

Archaeological Evidence for Dating the Loma Caldera Eruption, Ceren, El Salvador*

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A Classic Period agricultural village in El Salvador was partially destroyed and encased in pyroclastic debris during the eruption of Loma Caldera about A.D. 590. The eruption was phreatomagmatic in nature, depositing alternating units of "muddy" pyroclastic surge beds and units of air fall lapilli, pumice, and volcanic bombs. This ephemeral eruptive left only a partially eroded collapsed tephra ring. The eruption began with earth tremors and possible steam explosions, giving enough warning to allow the inhabitants of the nearby village to flee, but violent enough that they left behind many of their most valuable personal items. The low temperature of wet ash surge units, which were likely emplaced as "ash hurricanes," preserved much of the vegetation and other botanical remains surrounding the village. Analysis of the maturity of maize preserved in agricultural fields, and the presence or absence of blossoming and fruiting plants indicates that the eruption occurred in the mid-rainy season, probably late August or September. The placement of artifacts within buildings indicate that the eruption occurred in the early evening, after the inhabitants had returned from their agricultural fields and eaten an evening meal, but before retiring for the night. Although the exact year of the eruption can only be estimated within the uncertainty of radiocarbon dating, the season of the year and the time of day can be identified with unusual precision. © 1996 John Wiley & Sons, Inc.

INTRODUCTION

The Ceren Archaeological Site in El Salvador consists of a prehistoric agricultural village and its surrounding landscape which was rapidly buried by pyroclastic debris about 1400 years ago (Sheets, 1992). Loma Caldera, the source of the pyroclastic debris, is 600 m north of the ancient village (Miller, 1992). The nature of the volcanic eruptions that buried the site led to unusually good preservation of almost all cultural materials, including buildings and their contents. Trees, bushes, and crops that grew in agricultural fields, and gardens surrounding the houses were also preserved. Because the eruption occurred with very little warning, the inhabitants fled, leaving most of their personal possessions, making this one of the richest archaeological discoveries in the Western Hemisphere.

* This article was part of the Archaeological Geology Symposium of the 1994 Annual Meeting of the Geological Society of America. Margaret Guccione was guest editor for the Symposium.

Many of the tephra units which buried the village, especially during the initial stages of the eruptive cycle, were deposited as wet surge deposits with a maximum temperature of about 100° (Miller, 1989). The relatively low temperature of these units during emplacement failed to ignite much of the organic material which they encased. Trees, bushes, fruit, and even flowers are almost perfectly preserved as voids which remained in the surge deposits after the organic material decomposed. Some organic material, such as roof thatch, was preserved with little decomposition while other plant material was partially burned or scorched during the higher temperature block and lapilli-fall events, and preserved as carbon residue.

A composite radiocarbon date derived from the mean of six dates performed on preserved roof thatch date the volcanic event at A.D. 590 ± 90 (Sheets, 1983). Although the actual year of the eruptive event can only be estimated within the standard error of radiocarbon analysis, the eruption can be precisely dated to the specific season and even the time of day the eruption began. This is accomplished by studying the seasonality of the preserved botanical remains and the context of artifacts within and around buildings.

VOLCANIC HISTORY

Located along the eastern rim of the Central American convergent plate margin, El Salvador has been an active site of trench-margin volcanism since the early Oligocene (Weyl, 1980). The majority of the surface and near surface rocks in the vicinity of the Ceren Site are made up of Holocene and late Pleistocene pyroclastic material and lava (Hart and Steen-McIntyre, 1983; Weyl, 1980; Williams and Meyer-Abich, 1955).

The Ceren Site is located in the northern portion of the Zapotitan Valley, about 30 km northwest of the capital city San Salvador (Figure 1). The Zapotitan Valley is ringed by large active composite volcanoes, which dominate the landscape. San Salvador Volcano on the eastern flank of the valley is the dominant volcanic complex in the vicinity of Ceren. A large fissure zone, which trends north-northwest from the San Salvador Volcano toward Ceren, was the locus of a number of volcanic eruptions during the last 2000 years, one of which was the Loma Caldera eruption that buried the ancient village (Miller, 1992). Loma Caldera is located about 600 m northeast of the site (Figure 1). Tephra units ejected during the Loma Caldera eruption make up what is called the Ceren Sequence (Miller 1989, 1990).

The Loma Caldera eruption covered at most 25 sq km with pyroclastic debris (Miller, 1993). The Ceren Sequence is 8–10 m thick along the flanks of the vent (Figure 1), thinning rapidly to the north with a thickness of only 10 cm 600 m from the crater (Miller, 1992). To the south and northwest the pyroclastic material thins to 10 cm within 2.5 km. The eruption created a bilobate distribution of tephra with one "tail" of pyroclastic debris trending to the south and one to the northwest. High-level winds may have been blowing from southeast to northwest during the time of the eruption, blowing fine-grained ejecta that

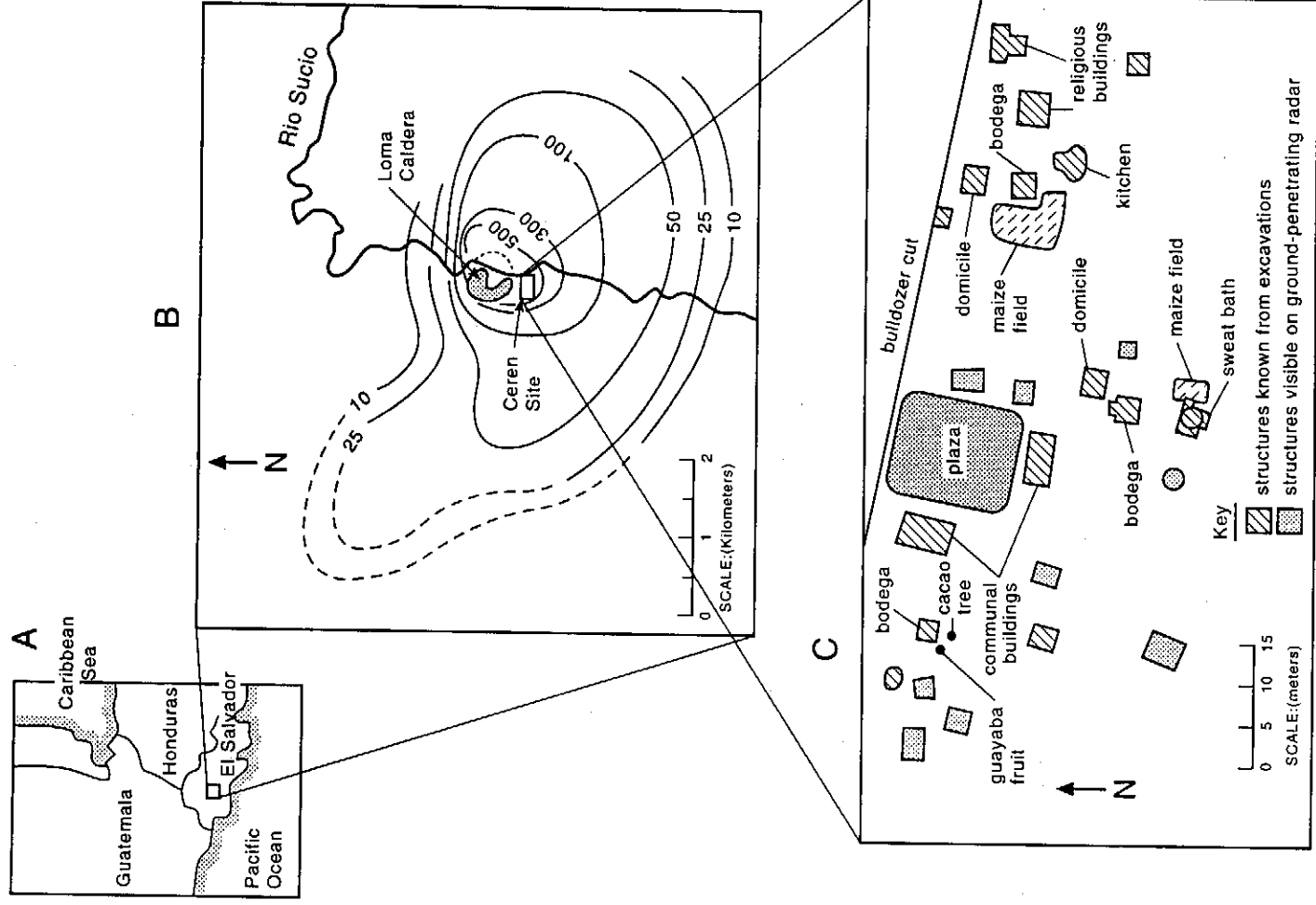


Figure 1. (A) location of the study area in El Salvador. (B) Isopachous map of the Ceren Sequence tephra with respect to the Ceren Site and Loma Caldera. Thickness contours are in centimeters. Modified from Miller (1992). (C) Generalized Ceren site map with the location of structures and their interpreted functions and features discussed in the text.

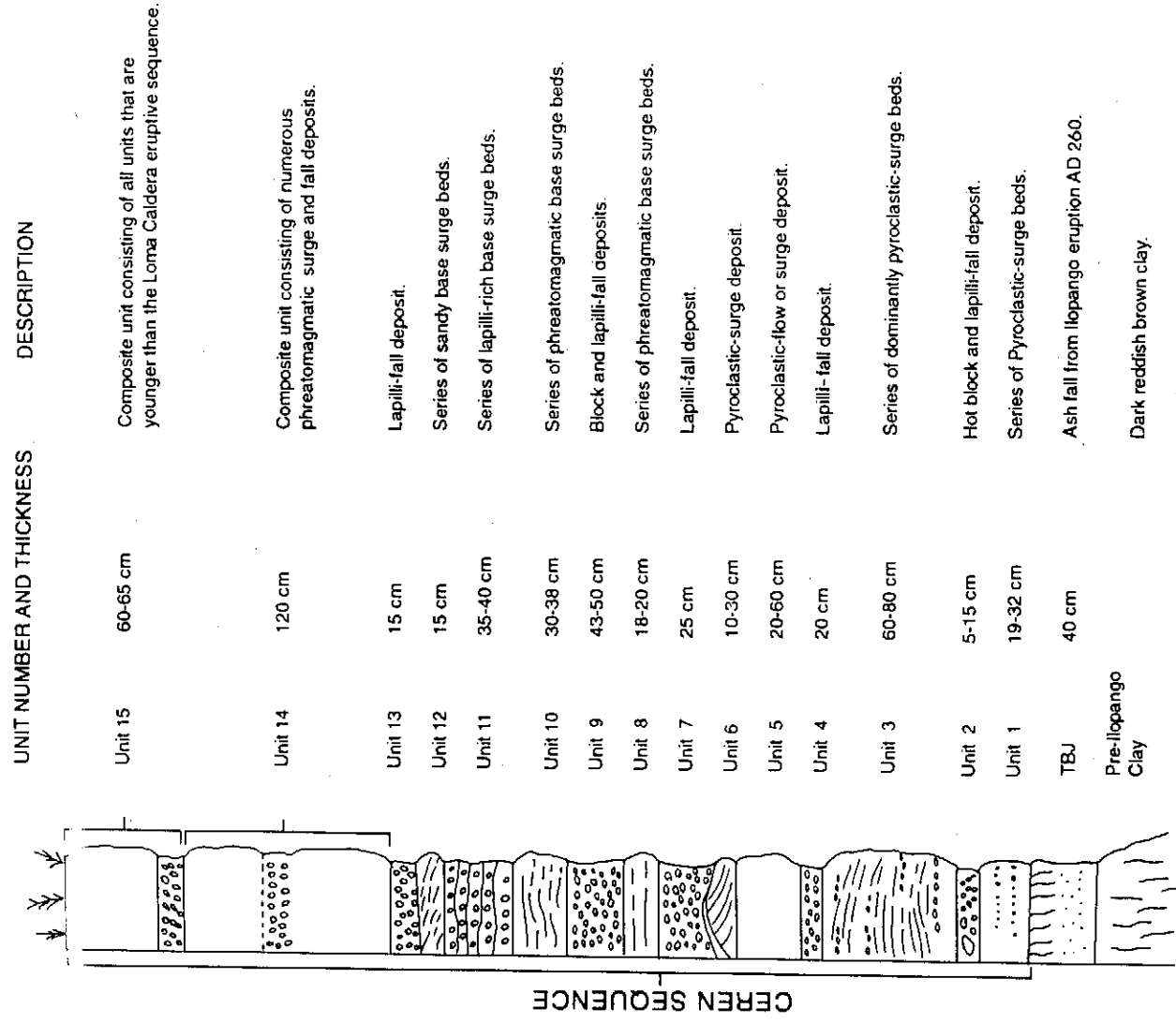


Figure 2. Generalized stratigraphic section of the Cerén Sequence. Units 1–14 were erupted from Loma Caldera. The living surface prior to the Loma Caldera eruption was either the top of the TBJ ash or the pre-Ilopango clay where the TBJ was eroded or removed. Modified from Miller (1989).

direction while the bulk of the surge deposits and coarser ejecta were deposited to the south (Miller, 1992).

Ceren Sequence units are numbered 1–15 (Figure 2). In general, the volcanic

sequence consists of an alternating succession of low temperature pyroclastic surge units and block and lapilli fall beds (Miller, 1989). Air-fall tephra was deposited at very high temperatures, perhaps approaching 575°C (Hoblitt, 1983). The air-fall units, which are massive and friable, contain abundant large ballistic bombs and finer-grained lapilli. The finer-grained surge units are well indurated and exhibit bedding and flow features. They were likely deposited as "muddy" surge clouds of ash, emplaced at temperatures less than 100°C (Miller, 1989). During the initial stages of the Loma Caldera eruption ash surge clouds entered the village at high speeds, perhaps as "ash hurricanes" (Miller, 1989). Their tremendous force pushed over portions of many of the less-substantial walls and columns of buildings.

The Loma Caldera vent is preserved as a partially eroded tuff ring, which is at most 30–40 m high (Miller, 1992). Its eastern rim has been eroded by the Rio Sucio, which flows through the center of the Zapotitan Valley near the Ceren Site (Figure 1). Minor faulting and slumping occurred immediately prior to the eruption of Loma Caldera as a consequence of seismic activity (Miller, 1992). In the eastern portion of the archaeological site, small normal faults and arcuate fissures are exposed on the ancient living surface. Two of these fissures display evidence of water erosion, probably during a rainstorm that occurred during the initial stages of the eruption.

The seismic shocks, slumping, and faulting of the ground surface just prior to the eruption probably gave the inhabitants of the village enough warning to allow them to flee prior to the emplacement of the first ash surge deposit. There may have also been violent steam explosions that preceded the first extrusive event, which would have been visible to the villagers who lived only 600 m away. No human bodies have yet been discovered, although the bodies of one duck tied inside a building and numerous mice and birds have been encountered during excavation (Sheets, 1992).

An outcrop of the Ceren Sequence about 1 km east of the Ceren site shows evidence of a brief lull in the eruption after the deposition of the Unit 3 surge deposit (Miller, 1992). Two small channels were cut into the top of the unit, indicating a brief pause in the eruption, followed by a rainstorm and gullyng by the run-off water. Heavy rain often accompanies eruptions of this sort due to the atmospheric turbulence created by upwelling volcanic ash. This pause in the Loma Caldera volcanic activity probably lasted at most about 3 or 4 h before the eruption recommenced (Miller, 1992).

It is not known how much time elapsed during the Loma Caldera eruptive event. It may have lasted as long as a few weeks or as short as a few days (Miller, 1989). It is certain, however, that the eruption began with little advance warning. The inhabitants of the prehistoric village fled without many of their most precious possessions such as obsidian tools, jade and shell beads, and other ceremonial and religious objects. They obviously had some warning because no bodies have been found, but probably not much more than a few minutes. If the eruption occurred at dusk or after nightfall, the first hot clouds of glowing

ash which blew to the south toward the village may have been visible, creating what must have been a terrifying sight for the fleeing villagers.

⁴A NORTH-DIPPING NORMAL FAULT, which truncates some of the higher units in the Ceren Sequence, is exposed in a quarry about 100 m west of the Loma Caldera rim. The fault exhibits thickening of tephra units on its hanging wall, indicating movement contemporaneous with deposition of the upper tephra units. This growth-faulting along the margins of the vent is probably related to crater collapse during the final stages of the eruption long after the villagers had fled (Miller, 1992).

ARCHAEOLOGY

The archaeological remains of the Ceren site were discovered in 1976 by a bulldozer, which was leveling a hill prior to the construction of grain silos (Sheets, 1992). Along this bulldozer cut, two structures and portions of preserved agricultural fields were exposed on the ancient living surface. To date 15 structures have been identified by excavation, 11 of which have been completely excavated (Figure 1). Portions of gardens, agricultural fields, and other human use areas have also been exposed in limited excavation areas between buildings. Approximately 900 sq m of the site have been uncovered in four major operations and scattered test pits. The unexposed portion of the archaeological site likely covers many tens of hectares.

Excavations have exposed portions of an agricultural village that existed on the southern periphery of the Maya area (Sheets, 1992). Each building in the village was constructed of adobe with thatch roofs. Households consisted of multiple structures for various uses, clustered together into units where families or extended families lived. From the archaeological data available, it is known that the structures which made up each household cluster were separated from each other by gardens and agricultural fields and connected by footpaths.

Buildings within each household cluster included a domicile for eating, sleeping, and daytime activities (Sheets, 1992). In addition, each household unit had one structure which served as a storehouse (*bodega*) and one as a kitchen. There were also other buildings, such as covered work areas, in the vicinity of the residential centers. So far three household clusters have been wholly or partially excavated (Figure 1) and others have been identified nearby using ground-penetrating radar (Conyers, 1995).

Other buildings have been discovered that did not have residential functions (Figure 1). These structures include a large domed sweat-bath and a communal building, where maize beer may have been dispensed from a large ceramic vessel. Artifact and architectural evidence suggests that one excavated structure was used by a religious association and another by a shaman for ritual activities (Sheets and Simmons, 1993).

Bodegas were built close to domicile and kitchen structures. They were constructed like domiciles, but lacked sleeping and sitting benches. A wide

variety of artifacts and stored foodstuffs have been discovered in bodegas, including ceramic vessels full of seeds, cribs with dried maize, and hanging chile peppers.

Evidence of maize and other plants growing in fields were encountered as hollow cavities during excavations. They are preserved as casts when the cavities are filled with dental plaster during excavation. Maize was planted in bunches of three to four plants, in rows aligned along ridges (Sheets, 1992; Zier, 1982). Each maize grouping was located about 80 cm apart along the ridges.

Evidence for arboriculture was also uncovered. Guayaba fruits and seeds were found on the ancient living surface and some large branches were encountered which had blown off trees in a nearby orchard by the volcanic eruption (Gerstle, 1990, 1992). A cacao tree in blossom was also preserved in the orchard (Gerstle, 1990; Sheets, 1992).

Samples were collected for microbotanical and pollen analysis from all excavations at the site (Lentz, 1993). Preliminary analysis of these botanical remains demonstrates that the prehistoric inhabitants had access to a wide variety of food, spice, and medicinal plants. Among the plant remains identified in these samples are maize, squash, cacao, avocado, manioc, beans, and numerous fruits, spices, and medicinal plants. A large variety of bean seeds were recovered which have produced the most extensive collections of bean species from an archaeological site in Mesoamerica (Lentz, 1993; Sheets, 1995, personal communication).

The majority of the plant remains recovered were domesticated varieties, indicating that the Ceren inhabitants had a vast horticultural knowledge and a varied diet. It is likely that orchards of avocados, guavas, nance, and cacao were located close to the village with maize, manioc, and maguey gardens located in small "in-fields" surrounding the buildings (Lentz, 1993).

DATING THE INITIAL STAGES OF THE LOMA CALDERA ERUPTION

Seasonality

Dating the Loma Caldera eruption to the season can be accomplished by studying the preserved botanical remains. One of the best seasonal indicators at the Ceren Site is the maturity of cultivated maize. Four ancient agricultural fields have exposed maize plants in growth position (Kievit, 1992; McKee, 1990; Moble-Tanaka, 1990; Tucker, 1990; Zier, 1982).

In El Salvador, tropical rainfall patterns are highly seasonal, with the rainy season extending from May through October during which 94% of the total annual rainfall occurs (Daughtery, 1969). Because of the distinct seasonality of moisture available for plants, modern agriculturalists in El Salvador, who do not rely on irrigation, must carefully time planting and harvesting around the yearly wet and dry seasons. The prehistoric farmers of Ceren were also

subject to these same seasonal patterns and undoubtedly practiced many of these same agricultural practices.

Local farmers must plant many of their crops just prior to, or during, the first few weeks of the rainy season in order to assure that enough moisture will be available for seed germination and plant growth. In recent times the first maize planting in the Ceren area usually occurs in the first few weeks of May. Maize grown by traditional agriculturalists will usually reach maturity in late August, about 120–140 days after planting (Stadelman, 1940). Usually the majority of that maize crop is left to dry in the fields until harvested in October or November. Contemporary farmers in Central America, who still practice traditional agricultural methods, will many times harvest a portion of the first maturing ears of maize in what are termed roasting ears or “green corn” (Stadelman, 1940; Wilken, 1987). That portion of the field which was harvested is then immediately replanted in order to obtain a second crop. This planting practice is conducted partially as a method of risk aversion to overcome the vagaries of rainfall during any one rainy season. Because the duration, amount, and timing of rainfall usually varies year to year, second plantings are often made in case the rainy season is extended past October, which would allow for a second crop. The early crop of “green corn” is then consumed soon after it is harvested.

In one preserved agricultural field, two areas of contrasting maize maturity were found (McKee, 1990; Tucker, 1990; Zier, 1982). One portion of the field contained maize developed on large mature plants with ears 15–20 cm long, while the adjoining portion contained juvenile plants about 40 cm high with ears only 10 cm or less in length (Tucker, 1990). It is likely that the fully mature maize represents the first planting which occurred in May and matured 120–140 days later, thus dating the eruption to late August. The juvenile maize plants probably represent a second maize planting, which occurred after some of this first crop had been harvested as “green corn.” The presence of the juvenile maize about 4 weeks old, points to an early September date for the eruption, assuming the rainy season that year began in May. The presence of immature maize still in fields at the end of the rainy season in October is not conceivable. Moisture is rarely available to bring a maize crop to maturity after that time, and it is doubtful the prehistoric farmers would have wasted seed on a planting this late in the growing season.

Mature ears of maize were discovered in one ancient field with stalks which had been purposely bent over and left hanging (Figure 3), a method of field drying that is still used by the local traditional farmers today during the middle to late rainy season (Figure 4). Doubling over facilitates drying during the mid-rainy season because the husks shed rain water and the bending of the stalks cuts off water and nutrients from the roots, speeding the field drying process. The presence of maize with stalks doubled over (Figure 3) indicates that the rainy season was still under way at the time of the eruption, also supporting a mid-rainy season date for the eruption.



Figure 3. Plaster case of a void in the Ceren Sequence tephra which represents a 6th century maize plant, with one bent over mature ear. This plant was found in a preserved field where all the ears had been bent downward, a method which allows the kernels to dry during the mid-rainy season. Photo by P.D. Sheets.

Beans made up a very important part of the prehistoric diet of Ceren (Lentz, 1993). The majority, which were discovered mixed together in storage containers in bodegas, are domesticated varieties, with a few wild types. It is interesting, however, that the only evidence of beans growing in fields are a few possible juvenile plants in one of the maize fields (Tucker, 1994, personal communication). It is possible that fields devoted to beans have not yet been discovered but their absence may indicate that they had not yet been planted, which can be used to imply seasonality.

In El Salvador today beans are usually not planted until the rainy season is well advanced so that the staple crop, maize, can be allowed to develop without competition. Beans are then planted after the maize plants are quite high, and the runners are allowed to grow up their stalks and along the ground between rows. The abundance of beans in storage, but an almost complete absence of plants in any of the fields indicates that beans had not yet been planted, or had not yet germinated at the time of the eruption. If the ancient

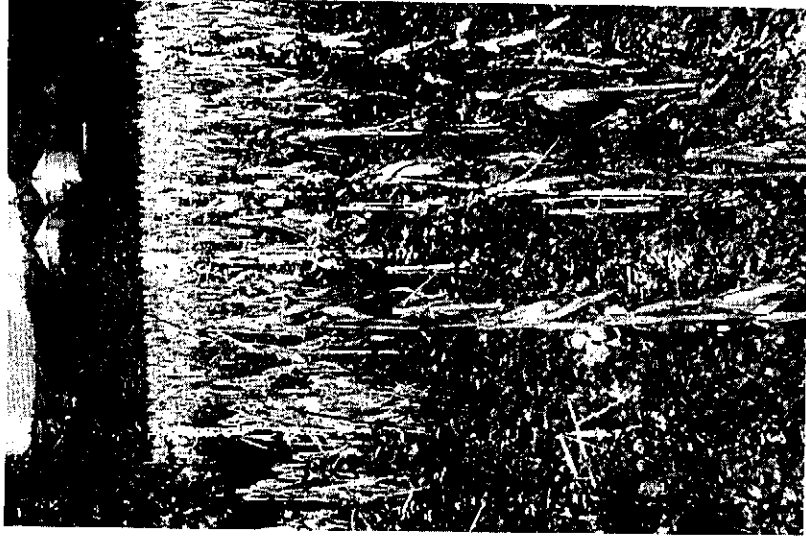


Figure 4. A modern maize field located about 200 m from the Ceren archaeological site. Maize ears were being field dried by bending over the stalks using the same method employed in the 6th century. The photograph was taken in September. Photo by P.D. Sheets.

Ceren farmers practiced this same bean cultivation method, then a mid-rainy season can also be inferred as the season of the eruption.

Chile peppers were discovered bunched together for drying inside the three excavated bodegas (Gerstle, 1990). No chile bunches were discovered hanging outside, which is a common practice today only during the dry season, also supporting a rainy season time for the eruption.

A cacao tree, approximately 30 cm in height, which had blossoms growing from its trunk (Figure 5), was discovered in one excavation (Gerstle, 1990). Cacao blossoms are white hermaphroditic flowers which are pollinated by small crawling insects, usually at night and in the early morning hours (Hansen, 1983). If not pollinated in a 24-h period, they usually fall off. Although flowering can occur throughout the year, the majority of blossoming occurs in the rainy season, with cacao bean harvest usually occurring during the dry season about 5 months later. The presence of cacao blossoms supports a rainy season burial, but their presence is not a definitive indicator because minor blossoming can sometimes occur throughout the year.



Figure 5. Plaster case of a 6th century immature cacao tree with an attached blossom on its trunk, which was encased in volcanic ash. Photo by A. Gerstle.

Guyaba fruit, which was nearly ripe (Figure 6), was discovered on the ancient living surface in many of the excavations (Gerstle, 1990). The fruit was likely blown off nearby trees during the initial stages of the eruption or during rainstorms which immediately preceded it. These trees, which usually reach heights of 7 m, are today mostly planted for ornamental purposes in Central America (Beach, 1983), but their fruit is also edible and likely made up a part of the prehistoric diet of Ceren. In El Salvador, guayaba fruit usually begins to ripen around late August or early September.

From the botanical evidence the most likely season for the eruption is late August or September, which is midway through the rainy season. This is best confirmed by the presence of two different maturities of maize. The lack of growing beans, but the presence of cacao blossoms and ripe guayaba fruit also support this time of the year for the eruption.

Time of Day

A number of lines of evidence indicate that the initial phases of the eruption occurred during the early evening. The placement of agricultural implements



Figure 6. Plaster case of a 6th century guayaba fruit on the left and a modern guayaba fruit on the right. The modern fruit was collected from a tree near the site in early September. Photo by A. Gerstle.

and sleeping mats, and the lack of cooking vessels on fires in the kitchen, all point toward a time period after the evening meal had been consumed but prior to bedtime.

In traditional Mesoamerican farming villages, most of the field workers spend a good portion of each day, especially during the rainy season, in their fields with their agricultural implements. This is especially true during the mid-rainy season when maize fields are hoed often to discourage weed growth, prior to planting beans between the maize plants (Vogt, 1970). Contemporary farmers almost always carry their tools home for the night after a day's work, storing them outside their houses, usually under the eaves. The artifact assemblage discovered next to houses at Ceren includes one well preserved digging stick, which was leaning against the outside wall of a building, and numerous digging stick weights, which had likely been attached to sticks that were not preserved. This placement indicates that the eruption occurred after the field workers had returned home in the evening or possibly prior to leaving in the morning.

During the daytime in traditional Mesoamerican households, fires are usually kept burning in the hearth, with a pot simmering ingredients for the next meal (Sheets, 1992). In the one kitchen structure excavated, only ashes and a few pieces of charcoal remained in the cooking fire, suggesting it had been allowed to die down after the evening meal had been finished. The cooking pots in this kitchen were empty and had been placed away from the fire, also indicating that food preparation had ceased for the day.

A number of ceramic cooking and serving vessels were discovered in domicile structures. These vessels contained the remains of food which had recently been consumed, and some of the serving bowls still exhibit finger swipes, probably made by the last person to eat from them. They had been stored away in niches and on shelves, perhaps after the evening meal. Some of the vessels were "nested" inside one another, with a large upturned vessel on the top, possibly to keep away flies or other vermin prior to washing.

Sleeping mats were preserved in the rafters of domicile buildings where they had been stored during the day. They had not yet been laid out on the sleeping benches for the night when the eruption occurred. If the occupants had fled after they had retired for the night, these mats would undoubtedly have been left on the sleeping platforms and not placed back in the rafters in their haste to escape the eruption.

Although each individual association of artifacts is not in itself definitive as to time of day, the integration of all lines of archaeological evidence points to early evening as the time of day when the eruption first commenced and the people abandoned their village.

CONCLUSIONS

The eruption of Loma Caldera occurred with little warning about A.D. 590, burying the agricultural village of Ceren with more than 5 m of pyroclastic debris. Erupted material covered an area of approximately 25 sq km, obliterated any trace of habitation and agricultural fields. The emplaced tephra alternated between wet ash surge deposits and hot block and lapilli falls. During the final stages of the eruption the crater collapsed, leaving only a depositional tuff ring surrounding an interior depression.

The exact year of the eruption is not known and can only be estimated from radiocarbon dates on preserved roof thatch. Preserved botanical remains which are indicative of seasonality, however, point to a mid-rainy season eruption, probably late August or the month of September. Evidence suggests that the eruption began sometime in the early evening, as indicated from the artifact placements within and around preserved structures. Agricultural implements had been returned from the fields, the evening meal had been prepared and consumed, and the sleeping mats had not yet been placed on the sleeping platforms within domicile structures.

The villagers were warned of the impending eruption by seismic activity accompanied by steam explosions from the vent, which opened up only 600 m northwest of their village. Their escape, accompanied by a rainstorm, was likely to the south, away from the source of the glowing ash hurricanes, which rapidly buried their houses and fields.

I am particularly grateful to C. Dan Miller of the U.S. Geological Survey, Cascades Volcano Observatory for introducing me to the volcanology of the Ceren Site. Most of the volcanological data presented in this article are derived from his field work, although all errors or omissions are

mine alone. Payson Sheets and Andrea Gerstle were helpful in numerous discussions and for supplying the photographs used in this paper. Thanks go to Margaret Guccione for organizing the symposium at the Geological Society of America Annual Meeting in 1994, where this article was presented.

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Received November 8, 1995

Accepted for Publication February 9, 1996