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# The Significance of Volcanic Ash Tempering in the Ceramics of the Central Maya Lowlands

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Volcanic ash or glass tempering in lowland Maya ceramics has been recognized for at least half a century. As early as 1936, Anna O. Shepard (1937:145), in her first year with the Carnegie Institution of Washington (Morris 1974), was struck by the implications of fresh volcanic materials in ceramics provenienced from a region geologically composed of Eocene or older marine limestone sediments. In numerous archaeological reports and publications on ancient Maya ceramics, Shepard (1937, 1938, 1939a, 1939b, 1942, 1951, 1956, 1962) commented on the presence of volcanic ash. She insisted that the clays of the lowland Maya pottery she examined were obtained locally, yet they were infused with apparently nonlocal volcanic ash as a tempering agent.

According to Shepard, ceramics tempered with volcanic ash occur predominantly in association with the late period, now known as the Late Classic (AD 600-900). She observed that the volcanic ash was relatively fresh, containing isotropic [1] glass with little devitrification and was uniform in its composition both in particle size and in mineralogy (Shepard n.d.). The pastes were found regularly in red slipped vessels of the "vinaceous tawny wares" from San Jose (Shepard 1939b), Uaxactun (Shepard in Smith 1955), and Benque Viejo or Xunantunich (Shepard 1942). The volcanic ash temper was used instead of carbonates, implying that it was not an accidental inclusion, but was purposely used in lieu of the local limestone material. From her geological training (see Kidder 1937:144; Morris 1974), Shepard asserted that the relative abundance of the volcanic admixture in the pottery pointed to a reliable and steady procurement source. While to this day no known deposit of fresh volcanic ash has been reported for the Maya lowlands, Shepard contended that the source must have been readily available and material from it traded, and she continually looked for geological substantiation of this position (cf. Shepard 1942, 1962:252-254; Shepard 1964:165; Jones 1984:59).

## STUDIES OF VOLCANIC ASH TEMPER OF THE MAYA AREA

Shepard's interest in explaining the origins of volcanic ash temper in lowland Maya pottery never diminished. The subject is constantly brought up in passing references, but as none of her archaeological colleagues recognized the significance of Shepard's findings, the issue dropped from sight for some decades. Not until the early 1970's, after Shepard's death (Morris 1974), was there some revived interest in her research on volcanic ash. Isphording and Wilson (1974) raised a cloud of doubt over Shepard's volcanic ash identifications by suggesting a local lowland material, palygorskite, was mistaken for volcanic ash.

This proposal of the misidentification of volcanic ash as palygorskite was put forth on the basis of X-ray diffraction analysis of palygorskite and implied that Shepard did not have a firm grasp of her data (see also Jones 1984:59-60). To the contrary, Shepard was a skilled geological petrographer and a methodical technician (Morris 1974; also Shepard 1962).[2] Her analysis of archaeological ceramics was thorough, as an examination of her thin section slide files and documenting index alone will demonstrate (University of Colorado Museum, Boulder).

Given this information, it is clear that Isphording and Wilson's (1974) doubts of Shepard's capabilities and identification of volcanic ash are unfounded. Reexamination of Shepard's own slides used for her analyses, from numerous lowland Maya sites, substantiates the correct identification of the presence of volcanic ash, including glass shards, pumice, hornblende, biotite, etc.[3] Moreover, she was completely aware of the palygorskite deposits in the lowland region, and had considered this material as a possible base for the pigment "Maya Blue" (Shepard 1971; also Hathaway et al. 1969).

Simmons and Brem (1979) corrected the misleading position of Isphording and Wilson. They analyzed petrographically a number of ceramic thin sections from the central and northern Maya lowlands and generally described the nature of the volcanic ash present, in the process confirming Shepard's identification of volcanic ash. Because the Maya lowlands are composed predominantly of limestone and no deposits of fresh volcanic ash are described in the literature, they propose a model of highland-lowland trade, linking ash trade with obsidian trade between the source areas in the highlands and the distribution zones in the lowlands (Simmons and Brem 1979:85-89). While this is a possible explanation for the presence of volcanic ash temper in lowland Maya ceramics, Simmons and Brem did not examine the quantity of ash that might have been traded and did not evaluate other possibilities.

Most recently, Lea Jones (1984), in an overview of the petrography of Maya ceramics, draws attention to the evidence for volcanic ash temper. She details the presence of volcanic ash in ancient Maya ceramics, verifying its use, to some degree, in all periods and recognizing the considerable abundance of ash in the Late Classic ceramics (Jones 1984:2, 55-84). The volume of ash tempered pottery, argues Jones, echoing the positions of Shepard (1939b, 1942, 1962) and Simmons and Brem (1979), suggests a readily available supply of the tempering material (Jones 1984:61). She is, however, pessimistic as to the possibility of identifying the ash source (Jones 1984:65-66). Acknowledging that fresh ash could not occur in ancient marine sediments, Jones feels that the ash temper was imported and follows Simmons and Brem (1979) in linking trade in volcanic ash with trade in obsidian. Beyond this, she does not pursue the implications or ramifications of volcanic ash use.

What are the implications of volcanic ash in lowland Maya pottery? Geologically, the entire Maya lowlands are composed of marine sediments older than 60 million years (Instituto de Geografico Nacional de Guatemala 1972). The core Maya area within the central lowlands is about 300 air km north of the nearest active volcanoes in the Guatemala highlands, and the nearest sources of ash are no closer than the northern Maya highlands, some 150 km from the core Maya area. Either there is an unrecorded ash deposit within the Maya lowlands, or the ash used in the ancient Maya pottery was imported.

## VOLCANIC ASH TERMINOLOGY AND CHARACTERISTICS

Pyroclastic material is composed of varying proportions of vitric, crystal, or lithic particles (Fisher and Schmincke 1984:91; Williams and McBirney 1979:149). Volcanic ash (Figs. 1 and 2) is defined as pyroclastic fragments, or rocks expelled from a volcanic vent that are less than 2 mm in diameter (Fisher and Schmincke 1984). Tephra is a more general term that refers to pyroclastic fragments of any size (Thorarinsson 1974).

The vitric particles of the volcanic ash are minute fragments of volcanic glass. Ash-sized vitric particles around silicic volcanoes such as those found in Central America commonly form from the fragmentation of pumice, a

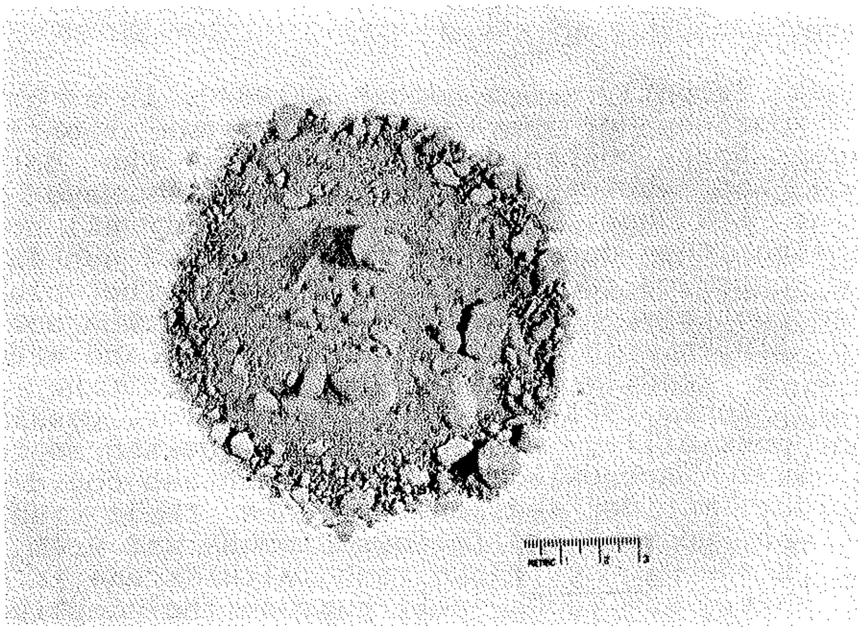

Fig. 1. Unsorted Los Chocoyos ash from the Quezaltenago valley, Guatemala.

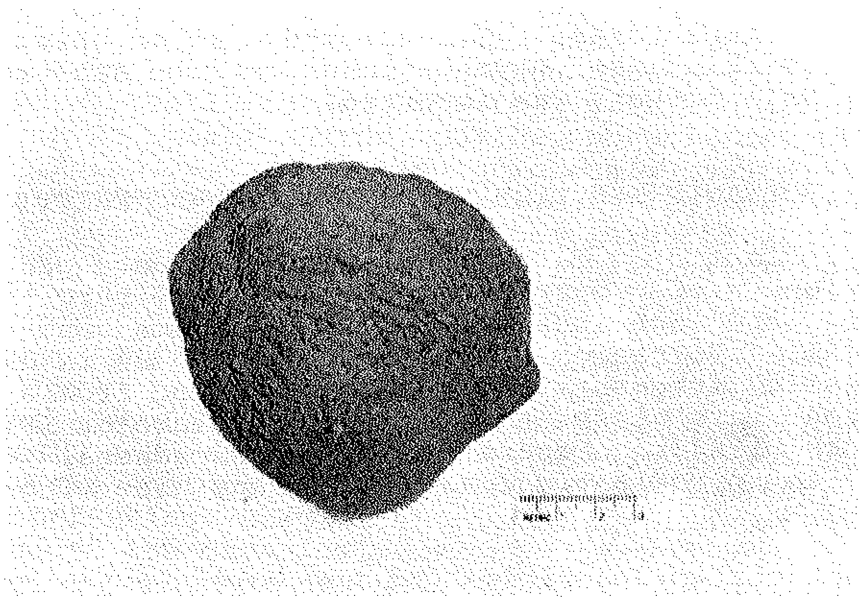

Fig. 2. Sorted Mount St. Helens ash from western Washington.

light-colored, vesicular volcanic rock that has cooled very quickly from magma and is comprised of predominantly glass and few crystals and lithic fragments. When the glass particles are fresh, they are very easy to identify with a petrographic microscope because of their characteristic shapes and their isotropic optical properties (Shepard 1964:379).

Crystals in volcanic ash around silicic volcanoes also originate from fragmentation of pumice. The minerals in pumice generally develop euhedral, or well-formed, crystals. The presence of euhedral crystals is a diagnostic characteristic for distinguishing pyroclastic material from non-pyroclastic sediments (Fisher and Schmincke 1984:103; Isphording and Wilson 1974:487).

Lithic particles are the dense, non-vesiculated fragments in a pyroclastic deposit (Wright et al. 1980). The lithics may form from non-vesiculated parts of the cooling magma or may be rock unrelated to the eruption that is incorporated into erupting pyroclastic material. Lithic particles in ash-sized material commonly consist of nonvolcanic particles or non-vesiculated glass with small crystals included.

Pyroclastic material is deposited in a number of ways (Wright et al. 1980). Pyroclastic flows (also known as ash flows or nuée ardentes) and pyroclastic surges are gravity-driven currents of pyroclastic material that rarely extend more than a few tens of kilometers from a volcanic vent. When pyroclastics are ejected into the air in an eruption column, they are moved by wind and fall through the atmosphere. The features that result are called pyroclastic fallout deposits or air fall deposits (Williams and McBirney 1979:149). Some geologists (e.g., Miller 1980) restrict the use of the word tephra to pyroclastic fallout. Fallout deposits can extend hundreds or thousands of kilometers from a volcanic vent, and they generally thin with distance (Williams and McBirney 1979:138-144; Kittleman 1979:55-61). In some cases, however, they are thin close to the vent and then thicken tens or hundreds of kilometers from the vent (Brazier et al. 1983). An example can be drawn from the 1980 eruption of Mount St. Helens, where the tephra fall thinned to less than 10 mm at 180 km from the vent and then thickened to greater than 35 mm at 300 km (Carey and Sigurdsson 1982).

Deposits of pyroclastic material can be reworked by wind, water, and biological activity so that the deposits lose their original sedimentary characteristics. In addition, the glass (vitric) particles of the pyroclastic material devitrify rapidly during weathering. Ash beds a few centimeters thick or less in tropical areas are especially susceptible to reworking and weathering. The devitrification process (Williams and McBirney 1979:146) is analogous to the hydration process of obsidian: water is absorbed on the surface of the glass through diffusion, and the glass matrix is destroyed (Fisher and Schmincke 1984:327-329). This devitrification of the glass shards in volcanic ash has been used successfully in tephrachronology to date the deposits (Steen-McIntyre 1975, 1978). Commonly, the only remnant of weathered volcanic ash beds are the crystals of the ash, such as hornblende, plagioclase, quartz, and biotite (Fisher and Schmincke 1984:103-105).

If any volcanic ash had been deposited in the original marine sediments of the Maya lowlands, the resultant material would be completely altered or devitrified due to the extensive period of weathering (e.g., northern Belize deposit reported in Simmons and Brem 1979:82-83). Volcanic activity in the Guatemala highlands has been continual in recent geological times (Williams 1960). Fresh ash deposits are known throughout the general area, including major deposits in the highlands as well as recognized deposits in all the oceans surrounding Mesoamerica (Drexler et al. 1980; Rose et al. 1979). Nevertheless, the full extent of the terrestrial ash deposits has not been investigated.

## NATURE OF VOLCANIC ASH IN MAYA CERAMICS

The ash of lowland Maya pottery is fresh and unaltered, retaining all the characteristic shapes and isotropic properties (Shepard 1964:29-380; Jones 1984:55-85). Thus, the ultimate source of the volcanic material must be significantly more recent than any conceivably found in the local limestone sediments. Volcanic ash is evident in Maya ceramics from all periods, but it is especially diagnostic in specific pastes of the Late Classic period. The Late Classic pastes demonstrate an effort to use volcanic ash as an exclusive tempering agent. This effort contrasts with earlier periods during which other materials, especially carbonates, were deliberately added or fortuitously included in the clays composing the paste.

Volcanic ash would be preferred as a temper over carbonates, which are abundant in the form of limestone throughout the lowland Maya region. Limestone decomposes into lime (CaO) at firing temperatures possibly as low as 600 degrees Celsius and, with cooling, the particles rehydrate causing expansion that can damage the vessel walls. Volcanic ash is one of the most stable additives under ceramic low firing conditions and will not alter until melting temperatures are attained, around 1000 degrees Celsius (Shepard 1964:378-381). Also, the angular shape of the ash particles confers added strength to the vessel as compared to more rounded carbonate inclusions

(Shepard 1962; Jones 1984:60-61).

In our research, Late Classic Maya ash-tempered sherds were examined from the Tikal-Yaxha area (Figs. 3 and 4), the center of Tikal, the upper Belize River area, and from a number of lowland sites represented in Shepard´s petrographic slide archives, including Uaxactun, San Jose, and Xunantunich. While some variety in the mineral composition of the sherds was noted, the majority were relatively uniform in their composition. The average glass shard size ranged from 0.15 to 0.40 mm with very little variability outside this range, indicating well sorted source material. The ash showed no signs of abrasion, which implies that it was not broken down from larger fragments. On the average, there was a 20% ash content to the sherds, although higher amounts were common. Accessory minerals included biotite in all examined specimens, quartz and hornblende in most, and plagioclase in some.

The Late Classic volcanic ash tempered pastes have a distinct fine sandy texture (see Shepard 1962; Jones 1984) and were oxidized in firing to a light color of yellowish brown to brownish yellow--10YR 7/4, 10YR 6/4, 10YR 7/6, and 10YR 6/6 of the Munsell Color Chart. The majority of Late Classic vessels with volcanic ash temper are red-slipped and make up a large portion of the basic household inventory: bowls, jars, and plates. Most Late Classic polychrome vessels (vases and plates) are composed of the same volcanic ash pastes as well.

There is no evidence of differential access to ash tempered ceramics on the basis of wealth, status, or distance from centers. In fact, evidence from the center of Tikal, the Tikal Sustaining area, the Tikal-Yaxha area, and the Yaxha-Sacnab area (our own analysis; see also Jones 1984; Fry 1969) suggests that all households in the Late Classic period had the same vessel inventories with volcanic ash temper. Specific forms characteristic of Late Classic assemblages consist of incurving bowls, narrow orifice jars, and tripod plates (Figs. 5, 6, and 7). The bowls and plates are the same serving and storing vessels discussed by Fry (1969, 1980, also Fry and Cox 1974) which are characterized as bearing "golden mica" (Fry 1969:209, 268, 1979:502) or "micaceous paste" (Fry 1980:70). These vessels reported by Fry are probably volcanic ash tempered (see Jones 1984:70), as petrographically analyzed sherds of Late Classic bowls and plates with volcanic ash have biotite, a type of mica, present. There have been no recordings of muscovite, another kind of mica, in Late Classic Maya ceramics (see Jones 1984:Chart 1; Shepard n.d.; cf. Fry 1980:7).

All volcanic ash tempered pottery is comparatively uniform in macroscopic and microscopic composition

Fig. 3. Thinsection from a Late Classic bowl from the Tikal-Yaxha intersite area (catalog number 280F) with c. 30% ash content, showing angular pumice, quartz, plagioclase, hornblende and biotite in reflected light.

Fig. 4. Thinsection from a Lte Classic bowl from the Tikal-Yaxha intersite area (catealog number 280F) with c. 30% ash content, showing angular pumice, quartz, plagioclase, hornblende and biotite with crossed polarized light.

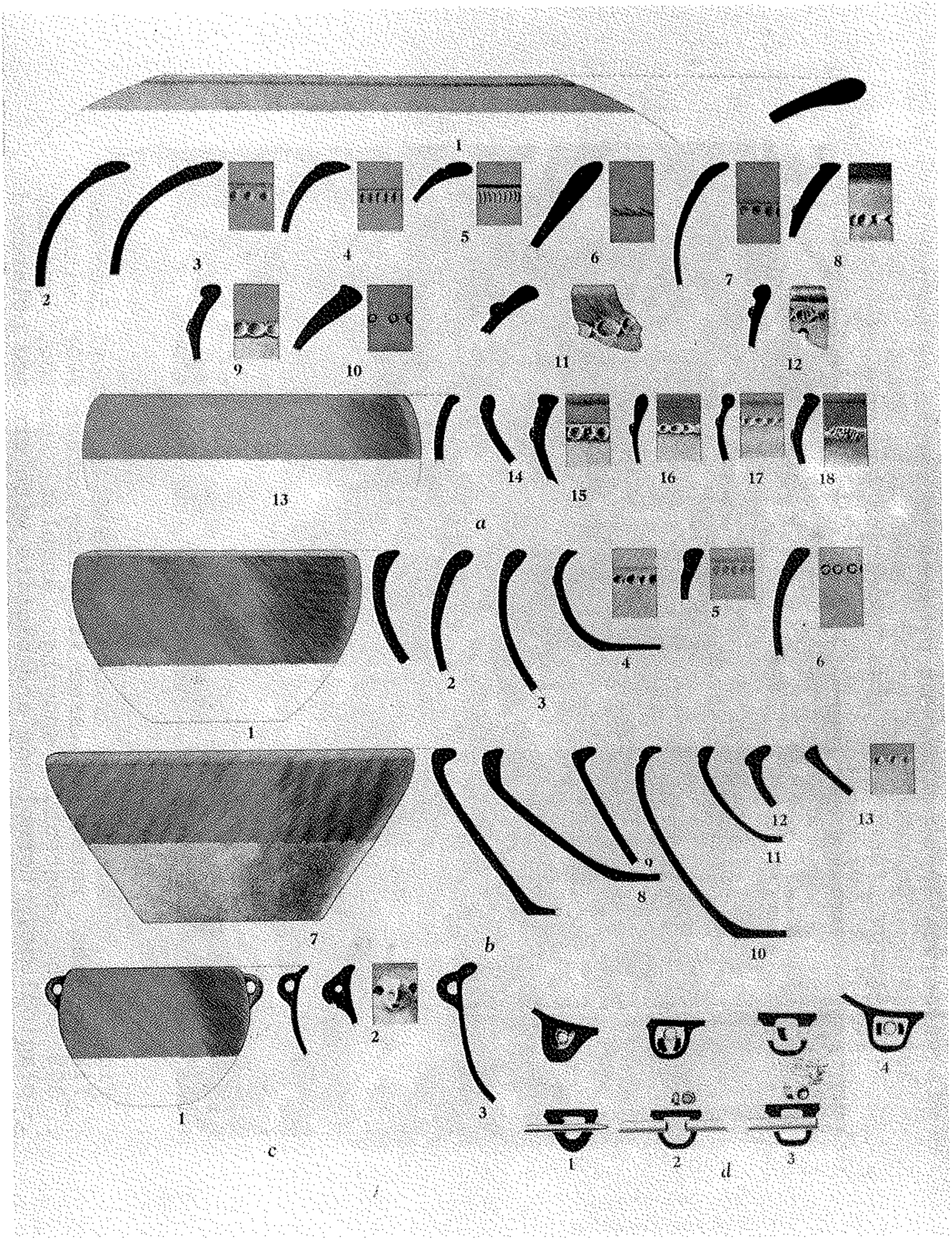


Fig. 5. Late Classic incurving bowls (after Smith 1955: Fig. 48).

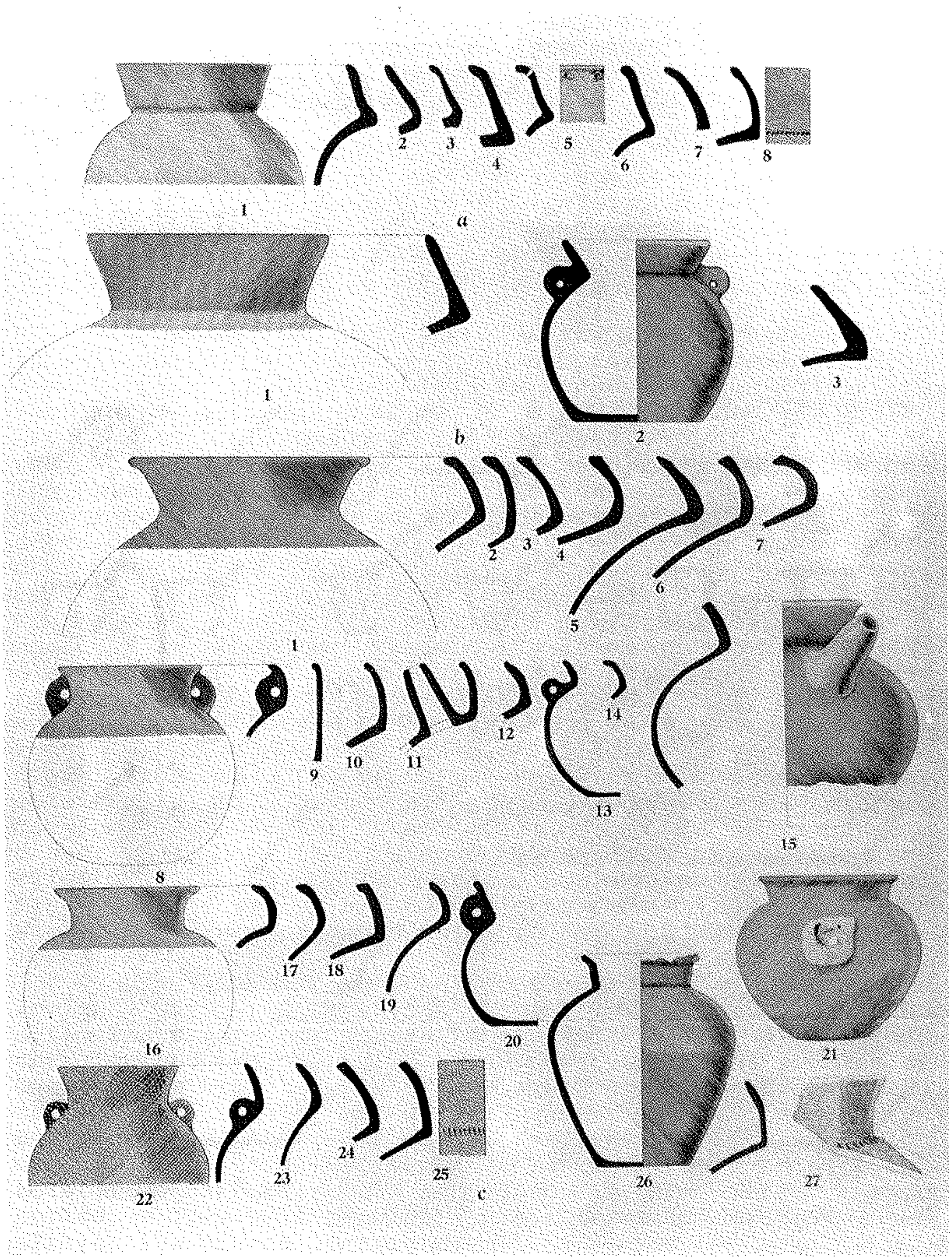


Fig. 6. Late Classic narrow orifice jars (after Smith 1955, Fig. 51).

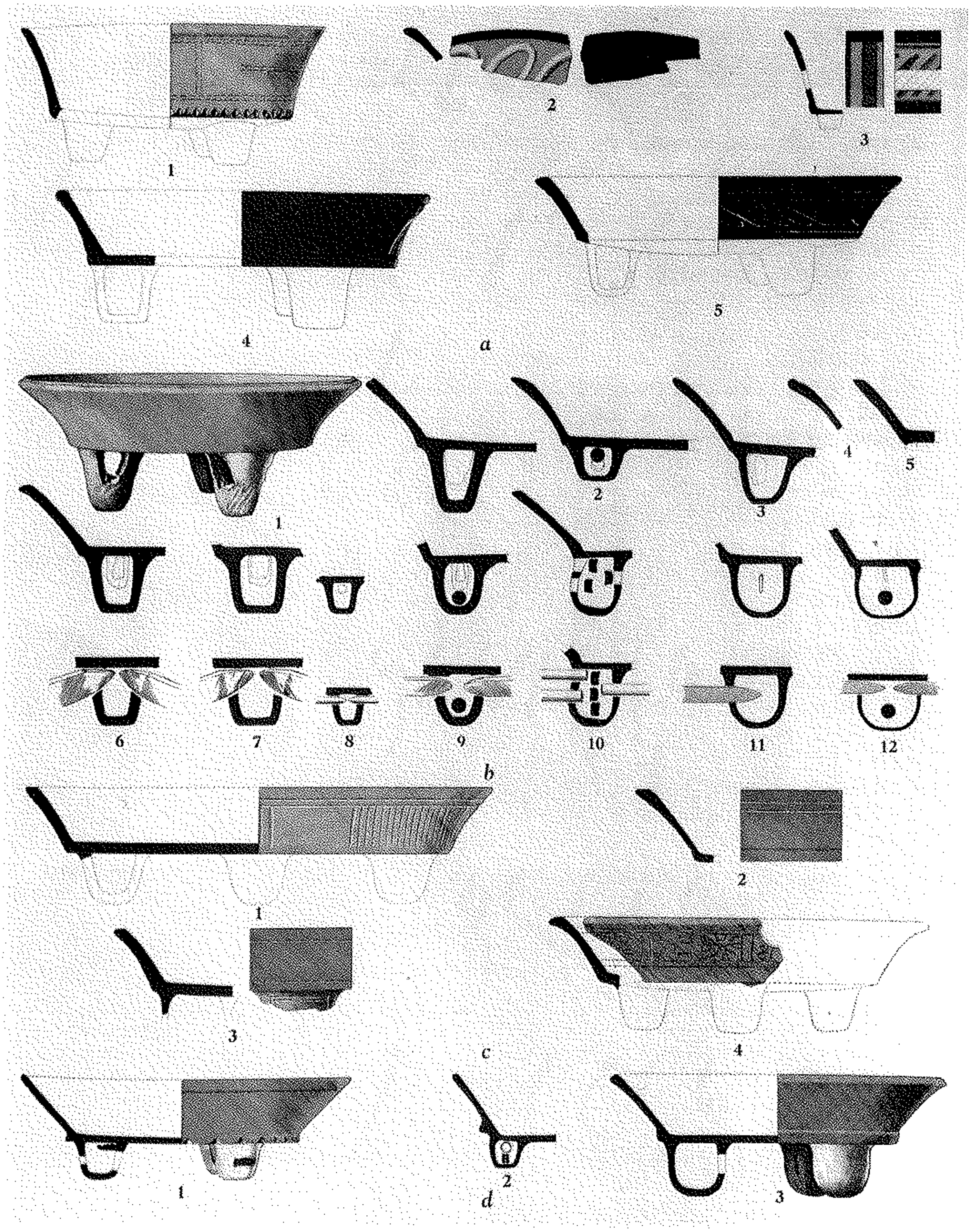


Fig. 7. Late Classic tripod plates (after Smith 1955: Fig. 47).

(Shepard 1962; Jones 1984). If any carbonate is present, it is in trace proportions and appears to be accidental. This suggests that deliberate efforts were made to avoid the unstable carbonates in these pastes. Volcanic ash was purposely sought for the manufacture of specific vessels used in general household activities as well as more restricted elite uses. The systematic use of volcanic ash in Late Classic household bowls, jars, and plates suggests that the supply of ash was steady and dependable in the Late Classic and that the "recipe" for the paste was standardized throughout the lowlands.

In considering the source of the volcanic ash temper, it is worth considering the resource procurement limits for ceramic materials. This is important when evaluating the costs of using volcanic ash in the Maya lowlands. Arnold (1980) considers the problem in a summary of worldwide ethnographic literature on ceramic production. In this summary, he emphasizes that there are preferred procurement zones for clays, tempers, and paints used for ceramic production (Arnold 1980:148-149). Beyond the preferred zone is a maximum procurement range where returns are still greater than costs and marginal procurement ranges where returns may equal costs. Arnold found that there was variability in procurement zones for clay, temper, and paints. In 91% of the cases, clays came from within a 7 km zone (with a maximum range of 31 km), and in 97% of the cases tempers came from within a 5 km zone (with a maximum range of 25 km). Only paints were drawn from distances up to 880 km, with the majority (67%) obtained within a 40 km zone. Arnold states that the marginal procurement range for temper was 50 km in extreme cases. Beyond that distance it would not be cost-effective to use. This distance would embrace the central Maya lowland region around the center of Tikal, but is not within the range of known volcanic ash sources.

Having identified the presence of volcanic ash in lowland Maya pottery, and having recognized that the ultimate origin of ash is from volcanoes that are outside the lowland Maya region, we now turn to the problem of determining the source of lowland Maya ash temper. While this issue cannot be settled at this time, we examine possibilities that can assist in directing the resolution of the problem. We begin this quest by examining the relative quantities of ash used in the Late Classic period. This will provide a scale for considering the two alternative source locations.

First, we assume that every Late Classic period Maya household replaced one bowl, one jar, and one plate of ash tempered ware in a single year. As bowls, jars, and plates are portable and were required by every household, replacements were likely made at a higher rate than one per year (see David and Hennig 1972; Beals 1975:326-340;

Fry 1979:479; Arnold 1980; Mallory 1984:267-269). We will also assume an average weight of each vessel to be 4 kg, based on the weight of modern ceramic vessels of a size similar to the ancient Maya vessels in questions and the weight of ancient Maya sherds tempered with volcanic ash. On the basis of Shepard´s petrographic analyses as well as our own [4] the proportion of ash within the vessels averaged 20%, even though some were considerably higher. Given these data, we may construct an estimate of the average household consumption of volcanic ash:

20% of 4 kg = 0.8 kg per vessel
3 vessels x 0.8 kg = 2.4 kg ash per household in 1 year

Taking the total area of the central lowlands as 10,000 sq. km (100 by 100 km around Tikal), estimating 200 persons per sq. km in the Late Classic (cf. D. Rice 1976:276), and assuming that six persons compose the average household, we find:

333,333 households x 2.4 kg ash per household =
ca. 800,000 kg of volcanic ash consumed per year

If the average individual can carry 40 kg, each carrier would bring a supply of ash that would satisfy the annual consumption needs of an estimated 17 families (0.04 cu. m of ash). [5] This translates into 20,000 40-kg bags of volcanic ash (800 cu. m) per year or 1,667 40-kg bags (67 cu. m of ash) per month consumed within the central lowland region. It may be recalled that this estimate includes only vessels made for domestic consumption, and not other items such as vases which were also made of volcanic ash pastes. Clearly, the Late Classic period use of volcanic ash was voluminous (see also Jones 1984:61).

This estimate of volcanic ash consumption provides us with a means of gauging its importance in the production of specific household pottery vessels. These computations have been useful in understanding the degree of dependence on volcanic ash supplies in the Late Classic. If the population density was only 100 persons per sq. km and the consumption of ash was only 1.2 kg per household, demand for ash in pottery production would still be high--200,000 kg of ash (200 cu. m) per year or 5,000 40-kg bags per year. Hence, it is not the absolute amount but the relative quantities that are worth considering.

By any standard, volcanic ash demand in the Late Classic was high. Far from being socio-economically restricted in distribution, ash tempered ceramic forms were standard utility vessels, employed at the basic household level and replaced at a high level (ca. 41% of midden sherd collections around Tikal; Fry 1979:496, 1980:5). Ash tempered pottery was not rare in the Late Classic; on the contrary, its absence is rare.

## SOURCE OF VOLCANIC ASH TEMPER

Exotics are always specialized in their use and restricted in distribution. The quantity of volcanic ash temper in Late Classic Maya household ceramics finds no parallel in other obvious long distance trade items. Unlike the ceramics with volcanic ash temper, exotic items such as obsidian are not as generally available and are not clearly employed in ordinary household ways.

Even though obsidian appears accessible to most households, the relative frequencies or densities are very low (Sidrys 1976). The highest overall Late Classic obsidian densities in the central Maya lowlands were found at Tikal, and even then they were only 15.3 gm/cu. m. In the residential zone between Tikal and Yaxha the average obsidian density is 2.7 gm/cu. m. These low densities of obsidian are contrasted with the fact that most of the fine household wares of the Late Classic were tempered with volcanic ash (see Fry 1969:209, 1979:502; Jones 1984:20-21).

If volcanic ash was a long distance import into the lowlands, transport costs would include the major movement between the Maya highlands and lowlands and the internal lowland Maya regional exchange. If the volcanic ash source was available within the lowlands, there would only be the costs of the local exchange. Either way, large amounts of volcanic ash, destined for tempering in Maya pottery, were regularly employed in ceramic production in the Late Classic period.

Long-distance trade in volcanic ash is conceivable when one recognizes that there are major waterways originating in the highlands on the east and west of the central Maya lowlands. The possible sources of volcanic ash would be about 150 km distance from the majority of lowland consumers and would be transported via water and land to the lowland distribution centers. On the east, water transport within the barrier reef, along the coast of Belize, and up the Belize River would bring goods within a three day walk of Tikal. The western rivers, draining directly from the highlands, would bring goods within a four-to-five day walk of Tikal. Both routes put the procurement distance beyond Arnold's (1980) marginal range, implying the importation of volcanic ash was uneconomical. The prehistoric lowland Maya, however, may present an unusual case when ceramic material needs are considered. The poor quality of the local alternative carbonate temper sources compared with the potential benefits of volcanic ash as a stable tempering agent could have been sufficient incentive to support long distance importation.

If there are ash deposits in the Maya lowlands, their origin must have been from eruptions of volcanoes outside the region, because there were no volcanoes active in Quaternary times within the lowland Maya area. There are, however, many volcanoes throughout Mexico and Central America that have produced air fall tephra that may have blanketed the lowland Maya region and, thus, provided a local source of volcanic ash. The Los Chocoyos ash, erupted from the Atitlan caldera in the Guatemala highlands about 84,000 years ago, is chemically correlatable with ash beds found in deep-sea drill cores in the Gulf of Mexico and the Caribbean sea, suggesting that the Maya area was covered with 1-10 cm of silicic tephra about 84,000 years ago (Drexler et al. 1980). Most recently, the 1982 eruption of El Chichon in Chiapas, Mexico, deposited a light dusting of ash over the Maya lowlands (Carey and Sigurdsson 1986; also personal observation). There are also many documented Pleistocene eruptions in Guatemala that produced more than 0.1 cu. km of tephra (Rose et al. 1981), and many of these probably also blanketed the lowland Maya region. It is likely that many undocumented Holocene eruptions produced tephra blankets widely dispersed enough to have covered the lowlands.

Geological field work in Belize in 1983 failed to locate any deposits of volcanic ash with abundant fresh glass shards such as those found in the Late Classic vessels. Stream and lake sediments from throughout Belize as well as middens from excavation by the Belize River Archaeological Settlement Survey in the Belize River area were examined with binocular and petrographic microscopes. Nevertheless, euhedral crystals of hornblende are present in stream sediments. These may be remnants of pyroclastic fallout deposits in the area, the tropical weathering having broken down the vitric particles that form the major component of ash.

The mineralogy of the volcanic ash temper of ancient Maya pottery is consistent with ashes that were erupted from volcanoes in northern Central America (Rose et al. 1981). Consequently, it is possible that an as-yet-undocumented eruption or eruptions of one or more volcanoes outside the lowland Maya area deposited layers of air fall tephra in the lowland Maya area. The ancient Maya could have collected this material for use as ash temper before it was reworked, weathered, and incorporated into the soil. The euhedral hornblende present in sediments in Belize is likely a relic of such tephra layers.

The Los Chocoyos ash mineralogy (Rose et al. 1979) correlates with that of the Late Classic ash-tempered ceramics (e.g., Fig. 3 and 4). However, this ash could only be the source of the ash temper in Maya pottery if it was imported into the area from the highlands. The Los Chocoyos deposit is about 84,000 years old and the 1-10 cm of Los Chocoyos ash fall in the Maya lowlands must have been reworked and weathered within a few thousand years of deposition. As a consequence, it would not have been available as fresh, unaltered ash in the Maya lowlands during the Late Classic period.

A well-known ash deposit called the "tierra blanca joven" or "tbj" tephra erupted ca. 260 AD from the Lago de Ilopango basin in central El Salvador (Hart and Steen-McIntyre 1983) and could have been available in the Maya lowlands during the Late Classic period. However, this cannot be the source of the ash temper, because the mineralogy is very different. The "tbj" tephra lacks quartz, which is present in abundance in the ash tempered Maya pottery, and the "tbj" tephra includes clinopyroxene (Hart and Steen-McIntyre 1983), which is not present in any of the ash tempered pottery of the Maya lowlands.

Currently, with no known fresh volcanic ash deposit within the lowland Maya region, it is difficult to determine how the ancient Maya may have procured their volcanic ash for ceramic temper. The quantity of ash used in the Late Classic period points to a local source, given the knowledge of procurement strategies of potters (Arnold 1980). Minerals and crystals of pyroclastic origin have been identified in the alluvial deposits of Belize, indicating that local air fall deposits of volcanics have occurred in the past. Also, pumice has been collected off the coast of Belize within the protected waters of the barrier reef (Nicolait 1984, personal communication) and has been excavated from archaeological deposits (Fig. 8) on Moho Cay (McKillop 1980, personal communication). This could have been collected and ground up for temper. It is unlikely, however, that pumice is the source of the volcanic material of central lowland Maya pottery. Experimental grinding of large pumice pieces collected in the coastal waters of Belize demonstrated that pulverized or ground volcanic glass appears abraded microscopically, and there are no free ash shards (see discussion in Shepard 1962, 1964:379) as identified in the Late Classic ceramic thin sections.

The object now is to develop a comparative study of the extent of volcanic ash use in ceramics of the central Maya lowlands and beyond. This should begin with a standardized description of the mineralogy of the ash tempered ceramics followed by a correlation of the mineralogy and chemistry of the glass and crystals with known volcanic ash descriptions from the highlands of Guatemala.[6] Tephra hydration measurements on the glass shards of the pottery temper could be attempted and may prove useful in associating tephra deposits with the ash temper (Steen-McIntyre 1978, 1981). These analyses would

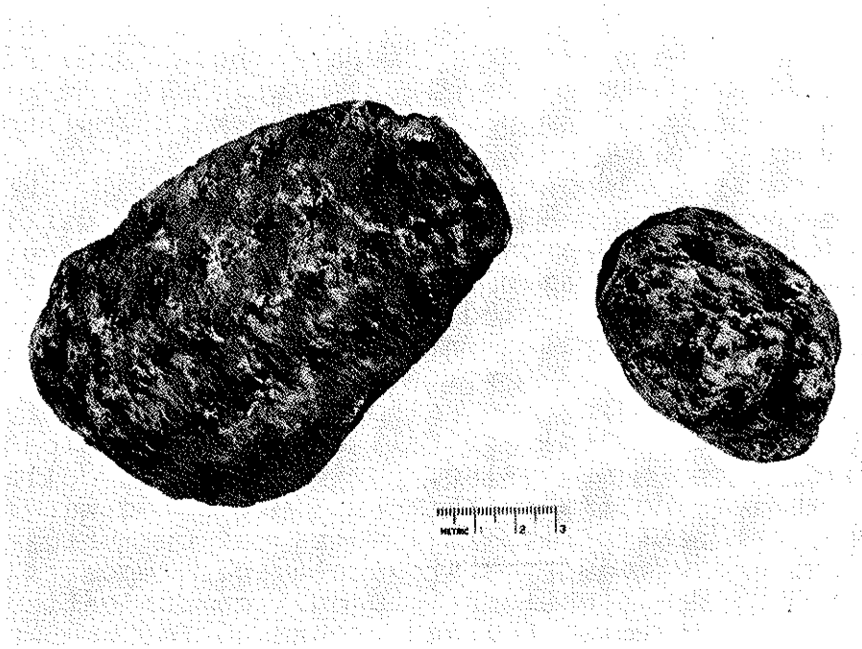

Fig. 8. Pumice from the archaeological deposits at Moho Cay (excavated by H. McKillop).

narrow the possibilities of source volcanoes and ash deposits and could provide clues to the origin--local or long distance--of the volcanic ash used by the Late Classic period Maya.

## CONCLUSIONS

In summary, fifty years ago Anna O. Shepard identified a significant issue in the production of Late Classic period household vessels: the use of volcanic ash temper. This issue has been largely left dormant and the implications uninvestigated. We have resurrected it here in an effort to draw attention to the magnitude of the problem and encourage more research toward its resolution.

In examining the data in their preliminary form it is clear that large quantities of volcanic ash were used regionally in Late Classic household ceramic wares. The projected annual consumption over 300 years translates into an ash deposit of at least 1,200 ha. and 2 meters thick or a 1 cm deposit over a 25 sq. km area.[7] Volcanic ash, if it exists within the lowlands, is certainly in discrete locations, as settlement and geological surveys in the central Maya area have failed to encounter such deposits. It is unlikely the ash was derived from pumice, known to be occasionally available on the coast of Belize and Yucatan. The presence of a regional lowland volcanic ash source would most parsimoniously account for the extensive distribution of ancient Maya ceramics with volcanic ash temper. On the other hand, the advantages of the use of volcanic ash as temper may have provided the incentive for long distance trade. Regardless of the source location, trade and exchange of volcanic ash temper figures prominently in the Late Classic period.

## Acknowledgments

This paper is the result of the help of many. An introduction to the importance of petrography is credited to the geologists in the Department of Geology, UCSB. Immeasurable assistance was freely given by Diana Kamilli, who spent much time with me over Shepard´s slides. Partial funding was given by sigma Xi for thin sections. Through this work, we have gained a great respect for Anna O. Shepard.

## Notes

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[1] Isotropic materials diffract light such that they appear black through a microscope with crossed polarized light.

[2] Ford has interviewed a number of individuals who knew Anna O. Shepard personally. All these individuals worked with her as archaeologists and geologists: J. Boles (1979) Professor of Geology, University of California at Santa Barbara; W. Towenhoffel (1980) U.S. Geological Survey, Special Projects, Denver, Colorado; V. Broman de Morales (1985) archaeologist, Guatemala City; M. Bullard (1980) anthropologist and historian, New Bedford, Ma.; E. Shook (1981) archaeologist, Antigua, Guatemala.

[3] Specific slides of central Maya lowlands ceramics from Anna O. Shepard´s archives at the University of Colorado, Boulder are noteworthy as they represent examples of volcanic ash tempering. These include the following catalog slides: San Jose: 1838, 1840, 1912, 1913; and Uaxactun: 2527, 2582, 2105

[4] Our analysis was aided by a number of professionals. We thank Jim Boles (Geology, University of California, Santa Barbara), Mac Beggs (Geology, University of California, Santa Barbara), and Diana Kamilli (University Museum, University of Colorado at boulder) for their valuable assistance.

[5] Ash volume was computed based on samples of ash collected in 1981 in the highlands of Guatemala and on Steen-McIntyre (1978:24) and Shipley (1983:31).

[6] Studies focused on the more recent eruptions are currently being assembled by Rose and others and will provide an important basis for this comparison.

[7] An average eruption of silicic ash discharges around 1 cu. km of material, larger eruption can eject as much as 16-24 cu. km (Williams and McBirney 1979:148).

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