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Cacao use and the San Lorenzo Olmec

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Mesoamerican peoples had a long history of cacao use—spanning more than 34 centuries—as confirmed by previous identification of cacao residues on archaeological pottery from Paso de la Amada on the Pacific Coast and the Olmec site of El Manatí on the Gulf Coast. Until now, comparable evidence from San Lorenzo, the premier Olmec capital, was lacking. The present study of theobromine residues confirms the continuous presence and use of cacao products at San Lorenzo between 1800 and 1000 BCE, and documents assorted vessels forms used in its preparation and consumption. One elite context reveals cacao use as part of a mortuary ritual for sacrificial victims, an event that occurred during the height of San Lorenzo's power.

chemistry | Mexico | tandem mass spectrometry | residue analysis | chocolate

In 1996, Sophie Coe and Michael Coe argued in their book *The True History of Chocolate* that cacao, specifically a chocolate beverage, originated with the Olmec. They proposed that cacao, originally pronounced “kakawa,” was a vocabulary term used by the ancient Olmec as early as 1000 BCE. Using linguistic evidence, the authors suggested that the Olmec could have been the first to domesticate the cacao tree, *Theobroma cacao* L., and discovered the chocolate-making process (1). The present study was initiated to test the Coe and Coe hypothesis and to determine whether or not the Olmec at their capital of San Lorenzo consumed cacao products in liquid form.

Previous Research

The natural and cultural history of the cacao bean has been the subject of intensive scientific inquiry during the past 25 y. Researchers have focused on the natural distribution of the cacao tree (*Theobroma cacao* L.) within tropical regions of South America and Mesoamerica (2). Scholars also have emphasized the geographical areas of domestication (2–4), and recent research on the botanical origins and domestication of cacao in South America has focused on the western headwaters region of the Amazon basin in the geographical vicinity of northwestern Colombia (2). Currently, there is no evidence to suggest that early inhabitants of this South American region prepared chocolate in the strict sense. In addition, archaeological identification of cacao plant remains (5–10), decipherment of hieroglyphic markings on ancient ceramics (11–13), and pottery residue analysis (8, 12, 14–20) have contributed to the growing corpus of knowledge regarding the pre-Hispanic history of cacao.

Within Mesoamerica cacao has a long, continuous history, with documentation along the southern Pacific Coast of Mexico at the Mokaya site of Paso de la Amada, where one neckless jar, dating from 1900 to 1500 BCE, tested positive for theobromine (19, 21). Of 50 contemporaneous samples from the Olmec sites of El Manatí, El Paraíso, and San Lorenzo, only one sample from El Manatí, dated to 1650 to 1500 BCE, tested positive for cacao residue (19). Although it now can be demonstrated that the early Olmec prepared and consumed cacao, possibly in liquid form, previously there was no direct evidence for confirmed use at the first Olmec capital of San Lorenzo (22).

Selection of San Lorenzo and Loma del Zapote Pottery Samples. The present study included analysis of 156 pottery sherds and vessels obtained from stratified deposits excavated under the aegis of the San Lorenzo Tenochtitlán Archaeological Project (SLTAP). Items selected represented Early Preclassic occupation contexts at two major Olmec sites, San Lorenzo ($n = 154$) and Loma del Zapote ($n = 2$), located in the lower Coatzacoalcos drainage basin of southern Veracruz State, Mexico (Fig. 1). Sample selection criteria included provenience, pottery type, vessel form, and temporal placement. The 156 pottery samples were obtained from 10 excavation localities at these two sites, taken from sealed domestic and ceremonial contexts located on the central plateau and habitation terraces of the Olmec capital of San Lorenzo and at the hinterland secondary center of Loma del Zapote.

Care was taken to represent a wide range of contexts with varying degrees of pottery preservation. Sampling strategy captured the diversity of vessel forms and types that could have been used in the processing and serving of cacao during the Early Preclassic. The selected samples spanned all early occupational phases: Ojochi (1800–1600 BCE), Bajío (1600–1500 BCE), Chicharras (1500–1400 BCE), San Lorenzo A (1400–1200 BCE), and San Lorenzo B (1200–1000 BCE). The frequencies of sampled types and forms are presented in detail in *SI Text* and *Tables S1–S3*. [The SLTAP pottery classification differs from the one presented by Coe and Diehl (22), with the exception of a few shared types, such as Xochiltepec white, Conejo orange-on-white, Chaya punctuate, and Hernández punctate.]

Residue Collection. The interior surface of each piece was lightly rubbed using a new piece of fine-grained sandpaper to remove any substances that may have permeated the vessel wall (18). Burr from each sample was captured on a new sheet of multipurpose white paper and the material funneled into clean, unused collection vials and immediately sealed. New sheets of sand paper and multipurpose white paper were used for each sample collected. This method was rigorously upheld throughout the collection process to eliminate potential cross-contamination of sample materials. Following collection, sealed vials were sent to the Department of Nutrition of the University of California, Davis, for analysis.

Laboratory Analysis. Cacao has a unique chemical composition of over 500 different compounds, including members of the methylxanthine class (primarily theobromine), with a lower concentration of caffeine. *T. cacao* is the only Mesoamerican plant that contains theobromine as the primary methylxanthine (17). Theobromine, therefore, is a unique marker for the presence of cacao in pre-Columbian artifacts.

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Fig. 1. Map showing the location of San Lorenzo and other early archaeological sites with evidence for cacao.

Liquid chromatography-tandem mass spectrometry (UPLC/MS-MS) analyses were performed on 156 samples to detect theobromine (Fig. 2). Briefly, 90 to 200 mg of each burr sample was extracted with 200 to 300 μ L milli-Q water at 80 $^{\circ}$ C for 30 min. The extracts were filtered and the filtrates were used for UPLC/MS-MS analysis. Two additional unknown samples supplied to the University of California Davis laboratory by T.G.P. (modern pottery samples) were included in the analysis as controls. Detailed methods for sample preparation and UPLC/MS-MS analyses are in the *SI Text*.

The UPLC/MS-MS analyses of some Olmec samples clearly showed the presence of a peak at 2.20 min (Fig. 3D) that matched well with the standard for theobromine (Fig. 3B), whereas, no peaks were observed at 2.20 min in extracts from the two modern pottery control samples (Fig. 3C).

Theobromine-Positive Pottery. The results of these analyses provide conclusive evidence for the presence of theobromine in 17% of the samples (Fig. 4 and Table 1).^{*} Sample #11 represents the earliest positive signature and confirms early cacao use

^{*}Radiocarbon dates in association with the theobromine-positive samples are provided here. A C14 date related to sample #11 is too recent as a consequence of bioturbation processes and therefore is not taken into consideration. No C14 dates are associated with the provenience of positive samples from the Bajío and Chicharras phases. San Lorenzo A phase-positive samples #119, 120, 124, 125, 126, and 129 are associated with C14 sample DRI-3416, with a two- σ range of 1550 to 900 cal BC (conventional age: 3027 \pm 114 BP; $\delta^{13}\text{C} = -25.80 \pm 0.05$). The positive samples from the San Lorenzo B phase have the following C14 dates in association: (i) samples #90, 100, 101, and 103 with DRI-3591, with a two- σ range of 1500 to 900 cal BC (conventional age: 2994 \pm 126 BP; $\delta^{13}\text{C} = -26.90 \pm 0.05$), and DRI-3594, with a two- σ range of 1700 to 1100 cal BC (conventional age: 3168 \pm 107 BP; $\delta^{13}\text{C} = -25.52 \pm 0.05$); (ii) samples #107, 108, 123, 133, 145, 146, 147, and 152 with DRI-3324, with a two- σ range of 1410 to 1020 cal BC (conventional age: 2988 \pm 68 BP; $\delta^{13}\text{C} = -27.43$) and DRI-3321, with a two- σ range of 1420 to 1050 cal BC (conventional age: 3010 \pm 63 BP; $\delta^{13}\text{C} = -28.49$); (iii) sample #85 is associated with DRI-3417, with a two- σ range of 1220 to 890 cal BC (conventional age: 2861 \pm 59 BP; $\delta^{13}\text{C} = -25.93 \pm 0.05$), and DRI-2901, with a two- σ range of 1770 to 1290 cal BC (conventional age: 3247 \pm 99 BP; $\delta^{13}\text{C} = -24.87$). Further contextual and depositional considerations of these samples are currently in preparation by A.C.

at the Olmec capital of San Lorenzo by 1800 to 1600 BCE. Two additional positive samples (#22 and 30) are contemporaneous with positive samples from the Olmec ritual site of El Manati and the Pacific coast Mokaya site of Paso de la Amada mentioned earlier.

Specific serving wares show multiple theobromine signatures, with 23 of 27 positive signatures falling into the following types: Tejón white (5 of 9 samples: 56%), Tigrillo black and white (4 of 15 samples: 27%), Tigrillo monochrome (5 of 21 samples: 24%), and kaolin types, specifically Xochiltepec white and Conejo orange-on-white (5 of 6 samples: 83%). Three samples corresponded to coarse wares, specifically Caamaño coarse, Garza smoothed, and Peje micaceous, and another to a medium-to-coarse ware, Pochitoca polished. All other pottery types were represented by only one positive sample each.

The nature of cacao products consumed in the theobromine-positive vessels is unknown. However, the presence of cacao in liquid form is suggested by the following 13 positive samples: nine open bowls and one cup (which are personal dishes suitable for beverage consumption), and two bottles that could be appropriate for storing and serving liquids. Whether or not the residues reflect chocolate in the strict sense, or traditional-style beer fermented from the pulp contained inside cacao pods, cannot be determined at this stage; hence, we prefer to use the term “cacao in liquid form” pending our further research. The eight positive samples with peak theobromine levels remain enigmatic and cannot be related to pottery type or form because they represent seven different types and six distinct forms (with three occurrences in open bowls).

The lack of plastic decoration in theobromine-positive vessels from the earliest phases is a particularly noticeable tendency. However, some decorated types appeared in the San Lorenzo A and B phases. It is notable that storage and preparation vessels always lacked decoration, whereas those used in serving and consumption displays included both decorated (8 of 22) and undecorated pieces. Only one of the four vessels decorated with the well-known wide-incised Calzadas series motifs showed a positive

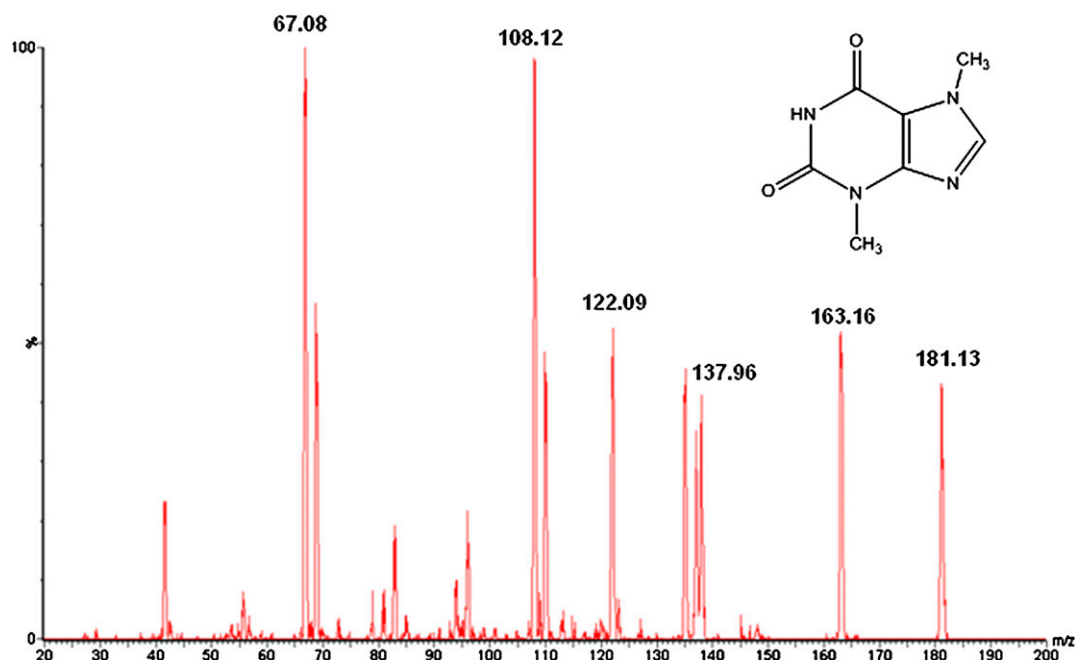


Fig. 2. MS-MS mass spectra of theobromine.

signature, in contrast to 4 of 13 positives with Limón series motifs made with thin incision.

The undecorated forms in the earliest phases that tested positive included an Ojochi phase bottle, a Bajío phase necked jar and open bowl, and two Chicharras phase open bowls, which suggest activities related to preparation, serving, and consumption. By the San Lorenzo A phase, a closed vessel and a neckless jar appropriate for storage have appeared, as well as an incurved rim bowl, a small ceremonial dish, and three consumption vessels, all open bowls. The remarkable array of theobromine-positive forms from the San Lorenzo B phase illustrates a gamut of activities related to cacao use, including preparation (large bowls, ladle, neckless and necked jars), serving (bottles and large bowls), individual consumption (bowls and cups), and possible dry seed storage (neckless jars).

Whether one of the products was an intoxicating beverage made from the fermented pulp of cacao pods, as suggested elsewhere for Honduras (15), remains unknown at this time because techniques cannot detect the presence of alcohol in pottery of these dates. Although the utility of fermentation has been documented in separating cacao beans from the pulp in some geographical localities (23, 24), a step thought to improve flavor, this process does not necessarily produce an alcoholic beverage. Furthermore, pulp fermentation in a watery medium need not be an obligatory step in the production of actual chocolate, because it may be noted that 20th century inhabitants of the southern Gulf Coast region simply suck or wash away the sweet pulp from the cacao beans before sun-drying.

Although the recovery rate of theobromine signatures in the present samples was significant, the relatively small sample size of positive sherds and vessels does not support more broad generalizations regarding temporal trends. That said, some preliminary observations, however, may be useful to guide the formulation of future research questions. For example, large vessels for serving cacao products appear in Chicharras times and are followed by large storage vessels in the San Lorenzo A phase. This finding may suggest a trend of increasing cacao production to supply larger and more frequent social festivities.

The samples examined in the present study also reveal a particularly interesting case of an elite festivity at San Lorenzo, where several hundred vessels cap a burial pit that contained the disarticulated remains of sacrificial victims (25). The vessel forms range from small cups to open bowls, pitchers, serving basins, and storage vessels, indicating a well-attended, postinterment celebration that included the preparation of stored cacao beverages that were ritually served and imbibed, perhaps along with other beverages. The pottery used in the event may have been intentionally broken at its conclusion, an undertaking involving the conspicuous destruction of wealth.

Four of the 11 vessels within this context tested positive for theobromine and included a coarse neckless storage jar with tripod supports (sample #110) (Fig. 4), a fine kaolin-paste necked serving jar (#101), a large serving bowl decorated with a supernatural face (#103), and a small cup (#90) (*SI Text* and *Table S3*). The positive decorated vessels in the ritual cache provide a basis for comparison with other contexts, where undecorated vessels seem to predominate in cacao-related activities. These vessels clearly point to the special nature of this mortuary event, which to date is unique in the Olmec world.

Concluding Comments. The present study applied a highly sensitive laboratory analyses to determine the presence or absence of theobromine residues from a broad array of early Olmec pottery. We affirm the presence of theobromine in 27 objects of variable forms, dates, and composition that span the Early Preclassic occupation of the earliest Olmec capital, circa 1800 to 1000 BCE. The hypothesis proposed by Coe and Coe (1) that the Olmec were involved in the production and consumption of cacao products at the very beginning of the Early Preclassic period, therefore, is supported.

Further questions remain: when, where, how, and by whom was the first actual chocolate—or chocolate in the strict sense—prepared in Mesoamerica? The answers remain elusive at this point. The present article clearly documents another early population center in the tropical lowlands of Mesoamerica where cacao products were used. The presence of a cacao product in an early ceramic bottle from San Lorenzo coincides temporally with a theobromine-positive neckless jar from the Pacific coast site of Paso de la Amada (19, 21). Insofar as bottles are suitable for

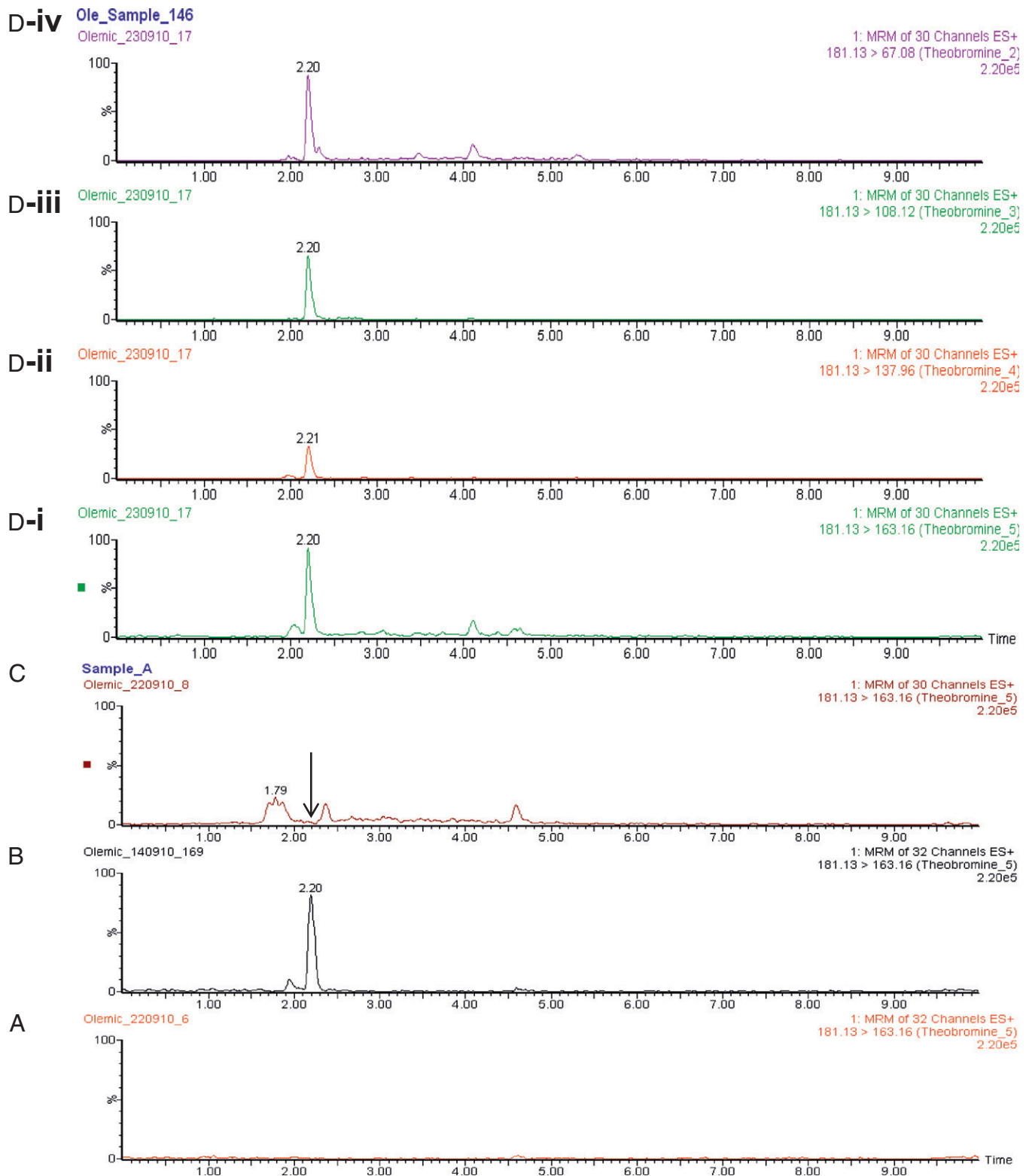


Fig. 3. UPLC/MS-MS chromatograms illustrating (A) blank, (B) standard theobromine, (C) modern pottery control, and (D) a representative Olmec sample confirming the presence of theobromine by four independent multiple reaction monitoring transitions (*i–iv*). Samples were extracted and analyzed as described in *SI Text*.

pouring as well as storage, it is feasible that the San Lorenzo bottle may have held cacao in liquid form, but whether it was actual chocolate or beer fermented from cacao pulp cannot be determined at this point. Despite this caveat, the evidence presented

here strongly suggests the persistent use of a liquid cacao product at San Lorenzo until its decline around 1000 BCE.

The documentation of a temporal trend involving a mounting variety of theobromine-positive vessel forms may relate to in-



Fig. 4. Theobromine-positive vessels from the San Lorenzo B phase of the San Lorenzo site that illustrate storage, preparation, and serving functions. (Left to Right) Sample 110, a Caamaño coarse neckless jar with supports; sample 97, a Pochitoca polished bottle; and sample 108, a Tigrillo black-and-white incurved-rim bowl. Images courtesy of Rogelio Santiago, San Lorenzo Tenochtitlán Archaeological Project.

creasing diversification and specialization in the cacao process, which culminated in the consumption of cacao products, for the most part beverages. This phenomenon parallels regional and local trends of population growth and increasing social complexity (26). Whereas the lack of an apparent inclination toward cacao storage in pottery vessels may be because of the nature of the present sample, it also may be interpreted in other ways, including generalized cacao availability, storage in perishable containers, and the extended mobilization of this resource to nonproducing sections of the Olmec region and to distant peoples eager to participate in Olmec social networks.

We confirm here that liquid cacao products played a role in an elite mortuary ritual for sacrificial victims, specifically at an event that occurred during the height of San Lorenzo's power. The Olmec elite used the pivotal association of cacao and human sacrifice as integral parts of the Mesoamerican cosmic theater of birth, death, and rebirth in their persistent legitimization of earthly prestige and divine authority.

Finally, as scientific studies once again have pushed the antiquity of Mesoamerican cacao use back to nearly 4000 y ago, claims to primacy are not the goal of these efforts, but rather the search for an increasingly profound understanding of its origins and cultural history. We expect that future research—especially analytical techniques differentiating theobromine content between actual liquid chocolate and that contained in pulp-fermented “beers” (fermented with or without cacao beans)—will provide surprising responses to unanswered questions.

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Table 1. Theobromine-positive types and forms per phase

Type	Form	Ojochi	Bajío	Chicharras	San Lorenzo A	San Lorenzo B	Total
Caamaño coarse	Neckless jar					1	1
Caimán polished	Bottle	1					1
Conejo orange-on-white	Open bowl					1	1
Eroded gray	Necked jar		1				1
Garza smoothed	Neckless jar				1		1
Mulato black	Cup					1	1
Peje micaceous	Closed form				1		1
Pochitoca polished	Bottle					1	1
Tejón white	Incurved rim bowl					1	1
	Low annular based open vessel				1	1	2
	Open bowl					2	2
Tigrillo black and white	Incurved rim bowl					1	1
	Open bowl			2		1	3
Tigrillo monochrome	Ladle					1	1
	Open bowl				2	1	3
	Small cup					1	1
Tigrillo white-rimmed black	Incurved rim bowl				1		1
Xochiultepec white	Collared jar					1	1
	Necked jar					1	1
	Open bowl		1		1		2
Total		1	2	2	7	15	27

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