Ritual drinks in the pre-Hispanic US Southwest and Mexican Northwest

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This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected in 2014. Contributed by Patricia L. Crown, August 7, 2015; for review July 6, 2015; reviewed by Randy McGuire and Ben A. Nelson

Chemical analyses of organic residues in fragments of pottery from 18 sites in the US Southwest and Mexican Northwest reveal combinations of methylxanthines (caffeine, theobromine, and theophylline) indicative of stimulant drinks, probably concocted using either cacao or holly leaves and twigs. The results cover a time period from around A.D. 750–1400, and a spatial distribution from southern Colorado to northern Chihuahua. As with populations located throughout much of North and South America, groups in the US Southwest and Mexican Northwest likely consumed stimulant drinks in communal, ritual gatherings. The results have implications for economic and social relations among North American populations.

Cacao | Holly | US Southwest/Mexican Northwest | Anthropology | Chemistry | Inaugural Article

The discovery of cacao residues in ceramics from Pueblo Bonito, Chaco Canyon, New Mexico, demonstrated exchange with populations in the tropical areas where Theobroma cacao grew in the past as well as consumption of ritual drinks by at least A.D. 1000 in the canyon (1, 2). It also raised questions about the time depth and geographic extent of this exchange in the US Southwest and Mexican Northwest. This paper reports the results of a large National Science Foundation-funded study designed to examine the temporal and spatial distribution of cacao use in the pre-Hispanic US Southwest and Mexican Northwest. It details the organic residue analysis of 177 samples of ceramics from 18 sites located in Arizona, Chihuahua, Colorado, and New Mexico. We analyzed residue samples using liquid chromatography–mass spectrometry (LC-MS/MS) and show that populations in the US Southwest and Mexican Northwest consumed caffeinated drinks at a number of villages from as early as A.D. 750 until at least A.D. 1400.

What many US archaeologists define as the Southwest Culture area encompasses southern Colorado/Utah to Sonora/Chihuahua, and from western Arizona to eastern New Mexico. The region was occupied continuously from at least 10,000 B.C. and the present study included material from sedentary farming villages occupied between A.D. 500 and 1450. We selected fragments of ceramic drinking vessels from sites that represent a range of time periods and locations. Because we were specifically targeting residues from a plant species whose range extends no further north than central Mexico (1), we primarily selected ceramics from sites that had other Mesoamerican trade items, particularly scarlet macaws, another species native to the humid lowlands of Mesoamerica (3–5). We also selected some samples from villages that lacked other known Mesoamerican trade items to avoid biasing the sample (Table 1).

Materials and Methods

For this study, we analyzed 177 samples from fragments of pottery excavated at 18 sites (Fig. 1). All samples came from fragments of ceramic vessels, but the conditions of those samples varied. Twenty-four samples were collected in the field for this study. Sixty-six samples came from ongoing artifact analyses that stored samples in bags within boxes in laboratories. Another 76 samples came from other project collections stored in bags in boxes within museums for many years. Eleven specimens were from older project collections stored uncovered in drawers within cabinets and thus were more susceptible to contamination. Unfortunately, analysts had cleaned some specimens of particular interest by washing them in water; as documented in Table 1, a lower percentage of cleaned samples had positive results. Cleaning also introduces the possibility of contamination.

In addition to considering geographic spread, sampling took into account temporal spread and vessel form. We primarily chose fragments of vessels designed to hold drinks from particular sites and time periods, but we also chose some more generalized forms, such as bowls, that might have been used for eating solid and/or liquid foods. We assigned samples to 100-year time periods based on type and decorative style (Table 2). However, many of the types were produced for longer than a century, so the particular century assigned is open to interpretation.

The analysis was conducted using LC-MS/MS at the Keck Center for Instrumental and Biochemical Comparative Archaeology at Millsaps College. For conservation purposes, pieces ∼1–4 cm3 in size were removed from larger fragments (sherds) of archaeological ceramics. Initial sample preparation involved using a tungsten-carbide bit attached to a Dremel tool to burr the exterior surfaces from the sherds to reduce the risk of contamination from

The combined evidence for widespread use of two different caffeinated plants, cacao and holly, as the basis for drinks used in communal, ritual gatherings. It is the largest study of its kind, both in terms of numbers of samples and in terms of temporal/spatial scope. It is the first to argue for holly beverage consumption in the US Southwest/Mexican Northwest. The combined evidence for cacao and holly beverage consumption has implications for our understanding of distant resource acquisition and shared cultural practices in North America.

Author contributions: P.L.C. and W.J.H. designed research; P.L.C., J.G., T.J.W., A.D.B., S.A., L.K., M.B., and E.R. performed research; P.L.C., P.D.L., J.M., D.A.P., L.S.R., and K.W. selected the samples; P.L.C., W.J.H., and T.J.W. analyzed data; and P.L.C., W.J.H., and T.J.W. wrote the paper.

Reviewers: R.M., SUNY Binghamton; and B.A.N., Arizona State University. The authors declare no conflict of interest.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1511799112/-/DCSupplemental.

This article presents the results of a large-scale National Science Foundation-funded study of organic residues from archaeological sites in the US Southwest/Mexican Northwest. It reveals widespread use of two different caffeinated plants, cacao and holly, as the basis for drinks used in communal, ritual gatherings. This is the largest study of its kind, both in terms of numbers of samples and in terms of temporal/spatial scope. It is the first to argue for holly beverage consumption in the US Southwest/Mexican Northwest. The combined evidence for cacao and holly beverage consumption has implications for our understanding of distant resource acquisition and shared cultural practices in North America.

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www.pnas.org/cgi/doi/10.1073/pnas.1511799112

PNAS Early Edition | 1 of 7
postexcavation handling and storage. Because the instrumentation is highly sensitive and the ceramics porous, samples may be contaminated from any contact with caffeine, so laboratory workers wore masks, gloves, and gowns and no caffeinated drinks entered the laboratory. Samples were then ground into a powder for analysis.

For methylxanthine analysis, ~500 mg of ground sample was weighed out into a test tube and ~3 mL of hot deionized water were added to the test tubes. The samples were then heated in the heating block at 85 °C for 20 min. Samples were then cooled to room temperature and placed in a centrifuge for 10 min at a speed of 16,000 × g. The supernatant was deanted into a 10-mL beaker and was reduced at 50 °C on the heating block until ~1.5 mL remained. Spiked solutions were created to confirm the trace peaks. Spiked solutions were made by taking a 495-μL aliquot of each 1.5-mL sample solution and spiking it with 5 μL of a standard solution of 1 ppm caffeine and theobromine. After mixing, this resulted in a spiked solution with an additional concentration of 10 ppb of caffeine and theobromine. All samples were transferred to autosampler vials for LC-MS/MS analysis.

The samples were analyzed using a Varian 325 LC/MS/MS. For methylxanthine analysis, the drying gas temperature was set at 400 °C; the voltage was set at 2030, and 2060, including chromatograms of standard and sample for quantification respectively for caffeine and theobromine. All samples were transferred to autosampler vials for LC-MS/MS analysis. There were no signals for any of the compounds detected in any of our blank solutions. Limits of detection (LoDs) were calculated based on the International Union of Pure and Applied Chemistry method 3.2.1 (noise of the blank/m (slope of the calibration curve). LoDs are defined by both the noise and the signal intensity. We set limits of quantitation (LoQs) of 2.0 ppb for caffeine and 1.0 ppb for theobromine as the lowest concentrations for meeting our goals for bias and imprecision. These LoQs provide conservative results. The number of samples analyzed with negative results (137 out of 177) confirms that we are not simply monitoring background contamination.

A study of museum contamination called into question results run from reconstructed or whole vessels sitting on open shelving in museums and sampled by pouring water onto the surface and analyzing this wash (6). That study concluded substantial contamination from particulate matter found as dust on artifacts in museums. As noted above, our samples came almost entirely from material collected in the field and placed in closed bags inside boxes in museums, and therefore it was not exposed to airborne contamnates. However, as noted in Table 1, 11 samples came from sherd s sitting open in drawers in museum cabinets, where the possibility of contamination is greater. Three of these 11 samples tested positive for methylxanthines, including two samples from Snaketown and one from Pueblo Bonito. However, we note that the other eight samples stored on the same shelves under identical conditions did not test positive. Our highest rate of positive samples (32%) came from recently excavated materials that were pulled for our study during or immediately after laboratory analyses because we burr off the exterior surfaces under controlled conditions and only analyze absorbed residues, we believe that airborne contamination of samples is not an issue in our study. In addition, experimental tests in the University of New Mexico laboratory where the samples were prepared demonstrated no detectible adsorbed or absorbed methylxanthine residues from airborne contaminants.

Few plants with the methylxanthines theobromine, caffeine, and theophylline grew in North America before contact (1, 7–9); these include Theobroma cacao, Ilex vomitoria Ait., Ilex cassine L., and perhaps Franklinia alatamaha, none of which is native to the US Southwest or northwestern Mexico. Indeed, there are no plants in the US Southwest or northwestern Mexico known to contain the methylxanthines of interest, so the residues must come from sources outside the area. Two plants that theobromine and theobromine are documented as having been used to create drinks during the pre-Hispanic period in North America: T. cacao, grown and used in Mesoamerica to make chocolate drinks, and I. vomitoria (the variety of holly also called yaupon), used in what is now the southeastern United States to create a caffeinated drink referred to in historic accounts as “black drink.” Populations in South America continue to use different varieties of holly to make caffeinated drinks (7, 8), so the residues we identified are most likely to be from plants that were introduced to Southwestern populations prepared drinks with cacao or I. vomitoria rather than the more distant varieties of caffeinated plants found in South America (8). Fig. 1 shows the distribution of T. cacao in about A.D. 1500 (10) and the current distribution of I. vomitoria.

Distinguishing which plant was the source for the residues in southwestern pottery is difficult. The two plants have different ratios of the methylxanthines and should be distinguished as useful. I. vomitoria has a ratio of caffeine to theobromine of about 5:1 (11), whereas T. cacao has a ratio of caffeine to theobromine of 1:4–1:7 (12). However, these are idealized ratios for plant parts rather than ratios derived from prepared drinks or archaeological contexts. A variety of factors can affect the ratios, including differential preservation due to conditions in the field or laboratory; differences in plant age and growing conditions; and differences in preparation, including fermentation, roasting/roasting, and dilution with water and other additives (7, 13). Groundwater tested in areas with native stands of I. vomitoria also has detectible traces of caffeine (14), which presumably may contaminate porous ceramics in those areas; because neither holly nor T. cacao was native or cultivated in the US Southwest and Mexican Northwest before contact, contamination from groundwater is not a source for the residues we identified. Direct contact with urine from individuals consuming caffeinated foods might also contaminate porous ceramics, because the methylxanthes are excreted in urine (15); however, this is also an unlikely source for the residues recovered from most archaeological ceramics. It is possible that southwestern populations used ceramics for many different varieties of drinks, possibly diluting or mixing the compounds found (13), so we cannot assume that the ratios determined represent a single episode of use. Finally, instruments vary in their detection of the methylxanthes, and the limits of detection for caffeine are considerably lower than for theobromine. As noted, our reported concentrations and LoQs take these differences into account.

Our reported concentrations for the third methylxanthe, theophylline, illustrate the problems with interpreting the results. Theophylline is not

| Origin                      | Site                                      | No. of samples | Unwashed | Washed |
|-----------------------------|-------------------------------------------|----------------|----------|--------|
| Field                       | Shabik’eshee Village                      | 10             | 10       |        |
| Field                       | Site 315                                  | 14             | 14       |        |
| Laboratory                  | Pueblo Bonito*                            | 34             | 34       |        |
| Laboratory                  | Windy Knob                                | 1              | 1        |        |
| Laboratory                  | Monsoon House                             | 3              | 3        |        |
| Laboratory                  | Meadow View                               | 1              | 1        |        |
| Laboratory                  | Aztec Ruins*                              | 10             | 10       |        |
| Laboratory                  | Lake Roberts Site                         | 10             | 10       |        |
| Laboratory                  | Upper Santan                              | 7              | 7        |        |
| Museum box                  | Chetro Keli*                              | 8              | 6        | 2      |
| Museum box                  | Guadalupe Ruin*                          | 10             | 5        | 5      |
| Museum box                  | Pottery Mound                             | 10             | 10       | 5      |
| Museum box                  | Pueblo*                                   | 1              | 1        |        |
| Museum box                  | Grasshopper Pueblo                        | 5              | 5        |        |
| Museum box                  | Kinship*                                  | 14             | 14       | 11     |
| Museum box                  | Point of Pines Pueblo*                    | 1              | 1        |        |
| Museum box                  | University Indian Ruin                    | 1              | 1        |        |
| Museum box                  | Galaz Ruin*                               | 20             | 6        | 14     |
| Museum box                  | Snaketown*                                | 7              | 7        |        |
| Museum shelf                | Pueblo Bonito*                            | 5              | 5        |        |
| Museum shelf                | Snaketown*                                | 6              | 6        |        |
| Total                       |                                          | 177            | 113      | 64     |

| Positive results             | 30       | 10     |
| Percent positive, %          | 27       | 17     |

Sites marked with an asterisk have other known Mesoamerican exotic items.
detected in \textit{I. vomitoria} but is present in \textit{T. cacao}, and is thus most useful in distinguishing the two potential sources of residues; unfortunately, it is rarely detected. Only two of our samples have detectible theophylline, indicating that the vessels unquestionably held cacao. However, both of these vessels had higher levels of caffeine than theobromine, which would indicate the presence of an \textit{Ilex}-based drink if we relied only on the ratio method for determining contents.

We have previously argued that ursolic acid may serve to distinguish \textit{I. vomitoria} from \textit{T. cacao} (7). We noted that ursolic acid occurs in many other plants but might provide an orthogonal approach to resolving the question of which plant left the organic residues. We note this can become problematic in areas where ursolic acid may come from different sources and not prove as reliable for distinguishing between \textit{I. vomitoria} and \textit{T. cacao}. Thus, we chose to concentrate on the presence and relative amounts of the methylxanthines.

**Results**

The results demonstrate various presence/absence combinations of theobromine, theophylline, and caffeine in 40 of the samples. We aggregate the results into three groups (Tables 4–6). Group 1 includes 12 samples characterized by the presence of theophylline in two samples, the presence of only theobromine and no caffeine detected in two samples, or the presence of more theobromine than caffeine in the remaining eight samples (Table 4). We interpret these results as strongly indicative of cacao, or

![Map of archaeological sites and plant distribution](image-url)
chocolate-based drinks. The samples come from six sites dating from about A.D. 750–1400 and spread from what is now northern New Mexico (Aztec Ruins and Pueblo Bonito) to east-central Arizona (Kinishba), southwestern New Mexico (Lake Roberts Site), southern Arizona (Snaketown and Upper Santan Village), and northern Chihuahua (Site 315). Forms include a seed jar/tecomate, bowl, flowerpot-shaped vessel, two pitchers, four small jars, and three mugs.

Group 2 includes 19 samples that have caffeine but no detected theobromine or theophylline (Table 5). Although it is possible that these samples held chocolate-based drinks, it is more likely that they held drinks containing *I. vomitoria*. The samples come from eight sites dating between A.D. 750–1400 and spread over much the same geographic area as the group 2 samples: southwestern Colorado (Windy Knob), northern New Mexico (Pueblo Bonito, Guadalupe Ruin, and Pottery Mound Pueblo), southwestern New Mexico (Galaz Ruin), southern Arizona (Snaketown and Upper Santan Village), and northern Chihuahua (Site 315). Forms include a beaker, a ceramic box, three bowls, three jars, two mugs, and nine pitchers.

Group 3 includes nine samples characterized by both caffeine and theobromine, but with more caffeine than theobromine and no detected theophylline (Table 6). They may have held drinks containing either *T. cacao* or *I. vomitoria*, or perhaps both at different times. The samples date between A.D. 1000–1400 and come from four sites located in southwestern Colorado (Monsoon

### Table 2. Vessel forms and types for each time period and site analyzed for organic residues

| Time period | Site | Sample Forms | Types | Samples | Positive results |
|-------------|------|--------------|-------|---------|-----------------|
| Pre-900     | Shabik’eesche Village | Seed jars | Lino Gray | 10 | 0 |
|             | Upper Santan Village | 5 jars, 2 bowls | Indeterminate red on gray and red on buff | 7 | 1 bowl/beaker, 1 jar |
| Totals      |                       |              | Santa Cruz R/B | 6 | 1 beaker |
| A.D. 900–1000 | Snaketown | 4 beakers, 1 jar, 1 box | Unknown | 23 | 3 (13%) |
| Totals      |                       |              | Sacaton R/B | 7 | 1 jar, 1 box |
| A.D. 1000–1100 | Pueblo Bonito | 1 bowl, 1 jar, 1 beaker, 4 boxes | Red Mesa B/W | 7 | 4 pitchers |
| Totals      |                       |              | 14 | 6 (43%) |
| A.D. 1100–1200 | Pueblo Bonito | Cylinder jars | Gallup B/W, Cibola White Ware | 5 | 1 cylinder jar |
| Totals      |                       |              | 52 | 9 (17%) |
| A.D. 1200–1300 | Aztec Ruins | 9 pitchers/1 jar | Gallup B/W, Puero B/W | 1 | 0 |
| Totals      |                       |              | 1 | 0 |
| A.D. 1300–1450 | Pottery Mound Pueblo | 9 interior lug vessels, 1 jar, 4 flowerpots, 1 bowl | Rio Grande Glazeware | 10 | 1 interior lug jar |
| Totals      |                       |              | 10 | 1 flowerpot |
|             | Kinishba | 4 bowls, 9 flowerpots | Fourmile PC | 5 | 1 flowerpot |
|             | Point of Pines Pueblo | 1 bowl | Point of Pines PC, Fourmile PC | 13 | 0 |
|             | Grasshopper Pueblo | 1 bowl | Rio Grande Glazeware | 1 | 0 |
|             | University Indian Ruin | 1 bowl | Fourmile PC | 1 | 0 |
|             | Site 315 | 1 bowl, 2 seed jars, 11 jars | Ramos PC, Babicora PC, Carretas PC, Ramos Black | 14 | 4 jars, 1 seed jar, 1 bowl |

| B/W, black on white; PC, polychrome; R/B, red on buff. |

### Table 3. Mass fragments used to monitor caffeine, theobromine, theophylline, and ursolic acid in the ESI mode

| Compound | Mode | Mass fragments |
|----------|------|----------------|
| Caffeine | Positive | 195.0 > 109.9 |
|          | Positive | 195.0 > 137.9 |
| Theobromine | Positive | 181.0 > 138.0 |
|          | Positive | 181.0 > 163.0 |
| Theophylline | Positive | 181.0 > 123.9 |
| Ursolic acid | Positive | 457.4 > 297.3 |
|          | Positive | 457.4 > 411.3 |
|          | Positive | 457.4 > 439.3 |
|          | Negative | 455.0 |
Table 4. Results of analysis for group 1 samples with only theobromine, higher theobromine than caffeine, or detected theophylline, interpreted as likely resulting from cacao drinks

| Sample no. | Theobromine | Caffeine | Theophylline | Site            | Pottery type | Form       | Washed/ unwashed |
|------------|-------------|----------|--------------|-----------------|--------------|------------|------------------|
| 2060       | 16.1        | ND       | ND           | Pueblo Bonito   | Red Mesa B/W | Pitcher    | u                |
| 2062       | 0.9         | 9.5      | 1.3          | Pueblo Bonito   | Red Mesa B/W | Pitcher    | u                |
| 2168       | 4.3         | ND       | ND           | Lake Roberts Site | Mimbres Classic B/W | Bowl    | u                |
| 2125       | 1.8         | 0.6      | ND           | Site 315       | Ramos PC     | Jar        | u                |
| 2126       | 1.5         | 1.0      | ND           | Site 315       | Ramos PC     | Jar        | u                |
| 2127       | 1.4         | 1.0      | ND           | Site 315       | Ramos PC     | Seed jar   | u                |
| 2129       | 2.3         | 1.7      | ND           | Site 315       | Babicora PC  | Jar        | u                |
| 2135       | 1.9         | 4.4      | 5.0          | Kinishba        | Fourmile PC  | Flowerpot  | w                |
| 2157       | 1.2         | 0.6      | ND           | Aztec Ruins    | Mesa Verde B/W | Mug    | w                |
| 2158       | 7.6         | 0.5      | ND           | Aztec Ruins    | Mesa Verde B/W | Mug    | w                |
| 2159       | 5.7         | 0.3      | ND           | Aztec Ruins    | McElmo B/W   | Mug        | u                |
| 2192       | 4.2         | 2.9      | ND           | Upper Santan Village | Indeterminate red on buff | Jar    | u                |

B/W, black on white; ND = not detected; PC, polychrome; u, unwashed; w, washed.

Table 5. Results of analysis for group 2 samples with caffeine only, interpreted as likely resulting from Ilex (holly) drinks

| Sample no. | Theobromine | Caffeine | Theophylline | Site            | Type      | Form       | Washed/ unwashed |
|------------|-------------|----------|--------------|-----------------|-----------|------------|------------------|
| 2018       | ND          | 5.7      | ND           | Snaketown       | Beaker    | w          |                  |
| 2020       | ND          | 6.2      | 3.2          | Snaketown       | Saca ton R/B | Jar    | w                |
| 2025       | ND          | 6.4      | ND           | Snaketown       | Saca ton R/B | Ceramic box | w                |
| 2030       | ND          | 8.0      | 1.1          | Galaz Ruin      | Mimbres Classic B/W | Bowl | w                |
| 2035       | ND          | 6.2      | ND           | Galaz Ruin      | Mimbres Classic B/W | Bowl | u                |
| 2052       | ND          | 3.4      | ND           | Pueblo Bonito   | Chaco B/W  | Pitcher    | u                |
| 2056       | ND          | 3.4      | ND           | Pueblo Bonito   | Chaco B/W  | Pitcher    | u                |
| 2057       | ND          | 3.5      | ND           | Pueblo Bonito   | Chaco B/W  | Pitcher    | u                |
| 2059       | ND          | 2.5      | ND           | Pueblo Bonito   | Red Mesa B/W | Pitcher | u                |
| 2061       | ND          | 3.6      | ND           | Pueblo Bonito   | Red Mesa B/W | Pitcher | u                |
| 2064       | ND          | 3.0      | ND           | Pueblo Bonito   | Chaco–McElmo B/W | Mug | u                |
| 2065       | ND          | 2.3      | ND           | Pueblo Bonito   | Chaco–McElmo B/W | Pitcher | u                |
| 2066       | ND          | 4.5      | ND           | Pueblo Bonito   | Chaco–McElmo B/W | Pitcher | u                |
| 2102       | ND          | 5.0      | ND           | Guadalupe Ruin | Gallup B/W | Pitcher    | u                |
| 2104       | ND          | 15.2     | ND           | Guadalupe Ruin | Gallup B/W | Pitcher | w                |
| 2113       | ND          | 8.4      | ND           | Windy Knob      | Mesa Verde B/W | Mug | u                |
| 2128       | ND          | 5.5      | ND           | Site 315       | Ramos PC   | Jar        | u                |
| 2183       | ND          | 8.4      | ND           | Pottery Mound Pueblo | San Clemente Glaze PC | Jar | u                |
| 2187       | ND          | 23.9     | ND           | Upper Santan Village | Grooved red on gray | Bowl | u                |

B/W, black on white; ND = not detected; PC, polychrome; R/B, red on buff; u, unwashed; w, washed.

House), northern New Mexico (Pueblo Bonito and Guadalupe Ruin), and northern Chihuahua (Site 315). Forms include two bowls, two mugs, four pitchers, and one cylinder jar.

Discussion

Historical documents do not mention use of either I. vomitoria or T. cacao drinks in the US Southwest and Mexican Northwest (16). However, previous research has indicated use of cacao drinks in a number of contexts in this area (1, 2, 17). No study has argued previously for the presence of I. vomitoria in the US Southwest and Mexican Northwest, but we believe our results suggest that many samples contained residues from drinks based on high-caffeine holly rather than low-caffeine cacao. Historically, native groups in the US Southeast used both wild and cultivated stands of holly, and they traded the leaves and twigs to groups outside of the area where it would grow (9). They prepared drinks by parching holly leaves and small twigs and then placing the parched plant parts into water and boiling it. The mixture was agitated to create froth before consumption (9). This process is similar to that used to prepare cacao drinks in Mesoamerica: cacao nibs were fermented, roasted, and winnowed to remove the thin outer shell and the inner nibs were ground. Ground cacao might be made into cakes for storage and later consumption. Bits of the cakes were then added to water (hot or cold), other substances were added to sweeten and flavor the drink, and the mixture was agitated to create froth. In both the US Southeast and Mesoamerica, these frothed drinks were consumed primarily in ritual, medicinal, and political contexts (9, 18), but cacao recipes varied with social status (13). In the US Southeast, historic documents describe men consuming large quantities of black drink and then vomiting as a form of ritual cleansing (9).

Cacao consumption in the US Southwest and Mexican Northwest fits a pattern of importation of other ritually significant Mesoamerican items, including live scarlet macaws and macaw feathers, pyrite mirrors, pseudo-cloisonné objects, and copper bells (5, 19–21). Of the six sites with definite cacao residues discussed as group 1 samples above, Pueblo Bonito, Aztec Ruins, and Kinishba have such Mesoamerican trade items (21), whereas the excavations at the Lake Roberts Site, Site 315, and Upper Santan Village have not recovered other Mesoamerican imports. The varied vessel shapes with cacao residues indicate that different forms were viewed as appropriate for consuming this ritually important and exotic substance, including at different times pitchers, cylinder jars, and mugs at Ancestral Pueblo sites (Pueblo Bonito, Aztec Ruins, and Guadalupe Ruin), bowls in the Mimbres area.
Southwestern populations thus could have procured cacao from the southeastern United States from Virginia to Florida and vessels in the Mogollon Highlands (Kinishba). The area of northern Chihuahua (Site 315), and flowerpot-shaped Arizona (Upper Santan Village) and later in the Casas Grandes (Lake Roberts Site), small jars in the Hohokam area of southern Arizona (Site 315), and flowerpot-shaped vessels in the Mogollon Highlands (Kinshipha).

*I. vomitoria* grows to 8 m tall and is native to the coastal plain of the southeastern United States from Virginia to Florida and west to Texas, as well as parts of Chiapas and Veracruz (Fig. 1). Southwestern populations thus could have procured *I. vomitoria* from groups living as close as coastal Texas or in Mesoamerica (7, 9). Acquisition of objects and species from areas to the east of the US Southwest, including coastal Texas, is not as well documented as exchange in objects and species from areas to the south, including Mesoamerica. However, freshwater shell found in some southwestern villages attests to acquisition of some items from areas to the east (21). For instance, freshwater shell found at Pueblo Bonito derives from Arkansas and Texas (22), in the same general geographic areas that *I. vomitoria* would be found.

Evidence for exchange between populations living in the US Southwest and groups living to the east increased after A.D. 1300, particularly among southwestern populations living in villages located east of the Rio Grande (21). However, *I. vomitoria* also grew in parts of Mesoamerica and could have been brought to the US Southwest from the south. The distribution overlaps to some extent with the distribution of cacao (Fig. 1). Interestingly, analysis of methylxanthines in vessels from Mesoamerica sometimes yields the group 2 pattern of caffeine without theobromine (23). The ritual drinking and purging associated with black drink in the US Southeast bears a resemblance to a ceremony enacted by the Tohono O’odham of southern Arizona, who prepare fermented saguaro cactus wine and then consume all of it, followed by vomiting, to bring rain (24).

Evidence for holly drinks, as interpreted for our group 2 samples, comes from varied vessels found in the Hohokam area of southern Arizona (Snaketown), bowls from the Mimbres area (Galaz Ruin), pitchers and mugs from both Pueblo Bonito in Chaco Canyon and an outlying Chacoan site (Guadalupe Ruin), a mug from the Mesa Verde area (Windy Knob), and jars from northern Chihuahua (Site 315) and the northern Rio Grande area (Pottery Mound Pueblo).

As noted, the residues found in nine samples constituting our group 3 could represent cacao drinks or holly-based drinks, or perhaps both were consumed in these vessels at different times. Apart from Monsoon House, located in southwestern Colorado, all of the other sites with group 3 samples also have samples that fell into groups 1 or 2, or both.

We are suggesting, then, that populations in the US Southwest and Mexican Northwest consumed both cacao and holly-based caffeinated drinks at various times and places. Fig. 2 shows the combined interpretations of this research by site and Fig. 3 presents the data by time period. The results indicate that caffeinated drinks were important ingredients of pre-Hispanic life from around A.D. 750 to at least A.D. 1400. Sample sizes are small, so any interpretation of spatial or temporal patterning must be made with caution. However, Fig. 4, which normalizes the data for two time periods, suggests a possible increase in the use of cacao and decrease in the use of holly after A.D. 1200. Four of the seven group 1 samples dating after A.D. 1200 come from a single site in northwestern Mexico (Site 315), so this pattern may have a spatial component as well, with populations living closer to the source of cacao having greater access. The diversity of vessel forms used for consuming stimulant drinks suggests variation in the preparation, serving, and consumption of the drinks as well (25). Ancestral Pueblo groups apparently preferred individual serving vessels, such as mugs, cylinder jars, and pitchers. The Mimbres people of southwestern New Mexico used bowls ranging in size from 11 to 25 cm in diameter, indicating drinks may have been prepared and perhaps consumed from communal vessels, then shared through the use of straws or dippers. Some Mesoamerican groups prepared cacao beverages in large ceramic bowls and then dipped them out with perishable gourd cups (13), and this practice would be a possibility for Mimbres groups as well. A smaller beaker/bowl and jar from southern Arizona and the small jars and bowl from northern Chihuahua again suggest preference for individual serving vessels in these areas.

Because consuming either stimulant drink used it up (24), any calendrical rituals or repetitive activities that required drinking these stimulants also necessitated ongoing means of procuring the ingredients, either through exchange or direct procurement, from...
populations that lived in areas where the plants grew. This created sustained economic interactions with populations in those areas. In the areas where cacao and holly grew, either to the south-east or south, populations consumed stimulant drinks largely in communal ritual and political contexts rather than as an everyday part of the diet, and it is highly unlikely that southwestern populations would drink them more frequently or more casually (but see refs. 2 and 17) than populations that had direct access to the ingredients. For this reason, we argue that these drinks were consumed in communal, ritual, or political contexts in the US Southwest and Mexican Northwest as well. Exchange in the ingredients to make caffeinated drinks created ongoing social and economic relationships between southwestern populations and distant populations. With the ingredients in hand, southwestern populations could create a variety of drinks and serve them in a variety of ways (25, 26). Preparing and serving the drinks provided opportunities for forging relationships and obligations, because the drinks served as tools of social inclusion and exclusion (26).

ACKNOWLEDGMENTS. Ellen Sieg and Jennie Sturm aided P.L.C. in preparing the archaeological samples. Ron Stauber and Jennie Sturm drafted Fig. 1 for this article. We gratefully acknowledge the following institutions for loaning samples for this project and the help of the individuals noted, in addition to the coauthors, in selecting samples: American Museum of Natural History (Anibal Rodriguez and David Hurst Thomas), Arizona State Museum (Michael Jacobs and Art Vokes), Aztec Ruins National Monument (Aron Adams and Gary Brown), Chaco Culture National Historical Park (Darney Ford and Wendy Bustard), Crow Canyon Archaeological Center, Eastern New Mexico Department of Land Management (Dave Batten, Gretchen Obenauf, and Cynthia Herhahn), Gila River Indian Community, Maxwell Museum of Anthropology (Leslie Cohen, Dan'yelle Dosumru, and the Wednesday volunteers), Office of Contract Archaeology/University of New Mexico/New Mexico Department of Game and Fish (Robin Cordero and Jack Young), University of Tulsa (Michael Whalen). Gayle Fritz told us about the research of Drs. Hassan Amjad and Quartel-Ayne Amjad, who generously shared unpublished data showing the methylxanthine content of the Franklinia alatamaha tree. We thank Randall McGuire and Ben Nelson for helpful comments on an earlier draft of this paper. This work was supported by National Science Foundation Grant BCS-1012438 (to P.L.C. and W.J.H.) and a grant to Millsaps College from the W. M. Keck Foundation.

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