

Evidence of cacao use in the Prehispanic American Southwest

Patricia L. Crown^{a,1} and W. Jeffrey Hurst^b

^aDepartment of Anthropology, University of New Mexico, MSC01 1040, Albuquerque, NM 87131-1086; and ^bThe Hershey Center for Health and Nutrition, P.O. Box 805, Hershey, PA 17033

Communicated by Bruce D. Smith, National Museum of Natural History, Smithsonian Institution, Washington, DC, December 16, 2008 (received for review December 4, 2008)

Chemical analyses of organic residues in fragments of ceramic vessels from Pueblo Bonito in Chaco Canyon, New Mexico, reveal theobromine, a biomarker for cacao. With an estimated 800 rooms, Pueblo Bonito is the largest archaeological site in Chaco Canyon and was the center of a large number of interconnected towns and villages spread over northwestern New Mexico. The cacao residues come from pieces of vessels that are likely cylinder jars, special containers occurring almost solely at Pueblo Bonito and deposited in caches at the site. This first known use of cacao drinks north of the Mexican border indicates exchange with cacao cultivators in Mesoamerica in a time frame of about A.D. 1000–1125. The association of cylinder jars and cacao beverages suggests that the Chacoan ritual involving the drinking of cacao was tied to Mesoamerican rituals incorporating cylindrical vases and cacao. The importance of Pueblo Bonito within the Chacoan world likely lies in part with the integration of Mesoamerican ritual, including critical culinary ingredients.

archaeology | Chaco Canyon | ritual | chemistry | organic residues

Organic residue analysis of ceramics from Pueblo Bonito, the largest site in Chaco Culture National Historical Park, reveals the presence of theobromine, a marker for *Theobroma cacao* or chocolate. Here, we analyze dry residue samples using HPLC coupled to MS, and show that cacao was consumed in the American Southwest circa A.D. 1000–1125. The ceramics used for this study are fragments of pitchers or cylindrical jars. This is the first demonstrated use of cacao north of the Mexican border and provides evidence for a specific ritual activity in Chaco Canyon.

Chaco Canyon lies in northwestern New Mexico. Although occupied for millennia, the florescence of Chaco culture began about A.D. 900 with the construction of multiple large masonry villages within the canyon. Villages with similar architecture and material culture occur in a large area outside the canyon, and archaeologists argue that extensive exchange and ritual cohesion characterized this regional system of pueblos. Pueblo Bonito is the largest site in Chaco Canyon (1). With an estimated 800 rooms in the multistoried masonry pueblo, tree-ring dates reveal construction between about A.D. 860 and 1128 (2). Archaeologists excavated Pueblo Bonito in two major projects. The Hyde Exploring Expedition (1896–1899) and the National Geographic Society Expedition (1920–1927) investigated most of the rooms in the site and portions of the two trash mounds just south of the pueblo (3, 4). Hundreds of thousands of artifacts from these excavations are housed primarily at the American Museum of Natural History and the Smithsonian Institution.

Among the many unusual objects from Pueblo Bonito are ceramic cylinder jars, vessels typically 2.4 times as tall as they are wide (Fig. 1). Most are painted with black designs on a white background, but red jars and white jars occur as well. Fewer than 200 cylinder jars are known from the American Southwest and 166 of these come from Pueblo Bonito. Excavation revealed 111 cylinder jars in a single large cache in one room at the site (5). While archaeologists generally agree that the vessels had a ritual



Fig. 1. Twelve cylinder jars from Pueblo Bonito housed in the Smithsonian Institution Department of Anthropology. Vessel in left center is 21.5 cm in height (Marianne Tyndall, photographer). [Reproduced with permission from Crown and Wills (8) (Copyright 2003, Society for American Archaeology).]

use, they disagree about the nature of this ritual and the specific use of the vessels in ritual (6–8). Various arguments for their specific use in ritual have included holding exotic items such as turquoise (6) or, with a skin cover, serving as drums (9). Ceramic pitchers come from the same contexts as the cylinder jars but are more common both at Pueblo Bonito and throughout the Chacoan region. The pitchers differ from the cylinder jars in having a large vertical handle and a bulbous base. Fragments from cylinder jars and pitchers are difficult to distinguish. Although pitchers occur more frequently than cylinder jars, their recovery in identical locations, including the large cache in Pueblo Bonito, suggests that they may have had similar or related functions.

Recent University of New Mexico re-excavation of trenches originally dug in the trash middens directly south of Pueblo Bonito in the 1920s recovered hundreds of thousands of fragmentary artifacts. For this analysis, we selected sherds from these contexts representing 5 different vessels that were either cylinder jars or pitchers. Three were characterized as probable cylinder jars, one as a definite pitcher, and one as an indefinite cylinder jar/pitcher. The selected sherds date between A.D. 1000 and 1125 based on decorative styles.

We used HPLC coupled to MS to analyze each of the samples. There were no visible residues on the sherds, so we extracted absorbed residues from the paste of the sherds. The procedure involved burring the surface from each 10 g sherd

Author contributions: P.L.C. designed research; W.J.H. performed research; P.L.C. and W.J.H. analyzed data; and P.L.C. and W.J.H. wrote the paper.

The authors declare no conflict of interest.

¹To whom correspondence should be addressed. E-mail: pcrown@unm.edu.

© 2009 by The National Academy of Sciences of the USA

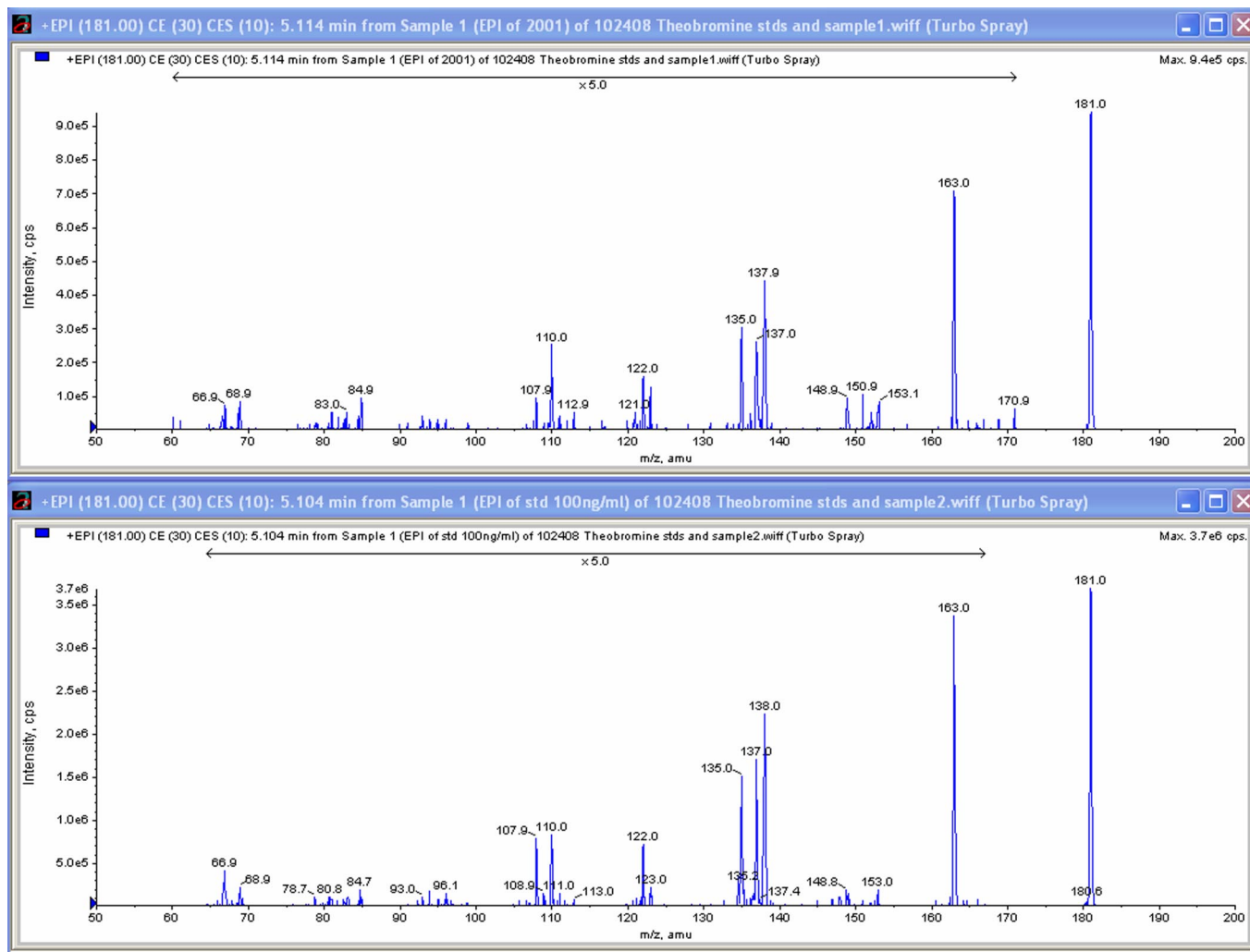


Fig. 2. Mass Spectrum of Sample 2001 (top) and Theobromine Standard (bottom).

and crushing the sample in a degreased agate mortar. We used about 500 mg of the powder and added 3 ml of distilled water at 80 °C to solubilize the materials. Before analysis, we passed each sample through membrane filters to eliminate particulate matter.

Cacao has a unique chemical composition of more than 500 different compounds, including members of the methylxanthine class (primarily theobromine, with a lower concentration of caffeine). Theobromine is used as a marker of cacao in organic residues studies of ceramics from Mesoamerica because *T. cacao* is the only Mesoamerican plant that contains theobromine as the primary methylxanthine. HPLC coupled to MS has previously revealed cacao residues in ceramics vessels from sites in Belize, Guatemala, and Honduras (10–14).

The MS was operated in positive-ion mode with MS/MS in Enhanced Product Ionization (EPI) mode to monitor for the major peak at $m/z = 181$ (theobromine) and other fragments using authentic theobromine as a standard. The results of the HPLC MS confirmed the existence of theobromine in 3 of the 5 samples analyzed. These 3 samples were those characterized as probable cylinder jars. The sherds from the pitcher and indefinite cylinder jar/pitcher did not show the peaks characteristic of theobromine. Peaks from the extract of the residue from Sample 2001 were evident in the mass spectrum of the sample (Fig. 2), which confirms the existence of theobromine.

There are 4 important implications of this research that we explore more fully below. First, it documents the presence of cacao north of the Mexican border, far outside the area of cultivation. Second, it shows the likely function of the ceramic cylinder jars found at Pueblo Bonito. Third, it reveals a specific ritual performed at Pueblo Bonito with possible ties to Mesoamerican ritual. Finally, it enhances our understanding of Pueblo Bonito as the center of the Chacoan ritual world.

This is the first recovery of cacao in a Prehispanic context north of the Mexican border. The presence of cacao in the sherds from Pueblo Bonito indicates exchange in cacao from Mesoamerica. *T. cacao* is a neotropical tree requiring a shaded humid atmosphere, deep alluvial soils, high rainfall, and high average temperatures for survival. Evidence for the distribution of cacao in Mesoamerica for the period around Spanish contact (or about 400 years later than the Chacoan vessels) is reconstructed from tribute lists (15, 16). Relative to the Chaco area, the closest cacao cultivation at contact was in Central Mexico (Fig. 3), including portions of northern Veracruz and Colima (15). Larger cultivation areas occurred farther south in Mexico and Central America. Other Mesoamerican goods, including copper bells; cloisonné; and Scarlet Macaws, a species native to the humid lowlands of Mexico, occur at Pueblo Bonito, so cacao may have come to Pueblo Bonito through exchange or acquisition that included additional exotic items from Mesoamerica.

the University of New Mexico Research Allocation Committee. The Hershey's Technical Center supported the organic residue analysis. Mass Spectrometric analyses were performed by Jenny Dai using an MDS Sciex 4000 QTrap located in the Mass Spectrometry/Proteomics facility at the Penn State College of Medicine. Lewis Borck prepared the samples for analysis. We thank the National Park Service for permission to conduct the field work, and the other participants in the project

for their contributions to the excavations and artifact analysis. We also thank the Smithsonian Institution Department of Anthropology for permission to use the photograph in Fig. 1 and Adam Nazaroff for drafting Fig. 3. Special thanks to Dorie Reents-Budet and Keith Prufer for conversations with P. L. C. that led to the current collaboration. We thank W. H. Wills, Bruce Smith, and two anonymous reviewers for helpful comments on earlier drafts of this paper.

1. Neitzel J (2003) in *Pueblo Bonito*, ed Neitzel J (Smithsonian Institution, Washington), pp 1–9.
2. Windes TC (2003) in *Pueblo Bonito*, ed Neitzel J (Smithsonian Institution, Washington), pp 14–32.
3. Pepper G (1920) *Pueblo Bonito* (American Museum of Natural History, New York), Vol. XXVII Anthropological Papers of the American Museum of Natural History.
4. Judd N (1954) *The Material Culture of Pueblo Bonito* (Smithsonian Museum, Washington), Vol 124 Smithsonian Miscellaneous Collection.
5. Neitzel J (2003) in *Pueblo Bonito*, ed Neitzel J (Smithsonian Institution, Washington), pp 107–126.
6. Washburn W (1980) The Mexican connection: Cylinder jars from the valley of Oaxaca. *Trans Illinois State Acad Sci* 72:70–85.
7. Toll W (1990) in *Clues to the Past: Papers in Honor of William M. Sundt*, ed Duran M and Kirkpatrick D (Archaeological Society of New Mexico, Albuquerque, NM), Archaeological Society of New Mexico 16, pp 273–306.
8. Crown P, Wills WH (2003) Modifying pottery and kivas at Chaco: Pentimento, restoration, or renewal? *Am Antiquity* 68:511–532.
9. Lekson S (1999) *The Chaco Meridian* (Altamira, Walnut Creek, CA).
10. Hurst WJ, Tarka S, Powis T, Valdez F, Hester T (2002) Cacao usage by the earliest Maya civilization. *Nature* 418:289–290.
11. Hurst WJ, Martin J, Tarka S, Hall G (1989) Authentication of cocoa in Maya vessels using high-performance liquid chromatographic techniques. *J Chromatogr* 466:279–289.
12. Prufer K, Hurst WJ (2007) Chocolate in the underworld space of death: Cacao seeds from an arly Classic mortuary cave. *Ethnohistory* 54:273–301.
13. Hurst WJ (2007) in *Chocolate in Mesoamerica: A Cultural History of Cacao*, ed McNeil CL (Univ Press of Florida, Gainesville, FL), pp 105–113.
14. Henderson JS, Joyce RA, Hall GR, Hurst WJ, McGovern PE (2007) Chemical and archaeological evidence for the earliest cacao beverages. *Proc Natl Acad Sci* 104:18937–18940.
15. Bergmann J (1969) The Distribution of Cacao Cultivation in Pre-Columbian America. *Ann Assoc Am Geogr* 59:85–96.
16. McNeil CL (2007) in *Chocolate in Mesoamerica: A Cultural History of Cacao*, ed McNeil CL (Univ. Press of Florida, Gainesville, FL), pp 1–28.
17. Powis T, et al. (2007) Oldest chocolate in the New World *Antiquity* 81. Available at <http://antiquity.ac.uk/ProjGall/314>.html.
18. Dreiss ML, Greenhill, SE (2008) *Chocolate: Pathway to the Gods* (Univ of Arizona Press, Tucson) p 109.