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Wet Site Archaeology

Barbara A. Purdy

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PREFACE

ARCHAEOLOGICAL WET SITES are found in permanently saturated deposits that entomb and preserve organic objects that seldom survive elsewhere. This description distinguishes wet sites from shipwrecks and from inundated terrestrial sites where degradation preceded submergence.

Wet sites are often located along old shorelines, like the famous Swiss Lake dwellings, or result from a catastrophic event such as Ozette Village on the Olympic Peninsula and Herculaneum in Italy. In other places, preservation occurs because materials were buried intentionally in organic deposits; examples include bog bodies of northern Europe and skeletons with surviving brain tissue from several sites in Florida.

This volume is the outcome of an International Conference on Wet Site Archaeology held in Gainesville, Florida, December 12–14, 1986. Papers cover waterfronts from Newfoundland to Chile, from Polynesia to Florida, and from the Late Pleistocene to the twentieth century. Despite this broad space and time representation, some unifying characteristics of wet site archaeology can be identified. These recur as common themes in many of the papers:

—Wet sites are invisible because they are entombed in organic deposits.

—Wet sites are usually discovered accidentally during development projects that often destroy them.

—Innovative methods to locate and excavate wet sites are required.

—Innovative methods to analyze and preserve materials from wet sites are required.

—Organic remains recovered from wet sites are very fragile and must be preserved immediately to avoid degradation.

—Wet sites offer new knowledge about past environments, subsistence, technologies, artistic expressions, skeletal structure, and pathologies.

—The unique and abundant biological and cultural remains from wet sites require adequate funding for processing, identification of species, preservation, and analyses. Archaeologists and granting agencies who are experienced with remains from terrestrial sites only should become aware of these increased needs.

—Erosion of wetland deposits results from accelerated modern activities such as drawdowns, commercial or recreational traffic on waterways, agriculture, dredging, and increased population.

—It is urgent that archaeologists, developers, and government bodies reach satisfactory agreements about ways to excavate or protect wet sites when modifications of wetland areas are unavoidable.

Other issues addressed in this volume concern the establishment of priorities for excavating wet sites given the realities of available funding and other considerations, and how to determine when enough of a wet site has been sampled.

Wet sites, such as those in Denmark, Switzerland, and Florida, have been reported since the nineteenth century. They have provided views of past cultures and people never known before. The information from wet sites can be preserved for future generations if it is recovered systematically and for the public welfare, instead of for personal gain. The increasing capability to alter the landscape using modern machinery, however, may raze them before investigations can be conducted. It is curious that most archaeologists, while realizing the anthropological potential of wet sites, do not actively search for them. Perhaps this volume will stimulate greater emphasis on wet site projects. The results are as rewarding as going to outer space or diving to the deepest parts of the ocean.

Florida is a logical place to hold a conference about archaeological wet sites. Rapid population increase has necessitated the development of hitherto undisturbed areas in the state, many of which are in wetland locations. As a result, paleontological and archaeological finds are constantly encountered. A dramatic example of this situation occurred during the first day of the conference when a dugout canoe was found during peat mining operations at Stricklin Peat Co. near Grandin, Florida. We took advantage of this opportunity and visited the site. The canoe was eventually radiocarbon dated at A.D. 1450. Mr. and Mrs. Ollie Stricklin have cooperated on many occasions when canoes, wooden bowls, and other items were found on their property.

The International Conference on Wet Site Archaeology was funded by the National Endowment for the Humanities and the University of Florida with additional contributions from the Florida State Museum and the Division of Sponsored Research at the University of Florida, and the Florida Phosphate Council. I acknowledge with gratitude the financial support from these sources and I am equally grateful for the time and services furnished by many individuals. Conference participants took a fieldtrip to the Windover Farms Archaeological site in Titusville where the owners, Mr. and Mrs. James Swann hosted a barbeque and hay ride for the entire group. (See the paper by Doran and Dickel for additional information about this site and the generosity of the owners.) Elise V. LeCompte, a graduate student in the Department of Anthropology at the University of Florida, shouldered a major portion of the burden of organizing the conference.

The success of any event depends upon the people invited. In this case, the success of the conference can be attributed to the speakers whose experience in diverse aspects of wet site investigations is unparalled. Future conferences should attract other well known archaeologists who have worked at archaeological wet sites not represented here.

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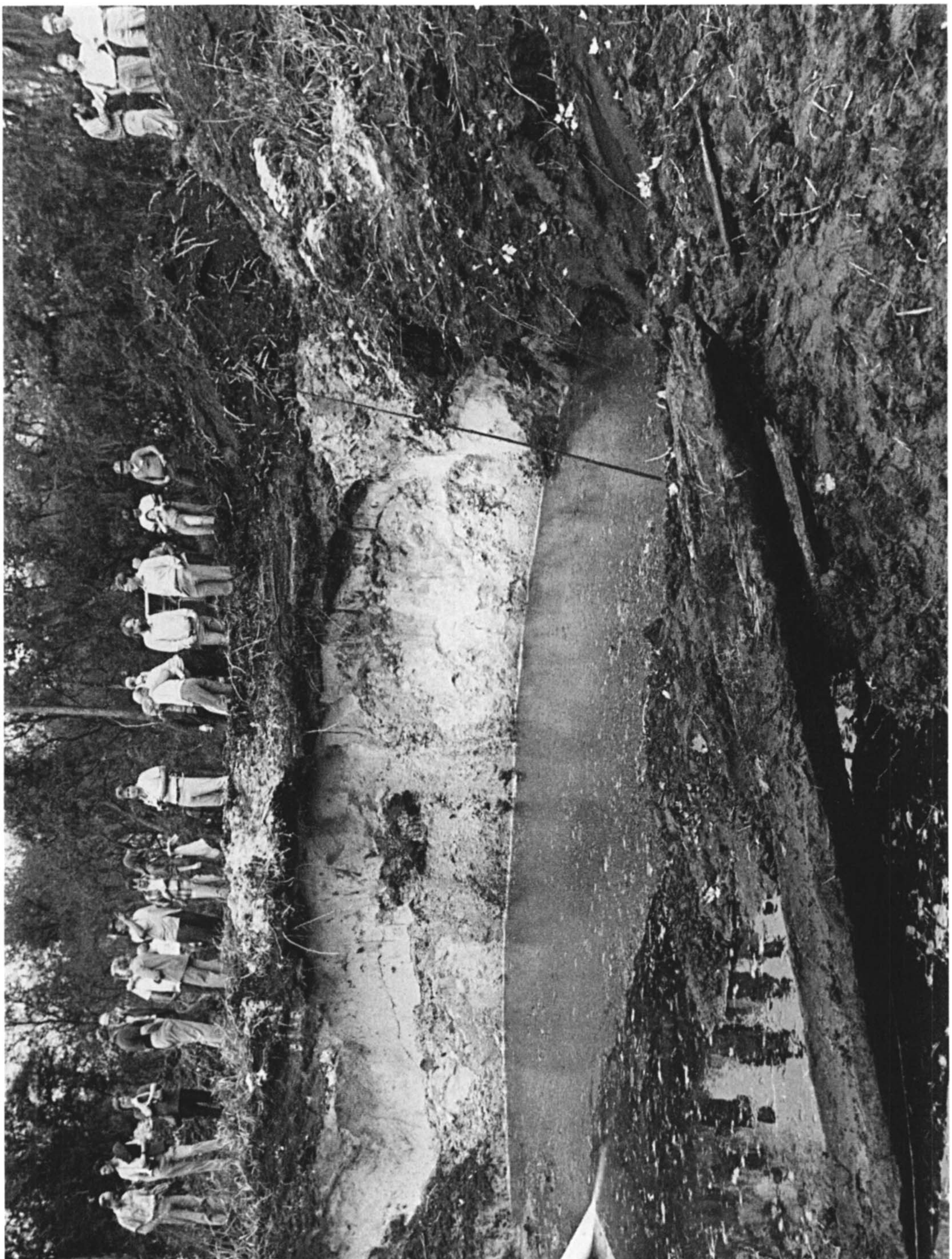
June 1987



Conference participants viewing a dugout canoe found at the Strickland Peat Company near Grandin, Florida.

A WETLAND PERSPECTIVE

John M. Coles

WETLANDS, those flat dreary waterlogged lands that are found in many parts of the world, do not appeal to everyone. Attractive to some, but unloved by many, wetlands conjure an overwhelming vision of endlessness and, to some, even a malevolence. Their dark fields, dank vegetation, and swirling mists can create a lack of focus that is unnerving when first encountered. One of Europe's largest wetlands, the Fens of eastern England, has inspired this description:

> And what are the Fens, which so imitate in their levelness the natural disposition of water, but a landscape which, of all landscapes, most approximates to nothing? Every Fenman secretly concedes this, every Fenman suffers now and then the illusion that the land he walks over is not there, is floating. . . . (Swift 1984).

Yet within these wetlands, whether they be swamp, marsh, fen or bog, landlocked, estuarine or coastal, is sheltered a myriad of wildlife unseen in other environments. Within the unprepossessing swamps and bogs there also lie vast arrays of cultural material, unique in the surviving world of ancient human craftsmanship. Also held in quiet balance in the marshes and bogs all over the world are the waters upon which we depend, cushioned against too ready a release and flooding, filtered to purity, and held in even flows for an unappreciative mankind. All of these wetlands are at risk today, threatened by modern life; many have perished and lie exposed, withering away in the winds, no longer housing life either present or past. There is no more depressing scene than a dead and abandoned wetland.

Other wetlands in a more restricted archaeological sense include drowned regions, lands once dry and inhabited by all manner of life until flooding by rising lakes or seas or collapse or subsidence of land, sealed them with waterborne silt or peat formation, or buried them in depths of water with sand or gravel. Here too the tide of modern life erodes, with quarrying on land and under the sea, alteration of natural water levels, or imposition of roads, factories or houses upon drained lands. Such wetlands have less impact upon natural wildlife but their cultural importance is as great as that of swamp or bogland.

The reason why we as archaeologists are interested in all these wetlands is obvious. But even without an accompanying cultural element, wetlands should interest us as part of living populations and societies. Wetlands are the last refuge of a multitude of plants and animals once widespread and now threatened by extinction. They also represent a living model of that environmental change and impact which we humans profess to comprehend in the dead world. For archaeology, the wetlands of the world hold the key to understanding past human behavior. No one could argue that this is as important as nature conservation or water purification, yet in its way it has a claim to be so elevated; the relevance of the past to the present has been debated many times and will not be repeated here.

What wetland archaeologists are after is the evidence of the past, and a better documentation than has been retrieved from desiccated and eroded landscapes in the past century. In America and Europe such sites have occupied well over 90% of archaeologists' time and over 95% of the funds and support for excavations even in the past decade. Doubtless the same tale is true for other regions of the world where wetlands exist. We seek today better data for the questions that remain unanswered after a century of dryland work and education in a dryland context. Through this, our expectations have been set so low that we can barely begin to grasp what is available to us with wetland survey and excavation. Our archaeological models are so fragmentary and skeletal that a gram of flesh and blood evidence may collapse them, and rightly so. Models used to explain the past must be suspect if they are based on fragmentary, desiccated, decayed, eroded, and ephemeral evidence of the kind that dry sites yield. What is needed is a reversal of the archaeological process, a time, all too short, to extract and retrieve new kinds of data, a time to create new models of the past, and a time to test current interpretations and to rethink the aims and possibilities for archaeology.

It is important to realize that there are various types of wetlands and that their ancient exploitation differed. Archaeological residues from these areas will also be of unequal quality and quantity. Some wetlands were used only for the gathering of wildlife, or were traversed by pathways leading into and out of the wet areas (Fig. 1). Others were exploited for crops, for animal grazing, or provided space for settlement and industry. Because wetlands are varied, were used differently, and have undergone unequal post-depositional processes, their archaeological contents will also be unstandardized. Some will be full of wood while others will astronish with their yield of materials of all kinds which were submerged in the wet deposits and sealed by peat, clay or silt. Protected from scavengers and from many of nature's own erosional forces, the structures and other artifacts remain in conditions of survival only dreamed of when excavating dryland sites (Fig. 2). Some entire landscapes, where ancient settlements have survived by waterlogging and bog formation, can be identified by field reconnaissance using field-walking, aerial surveys, remote sensing, and sub-surface coring. This can yield remarkable information about settlement patterns.

Wetlands of most types also yield immense quantities of environmental and economic data, including pollen and macroscopic plant remains of leaves, bark, and seeds; beetle, spider, and fly fragments; and larger animal remains and molluscs. Such an abundance of evidence can sometimes deter archaeologists and those who fund our work; however, without exploiting every opportunity, there is little point in arguing the case for wetland research. In addition, the results of detailed

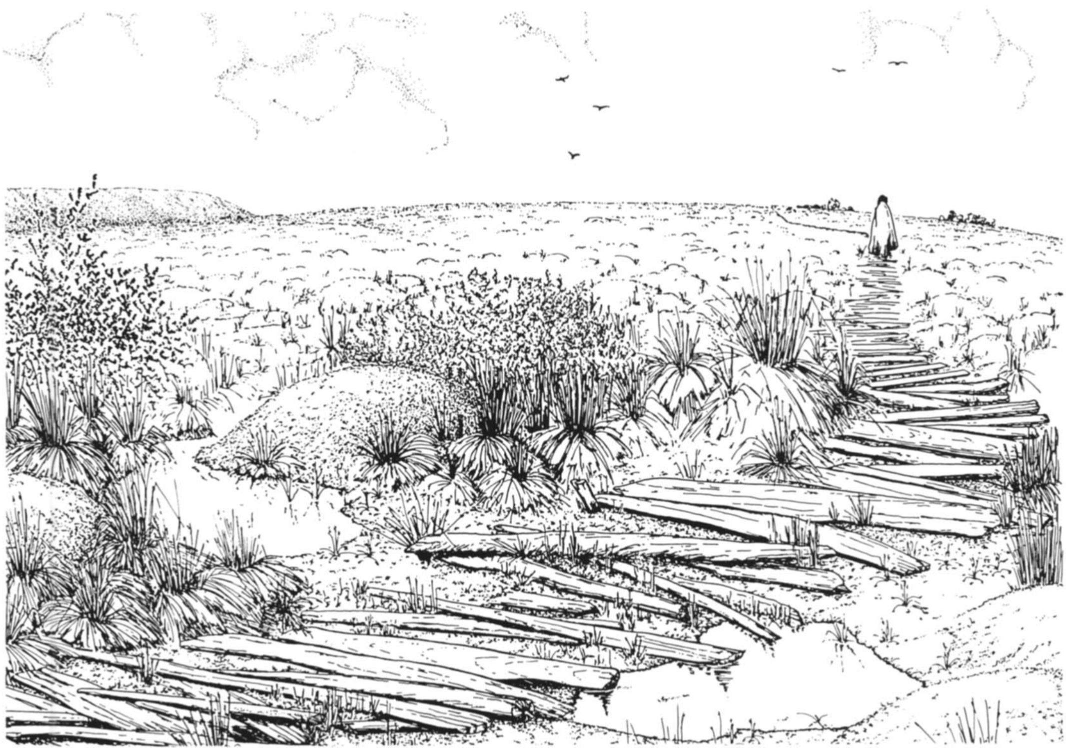


FIGURE 1 Reconstruction of a prehistoric wetland exploited for wildlife, and traversed by wooden roadways. The preservation of a variety of environmental indicators allows a high degree of precision in this environmental reconstruction. By a combination of archaeological, pollen, macroplant, and beetle and bird pellet analyses, all of these wetland plants and pools, birds, and wooden structures, can be envisaged in precise detail. (Drawn by R. Walker.)

extractive and analytical work can be impressive because they are precise. Precision in environmental reconstruction, for example, allows us to picture extinct landscapes down to individual tussocks of grass, boggy pools of water, a teaming insect life, and a detail for our interest in human activities that is quite beyond the reach and comprehension of dryland mentalities. Precision in another wetland sense comes from the tree-ring dating of preserved wood, which can provide not only absolute time (without the imprecision of radiocarbon dating), but also refinements of seasonality and the life and repair of individual structures, virtually imposing a dynamism of behavior upon the archaeologist (Fig. 3).

From time to time, wet sites also provide unexpected evidence that we could never have imagined existed—details about life and death, artistry and craftsmanship, and symbolism and ideology. Ethnographic and historic records assert that many societies do not create representations of their symbols of existence or their artistic achievements upon inert stone; rather they carve, engrave, weave and paint elements of their ideology on organic matter such as wood, textiles, and hides.

FIGURE 2 Part of the structural foundations and platform supports of the Bronze Age lakeside settlement at Fiavé, Lake Carera, Italy (cal 2000–1700) showing the extraordinary depth of preservation in a wet environment. (Perini 1984.)

These artifacts may survive in wet sites (Fig. 4) and, without such sites, we would be totally ignorant of many of these symbols of societies.

It is not only ourselves that we must satisfy by our archaeological work. The public supports our endeavors, and in the long run it is the public who will determine the fate of our subject. Without question wet sites allow the public to gain a better appreciation of the past. These sites are often spectacular and better preserved than dry sites, and therefore are more understandable. We can see

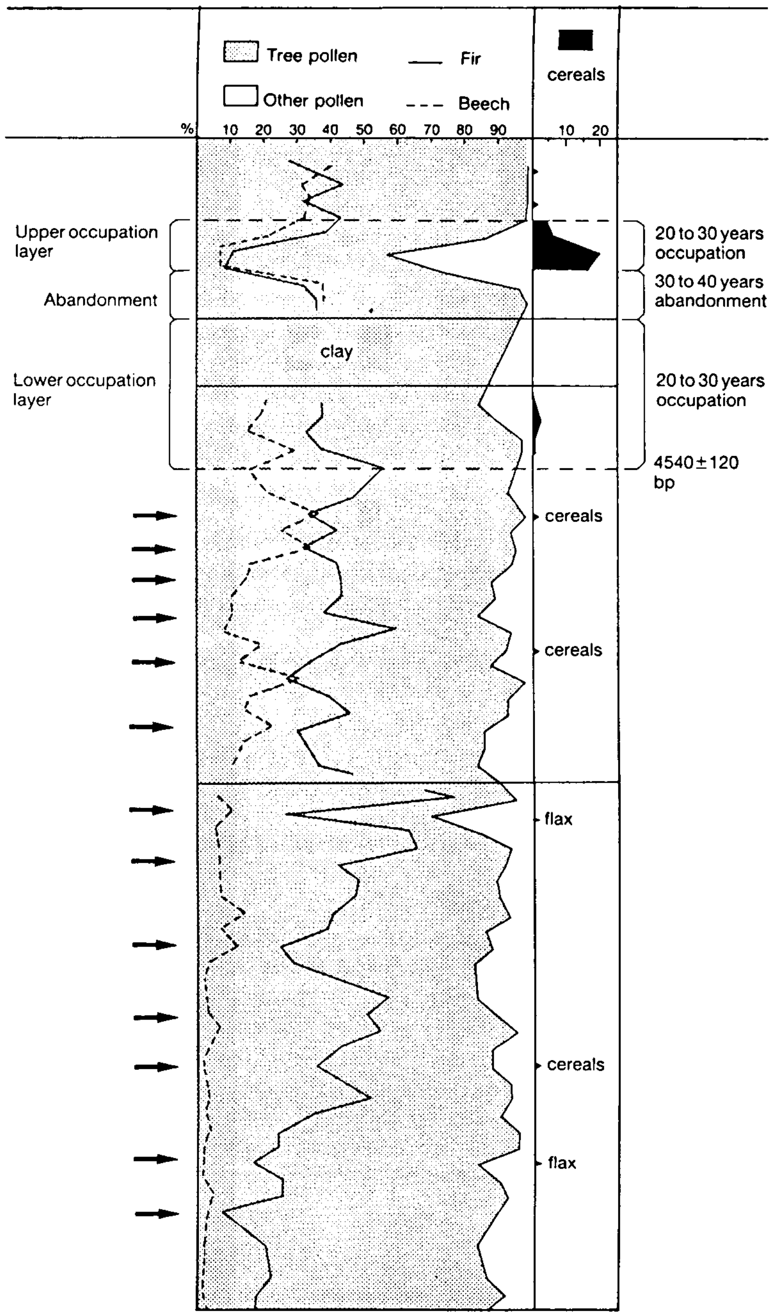


FIGURE 3 Pollen diagram of the Neolithic settlement Les Baigneurs at Charavines, France. The stratigraphy shown represents 600–700 years of sediments, with arrows indicating phases of deforestation of fir, some coinciding with episodes when cereals or flax were grown. The precision of chronological events from cal 3300 BC is based on dendrochronological analysis of the wooden structures. (Bocquet et al. 1987.)

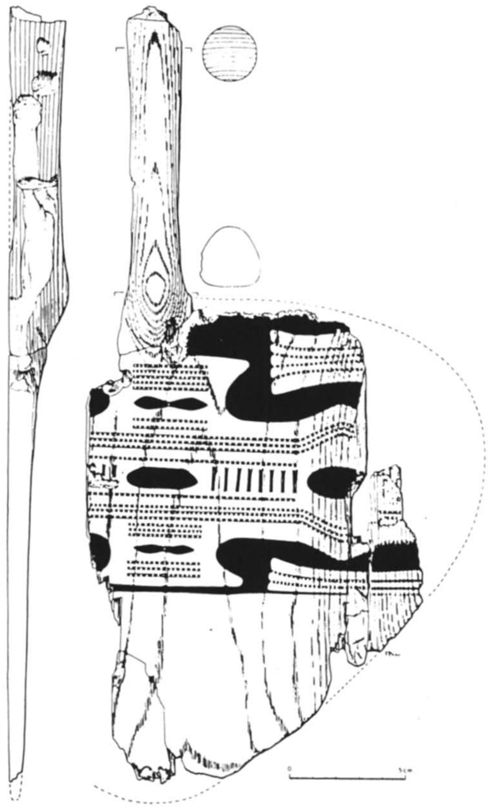


FIGURE 4 Decoration imprinted and painted with ochre on a paddle of ash from the Tybrind Vig Mesolithic settlement, Denmark, now submerged due to isostatic and eustatic factors. Date cal 4800 BC (Andersen 1985.)

houses, palisades, cattle stalls, tools with handles, wagons, and sometimes the people themselves (see the article on bog bodies in this volume). Our reconstructions can be more accurate and more precise, and will therefore encourage the public to believe that archaeologists really do know what they are talking about, so long as they speak a comprehensible human language.

In this discussion I am not necessarily trying to say that dryland sites, where only stains, stones, and bones survive, are no longer of any value. Not everyone in the past, or present, lived in or near a wetland, and the range of archaeological sites and landscapes is not all represented in wetland environments. It is patently obvious that drylands and wetlands hold complementary sets of evidence. But dryland archaeology has had over a century of sustained work and has generally failed to deliver the goods. That is, it has failed to inform us about the past in the ways we want to be informed: how did people live, what did they look like, what did they wear, what did they do and for how long, how did they organize themselves in their settlements and in their houses, what were their patterns of behavior, what were their social and economic systems, and what did they believe in? Wet sites allow us to put a shape on the dry and bare bones of past lives, to answer parts of these questions, and to pose new questions.

Dry sites give us a narrow perspective of the past. If we believe that the economic and social ordering of ancient people is preserved in the material record, then we have a very poor representation of that record in desiccated sites and landscapes (Fig. 5). On dry sites, 80–100% of all materials found are imperishable inorganics; we are left to ascribe an importance to these remains possibly far beyond their value to the society which used them. In contrast, wet sites provide a broader perspective where materials like stone can be seen to be relatively unimportant, and where we can get a very rich representation of material evidence for

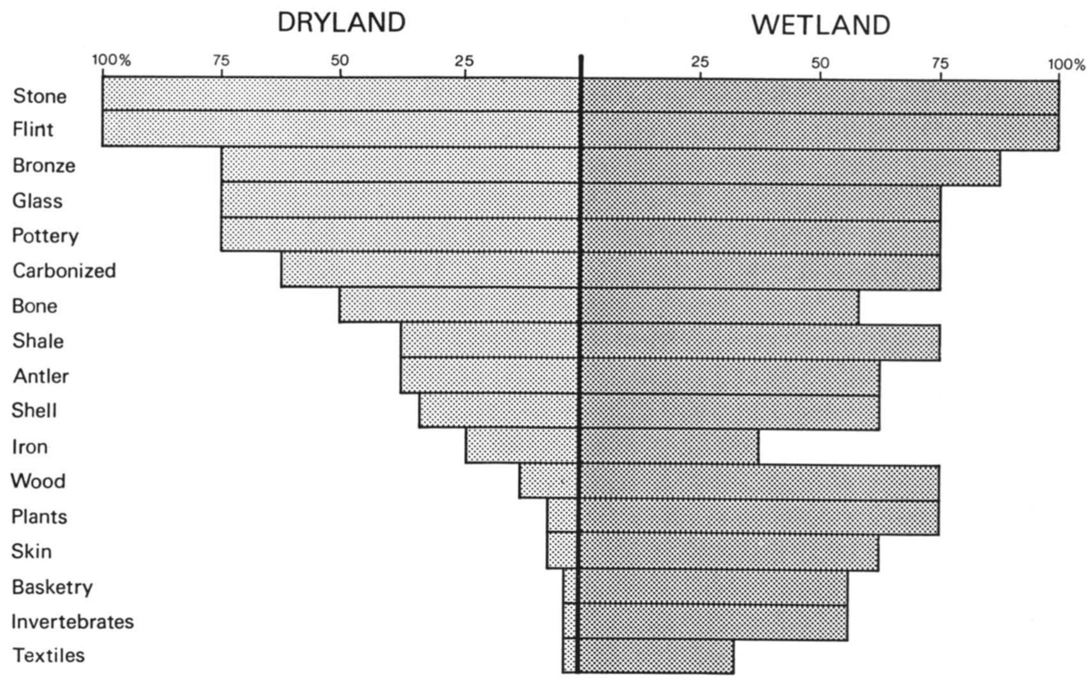


FIGURE 5 A general comparison of the preservation of materials on dry and wet sites, to demonstrate the greater variety of remains recoverable from wet sites. For example, stone will be preserved on all sites, dry or wet. Bone will be preserved on 50% of dry sites, 60% of wet sites. Wood will be preserved on 15% of dry sites, 75% of wet sites. Textiles will rarely be found on dry sites, but on 30% of wet sites. The percentages are based on a wide sample of European prehistoric and early historic sites in different environments.

our interpretations. Inorganic material comprises only 10–25% of a wet site assemblage, while organic remains such as wood, plants, skin, textiles, basketry, invertebrates, and other elements never encountered on dry sites account for 75–90% of the material recovered. On wet sites we can observe that inorganic materials like stone were used to help fashion, but were not themselves, the important artifacts for human life. Our enquiries should surely be directed towards those sites and regions where this scale of evidence survives.

Such an extension to archaeological enquiries will be expensive, as anyone involved in wetland work can attest. Field archaeology, conservation, and analytical work all cost far more than comparable activities on dry sites, yet the growth of wetland archaeology in western Europe, for example, has been remarkable. Here there has been widespread recognition of the worth of wetland research, as well as acknowledgment that wetland evidence is severely threatened. Support for archaeology does not increase in proportion to the threats and opportunities; thus it behoves us to consider what importance we attach to projects, in devising priorities for the future.

If we accept that the purpose of wetland archaeology is to expand our knowledge, then we must agree that not all wetlands are equally important. Table 1 attempts to set out certain priorities for wetlands and wet sites; much of it will be self-explanatory.

Table 1. Wetlands: archaeological priorities

ACADEMIC POTENTIAL

1. *Significance*
   - A. national or international, unique or nearly so
   - B. national importance, high priority
   - C. regional importance, good example of type
2. *Extent of archaeological remains*
   - 1. whole area or major site intact or nearly so
   - 2. significant area or substantial part of major site
   - 3. minor area only, or minor site, or small part of major site
3. *Current condition of surviving area*
   - a. undamaged or nearly so, or minor damage only
   - b. partially damaged and/or in process of being damaged
   - c. severely damaged, significant truncation
4. *Quality and range of evidence*
   - I. most materials, no significant exceptions
   - II. some organic materials survive, others decayed
   - III. no or few organic materials survive

HERITAGE AIMS

5. *Preservation*
   - i. intact preservation possible
   - ii. preservation in part or to some degree possible
   - iii. preservation impossible, or severe damage likely
     (other agencies: $ positive: conservation aid
     – negative: exploitation)
6. *Display potential*
   - H. possible *in situ* reconstruction and/or display, devoted museum
7. *Costs* (survey, excavation, conservation, analyses, etc.)
   $ –$$ –$$$ = low – medium – high costs

8. *Current action* (agency at work, potential, record to date)
   x. short record of work, publications, etc.
   xx. long record

1. A site may be of international, national, or regional importance because of its character (settlement, cemetery, etc.) within a particular territorial context.

2–3. The extent and the condition of the available area will help determine the probable scale of enquiry and its importance.

4. One crucial factor is the quality and range of evidence on the site—a wet site has to be in excellent condition to justify major archaeological work. It must have good organic preservation to warrant support; there is little sense in putting funds into a site where survival is poor. We all know that almost every ancient community used organic materials for houses, fences, tools, containers, clothing and so on, so it is not revolutionary to find traces of wood for example, on any site. It is only important if the materials are in a good enough state to give us more knowledge about woodlands, carpentry, chronology, food, use-wear of tools, clothing, decoration, and other aspects of culture. A dried-out infested plank, an eroded potsherd, or a bare bone is not much use if we are seeking new information. These aspects of site potential seem to me to sum up our aims and opportunities. But there are other aspects of wetland research to consider when we try to justify the work to a wider audience. It is not, in my opinion, the right or the role of archaeologists today to seize every seemingly intact and well-preserved site for excavation.

5. Many wetlands are indeed under serious threat and do require some rescue or salvage action, but others may be in positions where their preservation can be attempted. Therefore in assessing our priorities we should take into account these opportunities to preserve some areas for future research. Other agencies will, without doubt, also be interested in wetlands.

6. The public too deserves recognition when making decisions; we need to determine if displays, museums, or reconstructions are possible.

7–8. As resources for archaeology are finite, some indication of likely costs, as well as the existence of an archaeological agency already trained in wet site excavation, will have to be assessed; wetland archaeology is expensive and mistakes through inexperience are costly in terms of money and lost information. The growth of wetland research is assured in many areas of the world now that its fruits have been sampled, and there is a good case for training programs to be developed and offered.

The proof of any pudding, of course, is in its affect on the consumer, and it is tempting to produce here a priority list of wetland projects. Take the Fenland of eastern England, for example. Here is an immense area of wetland (400,000 ha) with thousands of archaeological sites, now discovered through wetland field surveys (Fig. 6). Its national significance is great (A) and much of the area is available for survey (2), but it is damaged now in the process of being drained (b). The quality of the evidence in places is extremely high, but generally variable (II). The Fens after having been drained and ploughed for centuries (Fig. 7), cannot be preserved intact (iii). They are too large for a single specialized museum and the archaeological

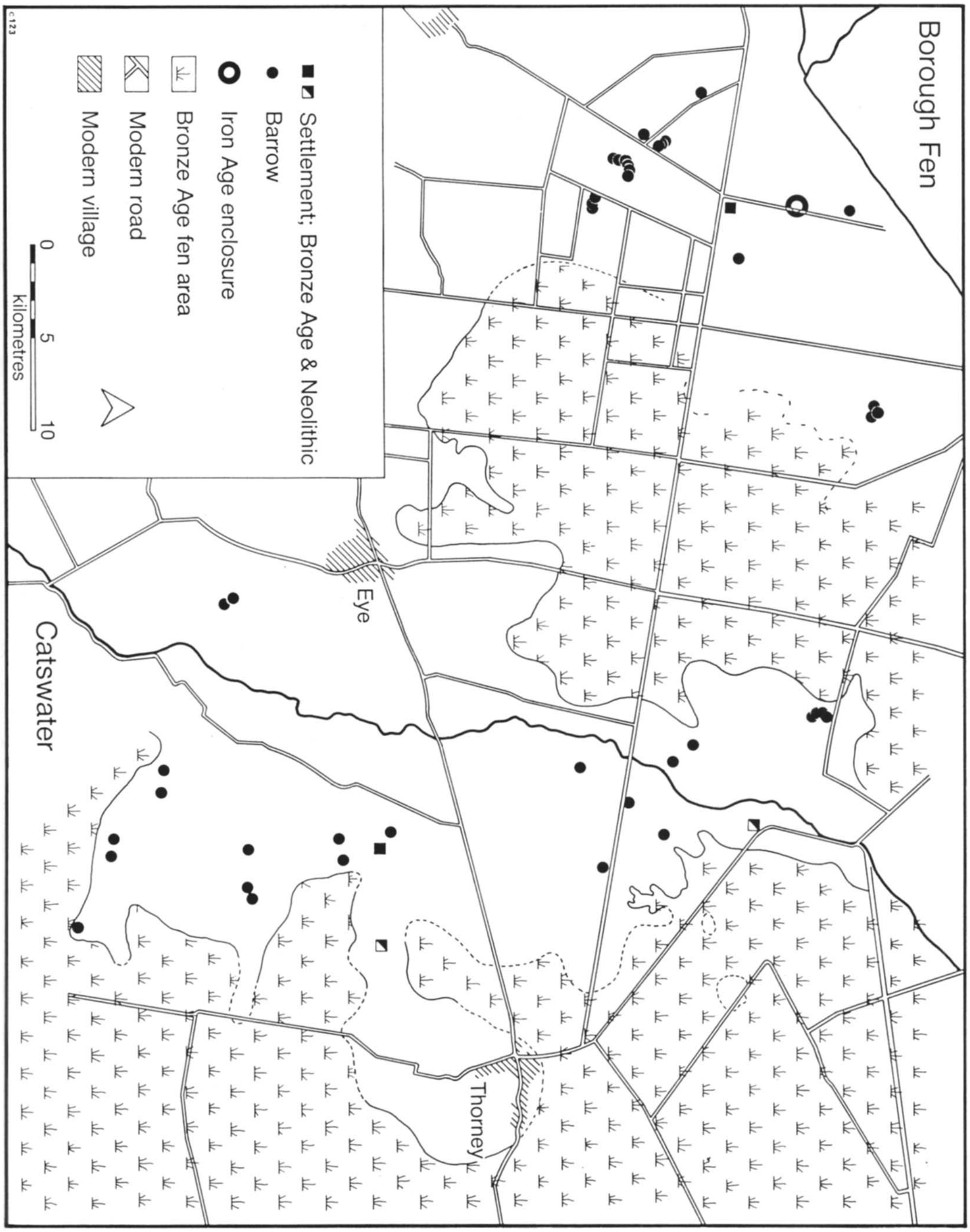


FIGURE 6 Distribution of ancient sites in Borough Fen, the Fenlands, England, to show the results of survey over a drying wetland. Most of the sites marked were invisible until drainage and erosion reduced the organic soils, thus allowing the still intact monuments to "emerge" from the flat landscape. Based on surveys by David Hall, Fenland Field Officer.

FIGURE 7 The Holme Fen post, Fenland, England. The post was driven into bedrock under Fenland peats in 1848, with its top exactly at ground level. The height now seen (over 3 m) represents shrinkage (not cutting) of the peat due to drainage of the area.

survey and excavation, now underway by experienced teams (xx), is costly ($$$). The sum of the assessments indicates the significance of the area, the rate of damage and the need for work, the likelihood of important yields, and the feasibility of excavation. A list of similar projects has appeared elsewhere[1], but several of the projects presented in this volume seem to me to fall at or near the top of any priority scheme. Except for Ireland, these are on-going projects which have already yielded much information (Table 2).[2]

Table 2. Wetland projects: an assessment

Sites	Significance	Extent	Condition	Quality	Preservation	Display	Costs	Action
Hauterive-Champréveyres	A	1	a	I	iii–	H	$$$	xx
Sweet Track	A	2	b	I	ii+	H	$$	xx
Ozette	A	2	b	I	ii	H	$$	xx
Windover	A	1	a	II	ii		$$	xx
Areas								
Fenland	A	2	b	II	iii–		$$	xx
Assendelver	A	2	b	II	ii–	H	$$	xx
Central Ireland	B	⅔	c	II	iii–		$$	

For wetlands only now recognized as potentially important, assessment should pose no difficulties. A small input of time and funds for field survey, sampling for environmental coring, and perhaps remote sensing, allied to standard literature searches particularly of early records of exploitation and exploration, can provide a clear appraisal of the region's potential. In this way the major projects in the English Fens, in the Somerset Levels, and in German Lower Saxony were initiated. Other more specific sites can emerge through underwater survey (Tybrind Vig, Denmark; Hauterive-Champréveyres, Switzerland), ditch survey (Flag Fen, England), river and lake-edge search (Hontoon Island, Florida), coastal wave erosion

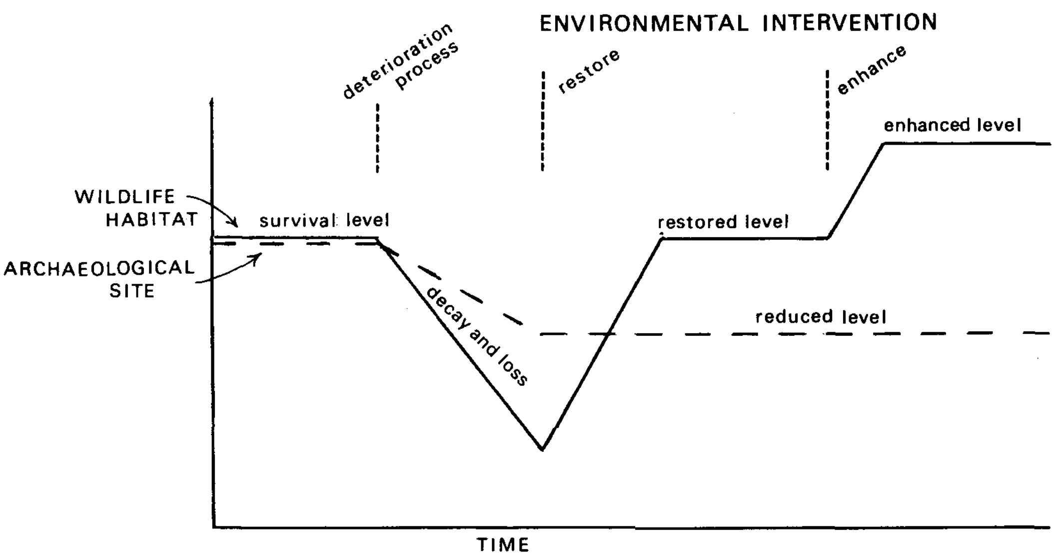


FIGURE 8 Environmental intervention in a wetland. Although survival levels of wildlife and of wet site archaeological remains may be held at broadly comparable levels (left), once drainage commences decay and deterioration of both elements will start to take effect unequally. Should the restoration of wet conditions occur, however, it is possible to recreate or even to enhance the wetland aspects of the wildlife plants and animals (although probably of different composition than the original). For archaeology, such restoration is impossible; the loss of waterlogged remains is irreversible.

(Ozette, Washington State), or drainage and peat extraction (Fiavé, Italy); in these cases it may not be necessary to demonstrate the significance of the site other than by trial excavation and sampling (e.g., Flag Fen, Tybrind Vig), or by recourse to earlier records of artifacts and structures at the site (e.g., Hauterive-Champréveyres, Ozette).

In conclusion, why should we be concerned about wetland archaeology? It has produced outstanding results by any method of assessment, and although it sometimes suffers from common but not universal delays in publication, its contribution to the record of the past is already very considerable. The reason why archaeologists cannot merely continue a rather opportunistic approach to wetland research is because the pace of change in the world has quickened. The slow and gradual uncovering of wet sites and the exposure of ancient wetland landscapes by traditional methods have now been accelerated by modern drainage, by deeper ploughing, by harbor, motorway and marina developments, by reservoir construction, and by levelling and filling of the land for housing or factories. Current governmental policies do little either to help preserve wetlands or to permit their investigation in advance of damage. For archaeology, this damage is irreversible (Fig. 8). A wetland once drained may be restored in part for nature conservation by the reintroduction of water, but once organic archaeological evidence has decayed, it is gone forever and no amount of fresh flooding or wetland wildlife will do any good. This is why archaeologists should not only join others in efforts to protect wetlands but should take the lead in the preservation movements; if we do not, we are playing a part in the destruction of the raw materials of our own subject.

Acknowledgments

Some of the general comments made in this paper are the result of contact and communication with many wetlanders in Europe and America, and to all these archaeologists, environmentalists, and conservators I extend my thanks.

Footnotes

1. A more detailed explanation of the priority statement, and a commentary on a variety of wet sites and wetlands, appears in J.M. Coles, 1986 Precision, Purpose and Priorities in Wetland Archaeology, *The Antiquaries Journal* (66):227–247.
2. Most of the European examples mentioned here are reported in a volume of papers presented at the Wetland Conference of the Prehistoric Society held in 1983: *European Wetlands in Prehistory*, J.M. Coles and A.J. Lawson (eds.), Oxford University Press, 1987.

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PROBLEMS AND RESPONSIBILITIES IN THE EXCAVATION OF WET SITES

Richard D. Daugherty

THE PAPERS presented in this volume cover a wide range of topics, including: the purpose and significance of wet site archaeology, different types of wet sites, special techniques associated with the excavation of wet sites, descriptive reports on the excavation of wet sites, special studies associated with wet site excavations, and problems specifically linked to wet site excavation. The fact that this conference was held, and that the range of topics discussed was so broad (essentially as diverse as that for any archaeology conference), certainly indicates that wet site archaeology has developed into a vital aspect of our discipline.

But, as with any developing field, it takes time for some of the problems to achieve general recognition, not only within our own profession at large, but also with governmental agencies, sources of funding, and the public in general. It is to some of the special problems associated with wet site archaeology, as well as the attendant responsibilities, that I shall address my remarks. I shall use my experience of over eleven years of directing the excavation of the Ozette Site to illustrate the points I wish to make.

Ozette Village (45–CA–24) is the southernmost of the five main villages of the Makah Indian tribe of the Cape Flattery area of Washington State. The Makah are closely related socially and linguistically to the Nitinat of southern Vancouver Island. Linguistically, all are Nootkan speakers.

Ozette Village is located on the Pacific coast of Washington, 14 miles south of Cape Flattery at Cape Alava (Fig. 1). The offshore area immediately in front of the site is a broad rock shelf which is exposed during most low tides. Offshore islands, Ozette and the Bodeltehs, and the tidal island, Tskawahyah or Cannonball, are a part of the Ozette Site complex. The main part of the site lies on a narrow bench, 75 m at its widest and varying in elevation above high tide from 1 to 5 m. Behind the site is a sharply rising hillside which levels off to form another bench at about 30 m in elevation. The offshore shelf and islands, as well as the village's elevation of above mean high tide, usually protect it from both surf and storm winds. The sheltered local surf conditions allow for the easy launching of canoes in most weather conditions.

Ozette subsistence economy focused on maritime resources. Whale hunting was a major economic activity. Hair seals and sea otters were taken from nearby

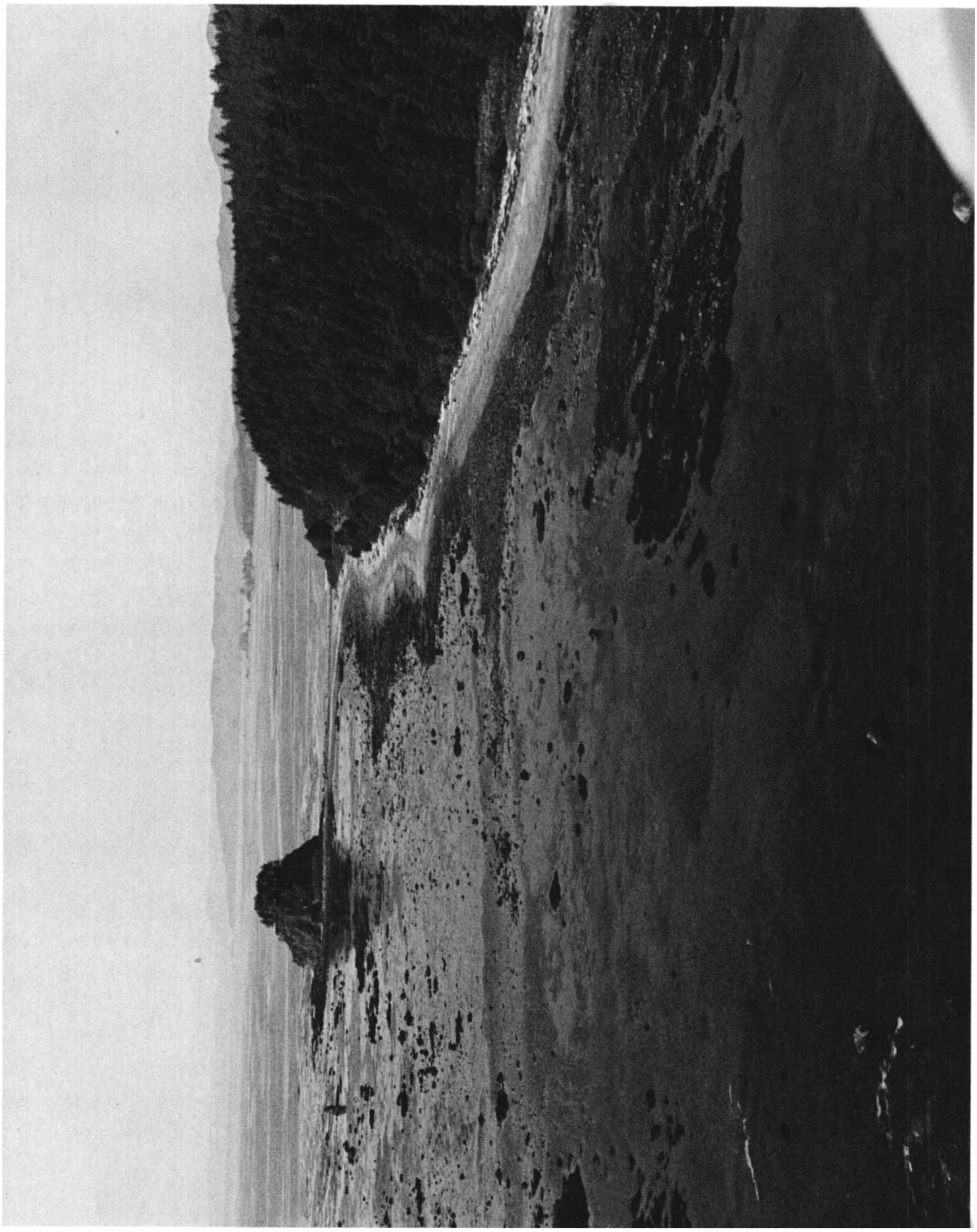

FIGURE 1 Ozette village is located on the low bench bordering the beach opposite Cannonball or Tskawahyah Island. The rocky reef in front of the site is exposed at low tide. In the distance are Point of Arches, Cape Flattery, and Vancouver Island (Photo by Ruth and Louis Kirk.)

kelp beds and sea lions from nearby rocks. The site lies close to the migratory route of the pelagic fur seal. Archaeological evidence from the site indicates that all these mammals were taken prehistorically (Gustafson 1968; Heulsbeck 1983).

Bottom fish, such as red snapper and ling cod, abound in the waters offshore from Ozette. To the northwest of Tatoosh Island at Cape Flattery lie excellent halibut banks. Along the littoral zone, resources such as kelp and various shellfish were harvested. Rivers such as the Ozette yielded salmon, including the sockeye, coho, chinook, and chum (Heulsbeck 1980, 1983).

Augmenting the maritime resources were forest products, including deer, elk, salmon berry, salal berry, and various other plants. Although the plants do not appear to have contributed a large amount to the diet, they may have been an essential source of certain minerals and vitamins.

The Ozette Village was occupied into the early twentieth century. It was abandoned when families moved to Neah Bay to be in compliance with Bureau of Indian Affairs regulations stipulating that all Native American children attend agency schools. By the 1920s, the village site was being used only as a seasonal fishing and hunting camp.

The initial excavations at Ozette, in the summers of 1966 and 1967, demonstrated that the site had extensive, thick midden deposits, and that occupation extended from the historic period back to 2010 ±190 B.P. (WSU−1123). The material culture and faunal remains reflected a well-developed maritime adaptation (Gustafson 1968; McKenzie 1974). Cultural features included historic house floors, and a succession of prehistoric house floors documented in the stratigraphic profile. The extent and the time depth of the deposits, as well as the preservation of various perishable materials at the site, made it obvious that the site could provide unique contributions to understanding past cultures on the coast.

The Ozette deposits were severely jeopardized in January of 1970. Abnormal winter storms had deeply eroded the bank, undercutting the midden and causing it to slump onto the beach, depositing bentwood box fragments, baskets, mats, arrows, boards, and stakes which were being collected by local beach walkers. This situation was brought to the attention of the Makah Tribal Council members who requested that I return to Ozette and start salvage excavations in the area where the midden was slumping onto the beach.

A visit was made to the site in January of 1970 to appraise the situation. Shortly thereafter a camp was established to recover exposed artifacts, and to provide security for the site. In the following months, an hydraulic excavation procedure was perfected. The method was well-adapted for this situation because one could create a pressurized flow of water strong enough to erode the matrix but weak enough to preserve the perishable artifacts. While the system had the capability of working for very delicate recovery, it could, with increased flow and pressure, remove the massive clays overlying and between the cultural deposits.

Also during this period, techniques were developed for the field stabilization of the water-saturated wooden artifacts. Although most of these artifacts had not been subjected to fungal decay, there had been some alteration of the cell wall structure. Earlier experience had taught that many artifacts would either check or develop radial splits when they were air-dried. After soaking in a 50% solution of polyethylene glycol and water, however, the artifacts held their shape and rarely checked or split. Additional benefits of this approach were that the baskets and other woven artifacts maintained their pliability.

The stratigraphy revealed a thin historic level (Unit I) underlain by Unit II, a massive clay deposit. Below this was another thin historic layer of preserved midden (Unit III), which in turn, was underlain by Unit IV, another massive clay deposit. Under Unit IV, there was a relatively thick midden deposit (Unit V) containing numerous planks of buried houses. Under Unit V, there was another clay deposit (Unit VI), which was underlain by the earliest cultural deposits in this area of the site (Unit VII). Unit VII rested on unconsolidated sands and gravels.

Excavations revealed a wealth of information. Units I and III contained ceramics, glass, and metal artifacts recovered in conjunction with wooden artifacts. Unit V was a protohistoric deposit dating to 440 ±90 B.P. (WSU−1778). This unit had many preserved wooden artifacts, but ceramic or glass artifacts were not encountered. Metal artifacts, not of any obvious European design, were recovered however. This was the first incontrovertible evidence for the use of iron and steel on the coast before known European contact. Numerous structural remains of houses also were recovered in Unit V. The most important of the structural remains was the lower portions of three sides of a house, which were still standing. Not only did these yield much information on house construction (Mauger 1978), but they provided a clear, culturally defined boundary between interior house floor deposits and exterior midden deposits. The mud slides at Ozette had preserved not only much of the material culture, but also some of the boundaries of the living space in which these artifacts had been used.

The excavations revealed that the Unit IV clay slide had hit this portion of the village and covered it almost instantaneously, removing all contact with air. The aerobic fungi responsible for the decay of wood and vegetal fiber became dormant or died. Consequently, these materials remained nearly as they were when the slide hit the village. So perfect was the preservation that leaves were still green when first exposed to air.

During the eleven years of year-round excavations (1970−1981), the remains of at least eight houses were uncovered. The house boundaries were determined by the remnants of the lower house walls consisting of wall planks, poles driven into the ground to serve as their supports, and roof support timbers. The house floor areas delineated by the walls were roughly rectangular areas that were as large as 21×11.5 m. The long axis of the structure was either parallel or perpendicular to the beach.

The slightly sloping terrace in this area of the village had been levelled to create house platforms by digging out high portions of the terrace and depositing the backdirt in the low spots. More than one house might occupy serially the same house platform. A house would be built, occupied, and abandoned; after an unspecified period, another structure would be built on the same platform. Two such platforms have been fully excavated at the site. One platform contained a single house (House 1; Fig. 2) and the other platform contained two houses (Houses 2 and

FIGURE 2 Sleeping benches, complete and broken house roof and wall planks, and the lower portion of the south wall of House #1 partially exposed. The pond is a settling basin for sediments washed from the site during excavation, and was constructed by the crew to protect the marine environment of the reef in front of Ozette Village. (Photo by Ruth and Louis Kirk.)

5). House 5, the first house built on its platform, was apparently abandoned because of the inability of its inhabitants to deal effectively with the massive amounts of water from hillside seeps that flowed across the house floor. Houses 1 and 2 were destroyed by the massive Unit IV mudslide that covered this part of the site.

The excavated area consisted primarily of interior midden. The houses were built close together, usually within 2 m of one another. The spaces between the houses appeared to have been refuse dumps, pathways, and drainage areas. There was no indication that these between-house areas were used for production or processing activities. Within the immediate area of the village such activities probably occurred on the beach in front of the site during warm, dry periods and within the dwellings during colder, wet periods of the year. Recovery of manufacturing and cooking byproducts around the hearth areas within the houses supported the concept of the houses as a location for production and processing activities.

Over 50,000 artifacts, in addition to faunal items and structural remains, were recovered. Three of the eight houses encountered were completely excavated. The Unit V deposit proved to be complex, with various episodes of rebuilding and reoccupation. A series of drainage features was also found in association with the structures.

Because of the unique conditions of preservation at the Ozette Site, an amazing collection of normally perishable artifacts survived. Of the artifacts recovered, over 29,000 were from the prehistoric and protohistoric levels, and most of these were made of wood or fiber. During the excavations, 179 categories of artifacts were identified in the field. Some of the categories of perishable artifacts not usually found in an archaeological context, but recovered at Ozette are:

Woven Materials
- 1330 baskets
- 1466 mats (Fig. 3)
- 142 hats
- 37 cradles
- 96 tump lines
- 49 harpoon sheaths

Weaving Equipment
- 14 loom uprights (Fig. 4)
- 14 roller bars
- 10 swords
- 23 spindle whorls
- 6 spools

Hunting
- 115 wooden bows
- 1534 arrow shafts
- 5189 wooden arrow points
- 124 harpoon shafts
- 22 harpoon finger rests
- 161 plugs from seal skin floats

FIGURE 3 Cedar bark matting and crushed wooden box exposed on floor of Ozette House #2. (Photo by Ruth and Louis Kirk.)

Fishing
- 131 complete bent wood halibut hooks
- 607 curved halibut hook shanks
- 117 blanks for making hooks
- 7 herring rakes
- 57 single-barbed hooks
- 15 double-barbed hooks

Containers
- 1001 wooden boxes and fragments (Fig. 3)
- 120 wooden bowls (Fig. 5)
- 37 wooden trays

Watercraft
- 361 canoe paddles (Fig. 4)
- 14 canoe bailers
- 14 canoe fragments

Miscellaneous
- 40 game paddles
- 45 carved miniatures (canoes, figurines [Fig. 6], etc.)
- 52 carved wooden clubs (Fig. 4)
- 1 carved effigy of a whale fin inlaid with over 700 sea otter teeth (Fig. 7)

Nearly two-thirds of the artifacts from Ozette are made from perishable materials; the balance are the usual items of stone, bone, and shell. Of particular significance in the Ozette collection is the occurrence of hundreds of composite tools made of wood and bone, wood and stone, wood and shell, wood and metal, wood and teeth, wood and antler, bone and shell, bone and metal, and shell and antler.

Another significant aspect of the Ozette collection is that the artifacts occur in all stages of production, providing key information for understanding the manufacturing technologies.

The Ozette artifacts reflect different age groups of the population. For example, the 115 wooden bows range in size from those used by adults, through young teenagers, down to those that must have been toys of little toddlers. The arrows reflect the same size range. Cradle boards are found in large sizes suitable for an infant, and in small sizes that young girls could have used for play.

Because of the nature of the Ozette artifact collection (preservation, numbers, composite tools, range in size, stages of manufacture), the proper reporting of each artifact category, through careful and thorough analysis, will stand as the baseline against which other collections, less complete in nature, can be compared.

All of us are aware that wet sites vary widely in the type of site, the nature of the deposits, the age and nature of the buried cultural material, the nature of the buried paleoenvironmental materials, and the degree of preservation of both cultural and environmental materials.

Aspects that wet sites generally have in common include: exceptional preservation of normally perishable materials, the recovery of large amounts of non-cultural

FIGURE 4 Wooden loom upright, canoe paddles, and seal clubs partially exposed in Ozette House #2. (Photo by Ruth and Louis Kirk.)

as well as cultural material and data, the development and employment of special techniques for excavation and data recovery, the employment of techniques and materials for the preservation of recovered materials, and often the need to employ a specialist for the identification of biological remains, including animals, plants, pollen, macrofossils, and even plant diseases.

Because of the complexity associated with the excavation, preservation, analysis, and interpretation of wet sites, the archaeologists digging these sites are frequently faced with monumental problems. This is not to say that some of the problems I

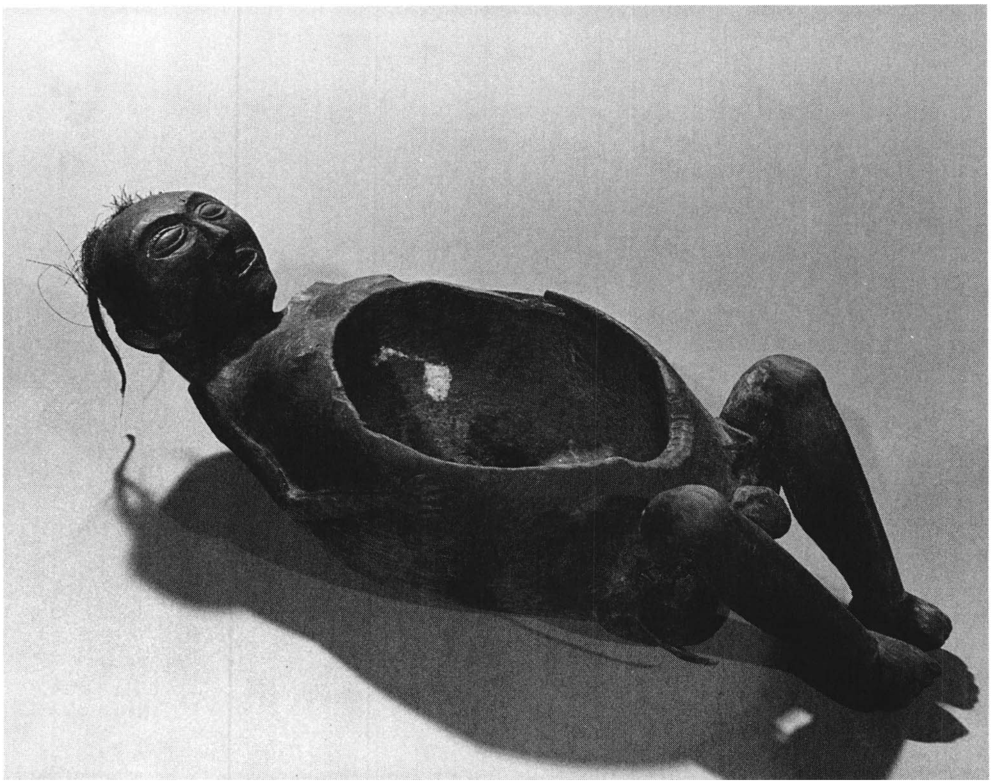

FIGURE 5 A wooden bowl realistically carved in the shape of a reclining man was used as a container for seal or whale oil. Real human hair is inset in a groove carved across the top of the head. (Ozette project photo by Mike Short.)

shall discuss may not be associated with a given dry site excavation, but certainly these difficulties are more common to wet sites.

Let me first discuss the problems associated with funding wet site excavations. We are all aware of the fact that one of the major, if not *the* major expenditure (if we are not dependent upon volunteer help), for archaeological investigations is salaries and wages. Supervisory personnel, field crew members, laboratory assistants, clerical help, and special consultants in supporting disciplines must all be paid. How much is to be spent will, of course, vary widely with the type and duration of the project. However, because of the nature of wet site archaeology, these projects are relatively expensive when compared with traditional dry site projects. Because of the characteristics of the deposits, the techniques that must be employed in excavation, the need to deal with delicate objects that may be destroyed or damaged if not patiently excavated, the need to conserve much of the recovered material, and because masses of cultural as well as paleoenvironmental data are recovered, more time is required for the excavation of a given volume of wet site deposits than for a comparable volume at a dry site. Increased time in the field and in the laboratory readily translates into a larger budget. Wet sites often have the same categories of artifacts as dry sites (items made of stone, bone, shell, and pottery), but they also add many new categories (items made from wood and fiber); thus, time for analysis is increased.

Several categories of specialist, the conservator, the botanist, the palynologist, and the plant pathologist must often be employed. Again, this leads to increased costs. The point to be made here is that in spite of the often substantially greater yield in scientific information from the excavation of a wet site, archaeologists working for granting institutions and federal and state agencies do not really understand wet site excavations and, hence, the need for more time and money to carry out a project.

A large, complex wet site such as Ozette may take many years to excavate. Yet in the United States, research grants from foundations rarely exceed three years. The reason is largely because of the wish to spread limited funds as widely as possible. If a project is related to federally licensed or funded construction activity, the time permitted for research rarely exceeds five years, and is usually dictated by construction schedules.

The funding for Ozette over a period of two summers (NSF support) and 11 years of year-round excavations (Department of Interior, Washington State University, the Makah Tribe, and private support) amounted to a very substantial sum. It concerns me that today I can think of no source of funds that would provide the time and money for the excavation of another Ozette, on a purely research basis. Even a well funded emergency salvage program might run into trouble with the time needed to complete the project.

An additional point concerning budgets needs to be made. Not only is adequate funding necessary, but decisions must be made as to how to allocate the available funds. Because of the generally excellent conditions of preservation, masses of material related to economic and paleoenvironmental reconstructions can be collected. In addition to the usual vertebrate and shell remains, plant remains of a

FIGURE 6 Small wooden figure from Ozette deposits. The figure lay face down and partially excavated with only the head projecting out from the moist clay deposits for nearly two years, when further excavation exposed the rest of it. The body portion that had remained buried in the moist clay deposits was in good shape when discovered, but the exposed, untreated head had become badly degraded as the wood dried. (Photo by Ruth and Louis Kirk.)

large variety and abundance are available for analysis. It is a heady experience to have all of this material available for study, and one can easily spend the entire budget on all of the fascinating possibilities. Because all of this is relatively new to us, I believe we are ill-prepared to make sound decisions as to how much is enough.

At Ozette with its water-saturated midden deposits and buried houses, we analyzed over 400,000 mammal, bird, and fish bones (DePuydt 1983; Heulsbeck 1983). Detailed taxonomic, morphologic, and contextual characterizations of over 300,000 pieces of shell were provided in one of our studies (Wessen 1982). Another of our efforts was a three-part study of the ethnobotany of the Makah-Ozette people (Gill 1983). Part One contains data concerning the distribution, habitat, abundance, and phenology for 398 vascular taxa representing 82 families, 228 genera, and 384 species. Part Two concerns traditional uses and names of plants by the Makah-Ozette people during the historic period. Part Three contains the analysis of 448,943 seeds that were recovered from the Ozette deposits and identified. We forged ahead with these studies intending to study masses of material. But part of our interest was to attempt to answer the question, "How much is enough?" Three doctoral dissertations (Gill 1983; Heulsbeck 1983; Wessen 1982) and one master's thesis (DePuydt 1983) later I feel that I am only slightly closer to the answer. We must continue to explore in a theoretical as well as practical way the basis of our analysis of nonartifactual materials. We must develop theoretically sound sampling strategies.

The need for ongoing curation and preservation of materials collected from wet sites often presents real problems insofar as space, facilities, and trained personnel are concerned. With respect to the Ozette collections, even though funds were found (approximately two million dollars) to build a beautiful museum in which to display the Ozette materials at Neah Bay on the Makah reservation, the total storage problem has not been solved. Only about 5% of the artifacts are on display, and the rest of the 50,000 artifacts are being stored temporarily under minimal conditions. Thousands of sea mammal bones, including perhaps the largest collection of whale bones in the world also are in temporary storage. Thousands of house planks and plank fragments, posts, beams, rafters, and a number of sleeping benches are suffering a similar fate. What is needed is a separate storage structure with proper facilities, and a full time trained curator and conservator to house and care for this collection indefinitely.

The lesson to be learned is that the excavation of a major site should never be attempted without first solving the problem of where and how the material is to be stored, and to whom shall fall the responsibility and expense for the perpetual care of the perishable materials. Even wet site excavations on a small scale can present problems if special storage facilities and care are required.

Finally, a very real crisis is developing throughout many areas of the world. I refer to the decline in the water table and the dewatering of large areas through increasing demands for water, reclamation projects, and general construction activities. There is no doubt that many wet sites have been lost through these activities. Others have been seriously damaged and many now in existence may not long

FIGURE 7 This cedar replica of a whale fin recovered from the Ozette deposits is inlaid with 700 sea otter molar and canine teeth. A thunderbird holds a double-headed serpent in its talons. (Photo by Harvey S. Rice.)

survive. Where wet sites are known they should be monitored, and in serious cases salvage efforts should be carried out.

The above represent only some of the difficulties, albeit major ones, associated with the study of wet sites. I believe there will be a continuing need for more, perhaps annual, meetings of the type like the International Conference on Wet Site Archaeology. Dr. Barbara Purdy and the University of Florida are to be congratulated for their vision in bringing us together so that the various aspects of wet site archaeology could be discussed.

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RECENT ARCHAEOLOGICAL DISCOVERIES IN LAKE NEUCHÂTEL, SWITZERLAND: FROM THE PALEOLITHIC TO THE MIDDLE AGES

Michel Egloff

AT THE SOUTHERN FOOT of the Jura mountains, Lake Neuchâtel extends from Yverdon (in the Canton of Vaud) to La Tène (in the Canton of Neuchâtel). The water flows in a northerly direction into Lake Bienne and from there into the Aar River, a tributary of the Rhine. The mean altitude of the lake surface today is 429 m, but considerable variations in the water level have occurred over the millennia. This explains why certain prehistoric and protohistoric sites are now submerged. Researchers have known of the existence of Neolithic and Bronze Age villages along the lake shore since 1855. In 1857 the famous site of La Tène, which gave its name to the Iron Age Celtic civilization, was discovered.

The development of archaeological excavation methods was just beginning when, in 1920, Paul Vouga produced a genuine stratigraphic record of the Neolithic site of Auvernier. Beginning in 1962, large-scale, continuous civil engineering projects (such as the second rerouting of the Jura River, highway construction and the creation of campgrounds) brought about numerous fruitful surveys and excavations. Archaeological sites in the region have been damaged by digging, filling-in, and erosion. This last phenomenon is extremely serious, and is a result of an artificial lowering of the water levels in the Jura lakes (Neuchâtel, Bienne and Morat). An additional 3 m of water protected the prehistoric villages before this operation was carried out at the end of the nineteenth century.

On a positive note, both the rerouting of the waters of the Jura (1962–1970) and the excavations along the planned highway routes provided archaeologists with the technical and financial means to enhance their knowledge of the prehistoric and protohistoric habitation of this vast region.

The type of problems which confronted the archaeologists working in this region can be summarized as follows: how to benefit from the construction projects in order to gather the largest body of data concerning the history of the natural and cultural environment of the area. In order to deal with this dilemma, multidisciplinary research projects, which relied in large part on computer science, were created. Several methods such as "site catchment" analysis, mapping entire villages, and the development of technological and artifact typologies contributed to the reconstruction of societies and their way of life.

Let us now consider some techniques and their principal results. Since 1971, several aerial surveys conducted during the winter months have located Late Bronze Age villages (Hallstatt A2–B2). At this time of year, the geometric layout of the villages would appear quite plainly under the water (Fig. 1). Subsequent underwater excavations were guided by features detailed on aerial photographs. During the summer of 1985, an area of 15 km^2 was systematically surveyed by side scan sonar and proton magnetometry, through the generous assistance of the Center for Field Research (Earthwatch) (see the paper by Stickel and Garrison in this volume).

Techniques developed by Ulrich Ruoff during underwater excavations in Lake Zurich were employed in Lake Neuchâtel. These included the use of a perforated tube connected to an electric pump, which allowed evacuation of the particles stirred up by the excavators. The largest site in this lake which has been explored by divers is the Late Bronze Age site of Cortaillod-Est (Fig. 2). During the winters

Figure 1. Aerial view of the village of Cortaillod-Est (Late Bronze Age, 1010 B.C.). The layout of the village is visible 3 m underwater in Lake Neuchâtel. Thousands of oak posts outline a palisade, rows of houses and lanes. (Photo by Béat Arnold.)

Figure 2. Diver over the village of Cortaillod-Est. (Photo by Béat Arnold.)

of 1981–1984, 5200 m^2 were meticulously excavated. A systematic exploration of a zone peripheral to the village, covering 12,800 m^2, was also carried out.

At other sites such as Auvernier and Hauterive-Champréveyres (Fig. 3) an enclosure of pile planks or a semicircular dike composed of earth and rocks reinforced by pilings allowed the sites to be drained before excavation. At the Portalban site in 1968, a system of wellpoints permitted excavation along the lake shore without being flooded by ground water.

With respect to conservation, the most striking progress has been made in the treatment of waterlogged wood, through the use of freeze-drying, sometimes preceded by impregnation with polyethylene glycol. Hundreds of prehistoric baskets (Fig. 4), tools (Figs. 5 and 6), wooden vessels (Fig. 7), and other artifacts (Fig. 8) have been preserved at the Neuchâtel Museum of Archaeology. The conservation of a Roman boat (crafted out of oak in the Celtic tradition, measuring 19.4 m in length, and dated to A.D. 180) was handled in a different manner. An exact

Figure 3. Hauterive-Champréveyres (Late Bronze Age): intact house wall and pottery. (Photo by Eric Gentil.)

reproduction was created of the boat by making a polyurethane cast; the original wood structure was then reimmersed in the sediments at the bottom of the lake.

Great progress has been made in the area of dating by using the tree-ring method. The laboratory of the Neuchâtel Museum of Archaeology, created in 1975 with the aid of the National Swiss Foundation for Scientific Research, has been able to establish, almost to year, the stages of construction of the Neolithic and Bronze Age villages. Because of this, the duration of human occupation in the Bay of Auvernier is known in great detail from 3728 to 850 B.C.; the history of the village of Cortaillod-Est has been reconstructed, house by house, from 1010 to 955 B.C. (Fig. 9). It is not only the absolute dates that interest us, but also the reconstruction

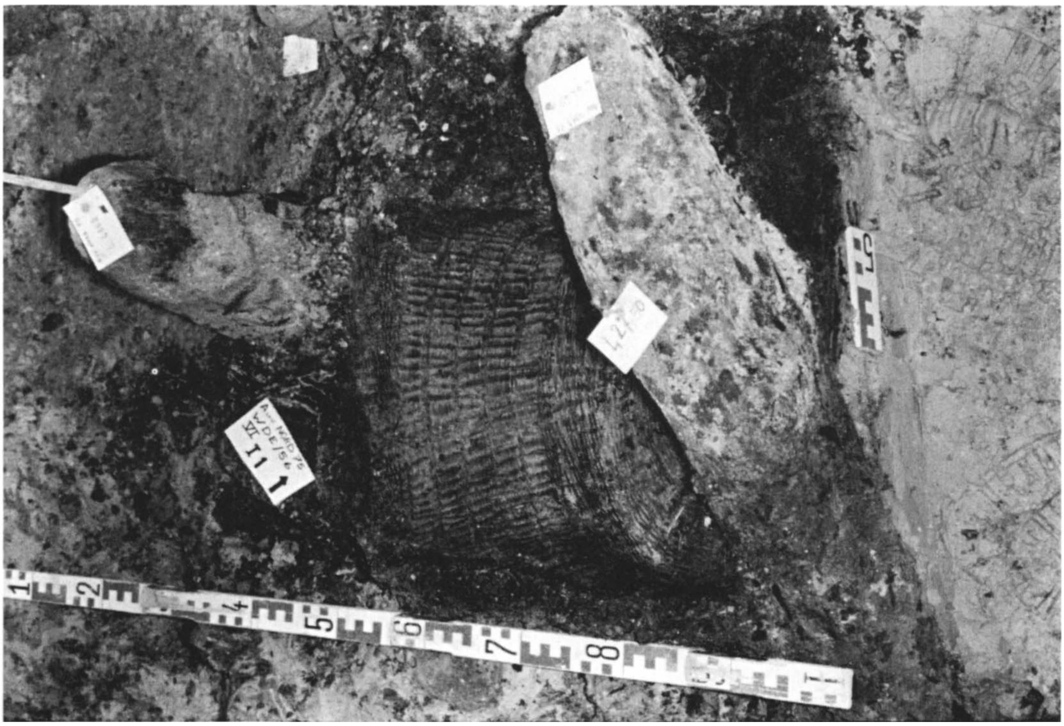

Figure 4. Discovery of a perfectly preserved basket in the village of Auvernier-Nord (ninth century B.C., Late Bronze Age). (Photo by René Charlet.)

of the region's early forest habitat and the drafts of the houses; this is done by establishing the synchronicity of the felling of the oak timbers used in the houses.

The archaeological accomplishments of the last three decades in the Cantons of Vaud and Neuchâtel can be summarized as follows:

1. One shipwreck of the sixteenth century, carrying ceramics, bronze cauldrons, and iron bars (Hauterive-Champréveyres).
2. Three Gallo-Roman vessels in the Celtic tradition (Bevaix and Yverdon).
3. More than 20 villages from the Neolithic to the Late Bronze Age, excavated on the shore or underwater (Thielle, Saint-Blaise, Hauterive-Champréveyres, Auvernier, Cortaillod, Yverdon, Yvonand, Gletterens, and Delley-Portalban);

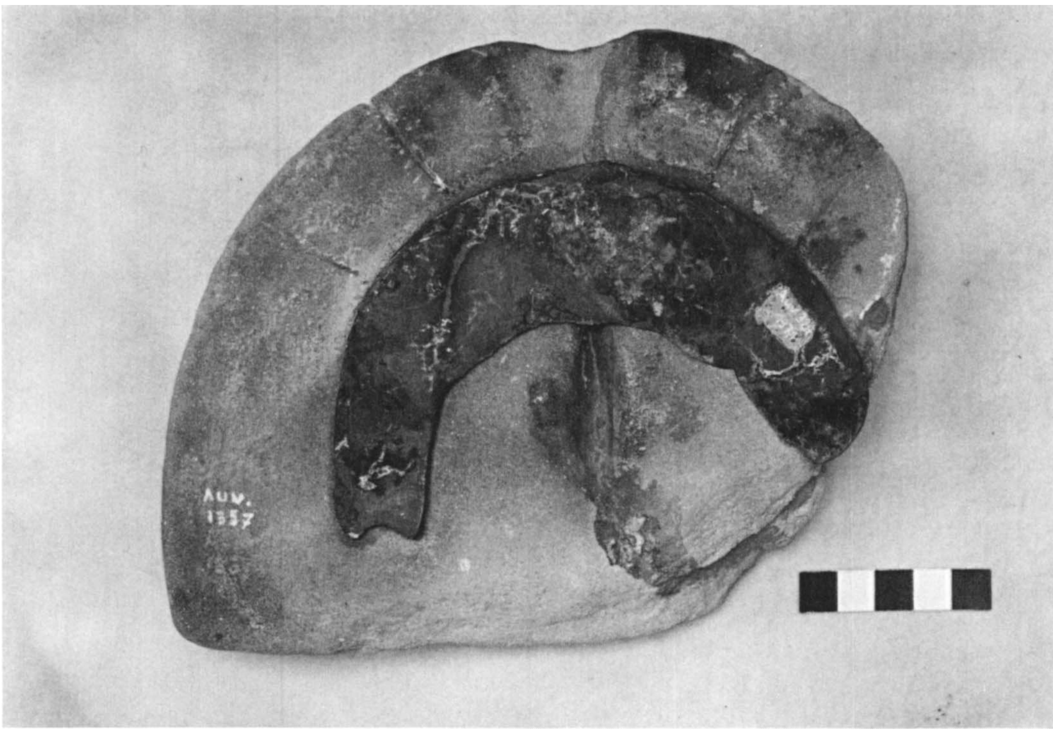

Figure 5. Sickle and the sandstone mold in which it was made in the ninth century B.C., from Auvernier-Nord. (Photo by René Charlet.)

Figure 6. A complete adze out of wood, deer antler and polished stone from Auvernier-Saunerie (third millenium B.C.; Auvernier culture). (Photo by René Charlet.)

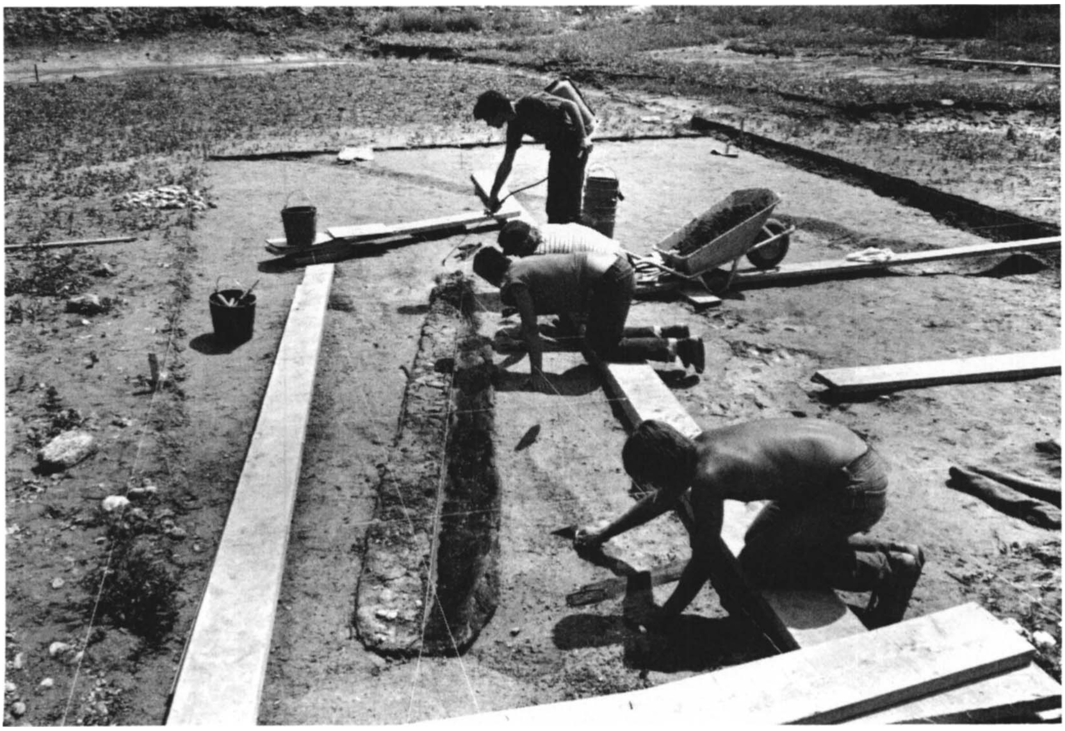

Figure 7. Excavation of a neolithic canoe (fifth millenium B.C.; Hauterive-Champréveyres). (Photo by Eric Gentil.)

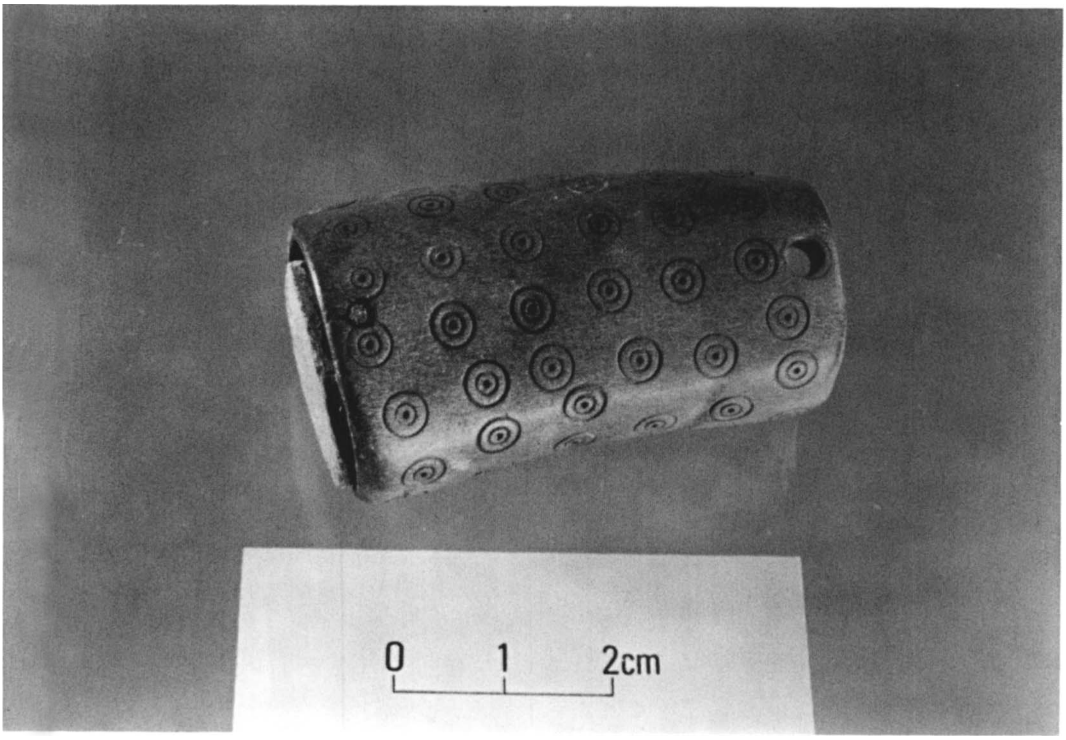

Figure 8. Little box made of deer antler and wood, from Hauterive-Champréveyres. (Photo by Eric Gentil.)

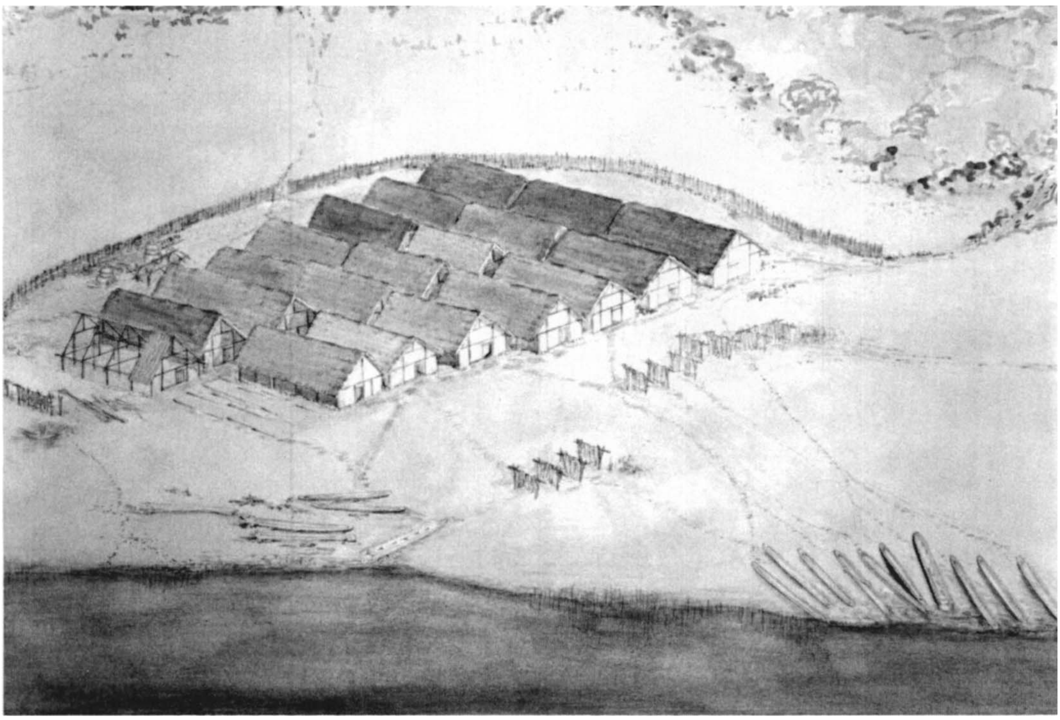

Figure 9. Reconstruction of the village of Cortaillod-Est. (Drawing by Karin Bosserdet.)

this research has taken place in the Cantons of Neuchâtel, Vaud and Fribourg. On Lake Bienne, the Neolithic site of Twann (in the Canton of Bern) was the object of a vast excavation, along the new highway right-of-way.

4. An upper Magdalenian and Azilian site (Late Paleolithic) at Hauterive-Champréveyres (Fig. 10); the fireplaces of horse and reindeer hunters, discovered there in 1983, are remarkably well-preserved.

Many of these finds are on display at the Neuchâtel Museum of Archaeology.

Thanks to this ensemble of archaeological work, forced upon us by unavoidable circumstances and ascribable to technical knowledge borrowed from the fields of anthropology and natural sciences, the history of a region has been remodelled.

FIGURE 10. Floor of the Magdalenian encampment of Hauterive-Champréveyres (eleventh millenium B.C.). (Photo by Eric Gentil.)

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THE PEAT HAG

John M. Coles

A PEAT HAG is an old pit cut in boggy ground and that sums up the state of wetland archaeology in Ireland today—bogged down and derelict.

About 16% of the land in Ireland is peatland of one sort or another. Two major types dominate the landscape, raised bogs, particularly in central Ireland, and blanket bogs in west and north Ireland (Hammond 1981; Fig. 1). Turf from these bogs has been cut by hand since recorded times, providing fuel for heating and cooking in all walks of life. Through this hand-cutting, particularly in the nineteenth century, many hundreds of archaeological finds have been made. Some of these remains survive, and together they form a major part of the holdings of the National Museum of Ireland (Fig. 2). It is estimated that as much as 60% of the Museum's collections are from bogland of one sort or another, and certainly a recent survey of such finds provides an excellent quarry for further research (Halpin 1984). These, however, are only the isolated and portable discoveries. There are a multitude of trackways, platforms and crannogs known to have existed (Lucas 1985; Wood-Martin 1886).

In a survey of peatlands carried out between 1810 and 1814, it was discovered that in all of Ireland there were 1.2 million ha of peat, uniquely rich in flora and fauna. This is because both blanket and raised bog have specialized acidic habitats which attract certain forms of wildlife, while repelling most others. Sphagnum moss, acting like a giant sponge to hold, cushion, and filter water, is only one of the favored plants of the raised bog which creates a totally isolated and irreplaceable ecosystem. So fragile are the strands of life making up the surface of such boglands, that a single footprint impressed into active moss may be identifiable for up to two years. Bursters, where an overloaded bog breaks at an edge and flows inexorably down-slope to engulf all in its path, is a phenomenon well-recorded in nineteenth century Ireland (Kinahan 1897) and, most recently, by a 2-m deep flow in December 1986 which effectively buried a major road in Co. Mayo.

The threats to bogland in Ireland today are not those of passing traffic or water in excess. They are the permanent exploitation by man, animal, and machine, and drainage of water from the bogs. Today, at the most optimistic estimate, only 6% of the original raised bogland remains undamaged. The single factor accounting for

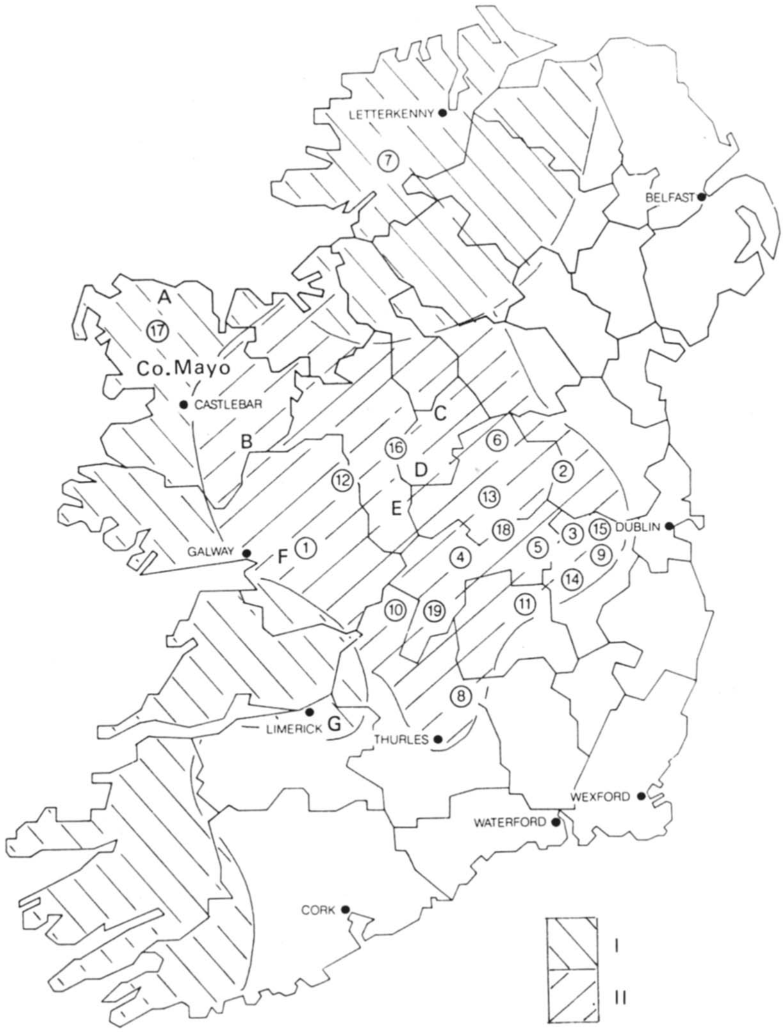

FIGURE 1 Sketch map of Ireland showing (I) blanket bogland and (II) raised bogland regions. Note that raised bog does not cover all of the midland region of Ireland, and that there are outliers of raised bog to the west and north of Belfast. Note that blanket bog is widespread in the west and north, but does not totally cover the region, and that there are outliers of blanket bog north of Belfast, south of Dublin, and west of Waterford. Only the general pattern of the boglands is shown here. Sites noted are: 1–17 Bord na Móna peat processing works. A) Belderg Neolithic landscape. B) Cloonlara. C) Clonbrin. D) Corlea. E) Doogarymore. F) Athenry. G) Lough Gur.

most of this situation was the establishment of a national peat body in 1946, Bord na Móna, with the aim was to produce peat for fuel, to provide employment in otherwise difficult areas of settlement, to assist in a state forestry scheme on peatland, and to help develop drained and cut bogland for agriculture. To achieve these ends, Bord na Móna had to acquire land, to develop it, and to produce peat from it through a set of Development Programs in 1946, 1950, and 1974. Many

FIGURE 2 Four shields of the Bronze Age (ca. 900–600 B.C.) from peat bogs in Ireland.
Upper left—Lough Gur, Co. Limerick. Diameter 69 cm. Sheet bronze.
Upper right—Cloonlara, Co. Mayo. Diameter 48 cm. Alder wood.
Lower left—Athenry, Co. Galway. Diameter 35 cm. Sheet bronze.
Lower right—Clonbrin, Co. Longford. Diameter 50 cm. Bark-tanned leather.
All are in the National Museum of Ireland, except the one from Athenry which is in the British Museum in England.

thousands of people were and are employed in these schemes, and this is an important economic and political factor.

By the end of 1984/85, Bord na Móna had acquired over 80,000 ha of peatland for production and development (Fig. 3), and a further 24,000 ha were surveyed for future development. Twenty-one production centers were established; the peatlands yield, in the year 1984/85, was about 8 million metric tons of peat, including

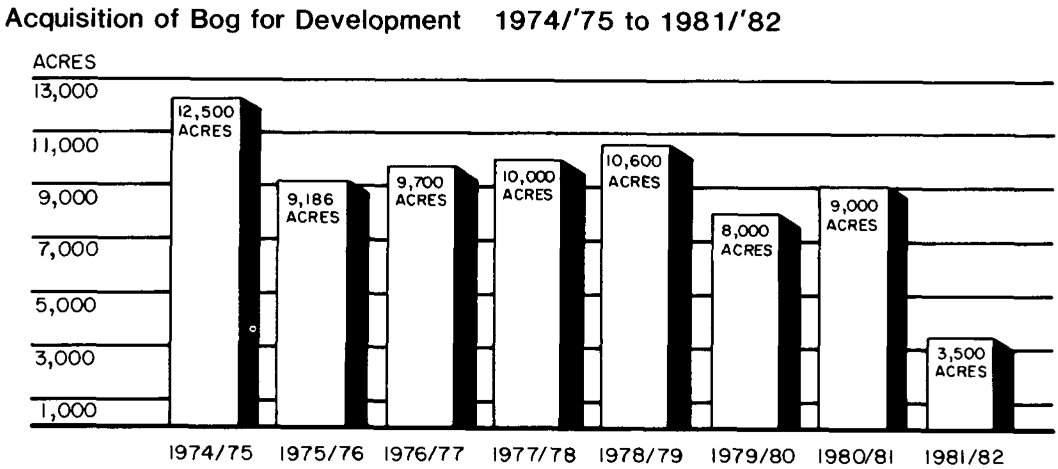

FIGURE 3 Acquisition of bogland in Ireland for development by Bord na Móna 1974–1982. (Bord na Móna 1986.)

546,000 metric tons of machine turf, 6,786,000 tons of milled peat, 417,000 tons of briquettes, and about 1,300,000 m^3 of moss peat. Over 3,500,000 metric tons of peat went to the Electricity Supply Board (Bord na Móna 1986).

At the present time, Bord na Móna is the second largest peat producer in the world—only the USSR achieves more, but from a rather larger area of bogland—and yet, by any reckoning, it would seem that peat is an inefficient energy producer. About one metric ton of peat is said to yield the energy equivalent of about two barrels of oil, or that about 3 metric tons of peat are the energy equivalent of about one metric ton of oil. This means that a staggering amount of peat is required to produce a relatively small amount of energy. In the USSR, for example, a combined total of 47 state electricity generating stations and 32 heat and power plants, all using milled peat, produce less than 1.5% of the nation's energy. In Finland, although the peat-burning stations are programed to use 8–10 million tons of peat a year by 1990, this will still yield only 2% of the energy requirements of that country and will, in the process, completely destroy much of central Finland's raised bogs before the year 2000 (Maltby 1986).

The annual output of oil from even one of the world's major resources would totally submerge all Irish peat in terms of equivalent energy. Of course, the argument is a bit sterile for Ireland if there is no local alternative to peat for energy. But peat supplies only about 20% of the primary electricity in Ireland at present. Unlike electric power from water and some other sources of energy, peat is exhaustible and finite; peat is not only dead plants, it is a dying energy source which is irreplaceable.

The peatland in Bord na Móna's hands at present is worked for its turf in many ways (Lee 1976), but the initial activity is the most dramatic and destructive to the ecosystem. Drainage channels are cut, up to 100 cm deep, then widened and deepened as time goes by, and enormous machines then cut, rotovate, shred, turn, push, blow and pick up the peat in the form of blocks or milled peat. Hand-cutting, still used in many areas of both raised and blanket bogs, can reveal and recover ancient artifacts (Fig. 4), structures, and buried landscapes as the many stone and metal objects in museums, records of bog roads, and field and settlement patterns

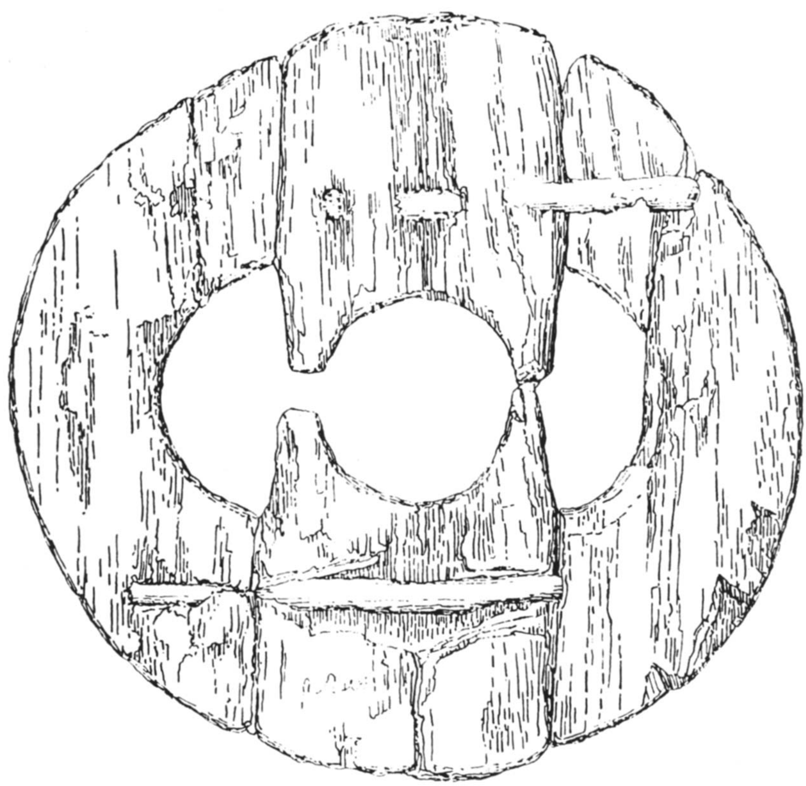

FIGURE 4 Wheel of alder planks with yew dowels from Doogarymore, Co. Roscommon. Dated by radiocarbon to the fifth century B.C. Diameter 1 m. A stray find from the peat.

attest. Machines are not as observant, and although it is acknowledged that Bord na Móna makes an effort to recover and record archaeological finds and to pass them to the National Museum, this is little more than lip-service; it cannot be an adequate response to the threat to Ireland's heritage. It is an archaeological presence that is required.

Up until 1985, Bord na Móna's land holdings, actual or potential, were about 100,000 ha. This represents over 80% of the classic midland raised bogs. Future development by Bord na Móna will be in western Ireland, in the much smaller raised bogs there. These range in size from 20–160 ha, and were thus characteristic areas for ancient exploitation of swamp and marsh; their archaeological components are totally unknown apart from stray finds that point to the wealth of information awaiting discovery. It is estimated that at present rates of development, machine turf production in Ireland will end in 2006, and commercially viable peat production in the country will cease in 2030; this is not so far in the future.

This, however, is not the whole story of Irish wetlands. There are other activities that affect the unique character and quality of Irish bogs, and these include forestry. Records suggest that vast areas of Ireland were wooded up to the sixteenth century, when drainage and destruction began, leaving the treeless expanses of modern day Ireland. Reforestation by the state is a relatively modern event, and in 1982 there were over 160,000 ha of Irish peatland which had been drained, fertilized, planted, fenced and cropped for wood. The effects of these actions on the natural vegetation need no emphasis here.

If not forested, then drained bogland provides enormous areas for cropping, pasture, and rough grazing. The three major exploitive activities then are turf-burning for fuel (greater than 80,000 ha), forestry (greater than 160,000 ha), and agriculture including pasture (greater than 180,000 ha). These figures are only for drained bogs, not for the vast adjacent areas affected by such desiccation. It is obvious that a drained area will draw upon itself the waters from nearby untouched bogland, so that all are affected in varying degrees. One rather ironic example comes to mind. In the Somerset wetland of England, two fields lie side by side; one is a nature reserve for wetland wildlife, the other is farmland. The latter is drained, for European Economic Community agricultural purposes; the peat thus shrinks, while partly drawing water from the nature reserve. When heavy rain descends, the farm field floods as it is now lower than all around it. So the reserve gets drier, and the agricultural field gets wetter—exactly the reverse of what each agency wants! The cleverness of man constantly amazes; his response is to drain the field more severely, thus accelerating the above results.

How much of the original huge bogland of Ireland still survives these activities is difficult to gauge, but at the present time there is partial protection of 1,680 ha of blanket bog and 480 ha of raised and transitional bog. This is not very much, since it has to satisfy the needs of many interested parties, all ecologists of one sort or another. Among these, botanists must figure largely as peatlands hold the best record of past environmental and climatic changes in the pollen and macroscopic plant remains. But specialists interested in insects, in vertebrates, and in recent wetland flora, are also involved. Education about ecological balance, the fragility of ecosystems, and the unique landscape of Ireland is hard to quantify in terms of energy, timber, and food, but it is nonetheless important for the Irish heritage.

In the cultural sense, the archaeological remains from the central bogland are as important as environmental factors. In the absence of an informed and consistent archaeological present, there is no doubt that a large body of evidence about the past 5000 years will perish unrecorded; much has already been lost according to local workers who notice, but cannot investigate, structures in the peat. In 1985 in Corlea Bog, Co. Longford, a wooden roadway was noted (Fig. 5), and since that date another four prehistoric trackways have been discovered (Raftery 1986). These discoveries are a direct result of having an archaeologist present in the area. Corlea Bog is only 120 ha in extent, a mere fraction of the central bogland; there seems little reason to doubt that its ancient structures were an equally small fraction of what once was preserved in all or many of the raised bogs.

The same can be suggested for the blanket bogs of the northern and western regions of the island. Presently being exploited for peat and forestry, these bogs also contain many archaeological structures and isolated finds (Coles 1987; Fig. 6). Here, however, new archaeological opportunities exist, because the formation of blanket peats has buried entire landscapes of the past. In Co. Mayo, for example, the formation of blanket bog over Neolithic settlements, fields, and tombs has protected them from destruction, and, as the bog is gradually cut away by hand, more and more traces become visible for recording, interpretation, and prediction

FIGURE 5 Wooden trackway in Corlea Bog, Co. Longford, discovered and excavated in 1985 in advance of destruction. The timbers are oak, and were felled in 148 B.C. (dendrochronological absolute age). (Photo by Barry Raftery.)

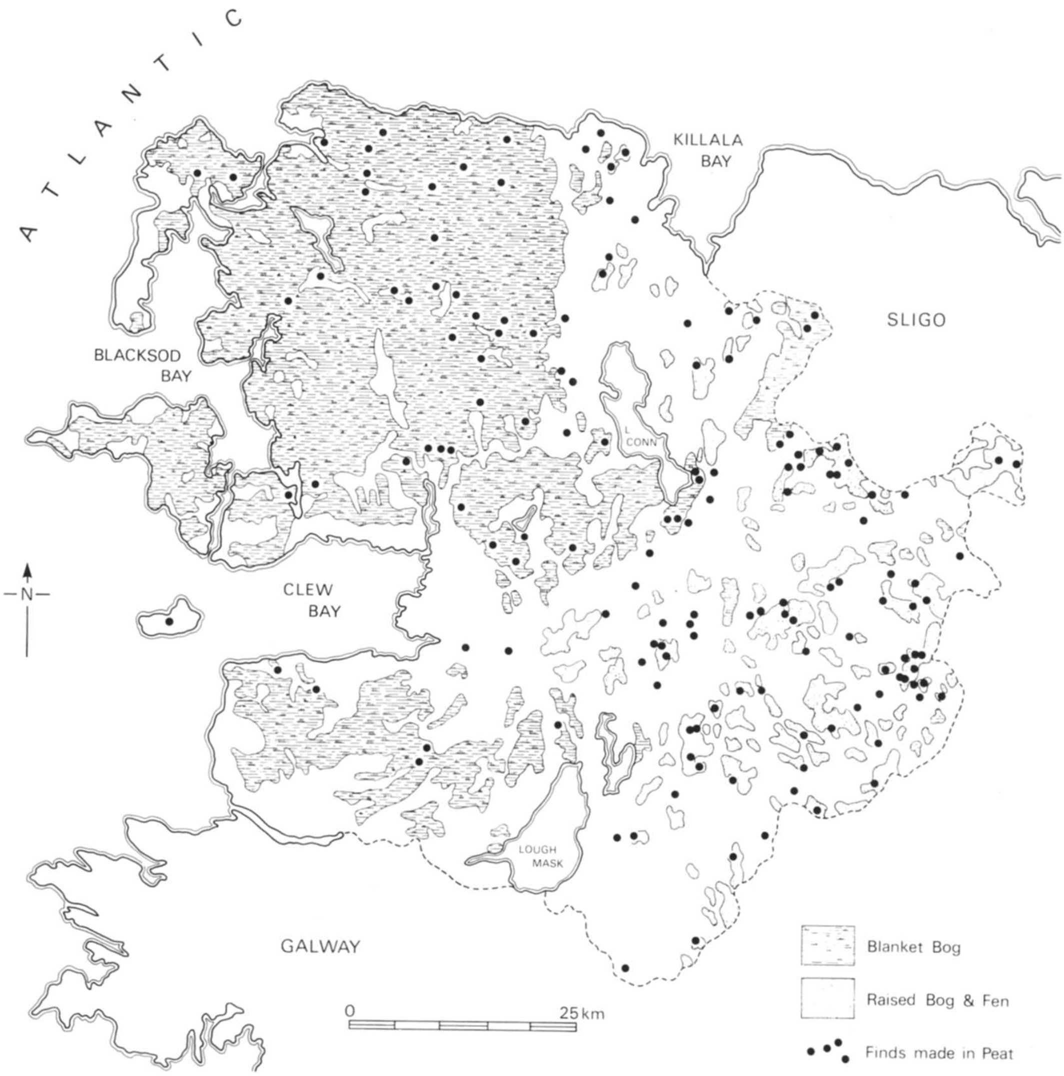

FIGURE 6 Map of Co. Mayo, northwest Ireland, showing the spread of blanket bog in the west, and raised bog and fen peats in the east. The dots represent archaeological discoveries made in the peat, much of which is now cut away. The extensive series of field systems, and other monuments of the Neolithic, Bronze, and Iron ages, are not mapped.

(Caulfield 1982). In this way, whole patterned landscapes can be seen, in some ways comparable to the reave systems and settlements in Dartmoor, England. However, the Mayo range of evidence seems better preserved as it has been sealed by a meter or more of blanket peat. In the Behy-Glenula area of Co. Mayo, for example, a series of settlements of the third millennium B.C. has been identified, with many kilometers of field fences of stone or earth recorded (Fig. 7). These are positioned in parallel rows about 150 m apart, running up and downslope, with the long strips of land thus formed further subdivided by short cross-walls. The 3–5 ha fields contain round enclosures, chambered tombs and other structures, and the whole system looks planned and organized. It is an unusual opportunity to see a functioning prehistoric landscape in complete condition, although only skeletal. All that is needed is a localized pool area where contemporary environmental evidence and cultural material might be preserved for organic analyses.

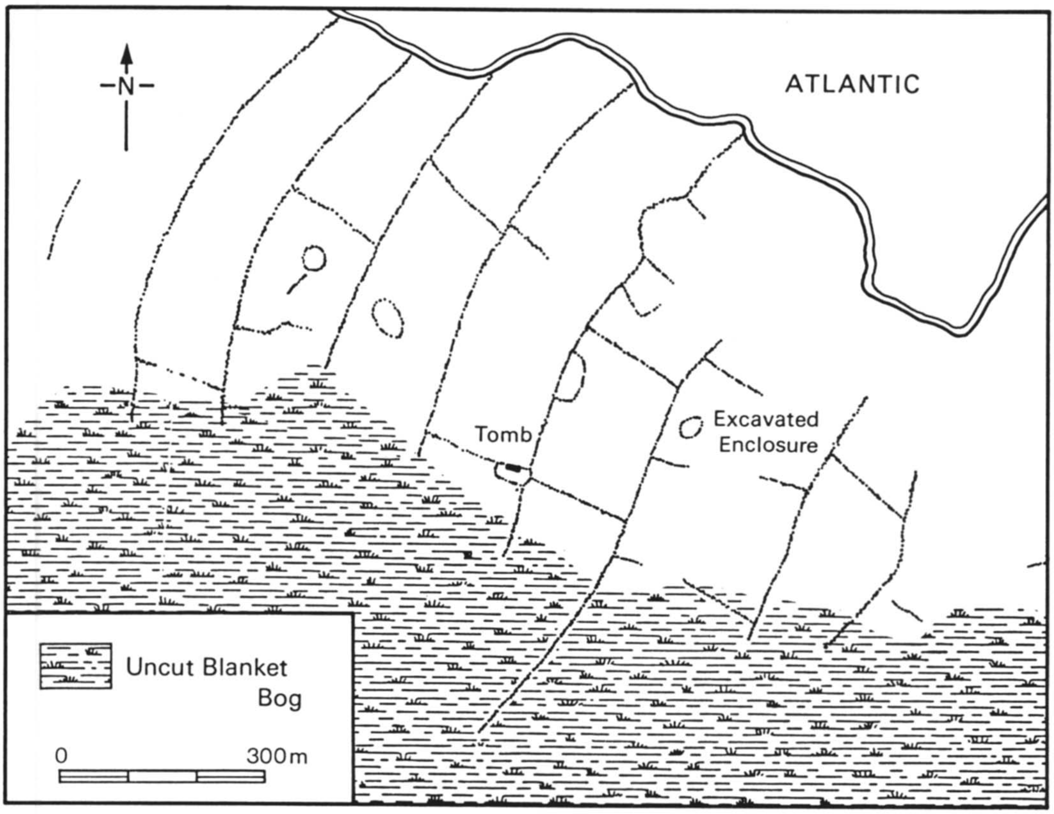

FIGURE 7 Map of part of the north coast of Co. Mayo, showing uncut blanket bog stretching upslope, with exposed stone field boundaries, enclosures, and tombs of the Neolithic (third and early second millennia B.C.) revealed by hand-cutting of peat. The prehistoric system has now been extensively uncovered by further removal of peat upslope and by field probing. (Based on Caulfield 1982.)

There is a lesson to be learned from the current position of wetland archaeology in Ireland. It is that archaeologists have persuaded themselves, but not the public, that what they do is both interesting and important. Many people would probably acknowledge that archaeology is interesting, but far fewer will accept that it is important. A widespread appreciation of the past can only be developed through education over time, and only if archaeologists do not neglect their opportunities to promote the concept of a people's heritage whenever possible. In Ireland, wetland archaeology lacks the immediate interest of the High Crosses, Early Christian art, prehistoric goldwork and tombs, and therefore its importance to a fuller understanding of the past can only be appreciated by a few, and by reference to the contribution of wetland archaeology in other countries.

The future for wetland archaeology in Ireland is certainly not assured, and the wetlands themselves pose the classic confrontation so often arising elsewhere: on one side, industrial and private turf-cutting, reforestation, agricultural reclamation, and rough grazing; on the other, ecology, science, and landscape. For the raised bogs of central Ireland, turf-cutting poses the greatest threat to all the conservation interests; for blanket bogs it is forestry that is the major source of conflict.

One solution that has been proposed to allow for some wetland preservation is logical yet probably unworkable (von Eck et al. 1984). It is suggested that in the short term, vital peatlands should be designated as nature reserves and national parks, and obtain protection as a part of the Irish heritage. In the long term, there should be a national committee of all interests, to make an inventory of peatlands, draw up priority lists based on different criteria, impose planning consent restrictions and inducements, and exercise a commitment to Irish boglands which will never vary in intensity.

In my opinion it is too late for this. Destruction of Irish peatland has been going on for decades, and there has been no national response which has succeeded in deflecting the commercial agencies from their avowed and state-directed aims. For archaeology, there has been no recognition of the unique quality of evidence and opportunity offered by work in the deep and waterlogged bogs.

What is required now seems to me to be one or more multidisciplinary projects, bringing together national natural scientists and archaeologists in collaborative efforts to investigate the wetlands. It surely has to be recognized that wetland sites cannot be saved except in very special positions, where adjacent drainage is controlled through topography or other circumstances; yet these places may well not be those of highest archaeological merit or potential. The research teams have to go straight to the best regions and begin work, using a sampling strategy based initially upon archaeological evidence, however fragmentary, and rapid environmental surveys to identify prime localities. Thereafter, keyhole excavation, more refinement in environmental analyses, dating by dendrochronology and radiocarbon analyses, can lead to major programs of excavation, conservation, and post-excavation studies. The last will cost about ten times as much as the survey and excavation. Is it worth it? We know almost nothing about Irish prehistory apart from the studies of the stone tombs and inorganic artifacts recovered (Herity and Eogan 1977). Unlike many areas in western Europe, we have the chance to know a hundred times as much, through wetland work. Ireland is the *only* country in Europe which has extensive wetlands, but which has *no* archaeological presence to deal specifically with them, and seemingly little interest to establish one. In the year 2000, it will all be gone, drained, or quarried to extinction, and we will be the poorer, in lost (or rather unfound) knowledge and in the lost landscapes which once made Ireland unique.

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THE LOCATION AND ASSESSMENT OF UNDERWATER ARCHAEOLOGICAL SITES

Reynold J. Ruppé

Introduction

MOST PEOPLE consider underwater archaeology to be synonymous with shipwrecks which are then equated with treasure hunting—an identification that inhibits scholarly and scientific research of all wet sites. Wet sites are of several types: drowned terrestrial sites, shipwrecks, sites inundated by dam impoundments, deliberate or accidental incorporation of cultural materials into water saturated deposits, and dry sites that became waterlogged due to a rise in the water table. Wet sites can occur almost anywhere but their locations usually conform to regular archaeological distributional patterns. Even shipwrecks, which might seem to be distributed randomly, have predictable locations due to navigation patterns practiced in different times and places.

Underwater archaeology is a new subject. Shipwrecks have been salvaged for millennia, but recovery of artifacts for archaeological purposes dates only from 1906. The first archaeology conducted on an inundated terrestrial site occurred in 1935–37 when Tyre and Sidon were investigated. In 1854 the Swiss excavated a number of lake dwellings as dry land sites when they were exposed by lowered water levels in the Alpine lakes. Elsewhere in the trans-Alpine region of Europe, drowned lake dwellings have been excavated since the 1960s. The outstanding preservational quality of wet sites was demonstrated when the Swiss recovered organic material in a remarkable state of preservation from the lake dwellings (Heer 1865). More recently, radiocarbon dates that confirm a fifth millennium B.C. date for the Swiss Neolithic have been derived from organic remains excavated underwater (Stickel and Berger 1979). Other early underwater work includes recovery of artifacts from the cenote at Chichen Itza in 1907–09, and Paleoindian skeletons from water filled caves in Florida in the 1960–70s.

Most scholars are not aware that scientifically acceptable archaeology on underwater sites is so recent. While he did not report on underwater archaeological research, Goggin (1960) identified the field and defined several types of underwater sites. A seminal article proposing that the continental shelves of eastern North America should have Paleoindian material on them, appeared in 1966 (Emery and Edwards). Early in 1973, the fourth skeleton from Warm Mineral Springs, Florida was excavated carefully (Cockrell 1978:1–3). In the summer of 1973 the Venice Beach site, 2 m under water, was sampled using standard land techniques (Ruppé 1978, 1980). In 1974, I was invited to Israel to give a series of lectures on drowned terrestrial sites at the major universities. Since that date the Israelis have become the leaders in such archaeological investigations. Also in 1974 I spent many hours debating drowned sites with Dr. Ripley Bullen, who, while he had reported on sites with underwater components, was not seriously concerned with them. As a result of those debates, Bullen retrieved an old manuscript that he had written in 1970 and revised and published it (Bullen 1975).

Most sites presently underwater, excluding shipwrecks, are coastal habitations that were drowned by post-Pleistocene rises in sea level. Sea level changes are linked to climatic changes, can be correlated with advances and retreats of the ice sheets, and are labeled eustatic change. Land levels also have changed, and that results in further apparent changes of sea level. These tectonic changes are labeled isostatic. Geologists now recognize that deflection of the earth's surface results from ice loading and is another cause of sea level changes that occur in glaciated regions. Consequently, the changes of the positions of sea level in relation to land level are complex. The world has experienced a vast number of sea level oscillations during the span of human occupancy and, theoretically at least, a vast number of sites of many time periods must exist in coastal zones and on the continental shelves.

Shipwrecks have occurred for about 8,000 years. They are estimated to number in the hundreds of thousands and are located in many parts of the world (Bascom 1975). A majority of the wrecks probably were destroyed by one means or another but many have survived. Shipwrecks are valuable because they are time capsules that provide inventories of cultural material dating to the same time period, and generally do not contain earlier material. Relatively few shipwrecks contain treasure; consequently the loss of information due to depradations of treasure hunters is tragic and enormously wasteful.

The excavation of shipwrecks often requires some amount of specialized equipment, but the archaeology of drowned terrestrial sites does not differ greatly from work done on dry sites. Scuba gear is required because both classes of sites are underwater, and the normal constraints of working under pressure for limited amounts of time are also present. Surprisingly, even work in a meter of water is accomplished more easily with scuba gear than with mask and snorkel. The greatest difficulty encountered is the much greater expense of doing archaeology underwater. Land sites that have been waterlogged for long periods are excavated in a similar manner as dryland sites. In most cases however, special techniques are needed to drain water from the site and, conversely, to keep material moist that has been exposed to the air. Sites in the peat bogs of Europe have been excavated under standard procedures for years. The wet sites reported at this conference (in Europe, Polynesia, and North and South America) are other examples, the geographic range of which is impressive. The major attribute that differentiates wet sites from the more mundane dry sites is the remarkable preservation of organic remains that often occurs. Some wet sites, however, have lost much of their organic material due to alternating wet and dry conditions and/or soil chemistry.

Drowned Terrestrial Sites

The post-Pleistocene rise of sea level and subsequent inundation of terrestrial sites on coastal plains is important to our understanding of the global distributions of early peoples. When sea level rose coastal plains became continental shelves, and the former coastal inhabitants were displaced in many parts of the world. Only inundated archaeological sites remain as evidence that people were once able to live there. These concepts have not been a matter of great concern up to the present time primarily because the sites are invisible, and because archaeological techniques currently in use are unable to find the evidence of these drowned sites. The recent development of remote sensing instruments for oil and gas exploration offers the possibility of retrieving evidence of archaeological sites on the continental shelves. For several years I have worked on the development of a new methodology to locate drowned terrestrial sites by means of predictive models developed from archaeology, geomorphology, taphonomy, and cultural ecology.

There are three major factors to be considered in a study of inundated terrestrial sites: sea level change, coastal geomorphology, and coastal settlement patterns. The first factor is sea level change and its effect on archaeological sites. The post-Pleistocene climatic shift melted the ice sheets and caused a cumulative rise of sea level of up to 130 m after 17 000 B.P. The encroachment of ocean waters on the once exposed coastal plains inundated Pleistocene coastal geomorphological features and the associated evidence of human occupation. Until that material evidence can be retrieved, an entire segment of the culture and ecology of early hunters and gatherers cannot be studied. The obvious difficulty is the fact that the archaeological evidence has been hidden from view and access is difficult.

Marine geologists agree that a cumulative rise of sea level has occurred over the past 17,000 years. Evidence from many parts of the globe insures that the phenomenon is worldwide. But marine geologists differ in their opinions concerning the effects of climatic change on sea level. Some geologists picture the post-Pleistocene sea level rise as a smooth curve (Blackwelder et al. 1979). An opposing view is held by Fairbridge (1961, 1974) and others who believe that sea level changed in an oscillating manner, which is best illustrated by an irregular curve. According to his theory, sea level rose irregularly and stood higher than the present level several times in the recent past.

This issue is important to archaeologists because many of the drowned terrestrial sites investigated so far which have been radiocarbon dated, would have had to be constructed underwater according to the smooth curve hypothesis. Therefore, some archaeological work indicates that the Fairbridge curve provides a better fit of radiocarbon dates to the age of diagnostic artifacts extracted from coastal sites (Holmes and Trickey 1974; Hurt 1974; Lazarus 1965; Ruppé 1980; Taira 1980).

The second factor that must be considered is the formation and re-formation of coastal geomorphological features in response to changes in sea level. Stillstands, periods when sea level was static, are required for the formation of all coastal features such as estuaries, lagoons, barrier islands, and sand dunes. When sea level rises, those features are smoothed out to some degree, and form the basis for underwater contours that are identified in bathymetric surveys. As a result of the inundation process, archaeological evidence associated with these features becomes an integral part of the drowned coastal geomorphology that is hidden from view. Inundated coastal deposits and associated archaeological materials, therefore, can be located only by surveying the underwater contours of continental shelves by acoustical means.

The third factor is the settlement patterns of prehistoric coastal populations that, characteristically, are associated with estuaries, lagoons, and river mouths. The long food chains found in estuaries provided rich resource bases which were exploited by prehistoric human populations. An estuary is a partially enclosed body of water characterized by the mixture of saline tidal water and fresh river water. Estuaries contain an abundant biota on land, in the boundary marshes, and beneath the water. Ethnographic settlement patterns and the distribution of recent prehistoric archaeological sites on coastal water bodies provide the basis for an hypothesis that early humans populated coastal zones in considerable numbers.

The association of archaeological sites and coastal contexts on or near estuaries and rivermouths is documented abundantly. Reports from such widely separated locations as Australia (Bailey 1975; Coutts and Higham 1971), Southeast Asia (Gorman 1971), the Middle East (Flannery 1969), Africa as early as the Middle Paleolithic (Volman 1978; Parkington 1981), Italy (Whitehouse 1971), South America (Cohen 1977), Mesoamerica (Coe and Flannery 1968; Hubbs and Roden 1964; Voorhies 1978), northeastern North America (Braun 1974; Salwen 1965), and the San Francisco Bay area (Nelson 1909) attest to the association of archaeological sites in coastal contexts. A recent compilation of sites drowned by rising sea level includes settlements in Israel, Cyprus, southern France, Sweden, Brittany, Denmark, Florida, California, and South Australia (Flemming 1983). Also noteworthy are the concentrations of modern populations on coastlines associated with river mouths, estuaries and lagoons around the world.

Introduction To The Problem

The post-Pleistocene rise of sea level and subsequent inundation of terrestrial sites on coastal plains has important implications for a more accurate understanding of the global distributions of early peoples. I believe that coastal zones provided an important subsistence base for early human populations. The implications of the human displacement that occurred as coastal plains were transformed into continental shelves are extremely important. The formulation of a methodology to locate inundated terrestrial archaeological sites on the continental shelves is a prime need, and I am involved in that endeavor at the present time. Once operationalized, the methodology (with the necessary modifications) can be used on coastlines in many parts of the world.

Few figures are available to judge the numbers or densities of terrestrial sites on or off present-day coastlines. Nelson (1909) recorded 425 shell middens in the San Francisco Bay region in an area encompassing approximately 483 km of coastline. Most of those middens were located within 15 m of the bay waters and 10 of the shell deposits extended below sea level. It is difficult to estimate how many other sites may exist completely underwater, or how many may have been eroded away due to wave action, but there must have been an astounding number of them.

A casual site survey, conducted over the course of several years, has produced a list of more than 30 drowned archaeological sites along the west coast of Florida for a distance of about 210 km from Englewood in Sarasota County north to the Withlacoochee River on the south border of Levy County. The sites range from ca. 4000 B.P. to A.D. 400. Some underwater sites are located a considerable distance offshore. With the exception of four Archaic sites, all of the sites that were located are shell middens. Some of these sites have also been excavated. Additionally, a survey of the city of Sarasota located 56 coastal sites, seven of which had underwater components (Almy n.d.). Flemming (1983) reports 61 Bronze Age, Neolithic and Paleolithic sites, many of which are submerged, along 225 km off the Israeli coast. It is difficult to judge whether or not such a relatively small number of cases is representative of coastal occupation by human populations on a worldwide basis. However, it does indicate that at least certain portions of the world's coasts exhibit relatively dense distributions of archaeological sites. The evidence strongly suggests that other estuaries, lagoons and rivermouths should be tested for evidence of drowned terrestrial sites.

Florida as a Research Area

All continental shelves and adjacent coasts are not equally promising locations for well-preserved archaeological sites. The choice of Florida as the research area to demonstrate the above hypothesis is based on several considerations. Geologists believe that Florida is one of the more stable regions on earth (Brooks 1973: 11E–17; Missimer 1976:14). That stability insures that the independent variable of earth movements can be ignored safely, at least for the past 10,000 years or so. Conversely, the rise of sea level on unprotected coasts in many areas of the world must have brought about the destruction or alteration of many coastal features by wave and current action. On the other hand, coastal marshes, barrier islands and sand bars do provide some protection for shell middens and sediments bearing archaeological remains. The west coast of Florida possesses these protective features in profusion, and is well suited to the type of research in which I am engaged.

Another important variable influencing the survival of an archaeological site is the intensity of wave action along the coast. Coastlines can be classified as high, moderate, or low energy (Tanner 1960:259). A coast that possesses large waves, long fetch and strong winds is a high energy coast and will most likely have drowned sites that are either severely damaged or destroyed. Fetch refers to the distance a wind blows across the sea surface without a change of direction; the longer the fetch, the greater potential for large waves. A coast with a narrow, steeply sloping coastal plain or a fiord configuration will not offer much protection from the wave action of rising seas. In contrast, the west coast of Florida, with its broad, gently sloping shelf and coastal plain, a low energy coastline, should contain sites that are relatively intact. However, tropical storms are a big problem in Florida, and in the summer of 1985 (the "year of the hurricanes"), two storms, Bob and Elena, struck the coast at Sarasota County. The wind generated waves and storm currents that altered the superficial bottom topography and removed some of the stratigraphy of the Venice Beach site. This experience forced a reappraisal of the concept of a low energy coast, at least in regard to archaeological sites.

Many archaeological sites are located on the west coast of Florida and many of them have basal levels that are below sea level. The 56 sites on Sarasota Bay provide a good example of the site density that can occur in a favorable environment. Bullen (1975) has documented several middens that possess drowned components. In addition, Bullen partially excavated two sites that had basal levels considerably below sea level, the Englewood Mound (Bullen 1971) and the Palmer site (Bullen and Bullen 1976). Several sites are represented by dredge spoil from the bottom of various bodies of water at Bayport (Bullen and Bullen 1953) and Tampa Bay (Goodyear and Warren 1972; Goodyear et al. 1980). Goggin is reported to have stated that in the Everglades, water halted work before he reached the bottom levels of any site (Bullen 1975). Griffin (1974) believes that the early levels of the Onion Key site in the Everglades are also beneath sea level.

The Venice Beach site (8–SO–26), which I excavated in 1973–74, provides solid evidence of an inundated shell midden on the west coast of Florida (Ruppé 1980). The heterogeneity of shellfish species, some of which have greatly different environmental requirements, demonstrates that the deposit could only have been formed by human activity. In addition, the site possesses undisturbed stratigraphy. The top of the upper undisturbed layer was 2 m below mean sea level. The layer consisted of large quantities of shell, potsherds, burned and unburned bone of fish and land animals, and charcoal *in situ* in a matrix of clayey sand. The charcoal yielded a radiocarbon date of 1981 ±85 B.P. (University of Miami).

The research I have been conducting on the west coast of Florida is based on predictions of settlement patterns derived from ethnographic analogy and late prehistoric site locations. The distribution of human populations, as reported by Fontenada for the ethnographic present in southwestern Florida, indicates that rivermouths, estuaries, and lagoons were favored locations of the Calusa Indians (True 1945).

Judging by the available ethnographic evidence, the Calusa on the west coast and the Indians on the east coast of Florida possessed similar settlement patterns and coastal adaptations. The villages were small, usually with 30–40 inhabitants, scattered along the coastal strips, on estuaries and lagoons, near the mouths of rivers and creeks, and, only rarely, a few kilometers up the streams (Andrews 1943; Andrews and Andrews 1981; Goggin and Sturtevant 1964; True 1945). Early travelers on the east coast of Florida also reported an indigenous settlement pattern similar to the Calusa (Andrews 1943; Andrews and Andrews 1981).

Subsistence patterns were remarkably alike due to a similar biota over the whole of south Florida. All sources speak to the great reliance of the Indians on seafoods of various kinds. Shellfish, fish, alligators, turtles, and sea mammals on occasion are reported both ethnographically and archaeologically. The same is true for land animals including dog, deer, raccoon, opossum, bear, and puma. Several varieties of birds are also reported. A wide variety of plants were utilized as well, including acorns, nuts, fruits, berries and a starchy root called Zamia or coonti. Morton (1977) lists more than 125 species, mostly native but some naturalized in south Florida and on the Florida Keys, that offer food, drink, salt, tobacco, and soap substitutes. Of those, 20 are listed as coastal strand plants and 15 occur along the inland waterways and swamps. Maize horticulture was not practiced in South Florida until historic times. The Venice Beach site also produced large numbers of bones of grouper (*Epinephelus* sp), which are reef and ledge fish; that evidence suggests the use of canoes and hook and line fishing techniques (Ruppé 1980)

The subsistence quest of the inhabitants of the Venice Beach site was one of hunting and gathering the abundant food resources of the coastal area. Some seasonality may have been practiced. The Venice Beach site produced thousands of oyster shells and out of 4,000 examined, we found that not a single oyster had been harvested in the winter. According to LeMoyne (Perkins 1875), the Timucua on the northeastern coast of Florida spent the winter months hunting in the interior in small family groups. It is unfortunate that other sources do not discuss the question of seasonality.

In summary, the historic and prehistoric inhabitants of the southwest coast of Florida enjoyed an abundant subsistence base provided by the rich marine, estuarine, and marsh environments. Techniques of food acquisition were fully adequate to exploit the abundant resources for thousands of years, until disruption of the pattern occurred when the Europeans arrived. The subsistence base was impressive and was unquestionably one of the prime reasons for the density of archaeological sites. This biotic wealth certainly can be duplicated at a large number of coastal locations elsewhere in the world, thus it is reasonable to expect that dense concentrations of archaeological sites should be found in those locations.

The Need for Instrumentation

The probable existence of large numbers of archaeological sites on inundated coasts remains unproven because a significant amount of evidence needed to reconstruct prehistoric settlement patterns and adaptations cannot be collected by conventional underwater archaeological methods. We have identified the characteristic underwater geomorphology with which drowned sites should be associated, and those features are unique and identifiable. The methodology, in order to be made operational in a cost effective manner, requires the formulation of a predictive statement about the association of inundated sites with certain kinds of coastal geomorphological features. Such a statement will minimize the search time and area to be surveyed, while the probability of locating drowned sites will be maximized.

On the basis of the above discussion, it is predicted that sites will be located in association with estuary or lagoon margins on the underwater contours formed by past stillstands. Formerly we had to use scuba divers positioned along swim lines to search the floors of continental shelves for geomorphological features and associated archaeological material. The search proved slow, inefficient, and ultimately costly because it was not possible to examine a sufficiently large portion of a known estuarine feature. On the other hand, we were able, in a few days' time, to survey the ledges of a river which divers could identify and confirm through the use of a fathometer. However, the fathometer only allows recognition of gross features while the minutia of estuarine morphology cannot be detected. It is evident that sophisticated remote sensing instruments are needed.

The remote sensing instruments used in marine surveys are the magnetometer, side scan sonar, and the sub-bottom profiler. Magnetometers are useful to locate shipwrecks, historic sites, and other sites where metals occur. It is possible that walls, pits, and fireplaces can be detected through the use of a magnetometer but the probability is small, given the low level of remnant magnetism in those features. The inability of sea-borne magnetometers to detect low levels of magnetism seems to render them useless in locating drowned terrestrial sites that would either be too early in age to contain metal artifacts or for some reason do not possess them.

Geophysicists have demonstrated that side scan sonars and sub-bottom profilers can detect the geomorphological deposits characteristic of estuaries, lagoons, barrier islands, and river mouths (Nelson and Bray 1970; Rigby and Hamblin 1972; Stuart and Caughy 1977; and Van Overveem 1978, among others). The side scan sonar monitors a wide area of the bottom and produces an image of surface relief. If the bottom is a featureless plain the side scan cannot produce a significant image. However, it does allow rapid and accurate mapping of the contours of drowned river systems and other geomorphological phenomena much faster than a fathometer. The side scan sonar cannot penetrate sediments that often mask the geomorphological features we seek. Therefore, a sub-bottom profiler must be used in conjunction with side scan sonar.

An impressive demonstration of the power of remote sensing is the research by Gifford in Koiladha Bay off the beach in front of Franchthi Cave in Greece (Gifford 1982). A Neolithic site downslope from the cave had been hypothesized to continue out into the bay. A sub-bottom profiler indicated the presence of a river channel and Holocene sediments. Gifford cored the bay material and recovered an exciting association of archaeological material from a depth of 5.5 m below the present bay bottom. The core contained 30 potsherds, building plaster, oxidized copper fragments, carbonized wheat, charred fish vertebrae, and a small burin. The potsherds were markedly angular, unlike those from the beach, which suggested that the core material "had been subjected to very little or no weathering and, therefore, was probably in situ" (Gifford 1982).

The sub-bottom profiler is an instrument that generates an accoustical pulse downward that is reflected back from bottom and sub-bottom strata and sediments (reflective surfaces). Echoes from the various strata are received and printed on a strip chart to form a profile of the sub-bottom stratigraphy. A major difficulty with state of the art profilers is their normal inability to produce understandable signals in less than about six meters of water. Because the proposed methodology requires that known sites in shallow water be tested with remote sensing instruments to determine the nature of the signals derived from archaeological sites, a more sensitive profiler is required. Once these signals are known it will be possible to recognize them when the sub-bottom sensor passes over a site and the same signals are detected. State of the art profilers, therefore, cannot meet the research requirements.

The remote sensing instruments produce a pattern of signal images drawn on strip charts. The signals produced by the sub-bottom profiler and side scan sonar can be entered in a three-channel recorder which draws both images on the same strip chart for ease in reading and comparison. Identification of the sources of the anomalous signals depicted on the strip charts must be accomplished by *in situ* examination of the bottom deposit (ground truth testing) as demonstrated by Gifford's work at Koiladha Bay. Ground truthing refers to the systematic investigation of specific entities that have been detected by the instruments. It is crucial that the sources of the anomalies be examined in order to create a catalogue of characteristic "signatures" that will allow an analyst to identify the signal sources. Anomalous signals from any site will be difficult to interpret unless known sites of various types have been tested systematically.

Once a characteristic set of signals has been produced through the systematic survey of known sites, they may be used to identify potential sites in deeper water. When promising geomorphological features are encountered and anomalous signals like those from the known sites are received, divers can investigate the loci, and, if necessary, take a series of cores to test the sub-bottom deposits. At the Venice Beach site and several other drowned sites along the coast of Sarasota County, it was possible to distinguish cultural from noncultural deposits by the use of core analysis (Ruppé 1978).

Conclusions

The significance of this research extends far beyond the west coast of Florida. Coasts in the vicinity of estuaries and rivermouths almost certainly have been used by human groups for a very long time, but now most of the evidence is underwater. Both prehistoric and historic sites are located off present coasts in Israel (Link 1962; Raban 1981), Scotland (Morrison 1969), Greece (Gifford 1982; Jameson 1974), the Persian Gulf (Larsen n.d.), the northern Gulf of Mexico (Gagliano 1977), and Egypt (Labeyrie 1979). Documented changes in sea level off the coast of Brazil (Delibras and Laborel 1971), in Panama Bay (Vinton 1962), off the coast of the northeastern United States (Emery and Edwards 1966; Fairbridge 1977), between Java and Asia (von Koenigswald 1954), and in the Aegean Sea (Kraft et al. 1977) attest to the possibility of inundated coastal sites in those locations as well.

The instrumentation and methodology here described should be applicable to any continental shelf possessing the geomorphological features of former coastlines. Excavation techniques using staked grids, leveling lines, and excavation in 10 cm levels can be used with little difficulty on submerged sites (Ruppé 1980). Similarly, once the methodology for the location of sites with acoustic instruments and ground truth testing has been refined, it will have worldwide applications.

It is important to note that the methodology must be adapted to the local geomorphology in each application. Archaeologists who plan to use acoustic instruments to locate inundated terrestrial sites must be familiar with both the coastal geomorphology and archaeology in their project areas. Catalogues of site signatures must be developed for the types of inundated sites which occur in any given coastal locale. Decisions concerning the choice of instruments to be used must be based on local geomorphology. The data that will be used to formulate the settlement patterns must always be derived locally, but the basic methodology will remain the same.

This methodology is not limited to inundated sites off coastlines. Submerged sites at the bottom of artificial lakes and reservoirs also can be located using the side scan sonar and sub-bottom profiler. The ability to retrieve substantive information through the use of remote sensing instruments in surveys of sites that are beyond the reach of conventional archaeological methods will be a valuable contribution to the field of cultural resource management. In cases where contract archaeology, due to time constraints, cannot complete preconstruction surveys or testing, the proposed methodology will allow recovery of some information despite in-undation of the area by man-made reservoirs and lakes.

As mentioned earlier, marine geologists hold a variety of opinions concerning the amount and dates of sea level changes. Geological methods to date sea level change lack accuracy because the dated material, shells and peat, can be transported easily by water action; consequently, the evidence is subject to a wide range of interpretation. Archaeological dating techniques for early time periods, while not precise, have demonstrated consistency of radiocarbon dated archaeological material between similar sites. Shell middens and other types of archaeological sites are datable features whose integrity and association with coastal geomorphological features can be firmly established. Archaeological sites are complex entities that cannot be transported intact, unlike the natural shell deposits and lumps of peat which are used by geologists to date stillstands (Blackwelder et al. 1979; Macintyre et al. 1978). Submerged archaeological sites, therefore, offer a great potential to date the geomorphological features with which they are associated, and that should help clarify some of the controversy concerning sea level change.

The Venice Beach site provides solid evidence of an inundated shell midden off the west coast of Florida (Ruppé 1980). Analysis of the shells from the excavation indicated that of the 35 species represented, oysters and clams comprised between 65% and 87% in each stratum of the midden, but that the frequencies of the species varied by levels (Ruppé 1978). Each species has different environmental requirements, and they are not associated in natural shell deposits. Scallops (*Pecten* sp.) occurred consistently throughout the midden and, since it is a free-swimming form, had to be brought to the site by human intervention. The frequencies and varieties of shell led to the conclusion that an *in situ* shell midden cannot be confused with a natural shell deposit. Drowned sites directly associated with coastal geomorphological features, therefore, can provide more reliable dates for these features than natural shell deposits and peat, which are normally subject to transport by currents and wave action.

Widespread population movements in the period ca. 17,000 to 10,000 B.P. cannot be documented firmly. Given our present knowledge we can, however, postulate such movements because human populations existed in such geographically diverse places as Australia, South Africa, and China. When sea level was about 85 m lower than at present, the resulting land masses were enormous. Few physical barriers existed to impede movement of early populations. Sea level stands were never low enough to provide dryland passages across Oceania or the Caribbean Sea but the continental shelves were exposed long and often enough to allow early human groups to travel relatively short distances over water. Passage by simple watercraft was not difficult and we do not have to invoke long sea journeys in large vessels to explain the population of the various island chains of the world.

Another line of evidence suggesting that human migrations occurred as a consequence of lowered sea levels is the presence of man in North America 13,000 years ago. Prior to 17 000 B.P., the passage across the Bering Strait would have been rendered difficult by the extensive ice sheets in Asia and North America. Therefore, the period between 17 000 and 13 000 B.P is a logical time to postulate population movements. This scenario in no way invalidates the possibility that earlier population movements into North America occurred at times when sea levels were low enough to allow passage via the Bering Strait.

The rise of sea level in the Holocene and the subsequent drowning of terrestrial sites has important implications for a more complete understanding of the settlement patterns and population distributions of early peoples in many places in the world. The direct results of sea level rise on prehistoric populations were profound alterations of the environments and settlement areas on coastal plains and sea coasts everywhere. Former inhabitants of coastal plains would have been displaced as sea level rose and the former coastal plains would have been transformed into continental shelves.

Until archaeologists can employ techniques to locate drowned coastal sites, we will be unable to understand the migrations and subsistence patterns of early prehistoric people. In addition, it is probable that present estimates of the size of early human populations in the past are too low. The large number of prehistoric archaeological sites along the coasts of most continents, both at sea level and below, provides evidence that many sites were inundated as sea level rose and thus have not entered into the calculations of population estimates. These problems are not only global in scope, but pertain to a significant portion of human cultural evolution.

The positive values of wet sites are impressive. The remarkable preservation of organic material never ceases to amaze us. Clues about climate, subsistence, food preparation and preservation, species of plants and animals utilized, and techniques of construction are only a fraction of the information potentially available to us. Intact human brains from wet sites in Florida are a treasure trove for physical anthropologists and neurologists. The side scan sonar image of the intact rigging of the American armed schooners Hamilton and Scourge, that were sunk in Lake Ontario during the War of 1812, is another example of the remarkable preservation to be found in wet sites. The other papers in this volume also provide us with an amazing knowledge that only wet sites can divulge.

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NEW APPLICATIONS OF REMOTE SENSING: GEOPHYSICAL PROSPECTION FOR UNDERWATER ARCHAEOLOGICAL SITES IN SWITZERLAND

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and
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Background

LAC DE NEUCHÂTEL, located beside the Jura mountains of western Switzerland, is one of the largest and most picturesque of all of the Alpine lakes (Fig. 1). In addition to its natural scenic beauty, Lac de Neuchâtel is internationally and historically famous for the Swiss Lake Villages discovered in the 1850s. It was once thought that only Neolithic and Bronze Age sites were predominant in this area (Keller 1878), but over the past 20 years it has been confirmed that a wide range of cultures are submerged in the Swiss lakes dating from Upper Paleolithic, Mesolithic, Neolithic, Bronze, Iron, Roman, and Medieval periods. Many questions regarding Swiss absolute chronology (see Stickel and Berger 1979), local adaptions, and settlement patterns relative to these sites remain unanswered (Arnold 1980a, 1983, 1984; Borello 1984; Egloff 1984; Stickel 1974). This is especially true in the Neuchâtel area.

Investigators of Swiss archaeology are currently posing questions concerning the topic of cultural identity, cultural periodization, and processes underlying culture change in the Alpine foreland (Stickel 1974; Egloff 1984). The Swiss have been diligent in identifying cultures. Because of this, a wide range of prehistoric and historic cultures have been identified in Switzerland. For instance, the earliest Swiss manifestation of *Homo sapiens*, neanderthalensis, was found in the area of Canton Neuchâtel (Egloff 1980a), and all principal cultures of the stone age (Egloff 1980a, 1984). The most recently discovered of these sites is Hauterive-Champréveyres (NE), the first underwater upper Paleolithic site. These cultures are unusually rich in material culture, settlement types, perishable goods, and economic floral and faunal remains, particularly those sites now submerged in the waters of Lac de Neuchâtel.

Neuchâtel is also home to remains of the European Bronze Age (Rychner 1980), as well as the type site of the late Iron Age—La Tène (Egloff 1980b). This famous site remains a provocative enigma as to its exact position in the elaborate Celtic culture. Successive historic cultures—Roman, Germanic, and their derivatives—have left material traces across the land and seascape of Neuchâtel (Arnold 1980a; Egloff 1980c, 1984). In addition, the discovery of ancient vessels (Arnold

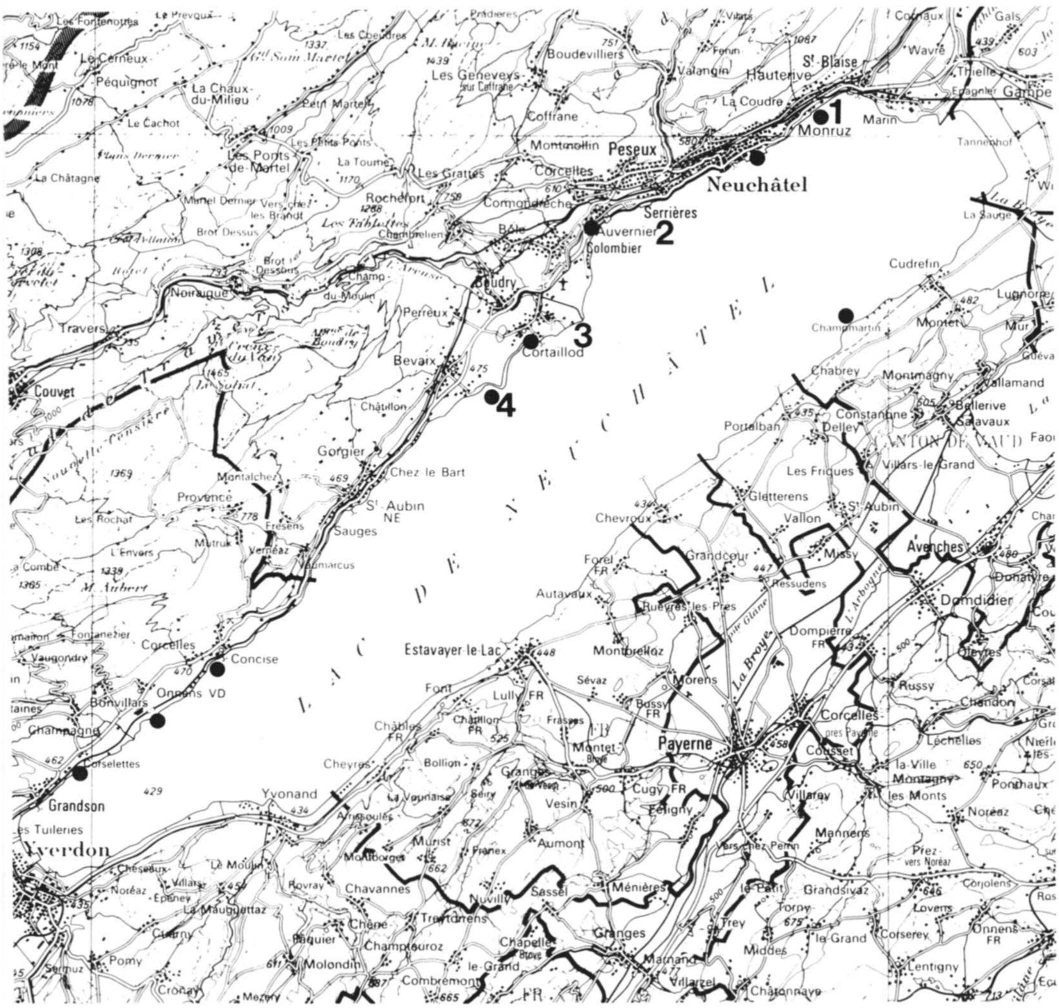


FIGURE 1 Key of major underwater village sites, Lac de Neuchatel
1 Champreveyres
2 Auvernier
3 Cortaillod
4 Bevaix sud

1980a, b, 1982) in the lake has raised exciting issues about their origin, evolution, and use. Clearly linked archaeologically to the lake shore and hinterland cultures of Neuchâtel, they offer new perspectives on those cultures when properly studied by historical scientists. It is essential to discover and properly inventory, using systematic archaeological survey, these submerged sites of such a diverse variety of cultures.

The immediate tasks are to refine the actual limits of important known sites (such as Hauterive-Champréveyres and Cortaillod, the type site of the Neolithic Cortaillod culture), and to find new sites of both habitation and lost watercraft.

Continuing development along and in the lake make it imperative to locate sites before their destruction, so that investigators can assess their archaeological research potential.

Research Objectives 1985–1986

Archaeologists of the Service Cantonal d'Archéologie Neuchâtel, whose job it is to research and conserve the prehistoric record of Neuchâtel, have defined three principal research objectives:

1. Relocate and categorize by instrumental and diver surveys previously reported sites in Lac de Neuchâtel. These sites range from habitation sites to vessels wrecked on a drowned plateau in the central area of the lake.
2. Locate new sites in the lake proper and in selected areas of the shore, particularly in areas threatened by current and future development.
3. Assist in Swiss excavations of sites such as Hauterive-Champréveyres and St. Blaise in the path of new autoroute construction.

One of the primary methodological questions raised in this research concerns the feasibility of searching for underwater central European sites by systematic instrumental survey. To evaluate this question, we tested our instrumentation's sensitivity on known sites, such as Cortaillod, Bevaix-Sud and La Tène, that exist in the lake. Instrumental signatures associated with known cultural and geoarchaeological phenomena (artifacts, structures, cargo, fill, and deposition) refined the detectability of unknown sites. Magnetic signatures of culturally related anomalies (magnetic attributes of buried materials) pattern themselves in a discrete and repeatable manner. Likewise, acoustic reflections of structures such as pilings, palisades, and hulls manifest themselves in a way that are identical attributes of those sites still to be found. Once defined, these signatures, and higher level hypotheses concerning the type, distribution, and explanation of the sites can be made using information from intensive reconnaissance survey and excavation.

The research described in this paper is an initial phase of a long-term project between the principal investigators and the Service Cantonal d'Archéologie, Neuchâtel.

Relocation and Categorization by Instrumental and Diver Surveys of Previously Reported Sites in Lac De Neuchâtel

This aspect of the research results in division along the common partition inherent in the rich archaeology of Lac de Neuchâtel: that between drowned habitation sites and shipwrecks. Resurvey of the relocated habitation sites included the Bronze Age settlements of Cortaillod-Est, Cortaillod les Esserts and Bevaix Sud (see Fig. 1). Known from early (1927) aerial photographs, these sites represent a major occupation of the western lake shore by Urnfield cultures of the late Bronze Age and early Iron Age, so-called for their common practice of cremation burial in ceramic urns. Photographed again in 1971 by Michel Egloff of the Cantonal Service d'Archéologie, significant degradation of these sites was observed. This degradation is due to natural erosional processes at work since the nineteenth century control of the levels of the three interconnected lakes of Neuchâtel, Bienne, and Morat (Fig. 2). Lowered water levels in Lac de Neuchâtel (as much as 6 m) have facilitated the discovery of numerous underwater sites, but have also exposed these sites to the dynamic hydrological processes of the littoral zone of the lake, with its wind generated waves and currents.

From 1981 through 1983, the Cantonal Service d'Archéologie, under the direction of Dr. Egloff, launched a major underwater salvage excavation of Cortaillod-Est. Cortaillod les Esserts and Bevaix Sud were extensively surveyed but remain unexcavated at this time. A prime use of equipment such as magnetometers, side scan sonars, and precision navigation gear, was to verify the detection of sites by instrumentation as well as further characterize erosional damage and geomorphological aspects.

Seen in previously published illustrations, Cortaillod-Est and les Esserts represent two major villages that adjoin each other (Fig. 3). Due to the precise knowledge of their location, the relocation was an easy matter instrumentally. Nevertheless, this is the first direct instrumental detection of underwater prehistoric sites. With good water visibility, the exposed pilings of ruined Bronze Age struc-

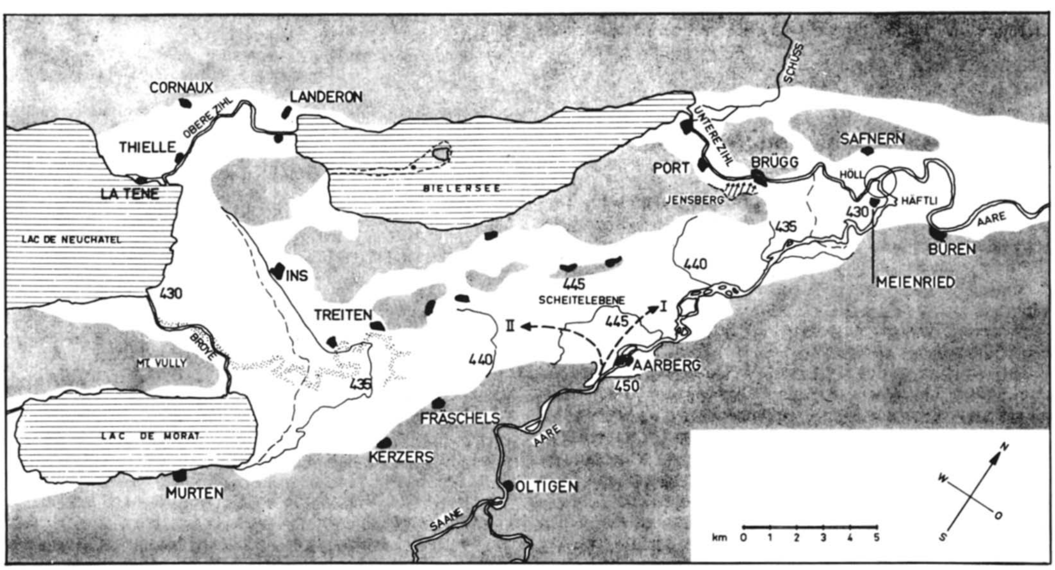


FIGURE 2 The three Jura lakes: Neuchatel, Biel (Bienne) and Morat.

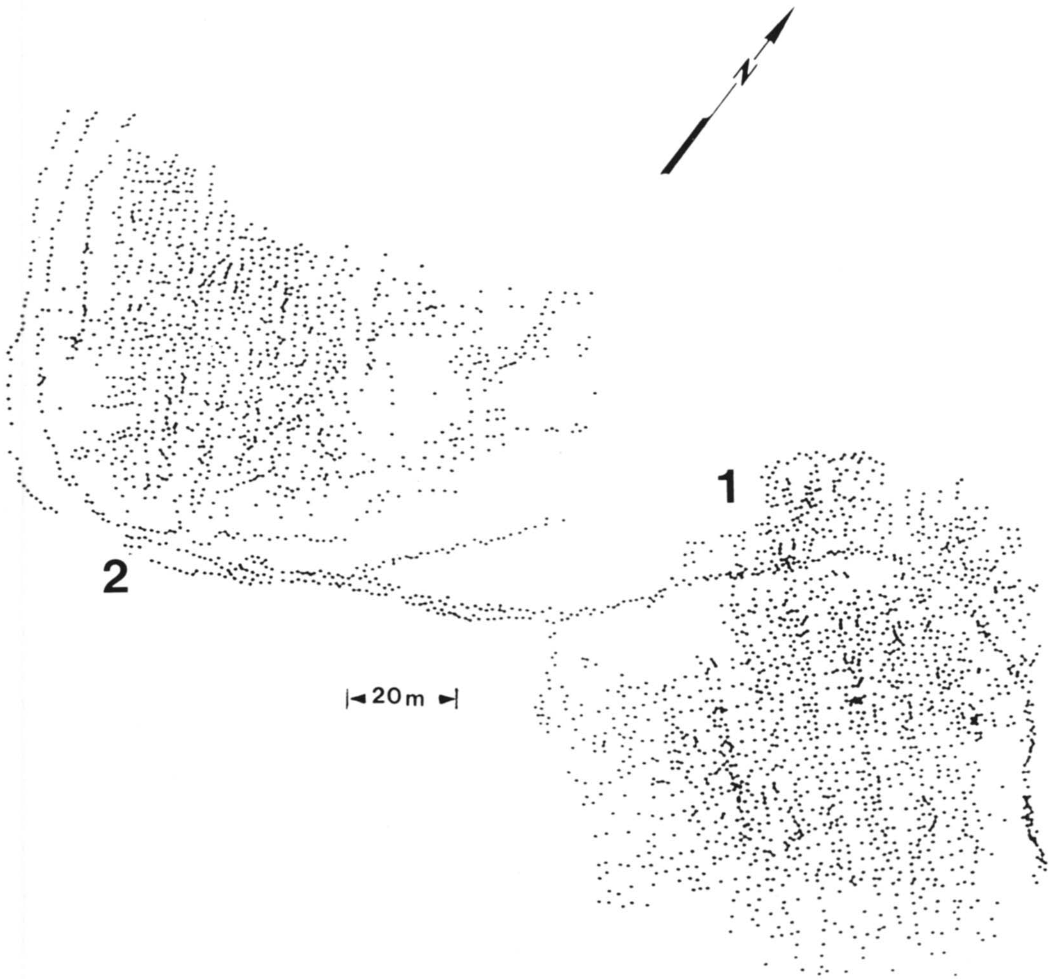


FIGURE 3 Cortaillod—complex of two Bronze Age villages. (1) Cortaillod-Est. (2) Cortaillod-les-esserts (after Egloff 1981). Note palisades that encompass the pilings of village structures. C.F. Figure 4 this article.

tures could be easily seen under the survey craft. They exhibited distinctive signatures on the side scan sonar records which will be useful for the future detection of less obvious and undiscovered sites.

Several survey transects were run over these sites using all of the instruments. Sonographs produced by the 100 kHz side scan sonar were very informative. With the sonar set at maximum resolution, for example 50 m range in survey mode, maximum discrimination of *in situ* features of the sites was obtained. The results were striking, particularly when compared to the 1971 photographs made by Egloff.

Pilings and topographic features seen in the sonographs (Fig. 4) correlated well with earlier records and allowed assessment of significant changes in the sites since the excavation of Cortaillod-Est in 1981–83. The creation of a large mosaic of the sonographs allowed a better understanding of the lake floor topography. Magnetometer data for the sites proved to be somewhat ambivalent. The most pronounced anomalies tended to be the result of modern debris (i.e., littering) and gear or tackle lost from boats anchoring or sailing over these sites. Cortaillod Port is a routine stop for the large lake boats that carry passengers and cargo about the lake, as was clearly evident to our team divers surveying Cortaillod-Est. A large lake boat making a stop, created a noticable surge and erosion due to propeller action. Diver surveys located a variety of ceramics and structural elements across the lake bottom. A tantalizing find by one pair of divers was a large tree trunk in the area of Cortaillod-Est. Inspection was done for any signs of reworking, as seen in the production of a dugout craft, but none were found. The possibility exists that the log was contemporaneous with the occupation of the village, but only the direct dating of the tree by dendrochronology can address this issue. Beyond this, the tree may possibly be an unbuilt boat.

Logboats are known to exist at Bevaix Sud. This site, when surveyed instrumentally, showed the complexity evident in earlier aerial photographs. Bevaix Sud,

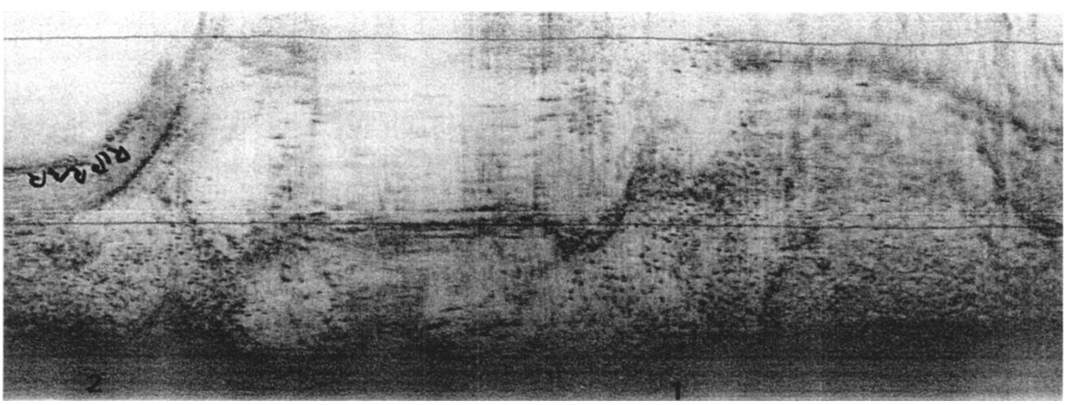


FIGURE 4 Side scan sonar view of north edge of Cortaillod Est (after excavation). The remaining pilings of est are visible as dark points above (1) as are those of adjacent Cortaillod les esserts above (2). The parallel scale lines are 25 meters apart. (Reproduced from Arnold 1986). C.F. Figure 3, this article.

as the name implies, lies just south of Pointe du Grain, a major landmark on the western shore whose projection into the lake creates the Bay of Bevaix, and was the site of the discovery of a Gallo-Roman boat excavated in 1979. Located further from current anchorages and washed-in debris, the magnetic anomalies of Bevaix Sud should be more archaeologically related than those found at the Cortaillod sites. Diver inspection of Bevaix Sud, not possible at the time, remains a prime goal of further work at this site. Relocation of the logboats by the side scan sonar was attempted, but no definite targets were seen.

An important aspect of the relocation and instrumental survey of these famous sites was the opportunity to develop a set of expectations in terms of instrumental signatures that led to the discovery of sites in areas of the shore beyond easy detection by aerial photography. As this was the second principal objective of the research, we shall now address the results of this work.

Location of New Sites in the Lake Proper and along Selected Areas of the Shore

Archaeologically and geographically, Lac de Neuchâtel is a large, open body of fresh water 40 km long and 10 km wide at its broadest point (Fig. 1). Politically, the lake divides into four unequal zones administrated by the Cantons of Neuchâtel, Berne, Fribourg, and Vaud. The survey teams were officially limited to the lake area under the Canton of Neuchâtel's jurisdiction. This comprised roughly 50% of the lake's northern area. Operationally, the multi-jurisdictional nature of the lake posed no problems for our survey teams. The Swiss are quite pragmatic in dealing with activities at inter-Cantonal levels. In most cases, as with the observation of strict boundaries on a lake such as Neuchâtel, the officials simply do not concern themselves with inadvertent transgressions. Unofficially, they often support such efforts as ours, although the requisite permits for each Canton were not in hand. Because significant archaeological sites exist in Canton's Vaud and Fribourg, such as the drowned habitation sites of Champmartin (VD) and Estavayer-le-Lac (FR) and the offshore sector of the Roman quarry site of La Lance near Concise (VD), such sites were excellent study areas for instrumental survey. They could not be examined, however, due to lack of time rather than administrative exclusion.

Each project has constraints other than physical limitations, such as time, weather, personnel, and equipment. None of these prevented the successful instrumental survey of over 150 linear km of survey tracks on the lake. Principally, this work was concentrated in three major areas: (1) the St. Blaise/Thielle-La Broye Canal Areas, (2) the coast from St. Blaise to Bevaix, and (3) La Motte. For the initial survey, work began in the area between the two canals, Thielle and La Broye. These canals, located at the northern end of the lake, connect Lac de Neuchâtel with Lac de Bienne and Lac de Morat, respectively (Fig. 2). The chosen methodology called for the use of side scan sonar, magnetometer, and a microwave radar positioning system to be deployed in a consistent and systematic survey in order to detect archaeological features.

Instrumentally, it is difficult to determine whether a sonar target or magnetic anomaly is of archaeological interest. For this reason, the use of divers to investigate the exact nature of these targets was crucial. The survey team deployed the detection instruments from the Service Cantonal d'Archéologie's survey craft. The craft's design, a self-propelled aluminum catamaran barge, was provided by the Canton with an operator and an assistant. From the vessel we deployed an EG&G 100 kHz side scan sonar, a Geometrics G-866 marine-tow recording proton magnetometer, a Del Norte X-band radar positioning system, and a Hewlett-Packard 85 microcomputer.

Shore stations for the radar transponders used in the positioning system were located on opposite shores at elevations of 490 m (60 m above the lake). One remote station was at Montet (VD) and others at Cortaillod (NE) and Estavayer-le-Lac (FR) (Fig. 1). The distance between the remote stations and the survey baseline, from which vessel positions could be fixed to within 3 m accuracy, was established. A survey lane or offset distance from subsequent vessel tracks was established at 30 m. The side scan sonar, set primarily on the 50 m range setting, provided excellent overlap in contiguous data records. The towfish, one each for the side scan sonar and the magnetometer, were deployed beneath and astern the survey craft at fixed depths. For the shallow parts near the northern end of the lake, the fish were towed near the surface (1–2 m). For deeper parts of the lake, the vehicles were lowered accordingly. The decision to survey within the 30 m lake depth was made, in part, to allow ground-truthing by divers to be carried out without risking decompression dives. The area within the 30 m contour covered over 13 km^2 in the Thielle-La Broye region alone. Of this area, over 8 km^2 were surveyed along 26 survey tracks running east-west across the northern end of the lake. Within this area, 61 targets were defined based on a preliminary analysis of the instrumental data (Fig. 5). All of these targets were examined by divers; this resulted in the relocation of three previously known shipwrecks and the discovery of one possible wreck site near St. Blaise. Because the survey vessel was also the dive platform, it had to be converted before each specific dive. Throughout the survey, the amount of time spent surveying and diving had to be alternated. Swiss safety regulations limit the number of personnel on a vessel to 10 when diving and less (6–8) with survey instruments on board. As a result, the general rule was to survey for a week and dive the following week. In routine usage, this schedule worked well and allowed for maintenance of instruments and diving equipment.

Two survey tracks were run along the western shore of the lake inside the 30 m depth contour from St. Blaise to the Bay of Bevaix. They represented 32 linear km of survey, and utilized the instrument's highest resolution capabilities. Previously (1979), the Service d'Archéologie had a side scan sonar survey of sections of the area conducted by a local Swiss hydrographic firm, but at lesser resolution acoustically, and without simultaneous magnetometer survey. Both surveys, ours and the 1979 effort, used comparable navigation, which made it possible to re-examine sonic targets detected by the earlier survey. Two of these targets were modern (nineteenth and twentieth century) shipwrecks, one off St. Blaise and the other off Neuchâtel Port. Both were relocated and records were taken. A third suspected wrecksite off

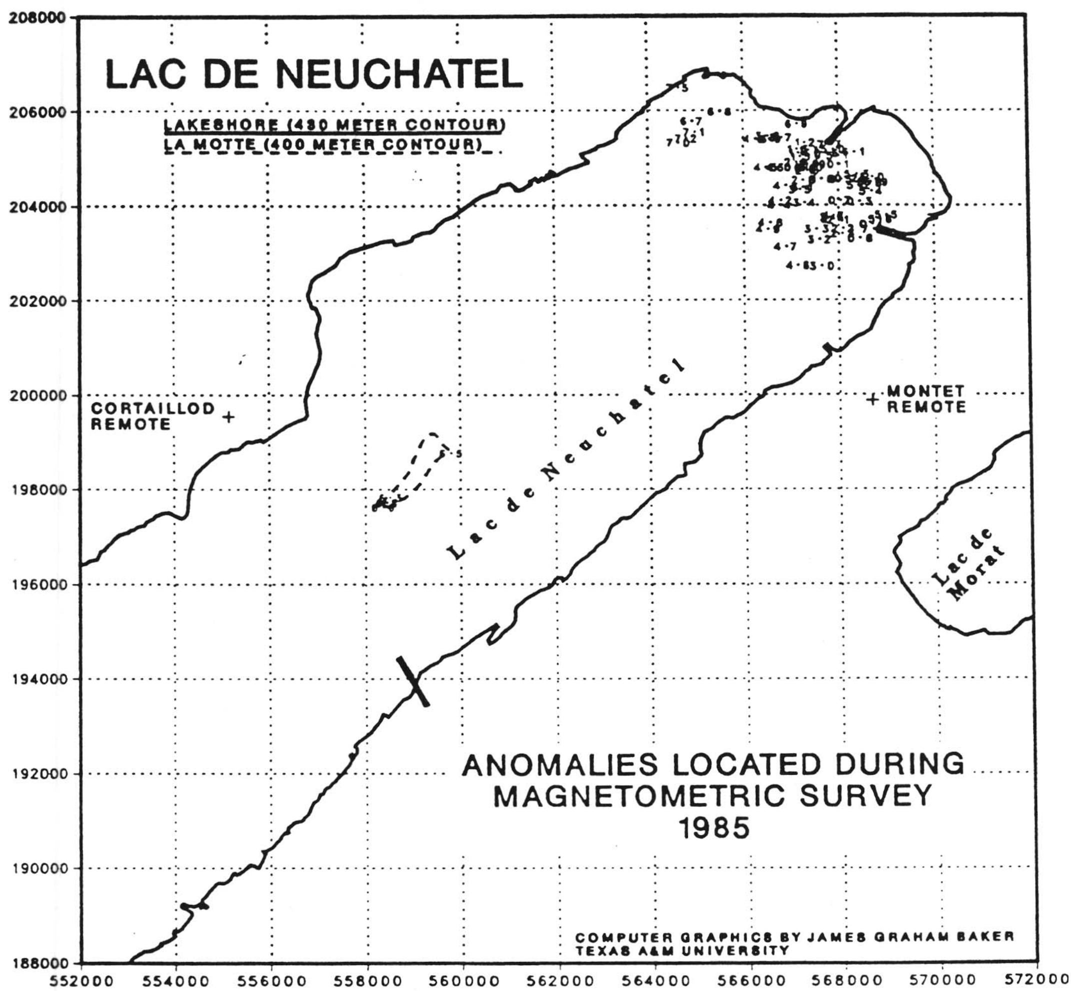


FIGURE 5 Anomalies located during magnetometric survey, 1985.

Hauterive-Champréveyres was confirmed with resurvey, but a newly reported wrecksite off Auvernier could not be located. The latter site, reported by local fishermen, was not a very precise location relative to present onshore landmarks at Auvernier. The wreck report may have veracity, but, at the detection limits used by the survey team, its location could not be determined.

Numerous magnetic anomalies were detected along the lake front of the city of Neuchâtel to Auvernier. The exact nature of these features could not be determined by diver inspection. As this area has undergone heavy urban development together with commercial dredging, much of these are thought to be from modern debris. The possibility that recent or even ancient shipwrecks exist there would require these anomalies to be examined more closely in the forthcoming analysis of the data, as well as inspected by divers in the future.

A reported drowned village site in the offshore vicinity of La Tène was searched for but not found. The general location was known through secondhand reports by sport divers and individuals involved in the illegal looting of these types of sites. A detailed analysis of the instrumental data has not revealed the location of this site if, indeed, it does exist. In cases where sites remain unreported and subject to looting, surveys conducted by the project are extremely valuable. Precise locations of sites and their nature can be given to the Cantonal authorities; subsequently these sites can be protected and scientifically investigated. The results of these studies can be examined and enjoyed by all rather than remain lost or provide ill-gotten gain for the few at the expense of present and future knowledge.

In the 1986 field season, 24 lines of over 2 km each were surveyed instrumentally over the shallow central plateau of the lake called La Motte or "the hill" (about 10 m at its shallowest depth). Thirty-six magnetic anomalies were located with little or no associated side scan data. Diver reconnaissance on the enigmatic plateau found a deep sediment of the upper portions of La Motte. Systematic surveys of these anomalies were planned but were delayed until future seasons due to inclement weather at the end of the 1986 season. La Motte remains a geographic feature of great interest because of its location on past sailing routes and fishing locales as well as reported finds of early historic (Roman) artifacts such as tiles and boat timbers.

Another important aspect of the 1986 season prospectus, that was aborted due to environmental conditions, was the sub-bottom profiler survey of offshore areas of Hauterive-Champréveyres and Cortaillod. This acoustical instrument allows high resolution of sedimentological features of the lake's sub-bottom strata up to over 30 m. Lush growth of water plants, due to warm lake waters, dispersed the instrument's acoustical beam preventing penetration of the layers, both archaeological and geomorphological. The sub-bottom profiler survey was completed in March 1987, however, at St. Blaise, Champréveyres, and Cortaillod. Preliminary analyses indicate excellent data on geomorphological and archaeological strata for these sites.

Assistance in Current Excavations of Sites

The final aspect of the Neuchâtel project was the assistance of the Service d'Archéologie in its rescue excavation of the site of Hauterive-Champréveyres, since it lies in the path of Autoroute construction in the Neuchâtel/Hauterive-Champréveyres region. This site was formerly an underwater complex of villages, and is now enclosed within a rock dike (cofferdam). This enclosure forms a 0.5 km impoundment around the site with large pumps keeping the 2-ha area within the cofferdam dry (Fig. 6). Under excavation for two years as of June 1985, the pumps

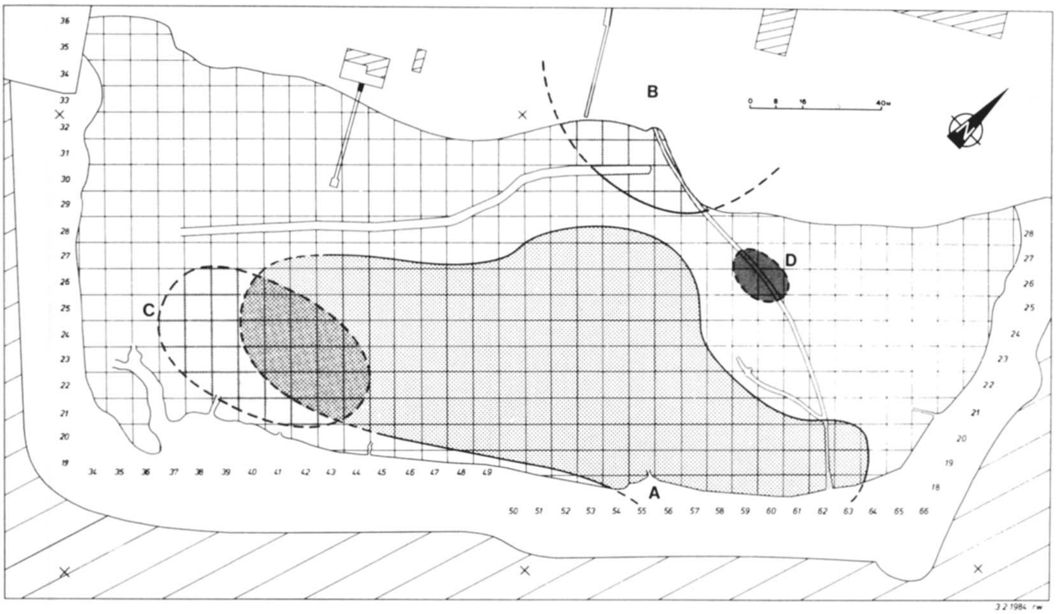


FIGURE 6 Plan of the Hauterive-Champreveyres site.

were turned off in August 1986 to allow the sediments from the continued construction of N5, the major east-west highroad from Bienne to Geneve, to fill in this area.

In terms of spectacular archaeological discovery, the project team, excavating the Late Bronze Age sectors of the site, clearly made the most important find of the last two seasons by recovering a cache of bronze artifacts. The nature of this discovery necessitates a brief background in terms of the cultural history of Hauterive-Champréveyres, in particular, and Neuchâtel, in general.

As seen by the plan (Fig. 6), Hauterive-Champréveyres is the location of four separate sites ranging from the Upper Paleolithic, Zone D (ca. 13,000–11,000 B.C.), Neolithic, Zones B and C (ca. 3600–3000 B.C.), to the Late Bronze Age, Zone A (ca. 1000–900 B.C.). In terms of historical cultures, these sites represent major segments of the cultural continuum for western Switzerland. This continuum begins with the Middle Paleolithic (50,000–40,000 B.C.), which is represented by the famous Neuchâtel Neanderthal cave site of Cotencher where a human maxilla, stone tools, and extinct animal remains (including wooly rhinoceros and giant cave bear) from the last Ice Age were found. No human occupation sites in open areas have been found for this period. Indeed, a hiatus of human settlement for Lac de Neuchâtel exists from this interglacial period through the last (Würm) glaciation.

The retreat of the ice (ca. 11,000 B.C.) finished carving the present day bottom of the lake, and fully modern-looking humans reoccupied the vicinity of Neuchâtel. Known primarily from the beautiful cave art sites of France, the Upper Paleolithic cultures are rarely known from open settlements. This singular fact makes the discovery of the first European Upper Paleolithic site, found underwater in Zone D at Hauterive-Champréveyres, of great significance. Represented by numerous hearths with unexpected activity areas around them, flake-blade tools and bones of extinct horse and reindeer, the Hauterive-Champréveyres Upper Paleolithic site has distinct occupation periods spanning a few hundred years. As an open site on a small bay or stream near the retreating glacier, the Zone D settlement probably represents temporary camp sites of nomadic hunting groups that exploited this rich ecozone from Magdalenian to Mesolithic times.

After the Upper Paleolithic era ended, a new cultural expression, the Mesolithic, appeared about 6000 B.C. and lasted until the beginning of settled agriculture of the Neolithic Period around 4000 B.C. (Fig. 7). Evidence of the Mesolithic hunting and gathering groups has appeared at Hauterive-Champréveyres, although such sites are rare for Neuchâtel. Basically interpreted as a transitional culture from the nomadic hunters to settled farmers, they may have melded with groups migrating into the Neuchâtel region from the Upper Danube or Rhone Valleys.

The early Neolithic farmers did not settle the lake shores of Neuchâtel until the period called the European Middle Neolithic Period with the Cortaillod Culture, so-named after its discovery at the site of Cortaillod mentioned earlier in this text (Fig. 3). This Neolithic culture, distinguished by the exploitation of domesticated plants such as millet and wheat, as well as domesticated cows, pigs, and sheep, was composed of skilled gatherers of wild plant crops, fishermen, and hunters. The Cortaillod groups at Hauterive-Champréveyres, Zone C, were contemporaneous with other European Neolithic cultures such as Rössen (Germany), Pfyn (central and east Switzerland), Chassey (France), and Logozza (Italy). In terms of material culture, the Cortaillod culture was distinguished by its simple but aesthetically pleasing ceramics. Little decoration was applied, except in rare instances where applique of brichbark was used. The variety of vessel forms express a precise control of shape and firing technology as seen in Figures 7 and 8.

A later village built at Hauterive-Champréveyres by a group of the Horgen culture, a pan-Swiss culture manifestation dating from 3400 to 3000 B.C., was believed to be affiliated in cultural traits with French Neolithic groups such as the Somme-Oise-Marne (S.O.M.) culture. The Horgen culture continues the Neolithic tradition of settled village life. This culture is distinguished by the aesthetic "poverty" of its ceramics as opposed to the earlier Cortaillod culture (Figs. 7, 8 and 9). Although the flint industry was well-developed and had elegant polished stone adzes and other tools, the ceramics are plain and coarsely made with crude temper. After the Horgen occupation of Hauterive-Champréveyres, no further habitation of the site during the Late Neolithic or the Early to Middle Bronze Ages, a hiatus of over 2,000 years, occurred. This period is known from other sites such as Lüscherz (Berne) and Cortaillod.

Some time before 1000 B.C., a sizeable village with a wooden palisade was constructed at Hauterive-Champréveyres. In climatological terms, this was the Sub-Boreal period characterized by a somewhat cooler but drier climate. The forests were primarily deciduous and produced abundant timber, as seen by the

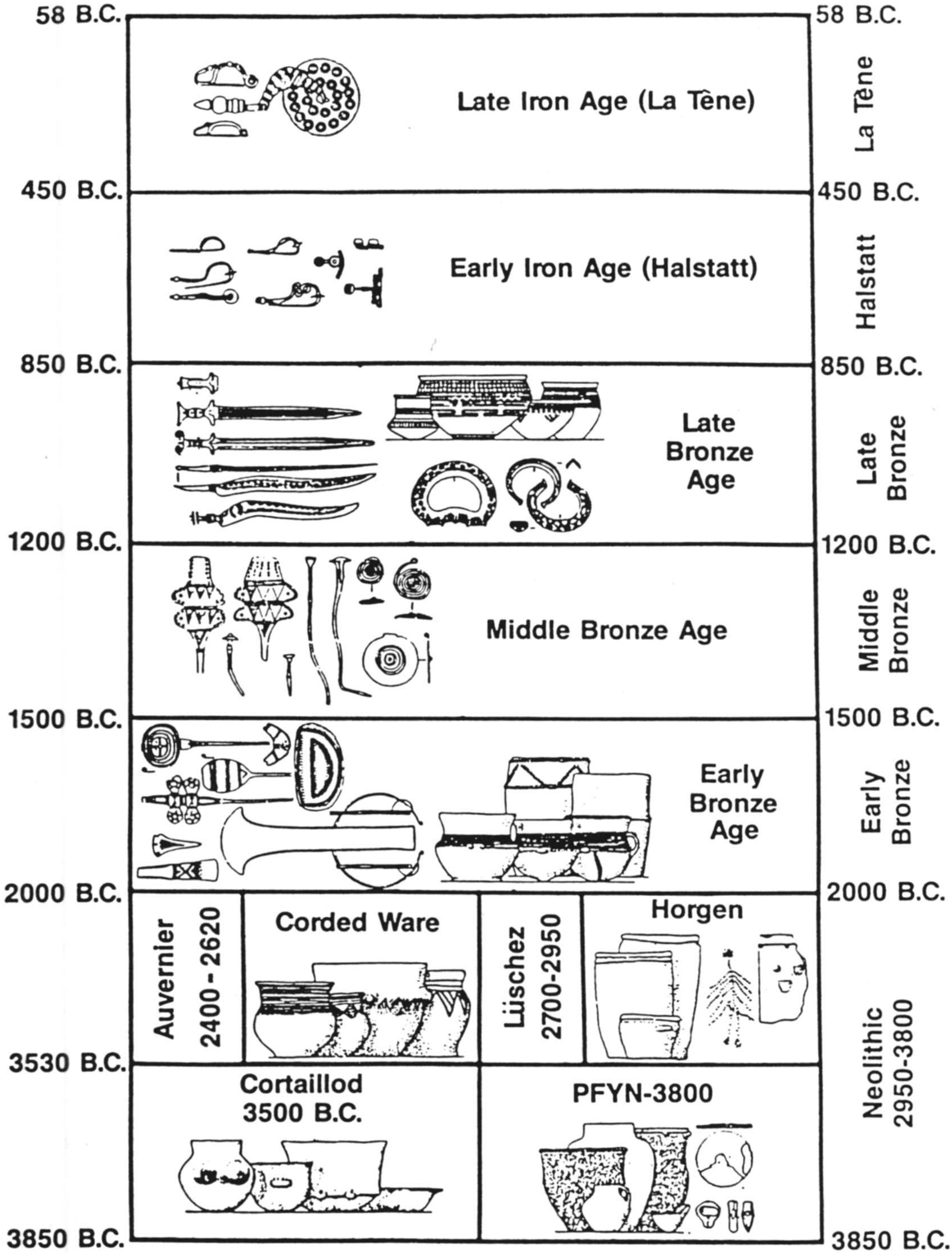


FIGURE 7 Swiss chronology Neolithic through Iron Age.

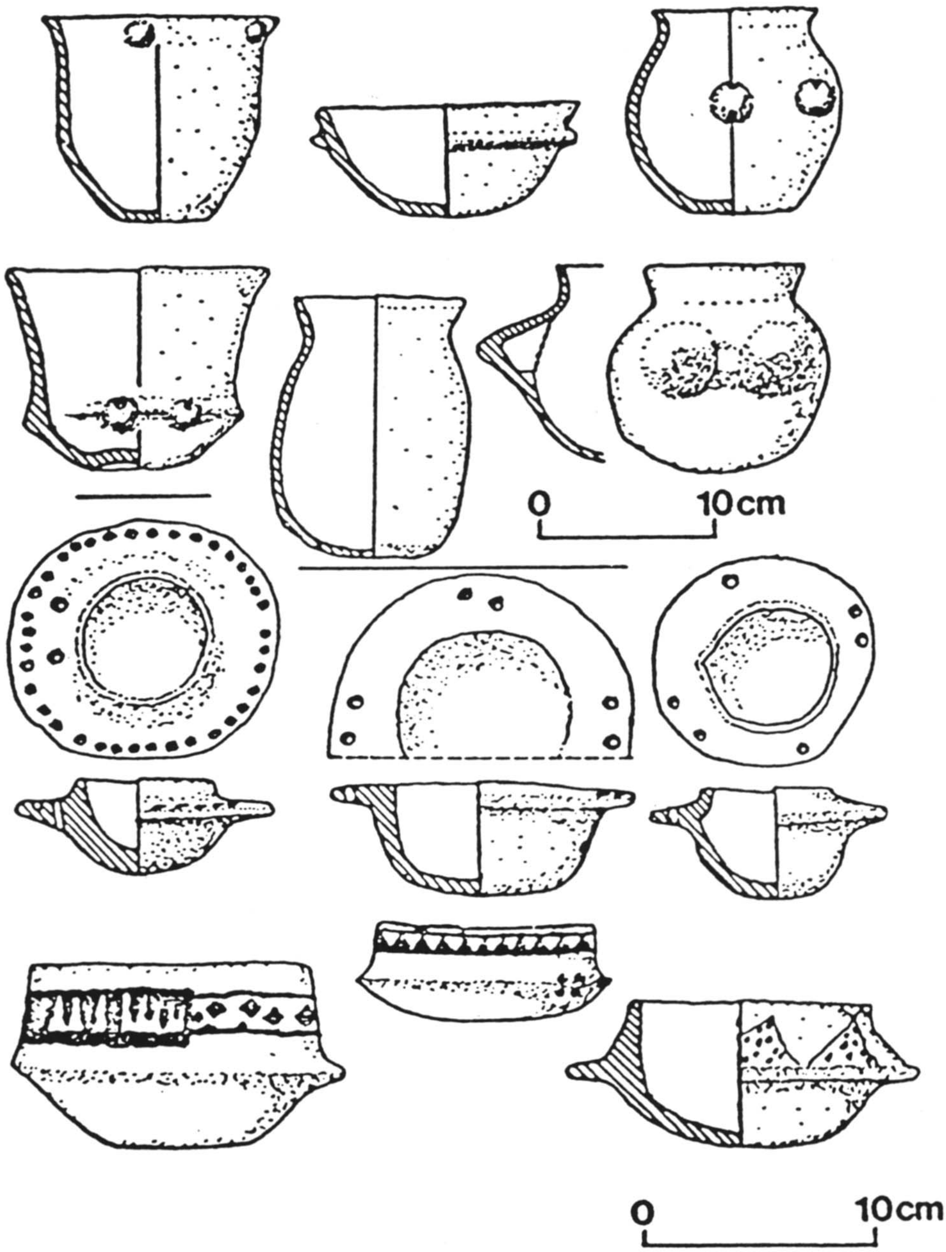


FIGURE 8 Cortaillod pottery types.

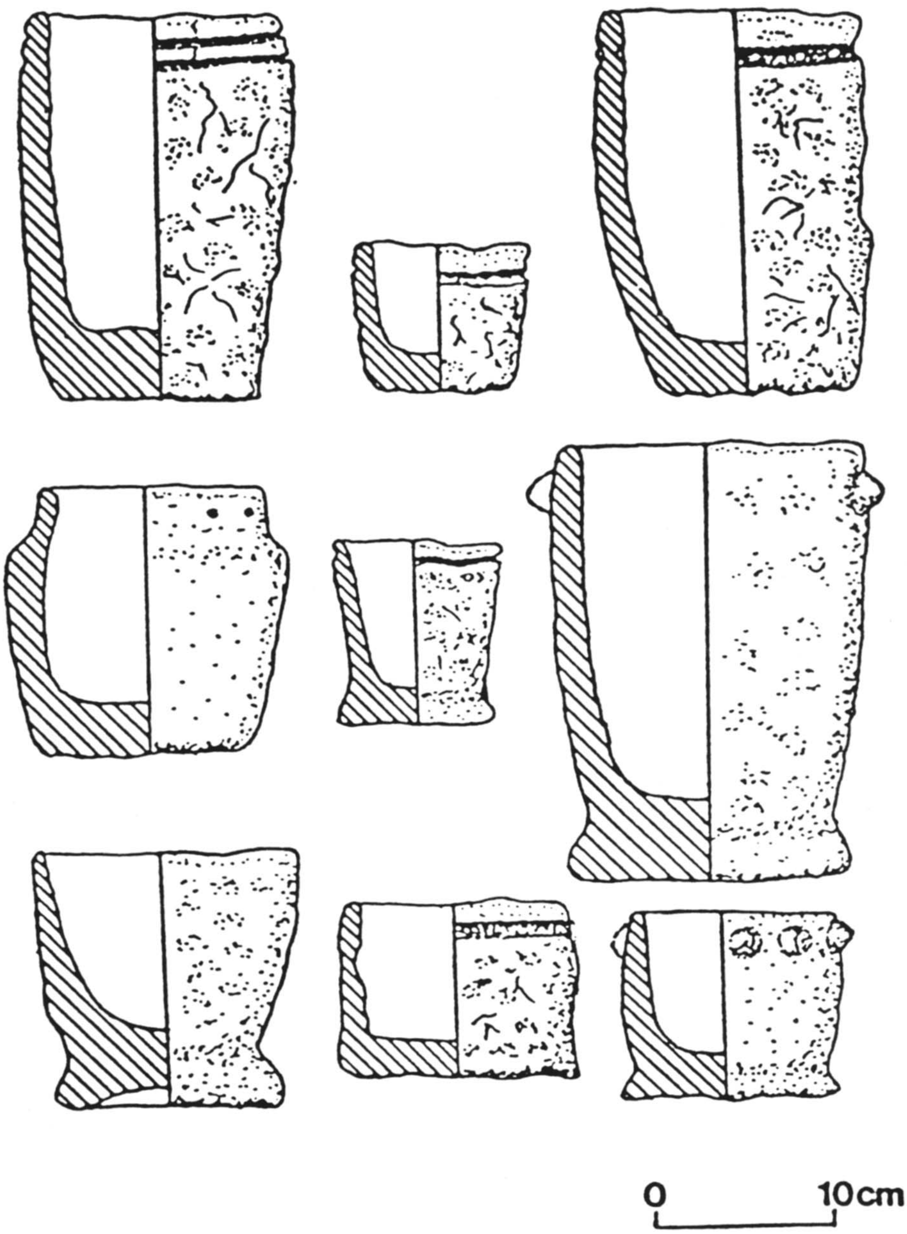


FIGURE 9 Horgen pottery types.

extensive use of oak and other species for construction. Contemporaneous with upper levels of Auvernier-Nord, Cortaillod-Est and Les Esserts, Hauterive-Champréveyres' village found in Zone A (Fig. 10) represents the final archaeologically identifiable occupation of the site. Clearly the largest settlement in terms of size and remains, the Late Bronze Age village has produced over 2 tons of ceramics, bone, and bronze materials. One of the richest sites in Europe, this village has allowed a fuller reconstruction of Bronze Age society based on its archaeological remains.

Two basic varieties of ceramics, plain utilitarian and finer, thin-walled ware, comprise the bulk of the Zone A finds (Figs. 10 and 11). Bronze metallurgy was well-developed and was represented by several finds such as pins, spirals (for necklaces), fish hooks, rings, knives, and axes (Figs. 11 and 12). Compared to the quantity of ceramics, these artifacts comprise only a few hundred items. Amber from the Baltic and glass beads from the Mediterranean demonstrate participation by the inhabitants in extensive traded networks outside central Europe. What the ancient Swiss traded for these items can only be speculated upon at this time. That they did trade, and that wealth did accumulate in a few persons' hands, was clearly demonstrated by the 1985 find made during the excavation of one sector of Zone A.

Project members participated in the excavation of several of the cultural zones at Hauterive-Champréveyres, including the Neolithic (Cortaillod sector where rock

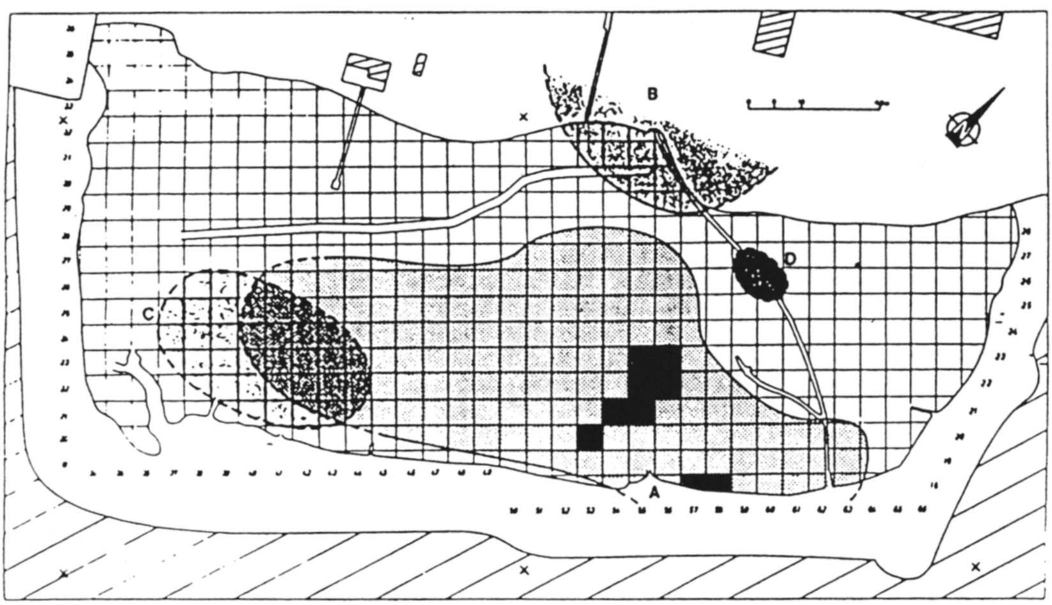
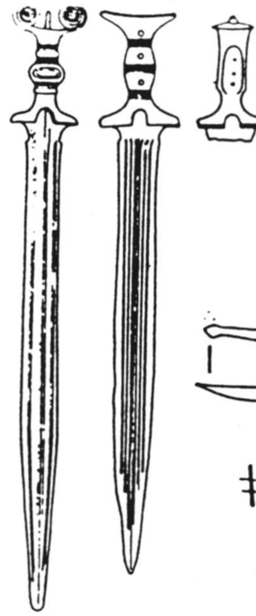
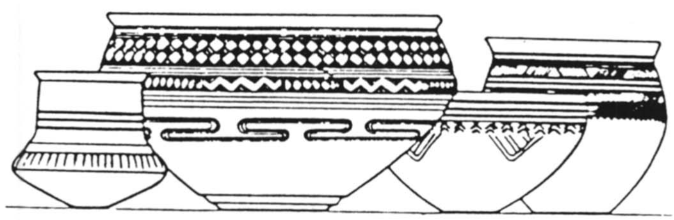


FIGURE 10 General plan of the Champreveyres site showing the earthwatch excavated area in black.



Late Bronze Age (Ha B); typical sword types. Left: with antennae, Cortaillod NE; centre: Mörigen type, Grandson VD, Corcelettes; right: Auvernier type, Nidau BE. Max. length 60 cm

Late Bronze Age (Ha B); knife blades (the top knife is typologically the oldest). Length of top knife c. 24 cm

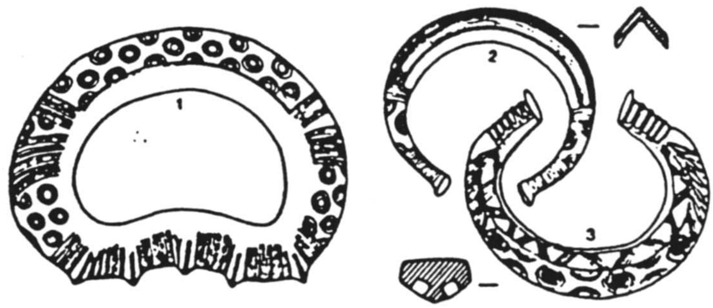


Late Bronze Age; Zug-Sumpf; pottery from the two levels. Left: Ha A; centre and right: Ha B. Max. ht. c. 15 cm

Late Bronze Age (Ha B); Möriken AG, Kestenberg; pottery. Max. ht. c. 17 cm

FIGURE 11 Late Bronze Age swords, knife blades and ceramics.

Late Bronze Age (Ha B); bronze bracelets from lake-dwellings on lake Neuchâtel, 1–2, Auvernier NE; 3, Concise VD. Ht. of (1) c. 9 cm



Quelques formes d'épingles en bronze. De gauche à droite: Bronze ancien (1–3); Bronze moyen (4–6); Bronze final (7–10). Provenances: Hauterive. Cortaillod. Indéterminée (3–4). Bevaix. indéterminée. Auvernier. Cortaillod (8–9). Auvernier. 2:3.

Nadeln aus Bronze. 1–3: Ältere Bronzezeit. – 4–6: Mittlere Bronzezeit. – 7–10: Späte Bronzezeit.

FIGURE 12 Late Bronze Age artifacts.

features, pilings, and stone tools such as polished axes and large milling stones were carefully recorded *in situ*) and the Upper Paleolithic (the late Magdalenian sector where new areas were opened up to expose living floors, hearths, extinct animal bones, and beautiful flint microtools.) The majority of the excavation, however, was devoted to the largest zone (A) which was the Bronze Age component of Champréveyres. The Late Bronze Age dates from 1200 to 850 B.C., in general; at Champréveyres the Late Bronze Age is represented by materials that are classified in the Hallstatt chronological scheme as Hallstatt $A_1-B_1-B_2$ (Benkert, Reinhard and Schifferdecker 1984). Hallstatt A and B are phases of the Late Bronze Age Urnfield period under this classification, which is based on the finds from a large Urnfield cemetery excavated in the nineteenth century near Hallstatt, Austria. The project team excavated carefully, but rapidly, as much as possible of the northern half of the Bronze Age sector. The primary goal was to expose the numerous remains of the pilings in order to map the village-house plans for the settlement pattern analysis.

A major discovery was made during the last two weeks of the 1985 season. In an area less than 1 m^2 and 0.5 m deep, over 250 items including bronze rings, spirals (remains of necklaces), pins, belt and harness bosses, and glass beads were found lying beside a collapsed ceramic vessel. Interpreted as either a cremation urn burial or a hoard, the find represents a high point in the excavation of Hauterive-Champréveyres.

Perhaps the most satisfying find from a theoretical standpoint, the discovery of a nearly intact early Iron Age pot, was made the last day of the 1986 excavation. This find strongly indicates that Champréveyres did have an early Iron Age (Hallstatt) component. It was further determined that the cultural strata of this late period dive down under the surrounding structure of a modern dam, into the lake bottom. Soundings of the remaining drowned segments were the subject of a sub-bottom profiler survey, completed in March 1987.

Summary

The archaeological instrumental survey of Lac de Neuchâtel was an unqualified success in both scientific terms and international cooperation.

To date, .he project teams have:

1. Located two previously unreported sunken watercraft—a prehistoric logboat and a historic period framed vessel.
2. Located a possible drowned habitation area or early historic "dump" off of Pointe du Grain (evidenced by possible Roman ceramic building tiles recovered over 100 m offshore).
3. Assisted in the completion of the major excavation of the Late Bronze Age village at Hauterive-Champréveyres.
4. Completed the systematic instrumental mapping of the archaeologically unexplored La Motte in the central area of Lac de Neuchâtel.
5. Begun a radiocarbon dating program of prehistoric and historic Swiss watercraft and the prehistoric high water stands of the lake.

This survey is the first extensive systematic underwater survey of a European lake by remote sensing. It is the first survey conducted in Europe to utilize multiple geophysical systems for the discovery of submerged archaeological sites. These Lac de Neuchâtel surveys have resulted in the first direct detection of prehistoric drowned habitation sites (although they were indirectly identified in the survey of 1979). This is, hopefully, only the first step in a more sophisticated direct detection of prehistoric sites. Finally, the accomplishments of this instrumental survey will allow the rapid development of a regional data base that can be fruitfully utilized in answering significant research questions.

Acknowledgements

This research was funded under expedition grants from the Center for Field Research, Watertown, Massachusetts. The authors wish to express their grateful appreciation of this support. Our deepest thanks go to Jacques and Phyllis Pritchett and Kevin and Shirley Kearney for all their assistance in Switzerland. Thanks to all the EARTHWATCH expedition volunteers of 1985–86.

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THE SOMERSET LEVELS
Multidisciplinary Investigations and a Wealth of Results

Bryony Coles

THE SOMERSET LEVELS lie in the southwest of Britain, a former bay of the Severn estuary (Fig. 1). The modern landscape is flat, broken by an occasional small low island, divided in two by the narrow Polden ridge, and bounded north and south by the Mendip and the Quantock hills. Today the Levels are heavily exploited for dairying and peat extraction. The peat formed under wet conditions from ca. 6000 to ca. 1500 years ago and is responsible for the preservation of the organic structures and artifacts that make the archaeology of the Somerset Levels so significant. Wooden structures, such as trackways and platforms, have been preserved. These structures were built by the early inhabitants of the region who sought to maintain their traditional routes across the Levels as conditions fluctuated from dry to wet and back again (Fig. 2). Alongside the trackways, around the platforms, and scattered elsewhere in the peat, artifacts of wood are to be found, not in profusion, but structures and artifacts together amount to a more substantial body of organic material culture than is to be found in any dryland context. To add to the significance of this, there is an accompanying environmental record which has been well studied through varied analyses, and which is exceptionally well associated with the archaeological evidence.

The potential of the Somerset Levels for the study of prehistory has long been recognized. Bulleid carried out pioneering work in the 1890s and Godwin developed the work, especially the environmental studies, in the mid-twentieth century. From the 1960s, John Coles has been active in the area, setting up the Somerset Levels Project in 1973, the author being co-director. The Project, funded largely by the Department of the Environment (and now by English Heritage) and aided by the Universities of Cambridge and Exeter, has maintained a full-time field archaeologist in the area and taken a multidisciplinary approach to the investigation of the prehistory of the Levels. A longer account of these developments and the Project's methods is given in Coles and Coles 1986. In the present paper, the emphasis will be on results. To underline the wealth of information available in a wetland context a single structure, the Sweet Track, will be examined.

The early Neolithic builders of the Sweet Track (nearly 6000 years ago) wanted a raised walkway to cross what was then a wet reedy marsh. They felled trees on the dryland, processed them, and carried the wood to the marsh edge where they

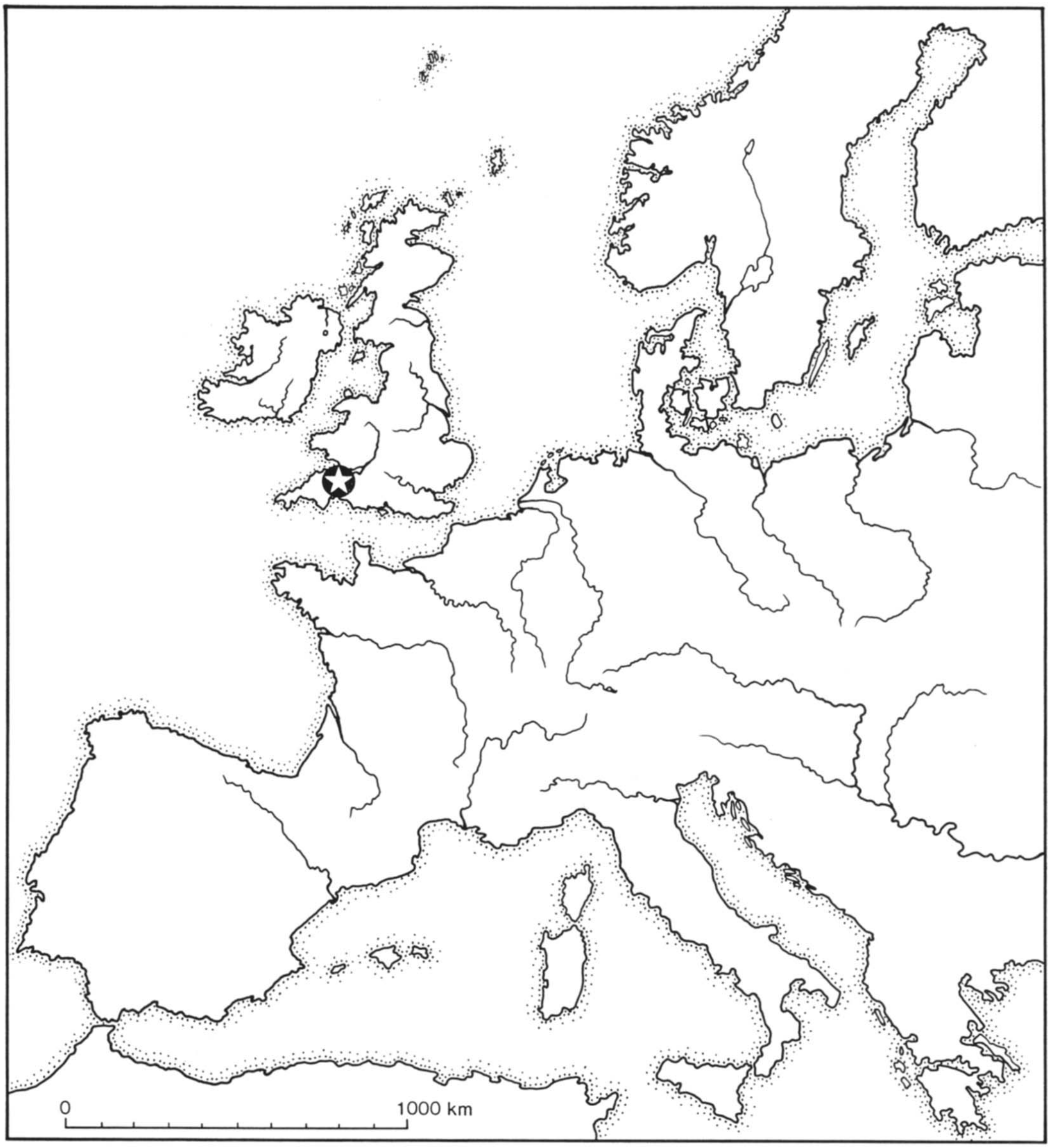

FIGURE 1 Map showing the location of the Somerset Levels, England.

began to build by putting long poles or rails on the marsh surface, end-to-end along the desired route. The rails were usually straight young trunks of ash, alder, hazel and elm. At intervals of about one meter, pairs or groups of straight roundwood stems (pegs) were pushed or driven obliquely down into the soft, unstable surface to either side of the rail. They crossed over the rail, making a v-shape. Planks about 40 cm wide and 2–5 m long were then lodged in the cross to make a walkway suspended about 40 cm above the rail. Occasional vertical pegs helped to anchor the planks, which were also stabilized by cutting notches in the underside edge to

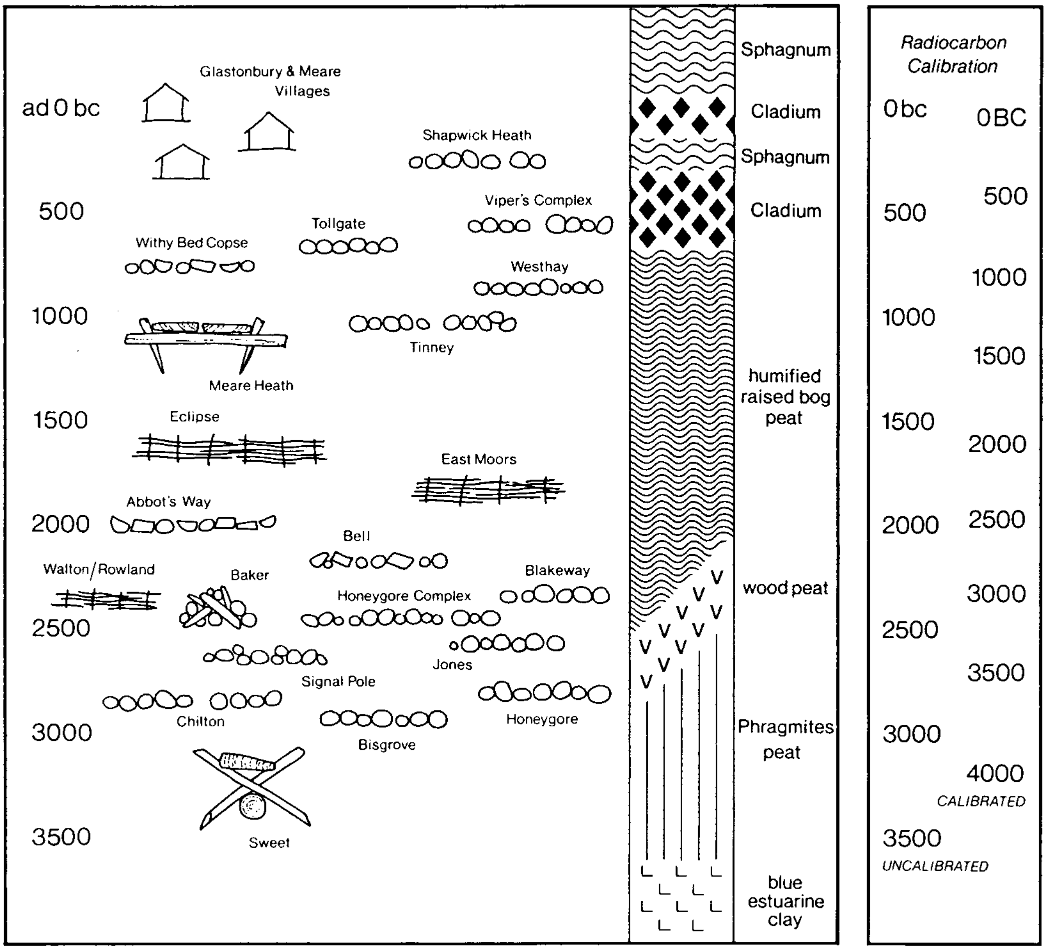

FIGURE 2 Chronological diagram illustrating the variety of prehistoric structures and changing peat types in the Somerset Levels.

fit over the pegs. The finished trackway was 1800 m long and linked a small island at the foot of the Polden ridge with a larger island out in the marsh (Fig. 3).

Since its discovery and first excavation in 1970, the Sweet Track and its associated peats have provided material for pollen and macroscopic plant analyses, for studies of insects and fungi, for tree-ring investigations, for the identification of woodworking skills, and for use-wear analysis of flints. The range of possible investigations has been steadily extended, as may be seen by comparing the first published report (Coles, Hibbert and Orme 1973) with the collection of papers published in *Somerset Levels Papers 10* (Boddy and Ainsworth 1984; Caseldine 1984; Coles and Orme 1984a, b; Girling 1984; Morgan 1984; Morris 1984).

As far as possible, different avenues of investigation have been related to one another, as, for example, with the insect and plant macrofossil work carried out on samples taken from an excavation toward the northern end of the track. Pairs of

immediately adjacent peat samples were taken at intervals along the length of the site for analysis of insects and of plant macrofossil remains by Girling and Caseldine. As expected, high numbers of aquatic species were recorded in both cases, and there were abundant indications of the reed and sedge vegetation that clogged the shallow waters crossed by the trackway. Samples taken where the track level dipped slightly showed variation in both plant and insect species. There were more open water plants, like the white waterlily, than usual. Insects occurred which live in open water habitats, including diving beetles and whirligig beetles; the giant spider *Dolomedes* was also present. The latter, known colloquially as the Raft Spider, lives by hunting aquatic insects and small fish that inhabit permanent water. The analyses indicated an area of open water amidst the reeds, perhaps slightly deeper water than elsewhere along the track line (Caseldine 1984; Girling 1984). The track structure itself was adapted in an appropriate way to wetter

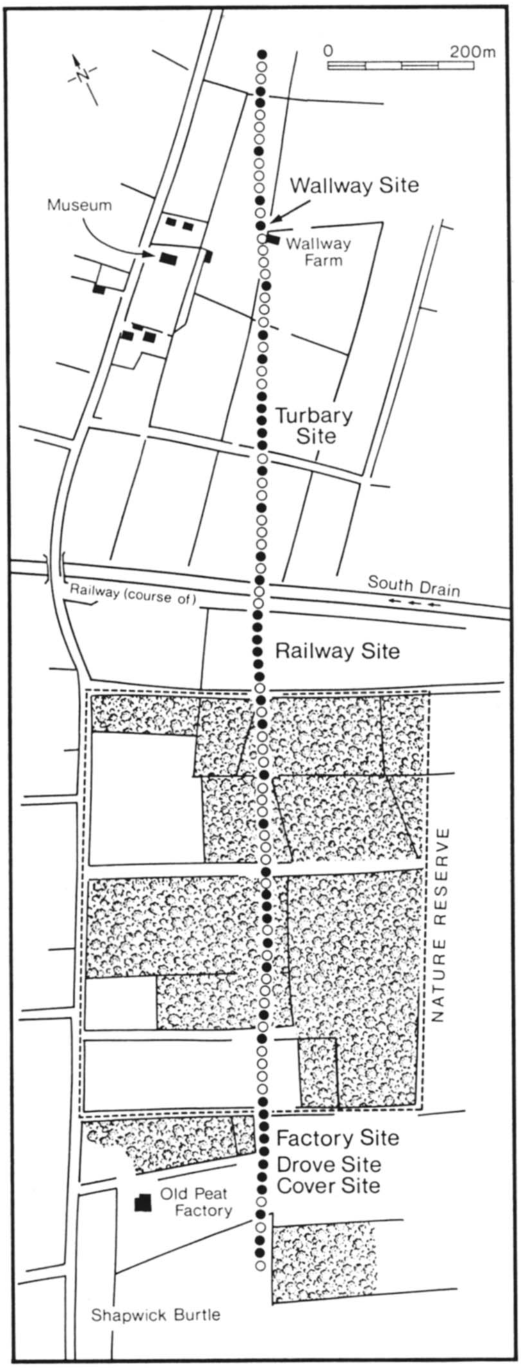

FIGURE 3 (a) View of the excavated Sweet Track near its southern end. Planks in the foreground have been dislodged by flooding in antiquity; in the center one plank remains in its original position. Several meters of peat have been removed from above the trackway, mostly cut away for fuel during past centuries. (b) The adjacent map shows the course of the track, solid dots indicating where it has been seen. The major excavation sites are named, and the Nature Reserve is outlined.

conditions, with the use of two extra rails to raise and reinforce the substructure of the path (Fig. 4).

The survival of great quantities of prehistoric wood in the Sweet Track has encouraged the development of tree-ring analyses by Morgan. In the early 1970s, samples were taken from oak planks with a view to building up a floating chronology to check against the radiocarbon dates of samples from the same wood. Shortly, however, the range of studies was expanded to include ash and hazel, and by the early 1980s almost every species used to build the trackway was sampled, as were all the components. These included pegs, rails, and stray pieces as well planks. The aims of the tree-ring studies also diversified to include aspects of internal chronology, the nature of tree-growth, and a study of the carpentry techniques used in preparing planks for the walkway.

The many oak samples examined now provide a mean curve over 400 years long; a few examples extend to sapwood and bark edge to give a felling year. Cross-matched samples exhibit a pattern which is interpreted by Morgan (1984:49) as resulting from the felling of mature oak trees up to four centuries old. The trees were then split up into planks, some coming from the outer part of the trunks, some from the inner wood, and a few spanning all the rings. An ash chronology 162 years long has also been established, matching the oak curve closely enough to indicate that the trees used to build the trackway were felled in a single episode (Fig. 5). It follows that the Sweet Track was probably built quite rapidly in a single season. A few ash samples have a pattern which extends at least seven years beyond the mass felling date, suggesting that repairs were carried out after a short while. It is interesting to find that these samples come from ash planks used in the wet northern stretch discussed above. Despite the reinforcement of triple rails, this was a spot where the original structure came apart. Other repairs are indicated by an examination of hazel wood, where again a few samples were cut several years later. None of the wood so far examined indicates repairs beyond about ten years from the time of first building, which suggests that the trackway was in use for a decade and then abandoned.

Morgan's tree-ring analyses have also revealed differences in the trees used to build the Sweet Track. Large old oaks provide the planks for most of the length, except for the southern 200 m where younger and slighter oak trunks were used. The hazel wood falls into a northern and a southern group, though not as clearly separated as the oak. There are variations in the proportion of different species used along the length of the track; holly, for example, is found only to the south, while poplar occurs to the north. It is tempting to link these differences in age, growth-pattern, and species distribution with slight differences noted in the pollen analyses from either end of the Sweet Track. Perhaps the sandy soils of the southern island maintained a different forest composition to that growing on the limestone island at the northern end of the track. Furthermore, the southern predominance of young oaks, about 120 years old, indicates an earlier clearance not seen on Westhay island where the oaks had grown undisturbed for four centuries.

The age and size of oak trunk available determined plank-making techniques (Fig. 6). Examination of cross-sections of the planks shows that the majority of the

FIGURE 4 A reinforced section of the Sweet Track, Turbary Site; with triple rails to stabilize passage across a stretch of marsh that was wetter than the norm.

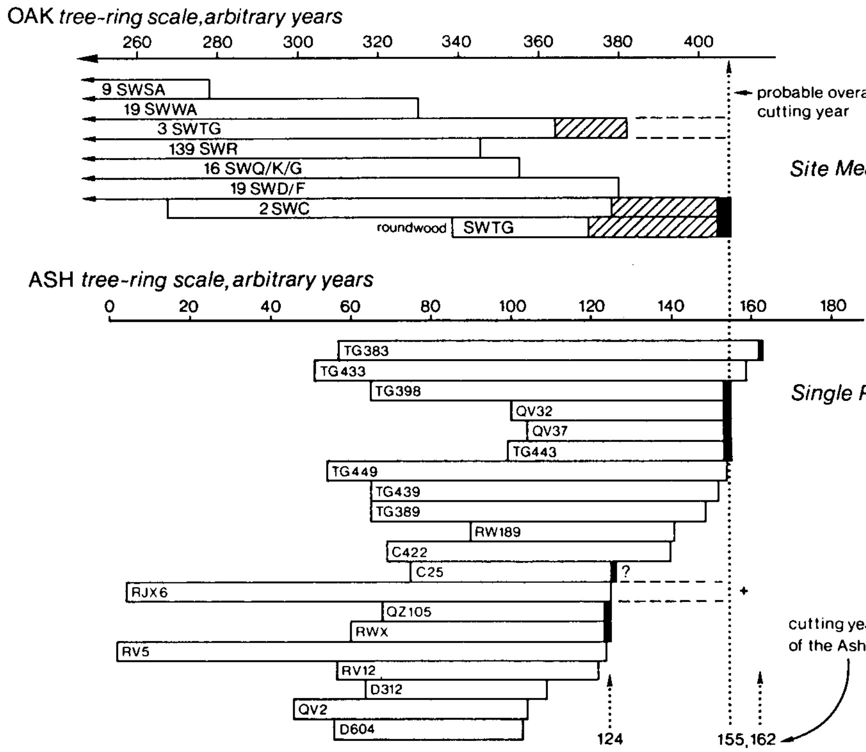

FIGURE 5 Sweet Track tree-ring studies. Oak and ash bar diagrams (at different scales) are aligned to show common felling year. A few ash pieces were felled later, for repairs, and a small groups was felled three decades prior to track building.

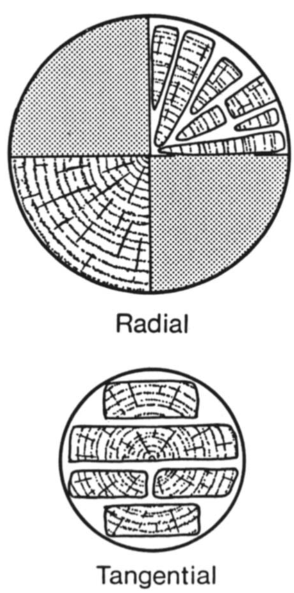

FIGURE 6 Diagram to illustrate contrasting methods of splitting large (top) and small (lower) oak tree trunks.

older trees, which had probably grown to a diameter of 1 m, were split along the rays into planks with a wedge-shaped cross-section. Each plank width was half the diameter of the tree, or less, but that was wide enough for the walkway. Half the diameter of the young oaks used for the southern planks was rarely wide enough, and a different tangential technique was employed to produce planks split right across the trunk. These tangential planks are more difficult to make than those split radially, because they cross the lines of natural weakness in the wood (lines exploited in the radial splitting). The Neolithic woodworkers clearly had the skill needed to produce planks of the required size from both old and young trees, and they were not deterred by the problems of tangential splitting.

Wooden wedge, wooden mallet, and stone axe were the likely tools for plank-making. It seems likely that simple flint flakes were used for small-scale trimming. This is indicated by the use-wear analyses carried out by Morris (1984) and by Brown (1986). A number of flint flakes have been found beside and amongst the track wood; these were dropped or discarded when the pathway was built and in use, and were subsequently protected by the developing peat from any further damage. It is rare that one can be so sure that worked flint has not been trodden on, ploughed up, rolled, or otherwise subjected to maltreatment. Examination of the flakes (Fig. 7) has revealed two distinct types of wear coinciding with differences in the type of flake: the deliberate production of flakes with a natural cortex back for woodworking, and longer flakes without cortex for cutting reeds. A third group of short flakes was found to be smeared with a rainbow-colored deposit identified as fibrous plant material, but as yet no more specific suggestion can be made as to what these were used to cut. None of these flakes had any of the retouch which is the accepted sign of deliberate tool production for the period.

Other artifacts were found protected in the peats around the trackway, including several arrowheads of retouched flint. In this case, the interest lay not so much in the flint as in the remnants of shaft, glue, and binding attached to the arrowheads. The presence of a flint arrowhead in itself implies the latter, together with bow and bowstring, but the survival of the organic remnants enables us to be precise about form and material: a split hazelwood shaft, fine binding thread made from a nettle-like fiber, and bows of hazelwood in varying sizes. Another artifact that would leave neither direct nor indirect trace on a dryland site is the yew-wood pin, a curved and pointed piece of polished wood up to 20 cm long. Several such pins have been found lying close to the track wood (Fig. 8); although their function is unknown, various suggestions can be made (Coles and Coles 1986:62).

The condition of the pins and the bows underlines the excellent preservation of wood and enables the following observation. Two imported axe blades, one flint and one jadeite, have been found associated with the Sweet Track. Both were in undisturbed contexts, and neither had any trace of a haft (Fig. 9). It is therefore likely that they were dropped or deposited without a haft, negative evidence that has to be considered when discussing their significance. With the wealth of organic material available from wet sites, it is easy to overlook what is missing. However, a clear indication of the *absence* of certain components is only possible in such a context, in contrast to a dry site where there would be no indication of whether or not the blades had been hafted.

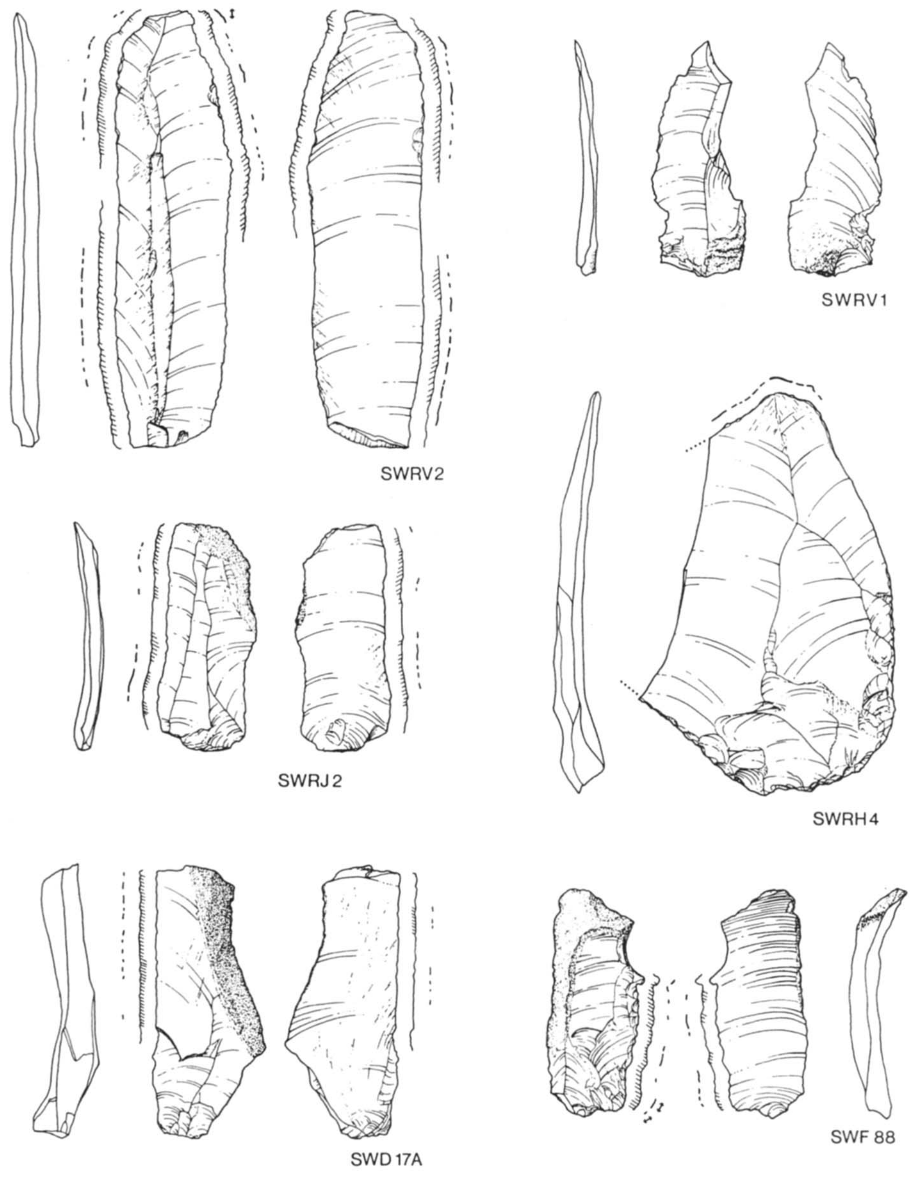

FIGURE 7 A selection of flint flakes associated with the Sweet Track and examined for use-wear. SWD17A and SWF88 were used for woodworking; SWRV2 and SWRJ2 were reed-cutting tools; SWRH4 was used to cut hide; SWRV1 was unused. (Scale 1:1.)

This paper has been no more than an introduction to the results which have come from studying the Sweet Track; interested readers will find further detail, and full references, in Coles and Coles 1986. By and large, these results come from excavations carried out at various sites along the line of the trackway. At these locations, the structure no longer exists *in situ*, yet it survives as conserved wood in museums, in the written and photographic record of the excavators, and in the

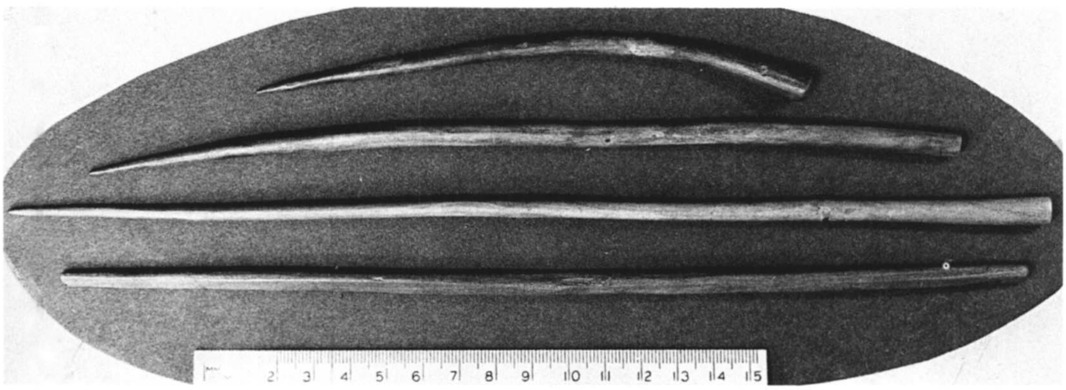

FIGURE 8 Yew-wood pins found in association with the Sweet Track. Finished examples are pointed, polished, and slightly curved when found. Their function is uncertain.

records of the paleo-environmentalists. As with the majority of wetland sites, display of excavated remains *in situ* is out of the question, for both financial and technical reasons. In the case of the Sweet Track, excavation has taken place only in a rescue context, where peat cutting or agricultural drainage threatened the structure and, for this reason also, *in situ* display is not possible.

Two developments arise from this situation: one, the construction of experimental or replica sections of the trackway for public display (and use!), and two, a determined effort to preserve *in situ* the remaining undamaged, unthreatened lengths of the Sweet Track. Long-term preservation is planned for a 500 m length of the track which now lies within a nature reserve owned and managed by the Nature Conservancy Council. The reserve is surrounded by a clay bank to minimize drainage into the surrounding, lower peat fields, and water levels are monitored regularly. The track lies undisturbed at a known level below ground surface, and whenever the ground water falls to a level near that of the highest wood of the track, a pumping system is activated to ensure that the whole structure remains fully waterlogged. Preservation in this case requires constant checks on water levels, and such must be the case for all wetland sites where an attempt has been

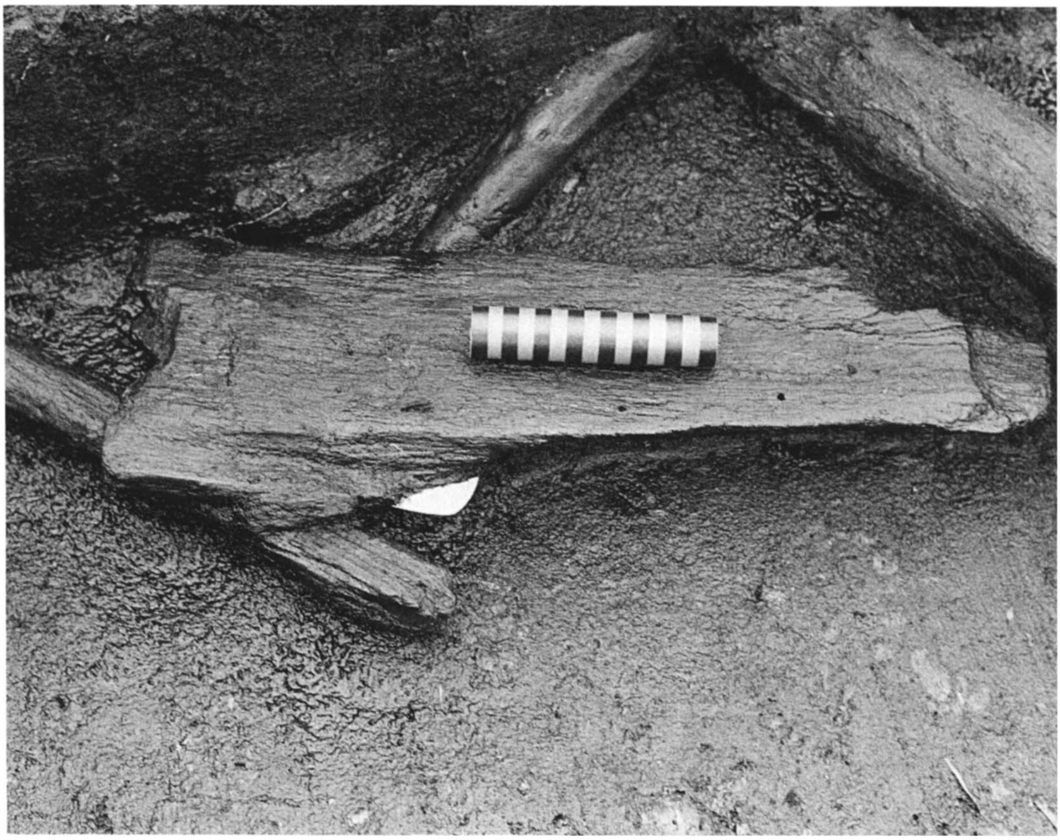

FIGURE 9 (a) Jade axe lying beneath a plank from the Sweet Track, Railway Site, with (b) a view of the complete axe. No haft was present. A flint axe was found in similar circumstances at the Factory Site.

made to keep them permanently waterlogged. A single short dry episode can defeat the whole object of the exercise.

The Somerset Levels as a wetland region, rich in archaeology, can be seen to have the same need of display and preservation as the Sweet Track, and the efforts of the Somerset Levels Project are directed increasingly towards these ends. Our success will depend on many variables, from national environmental policies and

the changing nature of agricultural subsidies, to the level of local interest in and concern for the unique character of the Levels.

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WET SITES ARCHAEOLOGY AT RED BAY, LABRADOR

James A. Tuck

DURING THE PAST DECADE Memorial University of Newfoundland has been part of a large project to investigate the remains of sixteenth century Spanish and French Basque whaling stations along the north shore of the Strait of Belle Isle. The Straits, which separate northern Newfoundland from the mainland of Canada—southeastern Quebec and southern Labrador—are a "resource funnel" through which many species of fish, birds, and mammals migrate annually. The area has therefore attracted many visitors—Eskimos and Indians, the Norse, Basques, Bretons, Jerseymen, Americans, and others—since before the beginning of recorded history. Soon after the rediscovery of the Strait of Belle Isle in the early 1500s Europeans began a regular summer codfishery there and must immediately have noticed the presence of large numbers of whales which passed through the Straits annually. Since some of these codfishers also participated in the Bay of Biscay whale fishery, exploited by Basques since at least the twelfth century (cf. Proulx 1986: 15ff), the economic potential of whaling in the area was soon recognized. By the late 1530s ships were fitted each spring to sail to one or another of more than a dozen southern Labrador harbours to exploit the whale fishery. In 1977 our attention was called to the area by Selna Barkham whose archival research in the Spanish Basque country indicated an industry of unexpected proportions and, furthermore, suggested specific locations where the remains of Basque shore stations might be found (cf. Barkham 1977, 1978).

Among these places was a harbour called *Butus* or *Buteres* by sixteenth century Basque mariners, and one which could be equated, on the basis of sailing directions and descriptions of the harbor, with the present-day port of Red Bay. Beginning with a brief survey in 1977, Red Bay has been the scene each summer of intensive investigations, both on the land and below the waters of Red Bay Harbour.

Parks Canada divers have discovered the remains of three large whaling ships of the sixteenth century, a smaller *pinaza* (or pinnace), and several smaller boats from which the actual whaling was done (Grenier 1985; Tuck and Grenier 1981). The cold waters and rapidly-accumulating silt in Red Bay Harbour have preserved the undersea remains to an extent not found in more southerly locations. The vessels are probably the best preserved examples of ships of the early period of exploitation known from anywhere in the world.

Surrounding Red Bay Harbour are found the remains of shore stations which were in use from the mid-sixteenth to early seventeenth centuries and which have been the object of our investigations. This work has been funded by the Social Sciences and Humanities Research Council of Canada and the Province of Newfoundland and Labrador, and, since 1978, has proceeded with the assistance of the Canadian Conservation Institute without whose help the project would have been much less successful if, indeed, possible.

Our excavations have revealed the remains of portions of more than 15 shore stations. Stages or wharfs where whales were flensed have been recorded. These are now submerged at all but extremely low tides and, hence, are the domain of Parks Canada divers. The most impressive features are those of the tryworks, stone structures which once supported up to six large copper cauldrons in which the actual rendering of blubber to marketable oil was done. The stone structures were usually covered by a structure framed of substantial posts and beams, surmounted by a roof of red tile brought from the Old World. Cooperages, where casks were assembled, repaired, and probably occasionally manufactured, complete the features which comprised the actual industrial buildings at each shore station. In addition to coopers' tools which indicate the kinds of operations performed within the cooperages, large amounts of domestic refuse have been found suggesting not only that the coopers lived there but that they also might have enjoyed a somewhat more comfortable life style than at least some other members of the whaling crews.

Small living sites have also been explored. Some of these were for the boat crews and some were occupied by those assigned to tend the tryworks; others, whose meager remains and locations wherever shelter from the wind and blackflies was available, give no indication of who might have occupied them. Finally a large cemetery and several outlying graves have been excavated, thereby providing us with a look at the whalers themselves.

Thus far, this is all pretty standard except for the early age of the sites and the surprisingly large scale of the whaling operations which reached truly industrial proportions during the latter half of the sixteenth century. As many as one thousand whalers may have been at Red Bay alone during peak seasons, with another thousand scattered at other ports along the southern Labrador coast. The value of oil and codfish produced by these fishermen and whalers probably had a much more significant effect on the economy of Spain than is presently realized.

One of the factors which has made the sites at Red Bay of particular interest is a number of deposits containing unusually well-preserved organic materials, occasioned mostly by wet conditions. Aside from the shipwrecks and other material from the harbor bottom, these deposits include damp areas where water collects seasonally in small bedrock depressions, permanently saturated rock basins now overgrown with vegetation, peat bogs, and small ponds which have served as receptacles for refuse since the sixteenth century. The areas of preservation crosscut the entire range of features thus far discovered—from cooperage refuse to human burials—and have provided a glimpse of the many aspects of both industrial activities and day-to-day life not ordinarily available. The remainder of this paper will be devoted to brief descriptions of some of these finds and some techniques we have employed or developed to deal with them.

Good examples of the problems presented by areas which have been "damp" but not saturated since the sixteenth century are to be found in the burial areas used by the whalers. In some areas bone preservation is excellent owing to the presence of a reasonably well-drained beach deposit containing crushed shell; this preserved the bone to the extent that it could be removed easily for study. In other areas conditions were much less kind; bone was visible as dark stains *not* containing bits of gravel, which was about the only way the bone could be distinguished from the surrounding soil. The condition of the bone was so degraded that it could be removed only with the aid of a support. The use of car body filler as a substitute for plaster of Paris in otherwise standard block-lifting techniques, proved successful for this purpose and was employed on two burials. However, since the bone could not be conserved after removal and no useful information was obtained from the skeletons thus removed, the practice was discontinued, observations made in the ground, and the skeletons reburied in a layer of sifted shell which might preserve them for a few more decades.

In a few instances the same conditions which worked against the preservation of bone were favorable to the preservation of other materials. In one case a set of preserved clothes, consisting of a pair of knee breeches and upper garment, were exposed after approximately ten days of careful excavation (Fig. 1). Because of the flat and very thin nature of the textile it was obvious that traditional block-lifting systems using plaster or car body filler would not work. Nor was it possible to undercut the burial since it rested on bedrock. Instead, Judith Logan, of the Canadian Conservation Institute, adapted a "nap-bonding" technique to provide support for the garment. Strips of gauze saturated with Rhoplex, an acrylic emulsion, were applied directly to the textile using acetone as a solvent. This bonded to the textile and provided support during the lifting process. The object has now been conserved and is stored in a padded support which allows it to be inverted for study. A plexiglas cover also allows the object to be displayed.

Other burials in a poor state of degradation were discovered during the summer of 1986. One example consisted of a typical extended burial bearing on the chest a large wooden cross and resting on what once was textile (Fig. 1). Since the cross was the first item of grave goods to be found in more than sixty burials, and since the textile appeared to be the remains of a cloak or cape, including braided(?) ties on the front, it was decided to attempt to remove the entire feature *en bloc.* Plaster was clearly unsuitable, and the nap-bonding technique would clearly have failed since so little remained of the textile. Instead, it was decided to solidify the entire feature using dry ice to freeze it. In this case the technique worked remarkably well. The saturated organic material froze within 45 minutes while the better drained sand and gravel substrate remained unfrozen and could easily be removed. The undercut burial was lifted and placed on sphagnum moss in a custom built crate for transportation to the field laboratory. There it was cleaned and encapsulated in layers of foaming polyurethane, separated from the textile by aluminum foil, for transportation to the Canadian Conservation Institute in Ottawa. Subsequently this technique was employed successfully on a larger feature, the burial of three individuals, measuring about 2×1.1 m and less than 5 cm. thick; it weighed in the

FIGURE 1 The torso of a human burial from the late sixteenth century preserved by damp conditions.

neighborhood of 223 kg. Examination at the Canadian Conservation Institute (including a series of overlapping X-rays) revealed several long, slender iron objects and three iron keys accompanying the burials. If the feature had not been removed in its entirety and undergone this analysis, this information and the objects would very likely have been lost.

Perhaps the most difficult technological problem faced during the decade of work at Red Bay was the excavation of a number of small ponds used as receptacles for refuse since the sixteenth century. During the 1983 field season several such ponds on Saddle Island, the scene of most of our excavations, were found to contain organic refuse including wood, leather, and bone, as well as inorganic material such as ceramics and glass. We were more or less familiar with the techniques used to excavate mud-covered sites on the west coast of North America and, given the silty nature of the pond bottoms, this seemed to be the best way to proceed in recovering the material contained therein. The technique of draining the ponds and using a fine spray of water to wash the silt from the artifacts proved to be unworkable because there was insufficient relief to the pond bottoms to provide run-off for the water. A sump was dug in one corner of the pond but the cohesive nature of the silt was such that a great deal of pressure was required to move it when the water in which it was semi-suspended was only partly removed. The result was that all material including the artifacts ended up in the sump and all provenience was lost. The silt was not sufficiently stable to allow the ponds to be drained and excavated by traditional means.

During the last days of the 1983 season we experimented with what we think is a novel technique for dealing with these deposits. Several sections of flexible PVC pipe were used to create a siphon by means of which the silt was gently removed from the pond bottom and around the artifacts. The action of the siphon was remarkably gentle and left the artifacts in place and undamaged. There were certain drawbacks to this system, however, including the facts that water in the pond was soon depleted so that the system ceased to function, the flexible hose was not really flexible enough to manipulate easily, and priming the siphon proved a continual nuisance. There was also the possibility of artifacts being accidentally removed by the siphon, especially when the excavator inadvertently pointed to a new find with the hose. The last problem was solved simply by installing a screen at the outflow but the others proved somewhat more difficult.

At the same time that these experiments were taking place, another pond on an adjacent island and with a much greater elevation above sea level, proved to contain a wealth of sixteenth century material. Over the winter of 1983–84 an improved system of siphoning was designed. This consisted of a 3″ semi-rigid exhaust hose fitted with a shut-off valve, a small pump for priming at the lower end, and provision for dividing the upper end into six smaller, flexible hoses for removing the suspended silt from the pond bottom. A smaller pump was used to maintain a water level a few centimeters above the silt which provided good visibility and allowed the system to function continually at least in theory. This technique was used to good advantage during the 1984 season. Repriming was occasionally necessary but, for the most part, the system worked as planned and the biggest problem proved to be the fact that the only source of water to maintain a workable level in the pond was the Strait of Belle Isle in which the water temperature varied between +5° and −3°C. Heavy rubber gloves worn by fishermen and fish plant workers proved too cumbersome for excavating while the suction in the system was so great that the type of gloves favored by dishwashers had holes sucked in them within a few minutes. The cold water eventually became an inconvenience we learned to live with, if not enjoy.

A further improvement, which owes its derivation to the presence of underwater archaeologists at the Red Bay site, was developed during the ensuing winter to deal with several small ponds on Saddle Island. These ponds were located on large flat areas and at relatively low elevations. Problems with siphoning under these conditions were almost certain to be insurmountable. We therefore replaced the lower valve arrangement with an aluminum suction dredge powered by a 3″ pump using water from the Strait of Belle Isle. Water level was maintained by a smaller pump using the same frigid water. This technique worked remarkably well. The system was self-priming, no problem was experienced with clogging or with "stoggs" (as they are locally known), and the amount of suction generated was more than sufficient.

Mapping the ponds and plotting the artifacts was accomplished by a sort of "mechanical alidade" using a sheet of plywood as a plane table covered with waterproof paper. Distance and direction of finds were plotted by stretching a tape from a fixed point on the plane table centered over the same point on the ground, and depth below datum calculated with a level line and measuring tape.

The technique of excavation worked very well. Artifacts were exposed *in situ* without damage or disturbance and their positions plotted without difficulty. Most of the material from the ponds was made from wood although ceramics, glass, textile, stone, and bone were also recovered. The most informative of the seven ponds excavated was that on Twin Island because it was uncontaminated by more recent material. Such contamination was a problem in several other ponds wherein objects were sorted in the suspended silt by specific gravity rather than remaining in the relative positions in which they had been deposited. The only material from Twin Island not of Basque origin were two small carvings, a bow fragment, the shafts of several arrows, a polished slate end blade, and a nephrite(?) drill bit made by Inuit of the Thule culture. While the latter two had apparently settled to the bottom of the pond probably because they are made from stone, the other specimens were directly associated with sixteenth century Basque material. They appear, therefore, to date from the sixteenth century and may be the first evidence of a more or less contemporaneous native and European presence in southern Labrador. Subsequent discoveries have revealed both Inuit and Indian material in association with Basque features, which suggest that native people were visiting seasonally-abandoned settlements in search of European objects and raw materials, initially for their own use and eventually for exchange with other native groups.

The Basque objects originated from a nearby lookout/living site located on the bank of the pond. They include fragments of barrel staves, hoops, small boat frames and planks, chunks of much larger vessels, and native softwoods, many of which

FIGURE 2 A sixteenth century Basque whaler's costume preserved in a bog at Red Bay, Labrador. The acid soil dissolved the human bones completely, but preserved a knitted cap and human hair, a shirt and jacket, knee-length trousers, and stockings and shoes. The shoes are of leather; all other garments are of wool. (Photo by Jerimy Powell, Canadian Conservation Institute, National Museums of Canada.)

had been modified for purposes for which they were not originally intended. Long roasting spits are common and most of them still retain traces of burning. They must have been used to roast some of the many species of birds whose bones also abound in the deposit. Some of these birds may have been frightened into nets by throwing a device resembling a table tennis paddle over their heads, as is still done in the Basque country. Other objects range from a "paddle" probably used to clear blubber from the mincing table to a fine drinking glass whose sherds were scattered over about 8 m^2 of pond bottom, but which were recovered in place by carefully removing the silt in the fashion outlined above.

As most archaeologists who have dealt with wet sites are aware, perhaps the least difficult to excavate are those in which the cultural deposits have been covered with peat. Drainage may be a problem, but siphoning or pumps usually are adequate to remove standing water. At Red Bay the surrounding peat is removed with bare hands, a process which is not only the most effective technique of excavation, but also results in the excavator developing a grip equal to that of the average National Football League defensive lineman.

At Red Bay these kinds of deposits have provided evidence of construction techniques, such as the squaring of beams for the tryworks which leaves characteristic wood chips, as well as industrial activities like coopering where preserved offcuts, damaged staves, split and unused hoops, and so forth indicate the kinds of activities performed by the coopers and the tools used to perform them.

In 1986 the discovery of a human burial in a similar environment provided an unexpected look at the costume worn by one sixteenth century whaler to his grave. At some distance from the main cemetery, lying in what might originally have been a natural depression in the peat and covered by several large and small rocks, were the remains of an individual wearing a knitted cap, long-sleeved shirt and outer shirt or jacket, knee length breeches not gathered at the knee and sometimes referred to as "slops," stockings or leg wrappings, and a pair of leather shoes (Fig 2). The same conditions which preserved the woolen clothing also preserved hair, a beard, fingernails, and I suspect when Canadian Conservation Institute personnel remove his shoes, toenails as well. Many fragments of the damaged left side of the garments were recovered, hence it seems that not only will a pattern soon be available for reproduction, but that the costume itself is complete enough to be mounted in three—dimensional fashion. The condition of the wool was such that the entire costume could be lifted without support and transferred to a support for transportation to the field laboratory. Cleaning in the field allowed parts of the costume to be isolated and shipped to the Canadian Conservation Institute in Ottawa, where conservation is now taking place.

This has been a brief summary of the wet site conditions encountered in southern Labrador and how we have dealt with them. In every case the exploration of such deposits has been profitable and the information gained has far outweighed the cost of employing, modifying, or developing techniques to explore them effectively.

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A WATERLOGGED SITE ON HUAHINE ISLAND, FRENCH POLYNESIA

Yosihiko H. Sinoto

BETWEEN 1973 AND 1984 a large site complex on the grounds of Hotel Bali Hai Huahine was excavated under my supervision. The site was accidentally discovered during hotel construction. Portions of the hotel were located in low-lying, swamp lands, that needed to be filled. Fill materials were easily acquired from the spoils of digging ponds on the hotel property. Numerous artifacts were uncovered during the digging of the ponds. Among these was a whale bone object similar to the New Zealand Maori hand weapon called *patu*. Until then, such artifacts had been found only in New Zealand. To determine whether or not this object came from an archaeological context, I conducted test excavations in 1973 and, with the discovery of another *patu*—this time a wooden one—in an archaeological context, I was able to confirm that intact cultural deposits did exist. This test excavation also revealed that the site was waterlogged, and wooden objects as well as other perishable organic materials were preserved. This was the start of the long salvage project that continued for the next 10 years.

Since the site was located on the grounds of a hotel that had extensive expansion plans, I had to work quickly in order to salvage as much materials and information as possible before permanent destruction occurred. After each field season a report was submitted to the Territorial Government of French Polynesia and articles regarding the site were periodically published (see the References).

In this paper, I would like to discuss some of the problems concerning interpretation of the site as well as the conservation of the artifacts and midden materials from the site.

Huahine Site Summary: Vaito'otia and Fa'ahia

Huahine Island is in the Leeward group of the Society Islands, 177 km northwest of Tahiti, capital of French Polynesia. Huahine actually consists of two small volcanic islands, Huahine Nui in the north and Huahine Iti in the south. The islands are connected by a bridge built across a narrow pass between Port Bourayne and Maroe Bay.

Hotel Bali Hai Huahine is located in Fare, the commercial and administrative center of Huahine, opposite Ava Mo'a pass in the northwestern part of Huahine Nui.

The hotel property straddles the traditional land divisions, Vaito'otia, in the south, and Fa'ahia in the north (Fig. 1). Extensive excavations were undertaken in 1974 and 1975 in Vaito'otia, and in 1977, 1979, 1980, 1981, and 1984 in Fa'ahia. Although actual hotel expansion was not fully realized, we surveyed the areas to be affected ahead of time as we could not predict when actual construction would begin.

Both sites have two cultural Layers, IV and V. Layer V contains the cultural deposit of major importance and Layer IV contains beach sand deposited by wave action with many artifacts haphazardly mixed in from Layer V. Evidence from the top of Layer IV indicates that certain limited areas were reoccupied for religious and chiefs' residential use. The layer desginations sometimes differ in the cited references, but in this paper they have been correlated for consistency with Layers IV and V. The calibration of one wood sample from Layer V in Vaito'otia and two charcoal samples from Layer V in Fa'ahia, produces a range from A.D. 700 to A.D. 1150 (95% confidence level, Stuiver and Becker 1986).

Vaito'otia

It was while excavating at Vaito'otia that we realized the site area must have been struck by huge sea or tidal waves because of the way objects and debris were scattered in the area. We also noted the unusual vertical deposition of some artifacts in the deposits. Later, similar observations were made in the Fa'ahia site confirming our hypothesis of sudden destruction and subsequent halt of community life by a natural disaster.

After an assessment of the excavated area in Vaito'otia, I concluded that the area was used for storage houses that were built on stilts. We found the remains of stone and wooden stilts for at least four storage houses and the remains of whale bone stilts (one of them partially standing) for one house. The height of the stilts averaged about 30 cm. I based my reconstruction of the gable framed storage houses on the floor boards of hewn coconut tree trunks 4 m long, 25 cm wide, and on the inward tilt of a large post base nearby a slightly curved large post. The houses would then measure about 4 to 6 m in length, 1.5 m in width, and 2.5 m in height. The reason to assume that these structures were probably storage houses is that they were located away from the main area of activities; this is indicated by the distribution pattern of portable artifacts, the lack of fire places, and no evidence of a cooking facility or midden deposits near the structures. We still do not know what was stored in the houses, but yams seem to be a reasonable possibility.

Artifact distribution in Area A, south of the pond, and Area B, north of the pond, indicates that the center of the activities within the site complex (especially pearl shell fishhook manufacturing) was in the area already dredged by hotel construction crews, that is, the area where the first *patu* was found.

After the big storm or tidal waves, the area was covered by sand and debris and

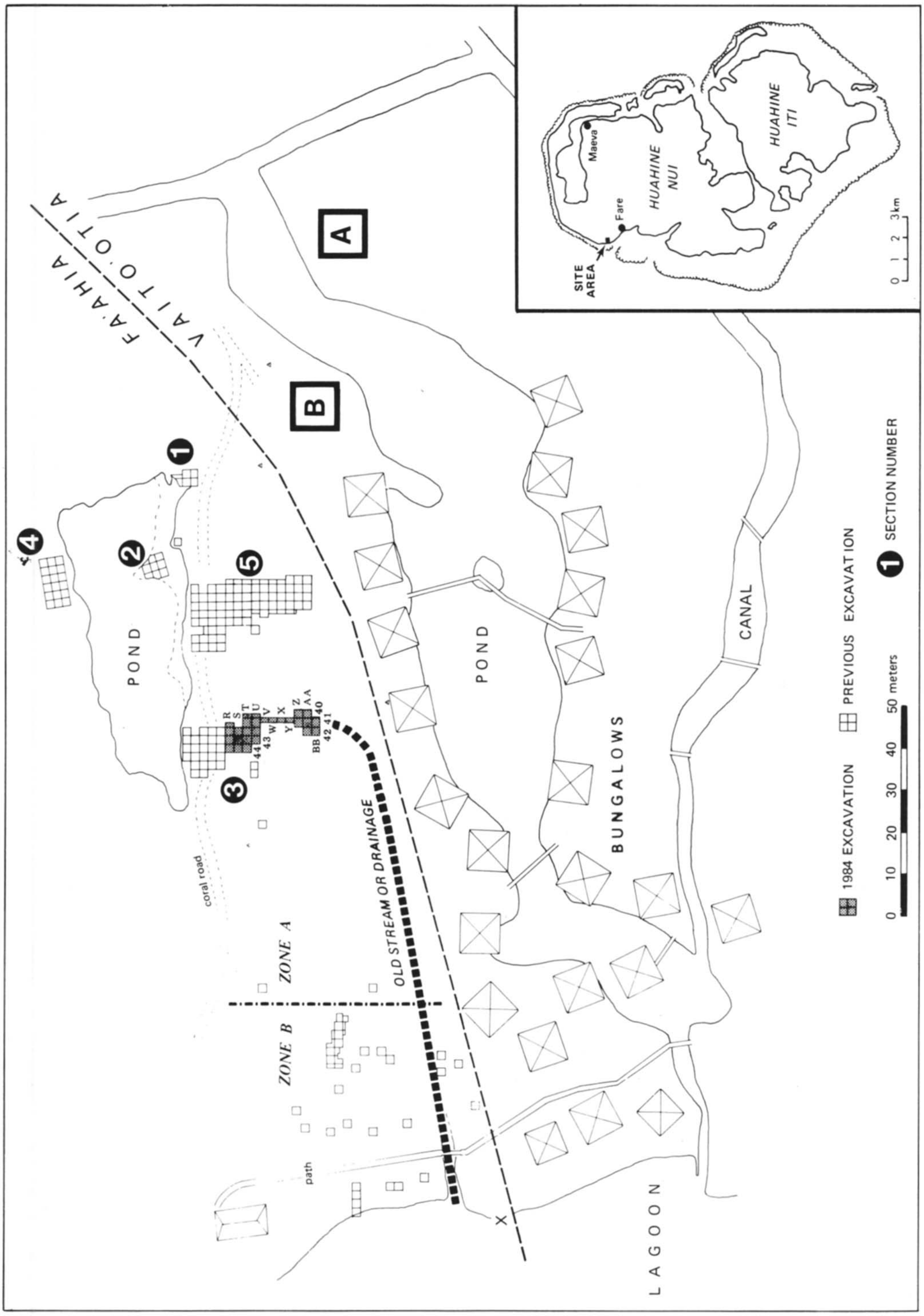

FIGURE 1 Map of Vaito'otia and Fa'ahia sites on the grounds of Hotel Bali Hai, Huahine, French Polynesia.

previous activities were not resumed. Instead, the area was reserved for religious purposes as indicated by an upright stone, a small well, and a small stone pavement, all next to each other. I have hypothesized that the small stone pavement probably supported a structure used as a gathering place for men.

The significant artifact types uncovered from the Vaito'otia excavations are archaic East Polynesian stone adzes, wooden adze handles, a wooden bow, shaped whale tooth pendants, and a wooden *patu* (Sinoto 1976, 1983 a, b, c; Sinoto and McCoy 1975 a, b).

Fa'ahia

In 1977 the hotel started to construct a tennis court near Area A of Vaito'otia. In order to construct the court they again needed fill materials and began digging another pond, this time in the Fa'ahia area. A backhoe brought up numerous wooden objects and the hotel architect, Richard Soupene, temporarily halted digging. He notified me of the findings, and with emergency funds provided by the National Geographic Society, we salvaged as many materials as possible. At the same time we placed test squares in the vicinity and divided the Fa'ahia site into two zones. Zone A is on the inland side and Zone B is on the lagoon side. Zone A was further divided into five sections. Sections 3, 4, and 5 are the significant areas in Zone A and were excavated in 1977, 1980, 1981, and 1984, and Zone B was excavated in 1979.

Zone A, Section 3.—Two large, canoe side planks (Fig. 2), a steering paddle, small one-man canoe hulls (v-shaped), small canoe paddles, canoe bailers, and numerous wooden and organic materials were uncovered from this area in a stream bed. Because we lacked experience in dealing with large pieces of wet wood (the planks are nearly 7 m long), these objects were reburied. Originally, I identified a large plank as one of several that form the platform of a large double canoe (Sinoto 1979). However, when it was reexcavated with other planks in 1981, I found them more likely to have been the side planks of a large ocean-going canoe. We also uncovered a steering paddle about 4 m long, and both finished and unfinished canoe bailers. One of them measured nearly 50 cm long and 18–20 cm wide.

Section 3 has an unusually deep deposit of nearly 2 m compared with the usual depths of 60–80 cm. Further examination determined the excavation area to have been an old stream about 6 m wide. When the big storm or tidal waves receded, the debris—including a number of artifacts that were either completed or still in the process of being made—were washed into the stream and deposited there. In addition, roots of coconut trees and other kinds of trees, probably standing nearby, fell into the stream when the banks were undercut. The trees, canoe planks, and many other long wooden objects were found lined up parallel to each other following the direction of the flow. The steering paddle and several canoe bailers found in this deposit were unfinished. This suggests that those canoe accessories were being manufactured somewhere upstream, probably at the site where the hotel dredging operation took place.

FIGURE 2 Canoe planks from Section 3, Fa'ahia.

Subsequent excavation revealed that the stream bent sharply and became shallower as it flowed towards the lagoon (Fig. 1). Our great hope was to find at least a piece of a large canoe hull in order to determine its shape. We conjectured that it would be either a rounded, dugout hull, or a square or v-shaped hull. Unfortunately, we never found any of these. The hull would have been floatable and, most likely, was swept away to the sea by the receding waters. We did find, however, a large canoe rack buried in the water at the stream mouth in the lagoon.

Zone A, Section 4.—This area was used for habitation. The standing house post bases, fallen house beams, *tapa* (bark cloth) making beater, and stone anvil indicate that houses once stood here. Also, ash deposits indicate the existence of fireplaces or cooking areas nearby. Since this area was not in the hotel expansion plan, I postponed its excavation. In 1983 and 1984, the site was excavated by the Department of Archaeology, the Polynesian Center of Human Sciences, French Polynesia.

Zone A, Section 5.—This area is identified with an adze finishing workshop in the north and what appears to have been a meeting house for high ranking community members in the south.

The raw materials of adze making, basalt dyke stones, were brought here and finished by chipping, pecking, and grinding. Grinding and whet stones also were found in this area. Yoshio Kitagawa, geologist from the Historical Museum of

Hokkaido, identified olivine basalt dyke stone as the preferred material, but the source of the rock has not yet been established (Kitagawa 1975).

Tanged adzes, indicative of late East Polynesian culture, were absent from the site, although five specimens with incipient tangs were found. It is interesting to note that 8.6% of the adzes in the Vaito'otia assemblage and 8.3% in the Fa'ahia assemblage are incipiently tanged. If we look at only those from Section 5 (Fa'ahia), 23% are incipiently tanged. This high percentage of incipiently tanged adzes in Section 5 may be significant in that it indicates the beginnings of the use of tangs to facilitate the lashing of handles. If this is the case, then tanged adzes in the Society Islands were a gradual development within the island group.

A round ended house flagstone foundation was embedded in Layer IV. The northwest rounded end and the long side on the west were intact. This is enough evidence to show that the round ended house was built during the early periods of the Society Island's prehistory. This type of the house is historically known to have been a chief's house or communal meeting house. If this type of house was built right after the disaster, it was likely to have been known earlier. The assumption that this area was reserved for either high ranking people or community leaders may be supported by the uncovering of seven large post bases by and under the round ended stone foundation. These posts were two to three times larger than those found in Section 4. Since we advised hotel executives to preserve the area for future investigation, further excavation was not carried out.

Zone B, Section 5.—According to the hotel expansion plans, the area along the beach (lagoon side) of Fa'ahia was the first to be affected by construction. We therefore returned to the island in 1979 to work in this area. We excavated more than 25 2-m^2 test pits and found no significant features except for what appeared to be the remains of a cooking house. However, due to the effects on the site of the natural disaster described earlier, many artifacts were found in a secondary deposit. One was a 12 m long log, possibly a mast for a canoe, (Fig. 3). The wood was in a good state of preservation and was sent to the Tahiti Museum. Next to it, in a parallel position was a debarked coconut log possibly used for a large house beam. Although the exterior looked very good, it was impossible to lift it as the interior was very soft and spongy. Thus, it was left *in situ*. It is interesting to note that the debris along with the artifacts was piled up against the north sides of these logs indicating the direction of the flow of the receding waters.

We placed a test square at what we thought might be the stream spill area, but no evidence for a spill was found. Later in 1982, after heavy seas eroded the beach, the spill area was located when several artifacts, including a large canoe rack, were exposed.

Test squares placed directly on the lagoon shore revealed 83 small posts in a line that continued into the lagoon. Charcoal and burnt stones located nearby indicated that this was probably a cooking house. The posts were similar to the wall posts of historically known cooking houses. There was no evidence of house foundations to the back or side of the cooking house. Also, the direction of the tradewinds from the sea suggested that habitation houses were probably built in an area that is now inside the lagoon.

FIGURE 3 Possible mast from Zone B, Fa'ahia.

Erosion of the land by the sea was indicated by fallen coconut trees in the lagoon. These trees were planted for the copra industry over the last hundred years or so. Elders in Fare also told me many times that, when they were small, the beach used to extend farther out into the lagoon than at present.

Significant Artifacts from Vaito'otia and Fa'ahia

Over a dozen *patu* (Fig. 4) made of whale bone and wood were found from the excavations and dredged sands. There is no doubt now that the *patu* were made and used at the sites. In fact, one whale bone *patu* was accidentally dug up elsewhere on Huahine. That specimen is now in the Tahiti Museum on loan. These *patu* probably influenced the later development of *patu* in New Zealand Maori culture. However, I strongly question whether the function of the Huahine *patu* was the same as that of the Maori (i.e., as hand weapons). Rather, I think they had a utilitarian purpose in the early life of the Huahine islanders. Some of the *patu* show wear on their sides, which was probably caused by a striking action. It is also possible that they had a ceremonial function.

Shaped whale tooth pendants have been associated exclusively with Maori

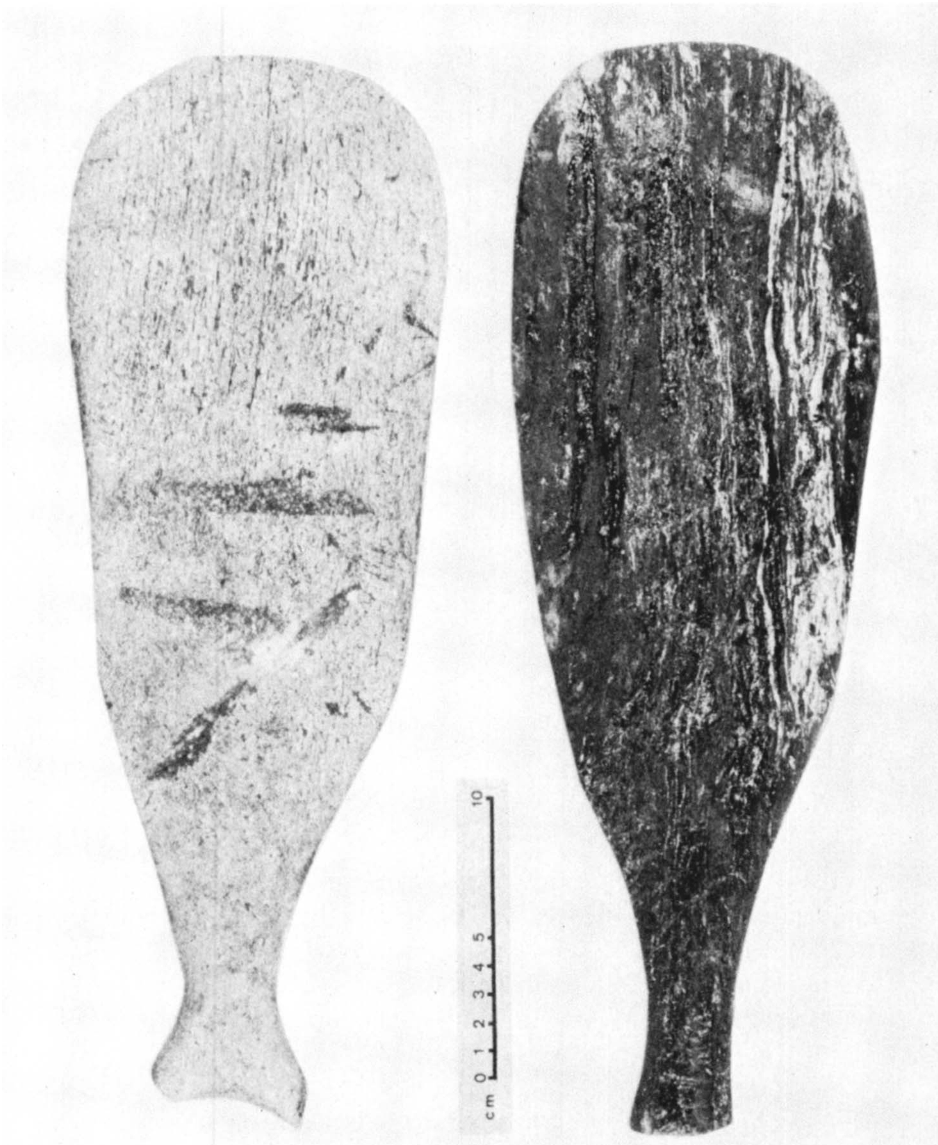

FIGURE 4 Whale bone (left) and wooden right *patu* (hand clubs) from Vaito'otia.

culture. However, in 1962 such pendants were found as burial offerings from a Maupiti burial site (Emory and Sinoto 1964) and later they were found in the Hane dune site, Uahuka, Marquesas (Sinoto 1966). Three such pendants were found from Area B of Vaito'otia and six from Fa'ahia.

Two beads similar to "reel" beads in Maori ornaments (Duff 1956) were also found. One was made of whale bone and the other of stone. The beads from Fa'ahia are more like elongated abacus beads with a hole running through either the entire longitudinal axis or just under the middle ridge.

Bows and arrows are known historically in Tahiti and some were collected by Captain Cook. In Polynesia bows and arrows were not used as weapons. In Tahiti archery was chiefly a sport where distance shooting rather than target shooting was practiced. A piece of a bow from Vaito'otia shows the long history of archery in the Society Islands. Seven wooden arrow points were found for the first time in Fa'ahia in 1984.

One of the most remarkable discoveries from Fa'ahia (Section 3) was an intact, lashed, hafted stone adze (Fig. 5). Numerous unfinished and finished adze handles were also recovered from Section 3. It is very important to our understanding of Polynesian prehistory to have a record of adze handle types and lashing methods, and these specimens are probably the first such examples from an early context in Polynesian prehistory (Sinoto 1983 a, b, c).

One of two large wooden containers from Section 3 of Fa'ahia was found under one of the canoe planks. Although it was shaped, it was never finished. The container is boat shaped with protruding handles at both ends and has a rounded body cross-section. The form is typically Tahitian, and is made even today. The other container is a much larger one with badly deteriorated sides. It also has handles on both ends, but its shape is rectangular. The large container is 208 cm

FIGURE 5 Hafted adze from Section 3, Fa'ahia.

long, 70 cm wide, and 31 cm high. Historically, such large containers were used to prepare tapioca flour or brew beer.

Pearl shell scrapers and graters (serrated edge) were made in great quantities at both the Vaito'otia and Fa'ahia sites (Fig. 6). A number of broken coconut shells showed grating marks on their interiors indicating that the grating of coconuts to produce milk was already practiced at that time. Scrape marks found on the interior of the shells indicate that the meat had been removed (Fig. 6). A total of 174 pearl shell scrapers and 50 pearl shell graters were found.

There are also 91 turtle bone scrapers from both sites. Based on early historical information and the remains of matting found, I think these were probably used to prepare pandanus leaves for making mats and baskets (Fig. 6).

Fishhooks were made of pearl shell and mussel shell, *Pinna* sp. Mussel shell was not commonly used in Polynesia to make fishhooks, but they were used during the early period in Huahine. Mussel shells found in an archaeological context are extremely fragile and until we started excavating Section 3, we were not able to retrieve them. When the shell is fresh it is strong, but in the site even a drop of water shattered the shell into fiber-like pieces. Extreme caution was required to retrieve them. The mussel shell hooks were made from the outer layer, which is usually two or three times thicker than the inner shell. Mussel shell hooks from

FIGURE 6 Pearl shell grater and scraper, and turtle bone scrapers from Vaito'otia.

Section 3 are large and recognizable in the mud. The height of these hooks range from 24 to 136 mm, the width from 22 to 74 mm, and the thickness from 3 to 7.5 mm (Fig. 7). Two pearl shell hooks from Vaito'otia are comparable to the large mussel shell hooks (Fig. 8).

We found a number of large bonito lure shanks. Their forms are typically archaic East Polynesian. Notably, none of them are finished (Fig. 8). Holes used for tying the shank to the main line had not yet been drilled, and no lure point (hook) attachments were found. This seems especially strange since the midden analysis from the sites indicates that tuna and bonito were caught in greater quantities than other fish.

Midden Material Analysis

Foss Leach and his colleagues from the Anthropology Department at the University of Otago were kind enough to identify and analyze shells and bones from Sections 3 and 5 of Fa'ahia (Leach et al. 1984). Two turtle species, Green turtle (*Chelonia mydas*) and Hawksbill (*Eretmochelys imbricata*), are the most abundant. Leach and his colleagues counted 25 individuals in Section 3. Small quantities of dolphin, large cetacean, pigs, and dogs were identified.

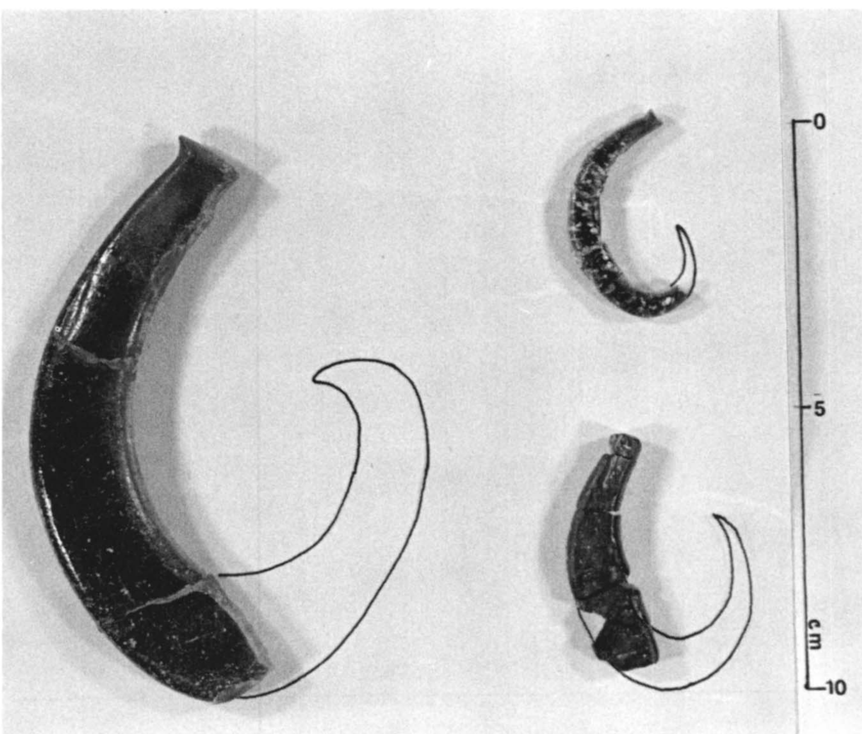

FIGURE 7 Mussel shell fishhooks.

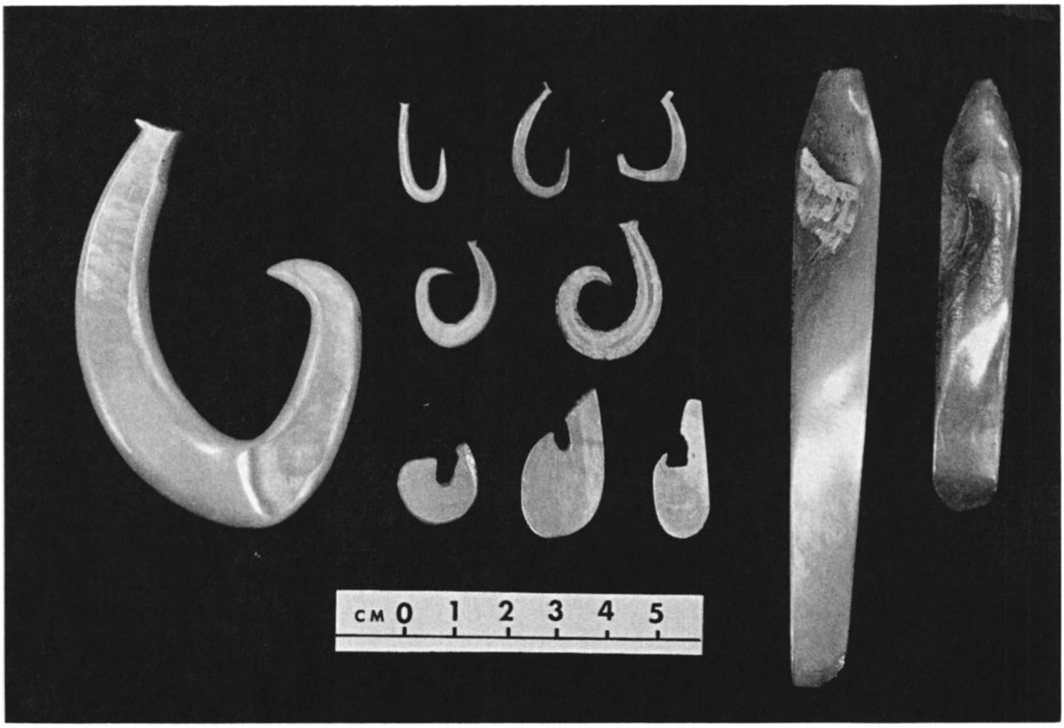

FIGURE 8 Pearl shell fishhooks, fishhook tabs and unfinished bonito lure shanks.

A total of 25 species of fish were identified in the midden. The most abundant, about 20%, were tuna and bonito, about 18% were trevally, and about 14% were parrot fish. Since there was so little evidence of completed bonito lure hooks, baited hooks and nets were probably used. It is possible that some kind of fish weir was built in the lagoon. A small fragment of 6-cm mesh net was uncovered from Section 3, which supports the idea that net fishing was probably already being used in this early context (Fig. 9).

Identification and analysis of fishbones from the 1984 excavation of Section 5 were performed by Akira Goto, of the Anthropology Department of the University of Hawai'i, with similar results (Goto 1986). Twenty-five per cent of the bones are identified as tuna and bonito.

Harpoons could have been used to catch dolphins and large tuna. A small fragment of what may well have been a harpoon was found at Vaito'otia. Toggle head harpoons were found from similar cultural assemblages in the Marquesas (Sinoto 1970). It is probable that harpoons existed in Huahine at that time. Goto found a hole in a large parrot fish skull pierced from the back, suggesting that spear fishing was practiced.

Botanical remains include great quantities of pandanus pods, coconut husks and shells. Small pieces of *kava* plant (*Piper methysticum*) were found from Area A at Vaito'otia.

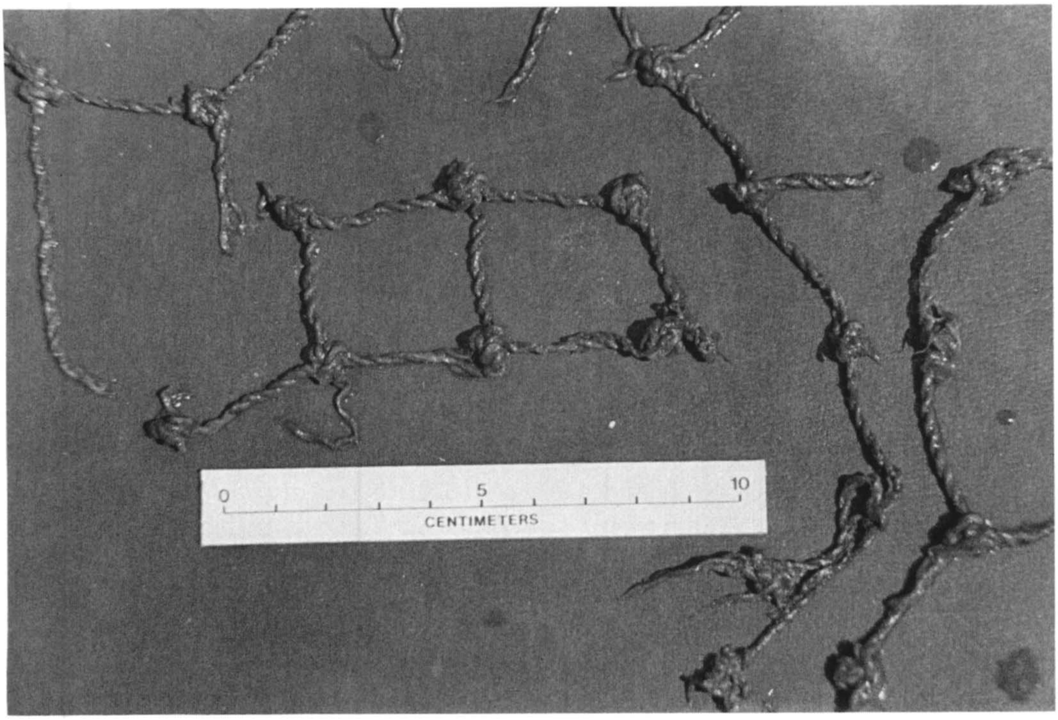

FIGURE 9 Fish net fragments from Section 3, Fa'ahia.

Some interesting circumstances surrounded the identification of the wood used for the canoe planks. Someone in Tahiti had informed the New Zealand Maori that the Huahine canoe planks were made of *kauri* wood, a wood indigeneous to New Zealand. This caused great commotion in the Maori community. As far as is presently known, there were no return voyages from New Zealand to Tahiti and if the Huahine canoe was indeed made from this indigeneous New Zealand tree it would certainly have exciting implications.

The Department of Internal Affairs in New Zealand requested that I provide small wood samplings from the canoe planks for analysis by the Department of Scientific and Industrial Research, Physics and Engineering Laboratory, Lower Hutt, New Zealand. The results of that analysis indicate that the wood samples from both the planks appear to be of the same species and are clearly of an angiosperm wood (hard wood), which did not come from New Zealand (B.A. Meylan letter of October 27, 1982). Samples were then sent to the Forest Products Division, Forest Research Institute, Rotorua, New Zealand. There, both samples were identified as *Terminalia* sp., similar to *Terminalia catappa*, which is common throughout the Pacific; however, the genus *Terminalia* and its family (Combretaceae) do not occur in New Zealand (L. Donaldson letter of Nov. 19, 1982). The wood, therefore, did not originate in New Zealand.

Soil samples were collected for soil analysis as well as for pollen analysis. Since

United States agricultural regulations precluded the sending of this untreated soil to an American laboratory, an analysis is presently being undertaken in Japan; we have also just received an offer from a laboratory in England interested in performing the analysis.

Why the Site was Waterlogged

According to Kitagawa (1975), a large *motu* (coral islet) at the northwest end of the island provides clues to the waterlogged nature of the site. The *motu* fills a part of the ancient lagoon with sedimentation and connects the outer reef to the volcanic island. The microtopography of the *motu*, such as the slight depressions in the surface, is the result of the original topography being submerged. The distribution pattern of the island's *motu*, which are concentrated on the northern and eastern sides, may indicate that the island has tilted due to recent crustal movement. Kitagawa also states that the seaward part of the site seems to have been higher than the inland area from a microtopographical point of view, and that the site is situated in a slightly depressed area. This is important for considering the environment in which the site was formed. Although these tentative conclusions are based on preliminary analyses, the possible tilting of the island might explain the submergence of the cultural layer. Kitagawa has not yet determined when this recent crustal movement occurred. He conducted his second field survey in 1984 and is presently analyzing his findings.

A recent study of coral reefs in the Society Islands, including Huahine, indicates that sea level is at least 35 cm higher today than it was about 3,600–4,000 years ago (Pirazzoli 1985). Since the site is located on an uplifted reef platform, the area must have been elevated before occupation. If one assumes that this elevation inhibited runoff, it would be the most likely cause of the waterlogging, though as a very local phenomenon (Leach et al. 1984). The water level, however, changes with the tide as well as with the amount of rainfall in the uplands, so that runoff is not completely inhibited. In any case, at the moment there is no clear explanation of why the occupational level has subsided. It does seem likely that the ground at the time of occupation was low-lying, and when it rained, swampy, which was probably one of the reasons why the storage houses were built on stilts.

Wood Conservation

In compliance with the regulations of the Territorial Government of French Polynesia, we transferred all the artifacts, including wet woods, to the Tahiti Museum. The waterlogged woods are being stored in water tanks at the museum. We have worked with the Museum in finding effective and feasible conservation methods.

In order to gain some basic knowledge of the treatment and storage of the large wet wooden objects we reburied in 1977, I requested the help of Richard Daugherty and Dale Croes, Washington State University archaeologists, as they had been working on the famous Ozette and Hoko River sites. I sent my assistant, Toni Han, to the conservation laboratory in Neah Bay, Washington to learn the basics of waterlogged object treatment. Afterwards, Jamie Barbour, wood specialist then with the Forest Resources Department of the University of Washington, was contracted to study how best to conserve our particular materials. He soon realized that conservation work on tropical woods had not been done anywhere. The first step was to identify the woods, but no reference materials were readily available. He visited Tahiti to examine the objects and take wood samples to his laboratory. He is still in the process of preparing a wood reference collection in order to determine the proper conservation procedures. The problem of establishing a conservation program was then taken over by the Tahiti Museum. They contracted Rod Wallace of the University of Auckland, New Zealand, and he is currently experimenting with various methods of conserving different types of woods. This year the Museum received a special grant to send smaller objects to a French conservation laboratory where freeze-drying methods will be applied. The large objects will be treated chemically as it is economically unfeasible at this time to provide the proper vacuum tanks for freeze-drying. Wallace is now working on polyethlyene glycol mixtures as a bulking agent for the waterlogged wood.

Understanding the Site Complex

Specialization of labor such as canoe building, stone adze manufacture, fishhook making, and wood crafting were associated with specific areas and indicate a fairly advanced society with community leaders (Fig. 10). There was also enough surplus food to create the need for specially built storage houses on stilts.

Presumably there were clusters of houses in Section 4 and also in the lagoon area. How were the people who lived there related to each other? It may be possible to approach this question in relation to the traditional organization of Tahitian society as is known from early historical times. In this sense, this early prehistoric community may have functioned as a *mata'eina'a*, or kin congregation, identified with a particular *fenua*, or district. I do not believe this community represents the initial settlers to Huahine. Rather, the people who lived in Vaito'otia and Fa'ahia had spent some time there, and developed local specializations and resources. It seems the newly calibrated dates indicate the initial occupation could now be closer to my previous assumption of A.D. 650 in view of the similar material culture assemblages of the Hane and Huahine sites (Sinoto 1983c).

Since the site is located on hotel grounds, a good portion of it has been dredged up or is still under the hotel facilities. For example, we found evidence of stone pavements and artifacts under and in the old hotel garbage pits on the east side of Vaito'otia, which indicated the existence of more features in the area. Certainly the pond areas are critical to our understanding of the whole complex of community activities and its organization.

It was unfortunate that there was so much unintentional destruction of such an

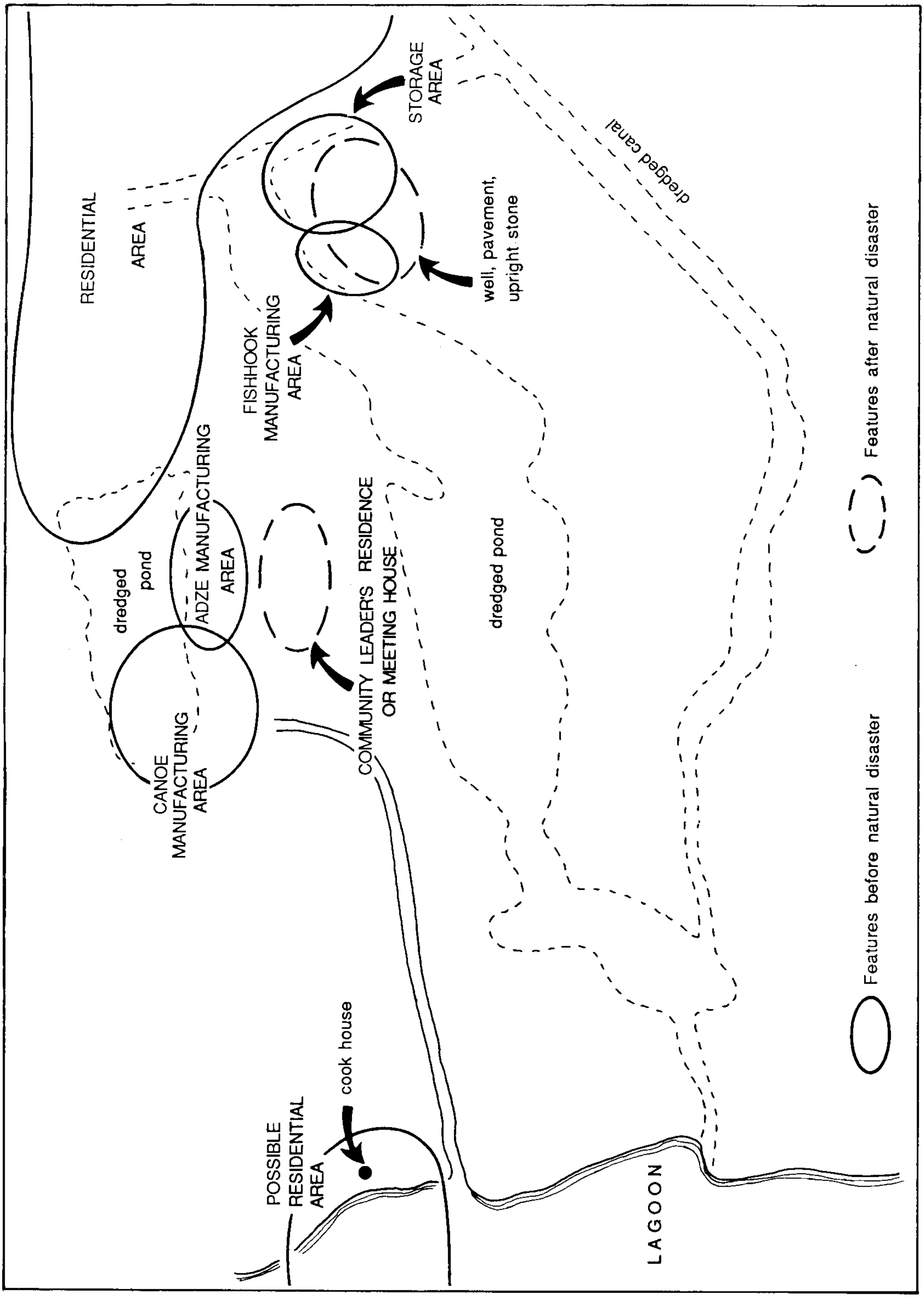

FIGURE 10 Map showing activity and residential areas in the ancient community.

important site. Yet, if the hotel had not been constructed we would never have had this wonderful opportunity to recover these intact ancient artifacts and increase our knowledge of the Tahitian and Polynesian prehistoric culture. When I was prospecting along this beach area in 1963, I never thought that such a swampy lowland contained one of the most important and oldest sites so far known in the Society Islands.

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THE SIGNIFICANCE OF THE 3000 B.P. HOKO RIVER WATERLOGGED FISHING CAMP IN OUR OVERALL UNDERSTANDING OF SOUTHERN NORTHWEST COAST CULTURAL EVOLUTION

Dale R. Croes

Introduction

Hoko River Archaeological Complex

THE HOKO RIVER site complex is located about 30 km from the northwest tip of the Olympic Peninsula, along the Strait of Juan de Fuca (Fig. 1). The complex consists of two temporally distinct areas of prehistoric occupation: (1) an upriver waterlogged (wet) and adjoining (dry) campsite area (45-CA-213) dating from 3,000 to 2,200 B.P., and (2) a rivermouth site within a large rockshelter (45-CA-21), occupied from about 900 to 100 B.P. (Fig. 1).

Excavations of the upriver "wet/dry" site (45-CA-213) began in 1973 (Croes 1976; Croes and Blinman 1980; Gross 1986; Howes 1982; Stucki 1983). Water-saturated silt/sand deposits exposed along the edge of the Hoko River contain over 25 layers of well-preserved organic vegetal mats that encase discarded perishable artifacts, including basketry, cordage, fishing hooks, hafted microlith "fish" knives, woodworking tools, and carved wood art as well as animal bone and rare shellfish remains (Croes and Blinman 1980; Flenniken 1981; Figs. 2–7). A predominance of flatfish, roundfish, and rockfish remains have been recovered from the wet site in association with over 400 wooden offshore-fishing hooks, indicative of the fisheries focus at this early site (Croes and Blinman 1980; Hoff 1980; Stucki 1983, Fig. 4).

The cut bank above the wet deposits represents a cross section of an ancient point bar, upon which the original fishing camps were established (Stucki 1983; Figs. 1 and 2). These dry campsite deposits can be stratigraphically traced to corresponding wet layers of organic material below the river high-tide line. The dry deposits lack any preserved organic debris, but they include campsite floors and contain numerous features, such as slab-lined pits, concentrations of fire-cracked rock debris, and vein quartz microlith manufacturing areas (Flenniken 1981; Gross 1984, 1986; Howes 1982). Spatial patterns of these remains suggest distinct activity areas, including part of a dwelling (Gross 1986; Howes 1982:119–121). Because of poor preservation, the dry site yielded only stone artifacts, including thick, ground-slate points, bifacially-flaked contracting-stem points, and quartz crystal microblades (Howes 1982:38–49).

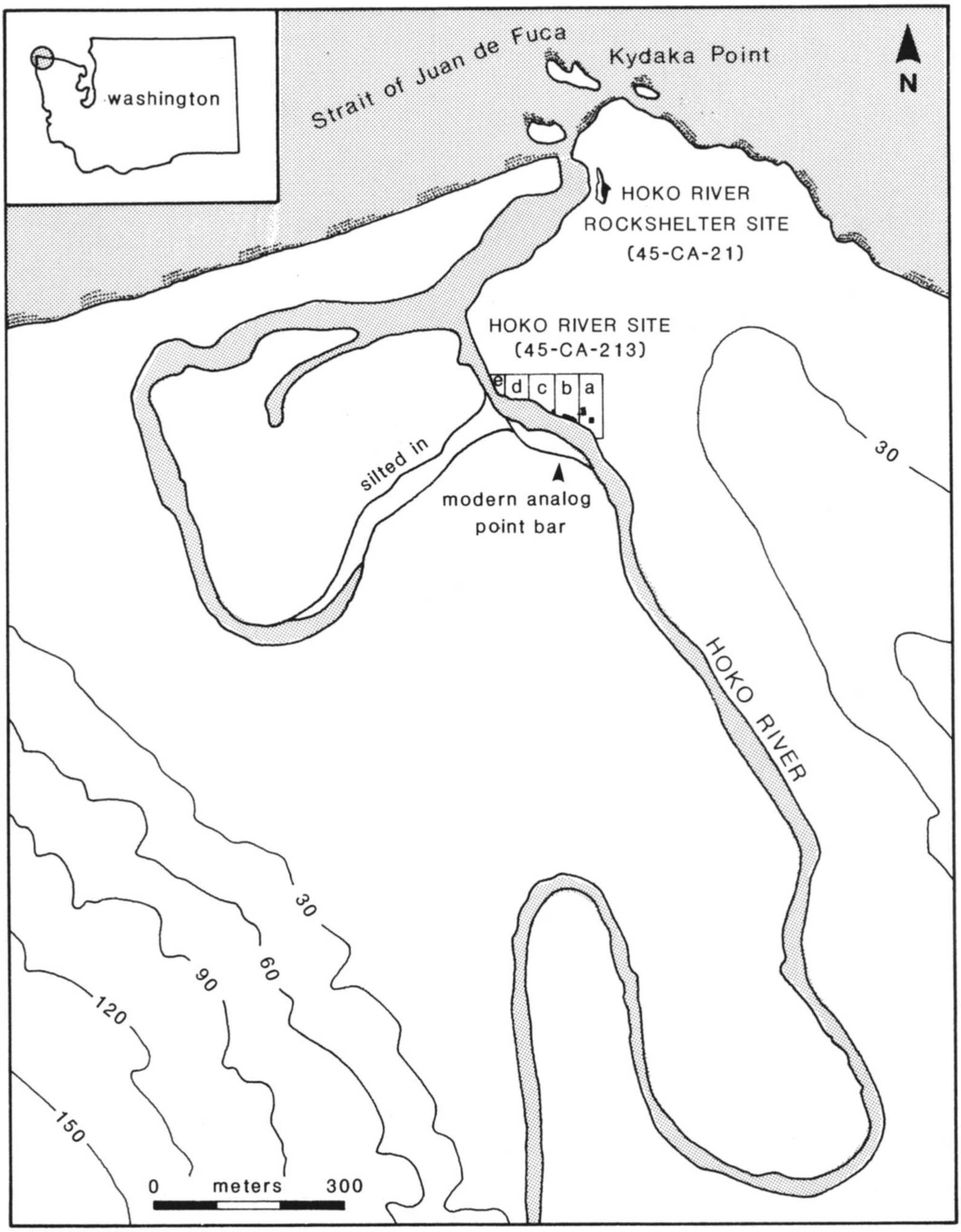


FIGURE 1 Location of the Hoko River site complex. (map by Vicki Mason.)

The rivermouth rockshelter site (45-CA-21), investigated since 1979, contains over 3.3 vertical meters of relatively undisturbed shell midden. Over 1,300 distinct layers have been recorded, representing several types of depositional features associated with occupations from the historic period back to about 900 B.P. (Peter 1986). High frequencies of fishbone indicate a primary use of roundfish/rockfish,

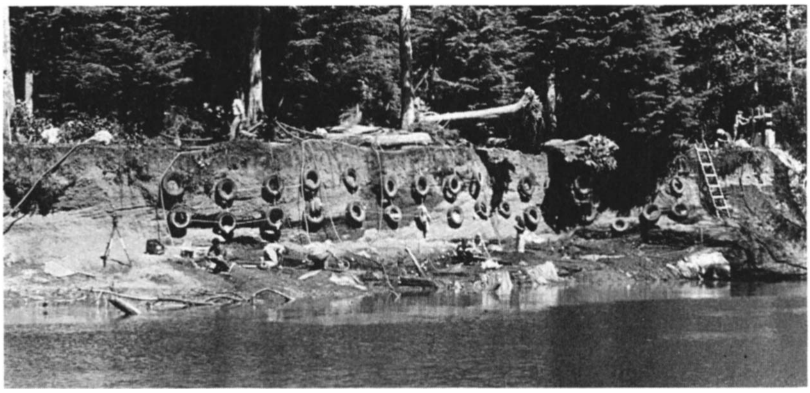


FIGURE 2 1979 excavations of the offshore wet site areas (45-CA-213 A & B). Site excavation is hydraulic using fine gauge water nozzles. Note dry campsite excavations above and to the right.

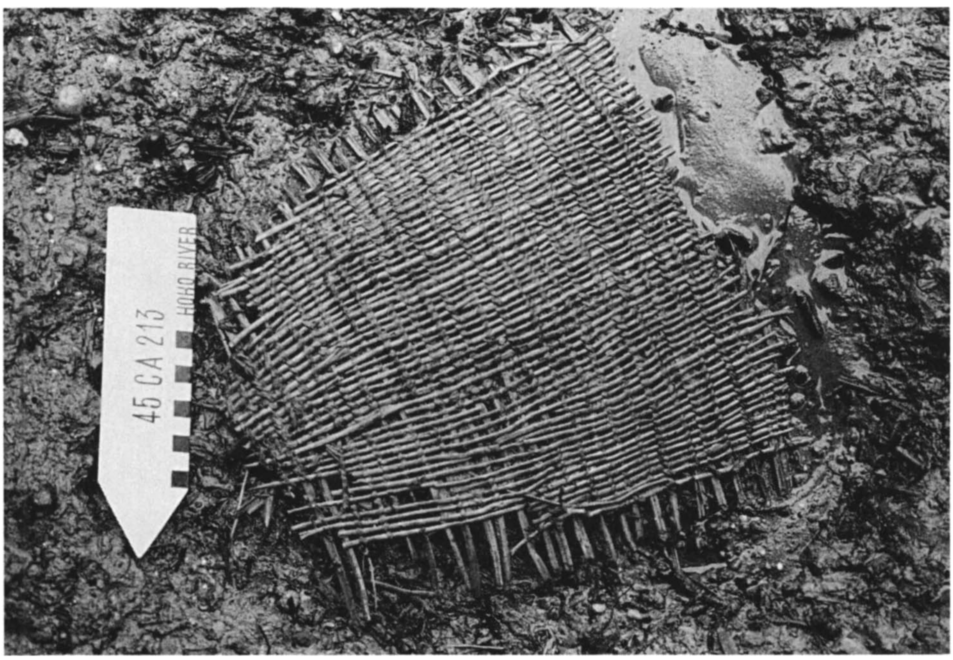
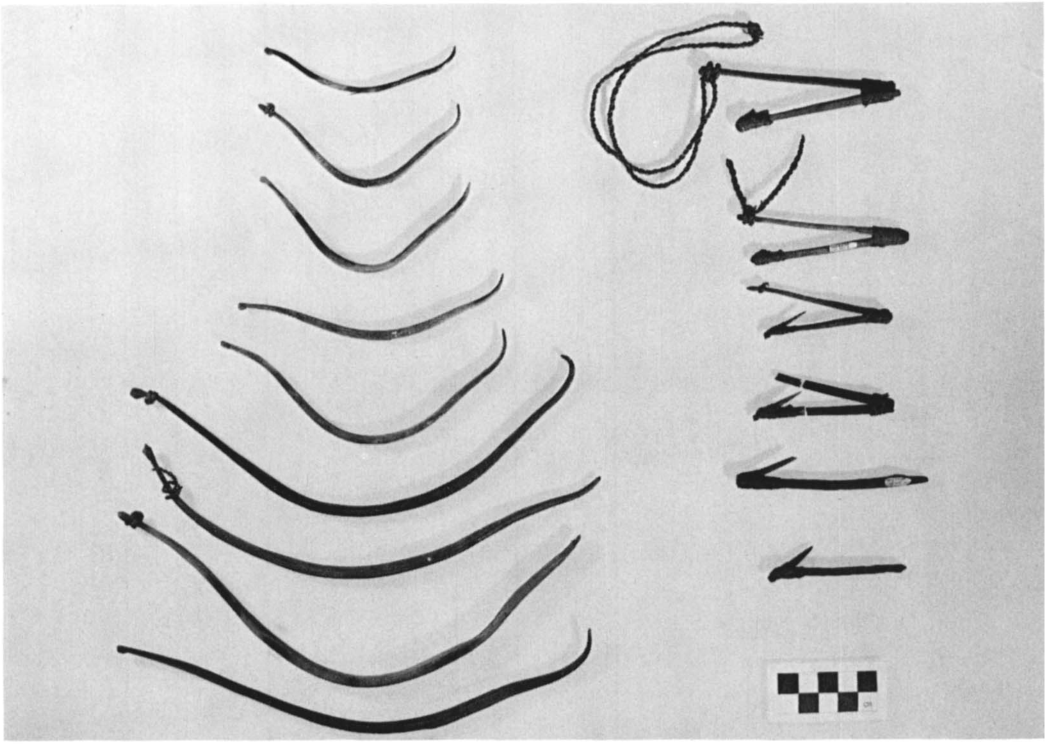


FIGURE 3 Burden basket fragment being recovered from 2,500–year–old deposits in the wet site excavations. Baskets such as this were probably used to transport fish from the beach to the onshore camp.

followed by salmon, and only limited amounts of halibut/flatfish (Wigen 1985; Wigen and Stucki 1988).

The earlier Hoko River wet/dry site, the primary focus of this paper, seems to have served most consistently as a spring and summer halibut/flatfish and Pacific cod/roundfish camp (Croes and Blinman 1980; Croes and Hackenberger 1988). We infer that the rockshelter site was used most consistently as a fall-winter and/or



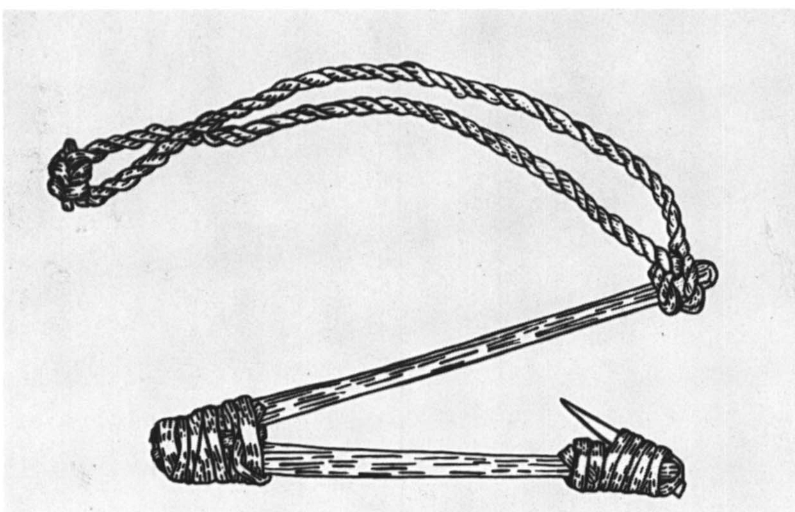


FIGURE 4 Over 400 bentwood and composite fishhooks have been recovered from the Hoko River wet site. Both fishhook types are found with double twisted spruce root string leaders. These were used to catch offshore marine fish, particularly halibut and Pacific cod.

FIGURE 5 A complete Hoko wooden wedge with rope collar set next to a broken wedge tip (left), found in a split piece of cedar. Evidently the woodworker got too close to a knot—*in situ* 3,000-year-old frustration!

spring station, from which salmon, roundfish, sea mammals, and a variety of other resources were taken (Croes and Hackenberger 1988).

Regional Archaeological Phases

The Hoko River wet/dry site (3000–2000 B.P.) produced lithic artifacts technologically identified with the Locarno Beach Cultural Type (Gross 1984, 1986; Mitchell 1982). These assemblages include thick, faceted ground-slate points, quartz crystal microblades, bifacially-flaked contracting-stem projectile points, microlithic technology, formed whetstones, chipped schist "knives," and slab-lined "pits" (Gross 1984, 1986; Howes 1982:38–49). On the basis of the lithic artifact assemblage and other data, Mitchell (1982) has designated the Hoko wet/dry site occupations as a westerly extension of Locarno Beach. This period of southern Northwest Coast prehistory has been considered a formative era of the classic Northwest Coast ethnographic pattern and is believed to reflect "a more specific adaptation to the coastal environment than did earlier types" (Mitchell 1971:70). The wood and fiber artifacts represent over 90% of the total number of discrete artifacts recovered from

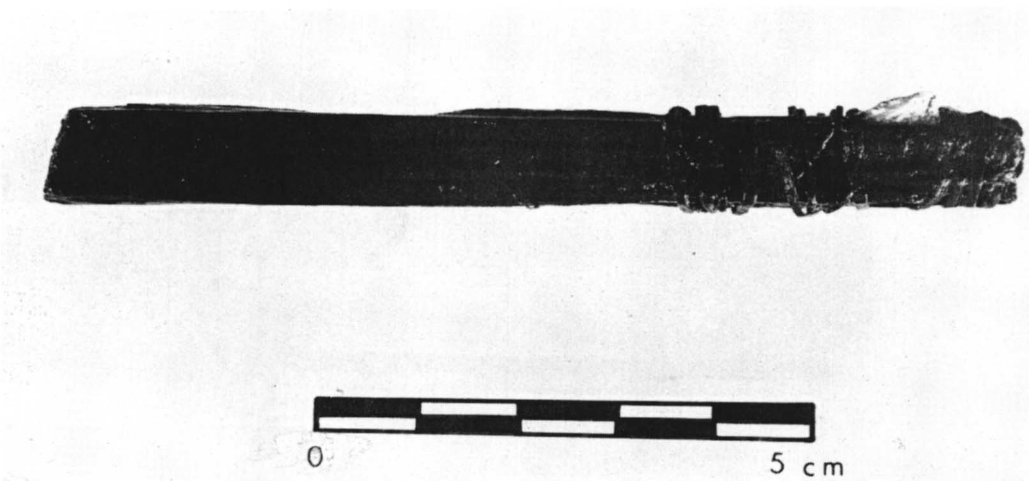


FIGURE 6 Hafted vein quartz microlith knives recovered from the offshore area. These tools are believed to have been used in processing fish. Note careful binding with spruce root strips.

Hoko and provide a new perspective on this formative period (Croes 1976, 1977, 1980a-d; Croes and Blinman 1980).

Hoko Basketry and Cordage as Indicators of Regional Style Continuity

The Hoko River wet site excavations have produced numerous basketry (n=272) and cordage (n=2,792) as has work recently completed at several other Northwest Coast wet sites (Bernick 1983 Croes 1974, 1975, 1976, 1977, 1980a-c). Since these artifacts (particularly basketry) are stylistically sensitive, they are ideal for comparative studies, often revealing measurable degrees of stylistic similarity among sites through time and across space. This degree of sensitivity is particularly useful in constructing hypotheses about cultural interrelationships between Hoko River and other coastal wet sites.

Careful comparisons of all distinct Hoko River basketry and cordage modes or attributes, types or classes, and functional categories with those from the other major excavated Northwest Coast wet sites produce statistical (degrees of similarity) dendrograms that reveal three regional clusters; these have been proposed to represent 2000–3000 years of *in situ* style continuity (Croes 1977, 1980a-c, Fig. 8).

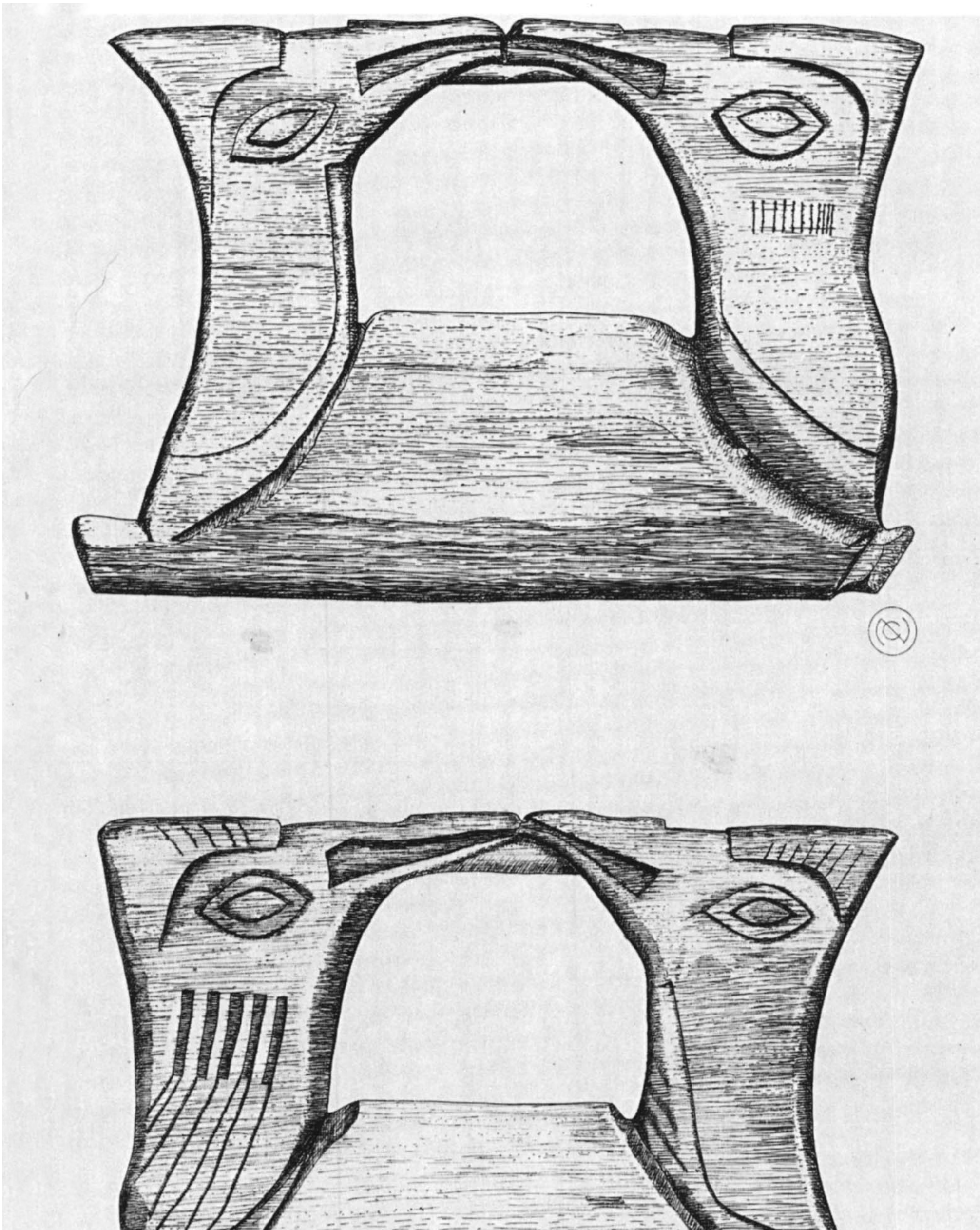


FIGURE 7 Wood sculpture, depicting two birds (kingsfishers?) beak-to-beak, forming the handle of a weaving tool called a "matcreaser." This specimen comes from below layers dating to 2750 B.P., and is considered the earliest known example of wood carved art on the Northwest Coast.

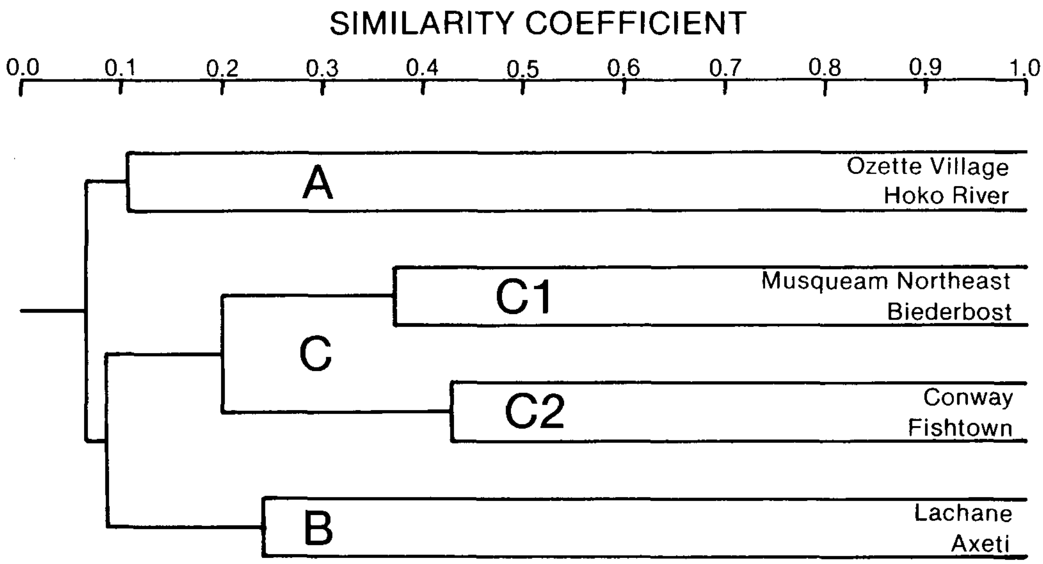


FIGURE 8 Dendrogram representing average linkage cluster analysis of Northwest Coast wet site basketry and cordage classes on a matrix of Jaccard's Coefficient. Degrees of similarity: 0 = No similarity to 1 = Complete similarity. Number of basketry and cordage classes defined = 117.

The west coast cluster of the spacially close Hoko River and Ozette Village (Figs. 8 and 9) may not appear strong, yet the wide array of primary deposited Ozette basketry and cordage recovered in a Pompeii-like preserved winter village house would be expected to be different from an assemblage of secondarily deposited basketry and cordage fragments discarded at the Hoko River fishing camp 2,500 years earlier. That a consistent similarity occurs with this difference in deposition and considerable temporal distance is distinctive, and is hypothetically proposed to reflect a west coast or Wakashan style pattern through time (Fig. 9). Interestingly, this basketry trend is also distinctive as a west coast style into the historic time period (Jones 1976: 169, especially style group 4). Prehistoric basketry and cordage to the east, from wet sites in the Puget Sound-Gulf of Georgia region, reveal a spacial and temporal sequence of similarity among Musqueam Northeast (approximately 3000 B.P.), Biederbost (approximately 2000 B.P.), and Conway and Fishtown (approximately 1000 B.P. each) (Figs. 8 and 9). This pattern is considered a hypothetical Salishan style development, progressively linked through time and across space. With the considerable spacial separation, the north coast wet sites cluster associating Lachane and Axeti sites are viewed as a northern trend (especially

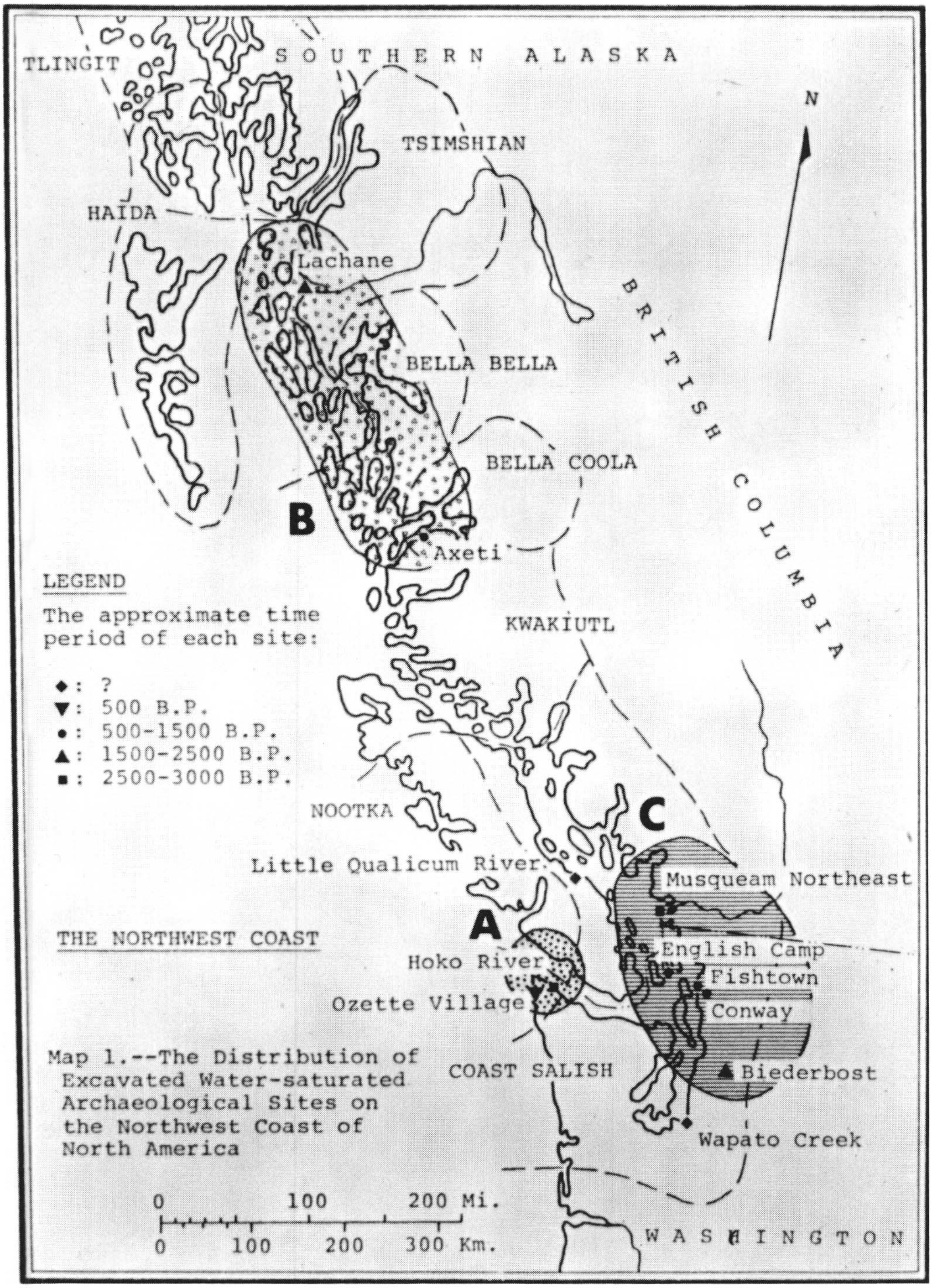


FIGURE 9 Regions of basketry and cordage style continuity on the Northwest Coast, based on Average Linkage Cluster Analyses. Region A, Southcentral Coast; Region B, Northern Coast; Region C, Puget Sound/Gulf of Georgia; Subregion C1, sites dating 2000–3000 B.P.; Subregion C2, sites dating to about 1000 B.P. (Reproduced from Croes 1977.)

with an emphasis on cedar bark basketry and cordage), but not as closely associating cultural styles across this distance (Figs. 8 and 9). A distinct pattern of similarity does exist when comparing the approximately 1,500– 2000 B.P. Lachane basketry/ cordage with the unique Tsimshian basketry/cordage in that area into the historic period (Croes 1975). Therefore, presently available Northwest Coast basketry and cordage artifacts provide senstitive data for hypothesizing continuity of cultural styles and general ethnic groups in the West Coast and the Puget Sound-Gulf of Georgia areas for as much as 3000 years.

This hypothesized regional ethnic continuity in the south Northwest Coast region appears to crosscut well established cultural phases or types (Fig. 10). This conclusion became particularly problematic as Hoko River lithic artifacts revealed nearly identical phase assemblages of Locarno Beach (45-CA-213) and Gulf of Georgia (45-CA-21), yet the Hoko River wet site basketry was analytically distinct from Musqueam Northeast (a classic Locarno Beach Phase site) and Biederbost (basketry and cordage similar to Musqueam Northeast). If this style conflict exists between regional wet site basketry/cordage artifact assemblages, but not stone and bone assemblages, then we must explain why horizontal phase lithic assemblages

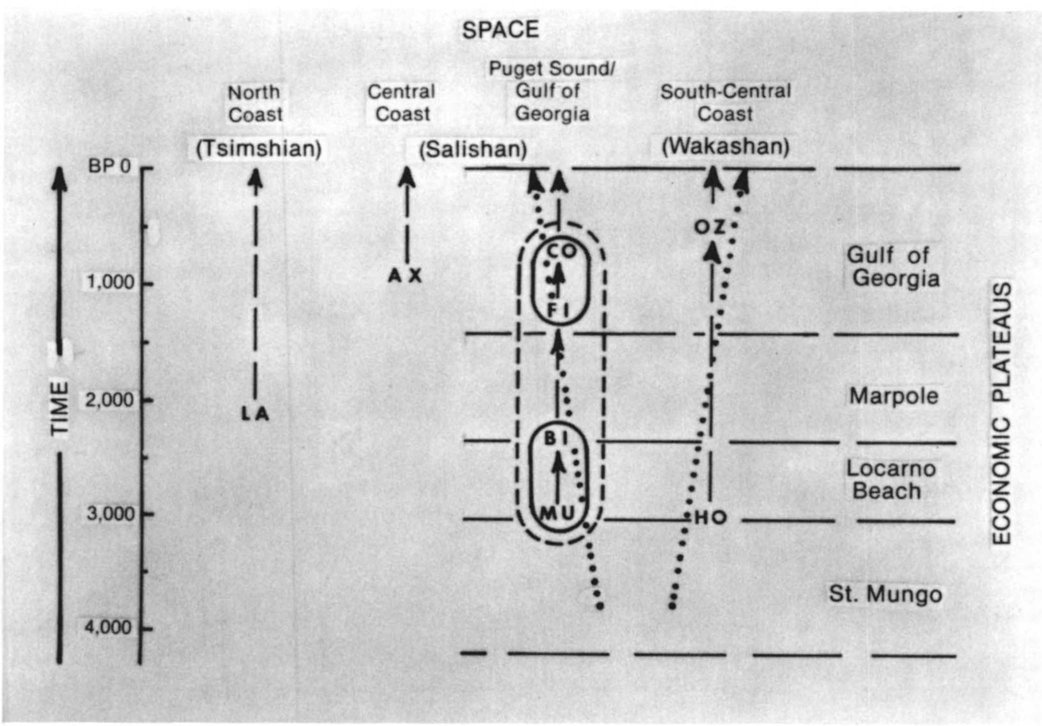


FIGURE 10 Hypothetical stylistic/ethnic continuity patterns based on basketry/ cordage artifact analyses. LA: Lachane; AX: Axeti; CO: Conway; FI: Fishtown; BI: Biederbost; MU: Musqueam NE; OZ: Ozette Village; HO: Hoko River.

might crosscut vertical cultural style trends in stylistically sensitive basketry/cordage wet site assemblages on the Northwest Coast (Fig. 10). Horizontal phases of Locarno Beach, Marpole, and Gulf of Georgia are statistically "real" (Matson 1974), but *what do they actually mean*? We have argued elsewhere that the well established Northwest Coast phases, that groups experienced in their cultural evolution, should be better termed economic stages or plateaus throughout this region (Croes and Hackenberger 1988). As populations increased, coastal groups adopted similar solutions to subsistence problems, reflected in subsistence related artifacts (stone and bone) over broad regions. Therefore, regional subsistence patterns created temporal trends commonly interpreted as phases or, as we interpret it, as a series of economic plateaus. The wet site basketry and cordage continuity patterns are proposed to be much more indicative of regional cultural continuity patterns and crosscut these broad regional economic plateaus.

In the remainder of this paper I will discuss how we would actually characterize the 2,500 to 3,000–year–old Hoko River fishing camp based on our simulation models predicting economic patterns, and as reflected by the archaeological remains from the wet and dry sites.

Reconstructing Economic Trends In The Hoko River Region

We have explored two computer simulation models for predicting the Hoko River region economic evolution (Croes and Hackenberger 1984, 1985, 1988). Model 1 projects a pre-storage economy and Model 2 represents a transition into a storage economy pattern. These computer simulation models form the basis for accessing the use of the Hoko River area over the past 3,000 years. First we will consider the prestorage and then the storage model predictions to set the stage for evaluating this 3000 B.P. time period (often considered a transitional period on the Northwest Coast).

Computer program runs of Model 1 produce a predicted proportional use of key resources by season for the Hoko region, reflecting a prestorage and, therefore, possibly early coastal economy (Fig. 11). The four seasons reflect three major economic time period divisions, with spring appearing as a transitional period. The spring season includes an emphasis on roundfish, halibut/flatfish, and elk, but a decline from winter in the use of roundfish, elk/deer, and shellfish. Fur seal and sea lions receive only a relatively limited use in spring, as they move in routes adjacent to the Hoko region in their migration north. Halibut/flatfish become a very important resource as summer approaches. In fall, salmon procurement in the region's four main rivers dominates all other resource use. In winter, the greatest emphasis is on roundfish, followed by elk/deer and shellfish.

In the storage Model 2, seasonal cycles have been programmed to occur through a sequence of several years. This model allows the exploration of resource population trends that would be affected by intensified human use (e.g., possible resource depletion). The estimated proportion of resource calories procured in summer and fall for use in winter and spring is graphically illustrated in Figure 12.

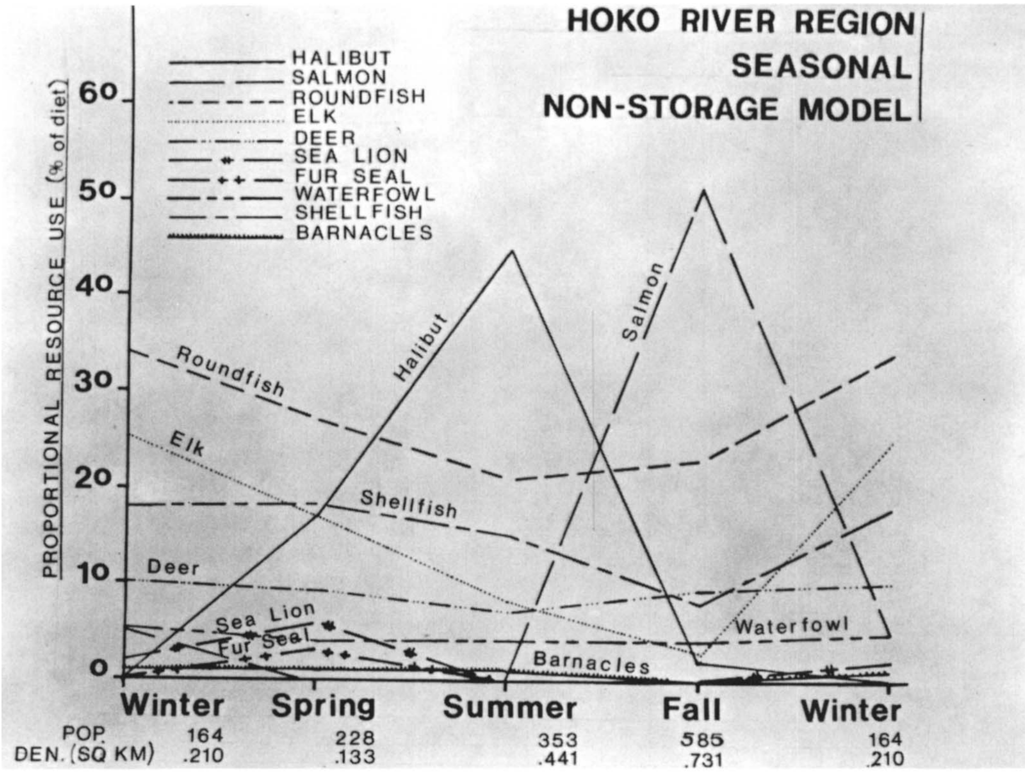


FIGURE 11 Seasonal proportional resource use and population levels as simulated in the computer program predictions for Model 1. (Croes and Hackenberger 1988.)

Shaded areas represent possible changes in proportional procurement represented in a computer run for over 50 years. In winter and spring, when shellfish populations are most susceptible to overexploitation (given desired levels of use), shellfish densities can be depleted in the Hoko region to levels where their procurement would have to be greatly reduced. The exploitation of halibut and salmon intensified with storage, as enlarging human populations increased harvesting pressure on other resources, especially deer/ elk, roundfish, and shellfish, decreasing their relative availability. In contrast to Model 1, the emphasis in Model 2 on halibut and salmon summer/fall proportional procurement would increase to 80% and 100% respectively.

From previous research, and as reflected below, we conclude that the Hoko River site fauna, artifacts, and site features reflect a storage economy that was established in this region of the Northwest Coast by 3000 B.P. Therefore we base the following reconstruction on an early storage-based economy, projecting the pattern of activities according to our archaeological evidence.

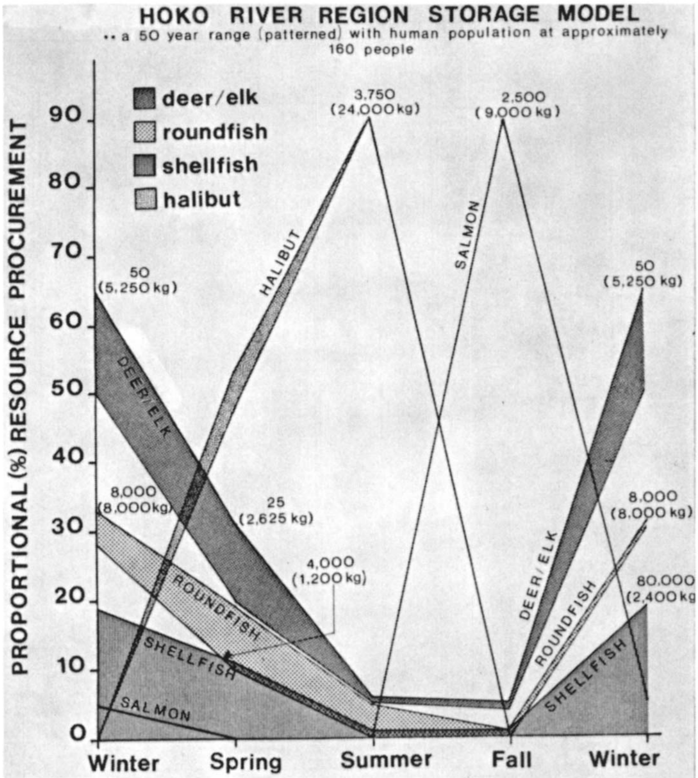


FIGURE 12 Proportional resource procurement by season as predicted by Model 2. Shaded areas illustrate range of variation over 50 or more years; absolute resource quantities are estimated for a population of 160. (Croes and Hackenberger 1988.)

Archaeologically Reconstructing The Hoko River Fishing Camp

The Faunal Evidence

At the Hoko River wet site, approximately 13 m^3 have been excavated directly from 28 well-separated and preserved vegetal mat strata dating to 3000–2200 B.P. (Stucki 1983; Fig. 2). Combined, these strata have thus far yielded 3,322 identifiable and analyzed fish, waterfowl, and land/sea mammal faunal elements. Using meat weight estimates per element, Table 1 presents estimates of proportional resource use from the nine best-represented layers (each containing 9% or more of the faunal elements recovered). Though many problems exist in estimating resource food values from faunal remains (Grayson 1984, Klein and Cruz-Uribe 1984), the predictive modeling can best be evaluated by observing general patterns observed in the faunal remains. The vegetal mats under study contain the faunal and perishable cultural refuse discarded along sequential shores of fishing camps located upon a depositional river point bar (Stucki 1983).

Land mammals (9%), sea mammals (5%), and waterfowl (6%) constitute 20% of resource use by meat weight. In terms of fisheries, halibut/flatfish overwhelmingly

TABLE 1. Percentage of resource use by wet site level estimated from meat weight using MNI for mammals and element counts for fish and waterfowls

Estimated Time Period	Level	Roundfish	Salmon	Halibut and Flatfish	Deer and Elk	Sea Mammal	Waterfowl
2200 B.P.	9 C	30	4	52	16	0	14
↑	8 AE	13	19	67	0	0	0
	7 AN	19	18	27	13	19	4
	6 AO	22	15	24	30	0	8
	5 AP	5	37	52	0	0	6
	4 AV	12	8	70	0	0	8
	3 AX	1	1	48	24	24	2
	2 AZ	16	9	63	0	4	8
3000 B.P.	1 AZZ	11	22	59	0	0	7
	$\bar{x}$	15	15	53	9	5	6

constituted the highest percentage of resource use, averaging 53% followed by roundfish (15%) and salmon (15%). Since flatfish and roundfish (averaging 68% of use) are pursued offshore and the salmon may also be caught offshore, we can expect that this procurement emphasis is not riverine.

Assuming a possible spring through fall occupation at the wet site, the prestorage model (Model 1) predicts an average of about 19% use of salmon, 25% use of roundfish, and 23% use of flatfish. These predicted proportions differ from observed average values for these fish (15/15/53%; Table 1); halibut/flatfish occur in greater proportions than expected. This discrepancy may be due to the site's occupation having typically begun or increased in size in late spring or early summer, when halibut use is expected to be high (approximately 18-46% use), possibly in combination with offshore salmon (as opposed to fall riverine salmon). However the higher emphasis on halibut use, averaging 53% at the site, does not support the prestorage pattern.

The storage model (Model 2) predicts a fishmeat weight ratio of 0.375 salmon to 0.05 roundfish to 1 flatfish, based on resource procurement. Therefore, wet site data for estimated fishmeat weight ratio (0.28:0.28:1) differ from those predicted. Roundfish occur in higher percentages than predicted by Model 2, whereas salmon occur in lower percentages than expected. Considering the storage assumption of Model 2, we would predict that storage was in practice at Hoko, possibly in an early stage of emphasis, and that camp occupations began in early spring, with a subsequently greater reliance on sun-drying spring/summer flatfish and roundfish for winter use.

Several taphonomic expectations, such as possible differential disposal of roundfish, flatfish, and salmon remains, were examined to see if they reflect a storage or prestorage pattern. If fish are being thoroughly processed for drying and storage, then considerable skeletal elements may be removed from the site; the use of fish during site occupation however would result in more of their skeletal elements being discarded on location. Examination of types of elements reveals that more flatfish (28%) than salmon (12%) cranial bones were deposited in comparison to their postcranial remains. Many flatfish appear to have been brought to the site and processed for drying; the heads were possibly consumed and discarded into the river, while the backbone sections were dried for later use. In contrast, salmon brought to the site may have been eaten fresh and all their remains discarded. This procedure may be expected to result in conserving the majority of the flatfish meat for storage but consuming fresh ocean-caught salmon, which are fatty and poor for drying.

The Fishing Equipment

Several wet site artifacts reflect the fishing industry projected from the preserved faunal remains. Foremost, over 400 wooden shank fishhooks have been recovered from along the riverbank, mostly broken and discarded, but easily reconstructed (Fig. 4). Approximately one—third of these hooks are bentwood types, believed from experiments to be used mostly for Pacific cod. The remaining two–thirds are composite hooks formed in a v-shape by binding two Indian plum wood shanks together and adding a bone barb (Hoff 1980). This hook type is believed to have been used mostly for flatfish. The large numbers of these preserved wooden hooks nicely compliments the faunal data, demonstrating the offshore emphasis on hook-and-line fishing from the Hoko camp.

Other related equipment includes thousands of pieces of spruce root two-strand strings, some of which are attached as leaders to these hooks (Fig.4). Also found are cedar split-wood line-floats. In combination with ethnographic data, we can confidently reconstruct the composition of the entire fishing gear, and have replicated the procedure.

As an experimental archaeological study, and to better understand the function of these common 2500–3000 B.P. hooks, we have worked with Makah elders in duplicating and using this fishing gear off the Hoko River mouth. Since we had little success at first, we tried the fishing experiments under more controlled circumstances at the Seattle Aquarium. In this setting we could observe how the hooks performed, *and* how the fish actually reacted to the hooks. Although the aquarium did not have any halibut, they had many of the other fish reflected in our Hoko fauna, especially Pacific cod. From these experiments we realized our hook barbs were adjusted wrongly, needing to be moved further into the v of the composite hooks, and with that adjustment the hooks performed well, catching several varieties of fish. The Pacific cod would strike very hard, often breaking the replicated composite hooks exactly as we find them in the Hoko site. From this information, and the fact that ethnographic northern tribes (e.g., the Haida) use more flexible bentwood hooks to catch Pacific cod, we conclude that the composites were mostly designed for flatfish and the bentwood for the more aggressive cod. In fact, once we adjusted the composite hook barbs, we were successful in catching flatfish in the traditional fishing grounds off the Hoko River.

Other pieces of equipment probably relating to fishing include a high proportion of open wrapped pack baskets (Fig.3), no doubt used to transport the large amount of fish being caught, and a number of small tight-weave baskets that may have functioned as fishhook bags.

Once the fish is brought to the camp it must be promptly butchered for drying or consumption. The hafted-microlith knives recovered from along the river bank site have been identified as fish cutting knives (Flenniken 1981; Fig. 6). These knives have split cedar stick handles, typically with a vein quartz microlith blade bound into the top edge, forming an *Exacto*-like knife. From edge wear analysis, replicative experiments, and working with Makah elders, we have demonstrated the efficiency of using these knives to butcher halibut, salmon, and other fish (Flenniken 1981). Tom Loy has completed an analysis of red blood cell residue from Hoko microblades (quartz crystal), identifying fish blood on some of them (Loy 1983).

In combination, these examples of fishing equipment demonstrate the commom hook-and-line for taking the fish, the basketry for transporting and storing them, and the knives for butchering and preparing the fish for drying or consumption.

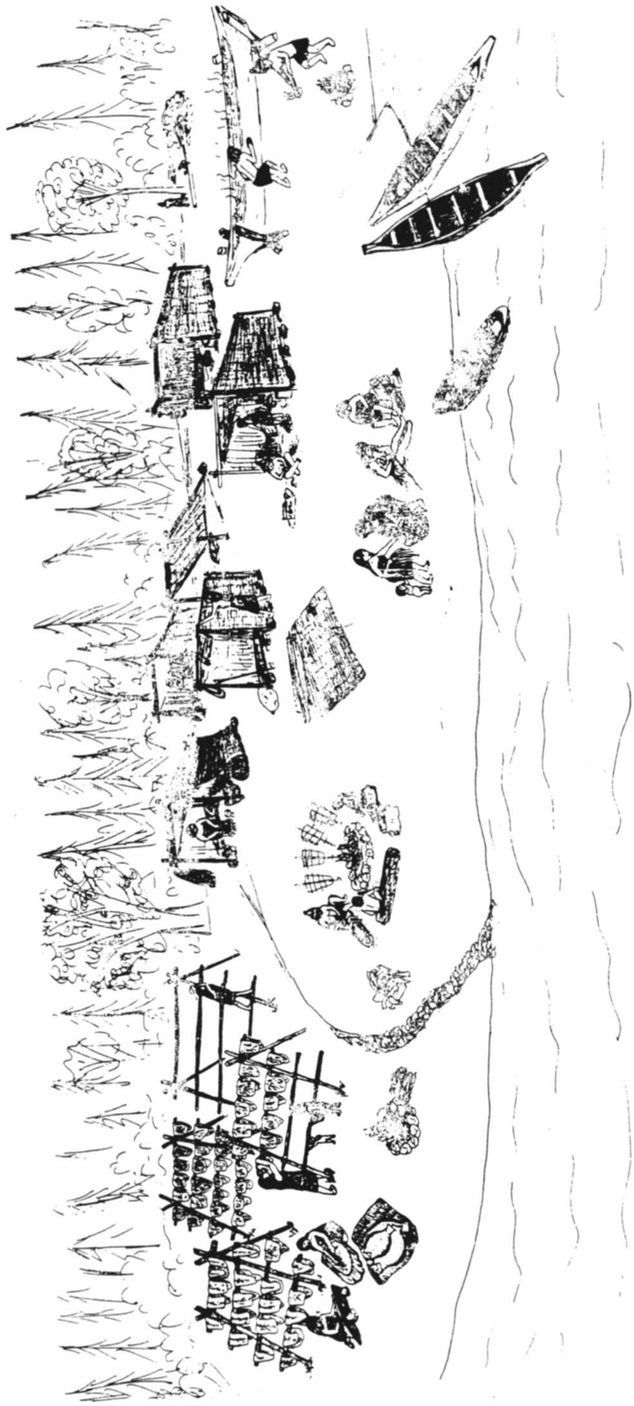


FIGURE 13 View of reconstructed 3,000 B.P. fishing camp on analog point bar (Fig. 1). Main facilities, from left to right, include fish drying racks, hearth cooking areas, tule mat covered shelters and canoe landing and manufacturing areas. (Drawing by Eileen Draper.)

The Fishing Village

The camp itself was situated on a river point bar, providing a clear grassy meadow on which to build the dwellings and drying racks. The ancient river point bar has been tectonically uplifted approximately 1 mm per year since occupied, and therefore is now about 3 m higher in surface elevation (Stucki 1983). A recent shift in the river (in the 1930s) has cut into this ancient bank, exposing the uplifted riverbank and riverbottom containing the waterlogged deposits. This shift has also begun depositing a new river point bar directly opposite the Hoko wet site. Since this recent river bar is a close analog to what existed on the archaeological site side of the river 3,000 years ago, we have carefully examined this point bar to determine how it has formed three-dimensionally (Fig. 1). Since our site exposure is a two-dimensional riverbank, we used back-hoes to "dissect" the recent analog river point bar to record and analyze its depositional characteristics. From this work we gained an excellent idea as to how the ancient point bar was formed and how the village sat on this bar (Stucki 1983; Figs. 1 and 2, and 13).

Excavation of the surface of the 2000–3000 B.P. dry site gave us an understanding of how the ancient camps were actually organized (Gross 1986; Howes 1982). The remains of a dwelling indicated the shelters were approximately 5x6 m in surface area and were probably pole structures covered with mats (anchor rocks lined the edges). This kind of mat covered dwelling is common in ethnographic fishing camps, since they are seasonal and, as predicted, occupied in the seasonally pleasant spring/summer coastal weather. From this information we reviewed the basketry materials recovered from the wet site and concluded that these shelters were probably covered with the sewn tule/bullrush mats commonly found in the excavations (Croes 1980b:217–218). Also common are pierced strips of cedar bark, possibly forming sheets or "boards" that would cover the roofs of these shedlike structures. This is a common roofing construction for temporary fishing camp structures ethnographically used further north (Croes 1980b:219, 221; Stewart 1984:118–119; Turner 1979:85). These dwellings had a hearth near their entrances where mostly domestic debris was found. The inner walls had less debris, indicating that mats and furs for bedding were probably laid on the floors along these walls (Howes 1982: 119–121).

Around the outside of the shelters we find discrete workshop areas with preserved evidence of the production of the vein quartz microliths and chipped schist knives. Discard areas for the broken boiling stones are found especially concentrated in old chute canals on the river bar, where the area would be too muddy for easy foot traffic.

Other main facilities were the canoe runs and drying rack areas. Along the upper areas of the waterlogged river bank we have encountered rows of horizontal poles that had been staked into position and were probably platforms for moving dugout canoes onto the beach without damaging their bases. On the sunny southern reaches of the bar we find signs of numerous postmolds, probably forming the base of fish drying racks (Gross 1986). Around the base of these racks we find less structured charcoal hearths, probably to keep insects away, and possibly to assist in drying.

Other village equipment found in the excavations include wood-working tools and debris in the form of adze blades, wooden wedges, and thousands of woodchips (Croes 1980d; Flenniken 1980; Paden 1980b; Fig. 5). The production of shelter poles and drying rack poles, splitting firewood, splitting planks, line-floats and boards, and possibly adzing canoes may have been common tasks at this camp.

Basketry and textile manufacture was also common, as evidenced by the thousands of pieces of basketry and cordage debris found at the wet site (Paden 1980a). The inhabitants were probably making and repairing the sturdy pack baskets, flexible bark bags, and clothing.

The People

The occupants of the early Hoko fishing camp, besides being hypothetically related to the later Westcoast cultures, as suggested from their basketry and cordage styles, dressed in similar woven clothing. Shredded cedar bark capes and skirts that are open-twined are common (Croes 1980b:218–219). Hats are of two styles, a distinct knobtop and a flat top variety. Since the knobtop hats were strictly associated with noble class status people in the historic West coast period and at the late prehistoric Ozette site, these ancient Hoko hats may reflect an early formative period of social statuses and their markings (Croes 1977:409–439, 1980b: 215–217).

Conclusion

The combination of wet site perishable artifacts, and dry site camp context data, give us a unique reconstructed glimpse of life 3,000 years ago in this area of the Northwest Coast of North America. The predictive modeling produces a possible range of economic settings for this formative period. From the archaeological data, the Hoko River site prefigures a Northwest Coast storage-based cultural complexity, established by 3000 B.P. We emphasize that this should not be equated with the proto-historic period, and probably was considerably different from the cultural complex at the Ozette Village wet site (which flourished 2,500+ years later). However, the stage was certainly set for the later developments we see at 2000 B.P., at 1000 B.P. and during the historic period.

As future and possibly earlier Northwest Coast wet sites are discovered and properly investigated, we will gain a much improved perspective of the cultural evolution in this region. Since Northwest Coast hunting-gathering-fishing societies developed a cultural complexity unrivaled by other non-agricultural societies into the proto-historic period, we may be able to use these kinds of data to better understand stages that other complex hunter-gather societies of the world may have experienced at much earlier time periods (for example, Jomon in Japan).

The next step in the archaeology of this region will hopefully be regional surveys accessing the distribution and characteristics of the Northwest Coast wet sites. Since eleven wet sites have been excavated, it is time to focus on the inventory of this resource in order to understand its full extent. As specific questions about Northwest Coast prehistory need to be addressed, the site which might provide possible answers could then be identified. Instead of excavating wet sites as encountered, we need to evaluate their distribution; and only excavate if (1) the site is undergoing rapid and irreversible destruction, or (2) its sampling provides the best means for examining a particularly important question of prehistory in this region. If the latter is chosen as a reason for excavation, careful preparation and appropriate funding must accompany the effort, since this resource can answer multiple questions impossible to approach without wet site preservation.

Acknowledgments

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RESEARCH DESIGN AND WET SITE ARCHAEOLOGY IN THE NETHERLANDS: AN EXAMPLE

Sander E. van der Leeuw
and
R.W. Brandt

Introduction

IN VIEW OF THE FACT that at least 40% of the total surface of the Netherlands is presently below sea level, it need surprise no one that the country has an old tradition of wet site archaeology, perhaps one of the oldest in the world. Areas below sea level have been diked in and pumped dry since at least the twelfth century and, in the process, many archaeological finds were made.

Presently, the topsoil of the areas of concern in the western Netherlands (dating to the Holocene) is 10 cm or more above the tightly controlled artificial water table but 1–10 m below mean sea level. Thus, any finds made in these areas are, in essence, made at levels directly tied to ground water. Some of the more famous finds are fishweirs like those in the Neolithic hunting camp of Bergschenhoek dated at 4300 B.C., a number of boats such as those found at Valkenburg (Roman period), and the complete settlement found on an artificial mound or "terp" at Ezinge dated about 700 B.C.

In the eastern part of the country, wet sites dating to the Pleistocene are located above mean sea level in bogs on the sandy soils left after the Ice Ages. Here, some of the famous finds are the 6500 B.C. logboat found at Pesse and the Bronze Age trackway of Bargeroosterveld which is comparable to some of the trackways at the Somerset Levels.

Not all periods of the Dutch prehistoric past are represented by finds made in wet environments. The reason for this is demonstrated by the averaged curve showing the rise in mean sea level (Fig. 1) over the last 10,000 years. Habitation remains from before about 5000 B.P. are so deep below the present mean sea level that they are outside the reach of terrestrial or even wet site archaeology. Such finds occur underwater off the coast.

Very early on, the Netherlands developed a tradition of applying ecological research to archaeology. This is partly a result of the circumstances of preservation which facilitated such research. On the other hand, it was vigorously developed and stimulated by van Giffen and Waterbolk when they were directors of the Biological-Archaeological Institute of the University of Groningen. Both men were biologists by training and, notably, van Giffen saw possibilities for this kind of research as early as the 1920s and 1930s.

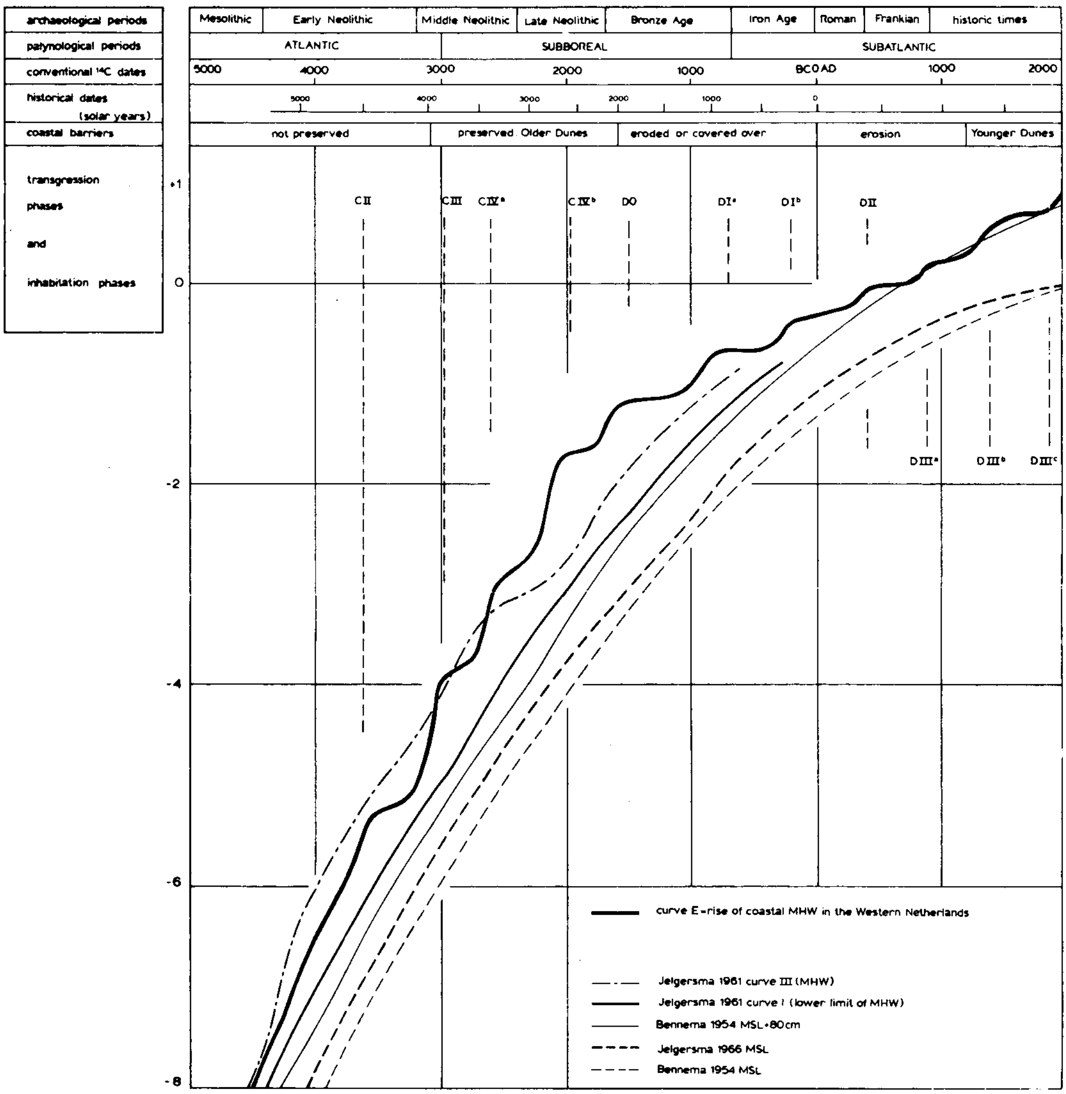

FIGURE 1 Rise of mean sea level since 4000 B.C. (Louwe Kooymans 1974).

As a result, much of the later prehistoric and medieval archaeology in the western part of the Netherlands is wet site archaeology. Often, excavations occur at levels as deep as 2 m or more below the present water table.

The older excavations were done in a detailed manner, by hand, without the benefit of power equipment just as wet site archaeology is presently executed in other parts of the world. Much often remained to be improved, however, in the ways of registering, preserving, and conserving finds.

Since the Second World War, many changes have occurred which can be categorized under two headings. First, there were technical changes brought about by general developments in technology, rising labor costs, and other circumstances. Here I might mention the artificial drainage of sites with well-pumps and coffer dams, mechanization of excavation using backhoes to remove soil, the concomitant trend toward exposing larger areas which lay bare an entire settlement rather than parts of it, and a stress on survey and sampling as opposed to complete excavation. Second, there were developments in ecology, such as increasing sophistication of investigations with bone, seed, plant remains, pollen, diatoms, beetles and other insects. Further, systematic sieving and/or flotation of large samples of soil was instituted in order to retrieve data otherwise missed. Archaeologists began to collaborate with quaternary geologists in order to reconstruct the Holocene history of the area, which resulted in detailed knowledge of its morphogenesis. Other important, more theoretical developments worth mentioning are changes in perspective (1) from one in which humans are solely influenced by nature to one in which both of these components interact mutually, and (2) toward one in which the sociology of plant communities plays an increasing role in interpretation.

Since the late 1970s there have been other major changes in the theoretical field, mainly in response to developments in the English-speaking archaeological world. Thus, the systems theory approach was increasingly used with regard to cultural aspects of the past, and more recently with regard to the interaction between man and environment. Moreover, there was the introduction of sampling techniques, both for spatial and content analysis. This included such procedures as three-dimensional registration and computer handling of large amounts of data.

It is in this perspective that the following description of techniques and summary of results of a project executed at the Institute for Pre- and Protohistory of the University of Amsterdam should be viewed. This paper concerns the results of the first three campaigns of, what turned out to be, a longterm research commitment of a number of workers in many fields. The first results have been published in papers by Brandt and van der Leeuw (1987 a,b), Brandt et al. (1983), Groenman-van Waateringe and Pals (1983), Therkorn (1987), and Vos (1983) The first volume of the final publication has appeared recently under the editorship of Brandt, Groenman-van Waateringe and van der Leeuw (1987).

The Assendelver Polder Project

The project is a regional one, aimed at reconstructing the natural and cultural dynamics occurring in part of a coastal estuary, the Oer-IJ Estuary, from prehistoric times well into the Middle Ages. Because of the above-mentioned rise in sea level, such a project is inevitably concerned more with the morphogenesis of the area before about 3000 B.C., with the ecology between that period and the time people began to occupy the landscape around 600 B.C., and with the relationship between people and the environment only in later prehistory from about 600 B.C. onward.

In the original phase of the project, we sampled and excavated a relatively small part of the estuary, an area of 26 km^2, a short distance northwest of Amsterdam. This phase was carried out between 1978 and 1981 with the generous financial assistance of the Netherlands Organization for the Advancement of Pure Research (ZWO). Since then, much larger areas of the estuary have been surveyed and excavated and research was carried out in areas outside the estuary in order to gain knowledge of the broader picture and in order to work in a contrasting cultural and ecological environment. In this last phase, the research has been carried out under various contracts between regional and local authorities in the Netherlands and the Stichting Regionaal Archaeologisch Archiverings Project (RAAP), under the directorship of Dr. R.W. Brandt. RAAP has close ties with the University. This paper focuses on the first phase of the project as an example of the methodology developed, and also presents some of the results of that phase.

Aims, Theoretical Aspects, and Choices

The aims of the project as stated above were set rather high: nothing less than understanding the totality of geological, ecological, and cultural change that took place along part of the Dutch coast over some 4,000 years.

It is often customary to adhere to one very rigid theoretical framework from which the data are interpreted. However, we felt that would be counter-productive. There is a demonstrable relationship between the amount and nature of data gathered on a topic and the conceptual structure of the models which may be used in order to summarize these data (van der Leeuw 1982, 1987). As research on the various aspects subsumed under our aims is in different stages, it would be impossible to use the same models for all situations. Thus, we have chosen descriptive as well as interpretive models, atomistic models as well as continuum and/or more holistic ones, and systemic and nonsystemic dynamic models as well as static ones where the dynamics could not be inferred. In general, we would prefer a more sophisticated model wherever possible without running the risk that the relationship between the data and model would become too tenuous. This, however, did not imply that the model would always be testable in strictly significant statistical terms. We would use morphogenetic models (van der Leeuw 1982) over systemic ones as they can accomodate both change and stability, and endogenous and exogenous stimuli for change. Only when such models could not be applied did we use the other kinds of models mentioned above.

In order to approach our aims, we have chosen the Oer-IJ Estuary for the following reasons: (1) spatially the estuary is very diverse and areas of one kind are interspersed with those of another, and (2) temporally the influence of the sea causes relatively major changes over a short time so that processes may be studied in a condensed form.

Research Design

Fundamental for the research design was that the area in which work was undertaken was defined arbitrarily, that is, not on grounds inherent in the archaeological data themselves. Rather, we thought of our research area as a sampling universe which crosscut various natural and archaeological phenomena. Hence, it was logical later to add other sampling universes in different locations, chosen where we would expect our work to provide new information.

As it was, we chose to work at four different levels in order to get a detailed picture with a broad scope. These levels were:

1. The supraregional level which encompasses the coastal areas and their direct hinterland along much of the present-day Dutch coastline. It was (and is) approached by a long-term research strategy which includes survey and excavations.
2. The regional level, here represented by the Assendelver Polder proper, which was mapped mainly by means of survey techniques (Fig. 2). Under these methods, I include the interpretation of regular aerial photographs, false-color remote sensing, contour mapping, and the use of ancient maps, along with sampling by coring and drilling holes of 90 cm diameter along systematic unaligned transects. Detailed surveying of high-probability areas was also carried out. Later these surveys were expanded to other polders in order to cover more of the estuary and different ecological zones.
3. The settlement level at which a number of sites were sampled, complete with their infields and possible outfields, drainage systems, gardens, and other features. Such sampling was undertaken by excavation of systematic unaligned transects across the sites.
4. The level of intrasettlement phenomena, such as houses and activity areas. These were sampled by the complete excavation of large parts of certain settlements (23 in all). In them, we collected loose finds in 1×1–m squares within houses and 4×4–m squares outside to obtain a spatially representative sample. Finds were registered in context three-dimensionally. In addition, a 20% volumetric sample was taken to assess the contents of ditch fills etc.

It could be claimed that we also worked at different levels of time resolution, although they were not as clearly separated. These were:

1. The level of the *longue durée*, a study of the morphogenesis and ecological development of the area over 4,000 years (ca. 3000 B.C. to A.D. 1000).
2. The intermediate level, an examination of the cultural and natural developments in the area for two major periods, the Iron Age (ca. 600 B.C. to A.D. 250) and the Middle Ages (from ca. A.D. 900 onward). In Westfriesland, an area not very far from the Oer-IJ Estuary, a major research commitment by the Dutch State Service for Archaeological Research (ROB) has allowed archaeologists to finish a similar study for the period 1200 B.C. to 600 B.C.
3. The level of the life span of the individual settlement which varied from

FIGURE 2 Map showing the systematic unaligned drillings at 30 m intervals (lines) and drillings prompted by field observations.

approximately 30 years for some single homestead sites to nearly 400 years for one multiple homestead site.

4. The level of the individual homestead and, where possible, fractions of the time it existed.

Crucial in the choices to be made about sampling, excavation, and interpretation was the desire to have all the information coming from the excavation at our fingertips immediately while digging and planning were going on. Thus we considered laboratory personnel as important as the excavation crew. The laboratory staff cleaned finds and analyzed pottery, bone, botanical remains, and pollen samples during the campaign. After an initial delay, a major part of the data processing was handled during the excavation on a micro-computer.

Geomorphology of the Region

Rather than work in the usual way, with extant geological maps of the area as a basis from which to interpret the archaeology, we chose to make our own dynamic model of the processes responsible for the geology and genesis of the region. To this aim, one of our team, Dr. P. Vos, using the available data, cored to considerable but variable depths. These numerous cores were closer together than is usual for geological or soil science purposes. Thus, a more detailed map of the area, showing its spatial variability, was constructed. At the same time, Dr. Vos drew heavily upon the experience and data of a number of scientists at the Dutch Department of Waterways (Rijkswaterstaat) who were involved in the detailed monitoring of the interaction between land and water in tidal estuarine environments. Thus, the basis was laid for (1) a detailed history of the geomorphology of the area and (2) a simulation model of the processes involved in the development of the estuary. The variables of the second model can be summarized as follows:

1. The relative rise in sea level since the last Ice Age. Its influence is felt as relative phases of enhanced (transgressions) or reduced (regressions) marine activity.
2. The frequency of storms.
3. The position of and size of coastal barriers and their relation to marine currents.
4. The position and nature of the various sediments in the hinterland.
5. The amounts of freshwater debitage coming from the rivers which create the estuary.

Around 3000 B.C., the coastline stretched more or less between the present-day towns of Haarlem and Uitgeest, while the mouth of the estuary was located directly west of Assendelft. In the following period the dunes spread westward so that the area behind was better protected from the sea. As a result, peat grew abundantly.

Around 1900 B.C., the estuary served as the mouth of several rivers, among them the northernmost branch of the Rhine. From then on, one may distinguish four phases of marine sedimentation (Calais IVb, Dunkirk O, Dunkirk I, and Dunkirk III, respectively) stratigraphically separated by phases of peat growth in the estuary. Further away from the coast, peat growth was continuous.

During the Dunkirk O phase, the mouth of the estuary was situated near Beverwijk, while the dunes between Heemskerk and Uitgeest were uninterrupted (Fig. 3a). Around 1000 B.C., the mouth of the estuary silted up. As a consequence, oligotrophic peat spread westward. Locally, this led to the development of small isolated areas of oligotrophic peat (cushions) in the surrounding reed peat. In the central area of the estuary, a freshwater lake was formed (Fig. 3b).

In the early Iron Age (ca. 650 B.C.), the sea broke in again (Dunkirk I transgression). A system of drainage gullies developed at the edge of the peat. The gullies drained the peat adequately for some 75 years so that the area became habitable. Drainage, however, also caused the peat to subside. This situation, and the increase in the level of the high tide in stormy weather, caused inundation of the region from about 550 B.C. onward, bringing an end to possible human occupation in that area.

Due to the movement of sand along the coast by longshore currents, the mouth of the estuary was pushed north in the direction of Egmond. The increasing wetness caused reed peat to begin to grow again in the area between the salt marshes and the oligotrophic peat. It is probable that during the Dunkirk I phase, the estuary was connected with the northern branch of the Rhine (Fig. 3c).

Around 300 B.C., large areas of salt marsh became covered with so much silt that the area became habitable again. In the adjacent area, small isolated oligotrophic peat cushions formed again, which points to a decrease in marine activity in this zone. The deposition of silt eventually reduced the influence of the sea in the estuary to next to nothing around 100 B.C. Large areas became permanently dry; the water table dropped in these places because, among other reasons, the mean high water level receded and the tidal gullies now kept the area well drained. The dry areas became suitable for permanent settlements.

From 100 A.D., the gullies began to fill with silt and sand. This situation reduced the effectiveness of drainage, raised the water table, and rekindled extensive peat growth. The gullies which remained in function after the Dunkirk I transgression once again formed a freshwater lake (Fig. 3d). In the succeeding period, this lake grew considerably. When the mouth of the estuary at Egmond closed around A.D. 800 or A.D. 900, the only contact between this lake and the sea was through the most northerly gaps in the coastal barrier. At the end of the nineteenth century, the area around the freshwater lake was finally pumped dry (Vos 1983).

As a result of these processes, at the time of human occupation (ca. 650 B.C.), we have the following landscape elements in this region (Fig. 4):

1. The dunes and coastal barriers, consisting mostly of sand (legend 1, 2). They are permanently inhabitable from an early date onward. Settlement location was primarily determined by the shifting patterns of dunes and vegetation. Individual settlements probably were shortlived once the sand started moving. Little is known about the nature of settlement because of the later accumulation of sand over the area (from the twelfth century A.D.), but habitation has been attested to from the Neolithic and is presently being excavated near Velsen.
2. The tidal flats, just east of the dunes, which became inhabitable from around

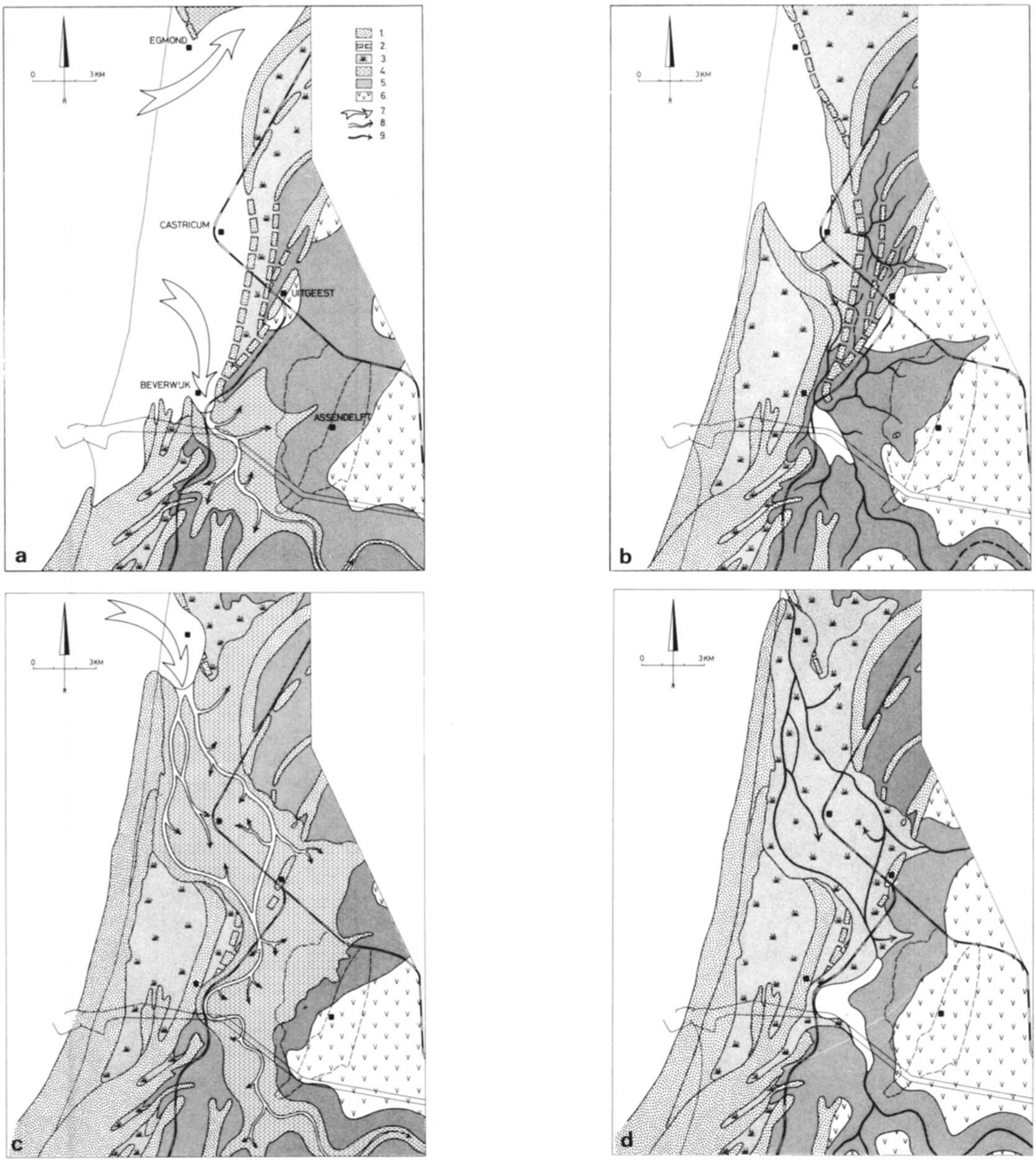

FIGURE 3 Series of maps showing the development of the Assendelver Polders and the surrounding coastal area, (a) ca. 1200 B.C., (b) ca. 700 B.C., (c) ca. 400 B.C., and (d) ca. A.D. 300. The legend in 3a pertains to all of the maps and delineates:

1. Sand bar, later covered by dunes
2. Presumed sand bar
3. Dry sandy estuarine deposits and the areas between them on which peat growth may have occurred
4. Clastic sediments in the estuary (sand, clay, levees, lagoons, and others)
5. Peat dependent upon ground water
6. Peat dependent upon rainwater
7. Areas open to the sea
8. Large tidal gullies
9. Peat drainage creeks

FIGURE 4 Map of the Oer-IJ area showing ecological zones and settlement location. Legend:

1. Find locations
2. Areas of excavation
3. Creek and levee deposits
4. Lagoonal deposits (clays thicker than 1 m)
5. Clay formed in fresh water basins in the peat (thinner than 1 m)
6. Reed peat
7. Oligotrophic peat
8. Reed peat over the Dunkirk I sediments
9. Maximal area of peat growth between the Dunkirk O and Dunkirk I transgressions
10. Location of the section cut through the Polders

the first century B.C. (legend 3). Here, the settlement pattern is not really limited by any natural factors; good agricultural land abounds and there are no special physical features of the landscape which constrain habitation. Continuous settlement must have been possible in the western part of this zone until well into the Middle Ages, and in the eastern part until about A.D. 250. An important settlement excavated in this area is located at Uitgeest (excavations ROB 1980–1981).

3. The western edge of the peat, briefly occupied from 600 to 550 B.C. and again from 350 B.C. to A.D. 250, consisted of salt marsh, tidal levees, and the adjacent drained peat (legend 4, 5). Settlement was highly constrained by natural factors; at first it was on the peat cushions, especially those close to creeks, and later on the levees.

4. The oligotrophic peat (legend 6) on which settlement was impossible because of the high water table, but on which the inhabitants of nearby settlements may have grazed some of their animals in the summers.

Ecology

Work on the ecology of the area has been done by a number of people (Groenman-van Waateringe and Pals 1983; Brandt et al. 1983). The work is too extensive to do justice to here, but a short summary of some of the most important results follows.

In order to reach the conclusions presented here a great variety of ecological data was collected at all four levels of analysis. In excavations, animal bones were collected by hand, but to avoid bias toward larger specimens, an extensive sieving program was executed that yielded remains of fish and smaller bones. Samples for pollen and diatom analysis were also taken from all excavations. Sampling for macrobotanical remains was carried out by means of sieving and flotation. Waterlogged creek and ditch fill, postholes, housefloors, and hearth and pot contents were analyzed. Similarly, samples were taken of all wood and macroscopic plant remains as well as mollusk shells, coprolites, and dung. Preservation on the levees and tidal flats favored bone and was biased against pollen, wood, and plant remains. In the acidic peat, preservation was just the reverse.

Estuarine habitats support large populations of benthic and epiphytic algae, which in turn can support high population densities of heterotrophic organisms such as crustaceans, mollusks, fishes, birds, and, one step up the food chain, larger mammals such as seals, beavers, otters, and elk. Geographically, the many varied econiches alternate often and a fragmented spatial pattern consisting of tidal flats, creeks, peat, lagoons, marshy low-lying backswamps, and other elements is the result.

Through time, there are daily fluctuations (tidal) seasonal variations (storms, droughts), and the longterm changes mentioned above. The interfaces between freshwater and saltwater, streams and stagnant water, water and land, lower and higher ground are ever-changing.

At the end of the period under consideration (the nineteenth century A.D.), most, if not all of this variability, was gone. Spatially, virtually only meadows and some arable land separated by ditches remain. Temporally, all variation has been under control since the area was pumped dry.

We are primarily concerned with the reconstruction of the processes that changed a variable habitat in which people lived and from which they fed themselves, to one under almost complete human control. The reconstruction to be presented here will first approach the topic through time, and then through space.

Table 1 presents a summary of the various elements of the ecosystem which were used by the inhabitants to feed themselves. Clearly, there is evidence of agriculture, gardening, husbandry, gathering, hunting, and fishing. In view of these results, of the spread of various kinds of foodstuff remains over sites with different dates, and of the nature of the sites themselves (to be discussed below), the following model of the exploitation of the area seems acceptable.

Settlement, based on subsistence procurement in all of the ways listed above, seems to have been continuous in the dunes and adjacent areas (Zone 1) since the Neolithic, even if the settlements are relatively short-lived and the settlement pattern mobile. Various settlements at Velsen, as well as elsewhere among the dunes, attest to such a pattern up until the Middle Ages.

From the early Iron Age on, we have proof that the population also made use of

Table 1. Subsistence remains from sites in the Assendelver Polders (Iron Age)

Cultivation
Emmer (*Triticum* sp.)
Barley (*Hordeum* sp.)
Oats (*Avena* sp.)
Millet (*Panicum* sp.)
Turnips (*Brassica* sp.)
Flax (*Linum* sp.)
Pleasure-of-Gold (*Camelina* sp.)

Gathering
Orache (*Atriplex* sp.)

Husbandry
Cattle (*Bos taurus*)
Goat/Sheep (*Capra/Ovis sp.*)
Pig (*Sus domesticus*)
Horse (*Equus caballus*)
Dog (*Canis familiaris*)

Hunting
Wild duck (*Anas* sp.)
Geese (*Anser* sp.)
Swan (*Cygnus* sp.)

Fishing
Cyprinids (*Cyprinidae*)
Flatfish (*Platichthidae*)
Eel (*Anguila anguila*)
Catfish (*Siluris glanis*)
Pike (*Esox lucius*)
Perch (*Perca fluviatilis*)
Cod (*Gadus morrhua*)

Zones 3 and 4 of the estuary through the many settlements discovered in the Assendelver Polder proper. It seems that this expansion, alternating with phases of contraction of the settlement system (such as between 550 B.C. and 250 B.C., and A.D. 250 and possibly A.D. 1000), may have occurred more or less in the following manner. Initially, the particular estuarine character of the region would have been exploited; that is, there would have been considerable reliance on hunting, gathering, and fishing. There was no fresh water available locally, as all water was salty or brackish, so that permanent settlement and/or husbandry would have been difficult. Thus, there were no permanent settlements during this phase. We believe that human use of the region consisted of forays into the area from a base in or near the dunes. There is evidence of the exploitation of local vegetal resources, and the many creeks would have made the area ideal for hunting waterfowl and for fishing from a boat. A wooden paddle was found on the earliest known site.

As the region became more accessible and better known, people might have attempted to stay there for longer periods. One of the major limitations would still have been the water supply, but drainage of the peat must have resulted in freshwater creeks as the sea and the salty ground water table regressed. Trips to the area probably became seasonal as attested to by the remains of a seasonal camp found on one of the sites. Such visits clearly would have led to exploitation of other resources, such as the use of the higher peat cushions for summer grazing. A pattern of transhumance could have evolved. This has been sketched in an idealized manner in Figure 5. Continued use, and the concomitant selection in favor of particular vegetation, must eventually have contributed considerably to the homogenization of the landscape along with the closure of the mouth of the estuary and the resultant changes in salinity and, thus, vegetation.

Eventually, the increase in grazing acreage would have led to settlement by permanent pastoralists grazing cattle and ovicaprids. These inhabitants did a bit of gardening on the side of *Camelina sativa* (pleasure-of-gold) and planted cereals on the creek levees. They relied nevertheless on the agricultural potential of their neighbors' lands to the west (to be discussed below). From the earliest permanent settlement, there is clear evidence for both of these activities as well as some exploitation of fish and wild animals, which probably served as a buffer during lean times. Later, herds must have grown in size, as evidenced by different stabling methods. Increasing specialization in herding activities may have been counterbalanced with increasing dependence on agriculture through exchange.

Crop raising took place on the tidal flats of Zone 2 which became inhabitable somewhere around the second century B.C. They were settled almost immediately as demonstrated by the excavations in Uitgeest. These settlements are of a different character than those mentioned above and have features, such as numerous facilities for grain storage, that are lacking in the Assendelver Polder. The macrobotanical remains also point to cultivation as the major means of subsistence at these settlements.

When the area became too wet again, the permanent settlements must have been abandoned, and the cycle was set in motion in the reverse order as summarized in Figure 6.

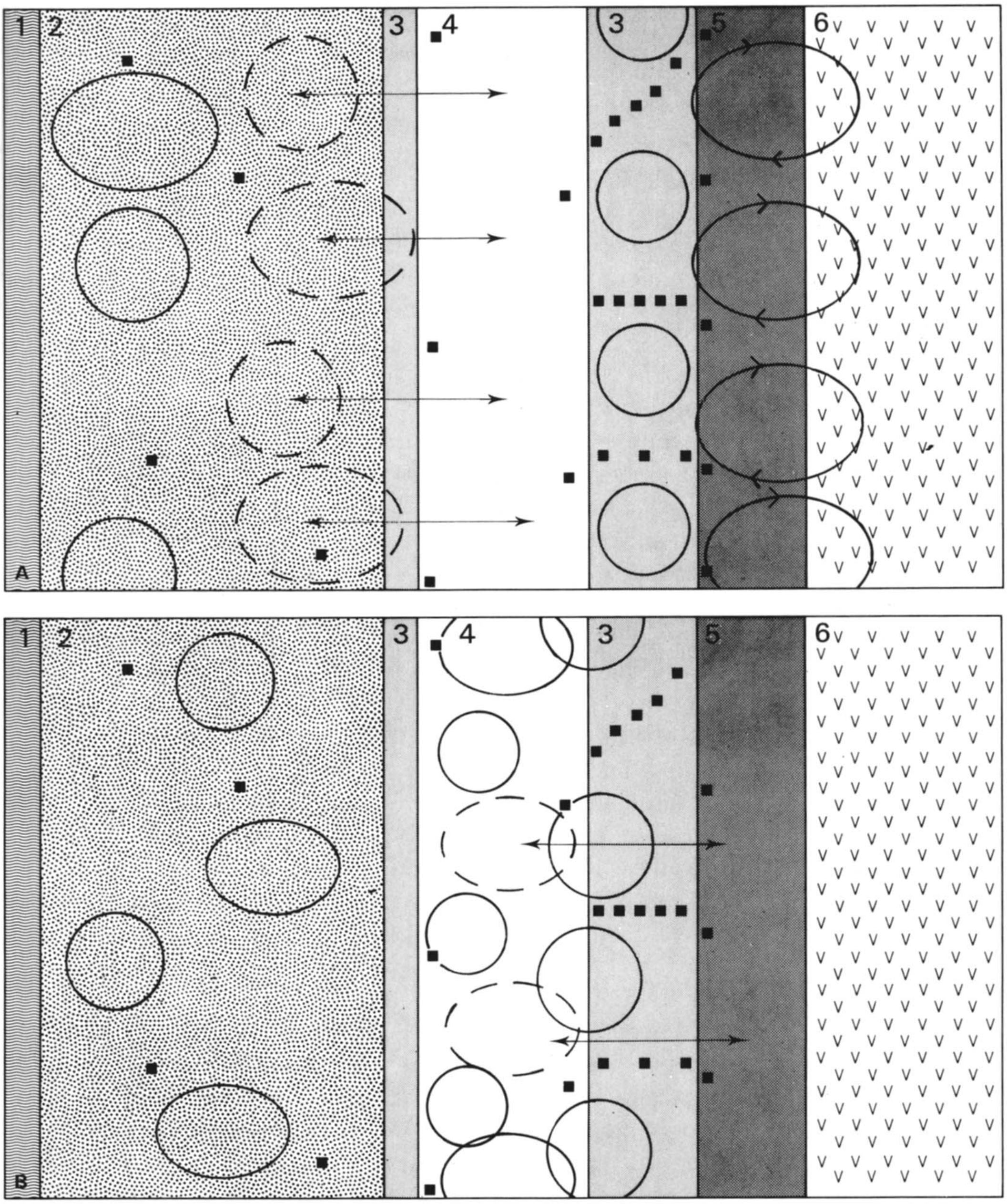

FIGURE 5 Schematic representation of seasonal transhumance as occurring in the Oer-IJ estuary (Brandt and van Gijn 1986), (a) the summer situation—circles indicate cattle pasture, ellipses represent sheep/goat pasture, dotted lines with arrows indicate movement of herds, (b) the winter situation—symbols represent the same elements as in 5a. Legend:

1. North Sea
2. Coastal barriers
3. Ancient tidal flats with creeks, levees, and other features
4. Ancient intertidal area
5. Reed peat
6. Oligotrophic peat

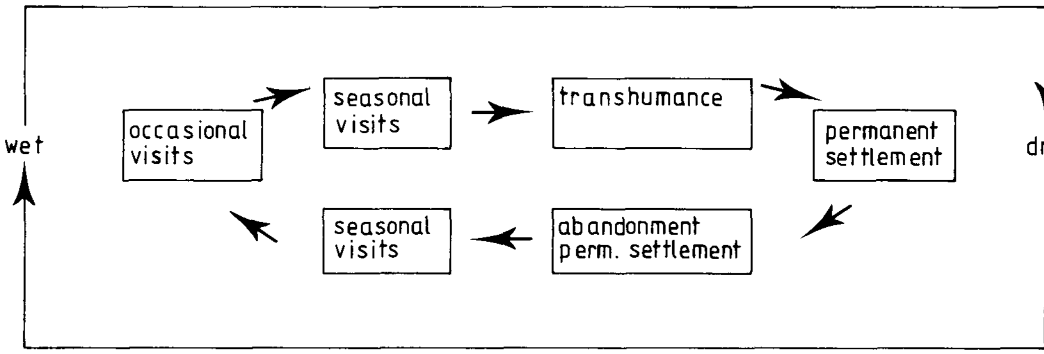

FIGURE 6 Schematic representation of the cycle of discovery, settlement, and abandonment which may have occurred in the Oer-IJ (Brandt, van der Leeuw and van Wijngaarden-Bakker 1983).

Spatially speaking, we must conclude that in each cycle the population began by using the heterogeneous aspects of the estuary whereas with time, people came to focus on a large scale on some of the many possible modes of subsistence. This selection contributed substantially to the homogenization of the area by dividing it into a region consisting largely of pasture and another of cultivated land.

To extend this point through time, we could look briefly at two other periods, one immediately preceding 600 B.C. and the other the recent past. In the former, in the nearby area of Westfriesland between 1200 B.C. and 600 B.C., we find settlements on the levees which were clearly based on mixed farming. Each farm was situated in the middle of its own cultivated fields with the herds roaming around in a wider area, but based in the same settlements. If, on the other hand, we look at the recent past before large-scale EEC intervention, the region as a whole was focused essentially on herding. As the size of the interactive system grew, so did the area devoted to any of its subsystems; this resulted in the ever increasing homogenization of the landscape.

Clearly, this summary has not done justice to the data, notably in the way in which it treats the spatial effects. For more detail, the reader is referred to the pertinent papers in the first volume of the final publication (Brandt et al. 1987).

Human Environment

Thus far, we have looked essentially at the mechanisms which play a role at the highest levels of synthesis, that is, long and medium term processes which affect the estuary in relation to its environment, and as a whole. As we focus on the human side of the equation, we move to a more narrow temporal and spatial framework. At the same time, we adopt a different perspective. In a sense, the processes discussed so far escape human perception as their temporal scale exceeds that of the human lifetime and their spatial scale exceeds that of the region familiar to the population of the individual settlement. Thus, from an emic point of view, these processes are seen as constraints which are inflicted upon the participant rather than as regulations which the participant inflicts upon the environment. We move from an area which initially escaped human control toward an environment which was controlled from the beginning.

Just as in the former region we moved from the large-scale geologic phenomena to the smaller ecological phenomena (i.e., toward the scale of the human population), we will in this part of the paper move from the lowest level of detail toward higher levels, thus equally ending up at the level of the human population.

Level 1: Activities in and around the house.—The data which we have at our disposal invite us, at this level, to look at: (1) spatial organization of the house, (2) delineation of areas for functions executed in and around the living quarters, and (3) provision for water, fire, and garbage disposal. Each will be discussed briefly following the work of Therkorn (1987).

The spatial organization of the dwelling is such that the buildings house either humans, animals, or both. Buildings for grain storage and other functions, such as specialist craft activities, are absent. By implication, therefore, the houses must have been multipurpose. This is corroborated by their internal subdivisions. They are, with the exception of the wall-ditch structures to be discussed below, of the long, three-aisled kind which occurs all over western Europe at this time. They have been subdivided into a living area for humans and a stalling area for animals. The latter doubles in the summer as a workshop when a fire is lit at the far end of the stall. The former is further subdivided into sleeping quarters and a living area, at least in the one case where this could be established with certainty. The house was well-preserved because it was waterlogged.

The wall-ditch structures date to a later period and do not have any traces of subdivisions. They do not occur on the peat cushions, only on the levees. Their reduced size initially gives the impression that differentiation in internal use must have been reduced with time. Upon consideration, however, that does not seem true because they occur simultaneously with areas which are ringed with a ditch, extremely rich in phosphates, over which there was no roof. These areas must have served as corrals for the herds as they grew too large to be contained in houses (possibly because of a scarcity in wood). Thus, there seems to be a tendency toward the spatial separation of functions rather than toward the merging of separate spaces. Within the wall-ditch buildings, which are about as large as the living and sleeping quarters in the three-aisled houses, we were not able to discern spatial divisions because of the archaeological situation. These structures all occur on the levees where we do not have the ancient floor levels available for scrutiny.

How far did this tendency extend itself to other phenomena? It is very noticeable, for example, that in and around all settlements, there is a complete or nearly complete lack of delineations which served to mark activity areas connected with the profession of the inhabitants of the houses or which served to mark the location of wells, sheds, or other farmyard features. But when pointing this out, it must also be remembered that most if not all of the houses were standing alone among the wilds in naturally delimited areas, that is, peat cushions or levees, and that there were no provisions for storage or fresh water. The absence of the former has already been discussed. Fresh water was not needed even in the phase of permanent settlement because it was essentially ubiquitous.

Hearths, on the other hand, point to further spatial differentiation. The occurrence of hearths during the summer months in the stalling end of the three-aisled structures has already been mentioned. They occur amidst debris of woodworking, flint knapping, boneworking and other activities. Their presence indicates that the stables were used as workshops during the warmer months. With the wall-ditch buildings, we often find outside hearths which may have fulfilled the same function of providing the heat necessary for some workshop activities.

Hearths are also interesting on a different level. The earlier hearths are generally roughly constructed and spatially ill-defined with ashes and carbonized material lying all around them. Later hearths seem to be more purposefully built having a well-laid floor of potsherds covered with a dome of sand or clay, and are better circumscribed spatially. They were also kept cleaner so that there is no association with debris and charcoal. Altogether, we are better able to distinguish them from their surroundings.

Garbage disposal is the last topic on this level. Neither on the levees nor on the peat cushions do there seem to be provisions for garbage disposal. In the peat, garbage, such as potsherds, was dumped in the stall area where it served to solidify the floor. On the levees, the garbage seems to have been disposed of in pits and ditches dug for other purposes. Thus, although garbage was not disposed of just anywhere, there are no structures specifically for that purpose.

Level 2: The house as a spatial unit.—It is especially interesting to look at the location of the houses. First, it is noticeable that of the twenty-three sites excavated, only three had more than one building. Houses were probably always built in a suitable place and there are two levels of decision making to consider for their location. Of the total area under consideration in Zone 3 (the only one for which we have excavated enough settlements to be able to make generalizations), only a very small part was deemed appropriate for settlement. This location was the narrow zone of contact between the peat and the tidal flats and included the creeks draining the peat. Within that zone, further constraints apparently caused settlement to occur only on the peat cushions and the narrow levees along the creeks. We assume that these choices were dictated by the fact that these areas were the first ones to drain naturally, and that their location was close to all three of the main ecological niches initially used for subsistence.

Within these constraints, choice is a different matter. It seems that there were ample adequate locations available and that the inhabitants did not limit themselves to one specific area. This impression is created by the combination of the short-lived nature of the buildings (cf. Brandt and van der Leeuw 1987b) and the absence of traces of rebuilding on the same spot. Only in the case of three later settlements do we find overlapping foundations of houses. We are tempted to ask whether the later inhabitants attached more importance to location than the earlier settlers.

Level 3: The settlement as a spatial unit.—The phenomena we are concerned with here are the buildings in their total context, that is, the structures included with the remains of all other activities undertaken in and around them. The two major categories of archaeological features involved at this level are ditches and platforms. Ditches are of various kinds, and are distinguishable by the way in which they relate to the local (micro) relief in their depth and width:

1. Ditches which run at right angles to the slope of a levee or peat cushion and which generally end in a low-lying area such as a stream or a backswamp. These, it seems, served as drainage ditches and contributed to the control of the environment.
2. Ditches which enclose raised areas. These did not drain and, thus, did not contribute to physical control over the environment. Rather, some seem to have served as boundary markers. Among these are (a) shallow ditches which enclose a building just outside the wall. These can probably be interpreted as driplines from the eaves of a building rather than as spatial demarcation, although the functions could be combined; (b) wider and/or deeper ones which enclose a building somewhat further from the wall. In shape, they are usually rectangular and have one or more breaks opposite the entrances to the building concerned. They seem to delineate the boundary of the immediate territory belonging to the building.
3. Ditches which enclose an area in which no building occurs. Among these we may distinguish between (a) those which enclose areas with high phosphate content. These are generally round or oval, and are interpreted as corrals. The ditches seem to serve as spatial demarcation both in a physical sense to keep the animals in and, in a more symbolic sense, to keep out humans who do not belong there; (b) those associated with cultivation which often enclose rectangular or square areas. The area delineated may differ considerably in size from about 4×4 m (probably used for gardening) to about 25×25 m (probably used as arable land). These ditches may also have served physically to keep animals out and symbolically to keep humans out.

The rectangular ditches around buildings and the rounded or oval ones which delimit corrals sometimes occur around an artificial platform. Some of the platforms are only 10 cm high. Their low height seems to indicate that these platforms, unlike those in Friesland and Groningen, would not have been effective against rising water levels. In fact, it is doubtful that they served any protective function at all. We also find both the platforms and the ditches separately. The relationship between the two phenomena seems to be important here, as it might be assumed that these ditches were either a side effect of the need to accumulate soil or the platforms were only a side effect of the need to delineate an area.

Detailed scrutiny of the height and the location of the platforms in cases where platforms and ditches occur together, as well as where the two occur separately, leads us to conclude that platforms with buildings on them served to demarcate the house spatially in three dimensions. Such platforms occur in relatively low-lying areas, such as on the levees (which were considerably lower than the surrounding peat) or in an area next to a shallow puddle which probably contained fresh water. Here, it seems, the platforms brought the total height of the building up to such a level that these houses could be seen in a landscape where the total visibility must often have been limited by tall reeds, trees, and other vegetation. Elevation by the platform was therefore an important vertical marker, whereas the ditch was a horizontal marker. Thus, the two were in all probability conceptually linked. The fact that the platforms on the levees occur where the levees are lowest, that is, the farthest from the mouth of the creeks involved, seems to corroborate the fact that elevation is a crucial variable.

On one site, we find both platforms with a building and without a ditch around them, and platforms with a ditch but without a building. This seems to indicate (1) that vertical marking of the houses was more important than horizontal marking and that, in the case of platforms with buildings, the ditch may have been secondary, whereas (2) in the case of the platforms without a building, the ditch was an essential element. This reinforces the latter's interpretation as corrals and leads us to argue that there the platform was a side effect of the need to contain the animals.

What makes all of this so interesting is the chronological element. Both the platforms with buildings and the corrals occur only in the later phases of settlement. None of the earlier three-aisled buildings is built on a platform. Therefore, it seems as if the increasing impact of man on the environment, which is intimately tied to the growth of the grazing acreage, the size of the herds and the need for corrals, may also have led to a lack of wood for building. Wood was never a strength of the local ecosystem. This may have led to the change in architecture from the three-aisled to the wall-ditch structures. The latter were probably lower and required the platform for long distance visibility.

Indubitably, the much higher platforms, which were used elsewhere and later under wetter circumstances, served to keep people, animals, and harvest dry. It is noteworthy, however, that they follow in a cultural tradition which used these platforms for other reasons.

Level 4: Regional patterns of settlement.—At the present stage of research, it is not possible to offer a more complete view of this level as most of the excavations have focused on Zones 3 and 4. Some excavation has been done in Zone 2, and excavations in Zone 1 are underway.

Within Zones 2, 3, and 4 initial settlement occurred, as we have seen, primarily on the narrow area of reed peat cushions between the tidal flats and the ombrogenous peat. Within that area, locations were preferred where fresh water was close at hand. Hence settlement took place along the creeks. Drainage depended entirely on the natural channels available. Once settlement on the peat cushions got underway, drainage channels were cut into them. This led to the oxidation and subsequent subsidence of the peat so that the cushions became uninhabitable. Settlement increased on the sandy and clayey banks of the creeks. These also needed draining but there the results were not quite so disastrous.

In both cases, it seems that apart from the presence of water, settlement location is at the interface of more than one soil type. As such, the settlement system is more or less linear along the boundary of the soil type zones, except that the settlements on the creek banks are in lines at right angles to those in the reed peat zone.

In between the settlements, in the shallow basins between the creeks and the peat hinterland, there is uninhabited land. It is not artificially subdivided in any way. High concentrations of phosphates and a pollen profile that indicates the presence of grassland, points to the use of this land as grazing grounds for herds. As a consequence, the settlements are isolated and, whatever spatial organization there is, is natural except in and around the individual settlements.

At the end of the first century A.D., a reorganization of the landscape occurred around the tidal flats. The linear settlement pattern was replaced by a large-scale system of fields separated by ditches which ran independent of the geomorphology of the area. Thus control was gained over the landscape. These large-scale ditch systems are located, notably, around the two largest settlements. These two settlements are located in relatively elevated places and were deserted last. Although the ditches were clearly used for drainage, they obviously served as spatial demarcations as well. This was probably the result of spatial pressure due to the decrease in the amount of useable land in the Polder as the water table rose. Instead of roaming freely around with his herds, each farmer was given his own smaller territory to manage. We might say that at the end of the first century, the primary function of the ditches had become sociopolitical, as is to be expected when human aggregates grow beyond a certain point.

It is interesting, moreover, that control over the landscape at this scale must have required the collaboration of the settlers in deciding on where to place the ditches and in digging them. Some 800 or 900 years after the moment when the area was left uninhabited (around A.D. 300), this cooperation was taken a step further when firm control was established by building dikes around polders like the Assendelver.

In sum, we see on the human side of the dynamic equilibrium, increased control over the environment which reduced geographical heterogeneity, the number of components of the environment on which human existence depended, risk, and temporal variability such as in the water table. Next we see increasing spatial circumscription of regions under human control, such as with areas involved in specific activities. Thus, there is more use of boundaries between fields, houses, and settlements and, at another level, spatial circumscription of hearths, pottery shapes, and other features. Concomitant with this is a tendency toward standardization, especially in the pottery. Standardization was intraregional and led to regional differentiation as seen, for example, in the houses. This also occurred economically between husbandry and cultivation, and among those who undertook the manufacture of certain kinds of goods, such as pottery, wool, and metal objects. The inevitable dependency which differentiation entails must have eventually brought about an increase in exchange and trade.

Conclusion

In the archaeological record of the wet sites in western Holland, we have seen, at a very low level, some of the same processes which are, in more evolved situations, responsible for increases in population aggregation, social stratification, and social complexity. Aside from these aspects, which are important for the study of the European Iron Age, there are some more general conditions which I would like to point out.

First, looking over the total period of some 3,000 years (i.e., from about 1200 B.C. to the present), we see both continuity and discontinuity. Continuity is manifest in the long-term trends which transcend the shorter fluctuations. On the one hand, we find that more control over the environment is gained: the region is homogenized spatially so that there is a decrease in entropy. Another aspect of decreasing entropy is that fewer and fewer different plants and animals are utilized for food and other species disappear gradually. Dependency increases with control as the two are different sides of the same coin. Spatially, the area that is exploited by a community grows as does the number of people in the interactive group. The mode of existence relies on fewer resources and, thus, becomes increasingly dependent on them. This sitution increases the risk of abrupt breaks or even crashes in the trajectory of the system. On the other hand, human culture becomes ever more diversified. Craft differentiation, social differentiation, regional differentiation, spatial circumscription, standardization, functional differentiation of objects, and more are all aspects of the other side of the equilibrium.

The development is continuous in that the basic process of the transformation of relatively raw energy and matter, less organized by human manipulation, is converted into harnessed energy and matter. On the one hand, the natural environment is brought under human control and "simplified," while the human environment which was under control from the outset becomes more complex. This is due to a process whereby categories, channels of communication, and other functions are separated. Some of the theoretical aspects of these long–term trends, which in my opinion underlie all of human evolution for reasons inherent in the structure of the human nervous system, have been discussed elsewhere (van der Leeuw 1987).

If we look at the discontinuities involved, we see time and again that at the level of the *histoire de moyenne durée*, a group of people moves into an area, gains a degree of control over it, and then sees this control escape them in the end. After an interval, the same area is settled by people with a slightly different cultural toolkit who also achieve a measure of control usually somewhat superior to the last group. They manage to live in the area for some time before the system crashes again. Such a combination of an ongoing trend toward increasing complexity with a cyclical aspect has also been found in reconstructing the last few centuries of the Motupore trade system (located on the south coast of Papua, New Guinea) on the basis of both archaeological and ethnohistorical research (Allen 1984; Fig. 7). Van der Leeuw (1987) has discussed some of the purely theoretical aspects of such cycles.

The combination of continuity and discontinuity seems, at the most general level, to be explicable by assuming that the longer the system operates within a specific set of variables and modes, the more its response time to disturbances is reduced. Such a process ensures that a much wider range of solutions is found (Allen and McGlade 1987). Thus, the chance that a culture will choose a radically

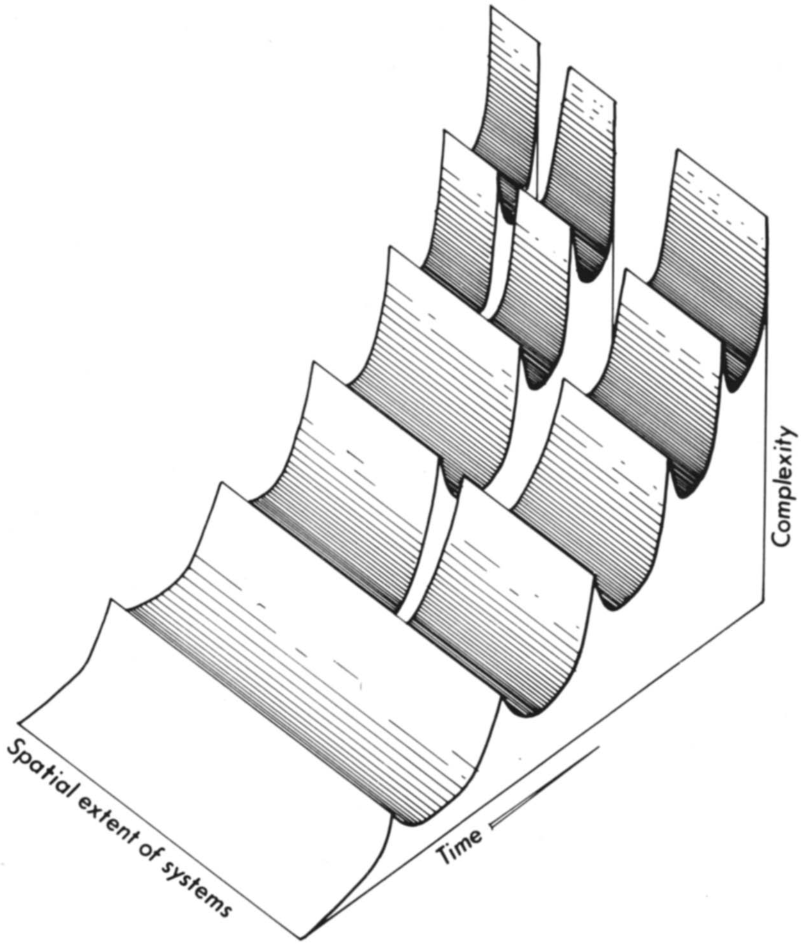

FIGURE 7 Graph of long-term development of trade in pottery on the southern coast of Papua New Guinea, showing rapid phases of expansion alternating with even more rapid crashes and restructuring (Allen 1984).

different solution to any disturbance which it encounters, increases with time.

At another level, we might look at it in the following manner. The longer the system operates in a certain mode, the more the population invests in a certain set of values and strategies. The consequences are as follows:

1. The environment of the system is heavily altered in the areas in which the exploitative and interactive strategies of the system articulate with its environment, so that the balance between system and environment comes under stress wherever there are nonrenewable or overexploited parts of that environment.

2. The system itself becomes less flexible. It moves from a generally favorable mix between stochastic (generalist) behavior and cartesian (specialist) behavior toward a more rigid cartesian behavior in an environment which makes that action less effective and more risky as time goes on. Thus the system and environment, in their articulation, push each other toward a collision course. This is built into the trajectory from the beginning and is not only unavoidable, but also occurs inevitably

at the point where the system is the most vulnerable (i.e, the most specialized).

This paper has attempted to summarize some of the strategies and techniques used in recent wet site research in the Netherlands, with special emphasis on some of the more general issues. The success of the project in making a dynamic model of part of a system's trajectory has depended on the very rich potential for environmental and cultural reconstruction which is offered by wet sites, coupled with a long tradition in wet site archaeology and adequate funding. Because of these circumstances, we feel that the extra cost has been amply rewarded by results which could not have been achieved in an area with poorer preservation.

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EARLY RAINFOREST ARCHAEOLOGY IN SOUTHWESTERN SOUTH AMERICA: RESEARCH CONTEXT, DESIGN, AND DATA AT MONTE VERDE

Tom D. Dillehay

Introduction

Extreme environmental conditions such as very dry deserts, wetlands, and frozen tundra hold the greatest potential for the preservation of organic cultural remains in archaeological sites. To date, many temperate and dryland sites of Pleistocene age have been discovered throughout the world; on occasion, they have produced limited amounts of biotic materials, mainly botanical remains. Very few early sites in frozen and wetland environments have been found, and fewer still have yielded a significant amount of perishable remains. These sites include Kalambo Falls in Kenya (Clark 1969), Windover in Florida (Doran and Dickel, this volume), and Monte Verde in Chile (Dillehay 1984, 1986). While these kinds of sites may provide an invaluable insight into paleoenvironments and early cultural lifeways, they may also present added problems for data recovery and interpretation. Wet organic remains can be difficult to excavate, conserve, and identify in terms of the cultural or natural origin of certain material forms or artifact attributes. In order to minimize any uncertainties about the perishable data and to reconstruct the paleoenvironment and the past economy and technology of the occupants, an interdisciplinary research team involved in all phases of the research is required. The study below reports on one early wetland site, the late Pleistocene settlement of Monte Verde in the cool rainforest of south-central Chile.

Monte Verde is a wetland habitation site that contains well-preserved cultural evidence of a late Pleistocene society. What makes this site important is the presence of a diversified stone tool technology, a wood industry, wooden architectural features, the bone remains of extinct animals, and a rich array of economic plants. Of equal importance is the form and arrangement of the architecture and activity areas at the site; these reveal a social and economic organization much more generalized than previously suspected for a late Ice Age culture of the New World. A long sequence of radiocarbon dates on stratigraphic noncultural and cultural deposits place this cultural episode at around 13,000 years ago. One and a half meters below these deposits are stone tools and wood charcoal features that seem to belong to an even older culture. Since no other organic remains were found in the deeper levels of the site, only the younger well-preserved component is discussed in this paper.

The preservation, diversity, and complexity of organic and inorganic remains at Monte Verde have necessitated the inclusion of an interdisciplinary research team in the project to study the geological and ecological contexts of the area, and to analyze special ecofactual and archaeological items recovered from the site. These specialists include more than 35 scientists from such disciplines as geology, palynology, botany, entomology, animal pathology, paleontology, ecology, forestry engineering, malacology, diatomology, and microbiology.

The purpose of this paper is to present an overview of (1) the general research problem and history of investigative findings at Monte Verde, (2) the environmental conditions that preserved the cultural materials, (3) the research design employed to recover, conserve, and interpret these remains, (4) the archaeological findings and their general cultural meanings, and (5) the implications of these finds to studies of early prehistory and past environments. Since the principal focus is a general characterization of the wetland archaeology and methodology at Monte Verde, little attention is given here to the broader cultural and theoretical relevance of the data.

The presentation is divided into three parts : (1) the history of the project and research objectives, (2) the research methods and findings, and (3) the reconstruction of the paleoenvironment and landform.

General Research Objective

For me, the Monte Verde project began in 1976, when Professors Mauricio van de Maele and Carlos Troncoso of the Universidad Austral de Chile, Valdivia, informed me of the discovery of the bone remains of extinct mammals in Chinchihuapi Creek, a small tributary of the Rio Maullin (Fig. 1). During a visit to the site in 1976, my students and I determined the exact places in the creek banks where bones and human artifacts were being eroded and where Professor Troncoso had excavated a collection of wood and bone. In 1977 and 1978, we conducted a subsurface testing program at the site; we discovered that several elephant bones, split pebbles, and wooden pieces were associated in a patterned spatial distribution and that some of them had been modified. The primary objectives of these first field seasons were to salvage the archaeological and paleontological remains buried at the site, to characterize the nature of any human activity at the site, and to define the site's chronology, geology, and environmental setting. During the following field seasons, between 1979 and 1985, extensive excavations were conducted to delimit the full vertical and horizontal extent of human activity, to reconstruct the past environment and climate through the analysis of ecofactual materials, and to understand the internal structure of the social, technological, and economic organization represented by the type and patterning of artifacts. Additional guiding concerns were such standard research problems as seasonality and duration of occupation, size and composition of the occupying group, activities carried out at the site, and the relationship of the site to other sites.

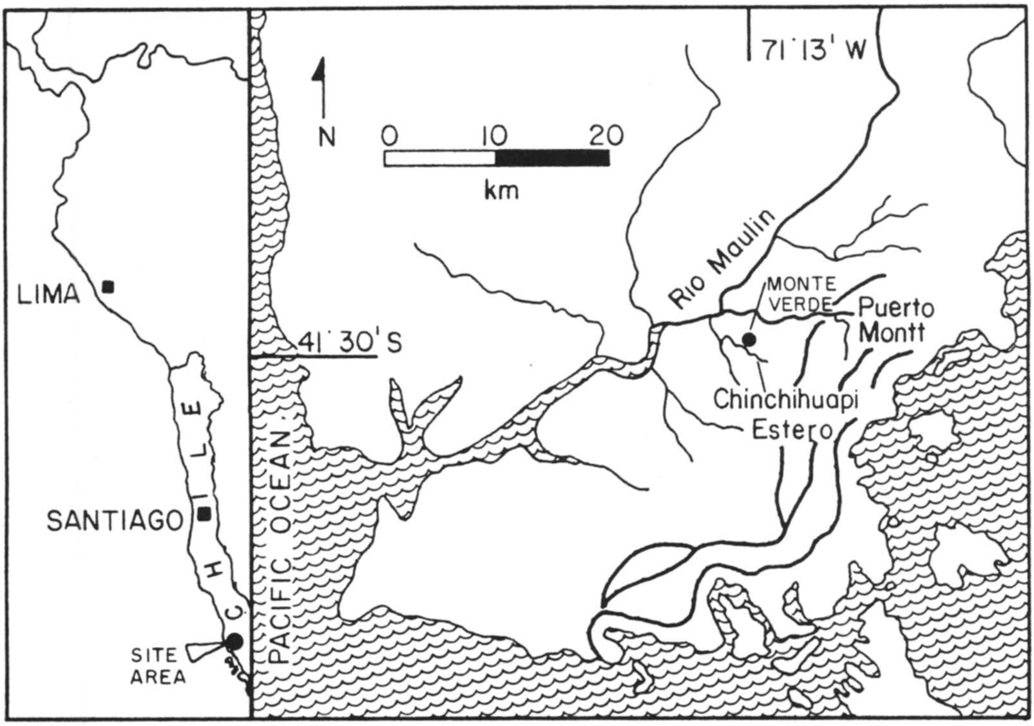

FIGURE 1 Location of the Monte Verde site in southern Chile. The site is indicated by the dot on Chinchihuapi Creek. The three lines to the southeast of the site represent moraines.

Overview of Ecology and Geology

The area around Monte Verde today has moderately warm, dry summers and cold, rainy winters, with a mean annual temperature fluctuating between 12° and 15°C. The climate that prevailed in the late Pleistocene after the glaciers had receded resembled this pattern, although it was probably slightly cooler and more humid (Dillehay 1986).

A forest made up of a mixture of deciduous and coniferous species covers the region; it supplies numerous varieties of edible tubers, nuts, berries, fruits, and soft and leafy plants abundantly throughout the year. There are also small game, freshwater mollusks, and fish. The nearest point on the Pacific coast lies about 55 km west and 20 km south of the site and offers many edible species of marine organisms. All of these sources of food were probably available to the early inhabitants.

Mario Pino, the project geologist, has defined two geologic formations, the Salto Chico Unit and the Monte Verde Unit (MV—1 to SCH—4), in the immediate area of the Monte Verde site (Fig. 2). The SCH—4 unit (defined as Strata MV—7 and MV—8 previously; Dillehay et al. 1982) contains surface strata of the Salto

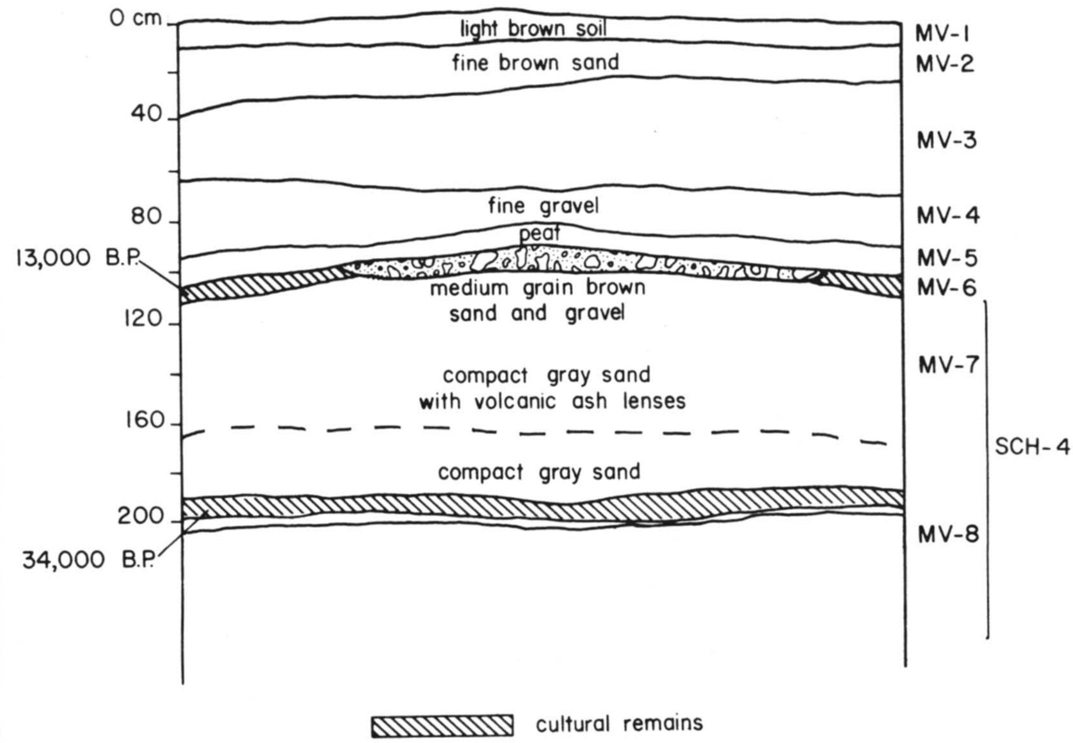

FIGURE 2 Schematic view of the general stratigraphic sequence at Monte Verde. The peat layer (MV-5) is denoted by the black band. The younger 13,000–year–old cultural materials are found on top of the contemporaneous surfaces of the old creek shoreline and its sandy beaches and point bars (MV-6) and the adjacent sandy banks (SCH-4 and its upper substratum, MV-7).

Chico Unit, the high terrace formed by the Rio Maullin drainage system during late Pleistocene times. This unit is made up of large-grained sands, and igneous and metamorphic stones. The presence of matrices of sandy silt with some volcanic ash is also a common characteristic of the unit. The age of the Salto Chico Unit has been estimated to be no younger than 19; 500 years (Pino n.d.). This unit is overlain by the Monte Verde Formation (strata MV–1 to MV–6).

Strata MV–6, an ancient creek bed deposit 4 m wide, lies unconformably on a narrow strip of the eroded surface of the upper unit of SCH–4 (or Stratum MV–7). The fluvial materials that comprise the ancient stream bed are not the product of primary transport or sedimentation processes of the Rio Maullin drainage system; rather, they are the result of secondary local selection of the smaller sized particles (for example, sand and smaller gravels) from the upper levels (SCH–1 to SCH–3) of the Salto Chico Unit. A minority of the stones in Stratum MV–6 are fractured. This fracturing is accounted for by sedimentary processes that occurred during the formation of the SCH–4 unit and not during the later development of Stratum MV–6 itself. Coarse gravels of granodiorites, trachytes, andesites and basalts, and quartz-rich sands are the most common rock types in both the ancient and modern creek beds.

In the area of the site, the maximum extent of gravel fill of the ancient stream bed (MV–6) is 4 m wide and 20 cm thick. The gravel tapers to a lightly scattered layer of stones along the edges of the ancient creek bed where cultural debris is deposited in close association with other materials. No naturally occurring stones are found on the contemporaneous surface of the sandy creek banks.

The present Chinchihuapi Creek has cut into and partially exposed the earlier, filled channel (MV–6) of the same creek. Most of the cultural materials dated around 13,000 years ago rest on a series of adjacent gravel strewn sand bars, beaches of the old channel (MV–6), and on the gently inclined sandy banks (SCH–4) of that channel (Fig. 2). The dental remains of an infant elephant have been excavated 300 m downstream, on top of an ancient sand bar. It is clear that the site occupants made their camp on sandy surfaces adjacent to the water's edge. All artifacts were spatially patterned, are lying flat, and have not been disturbed. The cultural materials, radiocarbon dated at approximately 33,000 B.P., are found at the base of the SCH–4 (MV–7) about 50 m south of the old creek channel (see Dillehay 1986).

Strata MV–6 (sand bars and beaches) and SCH–4 (sandy banks) are both superimposed by MV–5, a peat layer. Core drilling and test pits outside of the site area show that at the time Stratum MV–6 was deposited, the stream was flanked by low sandy knolls and small, shallow bogs that restricted access to the creek. Later a more substantial bog, represented by Stratum MV–5, developed in the old channel where water accumulated and plants, such as *Juncus procerus* and *Spagnum* sp., flourished. The bog gradually expanded with rising water levels to cover the creek bank and lower terrace slopes. The plant mass and organic cultural debris decomposed to form a 1–25-cm thick peat deposit that covered and sealed the archaeological materials. All of the features, and bone, lithic, and wood artifacts are contained within a 2–5-cm thick occupational layer.

This measure represents the vertical distribution of features and artifactual debris in the stratum, not the thickness of individual architectural limbs which often measured as much as 40 cm in diameter. This deposit is composed of the contemporaneous upper surfaces of Strata MV–6 and SCH–4, and is covered by the base of MV–5. In some excavated units of Area A, the organic artifacts were differentially preserved by the uneven thickness of the peat layer, which is explained by differential development of the peat across low and high areas and by uneven surface erosion across the site during a later geologic time. The architectural features, which lie on the old creek bank (SCH–4) adjacent to the cultural materials on the sand bar (MV–6), have a maximum height or thickness of 40 cm and are unevenly covered by the peat of Stratum MV–5.

There has been no post-depositional disturbance (other than the partial erosion of the upper layer of MV–5) of Strata MV–3 through SCH–4, except that the modern stream has cut a channel through them, thereby exposed the edge of the ancient MV–6 creek bank that contains the cultural materials.

Table 1. Radiocarbon Dates and Stratigarphy

Stratigraphic Provenience Sample No.	Material	Material	Age B.P. 5570 half-life	Age B.P., 5730 half-life
Non-Cultural Deposits				
Upper Layer of MV–3				
Beta–6756	wood sliver	Area A2	4750 ± 90	4890 ± 90
Lower Layer of MV–3				
Beta–6753	wood sliver	Area A2	8270 ± 110	8520 ± 110
Lower Layer of MV–4				
TX–4436	wood sliver	Area A1, Column 2, Unit 9	8030 ± 130	8270 ± 130
Upper Layer of MV–5				
TX–3207	wood and charcoal	Area A1, Column 4, Unit 7	10 860 ± 130	11 155 ± 130
TX–3210	wood sliver	Area B, Column 4, Unit 10	11 760 ± 470	12 115 ± 470
Lower Layer of MV–5				
TX–3472	wood sliver	Area C, Column 9, Unit 7	11 600 ± 120	11 950 ± 120
Cultural Deposits				
Upper Layer of MV–6 (ancient creekshore, sand bar and beach)				

TX–3760	bone	Area B, Column 4, Unit 9	11 990 ± 200	12 350 ± 200
Beta–6755	wood artifact	Area D, Column 5, Unit 4	12 230 ± 140	12 600 ± 140
TX–3208	charcoal	Area D, Column 3, Unit 11	13 560 ± 250	13 965 ± 250
OXA–105	amino acids from collagen in bone artifact	Area B, Column 9, Unit 5	11 800 ± 250	12 155 ± 250
TX–5374	carbonized wood	Area D, Column 11, Unit 6	11 790 ± 200	12 140 ± 200
TX–5376	charred wood	Area DW, Column 6, Unit 1	11 920 ± 120	12 280 ± 120
OXA–381	wood artifact	Area D, Column 2, Unit 6	12 090 ± 150	12 450 ± 150
Upper Layer of SCH–4 (MV–7) (ancient creek bank)				
TX–4437	wood artifact	Area A2, Column 1, Unit 10	12 650 ± 130	13 030 ± 130
TX–5375	wood artifact	Area DW, Column 7, Unit 10	12 740 ± 440	13 120 ± 440
Lower Layer of SCH–4 (base of MV–7)				
Beta–6754	charred wood	Test Pit 5	33 370 ± 530	34 470 ± 530
Beta–7825	carbonized wood	Test Pit 44	greater than 33 020	> 34 010

Radiocarbon Chronology

Seventeen radiocarbon ages have been processed at the University of Texas, Beta Analytic, and the University of Oxford radiocarbon laboratories (Dillehay and Pino n.d.; Dillehay et al. 1982). These dates were obtained on samples from stratigraphic levels between the top of MV−3 and the lower SCH−4 (base of MV−7), 8 m below the top of the Salto Chico Formation. There is no older organic matter or other contaminants in the MV−6 or SCH−4 cultural layers which might have altered the radiometric measurements of the samples. The buried surfaces of these two strata are located a few centimeters above the watertable and are sealed in by the cement-like MV−3 stratum in the upper layer of the stratigraphy. However, because contamination from the younger, overlying MV−5 peat layer is possible, the dates must be taken as minimum ages (Dillehay and Pino n.d.). Table 1 provides the stratigraphic and radiometric data.

The two ages for Stratum MV−3 correspond to the upper 5 cm (4750 ±90 B.P., Beta−6756) and the lower 5 cm (8270 ±110 B.P., Beta−6753) of that bed. Although the age for MV−4 (8030 ±130 B.P., TX−4436) is slightly younger than the date at the base of MV−3, no significant disagreement is seen between them.

Contact between Strata MV−4 and MV−5 is unconformable across the site. The lower 5 cm of MV−4 and the upper 5 cm of MV−5 are truncated in the outcrops where the dated materials were collected. For this reason the 10 860±130 B.P. (TX−3207) and 11,760±470 B.P. (TX−3210) dates indicate different depositional episodes of the MV−5 peat, but not necessarily the end of its development. The base of MV−5 is dated at 11 600 ±120 B.P. (TX−3472).

The MV−5 peat fills the spaces between the small pebbles in the old MV−6 creek bed and covers cultural objects lying on the surface of the ancient sandy beach, creek shoreline, and creek bank. Eight dates were processed on materials recovered from hearths, food pits, or other features buried in the cultural level in these contemporaneously occupied areas along the creek. These radiometric measurements range in age from 11 790 ±200 B.P. (TX−5374) on carbonized wood and 12 000 ±250 B.P. (OXA−105) on bone to 13 565 ±250 B.P. (TX−3208) on charcoal. The range of dates is accounted for by the difference in materials dated, differential preservation of these materials across the site, and three radiocarbon laboratories processing the samples. An average of the dates suggests the site was inhabited sometime between 12 500 and 13 500 B.P. (Dillehay et al. 1982). The dates for Stratum MV−6 are interpreted as the minimum ages of the formation and principal development of the creek which deposited the gravels.

The two ages for Stratum MV−7 (33 370 ±530 B.P., Beta−6754 and greater than 33 020 B.P., Beta−7825) were excavated on the unconforming plain of SCH−4 (the base of MV−7). The two samples were collected from two different, but spatially contiguous, charcoal scatters in direct association with modified stones at a depth of 2.0 m below the present surface at the Monte Verde site and 8 m below the top of the intact Salto Chico Formation elsewhere in the area. The age of this stratum thus represents a geologic, or posssibly a cultural, event (Dillehay 1986:336) which took place approximately 20,000 years earlier than the 13,000–year–old cultural episode.

Excavation Grid and Procedure

In 1977, a checkerboard grid system of columns and rows of 1×1 m was laid out over the site. The deposits were excavated by natural stratigraphy. Horizontal excavation of the cultural layer was carried out from unexcavated 1×1 m units or, in some areas of the site where several square meters had been opened, from slats 50 cm wide suspended over the wooden materials. Since individual 1×1 m columns were dug, access to the deposits was not a major problem until long, waterlogged wooden poles spanning several units were found. At this time, larger excavation blocks were opened. Excavators used extreme caution in moving around and between these areas when they were cleaned, mapped, photographed, drawn, and analyzed *in situ*.

The overburden and peat layer were first removed and the occupational surfaces of Strata MV–6 and SCH–4 were uncovered a square meter unit at a time with bare hands or small, soft tools. The ecofactual and artifactual materials were then cleaned, bagged, and numbered. During all field seasons the distribution patterns of all artifacts and features on these surfaces were piece-plotted. After initial checking with sieves of 1.5 mm, 3.0 mm, and 6 mm mesh to ensure that no small finds, such as lithic debris or tiny bones, were being missed, it was found that constant sifting was unnecessary except as a periodic check. This was the case with lithic workshop areas and well defined use-surfaces inside the architectural structures. For the recovery of microfloral and faunal remains, large quantities of soil flotation samples were systematically collected and processed in the laboratory of the Institute of Geological Sciences at the Universidad Austral de Chile.

The quantity of wood and organic vegetable remains covered by the MV–5 peat layer posed a logistical problem as to excavation and preservation. Most of the artifacts lay immediately above the low water level in the present-day creek. As a result of this and filtering rainwater, the water content of these deposits was high. Most wood was completely waterlogged, since presumably, the time of its burial by the peat, and was so soft that it was easily marked by hard, hand excavating tools. Therefore, hard tools were never used to excavate in the cultural layers.

The only secure way to excavate the wood and vegetable remains undamaged was to use fine-haired brushes, small manual airpumps, and fingers. By these means it was possible to be certain that a cut or other mark visible on a piece of wood was contemporary with the piece, and not the result of damage attributed to excavation. This excavation technique also assured that small artifacts or ecofacts would not be missed. The soft, gritty peat was pressed and gently felt for materials. In fact, the site was excavated by surgically removing millimeter-thin layers and chunks of peat or clusters of tiny twigs, leaves, and other small particles. This task, often performed in cold, wet conditions, usually required a full week or more for one excavator to remove a cultural layer 5–10 cm thick in one 1–m^2 unit. Needless to say, the excavation of Monte Verde was slow, difficult, and tedious work, often taxing the physical health, fingernails, and *esprit de corps* of the excavators.

Top priorities during the excavation were to keep all of the organic debris saturated with water and to excavate the wooden artifacts with extreme caution. Initially, Monte Verde was dug by using water. A water pump and fine hand-sprayers were employed to wash away the loose overlying peat sediments. After the first day of work, this technique was abandoned for two reasons. First, the creek held only 10–30 cm of water, and there was never an ample volume from which to draw. The next closest source of water was a small laguna located about 1.5 km from the site. Second, the pump tended to dredge sediments and heavily contaminate the deposits with elements of foreign debris. Since we were fine screening and floating the sediments of features and use-surfaces for reconstruction of the site economy, we decided not to risk further contamination.

Various techniques were employed to protect the uncovered cultural remains while they were being mapped and photographed. There was regular spraying (sometimes with propanol), flooding the excavation units deliberately, and shielding them entirely by covering them with plastic tarps. Anytime it showered, which was usually 5–10 times a day during the summer months, we would uncover the deposits, allowing the light rain to wash the artifacts. This not only kept them wet but also removed loose particles of sand from the surface. The use of rainwater and water sprays also allowed overlying sediments to be washed gently from features embedded in the use-surfaces of the occupied sand bar (MV–6) and sand bank (SCH–4). Covering the site with plastic tarps was a useful technique for maintaining the moisture level of the deposits. Since southern Chile is very wet and usually cool year round, excessively warm temperatures and high humidity did not develop under the tarp.

Once removed from the excavation, the wooden materials began to dry, crack and split within a few hours, if not kept wet. All possible implements, wood, bark, fragments of animal skin, leaves, and smaller finds, were processed in water, propanol or polyethylene glycol (PEG) and preserved in cheese cloth in trays or in long metal vats. These were then wrapped in plastic to prevent evaporation and to maintain a constant level of humidity. Upon their arrival at the laboratory, the pieces were subjected to various chemical processes to insure their permanent preservation. This process normally took 6–8 months depending upon the size, type, and condition of each wood piece. Due to logistical problems in containing, transporting, and processing large pieces of wood, several logs of the architectural foundations were reburied in a wet sand and peat matrix in a distant, noncultural area of the site. Items made of glass and plastic were buried with the logs to signal the chronology of reburial. Each pit was mapped to insure relocation at a later date. Wood and vegetable remains preserved in the laboratory are housed at Universidad Austral de Chile.

Geological, botanical, faunal, pollen, soil flotation, and other samples were collected from all the culture-bearing and culturally sterile deposits. Pollen, mollusk, insect, and diatom samples were collected from all stratigraphic deposits that were expected to preserve these materials. Material for radiocarbon dating was also collected in abundance from all kinds of organic remains in all strata.

Natural Versus Cultural Facts: Research Design and Context

When my students and I first began to excavate at Monte Verde in 1977, we were somewhat puzzled by the materials recovered from the site. We had our doubts about whether the site was a valid human settlement. Even though we recovered stone tools and cut elephant bones in direct association from within the site, we were dubious of the patterned concentration of associated burned and modified wood and of the site context. I, like most archaeologists, was taught to expect a site with poor preservation and primarily with stone and bone materials. In spite of our initial doubts, we decided to return to the location in 1978 and 1979 with geological and ecological specialists to gather more information. Validation of the site and understanding of the cultural and/or natural processes that might have deposited associated and morphologically altered materials were the major problems of the multidisciplinary research team during all of the field seasons.

In 1979, the core group of multidisciplinary specialists was integrated into the project to study the ecological context of the area, to analyze the well-preserved organic remains, and to initiate experimental, ethnoecological; ethnoarchaeological, and natural history studies. This was to be done in conjunction with archaeological inquiries into the life history of the associated materials buried in the cultural deposits. Professors Carlos Ramirez and Claudio Briones (Universidad Austral de Chile) studied the local modern-day biotic zones. Pollen analysis was performed by Dr. Calvin Heusser, Department of Biology, State University of New York, Tuxedo. Faunal remains were examined by Dr. Rodolfo Casamiquela, Centro de Investigaciónes Científicas, Viedma, Argentina. Dr. Juan Diaz-Vaz O., Director of the Instituto de Tecnología de Madera, Universidad Austral de Chile, investigated the archaeological woods. Dr. Michael B. Collins, then of the University of Kentucky, joined the project in 1981, as a lithic specialist to aid in the comparative, analysis of morphological culturally modified stones. Over the years another 34 specialists from several other disciplines worked with the research team to analyze different kinds of abiotic and biotic elements recovered from the site or to carry out experimental studies in the forest.

The preservation of organic remains was so good at Monte Verde that it presented the team with an archaeological paradox. On the one hand, the presence and patterning of a majority of the charred and uncharred food remains, clearly worked stone and wood artifacts, and fragments of animal tissue made it easy to interpret the kinds of domestic activities carried out at the site. On the other hand, the presence of insects, leaves, twigs, small branches and other organic debris made it difficult in a few areas of the site to determine whether some of the perishable remains were physically modified and spatially patterned by human or by natural forces. Since a few of the lithic and wood artifacts were only somewhat modified from their natural state, it was sometimes difficult to define the vague boundary between some natural and cultural forms, even though the contextual location of these materials was clearly cultural (Dillehay 1986).

To understand how natural forces such as stream deposition, tree fall, carnivore activity, and plant growth might have altered the depositional context and the physical appearance of perishable materials, the interdisciplinary research team was challenged to study Monte Verde in a way that no other early site has ever been researched in the Americas. Much of the field, laboratory, and experimental work (see Binford 1981, Bonnichsen 1979, Coles 1979, and Morlan 1981 for examples of the utility of this kind of research) was oriented toward an examination of the selection, transportation, deposition, distribution, composition, association, alteration, and preservation of materials in the cultural site and in noncultural areas in the same depositional basin of the ancient creek system (MV–6 and SCH–4). Investigation of uncontaminated or noncultural localities provided the opportunity to determine the natural attributes in the same depositional units or buried creek contexts, so that these could be separated from the cultural ones in the archaeological site. The experimental, ethnoecological, ethnoarchaeological, and folk natural history studies were done in the active present-day environment, and in controlled experimental areas. Data derived from these studies have been compared with those generated by the archaeological and environmental excavations in order to establish a series of plausible hypotheses to test the cultural and natural processes of the selection, deposition, association, distribution, patterning, and preservation of ecofactual and artifactual materials in the contexts of the creek setting (Dillehay 1977, 1981, 1982).

We can look at the lithic research to give an example of the type of work being done. The experimental lithic samples have provided control over certain variables such as angle and pressure of application, number of strokes, angle and form of worked edge, size, form and material types of stone, and so on. The naturally-occurring buried (ancient MV–6 creek bed) and surface (modern MV–6 creek bank) samples give control over the random or patterned distribution of form, type, and size of modified stone as well as definition of the specific natural mechanisms that can alter specimens. The end result is the documentation of (1) natural alteration as a result of being buried for 12 000 to 14 000 years, and (2) the culturally-induced mechanisms that can modify stones (see Collins and Dillehay 1986; Dillehay 1986).

Additionally, analyses of the distribution of various extant tree species, the form and location of different sizes of branches in these trees, and the natural processes determining the physical condition and contextual displacement of fallen or water transported branches were performed. These were carried out for the purpose of obtaining a natural type collection for comparison with the excavated wood assemblage in both the cultural and noncultural sites along the creek. The morphological characteristics of these type collections are also being compared to both the archaeological materials and the excavated natural control specimens. Ultimately, these analyses will aid our effort to define the natural/cultural boundary, and to better understand any competing environmental and cultural factors.

Taphonomical studies on animal skeletons in the forest and experimental studies on fresh bone have been carried out for purposes similar to those described above for the stone and wood. The same methodology was applied to different plant species, mollusks, and peat deposits.

Overall, this research has elucidated many important differences and similarities in the way natural forces and human actions morphologically alter materials and deposit them on the landscape. It has also provided a more controlled, scientific technique for identifying and interpreting some of the ambiguous materials excavated from the site, and has offered the opportunity to test a set of complementary hypotheses about the causation of form and change of different materials. These hypotheses have been reduced to a set of ranked possibilities with which to explain the observations made in the archaeological and ecofactual contexts of the creek.

It should be noted that SPSS FREQUENCIES, CROSSTABS, and BREAKDOWN statistical procedures have been used to aid in the characterization of the ecofactual and artifactual assemblages. The SPSS SCATTERGRAM, SASPLOT, CMAP, and SYMAP programs have been employed to examine the spatial distribution of materials at the site. To investigate spatial variability between 1×1–m subunits across all of the excavation blocks, the CMAP program has been used to generate chloropeth density maps. Lastly, more advanced statistical applications are being employed to analyze specific problems of inter- and intracollection and assemblage, and attribute similarities and dissimilarities.

Recovered Archaeological Materials

Four distinct zones of buried cultural remains have been located along the ancient banks and terraces of Chinchihuapi Creek (Fig. 3). They are: (1) Zone A, on the west side of the north bank of the creek, where the wishbone-shaped architectural structure and patterned concentrations of wood, bone, and stone artifacts were found, (2) Zone B, in the south bank of the creek about 300 m downstream from Zone A, where the dental remains of an infant mastodon and two modified pebble flakes were recovered *in situ*, (3) Zone C, on the bank and along a low, sandy terrace of the south side of the creek, where modified pebbles, the remains of a poorly preserved architectural foundation, and scattered charcoal hearths were located, and (4) Zone D, on the east side of the north bank of the creek, where the tree branch and limb foundations of agglutinated residential huts and associated activity areas were found in 1983 and 1985. In total, approximately 450 m^2 have been excavated in all areas of the site.

The yield of artifacts across the site depended upon the location of an excavation unit within an activity area. The maximum yield was 60 stone artifacts, 5 bones, 54 pieces of wood, and numerous tiny twigs, leaf fragments, wood slivers, and several other miscellaneous items; this did not include the microscopic elements. Everything visible was recorded, catalogued and stored, including what seemed to be useless twigs and small pieces of wood.

Table 2 presents a list of the varieties and quantities of materials preserved at the Monte Verde site. A rough estimate shows that although lithics constitute approximately 47.4% of the total cultural inventory, they represent only one of four technological industries and one of several categories of assemblages that yield data. When viewed from the perspective of the amount of labor committed to the procurement and preparation of these materials for use, the macrobotanical and wood remains constitute the most important assemblages.

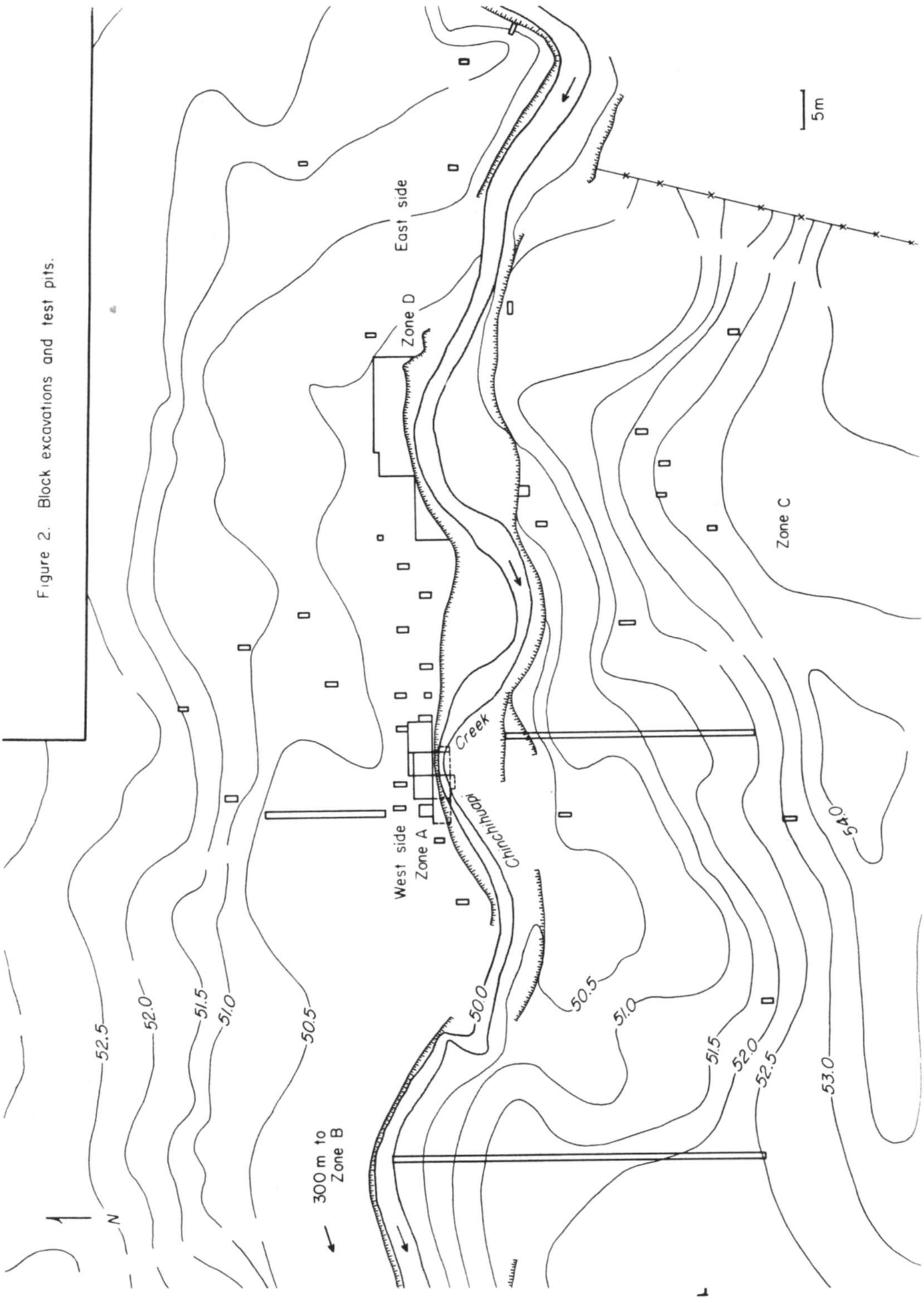

FIGURE 3 Topographic map of the Monte Verde site showing the present-day relief of the terrain, and the location of the excavation blocks and test pits.

Table 2. List of type and quantity of preserved materials recovered from the Monte Verde Site

Material Type	*Quantity*	*Artifact Assemblage (%)*
Stone	747	47.4
Bone	345	21.5
Wood	470	29.8
Hide	18	1.3
Plant	20,559	—
Shell	8	—
Insects	Indeterminable	—
Microorganism	Indeterminable	—
Miscellaneous	Indeterminable	—

During the excavation, no professional conservator was at hand except for the author, who had some previous training in the conservation of archaeological woods. However, a professional conservator, the late Mr. Ivon von Leiftner, was stationed at the Universidad Austral de Chile, where the excavated materials were taken within a matter of a few days and placed in the appropriate chemicals for treatment. The protection, lifting, packing, and transporting of all artifacts was done by the author and experienced crew chiefs. All large wooden pieces have been stored in nearby peat deposits. Furthermore, all artifacts were recorded, measured, and mapped in the field prior to their removal, transportation to the laboratory, and their conservation treatment.

Architecture and Activity Areas

The principal site is located on the north side of Chinchihuapi Creek and covers approximately 800 m^2 arbitrarily divided into the east side (Zone D) and the west side (Zone A) (Fig. 3).

On the east side of the site the remains of 10 or 11 foundations of residential huts have been recovered. The foundations are formed by small timbers, limbs, and roughly shaped planks usually held in place by stakes. Fallen branches and vertical post stubs reveal that the hut frames were made primarily of *luma* and other hardwoods. The side walls were placed about 1 m apart against a wall foundation and then apparently draped with animal skins as suggested by the presence of a few small fragments of skin still clinging to the fallen side poles. Results of amino acid tests and microscopic analysis by microbiologists and animal pathologists at the Universidad Austral de Chile and the University of Kentucky suggest that the skins are most likely from a large mammal, probably elephant.

Although the individual house plans differ slightly there are several common features. The hut foundations have the same basic rectangular shape, though they vary in size from approximately 1.3×2.3 m to 4×4.5 m. Entrances into the huts were evidently along an outside wall, probably through hanging hides. A wide variety of plant remains, stone tools, food stains, and small braziers (shallow clay-lined pits for holding burning coals) was found on the living surface inside each hut. The braziers, which contained ash and specks of charcoal, were probably used to heat each hut and warm the food. Cooking was evidently a communal effort, as shown by the discovery of two large clay and charcoal hearths centrally located outside the huts. Flotation studies of brazier and floor contents revealed carbon and edible seeds, nuts, fruits, berries, and tubers. The discovery of three roughly-shaped wooden mortars and several grinding stones near the hearths suggest that the preparation of plant food took place next to the hearths.

The most informative aspect of the architecture on the east side is that these huts were agglutinated and laid out in two roughly parallel rows of attached units along the north bank of the creek (see Dillehay 1984, 1986). The presence of lumber piles, limbs, wood shavings, and other modified and partially burned pieces of wood lying close to the hut foundations and hearths show that the occupants stored firewood and made wooden tools. Several pieces of charred and partially shaved and carved wooden objects indicate that time was devoted to woodworking. Some of the finished products include three wooden mortars, three hafts on which are mounted stone scrapers (Fig. 4), a sharply pointed lance-like implement measuring about 1.5 m long, several digging sticks, and an assortment of other miscellaneous artifacts (Fig. 5).

No human bones have yet been recovered from the excavations at Monte Verde, but there are two indirect indicators of information about the site's inhabi-

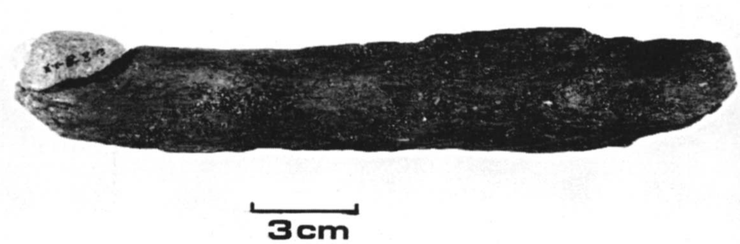

FIGURE 4 Stone scraper mounted on a handle of *luma* (*Amomyrtus luma*) wood. The stone is attached with bitumen.

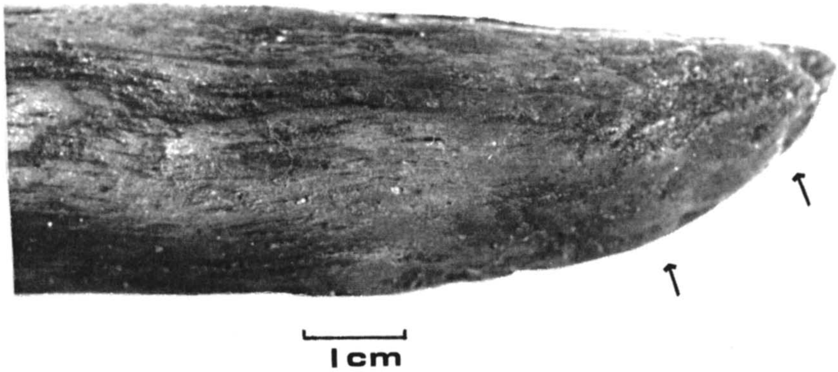

FIGURE 5 Pointed and blunted end (arrows) of a smoothed stem (0.5 m) of *luma* (*Amomyrtus luma*) found in a cache of modified wooden pieces at the east end of the site. In experimental studies, similar blunted ends were replicated on fresh *Puma* wood by use as a digging stick.

tants. One is the imprint of a foot (about 16 cm long) preserved in stored clay around one of the communal hearths. The other indirect source of information consists of possible coprolites that appear to be of human origin. These were recovered from small pits dug in the ground near a large communal hearth.

The west side of the site, which was the main focus of research prior to 1983, is characterized by a nonresidential structure and activity area (Fig. 6). The central feature is a roughly ovoid-shaped artificial rise of sand and a few gravels. Resting on this rise is an architectural foundation made of sand and gravel compacted to form a peculiar wishbone shape with a rectangular platform protruding from its exterior base. The total areal extent of this structure measures about 3 m wide, 3.9 m long, and 0.6 m high. Fragments of upright wooden stubs were present approximately every 20 to 30 cm along both arms of the structure. Presumably these are the remains of a pole frame probably draped with hides. Fronting the entrance was a large hearth and a partially preserved rectangular-shaped, wooden, branch-lined plaza. A few stone tools were scattered around the open yard of the structure. The same type and size of clay-lined braziers recorded on the east side of the site were found on the occupation surface inside the structure and the court-yard. Of particular interest is the association of the hearths and protruding platform with preserved bits of apparent animal hide, of burned seeds and stalks of bulrush reed (*Scirpus californicus*, a brackishwater plant found today about 30 km west of the site), and of masticated *boldo* leaves (*Peumus boldus*, an imported plant found in warmer environments and used by the present-day Mapuche Indians for medicinal purposes).

No other architectural features have been recorded in the immediate vicinity of this structure. There is, however, a semi-circular concentration of hearths, wood piles, wooden artifacts, stone tools, and elephant bones formed around the south

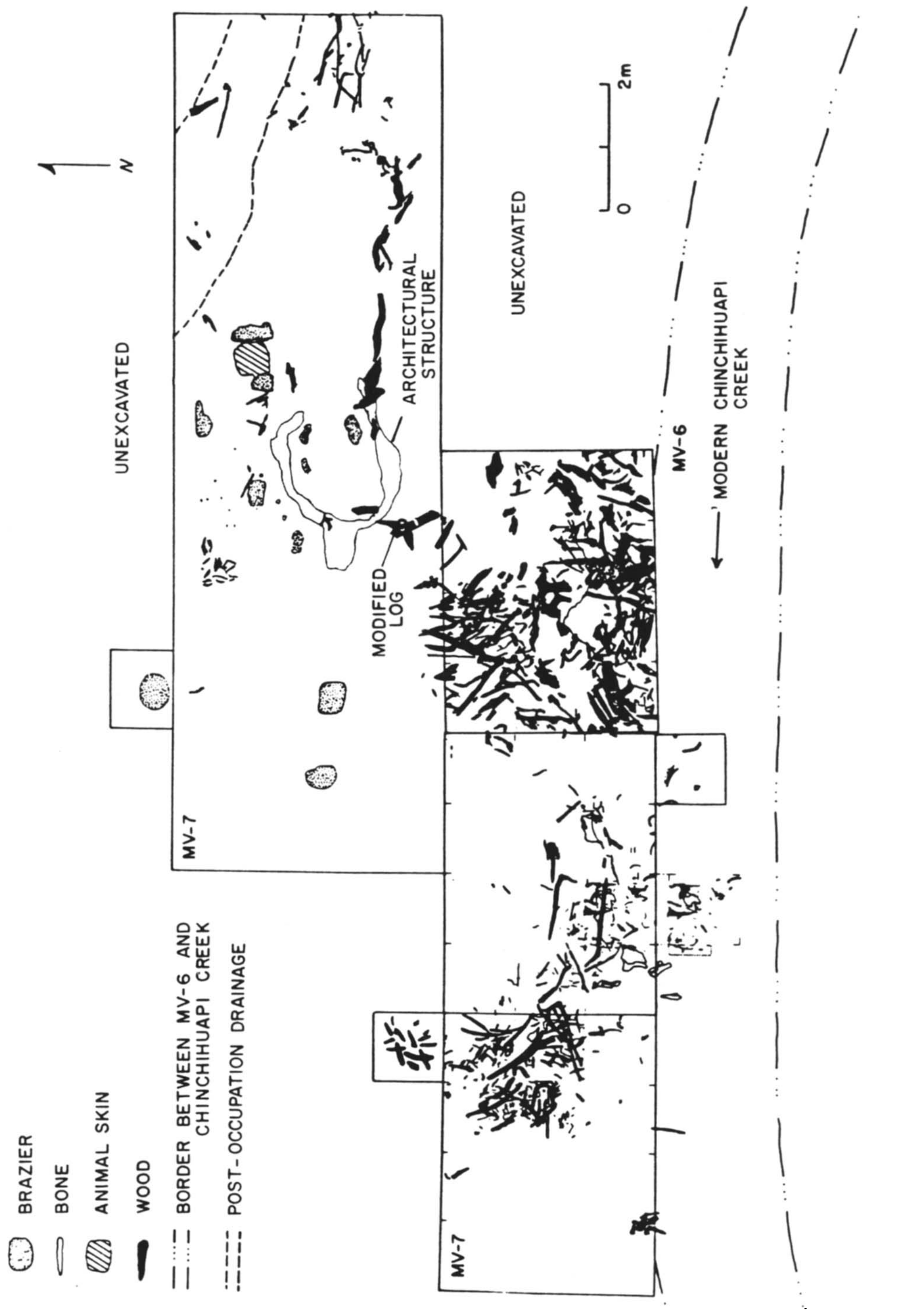

FIGURE 6 Plan of the west end (Areas A-C) of the site showing the location of the wishbone-shaped structure and front plaza in association with the surrounding concentrations of bone, wood, and stone materials.

and west side of this structure. The majority of the elephant bones, stone tools made of nonlocal lithic material, and percussion flaked and bifacially worked stone at the site are found in this concentration. The shape, the location, and the artifactual content of the wishbone feature suggest that the structure and this end of the site on the north bank of the creek served a special purpose, rather than as living quarters.

Two areas have been excavated in Zone C on the south side of the creek. Test pits on the bank of the south creek yielded charcoal scatters, naturally fractured and culturally utilized stones, and poorly preserved wooden limbs laid out in a rough rectangular fashion. Since the south side of the creek is slightly higher in elevation, the MV-5 peat layer was poorly developed here; thus the organic remains were very fragile. This evidence might have suggested the presence of a buried occupation zone arranged in a linear fashion along the creek bank, like the one described for the north side of the creek. Other test pits on the higher sandy knoll (or terrace) some 50 m from the creek show a light scatter of charcoal and a few modified stones, which points to some human activity in this area of the site as well.

There is no doubt that all of the recovered architectural features and artifact concentrations represent a contemporaneous cultural event. Except for the deeper materials dated around 33000 years ago of the archaeological materials at the site lie on the buried surfaces of Stratum SCH−4 or MV−6, indicating their stratigraphic contemporaneity. Although the whole of the site has not been opened and some possible house outlines and work areas have not been completely revealed, the exposed cultural remains make it evident that the site consisted of distinct work and residential areas functionally and spatially integrated into a planned settlement. The fact that some of the structures and work areas overlap, that no vertically intrusive features occur, and that the same kinds of hearths, braziers, lithics, wooden tools, plant remains, and animal bones are found in both areas, though in different proportions, also attest to contemporaneous occupation and a single cultural episode.

Artifact Categories

Stone

Three different methods for making stone tools are represented among the specimens from Monte Verde: flaking (Fig. 7), pecking-and-grinding and modification through use on some unflaked stones. The flaked and pecked-ground tools resemble artifacts found in the remains of later South American cultures, but the use of naturally fractured stones has not been duplicated among other known assemblages in the Americas (Collins and Dillehay 1986; Dillehay 1984), although single artifacts from some sites are very similar in form to those found at Monte Verde.

FIGURE 7 Bifacially and bipolar chipped stone tool made of quartz. Note the impact scar and cortex on the proximal end (top) and the multiple flake facets on the body. This tool was found at the east end of the site in a woodworking area.

Bone

Three-hundred and forty-four bones, including those of elephant (*Cuvieronius sensu Casamiquela*), paleocamelid (*Paleo-Llama*) (Fig. 8), and small game, such as rodents and amphibians, were recovered from the site. A majority of the bone remains are rib fragments of at least seven individual mastodons. Between 7 and 10 bones were modified as possible digging sticks, gouging tools, or other implements.

Wood

In addition to the wooden architectural foundations, several types of artifacts made of wood were recovered, including a sharply pointed lance-like implement, 3 crude wooden mortars, 4 tool hafts or handles, 4 digging sticks, and more than 200 pieces of wood exhibiting cut or planed facets, burned areas, cut marks, and/or smoothed and thinned surfaces (Fig. 9).

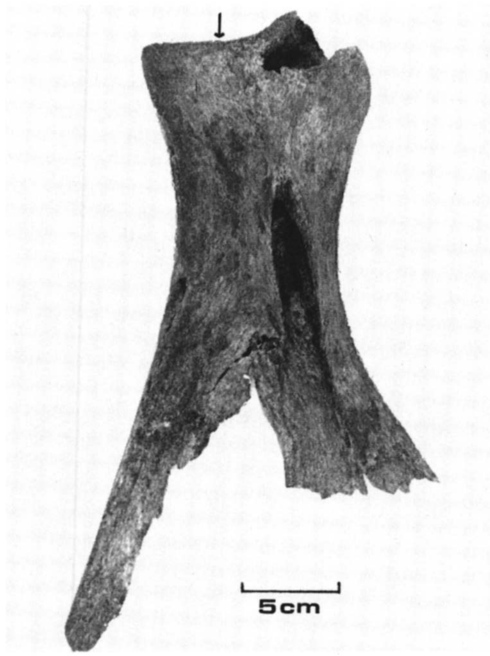

FIGURE 8 Scapula of *Paleo-Llama* bone recovered from the use-surface of a residential hut in Area DW on the east side of the site. Although not shown here, two transverse cut marks (arrows) are located on the upper interior lip of the glenoid cavity. The jagged edges on the distal end of the thin bone were heavily damaged by being in a waterlogged deposit. The bracchia may have been deliberately smashed, probably with a hammerstone. The scapula, two hammerstones made of tonalite, and four small bone fragments that fit the impacted area of the scapula were found in direct association on a use-surface inside a residential hut.

Interdisciplinary Studies: Sampling Procedures

As mentioned earlier, the wealth of biotic and abiotic remains found at the site required a highly diversified group of specialists to identify and analyze these materials for the purpose of reconstructing the paleoenvironment, the paleoclimate and the economy at the time of site habitation. Although the team's reconstruction is preliminary, project scientists have tentatively concluded that cool and wet conditions similar to the present-day environment prevailed in the region some 16,000 to 12,000 years ago. Insects, diatom, pollen, and macrobotanical remains from hearths and occupational surfaces in the living area suggest a slight warming trend (perhaps 2–4°C warmer than the previous period, though slightly cooler than that of today) during the habitation of Monte Verde.

Sampling techniques were applied in accordance with special problems and the needs of particular disciplines. For instance, all wood pieces were recorded and collected, and most of them were preserved. However, only 95 wood samples (21% of the total wood assemblage) were collected for special microscopic analysis to identify wood structure, type, and modification. An additional 75 samples were collected especially for tree-ring analysis. Soil flotation, pollen, and soil samples

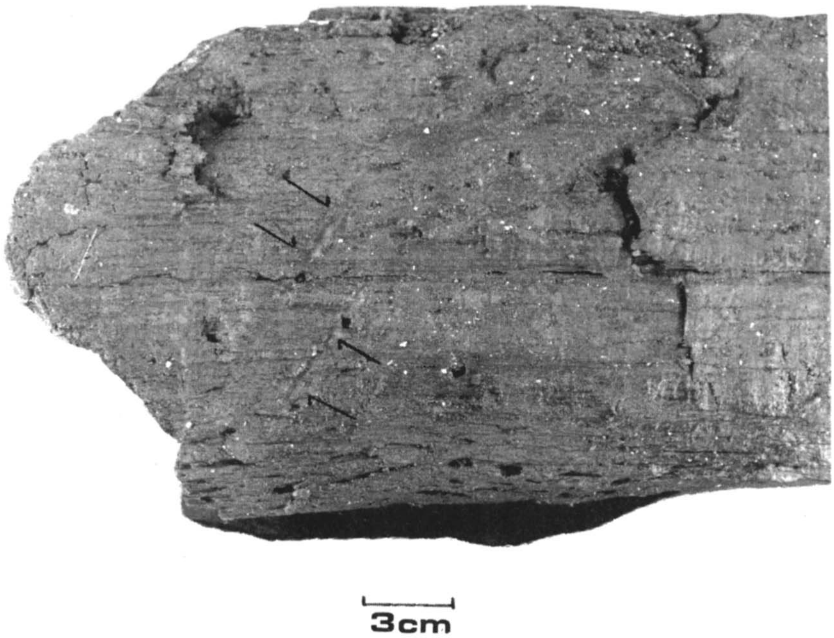

FIGURE 9 Worked slat of *mañío* (*Saxegothaea conspicua*) wood showing partially burned (lower central section and edge) and planed surface. Note the two parallel cuts transversing the left central side of the slat and the shallow pits in these cuts (indicated by lines). These pits were probably formed by a stone tool with a thick edge characterized by large protruding crystals. Such tools made of tonalite and quartzite such as the one shown in Figure 7 were found at the site. Pits formed by the deeper penetration of protruding crystals are not always obliterated by the remaining drag of the cutting edge. A natural crack in the wood is seen on the right side.

were taken in quantities and from locations advised by specialists and from the use-surfaces across the site. The entire soil matrix was collected in food pits, stains, hearths, or other miscellaneous features. Additionally, extra samples of every eco-factual and artifactual category were kept for future analysis.

Although a sufficient quantity and representative collection of samples were taken for each material category, only a selected lot of each collection actually required analysis. The two exceptions were feature fill and use-surfaces inside occupational structures. As a means of direct reconstruction of economic and dietary practice, all hearth, food pit, and stain fills were processed. However, only 50% of the soil samples taken from the use-surfaces outside the structures were analyzed. Furthermore, since all of the organic remains from the cultural layer provided data on climatic episodes, local environmental conditions, chronology, human alteration of the landscape, economy, and other aspects of cultural behavior, it was decided that the "law of diminishing returns" would eventually take over, with a lower yield of new or significant information at an increased cost. As it turned out, this was the case. All of the specialty studies were in general agreement on the similarity of past and present climates and environments in the region. The real value of each discipline related to specific details provided about particular aspects of human-environmental relations and of cultural and natural processes which might have deposited or altered artifacts.

Wood

There are several different factors that conditioned the preservation and conservation of the wood recovered. Where the preservation of materials differed across the site, where woods were associated with different kinds of organic debris such as excrement, leaves and organic residue, or where they were burned or subjected to different treatments and substances at the time of their use, problems have occurred in their conservation. In contrast, woods associated with inorganic remains, such as clay, were well preserved.

Two laboratory techniques were employed to conserve plant and wood remains. One consisted of propanol and liquid wax. This technique, was used on artifacts recovered during the 1977, 1978, and 1979 field seasons. It proved to be very successful in preserving the size and form of the wood specimens, but unsuccessful in preserving the cellular structure. Because this technique required large amounts of alcohol and wax and a long period of saturation time in the laboratory, it was abandoned and replaced by polyethylene glycol (PEG). Woods recovered during the remaining field seasons were impregnated with PEG of different grades.

Diaz-Vaz (n.d.) carried out a microscopic analysis of the 95 specimens of the archaeological wood collection to identify the types of species exploited, to reconstruct the environment, and to determine the presence of human modification. Due to the poorer preservation of woods in some areas of the site and to partial dehydration caused by the propanol liquid parrafin technique of conservation, approximately 34% of the wood samples had collapsed/compressed cellular structure. Thus, while many wood specimens had not lost their form, they had lost their cellular structure and, in turn, their abililty to be identified. Sixty-nine percent were partially identified and twenty one percent were unidentified. Diaz-Vaz also discovered that, despite the fact that the wood was largely free of the deterioration caused by wood-attacking fungi (due to the rapid peat development which covered the site), the cell walls had lost a large part of their strength simply through the effect of the surrounding soil matrix on the compounds which make up the cell walls.

The wood samples which could be positively identified together with those which were negatively identified, belonged to the following species: 39% *luma* (*Amomyrtus luma*), 23% *arrayán* of myrtle (*Luma paiculata*) and 14% *coigue* (*Nothofagus dombeyi*). Species such as *mañio* (*Saxegothaea conspicua*), *tepú* (*Tepualia stipularis*), *mañio* (*Podocarpus nubigena*), *temu* (*Temu divaricatum*), *ulmo*

(*Ecicryphia cordifolia*), and *tineo* (*Weinmannia trichosperma*) occurred less frequently. The species identified correspond in their totality to trees which, at present, prefer conditions of high humidity, a conclusion also reached by complementary studies in palynology (Heusser n.d.) and geology (Pino n.d.).

Diaz-Vaz also carried out microscopic analyses of surface modifications on a small group of archaeological wood samples. These modifications, that is, pits, grooves, depressions, and other regularities, were attributed to different causes, one of which was human action (Diaz-Vaz n.d.; Olson n.d.). Macroalterations, such as chopping facets, breakage fractures, bark removal, perforations, buring and other indications of human modification, were relatively easy to detect. Microalterations such as surficial shaving, peeling, and smoothing on selected areas of a branch or log were very difficult to find because small randomly removed samples represented a tiny fraction of the entire surface of a worked timber, and thus under microscopic study they did not always show any modification.

Alterations on the surfaces of modern woods from variable contexts, such as fallen limbs and creek-rolled branches, were also studied and compared with alterations on the surfaces of the archaeological woods for purposes of identifying natural versus cultural processes. In brief, it was discovered that most of the natural modifications can occur before and during deposition and also during and after excavation. For instance, woods separated from a tree may exhibit external and internal fractures, attack by insects and fungi, and internal and external cracks caused by drying of the trunk and branches. While the wood is buried, compression of the cell structure, deterioration through the leaching of components of the wood, and the proliferation of bacteria which break down the wood may all occur. In addition, hard materials (for example, tiny rock crystals) in the soil matrix can compress the surface of the wood, becoming incrusted on it. There is also collapse by dehydration. Identification of these attributes and of the processes that account for them are very important for distinguishing cultural marks, cuts, and forms from natural ones.

A great deal of environmental and cultural information was also obtained from wood studies. Specifically, data on forest species exploited by the site's inhabitants, the nature of past woodlands, the development of wood technology, and woodworking techniques were all examined by various specialists.

Most of the stems and branches brought to the site were removed from trees by means of snapping and tearing or slicing and breaking; this might provide information on the difficulty of procuring and cutting large timbers and of the ability to use only small pieces. Of course, it might also indicate that the size of the hut frames did not require large timbers. Most of the worked stems and branches measured between 1.5 and 2.5 m in length and 10 and 25 cm in diameter. Preliminary tree-ring analysis of individual stems from collapsed structures suggests that the site was occupied for a period of at least one year, and that some of the wood was probably procured during both the summer and winter months. Since tree species in southern Chile grow no older than 2500 years, and since no dendrochronological studies have ever been performed in southern South America, no data of this kind was obtained from the wood samples; future work, however, may be performed on stored samples.

Sediments

Most of the general geologic findings have been presented above; however, a few other points are worth mentioning. The MV–6 gravel deposits and the SCH–4 sand layer indicate that the site's inhabitants camped at the edge of a small creek on a sand bar and sand bank. Patches of three types of clay (both used and unused) recovered from the site show that this resource, not found along Chinchihuapi Creek, was imported from swamps located in the larger Río Maullin drainage 8 km to the north. Analysis of the utilized lithic sources reveal that both local and distant rock types were collected. In particular, a laminated quartzite was obtained from the precordillera region to the northeast, and several discoidal, abladed beach-rolled pebbles of quartz and metamorphic rock were obtained from the coast to the west.

Various species of diatoms taken from the lower sediments of the MV–5 peat layer show that the posthabitational wetland environment was characterized by a low depression, perhaps a localized shallow marsh or bog with a maximum depth of 1.0 m (Harris n.d.; Pino n.d.).

Mollusks and Beetles

Freshwater mollusks (*Diplodon* sp.) were recovered from the surfaces of work areas and the dwellings. Assuming that these mollusks were collected from Chinchihuapi Creek, where they still occur today, they show that the stream was shallow, slow-moving, and rich in plants (Stuardo personal communication).

The remains of several species of beetles and other insects have been recovered from the site. Results of the beetle analysis confirm the findings of other studies about temperature, moisture, and plant communities. Of particular interest is the spatial distribution of beetle species across the site. Although not all excavation units were sampled, there might be enough information to indicate a presence/absence grid of certain species and suggest which types of trash and microenvironments within the habitation area influenced the distribution pattern of the beetles that live in dead wood, fresh wood, and various plant species. Also, the creek edge to creek bank transition is revealed by the spatial distribution of beetles that prefer mature, undisturbed forest, shallow, slow-moving water, and higher, drier ground (Hoganson, et al. n.d.).

Pollen and Plants

Studies of plants from the site include wood, bark, leaves, seeds, resin, and pollen. Pollen provided the basic data for a study of the regional environmental conditions and for the establishment of a general chronological sequence. This was done by Heusser (n.d.) through the identification of pollen zones characterized by certain groups of plants, such as *Nothofagus dombeyi* (indicating a forest zone) and *Lycopodium fuegianum* and other indicator species (which declined around 12 000 B.P.).

Macroscopic plant remains from Monte Verde have been most revealing, but rather than broad regional conditions they reflect the environment near the site, the type of plants exploited, and their resource catchment area.

The organic record from the site is rich in the remains of economic plants. Only specimens collected from food stains, hearths, braziers, possible coprolites, small storage pits, and use-surfaces were utilized to determine the economy of the occupants. The possibility that the inhabitants lived at the site throughout the year and exploited multiple ecological zones as far away as the coast (some 55 km to the west) is supported by a wide range of edible seeds, stalks, leaves, fruits, nuts, berries, soft leafy vegetables, and tuberous and rhizomatous plants that sequentially mature during all of the months of the year in different ecological zones. Particularly noteworthy is the discovery of the fruits, seeds, and flowers of several species of coastal plants that yield a high salt content. Some of these species are *Anagallis alternifolia, Podocarpus* sp., *Nothofagus obliqua, Tepualia stipularis, Atriplex* sp., *Boguila trifoliolata, and Coronopus* sp. (Ramirez n.d.). These are located only in river deltas along the southern Pacific coastline to the west. The inclusion of plants from all seasons provides direct archaeological evidence for year-round occupancy at the site—a living pattern also implied by the type and plan of the architectural features and by tree-ring analysis of architectural wood. Of additional significance is evidence of the potato (*Solanum maglia*) (Ugent et al. 1987).

Nonedible plants also were used extensively. In addition to the previously mentioned *boldo* plant associated with the wishbone-shaped structure, thousands of burned and unburned spora of *Lycopodium* sp. (a medicinal plant used in modern times to cure skin ailments and make talcum powder), and fourteen other plant species (also probably used as medicinal herbs) were scattered throughout the site. Various species of local trees, shrubs, vines, and canes were used for miscellaneous wooden tools and for the foundation logs and pole frames of the huts.

Animal Tissue

Several small pieces and one large chunk (about 28×39 cm) of apparent animal tissue are currently under study by pathologists and microbiologists. Preliminary results of amino acid, cellular structure, and DNA analyses of these fragments suggest that both muscle and hide were preserved at the site, and that these tissues were probably taken from a large mammal, most likely elephant (Cibull n.d.; Higuchi n.d.; Rosenthal n.d.). The majority of the specimens were found in direct association with the wooden poles of collapsed hut frames and with elephant bones in work areas. The preservation of these tissues and the general absence of microbial activity in them suggests that the site was covered very quickly by the wet, anaeorobic peat layer.

Site and Landform Reconstruction

The majority of Early Man sites so far excavated in the Americas contain flint tools, animal bones, and some plant material. The finds rarely consist of organic remains such as wooden implements, and thus may be concerned only with a small portion of the cultural evidence. Clearly the Monte Verde site has demonstrated the types of early prehistoric material culture utilized by one forest-dwelling group and the kind of lifestyle it had.

Perhaps some of the more important aspects of the site are the internal social organization, residential pattern, and activity areas revealed by the archaeological data (Dillehay 1986). We have now identified one nondomestic architectural unit and 10 or 11 completed or partially constructed huts, probably occupied by as many as 10 families of perhaps 25 to 35 people. Without the preservation of the wooden hut remains we would have recovered only stone tools, postholes, stains, and possibly bones. Although this assemblage of features and materials are indicative of habitation, they do not provide confirming evidence of the kinds of residence patterns and the wood and subsistence technologies which characterize a culture. In fact, if the organic remains had not been present, the site would have been interpreted as a kill-site, with a small temporary habitational component; this was exactly the proposition I put forward in 1979 before we had discovered the well-preserved residential area at the site (Dillehay 1981).

Of greater significance is the ability to define clear activity areas, use-patterns and functions of tools, and the site catchment zones. Specifically, cooking and food preparation took place outside of the houses around two large communal hearths positioned at each end of the domestic area. The abundant remains of wooden tools, weapons, architectural features, economic plants, stone and bone implements, and other artifacts indicate the types of technological materials utilized at the site. Wooden implements, food pits, and braziers, were common over much of the settlement, and some traces of food residue survive. The discovery of several *bola* stones with an index of sphericity greater than 0.95, and one wooden and one bone lance or projectile point suggests that the people used several methods of hunting. We can determine from the presence of the wide array of both organic and inorganic remains that the site's inhabitants were exploiting resources in a number of distant environmental zones within the lower and upper reaches of the Río Maullin. Most of these resource zones were aquatic areas such as swamps, bogs, riverbottoms, marshes, estuaries, and lagunas.

We have also learned that as the peat bog covered the site soon after its abandonment, the artifacts left behind were not subject to displacement by wind, water, or other natural forces. Therefore, reconstruction of a variety of activities, through both distributions and analyses of use-wear traces, are reliable. Rapid encasement of the site in peat is also indicated by the good preservation of animal tissue and by the general absence of microbial destruction in the organic debris recovered from the site.

Further, extensive buried layers of peat more than 20 m long and 5 cm thick are found only at two locations along Chinchihuapi Creek and at one place on the neighboring El Gato creek to the north; all three of these locations are late Pleistocene archaeological sites. Although too little survey work has been done in the region to draw any conclusions, it can be proposed that the organic mass accumulated by human settlement possibly both accelerated and nurtured the peat development by allowing the growth of plants such as *Spagnum* sp.

We experimentally field tested this proposition during the 1983 field season by damming an area of the creek and allowing the water to build up. We witnessed the rapid intrusion of *Spagnum* sp. into the area, the build-up of an oxidized organic gel, and the formation of a wet peat layer 10 cm thick. The entire process took about one month, demonstrating the potential for rapid inundation and growth of peat, and thus preservation of the archaeological materials. In one area of the creek we experimented with the addition of human waste products such as food, excrement, and trash to the naturally forming peat. The increased organic mass accelerated the growth of plants and the development of the oxidized gel.

The peat bog in the creek basin is not the raised bog or blanket bog typical of many areas in northern Europe. Rather, it is a small, localized bog that developed in a low, damp depression along the creek. The maximum depth of the ancient bog and the maximum thickness of the peat that sealed the material remains of the 13,000–year–old cultural episode are not known because of the subsequent erosion that occurred sometime during the 11 000–8000 B.P. time interval. Whatever it was, only the foundations and the lower parts of walls, and a wide range of debris remaining in *situ* on the living surfaces were preserved.

In conclusion, three final points are worth mentioning. First, the wooden materials and other objects lying on the sandy beach and bank probably acted like a barrier to prevent some erosion of the peat layer during subsequent geologic periods. Second, the presence of perishable remains in peat deposits provides new opportunities to employ archaeochemical methods (for example, amino acid and phosphate tests) to possibly detect archaeological sites and to determine the identity of any decomposed organic compounds which might have altered the chemical and morpho-logical constituency of the surrounding soil matrix. And third, as a result of the discovery of the Monte Verde site, five other elephant bearing sites, two of which show some signs of cultural activity, have been located in the region. These sites have been found through unsystematic observation of exposed creek banks. To date, none of these sites have been excavated archaeologically. It is my educated guess that systematic survey of river and creek drainages and of late Pleistocene lagunas will yield a wealth of well-preserved wetland sites.

Summary and Conclusion

South-central Chile has never been systematically surveyed for archaeological sites. As land-use patterns change and modernization modifies the landform, surveys must identify areas of interest for preservation or examination. Just as along Chinchihuapi Creek, other creeks may contain small pockets of peat that might hold well-preserved archaeological materials. Based upon the Monte Verde site and upon the presence of numerous peatbogs in the region, it can be concluded that the scientific potential of wetland archaeological research in Chile is very high.

In attempting to define the variety of cultural lifestyles of Early Man in the Americas, a localized model based on evidence from a wetland site like Monte Verde provides a more complete, accurate, and reliable idea of the culture of the local occupants. The collected material provides a less biased record of the site, since most categories of material culture (both inorganic and organic) are represented. We can determine from the Monte Verde data that a combined wood, bone, and stone industry comprised the technology, and that the site's inhabitants had a diversified economy focussed on hunting or scavenging big-game and plant collecting.

Furthermore, when viewed from a wider geographic perspective, the Monte Verde site reveals that boggy wetland environments were very important economic resources that contributed to the early transition from semisedentary to sedentary collectors and hunters during the terminal Pleistocene period, in at least one region of the world. It is my guess that with the increased land modification going on in many areas of the world and with more archaeological and geoarchaeological research focused on areas with a high potential for wetland sites, it is likely that other well-preserved Pleistocene sites will be discovered. In turn, these will probably add to and alter our current perception of early human cultures.

Finally, the scientific uniqueness of the Monte Verde site, in comparison with the vast majority of other sites around the world, lies in its preservation of the perishable materials and in the diversity of the social, technological, and economic activities represented there. As future investigators find similar sites, it would be well for them to keep an open mind toward the flexible and diverse lifestyles of early humans, particularly in regard to the types of cultural materials and ways in which these lifestyles may be expressed and preserved in the local archaeological record. Of course, it is possible that a site similar to Monte Verde has been found before somewhere in the New World, and that because the investigator was taught to look mainly for stones and bones, the site has been misinterpreted; if non-traditional stone tools and wooden objects were present, they may have been innocently overlooked, unanalyzed, or discarded. Only future research performed by specialists with very cautious approaches to the archaeological record of the late Pleistocene period in wetland and other environments will enhance our understanding of the dispersion and adaptation of early human populations.

Acknowledgments

The Monte Verde site was initially discovered by local lumbermen of the Barria family. In 1976 Professors Mauricio van de Maele and Carlos Troncoso dug into the buried deposits after finding bones and stones in the shallow creek bed below a cut bank. I thank these colleagues and friends for sharing their knowledge of the site with me, and particularly the late Professor van de Maele who encouraged me to excavate Monte Verde

The regular crew chiefs at the site consisted of Tomás Aguila (1977–78), Nelson Schwenke (1977–79), Patricio Sanzana (1977–85), Gaston Muñoz (1978–1985), and José Saavedra (1979–85). In addition to these friends and coworkers, more than seventy students and personnel worked at Monte Verde during different field seasons. I thank them. I also thank the Gerardo Barria family for their sincere friendship and hospitality during our stay on their land. Without their help and oxen team the project could not have been completed. Of additional value was the highly spirited interaction between individuals representing many different areas of scientific expertise.

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THE SKELETONS OF HERCULANEUM, ITALY

Sara Bisel

SINCE FEW SKELETONS had been found at Herculaneum, scholars believed for many years that almost all the people had left town before the eruption of Vesuvius on August 24, A.D. 79. However, in the spring of 1982 a large number of skeletons was discovered on the ancient beach front and in adjacent chambers (Fig. 1). This accidental discovery changed our interpretation of history. The skeletons were in

FIGURE 1 A desperate retreat to the back of a boat chamber during the eruption of Mount Vesuvius proved futile, as these skeletons testify. They appear, in the words of one observer, like souls "floating down the River Styx."

good to excellent condition, because they had been in an unchanging environment in terms of temperature and humidity (Fig. 2). They were buried under 20 m volcanic material and were continuously bathed in fresh water of neutral pH. Parts of many of the skeletons were carbonized from the extreme heat, as high as 400°C, in some parts of the pyroclastic material. When exposed to a fluctuating environment, decay proceeded rapidly. The skeletons had to come into equilibrium with each change. Therefore, it was vital to remove the skeletons from the ground as soon as they were exposed.

These skeletons are of utmost importance to anthropologists, historians, archaeologists, and others interested in Roman history since they are a unique population to study. Romans of that time cremated their dead, and ashes do not tell us very much. From this population, we can obtain information about health, nutrition, disease, and occupation, as well as get a glimpse of social structure (Figs. 3 and 4).

But this uniqueness creates a problem—there are no other contemporary populations from the Italic peninsula to use for comparison. We will use Hellenistic Greeks and modern Americans instead. At Herculaneum we have excavated, restored, and studied 139 skeletons: 51 males, 49 females, and 39 children. There

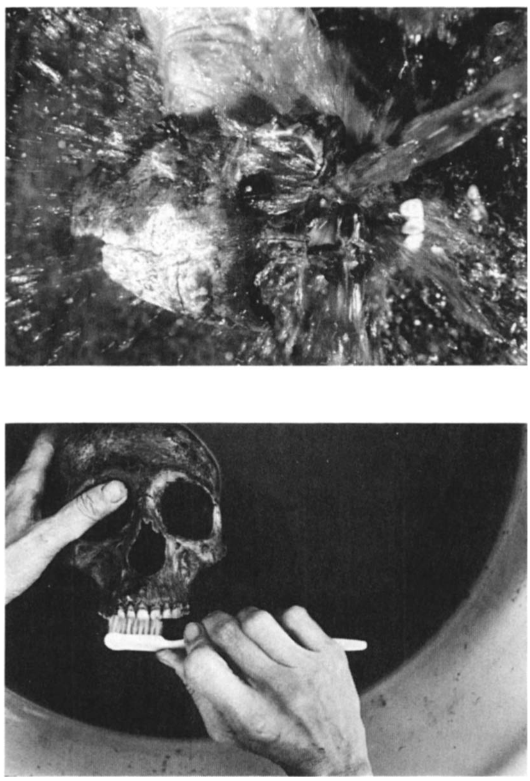

FIGURE 2 A jet of water and a soft toothbrush are used to clean a skull. The skeletons are so well-preserved because they have been kept continuously wet by ground water percolating through the volcanic soil. With exposure comes quick deterioration. After cleaning, the bones are dipped in an acrylic emulsion, after which they are ready for reconstruction.

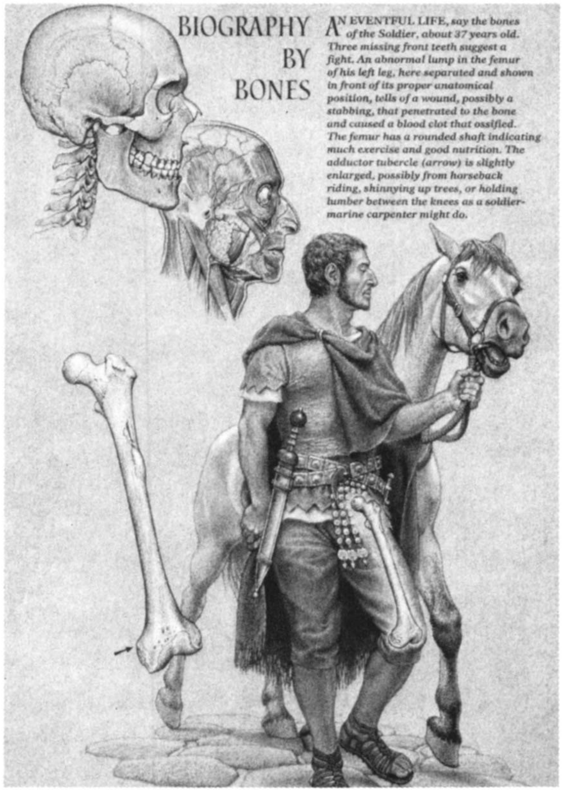

FIGURE 3 The bones of this soldier indicate an eventful life of about 37 years. Three missing front teeth suggest a fight. An abnormal lump in the femur of his left leg (here separated and shown in its anatomical position) tells of a wound, possibly a stabbing, which penetrated the bone and caused a blood clot that ossified. The femur has a rounded shaft indicating much exercise and good nutrition. The adductor tubercle (arrow) is slightly enlarged, possibly from horseback riding, shinnying up trees, or holding lumber between the knees as a soldier-marine carpenter might do. (Drawing by Jay H. Matternes of the National Geographic Society.)

are more skeletons waiting to be excavated. There are also more methods of analysis to be employed; therefore, this report is merely preliminary.

Some of the observations and measurements that can be made of skeletal material give anthropologists insight into the health and nutrition of a population. Longevity of adults is a parameter of primary importance. At Herculaneum everybody died accidentally before his time; therefore, age at death statistics are meaningless. Stature is also a very important indicator of general health and nutrition. Of course, heredity dictates the maximum stature possible for each individual, but poor nutrition or disease can interfere with the potential that an individual might otherwise achieve. Therefore, mean stature statistics, particularly in comparison with other populations, can be useful. Stature at Herculaneum is comparable to Hellenistic Greeks, but shorter than modern Americans (Table 1). With this parameter, we also have modern Neopolitan statistics to consider. The male mean stature is 164.0 cm and the female is 152.6 cm, both considerably shorter than the Roman period people (d'Amore, Carfana and Matarese 1964).

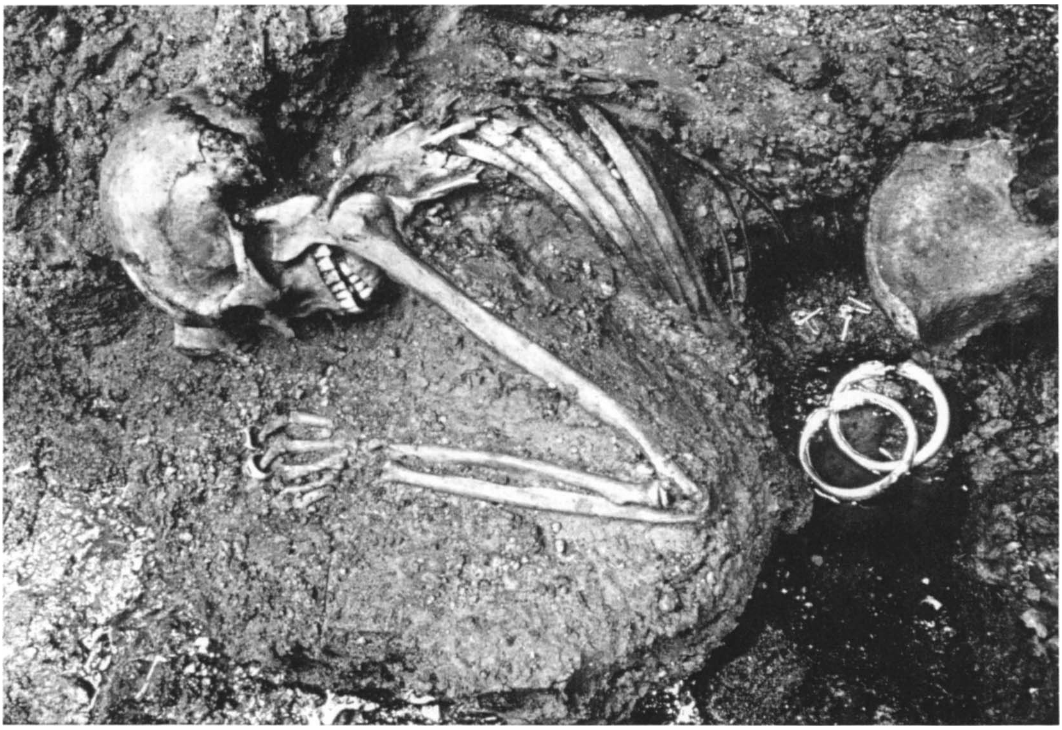

FIGURE 4 The skeleton of this 45–year–old woman was found with a treasure of jewels, indicating that she probably had high status.

Other important indicators of health and nutrition are the relative flattening of long bones and the pelvis. Muscles get larger with heavy exercise, but long bones become slender and small with poor nutrition. They must flatten to accomodate the increased muscle. Thus, flat long bones suggest heavy exercise in the presence of poor nutrition. Comparison of upper femoral flattening (platymeric index) indicates that the Herculaneans and the Hellenistic Greeks are roughly equivalent, but both are somewhat flatter than those of modern U.S. people (Table 1). The pelvis is located in the body at an angle of 60° to the horizontal. So if there is any softening of the bone due to poor nutrition, the weight of the upper body pressing down on the pelvis will cause it to flatten somewhat. The mean pelvic brim index of both the Herculaneans and the Hellenistic Greeks is flatter than modern Americans. Differences between the sexes in respect to pelvic brim index in both populations are probably due to sampling errors and are not likely significant. The mean pelvic brim index of male and female together for Herculaneum is 83.9 (N=78), and for Hellenistic Greeks is 85.8 (N=7). Perhaps this is a more valid way to look at this statistic.

Dental health is also revealing. Its study shows another aspect of differences between an ancient and a modern population. Those ancient Mediterranean peoples

Table 1. Selected statistical indicators of health and nutrition

	Herculaneum				Hellenistic Greece[1]				U.S. Modern White[2]			
	Females		Males		Females		Males		Females		Males	
	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N
Stature (cm)	155.2	43	169.1	51	155.5	13	171.1	7	162.4	70	175.0	88
Platymeric Index	83.1	43	81.9	48	78.8	14	83.5	6	86.3	72	88.2	87
Pelvic Brim Index	89.5	35	82.9	43	82.7	4	90.0	3	93.5	55	93.1	58
Total Number Dental Lesions	3.9	35	3.6	44	5.2	114[3]			15.7	170[3]		
Slight to Severe Arthritis (%)	36.4	44	47.5	53	66.7	6	42.1	14	55.1	60	69.8	75
Trauma (%)	11.4	44	32.1	53	50.0	6	35.7	11	16.9	106	18.4	125
Healed Anemia (%)	40.9	45	28.3	53	66.7	6	46.2	13	9.0	205[3]		

[1] Bisel 1980
[2] Angel and Bisel 1986
[3] Male and female reported together; Bisel and Angel 1985

that I have studied, have, in general, much better teeth than modern Western peoples. Most of the Herculaneans have perfect edge-bite occlusion, and few lesions (defined in this paper as the total of antemortem loss), caries, and abscesses per mouth. In Table 1, note that the Herculaneans have slightly better teeth than the Hellenistic Greeks and much better teeth than modern Americans.

There are other observations we can make from bone that tell us about the people; however there are many other problems we cannot discover from skeletal remains. Most disease is of the soft tissue but few long-standing conditions leave traces in the bone. I did not see much pathology in the Herculaneum skeletons. Slight to moderate arthritis is observable and fairly common in ancient and modern populations. The higher levels reported in the U.S. modern population (a mean of 63.8% for both sexes in the U.S. [N=135] compared to a mean of 42.3% at Herculaneum [N=97]) is an artifact of a somewhat older population (Table 1). Trauma, healed fractures, and dislocations can readily be assessed in the skeletons of Herculaneum (Fig. 3). Almost three times as many males suffered some accident as did females. The population average of 22.7% for trauma in Herculaneum skeletons is close to that for the modern U.S. population, with a mean of 17.7% (Table 1). Healed anemia is detectable in skeletons as porotic hyperostosis, a

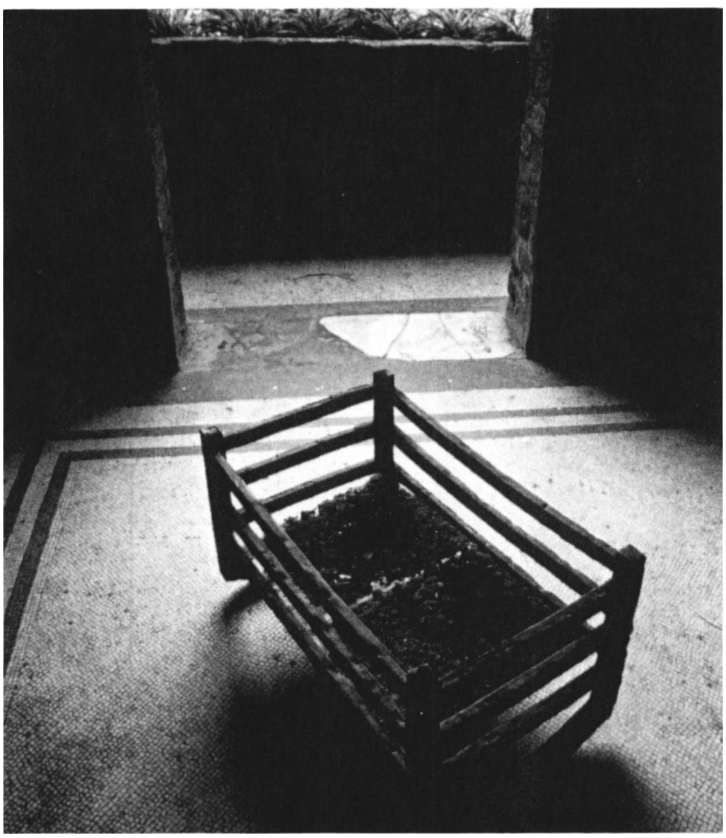

FIGURE 5 The skeleton of a baby was found inside this charred crib. Here displayed in a Herculaneum residence, the crib has since been restored. The baby cannot be found.

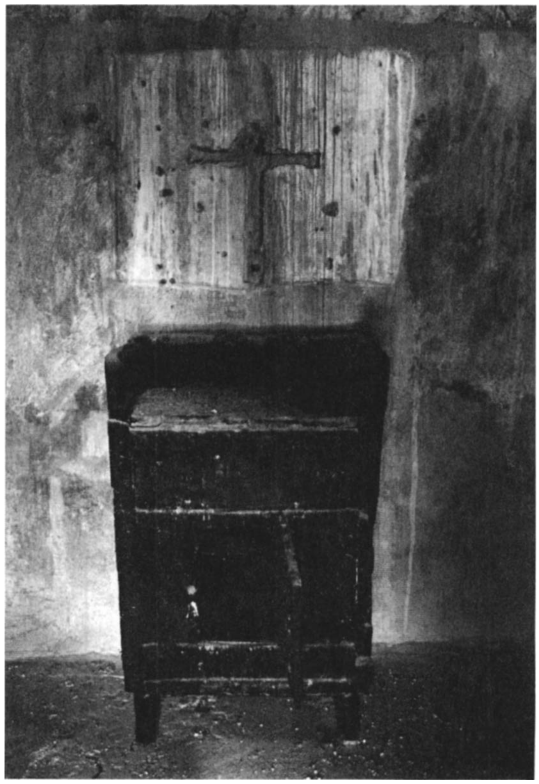

FIGURE 6 The heat from the volcanic eruption carbonized a wooden cabinet in the upper floor of the "House of the Bicentenary." An imprint in the wall above it is probably not a cross, appearances not withstanding.

swelling of the inner table of the parietal bones of the skull. Both ancient populations have levels of healed anemia far higher than those of modern Americans (Table 1). This may reflect nutritional problems, but it is more likely to be a result of heterozygotic thalassemia (Angel 1966).

In addition to observations and measurements of bone, chemical analysis of bone mineral is being used to study the Herculaneum population. Bone mineral can give us insight into nutrition and social factors of a population. Atomic absorption spectroscopy was used to determine concentration of calcium, phosphorus, strontium, zinc, and magnesium content. Animal bone and soil were also analyzed as controls (Bisel 1980). A study of lead in bones of ancient populations was also begun with the Herculaneum material.

Strontium is the most interesting mineral for the study of nutrition. It is present in bone only in trace amounts, where it substitutes for calcium in the apatite structure. The strontium/calcium ratio in bone can be used to demonstrate relative amounts of animal versus vegetable-source protein in the diet of a particular population (Bisel 1980; Brown 1973). Calcium and strontium are present in vegetables in about the same proportion as in the soil. Herbivores, feeding on the plants

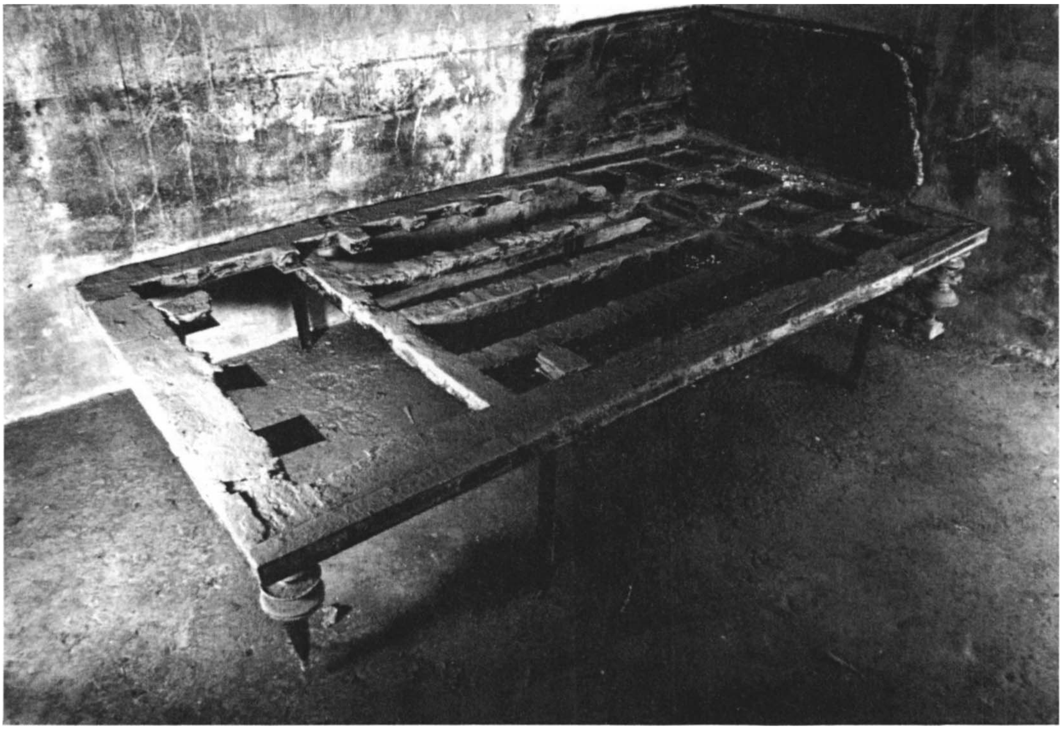

FIGURE 7 A wooden bed still retains the latticework pattern of slats that supported a mattress of fine-spun wool or sweet grasses. Raised panels at the head and one side protected against the chill walls.

incorporate a small amount of strontium in their bones, but none into their soft tissue. Carnivores, eating flesh, have much less strontium in their bones. Omnivores fall in between herbivores and carnivores. Animal bones of known species can be used for comparison with human bones to give relative amounts of animal- or vegetable-source protein nutrition. Since strontium in bone is so dependent on the quantity of strontium in the soil, a site-specific sheep or goat bone is used with human bones to create ratios for comparison of one population to another. One problem with the interpretation of the soil, plant, and animal system described above is that it does not take into account protein incorporated from seafood. This high quality animal protein also has high strontium values. Seawater is very rich in minerals, including strontium, and animals living in this environment absorb high quantities of them into their flesh. This fact can make reconstruction of human diet more complicated. A laboratory procedure which addresses this problem is the assessment of the relative amounts of C-12 and C-13 isotopes in the bone by means of mass spectroscopy (Schoeninger, DeNiro and Tauber 1983). I have not yet performed this analysis; therefore, data and conclusions about protein are preliminary both by their number and methodology. I analyzed samples from 97 of the Herculaneum skeletons (51 males and 46 females). There was no real sex-related

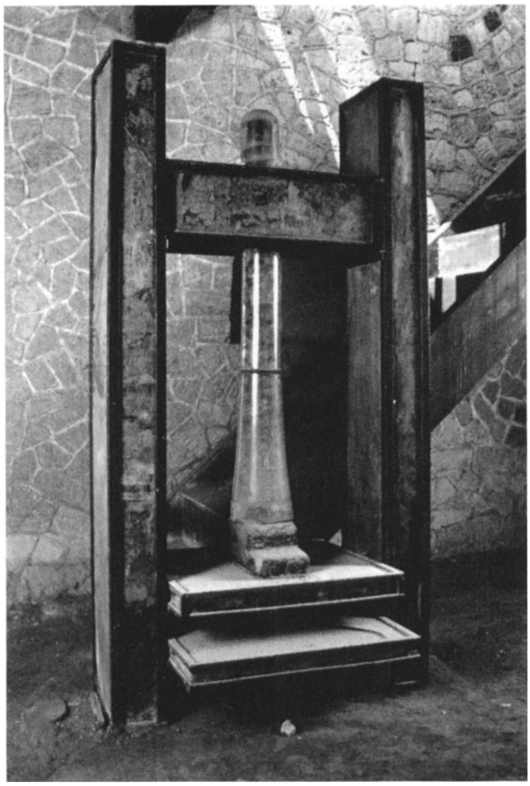

FIGURE 8 A carbonized cloth press utilized the same principle as the printing press invented 14 centuries later.

difference in any mineral. The mean site corrected strontium/calcium ratio at Herculaneum is 0.672, at Athens it is 0.466 (N=17) (Table 2). The higher level at Herculaneum could reflect a higher vegetable protein diet, a higher seafood diet, or a combination, as opposed to a reliance on terrestrial animal sources. As both ancient groups are almost equally healthy, it seems reasonable that both consumed equal amounts of complete animal-source protein. It would appear that the Herculaneans relied on seafood protein, while the Athenians exploited terrestrial animal sources. However, nothing definite can be said until the C-12/C-13 ratios are studied.

The analysis of lead in the bones of Mediterranean peoples began with the Herculanean population. The methodology involved sample preparation in a controlled environment, desiccation in an oven, digestion in concentrated nitric acid, and analysis with flame-less atomic absorption (McCall personal communication). Results are preliminary and difficult to interpret. Of the 43 skeletons sampled at Herculaneum, there were 26 males and 17 females. Determinations were done on the outermost layer of bone cortex, the "periosteal" layer, as well as on samples of mixed layer cortex. In almost all instances, lead levels from the periosteal layer were higher and, in some cases, much higher (Table 2). Also, comparison samples

Table 2. Bone mineral: strontium and lead

	Herculaneum						Hellenistic Greece[1]						Neolithic Franchthi Cave		
	Females			Males			Females			Males					
	$\bar{x}$	s.d.	N	$\bar{x}$	s.d.	N	$\bar{x}$	s.d.	N	$\bar{x}$	s.d.	N	$\bar{x}$	s.d.	N
Sr/Ca Site Corrected	.638	.142	46	.702	.119	51	.369	.069	12	.520	.310	5			
Periosteal layer Pb (ppm)	249	157	16	380	453	25	435	449	6	496	530	5			
Mixed layers Pb (ppm)	63	43	17	100	56	26	204	107	6	124	177	5	3.3	1.1	5

[1] Bisel 1980

from Hellenistic Athens of 5 males and 6 females were run. Again, the periosteal layer lead was higher than the mixed layer lead (Table 2). In addition, all Athenian means were higher than the Herculean ones. However, the numbers of samples were so small that these differences are probably not significant. Also, comparison of 5 samples from the neolithic Franchthi Cave in Greece were analyzed. These people, who never used lead, had only trace amounts in their bones (Table 2). A closer look at the lead levels of the Herculeans shows a few who deviate widely from the mean. There are two people with very high lead in the mixed layers as well as in the periosteal layer. The bone cortex of one individual contained a lead concentration of 2,790 ppm, while that of the second individual had a concentration of 6,350 ppm. The figures have remained constant upon repeated rechecking. These two people have been excluded from the reported statistical mean of mixed layer levels. There are also six other people with levels of 1,000–2,000 ppm in the periosteal layer, but with more usual levels of 25–150 ppm in the mixed layers. Although the metabolism of lead into bone is not completely understood, it stands to reason that these eight people must have had, at least some time during their lives, some problems from high concentrations of lead in their systems. Of the Athenians, there are two out of eleven with periosteal lead levels of 1,100 and 1,280 ppm, and mixed layer levels of 280 and 440 ppm. These Athenians may also have had problems. The lead study is still preliminary; more samples need to be analyzed and checked and statistics reanalyze.

This paper is an overview of a study in progress of the people of Herculaneum, a unique Roman period population. At this writing 139 individuals have been studied. There are 45 more skeletons exposed and waiting to be excavated, preserved, and studied. It is certain that many more are waiting in the unexcavated chambers and adjacent areas of the beach. What their fate will be, we do not know.

Acknowlegments

I want to express my deepest appreciation to the Superintendency of Herculaneum and Pompeii and its successive superintendents, Guiseppina Cerulli Irelli and Baldasarre Contecello, and to the successive directors of Ercolano Scavi, Guiseppi Maggi, Umberto Pappalardo, and Tomassa Budetta. I also thank the Mayo Clinic Trace Metal Laboratory in Rochester, Minnesota, where I performed the bone chemistry analyses. The National Geographic Society provided the funding for this research. My appreciation and thanks must also go the National Geographic Society and to Walter J. Silva, former U.S. Consul-General to Naples, for making the necessary arrangements, so that I could carry out this study.

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AN ASSEMBLY OF DEATH: BOG BODIES OF NORTHERN AND WESTERN EUROPE.

John M. Coles

IN MAY 1983, two men were working in a peat-processing factory at Lindow Moss, Cheshire, England. Their task was to remove any extraneous objects, such as wood or stone, from a conveyor carrying peat for bagging; the peat was to be sold for fertilizer. On May 13, a soft round object, rather like a collapsed football, was retrieved from the conveyor and tossed to one side; later, it was taken outside and hosed down out of curiosity. It revealed itself as a female human head, with some skin, hair, brain and one eyeball still present. The police were called in, and began to investigate the "incident." Some years previously, a woman had vanished from a house which lay on the edge of Lindow Moss; her husband had been suspected of causing her disappearance but there was no evidence suitable for a conviction. When news of the discovery of the woman's head became known in the area, the husband confessed to the police that he had killed his wife. The police, however, were not so certain that the wife had been found, and a sample from the head was sent for radiocarbon dating; the date was ca. A.D. 200, rather too old for the Lindow Moss murder victim. Nonetheless, the husband was tried and convicted of murder on the basis of a confession which had been inspired solely by the discovery of the head. This is the second time in recent years that a bog body out of the past has claimed a life from the present.

Bog bodies are a widespread phenomenon in northern and western Europe. Hundreds of bodies have been recorded from the peat bogs in Germany and Denmark in particular, with other examples known from all of the other countries of the north and west (Dieck 1965, 1972; Ebbesen 1986; Glob 1969). Many of these are no more than skeletons, parts of skeletons, or fragments of clothing, and it is difficult to consider them all as representing any one particular cultural or chronological episode. Very few of the human remains have been investigated scientifically, and hardly any have been preserved for modern examination. However, a group of bog bodies does exist, dated to the centuries from ca. 700 B.C. to ca. A.D. 100, which seems to make a coherent and unified picture, even if some puzzles remain unsolved.

The earliest authenticated discovery of a bog body occurred in 1773, and the first photographic record of a bog body (from Rendswühren Fen in Germany) dates to 1871 (Glob 1969). All of these early finds were made by peasants cutting peat, and there were and are many traditions and tales about these discoveries. Some were lifted from the peat, boxed, and buried in the local churchyard; others were deliberately or accidentally destroyed. Some were abandoned and left to rot away in the air, through ignorance, neglect, or fear and superstition; some were hastily covered up and treated as if never found. In 1450, for example, peasants at Bonsdörp in Germany informed the parish priest that they had found a dead man stuck fast in a bog up to his neck. The priest's advice was to leave him alone as elves had lured him to his death and anyone associating with elves could not be Christian, hence burial in a churchyard was unthinkable. The man was never seen again. Peasant society in northern Europe in the eighteenth and nineteenth centuries was possibly more enlightened than that of the fifteenth century, but even well into the twentieth century there was much speculation and uncertainty about the bodies that were encountered in the bogs.

Some of the reasons for people to feel uneasy about the human remains were that often the bodies were incomplete, like the single hand at Hørby Mose, a leg at Tved Mose, or a pair of hands and lower legs at Søjards Mose. These probably represented the remains of complete bodies truncated by earlier peat-cutting or decayed away differentially. Notwithstanding these logical explanations, the discoveries, often made by a lone person working in the peatbog, probably caused surprise and fright.

The bodies are often differentially preserved by particular chemical conditions in the bog. One example is the Damendorf man who survived only as a skin with hair but with no trace of bone or flesh; his leather shoes and belt lay beside him. Many have only the bones and hair remaining and no skin or flesh, as at Vester Thorsted. Other partial remains, however, seemed more deliberate and less accidental. Human heads were found in Roum Mose and Stidsholt Mose. At Roum, a male head had been chopped from the body between the second and third cervical vertebra. The Stidsholt female head had been similarly detached between the third and fourth cervical vertebra, the blow carrying through to chop away part of the chin.

The most famous bog body was found in 1950 in Tollund Mose in Jutland (Thorvildsen 1950). The bog area, called Bjaeldskovdal, had been cut for peat for many centuries. In 1927 a body was found and abandoned under a collapsed peat bank and in 1938 another body was found at a site called Elling. Then in 1950 the Tollund Mose yielded its body. The body was found 60 m out from the edge of the small bog, and at a depth of 2.5 m it was clearly not recent; thus, it received prompt treatment and care. The body lay on its right side, legs drawn up and arms bent. It was naked except for a leather cap and belt. The peat upon which it lay was undercut, and it was then boxed *in situ* for transport to the National Museum of Denmark. In its removal from the fen, one of the assistants suffered a heart attack—the bog claimed "a life for a life."

The parts of the body uppermost in the peat were partly decayed, and the arms and hands had relatively little flesh remaining; the body itself was collapsed due to bone and flesh deterioration, so the skin lay in folds. The feet were well preserved, and the right sole bore the scars of cuts probably caused by thorns or stones. Only one finger retained its print, and this fitted unobtrusively into those of the modern Danish population. The head was in excellent condition (Fig. 1). The chin stubble, the leather cap, and the preservation of the sexual organs showed that the body was that of a man. He was about 30–40 years old and just over 1.6 m tall. His face was startling to behold, and many spoke of his tranquil expression, lips closed together, forehead barely wrinkled, eyes shut. However, around his neck was a noose of braided leather which had left a furrow on the skin at the sides and throat, yet not at the nape. From this it is deduced that he was hanged, not strangled. All of his internal organs were intact, including the gastrointestinal tract, which held the remains of his last meal, eaten 12–24 hours before his death (Helbaek 1950). This was a gruel or porridge of barley, linseed, *Camelina* sp. (gold of pleasure) and pale persicaria (willow herb seeds), with smaller amounts of about 30 different kinds of wild seeds, including fat hen, corn spurrey, black bindweed, violet, hemp nettle, and mustard; none of the plant remains indicated a time of the year when fresh vegetation was available. Radiocarbon tests suggest that the winter or early spring thus indicated occurred about 200 B.C.

Two years after the discovery of Tollund man, a further well-preserved body was found by peat-cutters in Nebelgårds Mose near Grauballe (Glob 1956). The bog

FIGURE 1 The Tollund Mose man, executed by hanging ca. 200 B.C. (Glob 1969.)

is small, only 140 m across, and the body had been placed near the center, in an old peat cut. The body, again male, was naked with hair about 5 cm long and a stubble on the chin. The man was approximately 30 years old and was 1.75 m tall. His skin had been almost tanned by the bog acids; the bones were soft and the inner organs were partly decayed. Unlike Tollund man, the face of Grauballe man was not in repose, and for good reason; his throat had been cut from ear to ear (Fig. 2). In addition, he had probably been struck on the right temple, and his left shin was fractured. His hands were well preserved, and showed a lack of wear on the fingers, surprising in one who might have been considered to be a land-worker (Vogelius Andersen 1956; Fig. 3). His teeth were worn, three were lost during life, and several had caries. Just before death, he had had a meal, like that of Tollund man—a gruel with barley, willow herb and brome grass, "chess" seeds, some emmer and oats, and about 50 species of wild seeds, several of which were not local (Helbaek 1958). Among the seeds were clover, spelt, rye-grass, lady's mantle, camomile, smooth hawksbeard, goosefoot, buttercup, yarrow, and black nightshade, gathered perhaps during the harvest of grown crops sometime around 100 B.C. There were also slight traces of meat and some animal hair. Again there were no summer or autumn fruits or berries, nor were there any traces of "greens."

Because of the great interest in these "last meals" of Tollund and Grauballe man, a rather light-hearted television experiment was organized by the BBC (Johnstone 1957). After much scurrying around botanic gardens and bird food shops, the gruel was assembled; it included many of the species noted above, but not the fragments of Sphagnum moss and the teaspoonful of sand that Tollund man had also swallowed with his meal. The seeds were boiled slowly and eventually

FIGURE 2 The Grauballe Mose man, killed by throat-cutting ca. 100 B.C. (Forhistorisk Museum, Moesgård, Denmark.)

FIGURE 3 The hand of Grauballe man. (Forhistorisk Museum, Moesgård, Denmark.)

produced a rather oily porridge, greyish-purple in color, with flecks of orange and black. After a taste, one of the experimenters, Sir Mortimer Wheeler, exclaimed, "Tollund man probably committed suicide to escape his wife's cooking." His colleague, Glyn Daniel, explained later that it was necessary to wash it down with good Danish liquor. Pliny describes the peasant foods of Greece and Rome as a gruel made of barley, linseed, coriander seed and salt, which is not much different than that eaten by these two men; salt if present would not have been detectable in the Tollund and Grauballe intestines. A fair description of this gruel in modern terms is farm-house mash.

The preservation of these two bog bodies, and many others less well-known, is due to a combination of circumstances only now becoming clear (see Bennike et al. 1986; Munksgaard 1984; but foreshadowed by Ellerman 1916). The varying condition of the hundreds of human remains from Danish and North German bogs demonstrates the range of survival, thereby pointing out the exceptional circumstances that permitted some bodies to survive almost intact. In essence, the preservation of bog bodies depends on three factors: (1) Deposition of the body must be in water deep enough to prevent attack by organisms such as maggots, rodents, and foxes, and still enough to be oxygen-deficient (as most raised bog waters are) to inhibit decay by bacteria. Thus the records of bodies placed in old peat cuttings, that is, in deep holes or pits, are relevant; (2) The bog pools must contain water with tannic acid of sufficient strength to begin to preserve the outer layers of the body by tanning; Grauballe man was noted as partially tanned upon discovery, and has been conserved by tanning with oak-bark (Lange-Kornbak 1956). If the water was not acidic, the bones would survive but the flesh would rot way. (3) The temperature of the water in the bog pool must be below 4°C; this (normal refrigerator) temperature prevented decay and inhibited rot. If the water was warmer, the flesh would rot, and the acids in the water would decay the bone as well.

Therefore, it appears that the bog bodies must have been deposited in acidic bog pools in winter; if put in the pools during the summer, they would not have survived. This conclusion is supported by the stomach contents of the Tollund and Grauballe men, which had no remains suggesting summer plants. The skeletal remains, or partial remains, of many other humans from the bogs may represent deposition under different seasonal or environmental conditions. The Vester Thorsted skeleton with hair and hide coat, but no flesh, must represent one of these other conditions (Andersen and Geertinger 1984). The observation that some of the better-preserved bodies had decomposed in the parts protruding above the rest, such as shoulder or uppermost arm, suggests that these were within the decaying zone of the particular conditions of tannic acid and water in the bog pool. Of course, many bodies may have been placed in bog pools during the summer, and thus have not survived at all. Hence the argument (to be advanced below) that the surviving bog bodies represent an activity of seasonal significance should not be accepted too readily.

Both Tollund and Grauballe man were naked (apart from the cap and belt found with Tollund man), and other bog bodies dating to the same general period, the pre-Roman Iron Age, are rarely clothed. Some, however, have clothing placed nearby. From Borum Mose, three such bodies have been recovered. The first, found in 1946, was a naked male, with two sewn sheepskin capes at his feet; one of the capes had a collar (Thorvildsen 1947). In 1947 a female was discovered, naked on a sheet of birch bark and covered by a skirt of four-strand twill and a fringed shawl. It is worth noting that the skirt had previously been worn as a cape, judging by the pin holes and wear on it; such capes are generally found with males (Munksgaard 1984). A year later, the bog yielded a third body; this prompted a note which accompanied it to the National Museum, stating, "I have great pleasure in sending you the customary annual bog body from Borre Fen." Since then, no more have been found. The third body was a female covered by a blanket-skirt like that of the other Borum Mose female; there was also a leather strap (Thorvildsen 1952).

The male had been put into an old peat cutting in a sitting position with legs bent and crossed; he was hunched forward so that his right shoulder almost touched the left knee. There was stubble on the chin, and the left eyeball, yellow-white with a black iris, was well-preserved. The hands were not worn. The back of the skull was crushed, and the right thigh-bone was fractured. The cause of death, however, was a hemp rope about 1 m long with a slip-knot tied around the neck (Fig. 4); he had been strangled or hanged. The last meal of Borum man had been a gruel with corn spurrey and knotweed, as well as many other weed seeds. He may

FIGURE 4 The Borum Mose man, strangled by rope ca. 650 B.C. (Glob 1969.)

have eaten this just before his execution, which has been radiocarbon dated to ca. 650 B.C.

The woman found in 1947 at Borum Mose lay on her stomach in a deep old peat-cutting. Around her neck was a leather strap with an amber bead and a bronze disc; her hair was 2–3 cm long. Her right leg was broken, perhaps before death.

Just above the body were several small sticks, .and the bones of an infant. An associated potsherd was of a type identified in an Iron Age bog settlement in the same fen; the date of her death was ca. 400 B.C.

In 1948 the final body (a female) was found, lying face down and covered by a blanket-skirt. She was about 20–35 years old. Her right arm was bent up against her face and her left arm lay beneath her left leg (also bent up). Her face was smashed and she had, in effect, been scalped at the back of the skull. There is some discussion about these injuries which will be considered below. The date of this body is ca. 600 B.C.

From these and other bog bodies, it would appear that males of the period wore skin capes, woven coats or kilt-like garments, possibly leggings, shoes, and a cap. Females had woven skirts (Fig. 5), scarves, and skin capes (Fig. 6) which reached to the hips or below (Hald 1980; Munksgaard 1974). The Elling Mose female (hanged around 200 B.C.) had a cloak of sewn pieces of sheepskin, gathered at the front by leather thongs, and a woven wool belt (Fischer 1979). None of these clothes and coverings shows signs of cuts or blood; the victims may have been stripped before execution.

The hair of the women was sometimes elaborately coiffured (Munksgaard 1976). The hair of the Elling Mose woman was about 90 cm long and arranged as follows (Fig. 6): all the hair, except that on the back, was combed up and braided in a three–strand plait down to the back hair; all the hair was then divided into seven switches, each twisted, and braided together in two pairs and one triple, to make a

FIGURE 5 Pleated skirt of coarse woollen cloth from the Ruchmoor at Damendorf, Germany. (Schleswig-Holsteinisches Landesmuseum.)

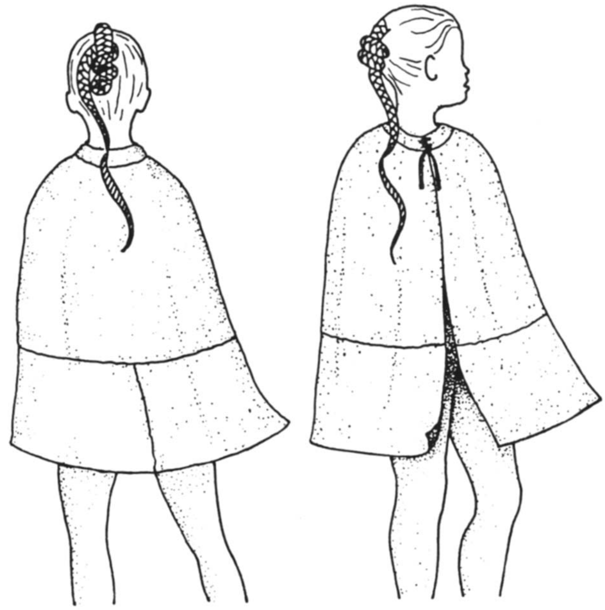

FIGURE 6 Sketch of the sewn sheepskin cloak of the woman from Elling Mose, Denmark ca. 200 B.C. Her hair was elaborately coiffured. (Ebbesen 1986.)

three—strand plait. At the end of the plait, the hair was twisted into two switches. Then the plait was wound twice round itself above the nape of the neck. Males occasionally wore their hair in a comparably elaborate fashion. The Kohlmoor, Osterby find consisted only of a head wrapped in a sewn cape of roe deer skin (Kersten 1949). The male, age 50-60 years, had been beheaded with an axe and, although little skin survived, the hair, originally blond with some grey, was well preserved (Fig. 7). It was approximately 25 cm long, parted at the back and gathered at the right temple into a knot, called a Swabian knot, after the recorded male coiffure of Classical times in that area of Germany (Schlabow 1949).

A particularly evocative discovery was made at Windeby in north Germany, which casts some light upon the whole assembly of death that we are witnessing in this region in the few centuries before and after the birth of Christ (Schlabow et al. 1958). The Windeby bog was barely 0.5 ha in area but two bodies were found during its cutting in 1952. One was a naked elderly male, represented only by skin and hair. He was laid on his back, arms crossed, and held down in an old peat-cutting by thick branches and forked sticks; there was a hazel withy across his neck, possibly a strangling bough. Five meters away in another old peat-cutting was the body of a young girl, lying on her back, head turned to one side and left arm out-stretched (Fig. 8). Between that arm and her hip was a heavy stone, and branches of wood lay over her body. The girl was about 14 years old, and her body appeared rather thin and undernourished. She was naked except for a double collar of ox-hide

FIGURE 7 The head of a man from the Kohlmoor, Osterby, beheaded by an axe. The hair was arranged into a Swabian knot. (Schleswig-Holsteinisches Landesmuseum.)

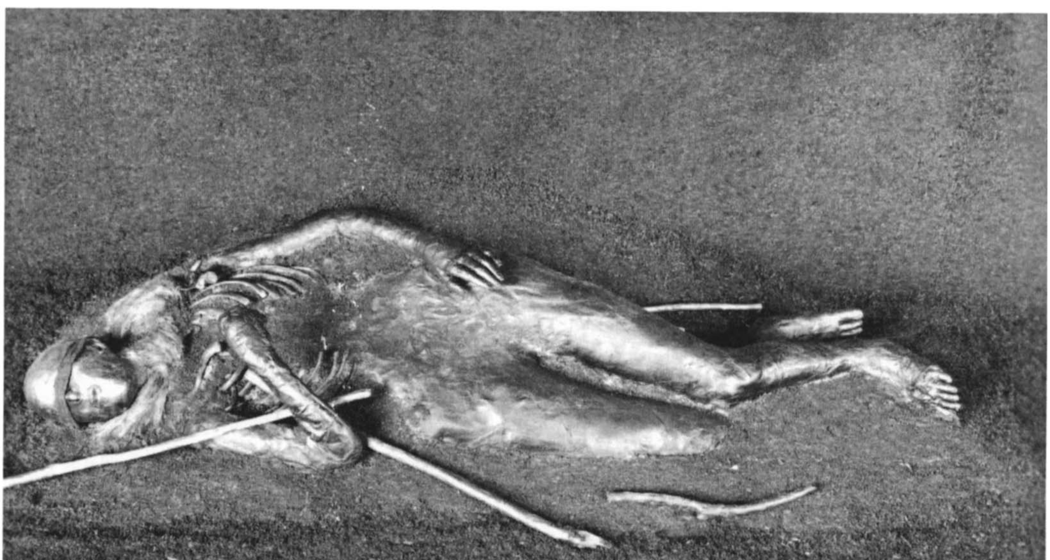

FIGURE 8 The young girl from Windeby, Schleswig, blindfolded, partly head-shaven, and pinned into a bog pool. (Schleswig-Holsteinisches Landesmuseum.)

and a woven band tied tightly over her eyes. This band was probably a brightly-colored headband of 38 threads in a tablet weave of brown, yellow and red repeating, and ending in twisted strings. The girl's hair, light blonde in color, was about 5 cm long on the right side of the head, but had been shaved off on the left, where it was only 3 mm in length. Her brain when exposed for examination in the laboratory was extraordinarily well preserved, perhaps due to the presence of water-insoluble chlorestin.

The excavations at Windeby revealed a group of heavy branches, forked sticks and a large stone which were a part of the act of deposition. A find made near Jelling a century earlier had also included branches; here an elderly female had been pinned into the bog by wooden crooks driven over her knees and elbows, and branches had been laid across her chest (Oldsag-Committeen 1836–37). The body was identified in the mid-nineteenth century as that of Queen Gunhild, the beautiful, shrewd and cunning Norwegian consort of King Erik Bloodax. The Danish Harald Bluetooth invited her to marry him, but on her arrival in his land, she was met by Harald's men who maltreated her and drowned her in a deep bog. The story was soon disputed and it seems clear that this woman was yet another Iron Age victim. The Jelling woman and the Windeby girl may have met death in the same way—pinned into a bog pool and drowned, for there was no sign of a wound or strangulation on the Windeby girl.

Finally we come to the latest discovery of a bog body, in Lindow Moss, England—the same bog where the woman's head led to a confession of murder in 1983. One year later, peat workers discovered a human lower leg on the factory conveyor, and called in the police, and the archaeologists (Stead et al. 1986). This led to the peat section in the bog, where a flap of skin was seen *in situ*; the machine which cut the peat had removed all of the lower part of a body; the lower leg was all that survived. The rest of the lower body is presumably now in numerous bags of peat, or spread as fertilizer on the rose and mushroom beds of England. The upper body was found to be that of a male, about 25 years old, perhaps 1.67 m tall, with a short beard and moustache (Figs. 9 and 10); he wore nothing on his upper body other than a fox fur band on his arm. In his intestine (Fig. 11) were the remains of a meal of breadcake (made of spelt and emmer) and barley, as well as the ova of worms. The sequence of his death is particularly gruesome. He was hit on the top of the head twice, the blows crushing through the skull; at the same time he may have been kneed violently in the back, breaking a rib. A thin rope, tied around his neck, had been twisted to throttle him and this may have broken his neck. When death finally came, his throat was slit, severing the jugular vein, in an act of possible blood-letting (exsanguination). He was then tipped into an old bog pool which filled with water and effectively sealed and preserved his body, until truncated by a peat machine some 2,000 years later. The date of Lindow man's death is still not resolved, but the best estimate is ca. 100 A.D., although there is a wide divergence in the determinations from different laboratories (for reasons as yet unexplained).

There are now about ten bog bodies which have been radiocarbon dated to the Iron Age in northern and western Europe; there are many others which can also be

FIGURE 9 The head of a man from Lindow Moss, England, in the laboratory before conservation. The wound on the top of the head can be seen. (British Museum.)

assigned to this general time period on the basis of bog stratigraphy, proximity to Iron Age settlements or watery votive offerings, association with Iron Age artifacts or clothing, or context of death and deposition. Another view, however, sees humans in bogs, whether skeletal, partial or fleshed bodies, as part of a very long

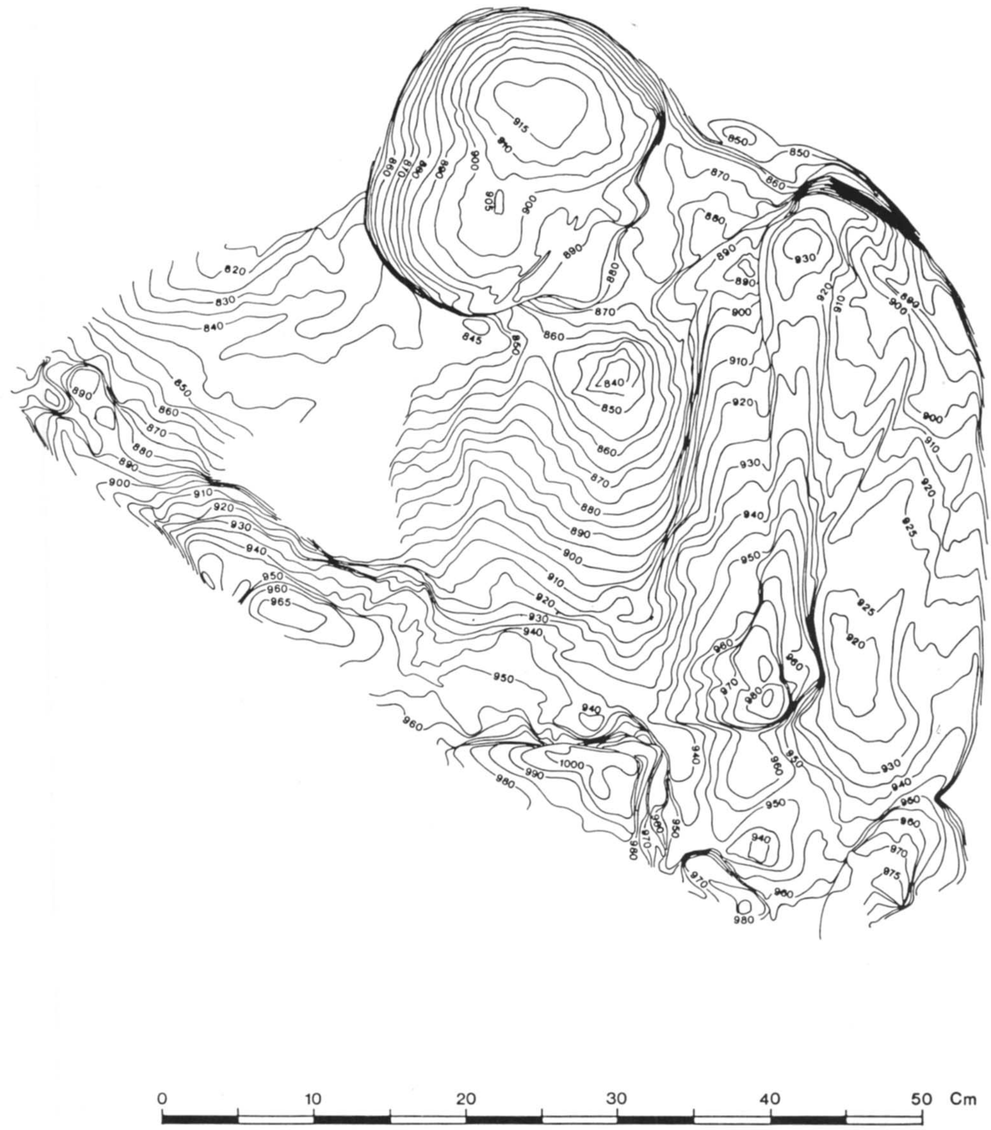

FIGURE 10 Contour stereoplot of Lindow man before conservation. (Stead et al. 1986.)

tradition of sacrifice for fertility, which was manifest from at least the Neolithic to the Viking Age in Denmark (that is, for about 4,000 years) (Bennike et al. 1986). This interpretation regards the bog bodies of the Iron Age as merely one element in this cult, more vividly demonstrated for us by the conditions of burial at that time.

Another hypothesis is that the human lives sacrificed to the bog waters were but a part, and perhaps a small part, of the dominating practice in the Iron Age of ritual deposition of valuable objects in watery places. These may be pottery vessels containing food, bronze or silver vessels, torcs, weapons, parts of carts, animals, or war booty, cast or laid in lakes, marshes, and pools in order to propitiate the gods

FIGURE 11 The stomach of Lindow man, lying across his spine with the duodenum and upper jejunum visible. (British Museum.)

or demonstrate the power of those who chose to (or were allowed to) dispose of property (for references see Jensen 1982). Among these offerings, the Gundestrup silver cauldron is perhaps the most remarkable (Klindt-Jensen 1961). Its first century B.C. representations of supernatural beings, sacrifices, and processions, in a fascinating juxtaposition of ideas and beliefs, may reflect upon the whole concept of sacrifice and renewal in Iron Age northern Europe; whether this was a depiction of old traditions is uncertain. The cauldron was found stacked in pieces near a vantage point overlooking Borum Mose, a bog containing a formidable and protected Iron Age settlement and the three bodies already noted. Other finds in the bogs of the north include stone heaps and carved wooden effigies of male or female humans, with the sex clearly indicated; at Foerlev Nymølle, a female form in a split oak stave lay under a cairn (Andersen 1961) while at Broddenbjerg a distinctly phallic effigy lay beneath a cairn with pottery vessels of the Iron Age (Glob 1969), and a pair of human effigies were recovered from the Aukamper moor, Schleswig (Fig. 12).

These artifacts of all kinds demonstrate the powerful forces at work in the Iron Age society of northern Europe. The bog bodies of the period must have had a place in this episode. The number of individuals apparently executed may represent only a small part of the seemingly wholesale sacrifice of wealth, or the burial of ritually important artifacts, during this period. Perhaps human sacrifices, disposal of wealth, discard of war booty, and concealment of effigies formed a coherent pattern of appeasement to the forces of nature and of the other world, so that societies and individuals could feel more comfortable with their unequal lives, their uncertainty of survival, and their acceptance of a fate over which they had little control.

But there is another view as well, which sees the bog bodies as unconnected to the votive offering and sacrificial cult of the north (Munksgaard 1984). It receives strong support in the writings of Tacitus, who described in some detail the practices

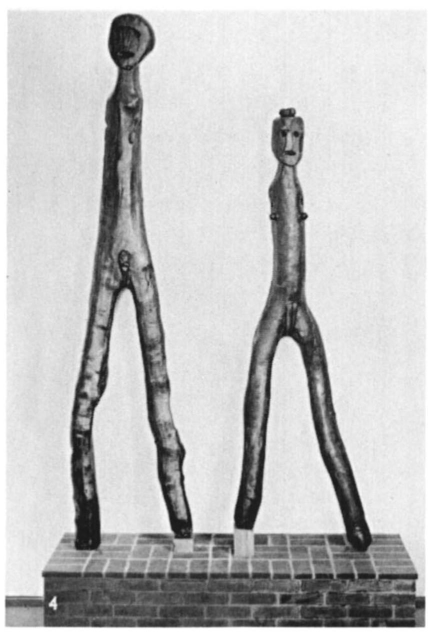

FIGURE 12 Wooden male and female effigies from the Aukamper Moor at Braak, Schleswig. Heights 2.75 and 2.27 m respectively. (Scheleswig-Holsteinisches Landesmuseum.)

and beliefs of certain of the Germanic tribes with which the Romans were in contact. Tacitus was writing in the late first century A.D. and part of his texts refer to Germanic law:

—Traitors and deserters are hanged on trees.
—Cowards, shirkers and sodomites are pressed down under a hurdle into the slimy mud of a bog.
—Wives guilty of adultery are taken from the house, stripped, shaven and flogged by their husbands.
—Criminals are taken to the place of execution, and the body from the execution, on a cowhide so as not to touch cultivated land.

From these comments we may envisage hanging, pinning into a bog pool, victims naked and shaven, and cowhides laid beside the bodies—all elements of which are recorded at the sites of Tollund, Borum, Windeby, and Lindow. Tacitus also refers to the ritual offerings made by the Germanic peoples, with both material possessions and human lives sacrificed to propitiate the gods and ease the passage of the seasons. The Gundestrup cauldron depicts what seems to be a bloodletting, with the victim held over a cauldron, and the throat-cutting of the Grauballe and Lindow man may relate, if distantly, to the practice of exsanguination for ritual purposes. Nonetheless, the image of punishment for misdeeds is strongly projected by some of the bog bodies. The original report on the second Borum Mose female makes harrowing reading. It depicts the unfaithful wife being shaven and driven by her husband out of the village into the bog: "Out there in the bog, the walkers slowly formed a circle around the two, and while the men began to dig her grave in the black peat the man came forward..." (Thorvildsen 1947). After the final crushing blow to the head she was thrown into the grave, and it was then filled in. It is necessary to note here that modern forensic examination of the Borum body does not support all of this scenario; her smashed face might be post-mortem damage, and she certainly did not attempt to fend off any blows with her arms. Yet she, and her fellows over a number of centuries from ca. 700 B.C., did end up in the bogs of the north and west, slain under unusual circumstances. They provide us with our first real look at our European ancestors—their flesh and blood, their physical condition, their clothing, some of their food, and their precise manner of death. It hardly makes one yearn for olden times.

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TREATMENT OF WATERLOGGED WOOD

David W. Grattan.

Historical Perspective

"TO PRESERVE adequately articles of moist wood, and they are generally in this condition when first excavated, preliminary measures to prevent their drying in the air must be taken immediately after they are dug out of the earth. If found in water, as for instance articles from pile-dwellings, they should be conveyed in water; moist objects should be wrapped in several thicknesses of moist cloth, and the whole wrapped in gutta-percha membrane, or in a layer of moist moss" (Fig. 1).

Thus wrote the great German conservation scientist Fredrich Rathgen in his book *The Preservation of Antiquities, A Handbook for Curators* (Rathgen 1905). As Christensen (1970), a Danish conservator, has described, treatment of waterlogged wood has a surprisingly long history of development. From Rathgen's advice you will note that simple and sensible ideas for handling were well established at least 80 years ago.

Wet site archaeology seems to have its origins in Denmark in the early nineteenth century (Glob 1970). In northern Denmark, peat cutters occasionally encountered well-preserved bodies, sometimes in oak coffins (Fig. 2). Although it was thought at first that these were recent murder victims, it was eventually established that the bodies were of ancient origin. This excited the interest of eminent Danish antiquarians, in particular King Frederik VII of Denmark himself. The need for conservation must have become apparent immediately because the bodies must have begun to decay quickly upon exhumation, and the associated wooden objects and textiles would have distorted and crumbled on drying.

Little is known about the first experimental conservation treatments. The early conservators did not publish their methods until they were well established. The first mention of the alum method was a penciled reference to it by Jorgensen, a servant of King Frederik VII in 1859 (Christensen 1970). It should be noted, however, that treatment of wood with alum to fireproof it has a very long history. Aulus Gellius recorded that in 73 B.C. the Greek general Archeolos prevented the Romans under Sulla from burning down a defensive tower in Athens by having it treated with alum (Gellius 1863).

A paper describing the alum method for waterlogged wood was published by

FIGURE 1 Carved wooden artifact *in situ*. (Canadian Conservation Institute, Ottawa.)

the Danish archaeologist, C.F. Herbst in 1861 (Herbst 1861). The process was carried out as follows: by placing objects in a hot (95–100°C) super saturated-solution of alum (potassium aluminium sulphate, $KAl(SO_4)_2.12(H_2O)$ for two hours. Herbst aimed to displace the water within the pores of the wood with a mass that would congeal, and therefore prevent shrinkage upon drying. There is no doubt that this simple approach essentially followed the right course. It was so successful that it remained in use, little changed, until the 1960s.

The alum method had several disadvantages. It did not prevent shrinkage entirely. Treated wood was heavy, brittle and unnaturally hard. Conservators found the boiling hot alum solutions difficult to work with and dangerous. Improvements were sought, particularly by Rosenburg of the Danish National Museum who introduced a number of changes (Rosenburg 1934). Most notably he altered the recipe to include a substantial proportion of glycerol. Unfortunately, this often caused worse problems. The glycerol made wood more hygroscopic, so that it absorbed more water in humid weather. In these circumstances, alum gains water of crystallization, alters crystalline form, and expands (Christensen 1970). Worse still, it does this during every period of high relative humidity. The effect on wood can be catastrophic. As the alum within the wood expands, weak fibers are burst apart; complete destruction is the eventual result. Some alum/glycerol treated objects have been found to have a consistency resembling cigarette ash. Many wooden objects from Scandinavia

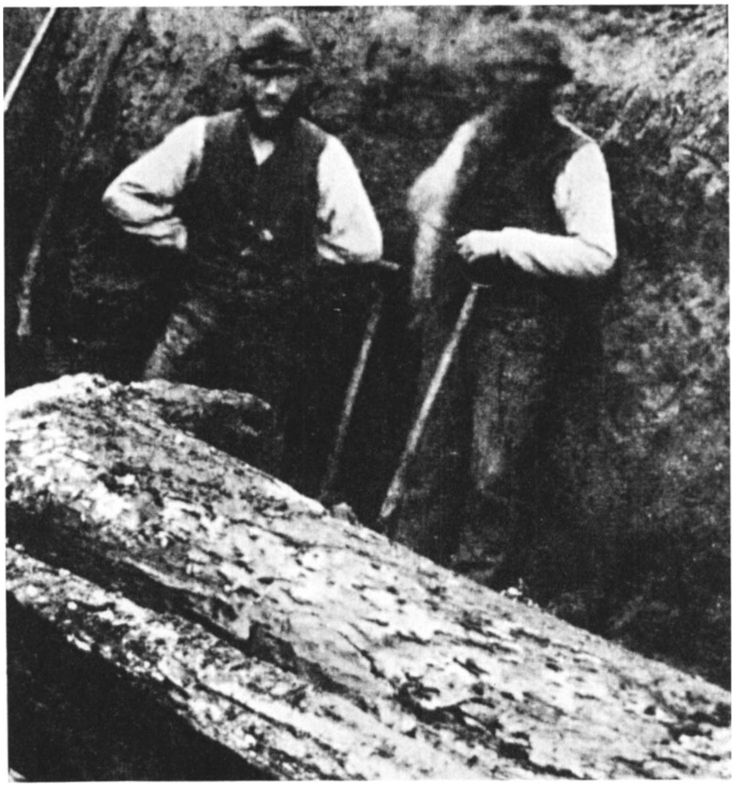

FIGURE 2 Remains of a coffin as encountered by peat cutters. (Glob 1970.)

treated by early alum/glycerol methods have had the alum extracted and have been reprocessed with other methods (Rosenqvist 1969).

Advent of Synthetic Polymers

In the late 1940s two developments changed matters radically. The first was that diving and salvage techniques had advanced so that it was feasible to locate, excavate, and lift an intact shipwreck in a unit. Second, a number of new polymeric materials became available which offered alternatives to alum.

In Sweden, the long lost warship Wasa was uncovered in Stockholm harbor (Fig. 3). At the same time in Denmark, a number of Viking ships were discovered in Roskilde fjord. Thus, all at once there was a need to develop new processes of conservation.

At this time, the manufacture of polyethylene glycol (also known as PEG, Carbowax or polyoxyethylene) began in the United States and elsewhere. PEG's antishrink effect on wood was discovered in the early 1950s by Stamm (1956) in the United States and perhaps more significantly for the archaeological application, by two Swedes, Morén and Centerwall (1960).

FIGURE 3 The Wasa entering dock. (Wasa Museum, Stockholm.)

Morén and Centerwall patented a process of rendering wood shrinkproof by treating it with PEG 4000. Conservators quickly realized that the same method could be used for waterlogged wood to prevent collapse and shrinkage upon drying. This method arrived with perfect timing to be tried on the Wasa. The process was simple; wood was placed in a heated solution of PEG 4000 and the temperature was increased gradually. Evaporation took place, so that the submerged wood was exposed to a gradually increasing concentration of resin. Eventually, all the water evaporated leaving pure molten PEG 4000 surrounding the wood in the bath. All the water in the wood was intended to be extracted so that on cooling, the cell cavities would be entirely full of the wax.

PEG 4000 resembles paraffin wax in its appearance and physical properties (though not in its moisture relations), and thus quite effectively gives strength and cohesion to deteriorated wood. For many wooden objects, particularly the more deteriorated ones, the Morén and Centerwall method worked very well. Certainly it preserved form, but there were drawbacks. The PEG solution and contents tended to turn inky black. In many instances this did not matter but it was annoying, nonetheless. After treatment the wood became unnaturally heavy, and had a waxy feel and appearance. The process also tended to obliterate fine surface detail. As time went on more problems became apparent. These were principally connected with penetration.

Treating the Wasa with PEG

The Morén and Centerwall method as it stood was clearly not suitable for treating an entire ship such as the Wasa. Just imagine the size of tank and the cost of heating! Thus for the Wasa, the PEG solution was applied by spraying in a very humid atmosphere (Barkman 1978). Although Morén and Centerwall had used waxy, solid PEG 4000 in their treatments, PEG 1500, a softer and more hygroscopic wax, was used for the Wasa. It had been recognized that the large timbers would be difficult to penetrate, but it proved much more difficult than anyone imagined. The PEG penetrated the massive timbers very slowly. Thus spraying frequency was increased and halfway through the treatment the lower molecular weight PEG 600, a viscous liquid, replaced the PEG 1500 as impregnant. Spraying terminated before impregnation was complete. The final concentration of spray solution was 45% (Barkman 1978).

There is still disagreement as to whether the PEG process has been completely effective for the Wasa. Penetration of PEG was never fully achieved for the larger framing timbers, but stabilization of the outer planking has been obtained (Hafors 1984). The Wasa remains as one of the most successfully preserved large wooden shipwrecks (Fig. 4).

The Use of PEG at the National Museum of Denmark

During the same period as the Wasa treatment, Christensen (1970) began experiments with the much more slender oak timbers of the Danish Viking ships. Having found that alum gave unsatisfactory results, he tried PEG. The problem was somewhat different from that of the Wasa. The timbers were much older and therefore more deteriorated; however, since the ships were much smaller and not intact they could be treated in tanks. Yet Christensen found that even with these 2–4-cm-thick oak timbers, he could not obtain PEG penetration using the Morén and Centerwall method. He considered the first batch of PEG treated wood to have a failure rate which was too high, and he thus began to experiment.

Christensen classified wood into three groups, according to the proportion of deteriorated wood. This was possible because in white oak rot penetrates slowly from the outside toward the interior, and there is usually a sharp delineation between sound wood and that which is very deteriorated. Thus, simply by probing with pins, the following categories could be established:

Category I contained wood with a fairly soft core, and proved amenable to treatment by the Morén and Centerwall "total impregnation" approach, if carried out slowly over two years.

Category II usually consisted of frame timbers of larger section, and had a more substantial core. These were treated successfully without heat, starting at a 25% PEG 4000 solution and finishing with a 50% solution after twelve months. Slow drying of the wood then took place. This method allowed the PEG to penetrate the outer deteriorated wood but not the sound core. However, the results were quite satisfactory.

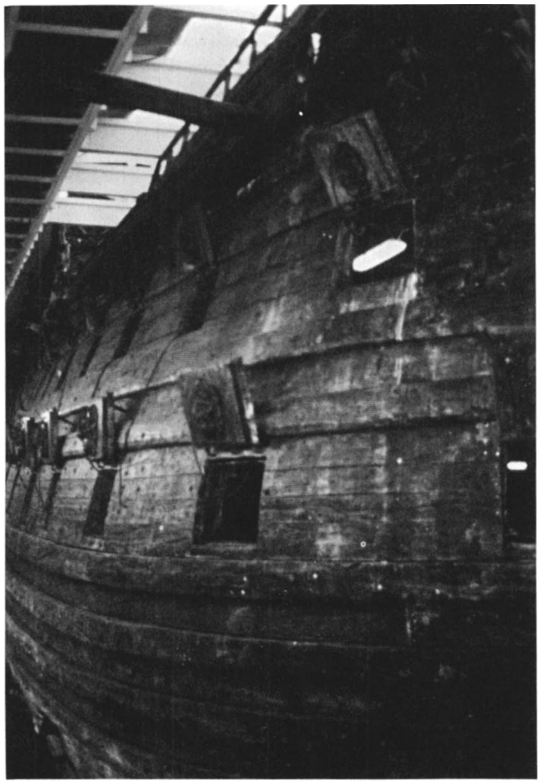

FIGURE 4 The Wasa, in 1984, dry and stable. (Wasa Museum, Stockholm.)

Category III, usually the stems and stern posts, was made up of wood with a considerably hard core, and proved most difficult to treat. The impermeability of this oak meant that if it dried untreated it tended to collapse, forming honeycomb voids on the interior. Treatment with a PEG 4000 solution produced the same effect. If PEG did not penetrate, then the PEG impregnation solution caused rapid dehydration and collapse.

Christensen eventually developed a process for his third category (Jespersen 1979). In this, the water in the wood was first exchanged with tertiary butanol. This alcohol was then used as a solvent to dilute the PEG 4000. He increased the PEG solution strength in stages, finally reaching 66% after about one year of impregnation. Use of this nonaqueous solvent proved to allow much better penetration of PEG 4000 than was possible with water. When impregnation was complete, objects were frozen and then freeze-dried. That is, the tertiary butanol was removed as a vapor under vacuum while the object was kept frozen in a block of the solidified alcohol. Freeze-drying took place in a cooled vacuum chamber. This avoided many of the problems associated with normal drying which caused the wood to shrink and collapse (capillary tension effects), and also prevented the tertiary butanol vapor from escaping into the atmosphere.

This method worked very well not only for the Category III oak but also for most other waterlogged wood. It continues to be used in Denmark, at the National

Museum, in Japan in at least two institutions, and, in a modified form, in Holland. It does have two difficulties, however. It is expensive and requires a semi-industrial scale plant to allow for proper handling procedures.

Use of Resins Other Than PEG

Rosin

The difficulties of treating impermeable hardwoods as well as the disadvantages of PEG have inspired a variety of other approaches. Perhaps the best known is the acetone-rosin method developed by McKerrell and his colleagues (McKerrell et al. 1972). In this procedure, wood is first thoroughly dehydrated with acetone. Acetone is then used as a solvent to allow the rosin (colophony), to penetrate the wood. The final concentration of the solution is 66% weight/volume. The process, like all of those using nonaqueous solvents depends on thorough dehydration. Any remaining moisture impedes impregnation. A number of variations on the original method have been tried, and replacement of acetone by ethyl or isopropyl alcohol is commonly done (and apparantly successful). Recently conservators at Parks Canada have been carrying out the acetone-rosin process successfully at room temperature (Fox 1986).

Wood impregnated with rosin is very acceptable aesthetically, but has the reputation of being brittle. Opinions differ on this point, and the simple fact is that the resulting brittleness of the wood has never been tested properly. I am concerned about the long-term stability of rosin in wood. It is acidic and it is known to oxidize. There is considerably less information about the long-term stability of rosin than there is about PEG, which has been the subject of a number of aging studies.

Condensation Resins

In Switzerland, at the same time that the Wasa and Roskilde ships were being treated, interest in the problem of the treatment of waterlogged wood was increased by numerous excavations of ancient lake settlements. There was a need to preserve very deteriorated wood that ranged from 2,000 to 4,000 years old. Conservation techniques were developed which differed strongly from the Scandinavian methods described above. Of particular note is the Arigal-C method (and its derivatives) of Muller-Beck and Haas (1960).

Arigal-C, marketed by the Ciba-Geigy company of Switzerland, was a water miscible condensation resin based on melamine and formaldehyde. The two components were mixed with water and the wood was then soaked in this solution. Hardening was achieved by heating the well-wrapped wood in an oven. The result of this process is wood which possesses a structurally strong surface, enabling deteriorated wood to resist the forces causing collapse and shrinkage. Years have been spent refining this process to make it reliable and effective. The advantages are that strong and aesthetically pleasing objects are obtained and shrinkage is controlled. The principal disadvantage is that the process is final and cannot be reversed. If the result is not satisfactory there is a problem. Since only a short time can be allowed for immersion, penetration is likely to be superficial. Thus the method is unsuitable for large objects. Its main value is that it provides a simple procedure for producing very durable samples.

This method has also been beset by problems with the supplier. First, Ciba-Geigy discontinued production of Arigal-C, then, after much work by Arnold Haas, another Ciba-Geigy condensation resin (Lyofix DML) was developed as a satisfactory alternative. In the early 1980s however, this too was discontinued. With the help of Ciba-Geigy, Haas (1984) finally developed a process which used basic chemicals rather than a manufactured product. This should be invulnerable to future vagaries of the marketplace.

Other Natural Resins

The Swiss have also developed the alcohol-ether-dammar resin method. Early work on this method had been carried out in Denmark by Christensen, but Kramer and Muhlethaler (1967/1968) have developed it into a routine process on a moderate scale. In this treatment, waterlogged wood is dehydrated with alcohol; the alcohol is then replaced with diethyl ether. The ether is used as a solvent to dissolve a mixture of resins which can then impregnate the wood. The method is reported to yield an especially pleasing result. In particular, it preserves fine surface detail.

Use of diethyl ether presents a real safety problem however. It has such a low flash point, that it has to be used very carefully. Fire regulations in many parts of the world are such that equipping a conservation laboratory to carry out this process can be prohibitively expensive.

Comparative Experiments

Like the Scandinavians, the Swiss have provided much of the leadership in developing treatments for waterlogged wood. Furthermore, they have been concerned about the relative merits of each procedure. Many had been developed, but no criteria had been established for comparing their effectiveness. Thus in the late 1970s, they carried out a comparative study involving one French and several Swiss laboratories. The treated wood was examined impartially and the results published. According to their criteria, the Lyofix DML treatment performed best. However, PEG methods were not properly assessed and since that time, freeze-drying techniques have been improved (Braeker and Bill 1979). The gamma ray initiated polymerization of styrene-polyester resin has since been further developed by the Grenoble laboratory of the "Centre d'Etude et de Traitement des Bois Gorgés d'Eau" (CETBGE), so that it gives treated wood of excellent appearance and strength. (The latter method is not discussed here because of its specialized nature.)

By coincidence and in ignorance of the Swiss study, this author was also carrying out a comparative study of treatments at the same time. A very different approach was used; there was more emphasis on PEG methods and freeze-drying, and criteria did not emphasize strength as much as the Swiss study. The results of the Canadian study favored the PEG/freeze-drying technique as the best option (Grattan 1982). An important result of both these studies was that true comparative shrinkage measurements were obtained.

An interesting development has arisen directly as a result of these two studies. A worldwide collaboration involving laboratories in Europe, Japan, North America, and Australia is continuing the comparative approach with six samples of wood each from a wide variety of sources. Results were presented at the meeting of the ICOM Working Group on Waterlogged Archaeological Organic Materials in Fremantle Western Australia in September 1987.

Freeze-Drying

Several attempts to freeze-dry wood have been made since the 1950s, but the results were rather poor until Christensen invented the tertiary butanol method described above. Although the latter process gives good results, it is expensive and difficult to carry out because of the handling problems imposed by the alcohol. What many laboratories were looking for was an approach that did not entail the use of a nonaqueous solvent. Fortunately, in the early 1970s Ambrose (1975), in Australia, and Elmer (1973), in Switzerland, independently arrived at a successful solution to this problem.

Wood was placed in a cold bath of dilute PEG 400 (a viscous liquid) and, after an impregnation of about three months, it was freeze-dried. Ambrose used a PEG concentration of about 10 to 15% and adjusted it to suit the density of the wood. He argued that this was necessary in order to maintain a constant ratio of one part PEG by weight to four parts wood. The theory behind the freeze-drying was that the PEG would remain solid and prevent deformation as the moisture passed from the ice to vapor phase and then out of the wood.

This method usually gave good results; however, it was found that with very deteriorated wood not all the collapse or shrinkage was prevented and the resulting wood was very fragile, spongy and moist to the touch. This method worked well for wood belonging to Christensen's Category III. Elmer got around the difficulties for very deteriorated wood by using low concentrations of PEG in the impregnation, and by coating the wood with an epoxy resin after treatment. Others have simply melted PEG 4000 onto the surface to achieve a similar effect.

Recent Developments in Freeze-Drying at the Canadian Conservation Institute

Since the Ambrose/Elmer discovery of the PEG freeze-drying process, it has been the subject of much research. This is because it is simple, rapid, effective, and gives wood a pleasing appearance without the need for much cosmetic post-treatment. It has become apparent that the method can be adapted to suit wood in many conditions by adjusting the concentration of PEG and by using mixtures of two grades of PEG. This is discussed below in more detail. Because of this development and a general desire to understand treatments better, conservators have now begun to examine various ways to describe and measure deterioration in wood. There have also been studies on the interaction between PEG and wood. It has become quite obvious that PEG accomplishes much more than acting as a solid and benign bulking agent.

Deterioration

A simple approach to deterioration.—methods of assessing deterioration have varied from detailed taxonomic studies, to summative chemical analyses. Recently, I presented summative chemical evidence that waterlogged woods from a variety of sources have similar patterns of decay (Grattan and Mathias 1986). Without exception, deterioration removed the cellulose, leaving the other main component of wood, the lignin, almost unaffected. Since only one major chemical constituent of wood is destroyed, deterioration can be quantified approximately by the percentage loss of matter. This gives a very simple way of categorizing wood (Grattan and Mathias 1986).

This approach is not advocated to the exclusion of other types of analysis, but simply as a useful practical tool for the conservator. Other kinds of analysis are important too. Identification of species is crucial and ash content is important, especially if mineral replacement is suspected. In addition, it is often useful to assess strength. This can be done most simply by probing with pins for small objects, and with the Pilodyn impact penetrometer for large objects (Clarke and Squirrell 1985). Probing with a pin is always informative and should be among the first tests made by the conservator

The important function of cellulose in wood.—Determining the percentage of matter lost gives a very good indication of the amount of residual cellulose, which can be very useful to know. Cellulose, arranged in spiralling strands within the inner cell wall, determines the strength and moisture related behavior of wood. Between the strands (fibrils) of cellulose, are microcapillaries. The volume in these structural elements is termed the secondary space and it is here that absorbed water resides. In humid conditions more water enters the secondary space, which enlarges accordingly. The result is that the cell wall expands and thus the wood swells.

In deteriorated waterlogged wood the secondary space is much enlarged due to a loss of cellulose. Under extreme conditions of deterioration, such as commonly comes from sites such as the Somerset Levels, it is found that there is almost no cellulose present (Grattan and Mathias 1986). All that remains is the compound middle lamella, the material which lies between cells and acts as a cement. This is soft and very weak when wet, and is composed almost entirely of lignin.

PEG penetration of the wood cell wall.—Since the success of freeze-drying depends to a large extent on the penetration of PEG into the secondary space, it is important to assess how much cellulose remains. The condition of the wood thus determines the treatment to be used. It has been shown that, in many instances, PEG has the ability to enter the secondary space and remain there during freeze-drying, thus preventing shrinkage. The ability of PEG to enter the cell wall depends very much on the wood species and condition. Young and Sims (1986) found that there was almost no penetration of the cell wall of undeteriorated oak by any grade of PEG. Other woods such as *Populus* sp. or softwoods allow more penetration. Also, penetration increases with increasing deterioration, presumably because the microcapillaries in the wood cell wall are enlarged.

Suggested PEG Solutions for Freeze-Drying

Deteriorated wood.—It is rather pointless to treat wood with no remaining cell wall with a liquid grade of PEG (e.g., PEG 400), since there is no residual secondary space remaining for it to occupy. Wood in this poor condition is best treated by using a solid grade such as PEG 4000 or PEG 3350, which can easily penetrate the enlarged vascular system, and can give better consolidation than PEG 400 or PEG 200. (It should be noted that very deteriorated wood is sometimes very impenetrable.)

Intermediately deteriorated wood.—Using the above logic one might suppose that the best approach would be to use a mixture of high and low molecular weight grades of PEG, and this is what is advocated. This procedure is discussed further below.

Undeteriorated wood.—As mentioned previously, it is important to choose a grade of PEG which will penetrate the cell wall, this often calls for the use of low molecular weight PEG 400 or even PEG 200. No consolidation is necessary for wood with plenty of residual strength. The method advocated is much the same as the original Ambrose procedure.

Generalized treatment scheme.—The approaches mentioned above suggest a treatment scheme that calls for: (a) impregnation by liquid PEG 400 for relatively undeteriorated wood, (b) the use of mixed solid/liquid grades for intermediate deterioration, and (c) solid PEG 4000 for very deteriorated wood. In reality, however nearly all woods fall in the category of being intermediately deteriorated. There is thus the question of how the strength of a PEG solution should be selected. In practical situations, mixtures of 15% weight/volume of each type of PEG work quite well. These are not suitable for the wood that is highly deteriorated or undeteriorated, however.

It is possible to calculate the ideal solution strength exactly. This procedure is based on the idea that there should be just enough PEG 400 (or 200) to occupy the secondary space in the remaining cell walls, and an amount of PEG 3350 (or 4000) equal to the loss in cellulose. Obviously the two grades of PEG will not end up located precisely in these zones, but it does provide a working basis for the calculation. The method can also be used to predict how much PEG 400 is needed for undeteriorated wood and the amount of PEG 3350 necessary when all the cellulose is gone. (This is expressed graphically in Figs. 5 and 6.)

This calculation of PEG solution strength is meant to be a helpful guide rather than an absolute recipe which must be followed. Other considerations that should be taken into account are the distribution of deterioration, the penetrability of the wood, and that PEG solutions do not freeze at a concentration around 50%. When mixed PEG solutions are used, impregnation with the lower grade should start first, building up to the final mixture in 5 or 10% stages.

The calculation is somewhat cumbersome, but is easily accomplished with a simple BASIC program listed in Appendix I. In Appendix II, an algebraic development of the equations is given.

Supporting evidence for the "double PEG" method.—Support for this approach comes from work carried out in various laboratories. At the Canadian Conservation Institute, we have shown the efficacy of impregnation solutions composed of mixtures of PEG 400 and 3350 for the freeze-drying of moderately deteriorated wood (Cook and Grattan 1984), and of PEG 400 alone for undeteriorated wood. Watson (1982) of the Ancient Monuments Laboratory in London, who first proposed the use of mixed PEG 400–4000 solutions, has also shown their value in treating very decayed wood. Murray (1982), formerly of the Mary Rose Trust, successfully freeze-dried very deteriorated wood from PEG 4000 solutions.

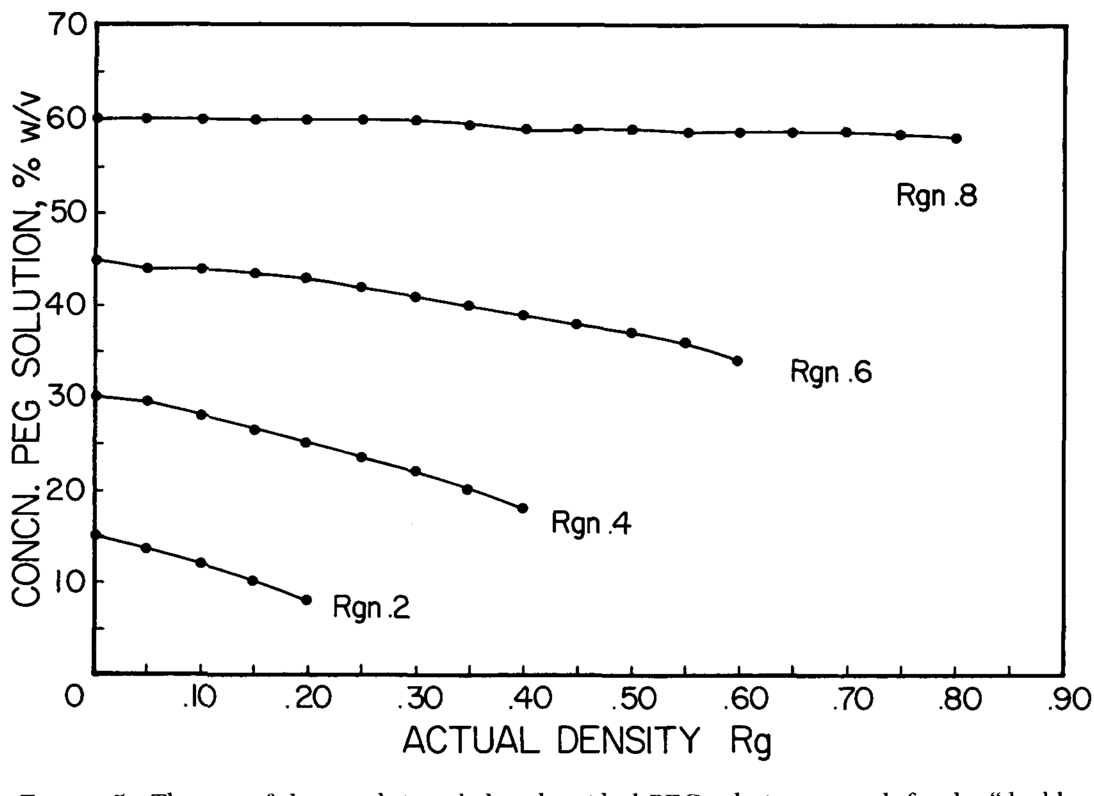

FIGURE 5 The aim of this graph is to help select ideal PEG solution strength for the "double PEG system." It shows a plot of ideal total PEG concentration (both the 400 and 3350 grades) for the impregnation solution. Separate plots are made for woods of different normal densities; Rgn (oven dry weight/waterlogged volume) is equal to 0.2, 0.4, 0.6, and 0.8. For each Rgn value, PEG solution strength is plotted against Rg (the actual density). When Rg=Rgn, the wood is undeteriorated, but as Rg decreases this means greater deterioration of the wood for any given Rgn. Thus for a wood sample of known Rg and Rgn, a solution concentration that would provide sufficient PEG to fill the secondary space in the residual cell wall and replace missing cell walls can be determined. The ratio of PEG 400 to PEG 3350 is given in Figure 6.

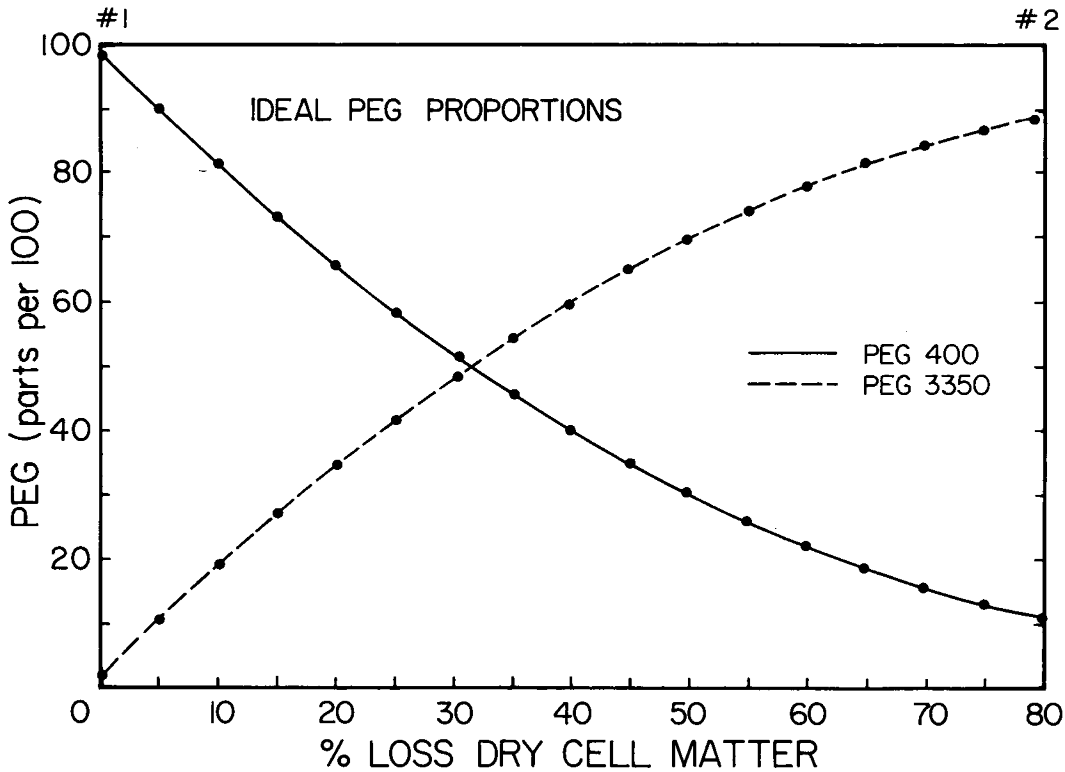

FIGURE 6 This graph shows the ideal proportions of PEG 400 and PEG 3350 for application of the "double PEG system." (See Fig. 5 caption.) The percent loss in dry cell matter is given by 100 (Rgn-Rg)/Rgn, and is a good monitor of the amount of residual cell wall. Proportions of each PEG grade in parts per hundred are plotted against percentage loss. By this means a suitable solution composition may be selected.

Hoffmann has produced some of the most compelling evidence, although the PEG treatment under examination was not intended as a freeze-drying method. Hoffmann (1984) studied the shrinkage of oak of various degrees of degradation after impregnation with 50% solutions of PEG 200, 300, 400, 600, 1450, 3350 and 4000. He showed that deteriorated oak shrunk the least with PEG 4000, while the sound wood fared best with liquid PEG 200. The intermediate 1450 grade proved to be the least effective under all circumstances.

Other Methods

This paper does not cover many of the treatments which have come and gone over the years. One recent method which should be mentioned, however, because it usually gives good results for small wooden objects, employs sucrose as an impregnant/consolidant. (Cook and Grattan 1984; Grosso 1981; Parrent 1985). Overall the evidence suggests that sucrose does not exercise as much control over wood shrinkage as PEG. However, the results are so promising and the method so simple that research with it should be encouraged.

Conclusion

This paper has given a brief account of the history and theory of some of the more successful treatments for waterlogged wood. It is intended primarily to alert you to the possibilities and to suggest some profitable approaches, rather than to help you choose or modify treatment methods. It should be emphasized that for small objects there are now a wide variety of approaches which allow the conservator to choose procedures according to particular circumstances. The following illustrates some of the factors that must be taken into account when deciding which method to use: (1) wood condition, (2) laboratory facilities, (3) time allowed, (4) budget, (5) purpose (exhibit only, study collection, or school service), (6) value, (7) likely shrinkage, (8) fit with other components, (9) display/storage humidity, and (10) aging properties of consolidant. We are fortunate in having a wide selection of methods available. We have progressed a long way from the days when treatment was risky, and limited to alum.

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Appendix I

```
10   DISP "CALCULATION OF THE DESIRED CONCENTRATION OF PEG PRE-
          TREATMENT"
20   DISP " "
30   DISP "SOLUTIONS FOR FREEZE-DRYING WATERLOGGED WOOD."
40   DISP " "
50   DISP "..............................................................................."
60   DISP " "
70   DISP "The calculation is based on the aim of filling the secondary"
80   DISP "space in the residual wood cell wall with PEG 400 (or 200)"
90   DISP "and adding an amount of PEG 3350 (or 4000) equal to the volume"
100  DISP "of cell wall missing through deterioration."
```

```
110 DISP "Three pieces of information are required to obtain a result;"
120 DISP "(1) The actual density of the sample, or the maximum water content."
130 DISP "(2) The average density of normal wood of the same species."
140 DISP "(3) The fiber saturation point of the normal undeteriorated wood."
150 DISP " "
160 DISP " Press 'CONT' to continue "
170 PAUSE
180 DISP "Listing of normal densities and fiber saturation points are given"
190 DISP "for most common North American species."
200 DISP " "
210 DISP "IF ACTUAL DENSITY KNOWN ENTER 0, IF ONLY WATER CONTENT
         KNOWN ENTER 1"
220 INPUT A
230 IF A=0 THEN 290
240 DISP "INPUT WATER CONTENT (PREFERABLY MAXIMUM VALUE)"
250 INPUT WC
260 RG=100/(WC+66.667)
270 DISP "DENSITY (Rg) ESTIMATED FROM WATER CONTENT = ";RG;" g/ml"
280 GOTO 310
290 DISP "INPUT VALUE OF Rg, ACTUAL DENSITY OF WOOD"
300 INPUT RG
310 DISP "DO YOU KNOW THE AVERAGE NORMAL DENSITY ENTER 1 IF YES, 0
         FOR NO"
320 INPUT B
330 IF B=0 THEN 500
340 DISP "INPUT THE NORMAL DENSITY OF THE WOOD SPECIES"
350 INPUT RH
360 DISP "DO YOU KNOW THE FIBER SATUTATION POINT FOR NORMAL WOOD
         OF THIS"
370 DISP "SPECIES, ENTER 1 IF YES, 0 FOR NO."
380 INPUT C
390 IF C=0 THEN 700
400 DISP "WHAT IS THE NORMAL FSP OF THIS WOOD?"
410 INPUT F
420 X=1.5×F×RG/100+RH−RG
430 Y=1/(1+66.667×(RH/RG−1)/F)
440 Z=1/(1.5−RG)
450 P1=1.128×X×Y×Z×100
460 P2=1.128×X×Z×(1−Y)×100
470 DISP "Concentration of PEG 400 = ";P1;" %W/V"
480 DISP "Concentration of PEG 3350 = ";P2;" %W/V"
490 GOTO 830
500 DISP " "
510 DISP ,,"Alaska Cedar 0.42 Baldcypress 0.42 Douglas Fir (coastal) 0.45",,"Douglas-Fir
         (inland) 0.45 Fir, balsam 0.34 Fir, white 0.35 Hemlock, E 0.38"
520 DISP ,"Hemlock, W 0.42 Incense cedar 0.35 Larch, W 0.48 Pine, E white 0.34" ,,"Pine-
         jack 0.40 Pine, loblolly 0.47 Pine, lodgepole 0.38 Pine, longleaf 0.54"
530 DISP ,,"Pine, ponderosa 0.38 Pine, red 0.41"
540 DISP "Press 'CONT' to continue"
550 PAUSE
560 DISP ,"Pine, shortleaf 0.46 Pine, slash 0.56 Pine, sugar 0.35",, "Pine, western white
         0.36 Port Orford Cedar 0.40 Redcedar, E 0.44"
570 DISP ,"Redcedar, W. 0.31 Redwood 0.38 Engelmann and E Spruce 0.36",, "Sitka
         Spruce 0.37 Tamarack 0.49 Atlantic White cedar 0.31"
580 DISP ,"E or N White cedar 0.29 Pacific Yew 0.60" ,,,,,,"HARDWOODS ------",, ,"Alder
         red 0.37 Ash, black 0.45 Ash, white 0.55 Aspen, quaking 0.35"
590 DISP "Press 'CONT' to continue"
600 PAUSE
```

```
610 DISP ,"Basswood, Am 0.32 Beech, Am 0.56 Birch, paper 0.48",, "Birch, yellow 0.55
        Buckeye, yellow 0.33 Buckthorn, cascara 0.50"
620 DISP ,"Butternut 0.36 California laurel 0.51 Catalpa, N 0.38 ",," Cherry, black 0.47
        Chestut, Am 0.40 Chinkapin, golden 0.42"
630 DISP ,,"Cottonwood, E 0.37 Dogwood, flowering 0.64 Elm, Am 0.46",,,"Elm, rock 0.57
        Elm slippery 0.48 Hackberry 0.49 Hickory, shagbark 0.64",,"Holly, Am
        0.50"
640 DISP "Press 'CONT' to continue"
650 PAUSE
660 DISP ,"Honey locust 0.60 Hophornbeam, E 0.63 Hornbeam, Am 0.58,",, "Locust, black
        0.66 Madrone, pacific 0.58 Magnolia, Southern 0.46"
670 DISP ,"Maple, red 0.49 Maple, sugar 0.56 Oak, live 0.81 Oak, red 0.57",, "Oak, white
        0.59 Osage orange 0.76 Persimmon, comm 0.64 Sassafras 0.42"
680 DISP ,"Sourwood 0.50 Sweetgum 0.46 Sycamore Am 0.46 Tupelo, black 0.46",, "Walnut,
        black 0.51 Willow, black 0.34 Yellow poplar 0.40"
690 GOTO 340
700 DISP " "
710 DISP "CONIFERS", "HEARTWOOD INDISTINCT",,,"....... fir spruce ....... 30-34%"
720 DISP "CONIFERS", "HEARTWOOD DISTINCT",,," ..pine, white pine, larch, douglas
    fir"
730 DISP " sapwood...30-34%",,," heartwood, moderate resin content.. 26-30.5%",,"
        heartwood, high resin content............................................ 20-24%"
740 DISP "Press 'CONT' to continue"
750 PAUSE
755 DISP ,,,,
760 DISP "BROAD LEAVED HEARTWOOD DISTINCT RING POROUS",,,
770 DISP "black locust, chestnut, oak, ash, black walnut, cherry................................... "
780 DISP " ......................heartwood 22-24% ........................sapwood 32-35%",,,,,
790 DISP "BROAD LEAVED HEARTWOOD INDISTINCT DIFFUSE POROUS",,,,
800 DISP "lime, (bass), willow, poplar, birch, hornbeam, alder, beech"
810 DISP " ..............................................................heart and sapwood 32-35%"
820 GOTO 400
830 END
```

Appendix II

Calculation of the "correct" amount of PEG for the pretreatment of waterlogged wood, before freeze-drying.

The concentration of PEG in the pretreatment solution may be calculated assuming the following criteria:

1. That enough PEG 200 or 400 should be present to occupy the secondary space in the residual cell wall; that the secondary space is given by the fiber saturation point.
2. That PEG 3350 should be added in an amount equal to the volume of the cell walls missing through deterioration.
3. That the amount of PEG solution entering the wood is determined only by the available free volume (i.e., lumen volume) and not by the rate of diffusion into or permeation through the wood.
4. That the density of the cell wall material is 1.5.

Derivation

Let the normal saturation point of a given species = F
Let the actual density be Rg (oven dry weight/volume, water-logged)
Let the average green density of undeteriorated wood (same species) be Rgn
PEG requirement for filling the secondary space only

$$= \frac{F}{100}(Rg) \text{ ml PEG/ml Wood.}$$

However in each ml of wood, the volume of free water

$$= (1 - Rg/1.5) \text{ ml.}$$

Thus to achieve the necessary amount of PEG in the cell wall, the strength of the PEG solution should be:

$$\frac{F\ (Rg)}{100\ (1-Rg/1.5)}\ \text{ml PEG/ml Water.}$$

Or expressed as weight percent, the concentration of PEG solution should be:

$$\frac{1.128\ (F)\ (Rg)}{(1-Rg/1.5)}\ \%\ \text{w/v.}$$

As wood density becomes greater, the concentration of PEG must increase to satisfy the requirement of the cell wall. Not only does higher density wood have less free volume for holding the impregnant solution, but the requirement for PEG is also greater because of the greater amount of cell wall material per unit volume of wood.

Effect of Deterioration

One way of describing deterioration is by the use of an imaginary fiber saturation point (Fi). This does not represent a real value, although deteriorated wood does in actuality have a much increased fiber saturation point. For the purposes of this calculation only, we include cell wall losses with the secondary space, and define an imaginary fiber saturation point as the percent weight of water necessary to occupy the secondary space and the losses in the cell wall. This allows us to calculate the necessary PEG solution concentration, which will leave enough PEG in the wood upon freeze-drying to fill up the secondary space and replace the volume of wood substance lost. For each ml of wood, the loss in volume of wood substance due to deterioration equals:

Thus, the ideal PEG concentration can be calculated as before:

$$\begin{aligned}\text{PEG (deteriorated wood)} &= 1.128\left[F + \frac{(Rgn-Rg)}{1.5\ Rg}\right]\frac{100(Rg)}{1-Rg/1.5}\ \%\,\text{w/v}\\ &= 1.128\left[\frac{(F)(Rg)}{100} + \frac{Rgn}{1.5} - \frac{Rg}{1.5}\right]\frac{100}{1-Rg/1.5}\ \%\,\text{w/v}\\ &= 1.128\left[\frac{1.5(F)(Rg)}{100} + Rgn - Rg\right]\frac{100}{1.5-Rg}\ \%\,\text{w/v.}\end{aligned}$$

Now the ratio of PEG 400 to PEG 4000 is also given by the normal fiber saturation point "F" (which represents the secondary space in the undeteriorated wall), the imaginary fiber saturation point "Fi" which stands for the loss in volume of the cell wall, plus the secondary space in the residual cell wall.

$$\begin{aligned}\text{The PEG 400 proportion in parts by weight per 100 parts total PEG} &= \frac{}{F + \left[\frac{Rgn}{Rg} - 1\right]66.7}\\ &= \frac{100}{1 + \left[\frac{Rgn}{Rg} - 1\right]\frac{66.7}{F}}\ \text{parts PEG 400 per 100 parts total PEG.}\end{aligned}$$

Thus treatment solution concentrations are given by:

$$\text{PEG 400 Concentration} = \frac{1.128}{1 + \left(\frac{Rgn}{Rg} - 1\right)\frac{66.7}{F}}\left[\frac{1.5(F)(Rg)}{100} + Rgn - Rg\right]\frac{100}{1.5-Rg}\ \%\,\text{w/v}$$

$$\text{PEG 4000 Concentration} = \left[1 - \frac{1}{1 + \left(\frac{Rgn}{Rg} - 1\right)\frac{66.7}{F}}\right](1.128)\left[\frac{1.5(F)(Rg)}{100} + Rgn-Rg\right]\frac{100}{(1.5-Rg)}\ \%\,\text{w/v.}$$

MARCO'S BURIED TREASURE: WETLANDS ARCHAEOLOGY AND ADVENTURE IN NINETEENTH CENTURY FLORIDA

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THIS PAPER was meant to give historical perspective to this conference, but after hearing the various papers, it is obvious that some things about wet site archeology are much the same as they were one hundred years ago.

Marco is an important site. A small island at the northern end of the Ten Thousand Islands off the southwest coast of Florida, it is higher than most of the surrounding mangrove islands, reaching a height of 18 m.

The first finds at this site were made accidentally by the owner of the property while digging muck for his orange grove. He showed these finds to a visiting fisherman who described them to a visiting British army officer who recognized their significance. He in turn carried them to an acquaintance at the University of Pennsylvania at a time when Frank Hamilton Cushing happened to be there. This was in the spring of 1895.

Marco had known permanent settlers but 24 years. There was no effective network of roads or railroads throughout the state and south Florida had few kilometers of either. When Cushing made his reconnaissance visit to Marco in the spring of 1895 it took him nearly two weeks to travel from New York to Punta Gorda at the mouth of the Peace River. He traveled from New York to Jacksonville by steamer, then by river boat up the St. Johns River to Sanford where he boarded a train to take him diagonally southwest across Florida. The last 48 km to Punta Gorda was on horseback. From there to Marco there was neither road nor rail, so he hired a small sloop and its crew of two so he could explore and make surface collections along the way.

At Marco he dug a small test pit in the muck near where the island's owner had recently found some organic remains and in a very short time he had more than duplicated those earliest finds. He returned north greatly enthused, having secured the owner's permission to dig and to retain all recovered artifacts in return for saving all muck removed for use on the owner's orange grove.

Later, in the fall of 1895, after securing materiel and key personnel, Cushing once again set out for Marco. This time he had been promised the use of a sponging vessel from Tarpon Springs to transport the party to Marco.

When they reached Tarpon Springs, the vessel was at sea and did not return for several weeks. Cushing put those weeks to good use. In Tarpon he hired excavators and trained them in nearby mounds. When, late in February, they set sail for Marco there were 14 persons aboard, including the vessel's crew: Cushing, his wife, who assisted in the cleaning and preservation of artifacts, a field secretary, an artist-photographer, a preparator, and the excavators trained at Tarpon Springs.

The schooner was anchored just northeast of the island far enough offshore to be out of reach of the mosquitoes and here they all lived for the duration of the expedition. They ate on deck, using the cabin roof for a table, and in good weather many of them also slept on deck.

When they reached Marco, arrangements were made to proceed with the digging without delay. Sawyer, the artist-photographer, said:

> I shall never forget the first impressions of the muck hole at Marco. The little shoots of mangrove coming up here and there, many curious weeds growing not more than twelve or sixteen inches high, all underlaid by foul-smelling black muck, into which a few trenches had been dug. These were filled with water, and indeed, the whole place was like a thick sponge saturated with water holding a great quantity of salt and a large variety of smells.
>
> Almost to a man they looked with absolute revolt upon the unpromising hole. Cushing waded into the mud, moved boards about [for firmer footing], and in a short time the men, who reluctantly began work, were following him and working with an enthusiasm and will which hardly flagged through the weeks of wading in mud and slime and of working under a semi-tropical sun in a muck-covered swamp, where mosquitoes [this before the days of effective repellents] were plentiful and the sand-flies almost like the sands of the sea, the annoyance of the insects alternating with the smoke of the smudge supposed to bring relief (Sawyer n.d.; Fig. 1).

The site was between shell ridges, triangular in shape, covering little more than half an acre. It was flooded with water for the rainy season had set in, and the long canal by which it once communicated with the sea was so clogged with vegetation that it no longer served as an outlet. The entire tract was overgrown with a heavy forest of mangroves and overlaid with a uniform covering of black, spongy peat some two feet in thickness. Underneath this in turn was a stratum of peaty, foul-smelling blue-gray marl, more and more solid as the depth increased, until at about 1.5 or 2 m below the surface in the center of the basin, it merged into a compact mass of tough blue clay, still intermingled with numberless broken and worked shells and wooden remains of every description (Figs. 2 and 3). All levels were artifact laden. It was impracticable to penetrate this cement-like bottom layer, not so much on account of its solidity, but because it was the only protection against the waters of the sea. A small cut through it into the underlying shell near the sea wall, to determine its nature and depth, resulted in instant flooding of the entire area and the cut had to be packed and tamped that the work might go on; this they profoundly regretted for every foot of the underlying material contained charcoal, bones and priceless remains of wood, fiber and other perishable materials. At the edges of this basin the muck was from a few centimeters to nearly 0.6 m deep; in the center of the depression it was nearly 2 m.

FIGURE 1 Partially excavated site showing flooding.

Excavation presented many problems. The entire court was thickly overgrown and almost continuously underwater, making it necessary to uproot the mangroves and remove the water before work could proceed. The men stood on heavy planks on the boggy surface and bailed with buckets. As the area to be excavated was below the level of the surrounding tide-swept mangrove swamp, it was difficult to bail out enough water for the work to progress uninterruptedly. Indeed, at first, shifts of men had to bail constantly while others dug.

This was very difficult, but by digging a viaduct through the banks, the water, as it was bailed out, was carried off through a trough constructed of ship planks raised above water level on stakes, one end above the excavation and the other end resting in a trench dug through the sea wall to just above the level of the sea outside (Fig. 4). At first the water flowed back in as fast as they bailed it out, but after a few hours of steady work the level began to lower, not only in the area of the excavation but in the entire court. It was necessary to repeat this bailing process, though to a lesser extent, each morning and, by banking up the place last excavated, the water could be kept sufficiently low to enable the work to progress.

But this produced another worry. The draining of the basin caused the peat and marl containing the specimens to sink over one-half meter in the middle of the basin, and the carrying off of so much water or brine, would, at last, after all those

FIGURE 2 Field photograph of wooden artifacts *in situ*.

centuries expose the specimens more or less to the air and lead to their rapid decay if left for any length of time.

Sometimes squatting on their knees in the slime, with hands and arms covered with mud, or provided with stools and protected with long-legged rubber boots and oilskins, three or four men worked side by side in each section, digging centimeter by centimeter and meter by meter, horizontally through the muck and rich lower strata, standing or crouching in puddles of mud and water.

Much of the work was done with small trowels, garden tools with flexible claws, and with bare fingers feeling through the mud. Each man in the muck did his best to secure and preserve the objects found. These were for the most part scarcely more than pulpy masses when found and a careless stroke or ill-timed movement would have destroyed any of the more fragile ones at once.

Removal of objects of shell, bone, and other more durable substances presented no problem. However, articles of wood, many painted in black, white, blue-gray, or brownish-red pigments far outnumbered all other types of artifacts. In many cases the wooden objects were so decayed and soft that it was with difficulty, even by feeling with their fingers, that the excavators were able to distinguish the fiber of even larger artifacts from the muck and peat in which they were embedded. Some were distinguishable from the environment in which they lay only by the re-

FIGURE 3 Field photograph of mortar, pestles, and shell *in situ.*

maining pigments with which they had been painted, the wood underneath having become part of the peaty mush. There were masses of netting and cordage made from local fibers, very difficult to distinguish from the masses of rootlets so prevalent in the muck. When the artifacts were discovered in time, they were cautiously uncovered and washed by splashing water on them or trickling it from a sponge. Still many of them were too decayed for removal. Sometimes the men were able to take up the artifacts on broad, flat shovels. They were then placed on large trays and carried to the schooner on the heads or in the arms of the workers. There they were washed on the rail of the schooner by trickling water over them. In the ship's cabin Cushing and his wife catalogued, cleaned and tried to preserve the specimens.

Cushing was constantly disturbed that so many of the unique specimens he was uncovering could be neither removed nor preserved. He tried everything he could to retain the specimens in good condition. He tried glue, shellac, and silicate of soda (then often called water-glass), all of which gave poor results. Some were preserved by very slow drying, accomplished by packing them in dry sand for a time, then placing them on shelves under dry clothing for an additional period. If dried in the open air, (even indoors) they warped, shrunk, split, and checked, or disintegrated entirely on being exposed to light and air for just a few hours.

FIGURE 4 Wooden trough in place to carry off water as it was bailed out of excavation area.

Fortunately, photographs, water colors, and casts of many of the artifacts were made in the field, and later in Washington, for it is impossible to recognize the remains of many of them at the present time. Many are missing altogether. Since many of these articles have crumbled to dust or warped out of all resemblance to their original forms it is largely to the drawings and photographs that we must turn to view the remains of this remarkable collection (Fig. 5).

Cushing recovered ceremonial paraphernalia, art objects, a complete range of tools and the articles made with them, weapons, fishing nets, floats and sinkers, a paddle, shell and stone anchors, and many articles of daily use. The technology exhibited is very sophisticated and of high quality. In spite of the many difficulties of the expedition, Cushing shipped 11 barrels and 59 boxes of artifacts back to the University Museum in Pennsylvania, a collection yet to be equalled elsewhere.

FIGURE 5 Deer figurehead *in situ*.

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MULTIDISCIPLINARY INVESTIGATIONS AT THE WINDOVER SITE

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THE SCIENTIFIC SIGNIFICANCE of Florida wet sites is becoming increasingly obvious. The abundant research opportunities so long recognized in Europe (see Coles 1984 for a review) are also evident in Florida wet sites (Clausen et al. 1975; Cushing 1897; Newsom and Purdy 1986; Purdy 1979, 1980, 1981; Royal and Clark 1960).

Discovery of Florida wet sites is typically accidental and no reliable locational models currently exist. In Florida, as in many areas, the anthropological community is deeply indebted to landowners, developers, and private citizens who take the time and make the effort to contact archaeologists when prehistoric or historic sites are accidentally discovered. How many of these kinds of sites go unreported remains an ever present concern.

Types of Florida Wet Sites

Landlocked Florida wet sites fall into several categories:

1. Large flowing springs upwelling through the karst limestone formations, such as Little Salt and Warm Mineral Springs (Clausen et al. 1975; Clausen et al. 1979; Cockrell 1973; Cockrell and Murphy 1978), are often associated with megafauna, bone and wooden artifacts, limited quantities of human skeletal material, some with very early radiocarbon dates (Table 1), and occasionally preserved brain tissue (Royal and Clark 1960). It has been hypothesized that these springs retained water during the late Pleistocene and early Holocene when water resources would have attracted human populations and wildlife.

   Investigations of spring sites require sophisticated diving technology, which results in short excavation periods and modification of excavation strategies. Small quantities of human skeletal material have been recovered from peat strata within the springs.

2. Peat deposits in poorly drained locations are common in central and south Florida. Some deposits form in outflowing sloughs such as at Little Salt Spring, most are 1–2 m thick, ar.d most began forming around 6,000 years ago when water tables rose and climatic changes resulted in a surplus in the hydrological budget

Table 1. Florida wet site radiocarbon dates from sites producing human skeletal material[1]

Warm Mineral Springs (8-SO-19) (Clausen et al. 1975)			
9370 ± 400	Charcoal	(W-1245)	
9500 ± 400	Charcoal	(W-1212)	
9870 ± 370	Charcoal	(W-1153)	LARGE FLOWING SPRING
8920 ± 190	Peat	(Gak-3992)	
9350 ± 190	Peat	(Gak-3993)	
9220 ± 180	Peat	(Gak-3991)	
10 000 ± 200	Burned log	—	
Little Salt Springs (8-SO-18) (Clausen et al. 1979)			
5220 ± 90	Human bone	(Gak-3548)	
6180 ± 95	Human bone (slough)	(UM-1102)	LARGE FLOWING SPRING
Bay West (8-CR-200) (Beriault et al. 1981)			
6520 ± 135	Wooden post	(UM-2085)	
6675 ± 85	Wooden post	(UM-2087)	
6630 ± 80	Wooden post	(UM-2088)	POND/PEAT DEPOSIT
6780 ± 135	Peat	(UM-2169)	
5500 ± 80	Peat in contact with human bone	(UM-2170)	
Republic Groves (8-HR-4) (Wharton et al. 1981)			
5745 ± 105	Wooden stake	(RG-409)	
2485 ± 80	Wooden stake	(RG-417)	POND/PEAT DEPOSIT
6430 ± 80	Wooden stake	(RG-418B)	
6520 ± 65	Wooden stake	(RG-420D)	
Windover (8-BR-246)			
6990 ± 70	Human bone (AMS)	(TO-207)	
7050 ± 80	Peat near highest bone	(Beta-14132)	
7210 ± 80	Human bone (C-14)	(Beta-7186)	
7330 ± 100	Human bone (C-14)	(Beta-5803)	POND/PEAT DEPOSIT
7360 ± 70	Peat beneath crania	(Beta-11381)	
7410 ± 80	Peat from brain surface	(Beta-11383)	
7830 ± 80	Human bone (AMS)	(TO-518)	
7930 ± 80	Wooden stake with burial	(Beta-18295)	
9530 ± 110	Peat beneath crania	(Beta-14649)	
8120 ± 70	Bone (AMS)	(TO-241)	

[1] Uncorrected radiocarbon dates. Klein et al. (1982) report radiocarbon dates between 7000 and 8000 B.P. are approximately 800 years too young. Thus the 7210 B.P. date (Beta-7186) is corrected to 8010 B.P. or 6060 B.C.

(Gleason et al. 1974; Purdy 1981). Such deposits have produced one of the largest collections of prehistoric watercraft in the world. One recovered from the base of the peat stratum at DeLeon Springs has been radiocarbon dated to 5140 ±100 B.P. (Beta–14893; Newsom and Purdy 1986).

Habitation features and debris accumulating in peat deposits could also be placed in this category and would include such striking sites as Key Marco (Cushing 1897; Gilliland 1975) and Fort Center (Sears 1982). Other sites such as Hontoon Island (MacDonald and Purdy 1982; Purdy 1981) and Tick Island (Jahn and Bullen 1978) have components that, if not originally deposited at the water margins, have at least become inundated as water levels reached modern highs.

3. Sites containing megafaunal remains and/or stone tools, less frequently bone and antler tools, are sometimes recovered from streams and creeks, particularly large north-central Florida streams and rivers such as the Aucilla and Suwannee (Waller 1969). Contextual integrity has been problematic, though this is changing as rigorous investigative techniques become standard (Dunbar and Waller 1982; Dunbar et al. 1987).

4. Isolated peat deposits underlying small ponds have been found to occasionally contain intentionally buried human skeletal material (mortuary ponds). Such sites have been reported since the late 1970s and have been found only in south and central Florida, despite extensive peat deposits in the southeastern United States (Beriault et al. 1981; Wharton et al. 1981). All known sites are datable to Archaic occupations (Table 1). They were discovered by construction or land clearing operations, and all were investigated to varying extents due to the interest of the land owners. Windover, discovered in 1982, is the only site of this nature where circumstances allowed controlled excavation and the development of a multidisciplinary research program.

The Windover Site (8-BR-246)

Shortly after the discovery of human skeletal material in the small Windover muck pond, approximately 8 km from Cape Canaveral, and with the encouragement of Florida State Museum representatives, the developer (Windover Farms, Inc.) rerouted the road to protect the materials. In the fall of 1982, Windover Farms, Inc. paid for radiocarbon dates on human bone from two individuals. Both radiocarbon dates on acid extracted collagen fractions were in excess of 7000 years B.P. (5320 B.C. uncorrected), (Beta-5803 and 7186, Tables 1 and 2). The research potential of the skeletal population was thus enhanced because approximately 80% of all New World human skeletal material available for study is less than 2,000 years old.

Development of a research design and proposal preparation, begun in 1982, was brought to fruition in 1984 when the Florida Legislature appropriated funds to begin investigation at Windover. Windover Farms, Inc. absorbed all of the 1984 costs for heavy equipment, construction, and dewatering, which were necessary for controlled excavations to begin. Without the continued support of the Florida

Table 2. Radiocarbon dates from Windover (8-BR-246)[1]

RADIOCARBON DATE YEARS B.P.	SOURCE OF DATE	SAMPLE NO.	STRATA[2]
4790 ± 100	Peat, base of black peat	(Beta-10763)	(black)
6070 ± 90	Peat, base of black peat	(Beta-13910)	(black)
5800 ± 80	Upper red-brown peat	(Beta-10764)	(upper red-brown)
7050 ± 80	Peat near highest bone	(Beta-14132)	(upper red-brown)
6990 ± 70	Human bone (AMS)[3]	(TO-207)	(bone)
7210 ± 80	Human bone (C-14)[3]	(Beta-7186)	(bone)
7330 ± 100	Human bone (C-14)[3]	(Beta-5803)	(bone)
7830 ± 80	Human bone (AMS)[3]	(TO-518)	(bone)
8120 ± 70	Human bone (AMS)[3]	(TO-241)	(bone)
7360 ± 70	Peat beneath crania	(Beta-11381)	(lower red-brown)
7410 ± 80	Peat from brain surface	(Beta-11383)	(lower red-brown)
7930 ± 80	Wooden stake with burial	(Beta-18295)	(lower red-brown)
8430 ± 100	Peat, base of red-brown	(Beta-13909)	(lower red-brown)
7950 ± 140	Top of rubber	(Beta-10855)	(rubber)
8990 ± 90	Peat, base of rubber	(Beta-13908)	(rubber)
9530 ± 110	Peat beneath crania	(Beta-14649)	(rubber)
10 160 ± 120	Peat, base of deposit	(Beta-11382)	(waterlily)
10 750 ± 190	Peat, base of deposit	(Beta-13907)	(waterlily)

[1] Uncorrected radiocarbon dates. Klein et al. (1982) report radiocarbon dates between 7000 and 8000 years B.P. are approximately 800 years too young. Thus the 7210 B.P. date (Beta−7186) is corrected to 8010 B.P. or 6060 B.C.

[2] The peat stratigraphy is (top to bottom) black, upper red-brown, lower red-brown, rubber, and waterlily peat. Elevations vary across the lenticular deposit and precise boundaries between peat strata in several locations are ill-defined. In general, dating gives the following scenario:

Black peat
Active formation at present back to at least 4790 B.P., possibly extends back to about 6000 B.P.
Red-Brown peat (upper zone)
Deposition ends 5800 to 6000 B.P. Highest bone occurs in peat dated 7050 B.P. and probably represents upward "float" or displacement of bone by human and/or nonhuman agents.
Red-Brown peat (lower zone) (densest bone concentrations)
Deposition ends around 7100 B.P. (7360 B.P., 7410 B.P.) and extends to no earlier than approximately 8500 B.P. (8430 B.P.)
Rubber (ill-defined in southern pond regions)
Deposition terminates no later than 8000 B.P. (7950 B.P.) and probably began around 9500 to 9000 B.P. (9530 B.P., 8990 B.P.).
Waterlily peat
Earliest basal dates are around 11 000 B.P. (10 160 B.P., 10 750 B.P.). Terminated deposition around 9000 to 9500 B.P.

[3] Human bone
Radiocarbon analysis of acid extracted collagen fraction—7210 and 7330 B.P. Accelerator mass spectrometry dating of acid extracted collagen fraction—6990 B.P., 7830 B.P. and 8120 B.P. Human bone is predominantly found in the lower red-brown peat stratum. Some human skeletal material has been found in the lower portions of upper red-brown peat and in the underlying rubber peat.

Legislature, Windover Farms, Inc., and its parent company (EKS, Inc.) these investigations would never have been possible.

Dewatering Procedures

A fundamental problem was how to excavate material that appeared to be buried in a peat deposit more than 2 m below the bottom of the pond (which then contained 1–3 m of standing water), and simultaneously maintain site integrity.

There were several possible courses of action considered, one of which consisted of excavating an 8-m-deep rim ditch, which would encircle the pond, thereby providing drainage of the peat deposit. Frequent pumping of the waters seeping into the rim ditch would keep the peat deposit dry enough to excavate.

The problems with this approach included the necessity of excavating through the peat deposit on the west margin of the site adjacent to the existing hard surface road and the high probability of encountering human skeletal material in the process. Such an approach would more than likely result in the encircled block continually "shedding" its outermost edges, thus gradually and inadvertently destroying the margins of the peat deposit and any archaeological material with it. The difficulty of rehydrating the block after each excavation season seemed excessive, and extensive slumping and shedding seemed a certainty. A subsurface spring slowly seeping into the lower reaches of the peat deposit was a possibility the rim ditch could not easily defeat (no such spring was ever identified).

A reasonable alternative to the rim ditch approach, favored by some Windover Farms, Inc. representatives, was the installation of a dewatering (wellpoint) system capable of capturing both the surface and subsurface waters, and discharging them away from the excavation area. This was the method chosen.

Each wellpoint consists of a galvanized pipe (the riser, 11–12 ft in length) which screws into a 4 ft plastic and steel point. Wellpoints can be inserted into the ground using physical force (driving the wellpoints) or with a jet pump which produces a high pressure jet of water which erodes a hole into the peat. Wellpoints are then dropped into the hole. We chose the latter method so the points could be "sanded." In a matrix with fine particulate matter (such as peat), each wellpoint is packed with coarse sand (approximately 55 gallons per wellpoint) which acts as a filter. Each wellpoint is then connected to an 8 in PVC header pipe system by a flexible plastic tube (swing). The header is connected to a rotary diesel pump which places the entire system under a vacuum open only at the subsurface ends of the points.

The pump has a 12×12 in suction inlet and discharge outlet diameter, a maximum displacement of 3,400 gallons/min and weighs 3,800 lbs (Thompson Pump and Manufacturing, Inc., Model 7200 Rotary Wellpoint Pump). The water is drawn to the pump where it is ultimately discharged out of the pond area.

A wellpoint system would hypothetically dry out the peat within the encircling ring of wellpoints thus allowing excavation in a controlled manner. System installation would minimally disturb the intact deposit, and allow rapid rehydration once excavations were completed. Only minor changes in wellpoint placement would be necessary to deal with water from any possible spring.

In many coastal and wetland areas dewatering is often a construction necessity. Normally, dewatering is for short range construction goals (a few days to a month) in relatively limited areas and, more often than not, in sandy soils lacking peat components. The archaeological goals at Windover were at considerable variance to normal construction necessities. We wanted to dry a pond out (but not too much), maintain the integrity of the sponge like peat deposit, and continuously maintain the dewatering system for five months during several consecutive years.

Representatives from Thompson Pump and Manufacturing, Windover Farms, Inc., and Diversified Construction were uncertain if the wellpoint procedure would be effective within a peat deposit. However, it seemed to offer the most hydrological control with the least disturbance of the archaeological materials.

The installation of such a system came in September 1984 when a 12×24 m block in the northwest section of the pond was chosen for excavation. The pond was subdivided by dikes made of sand brought in from local sources. A track mounted backhoe and a high volume "jet pump" were used to install wellpoints around the perimeter of the subsection chosen for excavation. The wellpoint system consisted of

Table 3. Comparative subadult/adult ratios of New World skeletal populations

SAMPLE ORIGIN	SUBADULT/ ADULT RATIO[1]	Reference
Larson	71/29	Owsley and Bass 1979
Pecos Black and White	54/46	Mobley 1980
Libben	54/46	Lovejoy et al. 1977
Windover	52/48	Doran 1986
Pecos V	52/48	Mobley 1980
Tabor Hill	49/51	Churcher and Kenyon 1960
Indian Knoll	48/52	Webb 1946
Etowah	46/54	Blakely and Mathews 1975
Nanjemoy Creek, Ossuary I	45/55	Ubelaker 1974
Forked Lightning	45/55	Mobley 1980
Real Alto, Valdivia	44/56	Mobley 1980
Pecos Glaze I	44/56	Mobley 1980
Pecos Glaze II	41/59	Mobley 1980
Pecos Glaze III	41/59	Mobley 1980
Point of Pines	41/59	Bennett 1973
Nanjemoy Creek, Ossuary II	40/60	Ubelaker 1974
St. Elena	36/64	Ubelaker 1980
Pecos IV	39/61	Mobley 1980
McCutchan-McLaughlin	32/68	Powell and Rogers 1980
California, Middle Horizon	28/72	Doran 1980
California, Early Horizon	24/76	Doran 1980
Dickson Mound	19/81	Blakely 1971
California, Late Horizon	18/82	Doran 1980

[1] Ratios have been converted to percentages for simplicity. Windover data is based on skeletal material from the 1984 and 1985 field seasons. The 1986 sample analysis is in the preliminary stages but field observations indicate that the subadult/adult ratio is relatively unchanged.

ninety-six 13 and 19 ft wellpoints. Initial problems of water seepage were eliminated by the installation of forty-five additional 15 and 19 ft wellpoints and by discharging the water 37 m further from the excavation area. Excavation continued until early January 1985 when the points were removed by the backhoe, the excavated area backfilled, and the rising waters gradually refilled the pond.

The effectiveness of this procedure was clear. However, to avoid the serial wellpoint installation of 1984, and to increase water control, it was felt a larger area, 5,400 m^2—(essentially the entire pond), could be encircled with one hundred fifty-eight 25 ft wellpoints (21 ft risers and 4 ft points). Again, varying opinions existed about the efficacy of such a procedure. The main concern was that the center of the peat deposit would be so far from the wellpoint perimeter (maximum distance of approximately 30 m) that it would never dry out. The longer points and use of coarser filter sand eliminated water seepage, except from temporary problems related to occasional torrential rains. These were dealt with by always having one excavation unit at a lower level than any of the others. The deep unit served as a sump from which the rain water could be quickly pumped out.

The expense of reinstalling the wellpoints in 1986 was avoided by leaving the wellpoints in the ground from January to August of 1986 when no field excavations were in progress. The operational assumption was that the wellpoints would function when the header system was reconnected. There was concern that the points might not survive eight months in the ground in contact with heavily mineralized water (see Table 4). On August 16, 1986 the header system was installed and within minutes the system was pumping an estimated 700 gallons of water a minute. However, the amount of rust and minerals deposited in this short time indicated the points could not have been left in the ground indefinitely.

After the initial dewatering from mid-August through September it was only necessary to run the pump for 15-hour periods every second to third day (the fall of 1986 was an unusually dry season in this area of Brevard County), or as local rain dictated. Discharge volumes declined to approximately 200 gallons a minute by mid-October as a result of the regionally lowered water table and a seasonal decline in rainfall.

The costs of installing and maintaining the system in 1985 included: a dragline/backhoe at $65 an hour (and transport) for 2 weeks ($5,500), front end loader at $55 an hour for 2 weeks which was also used to remove the massive spoil banks generated by 5 months excavation ($4,400), dump truck, loader and bulldozer costs to remove surface vegetation once the surface water was removed ($1,720), wellpoint sand (296 metric tons, plus shipping—$5,709), wellpoint lease and maintenance for a 5 month period ($23,000), and diesel fuel for a 5–month period at $1,500 a month ($7,500). The total cost came to approximately $47,829. A conservative estimate for the total dewatering and heavy equipment costs for the three years of excavation is $120,000.

Wellpointing a large area is expensive and cannot be used in all wet site settings. However, smaller systems have been effectively employed in other archaeological contexts.

Table 4. Windover water data (1984 and 1985 field seasons)

	Sample No.*							
Water Feature	8789 Pond A	8795 Pond A	8797 Wpoint	9162 Wpoint	10492 Pond C	10493 Wpoint	10604 Seep HOH	Warm Mineral Springs
Calcium[1]	160.0	160.0	81.5	117.6	104.0	109.0	94.0	470.0
Magnesium[1]	77.0	65.0	60.5	182.7	68.0	97.0	68.0	600.0
Total Dissolved Solids[2]	1447.5	1217.5	1420.0	3872.0	3032.5	3520.0	1418.0	18400.0
Total Hardness	716.4	667.0	452.5	1045.0	539.6	671.4	27.5	ND
Carbonate Hardness[3]	31.2	22.8	8.9	57.2	30.5	125.7	ND	ND
Noncarbonate Hardness[3]	685.2	644.2	443.6	988.4	509.1	545.7	527.5	ND
Total Alkalinity[3]	31.2	22.8	8.9	57.2	30.5	125.7	498.2	ND
Bicarbonate[4]	31.2	22.8	8.9	57.2	30.5	125.7	ND	ND
Carbon Dioxide[1]	38.1	55.3	34.3	87.4	248.3	76.6	6.4	ND
Sulfides	ND	8.8	1.6	1.4	0.1	0.1	0.0	ND
Strontium[1]	4.3	4.0	2.3	3.5	4.2	5.2	4.8	10.0
pH	6.1	5.9	5.6	6.0	5.3	6.4	6.9	7.8
Sulfates	381.9	98.9	33.9	470.0	ND	ND	ND	ND

ND no data
[1] mg/L
[2] mg total dissolved solids /L
[3] mg $CaCO_3$/L
[4] kalmg $CaCO_3$/L

Pressure extracted water from the upper red-brown peat has a pH of 6.6, the lower red-brown peat has a pH of 5.9 and the fibrous peat has a pH of 6.1. Respectively bicarbonates are 64, 77 and 40 mg $CaCO_3$/L (Frazee personal communication).

All wellpoint and water analysis performed by Flowers Chemical Lab, Altamont Springs, Florida
* Pond A and Pond C were water samples from different sections of the Windover pond.

Archaeological Conservation

Skeletal material from the 1984 season was conserved with PEG 3350 while materials from the 1985 and 1986 seasons were conserved with Rhoplex AC-33 (Conservation Materials, Ltd., Sparks, Nevada). The Rhoplex appears more satisfactory (Stone et al. 1986).

Conservation of wood and other floral material with either PEG or dammar has been disappointing. There are indications that the internal structure of some of the wooden material is so degraded (perhaps due to its antiquity) that alternatives to standard conservation treatments are being examined. It has been demonstrated recently (Adovasio and Gardner personal communication) that desalinization may dramatically improve fabric conservation attempts. Various combinations of PEG, ethulose, Rhoplex, neocryl, and Acrysol have been tested. A combination of ethulose 100 and PEG 4000 presently appears to be the most promising consolidant. Fabrics and several wooden artifacts are being conserved at the Department of Anthropology, University of Pittsburgh. The effort to conserve the fabrics in particular has benefited from the gracious and expert assistance of Judy Logan (Canadian Conservation Institute) and Joan Gardner (Carnegie Museum of Natural History). After careful recording of surface details, conservation will be directed at the removal of salts, consolidation, and stabilization involving freezing and freeze-drying. Joan Gardner (personal communication) has indicated these efforts may ultimately produce effective methods of conserving highly degraded cellulose-based materials of this antiquity.

The research opportunities at Windover can be summarized here. The most striking feature of such a wetlands project is the obligation to maximize the data recovery for the anthropological discipline and for allied fields of science. The areas of research currently emphasized at Windover include:

1. Archaeological overview of burial practices, technology, and anthropological implications for the Early Archaic.
2. Osteological analysis (metrics, nonmetrics, pathology, demography, metabolic stress, trace elements, and microscopy) aimed at studying biocultural adaptation.
3. Bone protein analysis specifically assessments of stable and soluble proteins, and stable isotopy for studies of population polymorphisms and diet.
4. Molecular biology—analysis of preserved mitochondrial DNA and cell structure for population and microevolutionary studies.
5. Faunal and floral analyses for environmental reconstruction and resource utilization.
6. Palynological and phytolith analyses of peat, intestinal remains, and fabric components for environmental reconstruction, resource exploitation, and diet.
7. Petrographic and chemical analyses of peat for depositional context, environmental reconstruction, and conservation guidelines.
8. Hydrological overview for preservation and conservation parameters, environmental reconstruction, and the evolution of the central Florida hydrological system.

Archaeological Overview

Assessment of early Florida burial practices (direct burial in the subaqueous zone of a wooded marsh with associated wooden stakes) provides for the first detailed recovery of contextual data of Florida burial practices of this time period. Analysis of organic artifactual remains (bone, antler, wood, and fabrics) furnishes details on technology and craft information not typically observed at terrestrial sites.

Bodies were probably placed in the pond within 48 hours after death (Doran et al. 1986). Out of over 4,000 elements examined from the 1984 and 1985 excavations, fewer than 20 exhibit evidence of rodent gnawing or other damage. Both rapid burial and burial below the water table would ensure the chemical preservation of the buried remains as well as the physical protection from scavengers. In the sloping pond margins south and west of the 1986 excavations disarticulation is common as bodies gradually moved downslope toward the deeper center of the pond. Bodies interred in flat locations on the east (Fig. 1) and north side of the pond (1986 excavations) have remained relatively stationary and articulated (Fig. 2). Such burials are predominantly flexed on their left side with heads oriented to the west.

FIGURE 1 The east excavation area produced well-articulated burials and fabric. Tarps covered the excavation area to prevent sun bleaching and to reduce drying of the archaeological material. All bone and antler specimens were immediately preserved in Rhoplex, an acrylic emulsion.

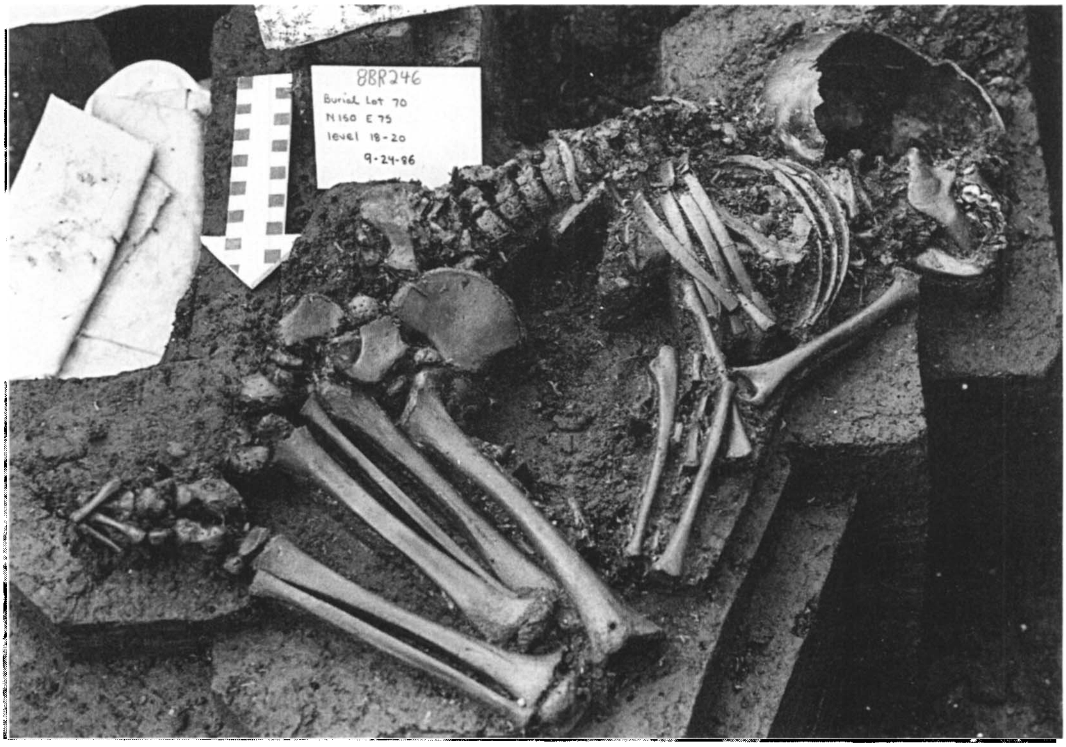

FIGURE 2 Burials probably took place within 48 hours after death, preservation was promoted by anaerobic conditions, neutral water pH, neutral peat pH, and continuous submersion in saturated peat.

In contrast to later mortuary sites, subadults tend to have more burial goods than adults (Rothschild 1979; Webb 1946; Fig. 3).

Textile materials were also recovered with many of the burials during the 1986 field season (Fig. 4). Seven twining/weaving variants have been identified to date, including fine balanced plain weave of inner garments (possibly tunic-like garments with 10 strands/cm), more durable, complex twined materials with two−strand wefts, and an unusual three stranded weft over flexible warps (both simple and diagonal twining techniques) possibly representing poncho or blanket-like items, a twined globular bag, open twining, and matting (Adovasio 1977; Fig. 5). It is felt the Windover fabrics are the most complex and diverse set of textile materials from this time period currently known in the New World (Adovasio personal communication).

Identification of the plant fibers used in manufacture of the fabrics is under investigation. At the present time fibers from the Sabal palm (*Sabal palmetto*) or saw palmetto (*Seronoa repens*) appear the most likely source of the textile fibers. The fabrics and other features suggest a human population well adapted to a rich ecological area with substantial amounts of time, energy, and resources to devote to

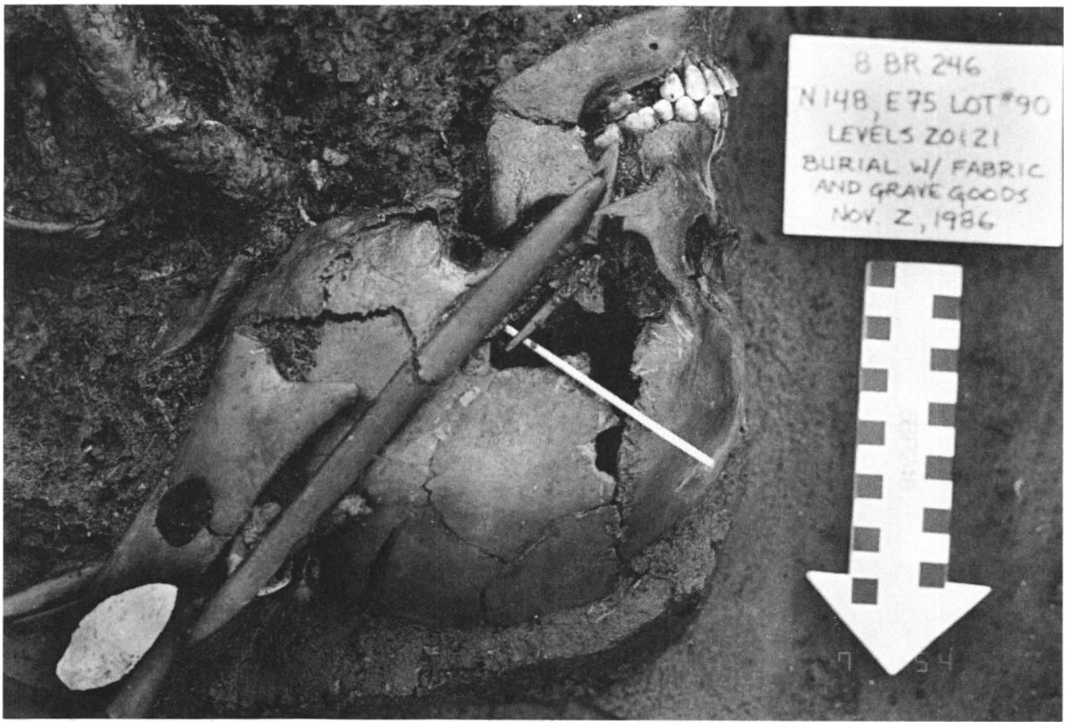

FIGURE 3 This subadult (about 12 years old) was buried with a large and diverse array of artifacts including a stone biface, several bone awls, a drilled sharks tooth, a pitch-coated dog canine, two barbed bone points, and an antler tool. (The white stick at right angles to the artifact cluster is a bamboo splint inserted to prevent displacement of the artifacts during photography.) (Burial 90.)

nonessential activities. These findings have anthropological implications for the understanding of hunter-gatherer complexity, efficiency, mobility, and stability (Price and Brown 1985).

Bone artifacts, such as pins, tubes (Fig. 6) and awls were manufactured from aquatic species (manatee) and upland game including deer (Figs. 7 and 8), canids and felids. Marine, freshwater, and marshland ecozones were all utilized and attempts to identify specific utilization patterns as well as seasonal variation are underway.

Osteological Analysis

The osteological remains allow us to look at a human population of the early to mid-Holocene. At the present it appears to be one of the largest, most demographically intact skeletal samples from this time period in the New World (Doran 1986; Protsch 1978; Stothert 1985; Ubelaker 1980). The importance of this collection is that it gives an accurate representation of the subadult years. The osteological

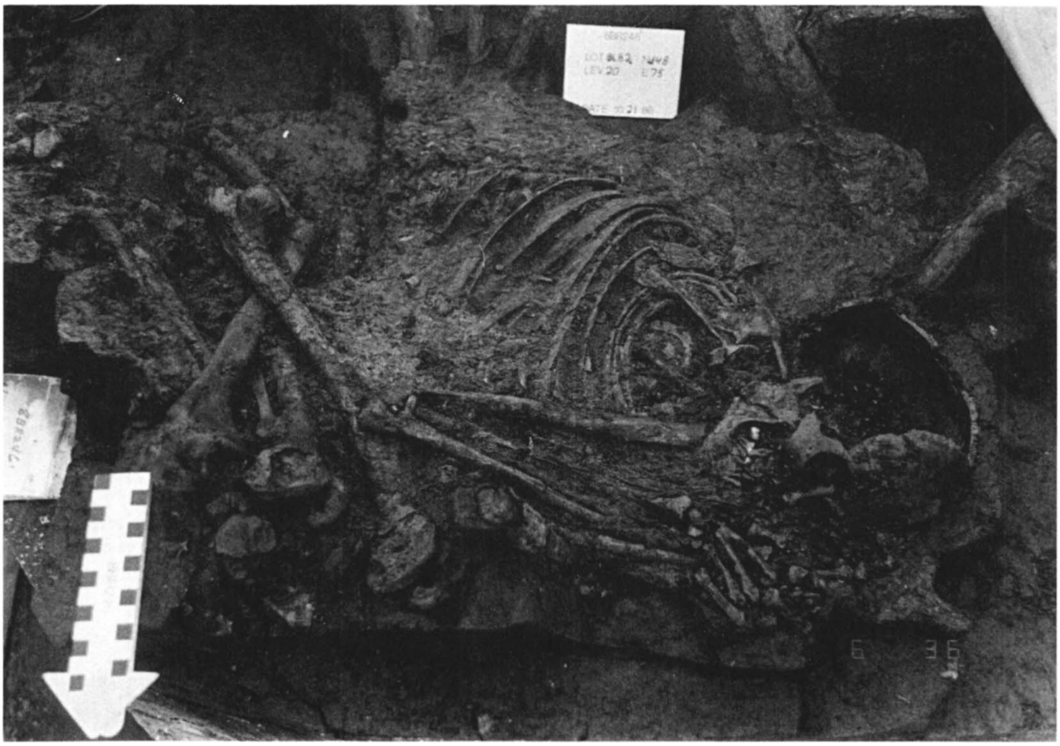

FIGURE 4 Excavation required care since a variety of fabrics were recovered with many of the articulated burials. Fabric remains are visible as a solid exposure of fabric over the stomach area and along the back. (Burial 82.)

analysis has been undertaken within a biocultural focus (Blakely 1977), which emphasizes the interactions of biological, social, environmental, and cultural parameters (Dickel et al. 1984). In order to facilitate these analyses, paleodemographic profiles using standard methods (Acsadi and Nemeskeri 1970; Hassan 1981; Johansson and Horowitz 1986; Meindle and Lovejoy 1985) are being developed. Studies of metric and nonmetric variation (Dickel 1980) and health and disease patterns (Ortner and Putschar 1981; Steinbock 1976) will be supplemented by radiographic and CT scanning imagery (computer assisted tomography). The abundant subadult material provides an excellent opportunity for studies of growth and development (Armelagos et al. 1972; Van Gerven et al. 1985) and enhances the reliability of paleodemographic reconstructions. A tabulation of subadult/adult ratios (Table 3) derived from archaeological samples, regardless of time period, clearly indicate the relative rarity of New World prehistoric populations with high numbers of subadults.

Dickel (1986) has summarized the preliminary evidence for nutritional/metabolic stress (Huss-Ashmore et al. 1982) including transverse lines (Buikstra and Cook 1980; Hummert and Van Gerven 1985), cribra orbitalia (Carlson et al. 1974), enamel

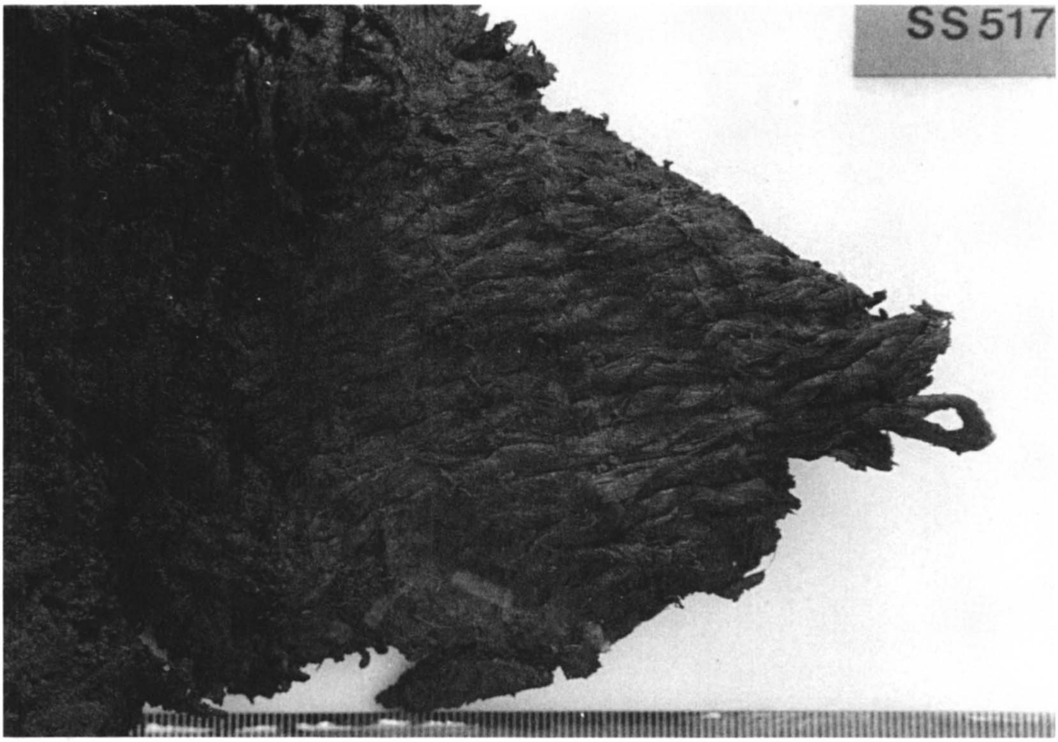

FIGURE 5 Many fabrics are closely packed twined specimens exhibiting a great deal of diversity in the fiber arts. Seven twining variants, including the heavy twined materials shown here, were recovered. Detailed studies of the fabrics by James Adovasio and R.L. Andrews (University of Pittsburgh) are underway. Conservation efforts directed by Joan Gardner (Carnegie Museum of Natural History, Pittsburgh) will ensure the survival of these unique, perishable fabrics.

defects (Goodman, Armelagos and Rose 1984; Goodman, Martin, Armelagos and Clark 1984), and cranial hyperostosis (Mensforth et al. 1978) in the Windover sample. An individual exhibiting spina bifida coupled with sensory loss to the lower leg, extensive osteomyelitis, and probable renal failure has also been identified. The combined debilitating effects of these health problems led to death at roughly 16 years of age after at least three years of illness and severe mobility impairment (Dickel 1987). Detailed analysis of the interrelationship of age, sex, mortality, and pathologies will provide a much needed biocultural profile from this early time period.

Additional analyses related to postmortem (diagenetic) changes and dietary parameters are underway (Gilbert 1975; Klepinger et al. 1986; Price et al. 1986). Preliminary analysis of trace elements of human bone indicate that some diagenetic changes have occurred in the Windover materials (Hancock 1985, 1986). Collagen percentages, normally around 25% by weight (Michels 1973), appear to have been reduced in some samples (Beukens 1986). Some specimens appear to retain greater amounts and may reflect differential preservation due to specifics of placement

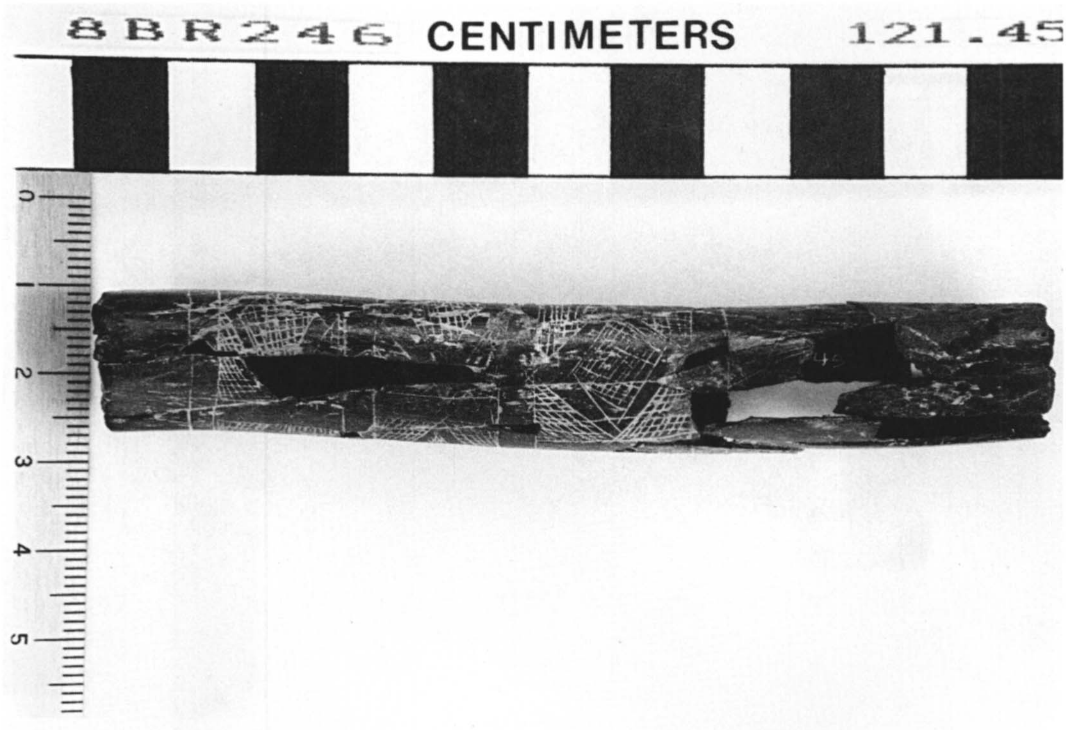

FIGURE 6 Cut and incised bone tubes are made of bird bone (Pelecanidae). On some, incising produced striking decorative patterns. Function of the arifacts is uncertain.

within the Windover pond. Individuals buried closer to the shallow pond margins appear to be more poorly preserved and exhibit greater root and oxidative damage. Diagenetic and preservation variability may affect some analyses, but collagen amounts are sufficient for accelerator mass spectrometry dating and standard radiocarbon analysis. The dates from the AMS were 8120 ±70 B.P. (TO−241), 7830 ±80 B.P. (TO−518), and 6990 ±70 B.P. (TO−207), and standard radiocarbon dates on bone collagen provided dates of 7330 ±100 B.P. (Beta− 5803) and 7210 ±80 B.P. (Beta−7186) (see Table 2). Bone strontium, normally around 98−1,045 ppm (Becker et al. 1968; Price et al. 1986; Spuznar et al. 1978) is elevated to 1,740 ppm. This probably reflects continuing absorption from subsurface water (Table 4), which typically has strontium concentrations of 3−5.2 mg/liter (Flowers 1985). Sodium (2,900 ppm) appears substantially depleted while iron levels appear elevated.

Sensitive new chemical assay techniques (isoelectric focusing) provide mechanisms to test for a variety of proteins in the archaeological material. The process involves solubilization of bone and then extraction, concentration, isolation, and study of soluble and matrix bone proteins. Initial protein analysis has tentatively identified transferrin, albumin, IgG, IgN and IgA (Smith personal communication). Additionally, research on amino acids (Von Endt and Ortner 1982), elemental composition (Sillen and Kavanaugh 1982) and ultimately assessments of stable carbon/

FIGURE 7 Antlers (*Odocoileus virginianus*) provided a commonly utilized resource for the manufacture of many tools. Specimens in various steps of production were found, and provide an opportunity for detailed studies of tool manufacture. The tine from Specimen 158.23 was carefully girdled and then snapped off.

nitrogen isotopes (Walker and DeNiro 1986) are underway. Cystine and methionine, both amino acids rarely preserved in archaeological contexts, have recently been identified in Windover specimens (Tuross personal communication). These procedures may provide steps toward developing a biogenetic reconstruction of this archaeological population with implications for understanding small population biology and evolution (Weiss and Smouse 1976).

Molecular Biology

The recovery of preserved brain tissue in 1984 led to an assessment of structural integrity of the tissue utilizing x-ray, CT scanning, and magnetic resonance imaging coupled with light and scanning electron microscopy. Tissue samples have also been processed for isolation and study of remnant mitochondrial DNA (Doran et al. 1986). Nine individuals with brain tissue were recovered in the first two field seasons. More than 80 individuals from the 1986 season have produced preserved brain tissue.

Tissue was removed from the cranium in the field, sealed in nitrogen flooded containers and frozen at −20°C. These materials were ultimately transferred to the

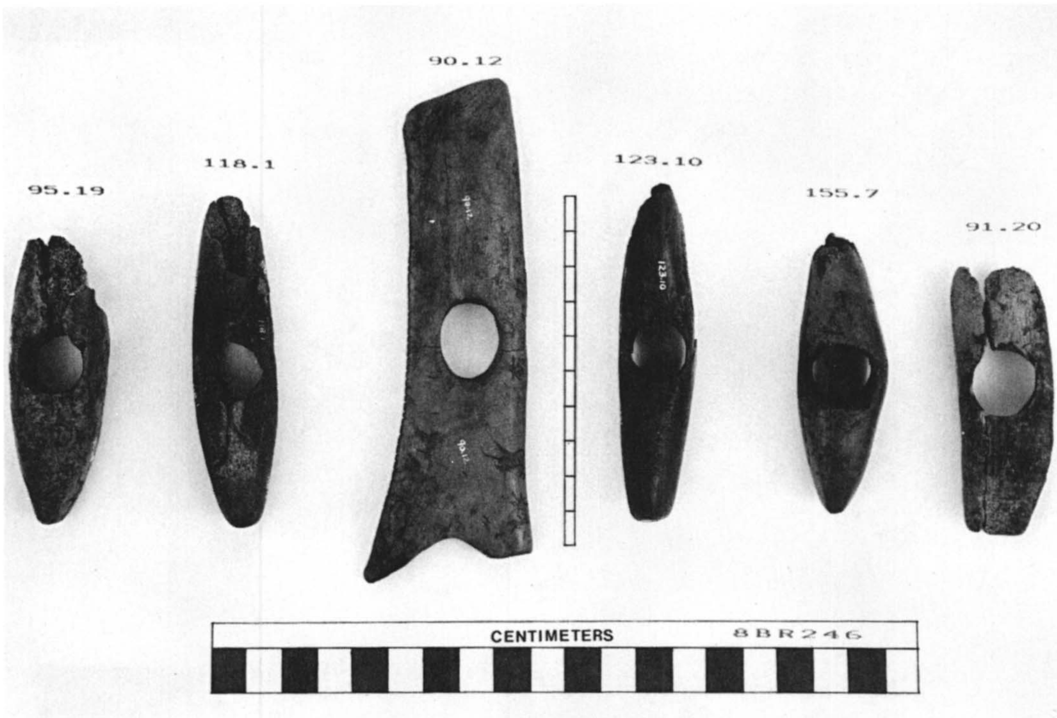

FIGURE 8 Drilled and shaped antler artifacts may have been used with atlatls. Some show damage to one end suggesting other uses; the exact function is still being investigated.

University of Florida, School of Medicine where they are maintained at −70°C until needed for further analysis.

Visual inspection identified external gyral patterns, intact cerebral hemispheres, and longitudinal and Sylvin fissures. No meningeal covering or vesicular tissues were identifiable. In all cases the brain stem is amorphous and no fine structure remains. Transverse sections revealed internal structure including the thalamus, parietal, temporal, and occipital lobes, the lateral ventrical and the cingulate gyrus. Some fissures are filled with peat which has been radiocarbon dated to 7410 B.P. (Beta-11383; Table 2). Other invasive procedures have identified the interhemispheric fissure, the corpus collosum, the insular cortex, the putamen, the internal capsule, and the third ventricle.

Cytoarchitectural detail has been retained and biogenetic studies have succeeded in isolating human mitochondrial DNA (Doran et al. 1986).

Faunal and Floral Analyses

Controlled volumes of peat from all stratigraphic levels were fine screened (0.12–cm mesh) and all identifiable material (plant and animal) were retained. Peat from the vicinity of burial areas was water screened, and materials encountered during excavation were bagged and retained for subsequent analysis. A series of columns varying in size from 10×10×5 cm to 20×20×5 cm was removed, bagged,

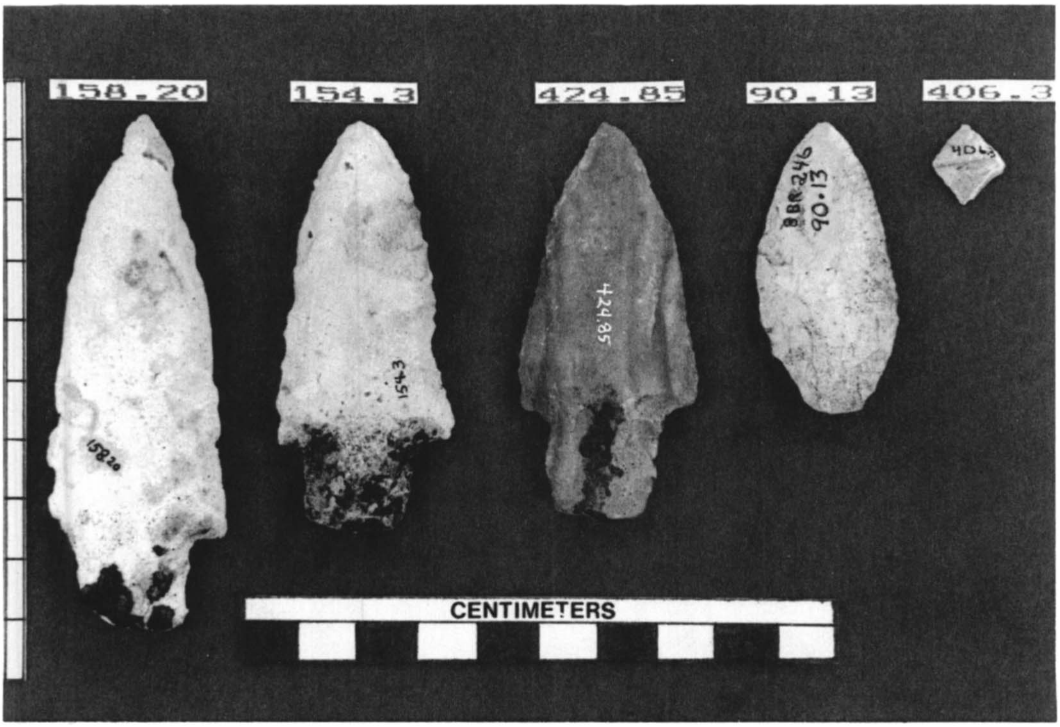

FIGURE 9 These four bifaces and single biface tip represent the entire lithic artifact inventory from the Windover site. Stone tools were presumably heavily curated due to the scarcity of lithic resources in the area. This would account for the fact that only a small number was recovered at Windover. The three specimens on the left retain traces of pitch, which is being studied further.

and processed in the laboratory through nested geologic screens. These diverse collection techniques provide for studies of environmental change through time.

To date, eight invertebrate species (one marine, two terrestrial, and seven aquatic have been identified. Vertebrate species include 11 mammals, 6 birds, 11 reptiles, 6 amphibia, and 7 fish (Nabergall 1986; Table 5). By weight, reptiles and fish make up the largest portions of the vertebrates followed by birds, mammals, and amphibia. Twelve species of woody plants (Newsom personal communication) and the seeds, seed fragments, nuts, stem parts, and fruit skins of approximately 30 plant species have also been identified (Alexander 1986).

In the last 11,000 years changes in water levels, biotic communities, and general environmental conditions have been reflected in the fauna and flora. Some of these environmental changes result in the differential preservation of faunal and floral remains and must be considered in any interpretation of environmental reconstruction (Nabergall 1986).

Palynological and Phytolith Analysis

Palynological analysis facilitates identification of environmental changes from the early Holocene to the modern era (Holloway 1985a,b). Environmental changes

Table 5. Faunal species represented at Windover

Taxa	Common Name	Habitat
Large Mammals	bear, deer, coyote, dog, fox	T
Small Mammals	raccoon, rabbit, opossum	T
Lutra canadensis	river otter	T, W
Procyon lotor	raccoon	T
Neofiber alleni	Florida water rat	T, W
Neotoma floridana	eastern wood rat	T
Sigmodon hispidus	cotton rat	T
Sciurus spp.	gray or fox squirrel	T
Sylvilagus spp.	eastern cottontail, marsh rabbit	T
Didelphis virginiana	opossum	T
Aves	birds	T, W
Turdidae cf. *Catharus* spp.	thrush	T
Fulica americana	American coot	T, W
Anatidae	swans, geese, ducks	T, W
Ardeidae	herons, egrets, bitterns	T, W
Ardea herodias	great blue heron	T, W
Phalacrocorax spp.	double-crested, great cormorant	T, W
Podilymbus podiceps	pie-billed grebe	T, W
Reptiles	turtles, lizards, snakes, alligators	T, W
Alligator mississippiensis	American alligator	F
Testudines	turtles	T, F
Trionyx ferox	soft shell turtle	F
Pseudemys floridana	pond turtle	F
Terrepene carolina	eastern box turtle	T
Kinosternidae	mud and musk turtles	T
Kinosternon spp.	mud turtle	T
Sternotherus spp.	musk turtle	T
Chelydra serpentina	common snapping turtle	F
Serpentes	snakes	T, F
Colubridae	nonpoisonous snakes	T, F
cf. *Drymarchon corais*	indigo snake	T
cf. *Nerodia* spp.	water snake	F
Amphibia	amphiumas, frogs, newts, sirens, salamanders, toads	T, F
Sirenidae	sirens	T, F
Siren lacertina	greater siren	T, F
cf. *Amphiuma means*	two-toed amphiuma	T, F
Ranidae	true frogs	T
Rana spp.	bull, pig, southern leopard frog	T, F
Osteichthyes	fish	F, B, S
Centrarchidae	sunfish and bass	F
Micropterus salmoides	largemouth bass	F
Lepomis microlophis	red-eared sunfish	F
Lepomis spp.	sunfish	F
Ictalurus spp.	bullhead or catfish	F
Amia calva	bowfin	F
Lepisosteus spp.	Florida gar	F, B

T = Terrestrial, F = Freshwater
S = Salt Water, W = All Waters, B = Brackish Water
Salt water & brackish water species remains introduced by human agents
Faunal analysis by L. Nabergall, Department of Authropology, Florida State University (Nabergall 1986)

at approximately 6,000 B.P. led to wide scale peat formation in Florida and the southeastern United States (Brooks et al. 1979; Frazier 1967; Gleason et al. 1974; Purdy 1980). Florida peat deposits provide data for periods earlier than 6000 B.P. only in restricted locations. It is felt that a good general picture of the local environmental transitions has been developed, but we plan on sampling similarly deep peat deposits within a 25-km radius of Windover to establish more detailed regional reconstruction.

Palynological studies will also contribute to the recovery of data on diet and seasonality of death by the detailed analysis of peat samples from the gut area of the flexed burials recovered in the 1986 field season. A variety of parasite eggs and chitinous fragments have been identified in preserved alligator fecal material (Holloway and Rheinhard 1985), and similar data for humans may be forthcoming.

Samples of fabrics found in association with many of the burials removed in 1986 are being examined for phytolith remains in an effort to identify the species of plant used in the fabrics' manufacture. Phytoliths may also provide additional information for environmental reconstructions.

A minimum of five distinct peat strata (from bottom to top) have been identified palynologically and petrographically.

The oldest and deepest stratum is the waterlily peat (Spackman personal communication) which began forming shortly after the end of the Pleistocene. Just beneath the basal levels of waterlily peat a sandy, dark peat stratum has been dated to 10,750 B.P. (Beta-13907; Table 2). In these lowest strata the dominant macrofloral remains are enormous quantities of waterlily (*Nymphaea*), which requires water depths of 45–91 cm, and occasional buttonwood root remains. Pine pollen and ash levels, are highest in the waterlily peat, while sulfates and pyritics are relatively low.

The waterlily peat grades into a colloidal (rubber) peat stratum with a high density of snail shells (Spackman personal communication). Deposition runs from approximately 9000 to 8000 B.P. and represents a highly degraded peat with almost no identifiable plant material except for occasional small twigs. This stratum may have resulted from salt water intrusion coupled with high algal/bacterial activity, but analyses are still underway. This zone is chemically distinct and represents a dramatic change from both the overlying red-brown peat and the underlying fibrous water lilly peat. Planorbid snails appear in this zone, pine pollen drops dramatically and Cheno-Am and oak pollens begin to climb. Sulfates, calcium and pyritics also rise dramatically. Water levels are felt to be in excess of 1 m and possibly as much as 2 m when this layer was being deposited.

The rubber peat is replaced by red-brown peat (lower), marking the beginning of a prolonged drying trend. Snail shells are occasionally still found in this stratum. The red-brown peat is very distinct from floral, palynological, and petrographic standpoints. Naturally occurring wood (limbs, sticks, a few stumps, and occasional roots are encountered. Intentionally debarked, charred, and sharpened wooden stakes are associated with the human burials in this stratum. The pond was probably no more than 20 cm deep at seasonal maximums. During this interval (and that of the later upper red-brown peat) the area is best described as a woody marsh with water at or slightly above the marsh surface. Formation of the lower red-brown peat stratum begins around 8000 B.P. and terminates at approximately 7000 B.P. Human bone is largely restricted to this stratum. Cheno-Am and oak pollens decline slightly, sulfates remain relatively high, and pyritics decline.

The upper red-brown peat began to develop around 7000 B.P. and ended at approximately 6000 B.P. Wood debris is highest in this stratum and suggests maximum drying and maximum pond margin encroachment. Cheno-Am pollen continues to decline and pine pollen begins to rise slightly.

The last peat layer, the black, or sawgrass peat, began formation approximately 6000 B.P. with recent deposition forming the current pond bottom. Much of the black coloration comes from high quantities of burned vegetation, resulting from seasonal dry periods and frequent natural fires. Such fire prone habitats are a common feature of central and south Florida. Sulfates and pyritics virtually disappear; wood is scarce except for occasional pieces of charred material. Pine pollen gradually rises and oak pollens are at their lowest levels. These, and other features, are taken to indicate an appearance of essentially modern climatic features characterized by higher water levels and marked seasonal fluctuations in rainfall.

Petrographic and Chemical Analyses of Peat

Petrographic, microscopic, and macroscopic investigations coupled with extensive chemical characterization of the peats complement the palynological analysis (Stout 1986). Changes in water depth, related to changes in the hydrological budget, are inferred from changes in chemical composition and plant community shifts (Holloway 1985a,b, personal communication; Spackman personal communication). Sulphur and pyritic concentrations in particular suggest strongly that the rubber peat was formed when water levels were higher, possibly with an infusion from subsurface sea water intruding into the pond (Frazee personal communication; Spackman personal communication). Some petrographic characters of the rubber peat chemically resemble brackish-water peats (Cohen et al. 1984). The chemical analysis is also providing background data useful in developing effective conservation techniques.

Hydrological Overview

Chemical characterization of water from the pond, adjacent wetland areas, and water pumped out over the course of the excavation season provided insights to preservation conditions, local hydrology, and information useful in conservation studies (Flowers 1984, 1985; portions of this data set are presented in Table 4). Seepwater from a surface pool (Sample 10492, Table 4) and a deep excavation location (Sample 10604) taken during mid-season (1984) show marked differences, and suggest that hydrological barriers may exist between different peat strata and between subsurface and surface waters. Samples 8789 and 8795, taken prior to pumping at the beginning of the 1985 field season, were compared to wellpoint discharge taken over the course of the season (Sample 8797—August 23, 1985; Sample 9162—October 2, 1985). This revealed a gradual upwelling (salt water intrusion) of trapped paleo-seawater as the dry season progressed and pumping continued.

Chlorides increased ten-fold, total dissolved solids doubled, and magnesium, zinc, and potassium levels climbed as the paleo-seawater became a more significant hydrological feature. Water and peat studies showed that the pH of the site is relatively neutral (in contrast to many peat bogs.). The high calcium and carbonate levels in the rubber peat (possibly from the snail shells) apparently act as a buffer and reduce the acidity of the adjacent peat strata, enhancing preservation of non-vegetable organic materials.

Studies of an adjacent pond's water (not connected to Windover) provided a pH of 2.9, indicating that hydrological differences can be dramatic within a very restricted area. In general, Windover pond and Bird Lake Marsh to the east are felt to be strongly influenced seasonally by the paleo-seawater, while being hydrologically isolated from adjacent waters (Frazee personal communication).

In comparison to local waters and Warm Mineral Springs, the Windover water is relatively neutral, with a relatively low bicarbonate hardness and low concentrations of magnesium and strontium. The pond waters are more heavily mineralized than adjacent ponds but have much lower concentrations of total dissolved solids than Warm Mineral Springs (Table 4). The roles of water and peat chemistry as critical variables in preservation are undergoing further study.

Representatives of the St. Johns Water Management District are utilizing the Windover data to develop a more accurate hydrological profile of east-central Florida. Increasing urbanization necessitates a better understanding of the interaction of geomorphology, hydrology, and water management (Frazee personal communication).

Statement of Wet Site Importance

Given the geologic, hydrologic, and climatic setting of Florida, there is an incredible potential for wet site archaeology. As increasing urbanization forces modern populations into undeveloped wetland areas, sites will be discovered more often and become increasingly important in assessing Florida prehistory.

Whether the data is collected in salvage contexts or in a controlled manner, depends on the cooperation of developers, state and county planners, anthropologists, geologists and other related researchers, and funding agencies. The Windover project has maximized publicity about the role of the developer in preserving the site, as well as providing formal tours for schools and other members of the public. In the last two years, more than 16,000 people have toured the site. Our goal has been to increase awareness of the public's pivotal role in the preservation of Florida's wet sites, so that Florida's prehistoric heritage does not disappear beneath a backhoe blade.

Acknowledgments

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SETTLEMENT, SUBSISTENCE, AND ENVIRONMENT: ASPECTS OF CULTURAL DEVELOPMENT WITHIN THE WETLANDS OF EAST-CENTRAL FLORIDA

Brenda Sigler-Eisenberg

Introduction

THIS PAPER PRESENTS EVIDENCE of the relationships between environment, subsistence, and settlement pattern development of hunter-gatherer populations within the wetlands of east-central Florida, specifically, the freshwater lake-emergent marsh and the lesser developed riparian ecosystems within the upper St. Johns River basin. Emphasis is placed on the environmental context of settlement location, changing subsistence patterns, increased productivity, and the shift toward sedentism. The temporal span is approximately 500 B.C. to A.D. 1400, and involves the late Orange, Malabar I, and Malabar II archaeological cultures. The archaeological record suggests continuity of many cultural characteristics; therefore, these groups are considered ancestral to the historic Ais (Rouse 1951; Sigler-Eisenberg 1985).

First, a review is given of the chronology of late Holocene events that culminated in the development of the unique wetland environments of peninsula Florida, and the environmental structure and variations in primary and secondary productivity of the upper St. Johns River basin.

Second, an overview of the analysis of the archaeologically recovered faunal assemblage from the Gauthier site, 8–BR–193, (Russo 1986) is presented. This analysis illustrates the nature of the changes which occured in subsistence strategies, and documents an increase in productivity. Although faunal preservation was excellent, botanical preservation was very poor. Because of this differential preservation the faunal assemblage is given prominence in subsistence analysis. This emphasis, therefore, is not an attempt to equate subsistence with diet, nor diet with fauna. It is a compromise with the reality of preservation and recognition that the faunal assemblage is a direct link to the environment. The patterns of faunal exploitation are placed within the context of environmental development and the changing social and settlement conditions.

Third, a preliminary model is suggested which stresses socially induced economic intensification and environmental circumscription, rather than environmental change, as the primary contributing factors in the developmental characteristics of the Malabar II period. Ethnohistoric observations on Ais settlement structure and social interactions are used for comparison with archaeological data.

Environmental Parameters

Wetlands are a stiking component of the present landscape of the South Atlantic/Gulf Coastal Plain, and especially of peninsular Florida. Wetlands are generally variable in origin, size, characteristic biota, species richness, productivity, and sediment type, but all (except nonvegetated mudflats) are vegetational communities adapted to saturated or periodically inundated soils (Mitsch and Gosselink 1986). Riparian ecosystems (predominantly bottomland hardwood forests in the Southeastern United States), inland freshwater marshes and wet prairies, salt and freshwater coastal marshes, and shallow coastal estuaries are among the most extensive features of peninsular Florida.

Riparian and freshwater marsh ecosystems of interior Florida are characterized by the combination of high species diversity, high species densities, and high productivity. Equally important is that the wetland environments are interspersed among pine dominated forests of much lower biological diversity. In Florida, slash pine (*Pinus elliotti*) and longleaf pine (*Pinus palustris*) are dominant. The consequence , region-specific ecological gradients, the most recent history of which is anchored in the mid-to-late Holocene, is dramatic. The critical question is at what point in the past are "modern" environmental parameters reliable aids in interpreting the archaeological record of peninsular Florida.

The Holocene

It is generally accepted that the Holocene was a period marked by increased precipitation and sea level rise. For the interior marshes and riparian wetlands of Florida, rainfall patterns have been critical in both development and maintenance. Pollen sequences which support a change to wet conditions are available from Lake Louise (Watts 1980) and the Okefenokee Swamp in southern Georgia (Bond 1970; Cohen 1974, 1975), from central Florida at Lake Annie (Watts 1975), as well as other parts of the Southeast. Generally, pollen studies show that within the lower Southeastern Coastal Plain pine increased at the expense of oak during the late Holocene. The change from oak to pine is correlated with a high stable water table and the expansion of swamps and bogs. The analysis of pollen from Lake Louise, for example, indicates that pine was spreading before 6710 B.P., and stabilized at approximately 65% pine to 15% oak pollen around 5000 B.P. From 5000 B.P. bayhead plants became prominent. Cypress (*Taxodium* sp.) was expanding at that time and has increased even more over the past 2,000 years (Watts 1980:404).

The differences in geomorphology, topography, hydrology, soils, and rainfall within the Floridian peninsula, however, contribute to significant locational differences (e.g., a mosaic) in vegetational communities. Of particular importance, therefore, is evidence for episodic variability of rainfall within central and south Florida during the Holocene. Geologic data are available from the Okeechobee/Loxahatchee area, which is near the upper St. Johns River basin, and Marion County in central Florida. Gleason et al. (1984:321) report a calcitic mud-peat sequence which indicates increased rainfall within the Okeechobee basin at 6320 ±250 B.P. and again around 4860 ±200 B.P. That the last wet period was followed by four periods of severe drought is indicated by evidence obtained from a perched peat bog in Marion County. The sequence of drought and fire episodes, dated from the oldest episode to the youngest, occurred "... on or about 4030 years B.P., again subsequent to 3830 and prior to 3620 years B.P., on or about 2970 years B.P., and again subsequent to 2900 years B.P." (Gleason et al. 1984:321). They also note that since that time drought conditions have moderated considerably. Thus, based on currently available data, rainfall began to increase at an unknown rate at some point after 950 B.C. It is worth noting that recent archaeological evidence from the Everglades (Carr 1981; Carr et al. 1979), Big Cypress (Ehrenhard et al. 1978; Taylor and Komara 1983), and Lake Okeechobee (Hale 1984; Sears 1982) seem to indicate increased occupation of the wetlands of south Florida around 500 B.C. or later. Within the upper St. Johns River basin, interpretation of archaeologically recovered fauna suggest that near modern conditions were not achieved in that region until after the late Orange period (Russo 1986).

The Upper St. Johns River Basin: Environmental Structure and Productivity.

The St. Johns River is actually a series of shallow lakes connected by a channel. This distinguishing characteristic was reflected in its aboriginal name, Ylacco (Welaka) which meant river of many lakes (Brinton 1969). The upper basin contains six lakes, Blue Cypress, Helen Blazes, Sawgrass, Washington, Winder, and Poinsett. The marshes adjacent to the lakes and channel vary in width from 2 to 36 km (Cox et al. 1976:1.15). Thus, the St. Johns River has the largest basin and is one of the longest rivers in the state at 507 km. It is also unique in that it flows in a northerly direction and has a very low gradient, a drop of less than 8 m along its entire length (St. Johns River Water Management District 1979:3) The eight principal tributaries within the upper basin enter the river from the west and include the Econolockhatchee River, and James, Taylor, Cox, Wolf, Jane Green, Blue Cypress and Fort Drum creeks (Fig. 1). The major aquatic environment is, therefore, the north-south lakes/marsh ecosystem. Secondary to this are the east-west streams and their riparian wetland borders. These major aquatic environments are surrounded by extensive pine flatwoods of comparatively low natural productivity. While these are the outstanding regional features, far greater environmental heterogeneity exists, the foundation and consequences of which are very subtle and still under active investigation.

The structure and stability of the biological communities rests on the interaction of topography, soils, geomorphology, and rainfall. East-Central Florida lies within the Coastal Lowlands physiographic province which borders the entire coast of Florida. Generally the Coastal Lowlands lie less than 30.5 m above present sea level. Within east-central Florida, topographic relief is provided by terraces created by the Pamlico, Talbot, and Penholoway seas of Pleistocene origin. The Pamlico Terrace, at approximately the 8-m contour, is dominated by the "Eastern Valley" which contains the St. Johns River and marsh. To the west of the "Valley" lies the Talbot and Penholoway terraces which give rise to the stream tributaries that enter the marsh and river. East of the "Valley" lies the Atlantic Coastal Ridge, the Indian River, and the barrier islands (Cooke 1945; White 1970) which constituted the settlement range of the coastal Ais Indians.

The soil range includes the very wet muck and peat of the lakes and marsh, the sandier but poorly drained flatwood soils, and the level to gently sloping sands of the knolls and ridges (Huckle et al. 1974:57-60; Readle 1979:4-9). This surficial mantle of Pleistocene and Holocene age is, in turn, underlain by sediments of the late and middle Miocene which confine waters of the artesian aquifer (Cooke 1945). Unlike the middle and northern St. Johns River, it is the rainfall-dependent, shallow groundwater aquifer, and not the artesian, that dominates the upper basin. As the shallow ground-water aquifer is not under pressure, it is free to rise and fall directly in response to recharge and discharge, events that are directly tied to rainfall, evapotranspiration, and surface runoff (Lichtler 1972:17).

Seasonal cycles in subtropical Florida tend to be defined by the occurrence of rainfall rather than temperature. Average annual rainfall is about 145 cm, 60% of which occurs in the form of showers and thunderstorms from June through October. The remainder is relatively evenly dispersed within the dry months of November through May. While this is the average, important variation occurs within and between years, due to droughts and hurricanes (Cox et al. 1976). Given a defined climatic regime the distribution and composition of plant communities generally follow soil types and drainage, which in turn influence the density and distribution of dependent fauna.

The Marsh/Lake Communities

The St. Johns Marsh is one of the largest emergent marshes in Florida. Marsh communities are an open expanse of grasses, sedges, rushes, and herbaceous plants, and are classified according to dominant vegetation. Vegetational characteristics (along with fire, and depth and duration of water fluctuations) influence the diversity, density, and survival of the animal communities of the system. Figure 2, adapted from Odum (1971), illustrates the major structural components of the marsh/lake system: the littoral, limnetic, and profundal zones. The littoral zone is the shallow region and is composed of two subdivisions, emergent and submergent. This zone is valuable for food, cover, and spawning habitat for a wide range of animals (Odum 1971). It also offers many edible plants and tubers which are available year-round for human consumption. The emergent portion contains aquatic plants which have the greater amount of their photosynthetic surfaces extending above the water surface. These plants include several species of cattail (*Typha* spp.), bulrushes (*Scirpus* spp.) arrowhead (*Sagittaria* spp.), and pickerel-weed (*Pontederia cordata*). The submergent region contains rooted plants with floating leaves such as various species of waterlilies (Nymphaeaceae) (Cox et al. 1976).

The limnetic zone of lakes and ponds is the open, upper surface of deep water and extends to the depth of light penetration. Many fish species move freely between the littoral and limnetic zones, while others spend a greater part of time in the littoral region. For example, McLane (1955:32) reports that bowfin (*Amia calva*)

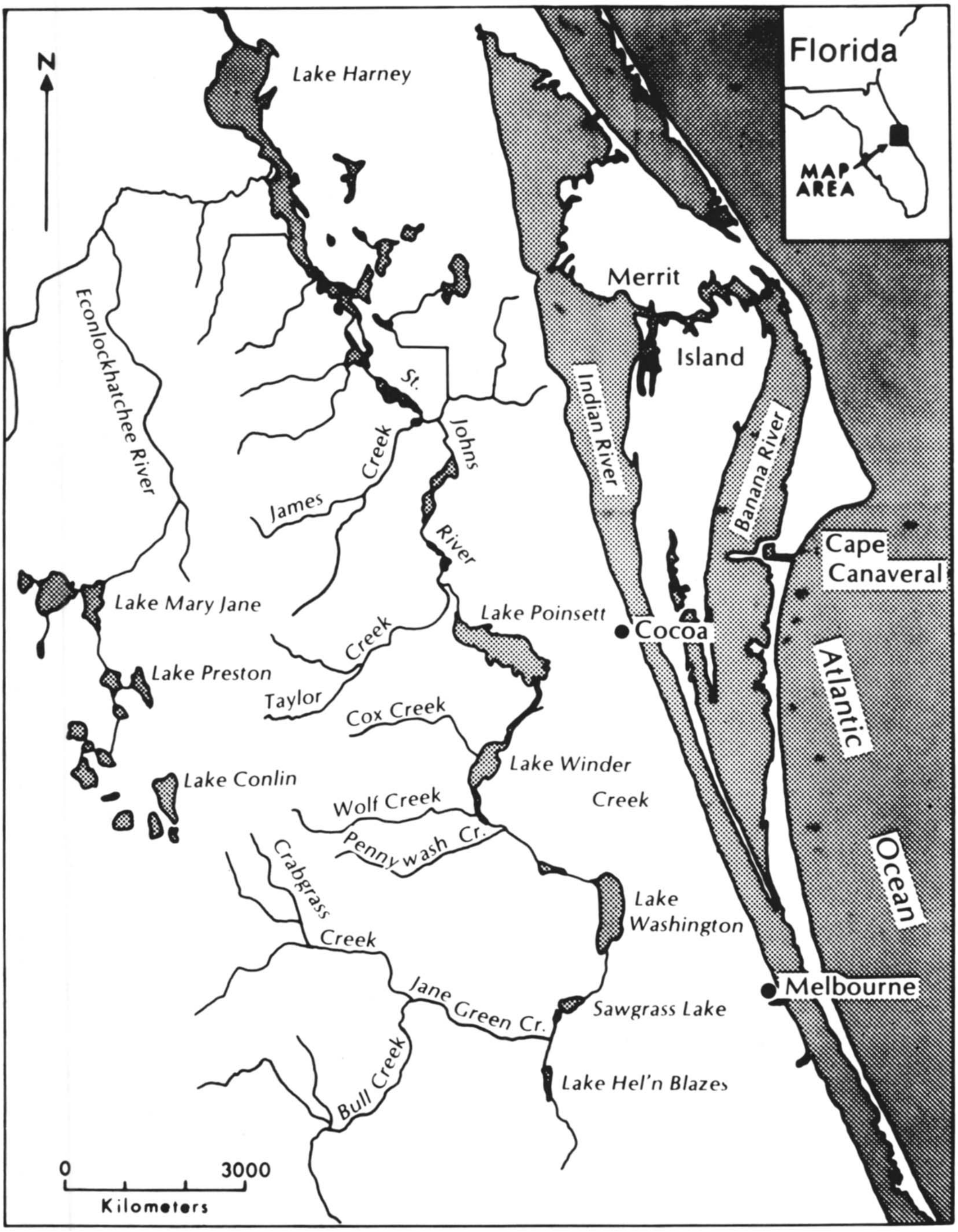

FIGURE 1 Lakes and tributaries of the Upper St. Johns River basin, central-east Florida.

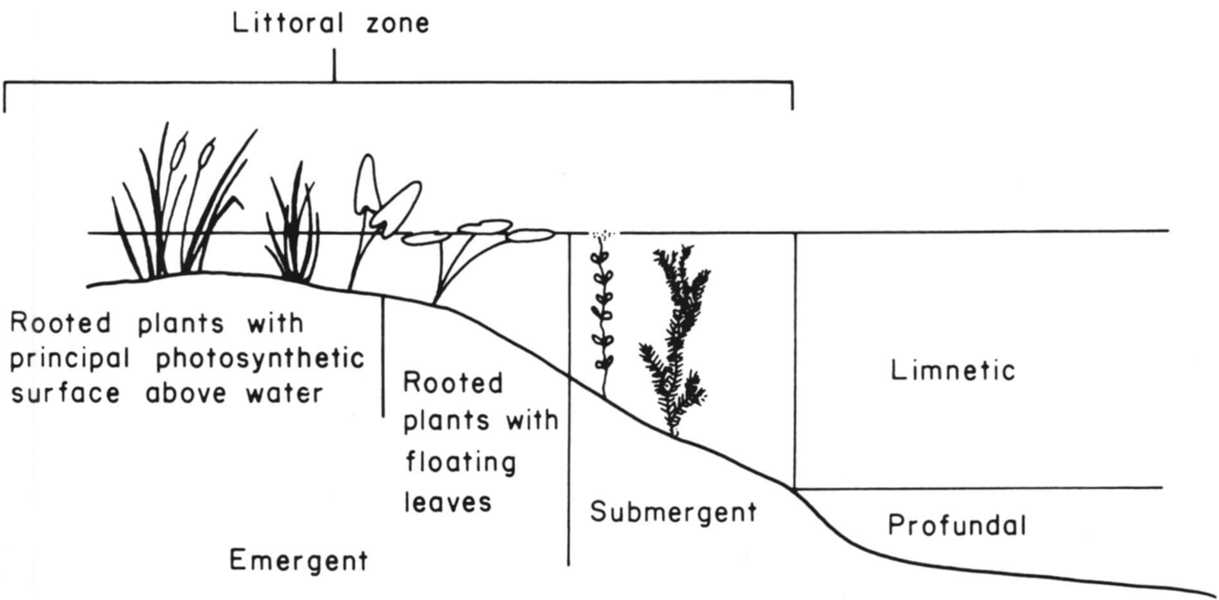

FIGURE 2 Major structural components of the lake/marsh system (redrawn after Odum 1971).

prefer densely vegetated marginal areas. Both the young fish school and adults have been observed feeding in beds of bulrushes. Others such as bluegill (*Lepomis macrochirus*), shellcracker (*Lepomis microlophus*), and black crappie (*Pomoxis nigromaculatus*), move freely between the littoral zone and deeper waters. Submergent vegetation such as eelgrass (*Vallisneria* sp.) and pond weed (*Potamogeton* sp.), however, may be preferred by the young (McLane 1955:238, 243, 281).

Below the limnetic is the profundal zone, which is beyond the depth of effective light penetration. This zone is not well represented in the ponds and mainstem lakes of the upper St. Johns River basin. This stands in contrast to conditions in most lakes, in which the limnetic and profundal zones are larger in comparison to the littoral (Odum 1971:309).

The St. Johns marsh and river system supports an excellent fishery (McLane 1955; Cox et al. 1976). During the annual reflooding of the marsh there is an explosive reproductive expansion of the small aquatic animal species (Cox et al. 1976). The St. Johns River Water Management District reports small fish density at three individuals per square meter, while under conditions of exceptional spawn (e.g., related to high water) one study showed "the density of small fishes to have increased from 3 individuals per square meter to 51 per square meter after 7 months of inundation" (St. Johns River Water Management District 1979:187–188).

The marsh and associated water courses also provide varied resident and migratory water fowl populations (Cox et al. 1976).

Streams and Their Borders

The dendritic stream systems which occur to the west of the lakes and marshes support a variety of hardwoods which provide acorns and other hard seeds and nuts that can attract mast-consuming species such as deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), black bear (*Ursus americanus*), and over-wintering migrant birds, on a seasonal basis (Harris and Gosselink n.d.:3–4). Water adapted reptiles and mammals such as river otter (*Lutra canadensis*), beaver (*Castor canadensis*), and the American alligator (*Alligator mississippiensis*), are also economically important resources (USDA Soil Conservation Service 1985). Although the streams are geographically restricted and tend to have narrow stream borders, they are the second most productive environment in the basin.

Pine Flatwoods

Pine flatwoods cover an enormous area within east-central Florida. The land is nearly level and poorly drained, with ground-water at or near the surface during the rainy season. Flatwood communities may cover several thousand acres, a monotony broken only by interspersed sloughs, cypress domes, shrub bog/bayheads, oak/palm hammocks, and wet prairies. The effect is a mosaic of heterogeneous communities (Fig. 3), different in size and productivity, and subject to recurring variability because of rainfall fluctuations and fire (USDA Soil Conservation Service 1985). Some species of fish, as well as reptiles, amphibians, and birds inhabit these communities. Large and small mammal inhabitants are more frequently found where flatwoods join the other communities. Overall, the patchiness of the environment contributes to the high degree of mobility for animal inhabitants.

With respect to large game animals, such as white-tailed deer and turkey, Eisenberg (1984:Table 1) estimates the following densities for optimal and marginal habitats. Deer in marginal habitats were estimated at $0.28/km^2$ as compared to $2.9/km^2$ for optimal habitats. Turkey was estimated at less than $0.50/km^2$ in marginal habitats and $0.92/km^2$ in optimal habitats. He also notes that the Florida Game and Freshwater Fish Commission (Newman and Griffin 1950) lists Brevard County with 38% of its contemporary area suitable for deer and 27% suitable for turkey. Correspondingly Osceola County had 20% of its area as good deer habitat and only 17% graded for turkey. Both counties are within the research area under question and were relatively undeveloped in 1950.

Turning to small game, Eisenberg (1984:6) notes that densities can oscillate widely during an annual cycle but, at the peak density in the Southeast, rabbit (*Sylvilagus floridanus*) ranges from greater than $100/km^2$ in optimal habitats to less than $10/km^2$ in marginal habitats, while the opossum (*Didelphis virginiana*) and raccoon (*Procyon lotor*) range from 15 to $4/km^2$ and from 12 to $0.8/km^2$, respectively. He concludes that "secondary productivity which may be harvested thus is anchored firmly in aquatic resources rather than the terrestrial" (Eisenberg 1984:11), and that this has definite implications within the research area.

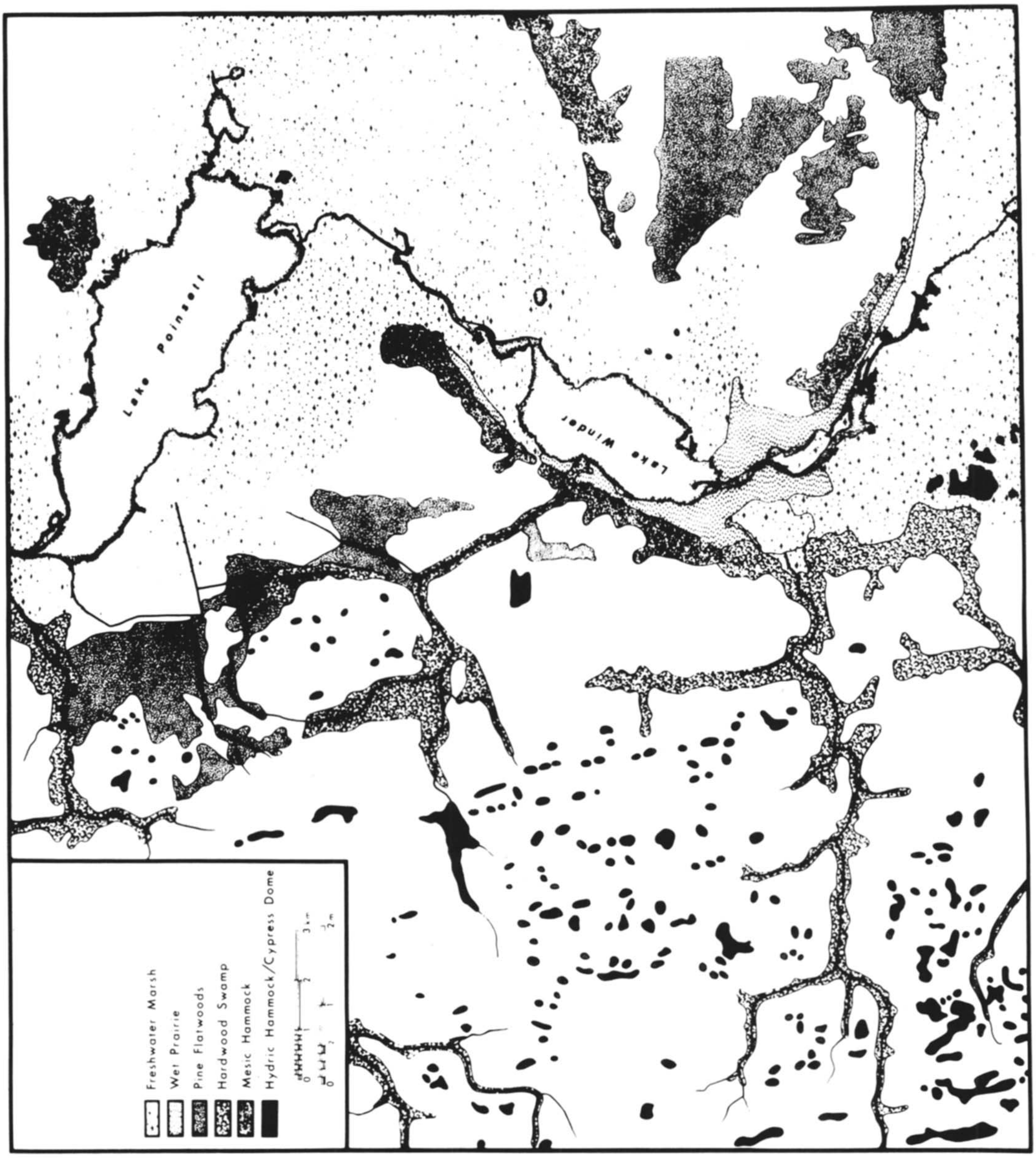

FIGURE 3 An environmental mosaic characteristic of the Upper St. Johns River basin.

Subsistence and Settlement

In the following discussion a comparison of faunal exploitation and settlement patterns is made between three cultural periods, the Orange, Malabar I, and Malabar II. Historic observations on settlement structure and socioeconomic interaction are used for comparison and interpretation of the events of the Malabar periods, especially Malabar II. The summary of pertinent findings on the patterns of fauna use are taken from Russo (1986). His goals within the total research project were identification and comparison of animal resources from the three periods. Russo illustrated an overwhelming preference for aquatic over terrestrial resources; by concentrating on age/size and species of fish examined, he traced their distribution vis-a-vis the habitat structure of the marsh/lake system and, by implication, the zone of exploitation. His data from the Gauthier site (8-BR-193) were first compared to resource distribution and abundance within a region surrounding the site; this was designated as the site catchment area (Eisenberg 1984; Sigler-Eisenberg 1984). This research showed that faunal use reflected the secondary productivity of the environment. The regional environmental structure and productivity were then analyzed and compared to data obtained on the regional settlement pattern for further documentation of the environment-subsistence-settlement links (Sigler-Eisenberg 1985).

Excavation of the Gauthier site was completed under my direction during the 1981 University of Florida Spring Field School. Recovery techniques included both dry and water sifting through 0.12-cm screen, thereby allowing recovery of both small species and small individuals of larger species. Overall, the identification and analysis of the faunal assemblage showed that the species found in the prehistoric middens are the same species found in the environment today. Given that parameter, however, very significant shifts in the exploitation strategies were indicated between the three cultural periods (Russo 1984, 1986). The regional site survey also indicated a shift in settlement strategies between the Orange and Malabar periods, but revealed continuity in settlement pattern from Malabar I to Malabar II and a similarity of the Malabar settlement structure to the historic Ais Indians.

The Orange Period

The Orange period at the Gauthier site dated to 30 ±90 B.C. By ranking the importance of fauna, Russo (1986) showed that freshwater fish (87% of MNI [Minimum number of individuals]) ranked first in importance, while reptiles were second (7% of MNI), mammals were third (3% of MNI), and birds and amphibians were last (2% of MNI each). The calculations of minimum edible meat weight from vertebrate remains also supported this ranking. This subsistence pattern clearly reflects secondary environmental productivity. In analyzing species' behavioral characteristics and their age/size he showed that only 12% of the sample were large adults, while 79% were either small species or the immature of large species. This situation appears to indicate a cultural preference for exploitation of the littoral zone. He further suggests that given the extremely small average fish size and vegetational characteristics of the littoral zone, a mixed technology was employed for capture, but that the primary means probably did not involve hook, net, or spear. Rather, capture could have been easily and quickly achieved by cooperative effort—a small circle of foragers thrashing the vegetation and scooping up the fish with baskets. In addition, the number of immature individuals probably indicates a spring/summer harvest period given the correlation of the spawning cycle with increased rains of the wet late spring and summer season. Russo also concludes that given the shallowness of the lakes, if rainfall was lower during the Orange period as predicted, the reduced areal extent of the wetland community would have resulted in reduced productivity. Thus, fishing shallow water habitats and the capture of small fish under conditions of lower water levels, reflects an optimal fishing strategy (Russo 1986:47).

When the trends observed in the faunal analysis are correlated with settlement data, it is clear that sites were located near the most critical resources. Figure 4 illustrates a linearity of settlements for all three periods. Orange period sites within the upper basin tend to be small midden scatters that seem to indicate temporary camps of mobile social segments and an overall low population density (Sigler-Eisenberg 1985). The fact that many Orange period sites are now underwater also supports Russo's conclusion that there was a reduced wetland area during that time. Additional evidence for low population density during the Orange period comes from the cemetery at the Gauthier site. The cemetery contained less than 200 people (Maples personal communication), who were buried over a 3,000-year time span (ca. 3,030 B.C. through A.D. 390; Sigler-Eisenberg 1984). The common interment of young/old and male/female is also characteristic of egalitarian hunter-gatherers. Although data are too scanty to conclusively indicate seasonal transhumance, the occurrence of numerous small sites suggests a form of "residential mobility" (Binford 1980). In addition, the linear settlement reflects a response to environmental circumscription. Given the approximate 500 B.C. date for occupation of adjacent wetlands, it would appear that social circumscription might also have affected mobility options.

Malabar I and Malabar II

Events which occur during the Malabar I and Malabar II periods (ca. A.D. 390 through 1400) stand in striking contrast to the Orange period. As in the Orange period sample, freshwater fish ranked highest in the Malabar I and II periods. Aquatic reptiles increased while terrestrial reptiles and mammals decreased somewhat. Comparison of the preferred habitat of the captured fish shows increased exploitation of the deeper waters of the limnetic zone, thus, a more balanced exploitation between the littoral and limnetic zones. A slight shift in fishing strategies is also indicated in the Malabar I period sample by an increase in the average size of both large and small fish species (Russo 1986).

The Malabar II fishing strategies changed substantially by A.D. 1080. Most of the same species were exploited but the demographic pattern of fish is just the reverse of that observed during the Orange period. Seventy-eight percent of the

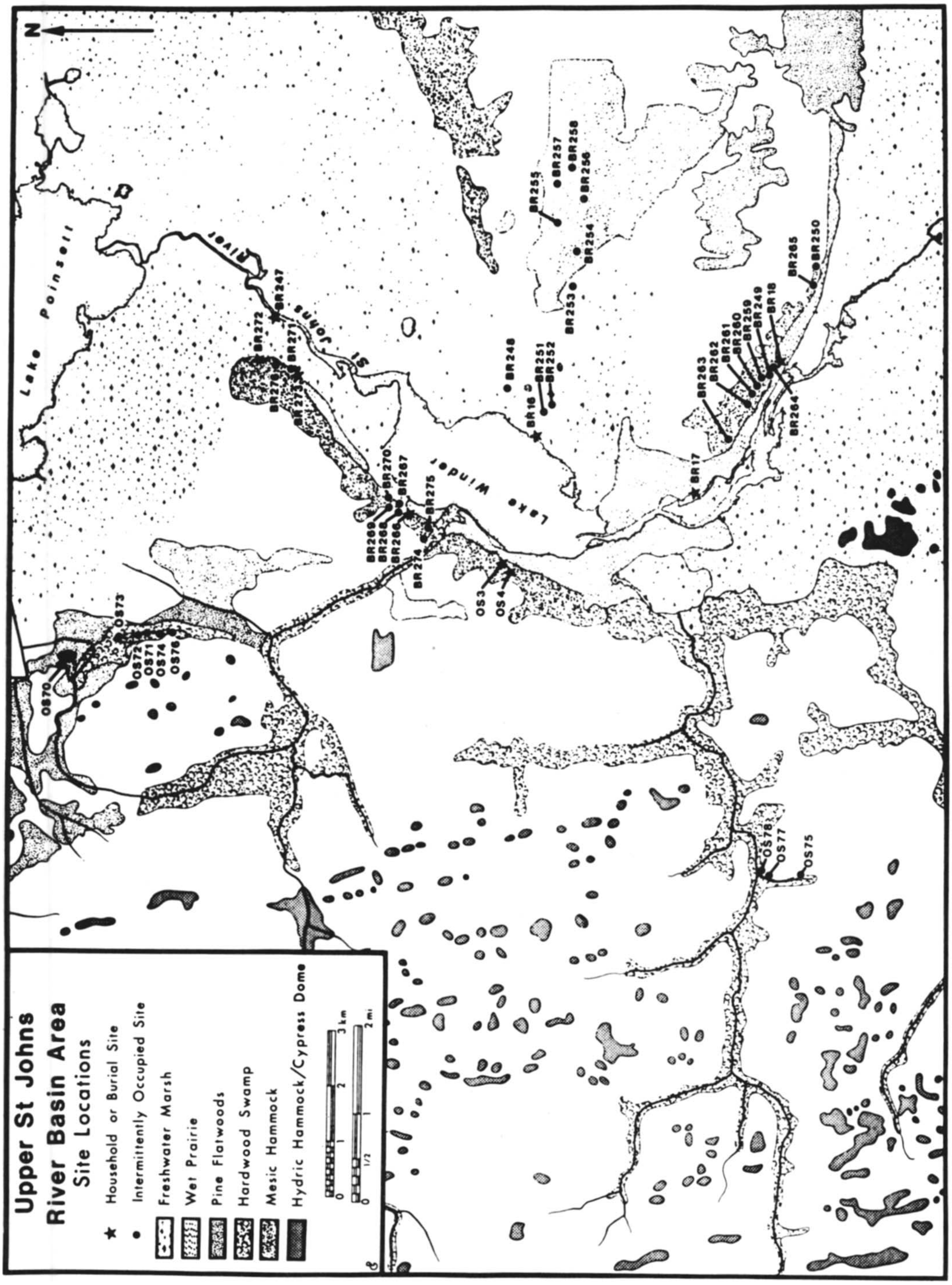

FIGURE 4 Site types and their location from Orange through Malabar II periods.

fish were large individuals, and the average size of the large individuals increased dramatically. For example, in the Orange period the average weight for each individual was only 200 g while by Malabar II it had increased to 1,000 g. The preference for large fish was accompanied by a decrease in fish MNI, which was offset by increased harvest of aquatic turtles, waterfowl (surface feeding ducks), and rabbits. The tremendous increase in economic productivity which began during the Malabar I period and continued into the Malabar II period therefore, was associated with a slight shift in subsistence mix (Russo 1986).

Russo (1986:50) attributes this increase to continued development of the wetlands but suggests that by Malabar II the Gauthier site was probably a specialized production site. The foundation for this explanation rests on fauna analyzed from similar household sites identified during the regional survey. These samples, however, were neither comparable in size nor in recovery techniques to those obtained from the Gauthier site. While quantification of fauna obtained from future research on additional household sites may well prove this suggestion to be true, current evidence is not sufficient to support it. What is clear is that productivity did increase at the Gauthier site and the increase was particularily dramatic during the Malabar II period. The balance achieved between resources obtained from the limnetic and littoral zones during Malabar I could indicate alternatively that deeper water habitats were well developed at that time, and that the wetland communities had achieved near "modern" conditions prior to A.D. 1080. While future research should address this question for further clarification, the settlement pattern data clearly suggest that the apparent economic intensification observed at the Gauthier site during the Malabar I and II periods was also associated with population expansion, a greater degree of sedentism, and ceremonial intensification.

The sites of the Malabar I and II periods are linear in distribution (Fig. 4), but are larger, more numerous, and show greater intersite variability than those of the Orange period. Site types include sand burial mounds (as opposed to cemeteries), small household sites, intermittently occupied fishing and hunting stations, and single episode sites. An artifact inventory of the Gauthier site shows a diversity of maintenance activities characteristic of more sedentary households. Tools include bone awls, bone projectile points with evidence of hafting, shell chisels and gouges, a shell dipper made from *Busycon contrarium*, worn fragments of coquina and sandstone that could have functioned as abraders, pottery and unfired irregularly shaped clay fragments suggesting ceramic manufacture, and shark teeth. No wooden or fiber artifacts were recovered. Household sites constructed of mounded shell were restricted to areas immediately adjacent to the marsh. Other households contained very little shell and were located within oak/palm hammocks on the 6–m contour adjacent to the lakes and marsh. The size of these households varied somewhat but were similar in size to the Gauthier site, approximately 90x150m. Isolated stone projectile points and small chert scatters were obtained from the pine flatwoods, but chert scatters were more numerous along the streams west of the marsh. Intermittently occupied fishing stations were located along the river or along the marsh edge (Siger-Eisenberg 1985).

Discontinuities of occupation occurred between the Malabar I and II periods on some household sites, but most were multi-component sites that may have been occupied continuously. This settlement pattern indicates a shift to a "logistical" (Binford 1980:10) form of mobility, whereby sedentary households are located close to the most critical resources. Certainly the faunal assemblage and the characteristics of the environmental structure and productivity demonstrate the critical nature of the marsh-lake system. Other important resources would have been obtained by small task groups or individuals going out from the residential base—conditions that seem to be satisfied by the presence of intermittently occupied and single episode sites.

The Historic Ais Indians

Ethnohistoric observations are available only on the coastal Ais, but they still offer some indications of the settlement-subsistence organization, inter and intra-community social obligations and regional alliances. Given the similarities in settlement structure between the late prehistoric and historic periods it is suggested that the social obligations and interactions observed historically are a reasonably accurate "window" to the processes of economic intensifications of the Malabar I and II periods.

Spanish and English observations between 1605 and 1669 report that the Ais Indians occupied east-central Florida from approximately Cape Canaveral south to the St. Lucie Inlet and an area inland which included the upper St. Johns River basin (Andrews and Andrews 1945; Higgs 1951; Rouse 1951). In 1605 Mexia reported four subgroups each with its own chief (Higgs 1951). In 1696 Dickinson observed that greater deference was shown to the chief of the Ais proper (Andrews and Andrews 1945). Locations of the residence of the four chiefs were given as the Banana River, the St. Lucie River, the upper St. Johns River, and the central portion of the Indian River area (Rouse 1951).

Each chief presided over a settlement that consisted of his village, but there were also dispersed *rancherias* which Higgs (1951) translated as hamlets. A more accurate translation of the seventeenth century Spanish meaning of that term, however, is an extended household (Chappel personal communication). The chiefs had multiple wives and their residence was the social nucleus of the community which presumably included the dispersed households. Almost nothing is known about the relative size of the village or the arrangement of the houses, however. Houses were wooden frames covered with palmetto thatch, with low wooden benches for seating and sleeping. Some dwellings were placed on mounded shell, which offered protection during periods of high water (Andrews and Andrews 1945). The location of mounded shell sites within the St. Johns River floodplain indicates similar adaptation.

In addition to a chief, the subgroups had a council of principal men and a religious practitioner. Political and religious ceremonies were conducted at the chief's homesite and included residents of the local community and visitors from neighboring communities. Jonathan Dickinson also notes that after one ceremony "great baskets of dried berries were brought in from divers towns" (Andrews and Andrews 1945:61). This may indicate that social obligations between communities or between households within a community were incurred. Interregional marriage alliances were also noted (Rouse 1951).

The coastal Ais economy was based on intensive fishing and collecting along the Indian River, and all sources are in agreement that the Ais practiced no horticulture. Fish, shellfish, deer, manatee, palm berries, coco plum, and sea grapes are listed as important dietary staples. The division of labor was apparently based on age and sex. The men fished, frequently in pairs from canoes, but little information is available on women's activities except for cooking and infant care.

The material inventory reflects a relatively simple technology for exploiting local resources, and interregional exchange of prestige and ceremonial objects, as well as some subistence items (manatee and whale). Items produced from locally available resources include baskets, nets, ropes and fabric woven from natural fibers, wooden canoes, paddles, poles, benches, fishing staffs and arrow shafts, bone projectile points, awls and ornaments from deer, resins for hafting projectile points, shark teeth for cutting and incising, deer skin for drums and clothing, and shell celts, picks, dippers, and pendants. Nonlocal items included tobacco and cassina, chert, gourd dippers, hematite, and brass, gold and silver ornaments.

The basic production and consumption unit apparently was the extended family household. Cooperation in subsistence production within and between communities is demonstrated in the literature, and can be reasonably inferred from labor constraints inherent in canoe construction, whale and manatee hunts, and probably house construction, to name but a few. In addition, surplus products and cooperative labor would have been required to discharge community social obligations in such tasks as feast preparation and burial mound construction.

A Preliminary Model

Anthropological views about hunter-gatherers have been drastically altered by research of the past two decades. Perhaps two of the most significant changes are an awareness of greater socioeconomic diversity and a recognition of a wider range in the levels of political complexity. Conditions that have consistently correlated with the development of greater social complexity are: (1) social and environmental circumscription, (2) abundant resources, and (3) higher population densities. The consequences of these conditions are sedentism, frequent linearization of settlement patterns, increased productivity and production, and changes in decision making processes (Price and Brown 1985:8–12). The conditions and consequences outlined by Price and Brown appear to be present in the changes that occurred in the upper St. Johns River basin during the Malabar I and II periods. In summary, the following developmental model is suggested as a guide for further research.

The Orange period subsistence strategies and the hypothesized residential mobility thought to be reflected in the settlement pattern of this period were responses to environmental parameters such as conditions of low rainfall and less abundant aquatic resources, seasonal fluctuations in the abundance of aquatic resources that were available, and the patchiness and relatively low productivity of the terrestrial habitats.

It is suggested, however, that by the Malabar I period the aquatic systems had reached near "modern" conditions, and that this is reflected in the balance achieved in fishing strategies that included both the shallow littoral and deeper water limnetic zones of the lake/marsh ecosystem. The associated change in the settlement pattern indicates a shift to a logistical form of mobility whereby sedentary households are located close to the most critical resources.

In light of the social changes that are reflected in the settlement pattern, the dramatic increase in productivity between Malabar I and II cannot be explained by continued development of the wetland environments. I suggest, rather, that the increased productivity which began during Malabar I reflects production demands that result from greater social integration and accompanying social obligations (see Bender 1985; Lourandos 1985), and that by Malabar II the social obligations and the settlement-subsistence organization was similar to that observed during the early Contact period.

Acknowledgments

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ENVIRONMENTS OF FLORIDA IN THE LATE WISCONSIN AND HOLOCENE*

William A. Watts
and
Barbara C. S. Hansen

Abstract

THE MAJOR FEATURES of the Late Wisconsin and Holocene vegetation and climatic history of Florida are known from palynological studies of lake sediments at several sites on the peninsula. Before about 15,000 years ago the pollen record is dominated by fluctuating amounts of pine and oak, and by shrubs and herbs of prairie and sand dune environments. The climate is believed to have been drier and windier, but not necessarily much colder than at present. There is some evidence for dune movement at this time. At Lake Tulane near Avon Park in south-central Florida the pollen record extends back without interruption from the present to about 50000 B.P., probably the longest complete record in eastern North America. At Sheelar Lake near Gainesville, the vegetation from 15000 to 12000 B.P. consisted of broad-leaved mesic forest, with beech (*Fagus* sp.) south of its present limit. The climate was slightly cooler than today's, with high precipitation. The Holocene had abundant oak and prairie plants with only a small representation of mesic trees or conifers until about 5000 B.P. This is interpreted as representing warmer and drier conditions than today. After 5000 B.P. extensive swamping took place, and the modern vegetation with pine flatwoods, cypress, bayhead, and peatland communities was established. Throughout the peninsula the water table was very low in the early Holocene. Most modern lake basins were dry, and lakes with at least 18 m of water depth today must be cored if success in finding sediments older than 8500 B.P. is to be hoped for. The contrast between the prairie/dry oak-forest communities before 5000 B.P. with few lakes, and the modern pine forests with numerous lakes and swamps is of great importance in understanding the environment in which human cultures developed. Although the temperate Florida peninsula is now well studied, little information is available from tropical Florida because of lack of suitable lakes for coring.

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Introduction

The Florida peninsula is rather homogeneous in its topography and geology. Even in the Florida Highlands elevations rarely exceed 60 m above sea level. Much of the peninsula is very flat, but the central ridge has low rolling hills. Tertiary rocks, most notably the Ocala Limestone of Eocene age, underlie the whole peninsula. It contains the main Florida aquifer from which most of the state's groundwater is derived. Locally, the overlying Hawthorne Formation (Miocene) contains phosphate-rich beds. The texture and nutrient status of soils derived from the Hawthorne Formation is adequate to support high broad-leaved deciduous forest of which some stands still exist. Elsewhere sand, often many meters thick, overlies bedrock. Locally, large fossil sand dune fields exist, indicating past wind action on unstabilized soils. Easy infiltration in upland sandy soils leads to vegetation of an arid aspect in spite of annual rainfall over 130 cm throughout the state. Over large areas the water table lies near the surface, leading to poorly drained soils with numerous peaty shrub-swamps or bayheads, marshes, and lakes, some of great size. Flatwoods, forested country usually dominated by pine where the water-table intermittently makes the surface damp, are widespread. Thus the homogeneous landscape is made heterogeneous by a mosaic of vegetation types varying with soil texture, nutrient status and drainage.

Florida lies between latitude 31°N and 25°N, just north of the Tropic of Cancer, which passes between the southern tip of the peninsula and Cuba. Although not technically tropical, plants characteristic of the West Indian tropics are frequent in the center of the peninsula from Lake Okeechobee southward and in a coastal strip looping up to Tampa Bay on the west coast and Cape Canaveral on the east. They are the predominant element of the flora of drier parts of the Everglades and of the Florida Keys. The area with tropical plants is essentially frost-free and winter-dry. Outside the tropical area, the incidence of frost increases and the difference between winter and summer rainfall decreases (Table 1). The role of occasional killing frost in winter in determining the range of plant species can readily be perceived by considering recent destruction of citrus groves in north-central Florida during exceptionally cold winters. More than half of the rain in Florida falls between June and September, usually as afternoon thundershowers. Lightning strikes associated with the showers may cause natural fires, especially if there is abundant dry plant material to burn. Lightning-caused fires favor fire-resistant species such as pines and palms against more sensitive broad-leaved trees.

The climatic diversity, in combination with availability of water and soil nutrients, leads to great habitat and floristic diversity. Upland woodland types may range from productive mesic broad-leaved deciduous forest to pine-dominated excessively drained scrubland. In general, the tropical flora of Florida is a relatively species-poor northern variant of the West Indian flora. The temperate flora is a species-rich southern variant of the forest and swamps of the Coastal Plain and Piedmont. The temperate flora has a significant number of narrow endemics, that is species with small local populations that do not occur elsewhere. Many of them are herbs or shrubs of sand dune or other open herb-dominated habitats.

Table 1. Some climatic data on a north-south transect in interior Florida

	Jan. Mean Temperature (°F)	July Mean Temperature (°F)	Number of frost days — 30-year record	Mean annual precipitation (inches)	Mean Jan. precipitation (inches)	Mean July precipitation (inches)
Monticello (North-West)	53.9	80.8	137	54.4	3.4	7.1
Lake City (North)	56.1	81.1	127	51.0	2.7	7.6
Gainesville (North)	58.0	81.1	112	52.5	2.6	7.5
Orlando (North-Central)	60.4	81.5	61	51.4	2.0	8.0
Avon Park (South-Central)	63.6	82.3	25	55.2	2.1	8.5
Homestead (Tropical)	65.6	80.2	22	54.7	1.8	8.8

Paleoecology and Paleoclimate

To a paleoecologist the history of the vegetation cover is of primary interest. It may be reconstructed by well-established procedures (Berglund and Ralska-Jasiewiczowa 1986) from the study of fossil pollen in cores obtained from lake-bottom sediments. However, the recent interest in reconstruction of past climates has caused fossil pollen data to be regarded as "proxy evidence" for former climatic conditions. Past climate can be reconstructed by suitable computerized procedures for handling data, "transfer functions," which depend on the availability of a data bank of pollen counts from present-day lake sediments that can be linked to established climate recording stations (Bartlein et al. 1984). Evidence of this kind inferred from pollen data can be used to check the validity of climatic models that assume certain boundary conditions in the past (Kutzbach and Wright 1985). Additional information can be provided by the quantitative study of charcoal in sediments as evidence for former fire frequency (Tolonen 1986). The study of plant macrofossils may add significantly to information by distinguishing between species which cannot be separated from one another by pollen morphology alone. There is a growing base of pollen and plant macrofossil studies in Florida; several pollen profiles are well-dated by radiocarbon analyses, and the first charcoal studies are available. As yet there is an insufficient data base of modern surface samples to permit transfer function procedures to be applied, and there may be difficulty in finding analogs for some past vegetation types. Under these circumstances, climatic inferences must be descriptive rather than quantitative.

Archaeologists in Florida are interested in the vegetation record primarily as evidence of the habitats available for hunting, food-gathering, cultivation, or shelter. Fortunately the pollen record is rich in relevant information. The questions that can most readily be answered are (1) Did any major habitat/vegetation type greatly expand or contract its area in the period when people might have been present? (2)Were there any vegetation types for which no modern analog exists? (3) What changes in the position of the water table took place in the past? (4) What evidence of the incidence of fires in the past does charcoal in lake sediments reveal?

Holocene Environments

All sites studied in Florida show that the modern flora and vegetation were established by 5000 B.P. The pollen assemblages are pine-dominated, with a strong component of swamp trees and shrubs, especially cypress (*Taxodium* sp.). A secondary expansion of cypress at about 2500 B.P. in both northern (Lake Louise; Watts 1971) and south-central Florida (Lake Annie; Watts 1975) suggests a further rise in the water table and swamping at that time.

Before about 7000 B.P. Lake Louise, which lies south of Valdosta, Georgia, close to the Georgia/Florida stateline, records a pollen flora in which oak was the most important element (Fig. 1). Pine was not very abundant (less than 20% of the pollen sum, a low value for a tree with exceptionally high pollen production), while

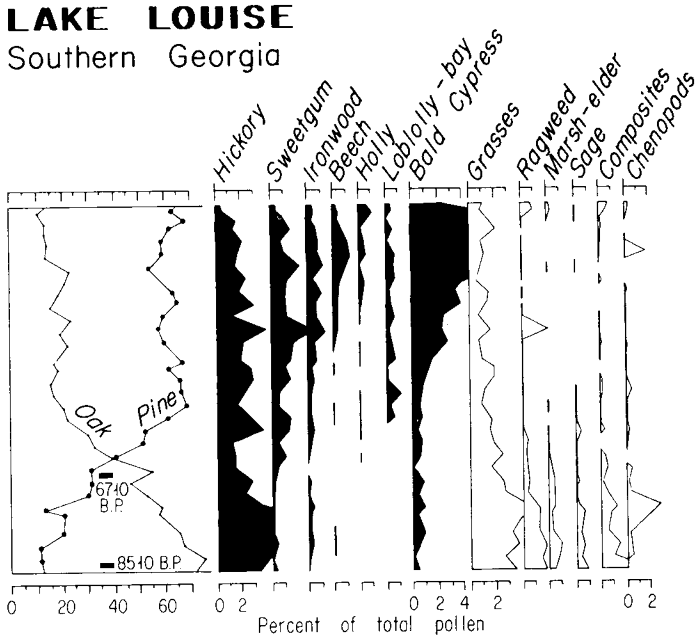

FIGURE 1 Pollen diagram from Lake Louise, Georgia.

grass (Gramineae), ragweed (*Ambrosia* sp.), wormwood (*Artemisia* sp.), and other herbs were frequent. Neither ragweed nor wormwood were natural components of the flora of this region at the time of settlement. This was a landscape with abundant oak trees or oak scrub, some prairie-like vegetation and few pines. Watts (1971) compared the herbaceous communities to those of the prairie which were recorded from the Black Belt of Alabama at the time of settlement. Similar vegetation is recorded from Mud Lake east of Ocala in north-central Florida (Watts 1969). Fossil wormwood is particularly characteristic of northern Florida, but similar plant assemblages in all other respects are recorded as far south as Lake Annie (Watts 1975) for the same period.

Charcoal has not been counted at Lake Louise, but at Lake Tulane near Avon Park in south-central Florida, the greatest influx of charcoal to the lake's sediments took place between 11 000 and 7000 B.P. (Fig. 2; Table 2). The presence of charcoal provides a record of upland fires caused most probably by lightning strikes or, less probably, by humans. Natural fires caused by lightning occur most readily when there is plenty of dry fuel on the ground (Christensen 1980).

At Lake Louise the transition from oak/prairie to pine/swamp vegetation was gradual between 7000 and 5000 B.P. At other sites (Lake Annie) the change occurred relatively quickly at about 5000 B.P.

Lake Louise is now about 6 m deep with 6 m of bottom sediment. The basal sediment, dated to 8500 B.P., rests on compact silt with some charcoal. Organic sediments too old to be dated by radiocarbon analysis lie under this layer. A similar situation exists at Mud Lake. Clearly, neither lake existed for a long time before

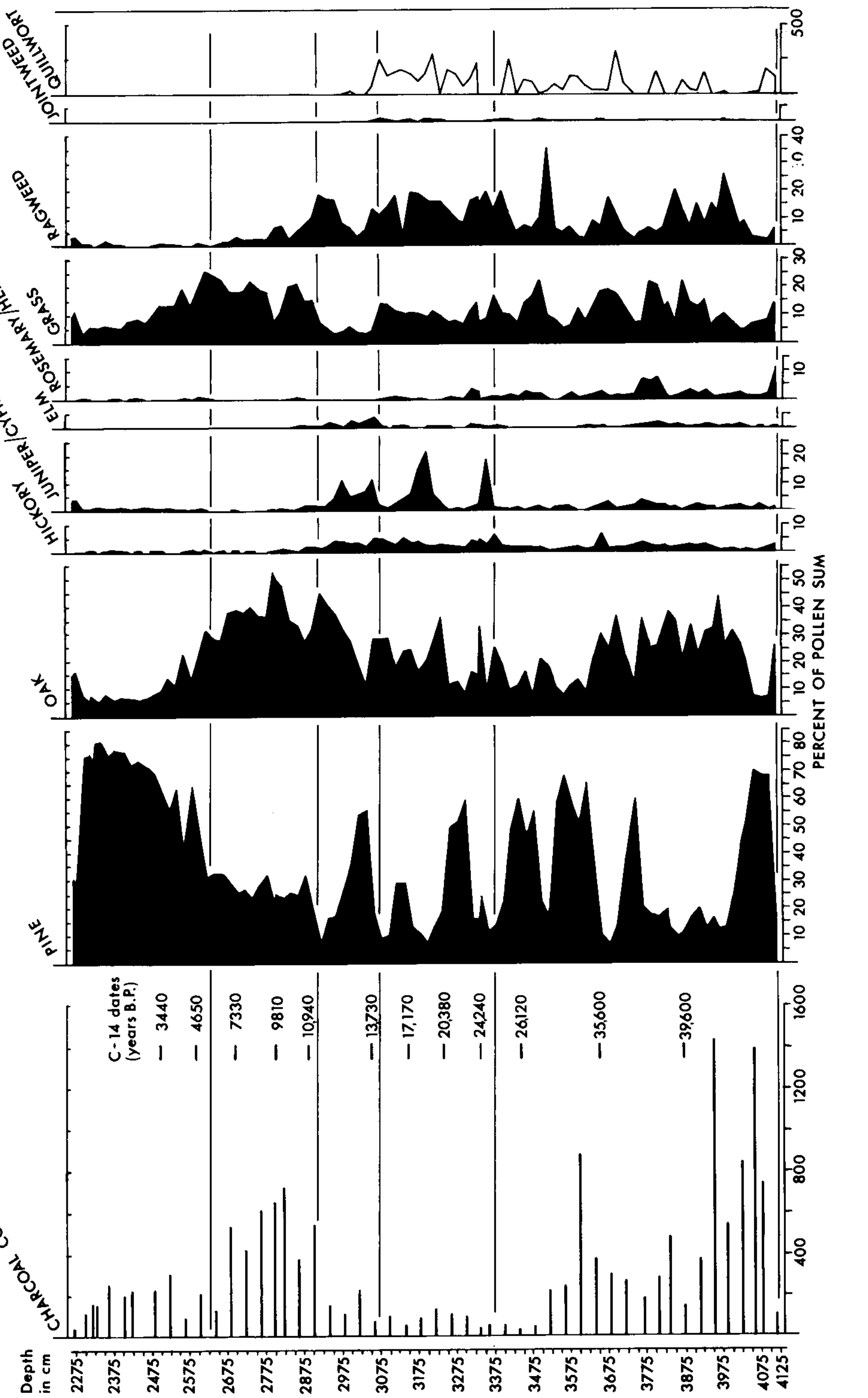

FIGURE 2 Abbreviated pollen diagram and charcoal concentration counts from Lake Tulane, Florida. Charcoal calculated by point count estimation (Clark 1982.)

Table 2. Radiocarbon dates of charcoal samples from Lake Tulane

LAKE TULANE RADIOCARBON DATES		
cm 2493-2503	3440 ±80	WIS-1646
2592-2602	4650 ±70	WIS-1752
2692-2702	7330 ±90	WIS-1647
2798-2808	9810 ±90	WIS-1753
2892-2902	10 940 ±120	WIS-1648
3052-3062	13 730 ±130	WIS-1649
3152-3162	17 170 ±210	WIS-1754
3252-3262	20 380 ±230	WIS-1650
3352-3362	24 240 ±400	WIS-1755
3452-3462	26 120 ±440	WIS-1651
3662-3672	35 600 ±400	QL-4057
3876-3886	39 600 ±500	QL-4058

8500 B.P., and their basins were dry. Buck Lake near Lake Annie, which now contains 19 m of water and 6 m of lake mud, also began to sediment about 8500 B.P. when shallow water peaty mud, rich in waterlily seeds, was deposited. It is certain that water levels were rising strongly throughout Florida by about 8,500 B.P. Before that time the overwhelming majority of Florida's present-day lakes and smaller rivers were dry. It has been shown by Clausen et al. (1979) that early humans lived on a ledge 26 m below the present water level in the cenote-like sinkhole of Little Salt Spring in southwest Florida. The occupation is dated to 12 000 B.P. Here the water level appears to have risen 26 m between 12 000 and 8500 B.P.

Clearly the environment for people in the early Holocene was very different from that of today. Surface water may have been scarce, making the use of cenotes like Little Salt Spring necessary, in spite of obvious difficulties of access. The possibilities of fishing and food-gathering in aquatic environments were clearly limited. On the other hand, prairie communities and scrub forest constantly opened by fire would have been suitable grazing ground for large herbivores, so that the possibilities of hunting large game may have been better than in the later Holocene.

The evidence from Lake Louise, Mud Lake, and Little Salt Spring, together with other sites, indicates that the paleoecologist who seeks records older than 8500 B.P. in Florida must study sediments of deep lakes. At Lake Annie, sedimentation began 27 m below the present water surface (19 m water, 8 m lake mud) at about 13 000 B.P., below which there is a hiatus, then older organic material. At Sheelar Lake northeast of Gainesville (Watts and Stuiver 1980; Fig. 3) sedimentation began 30.5 m below the present water surface (18 m water, 12.5 m lake mud) at 14 600 B.P., when there is a hiatus to 18 500 B.P. The newly studied Lake Tulane, within the city limits of Avon Park, south-central Florida, contains 18.5 m of sediment under 22.7 m of water (Fig. 2). The site has no hiatus and contains a well-dated, uninterrupted record of sedimentation for probably 50,000 years, the only such site in the eastern United States. The missing time segment at Sheelar Lake lies at about 31 m at Lake Tulane. While it would be naive to assume that the surface

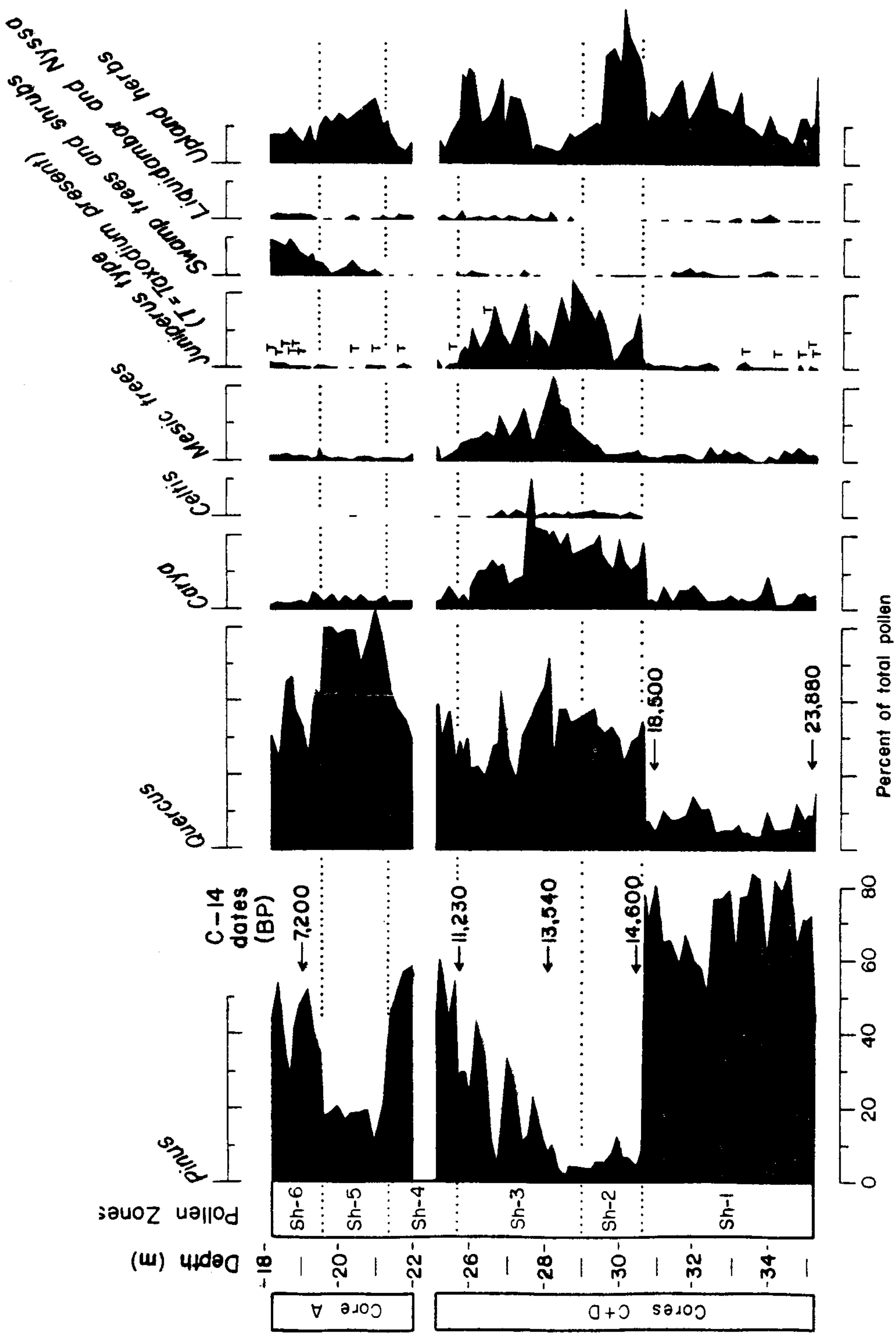

FIGURE 3 Pollen diagram from Sheelar Lake, Florida.

level of the main Florida aquifer fell uniformly throughout the state, the evidence is that a water lowering of more than 26 m and less than 31 m was widespread throughout Florida at about 15000 B.P. From then until after 8,500 B.P. the water level in the aquifer continued to rise. The relative roles of precipitation and rising sea level in this process are discussed below.

The Holocene-Wisconsin Transition

Vegetation records before 8500 B.P. rely on evidence from Lakes Sheelar, Annie, and Tulane (Tables 3 and 4). Lakes Annie and Tulane are geographically close and reveal almost identical records, while Sheelar Lake, 300 km to the north, shows interesting correlations and differences. At all three sites the early Holocene oak/prairie period is preceded by a period of abundant pine with a limited range of associated genera, either of trees or herbs. It appears to have been an unfavorable time for mesic trees, nor did it encourage the strong development of prairie species which followed in the early Holocene. The rather nondescript vegetation makes climatic inference difficult. At Sheelar Lake the pollen curve for pine is very saw-toothed, with some high and some very low percentages (Fig. 3). This may suggest that this was a time of instability and transition when fire-resistant pines replaced high broad-leaved forest on the upland by a progression of fires. Charcoal studies in progress at Sheelar Lake should test this hypothesis. At the southern sites the pollen curves are not saw-toothed, and a simple dominance by pines in the vegetation seems assured. Sand pine (*Pinus clausa*), a species that grows best in coarse sandy soils, occurs macroscopically at Lake Annie during this period. Completed charcoal studies at Lake Tulane show a low fire incidence during the period of pine dominance around 13000 B.P. Sedimentation at all three sites was organic, indicating that, although surface water was scarce, sedimentary processes in existing lakes were similar to those which followed later in the Holocene. This suggests that there was complete vegetation cover on the upland.

At Sheelar Lake from 14600 to 12000 B.P. (Fig. 3) there is important evidence for the occurrence of high mesic deciduous forest, which reached its best development at about 13500 B.P. (Fig. 3). For over two thousand years pine was scarce, while oak, hickory, beech, ash, elm, hornbeam, and other mesic trees were abundant (Watts and Stuiver 1980). Herbs had low percentage values, and little or no charcoal occurs in the sediments. Beech is south of its present natural range at Sheelar Lake (Ward 1967). The most southerly mass occurrence of beech today is at about the Georgia/Florida stateline and in the Florida panhandle. The highly drained coarse sands that occur around Sheelar Lake today seem an unpromising environment for a species-rich deciduous forest. A similar forest was present at Mud Lake in sediments beyond the range of radiocarbon dating, whereas sand-pine scrub prevails today. The broad-leaved forest at Sheelar Lake dates to a time when ice was still close to its maximum extent in the northern United States, showing that climatic change had taken place at low latitudes by about 15000 B.P. Such early climatic change is not readily detectable farther north. The flora is rather like the

Table 3. Summary of paleoenvironments at Sheelar Lake

NORTHERN FLORIDA — SHEELAR LAKE				
Yr B.P.	Vegetation	Water Level	Inferred Climate	Fire Frequency
0-5 000	pine forest with swamps	high	as today	high
5000-10 000	oak forest and scrub with prairie	high after 8,500 B.P.	less precipitation higher radiation	lower than today
10 000-12 000	pine forest with herbs	low	uncertain	lower than today
12 000-15 000	mesic broad-leaved forest	very low (26 m below present)	high precipitation summer warm winter cool	very low
15 000-18 000			no data	
18 000-24 000	pine forest with herbs	low, shallow lake present	dry, windy silt deflation	high

Table 4. Summary of paleoenvironments at Lakes Annie, Buck, and Tulane

	SOUTHERN FLORIDA — LAKES ANNIE, BUCK AND TULANE			
Yr B.P.	Vegetation	Water Level	Inferred Climate	Fire Frequency
0-5000	pine woodland with swamps	high	as today	medium
5000-12 000	oak forest or scrub with prairie	high after 8,500 B.P.	less precipitation higher radiation	high
12 000-14 000	pine forest with herbs and mesic trees	very low, down 28 m	cooler than present higher precipitation	low
14 000-28 000	pine woodland and herbs, fewer mesic trees	lowest L. Annie, Buck, dry	cooler than present higher precipitation	very low
28 000-50 000	pine woodland, scrub, herbs abundant	low	windy, dry some thunderstorms	high

modern rich forest stands in the Piedmont or in cove valleys in the Great Smoky Mountains. It suggests a summer-warm climate with high precipitation, probably with at least some frost and snow, not a fire climate.

To a biogeographer the flora points to northern Florida as the region in which broad-leaved mesic forest first built large populations before migrating northward over the next two or three millennia (Watts 1983). The inference is that small parent populations survived in this area during the Late Wisconsin. To the archaeologist it is clear that in this period there was a high closed forest, inimical to big game and without much surface water, with all that implies for food resources and shelter.

During the equivalent time in southern Florida there was much less development of mesic forest trees. Elm reaches a small peak at Lake Tulane (Fig. 2). Ash, hornbeam, and hackberry are also more abundant between about 14 000 and 15 000 B.P. than elsewhere. However, this phenomenon is a weak reflection of the very major change at Sheelar Lake. In both northern and southern Florida there is a strong expansion of juniper-type pollen. This pollen type is shared by juniper, cedar, and imperfect specimens of cypress. It is almost certain that the species involved is southern red cedar (*Juniperus silicicola*), represented by abundant fossil leaves at Sheelar Lake. The ecological preferences of this species are somewhat uncertain. It occurs by springs and watercourses, at the margin of mesic woodland, and on shores and islands on the Gulf Coast. It can form quite a large tree, up to 15 m in height, and it appears to require light and proximity to water. It seems to indicate mesic conditions, so that its co-occurrence with mesic trees in the fossil record is consistent with its present-day ecology. Its abundance at the end of the Wisconsin has no modern analog. Its peaks at Lake Tulane correspond with peaks in organic content of the sediment, an unexplained phenomenon.

A submerged rooted aquatic of shallow water, quillwort (*Isoetes* sp.), is constantly present in the Lake Tulane core from 14 000 to 50 000 B.P., indicating a lowered water depth in the lake throughout that period. This plant can grow in relatively deep water (6 m or more) provided there is adequate light penetration; the modern water depth in excess of 22 m presumably limits it to shallower water at the margin of the basin. It is present in the Holocene portion of the core only as traces.

Full-glacial Vegetation

The full-glacial period at Sheelar Lake (18 500 to 23 900 B.P., with a hiatus from 18 500 to 14 000 B.P.) is dominated by pines, with herbs and continuously low percentages of oak, hickory, and mesic trees. Sediments of the period throughout Florida have a distinctive appearance, grading from a somewhat higher silt content to the more obviously organic sediments of the Holocene, although the difference in organic content in percentage terms is not very great. It seems probable that wind was responsible for some deflation of silt particles into lakes and that some sand dune formation took place during the period. This requires further investigation for substantiation. The full-glacial environment at Sheelar Lake can be characterized as pine forest with some broad-leaved trees and herbs. It is possible that a mosaic of upland pine forest prevailed, with open patches dominated by herbs and with broad-leaved trees in sheltered, better-watered places such as by ravines or by lake and river margins. Gold Head Branch beside Sheelar Lake is a spectacular modern example of this type of environment. However, no technique is known at present by which such a mosaic could be documented in a pollen assemblage; more random distribution of the components of the vegetation cannot be ruled out.

Lake Tulane has a complete record back to 50 000 B.P. and, after a hiatus, Lake Annie dates from 30 000 to about 50 000 B.P. at the base. There are fluctuating percentages of southern red cedar throughout the time equivalent of the Wisconsin ice-advance. Before 25 000 B.P. there are fluctuating values of pine, oak, and hickory. The occurrence of jointweed (*Polygonella fimbriata*) and of Ericales (*Ceratiola* sp. [rosemary] and heaths) points to the extension of sand dune vegetation. The presence of Ericales is particularly strongly marked at Lake Annie, which is located near a large stabilized dune system. Rosemary/jointweed vegetation now occurs on high, very dry fossil sand dunes such as mark the extreme southern margin of the Florida Highlands in the Lake Placid area today. Slightly silty sediments in the lakes suggest a windy climate with locally forming dunes and deflation of silt particles. Before 28 000 B.P. at Lake Tulane, high to very high values of charcoal are recorded in the sediments. Fire was evidently more significant at this time than from 28 000 to 14 000 B.P., when charcoal has its lowest values in the profile.

Throughout the period there are strongly fluctuating percentage values for pine, with one long span of low pine values, seen both at Lake Tulane and Lake Annie, between about 40 000 and 45 000 B.P. Herb pollen is at continuously high levels. The high percentages of hickory, consistently higher than at any time in the Holocene, may record the abundant presence of scrub hickory (*Carya floridana*), a small tree endemic to the peninsula. The evidence for fire from charcoal counts suggests that pine stands and broad-leaved scrub were subject to frequent burning. Together with evidence for an expansion of sand dune plants, it can be argued that the vegetation of the time was sclerophyllous and arid in character and that the landscape was open rather than densely forested. Such an environment would have been very suitable for the diversity of large browsing mammals known to have existed during that period (Webb 1974).

Conclusion

For early inhabitants, the most important environmental change took place between 7000 and 5000 B.P., gradually at some sites, apparently more abruptly at others, but terminating by 5000 B.P. True prairie may have been present in northern Florida before that time. This has not yet been sufficiently studied. The sites at which it is best seen, Lake Louise and Mud Lake, are truncated below 8500 B.P., so that its expression in the few thousand years before 8500 B.P. is not known. The development of prairie in relation to soil and topography is also not understood. New studies in progress at Lake Barchampe in northern Florida, southeast of Valdosta, which is surrounded by broad-leaved forest, and at Camel Lake in the Apalachicola National Forest, which is surrounded by pine and sclerophyllous oak forest over coarse sandy soil, should throw light on these problems.

Although prairie was present until 5000 B.P., there was no shortage of surface water, because lakes were filling as early as 8500 B.P. This emphasizes the puzzling character of the behavior of the Florida aquifer. Evidence from Sheelar Lake shows that it reached its lowest level, with its surface at least 26 m below its present height, at between 15 000 and 18 000 B.P. Was this an effect of lowered sea level, reduced precipitation or both? If sea level fell by at least 61 m (Bloom 1971), the effect would have been to create a steeper gradient in the aquifer surface towards the new sea level, and the rate of flow within the aquifer towards the sea would have depended on factors such as the rate at which water can penetrate the local rock and the development of cavern and jointing systems within the rock. These factors may be too complex or unknown for modelling to be possible at present. High precipitation would tend to sustain a high aquifer surface. It seems likely that the lowered water table is derived from reduced precipitation complicated by lowered sea level. There is a poor synchronicity and correlation between known sea level positions and the position of the water table. This may occur as a result of lag effects as sea level has risen. Thus, by 8,000 B.P. sea level had come very close to its present level, although Florida lakes were still relatively shallow but rising. Furthermore, the continuing rise in water tables and swamping of new surfaces after 5000 B.P. accelerated after 2500 B.P. This must surely have been a direct consequence of increased precipitation unrelated to sea level, which had been stable for several thousand years at that time. The causes of the change in the water table at any one time are complex and require further study and analysis; however, they are central to an understanding of Florida's paleoclimates.

To obtain long records, it is necessary to core deep lakes. Lake Tulane, with a water depth of 22.7 m, is the deepest so far cored and has an apparently uninterrupted record. The technical problems of drilling from small boats or rafts at such water depths are considerable, and it is probably not possible to drill in much deeper water. However, very few Florida lakes are known with such deep basins. Unfortunately, comprehensive bathymetric surveys of Florida lakes do not exist, so the possibility of finding new sites in northern Florida that might yield very valuable information is complicated by the need for further survey. Recently some extinct lakes with thick sediments have come to light as a result of phosphate mining or highway construction in the Lakeland/Bartow area. These lakes are simply overgrown and grassed over or sand-filled. They offer the exciting possibility of getting farther back in time and perhaps may provide a complete glacial/interglacial cycle.

The contrast between temperate northern and southern floras within Florida has been noticed. The two areas have parallel behavior, which allows for some correlation. However, the period from 14 600 to 12 000 B.P., which yielded broad-leaved forest at Sheelar Lake, is only weakly reflected in southern Florida, while in the full-glacial period the vegetation of southern Florida was always more open than the apparently closed pine forests of northern Florida. This prompts the suggestion that temperate southern Florida has been a relatively isolated biotic province, with distinctive vegetation and climate. It is not surprising that it is a home for so many endemic species of dry and open habitats (Ward 1979).

Lake Tulane contains traces of tropical pollen genera throughout its profile, but none is ever more than a trace. Studies in Florida have yielded no evidence that the temperate/tropical boundary in vegetation moved north of its present limit at any time in the last 50,000 years. The converse, which has more inherent probability, cannot be demonstrated because, unfortunately, tropical southern Florida has very few lakes, and those so far examined are either shallow or otherwise unsuitable for study. The field situation for finding sites is not promising, so that the paleoenvironments of tropical Florida are the least known in the state and, barring some fortunate discovery of a suitable field site, are likely to remain that way.

Much of the climate analysis in this paper is inferential and descriptive, and lacks the precision that climatologists properly seek. A greater degree of precision can be achieved by more effective use of transfer functions for the pollen data. These depend on the assumption that pollen counts from sediments at the mud/water interface of modern lakes are an expression of the local climate, which may be quantified from climate recording stations. With a sufficient data base of surface samples, counts of fossil pollen from cores can be scanned by computer procedures to match modern samples. By reasonable inference a good match of pollen samples can be extended to an assumption of matching climate. In Florida there is as yet an insufficient data base for the use of transfer functions, but there is a potential difficulty in the universal abundance of pine forest and hence the overrepresentation of pine pollen in present-day sediments. It may be impossible to find analogs for pine-free or pine-poor pollen assemblages. This is a question which cannot be answered without further research.

Certain data relative to paleoclimate can be established objectively by measurement or by the geochemical analysis of fossils. Thus it can be shown by data from North Atlantic marine cores that the seas surrounding Florida may have had only marginally cooler surface temperatures than today at the height of the Wisconsin glaciation (CLIMAP 1981). Warm tropical ocean surfaces are a necessary precondition for major tropical storms and thus precipitation on land. The climatic response to changes of the earth's orbital parameters (date of perihelion, axial tilt, eccentricity) can also be calculated. From 16 000 to 6000 B.P., but especially after 9000 B.P. when the retreating North American ice sheet's effect on the climate had weakened, these factors caused an amplified seasonal cycle with larger seasonal radiation extremes. Summers were warmer and winters cooler than today (Kutzbach and Guetter 1986). These factors may be an important part of the explanation of the difference in climate between the earlier and later Holocene in Florida.

A general circulation model that simulates January and July patterns of temperature, precipitation, and wind for 18 000 B.P., and a comparison of the model reconstruction with the geologic record has been presented by Kutzbach and Wright (1985). It includes a discussion of the climate of the southeastern United States. The model tends to show reduced summer precipitation, perhaps a result of sea surface temperature lowered by about 2°C in the adjacent North Atlantic, a temperature lowering of a few degrees in both mean January and mean July temperatures, and an intensification of southwesterly winds which may be correlated with dune formation. The model provides a very valuable source of questions and comparisons with the paleoecological data which indicate the directions that new research is likely to follow.

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ARCHAEOLOGICAL WET SITES: UNTAPPED ARCHIVES OF PREHISTORIC DOCUMENTS

Barbara A. Purdy

WET SITES are storehouses that stock categories of materials that seldom survive at archaeological sites. Florida's wet sites furnish an excellent example of how these unique classes of objects broaden the data base and permit a more holistic view of the past.

People have lived in Florida for more than 12,000 years. Until recently, the people of the earliest periods were known only by their stone artifacts. Tools made from marine shell were added to the nonperishable inventory about 6,000 years ago, and ceramics were introduced about 4,500 years ago. These three classes of material culture (stone, marine shell, and ceramics), along with limited information about bone remains and settlement patterns, have been the major constituents used to reconstruct the entire prehistory of Florida. Major constituents are types of materials that are recovered in quantities large enough to be studied statistically.

Investigations at water-saturated archaeological sites yield a large portion of the estimated 90% of material culture that is usually missing from upland sites. This expansion of the data base can be used to understand the past more completely and confirm or correct previous interpretations. By assigning a number to each surviving category and by assuming that each category was of equal importance in the culture, a formula can be used to show how many relationships among material items are available for study:

$$\frac{k(k-1)}{2} = X$$

where k = number of categories and X = number of relationships. Thus, if only stone implements are available for study, there are no relationships:

$$\frac{1(1-1)}{2} = 0$$

It is no wonder that the rare find of an extinct mammoth with a point imbedded in its ribs or the recovery of a spearhead hafted to a wooden shaft captivate archaeologists as well as the general public.

If three major categories of material culture survive, for example, stone, shell, and ceramics, then three relationships can be studied:

$$\frac{3(3-1)}{2} = 3$$

At Hontoon Island, there are seven major constituents of surviving material culture: stone, shell, ceramics, bone, wood, noncultivated plants, and cultivated plants (Fig. 1):

$$\frac{7(7-1)}{2} = 21$$

The four organic categories, that is, bone, wood, noncultivated plants, and cultivated plants, when added to the three nonperishable categories, provide magnitudes of associations that usually do not exist. Obviously, these added relationships furnish greater possibilities for interpretation.

Now it can be argued that the use of any important cultural item is vastly more complex than I have depicted by assigning each category only one value. Stone, for instance, played an important part in all three of the major components of culture: technology, social organization, and ideology. Stone technology includes such matters as knowing where the quarries are, fracture properties, quality, and advantages of thermal alteration. Social considerations include such issues as how trips to the quarry fit into the rest of the schedule, what kinds of implements are manufactured, and how stone tools functioned within the social web. Ideology encompasses the concepts that people have about the items they use or the typologies they manufacture and how closely their skills permit them to adhere to an ideal. Who knows how many symbols were communicated by the object shown in Figure 2? Thus, by assigning a value of three to stone, one each for technology, social organization, and ideology, there are actually three associations within the stone category:

$$\frac{3(3-1)}{2} = 3$$

If each major constituent of material culture recovered is assigned a value of three, then stone, shell, and ceramics provide 36 relationships:

$$\frac{9(9-1)}{2} = 36$$

and the seven major categories from Hontoon Island can be expressed as:

$$\frac{21(21-1)}{2} = 210$$

Thus the four categories that usually do not survive, when added to the three nonperishable categories, increase the number of possible relationships from 36 to 210.

Considered in this way, we find that the added constituents available for study from archaeological wet sites are not just single additional pieces of material culture; they provide an exponential potential for increasing our understanding of relationships and interrelationships within the three major components of culture. The past, as the famous expression says, is seen through a mirror darkly, but the recovery of great quantities and varieties of additional classes of artifacts from wetland sites, despite a murky matrix, produces an image that has not been seen before.

With these thoughts in hand, I would like to insert a few words here about the promise that wet sites contain to unravel mysterious abstractions. There have been efforts recently by some archaeologists to "recover mind" from archaeological sites. The dictionary says that ideology is "a people's way of thinking about the body of

FIGURE 1 Specimens representing the seven major categories of material items recovered at Hontoon Island. Wood includes a cypress pole, a cypress chip, and a pine lighter knot. Cultivated plants include cucurbits and corn. Noncultivated plants include cabbage palm, saw palmetto, black gum, acorns, and hickory nuts. Pottery shown is St. Johns Checked Stamped. Stone includes a Pinellas point and a limestone plummet. Shell includes an adze or scraper, a gouge, and a fish hook. Bone includes decorative and utilitarian items.

FIGURE 2 Newman point: a 6,000-year-old spearhead from Florida.

ideas on which a particular system is based" (Webster's New World Dictionary 1970:696). Essentially ideologies are values which the dictionary defines as "that quality of a thing according to which it is thought of as being more or less desirable, useful, or important; that is, its worth or its degree of worth on a scale of values" (Webster's New World Dictionary 1970:1568). It is enlightening to apply these definitions to materials analyzed from archaeological wet sites.

1. The added categories available for study from wet sites furnish specific data about choices within a class of perishable material culture. For example, at Hontoon Island, Lee Ann Newsom has identified 30 species of wood. Eventually this information may permit us to understand why the aborigines valued particular woods over others for certain tasks. We may learn something about accumulated knowledge of wood properties, woodworking techniques, availability of species, environment, and much more.

2. The added categories furnish data about interrelationships; that is, the importance of one category relative to several other categories. This topic is particularly useful when considering the importance of one plant species to another, cultivated plants to non-cultivated plants, animals to plants, or aquatic to terrestrial resources. Seldom are there the quantities of plant and animal remains as exist at wetland sites (Hontoon Island for example) to make these determinations.

3. The added categories furnish data about cultural practices in ways not usually possible. Since wet sites supply information about diet, we can suggest the kind of food that was put into the ceramic and wooden bowls (Fig. 3) that are recovered. The adze marks on wood (Fig. 4) can be matched to the shell adzes themselves,

FIGURE 3 A 2,500-year-old bowl recovered from Stricklin Peat Co. near Grandin, Florida.

permitting a study of woodworking techniques and, perhaps, motor skills. If we are lucky, we may sometimes recover the finished products (Fig. 5). All of these actions involve ideals and values of the people who produced them and speak to us more clearly about the past. Just as society is not made up of a single technique or a single social practice, it is also not made up of one big generalized worldview but rather thousands of interlocking doctrines and opinions.

4. The added categories furnish data about continuities in cultural practices. For example, shark teeth were used as woodworking tools to produce 6,000-year-old specimens recovered from the Bay West site in Collier County (Beriault et al. 1981) and 2,000-year-old carvings at Fort Center in Glades County (Sears 1982). Northward and across the state, shark teeth finishing marks were found on a 1,000-year-old broken canoe paddle from Hontoon Island in Volusia County (Purdy 1987 a,b; Fig. 6). A 7,600-year-old double-ended wooden pestle was found with a child burial at the Windover Site (Doran, personal communication) and thousands of years later a similar type was deposited at Belle Glade (Willey 1949), in the charnel pond at Fort Center (Sears 1982), and in the court of the pile dwellers at Key Marco (Gilliland 1975). Firestarters have the same longevity (Beriault et al. 1981; Purdy 1987b).

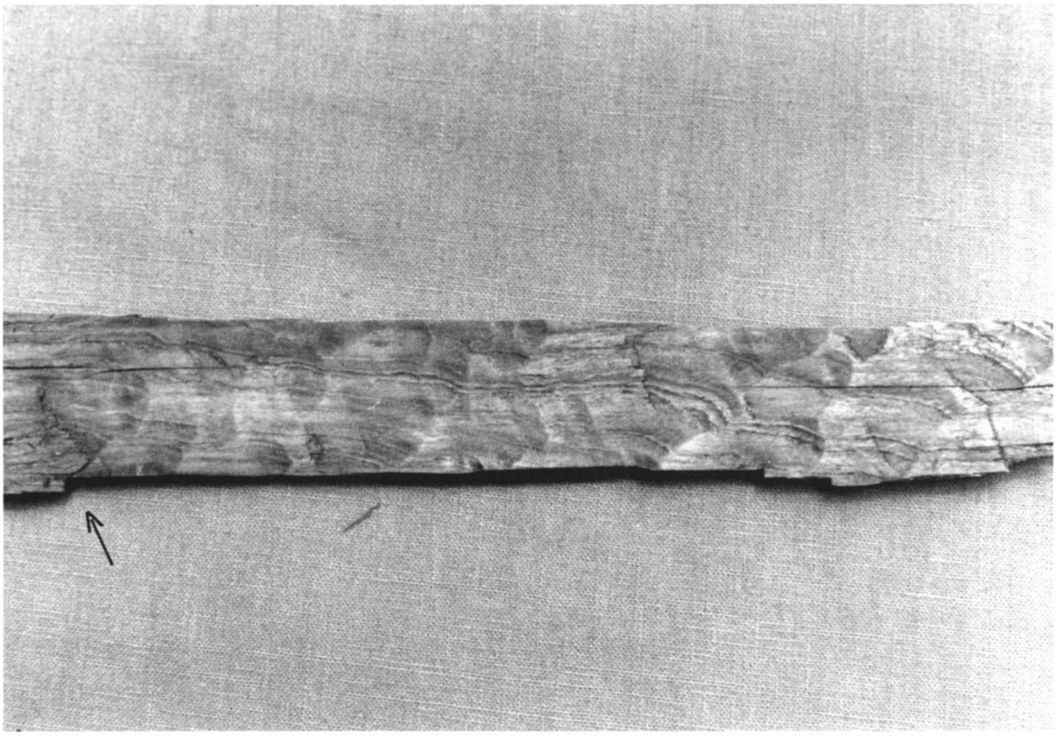


FIGURE 4 (a) Wood "slat" exhibiting extensive woodworking marks; (b) magnified portion of *a* showing tool marks in relief. Arrow on *a* points to area of magnification.

5. Wet sites furnish data about discontinuities or modifications in cultural practices. For example, a dramatic change in burial customs can be documented for Florida. Archaic Period burials were placed in moist depressions or ponds as at Windover (Doran and Dickel, this volume), Little Salt Spring (Clausen et al. 1979), Bay West (Beriault et al. 1981), and the Republic Groves site (Wharton et al. 1981). We would, in fact, have little or no significant information about these sites if it were not for this type of burial practice. Nearly all of the materials recovered from them were of a perishable nature and survived only because of anaerobic conditions. During the Late Archaic and more recent time periods, people preferred to bury their dead in mounds often constructed specifically for that purpose. Since disposal of the dead is usually associated with a concern for the supernatural and accompanied by prescribed rituals, one would expect traditional burial practices to endure for a very long time. It is interesting to speculate about the events that might have stimulated a change in prehistoric burial practices in Florida. Rising water tables during the mid-Holocene can be suggested as a practical reason for the adoption of a new type of cemetery arrangement.

At Hontoon Island it has been possible to document several major modifica-

tions or disruptions in Indian lifeways during the early sixteenth century, following European contact. These changes would not have been noted at all if excavations had been restricted to the terrestrial portion of the site (Newsom 1987; Purdy 1987a; Purdy and Newsom 1985; Wing and McKean 1987).

6. Temporal and regional differences in prehistoric wooden art styles can be identified as a result of the preservation of archaeological material in Florida's wetlands (Fig. 5). These art styles are not produced in stone as they are throughout the rest of the southeastern United States because the type of stone suitable for the production of art objects does not occur in Florida. With the survival of these unique artifacts, it is possible to propose that there may have been cultural divisions within the state that are not readily perceived through subsistence practices alone. See Schwehm (1983) for a comprehensive discussion of Florida's wooden carvings, especially those portraying animals.

Each wet site provides more diverse information than does an upland site in the same area, and each wet site is different with regard to what it reveals about the past. In Florida, some wet sites have yielded elaborate wood carvings like Key Marco (Cushing 1897; Gilliland 1975) or Fort Center (Sears 1982; Fig.5), human

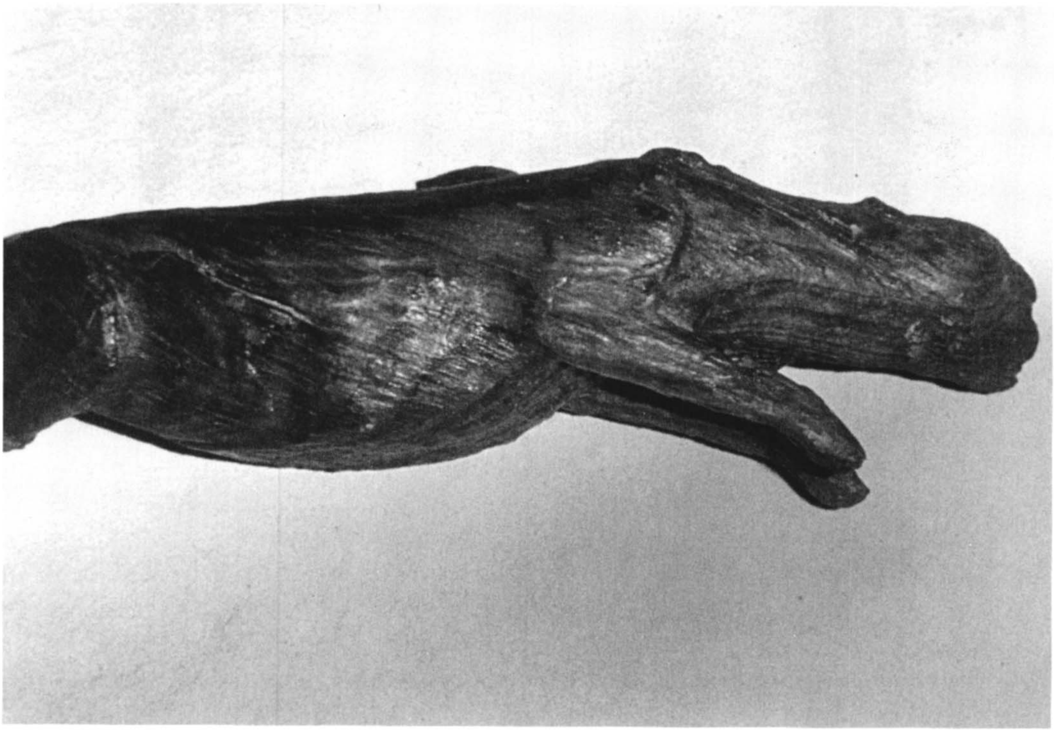
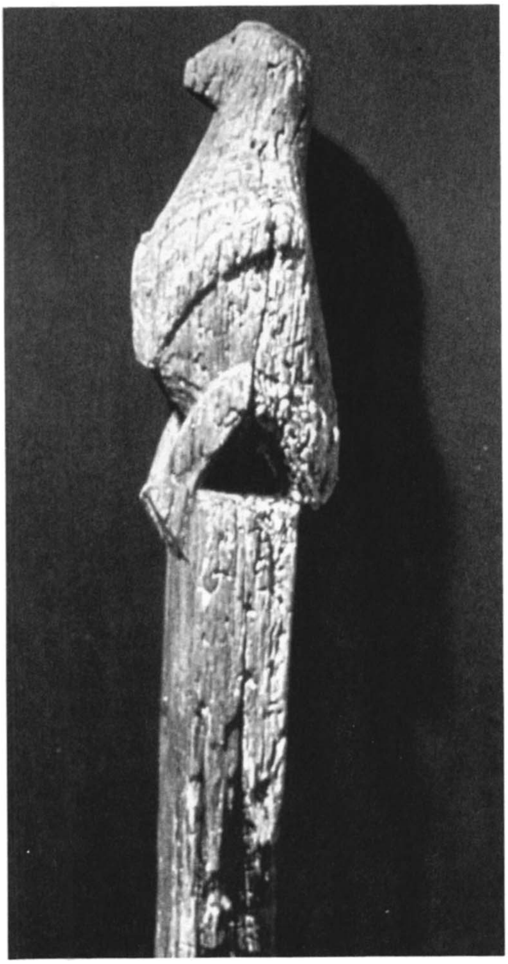


FIGURE 5 Wood carvings from Florida: (a) a 2,000-year-old otter from Fort Center Site on Fisheating Creek in south Florida (reportedly is holding a fish in its mouth); (b) front and side views of an otter (thought to be about 800 years old) from the St. Johns River near Hontoon Island in central Florida. This specimen is holding a fish. Note the contrast in art styles.

skeletons like Windover and Bay West (Beriault et al. 1981), grave goods like Windover and the slough at Little Salt Spring (Clausen et al. 1979), and dietary items like Hontoon Island (Newsom 1987; Purdy and Newsom 1985; Wing and McKean 1987), and all of them provide regional information about environment. From some areas of the world, for example the bog deposits of northern Europe, we have learned how people wore their hair, dressed themselves, and manicured their nails 2,000 years ago (see the paper by John Coles on bog bodies in this volume). This view of "real" people was not possible under any other conditions except in dry tombs and caves until the invention of photography in the nineteenth century.

In summary, each wet site has added categories of materials that are not usually preserved in the archaeological record and these constituents, as shown by the formula, can be used to enhance exponentially the view of the past that now exists. It is logical that information gained from wet site excavations can be used, with caution, to make reasonable extrapolations about objects and activities that were



formerly present on nearby upland sites. Analyses of wet site deposits detect continuities and changes in cultural practices that are ordinarily only distinguishable through stone and ceramic typologies. Wet site remains can be compared globally to each other and to organic materials preserved under extremely dry conditions, like on the coast of Peru. But archaeologists do not want to be the only beneficiaries of this increased knowledge. We want the public to be aware of and care about the cultural heritage that is lost when development projects are permitted to destroy wetlands before investigations can be conducted.

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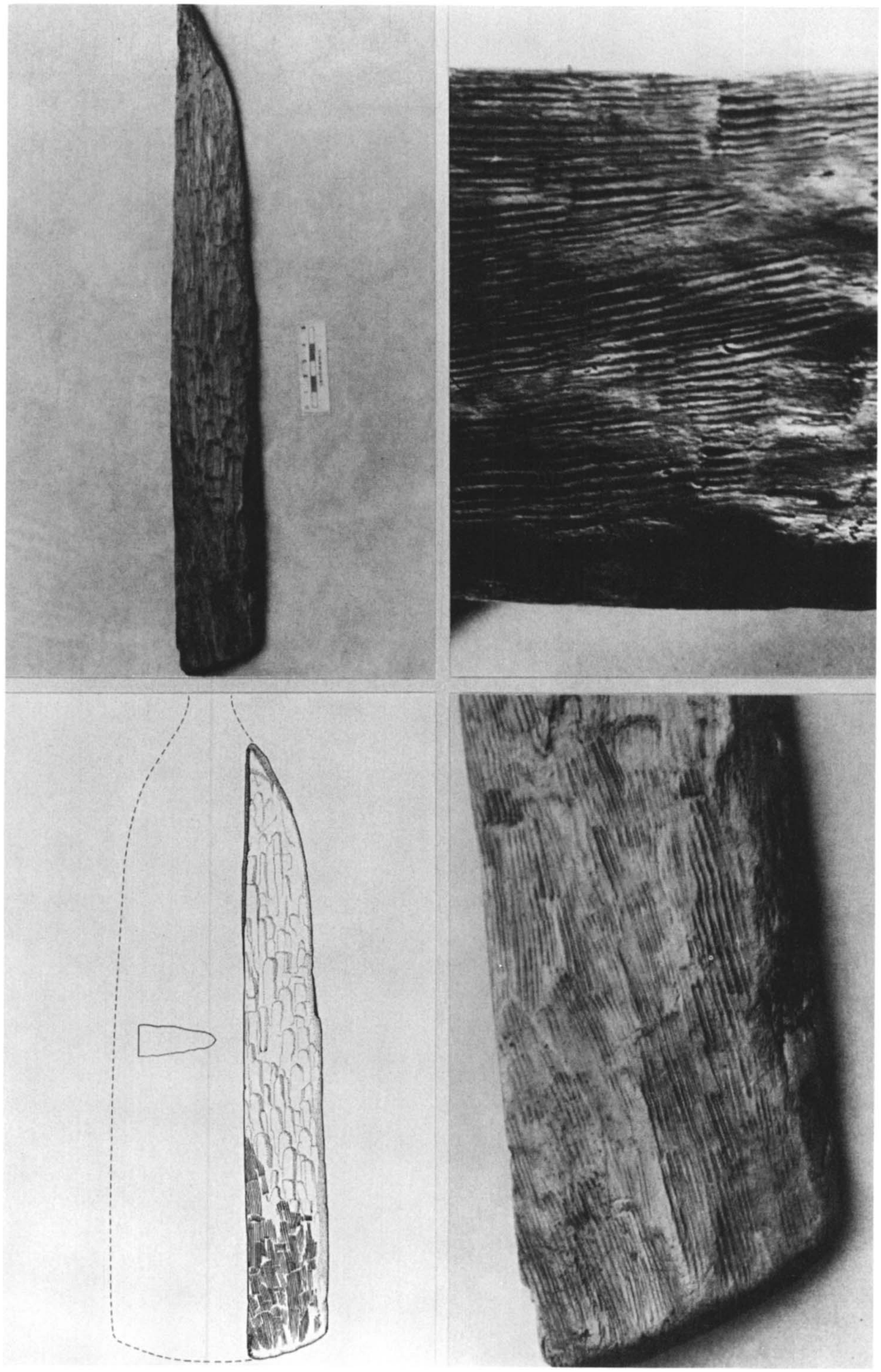

FIGURE 6 A 1,000-year-old canoe paddle showing shark teeth and stone or shell adze marks. Specimen was recovered from Hontoon Island in 1980.

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