp, and Raymond 1993), the La Emerenciana individuals fall in between in their carbon isotope ratios, suggesting a long-term trend in coastal Ecuador toward increasingly enriched carbon isotope ratios and increased consumption of maize. The presence of significant assemblages of maize phytoliths both in human dental calculus and in pottery residues demonstrates the presence and at least modest consumption of maize at La Emerenciana, which perhaps spread initially as a primary ingredient for the consumption of fermented intoxicants rather than a solid food staple. The higher nitrogen isotope ratios at La Emerenciana relative to Loma Alta and Real Alto, however, can only be explained by the relatively greater con-

tribution of freshwater fauna and/or marine fish to the protein portion of the diet, perhaps in part due to a decline in the availability of wild terrestrial fauna with the clearing of forests for cultivation. The enriched carbon isotope ratios of La Emerenciana relative to Loma Alta and Real Alto could also be explained by increased consumption of marine resources as well as maize, other C<sub>4</sub> plants, or CAM plants; nevertheless, the small number of samples from La Emerenciana suggests that maize was at most a modest contributor to the Late Valdivia diet and certainly not the dietary staple it had become by the post-Formative period (Pearsall 1999). The data from La Emerenciana are supported by a preliminary analysis of lake deposits in Chimborazo Province showing a sharp positive shift in soil carbon isotope ratios beginning about 4,000 B.P., which may be interpreted as a change-over to an ecosystem dominated by maize agriculture (Rifkin and Jahren 1998). They are also consistent with findings from coastal Peru, where maize was present at some sites in the Late Preceramic VI period but even during the Initial period was not present at all sites (Hastorf 1999). Similarly, maize contributed even less, if at all, to the early Valdivia diet (van der Merwe, Lee-Thorp, and Raymond 1993) and cannot be linked to the precocious shift to sedentary villages and the manufacture of ceramics in this region. Indeed, from an isotopic perspective, we may conclude that the economic role of maize does not appear to have crystallized until very late in the pre-Hispanic sequence of the Andes (Burger and van der Merwe 1990, van der Merwe, Lee-Thorp, and Raymond 1993, Staller and Thompson 2000). Nevertheless, it appears that the cultural significance of maize may have played an important role in its spread throughout the Andes. Perhaps the most important role of maize to the development of more complex forms of social organization is related to its ritual importance to Andean exchange. The stable isotope evidence presented here combined with results from pre-Hispanic skeletons from various regions of the Andes is consistent with the long-term consumption of maize as a fermented intoxicant (*chicha*).

The uncertainty of many archaeological contexts, combined with still limited recovery, analysis, and publication of archaeobotanical remains, has led some to take a conservative view of the antiquity of plant domestication until macrobotanical or microfossil remains are directly dated (e.g., Fritz 1994a, b). Stable isotope analysis of human skeletal remains, however, provides complementary evidence to studies of macrobotanical remains, pollen, phytoliths, starch grains, and other indicators of prehistoric subsistence strategies, since it alone can provide quantitative estimates of the consumption of maize and other food resources in the New World.

The presence of maize in Ecuador long before it became a significant dietary component would not be unique. In the Mississippi River valley, directly dated maize remains from the 1st century B.C. are known (Riley et al. 1994), yet changes in the carbon isotope ratio of bone collagen occur only about A.D. 750 (Stothers and

Bechtel 1987). In conclusion, we concur with Smith (2001) and others who call for the integration of multiple lines of subsistence information; in coastal Ecuador, as elsewhere, explanation of cultural change can only result when complex subsistence strategies are well documented and understood as behavioral adaptations to particular ecological settings and dynamic economic and sociopolitical systems.

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