10 FRESH VOLCANIC GLASS SHARDS IN THE POTTERY SHERDS OF THE MAYA LOWLANDS

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Pristine, fresh volcanic ash has been known as a dominant tempering agent in the Late Classic Maya (AD 600-900) ceramics. Archaeologist Anna O. Shepard first identified volcanic glass in Maya pottery sherds and struggled to solve the mystery of its origin as the lowland Maya lived on carbonate bedrock with the closest volcanic sources 350 km away. How did relatively large volumes (~ 10^6 m^3) of volcanic ash become available for manufacturing of ceramic products for the entire Late Classic Period? This question has never been answered. While it has been accepted that the ash was of non-local origin, this anomaly has never been explained. Identification of the source of the volcanic ash used by the ancient Maya has implications for the economy of ceramic production as well as the ecology of the Maya forest. Resolving the origin of the unexplained appearance of volcanic ash in the Late Classic, coincident with the apex of Maya civilization, will contribute directly to our understanding of the development of the Maya society and address the impacts of volcanic activity at a distance.

Introduction:

It was 1930 and the researcher Anna O. Shepard, then at the Carnegie Institution of Washington, applied innovative geological techniques to archaeological problems, and so doing discovered that there was volcanic ash in pottery from the non-volcanic limestone Maya lowlands (Shepard 1937). This incongruity – geologically recent volcanic glass used as temper with clay derived from geologically ancient marine limestone – presented an anomaly that followed her throughout her career. Shepard's challenge to identify the source(s) for the volcanic ash in the limestone Maya lowlands and recover evidence of cultural and environmental influences preserved in the potter's craft (Shepard 1936 cited in Cordell 1991) was the basis of our research endeavour. We have begun an inquiry to evaluate the origin of the volcanic ash used in ancient Maya pottery production with the use of 21st century geochemical tools and have completed the first phase of this research, combining microprobe with classical petrographic techniques to reveal new dimensions to the issue of origins of the ash temper. The resolution of the problem of volcanic ash shards in Maya pottery sherds bears significantly on our understanding of the development of the Maya civilization.

Historical View of Volcanic Ash and the Maya

Shepard's identification of diagnostic pristine volcanic glass shards is unexpected for clay deposits derived from chemical weathering of the Cretaceous/Eocene carbonates of the Maya area. Consequently volcanic ash has been interpreted as exotic tempering agent (Shepard 1937, 1951, 1956, 1962; Sunahara 2003). According to Shepard, and confirmed by all subsequent research, ceramics tempered with volcanic ash occurred predominantly in association with the Late Classic Period (c. AD 600-900). The consistency of the pastes pointed to a reliable and steady procurement source over the long period of use (Shepard 1939, 1942; in Smith 1955). Decades have passed since Shepard discovered this incongruity. We seek to rectify this.

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Figure 1. Photomicrograph of Sherd #1902 site 272-136 L 10x (2mm field of view) and R 40x (field of view is 0.2 mm). Glass is abundant, visible as the sharp edged white shards embedded in the clay matrix of the sherd. Glass is chemically and mechanically unstable material; the abundance of pristine glass shards is consistent with aeolian deposition (air fall); the glass shapes have no evidence of weathering or fluvial transport.

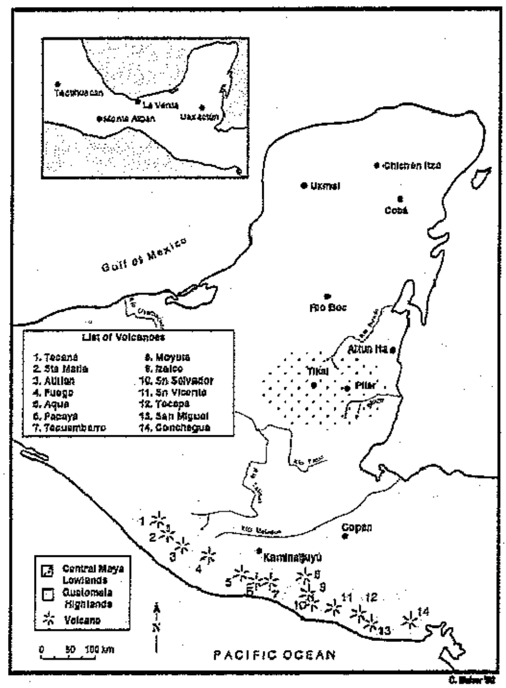

Figure 2. Volcanoes of the Central American Guatemala Highlands and Central Maya Lowlands of El Pilar and Tikal

Late Classic Maya ceramics have been well-described in the literature beginning with the Carnegie studies that involved Anna O. Shepard, through the intensive Barton Ramie project (Willey et al. 1965; Gifford et al. 1976), and up into the active projects in the region today (e.g., Jones 1984; LeCount 1996; Lucero 2001, Sunahara 2003). Ceramics from the earliest periods of the Preclassic, from c. 1000-800 BC through AD 250 are dominated by the local calcite (limestone) tempering as are those of the Early Classic (c. AD 250-600). The Maya mastered the unstable additive and produced finely made ceramics as well as the necessary cooking and storage vessels. It is in the Late Classic that there is a distinction of ceramic wares with the abrupt presence of serving bowls and plates as well as water jars tempered with volcanic ash, leaving the cooking and storage vessels consistently tempered with the local calcite. Ceramic pastes tempered with volcanic ash are remarkably uniform in appearance and texture permitting a rough identification based on inspection and simple methods such as reactivity with hydrochloric acid (Ford and Glicken 1987; Ford and Rose 1995; LeCount 1996:360; Gifford et al. 1976:255). Gifford marked ash-tempered ceramics as British Honduras Volcanic Ash Ware (Gifford et al. 1976:255-267). These pastes are found widespread at every residential unit occupied in the Late Classic from the environs of the major center of Tikal to the major center of El Pilar, used in the production of everyday wares such as bowls, jars, and plates, as well as in the production of specialized elite polychromes.

These distinctive wares of Maya ceramics, when examined petrographically (Figure 1), display fresh, unaltered volcanic glass, and retain all the characteristics of pristine volcanic air fall tephra (see Ford and Glicken 1987; Ford and Rose 1995). Without a doubt, the ultimate source of the volcanic ash in the Late Classic Maya ceramics must have been the active volcanoes themselves. Yet how did the volcanic ash get to the limestone lowlands, more that 350 kilometres away? (Figure 1)

Volcanic ash may be chemically sourced to the Central American Highlands (CAH) or the Mexican Volcanic Belt (MVB), just as obsidian is sourced, but it is unlikely that the distant deposits more than 350 km away were the source of ash in the Maya ceramics (Figure 2). Arnold's (1985) research on resource procurement for ceramic production provides a benchmark. Clays are heavy and make up the principal material of pottery; 84% of clay sources are collected within 7 km of production. Similarly temper is collected with 97% of the sources coming from under 9 km and none more than 25 km away. Only slips, paints, and décor are a comparatively minor component of the potter's craft, and sources can come from much greater distances; 56% of the resources were found within 30 km distance of where the ceramics were made (Arnold 1985:50-52).

What were the sources of volcanic ash that provided a ready and continuous supply for the Late Classic Maya? Importing volcanic ash from long distances would be prohibitive (Santley 2004) and the volcanological analyses support the hypothesis of an ash fall source (Ford and Rose 1995). There may have been a source or sources unidentified today but accessible and used by the Late Classic Maya. An ash fall source is logical and ash has fallen in the lowland Maya region from evidence in the Petén lake cores (Leyden et al. 1993) and records of the 1982 El Chichón (Espindola et al. 2000). Ash fall at once resolves procurement issues and provides a ready explanation for the morphology of the glass shards in the Maya ceramics.

Geological and Archaeological Issues

Geological

Advantages of volcanoes may be overlooked when considering immediate and direct impacts of volcanism. Benefits of volcanic eruptions include long-term positive effects related to soil fertility, well known from geothermal resources in volcanic regions all over the world (Williams and McBirney 1979; Ping 2000; Arnorsson 2000); and the availability of volcanic products for commerce and industry (Dehn and McNutt 2000). Both prehistoric and modern societies in the vicinities of volcanoes have used these products in various ways: volcanic ash as temper in ceramics (Arnold, 1985:59; Shepard, 1956:4,378- 381), obsidian (volcanic glass) for cutting implements or as semi-precious stone in jewellery (Gaxiola and Clark 1989), and other extrusive rocks have been used in construction, as stone implements or abrasives (Dehn and McNutt 2000). When considering the impacts of volcanic eruptions from a distance, the by-products of eruptions, such as volcanic ash, can present an opportunity and this appears to be the case for the Late Classic Maya.

The Maya lowlands are underlain by lithified marine sediments geologically older than 60 million years (Instituto Geográfico Nacional 1972). The sites where the volcanic ash tempered ceramics are recovered, essentially within the central core area of the Maya, lie more than 350 air kilometres north of the active volcanic vents in the of Central America Highlands and 550 air kilometres from the closest volcanoes of the Mexican Volcanic Belt. There are multiple candidates for volcanic sources that could have used by the ancient Late Classic Maya (Ford and Glicken 1987; Ford and Rose 1995; Carr et al. 2003; Espindola et al. 2000; Mercado and Rose 1992). Moreover, while the amount of volcanic ash used in the ceramics of the Late Classic is considerable if one regarded it as a trade item (Ford and Glicken 1987), such as obsidian, the total amount is easily accounted for in a deposit of a single eruption of about 0.007 km3 (Ford and Rose 1995:152).

For about 200 years during the Late Classic, volcanic ash was dependably available in sufficient quantity for use in ceramic vessels made for domestic purposes. You cannot make chocolate cake without chocolate; therefore you cannot make volcanic ash tempered pottery without volcanic ash. With this the central issue is clearly articulated: (1) there was a single eruption of significant volume to accumulate in the lowlands in sufficient amount for use throughout the Late Classic period or (2) there was repeated influx of volcanic ash into the lowland region that allowed for the continual use of ash as temper. If there is a single source, the glass elemental qualities should have a single compositional signature that links to one specific volcanic source. Multiple sources should demonstrate multiple compositional signatures and link to a sequence of eruptions over the Late Classic period at candidate volcanic source sites.

Analysis of Volcanic Ash Shards in Maya Pottery Sherds

Our findings demonstrate the challenge of research to source the volcanic ash in the Maya lowlands. We began with the petrographic descriptions, gaining an appreciation for the detailed work that Anna Shepard undertook. On average, from 20-50% of the pastes were composed of the volcanic ash and the glass shards ranged in size from 10 to 300 microns, with a mode near to 50 microns. Associated igneous phenocrysts, particularly biotite and plagioclase feldspar (Ford and Spera 2005; Ford and Rose 1995) reflect air fall qualities, with no evidence of reworking by water or other mechanical means (see Figure 2) supporting Shepard's early assessments. The pastes speak to the potter's craft, the "recipe" used for the ceramic pastes confirms the cultural influence in the production of the Late Classic volcanic ash wares.

Our electron microprobe of glass shards from four unique pottery sherds of different residential sites in the El Pilar area provided encouraging results. Four separate compositional groups with virtually no overlap were found based on the major elemental analyses. In particular the mass fraction ratios SiO2/CaO and Na2O/K2O were especially useful as discriminates (Figure 3). Although intra-sherd volcanic glass shard compositions are relatively homogeneous, inter-sherd glass shard

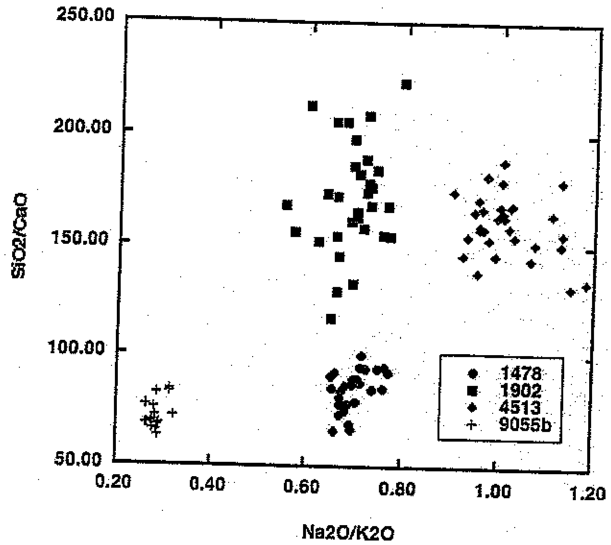

Figure 3. Ratio Distribution of Major Elements of Volcanic Ash Shards in Four Example Late Classic Maya Pottery Sherds

compositions are distinctly different. Our exploratory results also revealed that the glass shards used as ceramic temper by the ancient Maya have uniformly high silica content (75-77 wt %), typical of rhyolitic volcanic ash. This seems to rule out the El Chichón volcano (Espindola et al. 2000; Weintraub 1982) that covered the areas around El Pilar with an andesitic composition ash (~ 60 wt % silica). Further, even though the volume of ash needed for everyday ceramic ware in the interval between 600-900 AD seemingly requires a consistent supply that would imply more than a single ash fall event (Ford and Rose 1995), our initial compositional microprobe analyses have not succeeding in fingerprinting the source or sources. The material used by the ancient Maya was unlike the typical composition of CAH volcanic sources (58-72 wt % silica).

Silica, the primary component in rhyolitic glass, is resistant to thermal effects, yet other elements are more mobile. The prehistoric ceramic firing is at low temperatures with respect to melting (Ford and Lucero 2000), but there remains the potential to modify glass shard compositions by reactions between the rhyolitic glass and its surrounding matrix. Calcite (CaCO3) is an omni-present component in the Maya lowland soil derived from the chemical and physical weathering of lowland limestone and carbonate-bearing siltstones. Chemical weathering of carbonates in Maya lowland limestone leaves insoluble clays as a residue. Calcite decarbonates at 850 °C and is reactive with silicate glass at ceramic firing temperatures—500-800 °C (Rice 1987:87; Ford and Lucero 2000). It is possible, indeed likely, therefore, that there was chemical exchange of CaO between glass shards and surrounding clay-carbonate matrix. This effect would reduce the silica/lime ratio in glass shards because CaO reacts with and dissolves into pristine glass.

To test the nature of the changes in shard composition due to reaction with matrix and alkali element volatility, we initiated firing experiments with analyzed pumice, collected from the Moho Cay area of Belize, set in the Maya clay matrix starting material. Using clay collected in the field area, we prepared samples of clay and volcanic ash for firing. Controlled experimental tests were conducted at time and temperature intervals that parallel the firing conditions reported in the literature by Shepard (1963:83-91) and Rice (1987:90-93). We discovered that there were changes in the specific elemental levels and that the changes would affect the SiO2/CaO and Na2O/K2O ratios in particular. We observed a decrease in the ratio of both silica/lime and soda/potash with increasing firing temperature and the duration of the firing event. That is, the composition of the fired laboratory shards did not match the starting glass composition for the long duration-firing experiments.

These results have expanded the scope of our investigation, to leave the central problem of source unresolved. We clearly need to better understand the effects of firing on the composition of the glass shards. We are now at a point where we have a bird's-eye-view of the problem. We know the major oxide compositional span for ~ 1000 shards in the Maya ceramic sherds established via electron microprobe of analysis. We have an initial study of the candidate volcanoes from the CAH and MVB regions—both of which represent possible source areas. We have learned that there are elemental changes that increasingly shift the composition of glass shards with maximum firing temperature and firing duration. The problem remains: Where did the ash originate? To determine the volcanic ash source or sources, we need to know:

1) The range of volcanic ash compositions from Late Classic Maya ceramics,
2) The composition changes of ash with firing time and temperature,
3) The location of candidate eruptions, and
4) The distribution of ash from candidate volcanoes.

Our aim then is to develop accurate descriptions of the volcanic ash shards in the Late Classic Maya ceramic sherds and to determine the potential matches that exist with known volcanic ash falls for the region. We are examining information on the active volcanoes of Central America and Mexico. We are also compiling data on the environmental impacts of the ash at a distance.

Summary

Pristine volcanic ash has long been known as a specific tempering agent in the Late Classic Maya ceramics. While it has been accepted that the ash was of non-local origin, this anomaly has never been explained. Identification of the source of the volcanic ash used by the ancient Maya has implications for the economy of ceramic production as well as the ecology of the Maya forest.

For seventy-five years, archaeologists of the ancient Maya have recognized the presence of volcanic ash in the Late Classic Maya ceramics. Left dormant, there was no acknowledgement of the implications of the ash in the ceramics. Sourcing the exotic tempering materials will impact our essential grasp of the Late Classic Maya economy. Were the Maya opportunist when a single eruption deposited ash in their midst to exploit over several centuries? Or did a sequence of ash falls concentrate in the Late Classic promoting new ceramic production strategies and perhaps improving local production capacities for the soil? Our research brings together data from the distinct disciplines volcanology and archaeology into focus with an anthropological question that can only be answered with volcanological data. Our results will have far reaching implications for understanding the rise and fall of the ancient Maya civilization

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