Journal of Archaeological Science 36 (2009) 2560–2565

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Determining Olmec maize use through bulk stable carbon isotope analysis

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A R T I C L E I N F O

Article history:
Received 5 May 2009
Received in revised form
10 July 2009
Accepted 15 July 2009

Keywords:
Stable carbon isotope analysis
Maize
Mesoamerica
Formative period
Olmec
Feasting
Absorbed organic residues

A B S T R A C T

Bulk stable carbon isotope analysis on absorbed organic residues in ceramics can be an effective method for discerning patterns of maize use when the ceramics come from relatively uniform archaeological contexts. The bulk stable carbon isotope method is faster and less costly than the more commonly used compound-specific stable carbon isotope analysis. Moreover, the bulk stable carbon isotope method can determine the presence of C4 plant carbon in samples in which organic compounds have degraded. Bulk stable carbon isotope analysis was used to discern patterns of maize (*Zea mays mays*) use among a sample of 24 ceramic sherds from an Early Franco Period feasting deposit (ca. cal 650 B.C.) at the Olmec site of San Andrés, La Venta, Tabasco, Mexico. A comparison of the δ 13C results of different categories of ceramics showed that proportionally more maize was used in luxury beverage service wares than in utilitarian vessels, suggesting that maize-based beverages were prominent in this probable elite feasting episode.

1. Introduction

Maize (*Zea mays mays*) use patterns were inferred by comparing the results of bulk stable carbon isotope analysis in absorbed organic residues in ceramics from a deposit made over a relatively short period of time, apparently in the context of a feasting event. Higher proportions of maize-signature (C4 plant signature) carbon occurred in luxury beverage serving wares than in utilitarian ceramics. This study demonstrates the usefulness of bulk stable carbon isotope analysis of absorbed organic residues in ceramics for exploring patterns of maize use among categories of ceramics from relatively homogeneous archaeological contexts, such as ceramics from the same stratum. This method differs from compound-specific stable carbon isotope analysis (Reber and Evershed, 2004a,b) in that it measures the δ ^{13}C signature of all of the carbon in a sample rather than only measuring the carbon in specific compounds. Bulk stable carbon isotope analysis therefore enables researchers to detect C4 plant use even in samples in which organic compounds have degraded because of taphonomic processes. The bulk stable carbon isotope method is faster and more cost effective, with a far simpler sample preparation protocol, than the compound-specific technique.

Bulk stable carbon isotope analysis was conducted on absorbed organic residues in 24 ceramics from a Middle Formative period midden dating to ca. cal 650 B.C. (Pohl et al., 2002) at the site of San Andrés, located 5 km northeast from the major Olmec center of La Venta, Tabasco, Mexico. Mary Pohl and Kevin Pope excavated San Andrés in 1997, 1998, and 2000 (Pohl et al., 2004). Christopher von Nagy (2003) conducted ceramic analysis, and Daniel Seinfeld (2007) performed the bulk stable carbon isotope study. The excavations revealed an Olmec midden located within a single stratum of black–grey–silty clay (BGS clay) that was hypothesized to have been feasting refuse. The δ ^{13}C signatures of the ceramic samples demonstrated that luxury wares had a higher proportion of C4 plant carbon, most likely from maize, than the utilitarian ones. The prominence of maize-based beverages, including maize beer and gruels, in Olmec feasting explain this pattern found in the isotopic analysis.

1.1. Principles of isotopic analysis

Stable carbon isotope analysis measures the ratio of ^{13}C, a stable isotope of carbon, to ^{12}C. This difference is expressed as the δ ^{13}C value. C3 and C4 plants have different photosynthetic pathways that produce distinct isotopic ratios of ^{13}C and ^{12}C (Deines, 1980; Farquhar et al., 1989:503; Smith, 1982; Tykot, 2004). C4 plants have an approximate average δ ^{13}C value of −12.5‰, and C3 of −26.5‰ (Tykot, 2004). Experimental work conducted in the present study and by others (Hart et al., 2007; Morton and Schwarcz, 2004)

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0305-4403/$ – see front matter
doi:10.1016/j.jas.2009.07.013

demonstrates that these distinct isotope signatures are reflected in archaeological residues in ceramics.

The vast majority of terrestrial plants are C3 plants (Smith, 1982). The C4 photosynthetic pathway is a relatively recent adaptation by plants in warm, arid, semitropical and tropical environments to fix atmospheric CO_2 more efficiently. C4 plants are present in 16 of 300 families of flowering plants, and they constitute a minority in all families in which they exist (Smith, 1982:100). This rarity of C4 plants means that the distinctive $\delta\,^{13}C$ signature of C4 plants (−12.5‰) can only come from a limited number of plant species (Tykot, 2004).

Maize was the most prominent C4 crop in New World contexts before European contact (Reber and Evershed, 2004a; Smith, 1982:102). Maize and a species of *Chenopodium* were the only C4 plants recovered in paleobotanical work at San Andrés (Lentz et al., 2006; Pope et al., 2001; Smith, 1982). Paleobotanical analysis (Lentz et al., 2006; Pope et al., 2001) indicates that maize was the only major C4 food plant found at San Andrés, and therefore any C4 isotopic signature probably originated from maize.

2. Research design

The results of isotope analysis for the various ceramics in the San Andrés midden can be compared because they all came from a single, densely packed stratum and were subject to nearly identical taphonomic processes. Therefore, any post-depositional alteration of the ceramics' isotopic signatures should be uniform across the various vessel classes. This narrow archaeological context differs from the broad regional comparisons conducted by Reber and Evershed (2004a) and by Morton and Schwarcz (2004), where ceramics from many time periods and locations would be subject to differential postdepositional processes. The tempering of the San Andrés ceramics had no effect on their isotopic signature because they were all tempered with inorganic materials such as sand and volcanic ash. The carbon isotopic signature of the ceramics therefore reflects the types of foods used in the vessels over the period of their use.

Bulk stable carbon isotope analysis can be especially useful in determining maize-use patterns in some archaeological contexts because of problems with compound-specific stable carbon isotope analysis. The rapid decomposition of maize lipids during taphonomic processes can impede the compound-specific technique because the lipids examined in this form of analysis are often no longer intact (Reber and Evershed, 2004b). The bulk stable carbon isotope technique offers an advantage over the compound-specific technique in some cases because the bulk stable carbon isotope technique measures the isotopic signature of all the carbon in the sample, thereby avoiding difficulties associated with the degradation of lipids sought in the compound-specific technique.

3. Materials and methods

3.1. Samples

Twenty-four ancient ceramics from the San Andrés midden were analyzed and divided into four analytical categories based on the temper and the ware of the vessels as described in von Nagy's (2003) ceramic typology of the region. The categories are as follows: luxury volcanic ash tempered ($n = 14$), luxury sand tempered ($n = 4$), utilitarian sand tempered ($n = 4$), and an "other" category ($n = 2$) (Fig. 1). These categories also reflected differences in function based on their archaeological contexts across the region and on different amounts of labor that went into their construction (von Nagy, 2003). Luxury wares are those ceramics that were primarily used for ceremonial functions and serving foods and beverages in special events rather than for everyday use preparing foods (von Nagy, 2003:185). Ceramics at San Andrés classified as luxury wares come from a tradition of differentially fired wares that was the primary serving and ceremonial pottery for a millennium in the north Tabasco plain (von Nagy, 2003:269,833). Luxury wares tend to be found in more limited contexts and are rarely found in smaller, low-ranking hamlet sites (von Nagy, 2003:186). Utilitarian wares are more widespread and common. The production of luxury wares required more labor than that of utilitarian wares. Luxury wares tended to be finely made and decorated. More labor was also expended on procuring the tempering agents, such as volcanic ash, used in luxury wares (von Nagy, 2003:185, 199).

Fig. 1. Examples of complete vessels that are representative of the types of vessels within analytical categories including luxury volcanic ash tempered wares, luxury sand tempered wares, and utilitarian sand tempered wares (Photographs by Richard Brunck; pictures not to the same scale).

Luxury volcanic ash tempered ceramics included wares designated by von Nagy (2003) as Desengaño black-and-white, Encrucijada black-and-white, and Tanochapa black. Ceramics included in the luxury sand tempered ceramics included Naranjeño black-and-white and unspecified fine sand tempered wares. The high proportion of luxury serving ceramics in the feasting deposit at San Andrés is consistent with the serving of foods and beverages during feasts.

Utilitarian ceramics were sand tempered and represented by the Gogal plain and Bronce unslipped types during the Early Franco period in the Grijalva delta (von Nagy, 2003:832). These ceramics were crude, unembellished, and used primarily for day-to-day domestic activities.

The "other" category of ceramics included 2 samples that did not fit within any of the previous two categories. One of these samples was a censor base, not used in food preparation or service, and the second was a Flores Waxy vessel. Flores Waxy ware is distinct from all other ceramics from San Andrés in the Early Franco period and may be related to similar ceramics from the Maya area (von Nagy, 2003:294–295).

Sampling procedure maximized the possibility of detecting absorbed organic residues. Samples were taken from base and body sherds mostly from larger, thicker-walled vessels that were probably in contact with foods and beverages for extended periods of time.

The study involved a relatively small number of samples ($n = 24$) because the restricted nature of the feasting deposit at San Andrés limited the number of vessels available to test. The project's research design focused on understanding food and beverage use