ILOPANGO VOLCANO AND THE MAYA PROTOCLASSIC

A report of the 1975
field season of the
Protoclassic Project
in El Salvador.

"Just as the progress of a disease shows a doctor the secret life of a body, so to the historian the progress of a great calamity yields valuable information about the nature of the society so stricken."

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INTRODUCTION

Twice in the past few years it has been observed that the vast majority of archaeological research in Southern Mesoamerica has been performed in the Maya Lowlands, particularly in the Guatemalan Peten and environs (Adams 1969, Sharer 1974). This is not surprising, for it is the area where Classic Maya Civilization reached its full florescence. However, the Lowland Classic Maya cannot be understood <u>in vacuo</u>, and it is proposed here that one of the long-standing enigmas of Maya research may have its explanation in the Southeast Maya Highlands.

Numerous Lowland Maya excavators over the past seventy years have noted the sudden appearance of new styles of artifacts in the lowland sites at about the time of Christ (best summarized and illustrated by Willey and Gifford 1961). Potential explanations have been offered, including (1) that a new trade connection had been opened up, resulting in a sudden importation of foreign goods, and (2) that a migration had occurred, with the migrants bringing in their artifacts or at least their standards regarding what their artifacts must look like and how to make them. Uncertain as to the source of the trade goods or the migrants, Mayanists have posited two source areas as the most likely: The Southeast Maya Highlands (Guatemalan-Salvadoran Highlands) or the Eastern Highlands (the Ulua drainage basin of Honduras).

Research in El Salvador has now provided a clue as to the solution of both aspects of the problem, for it now appears likely that the densely-populated SE Maya Highlands was devastated by a massive natural disaster which forced some large migrations to the lowlands (Sheets 1971:25-31, Sharer 1974:172). Volcanic ash deposits in numerous locations in El Salvador have been found to bury Preclassic artifacts. We now need to answer the following questions: are these ash deposits from the same eruption, what was the total area affected, do the kinds of artifacts they made just prior to the eruption in the devastated area match the intrusive artifacts in the lowlands, what was the date of the eruption, and what was the nature of the pre-eruption settlement density and adaptation. Therefore, the hypothesis being tested by this 1975 research is that the introduction of Protoclassic (i.e., terminal Preclassic) artifacts into the Maya Lowlands was directly caused by the eruption in the SE Maya Highlands. The eruption, then, must be found to be of sufficient magnitude and short duration to render a substantial area of the SE Maya Highlands uninhabitable for at least a generation.

DESCRIPTION OF THE AREA

El Salvador, at 13 to 14° N Latitude, lies within the tropics (Fig. 1). However, the heat and humidity of the tropics are ameliorated by both elevation (Chalchuapa and San Salvador are at elevations approximating 2,000') and the fact that Salvador lies entirely in the Pacific watershed. The Pacific side of Central America receives rain on a seasonal basis, whereas the Caribbean side tends to receive convectional rain throughout the year. In fact, my own calculations, based on twenty years of records, indicate that fully 94 percent of the precipitation at Chalchuapa falls in the six-month rainy season which begins in May. The annual precipitation in central and western Salvador ranges from 1,500 to 2,000 mm in most years. Most of eastern Salvador receives between 1,000 and 1,500 mm.

The present topography of Salvador, dominated by the chain of some twenty major volcanoes, is predominantly a product of Pliocene and Pleistocene volcanism. Sedimentary and metamorphic formations exist only in the northern edge of the country. A further description of drainage, topography, and geology is presented by Sharer (1968), by Sayre and Taylor (1951), and by Williams and Meyer-Abich (1955).

HISTORY OF RELATED ARCHAEOLOGICAL RESEARCH

A chronologically-ordered review of related archaeological and geological research not only provides a perspective on the contemporary research, it also provides a summary of our knowledge on the topic. Resumes of previous archaeological investigations in Salvador are numerous; the most extensive accounts may be found in Longyear (1944, 1966), Sharer (1968, 1974, and 1975), and Sheets (1974). In brief, the earliest comments on archaeological remains in Salvador were made in the mid-Nineteenth century by Squier (1855). Squier (1855:313) was also the first to note the extensive volcanism of Salvador, commenting that the country "comprehends more volcanoes, and has within its limits more marked results of volcanic action, than probably any other equal extent of the earth."

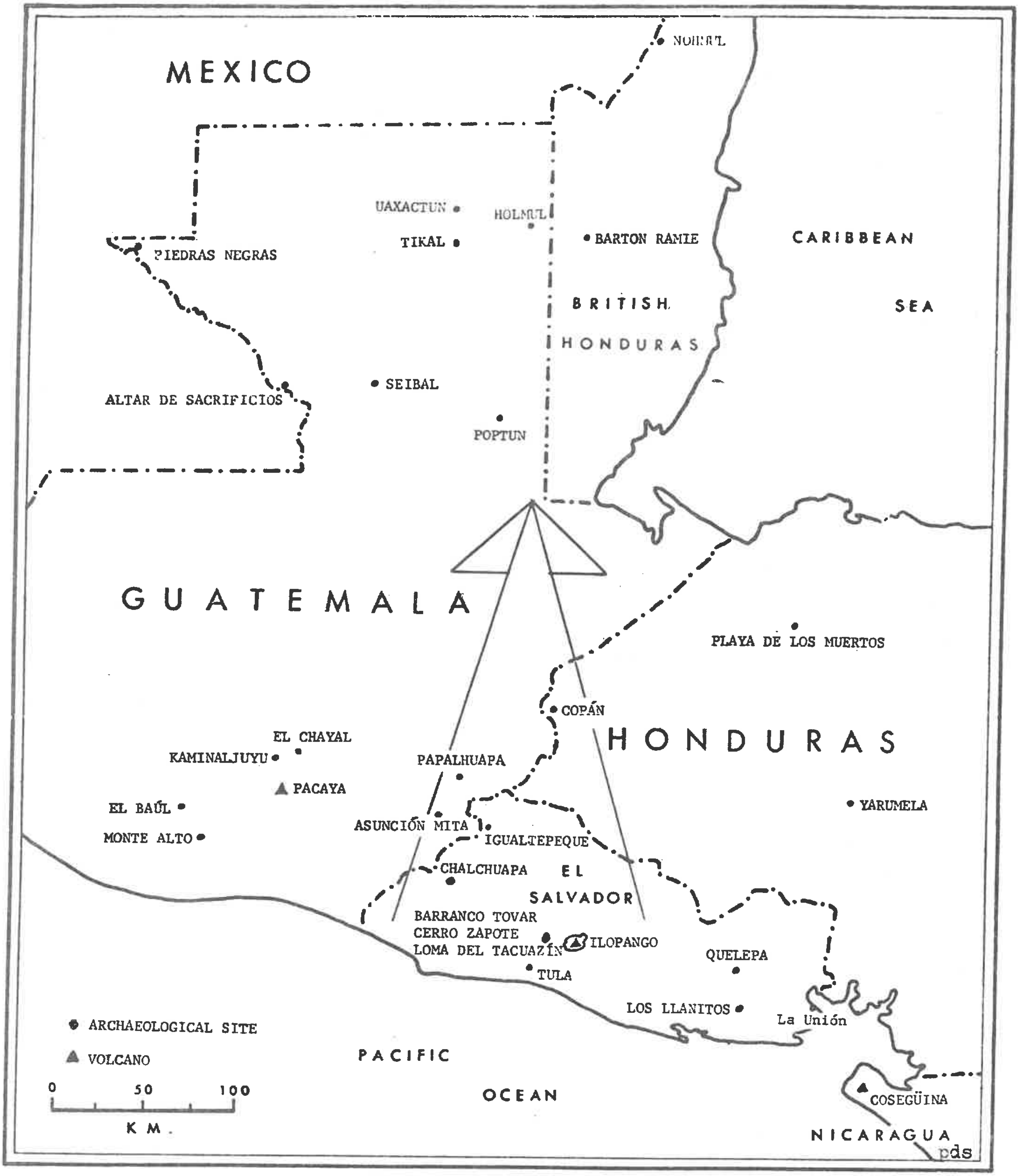


FIGURE 1. Map of sites in the Southeast Maya Highlands (El Salvador) devastated by the eruption, and sites in the Maya Lowlands (N. Guatemala, British Honduras) affected by population movements.

Spinden (1915) attempted the first descriptive synthesis of Salvadoran archaeology, and the outlines of his chronological scheme are generally valid today. His stylistically-derived periods are Archaic (Preclassic or Late Formative), Maya, Post-Maya Toltec (Postclassic), and Aztec.

It was not until Lardé (1926) began his investigations around 1920 that the era of scientific excavations begin in Salvador. Lardé is to be credited with the discovery of the stratigraphic relationships consisting of the early humic horizon with the artifacts buried by the volcanic ash layer, capped by the present humic horizon (see Fig. 27). Lardé's interest in volcanology began with the eruptions of Volcan San Salvador in 1917, and during the subsequent few years he encountered a site along the Rio Acelhuate (San Salvador area) with these stratigraphic relationships. He was able to determine that the humic horizon with artifacts buried by the ashfall was not an isolated occurrence, but in fact spread for a great distance. Further, he demonstrated that the artifacts in the buried humus were not intrusive, but were contemporary with the ancient soil zone.

Lothrop (1927) capitalized on Lardé's findings, publishing an extensive account of his excavations at Cerro Zapote, some 17 km west of the center of Lake Ilopango (Fig. 1). Lothrop's B layer (the volcanic ash, see Fig. 26) at Cerro Zapote is over 40' (12 m) thick.

Lothrop's C horizon is the buried humic zone containing Preclassic artifacts. Artifacts encountered included pottery vessel fragments, a figurine head and torso, and fragments of obsidian tools. Lothrop (1927: 173) correctly attributes them to the "Archaic," or what we now call the Preclassic or Formative. The figurine head (Lothrop 1927, Fig. 4h) is comparable with Sharer's Type 1 (1968:269, 271, Fig. 55a-c), which dates to the later Preclassic at Chalchuapa. Lothrop describes the decoration of the C-level pottery as having the appearance of a multiple-applicator wax resist technique resulting in lighter lines against a darker orange slip. His description is of pottery now called Usulutan, which also dates to the Preclassic, and predominantly to the later Preclassic (Sharer and Gifford 1970:445-446).

Lothrop's A horizon (Fig. 26) is the humic soil which has developed during the past two millenia on top of, and out of, the B layer ashfall. It contains the artifacts of the reoccupation of the SE Maya Highlands.

Lothrop (1927:182-202) quite correctly recognizes the Lowland Classic Maya character of the artifacts, which indicates that the Classic Period reoccupation was from a northerly direction.

One other locality is mentioned by Lothrop (1927:177) as having the same A-B-C horizon stratigraphic relationships as Cerro Zapote, but he was unable to confirm the report by actual field investigations. The report is from a locale near San Miguel, 90 km due east of Ilopango.

Lothrop (1927:214-215) summarizes his view of the impact of the ash-fall-eruption as having "rendered central Salvador uninhabitable...for a long time, as no remains are to be found for several feet above the lowest archaeological floor."

Archaeology languished in Salvador between the early work of Lardé and Lothrop in the 1920's and Dimick's excavations at Campana San Andrés, which began in 1939. Dimick (1941:29) encountered the same stratigraphic relationships of early artifacts in a soil horizon buried by a 25 cm thick layer of volcanic ash (eroded?), superseded by reoccupation and continued construction. It is highly likely that these directly correspond to Lothrop's A, B, and C horizons, but this remains to be firmly demonstrated. Significantly, San Andrés is located half-way between Chalchuapa, where the same strata have been found, and Ilopango, the apparent source.

Longyear spent eight months in El Salvador in 1941 and 1942 conducting an extensive archaeological survey of the entire country, and conducting some excavations in the small eastern Salvadoran site of Los Llanitos. Los Llanitos is located 100 km ESE of Volcan Ilopango, or 15 km south of San Miguel. Longyear (1944:45) dates Los Llanitos to the Late Classic, viewing it as a single-component site. He did encounter some intriguing traces of a volcanic eruption which deposited a white ash in the area prior to occupation. White ash was encountered in an evidently secondary deposit under the sloping slabs of the ballcourt surfacing. Also, the fill of Mound 3 was found to consist of a "fine-grained, almost white volcanic ash, completely lacking in cultural material of any kind" (Longyear 1944:32). The low, rectangular Mound 10 was found to have at its base a stratum of light-colored and artifactually-sterile volcanic ash in a primary deposit. Only revisiting the site and retesting the remaining structures for ash samples and stratigraphy will divulge the source of the ash. Ash thickness under Mound 10, judging from Longyear's illustrations, appears to be approximately 30-40 cm.

The discovery of a humus-ash-humus stratigraphy, very similar to that of Lardé and Lothrop, was reported by Boggs (in Longyear 1944:53-54) at Tula, a few km north of La Libertad, and some 30 km SW of Ilopango (in this report distances to Ilopango are measured to the center of the lake). Boggs claims that he found sherds toward the bottom of the volcanic ash layer (but not at the top of the buried humic layer?), and that because no complete vessels were encountered during his excavations, he concludes that the evidence indicates "a temporary camp of people wandering about during an eruption in search of safety, water, and food" (Boggs in Longyear 1944:54). At least Boggs is the first investigator to try to visualize what the white ash layer would have meant in human terms. The site of Tula deserves a careful geological and archaeological re-examination.

Boggs (personal communication, 1970) also had encountered a layer of white volcanic ash in his excavations at Tazumál (Chalchuapa) in the early 1940's. The ash layer was overlying a humic horizon and a prepared plaza surface at the edge of a structure. The layer of "sandy yellow soil" overlying the "dark brown soil" at Tazumál (Boggs, Fig. 29 in Longyear 1944:58) may well be the same strata as Lothrop's B anc C horizons. Boggs also informed Sharer (1968:301) of having encountered a volcanic ash deposit between construction phases at Tazumál.

Only a couple of years later, in 1946, Boggs (1966) assisted in the excavation of three "burial urns" and two jars under volcanic ash some 3 km southwest of San Salvador. The site, called Loma del Tacuazín, is located on an exposed hilltop. The site exhibits Lothrop's A, B, and C horizons as well as the D (underlying pumice-ash) layer. Judging from the exposed and elevated topographic location as well as the appearance of the ash (Boggs 1966:Figs. 3 and 4), the ash is a primary deposit. Estimating from Boggs' Fig. 2, the ash layer is presently some 90 cm thick. How much has been removed by two millenia of erosion is not possible to estimate at present. Numerous sherds, indicating nearby habitation, were encountered in the buried humic horizon (C), and the whole vessels were located 125 cm below the top of the buried humus in what may have been an intrusive pit. The vessels contained human bones, clearly a secondary burial, and it appears likely that the burial is contemporary with the C horizon occupation.

Further evidence of contemporaneity is the formal similarity noted by Boggs (1966:179) between the C layer sherds and the burial urns. Jar 2 carries as decoration a "low appliqued fillet, chain indented by blunt thumb impressions" (Boggs 1966:180). This decorative technique is characteristic of the Jocote ceramic group in western El Salvador, which dates to the Middle Preclassic (Sharer and Gifford 1970:Figures 5 and 6).

Boggs (1966:182-183) attributes the Loma del Tacuazín ashfall to Volcan San Salvador, basing this on earlier geological reports by Williams and Meyer-Abich (1953) and Weyl (1952). More recent evidence, presented below, indicates that the more probable source of this ashfall was Ilopango. Also, there is disagreement on whether there was a single eruption, as indicated by more recent evidence, or whether there was a series of eruptions, as claimed by Boggs (1966:183, 184).

Other mentions of the discovery of Preclassic artifacts under a white ash layer, yet to be published, are mentioned by Boggs (1966). They include the Hospital Cardiovascular site in San Salvador and the Modelo Bridge site in southern San Salvador. Construction at the former site uncovered a dense deposit of occupation debris in a humic horizon buried by white ash. At the latter site, figurines stylistically dated to the Preclassic were found with potsherds in a compact humic soil at the base of the Rio Acelhuate, upstream from Lothrop's Cerro Zapote site.

Again in San Salvador, at Barranco Tovar, Porter (1955) excavated over 3,000 potsherds, 47 pieces of obsidian, two metates, and charcoal in a humic horizon buried by a thick (primary?) deposit of white ash. She reports that ash layer to be between 10 and 20 m in thickness around San Salvador. Porter obtained one C14 date, run in the early 1950's, when the method was not too reliable, of 1040 $\pm$ 360 BC. This date now seems to be about a millenium too early. Barranco Tovar is unfortunately no longer available for re-sampling because it has now been bulldozed and a large apartment building has been built upon it (Boggs, personal communication, 1970).

The largest-scale and longest-duration archaeological project in El Salvador was sponsored by the University of Pennsylvania and the Ford Foundation at Chalchuapa, 75 km WNW of Ilopango. William Coe (1955) spent the 1954 field season excavating the Preclassic pyramids of El Trapiche, at the northern edge of the Chalchuapa site zone. Sharer (1968) continued Coe's excavations and research strategy in 1967, and subsumed both in his Ph.D. dissertation at the University of Pennsylvania. Full-scale operations in 1969 followed Sharer's testpitting program in 1968. These operations involved settlement pattern surveys, mapping, excavations in all the major pyramid clusters, and excavations in the extraordinarily important Lago Cuzcachapa strata (Sharer 1969, 1974). The 1970 season focused on excavating Classic and Postclassic materials, lithic workshops, and other specialized materials. The full report is now available (Sharer 1976).

We now know that by the end of the Preclassic, prior to the volcanic eruption, Chalchuapa was one of the major centers of those "vigorous Preclassic Highland Maya cultures" (Sharer 1974:172) first recognized by Shook and Kidder (1952:213-214) at Kaminaljuyu. Chalchuapa itself was a large ritual, trade, and residential center located in the center of a broad, fertile basin averaging 700 m in elevation. Some idea of its size and importance can be gleaned from the fact that just the central ritual zone of the site, characterized by formal groups of pyramids located on massive, artificially-leveled plazas, occupied an area more than 2 km in length. An architectural renovation and expansion program was in progress at the time of the eruption (Fig. 27), and it was summarily abandoned for some time. Various indigenous industries at Chalchuapa engaged in by occupational specialists include architect-contractors, religious-political leaders, and traders.

Deposits of white volcanic ash capping Late Preclassic archaeological materials embedded in a rich, black humic horizon were encountered in numerous places by Chalchuapa Archaeological Project staff members. The seven specific locations encountered in the Trapiche area during 1954 and 1967 operations are summarized by Sharer (1968:301), and they are subsumed into his Time-span 2, dating to ca. AD 200 to 300. From the data at his disposal, Sharer was not sure whether El Trapiche was abandoned immediately prior to the eruption, or whether the ashfall caused the abandonment. The source was unknown to him at the time; he speculated that either Volcan Chingo or Volcan Santa Ana might be the source. Sharer (1969:36-37) felt that the deliberate mutilation of monuments (stelae and other stone sculptures) was done as an immediate response to the first stages of the eruption, for the smashed monuments were encountered immediately under the ash.

The white ash layer sealing Preclassic deposits was encountered in numerous places in the Casa Blanca mound group, in the center of the Chalchuapa site zone. Excavations in Structure C3-6, conducted by the Principal Investigator in 1969, divulged the familiar humus-ash-humus stratigraphy, with Preclassic artifacts in the lower humus, along with a new discovery. The Preclassic inhabitants were actually in the process of surfacing ("plastering" with a clay-pumice mixture) the pyramid when the eruption struck. Figure 27 illustrates this: Feature (F) 6 is the uncompleted surfacing immediately overlain by the volcanic ash (F. 10). Some two centuries later, with the re-establishment of a humic horizon by chemical and mechanical weathering and plant recolonization, the area was reoccupied and Structure C3-6 was remodeled (F. 11). The remodeling utilized the same technology, using available materials, but it differed stylistically from the pre-eruption architecture. Finally, the pyramid was enlarged and resurfaced (F. 13). The present thickness of the ash layer in Chalchuapa varies considerably in different locations, depending upon topography, weathering, exposure to plant roots, cultivation, and so forth. The thickest primary deposits found to date at Chalchuapa measure approximately 60 cm, indicating that prior to compression, disturbance, and erosion the original thickness of the ash layer was probably greater than a meter.

The clearest stratigraphic relationships were exposed at Lake Cuzcachapa (see Sharer 1974, particularly Fig. 5), where fourteen layers of culture-bearing lakeshore and bottom sediments were capped by the white volcanic ash. The fourteen layers span the Preclassic, from ca. 1000 BC at the bottom to ca. AD 200 immediately below the ash layer. Above the ash layer are three layers composed of predominantly Classic deposits.

Based on the archaeological evidence collected at Chalchuapa, we are presently able to date the eruption to sometime between AD 1 and 300. Geological evidence collected by the German Geological Mission yields a corresponding date (H.S. Weber, personal communication 1974). Their C14 dating places the Ilopango eruption at AD 260 $\pm$ 85.

Sharer and Gifford (1970) recently performed a detailed comparison of Chalchuapa and Barton Ramie pottery. They found some extremely close stylistic resemblances between a number of ceramic artifacts of the terminal Preclassic in Chalchuapa and the Protoclassic at Barton Ramie. These include Aguacate Orange pottery (which they were not able to distinguish on a typological level!), mammiform tetrapod vessels, Usulutan-decorated ceramics, polychrome, and a post-firing stucco and painting decoration; all occur developmentally at Chalchuapa and suddenly at Barton Ramie.

There is a hiatus in the archaeological record at Chalchuapa between the end of the Preclassic and the Early of Mid-Classic, which evidently was due to the volcanic diaster. Its duration could have been as brief as a generation or as long as 200 or 300 years. It is clear, however, that Chalchuapa and the Southeast Maya Highlands never recovered the prominent political and cultural position which they occupied during the Preclassic (Sharer 1974:172). Chalchuapa remained henceforth a recipient area instead of a donor area, i.e. Chalchuapa was transformed from an innovator into an emulator. In fact, Sharer (1975) is presently investigating the possible impact of the eruption on the trade networks of the Preclassic. Sharer feels that the eruption may have severed the major southern trade route (Salvador-Xoconusco-Tehuantepec-Central Mexico), causing a far heavier reliance on the trans-Peten route in the Classic, with a Postclassic shift to the circum-Yucatan route following the collapse of the Classic Maya in the Peten (Sabloff and Rathje 1975).

Sharer's recent summary paper (1974), which incorporates the preliminary volcanologic-Protoclassic findings of an earlier paper (Sheets 1971), presents an interpretive culture history of Chalchuapa from 1000 BC to AD 1500. It received a generally favorable reaction, but one of the areas of controversy centered around the volcanic eruption and its effects, all of which emphasize the need for focused research on the problem. Among the comments on Sharer's article, Green (in Sharer 1974:177-178) feels that the Protoclassic phenomenon in the Maya Lowlands, previously puzzling to Mayanists, is partially explained by the eruption, but that it "awaits further documentation." On the other hand, Hammond disputes the connection between the eruption and the Protoclassic, preferring to interpret the Protoclassic spread in solely political terms. Further, Hellmuth is dubious of the effect of the eruption (in Sharer 1974:179-180), because Kaminaljuyu was not destroyed as well, for it is "a site within lethal proximity to active volcanoes." Hellmuth's assumption that if one volcano erupts they all should erupt is not in accord with contemporary volcanology. Finally, Paddock, Wetherington, and Willey feel that the hypothesis relating the volcanism and the Protoclassic has merit, but each voices reservations based, correctly, on the lack of extensive, reliable data. In short, Mayanists apparently feel that a potentially powerful explanation to an old problem has been proposed, but there is a need for more detailed research before the relationship may be considered demonstrated at a high level of probability.

In summary, we can see that much of the archaeology which has been conducted in the Southeast Maya Highlands has been done in terms of small, traditionally-oriented, and normatively-focused projects. Some of it has been good culture history, which does provide a partial data-base from which problem-oriented multi-disciplinary ecological research may now begin.

PREVIOUS GEOLOGY: EL SALVADOR

The geological source, or sources, of the volcanic ash burying Pre-classic materials has been much debated. This ash layer, locally referred to as the "tierra blanca," has been attributed to Volcan San Salvador (Williams and Meyer-Abich 1955, Weyl 1952), to Volcan Chingo or to Volcan Santa Ana (Sharer 1968), but recent detailed work by a team of German geologists indicates that the source was the caldera of Volcan Ilopango (H. S. Weber, personal communication, 1970; see also Meyer 1964). Interestingly enough, Lothrop (1927:168) suspected the source of the "tierra blanca" was Volcan Ilopango, but he gave no evidence for this. It now appears that he has an excellent chance of being proven correct.

Meyer's detailed studies (1964) of the Coatepeque tephra have yielded a number of highly pertinent conclusions. He found that the three major eruptions of rhyolitic tephra within the recent past in El Salvador, Empalizada, Coatepeque, and Ilopango, are macroscopically exceedingly similar. Fortunately, Meyer (1964:216) was able to identify these pyroclastics by their "quantitatively different heavy mineral assemblages." Further, he did discover the stratigraphic sequence: Empalizada as the earliest, Coatepeque intermediate in date (i.e., between 45,000 and 10,000 years ago), and Ilopango as the youngest.

Recent work by the German Geological Survey, most of it yet unpublished, has agreed with Meyer's work regarding the source of the "tierra blanca" as Ilopango. Their first publications are now becoming available, a 1:500,000 geological map of Salvador was published in June 1974, and a series of six detailed 1:100,000 maps should be available within the next few months. One of the German geologists, Michael Schmidt-Thome (1975:212, 216), found the thickest deposits of "tierra blanca" to be 50 meters near Lake Ilopango, and he agrees that the "tierra blanca" derived "from a center within the Lake Ilopango depression." He also presents a list of the eleven major earthquakes which have occurred in the San Salvador region alone that caused major to complete destruction of the city during the past four centuries (p. 222), ample testimony of the magnitude of ongoing tectonic activity within the recent past.

COMPARATIVE GEOLOGY

Parícutin Volcano, 320 kilometers west of Mexico City, erupted in the midst of a milpa on 20 February 1943 and continued active for nine years. Most of the pyroclastics, however, were erupted during the first year (Segerstrom 1950:1). The case of Parícutin is fortunate for our purposes of comparison with the El Salvador eruption, owing to Segerstrom's exhaustive study and to the fortuitous situation of a high degree of climatic similarity between the Parícutin area and highland El Salvador. Controlling for such climatic variables as temperature, mean annual rainfall, and seasonality of precipitation allows for a higher degree of comparability of phenomena and their impact on human settlement. The Parícutin eruption, however, was much smaller than the Ilopango eruption.

The mean annual temperature in the Parícutin area ranges from 19.5°C to 23°C (Segerstrom 1950:11) which is very similar to San Salvador. Mean annual rainfall is 1600-1700 mm at Uruapan, a nearby town, which compares with the 1500-2000 mm average in central and western El Salvador. Rainfall is also highly seasonal; approximately 87 percent falls in the six-month rainy season from June to December. Most of the rain falls in brief, high-intensity storms in summer and fall afternoons, which means that the erosion force per millimeter of precipitation is at a maximum. The dry season, with only 13 percent of the annual precipitation, and dry spells of two to four weeks with no rain whatsoever, are sufficiently dry to allow for considerable eolian erosion and redeposition of exposed ash.

The ash itself, judging from Segerstrom's photographs, would be toward the mafic end of the continuum. Indeed, he later states (Segerstrom 1950:34) that all ejecta are of a basaltic andesite nature. It is fortunate for the people living in the Parícutin area (but the opposite for the Preclassic Highland Maya) that basic, or mafic, tephra weathers much more rapidly than does an acidic tephra. Further, "basic volcanic ejecta are rich in ferro-magnesian minerals and soda-lime feldspars" (Butzer 1971:200) which weather into fertile soils containing ample nutriments for plant growth. Acid volcanic ejecta such as the "tierra blanca," on the other hand, "consist primarily of potash feldspars and quartz" (Butzer 1971:201) which weather slowly to less fertile soils.

Water erosion begins, at the finest level, with raindrop-splashes, and proceeds in an unbroken continuum through sheet erosion, to rill and channel (barranca) erosion. Massive but gradual ground creep may be noticeable on slopes greater than thirty degrees, by the angle of dead trees. As water permeates the sloping ash deposits, gradual creep may give way to a land-slide or a mudslide (a lahar).

Extensive pyroclastic deposition may wreak havoc with that critical human resource, water. Segerstrom (1950) notes radical alterations in surface and groundwater flow. Many springs either dramatically decreased or increased their flow, some new springs appeared, and some old springs completely dried up.

Prior to the eruption, roughly 75 percent of the pyroclastic-covered area was forested (70 percent pine, 15 percent oak, with some spruce, madrone, and crabapple). Virtually all trees within the one-meter isopach (i.e., with more than one meter-deep pyroclastic deposition) were killed, along with all crops, shrubs, grasses, and other plants. At the 50 cm isopach a number of trees were able to survive, but all other plants were killed. Most trees survived at the 25 cm isopach, but little else was able to continue living.

During the first year after the ashfall, no land covered by more than 10 cm of ash was able to be cultivated. However, four years later, some of the land covered by 10-25 cm of ash had been reclaimed, at least temporarily, for agriculture. Many schemes were devised to counteract the effects of the ash, only a few of which were successful. Some peasants unsuccessfully attempted to shovel ash off small plots to re-expose the pre-existing humic horizon. A ridge, fortuitously exposed to eolian erosion, did support almost normal crops after the removal of most of the ash. A mixed deposit of pre-eruption humic soil and ash did support maize, but at what productivity level is not stated.

Some maize was planted in pure ash near the town of Angahuan. It sprouted, grew in the mafic ash only to a height of 20-30 cm., turned yellow, and died. Nearby, maize, squash, and beans were planted in pure ash and fertilized with cow dung. The crop was harvestable. Fields covered with 25 cm of ash or more were not plowed, but in towns such as Corupo with an original ash thickness of 10 cm, plowing (a scratch plow with oxen) the ash into the humic horizon yielded an increase in productivity. This was apparently due to the ash killing many destructive insects as well as to the "mulch" effect of increasing soil porosity and perhaps fertility by the addition of a small percentage of mafic ash.

Malde (1964:10) cites an estimate of 200 years which would be necessary to re-establish normal forest growth near Parícutin, and for an even longer period to recover from the severe erosional effects. From this, a 200-year devastation and abandonment of much of the Southeast Maya Highlands would not be unrealistic, in that the Ilopango ash was more damaging, more extensive, and more voluminous.

A concise summary of the environmental effects of a substantial ashfall is presented by Malde (1964:8-9). Plants are quite vulnerable to ashfalls, owing to smothering and structural overloading as well as chemical attack. Animals die from inhalation and from the ingestion of chemical-laden ash on plants which they try to eat. Plant and animal life in both fresh and salt water is very sensitive to damage by tephra. In areas on land where plants were not killed by the actual ashfall, wind-blown ash, with its extremely sharp edges, has been known to "mow down" plants.

The Protoclassic eruption was probably much like the eruption of Mt. Vesuvius in AD 79 (Williams 1951). Mt. Vesuvius was a dormant cone, but the pressures of dissolved gasses accumulated and then were suddenly released. The result was an explosive eruption showering ash and pumice over the surrounding countryside and burying Pompeii and Herculaneum with its ejecta. The result is extraordinary preservation as well as a virtually complete material record of those communities. This is archaeologically significant, for people who are abandoning structure or villages at will or at a more leisurely pace will remove their most important possessions.

SOCIAL SCIENCE DISASTER RESEARCH

The study by Kates et al. (1973) of the "Christmas earthquake" which recently devastated Managua, Nicaragua points up how rarely social scientists have extensively studied the human response to environmental catastrophes. In anthropology the systematic study of natural disasters is all too rare; the best-known studies, and those most relevant to the proposed research, are by Paul Doughty (1971) regarding the human response to the Peruvian earthquake-avalanches of 1970, Schwimmer's study (1969) of the cultural response to a volcanic eruption in eastern New Guinea in 1951, and Nolan's thorough study (1972) of the response to the Parícutin tephra-fall.

Sociologists, occasionally in conjunction with other specialists, have investigated human behavior under disaster conditions more systematically than have anthropologists. Much of the social science disaster research of the past two decades has been conducted in conjuntion with one of the following five programs: (1) National Opinion Research Center, University of Chicago, (2) Disaster Research Group of the National Academy of Sciences, (3) Disaster Research Center of The Ohio State University, (4) Program of Collaborative Research on Natural Hazards, and (5) the Research Program on Technology, Environment and Man of the Institute of Behavioral Science, University of Colorado (Mileti, Drabeck, and Haas 1975:2). Emanating from some of these programs have been four extensive reviews of what has been learned from disaster research, with suggestions on directions that research should take in the future. Barton (1963, 1969) generated a number of testable propositions regarding human behavior in disaster conditions in his two reviews. Dynes' (1970) synthesis concentrated more on the societal-level response to disaster than the individual or family-level response of other researchers. Recently, Mileti, Drabek, and Haas (1975) conducted a thorough review of published disaster research, including a wider spectrum of phenomena than the above-mentioned reviews. The article by Quarantelli and Dynes (1972) is a concise assessment of popular misconceptions about human behavior during natural disasters. Despite the dominant focus of these studies on US society, they are a rich methodological and theoretical resource to be exploited by the proposed full-scale Protoclassic Project.

Schwartz (1970) has performed a valuable service by examining the ethnographic literature on migrations and by deriving cross-cultural regularities of postmigration communities. The "Pioneering Phase," the first of three developmental stages of community configuration, is characterized by mobilization for physical survival, and is "likely to be characterizedy by stronger solidarity and greater ethnocentricity than was the case in their premigration situation" (p. 178). This is consonant with the social science disaster research findings of altruistic behavior being the norm (Quarantelli and Dynes 1972; Mileti, Drabek, and Haas 1975:57-67).

The second stage is the "Consolidation Phase," which is characterized by permanent housing, the "crystallization of formal and informal social institutions and associations" (p. 178), and the like. The third phase is "Stabilization," when the "effects of the migration pass, and the community settles down to develop along lines not directly related to the move" (p. 178).

AREAL REPERCUSSIONS

Even in areas of southern Mesoamerica beyond the zone of direct environmental damage by substantial ashfall, it does appear that indirect ecologic and demographic effects may have been felt in a number of ways. Long-range floods and migrations of survivors may have been the most common repercussions. Floods resulting in the deposition of extensive sterile deposits of mud on riverine settlements apparently occurred toward the end of the Preclassic in northern Belize (Bruch Dahlin, personal communication 1973), in central Belize (Willey et al. 1965:565), and in northwestern Honduras (Stone 1972: 57-62). Flooding in the lowlands could have been caused by ash damage to plant cover in the headwaters of the lowland rivers, resulting in increased runoff and a heavy particulate load in floodwaters (Sheets 1975:133).

At Barton Ramie during the Floral Park Phase (the Protoclassic) a number of cultural and natural events occurred at approximately the same time, and I suggest that they may have been interconnected. The dating of these events is not exceedingly precise; they occurred sometime between 100 BC and AD 300 (Willey et al. 1965:26-7). These changes (cf. p. 565) include a more-than doubling of population as evidenced by a more than two-fold increase in "house occupations", new ceramic characteristics interjected into an autochthonous continuum, barkbeaters, perforated potsherd discs (probably whorls), and likely other artifacts. Among the ceramic changes, a new ceramic type appears, Aguacate Orange, which is so similar to sub-ash ceramics in El Salvador as to be indistinguishable by ceramicists working at Barton Ramie and Chalchuapa (Sharer and Gifford 1970). Significantly, these cultural changes are also accompanied by the virtual disappearance of freshwater mussels and univalves from Barton Ramie. The acute sensitivity of aquatic species (animals and plants) to damage by tephra (Malde 1964) may be directly relevant here. In fact, if a tephra fall radically diminished shellfish, fish, and related species in Belize, the same phenomenon should have occurred elsewhere. It may not be mere coincidence that the Ocos area of Pacific Guatemala-Chiapas, where the Formative occupation was heavily dependent on aquatic protein resources (Coe and Flannery 1967), was abandoned in the Early Classic (Shook 1965: 185-6), and then thoroughly reoccupied a few centuries later (Coe and Flannery 1967:84-91). At Bilbao, more inland on the Guatemalan Pacific coastal plain, Parsons (1967:24) found a marked diminution of cultural materials after the Preclassic (i.e. in the Early Classic) which may be indicative of a population decline, but not of an abandonment of the area. Because the Bilbao inhabitants apparently were not relying much on aquatic protein resources, I would expect their agricultural subsistence base to have been less sensitive to a tephra-induced perturbation at this distance from Ilopango than their Ocos neighbors. Bilbao is 140 km and Ocos is 215 km WNW of Ilopango.

The evidence of substantial flooding of the Belize River was encountered at Barton Ramie in the form of a sterile brown clay stratigraphically separating the Preclassic from later occupations and humic horizons:

> "We noted that mounds whose construction began in Preclassic Period times had their bases directly on or slightly into the [buried] black soil stratum, while mounds whose construction began at a later date had brown clay intervening between the bound base and the black soil" (Willey et al. 1965:31).

This flooding occurred at about the same time as the molluscs diminishing and the Protoclassic cultural-demographic intrusion. Flooding is a common result of tephra damage to vegetation in the drainage basin of rivers, often exacerbated by the greatly increased rainfall.

The "Protoclassic problem" was first recognized from data deriving from the 1910-11 excavations at Holmul, Guatemala, conducted by R.E. Merwin and sponsored by the Peabody Museum, Harvard University. Merwin's excavations, the first stratigraphic excavations in the Maya area, divulged a series of five periods. It is the first, Holmul I, that we can now place in the Protoclassic, based upon the presence of mammiform tetrapod vessels, Usulutan decoration, pot-stands, and spouted vessels. Merwin and Vaillant (1932:62, 64, 65) note that the Holmul I materials bear strong stylistic resemblances to the sub-ash artifacts encountered by Lothrop (1927) in central El Salvador. Exploration of the resemblance was not attempted by them at the time.

Numerous other sites in the Maya Lowlands have been found to have experienced a similar site unit intrusion sometime near the time of Christ. The artifacts have been known by a number of names, for example Holmul I, Cimi, Matzanel, Salinas, Contutse, and Floral Park, and the name Protoclassic may be used to subsume these similar materials. Still the best summary of the occurrance of Protoclassic artifacts in southern Mesoamerica, particularly in the Maya Lowlands, is that of Willey and Gifford (1961). They note the full occurrence of the Protoclassic at such sites as Barton Ramie, Holmul, Poptun, Mountain Cow, Douglas, Nohmul, Santa Rita, and Pomona. It has also been found at Altar De Sacrificios (Willey, Culbert, and Adams 1967:298, Willey 1973:34-39).

Sites with a few scattered Protoclassic artifacts, or lacking the evidence of a major, sudden infusion of the complete "Protoclassic package," are Uaxactun, Tikal, Finca Arevalo, Seibal, Chiapa de Corzo, Monte Alban, Kaminaljuyu, and southern Campeche. Willey and Gifford (1961:167) view the Protoclassic at Barton Ramie as an intrusion of a constellation of foreign characteristics into an indigenous stylistic and technological continuum. The intrusion does not break the continuum, and it is eventually absorbed into the general Early Classic culture.

Although the Protoclassic spread of artifacts could be explained by the opening of an exchange or trade network, Willey and Gifford (1961:168, 170) believe that a migration is the most likely explanation. They are uncertain of the source, mentioning northern Honduras, or, somewhat more likely, the Guatemalan Highlands. In retrospect, we can say that their suspicions may be able to add the reason for the migration as well as the specific area of origin.

From the Tikal Project excavations over the past two decades it is clear that the roots of the Classic Maya fluorescence in the Peten are deeply embedded in the Peten Preclassic, so we certainly cannot mechanistically derive the Lowland Classic out of the Highland Preclassic. However, it is likely that the sudden arrival of large numbers of people on the peripheries of the "core area" necessitated an intensification of social and political control mechanisms, therefore accelerating the rate of cultural development. The Protoclassic, then, may have acted primarily as a catalyst instead of being a critical reagent in the emergence of the Maya politic.

The controversy over the nature of the Protoclassic continues among Mayanists working in the Lowlands. Willey (1973) and Adams (1971) disagree on the explanation for the large amounts of Protoclassic materials encountered during their recent excavations at Altar de Sacrificios (Salinas Phase, AD 150-450). They both agree that the Salinas Phase was a time of rapid change in ceramics, trade, architecture, artifacts, and iconography. Adams explains this by an influx of population into Altar, accompanied by some violence and the invaders establishing themselves as the rulers, with the earlier resident population becoming the ruled. Willey (1973:38-9) had earlier favored the invasion explanation, but he now expresses some doubts by viewing the Protoclassic phenomenon as deriving out of "culture change benefiting by stimulation from foreign contacts."

Willey (1973:36) does note that the indigenous continuum of Altar utility wares was unbroken from the previous Plancha Phase through the Salinas Phase. Significantly, the first "luxury ware" at Altar is the intrusive Protoclassic. If there were a Protoclassic invasion, then these two traditions and their social functions may be used to trace the dynamics of ethnic interactions. Immigrant groups usually enter pre-existing societies either on the lowest or the highest socio-economic level; rarely are they accepted by the inhabitants at precisely the same level for a significant period of time. Given this line of inquiry, it would appear that the highland immigrants at Altar and Barton Ramie were socially (and probably politically and economically) dominant within the first few generations after the migration.

However, as Schwartz (1970:178) points out in discussing the developmental phases of postmigration cultures, the community may eventually develop along lines quite different than those of either of the two separate groups or of the original postmigration community. Even though at Altar and Barton Ramie the intrusive socio-technic artifacts are initially dominant, the overall Maya Lowland developmental continuum from the Late Formative into the Classic overwhelmed the Protoclassic cultural intrusion within a few generations. All the sites which may have received a significant site unit intrusion were, by the Fifth Century, fully within the Classic Maya Realm.

The late facet of the Cantutse (Chicanel, or terminal Preclassic) Phase at Seibal contains numerous elements of the Protoclassic complex, including mammiform tetrapod vessels (thick, flaring-sided bowls with mammiform supports), orange-slipped ceramics, and imitation "Usulutan" types (Sabloff 1975:11, 231-2). The Protoclassic at Seibal apparently is analogous to Tikal; in both cases there is no evidence of a full site-unit intrusion and sudden population increase, but rather Protoclassic elements showing up by trade or imitation. Even though the earliest ritual construction at Seibal dates to the late facet of the Cantutse Phase, Seibal evidently experienced a marked population decline as well as a "cultural decline" (p. 11-12), with "much of the site [being] abandoned to the jungle." As Sabloff summarizes, "There is no evidence of a separate Protoclassic complex such as the Salinas at Altar de Sacrificios or Floral Park at Barton Ramie. Nor is there evidence of an intrusion of new peoples such as Adams sees at Altar" (p. 232).

1975 RESEARCH: OBJECTIVES

The problems to which this research addressed itself involved the testing of the hypothesis that a massive volcanic eruption devastated a large area of the Southeast Maya Highlands with an intensity sufficient to warrant migrations out of the area. These migrations, viewed from the Lowland Maya perspective, could have resulted in the Protoclassic site-unit intrusions noted by Mayanists for over 70 years.

More specifically, the full testing of the Protoclassic-volcanologic hypothesis involves answers to the following questions:

1. Was there one eruption from a single source, or were there a series of eruptions which buried Preclassic materials?
2. What is the source of the "tierra blanca" tephra?
3. How fast was it deposited?
4. How many people were affected, and in what way? Where was the zone of lethal damage, where was the zone where people could survive but had to migrate, and where was the zone of minor damage wherein people could cope with their suddenly modified environment?
5. What was the pattern of Late Preclassic settlement, and what was its density?
6. What was the pre-eruption adaptation? What crops were cultivated, what wild flora were utilized, what animals hunted or fished, and with what degree of intensity? What was the potential for rapid technological intensification to deal with their changed circumstances?
7. What are the estimated parameters of the displaced population? What was the effect of their sudden arrival on the indigenous social order in the recipient area? Into what level of the nonegalitarian lowland society were they "accepted," and what were the social dynamics in the first few generations following their arrival?
8. Given the particular climate of Salvador, how much time was necessary for chemical and mechanical weathering and plant succession to build up a soil which has the specific nutriments necessary for the subsistence crops of the recolonizers?
9. What is the date of recolonization of the Southeastern Maya Highlands? Was it a sudden migration or a gradual infiltration? What is its

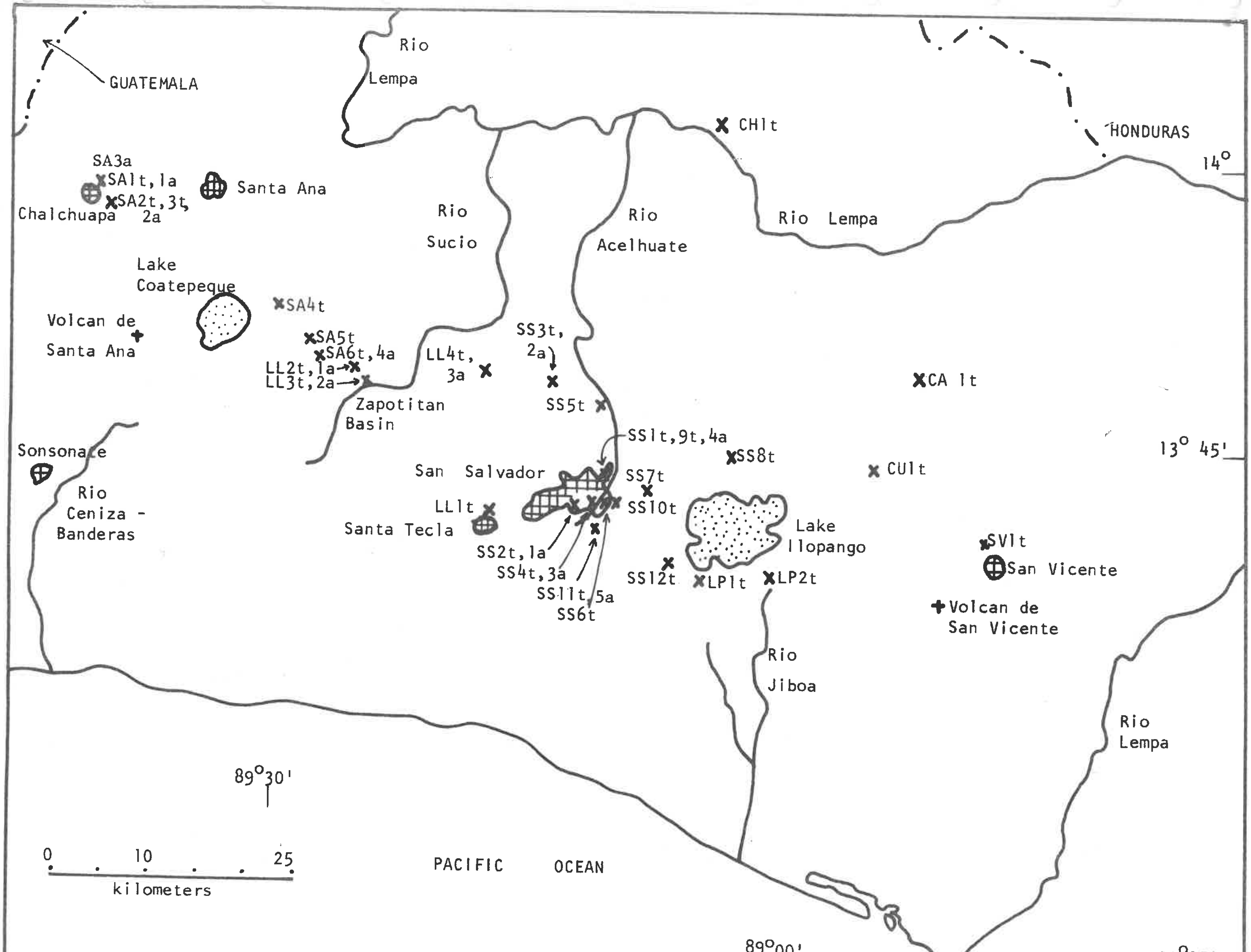


FIGURE 2. CENTRAL AND WESTERN EL SALVADOR: 1975 SAMPLING LOCALITIES

source? Was it motivated by population pressures, politico-economic objectives (e.g. control of Ixtepeque obsidian, therefore nullifying the Teotihuacán obsidian monopoly?), or both?

Attacking all these aspects of the eruption-migration hypothesis in two months of fieldwork would be sheer folly. In fact, preliminary data pertinent to only the first three questions were sought in the 1975 field season, while answers to the others will hopefully be sought during the projected 1976 and 1977 field seasons.

METHODOLOGY

Initial data pertaining to the first three components of the Protoclassic-volcanologic hypothesis were collected during June and July of 1975. Initial data on the source and duration of the eruption (or eruptions) involved both archaeological and geological sampling. Five of the localities sampled were already known to exhibit the sought-after stratigraphic relationships. To maximize efficiency, the 23 other localities where samples were needed along the transect were sought along already existing road, railroad, and river cuts (Fig. 2). Therefore, only in a few cases were time-consuming excavations necessary during this pilot project. Often cuts only needed to be cleaned and straightened prior to photographing, profiling, and sampling.

Once a sampling locality had been selected, the field methods utilized were as follows. If the locality were for sampling of tephra (volcanic ash or pumice) alone, then a tephra locality code was assigned to it. This code begins with two letters abbreviating the Salvadoran department in which it is located (El Salvador has 14 departments). Then, each locality within the tephra sample series received its own number sequentially, and each sample taken from a particular locality also received a number. Thus SA 5-2t identifies the second tephra (t) sample from the fifth locality recorded in the department of Santa Ana. If the tephra at the locality buried artifacts in the humic horizon below it, then an archaeological code was assigned, for example: SA 3-1a.

A "Tephra Sample Record" form was filled out for each ash or pumice sample taken. This form consists of 24 categories of data involving location, associated samples, setting, appearance, collection methods, owners, and so forth.

The "Archaeological Sample Record" is the form filled out for each artifactual sample taken. It consists of 32 components of information including the sample number, site name, location, setting, associated samples, description, comments, and so forth. Selected data from these two kinds of sample forms are tabulated in Tables 1 and 3.

Artifacts (almost exclusively ceramics and obsidian) or tephra (a liter in volume when possible) were placed into labeled collection bags for further lab processing and analysis. The strata were profiled at as detailed a scale as needed, ranging from 1:10 to 1:50, and tephra or archaeological sampling zones were recorded on the profiles (see Figures 3-25). Black-and-white and color photographs were taken of each locality and its surrounding terrain. Each site was plotted to within 100m on the field copy of the excellent 1:50,000 topographic maps of El Salvador. All artifacts were washed, dried, catalogued, and subjected to a preliminary analysis at our laboratory in San Salvador. They were then examined by Museo Nacional personnel and packed for shipment to the U.S. for technical analyses. The following technical analyses are either ongoing or have recently been completed: ceramic typological analysis (Dr. R. J. Sharer, University of Pennsylvania), obsidian hydration (Dr. Leonard Foote, Queens College), lithic technological and typological analysis (myself), paleomagnetic intensity dating on ceramics (Dr. Daniel Wolfman, Arkansas Archaeological Survey), tephra grain size, hydration and petrography (Virginia Steen McIntyre, U.S. Geological Survey, Denver), alpha-recoil tract dating of tephra (Dr. Wolfman), and radiocarbon dating on charcoal and on a buried soil (Dr. Sam Valastro, Jr., Radiocarbon Laboratory of the University of Texas, Austin).

RESULTS: ARCHAEOLOGY

Archaeological Sites

A total of 14 samples were taken from 12 archaeological sites during the 1975 season (Table 1). These archaeological materials, all along the east-west sampling transect, were all in direct stratigraphic association with tephra deposits. Each was collected with the aim of determining its relation with a specific geologic event, hopefully in most cases, the eruption of Ilopango Volcano. A total of four samples were collected from the department of La Libertad, five from Santa Ana, and five from San Salvador. This total, and the specific nature of their associations with tephra deposits, are considerably

TABLE 1: ARCHAEOLOGICAL SAMPLE SUMMARY

SAMPLE NUMBER	SITE NAME	ELEVATION (METERS)	NUMBER CERAMICS	NUMBER LITHICS	NUMBER GROUND-STONE	PERIOD
LL1-1a	La Cuchilla	475	639	48	1	Mid. & Late Preclassic
LL2-1a	Escuela	460	33	1	-	Late Classic, mixed with Preclassic(?)
LL2-2a	Escuela	460	80	7	-	Late Classic - Early Postclassic
LL3-1a	Primavera	505	21	-	-	Probably Late Preclassic
SA1-1a	Casa Blanca	702	55	4	-	Mid. & Late Preclassic
SA2-1a	Laguna Seca	702	8	-	-	Likely mixed
SA2-2a	Laguna Seca	702	4	-	-	Probably Preclassic
SA3-1a	Casa Blanca	703	Architectural surfacing		-	Late Preclassic
SA4-1a	Arce	510	194	17	-	Mid. & Late Preclassic
SS1-1a	San Mateo	730	155	1	-	Mid. & Late Preclassic
SS2-1a	Mercedes	480	12	7	-	Problematic
SS3-1a	Cerro Zapote	665	22	1	-	Mid. & Late Preclassic, Recent
SS4-1a	Cartografía	630	16	-	-	Likely Preclassic
SS5-1a	Israel	715	34	1	-	Mixed Historic & Prehistoric

more qualitatively and quantitatively than we anticipated discovering this season. The nature and significance of these sites are briefly discussed below.

LL1-1a, La Cuchilla Site, Fig. 6.

The Cuchilla site is located on the northwest edge of the Zapotitan Basin, some 45 km from Ilopango. It was buried by approximately 2m of volcanic ash. The site consists of a pyramid-plaza complex and an extensive habitation-trash-burial area. The most extensive collection of artifacts of the 1975 season was taken from this site. Three cached vessels were discovered in the buried humic horizon, just below the volcanic ash. These unfortunately were sectioned, and largely removed, by bulldozers constructing an overpass for the Pan Am Highway at this location (Fig. 32, 33).

Dr. Robert J. Sharer performed a detailed ceramic analysis on the typologically diagnostic ceramics from the La Cuchilla site, and eight of the other twelve sites. Not all sites yielded sufficient diagnostic ceramics to be datable. Table 2 tabulates the certain and the probable typological identifications of sherds, with certain identifications appearing to the left of the slash (/), and probable identifications to the right. The ceramic complex of each type is listed, or where the complex is unknown, the period is listed. My translations of his ceramic complexes into date spans or Mesoamerican periods are derived from Sharer (1974). The reader desiring more information on ceramics, such as type descriptions, dating, or external connections, may consult Sharer (1968), Sharer and Gifford (1970), or Sharer (1974) and (1976).

The predominance of La Cuchilla ceramics dated to the Caynac ceramic complex, 200 BC-AD 200, the Late Preclassic. A few of the ceramics were as early as the Kal ceramic complex (650-400 BC, Middle Preclassic), with some in the Chul ceramic complex as well (400-200 BC). It appears that this large and important site, in its strategic location, was occupied at least as early as 500 BC, with probable population growth culminating in the major occupation just prior to the eruption and ash deposition.

LL2-1a and 2-2a, Escuela Site, Fig. 7.

The Escuela site is located just a few kilometers southeast of the Cuchilla site. Artifacts dating to the reoccupation of El Salvador during the Middle or

TABLE 2: Ceramic Analysis
(R.J. Sharer)

Ceramic Type	LL1-1a	LL2-1a	LL2-2a	LL3-1a	SA1-1a	SA4-1a	SS1-1a	SS2-1a	SS4-1a	SS5-1a	Ceramic Complex/Period
Lamat. Inc-Punct.						2/					Tok-Colos
Izacuyo Inc.						1/					Colos
Lolotique Red							1/				Kal
Curaren Inc.						1/	2/				Kal
Anguiatu Inc.						1/					Kal
Jinuapa Str-Brn.							1/				Kal
Masahuat Unsl.						1/					Kal
Tecapa Inc.	1/										Kal
Cuitapan Cream									1/		Kal
Guaymango R-bff.	1/			/1							Kal-Chul
Jicalapa Usul.	/4			/2	3/						Chul
Tecana R & Cream				1/					/2		Chul-Caynac
S. Tecla Red	2/				2/2	/2	1/				Chul-Caynac
Copinula Graphite							1/				Chul-Caynac
Olocuitla Or.					/2			/1			Chul-Caynac
Opico Grooved						1/					Chul-Caynac
Pinos(?) Fluted						1/					Late Preclassic
Izalco Usul.	1/3				1/2	1/	1/				Caynac
Mizata Buff	2/				1/						Caynac
Conchalio Inc.	4/					3/2					Caynac
U/I Red-rim Inc.	1/										Late Preclassic(?)
Aguacate Or.	/1										Caynac-Vec
Finquita Red	/3							/1			Caynac-Vec
Chihanja Red/Usul.		1/									Vec
U/I Thin Red				3/							Late Preclassic(?)
Guazapa Sur-Slip			1/								Vec-Payu
Suquiapa R/Or.			1/								Xocco
Copador Poly.			/1								Payu
Arambula Poly.		/1	1/								Payu
U/I Poly.		1/	1/								Late Classic
U/I Red-Slip		4/1	3/								Late Classic(?)
U/I Or/buff			1/								Late Classic(?)
Guajoyo R/Brn			1/								Matzin-Ahal
Recent										6/	Recent

Late Classic were found in the humic horizon forming out of the volcanic ash (beds 5 and 6, Fig. 7). This site encapsulates the cultural, adaptive, and geologic phenomena which are the focus of the project, for here there is evidence of village life and subsistence prior to the eruption, the diaster itself, the abandonment, the weathering of the tephra and plant recolonization, and finally the human recolonization by the Classic Maya from the Copan area. This site deserves close excavation for cultural, biological, and geological data.

Two archaeological samples were taken from this site, one from above the ash, and one from below. No difficulties were encountered in collecting the supra-ash sample, LL2-2a, but some difficulties were encountered in collecting the attempted sub-ash sample, LL2-1a. The problem derived from two sources of recent disturbance: bulldozer cutting in construction this segment of the Pan Am Highway a number of years ago, and the subsequent slumpage along the vertical cut. We attempted to collect only sub-ash in situ artifacts, but at the time we were unsure of our success. Sharer's ceramic analysis clearly indicates that the bulk of the LL2-1a sample actually dates to the Late Classic (the same as LL2-2a), with some earlier material. I believe that collecting error is responsible for this dating anomaly, but the possibility of a later ashfall does exist. Further sampling during the next stage of the project should resolve this problem. Sharer's ceramic analysis dated the supra-ash sample predominantly to the Late Classic, with some earlier and some later material, as anticipated.

LL3-1a, Primavera Site, Fig. 8.

The Primavera site consists of a small trash deposit under tephra located just south of Quetzaltepeque. No architecture was noted. Sharer's analysis dated the ceramic materials largely to the Late Preclassic (Chul and Caynac ceramic complexes, 400 BC-AD 200), with a possibility of some earlier ceramics.

SA1-1a, Casa Blanca Site, Fig. 11.

The artifacts of this sample were extracted from plaza fill 5 meters north of the NE corner of Structure C3-3 in the Chalchuapa site-zone, and immediately under the white volcanic ash. Because the artifact sample derives from plaza leveling prior to the eruption, the artifacts were not expected to be all immediately pre-eruption, but mixed Mid-to-Late Preclassic. In fact, Sharer's

TABLE 3: TEPHRA SAMPLE SUMMARY

SAMPLE NUMBER	ELEVATION (METERS)	ANTICIPATED SOURCE	DISTANCE & DIRECTION
CA1-1t	665	Ilopango	24km NE
CH1-1t	220	Ilopango	43km N
CH1-2t	220	Ilopango	43km N
CH2-1t	220	Ilopango	42km N
CU1-1t	800	Ilopango	14km ENE
LL1-1t	1010	Ilopango	26km W
LL1-2t	1010	Ilopango	26km W
LL2-1t	475	Ilopango	45km WNW
LL2-2t	475	Coatepeque	10km ESE
LL3-1t	460	Coatepeque	17km ESE
LL3-2t	460	Ilopango	42km WNW
LL4-1t	505	Ilopango	31km WNW
LP1-1t	930	Ilopango	6km SW
LP1-2t	930	Ilopango	6km SW
LP2-1t	860	Ilopango	6km SE
SA1-1t	702	Ilopango	77km WNW
SA2-1t	701	Ilopango	76km WNW
SA2-2t	701	Ilopango	76km WNW
SA3-1t	702	Ilopango	75km WNW
SA4-1t	730	Coatepeque	7km W
SA5-1t	590	Ilopango	50km WNW
SA6-1t	510	Ilopango	48km WNW
SS1-1t	640	Ilopango	15km W
SS1-2t	640	Ilopango	15km W
SS2-1t	730	Ilopango	20km W
SS3-1t	480	Unknown	Unknown
SS4-1t	665	Ilopango	17km W
SS5-1t	470	Ilopango	19km NW
SS6-1t	590	Ilopango	15km W
SS7-1t	610	Ilopango	11km WNW
SS8-1t	755	Ilopango	7.5km N
SS9-1t	630	Ilopango	15km WNW

TABLE 3: TEPHRA SAMPLE SUMMARY
(Continued)

SAMPLE NUMBER	ELEVATION (METERS)	ANTICIPATED SOURCE	DISTANCE & DIRECTION
SS10-1t	675	Ilopango	13km W
SS10-2t	675	Ilopango	13km W
SS10-3t	675	Ilopango	13km W
SS10-4t	675	Ilopango	13km W
SS10-5t	675	Ilopango	13km W
SS10-6t	675	Ilopango	13km W
SS10-7t	675	Ilopango	13km W
SS10-8t	675	Ilopango	13km W
SS10-9t	675	Ilopango	13km W
SS10-10t	675	Ilopango	13km W
SS10-11t	675	Ilopango	13km W
SS11-1t	715	Ilopango	17km W
SS12-1t	875	Ilopango	8km SW
SV1-1t	775	Ilopango	24km E

ceramic analysis indicated all material dated to the Chul and Caynac ceramic complexes, from 400 BC to AD 200, and the materials were quite evenly distributed within these two Late Preclassic complexes.

SA2-1a 2-2a, Laguna Seca Site, Fig. 12.

Artifactual samples were taken from below and above volcanic ash at the base of this deep caldera. Both trash and ritual deposits have been uncovered here by archaeologists with the Chalchuapa Archaeological Project in 1970 (see Anderson in Sharer 1976), and by earlier investigators. Neither sample was sufficiently large or diagnostic for ceramic analysis.

SA3-1a, Casa Blanca Site, Fig. 27.

The architectural surfacing material utilized in western Salvador during the Preclassic is a wet-laid mixture of pumice and clay. Samples excavated in 1969 by the principal investigator from Structure C3-6 of the Terminal Preclassic surfacing (Fea. 6 in Fig. 27) buried by the volcanic ash (Fea. 10) were examined to see if they contained pumice from the Coatepeque eruption. If this surfacing did contain Coatepeque tephra, this would be further evidence of the stratigraphically superior position of the Ilopango tephra.

SA4-1a, Arce Site, Fig. 15.

A moderate-sized habitation site, with a pyramid some 10m in height, was blanketed with volcanic ash. Most of the pyramid has been destroyed by adobe brick makers during the past few decades, but much of the Preclassic domestic material is yet undisturbed.

The predominance of the ceramics, according to Sharer's analysis, date to the Late Preclassic (Chul and Caynac ceramic complexes), but there is a significant amount of earlier ceramics, some as early as the Tok-Colos complexes (1200-650 BC). Similar to Chalchuapa, and somewhat similar to the Cuchilla site, the earliest occupation seems to be early and relatively sparse, with population growth until the eruption.

SS1-1a, San Mateo Site, Fig. 17.

Artifacts were encountered during the bulldozing of fill for the new San Mateo subdivision in western San Salvador early in 1975. Ceramics, lithics, and moderately well-preserved skeletal material were collected during salvage efforts by Museo Nacional staff (Margarita Solís personal communication 1975).

By the time of our sampling of artifacts and tephra, June of 1975, bulldozing had proceeded to the point that we were able to recover little of scientific value. Judging from Sharer's ceramic analysis, occupation was largely during the Middle Preclassic, with some significant habitation continuing through the Late Preclassic.

SS2-1a, Mercedes Site, Fig. 18.

This site is problematic, for the association of the ceramic material and the humus buried by vast amounts of tephra is uncertain. This tephra is apparently not from Ilopango, and further work is needed to determine the contemporaneity of the artifacts and the buried soil horizon (bed 1 in Fig. 18). Ceramic analysis is unclear due to small sample size and preservation, but a Late Preclassic date is possible.

SS3-1a, Cerro Zapote Site.

Cerro Zapote is the site in southeastern San Salvador where Lardé, Lothrop, and the soldiers of the Zapote Fort in 1926 excavated a series of Late Preclassic ceramics, figurines, and lithics from a humic horizon buried by the "tierra blanca" volcanic ash (Lothrop 1927:172-7; see "History of Related Archaeological Research" above). The clear strata cuts visible in 1926 are now thoroughly obscured by continued bulldozing of the hill below the fort and by the growth of a thick grass cover. An extensive program of testpitting might divulge in situ artifacts and tephra. In 1975 we were able to collect surface artifacts ranging from Preclassic to contemporary. We were unable to encounter a single locality exhibiting the in situ ash-humus-with-artifacts stratigraphy, so there is no profile of this site.

The small sample of diagnostic ceramics were dated by Sharer to the Middle and Late Preclassic; other sherds not included in his analysis were recent glazed pottery and asbestos roofing tile.

SS4-1a, Cartografía Site, Fig. 21.

The evidence for this being an archaeological site consists of ceramics in the buried humic horizon. The largely unsorted volcanic ash at this location buries the archaeological site under as much as nine meters of tephra. This is either a very small habitation site, or the bulldozer sectioned it on a periphery. The ceramic sample was insufficient for stylistic dating.

SS5-1a, Israel Site, Fig. 23.

This site, in Colonia Israel in the extreme southern part of San Salvador, serves as a caveat against premature field judgments. We initially thought that the pit which intruded into bed 1 (Fig. 23) was intruded prior to the deposition of the volcanic ash (bed 2). Therefore, we interpreted the pit as dating to the Preclassic, assuming the ash to be Ilopango "tierra blanca", so the artifacts in the pit should be Preclassic as well. However, closer examination of layer 2 divulged small humus clumps in the ash, indicating disturbance. And, examination of the artifacts from the pit divulged Preclassic ceramics, an iron nail, and fired clay roofing tile fragments. The intrusion, it became clear, was in fact from bed 3, and it probably dated to sometime during the past 100 years. Sharer's ceramic analysis tabulates six recent artifacts: three comales and three glazed ceramics.

Cerron Grande Archaeological Salvage Project Sites

The Salvadoran government has decided to construct a large hydroelectric dam in the middle reaches of the Rio Lempa, approximately 35 km NNE of San Salvador. When completed, it will flood 125 km^2 of fertile agricultural land in the departments of Cuzcatlan and Chalatenango. The Museo Nacional and the Banco Central de Reserva have sponsored two field seasons of salvage archaeology under the general direction of Stanley Boggs. During the 1975 season two archaeologists, Howard Earnest of Harvard University and William Fowler of the University of Calgary, encountered Preclassic artifacts and architecture under a layer of white volcanic ash.

The Los Flores site, excavated by Fowler, is located on the north bank of the Rio Lempa, between the Rio Grande and the Rio Tamulasco, at 220m in elevation. Fowler found Mound 10 to be circular in plan, Preclassic in date, and overlain by a layer of white volcanic ash (personal communication 1975, Ball 1975:3). An ash sample, graciously furnished by Fowler, is catalogued as CH2-1t here. The structure is 40m in diameter, and is presently 6m in height.

Howard Earnest's 1975 efforts focused upon the Rio Grande site (CH1t on Fig. 2), located 2km NW of the Los Flores site. The comments which follow are taken from his preliminary report (Earnest 1975). Artifacts, apparently all Preclassic, are exposed along a river cut for .25km. A large 22 x 8m block was

TABLE 4: LITHICS BY TYPE AND PROVENIENCE

Type / Provenience	Prismatic Blades	Macro-Blades	Polyh-Cores	Flake Core	Decort. Flakes	Unclas-sified	% Non-obsid.	% Co-rtex	Totals
LL1-1a (gen)	3	1	1		3	18	4	11	25
LL1-1a (contact)	5	1			3	13	5	14	22
LL2-1a						1			1
LL2-2a	5	1	1						7
SA1-1a	1	1	1			1			4
SA4-1a	1	1			4	11		23	17
SS2-1a	1	1	1			4			7
SS3-1a	1			1			50		2
Totals by Type:	17	6	4	1	10	48			86

excavated through unconsolidated flood deposits, revealing a thick (60cm) layer of volcanic ash burying a regular series of some 20 ridges and swales in the humic horizon. The ridges are regularly spaced about a meter apart, and swale depth forms as regular a pattern. The most likely explanation for such a pattern is an irrigated agricultural field. It is not yet clear if cultigens were for subsistence or for cash-cropping. Four human burials were excavated from the humic horizon, but skeletal preservation was poor. Two of the burials were accompanied by ceramic vessels and jade beads. Earlier materials and features were also encountered, including an enigmatic fired clay T-shaped trough (a possible sluice-gate?).

LITHIC ARTIFACT ANALYSIS

The classification and analysis of lithic artifacts recovered during the 1975 field season followed the criteria established by the Chalchuapa Archaeological Project (see Sheets in Sharer 1976). These artifacts are classified and described in the following categories: prismatic blades, macroblades, decortication flakes, polyhedral cores, flake core, unclassified, and mano (the sole representative in this sample of the groundstone industry).

Prismatic Blades, 17.

The mean width of these prismatic blade fragments is 1.4cm, and mean thickness is 0.3cm. Only four of these fragments retain their platforms. Platforms are lightly to moderately striated, and average 0.3 x 0.1 cm in size, which is well within the range of expectation for Late Formative prismatic blades (Sheets in Sharer 1976). No edge abrasion clearly attributable to use is notable on these implements. See Table 4 for specific provenience data for prismatic blades and other lithic artifacts.

Macroblades (Large Blades), 6.

These macroblades, or large blades, are the debitage removed from the core by percussion prior to the shift into pressure removal of prismatic blades. The two specimens retaining the proximal end of the blade both evince percussion removal in the form of salient bulbs, platform crushing, fracture surface, and so forth. All are fragmentary, but at least mean width (2.2cm) and thickness (0.8cm) data are obtainable. One, LL2-2a, is larger than the others (width 3.3cm and thickness 1.2cm) and it carries four primary scars on its dorsal surface. It is possible that it is a result of deliberate core smashing rather than intentional macroblade production.

Decortication Flakes, 10.

Decortication flakes are here defined as flakes with a predominance of their dorsal surface covered with the cortex of the original obsidian cobble. This is not meant to imply that the primary objective in the ancient knapper's mind was the removal of cortex, because, for at least some of these flakes, core ridge formation and straightening probably was more important, and we currently lack the analytic tools to accurately probe the minds of deceased knappers. Mean length is 2.2cm, mean width is 1.8cm, and mean thickness is 0.4cm.

Polyhedral Cores, 4.

Only two of these polyhedral core fragments are sufficiently complete to furnish a diameter measurement; they have diameters of 2.0 and 1.8cm. One was complete enough to count the number of scars left from previous blade removals. It carries nine major scars and four minor scars. All four of these fragments contain the evidence of their being violently smashed after they had served their function of producing prismatic blades. The one specimen which still retains some of the platform was deliberately smashed around the peripheries of the platform causing relatively massive hinge fracturing and rendering further blade production impossible. This is consonant with the lithic analysis from Chalchuapa, but it is at marked variance with the Bustamante Site data (Sheets 1972) where evidence of deliberate core mutilation was rare. Further work will be necessary to determine how abberant the Bustamante Site lithic technology was from the SE Maya Highland pattern, at least in this regard.

Flake Core, 1.

This flake core from Site SS3-1a is a whitish-yellow opaque chert. Chert does occur naturally in the Metapán area and in the Asunción Mita area of Guatemala, as well as in a broad band across central-northern Guatemala eastward through Honduras. But the specific source for this chert is not known. The platform is a large, broad and flat percussion flake scar. Core dimensions are 2.0 x 3.2 x 2.5cm respectively. The core undoubtedly was used to produce chert flakes; eleven scars of previous flake removals are recorded around its peripheries. All but one of these eminated from the platform, the exception was a short flake removed by a blow to the distal end, probably to remove a projecting mass. The flake was successful, although it did cause a slight step fracture. One small patch of orange cortex (not stream cobble cortex) remains on one side.

Unclassified Lithic Artifacts, 48.

Included in this category are the fragments of debitage of various manufacturing operations which were either too fragmentary or too undiagnostic for reliable classification into a specific technological category. Most appear to be the wastage in core trimming activities, but surely some derive from scraper manufacture and resharpening, exhausted core smashing, or other lithic activities. No identifiable biface trimming flakes, or the bifaces themselves, were recovered. This is as expected, for almost all these samples derived from sub-ash contexts, and bifacial flaking was not common in the SE Maya Highlands until the Late Classic (Sheets in Sharer 1976) or the Central Maya Highlands until the Early Classic, with rare exceptions (Woodbury 1965:170-2).

Groundstone: Mano, 1.

One fragmentary mano (length unknown, width 8.1cm, thickness 5.3cm) was recovered from sampling locality LL1-1a, immediately below the volcanic ash layer. Formally and functionally it can be classified as a "Rectangular, Biconvex Mano" (Sheets in Sharer 1976). This type at Chalchuapa begins in the Late Formative and continues through the Postclassic; it is not a sensitive time indicator. The mano is made of a slightly vesicular andesite, as is common in central and western El Salvador, and it was used on both faces. Its original length is estimated to have been between 10 and 15cm.

General Observations on the Lithic Industry

If Chalchuapa Late Formative lithics were used as a prediction for lithics in central and western El Salvador, then there are few surprises. The technology is core-blade, the manufacturing behavior is comparable, and the resultant products virtually identical. Two samples do appear to be slightly "anomalous" (LL1-1a and SA4-1a) in that they both contain an unusual number of short (under

1cm), often hinged percussion flakes. Many may be the result of rough core edge preparation (overhang removal) prior to large percussion blade manufacture. However, their place in the overall reduction system is not well understood.

Three sites contained surprisingly high frequencies of cortex (see Table 4), but sample size is such that a great deal of confidence in this result is unwarranted. The small chert flake core is almost a welcome surprise in an industry so heavily dominated by obsidian.

SUMMARY AND CONCLUSIONS

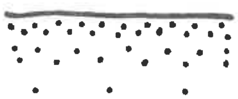
Numerous separate discoveries of artifacts under volcanic ash in central and western El Salvador have been reported over the past 60 years by Lardé, Lothrop, Dimick, Boggs, Sharer, Sheets, Earnest, Fowler, and others. Beginning a decade earlier are the reports from lowland Maya excavations of the intrusion of a foreign complex of artifacts into the indigenous continuum which led to the Maya Classic. This intrusive complex, now called the Protoclassic, is known to date to between AD 100 and 400 in the lowlands. The suspicion that there may have been a direct relationship between these two sets of observed phenomena led to the research reported herein. However, before a relationship between highland and lowland phenomena could be posited, basic data were needed from the highlands.

Work of the Chalchuapa Archaeological Project, particularly in 1969 and 1970, documented the gradual development of the elements of the Protoclassic complex, stratigraphically capped by the layer of volcanic ash (see Sharer 1974), making possible the formulation of the hypothesis that explosive volcanism rendered uninhabitable a significant area of the Southeast Maya Highlands, and that forced migration could be the explanation for the lowland Protoclassic intrusion. Prior to this research, a major deficiency in data derived from the fact that all the sub-ash artifact discoveries in the highlands were site-specific, and virtually all were without any geologic, let alone tephrochronologic, analysis. We had enticing fragments of data which might indicate a large scale natural disaster, but both a regional scope and a consistent, multidisciplinary research strategy were lacking.

With these problems in mind, the 1975 research was directed toward determining if there was a relationship among these disparate finds of tephra overlying archaeological sites in the highlands. If the tephra deposits were in fact related, i.e. from the same eruption or series of eruptions, was the volcanologic event of sufficient magnitude to serve as a potential explanation, in the form of a migration, for the Protoclassic intrusion in the lowlands? As can be seen from the geologic analysis, by Virginia Steen-McIntyre, of the samples collected in June-July, 1975 (Appendix 1), the tephra shroud which blanketed the Southeast Maya highlands is not a series of local, unrelated events separated in space and time, but a massive, complex eruption. As far as we presently know, this eruption occurred in three stages, two ashflows (nuée ardente or glowing avalanche) and an airfall ash. The ashflows, consisting of incandescent clouds of pumice, ash, and gasses, rolled downhill and buried villages and forests in their paths as far as 45km from their source. Shortly thereafter, perhaps hours to weeks, the airfall ash was deposited in a more uniform blanket over the countryside. Yet unpublished data from the German Geological Mission to El Salvador indicates Ilopango to be the source of these tephra, and our evidence is in accord (although not conclusive) with their source attribution.

In some areas the probability of human physical survival would have been slight. For example, the Cartografía site was a village suddenly buried by up to nine meters of hot ash flow material. Areas farther from the source which received less instantaneous destruction, but where the vegetation, soils and hydrography were severely altered by the acid ash, would be more likely source areas for human migrations.

I would conservatively estimate, based on present data, that the environmental impact of the tephra-fall was greater than the Preclassic Mayan technological capacity to adjust and continue their agricultural adaptation over at least 3000 km^2. The density of settlement was high in the Late Preclassic, for the Southeast Maya Highlands were settled by agriculturalists for over a thousand years preceeding the eruption, and archaeological evidence indicates a steady population growth throughout the Preclassic. So, even if we use a minimal population density figure of 10 people per square kilometer, some 30,000 people would not have been able to continue living in the highlands.

	Zone of Pumice
	Present Land Surface
	Humic Horizon, Contemporary or Buried
	Stones
	Intrusion; Human, Rodent, or Root
— · — ·	Limit of Profile (boundary artificial)
SS 7-4T	Tephra Sample (Volcanic Ash or Pumice)
SA 2-3 A	Archaeological Sample (Ceramics, Chipped Stone, or Groundstone)
	Bedding Planes within a Layer

KEY TO SYMBOLS USED IN PROFILES (FIGURES 3-25)

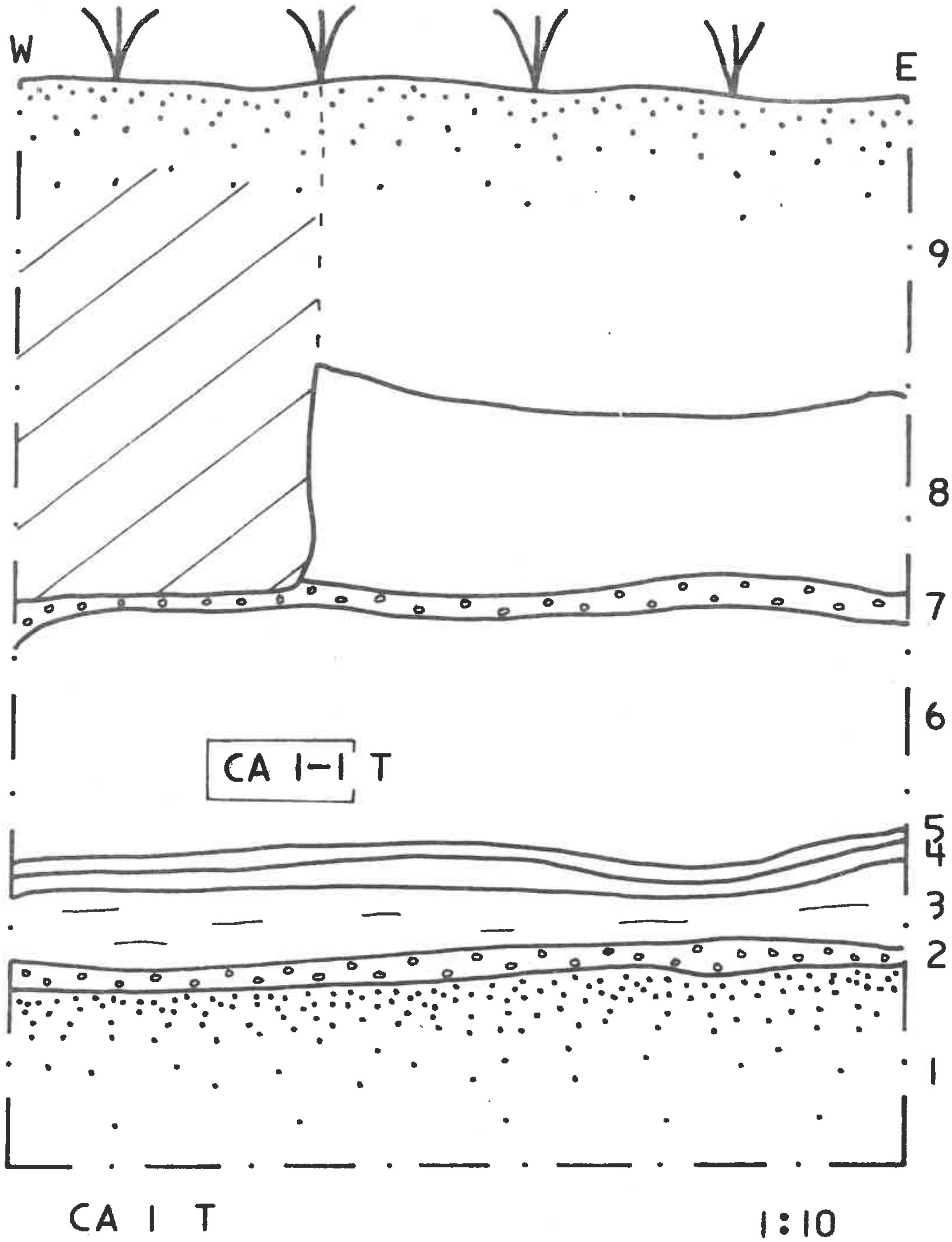


FIGURE 3. CA I T. 1: Medium to dark brown humic layer, some pumice, much clay. 2: Small angular pumice, dark brown. 3: Moderately fine-grained brown ash, some interbedding. 4: Fine-grained, light beige ash. 5: Brown coarser tephra, sandy in appearance. 6: Fine-grained white ash. 7: Zone of small pumice pieces mixed with ash, apparently some water sorting. 8: White ash, fine-grained, perhaps secondary. 9: Humic horizon developed out of layer 8, intrusive pit for pineapple cultivation on the left.

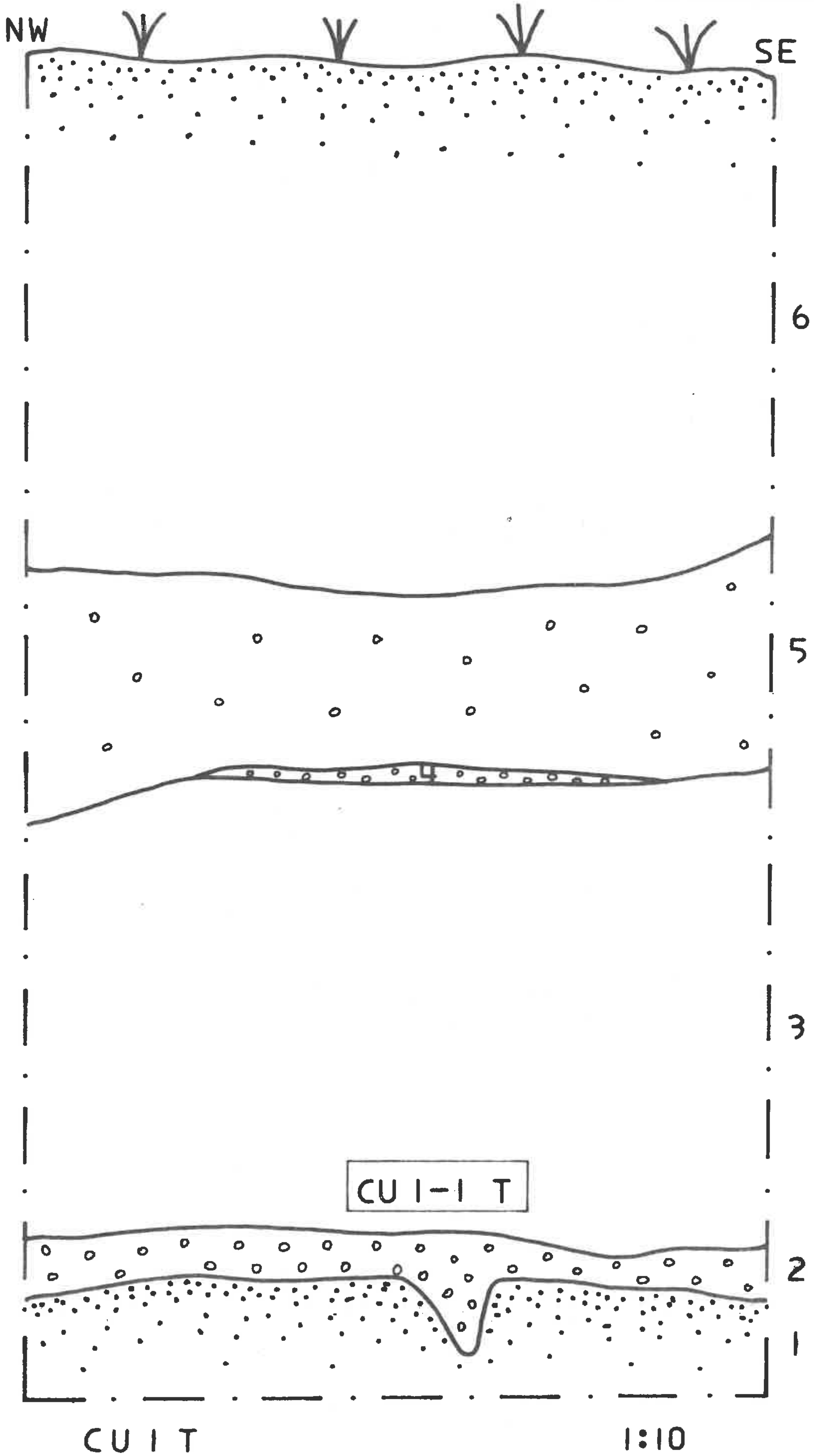


FIGURE 4. CU 1 T. 1: Buried humic horizon, orange-brown in color, with some pumice and clay. 2: Small pumice pieces (under 1 cm. diameter), little ash, dark brown in color. 3: Fine grained beige ash. 4: Pumice lens, some rounding. 5: Sandy gravel, some stone and pumice. 6: Present humic horizon grading from dark brown at top to light brown or beige at bottom.

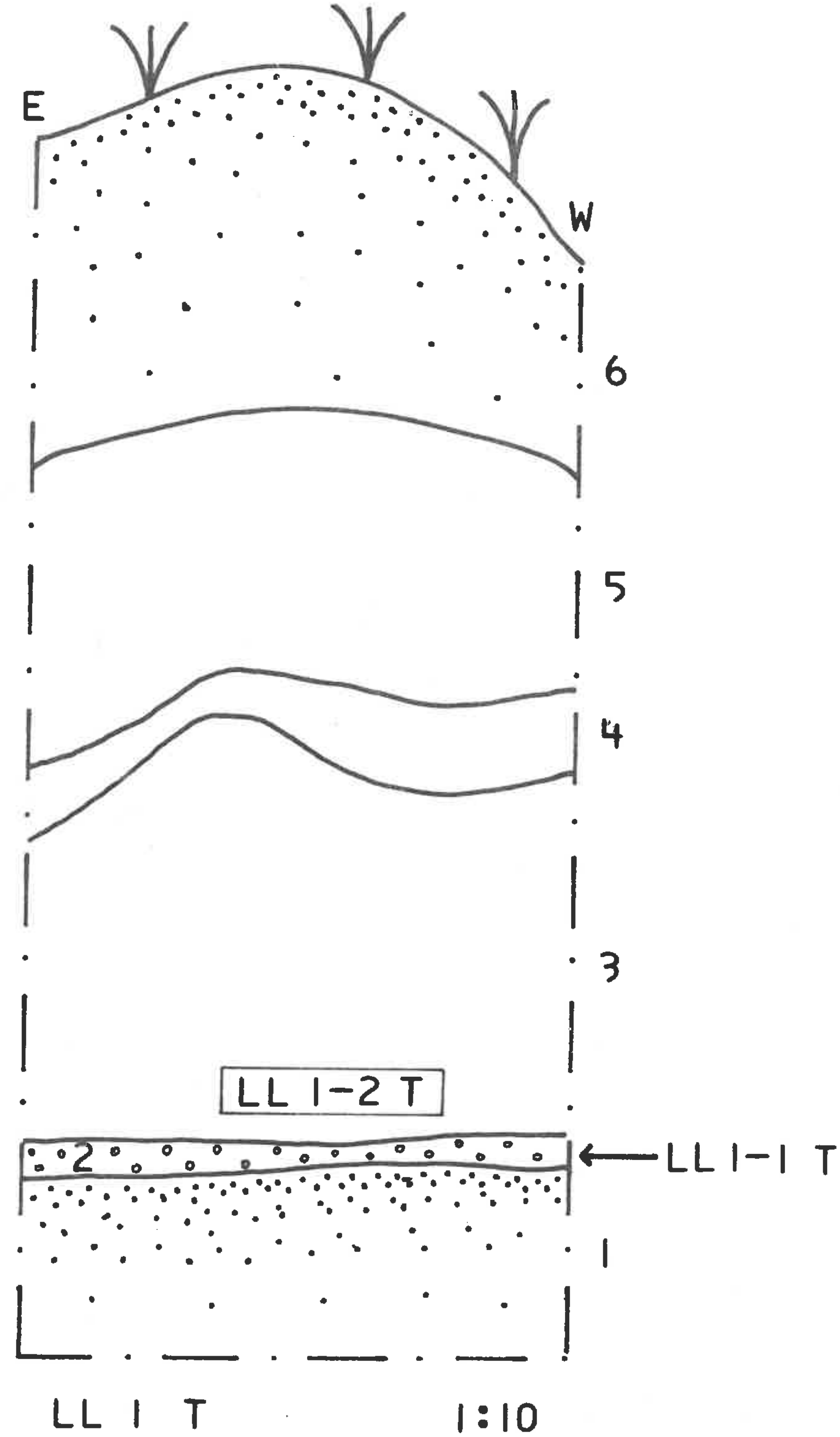


FIGURE 5. LL 1 T. 1: Pre-eruption humic horizon, very dark brown. 2: Coarse angular pumice. 3: Fine-grained, light beige colored ash. 4: Coarser sand-like tephra, beige or gray color. 5: Zone transitional between 4 and 6, gray to white ash grading to light brown toward the top. 6: Contemporary humic horizon, fine grained, brown.

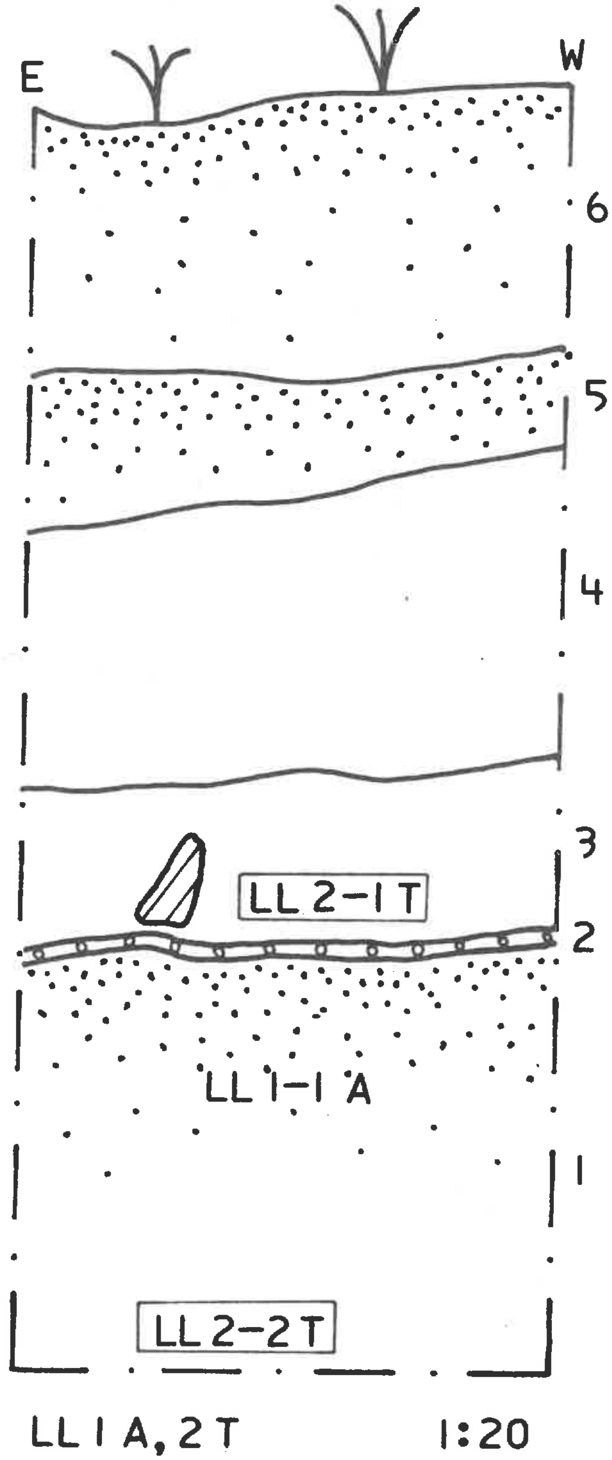


FIGURE 6. LL 1 A, 2 T. 1: Buried humus with many ceramic and lithic artifacts in situ, orange-brown at top, light brown at bottom, much clay, some pumice at bottom. 2: Level of angular, small (1 cm diameter) pumice pieces. 3: Fine, white ash, no pumice, some rodent disturbance. 4: Fine-grained beige transitional zone between 3 and 5. 5: Contemporary humic horizon developed out of the ash. 6: Roadfill added in 1974 for overpass on the Pan-Am Highway.

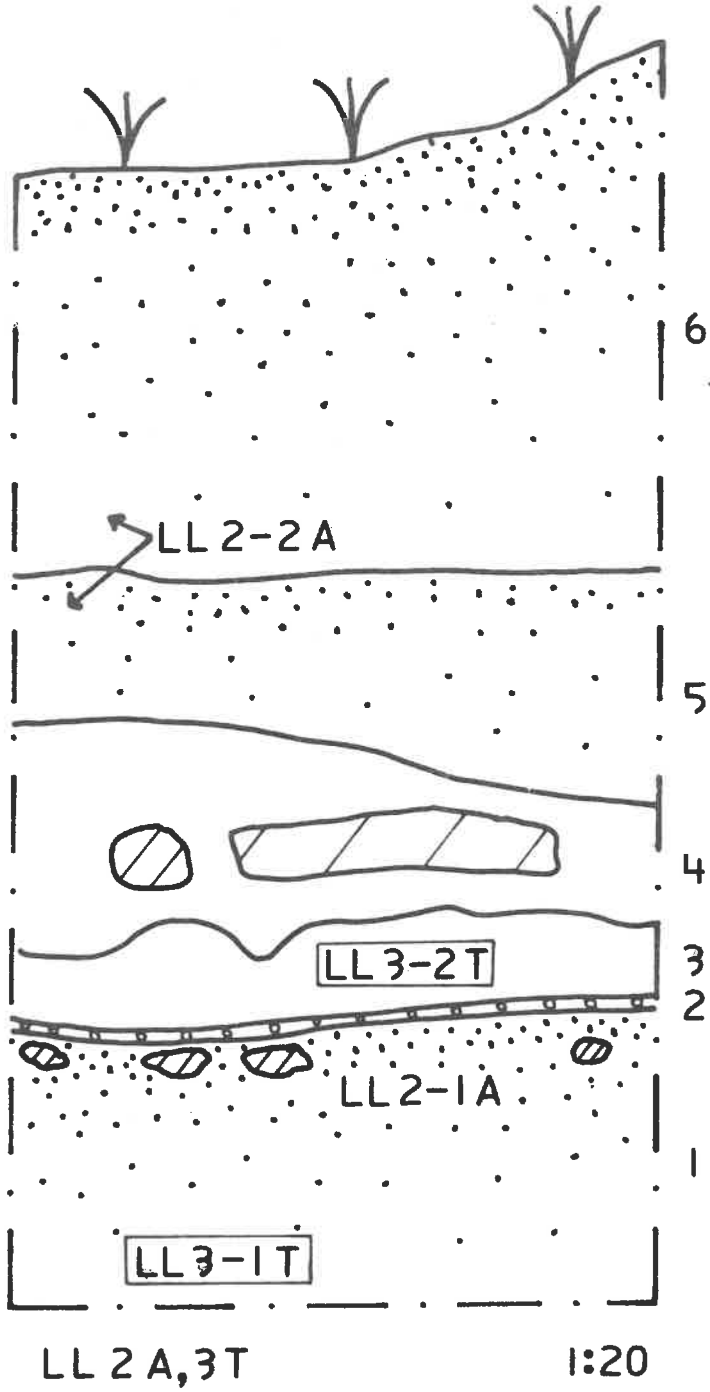


FIGURE 7. LL 2 A, 3 T. 1:Dark beige to brown humic horizon, some pumice at bottom, numerous lithic and ceramic artifacts in situ. 2: Thin layer of angular pumice. 3: Fine white ash, no pumice. 4: Dark beige ash-soil zone, some disturbance. 5: Probable humic horizon, dark brown, with numerous lithic and ceramic artifacts. 6: Mixed dark gray and brown fill with artifacts, perhaps Late Classic/Postclassic construction, but this may be more recent. Basal 2 cm is a dark brown granular material.

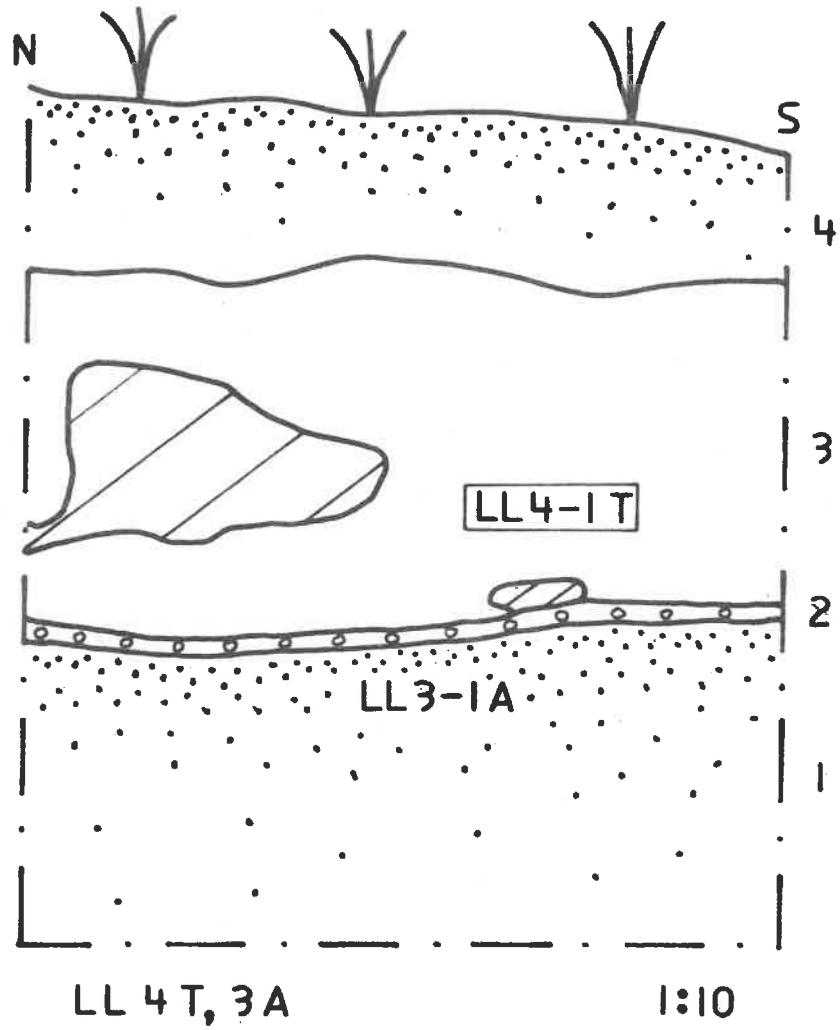


FIGURE 8. LL 4 T, 3 A. 1: Medium brown colored buried humic horizon, occasional ceramic artifacts in situ. 2: Angular-grained pumice layer. 3: Fine-grained white ash, no pumice, some disturbance by rodents. 4: Weakly-developed contemporary humic horizon, light gray in color.

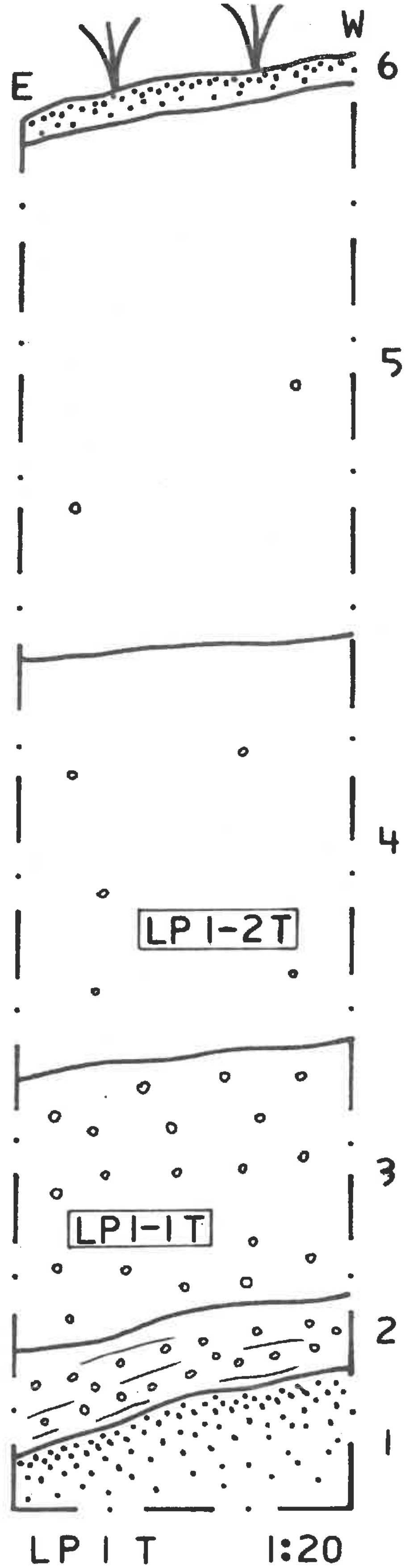


FIGURE 9. LP 1 T. 1: Dark brown humic layer. 2: Fine-grained interbedded mixture of pumice, ash, and rounded granular material, dark gray in color. 3: Pumice, some ash, gray, no interbedding. Pumice pieces generally smaller than 4 cm in diameter. 4: Moderately fine grained beige ash, occasional pumice pieces up to 1 cm in diameter. 5: Light beige to white ash, fine-grained, pumice rare. 6: Medium brown contemporary humic horizon.

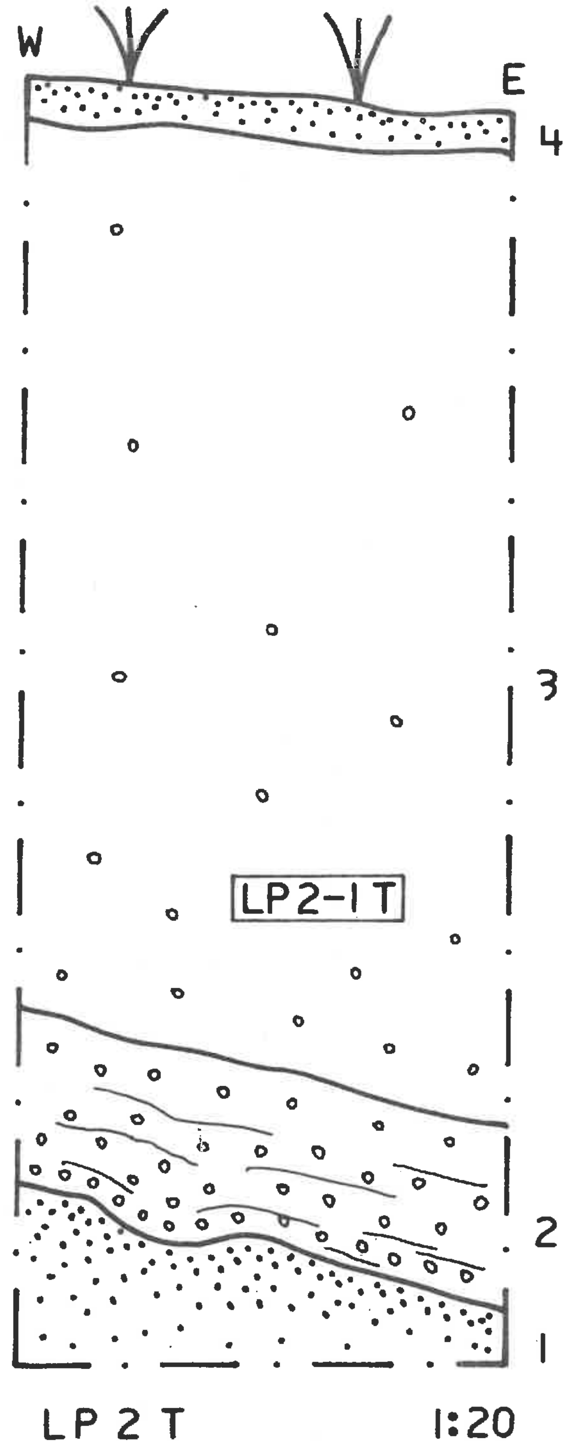


FIGURE 10. LP 2 T. 1: Dark brown buried humic horizon, some pumice, no clay visible. 2: Interbedded gray mixture of pumice, ash, and grit, completely unconsolidated. Some orange ash and pumice at base. 3: Beige to white ash with occasional pumice, particularly toward bottom. 4: Brown contemporary humic horizon.

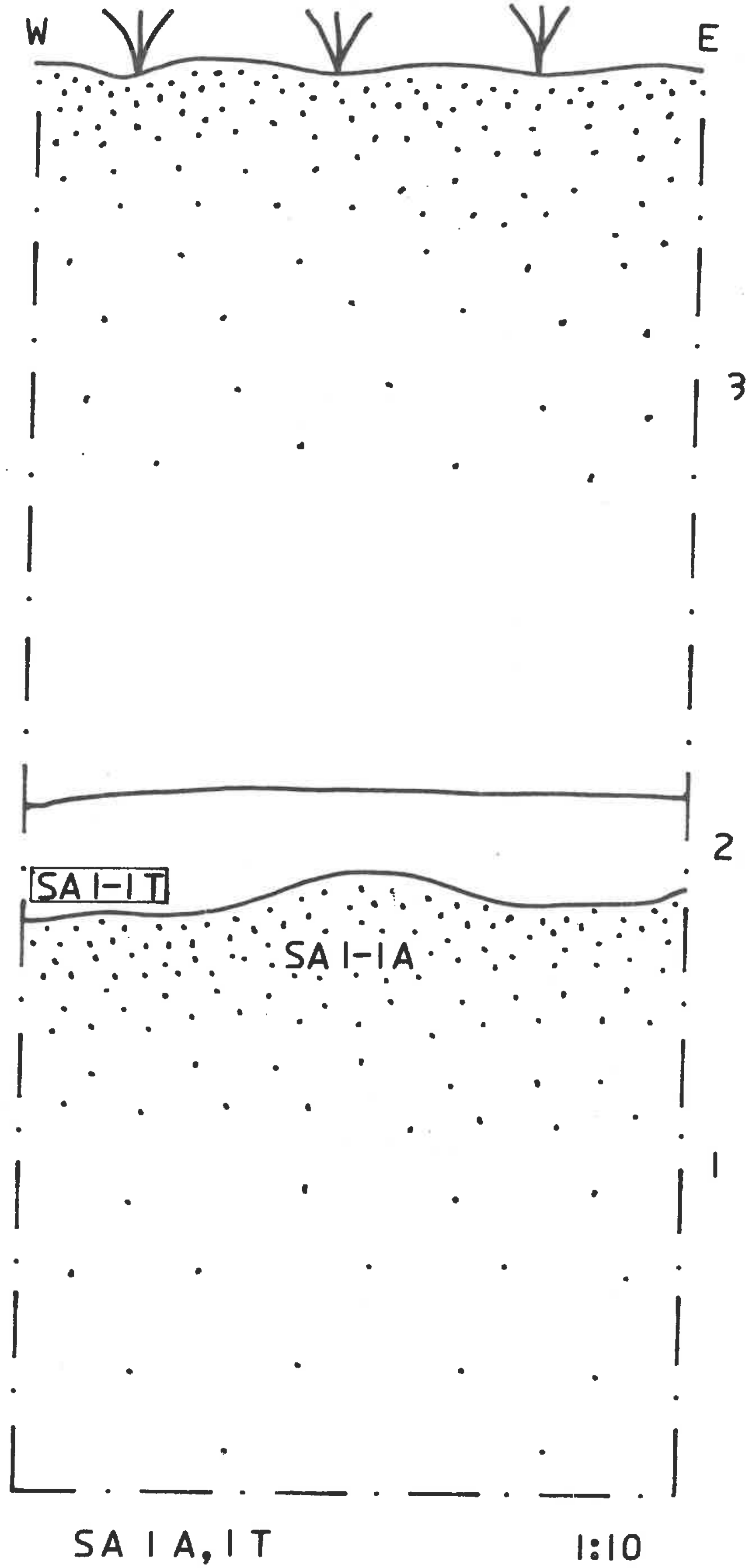
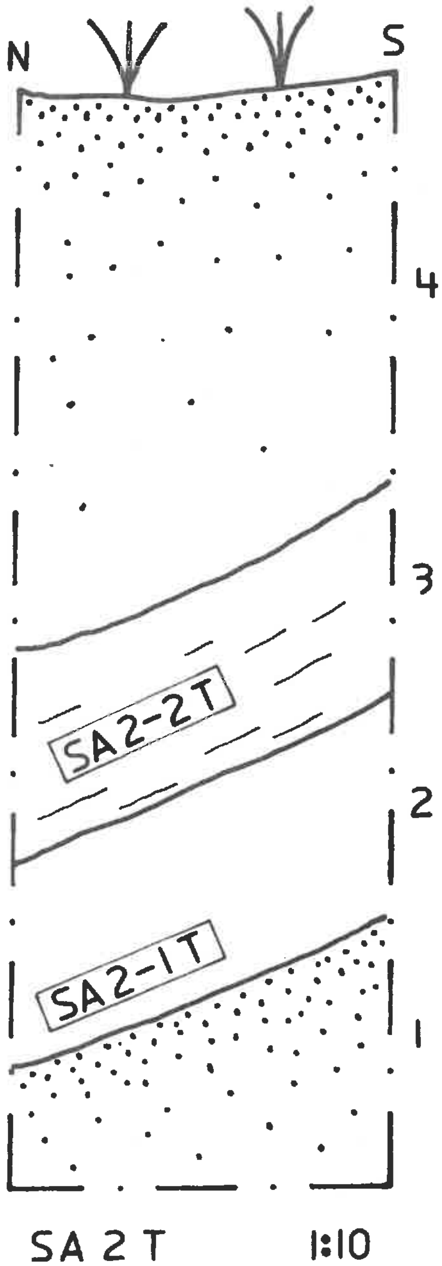


FIGURE 11. SA 1 A, 1 T. 1: Homogeneous medium brown humic horizon, occasional rocks (largely vesicular andesite) and ceramic and lithic artifacts. 2: Very fine-grained light beige to white ash, no pumice. 3: Homogeneous brown humic horizon and secondarily-deposited structural fill with artifacts.



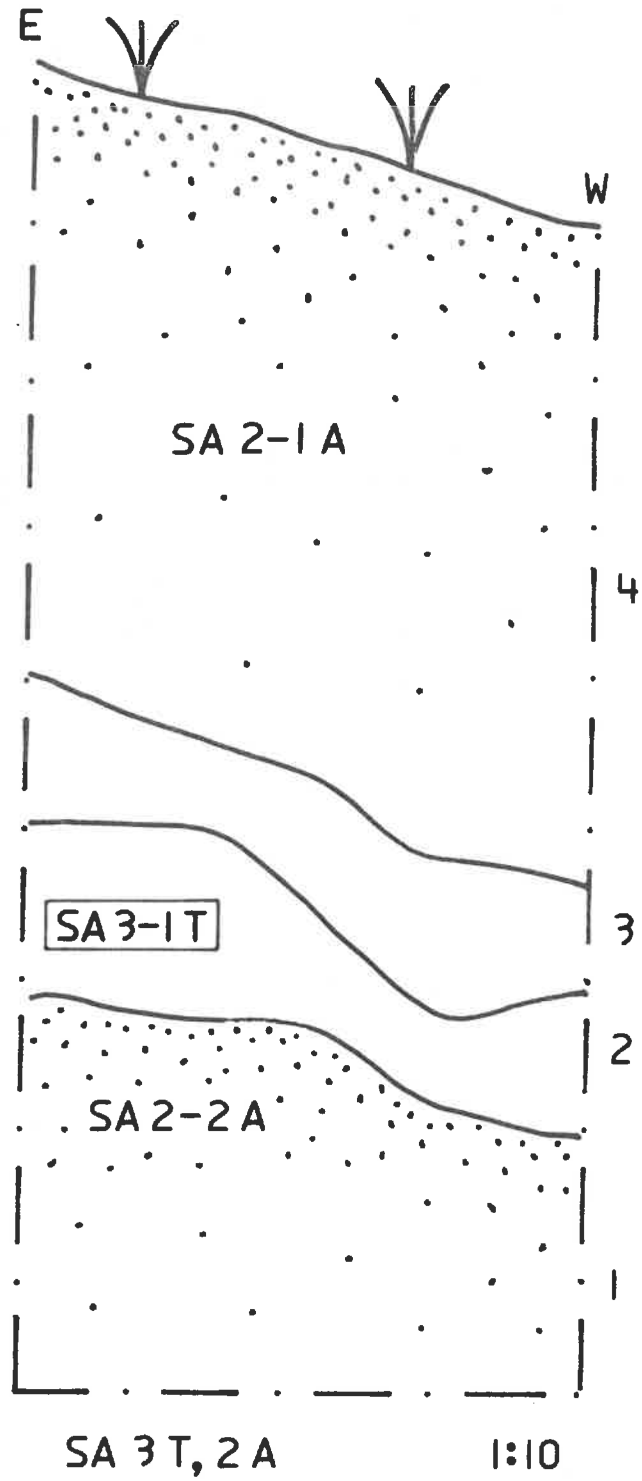


FIGURE 12. SA 2 T. 1: Dark black fine-grained humus, perhaps pre-eruption bog in the Laguna Seca. 2: Fine-grained white ash. 3: Interbedded white ash & soil, evidently washed in. 4: Contemporary humic horizon.
SA 3 T, 2 A. 1: Black humus with artifacts. 2: Fine-grained white ash. 3: mixed soil and ash, evidently secondary inwash. 4: Contemporary humic horizon with occasional artifacts.

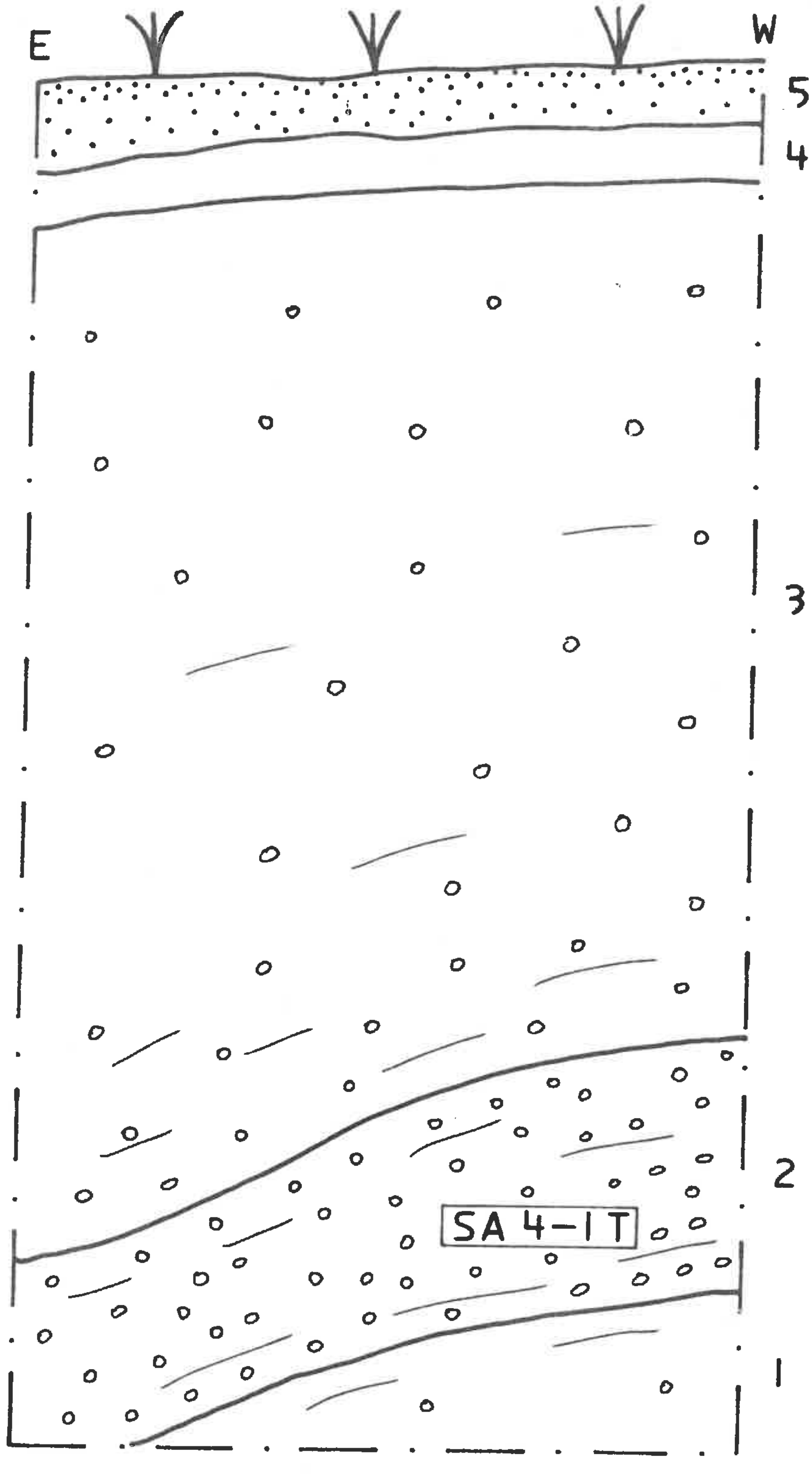


FIGURE 13. SA 4 T. 1: White, medium-grained ash, occasional pumice, some slight bedding. 2: White ash and pumice, some bedding. 3: Pumice, some ash, occasional bedding. 4: Mixed humus and beige-white ash; ash perhaps not from the eruption of layers 1-3. 5: Contemporary dark brown humic horizon.

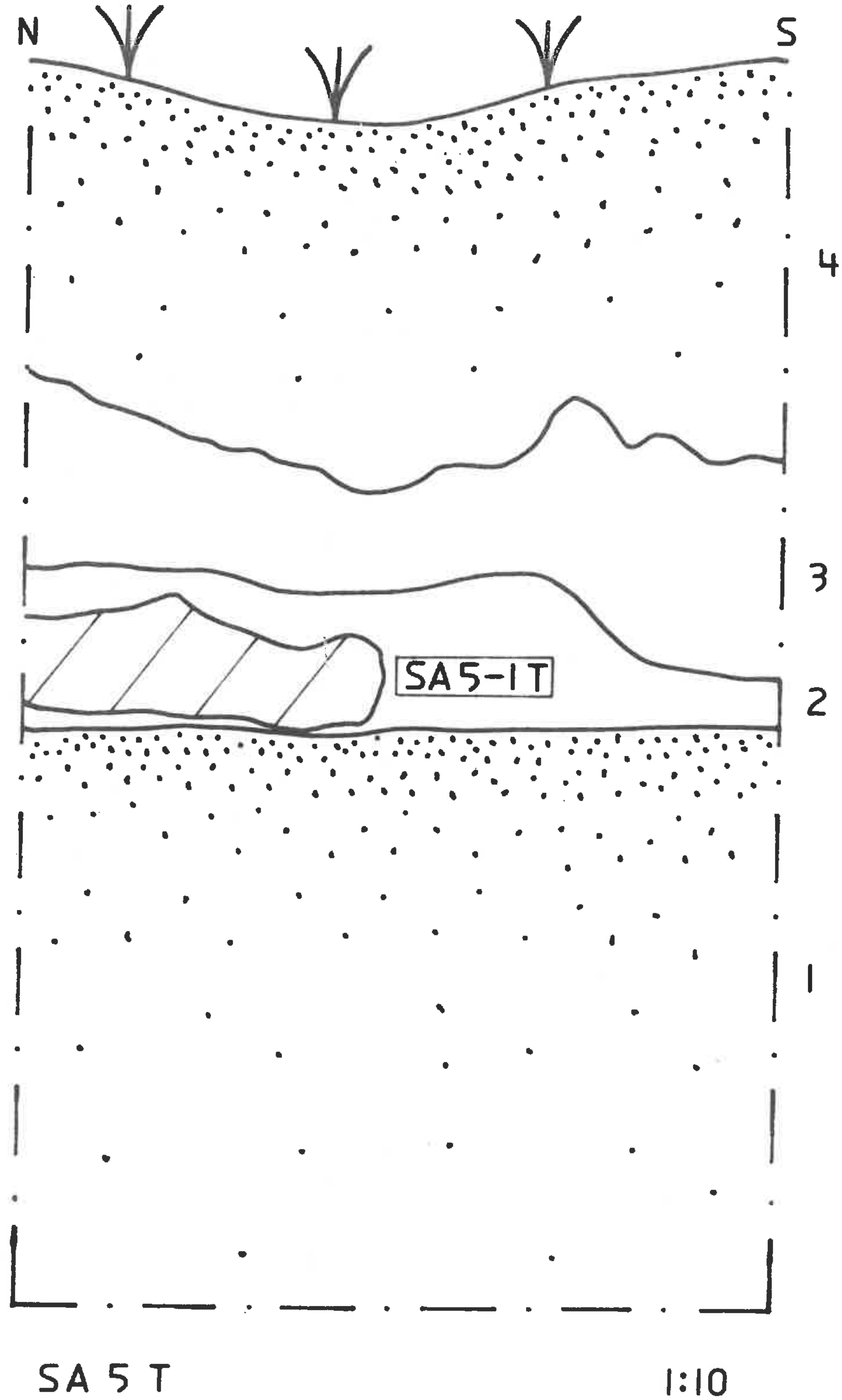


FIGURE 14. SA 5 T. 1: Buried soil, medium brown in color, some pumice toward the bottom. 2: Fine white ash, no pumice, rodent or root disturbance on left. 3: Mixture of ash and soil, white to dark beige in color. 4: Present humic layer, gray in color.

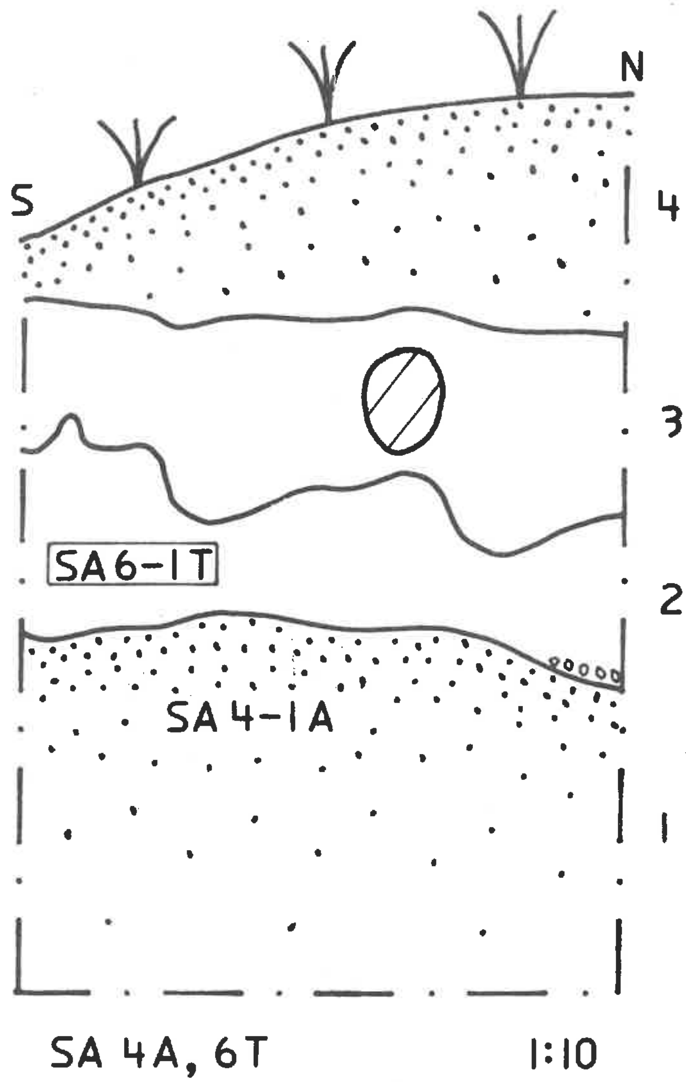


FIGURE 15. SA 4 A, 6 T. 1:Light to dark brown buried humic horizon, artifacts present. 2: Fine-grained white ash, with an occasional piece of pumice at the bottom. 3: Mixed ash and soil, intermediate between 2 and 4. 4: Dark gray contemporary humic horizon.

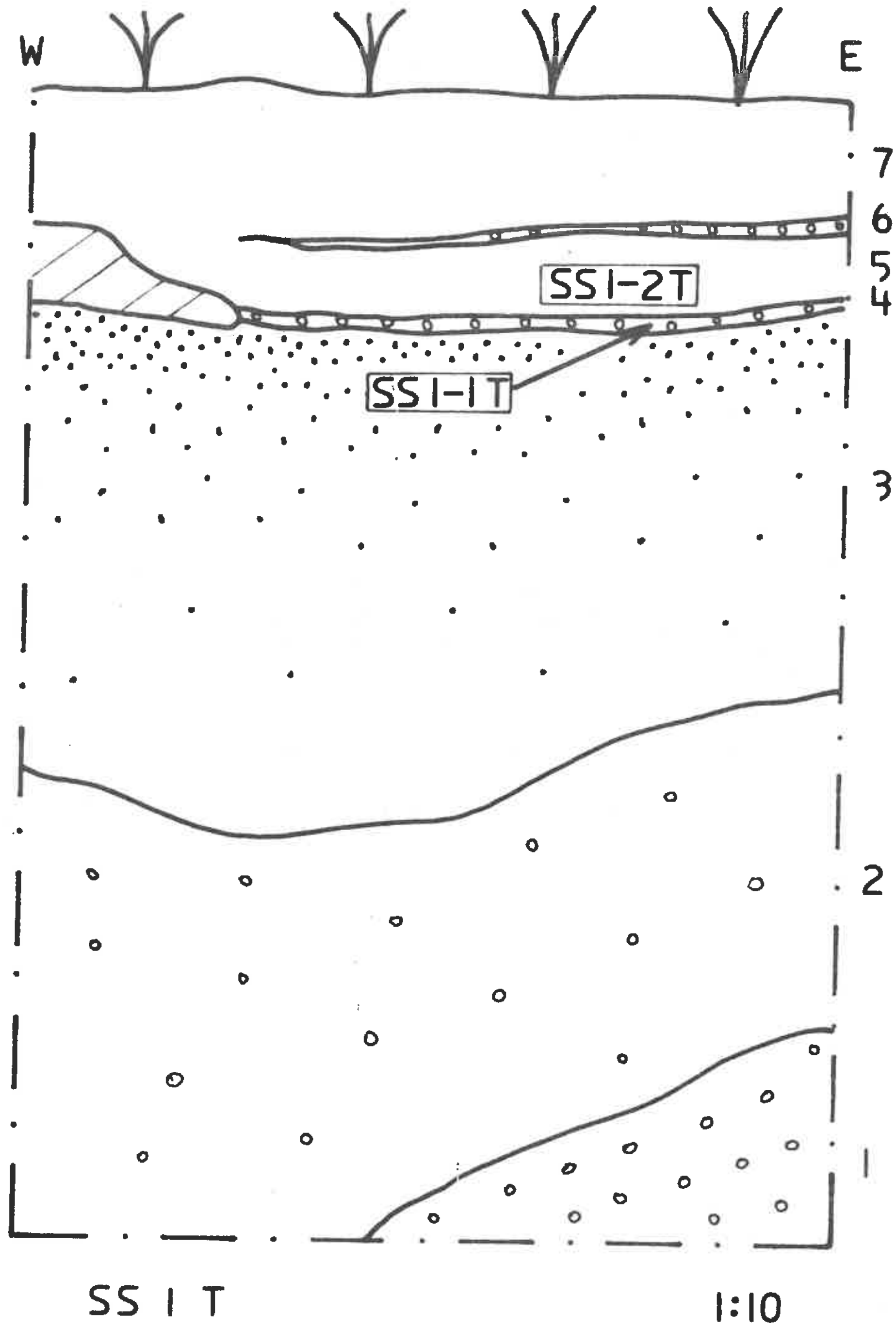


FIGURE 16. SS 1 T. 1:Beige colored pumice and ash. 2: Orange colored pumice, occasional stones. 3: Brown humus with occasional orange colored pieces of pumice. 4: Pumice layer with some compacted (waterlaid?) ash. 5: White fine-grained ash. 6: Thin lens of pumice, angular fragments. 7: Fine-grained white ash (same as 5).

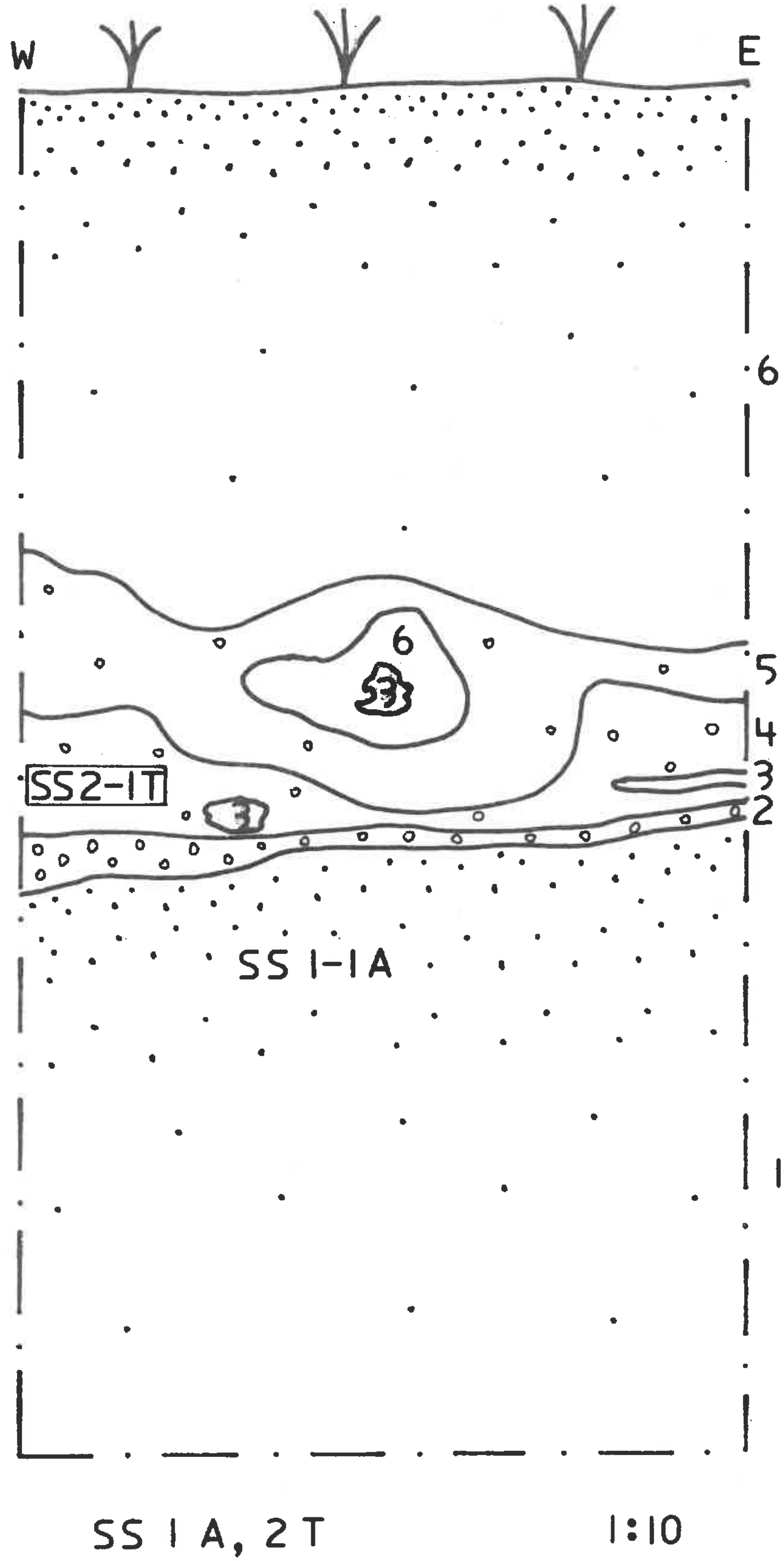


FIGURE 17. SS 1 A, 2 T. 1: Dark to light brown humic soil, high clay content, some pumice. 2: Layer of angular pumice pieces. 3: Fine-grained black material (ash or humus?). 4: White to gray fine-grained ash, occasional piece of pumice. 5: Moderate-grained sandy gray ash with some pumice. 6: Fine-grained beige ash with some pumice and an occasional small piece of the enigmatic #3 material. Note: Profile taken from bulldozed area; likelyhood of disturbance is high.

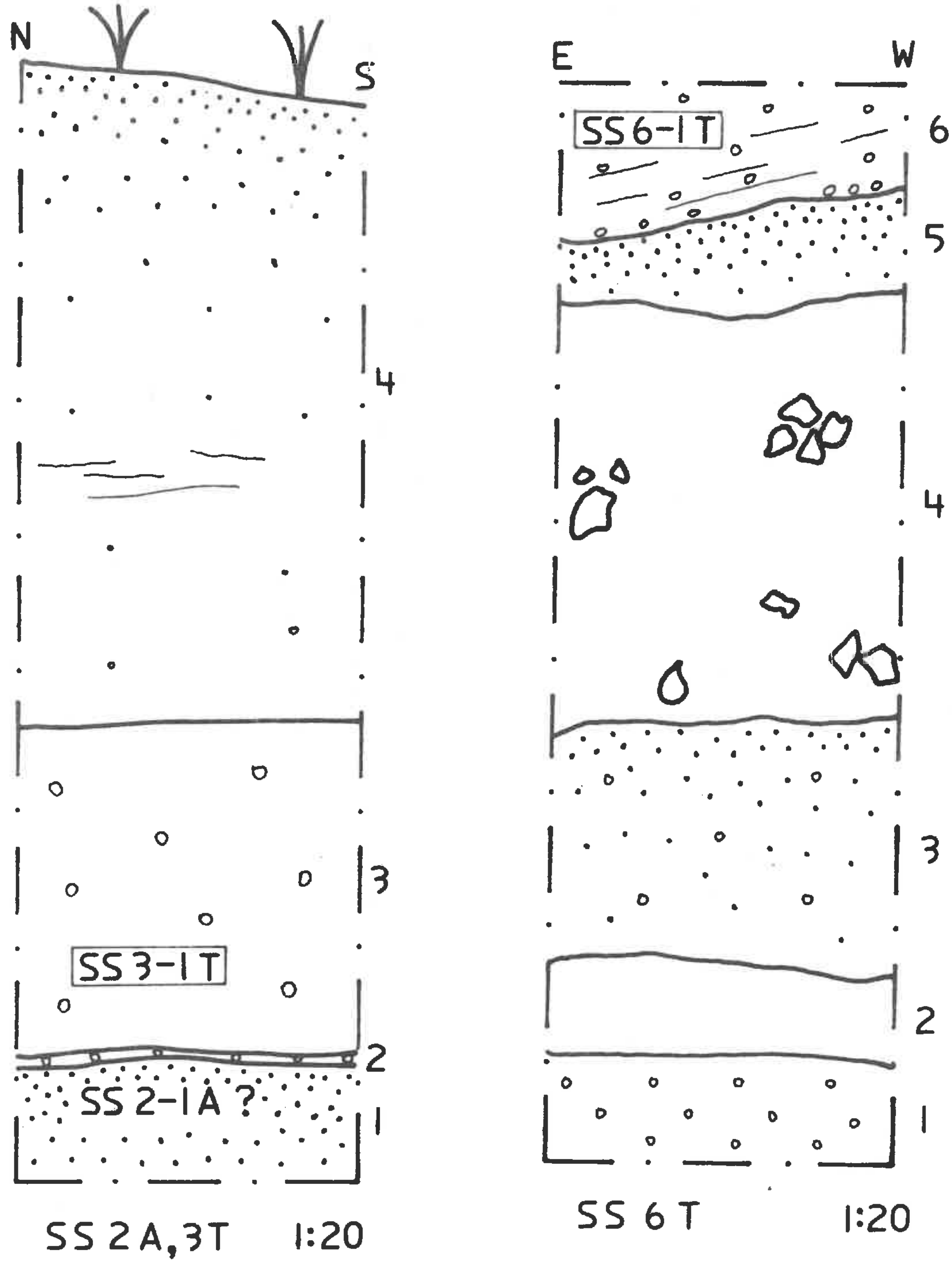


FIGURE 18. SS 2 A, 3 T. 1: Light brown buried humus level, high clay content, very hard, a few artifacts may be associated with this deposit. 2: 2-3 cm thick zone of pumice, white. 3: Mixed white ash and pumice, pumice to 6 cm in diameter. 4: Medium-grained beige to white ash with occasional pumice, some interbedded white ash in middle of deposit.

SS 6 T. 1: Brown colored angular pumice and cinders, all angular, under 1 cm in diameter. 2: Fine-grained dense brown-orange sand. 3: Possible humic horizon, dark brown, occasional pumice. 4: Light brown clay-laden layer, intermittent pumice & rocks. 5: Hard dark brown humic layer. 6: White ash with some pumice just above contact, some bedding and slight yellow-orange staining.

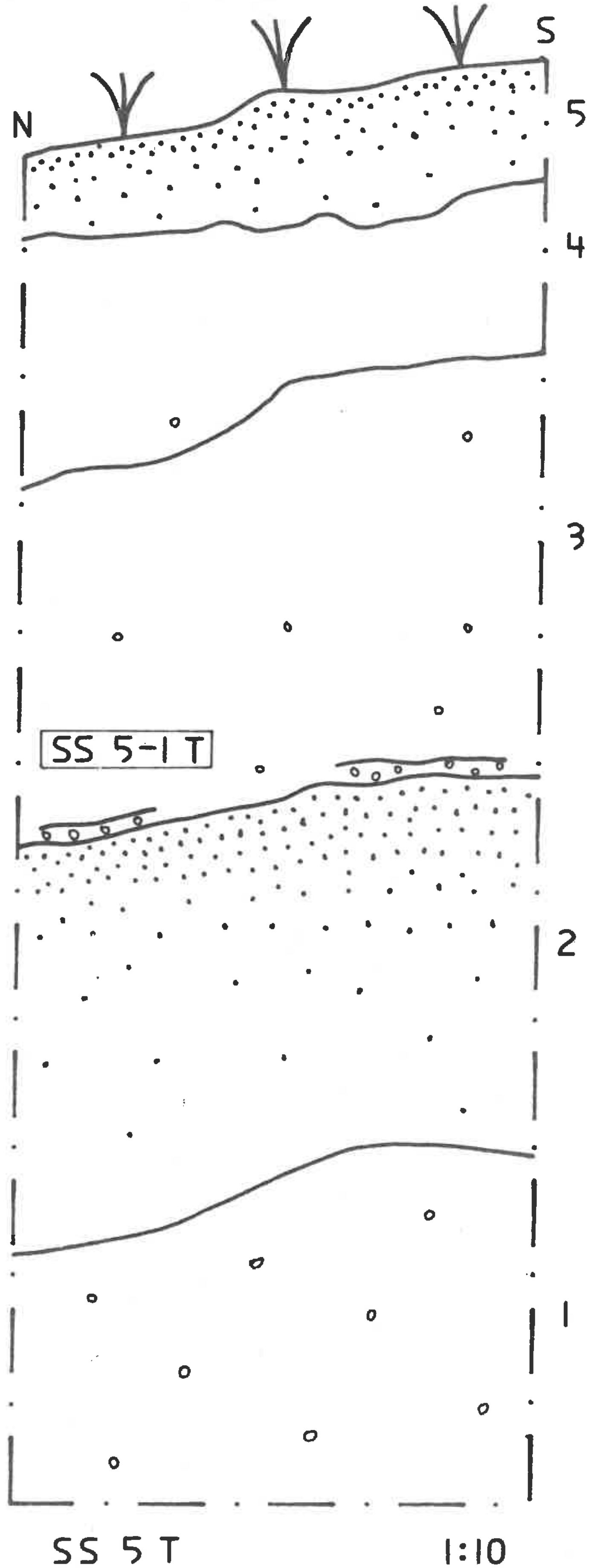
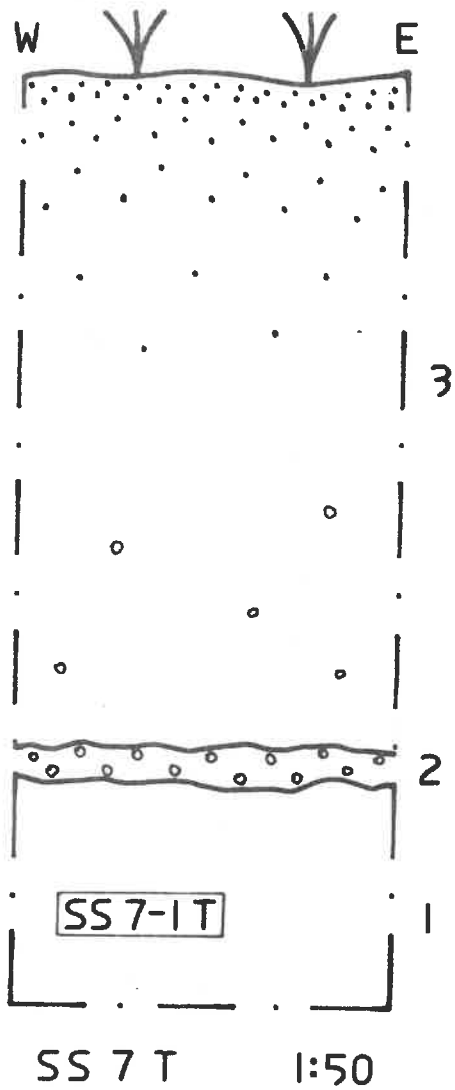


FIGURE 19. SS 5 T. 1: Mixed clay and weathered pumice pieces, light brown. 2: Dark brown humic horizon, high clay content. 3: Fine-grained volcanic ash with occasional pumice, particularly toward bottom. Pumice under 2 cm in diam. 4: Mixed ash and soil, beige. 5: Light brown contemporary humic horizon.



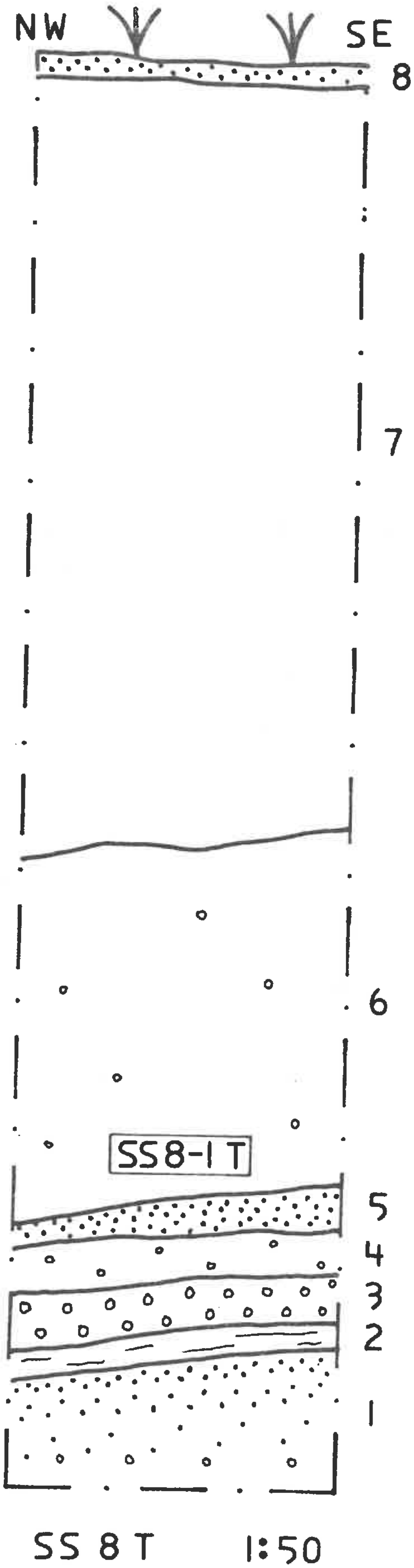


FIGURE 20. SS 7 T. 1: Moderate-grained white ash (humic horizon below not encountered). 2: Zone of pumice, angular fragments up to 7 cm in diameter. 3: Moderate-grained beige ash, occasional pumice, weak development of the contemporary humic horizon on top.

SS 8 T. 1: Early buried humic horizon, brown, much clay, some pumice. 2: Fine beige ash, some bedding. 3: Angular pumice, some ash, beige. 4: Brown mixture of pumice (under 4 cm diam.) and ash. 5: Hard, dark brown humus, much clay, some pumice (small). 6: Beige ash with some pumice. 7: Fine-grained beige to white ash with little pumice. 8: Brown contemporary humic soil.

FIGURE 21. SS 9 T, 4 A.
1: Pumice layer, little clay, light brown. 2: Buried soil, dark brown at top grading to an orange-brown.
3: Gray layer of Pumice, sand, and cinder, with occasional small pieces of obsidian (pumiceous, not worked).
4: Fine beige ash, little pumice, some tan staining. 5: Fine-grained light beige ash, small pumice pieces frequent.
6: Fine-grained white ash, little pumice.
7: Fine white ash, virtually no pumice.
8: Thin development of brown contemporary humic horizon.

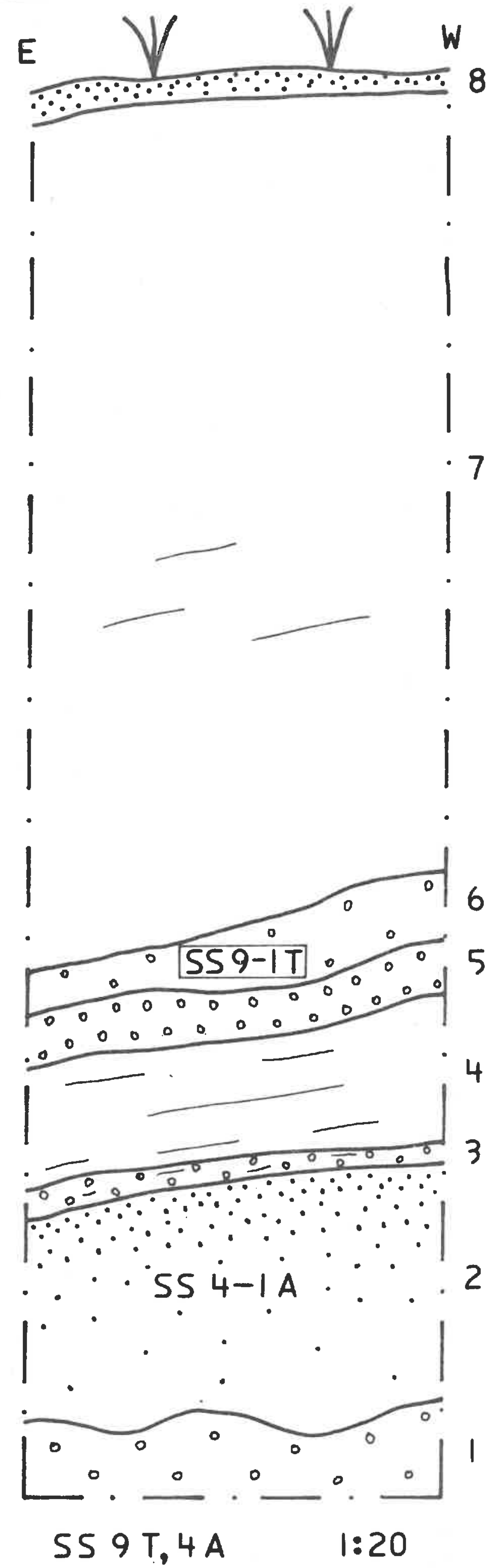
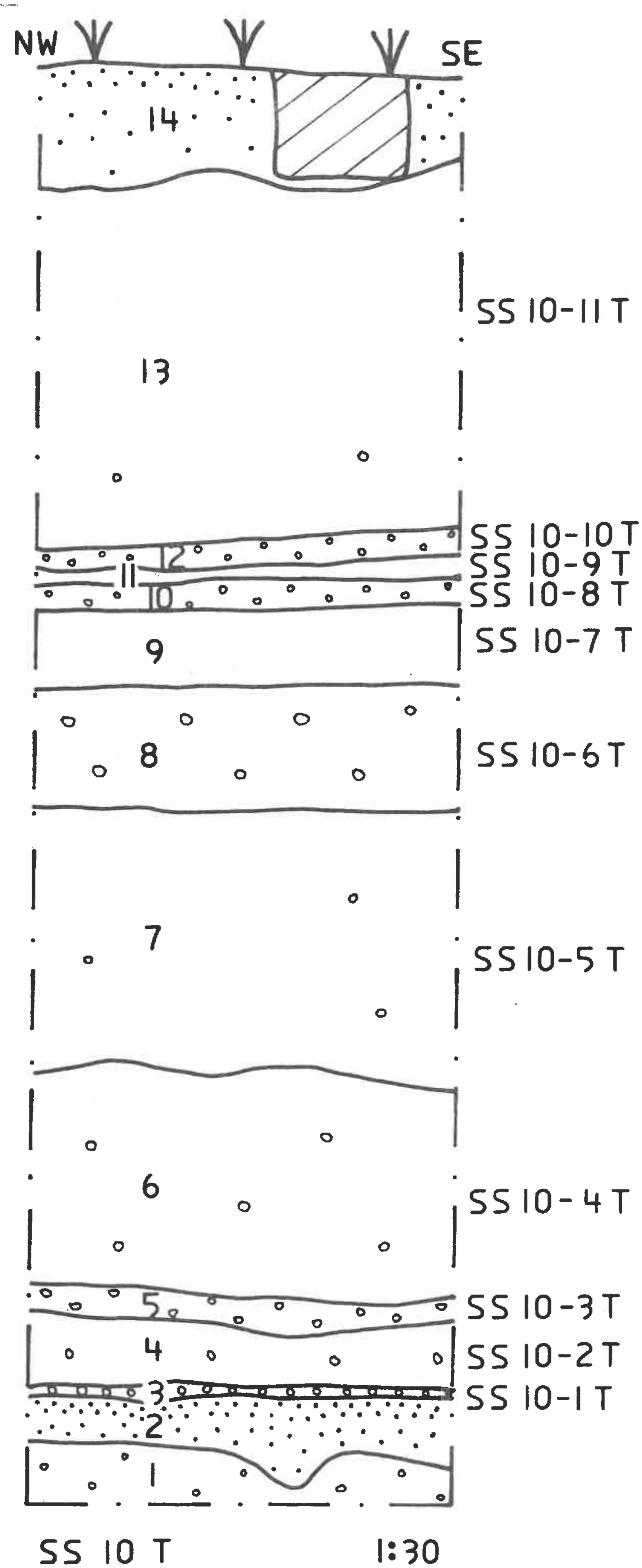


FIGURE 22. SS 10 T.

1: Beige to tan Pumice with some ash. 2: Dark brown humic horizon, much clay, some pumice. 3: Zone of pumice, almost no ash, beige. 4: Fine-grained gray ash, occasional small pumice pieces. 5: Beige ash with some pumice. 6: Moderate-grained white ash, occasional pumice. 7: Fine-grained white ash, pumice very rare. 8: Ash with pumice up to 1 cm in diam., one piece of lava 2 cm in diam., gray. 9: Light beige fine-grained ash, no pumice. 10: Light gray coarse sandy-like material, some pumice. 11: Fine-grained light beige ash, no pumice. 12: Ash and pumice level, light beige, pumice under 2 cm in diam.. 13: Fine-grained white ash, pumice rare at bottom & absent elsewhere. 14: Contemporary humic horizon, dark brown at top to light brown at bottom, coffee pit intrusion at right.



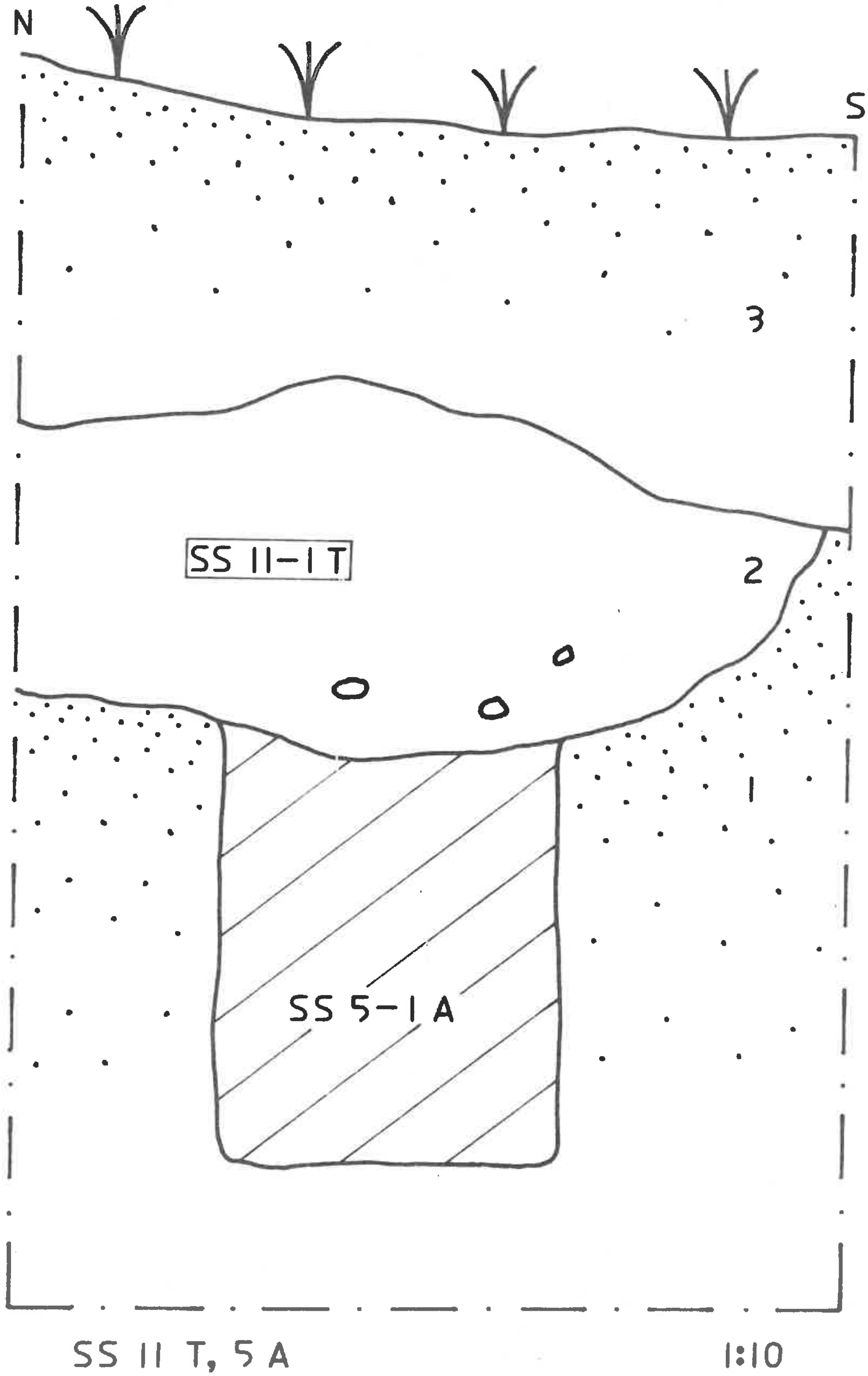


FIGURE 23. SS 11 T, 5 A. 1: Orange-tan ash and pumice zone, both ash and pumice quite weathered, grading into humic horizon at top.
2: White to light gray ash, fine grained, with occasional small pieces of pumice, and some small clumps of humic soil mixed in with the ash.
3: Dark brown contemporary humic horizon, thick, fine-grained.
Note: It was originally believed that the ash (layer 2) sealed the pit intrusive into level 1, but the clumps of humus in layer 2 indicated possible intrusion from higher, and the historic artifacts mixed with prehistoric artifacts in the SS 5-1 A sample indicated intrusion from layer 3.

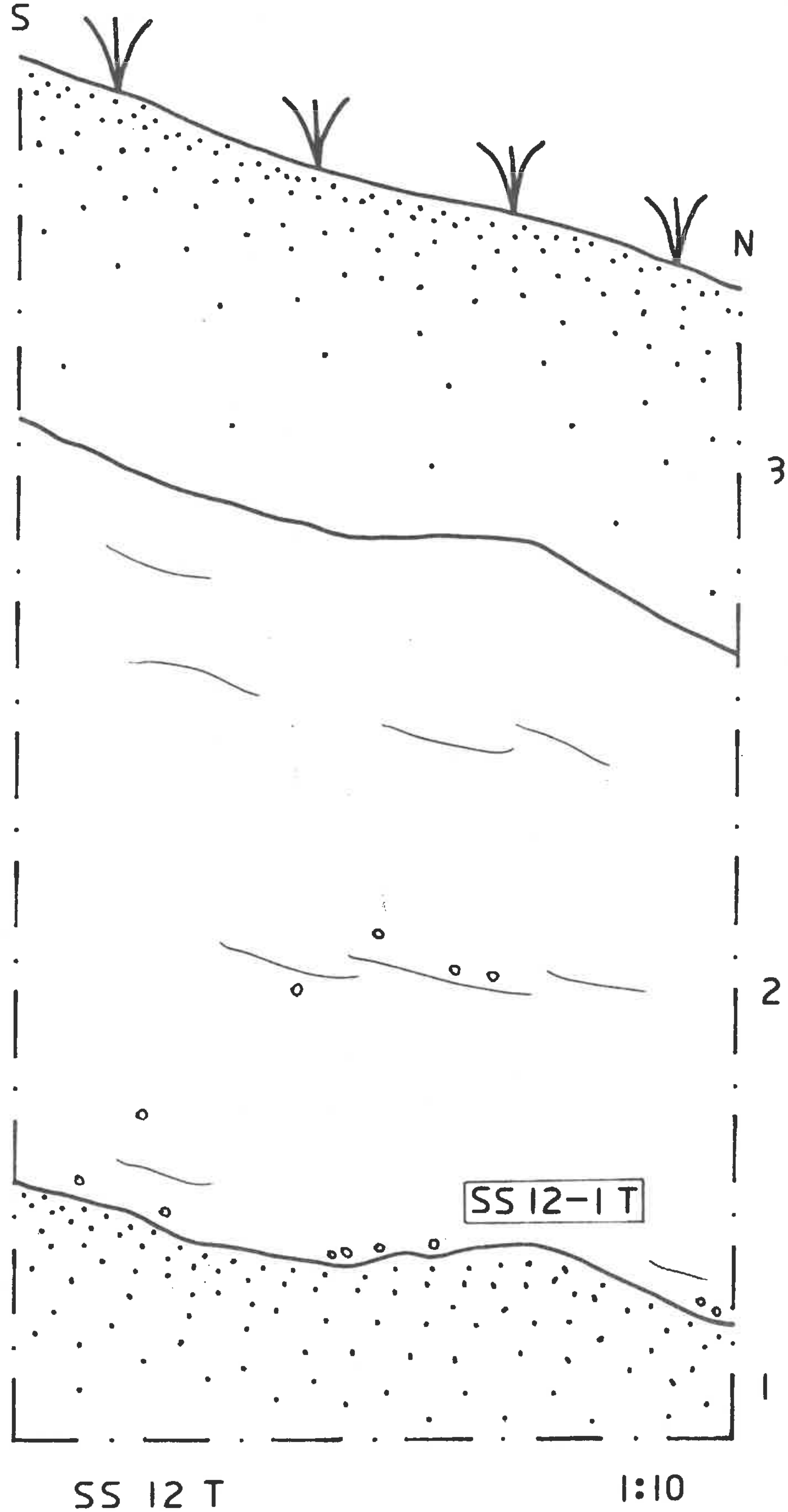


FIGURE 24. SS 12 T. 1: Medium to dark brown humic horizon, moderate-grained, little clay or pumice. 2: Medium grained ash, scattered pumice, particularly toward bottom. Much staining (from humic acids from level 3?). 3: Contemporary humic horizon, dark brown, little clay content.

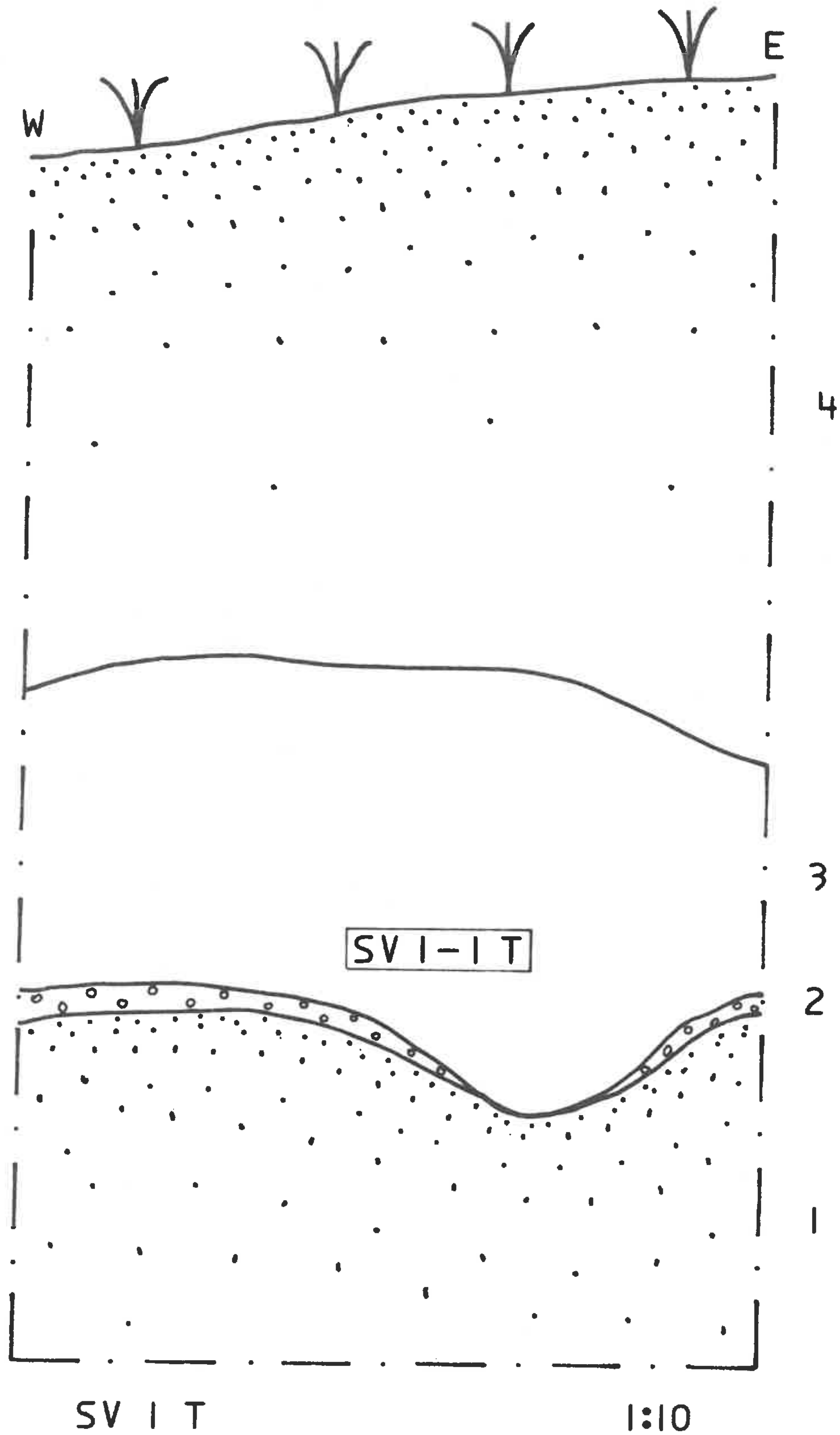


FIGURE 25. SV 1 T. 1: Dark brown buried humic layer, little clay, no pumice present. 2: Discontinuous pumice zone, most fragments less than 1 cm in diameter. 3: Light beige fine-grained ash, some tan staining. 4: Contemporary humic horizon, medium brown in color, fairly dense.

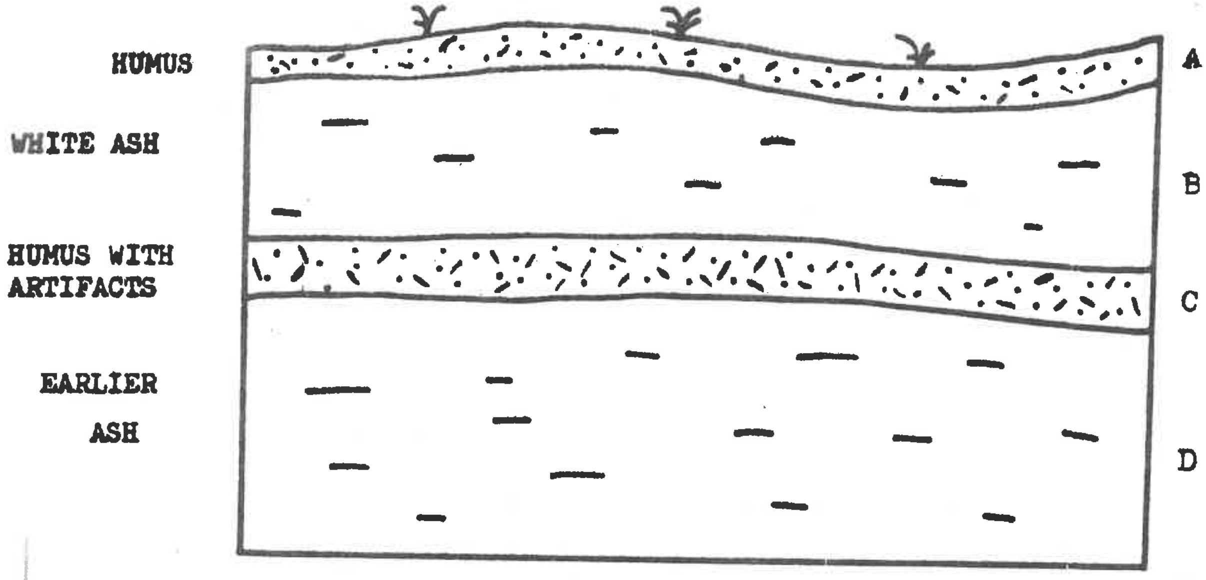


FIGURE 26. Idealized Profile, San Salvador Region. From Lothrop (1927) and Porter (1955). Early rhyolitic ash (D) with humus developed on it (C) containing Preclassic artifacts, buried by rhyolitic ashfall of ca. 2 millenia ago (B), and present humic horizon (A) containing Classic, Postclassic, and Historic artifacts.

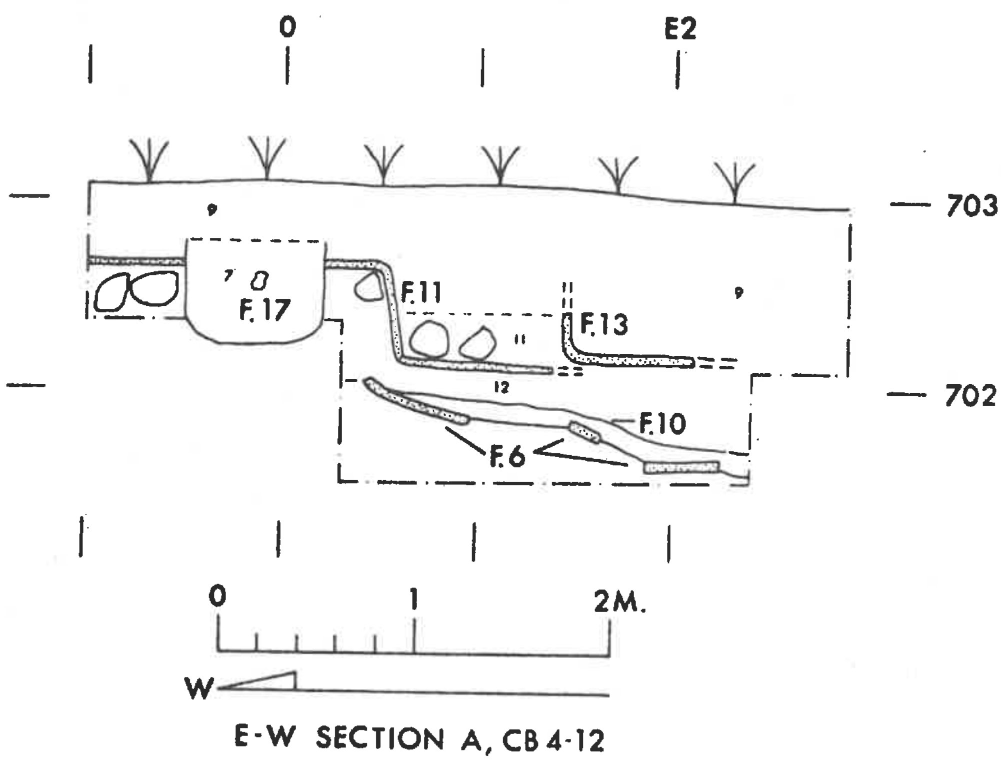


FIGURE 27. Excavation Section, Structure C3-6, Chalchuapa, El Salvador. Late Preclassic surfacing of pyramid (Feature 6) interrupted by rhyolitic ashfall (F. 10). Late Classic reoccupation resulted in 2 structural enlargements (F. 11 and 13); F. 17 is a Postclassic trash pit.

Fig. 28. (Neg. 75-A-10) SA 1t & 1a, CASA BLANCA SITE, Chalchuapa. Middle and Late Preclassic artifacts in humic horizon buried by white layer of volcanic ash. This ash, 77km from Ilopango, was thicker before the weathering and compaction of the past two millenia. R. Koll with metric tape for scale.

Fig. 29. (Neg. 75-A-22) SA 3t & 2a, LAGUNA SECA SITE, Chalchuapa. Somewhat disturbed layer of volcanic ash buries humus with Preclassic artifacts. A sample of this organically-rich soil from nearby was radiocarbon dated to AD 70 ± 70 (MASCA corrected).

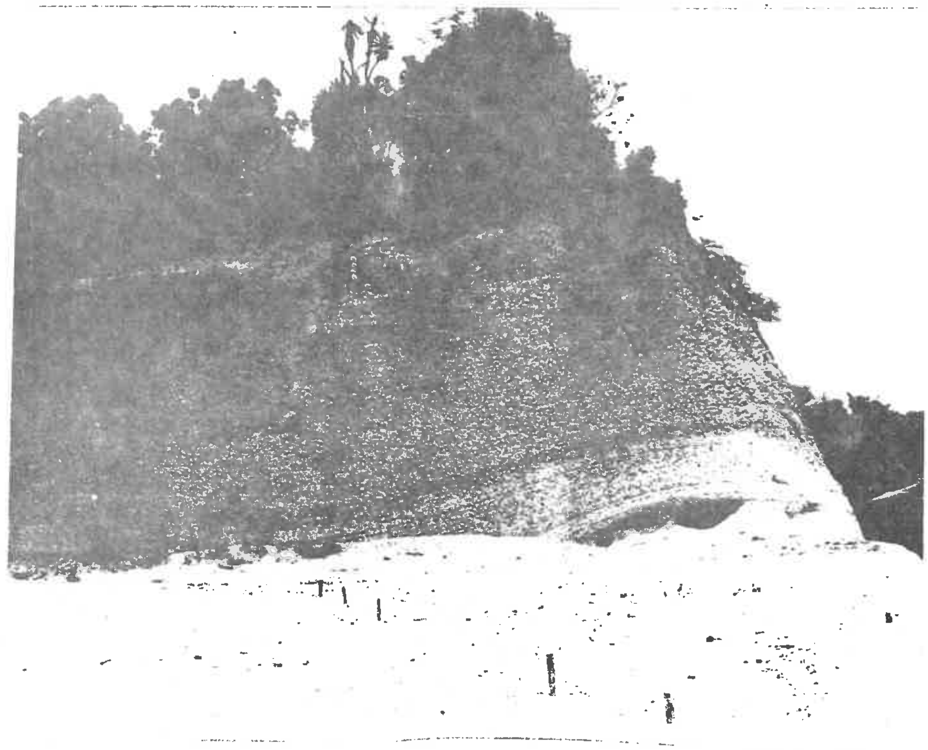


Fig. 30. (Neg. 75-A-26) SA 4t. Coarse-grained tephra from the Coatepeque eruption, c. 20,000-40,000 years ago. M. Foster provides scale.

Fig. 31. (Neg. 75-B-24) SS 3t & 2a, MERCEDES SITE, near Apopa. Humic soil, possibly with Preclassic artifacts, buried by tephra from a nearby source.

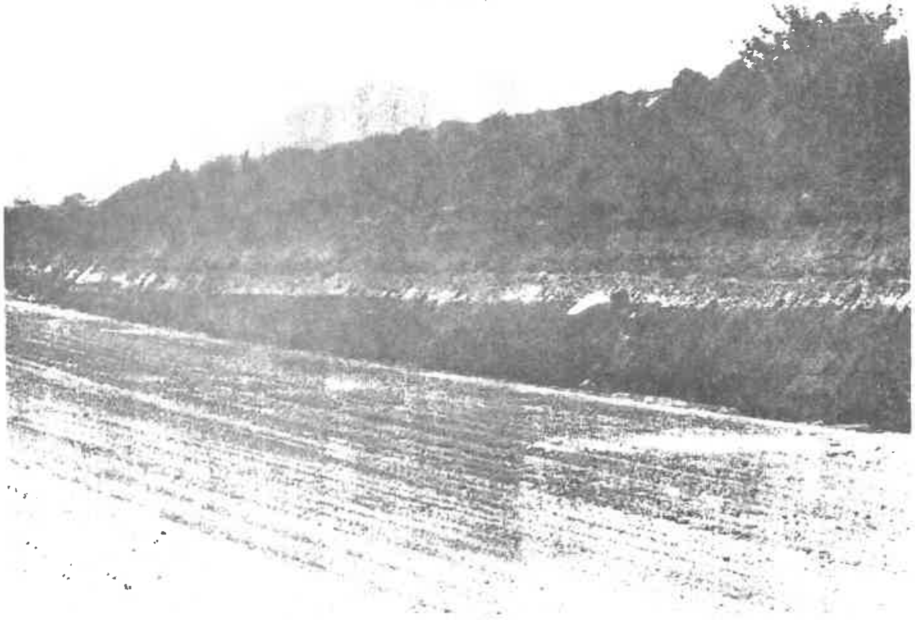


Fig. 32. (Neg. 75-A-35) LL 1a & 2t, LA CUCHILLA SITE on the edge of the Zapotitán Basin. Humus with dense Late Preclassic artifactual material buried by volcanic ash, exposed by a bulldozer constructing the Pan Am Highway. Pyramid group is 100m to right. M. Foster and V. Mejia examine cached vessels (see Fig. 33 below). Ilopango is located 45 km away, past Volcan San Salvador visible in the background.

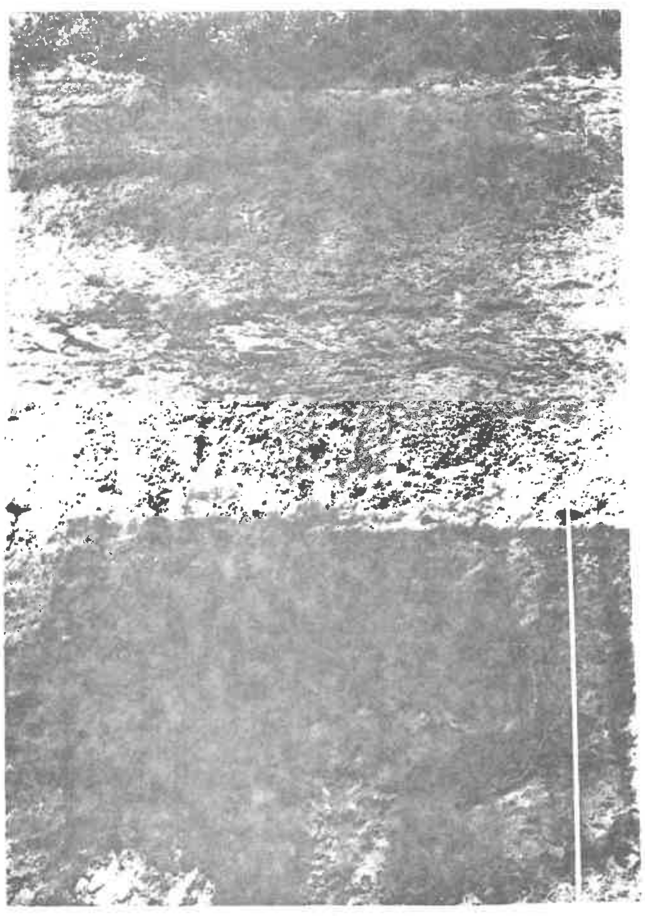


Fig. 33. (Neg. 75-B-8) LL 1a & 2t, LA CUCHILLA SITE. Closeup of three Late Preclassic cached vessels sectioned and largely removed by a bulldozer constructing an overpass along the Pan Am Highway.

Fig. 34. (Neg. 75-B-12) LL 2a & 3t, ESCUELA SITE. Some Preclassic artifacts were buried under volcanic ash 42km from Ilopango. Late Classic and Postclassic occupants deposited extensive artifacts in the top humic horizon. Note two possible small structures at center and right.

Fig. 35. (Neg. 75-B-22). LL3a and 4t, PRIMAVERA SITE. A thin scatter of Late Preclassic domestic trash was encountered in the buried humic horizon at this site near Quetzaltepeque. Note the very slight development of the contemporary soil on top of the 2000-year-old ash. Ilopango is 31 km distant.

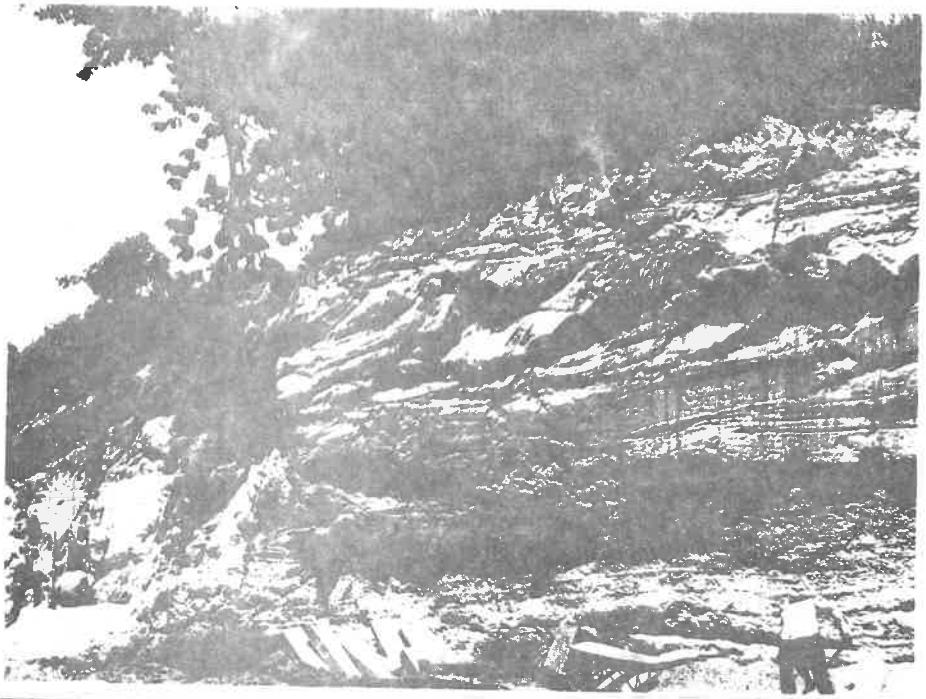


Fig. 36. (Neg. 75-C-16) SS 4a & 9t, CARTOGRAFÍA SITE in San Salvador. Probable nuée ardente ashflow buries Middle and Late Preclassic artifacts in the humic horizon. This instantly-deposited tephra measures up to 9m in thickness here, 15 km from Ilopango.

Fig. 37. (neg. 75-C-14) SS 4a & 9t, CARTOGRAFÍA SITE. Detail of Fig. 36 above, with R. Koll and M. Foster profiling the deposits. Note the thin pumice zone just above the Preclassic soil layer.

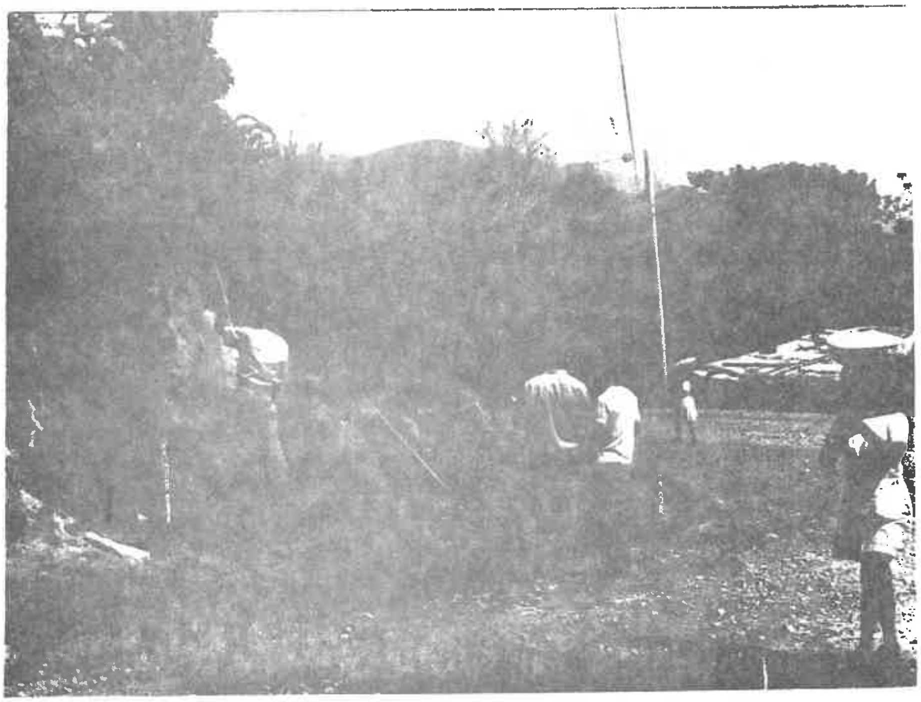


Fig. 38. (Neg. 75-D-10) SS 12t, near Santiago Texacuangos. No archaeological materials were encountered here, but charcoal collected from the buried soil was radiocarbon dated to 550±150 BC (MASCA corrected range 800-420 BC). This tephra may be from an eruption earlier than that which deposited ash on the archaeological sites illustrated above.

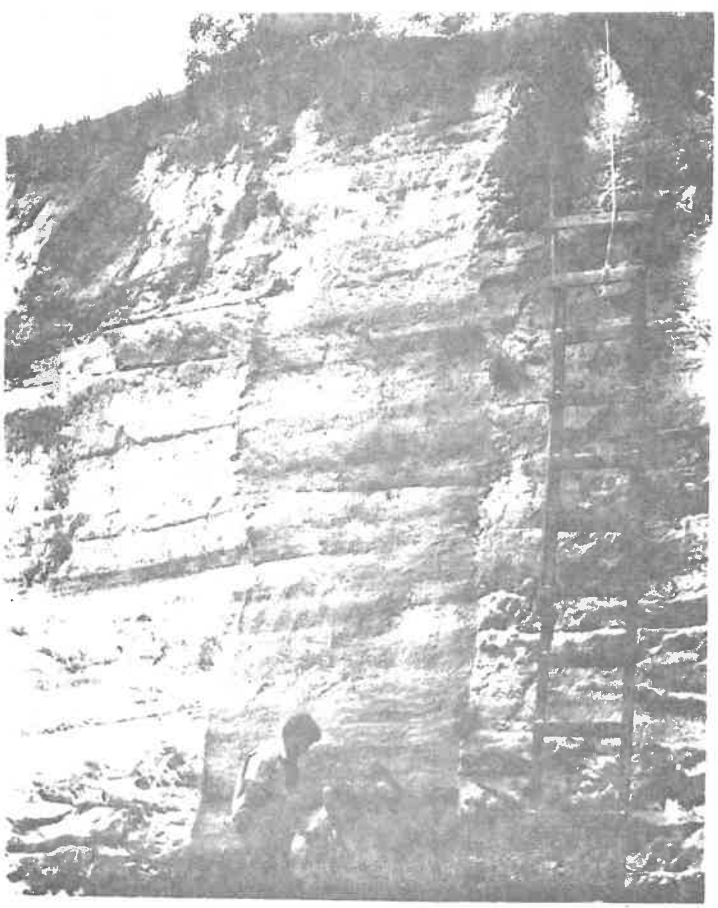


Fig. 39. (Neg. 75-C-22) SS10t. Humic soil with no artifacts buried by almost seven meters of volcanic ash. Note the pit for coffee tree intruded at top of profile. M. Foster and R. Koll complete the cleaning of the profile prior to recording and tephra sampling.

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APPENDIX 1:

PETROGRAPHY AND PARTICLE SIZE ANALYSIS OF SELECTED TEPHRA SAMPLES FROM WESTERN EL SALVADOR: A PRELIMINARY REPORT

Virginia Steen-McIntyre
March 5, 1976

RÉSUMÉ

Approximately 2,000 years ago, western El Salvador was devastated by a series of closely-spaced volcanic explosions which produced several pumiceous ash flows and culminated in an eruption of dacite pumice that covered the landscape with a blanket of air fall material. Petrographic study of the ejecta (tephra) from these eruptions suggest that the source for both ash flow and air fall material lies near present-day Lago Ilopango. Thickness measurements and particle size data agree that Ilopango is the likely source for the ash flow tephra, but data for the air fall samples are more ambiguous, and the source could as easily be an unknown vent to the southeast of the study area.

Deposits of tephra over one-half meter thick 75 km northwest of Ilopango imply that the eruptions were large and that their effect on the local flora and fauna was considerable. Near the source vent, plants and animals directly in the path of the ash flows would have been killed instantly by heat and suffocation; survivors would face the immediate problems of shock, injury, and choking dust, soon followed by those of fouled water and a disrupted food supply. Emigration of the local fauna would have been likely.

Lack of plant stems, root hairs, casts of insect burrows and incipient soil formation in the tephra suggest indirectly that the ejecta blanket smothered much of the vegetation and that its re-establishment was slow, probably due to drouthy conditions (decrease in effective moisture) caused by excessive internal drainage. How long such a condition might prevail could not be determined from the samples at hand.

INTRODUCTION

In January and February, 1976, 21 man-days were spent in the study of material from western El Salvador, collected by others the previous summer. Field data were reviewed, including stratigraphic sections of the collecting sites prepared by the Principal Investigator, and 41 individual samples were examined for grain size and petrographic properties. These included two samples of architectural adobe surfacing, two samples of soil that contained artifacts, and 37 samples of tephra (pumice lumps and volcanic ash).

The main purpose of the study was three-fold:

1. Determine whether tephra deposits which overlie late Preclassic artifacts at several locations are related in space and time.
2. Assign source(s) for these tephra.
3. Determine the type of eruption which produced the material and estimate the rate of deposition.

In the course of the investigation, the following information was also sought:

4. Petrographic data for a sample of tephra from Coatepeque volcano.
5. Identification of coarse fragments used in the Preclassic surfacing adobe at two Chalchuapa locations.
6. Petrographic data for tephra fragments from two soils buried by the ash.

Following is a brief report on procedures used in the study, the results, and suggestions for future research.

PROCEDURE

Utilizing Field Data

The handicap of not collecting samples personally or observing the ejecta in place was overcome to a great extent by the availability of detailed field notes, photos, and scale drawings (sections) of most of the collecting locations. These aided greatly in interpreting the laboratory data, especially when two or more tephra samples were collected from the same vertical section, and furnished clues to the nature of the eruptions and interval of time over which they occurred. The sections were used initially to help chose the samples to be studied later, after size parameters and petrographic data had been recorded, to help establish a sequence of events.

Sample Selection

The first task was to select from the several samples provided by the Principal Investigator those which could be studied in reasonable detail in the short time available, and which were most likely to provide the information required. In a region of active volcanism, the problem is never too few tephra deposits, but rather too many, and these mostly of unknown age. Fortunately, in western El Salvador, tephra layers of immediate interest to the project lie directly upon a time horizon that is easily recognized in the field--a soil or humic layer that contains late Preclassic artifacts--and tephra samples were chosen from 12 locations where this marker was exposed.

Additional samples included tephra from a unit that buried a humic horizon with no artifacts but with a ^{14}C date, three samples of Ilopango pumice, one sample of coarse Coatepeque pumice, and two samples each of soil and adobe. For most of the tephra, both fine-sand size fragments and coarse, crushed pumice were examined, providing duplicate samples from one collecting bag. A location map for the examined tephra samples is given in Fig. 1. Later, when attempts were made to correlate the samples using petrographic data, the sample suite was reduced until it included only the reference pumice from Ilopango and Coatepeque, and fine-sand size tephra from above organic-rich layers containing Preclassic artifacts or material dated by ^{14}C (Table 1). When data on particle size were considered (Figs. 3-5), the reference pumice samples were not included.

Sample Preparation

Samples were prepared in the following way: First, a small portion of the bulk material was stored for reference in a labeled glass jar. Noted at the time were size, shape, and roundness of the coarsest tephra fragments, and presence of absence of dried plant material or insect fragments. Next, 100 ml of sample was collected in a graduate cylinder, taking care to remove trapped voids by tapping and shaking the cylinder often during filling. The 100 ml subsample was placed in a beaker, flushed with water to remove most of the silt and clay (fragments smaller than 300 mesh), scrubbed in the ultrasonic cleaner, rins ed, and dried. Next day, the residue was hand-sieved in a set of small soil sieves consisting of screens with holes of 1 mm (18 mesh), 0.25 mm (60 mesh), 0.05 mm (300 mesh), and a bottom pan. A small amount of silt and clay in the pan assured that initial flushing of the sample to remove fines had not removed coarser fragments as well. The sieve fractions were then measured to the nearest ml in the graduate cylinder and the volume ratio calculated for -18+60 mesh/-60+300 mesh (coarse and medium sand : fine and very fine sand). For many samples, volume of fines was obtained by difference.

Because color of a tephra sample can give some indication of weathering, the silt and clay fraction was moistened and the color recorded using Munsell notation and color charts (1954). The fine sand fraction (-60+300 mesh) was given an additional ultrasonic cleaning, including a final rinse with acetone, dried, and saved for petrographic analysis. The coarse and medium sand fractions were stored intact, and the very coarse sand fraction (+18 mesh) often was sampled to provide pumice fragments for duplicate analysis. No evidence or worm casts or fossilized root channels was observed in the coarser fractions. Bulk samples of coarse-grained tephra were not measured by volume because of irremovable voids caused by packing geometry.

Permanent reference slide mounts were next prepared from the fine sand fraction of both naturally fragmented clasts and coarse, crushed material. The mounting media (Preservaslide), a synthetic resin with refractive index (n) near 1.52, dries at room temperature in about 48 hours. The relatively low n enables internal features of the glass shards to be studied while giving the transparent heavy minerals high relief.

The reference slide mounts next were placed on the microscope stage and the following information recorded: glass shard shape and density; approximate volume, size, and shape of vesicles in the pumiceous fragments; volume of water in certain enclosed vesicles in the volcanic glass; type and relative amount of the heavy mineral phenocrysts; and, using the Munsell Book of Color (1970), hue of amphibole crystals in the z' optical direction. In separate, loose-fragment mounts, using a special set of high dispersion, low n immersion oils and focal masking techniques (Wilcox, 1962, 1964), the n mode and range of hydrated glass was recorded for each sample, as well as the n range within single glass shards. In Cargille immersion oil 1.540, color of the dispersion rims that surround light-weight mineral grains when the apertural focal masking method is used distinguished plagioclase An_{30-100} from plagioclase An_{0-30}, potassium feldspar, and quartz.

RESULTS

Interpretation of Field Data

As set forth in the stratigraphic sections from relevant locations, field data indicate that tephra which buries the marker soil is composed of ejecta from at least two eruptions that were closely spaced in time. Laboratory data, described later, suggest the same thing. The lower unit contains deposits that appear to be from ash flows or directed explosions: the upper unit has the appearance of an air fall layer. While it is impossible at this stage to state their origins with certainty, to aid in distinguishing between them the lower set of deposits will henceforth be referred to as ash flow deposits and the upper set as air fall deposit.

Ash Flow Deposits

Lying upon the marker soil are a series of deposits that I interpret either as ash flow material (and air fall tephra associated with the ash flows) or air fall tephra from steeply-inclined explosions. Criteria for recognizing ash flow deposits in the field have already been established (Smith, 1960; Walker, 1971; Sparks and others, 1973). They are especially useful when the tephra-charged gas cloud was not hot enough to produce welding or sintering of the fragments or oxidation of the humic horizon over which the cloud traveled, as is apparently the case here. The criteria I used to recognize possible ash flow deposits while examining the stratigraphic sections and field notes were as follows:

> A basal coarse layer of well-sorted tephra that is often heterogeneous in nature, being composed of pumice fragments, crystals, glass fragments, and rock fragments in various proportions.
>
> Near the source vent, a deposit which lacks significant internal stratification, is in general poorly sorted, and which is composed primarily of fine-grained fragments.
>
> Presence of charcoal logs not in the position of growth.
>
> A tendency for deposits of this nature to be confined to the lowlands within 45 km of Ilopango, and for only the air fall component to have reached greater distances or higher elevations.

At five locations (San Mateo, Cartografía, Primavera, La Cuchilla, Esq. Nacional; see Fig. 1) at least one sequence occurs of basal coarse tephra overlain by a finer-grained, poorly-sorted deposit. At the Cartografía locality 15 km northwest of Ilopango, two and possibly three of these sequences are preserved with little evidence for intervening erosion. At San Mateo, a few km farther to the southwest, there is some evidence of scour and fill, with the deposits of one unit nested in those of an older one: this exposure also appears to contain fragments of carbonized wood which have been partially oxidized to organic ash.

The deposits thin in an irregular manner from more than four m at Cartografia to less than 20 cm at Esq. Nacional de Agricultura 30 km away, a strong suggestion that the source of this material is the Ilopango caldera complex. At La Cuchilla, 45 km from the lake center, fragments of pumice one cm in diameter, collected from the coarse basal layer, also suggest that the source vent is nearby.

The type of deposits described above has not been identified in samples collected farther than 45 km from Ilopango, although ejecta that is similar in petrographic properties but differs in being better sorted and with fine laminations occurs at Chalchuapa, 75 km from the vent. The Chalchuapa samples are believed to be air fall equivalents of the ash flow deposits. Both types of deposits occur directly beneath a younger air fall unit, described below, with no evidence for a period of soil formation or erosion.

Air Fall Deposits

Superposed at several sites upon the lower tephra (San Mateo, possibly Primavera, Esq. Nacional de Agricultura, La Cuchilla, Laguna Seca - Fig. 1) is a fine-grained beige ash called also "ash and soil" on the stratigraphic sections. At Laguna Seca, it lies conformably upon a fine-grained, laminated ash believed to represent the air fall equivalent of the ash flow deposits. At Arce, the unit rests directly on the marker soil. At location SS-12t, a meter-thick tephra deposit with similar petrographic characteristics rest on a soil dated at 550 ± 150 B.C. At both Arce and location SS-12t, the deposits have some characteristics that would suggest deposition by ash flow.

Field evidence for considering these deposits as air fall rather than of ash flow origin is scanty, although laboratory studies tend to support this view. The designation is used here mainly as an aid for distinguishing between the two sets of deposits. Negative evidence suggesting that the younger deposits are from an air fall includes lack of a coarse basal layer and carbonized wood fragments, although ash flows formed late in an eruptive cycle may also lack these components. Positive evidence is the relatively uniform decrease in thickness of buried units compared to the ash flow deposits, from slightly more than a meter at location SS-12t to 20 cm at Laguna Seca, and lack of scour and fill structures.

Petrographic Examination

Results of the petrographic examination for selected tephra samples is shown in Table 1. Not included in the table is information on the adobe and soil samples: the soil contained insignificant amounts of tephra, and the adobe grits were pieces of andesite and basalt scoria, probably locally derived. Also not included is information on tephra samples, other than the reference pumice from Coatepeque and Ilopango, for which there are no dates or stratigraphic control. When data for these samples were plotted along with the other, it tended to mask trends and similarities between samples where control, in the form of the marker soil, was good.

With the exception of one sample of Coatepeque pumice (SA-4t), all samples examined have a similar phenocryst suite which suggests, but certainly doesn't prove, a common origin: dominant olive green amphibole, abundant opaques and orthopyroxene, occasional clinopyroxene, traces of apatite and zircon, and plagioclase with anorthite content greater than 30. A sample of air fall tephra examined in detail in 1972 (71W3, the "'71 Chalchuapa sample" of Table 1) gave additional petrographic data which is summarized in Table 2.

The Coatepeque pumice sample differs from the rest in having some grains of a mineral I have not yet identified, mica phenocrysts, approximately equal amounts of amphibole, opaques, and orthopyroxene, a few plagioclase phenocrysts with anorthite content less than 30, and possible quartz and potassium feldspar. In addition, the sample of Coatepeque pumice is also crystal-poor when compared with samples of Ilopango coarse tephra. If this one sample is representative of the Coatepeque ejecta in general, there should be no danger in confusing the tephra when they occur as fine-grained deposits far from either vent.

Dated tephra and tephra samples collected at artifact localities all have volcanic glass shards that are incompletely hydrated. Incomplete hydration, especially in a tropical climate where hydration of volcanic glass is relatively rapid (Friedman and Smith, 1960), indicates that the tephra samples all are relatively young. Modal $\underline{n}$ of the hydrated glass ranges from 1.501 to 1.502, and extent hydration of individual shards appears directly related to shard shape and density. Dense, tabular shards are the least hydrated.

The type of shards observed in individual samples of naturally fragmented material ranges from primarily dense to mixed dense and pumiceous. When spindle-shaped vesicles from these shards were checked for water of superhydration, a preliminary step in the tephra hydration dating method (Steen-McIntyre, 1975, in press) it became possible to subdivide the samples into two groups. One group is composed primarily of samples with dense glass shards, platy to tabular in shape, in which over 90 per cent of the vesicles are free of water. These are from the upper air fall tephra, described previously, and are so labeled in Table 1. The second group has samples with shards that range from dense to pumiceous, and where 14 to 30 per cent of the vesicles contain at least a trace amount of water. These are the ash flow samples. In Table 1, they have been divided into two different ash flow units based on extent superhydration of the shards, but this may actually be an artifact of the method: field evidence suggests there are several ash flows. Superhydration curves for ash flow and air fall temphra samples can be easily distinguished in Fig. 2.

Particle Size Analysis

Detailed granulometric analysis for the tephra samples was considered unprofitable at this stage due to lack of time and to a pattern of sampling that was reconnaissance in nature. The particle size data that were utilized were those available during preparation of the tephra samples. This included diameter in mm of the largest pumiceous fragment observed in the sample, ratio of medium sand to fine sand size particles (-18+60 mesh/-60+300 mesh), and, for a few samples, median diameter of the tephra fragments. Median diameters were approximate, as only three points were available to construct the curve from which the values were obtained.

Particle size data are plotted in Figures 3-5. Diameter of the coarest tephra fragment observed in samples from 12 localities is plotted in Fig. 3. Size increases, in general, from west to east, suggesting that the source vent or vents for the tephra lie to the east. No more accurate location can be suggested from this data because the actual number of eruptions or eruptive units represented by the suite of samples is unknown.

In Fig. 4, the volume ratio coarse and medium sand: fine and very fine sand is plotted for 100 ml samples from the same 12 locations. Samples from ash flow deposits (data in parentheses) tend to become coarser towards Lago Ilopango, although in an irregular manner. Air fall temphra samples (data in boxes) form a more definite pattern, with particle size increasing towards Ilopango, but the source vent for this tephra could lie farther away. Because none of the examined samples collected northeast of Ilopango correlate with the airfall unit, it can't be stated at this time whether Ilopango is the source for this material (particle size would decrease east of the vent) or whether the source lies outside the study area somewhere towards the southeast (particle size would continue to increase).

In Fig. 5, median diameter is plotted against log of the distance from Ilopango for eight of the samples shown in Figures 3 and 4. Median diameter in phi units (Mdϕ) for three samples of air fall tephra plot in a straight line with a small positive slope, and a fourth sample has a Mdϕ value only slightly offset from the line. By contrast, Mdϕ for four ash flow samples form no pattern. In Fisher's study of statistical parameters for tephra from known eruptions (1964), he found that median diameter of air fall tephra decreased at a slower rate (ie, slope of the curve in Fig. 5 becomes flatter) with increasing distance from the vent. In addition, plots of Mdϕ versus log of the distance from the source for air fall tephra eruptions from Crater Lake, Hekla, and Kelut all form curves rather than straight lines for samples collected closer than 100 km from the source. The only plot on Fisher's graph (his Fig. 7) that approaches in shape and slope that of the curve for air fall tephra shown in Fig. 5 is the upper Hekla curve, when samples were collected for over 250 km from the vent. Obviously, no conclusions regarding the source of the air fall tephra can be reached at this point, but that the vent may actually be hundreds of kilometers away cannot be ignored.

SUMMARY AND CONCLUSIONS

In light of the initial objectives set forth for this study, the pilot project has been extremely successful. Field and laboratory evidence indicate that a series of tephra layers overlying late Preclassic artifacts at several locations in western El Salvador are related in space and time. At least two tephra units are recognized, a lower series of ash flow deposits and an upper air fall unit. Particle size suggests that Ilopango is the source of the ash flow tephra and perhaps the air fall tephra as well, although data for the air fall unit is ambiguous. Both units have tephra with petrographic properties similar to Ilopango pumice and different from Coatepeque pumice. The contact between these units shows little sign of erosion, deposition, or soil formation, suggesting that the series of tephra layers was deposited over a short span of time.

Lack of weathering products, organic matter stain, and iron stain in most samples and lack of fossil root channels, insect burrows, or plant stems suggest indirectly that the tephra blanket smothered much of the existing flora and that revegetation was slow, probably due to drouthy conditions caused by excessive internal drainage. An infertile growing medium, following directly upon the catastrophic events associated with volcanic eruptions of this nature, makes emigration by the local fauna as well as human inhabitants not only plausible but logical.

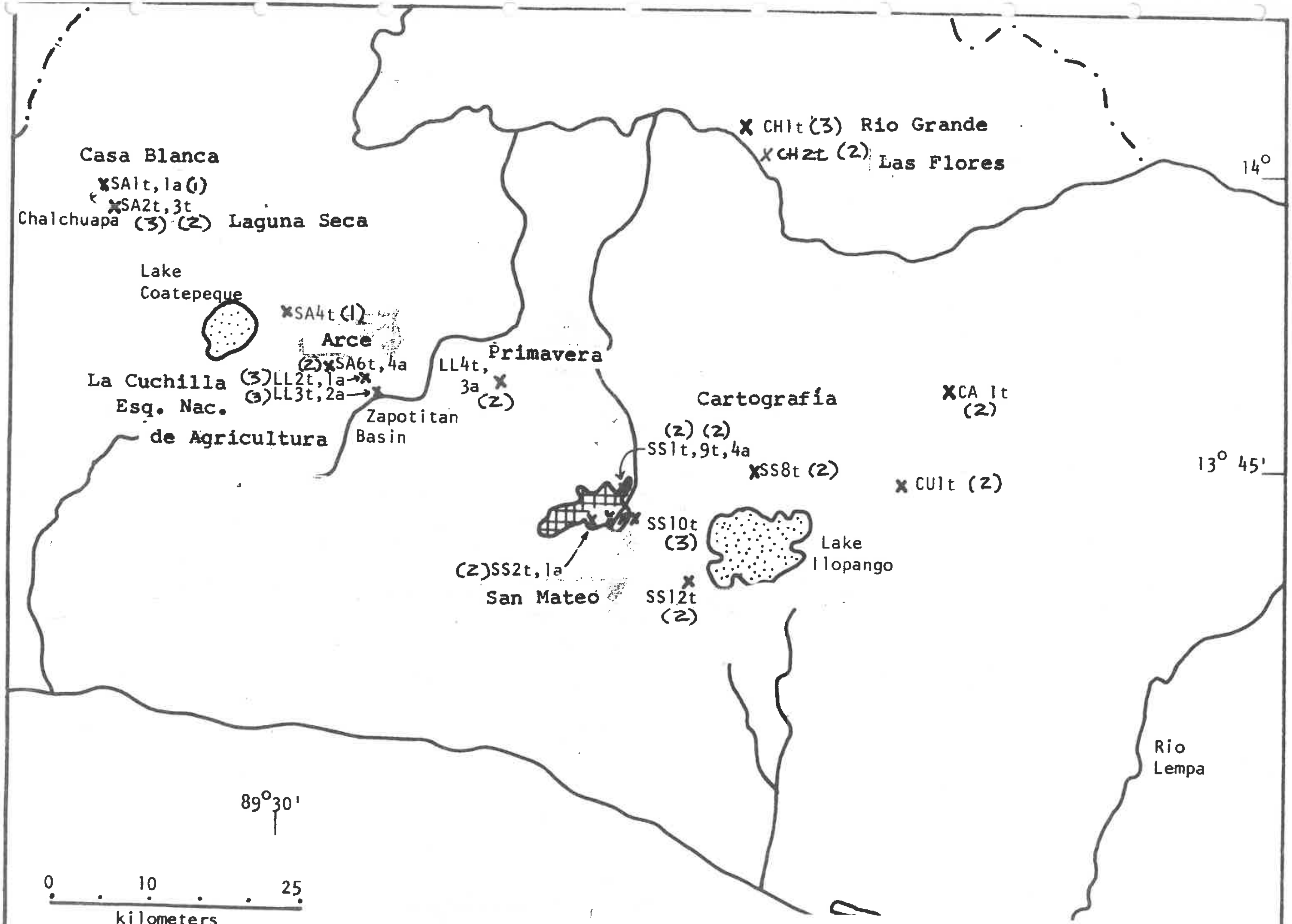

Figure 1. Locations of examined tephra samples. Number of samples examined from each site is given in parenthesis.

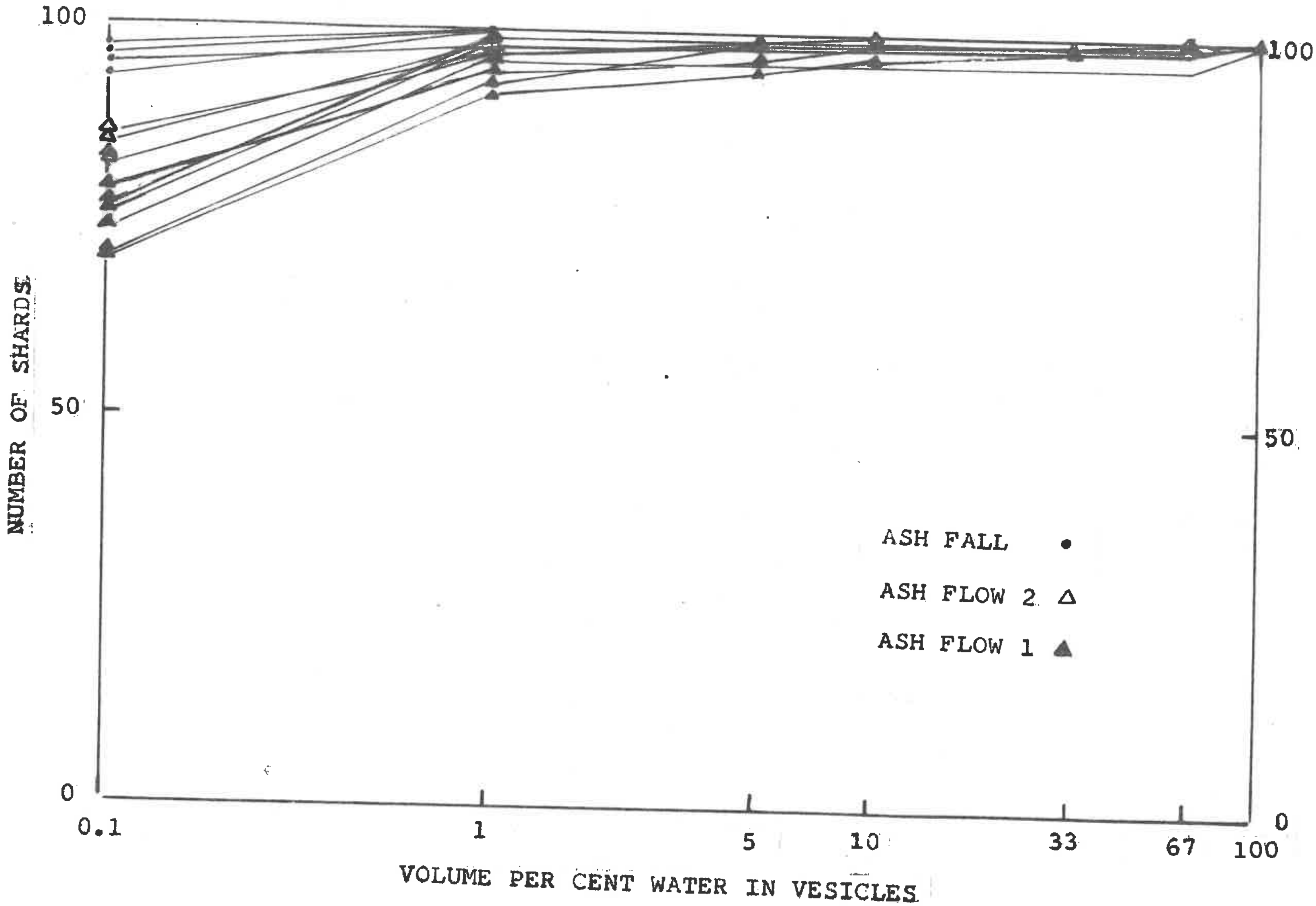

Figure 2. Cumulative curves measuring extent superhydration for ash fall and ash flow samples listed in Table 1. For each curve, 100 volcanic glass shards containing one or more enclosed spindle-shaped vesicles 10-50μm long were examined and the average volume per cent water in the vesicles estimated for each shard.

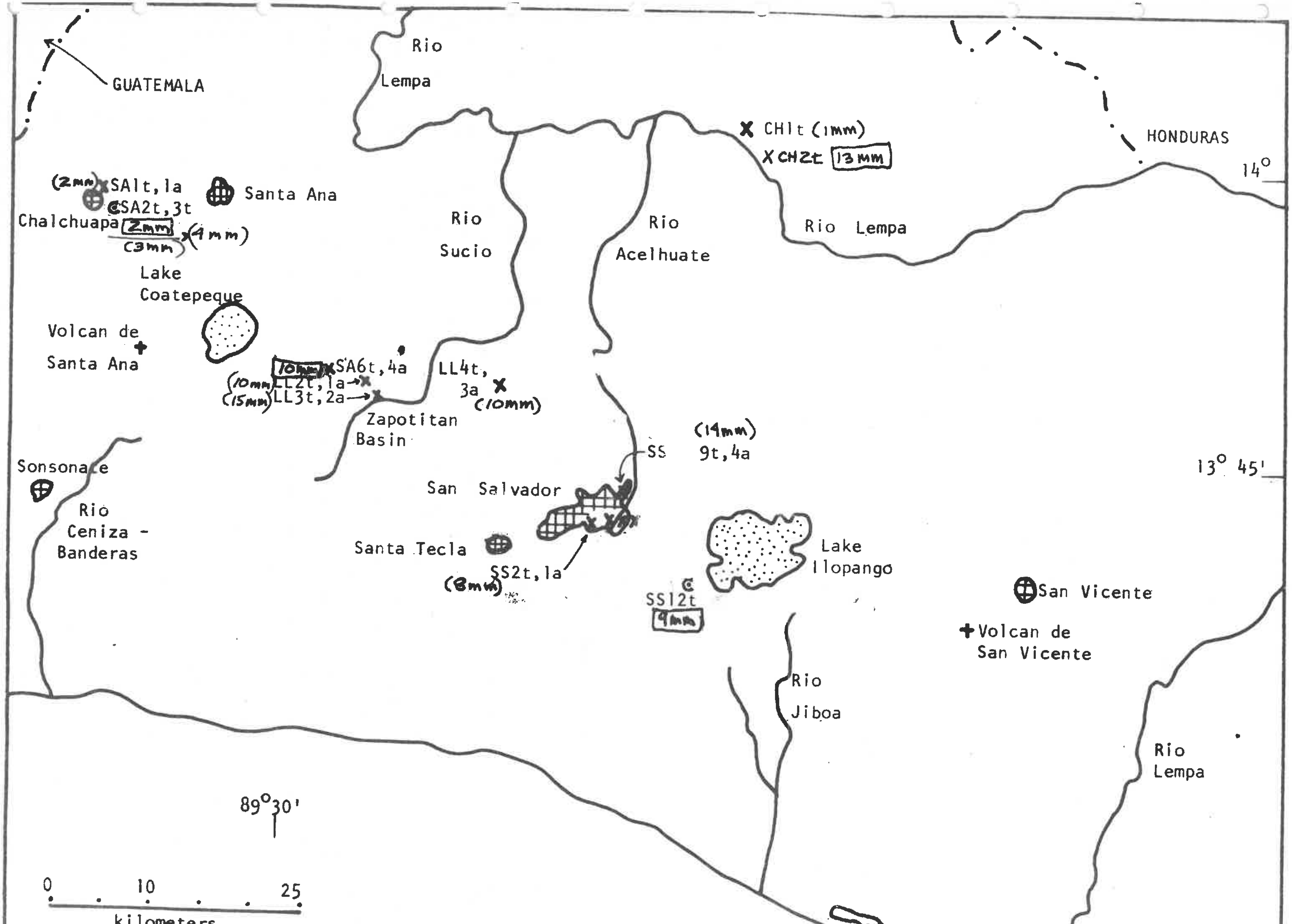

Figure 3. Exposures with buried artifacts (X) and radiocarbon dates (©). Numbers refer to the diameter of the coarsest tephra fragment observed in each sample. Boxed numbers indicate air fall tephra (Table 1).

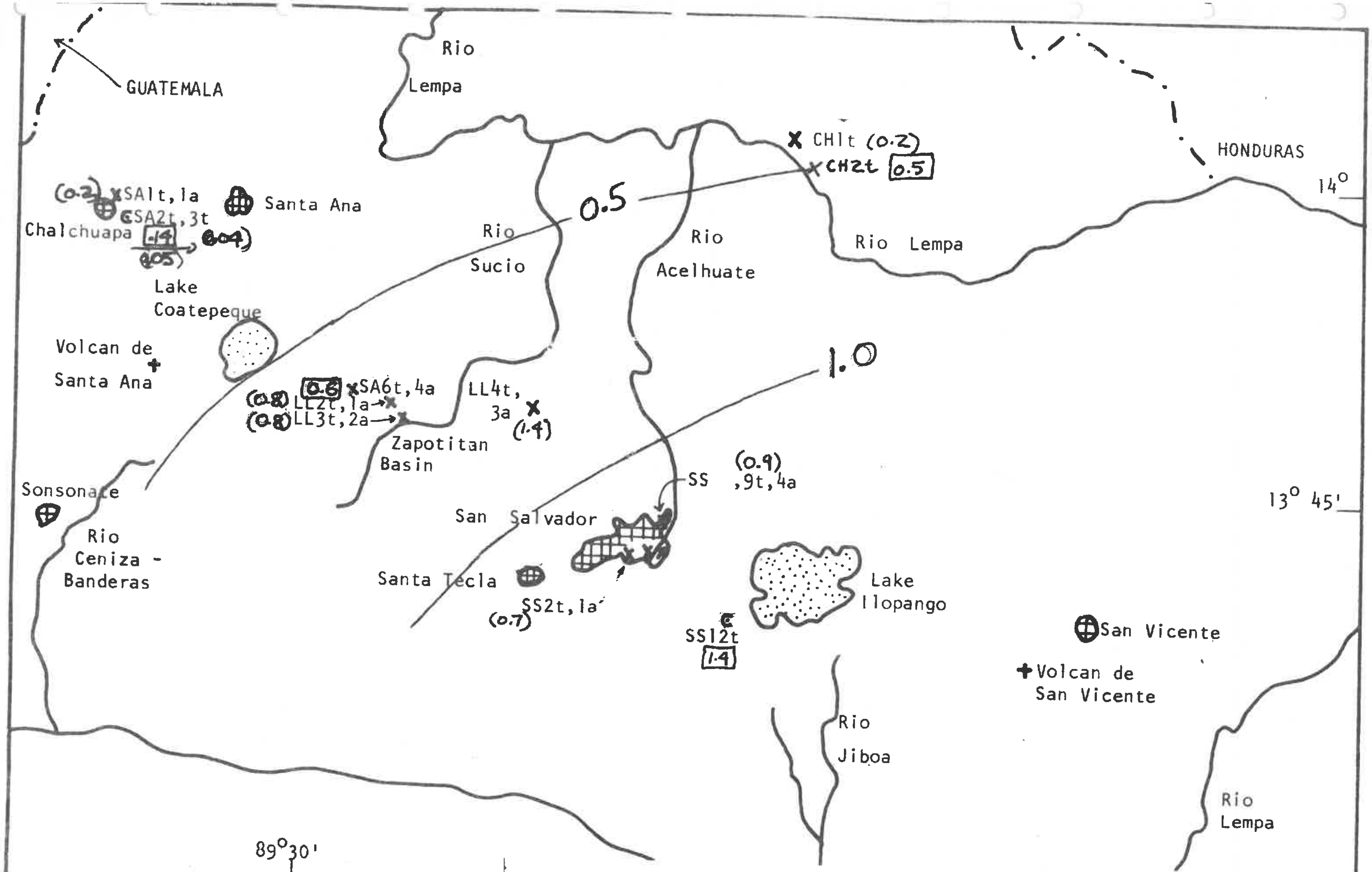

Figure 4. Exposures with buried artifacts (X) and radiocarbon dates (C). Numbers refer to the volume ratio of coarse and medium sand to fine and very fine sand-size particles (-18+60#/-60+300#) in the overlying tephra. Boxed numbers refer to values for air-fall tephra (Table 1), and isopleths have been plotted for this unit. Particle size for the ash fall increases towards the southeast.

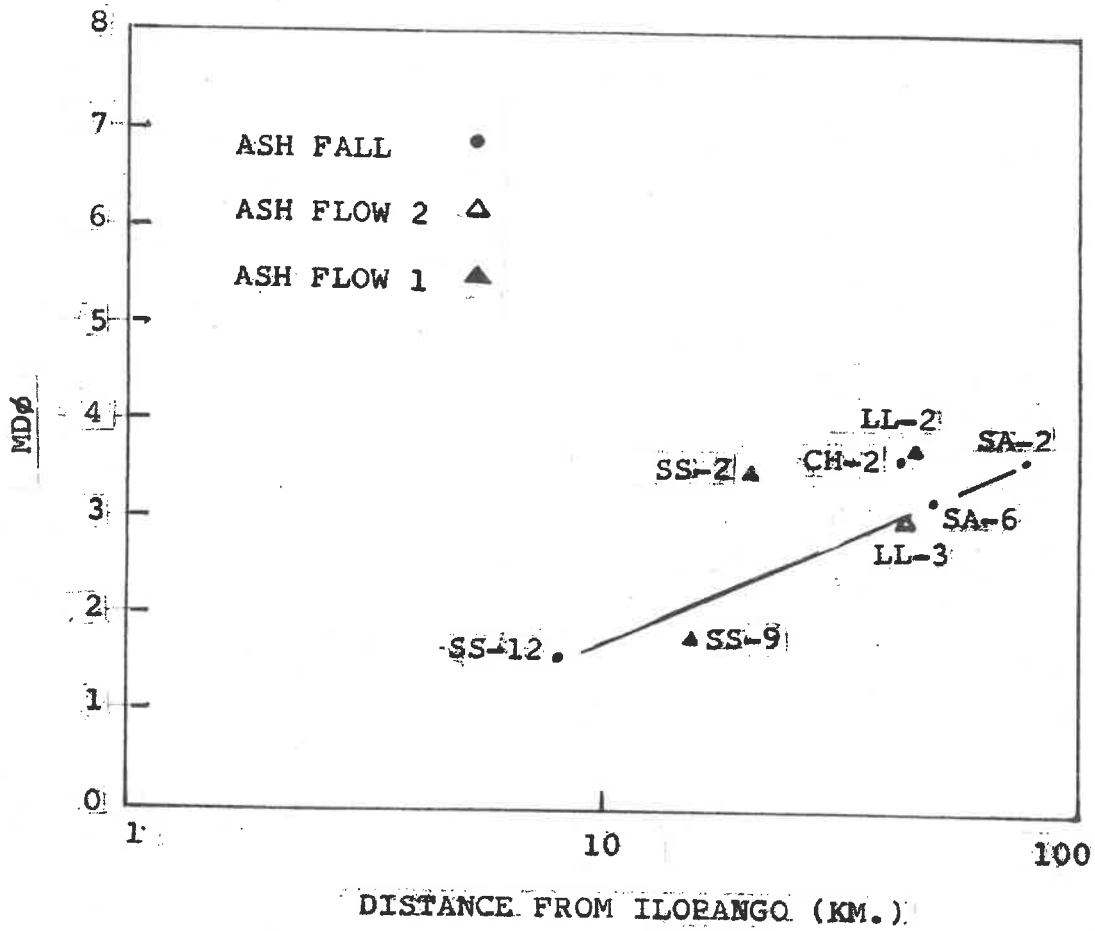

Figure 5. Medium diameter of tephra fragments for ash flow and air fall samples plotted against distance from the center of Lago Ilopango. Diameter is expressed in units of phi (ø) which is $-\log_2$ of the particle diameter in mm. Phi units increase with decreasing grain size.

Table 1. PETROGRAPHIC DATA FOR SELECTED TEPHRA SAMPLES

SUGGESTED [illegible]	SAMPLE NO. (ARTIFACT LOCATION)	14 C DATE	SIZE FRAGMENTS (MESH)	SHARD TYPE	VESICULARITY[1] OF PUMICEOUS SHARDS	MODAL N HYDRATED GLASS	EXTENT HYDRATION (N RANGE 1 SHARD)	EXTENT SUPERHYDRATION (AVERAGE VOLUME % WATER IN SPINDLE-SHAPED VESICLES OF 100 SHARDS)[2]. NUMBER OF SHARDS: ≤0.1 NONE	≤1 TR.	≤5	≤10	≤33	≤67	≤100	HEAVY MINERAL PHENOCRYSTS[3]. (FRESH LOOKING OR WITH GLASS): AMPHIBOLE	ORTHOPYROX.	CLINOPYROX.	MICA	OPAQUES	APATITE	ZIRCON	UNKNOWN	BRIGHT MINERAL PHENOCRYSTS[3]. (1.540 OIL): [illegible]	N [illegible]	GLASS: 0-20	0-100	SIGNIFICANT FIELD CRITERIA (SUBJECTIVE EXPLANATIONS)
YOUNGEST																											
	ASH FALL SAMPLES																										
	SS-12 Ash Flow 3?	550 BC ±150	-60+300	DENSE, SO. PUMICEOUS	PROFUSE FINE TO CO.	1.501	WIDE	93	7						D	X	TR		X	TR						D	NO BASAL COARSE PUMICE LAYER.
	CH-2 (LAS FLORES, MOUND #10)		-60+300	DENSE, SO. PUMICEOUS	MANY TO ABUNDANT, MEDIUM	1.501	WIDE	96	4						B	X			X							D	
	SA-6 (ARCE) Ash Flow 3?		-60+300	DENSE, SO. PUMICEOUS	PROFUSE, FINE	1.502	WIDE	95	3					2	D	X			X							D	NO BASAL COARSE PUMICE LAYER, BUT OCCASIONAL PIECES. OVER-LAIN BY BEIGE ASH?
	'71 CHALCHUAPA SAMPLE		-60+300	DENSE, SO. PUMICEOUS	MANY TO ABUNDANT, MEDIUM	1.501	WIDE	96	4						D	X			X	TR						D	
	SA2-2 UPPER BEIGE (LAGUNA SECA)		-60+300	DENSE, SO. PUMICEOUS	FEW TO MANY, FINE TO CO.	1.501	WIDE	97	3						D	X	TR		X							D	THE SA2-2, SA2-1 SEQUENCE DEMONSTRATES RELATIONSHIP BETWEEN BEIGE-COLORED ASH FALL AND ASH FLOWS. NO COARSE BASAL LAYER OBSERVED. (TOO FAR REMOVED FROM SOURCE?)
	ASH FLOW 2 SAMPLES																										
	SA2-1 LOWER (LAGUNA SECA)	20 BC ±60	-60+300	DENSE, PUMICEOUS	FEW TO MANY, COARSE	1.502	WIDE	85	13					2	D	X			X	TR		TR				D	
	SA-1 (CASA BLANCA)		-60+300	DENSE, PUMICEOUS	FEW TO MANY, COARSE	1.500	WIDE	83	14	1				2	D	X			X	TR						D	NO COARSE BASAL LAYER OBSERVED. (TOO FAR REMOVED FROM SOURCE?)
	LL-3 (ESQ. NAC. DE AGRICULTURA)		-60+300	DENSE, PUMICEOUS	FEW TO MANY, FINE TO MED.	1.500	WIDE	86	11	2	1				D	X	TR?		X	TR						D	THIN BASAL LAYER OF ANGULAR PUMICE. OVERLAIN BY BEIGE ASH.
	LL-4 (PRIMAVERA)		-60+300	DENSE, PUMICEOUS	MANY TO PROFUSE, FINE TO MED.	1.500	WIDE	82	14	2		1	1		D	X	X		X	TR						D	BASAL LAYER OF ANGULAR PUMICE.
	ASH FLOW 1 SAMPLES																										
	SA-3 (LAGUNA SECA)		-60+300	DENSE, SO. PUMICEOUS	FEW TO MANY, MEDIUM	1.501	WIDE	76	22					2	D	X	TR		X							D	NO BASAL LAYER OF COARSE PUMICE. (TOO FAR REMOVED FROM SOURCE?)
	LL-2 (LA CUCHILLA)		-60+300	DENSE, SO. PUMICEOUS	ABUNDANT, FINE	1.500	WIDE	71	22	5				2	D	X	X		X							D	BASAL LAYER OF ANGULAR PUMICE 1 CM. DIAM. OVERLAIN BY BEIGE ASH.
OLDEST	CH-1 UPPER (RIO GRANDE)		-60+300	DENSE, SO. PUMICEOUS	MANY, MED. TO COARSE	1.500	WIDE	74	22					4	D	X	X		X							D	CH-1 UPPER AND CH-1 LOWER COMPRISE ONE SEQUENCE. BASAL COARSE LAYER. (FOR LOWER SPLE., THE FINE FRACTION WAS EXAMINED. IT MAY BE CONTAMINATED.)
	CH-1 LOWER COARSE (RIO GRANDE)		-60+300	DENSE, SO. PUMICEOUS	ABUNDANT, FINE TO MED.	1.502	WIDE	77	22					1	D	TR	TR		X	TR			TR		TR	D	
	SS-9 (CARTOGRAFIA)		-60+300	DENSE, SO. PUMICEOUS	ABUNDANT, FINE TO MED.	1.501	NARROW TO WIDE	70	21	4	2	1		2	D	X	TR		X	TR						D	EVIDENCE FOR TWO AND POSSIBLY THREE ASHFLOWS AT THIS EXPOSURE.
	SS-2 (SAN MATEO)		-60+300	DENSE, PUMICEOUS	MANY TO PROFUSE, FINE TO MED.	1.501	MEDIUM TO WIDE	79	16	2	2		1		D	X	TR		X	TR						D	EVIDENCE FOR TWO ASHFLOWS AT THIS EXPOSURE. POSSIBLE OXIDIZED CHARCOAL AND ORGANIC ASH.
	ILOPANGO SERIES, UNKNOWN RADIOMETRIC AGE																										
	SS10-11		-60+300	PUMICEOUS	PROFUSE, MED. TO COARSE	1.502	MEDIUM TO NARROW	46	34	16	2	1	1		D	X					TR					D	
	SS10-8		-60+300	PUMICEOUS	PROFUSE, FINE TO MED.	1.500	MEDIUM TO WIDE	53	32	15					D	X	X		X		TR					D	
	SS10-1		5-20 MM. (CRUSHED TO -60+300)	PUMICEOUS	PROFUSE, FINE TO MED.	1.502	MEDIUM TO NARROW	62	33	5					D	TR	TR		TR							D	
	ILOPANGO SERIES OF UNKNOWN RADIOMETRIC AGE																										
	SS1-2 UPPER		-60+300	VERY PUMICEOUS	PROFUSE, FINE	1.503	NARROW	59	23	13	4	1			D	X	TR		X	TR						D	
	SS1-1 LOWER, COARSE		-60+300	PUMICEOUS	PROFUSE TO MANY, FINE TO CO.	1.502	MEDIUM	70	22	6	1	1			D	X	TR		X							D	
	COATEPEQUE SAMPLE, UNKNOWN RADIOMETRIC AGE																										
	SA-4		5-30 MM. (CRUSHED TO -60+300)	PUMICEOUS	PROFUSE, MEDIUM	1.500	NARROW		6	31	40	21	2		X	X	TR	TR	X			X	TR?	TR?	X	D	SPARSE PHENOCRYSTS.

[1]. Abundance: rare (<1%); few (1-5%); many (5-33%); abundant (33-67%) profuse (>67%). Size: fine (<10 μm); medium (10-50 μm); coarse (>50 μm).

[2]. By visual estimation.

[3]. D:dominant (>50%); X:present (50-5%); TR:trace (<5%).

Table 2. ADDITIONAL PETROGRAPHIC DATA FOR A SAMPLE OF AIR FALL TEPHRA

Hydrated Glass:			
N mode	1.501		
N range	1.498 - 1.504		
Light-weight Minerals:			
Plagioclase	Andesine (An_{33-37})		
K Feldspar	None		
Quartz	One fragment, believed to be a contaminant.		
Heavy Minerals (three grains each):			
Amphibole (Hornblende)	N_α 1.651 1.650-51 1.650	z:c	12° 13° 15°
Orthopyroxene (Hypersthene)	N_α 1.696 1.696 1.696	~2V	60° 60° 60°

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