FOSSIL POLLEN AND ITS BEARING ON THE ARCHAEOLOGY
OF THE LEHNER MAMMOTH SITE

by

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A Thesis Submitted to the Faculty of the
DEPARTMENT OF ANTHROPOLOGY
In Partial Fulfillment of the Requirements
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May 16, 1958
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PREFACE

This study deals with the preparation and analysis of fossil pollen grains. Pollen was extracted primarily from post-glacial sediments collected from the Lehner Mammoth Site, near Hereford, Arizona, which was excavated by the Arizona State Museum, University of Arizona, during the months of November to December, 1955 and February to March, 1956. The orientation is toward the application of pollen analysis to an archaeological problem.

The study represents only one phase of the geo-chronological approach that has been applied to the site, and is the first full scale problem in pollen analysis conducted at the University of Arizona. A grant from the Gila Pueblo Archaeological Research Fund made it possible to initiate and carry through to completion this research. The funds were used to purchase chemicals and equipment for the laboratory and for microscopic work.

I wish to thank Mr. Edward F. Lehner for his kind permission to work on his property and to collect freely sediment samples from the area of the excavation. As a rancher his interests lie not only with the present floral conditions but with those of the past as well.

Due to the nature of the work it has been necessary to enlist aid and to consult many people at the
University. Dr. Walter S. Phillips of the Department of Botany, University of Arizona, kindly provided laboratory space for the initial phases of the work. The later and final phases of the laboratory work were conducted at the Geochronology Laboratories, University of Arizona, under the guidance of Mr. Terah L. Smiley, Director of the Laboratories. The project would not have been possible without the help of both these men and the facilities which they made available.

Many thanks are due to those individuals who collected the sediments from the excavation area. In particular, I wish to thank Messrs. Dick Shutler, Jr. and Lloyd Collins, both of the University of Arizona, for the several sets of samples they collected, and to Mr. Shutler for the preliminary work he conducted in connection with testing for the occurrence of pollen in the sediments. Mr. William W. Wasley, Archaeologist, Arizona State Museum, supervised the field excavations at the Lehner Site. His detailed maps and photographs allowed me to interpret more easily the complexities of the geological situation at the site as they were related to this study.

Without a technique to extract pollen grains from the sediments, the analyst would find his work impossible. To Drs. Raymond M. Turner and Edwin B. Kurtz, both of the Department of Botany, University of Arizona, I am grateful for the first of three methods used on the Lehner sediments.
I thank Bernard C. Arms, University of Arizona, for his assistance and suggestions concerning Method 3 and problems encountered in the laboratory.

Mrs. Lucy Cranwell Smith kindly devoted her time and skill in introducing me to the microscopy of pollen grains. To Dr. Paul S. Martin, Research Associate, Geochronology Laboratories, University of Arizona, I am deeply indebted for criticism and advice. His indispensable assistance in identifying and helping me to identify the extracted pollen is greatly appreciated.

I feel a particular sense of gratitude to the members of my thesis committee: Dr. Emil W. Haury, Head of the Department of Anthropology, University of Arizona, Dr. Edwin B. Kurtz, and Mr. Terah L. Smiley. Dr. Haury, as director of the thesis, was an untiring advisor and counselor. His friendly and continuing interest in and enthusiasm toward the project was a constant source of encouragement. Dr. Kurtz gave freely of his time and effort to develop the project and initiate the laboratory work. With his searching inquiries he developed many lines of investigation that could have been overlooked. Mr. Smiley was in charge of the work at the Geochronology Laboratories. His advice and guidance were unfailing from the time he suggested that I undertake the problem until it was brought to completion. The many hours he devoted to discussion added greatly to this work.
INTRODUCTION

The Problem

The object of this study is to show what types of vegetation, as represented by fossil pollen grains, were present at a time when prehistoric men were hunting mammoth and other now extinct animals in southeastern Arizona.

During the winter months of 1955 and 1956, excavation by the Arizona State Museum at the Lehner Mammoth Site produced striking evidence of the association of human artifactual remains with skeletal material of several extinct animal forms. During the excavation, samples of the sediments were collected for various types of research including pollen analysis.

To recover the fossil pollen for microscopic examination three methods of extraction have been used, each with varying degrees of success. The reason for this was due to several problems that developed during the procedural steps of these methods. These problems are discussed in the chapter on Methods of Pollen Extraction.

Two phases of this problem, the construction of pollen spectra and a local diagram, could not be carried to completion due to the lack of facilities and the pioneer-
ing aspect of this work. Only in recent months has it been possible to develop the modern pollen herbarium. A pollen analyst must have a personal knowledge of modern pollen grain forms before he can identify and verify by comparison his observations of the fossil pollen recovered.

The History and Principles of Pollen Analysis

History

The study of pollen morphology has an impressive history in Northern Europe dating back some several centuries (Wodehouse 1935: 15-100), but it has been through the investigation of late-Quaternary plant remains in peat, and the necessity for some magnification of these remains that has led to the development of pollen analysis. In 1836 and 1838, Göppert and Ehrenberg brought to the attention of the Europeans the occurrence of fossil pollen in pre-Quaternary deposits. C. A. Weber and his followers (1893 and later) were the first to study pollen grains in a systematic manner. However, these initial studies were qualitative, and it was not until 1905 that G. Lagerheim, University of Stockholm, carried out percentage calculations. Lehnart von Post, a Swedish geologist, was the first worker to fully realize the potentialities of the stratified fossil record and to utilize the technique of percentage pollen analysis. With the publication of von Post's methods in 1916, the field grew rapidly as did the
vast body of European literature on the subject (Faegri and Iversen 1950: 12-13). From about the 1920's pollen analysis has been the dominant procedure for investigation of late-Quaternary vegetation and climate development. The elaboration of the pollen analytical technique has provided an instrument of research which allows for intimate glimpses into the conditions of life during prehistoric times (Iversen 1956: 36-41). Pollen analysis has gained the reputation of being one of the most important aids to the archaeologist, supplementing his knowledge of human artifacts (Faegri and Iversen 1950: 13). Vivid testimony of the value of pollen analysis to the European archaeologist is portrayed in such publications as Excavations at Star Carr (Clark 1954), and The History of the British Flora (Godwin 1956). The past four decades have then gathered many interesting facts and conclusions which have developed into a major source of knowledge of the past in the Old World.

The progress in America has not been similar to that in Europe. It was not until 1928 that P. I. Draper published the first paper on pollen analysis (Sears 1951: 241). The slow growth of pollen work in the New World and generalizations derived therefrom is due to many factors among which are: the richness of the forest flora, the diversity of techniques, the lack of standardization in reporting results, and problems of pollen identification
Most of the studies published have been primarily concerned with the general sequence of vegetational history. Of these reports, few are brought into an archaeological context and fewer still are incorporated in archaeological reports. From an archaeological point of view the reasons for this failure are perhaps many.

Deevey develops at least two of the reasons: pollen analysis is not a "precise chronological method", and at best deals with unknown time segments; and secondly, "the archaeologist is compelled by general considerations to doubt that any known culture can boast an antiquity measureable in the thousands of years required by the pollen analyst (Deevey 1944: 136)."

Exceptions in studies such as those of Benninghoff (1942), Hansen (1942, 1951), and Sears (1951) have provided data which are contrary to these thoughts and have worked to overcome the reluctance on the part of the archaeologist to adopt this "new" technique.

Prior to 1955, pollen analysis in the United States had its primary emphasis in the cool, humid, and glaciated areas. Like a large open fan, pollen studies have been applied over the United States from the Northwest Coast to the Southeast and Texas, but with one exception (Sears 1937) the base of the fan, the Southwestern United States has received little attention. Reasons for this void are in part due to the reliance upon other techniques of dating, both relative and absolute, and the difficulty encountered in extracting fossil material from arid land.
sediments. In 1937, Paul B. Sears reported the first attempts at exploring the fossil pollen record in Arizona with the analysis of canyon silts from Kayenta, Arizona. It was not until eighteen years later that another study was undertaken. This analysis by Roger Y. Anderson (1955) reported the results of his examination of extracted pollen from Ramanote Cave, southern Arizona. Clisby and Sears (1956) published a pollen profile for a core taken from the San Augustin Plains, New Mexico, which provides the longest and most complete record available for this area to date. Anderson (1958) later published the results of his investigations of cave deposits in the Grand Canyon.

These four papers represent to date the published pollen analytical studies in the Southwest. Other investigations have been made and sediment samples taken from archaeological sites, but as of the present time have not been reported.

From the published record it becomes quite evident that the data on the post-glacial changes in vegetation are only meager and tentative. The status of pollen analysis in Arizona is not at a stage where correlations can be made, for we have yet to establish the broad outlines of the vegetational history.

Principles

Pollen analysis is a method of studying the problems of Quaternary history through the quantitative changes in
the fossil pollen record. The method is based on the stratigraphic principle and the technique of studying pollen grains is applied micropaleontology.

An essential step in the reproduction of flowering plants is the formation and liberation of pollen grains. A tetrad of four pollen grains is formed within the anther of a flower as a result of the division of the pollen mother cell. When the pollen is shed from the anther, this tetrad usually breaks apart and liberates four mature pollen grains. Some of these grains will be transferred to the stigma of another flower and will fertilize and begin their role in the reproduction of the species (Kurtz and Anderson 1955: 113). Vast numbers of pollen grains are produced in this manner to be transported by insects and winds. The plants dependent on wind-pollination produce and disseminate into the air the largest quantities of pollen grains, the majority of which gradually sink to the earth's surface in a "pollen rain." Most of these grains are destroyed by oxidation, but many become trapped in terrestrial or aquatic deposits and are preserved. As such deposits accumulate they bury the "pollen rains" and in so doing preserve stratigraphic records of the local plant life.

By employing mechanical and chemical treatments to the preserving matrix, pollen can be concentrated on microscope slides and studied by the use of the microscope.
Grains, upon examination, display a wide range of sizes, shapes, arrangement of germ pores, wall thicknesses, and surface morphology.

Identification of post-glacial pollen grains is made by taxonomic keys and classification systems, and in the final analysis by comparative studies with material from a pollen herbarium.

After the pollen grains from a sample are identified or classified, the relative frequencies of each genus or species are calculated by counting the number of grains and determining the percentages of the total. "The number of grains which must be counted depends on the type of sediment, the number of species represented in the sample, scope of the study, and the statistical accuracy desired. Generally 100 to 200 grains are considered a minimum number under any condition (Kurtz and Anderson 1955: 118)."

The relative frequencies of each horizontal sample is called a pollen spectrum, and a stratigraphic series of spectra form a pollen diagram. The pollen diagram indicates the changes in composition of the vegetation of one locality for a certain period of time. By establishing a number of pollen diagrams, a region's vegetational history of post-glacial times can often be reconstructed. The interpretation of climatic trends and other environmental changes from a number of diagrams is one of the primary objectives of pollen analysis (Hansen 1947: 7).
Because the pollen analyst deals with material arranged in a vertical column, he must rely on the data derived independently from archaeology, climatology, geology, radiocarbon, etc. for time markers in order that all may form a coherent scheme (Godwin 1951: 7).
II
THE ENVIRONMENTAL SETTING OF THE LEHNER MAMMOTH SITE

The San Pedro Valley

The Lehner Mammoth Site is located in the upper basin of the San Pedro Valley, Cochise County, southeastern Arizona.

On reviewing a topographic map of Arizona, it becomes apparent that the state is divided into three physiographic regions: the northern plateau, the central mountain region, and the southern desert region (Arizona Underground Water Commission 1952: 10). The northern plateau occupies the northeastern third of the state with altitudes varying from 4,000 to 7,000 feet. The mountainous region, trending from the southeast in New Mexico to the northwest into Utah, lies between the northern plateau and the southern desert. This region is comprised of rugged mountains with narrow valleys and fast running streams. The southern and western parts of the state are included in the desert region. Eight greater valleys comprise this division, all of which are a part of the Gila River drainage system. One of these valleys is the San Pedro. This alluvial-filled valley in the Mexican Highland Section of the Basin and Range Physiographic Province extends through portions of Cochise, Pima, and Pinal Counties.
Topography

The San Pedro River, second only in importance to the Salt River as a tributary to the Gila (Gatlin 1926: 183), runs within the narrow structural trough of the San Pedro Valley. The river rises in the rolling prairie country east and north of Cananea, Sonora, Mexico at an elevation of about 5,000 feet above sea level and flows in a northwesterly direction some 170 miles to its confluence with the Gila at about 1,950 feet near Winkelman. The river is perennial in the upper valley, but intermittent in its lower reaches. Bordering the river are nearly parallel mountain ranges and range complexes, 10 to 20 miles apart, which vary in elevation from 6,000 to 9,000 feet above sea level.

The San Pedro Valley, in the vicinity of the upper basin, is about 10 miles across and is flanked by the Huachuca Mountains (west) and the Mule Mountains (east). Along its course the river falls from 5,000 feet in Sonora, Mexico to 4,225 at the international border and 4,000 feet near Charleston. On an east-west transection of the west side of the valley the elevation lowers approximately 100 feet per one mile from the base of the Huachuca Mountains over the alluvial fan to the river bottom.

"The upper basin, extending from Benson southward, contains extensive deposits of Pleistocene and Pliocene Age. Recent alluvium in the valley's axis is quite deep, quickly
Figure 1. General map of the Hereford area, Cochise County, southeastern Arizona (top). A plan view of the modern arroyo and the Lehner Mammoth Site, showing the approximate locations of the sedimentary columns and units (bottom). (after Haury and others, in press)
Figure 1.
deposited and quickly eroded because of the steep gradient. Fossil remains are found chiefly in the older alluvial deposits along the edges of the inner valley and away from it in tributaries (Haury 1953: 1). The Pleistocene beds and unconsolidated recent valley fill are composed of coarse unsorted boulders, gravel, sand, silt, and clay. These deposits are exposed in arroyo cuts produced by the present erosion cycle (Antevs 1952: 375).

A number of soil types have developed in this region due to the diversity of climate and vegetational types. The soils in the intermountain basins and valleys are of three major groups: Red Desert soils, Reddish Brown soils, and Noncalcic Brown soils (Darrow 1944: 316). In the upper basin the Reddish Brown soils on the piedmont slopes are associated with grassland-desert shrub types and the Noncalcic Brown soils which occur along the margins of the basin are under grass cover, chaparral, and lower oak woodland. These soils, mainly sandy in texture and low in humic content, are derived from the materials of the nearby mountains. A calcareous hardpan (caliche) underlies the soil in some locales. Soils found in the upper woodland and conifer forests are largely of the Gray-Brown Podsolie type (Wallmo 1955: 467). Studies of a definitive nature relating plant distribution to soil character have not been made.
**Climate and Vegetation**

Due to the 4,000 feet variability in altitude and exposure found in the upper valley, there is considerable change in climatic conditions. From the published weather and floral records available for the locale under consideration, it is possible to infer general characteristics about the upper valley. Southern Arizona climate is characterized by warm to hot summers and cool winters. In the mountain regions summers are cool and winters cold.

The climate of the San Pedro Valley is thought of in general terms as semiarid and mesothermal. Thornthwaite's detailed system classifies the region as follows: semiarid climatic type, with a moisture deficiency-super surplus index of -20 to -40; third mesothermal, with a thermal efficiency of 33.66 to 39.27 inches, with little or no water surplus in any season, and a summer concentration of thermal efficiency from 48.0 to 51.9 per cent (Thornthwaite 1948, plate 1, facing p. 94).

From the ecological position, the upper valley is Apachian in Dice's system of biotic provinces (Dice 1943: map I, facing p. 4). Four life belts are to be found in this biotic province: the desert belt, arid grassland belt, encinal belt, and the montane belt. Of the four characteristic life belts, three are fully represented in the upper valley - arid grassland, encinal, and montane. For the west side of the valley and the Huachuca Mountains three
vegetation zones are outlined by Wallmo: scrub and grassland, encinal, and forest (1955: 469–480). (These zones are generally coincident with Marriam's classification of Lower Sonoran, Upper Sonoran, and Transition Life Zones – Wallmo 1955: 469.) A brief characterization of Wallmo's vegetation zones follows:

Desert Scrub and Grassland Zone (4,000 – 5,000 feet)
The Desert Scrub is found over restricted locations in the vicinities of washes in the lower desert grassland. The dominant plants are whitethorn (Acacia constricta), creosotebush (Larrea tridentata), and occasional mesquites (Prosopis juliflora), yuccas (Yucca elata), and Mexican-tea (Ephedra trifurca). Grasses are sparse and typified by tobosa grass (Hilaria mutica). Moisture-loving plants such as the Arizona sycamore (Platanus wrightii), Arizona ash (Fraxinus velutina), willow (Salix spp.), and oak (Quercus spp.) are found in isolated stands along the river bottom. Desert grasslands, adjacent and rising above the desert scrub zone, show a dominance of black grama (Bouteloua eriopoda) changing with an increase in elevation to bluegrama (Bouteloua gracilis). Beardgrass (Andropogon barbinodis), curly mesquite (Hilaria belangeri), false mesquite (Calliandra eriophylla), and Mexican-tea complement the dominant grasses. The tall grass, Sacaton (Sporobolus wrightii), occurs along the drainage areas, bottom lands, and swails. Mesquite and blackbrush are encroaching upon locales once characterized by the blue grama grassland (Darrow 1944: 345). Above this zone lie two other zones (Encinal and Forest), primarily on the slopes of the Huachucans, neither of which is characterized by distinct elevational zones of vegetation because of the dissected nature of each mountain side (Wallmo 1955: 479).

Encinal Zone (5,000 – 7,000 feet)
Oak (Quercus) is the "dominant single genus of trees in the Huachuca Mountains (Wallmo 1955: 473)." Wallmo (1955: 473) breaks this zone into two types: oak woodland, at elevations slightly below 5,000 feet and upward; and chaparral, at 5,000 feet and higher. At the lower elevations the first oak to appear along the washes is the Mexican blue oak (Quercus oblollyfolia). Other oaks such as the Emory (Quercus emoryi)
and Arizona white oak (Quercus arizonica) follow with a rise in elevation. The oak woodland is best developed in the localities of canyons and northern slopes. Other trees and shrubs occurring in this zone are manzanita (Arctostaphylos pungens), squawbush (Rhus trilobata), and pinon (Pinus cembroides). Characterizing the canyons are Arizona sycamore, cottonwood, willows (Salix gooddingii, S. exigua, etc.). What is termed chaparral is a shrub mixture of the oaks and the other plants found in the oak woodland. Between 5,500 and 7,500 feet in certain locations and elevations are found pines mixed with the oaks, a pine-oak woodland. The mixture of forest trees includes Chihuahua pine (Pinus chihuahuana), Apache pine (Pinus latifolia), and ponderosa pine (Pinus ponderosa) and Mexican white pine (Pinus flexilis), as well as Douglas fir (Pseudotsuga taxifolia), ash (Fraxinus velutina), sycamore, juniper (Juniperus deppeana), pinon, and Arizona cypress (Cupressus arizonica) in the canyon bottoms.

Forest Zone (Above 7,000 feet)
This zone is subdivided into three smaller units (Wallmo 1955: 479-490). In the Pine-Douglas Fir-Oak zone the most abundant trees are Douglas fir, Mexican white pine, Arizona pine (ponderosa), Gambel oak (Quercus gambelii), maple (primarily Acer glabrum), ash and New Mexican locust (Robinia neomexicana). Pine-Fir forest - "The highest vegetational zone in the Huachuca Mountains is characterized by white fir (Abies concolor), Douglas fir, several pines and aspen (Populus tremuloides). This belt is mainly restricted to the cool north and northeast exposures of Miller Peak and Carr Peak from the summits (9,445 and 9,214 feet) down to about 7,500 feet (Wallmo 1955: 479)."

No attempt has been made to characterize the fauna of the upper valley because this subject is adequately treated by Hoffmeister and Goodpaster (1954), and is not directly involved in this study.

For a more detailed picture of the upper basin region one should consult Darrow (1944); Hoffmeister and Goodpaster (1954); and Wallmo (1955).

The growing season in the upper valley is long, 232 days at Ft. Huachuca (Wallmo 1955: 468). For the
natural vegetation there are two growth seasons which are a function of precipitation. Rainfall records provide data to show that precipitation occurs in two distinct periods: a summer maximum fall during July through September, and a secondary period from December through March, with the driest period from April to June. These two periods furnish 43 per cent and 35 per cent respectively of the year's annual precipitation (Smith 1956: 62). The summer rains are usually severe thunderstorms of varying distribution and duration. This is the time when the majority of growth occurs; a period when the perennial grasses grow and mature. Those rains of the winter and spring seasons are of relatively less intensity and of longer duration. Spring is a critical period because of the plants' dependence on the late winter rains (Wallmo 1955: 469). In the broad intermountain valleys precipitation falls during the winter primarily in the form of rain, however, in the higher elevations (conifer forests) snow is the prevailing form (Darrow 1944: 316). Rains in this region tend to be local in character, and vary from year to year: 9.12 inches in 1947 versus 22.27 inches in 1949 at Ft. Huachua (Hoffmeister and Goodpaster 1954: 9, after Wallmo 1951: 2).

In general terms the Upper San Pedro Valley lies within a region which receives 10 to 15 inches of precipitation annually (Darrow 1944: 316). Mean monthly and annual precipitation records for this part of the valley are not
available.

Relative humidity is low in Arizona, ranging from 40 to 60 per cent annually. Readings of 5 per cent or less are not unusual during the summer in southern Arizona. For the winter months the relative humidity is high, but drops during the warmer drier months of February through June. The humidity rises during the summer rains, however, not exceeding that of the winter period (Smith 1956: 84).

The upper basin is in an area which is reported to receive "more than 80 per cent of possible sunshine (Smith 1956: 88)." Both sunshine and wind have a relationship to the amount of water available to plants. Winds are persistent, but velocities light throughout most of the year, contributing to the evaporation of water from soils and free water sources. The evaporation rate is high, 80 inches per year (Wallmo 1951: 2), owing to the low humidity and high temperatures.

Differences in altitude not only effect the vegetation of the region, but also play an important function in the temperature extremes found in the valley. With an increase in elevation above 4,000 feet, there is a decrease in mean temperature of about 4° to 7° per 1,000 feet (Smith 1956: 15, 30). Spring brings on rising temperatures and from May to September days are usually hot (sometimes exceeding 100° F.), and the nights are cool.
Summary

The characteristics of topography, vegetation, and climate represent the conditions prevalent in the Upper San Pedro Valley today. These present day conditions form the foundation for further investigations into the paleo-climatic history of the region.
III
THE LEHRER MAMMOTH SITE

In the past ten years the San Pedro Valley has been the scene of much archaeological activity.

It is of interest to note that the excavations have produced remains that fall on the extremes of the prehistoric continuum in southeastern Arizona. The Amerind Foundation has formed its research activities on the historic and late prehistoric end of the continuum (Di Peso 1951, 1953). The Arizona State Museum, searching for more ancient evidence of man's occupation in the area has investigated two early man stations in Cochise County, Arizona: one near Naco, Arizona (Haury and others 1953), and the other is one and one-half miles southeast of Hereford. It is the period of time represented by these two sites with which this study is concerned. The excavation at the Hereford site on the ranch of Mr. Edward F. Lehrer is the second occasion in four years in which evidence of the association of man and his mammoth contemporary has led to a full scale investigation.

In the fall of 1952, while looking over a piece of land he contemplated purchasing, Lehrer came upon a short arroyo which crossed the property he was ultimately to acquire. A vertical bank revealed to him a series of
stratified deposits at the base of which lay exposed bones and sediments that he concluded might be of importance. Some of the material was removed from this bone bed and taken to Dr. Emil W. Haury of the Arizona State Museum who identified one fragment as an enamel plate of a mammoth tooth (Haury 1956: 23).

Two years elapsed before sufficient evidence was exposed by erosion to warrant a joint archaeological-paleontological program by the University of Arizona.

**Location**

The Lehner Mammoth Site, designated Ariz. EE: 12: 1 in the Arizona State Museum Archaeological Survey System, is geographically located (T.23S. R.22E., Sec. 21, NE\(_4^1\), NW\(_4^2\), NW\(_4^3\), N\(_4^3\)) about .4 miles west of the present day channel of the San Pedro River on a narrow ephemeral tributary which has been cut by arroyo action. The site lies in the south bank of the channel and has been covered by several meters of alluvium, which at the modern ground surface has an elevation of 4,190 feet (Haury and others, in press).

**Archaeological Excavations**

On March 28, 1955, excavation at the Lehner Site was begun under the overall direction of Haury and the field supervision of Mr. William W. Wasley, Archaeologist
Figure 2. The Lehner Mammoth Site. Plan view showing the bone bed proper and associated sediment samples, and a schematic Section of the geological deposits along the south bank of Mammoth Kill Creek. Lettering of the deposits coincides with those used in Haury (and others, in press) and Antevs (in press).
PLAN SECTION

LIMIT OF EXCAVATION

MODERN ARROYO CHANNEL

SOUTH BANK OF MAMMOTH KILL CREEK

LOCATION OF BEDS
g, h, j, m, i, k, l

LOCATION OF AREA OF BONE CONCENTRATION

a. RED BASE CLAY
c. SANDY RED CLAY WITH CALICHE
f. GRAY CALICHIFIED CLAY, SILT LENSES
g. COURSE SAND AND GRAVEL
h. GRAVEL AND REDEPOSITED RED CLAY
i. FINE SAND
j. SAND GRADING TO SILT AND CLAY
k. BLACK SWAMP SOIL
l. GRAY CLAYEY SILT
m. LOOSE SILT
z'. MAMMOTH KILL CREEK EROSION

Figure 2.
on the staff of the Museum. Two sessions of excavation were conducted at the site, from November 28 to December 19, 1955 and February to March 4, 1956. During the first session the area of highest bone concentration was fortunately discovered and investigated, while the second phase entailed uncovering a larger area to the west of that area excavated earlier.

A black colored layer or deposit, about 15 cm. in thickness (Fig. 2, layer k), which occurs immediately above the bone bed and is capped by two meters of alluvium has been extremely useful in assigning stratigraphic provenience.

Using this layer k as an horizon marker, a power shovel supplied through the good services of Mr. Austin Jay, Cochise County Supervisor, was used to remove an 11 by 17 meter area of overlying deposits to about 30 cm. above the black deposit. Beginning at the eastern edge of the excavation, the remaining material from layer (k) and bed (l) was stripped by hand labor to expose the bone bed. At the close of the first phase of the excavation, paleontological evidence for the presence of eight mammoths in the form of mandibles had been recovered from the bone bed, as well as skeletal remains of bison in the form of a mandible fragment with three teeth, and possible rib fragments.

Equally important from an archaeological standpoint
were the artifactual materials of man which were found in association with some of the paleontological remains. These associated artifacts were in the form of thirteen projectile points prepared in the Clovis tradition, and eight stone tools which were probably cutting and scraping implements (Haury and others, in press).

From the geological evidence it appears as if the mammoths were killed on a sand and gravel bar in an ancient stream channel which is called Mammoth Kill Creek. The stream channel in which the "kill site" occurs seems to parallel the modern arroyo along the south bank of Mammoth Kill Creek. There is geological evidence to indicate that a shallow, quiet pool of water once was present, which would have been a fine watering hole for animals and a place for hunting in prehistoric times. The depth of the bone bed, over 1.0 meter, indicates that man hunted his animal prey over a period of time extending from a few months to several years. (Haury and others, in press).

The second phase of excavation carried the investigation upstream (west) exposing more bones, which increased the faunal assemblage to include a portion of the lower mandible of a tapir, a horse podial, and the lower mandible of a ninth mammoth. In addition, two hearths, perhaps used for cooking, were exposed on the sand and gravel bar. Both hearths contained small fragments of charcoal that yielded several radiocarbon dates (Wise and Shutler 1958, 73).
Charcoal fragments from the bone bed have been identified as pine (Pinus spp.), ash (Fraxinus spp.), and oak (Quercus spp.) by Mr. Terah L. Smiley, Geochronology Laboratories; and the Forest Products Laboratory, University of Wisconsin, Madison, Wisconsin (Haury and others, in press).

Alluvial Stratigraphy

The foundation for this geological presentation is taken from Antevs' report (Antevs, in press) on the "Geological Age" of the Lehner Mammoth Site." A schematic section of the stratigraphic interpretation at the Lehner Site and the associated sediment samples is shown in Figure 2, page 23. Beds (b), (d), (e), (n), and (o) are not shown on this diagram because sediment samples have not been processed from these horizons.

The basal formation at the Lehner Mammoth Site is a red-brown clay (a), with soft white caliche inclusions. The eroded surface of this bed is overlain by a series of interdeposited erosions (Antevs, in press). The assignment of letters to the beds is in the order of their formation: red-brown clay (a), olive colored clay (b), reddish calichified clay with lenses of sand and fine gravel (c), gray clay (d), reddish silty sand (e), gray calichified clay with lenses of silt (f). Antevs feels these older beds represent an alternation of deposition and erosion presumably induced by climatic changes.
In relatively later times these older beds were cut by the action of a perennial stream of Pluvial age down into the base clay (g) to create what may have been a meander bow. In cross-section, the filling of this bow proceeded more rapidly against the inner north bank than at the outer south bank causing the water to be deeper towards the south bank. At the time of the mammoth kill this may have been a watering place for animals and a spot where man could trap his prey.

The south bank of the stream channel (g') is practically vertical and about 1.8 m. deep. Within this channel occurs coarse gravel (g) interfingered with red-brown clay containing caliche lumps and stream-brought pebbles (h). Bed (h) may have slumped from the bank or have been carried to the vicinity of the site by the stream. The gravels are superimposed by pink and white sands (i). Bed (h) is overlain by sands grading upward into silt and clay (j). Artifacts and bones occur in the upper 1.2 m. of channel beds (g), (h), (i), and (j). Following the deposition of the bones and artifacts, a flood, which changed the course of the stream, filled the old channel.

Overlying the old south bank and the channel fill is a black layer (k), 15-20 cm. thick, that Dr. Theophil Duerer of the University of Arizona identified as a silty clay loam, a portion of the A horizon of a swamp soil (Antevs, in press).
Directly over the black layer is a firm gray silt, clayey and calichified (m), 1.2 m. thick. This bed is overlain by a loose silt, light gray to light tan in color (n). Antevs recognizes two other beds: one 30 cm. thick of a firm red-brown mixture of silt, sand, clay, and pebbles (o) above which lies 45 cm. of dark gray silt (p). An erosional disconformity, probably of Altithermal age, separates beds (m) and (n). The present ground surface is on bed (p). At the time the sediment samples were collected from column 6 the finer breakdown into beds (m), (n) and (p) was not recognizable in the vertical column.

By inference and several assumptions, Antevs characterizes the climate at the time of the "mammoth kills" as dry subhumid or slightly moist subhumid, and the vegetation as a tall-grass prairie. Using the process of Geologic-Climatic dating (Antevs 1955: 317) Antevs concludes that man probably hunted mammoth in the San Pedro Valley long before its extinction which presumably occurred about 11,500 B.P.
IV
METHODS OF POLLEN EXTRACTION

The extraction of pollen grains from inorganic sediments in the Southwest has been a difficult problem, and one which has not been entirely solved. It has become apparent from this study that no single rigid procedure can be followed.

Prior to the undertaking of this problem, Mr. Dick Shutler, Jr. of the University of Arizona, initiated laboratory studies to determine the potentiality of pollen analysis on the sediments from the Lehner Site. His work showed that pollen grains in small numbers could be recovered from the material collected. With this knowledge, a program was outlined for developing a project to study the material then collected from the excavation. Concurrent with Shutler's tests, Drs. E. B. Kurtz and R. M. Turner of the Department of Botany, University of Arizona, developed a technique of oil recovery of fossil pollen grains (Kurtz and Turner 1957: 67-68). It was this technique that was first applied to the sediments from the Lehner Site. As will be outlined below, two other methods were also used.

The methods for extracting pollen grains from both organic and inorganic deposits fall into three general classes (Deevey 1944: 141):
1. The easiest method is dispersion with potassium hydroxide. This method is used when pollen is in sufficient abundance to be counted under a small cover slip (7/8 inch), and the nature of the sediment is amenable to this treatment, for example peat bogs. (This method has been tried on two samples from the Lehner Site without success.)

2. Pollen grains may be extracted from mineral sediments by flotation with a heavy liquid or some other media which separate the pollen from its preserving matrix. (This technique is the basis for Methods 1 and 2 presented in the following discussion of methods.)

3. Sandy sediments often require hydrofluoric acid to remove the silica, acelolysis to remove the cellulose material, and hydrochloric acid to remove the calcium carbonate. (These treatments are basic to Method 3 which is presented in the following material.)

Due to the very broad range of sediments with which the laboratory worker must deal, various combinations of these three general classes are often necessary and frequently used. This has been the situation for the material from the Lehner Site.

As the study is not aimed toward the examination of microfossils other than pollen grains, a hydrofluoric acid
step has been used to remove or reduce the fine silicious material found in inorganic sediments. The treatment does not attack organic remains and pollen grains (Faegri and Iversen 1950: 62).

The chemicals used in Methods 1, 2, and 3 are stock items purchased from several of the chemical warehouses. These chemicals are not recovered for further use.

Centrifugation is conducted between 2,000-3,000 r.p.m. for five minutes, and occasionally longer.

Contamination is a serious problem in palynology, and one which has been guarded against in this study. Caution has been exercised to avoid modern pollen contamination by using clean glassware, covering or sealing apparatus, and maintaining as airtight a working laboratory as the physical plant allows.

Repetition will be found as it has become necessary to present for each method the reason for its use and the results obtained by the method.

For the purposes of this study an effort has been made to maintain fairly constant procedures, both quantitatively and qualitatively, of extracting pollen from the material collected at the site.

The Collection of the Samples

Several individuals were involved in taking samples of the sediments from the excavation area, both during and
subsequent to the major excavations. Each group of samples was taken for a specific purpose (Appendix II), the plan being to attempt a sampling of as many of the recognizable facets of the site as possible. Immediate use (radiocarbon, pollen analysis, and soil analysis) was found for some samples, while others await future studies and new techniques.

Due to the firm nature of the sediments, the soil was removed from a freshly exposed vertical face by using a geology pick to loosen the earth, and then this loose material was transferred into a container. The sediments were removed from a vertical column upward to avoid the contamination of older material by the younger. One or more samples of sediment were taken from each discernible stratum, depending on the depth of the deposit. To facilitate collection and storage, new clean paper or plastic bags were used for containers. The amount of sample to be collected was not predetermined, however 200 grams of sediment was about the average weight for each bag brought into the laboratory. As the material was removed from a particular stratum its provenience was noted on both its container and a sketch map. The data from these sketch maps were in turn transferred to the master site map to insure proper stratigraphic correlations at a later date.

Sampling of the geological strata was primarily limited to vertical columns. This method of collection is referred to as a column or a sediment column, and is
represented by sediment columns 1, 2, 3, 4, 5, 6, 7, and 8. Another method of collection has been called a unit or sediment unit. A unit is comprised of one to six samples taken from one stratum. Each sample from a unit represents the sediment from one geological deposit. Figure 2 shows the vertical and horizontal relationship of column 6 and units 9, 10, 11, 12 and 13.

A group or a set of samples is taken to mean several sediment columns or units or a combination of the two. An example of this usage is: a total of 13 sets of samples, comprising 8 sediment columns and 5 sediment units, was taken from the Lehner Site excavation.

Each sample taken from the site was given a field number, which designated its location within a column or unit. Field designations were, for practical purposes, retained for the most part in the laboratory. Several sediment columns had to be re-numbered in order to expedite their handling and processing. Those necessitating a change were re-labeled in the laboratory and the field sketches changed accordingly.

The method for labeling specimens in the laboratory was to assign each set of samples a column or unit number (1 through 13). Each sample within a particular column or unit was then given a provenience number — beginning with the lowest sample stratigraphically (number 1) and numbering sequentially upward toward the ground surface, for
example: column 6—samples 1, 2, 3, ..., 14. An example of the unit designation would read: unit 9—samples 1, 2, 3, 4, 5, 6. Figure 2 illustrates this system.

The location of each column and unit sample is shown on Figure 1, and a catalogue of all the material collected appears in Appendix II.

Upon completion of the work, all of the sediments were turned over to the Geochronology Laboratories, University of Arizona, for storage.

The Methods of Extraction

Once in the laboratory the following general procedure was outlined: to extract, by chemical and mechanical treatment, fossil pollen grains from the matrix samples of the sedimentary material. Further, to concentrate, mount, and examine the fossil pollen grains, and by the use of analytical procedures to construct pollen spectra. The construction of pollen spectra was not accomplished for reasons stated on page 1.

Several trial runs were made with the Kurtz-Turner method to test the technique on inorganic sediments. These first treatments on samples from bed (m) proved satisfactory and the work was initiated using this method. All of the samples collected, with the exception of those from column 4 and units 11, 12, and 13 were treated by Steps 1 through 7 of Method 1. However, only column 8 was completed in
entirety by Method 1. Further work on column 8 was limited to experimentation when Methods 2 and 3 were put into effect. Nine samples (6-14) from column 6, 40 cm. north of column 8, were chosen to be used with Method 2. The reason for this change was due to the different manner in which the samples were collected. Column 6 included fewer samples (14) and a known stratigraphic provenience for each sample, whereas the 41 samples from column 8 were taken at 10 cm. intervals without respect to the geological deposits. After the excavation had been completed and more information was known about the geological situation at the site, it became necessary to eliminate those samples (1-5) from column 6 which occurred below bed (i) (Fig. 2) because of the confusing geological context in beds (g) and (h). This situation eliminated five samples from column 6 and led to the collection of units 12 and 13 from sediments known to represent beds (g) and (h). The samples from column 6 and units 9, 10, 11, and 13 were processed by Method 2. Units 9, 10, 11, 12, and 13 were run by Method 3.

The final sections of this chapter present the three methods used to process the sediments collected from the Lehner Site and a brief discussion of these methods.

Method 1

This method by Kurtz and Turner is a paraffin oil flotation process in which pollen is brought to the surface
of a water column.

The method appears in the laboratory notes, upon microscope slides, and in this text as either the Kurtz-Turner method (K-T) or Method 1.

Briefly the steps of Method 1 are:

1. preparation of the sample,
2. decalcification with concentrated hydrochloric acid,
3. adjustment of the pH to 8 or 9 with sodium hydroxide,
4. addition of paraffin oil to a water column,
5. removal of the first oil extraction and placement in a filter paper,
6. additional oil extractions,
7. removal of oil from the filter paper,
8. acetylation of first filter paper with acetolysis,
9. demineralization with hydrofluoric acid pouring all decants (9-17) into a second filter paper,
10. decalcification with hydrochloric acid,
11. deflocculation with sodium hydroxide,
12. dehydration with glacial acetic acid,
13. acetylation with acetolysis,
14. dehydration with glacial acetic acid,
15. deflocculation with sodium hydroxide,
16. neutralization with distilled water,
17. dehydration with acetone,
18. mounting of the material on a slide,
19. carry second filter papers through Steps 8-18.

Laboratory Procedure

A detailed account of the method and techniques employing an adaption of the Kurtz-Turner method (1957: 67-68) for fossil pollen recovery is as follows:

Step 1. A group of bags containing sediments representing the samples from one, part, or several sediment columns and units are laid out in numerical order, and each bag is matched
with a respectively labeled 1000 ml. beaker supplied with a glass cover. From the sample bag 100 grams of sediment are placed in the beaker. Screening is impractical because of the frequent occurrence of large lumps of sediment. Ample laboratory equipment and space make it possible to run, at one time, 20 samples through Step 7.

**Step 2.** Add slowly to the material concentrated hydrochloric acid until the evolution of carbon dioxide ceases. Best results are obtained from highly calcified material by stirring the sediments occasionally and letting them stand over night.

**Step 3.** While in the beaker adjust the pH of the liquid and residue to pH 8 or 9 with sodium hydroxide. (pH hydrion papers are used for this operation.) Dilution of the acid with distilled water is practiced for easier pH adjustment.

**Step 4.** Transfer sediment and liquid to a one liter graduate. Distilled water is used to bring the volume up to 800 ml. To this 15 ml. of white, light, U.S.P. paraffin oil is added. Shake vigorously the cylinders and their contents in a horizontal plane, and let the contents stand until the sediment, water and oil separate into phases.

**Step 5.** Remove the oil surface layer (upper phase) from each cylinder with a pipette and transfer it into a Whatman No. 1 filter paper in a six inch funnel set in a 500
ml. Erlenmeyer flask prepared for each sample. Glass plates are used to cover the funnels. Another piece of glass is used to cover the cylinders, and culture tubes are used to sheath the pipettes against contamination while they are not in use. Distilled water is used to speed up filtration. The filtrates from the flask are discarded.

Step 6. Add paraffin oil five more times and repeat Step 5 after each separation. Acetone and xylene are used alternately between filtrations. Paraffin oil is soluble in xylene and therefore washes away from the pollen and filter paper. Acetone is used to remove the xylene and dehydrate the filter paper, allowing easier filtration. After the removal of the final oil treatment, the cylinders are shaken again, without oil, and permitted to stand. The oil which failed to rise before is removed. Having completed the oil extraction operation, the contents of the cylinders are discarded.

Step 7. Wash the oily residues in the filter papers with alternating baths of xylene and acetone while remaining in the glass funnel. Small amounts, 20-30 ml. of xylene, are first used to wash the interior and exterior of the filter papers. This treatment is repeated with acetone, and the filter papers are allowed to drain. Washing of this nature is continued until it is felt that the greater portions of oil have been removed. The papers are then de-
hydrated with a small amount of acetone and are removed from the funnel. The filtrates of the acetone and xylene washes are discarded.

Step 8. At this point it is no longer possible to work with a large number of samples due to the four tube capacity of the centrifuge. The number is reduced to four. A clean cover, funnel, flask, and a new filter paper are made ready for each filter paper used in Steps 1-7, which are to be further processed through Steps 9-18. The filter papers which recovered the oil treatments are then immersed into a beaker of 50 ml. of acetolysis mixture, which contains 9 parts of acetic anhydride to 1 part concentrated sulphuric acid, mixed fresh daily (Ertdman 1954: 28). The amount of acetolysis used, over 50 ml., varies as to the amount of the residue on the paper. More is used when the paper contains a great deal of residue. After the filter papers are dissolved, the mixture from each beaker is then transferred to 50 ml. pyrex centrifuge tubes. The tubes and their contents are warmed slightly in a hot water bath for ten minutes and centrifuged. The supernatants are poured off, diluting with distilled water, into the second set of filter papers. Each sample has a respective funnel and filter paper. After the decantation, the residue in the glass tubes is transferred by glacial acetic acid into 50 ml. Nalgene (trade name) centrifuge tubes, is centrifuged and decanted. After each
centrifugation, all supernatants from Steps 8-17 are put through this second filtering process. The filtrates are discarded.

**Step 9.** Add to the residue in the Nalgene tube 25-30 ml. of cold hydrofluoric acid. The contents of the tubes are then permitted to stand for 24 hours, stirring several times during this period. Following this period, the material is centrifuged and decanted and the hydrofluoric treatment is repeated until the residue is 5 ml. or less.

**Step 10.** Centrifuge and decant after the last hydrofluoric treatment the contents of each tube. Then transfer the residue to 50 ml. pyrex tubes with warm 10 per cent hydrochloric acid. Suspend the residue in the hydrochloric acid, centrifuge and decant.

**Step 11.** Treat the residue with 10 per cent sodium hydroxide and place the tubes in a boiling water bath for 20 minutes, and follow with centrifugation and decantation.

**Step 12.** Wash the material with glacial acetic acid, centrifuge and decant.

**Step 13.** Treat each sample with 25 ml. of acetolysis mixture, warmed for 15 minutes, centrifuge and decant.

**Step 14.** Repeat Step 12.

**Step 15.** Repeat Step 11.
Step 16. Wash the sediments in the tubes with distilled water, centrifuge and decant. Repeat this operation twice.

Step 17. Wash the remaining residue twice in acetone, centrifuge and decant.

Step 18. Mount the material on a microscope slide. The mounting procedure practiced is to homogenize the residue of each sample with a small amount of acetone. Then in rapid succession the residue is placed on a microscope slide, stained with basic fuchsin, mixed with several drops of glycerin jelly (Wodehouse 1935: 107), and a cover slip is laid over the preparation. The slides prepared at this step of the operation are labeled with the provenience designation followed by the letter a. A slide may be labeled thusly: S-1a. The preparation of the material recovered on the first filter papers by Steps 8 through 18 is called the "a run."

Step 19. The filter papers which are made ready at the beginning of Step 8, and receive the supernatants from Steps 8-17 are then treated with acetone and xylene to free them of all oil and water. The papers are dehydrated with acetone and treated with acetolysis as outlined in Step 8, and are further processed through Steps 9-18. After each centrifugation the supernatants are discarded. If oil droplets appear on top of the acetolysis mixture (Step 8), the mixture is filtered a third time,
rinsed, dried, and processed as discussed at the beginning of Step 19. The residue derived from the second filter papers and mounted on slides is designated by the letter b (8-1b). This second and last half of the method is called the "b run."

Discussion

All of the sediment samples from the Lehner Site, with the exception of column 4 and units 11, 12 and 13 were processed through Step 7, prior to the undertaking of any other work. As the filter papers dried they were placed in clean film cannisters and stored. A separate cannister was used for each sample. This procedure was used for reasons of expediency and laboratory space limitations. Following a change in laboratories, work was initiated on profile 8. Using the above outlined method, all 41 samples of column 8 were completed to mounted slides. The remaining filter papers were left in cannisters for further study at a later time, and were not used in this analysis.

Experiments were carried on concurrent with the running of the material from column 8. These included: 1. testing for pollen lost when the supernatants from the "b run" were discarded, (This investigation showed that very little or no pollen was lost.); 2. treating the filter papers with larger volumes of acetone and xylene to remove all of the oil, (results unknown); 3. removing oil
droplets from the surface of the supernatants to determine whether pollen floated off following centrifugation, (negative results); and 4. incorporating new techniques into the existing procedures which were found to benefit the method. (An example would be the stoppering of the funnels to allow the filter papers to become immersed in xylene.)

No tests were made on the sediments disposed of following the final flotation in Step 6.

The results obtained by Method 1 are low in pollen grain yields per slide. In most cases they are far below the desirable minimum count of 100 grains per slide, and in some cases the a and b slides are void of pollen grains altogether.

The cause or causes for this low frequency of pollen grain return are not known, however, a few possibilities may be offered. 1. There may have been improper testing of the method on a wide range of soil and sediment types. 2. The great number of transfers involved in this method decreases the chances for pollen recovery. 3. Repeated acetolysis may have removed some of the pollen. 4. Difficulty is often encountered in adjusting the pH of the soil in Step 3, which has called for another adjustment in Steps 5 and 6. 5. It is difficult to determine if all of the oil has been removed from the filter paper. The filter paper must be digested in acetolysis before it becomes
clearly evident whether or not the oil has been totally removed. Possibly the frequency of recovery is due to the failure of the oil flotation treatment to raise fossilized (mineralized) pollen grains from inorganic sediments.

A conservative estimate of the amount of time consumed to process one sample by Method 1 is one 8 hour working day. Production could certainly be increased, but definitely not to twelve samples per day as in Method 3.

Appraisal

From the standpoint of time as a valuable commodity, and the amount of pollen extracted, Method 1 has not been found practical for arid terrestrial soils and sediments.

Method 2

Upon completion of the laboratory work and analysis of the slides made from the Kurtz-Turner method, another method was sought which would prove more adequate in the extraction of pollen from sediments taken from the Lehner Site.

The method selected was one patterned from Knox (1942) and Frey (1955), and used by Mr. Dick Shutler in his initial studies of the Lehner Site sediments. This method has been subsequently tested on many other non-consolidated sediments and sedimentary rocks, and has successfully extracted pollen and spores from samples of Quaternary,
Tertiary, and Cretaceous deposits.

In laboratory notes and on microscope slides this method appears as the Geochronology Laboratories method, Geo. Lab. method (G-L), or Method 2.

After learning the techniques and procedures of Method 2, they were used to process all samples which had a direct bearing upon the archaeological horizon of the site (Fig. 2). With exception of unit 13, the sediment material selected for treatment was taken from column 6 and units 9, 10, and 11. Samples from other columns (1, 2, 3, 4, 5, 7 and 8) were not dealt with as they did not relate directly to the problem. The texture of the sediments examined ranged from a coarse pebbly sand to fine silts and clays, and all contained fine plant material. Every sample treated with hydrochloric acid showed evidence of calcium carbonate, which evolved as carbon dioxide gas.

Method 2 employs a system whereby differential flotation of pollen is effected by a heavy liquid. The liquid used in this case is tetrabromoethane (acetylene tetrabromide, D. 2.950/200 C.) adjusted to a specific gravity of 2.0 to 2.2 with acetone in a 2:1 ratio. The heavy liquid mixture differentiates between the different specific gravities of organic (less than 2.0) and inorganic particles (more than 2.3). In simple terms the organic material floats on top of the heavier inorganic material because of its lower specific gravity. No attempt has been
made to calculate the specific gravities of the Lehner Site organic and inorganic components. Experiments at the Geochronology Laboratories and elsewhere (Frey 1955: 257-258; Knox 1942: 307-308) have proved the method successful. On the basis of pollen size frequency, it is assumed that the source of error due to density selectivity is not great.

It has been found most convenient after Step 3 to work with four samples at a time. Other samples may be processed during the slack periods such as centrifugation and warming of the acetolysis mixture.

Briefly the procedural stages of Method 2 are:

1. deflocculation with potassium hydroxide,
2. decalcification with concentrated hydrochloric acid,
3. demineralization with hydrofluoric acid,
4. decalcification with concentrated hydrochloric acid,
5. dehydration with glacial acetic acid,
6. oxidation with sodium chlorate (optional),
7. dehydration with glacial acetic acid,
8. acetylation with acetolysis,
9. dehydration with glacial acetic acid,
10. dehydration with acetone,
11. flotation with tetrabromoethane-acetone,
12. removal of residual tetrabromoethane with acetone,
13. mounting of the material on a slide.

Laboratory Procedure

The detailed processing schedule consists of the following steps:

Step 1. Place about 0.5-0.9 gr. of sediment in a 1000 ml. beaker, and add 20-50 ml. of 5 per cent potassium hydroxide.
Stir until all lumps have disintegrated and the material is suspended uniformly. Let stand 24 hours. Suspend material and pour into a 50 ml. Nalgene centrifuge tube. Repeat with fresh potassium hydroxide until all suspended material is collected in the tube, centrifuging when necessary. Supernatants are discarded. If carbonate nodules are found in the residue of sands, gravels, and pebbly sediments, rinse with concentrated hydrochloric acid followed by a second wash of potassium hydroxide (Faegri and Iversen 1950: 62). Decant into a centrifuge tube. The remaining very coarse residue in the beaker is discarded.

**Step 2.** Add carefully small amounts of cold concentrated hydrochloric acid to the residue in the centrifuge tubes until all carbon dioxide gas has evolved. Transferring the residue to a beaker is often necessary in cases of violent reaction with hydrochloric acid. This entails a re-transfer to the centrifuge tube. Centrifuge and decant.

**Step 3.** Add a small amount of cold hydrofluoric acid. Stir and let stand until the violent action (encountered in all sediments) subsides. Follow with increasing portions of hydrofluoric acid until 30 ml. of the acid has been added. Mix thoroughly, let stand 24-96 hours, stirring occasionally, and renew the hydrofluoric acid treatment if necessary. Centrifuge and decant. (Traverse 1955: 99-100).
Step 4. Repeat treatment with cold concentrated hydrochloric acid, centrifuge and decant.

Step 5. Transfer the sample to a 50 ml. pyrex centrifuge tube with glacial acetic acid, centrifuge and decant.

Step 6. Oxidize. This treatment is optional and used in situations where it is necessary to bleach residual humic matter in the sediment. The oxidation is carried out by: adding to the sample 4 cc. of glacial acetic acid, 5-6 drops of sodium chlorate solution (30 per cent), and 1 cc. concentrated hydrochloric acid (Faegri and Iversen 1950: 63; Traverse 1955: 100). The time required for bleaching is from several seconds to one minute. Centrifuge and decant.

Step 7. Wash sample with glacial acetic acid. Centrifuge and decant.

Step 8. Add a mixture of acetic anhydride and concentrated sulphuric acid to each tube and suspend the residues in this mixture. Approximately 10 ml. of mixture is added to each sample. Acetolysis is a mixture of 9 parts acetic anhydride and 1 part concentrated sulphuric acid. This is mixed fresh daily. Samples are heated gently in a hot water bath to the boiling point and left for 10-20 minutes. Centrifuge and decant. (Erdtman 1954: 27-28; Faegri and Iversen 1950: 63; Traverse 1955: 98).

Step 9. Suspend sample in glacial acetic acid and centrifuge
and decant.

**Step 10.** Suspend sample in acetone for a thorough dehydration. Centrifuge and decant.

**Step 11.** Add to each sample a mixture of 1 part acetone and 2 parts tetrabromoethane (the tetrabromoethane is poured into the acetone). The material is suspended in the mixture by shaking the tube in the palm of one's hand. The palm acts as a stopper on spouted centrifuge tubes. Centrifuge slowly at first, increasing the speed to 2,000-3,000 r.p.m. for 10-15 minutes, and decant twice into a clean 15 ml. pyrex centrifuge tube, centrifuging between decants. The liquid contains the material with a specific gravity of less than 2.0.

**Step 12.** Dilute the liquid with two volumes of acetone, re-suspend, and centrifuge. Repeat acetone again. The flotation processes may be repeated several times if low quantities of pollen result from one treatment (Frey 1955: 257-258).

**Step 13.** The final product of the schedule rests at the bottom of the 15 ml. centrifuge tube. A small amount of acetone is kept over the sample to prevent it from drying out. When eight to twelve samples have been completed through Step 12, the sediments are mounted by the following procedure: The residue is homogenized and pipetted from
the tube to a microscope slide. The acetone is allowed to evaporate and the material is tinted red with basic fuchsin stain. Heated glycerin jelly is added to the stained residue and the two are mixed thoroughly. A cover slide is laid gently over the still warm jelly. It is often necessary to employ a hot plate to keep the slides and jelly warm.

Discussion

Method 2 has several distinct advantages over other methods used. 1. The method does not involve heating any reagents other than the acetolysis mixture, except on an optional basis. 2. As time is an important element in studies of this kind, this system allows the operator to process four to eight samples per day. 3. The method can be used favorably on a wide range of geological deposits. 4. Relatively few transfers are necessary in processing the sediments, and only one is required if the newer heat resistant plastic centrifuge tubes are used.

There are four disadvantages readily discernible for Method 2. 1. Flotation by a heavy liquid may result in the loss of pollen. The amount of loss sustained in a quantitative sense has not been evaluated. 2. The use of cold reagents requires additional time for reactions to be completed. 3. Heavy liquid flotation seems to operate poorly in sediments that develop a colloid before the flotation step. 4. Because of the manner by which pollen is extracted from the sediment, much organic material is also
removed at the same time. This situation creates much inconvenience when a particular deposit is highly concentrated with organic remains.

The results obtained from Method 2 are encouraging after encountering an apparent "dry hole" with Method 1. Pollen grains are recovered in sufficient quantity (100-300) from most levels to allow for statistical analysis. The number of grains recovered became progressively smaller as the samples processed went stratigraphically deeper. This has been brought to light in studying the material prepared from column 6. The slide made from sample 6-14 has almost 300 grains as opposed to about 50 grains counted on the slide representing sample 6-6.

The depth of a sample has also produced evidence of two other phenomena. One is the increased reaction to concentrated hydrochloric acid by the lower samples, which have a higher concentration of calcium carbonate. The other noticeable trait of the stratigraphically lower samples has been the tendency to develop a colloid, particularly during Steps 4 and 5. Unless the colloid can be "broken" by repeated treatments with an acid (glacial acetic) or a base (potassium hydroxide) it is virtually non-profitable to continue with the procedure. This was made clear when slides were made from samples 6-7, 8, 9, and 10 in a colloidal state, and a rerun of the same samples without a colloid. A like situation developed for sample 11-1.
Appraisal

The problems which developed from using Method 2 would seem to preclude the wide use of this method on arid land sediments. However, the method has been used with considerable success when applied to recent alluvial material and much older sedimentary formations (Terah L. Smiley, personal communication).

Method 3

During the processing of the material from groups 6, 9, 10, 11, 12 and 13 by Method 2 and column 8 by Method 1, a colloid, forming in the residue after the hydrofluoric treatment, became a real problem. There is no apparent cause for its formation, and chemists at the University are not able to explain its nature. This colloid did not occur with every sample nor did it always happen on a re-run of one particular sample. Its appearance seems somewhat associated with sediments which are calcified or located near calcified material.

In an attempt to overcome the "colloid problem" Method 3 was used. The results were satisfactory but not to the point of eliminating the problem altogether.

The schedule of Method 3, as presented below, is not a standard method nor the product of any one person or persons research activity, but rather the employment of
several techniques arranged together in such a manner as to suit the nature of the sediments found in an arid land environment. Those who desire more detailed information concerning the various steps and general composition of the method may consult Faegri and Iversen (1950: 61-63) and Traverse (1955: 99-100).

In the laboratory notes and on microscope slides this method is designated as Method 3.

Dr. Paul S. Martin and Mr. Bernard Arms have jointly developed the procedure followed in Method 3. Their aim has been to develop a technique for processing arid land sediments which will concentrate a large number of pollen grains on one slide, and at the same time overcome the colloid problem encountered in this study.

Briefly the steps of Method 3 are:

1. deflocculation with potassium hydroxide,
2. decalcification with concentrated hydrochloric acid,
3. demineralization with hydrofluoric acid,
4. neutralization with distilled water,
5. decalcification with concentrated hydrochloric acid,
6. dehydration with glacial acetic acid,
7. oxidation with sodium chlorate (optional),
8. dehydration with glacial acetic acid,
9. acetylation with acetolysis,
10. dehydration with glacial acetic acid,
11. deflocculation with potassium hydroxide,
12. neutralization with distilled water,
13. dehydration with alcohol,
14. mounting of the material on a slide.

Laboratory Procedure

The detailed procedure of Method 3 follows:
Step 1. Place 2-3 teaspoons of sediment in a covered beaker and cover it with 5 per cent potassium hydroxide solution. Rotate the beaker with a circular motion to "swish" the material and liquid about the bottom of the beaker allowing both to mix freely. This mixture of 5 per cent potassium hydroxide and sediment is allowed to stand from ten minutes to several days. The amount of time is optional, but occasionally it is necessary to use longer periods for soaking clays and silts. After the deflocculation of the sediment has been accomplished, the potassium hydroxide treatment is completed and the material is again suspended in the potassium hydroxide by rotation. The very fine particles and pollen are then poured off into a teflon centrifuge tube and the coarser material discarded. The pouring stops when sand particles first appear and more potassium hydroxide is added to the sediments in the beaker. The process is repeated until the very fine materials are no longer suspended and the potassium hydroxide runs clear. Sufficient material should be collected to cover the bottom of the 50 ml. teflon tube. One or several centrifugations are necessary in order to remove enough of the finer material to produce a clear liquid decantation. With the clays and silts, sufficient material can be collected to be utilized for a run without proceeding to the clear running solution.

Step 2. Slowly add 20 ml. of cold concentrated hydrochloric
acid to the residue, stirring to insure that a thorough mixing occurs. Allow all carbon dioxide gas to evolve. Centrifuge and decant.

**Step 3.** Add 5 ml. of cold hydrofluoric acid, stirring the residue thoroughly and waiting until the initial reaction between the hydrofluoric acid and the finely divided silicates ceases. Continue to add more hydrofluoric until about 20 ml. of the acid has been added. Then place the teflon tubes in a paraffin bath at a temperature of 170°-180° C. When the acid begins to boil in very fine bubbles the tubes are left an additional twenty minutes in the paraffin bath, and then removed hot and centrifuged immediately for five minutes and decanted.

**Step 4.** Suspend the residue in about 5 ml. of distilled water and transfer to a 15 ml. pyrex centrifuge tube. Additional amounts of water are used to complete the transfer of the residue from one tube to the other.

**Step 5.** Repeat the hydrochloric acid treatment of Step 2 in the 15 ml. pyrex tubes. After the material has been suspended, place the tubes in a beaker of warm water and allow the mixture of acid and residue to heat for one minute. The tubes are then centrifuged and the warm acid poured off. If a colloid develops at this point it becomes necessary to apply repeated rinses of either a base or an acid until the colloid is "broken". If this action is
unsuccessful it is advisable to begin anew.

Step 6. Add glacial acetic acid and suspend the residue by shaking or stirring. Centrifuge and decant.

Step 7. The residue may then be bleached as in Method 2. This treatment is optional and is used when it is necessary to bleach residual humic matter in the sediment. The oxidation is carried out by: adding to the sample 4 cc. of glacial acetic acid, 5-6 drops of sodium chlorate solution (30 per cent), and 1 cc. concentrated hydrochloric acid (Faegri and Iversen 1950: 63; Traverse 1955: 100). The time required for bleaching is from several seconds to one minute. Centrifuge and decant.

Step 8. If the oxidation (bleaching) step is used, then wash the material with glacial acetic acid as in Step 6. When Step 7 is omitted, the procedure continues from Step 6. In either case the glacial acetic acid treatment precedes Step 9.

Step 9. Add a mixture of acetic anhydride and concentrated sulphuric acid to each sample. The residue is suspended in approximately 10 ml. of acetalolysis mixture. Acetolysis is a mixture of 9 parts acetic anhydride and 1 part concentrated sulphuric acid. This is prepared daily. Samples are heated gently to the boiling point in a water bath for 10-20 minutes (Erdtman 1954: 27-28; Faegri and Iversen 1950: 63; Traverse
1955: 98). The tubes are centrifuged and the acetolysis poured off hot. A mixture, using a 9:2 ratio, has been used with some success to reduce the amount of dark organic material in sediments where it is noticeably high in proportion to the lighter colored silicious material (Bernard C. Arms, personal communication).

**Step 10.** Wash the samples again with glacial acetic to remove the residual acetolysis mixture, then centrifuge and decant.

**Step 11.** Add about 20 ml. of 5 per cent potassium hydroxide to each tube and suspend the residue by shaking or stirring. Then warm the tubes and their contents in a water bath for 2-3 minutes. This base treatment neutralizes and deflocculates the residue. The potassium hydroxide is centrifuged and decanted warm.

**Step 12.** Suspend the residue in distilled water and wash to remove any fine humic material freed by the base treatment. Centrifuge and decant.

**Step 13.** Use alcohol (absolute) in small amounts to dehydrate the residues. This step is normally repeated twice.

**Step 14.** Add a few drops of alcohol to the residue to keep it from drying out prior to mounting and stoppering of the tubes. When eight to twelve samples are processed
they are mounted by the following procedure: The residue in the centrifuge tube is homogenized in the alcohol medium and then pipetted to a microscope slide where it is allowed to dry. A drop or two of basic fuchsin stain is added and allowed to dry. Poppy seed oil, 2 drops, is then added to the stained residue and the two mixed thoroughly. A cover slip is then gently laid over the mixture and permitted to settle into place. The preparation is then ready for microscopic examination.

Discussion

From the discussion at the end of Method 2 and at the beginning of this section, it becomes apparent that overcoming the colloid problem which developed so often has been necessary in order to assemble a sequence of slides representing each geological deposit shown in Figure 2. Not so obvious is the fact that the samples which created this problem are those associated with and underlying the bone bed. It is easy to understand that without pollen material from these levels the material found above the bones and artifacts would have little significance from an archaeological point of view.

A note in the section on Method 2 (p. 48) has briefly brought mention of the difficulty encountered in the flotation of material which has a very high organic content. Because the black swamp soil (k) is of this type
deposit and the best horizon marker at the site, it has been necessary to solve this problem. Samples 1, 3, 4, and 6 of unit 9, representing this layer, were run by Method 2 with little success and again by Method 3 with fairly good results. The reasons for the improvement may be due to the employment of Steps 7 (oxidizing) and 9 (increasing the strength of acelolysis). However, it must be noted that both of these steps are injurious to pollen grains. Whether Steps 7 and 9 have affected the reliability of the grains counted by perhaps destroying the more fragile grains is not known.

Like the two methods discussed previously, Method 3 has its advantages and drawbacks also. The following points for the method are: 1. The method can be used on both recent (Paul S. Martin, personal communication) and ancient material of an age at least roughly coeval with the existence of the mammoths. 2. The application of certain hot acids seems to alleviate a tendency that the sediments have to colloid when cold acids are used. 3. This method allows a methodical worker to process at least twelve samples a day. The number will vary depending upon the amount of procedural problems encountered during the running of a set of samples. 4. After Step 2, the original samples are retained throughout the procedure and the method of recovery is not subject to chance selection as those treated by Methods 1 and 2.

There are also disadvantages which accompany the
use of this method and they are: 1. Certain steps call for the warming or heating of powerful reagents, the fumes of which are definitely injurious to one's health when encountered over a few months time. Regardless of the precautions taken, such as baffles for the fume hood and enclosed hoods for centrifuges, the laboratory worker is not immune to frequent contact with escaping fumes. 2. After the series of decants in Step 1, there may be pollen left behind in the material discarded. 3. Pollen is oxidized by the bleaching (oxidizing) technique and the use of acetolysis of increased strength. The elimination of certain grains can influence the interpretation of a particular pollen spectrum.

The recovery of pollen grains from the lowest beds (Fig. 2, a, c, f, g and h) by Method 3 was made possible by the elimination of the colloid which so often developed when processing these samples. Because of the time limitations, the upper beds (Fig. 2, l and m were not processed by Method 3. However, on the basis of other data, the results of Methods 1 and 2, and the tests upon other recent material at the Geochronology Laboratories, it is quite reasonable to assume that these sediments should yield a great deal of pollen, 200-300 grains per slide.

Appraisal

Upon completion of the laboratory phase of this study,
Method 3 seems to be the soundest method for extracting fossil pollen from inorganic sediments.

**Summary**

Three methods of extracting fossil pollen grains from inorganic sediments have been discussed. The use of these methods makes possible some comparative statements of value concerning the individual merits of each method as applied to the recovery of pollen from terrestrial sediments.

Methods 2 and 3 appear to produce better results in terms of the number of pollen grains extracted than does Method 1. However, Method 1 has produced excellent results on dry cave material (Edwin B. Kurtz, personal communication), and has recovered pollen from the uppermost deposits (top 50 cm. of bed $m$) at the Lehner Site. This situation has led to the idea that perhaps long buried pollen grains become "mineralized" in arid sediments and because of their weight cannot be trapped and raised by oil flotation. Because Method 1 involves a great amount of labor, rapidly consumes chemicals, and produces relatively poor results, it would definitely benefit future workers to further test this method on arid land sediments.

Method 2 produced favorable results until the lower beds ($a$, $b$, $c$, $d$, $e$ and $f$) were run. Here a colloid problem appeared which prevented the recovery by heavy liquid flota-
tion of sufficient pollen grains for microscopic analysis. This colloid difficulty has been encountered at sites which have both older and younger sediments than the deposits at the Lehner Site.

Method 3 gives the most promise of eliminating the colloid. In addition, it reduces the organic residues from sediments having a relatively high humic content.

A qualitative difference between the pollen grains recovered when the same samples were run first by Method 2 and then by Method 3 suggests the need for research on the possibility that one of these methods does not extract a random pollen sample.
V

POLLEN FROM THE ARCHAEOLOGICAL HORIZON

Pollen has been extracted from several samples which represent the archaeological horizon (Fig. 2, g, h, i, and j). The pollen grains counted for one sample are not always in agreement with those from another. Four reasons come to mind which might account for this situation: 1. The deposits are not of the same relative age and each represents the pollen rain of a different time period. 2. One or several deposits are contaminated by pollen washed in from older deposits. 3. The decomposition of pollen grains in each deposit has proceeded at a different rate, causing perhaps the more fragile grains to be eliminated. 4. Either Method 2 or 3 or both are selective and will not extract a random sample of pollen grains.

The samples taken from beds (g), (h), (i) and (j) probably represent a fair range of time. On the basis of Anteys' interpretation of the geology, the entire bone bed could include extraneous pollen grains carried in by re-bedded material. Decomposition may have taken place and there is evidence from sample 10-1 to show that Methods 2 and 3 produce different results.

Because sample 11-1 has known associations (between remi of jaw 7 and probably bed j), it has been chosen to
represent what may have been the pollen rain at the time when the "mammoth kills" took place.

Seventy-four pollen grains were counted by Paul S. Martin and myself on four slides prepared from sample 11-1. Of these 74 grains, 39 per cent were pine, 28 per cent were composites, 4 per cent were grass, 5 per cent were spores, and 23 per cent were unknowns. The high percentage of pine pollen was not found in any other sample examined. Pollen studies currently being conducted at the Geochronology Laboratories on sediments from Matty Canyon (vicinity: Cienega Creek), 40 miles northwest of Hereford, also show a lower percentage of pine (Paul S. Martin, personal communication).

Assuming that selective decomposition is not responsible for the high percentage of pine pollen, it could be that a pine forest once grew closer to the Lehner Mammoth Site than it does today. The presence of pine, ash, and oak macrofossils (charcoal fragments) is further evidence to support this idea. By inference the climate was relatively less arid than that found in the San Pedro Valley at the present time.

The speculative nature of these interpretations is granted, but for the present they must stand for it is all we know. It remains with the pollen specialist to identify the pollen grains and aid the archaeologist in the interpretive process, for ordinarily he does not "have the back-
ground or the experience to extract the full significance from the data (Haury 1957: 17).
VI

CONCLUSIONS

Results of the Lehner Site Pollen Study

This study contributes to future pollen studies in southern Arizona by showing the following results: Fossil pollen grains are preserved in arid land terrestrial sediments in southern Arizona and can be extracted by certain mechanical and chemical procedures, of which Method 3 is preferred. The analysis of the pollen which has been extracted from the archaeological-paleontological horizon, when supplemented by other data, seems to indicate that a different type of vegetation once grew in the locality of the Lehner Mammoth Site.

Even though progress has been made, it should be realized that the results of these researches on the Lehner sediments are not conclusive. Future interpretations must wait until the materials are re-studied in a complete analysis, which will appear as part of a post-Pleistocene study currently being conducted by the Geochronology Laboratories.

Problems for Future Research

Several problems have been brought to light by this study which will require further research in future pollen
analysis programs in the Southwest to achieve maximum results. Some of the more important problems that need to be investigated deal with pollen preservation and contamination, soil chemistry, reduction of humic content, geological interpretation, and cooperation between the archaeologist and his co-workers from other disciplines. The problems may be stated as a series of questions:

1) What is the relationship between pollen preservation and the pH of the sediments in which the pollen grains are buried? Dimbleby (1957: 27) has shown that the "Preservation of pollen is not satisfactory in soils of which the pH is above 5, ....". Most of the soils around Tombstone (20 miles north of Hereford) fall in a range of pH 6.6 to 8.5 as determined by a Soil Survey of the Walnut Gulch Water Shed (H. V. Smith, Professor of Agricultural Chemistry, University of Arizona, personal communication). If the soils in the Hereford area are similar to those of Tombstone, the implications would be important from the standpoint of differential decomposition of pollen.

2) How can the pollen which is contemporaneous with a deposit be differentiated from the pollen grains which are carried into the deposit by water action from older eroding beds? This situation creates a problem of contamination by fossil pollen, one which cannot be detected so easily as contamination of a sample by the modern pollen rain.
3) In laboratory processing, why do some sediments develop a colloid and others do not, and how can the problem be overcome easily and efficiently? Though some progress has been made to control the difficulty by corrective measures, it would be desirable to prevent the problem before its onset.

4) Can the microfossil material (including pollen grains) extracted by two different methods be compared both quantitatively and qualitatively? Present information indicates that Methods 2 and 3 do not yield the same results.

5) What happens to the pollen when it is bleached or when a stronger mixture of acetolysis is used to lighten or remove much of the humic content of a sample? Laboratory experience suggests that some of the pollen grains are destroyed. Quantitative and qualitative tests will be necessary to understand this problem.

6) What can be done when beds are missing from a series of deposits? The interpretation of the geology at the Lehner Site reveals that certain deposits have been eroded and are missing from the stratigraphic record leaving gaps in the geological history of the site. This situation brings about the need for the development of a long uninterrupted sequence of deposits similar to those found in a peat bog.

7) Finally - How can the removal of sedimentary
material from a site be controlled to insure both accuracy and efficiency in collecting? The collection and recording phase of any earth science program lays the foundation for further study. The removal of materials without proper procedures and techniques is in a sense the same as none at all. During the excavation of any site (archaeological, geological, or paleontological) there should be one person in charge who is the central authority with whom other "guest" specialists must coordinate their activities. The random sampling of any site without the aid and consultation of the person in charge is indefensible in the conduct of research. Any specialist who is invited to participate in an excavation would be expected to write at least a brief summary of his activities, and for pollen analytical purposes also submit a map and diagrams for all the material he has collected. These documents should if at all possible conform to the existing procedures used by the person who is directing the operations. The basic records should not be the author's interpretations of the geology, archaeology, and paleontology of the site. In a sense, the excavation of a site should be under the authority of one person, a coordinator, who could bring about the cooperation of each specialist to insure that the maximum amount of information is recovered.

The increasing amount of interest in arid lands research and the usefulness of the geochronological approach
(Smiley 1956) has given a stimulus to new archaeological activities. The archaeologist in order to extract as much evidence from non-artifactual material as possible must call upon specialists for their services to better understand man's past environment (Taylor 1957).
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APPENDIX I

Chemicals, Apparatus and Equipment

The following is a list of the materials used to extract, mount, and study fossil pollen grains from the sediments at the Lehner Mammoth Site. One asterisk indicates those items unique to Method 1, a double asterisk denotes those utilized in Method 2, and a triple asterisk designates those unique to Method 3. Otherwise, the materials are the same for all three methods.

Non-expendable equipment and apparatus:
- Fume hood
- Centrifuge, 15-50 ml.
- Bunsen burner
- Tripod, iron ring
- Distilled water bottle
- Reagent bottles
- Single beam balance
- Hot plate, adjustable temperature
- Centrifuge tube racks, 15 and 50 ml.
- Funnel, polyethylene, 3½ in.
- Forceps, cover glass
- Teasing probe
- Leitz research microscope

Expendable equipment and apparatus:
* Cylinder, 1000 ml., pyrex
* Funnel, 6 in., short stem, pyrex
* Flask, Erlenmeyer, narrow mouth, 250 ml.
* Flask, Erlenmeyer, wide mouth, 500 ml.
* Whatman filter paper, No. 1, 24 cm.
* Pipette, volumetric, 10 ml.
* Graduate, 25 and 100 ml.
* Centrifuge tube, 15 and 50 ml., pyrex
* Centrifuge tube, 50 ml. Nalgene (trade name)
*** Teflon centrifuge tube, 50 ml.
* Culture tube, 30 ml., pyrex
* Rubber stoppers, 15 and 50 ml.
* Beakers, 1000 – 500 – 250 – 50 ml., pyrex
* Brushes, bottle and centrifuge tube
* Test papers, Hydron pH
* Film cannisters, 35 mm.
Expendable equipment and apparatus - cont.

*Plate glass, 6 x 6 in.
Glass marking pencil
Micro slides, 1 x 3 in.
Micro cover glasses, 22 x 40 mm., No. 1
Micro slide labels, 22 x 22 mm.
Micro slide boxes
Pastuer capillary pipette, 9 in., disposable
Dropping bottles
Basic Fuchsin stain

* ***Glycerin jelly (Wodehouse 1935: 107; Traverse 1955: 98)
***Poppy seed oil (Grumbacher, artist quality)

Chemicals:
- Hydrochloric acid (HCl)
- Hydrofluoric acid (HF)
- Glacial acetic acid (CH₃COOH)
- Sulphuric acid (H₂SO₄)
- Acetic anhydride (CH₃CO)₂O
***Potassium hydroxide pellets (KOH)
* ***Sodium hydroxide pellets (NaOH)
* ***Sodium Chlorate (NaClO₃)
* Paraffin oil, white, U.S.P.
**Tetra bromoethane (CHBr₂CHBr₂)
Acetone (CH₃COCH₃)
* Xylene (C₆H₆(CH₃)₂)
* ***Alcohol, absolute (CH₃CH₂OH)
APPENDIX
II

Sediment Columns and Units

This section is an inventory of the sedimentary material taken from the Lehner Mammoth Site for purposes of pollen analysis. The system of designating samples is discussed in the section on The Collection of the Samples. The sediment columns include numbers 1, 2, 3, 4, 5, 6, 7, and 8; and the units are 9, 10, 11, 12, and 13. Due to the fact that no less than 7 individuals collected sedimentary material from the Lehner Site, it was not possible to gather all of the pertinent information relating to each column or unit. Sketch maps and notes concerning the sediment material are on file at the Geochronology Laboratories.

List of the Sediment Columns and Sediment Units from the Lehner Mammoth Site:

Sediment Column No. 1 Samples 1-14
Collected: February, 1956 by: Edwin B. Kurtz
Purpose: To sample the sediments from deposits which occurred above and below layer (K)
Appraisal: Samples from the top 60 cm. of bed (m) were not collected. The column is of little value
for pollen analysis without material to tie it into the surface.

Sediment Column No. 2  Samples 1-16
Collected: February, 1956  by: Marvin Stokes
Purpose: To sample the deposits in a vertical cut which was made upstream (west) from the site
Appraisal: Sediment samples were taken from a three and one-half meter column upstream from the Lehner Site, the top 50 cm. of which was not sampled. The lower two meters of deposits cannot be defined in terms of the sequence of deposits at the Lehner Site proper. The value of this column for pollen work is doubtful.

Sediment Column No. 3  Samples 1-7
Collected: February, 1956  by: Edwin B. Kurtz
Purpose: To sample the deposits which were found between layer (k) and bed (a).
Appraisal: This set of samples could provide a record of the pollen grains in sediments below layer (k).

Sediment Column No. 4  Samples 0-18
Collected: February, 1956  by: Kurtz and Stokes
Purpose: To sample the deposits in a vertical cut made several meters to the east of the Lehner Site proper
Appraisal: The geology in this locality of the arroyo is not at all clear. It is possible that the samples collected could have been removed from material which had slumped from a higher deposit. If this should be the case, the material would be of little value.

Sediment Column No. 5  Samples 1-7
Collected: February, 1956  by: William W. Wasley
Purpose: To test for pollen in the sediments from beds which are thought to be of pre-Altithermal and post-Altithermal ages
Appraisal: The horizontal relationship of the deposits found in columns 5 and 7 make these two columns valuable for future study.

Sediment Column No. 6  Samples 1-14
Collected: December, 1955  by: Dick Shutler, Jr.
Purpose: To sample each observable geological deposit which occurred above and below layer (k)
Appraisal: The samples are valuable for their stratigraphic associations above bed (i), but unreliable below (i) because of interbedding.

Sediment Column No. 7  Samples 1-7
Collected: August, 1956  by: W. W. Wasley  A. J. Lindsay, Jr.
Purpose: See Column No. 5
Appraisal: See Column No. 5
Sediment Column No. 8  Samples 1-41
Collected: December, 1955  by: Dick Shutler, Jr.
Purpose: To sample at 10 cm. intervals the sequence of deposits above and below layer (k)
Appraisal: This column will be of value because of the close intervals used for sampling. This column is 40 cm. south of column 6. The samples from below layer (k) are unreliable.

Sediment Unit No. 9  Samples 1, 2, 3, 4, 5, 6
Collected: December, 1955  by: Dick Shutler, Jr.
Purpose: To sample the material from layer (k)
Appraisal: The evidence from extracted fossil pollen indicates that layer (k) is relatively homogeneous over the area in which the greatest concentration of mammoth bones occurred. (Fig. 2)

Sediment Unit No. 10  Samples 1, 2, 3
Collected: December, 1955  by: Dick Shutler, Jr.
Purpose: To collect sediments which would be representative of the material from the bone bed.
Appraisal: Judging the samples on the basis of texture and color it seems the sediments are a mixture of layer (k) and bed (j). A sufficient amount of pollen was not recovered from these samples to permit an assessment of their importance.
Sediment Unit No. 11   Sample 1
Collected: February, 1957 by: A. J. Lindsay, Jr.
Purpose: To collect sediments which were directly associated with a mammoth mandible (No. 7) and known geological deposits
Appraisal: This sample is useful because of its association and value in cross-checking with other material from the bone bed.

Sediment Unit No. 12   Samples 1, 2, 3, 4, 5
Collected: March, 1958 by: W. W. Wasley
Purpose: To secure samples from beds (a), (c), (f), (i) and (j) with a known geological context
Appraisal: These samples replace the material considered unreliable in columns 6 and 8. These samples are very difficult to extract pollen from because of their clayey texture and tendency to develop a colloid.

Sediment Unit No. 13   Samples 1, 2
Collected: March, 1958 by: W. W. Wasley
Purpose: To secure samples from beds (g) and (h) with a known geological context
Appraisal: Same as for unit 12.
Sediment Samples Processed

This appendix consists of a complete list of the sediment samples that were used for pollen extraction during the course of this study.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Method used to extract pollen</th>
<th>Slides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td>Nos.</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1-14</td>
<td>thru 7</td>
</tr>
<tr>
<td>2</td>
<td>1-16</td>
<td>thru 7</td>
</tr>
<tr>
<td>3</td>
<td>0-18</td>
<td>thru 7</td>
</tr>
<tr>
<td>4</td>
<td>1-7</td>
<td>(not processed by any method)</td>
</tr>
<tr>
<td>5</td>
<td>1-7</td>
<td>thru 7</td>
</tr>
<tr>
<td>6</td>
<td>5-14</td>
<td>thru 7</td>
</tr>
<tr>
<td>7</td>
<td>1-6</td>
<td>thru 7</td>
</tr>
<tr>
<td>8</td>
<td>1-41</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>assort. nos.</td>
<td>X</td>
</tr>
</tbody>
</table>

**Units**

| | | | | |
| --- | --- | --- | --- | |
| 9 | 1,3,4,6 | X | X | yes | yes |
| 10 | 1,2,3 | X | X | yes | yes |
| 11 | 1 | X | X | yes | yes |
| 12 | 1,2,3,4,5 | X | | yes | yes |
| 13 | 1,2 | X | X | yes | yes |

X = completed

thru 7 = Steps 1-7