2013

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Evidence for maize (*Zea mays*) in the Late Archaic (3000–1800 B.C.) in the Norte Chico region of Peru

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Edited by Deborah M. Pearsall, University of Missouri, Columbia, MO, and accepted by the Editorial Board January 24, 2013 (received for review November 7, 2012)

For more than 40 y, there has been an active discussion over the presence and economic importance of maize (*Zea mays*) during the Late Archaic period (3000–1800 B.C.) in ancient Peru. The evidence for Late Archaic maize has been limited, leading to the interpretation that it was present but used primarily for ceremonial purposes. Archaeological testing at a number of sites in the Norte Chico region of the north central coast provides a broad range of empirical data on the production, processing, and consumption of maize. New data drawn from coprolites, pollen records, and stone tool residues, combined with 126 radiocarbon dates, demonstrate that maize was widely grown, intensively processed, and constituted a primary component of the diet throughout the period from 3000 to 1800 B.C.

agriculture | origins of civilization | Andean archaeology

The Late Archaic period (3000–1800 B.C.) was a period of major cultural development on the Pacific Coast of Peru. It was during this time that large permanent communities were settled, monumental architecture first appeared on the landscape, agriculture was more fully developed, and indicators of a distinctive Andean religion are manifest in the archaeological record. This period has been the focus of extensive archaeological investigation over the past 30 y as archaeologists have sought to understand better the variables leading to the emergence of a complex, centralized society. One key question relates to the presence and role of maize (*Zea mays*) agriculture in the economy and diet of the Late Archaic population. For many years, it was debated whether or not maize was present at all in the Late Archaic (1–9).

Excavations of Late Archaic sites in the Norte Chico region of the Pacific Coast of Peru have yielded new evidence on the presence and consumption of maize during this period. The first maize recovered in this region came from excavations at the Supe Valley site of Aspero (Fig. 1), where a cluster of 49 maize cobs was uncovered over 50 y ago (10). At the time, this site had not been dated with radiocarbon and the possible significance of this deposit of cobs was not known. In the 1970s and 1980s, it became clear that Aspero dated to the third millennium B.C. (11, 12) and the maize cobs had great potential importance; however, the archaeological context of this cluster of cobs was uncertain and did not provide conclusive evidence of the early consumption of maize. Thirty years later, extensive excavations at the Late Archaic sites of Caral and neighboring Miraya (both also in the Supe Valley) have turned up numerous macrobotanical samples of maize in diverse contexts (13). It is not possible at this time to assess the importance of maize at these sites because quantitative data on the frequency of maize remains, as well as the methodologies used to gather the botanical samples, have not been published. More recently, Grobman et al. (14) reported on evidence of maize extending back to 6700 calibrated years before present (cal B.P.) at the sites of Paredones and Huaca Prieta in the Chicama Valley. Again, at these two sites, the scarcity of macrobotanical remains led to the conclusion that maize "was not a primary element of the diet" (ref. 14, p. 1775; see also ref. 15).

Broad botanical evidence from a group of large Late Archaic sites in the Pativilca and Fortaleza Valleys (immediately north of the Supe Valley) indicates much more extensive production, processing, and consumption of maize at inland sites in the third millennium B.C. This evidence comes from sample excavations between 2002 and 2008 at a total of 13 Late Archaic sites and more extensive excavations at 2 of these sites. Between 2002 and 2003, 13 sites were tested in the Pativilca and Fortaleza Valleys (Fig. 1). Testing consisted of excavating stratified 1-m × 2-m test pits in areas of domestic trash (16). The purpose of the test pits was to retrieve datable materials for radiocarbon dating (17) and a sample of stratified domestic refuse. Subsequently, in 2004, 2006, 2007, and 2008, excavations focused on residential housing and associated trash at the sites of Caballete and Huaricanga in the Fortaleza Valley. Excavations at both sites were all limited in scope and designed to retrieve information about the chronology of the sites, social organization, diet, and subsistence economy. The site of Caballete (Fig. S1) is located 8 km inland from the Pacific Ocean on the north side of the Fortaleza Valley. It is situated on an alluvial plain that is currently ∼6 m above the floodplain of the Fortaleza River. The site consists of a central architectural complex with six large platform mounds arranged in a rough "U" around an open plaza area. Residential complexes and smaller scale architecture cluster around these mounds, although the plaza area is largely vacant. The site of Huaricanga (Fig. S2), also in the Fortaleza Valley, is 23 km inland and situated on the south side of the river. It is positioned similar to Caballete on a broad alluvial plain well above the floodplain of the river. Huaricanga is somewhat unique in the Norte Chico in that there is a single very large mound, with several much smaller mounds on either side.

At Caballete, more extensive excavations were conducted in 10 different parts of the site. The areas targeted included high-status residences (operation VI), lower status residences (operations V and X), residences (operations V, VI, and X), trash middens (operations I, II, and XII), the side of a platform (operation VII), and temporary campsites (operations IV, IX, and XI). At Huaricanga, more extensive excavations were conducted in three areas, including low-status residences (operation VI), ceremonial rooms (operation VII), and a trench into the side of the main platform mound (operation I). To retrieve a maximum quantity of material for analysis, all material from all excavations was screened through 6.4-mm mesh screen. Two separate 2-L samples were taken from every excavation provenience, and each

Author contributions: J.H. and W.C. designed research; L.H.M., D.G., K.R., and C.V.R. performed research; L.H.M., D.G., K.R., and C.V.R. analyzed data; and J.H. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission. D.M.P. is a guest editor invited by the Editorial Board.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1219425110/-/DCSupplemental.

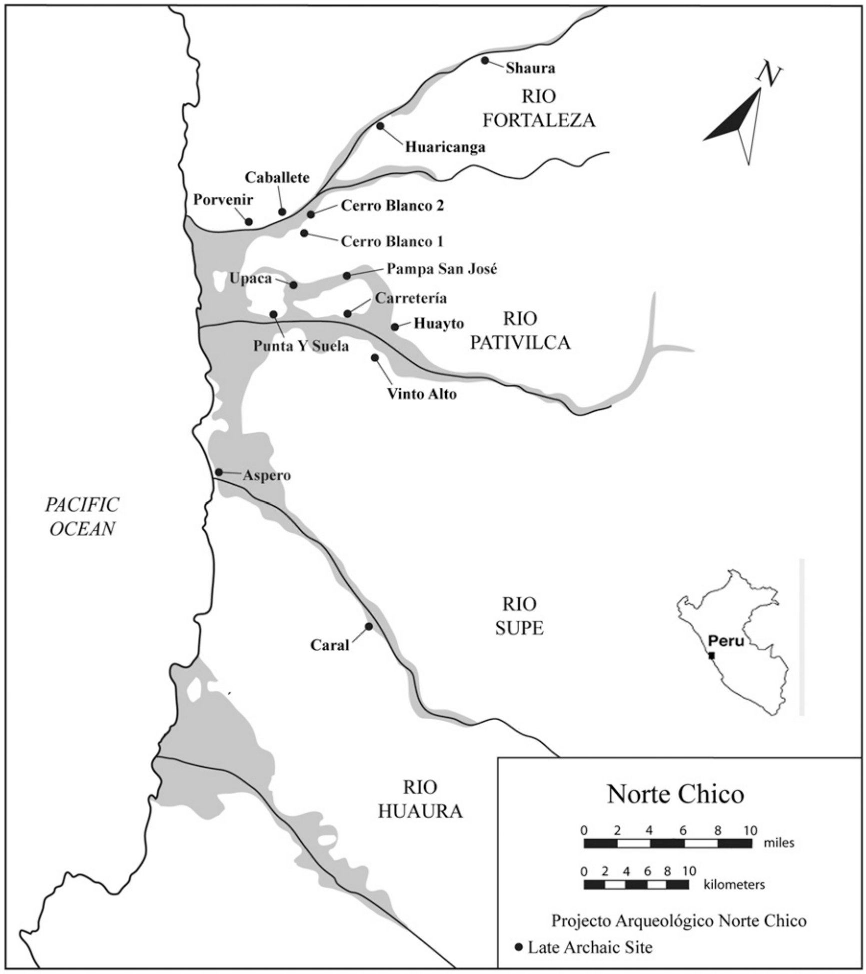

Fig. 1. Location of Late Archaic sites in the Norte Chico region of Peru.

was processed through fine screening and flotation, respectively, with graded fine mesh sieves down to 0.25 mm. Soil samples for pollen analysis were taken from every provenience unit.

A total of 212 radiocarbon dates were obtained through traditional and accelerator mass spectrometry (AMS) techniques in the course of all the excavations. For the present analysis, all proveniences with dates later than 1800 calibrated years before Christ (cal B.C.) have been excluded from consideration. Because it is widely accepted that maize was consumed by people living along the coast after 1800 B.C., its presence in later proveniences is to be expected. Removing all the material with later associated radiocarbon dates alleviates questions about mixed deposits or contamination of earlier occupations with later materials. Of the 212 total dates, 126 fall between 4100 and 1800 cal B.C. (Table S1). Samples associated with dates between 4450 and 9120 cal B.C. were also excluded from the present analysis because they are outside the range of continuity and the early dates cannot be confirmed by dating adjacent material or by context. Two dates, AA84546 and AA84547, both from an undisturbed lower deposit at Caballete and dating to the fifth millennium B.C., are included in the chart as an early baseline for a local botanical profile.

Macrobotanical

The first stage of identification of the botanical remains was an analysis of the macrobotanical remains from screening, fine screening, and flotation. Analyses of hundred of samples from screening and flotation revealed that macroscopic remains of maize, including kernels, leaves, stalks, and cobs, were rare. Although examples of whole maize cobs and ears were found at the Supe and Chicama Valley sites (13, 14), no such remains were found in any of the excavations in the Pativilca and Fortaleza Valleys. A large deposit of maize stalks with ears was encountered in one of the excavation units at Caballete in 2006; however, subsequent radiocarbon dating revealed that this was a secondary deposit with dates between 280 and 490 cal B.C., well after the Late Archaic. To date, over 400 macrobotanical samples with secure Late Archaic contexts have been analyzed, including coarse screen, fine screen, light fraction flotation, and heavy fraction flotation samples. Less than 10 examples of maize have been identified out of all these samples: stalks (3 examples), leaves (1 example), cob fragments (2 examples), and kernels (3 examples). The reason for the absence of macrobotanical remains of maize has yet to be resolved, but the absence of macro remains is not necessarily evidence of the absence of maize (18–20). It is also possible that the lack of macroscopic remains is a reflection of limited excavations at the sites described, given that the more extensive excavation of sites in the Supe and Chicama Valleys did yield much more macroscopic evidence of maize.

Pollen

The dearth of macroscopic remains of maize stands in marked contrast to an abundance of microscopic evidence for maize in the excavations. The first line of evidence comes from the recovery of

Z. mays pollen from soil samples. Maize pollen was identified based on specific characteristics, including morphology and size: monad (single pollen grain), spheroidal (polar axis to the equatorial axis ratio of 0.05:0.068), monoporate (single pore), surface with fine-grained roughness, equatorial axis between 90 and 100 μm (21, 22), polar axis between 90 and 100 μm, exine thickness of 2 μm, annulus width between 13 and 17.5 μm, costa thickness between 3.5 and 4 μm, pore diameter between 5 and 7.5 μm, and ratio of pore size to pollen size of 0.05:0.068. Based on previously published studies of maize pollen, we are only considering grain size between 72.5 and 120 μm (21–23) (Fig. S3). Maize pollen is also present in all eight of the control samples taken from the modern surfaces of select sites, raising the possibility of modern contamination. Three factors weigh against significant contamination. First, modern maize pollen grains are larger and turn dark red when stain is applied, whereas ancient pollen grains do not turn dark red. Second, extraction of pollen samples followed standard archaeological guidelines (24), and all crew members were trained in taking pollen samples. Third, the modern samples all contained pollen from a plant not found in the area prehistorically: Casuarinaceae *Casuarina* spp. This plant, whose common name is Australian Pine, is native to Africa, Australia, and Southeast Asia. It is wind-pollinated and produces an exceptionally large number of pollen grains (25). *Casuarina* pollen was found in only a single archaeological sample, which may indicate limited contamination in 1 of 126 samples. The prevalence of these plants in the modern samples and their scarcity in the prehistoric samples are indicative of a lack of modern contamination in the prehistoric samples.

A total of 126 soil samples were treated and analyzed for pollen grains from the test excavations in the Pativilca and Fortaleza Valleys and from the more extensive excavations at Caballete and Fortaleza (Table S2). (Eight additional samples of modern surface soils were also analyzed as controls.) A majority of the samples analyzed came from midden deposits associated with residential architecture. Others were taken from room floors, construction debris, and the fill of features. Of the 126 soil samples (not counting stone tools and coprolites) analyzed, 61 (48%; not counting modern "control" samples) contained *Z. mays* pollen. *Z. mays* pollen was the second most common pollen found in the total of all samples, behind only *Typha*, generically consisting of cattails with wind-pollinated flowers (Fig. 2). This figure is consistent with the percentage of maize pollen found in paleontological analyses from sites in other parts of the world where maize is a major cultigen and constitutes the primary source of calories in the diet (26). Radiocarbon dating associated with the pollen samples is both direct and indirect. In several cases, there are pollen samples taken exactly from the same context as a dated radiocarbon sample. Radiocarbon dates directly associated with maize pollen range from 2400 to 2090 cal B.C. In other cases, maize pollen was found in undisturbed stratified deposits immediately above or below dated deposits that provide an approximate chronology for the pollen material. It should also be noted that one significantly older deposit at Caballete did not contain any maize pollen. Operation I, level 9 at Caballete yielded two radiocarbon dates of 4110 cal B.C. and 4140 cal B.C. that extend the initial occupation of the site back into the Middle Archaic. Maize pollen was absent from two soil samples analyzed from this same level. The 126 radiocarbon samples dating the excavations between 4140 and 1830 cal B.C. for the excavations are provided in Table S1.

Stone Tool Residue

The pollen data are complemented by an analysis of residues on stone tools (27–29). Late Archaic stone tool technology on the Peruvian coast can best be described as "expedient." The raw material used is almost all local and consists of andesite and quartzites. The tools are simple cutting, scraping, pounding, and grinding implements. Chipped stone tools, primarily scrapers, knives, and drills, are most often primary flakes with minimal retouch. Ground stone tools are minimally shaped but show extensive evidence of pounding and grinding on one or more surfaces. A selection of stone tools was examined for evidence of plant residues, particularly starch grains and phytoliths (Table S3). Starch grain and phytolith analysis and identification followed standard methodologies (30–32). Fourteen stone tools were selected for analysis, all of which came from operation V, a complex of residential architecture and domestic trash at the

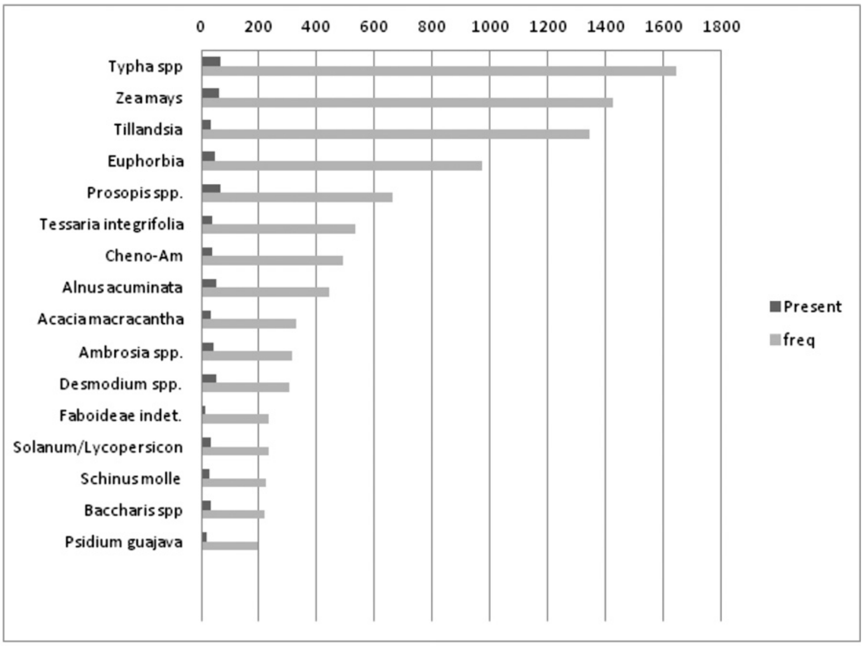

Fig. 2. Graph of the presence and frequency of the most common identifiable genera and species of pollen found at Late Archaic sites in the Pativilca and Fortaleza Valleys, Peru. freq, frequency.

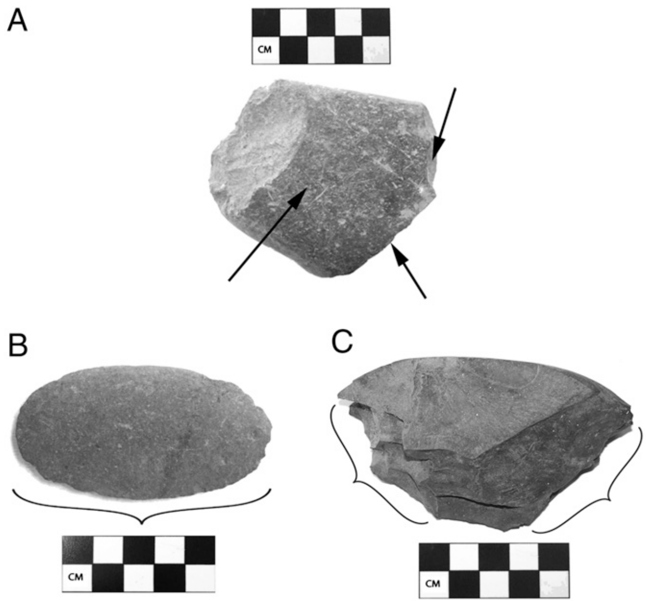

Fig. 3. Sample of stone tools analyzed for residues. (*A*) Arrows point to the three different working surface analyses separately. (*B* and *C*) Brackets indicate the working surfaces analyzed for residues.

site of Caballete (Fig. S1). A group of 27 radiocarbon dates from this complex cluster consistently between 2090 and 2540 cal B.C. (Table S1). (There are two significantly earlier outliers from this complex as well, which cannot be considered reliable at this time without further corroboration.) The stone tool sample contained four flake tools, four choppers, five pounded and polished cobbles, and one burned cobble (examples of stone tools are shown in Fig. 3). The results of the residue analysis are shown in Table S3. Eleven (79%) of the 14 tools had predominantly or exclusively maize starch grains on the working surfaces, and two working surfaces had maize phytoliths. In maize, starch grains commonly ranged from ~8–25 μm in maximum length (28, 29, 31) (Fig. S4). A few grass species have starch grains as large as in maize; however, in each case, their morphological characteristics distinguish them from maize. Mean size ranges from 11.1 to 15.8 μm, and maximum length ranges from 4 to 26 μm. Most races have an average length of >12.5 μm, and individual grains commonly reach or exceed 20 μm in maximum length. The 2 tools with maize phytoliths also had maize starch grains. Two tools had starch grains of sweet potato (*Ipomoea batatas*), and 3 had starch grains of beans (*Phaseolus* sp.).

Coprolites

In other areas inside and outside the Andes, starch grains have been shown to be a strong indicator of reliance on maize and maize-based foods (33, 34). Direct evidence for the consumption of maize in the Late Archaic comes from human coprolites (preserved fecal material) recovered from both Caballete and Huaricanga (35). The coprolite specimens were recovered in variable contexts, including domestic refuse, construction fill, and abandoned room fill. Forty-one coprolites were recovered and analyzed from Caballete and 21 were recovered and analyzed from Huaricanga (Table S4) in Late Archaic contexts. Of these, 34 were human; 16 were domesticated dog; and the others were a mix of cervids, fox, unidentified carnivores, and unidentified wild omnivores. Among all 62 coprolites of all types, 43 (69%) contained maize starch grains, as did 23 (68%) of 34 human coprolites and 12 (75%) of 16 domesticated dog coprolites. The second most common starch grain in humans came from *I. batatas* (camote or sweet potato), with only 9 (26%) of 34 samples and 5 (31%) of 16 dog coprolites. Maize constituted the dominant starch in the diet, as reflected in the starch grains in both humans and dogs. The coprolites also showed that the dominant source of sugar was coming from guava and that anchovies provided protein. Radiocarbon dates for these samples are shown in Table S1. Operation VI from Huaricanga had three radiocarbon dates later than the Late Archaic, and nine dates between 2370 and 3240 cal B.C. One human (CVR001) and one domesticated dog (CVR004) coprolite from this operation came from a small lens of trash which also yielded a radiocarbon date of 2940 cal B.C. (AA-84576) taken from annual plant fibers. Both of these coprolites contained maize starch grains, and the human coprolite contained maize phytoliths. A coprolite from a wild omnivore (CVR003), probably fox, containing maize starch grains was associated with a shallow intrusion into the sterile surface. Two samples of annual plant fibers from this same feature yielded radiocarbon dates of 2620 and 3240 cal B.C. (Table S1, AA-84570 and AA84581).

Conclusions

The combined evidence from soil samples, stone tool residues, and coprolite contents establishes that maize was actively grown, processed, and eaten during the Late Archaic at sites in the Fortaleza Valley. The prevalence of maize in multiple contexts and in multiple sites indicates that this domesticated food crop was grown widely in the area and constituted a significant portion of the local diet. These data support a conclusion that maize was a dietary staple and a major source of starches and not consumed only on ceremonial occasions. The data presented here do not resolve the question of how the maize was being consumed, although maize starch grains are more prevalent than maize phytoliths in the coprolites. This would indicate that maize cobs were being consumed as opposed to the stalks. There is an active discussion about whether early *Z. mays* may have been grown for the starches and sugars found in the stalks rather than for the grain (36, 37). This does not appear to be the case for the Late Archaic in Peru.

ACKNOWLEDGMENTS. We thank Alvaro Ruiz for his leadership in the field as well as Guillermo Gonzalez, Luis Verastequi, and Hernan Gamarra. We greatly appreciate the assistance of the Instituto Nacionál de Cultura (now the Ministerio de Cultura) of Peru in granting us permission to conduct the excavations and for oversight. The communities of Barranca, Pativilca, Paramonga, and Huaricanga provided years of support. All paleobotanical research was conducted at the Laboratorio de Palinología y Paleobotánica, Universidad Peruana Cayetano Heredia, Lima, Peru. The research was supported by the National Science Foundation (Grants OISE-0701243, BCS-0542160, BCS-0542088, BCS-0211014, and BCS-0211020) as well as Northern Illinois University, The Field Museum, and private donors.

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Supporting Information

Haas et al. 10.1073/pnas.1219425110

Starch Grain Analysis

For coprolite study, starch analysis must be done before pollen processing. Acetolysis procedure and hydrofluoric acid destroy starch and phytoliths. Starch and phytolith analyses are done immediately after rehydration and screening and before chemical pollen extraction. The manner and success of starch analysis in coprolites are dependent on the condition of the coprolites themselves. *Lycopodium*-based quantification in terms of starch granules per gram of material is ideal. This is achievable in rare studies in which coprolites are excellently preserved and contain an abundance of starch, such that it is possible to obtain 200 starch grain counts from a majority of samples. In a study of change in maize dependence between the Inka Late period (A.D. 1400–1532) and the pre-Inka Late Intermediate period, the extreme reliance of prehistoric populations on starches resulted in the fact that starch was the most abundant microfossil in ideally preserved coprolites (1). Thus, starch was readily recovered in postrehydration analysis. In such samples, dependence is signaled by high concentrations of starch grains. In other cases, the nature of the coprolite and food remains can make it impossible to obtain 200 starch grain counts with Ancestral Pueblo coprolites (2). In this case, the nature of a high-fiber diet reduced the number of starch grains observable per slide. In some cases, over 60 starch grains were encountered per slide. In a majority of cases, however, less than 1 starch grain was encountered per slide. Therefore, the nature of the diet has an impact on starch recovery. In this study, the ubiquity of maize starch in all samples signaled that maize was a major carbohydrate source at the site. However, with poorly preserved coprolites, such as those from Norte Chico, starch recovery is hampered by taphonomic conditions. The organic component of the coprolites had partly decomposed and was replaced by sand and carbonate material from the surrounding soil matrix. Therefore, after rehydration, the slides exhibited an overabundance of fine silica that impaired analysis. Thus, we scanned slides from the rehydrated coprolites solely for presence or absence of starch identifiable to a botanical taxon. As in other studies (2), maize reliance would be signaled by the overall ubiquity of the presence of starch in the coprolites.

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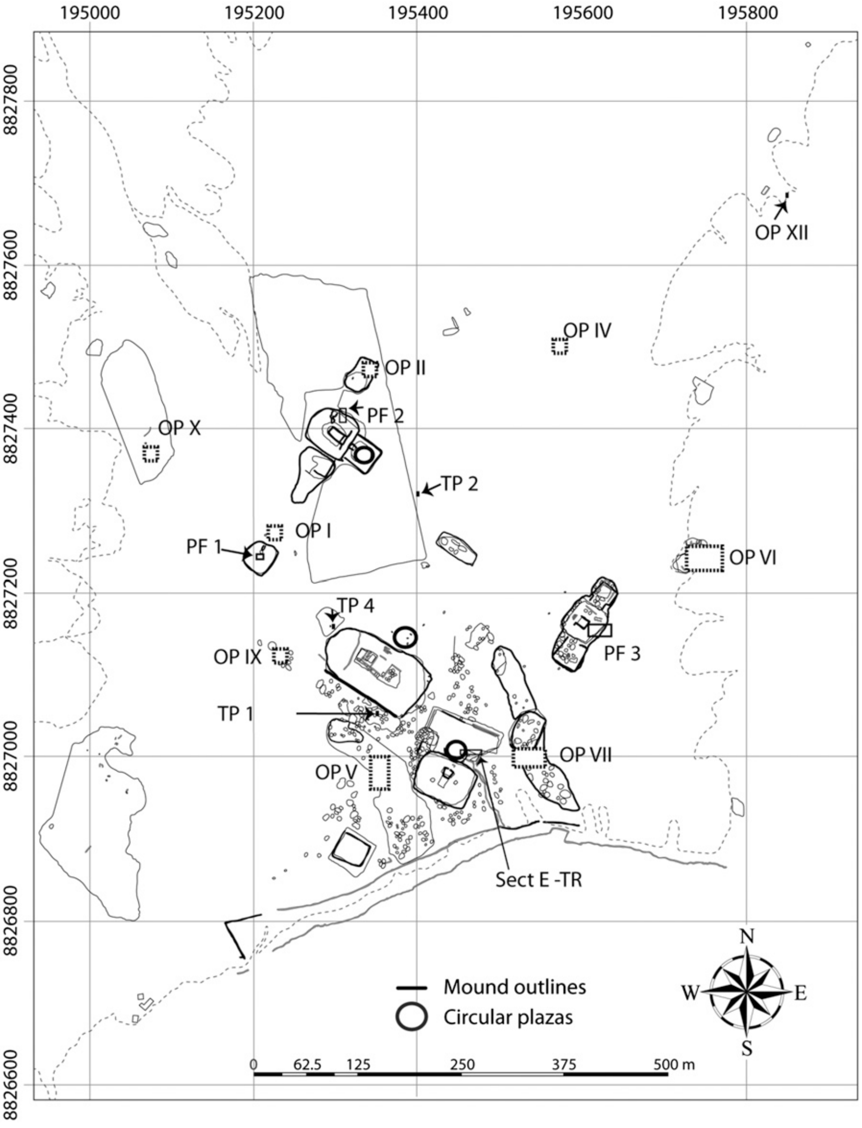

Fig. S1. Map of the site of Caballete.

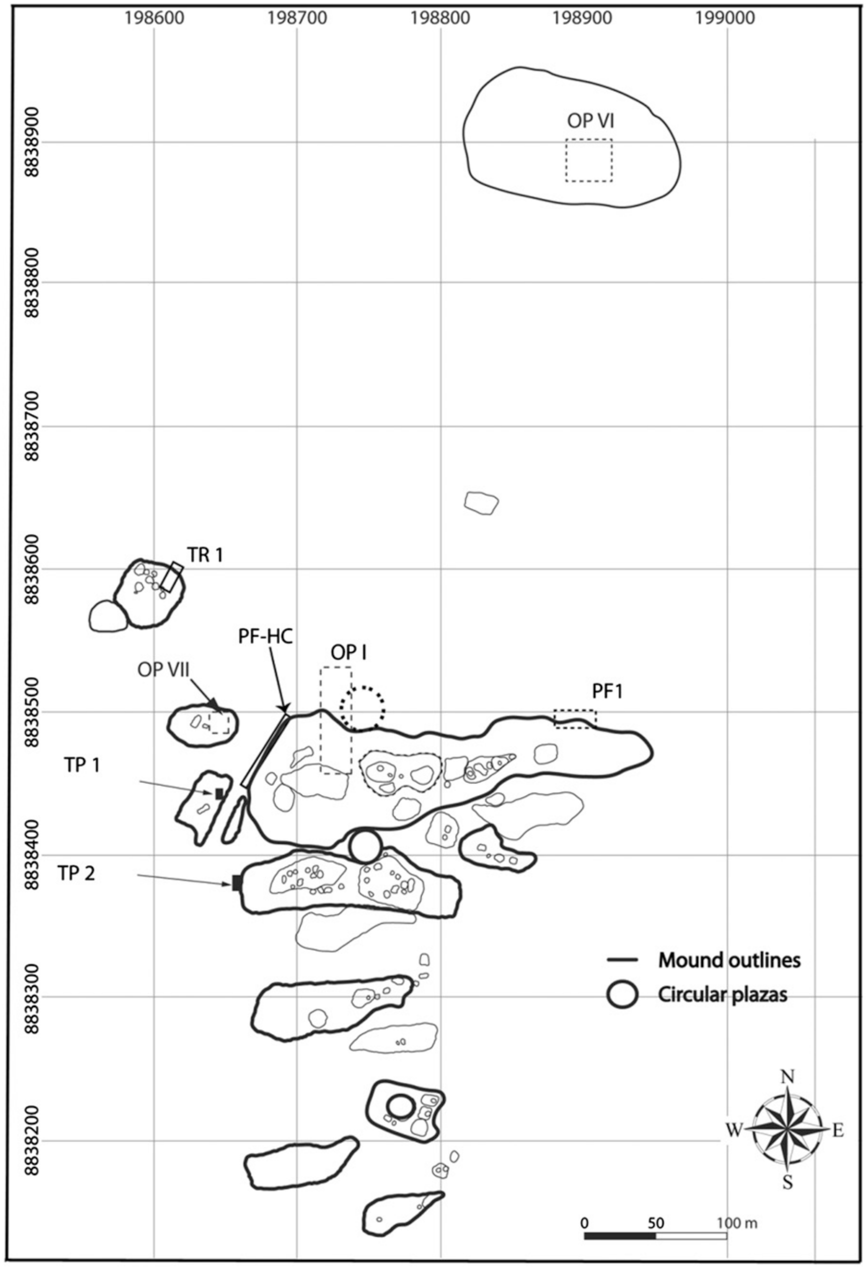

Fig. S2. Map of the site of Huaricanga.

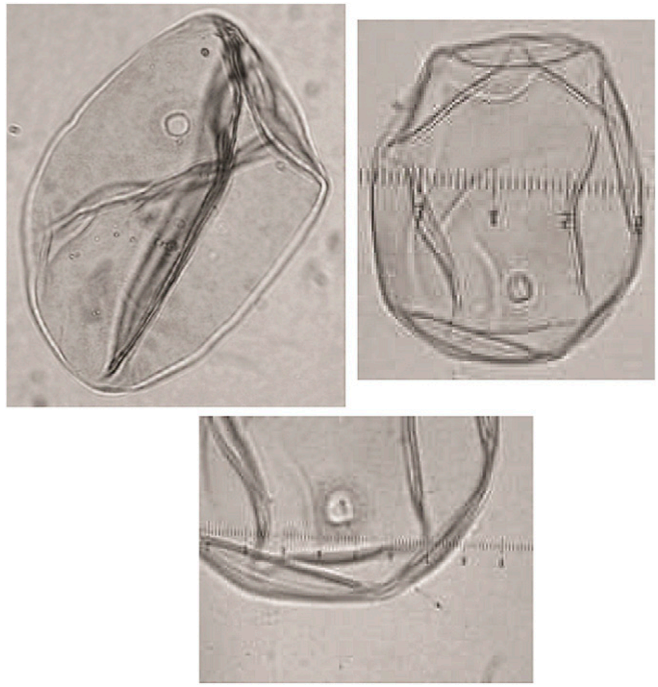

Fig. S3. Photographs of maize pollen. (*Upper Left* and *Lower*) Samples of prehistoric maize pollen from Caballete. (*Upper Right*) Sample of modern maize pollen.

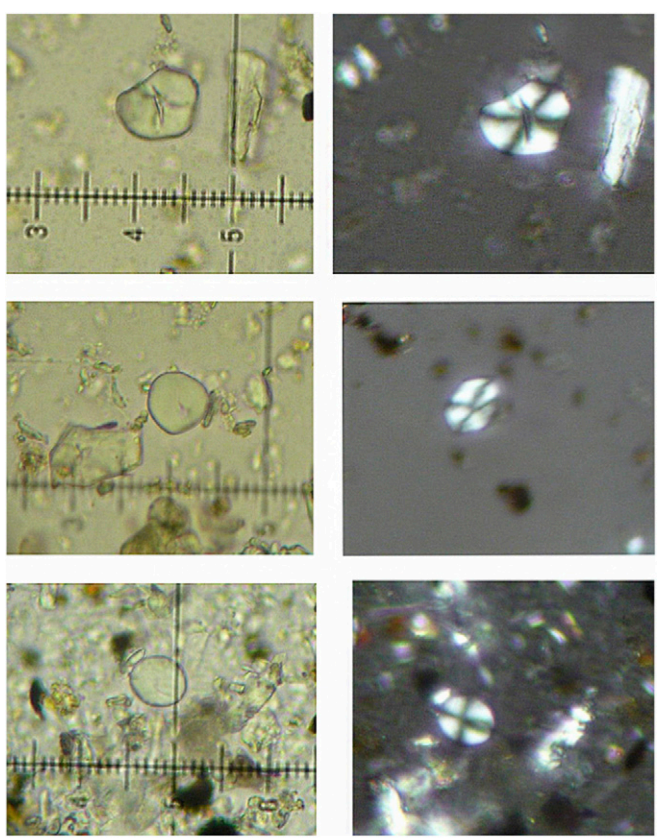

Fig. S4. Photographs of maize starch grains recovered from coprolites. Photos on *Left* are in normal light, those on the *Right* are the same grains in polarized light. Each space on the ruler is equal to 2.5 μm.

Other Supporting Information Files

Table S1 (DOC)
Table S2 (DOCX)
Table S3 (DOC)
Table S4 (DOCX)