Natural Hazard Research

ARCHEOLOGICAL STUDIES OF DISASTER: THEIR RANGE AND VALUE

by

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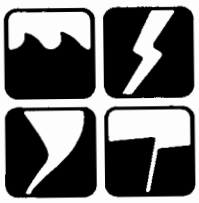

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ARCHEOLOGICAL STUDIES OF DISASTER: THEIR RANGE AND VALUE

Researchers frequently focus on the immediacy of a disaster and do not trace the long-term effects or the society's coping mechanisms. Though archeology can contribute a far longer perspective to such studies, archeological research has seldom addressed natural disasters from a comprehensive, social science view.

A number of disaster agents have been found to have operated in prehistoric times--volcanoes, floods, earthquakes, mudflows and disease. Changes in archeological method and theory applied to a particular disaster can be seen by observing the history of research on Ilopango Volcano, which erupted in central El Salvador in the third century A.D.

Recent data confirm that Ilopango erupted in two ash flows, followed by a blanket of ash. It is unlikely that any vegetation, animals or humans survived in the ash flow areas, and the larger acreage hit by the ash fall was unable to be farmed for some years.

There is some evidence of an immigration of Highland Maya northward at that time, and a good case can be made for it having been caused by Ilopango tephra. The arrival of the immigrants in the Maya lowlands accelerated already extant processes toward greater political, social and economic complexity.

Current archeological research is becoming more behavioral, interdisciplinary, and directed toward explaining human processes and patterns rather than just describing them. A mixture of inductive and deductive reasoning is used, as are objective sampling designs, regional analyses, and new statistical techniques.

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INTRODUCTION

Hazard researchers often have commented that a problem with the field is a short time perspective. All too often contemporary researchers have focused on the immediacy of the disaster, and not traced the longer-term effects and coping mechanisms. Some exceptions to the problem are becoming available; however, archeology can contribute a far longer time perspective than the decade or so of such studies.

Archeological literature is almost devoid of disaster research conducted on a social science basis. That is not because disasters are unknown archeologically; as can be seen below, the literature of prehistory is replete with cases of disasters. What archeology has contributed so far is empirical and largely incidental. Past disasters are described in the archeological literature on a case by case basis when they have been encountered and recognized in site excavation or survey. Almost no projects have been directed at a disaster and its repercussions.

A theoretical framework already exists, provided by human ecologic work by geographers and sociologists among others, that, combined with methods appropriate to archeology, can begin investigations of people, societies, and disasters over tens and hundreds of years. A number of disaster agents have been found by archeologists to have been in operation in prehistoric times: volcanism, floods, earthquakes, mudflows, and disease. Cases of these events are presented below.

VOLCANISM

Because one of the objectives of this study is to outline how hazard-disaster studies have been researched by archeologists, it is instructive to examine the changes in method and theory, explicit and implicit, used in respect to a particular disaster. The disaster in question is eruption of Ilopango Volcano in El Salvador, Central America in the 3rd century A.D. In many respects the changing methods and objects may be seen as microcosms of shifts in method, technique, and theory of the field as a whole.

The very first indications that an ancient volcanic disaster had occurred in the SE Maya Highlands were uncovered by Lardé (1926). Although not trained in anthropology or archeology, he became interested in archeology after discovering, as early as 1917, artifacts (particularly broken pieces of pottery) buried by a white volcanic ash in the San Salvador area. By making numerous field trips to streamcuts, roadcuts, and railroad cuts, and by using common sense more than disciplinary training, he was able to come to four conclusions. These conclusions, still valid today, are, first, that the humic horizon buried by the volcanic ash was extensive. Second, the cultural materials buried under the ash antedated the eruption. In other words, they were not intruded from higher levels in later times. Third, artifacts also occurred above the white ash, indicating reoccupation of the region. Fourth, Lardé noted the ash burying artifacts in the Ilopango area, but didn't find such localities to the west of Volcan San Salvador. From that observation he deduced that the most likely candidate for the ash's source was Volcan Ilopango, and that the eruption of the volcano created the depression

which filled with water, now called Lago de Ilopango. Although we now know that the ash did travel far to the west of Volcan San Salvador, Lardé's sourcing certainly has been borne out by recent geological research.

Lardé's report, published locally, received virtually no attention outside of El Salvador. He did mention his discoveries to Lothrop, an American archeologist, and he showed Lothrop many of the localities with the artifact-ash-artifact stratigraphy.

Lothrop (1927) lost little time in publishing a small monograph from the Museum of the American Indian in New York on Lardé's and his discoveries. It received wider attention, although still not great. Much of the interest underlying Lothrop's work with the ash and artifacts is methodological. Even though stratigraphy had been used by Old World archeologists for decades, its use by archeologists in the Americas was delayed to the early 20th century by a number of factors. Among them are the failure of PaleoIndian studies, by an anti-evolutionary bias, and the lack of interest in fine-scaled culture change among early 20th century archeologists in the Western Hemisphere (Willey and Sabloff, 1974:89). Lothrop, in his Salvadorean work, can be seen as a part of this belated interest in stratigraphy as a time-ordering device. In his foreword he notes the rarity of clear stratigraphic preservation of soils and artifacts in tropical areas. He does recognize the disastrous nature of the ashfall, but such concern rates a distant second to his methodological interests.

Lothrop combined stratigraphy with typological analysis of ceramic artifacts. Thus, he isolated an "Archaic" cultural horizon, a period which is now termed "Preclassic" or "Formative". The Archaic were

distinct from the later, "Upper Level" Mayan and Pipil (i.e., Central Mexican-influenced) artifacts. These latter kinds of artifacts derive from periods currently entitled "Classic" and "Postclassic". In retrospect, we can see that Lothrop was fortunate indeed that the ash-fall happened to fall at the close of the Formative Period, serving as a striking horizon marker. He was able to extend his analysis of in-situ artifacts to private collections and museums. The general outline of his cultural chronology for El Salvador is still valid.

Even though it was a distant secondary concern, Lothrop did recognize the ash layer as indicative of a natural disaster. His thoughts on the eruption, within his newly created Salvadorean culture history, are best presented in the following two paragraphs (1927:214-5):

> Many centuries ago a series of cataclysmic volcanic eruptions rendered central Salvador uninhabitable. This plutonic [sic] activity may not have been merely a local occurrence, and may have caused ethnic disorders over a great area. To some such cause may be ascribed the splitting of linguistic groups which are found in Mexico and Nicaragua, such as the Chorotega and the Subtiaba-Tlapanec. Possibly thus also, before the beginning of the Christian era, the Maya were induced to settle in the not over-attractive lowlands of the Peten and the Usumacinta valley. In all events, the abandonment of Salvador was probably complete, and lasted for a long time, as no remains are to be found for several feet above the lowest archeological floor.
>
> Afterward Salvador was again settled by tribes, who, if they were not Maya, certainly were under Maya influence and maintained trade relations with Copan. Thus, objects of plumbate were manufactured near Suchitoto in Salvador have been found in Copan tombs [Saville, 1916].

Lothrop's documentation of these relationships received at least some attention, but not all of it was particularly insightful. Vaillant (1934:92), for example, concluded that the "Archaic" cultures of El Salvador, because they were buried by volcanic ash, were of geological antiquity. By the same reasoning, the Jeep buried by the ash from the

1968 Volcan Arenal eruptions in Costa Rica is also of geological antiquity.

By the 1950's, archeology was beginning to use scholars from the natural sciences to aid in prehistoric research, and to use quantitative dating techniques such as radiocarbon. Interest in culture history continued, with chronology being a major preoccupation (Willey and Sabloff, 1974: 131). These conservative components of 1950's archeology are reflected in Salvadorean ash-artifact investigations. The innovative approaches of the 1950's, involving contextual and functional studies, settlement pattern analysis, and the beginnings of ecology, are not reflected in these Salvadorean studies.

Porter (now Weaver) visited El Salvador briefly in the mid-1950's, to follow up leads in Lothrop's earlier work and suggestions from the late geologist Howell Williams of UC Berkeley. Porter's primary objective was to identify Preclassic artifacts in El Salvador similar to those she had excavated at Tlatilco in the Basin of Mexico in 1948. The nature of this early Mesoamerican material, apparently antecedent to the civilizations of the Classic Period, was attracting considerable attention from Mesoamericanists.

Porter did use two geologists, albeit briefly, to assist in her research. Her profile of the humic layer with artifacts and the ash stratigraphy is much superior to Lothrop's recording, and her ceramic descriptions are more detailed. However, in my opinion, she became more lost in detail for its own sake than did Lothrop. This is reflective of the state of the art; much of mid-20th century archeology was a morass of progressively more detailed analysis and classification in the name of science, with little clear application or grounding in theory.

Porter did have a sample of charcoal analyzed by the radiocarbon dating technique. The date, 1040 ± 360 BC, is far too early according to present knowledge. Even a 2-sigma range, 1760-320 BC, does not encompass the time of the eruption, but given the inaccuracies of the radiocarbon dates run in the early days of the technique, it should not be too surprising that some of the dates are not accurate.

Boggs has conducted more archeological excavations in El Salvador than any other person, and some of his work has a bearing on the Ilopango disaster. His investigation of the Loma del Tacuazín site near San Salvador in 1946 was published in 1966. His descriptions and illustrations of strata are superior to his predecessors'. Described are three Preclassic ceramic burial urns from a sub-ash soil horizon. Although Boggs is not correct in attributing the ash to Volcan San Salvador (p. 183), he does speculate briefly on the ashfall's effects on human occupation (cf. Longyear, 1944:53-4).

The University Museum, University of Pennsylvania, and the Ford Foundation sponsored the largest archeological project yet conducted in El Salvador. Fieldwork continued from 1967 to 1970, with specialized analyses being conducted during the early 1970's. Noteworthy here is a detailed culture history of Chalchuapa from 1000 BC to AD 1500, and the beginnings of ecologic and processual concerns that dominate contemporary research into the Ilopango disaster.

Numerous instances where Late Preclassic artifacts and architecture were buried by a white volcanic ash were encountered during these excavations (Sharer, 1968:301; 1974; 1978). Primary deposits of airfall ash at Chalchuapa, 77km from Ilopango, measure more than 50cm in depth, indicating the eruption's magnitude. Stratigraphic excavations at Lake

Cuzcachapa documented the development of "Protoclassic" characteristics (as defined by Willey and Gifford, 1961; Willey et al., 1965; Willey, Culbert, and Adams, 1967:298) capped by the volcanic ash layer.

Just prior to the eruption, Chalchuapa was a major residential, economic and ritual center in the SE Maya Highlands. The central ritual zone was 2km in length, composed of numerous 15m-high pyramids arranged around plazas, and surrounded by habitation areas of the elite, artisans, and agriculturalists. Obsidian was imported in large quantities from Ixtepeque and manufactured into numerous kinds of tools and preforms by craft specialists. Monuments, some elaborately sculptured and bearing calendric dates, were carved and placed in ritual zones. Elaborate ceramics were manufactured, often using Usultán decoration with the mammiform tetrapod vessel form. Ceramic decoration during the Preclassic occasionally involved polychrome painting.

But one of the limitations of research into the Ilopango eruption prior to 1975 was that all projects were site-specific, and that no systematic tephra sampling and chemical or petrographic analyses were performed. These various finds of volcanic ash burying Preclassic artifacts scattered across central and western El Salvador could be interpreted in two different ways. Perhaps they represent a series of eruptions from numerous vents along the volcanic axis of El Salvador, each affecting a limited area and number of people, and separated by decades or centuries. Or, these finds could be indicative of a massive eruption affecting a large area simultaneously.

Geologists working in El Salvador since 1945 encountered the same ash layer or layers they christened the "tierra blanca". Much speculation has revolved around its source(s). Regional intensive work of the

German Geological Mission within the past decade, still largely unpublished, indicated it may have had one source--Volcan Ilopango (Schmidt-Thomé, 1975).

The 1975-76 research of the Protoclassic Project (Sheets, 1976; Steen-McIntyre, 1976) was able to further resolve the problem by sampling artifacts and tephra along a NW-SE transect through central and western El Salvador, and by petrographic and granulometric analysis of tephra samples (see Figure 1). To the best of our knowledge at present, one eruption consisted of three closely spaced components (Steen-McIntyre, 1976:68-78). The first two were hot ash flows, perhaps involving a base-surge, followed shortly by the deposition of an extensive blanket of airfall ash over the SE Maya Highlands.

An ash flow (nuèe ardente) is an incandescent cloud of ash and pumice which travels downhill at high speed (Bullard, 1976). Ash flow temperatures are often greater than 200°C, above the kindling temperature of wood; the nuèe ardente that killed 30,000 people in St. Pierre (on the island of Martinique in the Caribbean) in 1902 had a temperature over 700°C. Velocities range from 36 to 300 miles per hour, and generally they are accompanied by great turbulence.

The two ash flows occurring at the end of the Preclassic period in El Salvador apparently headed north and west, devastating low lying agricultural and habitation areas in the Rio Acelhuate-Sucio-Lempa drainages. The maximum known distance covered by these ash flows is 45km, longer than most historically known ash flows. It is unlikely that any vegetation, fauna, or people would have survived an ash flow, except, perhaps, on its periphery.

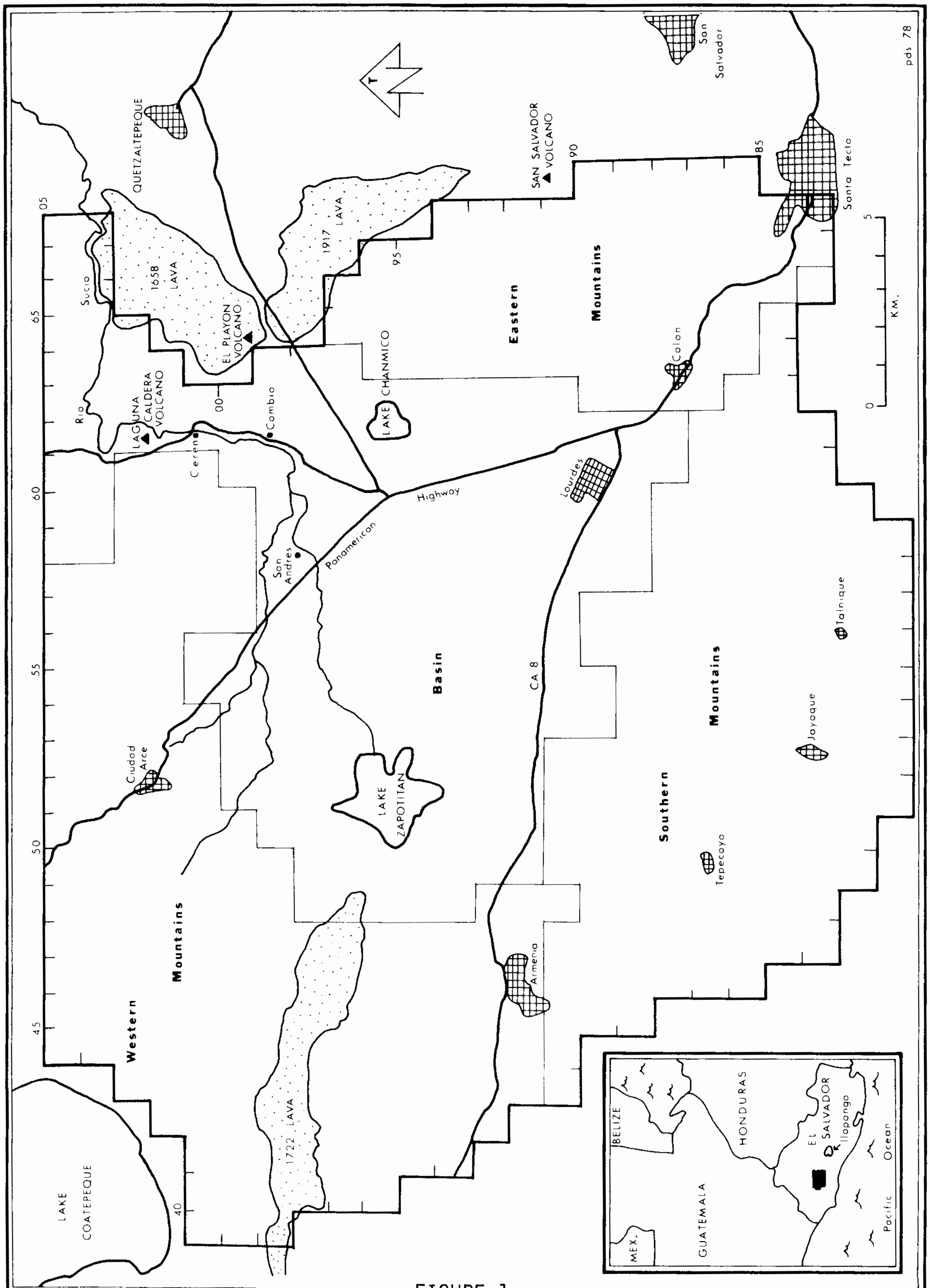

FIGURE 1

ZAPOTITAN VALLEY IN WESTERN EL SALVADOR

However, from a regional perspective, a relatively small fraction of the land rendered unarable by the eruption was hit by a nuèe ardente. Most of the damage was done by the ash fall deposits. The ash fall deposits are stratigraphically superior to the ash flow layers, and they extend much farther. Human physical survival under such conditions is probable, but according to the observations made during comparable eruptions (cf. Segerstrom, 1950; Bullard, 1976; Malde, 1964; and summary in Sheets, 1976), an ash depth of 10-25cm supresses non-industrialized agriculture for at least a few years. The intervening time between impact and agricultural recovery depends on a number of factors, including climate, weathering rate, the mafic-to-sialic character and particle size of the tephra, the depth and stability of the tephra, plant recolonization, and specific nutriments needed by cultivated plants. Recent salvage excavations along the middle Rio Lempa drainage in north-central El Salvador divulged intensive agricultural practices underway just prior to the eruption. Earnest (1975) encountered a ridged, apparently irrigated, agricultural field along the flood plain buried by airfall and probable ash flow (Steen-McIntyre, 1976) material from the Ilopango eruption (see Figure 2). Similar agricultural fields have been found under tephra in the Puebla area of Mexico (Kerr, 1973).

The direct and indirect regional repercussions of such a massive eruption in southern Mesoamerica have been investigated only slightly. Direct effects include flooding, short-term ash damage to plants, as well as the improvement of weak lowland soils by the addition of small amounts of ash. Indirect effects involve population movements, changes in adaptive strategies, and long-range economic and social effects of the disaster.

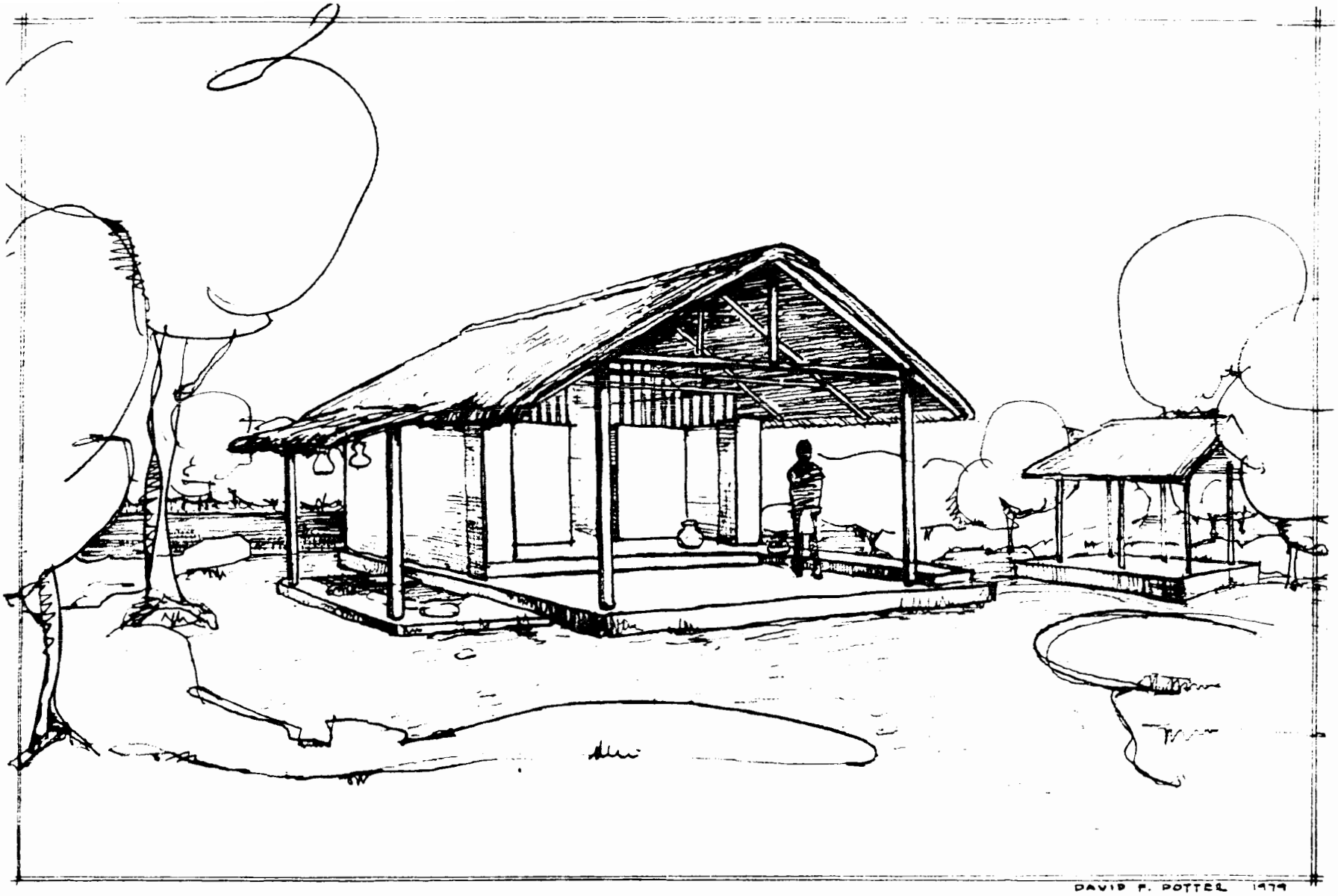

FIGURE 2

ARCHITECT'S RECONSTRUCTION OF BURIED MAYA FARMHOUSE AT CEREN SITE

Flooding apparently occurred in a number of localities at the close of the Preclassic, and it is possible that the greatly increased rainfall, runoff, and initial vegetation damage in the headwaters of drainages--so typical of large explosive eruptions--may have occurred with Ilopango. Flooding is known to have occurred at about that time in Belize (Willey et al., 1965:565) and at numerous sites in Honduras (Stone, 1972:57-62; Sheets, 1977). A reduction in shellfish populations occurred in Belize at this time (Willey et al., 1965) as did a probable reduction in shellfish at about the same time in Pacific coastal Guatemala (Coe and Flannery, 1967; Shook, 1965:185-6). Both may have been induced by Ilopango tephra.

Indirect effects include a constellation of short-term and long-term mechanisms used by people to cope with their changed circumstances. Migration is a common means of coping with large disasters, and there is some evidence indicating a migration of Highland Maya northward at about this time. Some towns and villages in the lowlands of northern Guatemala and Belize received an intrusion of foreign artifacts into their domestic continuum. The best-known sites where this occurred are Barlon Ramie (Willey et al., 1965), Altar de Sacrificios (Willey, Culbert and Adams, 1967:298), and Holmul (Merwin and Vaillant, 1932). Other sites with this Protoclassic intrusion are listed by Willey and Gifford (1961). It was not known until recently that the area where the Protoclassic artifacts developed was the SE Maya Highlands, including El Salvador (Sharer and Gifford, 1970; Sharer, 1974). Although it is possible that the Protoclassic artifacts could have developed elsewhere as well, as suggested by Hammond, the documented evolution of these characteristic artifacts capped by the Ilopango ash layer in El Salvador certainly makes

a strong case for a tephra-induced migration from Salvador to Belize and northern Guatemala.

The disruptions caused by the Ilopango eruption may have had long-range social and economic effects. Certainly the arrival of a few thousand immigrants in the Maya lowlands would not have gone unnoticed. Agricultural intensification would have been likely, as well as the strengthening of social, economic, and political institutions to deal with a sudden population increase. But this is not to argue that the fountainhead of Maya civilization was the highlands. Rather, the arrival of the immigrants apparently had the effect of accelerating already extant processes toward greater political, social, and economic complexity. Certainly the acceleration of pre-existing processes has been the effect of recent natural disasters, as noted by Mileti et al., (1975:137-9).

Rogers (1970), studying the long-range effects of the Alaskan earthquake, found that the burden of recovery was not equally shared among victims. Additionally, and more important for the Ilopango case, he found individuals and institutions which benefitted from the disaster. Such may be the case in SE Mesoamerican prehistory; following on the heels of economic disorder in the highlands, certain key groups may have reaped considerable benefits.

Such benefits may have accrued because of a realignment of the major trade route in Mesoamerica. As many scholars have noted (Sabloff and Rathje, 1975; Dahlin, 1976; and Sharer, 1975, for example), the dominant Preclassic (i.e., pre-eruption) long-distance trade route passed through southern Guatemala and into El Salvador. However, lowland sites such as Tikal seem to have greatly expanded their control of this trade

in elite and mundane commodities during the Classic Period (Dahlin, 1976:182-4). Thus the social, ecologic, and economic disruptions caused by the eruption may have been exploited during the Early Classic by the lowland Maya as they re-routed trade trans-Peten. It probably is more than coincidence that delegations from Teotihuacán, the power at the other end of the trade route in Central Mexico, established themselves at Tikal during the Early Classic.

Research over the past 60 years into what is now called the Ilopango disaster has evolved from occasional notes on stratigraphic relationships to regionally oriented research programs founded in ecologic/hazard theory. Early work was conducted for its own intrinsic interest or for methodological reasons, with few theoretical foundations. Individual sites were chosen for investigation on a haphazard, intuitive basis, and physical scientists were not used effectively. Present research attempts to utilize ecological theory in general, and social science hazard and disaster research specifically, for its theoretical foundations. Regional analyses are beginning to accomplish the kind of synthesis and integration which eluded earlier studies.

One of the most sophisticated ecologic articles yet written exploring the interrelationships among volcanism, people, and their environmental adaptations is that by Workman (1977) on volcanism and the aboriginal inhabitants of Alaska. He compares the boreal interior of Alaska and adjacent Canada with the highly productive marine ecosystem of the Aleutian Islands. Because of the dispersed resources of the interior, Indians were mobile and population density was very low. In contrast, the Aleuts lived in large and often permanent villages in their rich marine coastline environment.

Volcanism differs considerably in the two areas. Volcanism was common in the Aleutians, with a major eruption occurring every few years. These eruptions often caused extensive death or suffering for villages adjacent to the volcano, but in the entire Holocene of the Yukon, only two major ashfalls have been recorded (p. 43). From these observations one might generalize that the cultural effects of volcanism would have been far more significant upon the concentrated marine peoples.

Workman argues the opposite, that the infrequent interior volcanism had greater historic significance than the endemic volcanism in the Aleutians. His argument is based on a number of points. First, marine ecosystems may be more resistant to tephra perturbations than are terrestrial. Second, the interior ashfalls, albeit infrequent, were vast and thick, in contrast with the more localized pattern of Aleutian volcanism. Workman suggests the greater frequency of Aleutian volcanism may have resulted in a familiarity with such disasters, leading to the development of a cultural inventory of coping mechanisms which the interior Indians lacked. Migration out of a devastated zone and life as refugees before returning may have involved shorter distances and durations for the Aleutians than for the internal Indians, resulting in less disruption of cultural and adaptive traditions.

Black (1975) has encountered evidence of an early eruption in the Aleutians. Some 8000 years ago Okmok Volcano erupted, depositing 30m of tephra as far as 9km from the source. The site of Anangula was destroyed, and Black cites the eruption as a likely cause of Aleut westward migrations.

Mt. Mazama in Oregon erupted violently about 7000 years ago, depositing an airfall tephra over a broad area of western North America. Crater Lake now rests in the resultant caldera. Grayson (1977) has been researching its effects on eastern Oregon, and he does find evidence for considerable faunal and floral changes between 7000 and 5000 BC. However, evidence is insufficient to isolate the Mazama eruption as the cause, for a general climatic shift toward less precipitation was underway which may have been more directly responsible. Probable evidence of volcanic damage to pika populations is presented. Grayson's work, as with that at Sunset Crater discussed below, is a needed antidote to those who might find some tephra in a site, and immediately begin claiming vast ecologic and social effects. Not all eruptions cause disasters, and the short- and long-term repercussions and human adjustments made can vary considerably, for a multitude of reasons.

The Indians of the Flagstaff, Arizona, area had lived in sedentary villages and farmed the land since at least AD 600, but sometime in the 1060's Sunset Crater erupted. There may have been two eruptions, a small one in 1065 and a major one in 1067 (Breternitz, 1967). Until recently, Colton (1932) was the primary researcher investigating Sunset Crater's effects on human populations. He claimed the eruption had a major effect on the Sinagua living in the area, arguing that the eruption greatly increased the productivity of adjacent farmlands which resulted in migrations of several cultural groups.

Pilles (1977) has challenged that view. Based on recent archeological research, he claims the post-eruption sites are indicative of redistribution of indigenous populations as people adjusted their subsistence

technology to cope with changed circumstances. Hevly et al. (1977:16) have found that the three decades following the eruption were characterized by higher than average precipitation, and that much of this increase fell as summer rains which would have benefitted corn growth.

Pilles does recognize the need for inhabitants in the immediate vicinity of Sunset Crater to flee, and the eruption would have to be recognized as a disaster for them at that particular time. However, the Sunset Crater eruption, when viewed in a larger social and environmental context, is seen by both Pilles and Hevly et al. as having had relatively little effect on local inhabitants.

The Cuicuilco site near Mexico City, inhabited during Late Preclassic times, was buried by some pumice and then by a large lava flow from Volcan Xitli approximately 2200 years ago (Haury, 1975:195). Research into this natural disaster has been so erratic that it is not even agreed that the site was occupied at the time of the eruption. Although most archeologists apparently feel it was occupied at the time, Heizer and Bennyhoff (1958) did not find clear evidence to so indicate. Further research is needed in this area.

Recently, Renfrew (1977) has summarized the literature on the massive eruption of Thera (Santorini) at about 1500 BC and its primary and secondary effects on settlement in the Aegean. Much of this section is taken from his paper. Knowledge that a large eruption had occurred which had buried prehistoric remains is a century old (Fouquè, 1879). Excavations at Thera early in the 20th century indicated the time of the eruption to have been mid-second millenium BC. In the past two decades, Marinatos (1968-73), and after his death Doumas, have conducted extensive excavations at the Akrotiri site on the south coast of

the island. They have found architectural and artifactual preservation to have been excellent, due to the fact that tens of meters of pumice were deposited on the site within a very short period. Considerable archeological evidence of earthquakes preceding the tephra fall has been encountered by Marinatos.

For about half a century it also has been understood that Minoan civilization on Crete (120km S of Thera) suffered a "considerable set-back" (Renfrew, 1977:2) at about this time. Most major towns were destroyed, never to be rebuilt. Only the main site, Knossos, survived and prospered, even though it suffered at the same time as the other settlements. Because Mycenaean influences were evident after this set-back, most scholars in the early 20th century felt an invasion probably had occurred. Marinatos (1939) proposed an alternative explanation, generating a heated debate which continues to the present day. Marinatos argued that the Thera eruption was responsible for the Minoan civilization's decline, not an invasion.

At the core of the present controversy are questions of chronology and causality. Some scholars, such as Hood (1973), argue on the basis of ceramic analyses that the Thera eruption and the destruction of Akrotiri occurred as much as 50 years before the Cretan disruptions. On the other hand, based on a detailed re-analysis of ceramic, tephra, and contextual relationships, Luce (1976) argues for a "single phase" massive eruption of Thera and resultant simultaneous destruction of Akrotiri and the Cretan sites. Luce summarizes his interpretation (1976:16) by means of eleven distinguishable phases of natural and human events.

> As much as a year and half before eruptions began, earthquakes damaged settlements on Thera and Crete. Repairs were underway when the first stage of the eruptions began in the form of a pumice fall.

Pumice and ash eruptions built in frequency and magnitude to cover a large area of the Aegean Sea. Earthquakes overturned oil lamps, causing fires in Cretan houses. The tephra burden in Crete collapsed roofs, clogged streams, destroyed vegetation, and inhibited agriculture for at least five years. The central part of the Island of Thera collapsed, forming the present water-filled caldera. Giant tsunamis resulted, which were over 100 feet high when they destroyed coastal settlements on Crete. The combined effects of earthquakes, tephra deposits, and tsunamis were beyond the ecological resiliency of Minoan Civilization, and Mycenean Civilization expanded from Mainland Greece into the Aegean to take advantage of the misfortunes of its competitor.

FLOOD

The cases where archeologists have encountered artifactually "sterile" clays or silts in their excavations of sites in the New and Old Worlds are far too numerous to mention here. In most cases, little attention is paid to the flood itself; rather, the flood-caused layer is used as a horizon marker and a separator of phases of artifacts or architecture. For example, I recently conducted a search of the archeological literature of western Honduras for possible evidence of flooding approximately 2000 years ago (Sheets, 1977). To my surprise, more than half of the sites investigated did have evidence of flooding. The sterile layers separating occupational deposits were generally described as clay, silt, or sandy silt, and there is some recognition of these deposits as representing floods. But it is at that point that interest by most earlier researchers in the natural event ceases, and no effort is made to determine the causes of the floods, their effects on human habitation, means used to cope with them, or other related topics. Unfortunately, the Honduran literature is not unrepresentative.

However, there is a case in which investigation and interpretation has gone beyond the "horizon marker" stage, and that concerns the floods in the Indus Valley of South Asia almost 4000 years ago. By about 2000 BC, the Egyptians, the Sumerians, and the Harappans had developed the world's first civilizations. The Harappans, in the Indus Valley of Pakistan, had long been thought to have met their end by invasion of Aryan people sometime in the second millenium BC. The Harappan, or Indus Valley civilization, at its height at c. 2000 BC, controlled a larger area than its contemporaries (Dales, 1966:93). Research by Dales at one of its major cities, Mohenjo-Daro, during the 1960's turned up considerable evidence of flooding and structural damage, and no evidence of Aryan invasions. Thick layers of river silt indicate repeated floods, and massive construction efforts and slumped walls indicate efforts and failures to cope with them.

Geological evidence apart from Mohenjo-Daro and the other flooded sites also indicates massive Indus River floods. The Indian geologist Sahni presented evidence for large-scale flooding as early as 1940. He argued that tectonic action may have blocked the Indus temporarily, thereby flooding upstream areas behind the evanescent dam. Dales (p. 96) claims that as the impounded waters reached Mohenjo-Daro, massive community projects were undertaken to protect the city. They included large embankments; one excavated in 1964 was 70 feet wide and over 25 feet high. Their successes and failures are evident in preserved construction sequences; these occurred not once, but at least five times. Dales views the flooding as having a weakening effect on Indus civilization, which, when added to the other stresses it faced, finally led to its decline and fall.

EARTHQUAKE

Occasional references to earthquakes having caused particular distributions of artifacts or structural collapses may be found in the archeological literature. Cited above are the earthquakes which evidently preceded the Thera eruption in the Mediterranean, and which caused structural damage on Thera and Crete. Similar earthquakes probably preceded the Ilopango eruption in Central America, but direct evidence has yet to be uncovered.

Earthquakes preceded the large Vesuvius eruption of 79 AD (Bullard, 1976; Jashemski, 1977:221). Pompeii suffered some structural damage in AD 62, with walls collapsing and some roofs falling in. The 16 years preceding the large eruption were marked by numerous earthquakes, intermittent at first, but building in frequency and intensity. One particularly violent earthquake preceded the eruption by only a few hours. Some of the structural damage of the earlier earthquakes had been repaired by the time of the eruption (Jashemski, 1977:221).

MacKie (1961) claimed that earthquakes may have played a significant role in the collapse of Maya civilization in the 9th century. The evidence derives from 1959 excavations at Benque Viejo (Xunantunich) in western Belize, close to the Guatemalan border. Patterns of wall and vault collapse suggested a severe earthquake to MacKie, as contrasted with the common gradual process of vault collapse followed by wall deterioration. However, this commonality of structural decay after abandonment argues against MacKie. Even if an earthquake caused damage at Benque Viejo, it had little effect elsewhere in the Maya realm. Adams (1973:27) notes that explanations of Maya collapse based on natural disasters have not gained currency or credibility.

MUDFLOW

Evidence of a mudflow disaster which destroyed a Makah Indian village on the coast of Washington a few hundred years ago has been unearthed by Daugherty and his colleagues from Washington State University (Daugherty and Kirk, 1976; Kirk and Daugherty, 1974). Ozette, as the site is called, was a whaling village inhabited by the ancestors of the Makah Indians who still live in the area. Present-day Makah helped Daugherty not only with excavations, but with interpretations of artifacts unearthed. Ozette was founded sometime before the time of Christ, and was continuously occupied until the disaster in the 16th or 17th century. The site is located just above the beach, and immediately below a steep hillside composed of Pleistocene sands and clays. The mudflow itself probably was triggered by heavy rains. The adjacent active fault zone may have contributed an earthquake to act as a trigger to dislodge the hillside. At any rate, the mudflow buried the village in eight to twelve feet of sand and clay. Based on detailed analysis of artifacts and vegetative matter preserved in the mud, the disaster probably occurred at night during the month of June.

Certain methodological considerations derive from the Ozette research which are pertinent to the archeology of sites struck by natural disasters. A chronic archeological problem involves the vast number of factors which intervene between the abandonment of the site and its excavation. Natural factors such as organic decay, tree roots, rodent burrows, and so forth, disturb the context and preservation of artifacts. People gradually abandoning a village take with them their most needed possessions. Others, in the past or present, search through the

remains removing items of interest or value. Archeologists must expend considerable effort in trying to control for intervening variables. However, Ozette and many other sites destroyed by natural disasters afford more ethnographically detailed and sound reconstructions of past societies because many intervening variables can be removed. The mud at Ozette has preserved organic materials extremely well, so that wooden bowls for seal or whale oil still smell of that oil, houses are preserved with their sleeping benches and household goods intact, and seasonal items from the nearby forest are preserved--thereby allowing for the dating of the disaster to June. But, as is so often noted by hazard researchers, the site was reoccupied not long after the disaster occurred.

A much earlier and more massive mudflow, also in Washington, destroyed at least one Indian site near the present town of Enumclaw (Hedlund, 1976). The Osceola mudflow, according to Crandell (in Hedlund), occurred at about 3000 BC. It originated at a former summit of Mt. Rainier, and it travelled down the White River Valley faster than 80 km/hr before spreading out over 105km^2 of the Enumclaw Plateau to an average depth of 6m. The site was occupied both before and after the disaster, as was Ozette. Unfortunately, Hedlund presents little interpretation of past lifeways, and offers virtually no opinions about the effects of such a massive disaster on the people of the area. Rather, his concern is intra-archeological, focusing on dating techniques and artifact typology.

OTHER DISASTERS

A number of other disaster agents have been encountered by archeologists. Marine fluctuations, shipwrecks, and disease are considered here briefly.

Lischka (1975) is investigating "periodic catastrophism" along the coast of Peru. Approximately every 25 to 40 years a severe disruption occurs in the Peru Coastal Current. That current upwells from the south, carrying abundant nutriments and oxygen which support the greatest concentration of marine life anywhere in the world. But when the Peru Counter Current of south-flowing warm water diverts or overlays the Coastal Current, a disaster occurs for marine life. The major disasters, locally called "El Niño", not only result in a drastic marine biomass reduction, but severe flooding of coastal valleys develops from the heavy rains along the normally arid piedmont and mountains. The marine food chain recovers after a few years, but the water table in the coastal valleys remains unusually high for a couple years following El Niño, making possible an intensified reliance on agriculture for the years of marine biomass recovery.

As Lischka notes, sedentary villages were established along the coast by 2500 BC. Midden analysis indicates a primary subsistence reliance on the abundant marine resources, with domesticated plants a distant second. Lischka argues that people adjusted to the disaster of El Niño by progressively greater reliance on agriculture, and that agriculture was facilitated by the higher water tables. With the continued human population increases after 2500 BC, after the re-establishment of marine biomass following El Niño, agriculture during normal times was relied

upon more and more. In this case, slight adjustments to periodic disasters had a cumulative effect which transformed societies from a primary reliance on nondomesticated to domesticated sources of food.

Although they certainly are not large-scale natural disasters, shipwrecks can be considered as specific or localized disasters. Many have been researched archeologically by Bass (1963, 1971) and his colleagues from the University Museum, University of Pennsylvania. From such localized disasters, whether caused by storm or reef, inferences may be made as to exchange systems and political interaction among ancient societies.

Archeology can contribute knowledge about disasters in historic times as well. Beresford (1976) has been excavating a Medieval English village, contributing insights into Medieval life not revealed by written documents. During the last two centuries of the Middle Ages, following the 1200's, many villages were abandoned in England. In some areas as many as one-sixth of the villages were deserted. Although the Black Death, which began in the mid-1300's, certainly played a part, so did economic factors. As Beresford argues (p. 117), the expansion of the British wool industry led to the conversion of much peasant agricultural land into pasture for sheep, with disastrous consequences for many villages, and, furthermore, the concentration of population into urban centers had the effect of accelerating propogation of the disease.

CONCLUSIONS

One inescapable conclusion from this overview of the archeological literature on natural disasters is that archeologists are almost com-

pletely unaware of the hazard research conducted by social scientists within the past few decades. But the obverse also is true. Whatever piecemeal knowledge has been generated by archeologists with respect to natural disasters largely has been ignored by hazard researchers. Some beginnings of collaborative research can be seen in Sheets and Grayson (1979).

Barton's review (1969) of disaster research from the sociological perspective is thorough and excellent with regard to contemporary disasters. Dynes' (1975) overview includes much previously unpublished information. White and others have summarized the basic concepts, methods, and goals of the field in three volumes (White, 1974; White and Haas, 1975; Burton, Kates and White, 1978). All clearly establish the theoretical framework of hazard research as a component of human ecology, and both deal with appropriate methods to reach the theoretically oriented goals. The assessment by Mileti et al. (1975) organizes published material into a number of categories ranging from hazard preparedness to disaster response and long-term reconstruction. The latter is a very useful guide to areas of knowledge and ignorance in the field, both on descriptive and theoretical levels. An important attempt at popularizing hazard and disaster knowledge is the book Acts of God, Acts of Man (Marx, 1977). But all of these are replete with descriptive and theoretical material of recent and historically known disasters, with scarcely a mention of prehistoric disasters.

A partial exception is Bolt et al. (1975), who present a useful introduction to geophysical hazards from the earth sciences viewpoint. Their main interest is with earthquakes, volcanoes, landslides, tsunamis, subsidence, floods and avalanches. Historically known hazards and

disasters are, of course, the basic fare, but they at least mention some major prehistoric events (e.g., pp. 86-7, 98, 115-7, 120-2), although many occurred prior to the human occupation of the Western Hemisphere.

Hazard or disaster research, using social science methods and goals, is virtually unknown in archeology. Why has there been such an absence of archeologists attacking hazard research problems? It is not because disasters are unknown in prehistory. A problem is that virtually all prehistoric cases of natural disasters have been treated individually, without references to the wider human ecologic literature of which hazard research is a part. In too many cases archeologists have developed a vertical "tunnel vision" in their site-specific research. As they excavate deeper into successively earlier horizons of their site, the site tends to become the primary frame of reference. When evidence of a disaster is encountered and recognized, it often is used solely for explanation of intrasite phenomena or patterns, or as a temporal separator.

Another problem is sheer practicality. The archeologist today, attempting to reconstruct aboriginal subsistence, ritual, economic, technological and political systems, has to have at least a working familiarity with the other social science disciplines. A basic methodological familiarity with geology, pedology, palynology, chemistry and physics is mandatory as a minimum in the physical sciences. It is not surprising that archeologists, in trying to keep current with their own field as well as the pertinent aspects of these other disciplines, are generally unaware of the field of hazard research.

Only recently have archeologists begun to investigate social science issues in a serious way. In fact, it was a rare project prior to the 1960's which had at its core social science objectives and methods. Archeology prior to the 1960's, as with so many fields in the early stages of their development, was highly descriptive and classificatory in nature. Attention was focused within, as interpretive, descriptive and taxonomic standards were argued, along with at least some theoretical issues. As elaborate typologies were developed for lithic or ceramic artifacts, architecture, phases, foci, stages, and periods, archeologists often lost sight of people. Archeology in the early and mid-20th century, strongly influenced by the culture and personality school of American ethnology, was often aimed toward mentalistic (ideational) objectives, based on a normative view of culture. Inductive reasoning was dominant, and archeologists waited until all the information was collected before attempting to synthesize and explain.

Contemporary archeology is struggling to break away from the confines of past approaches, hopefully without discarding the useful findings of past research. Current research is more behavioral (phenomenal), interdisciplinary, and directed toward explaining human patterns and processes rather than just describing them. A mixture of deductive and inductive reasoning is used, as well as a greater reliance on statistical techniques, objective sampling designs, and regional analyses. The super-relativism in emphasizing the uniqueness of each site or society, a legacy of the humanities approach, has given way to the use of covering laws, theories, hypotheses, simulations, and predictive models. Only recently have archeological method and theory become capable of serious research into social science problems. To date, most of the prehistoric

social science research has been conducted in the domains of social structure, adaptation and ecology, and regional geographic-economic analyses. Both hazard research and archeology can be strengthened by the close collaboration which was not possible in the past, but which could be so productive now.

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