

SURFACE AND ARCHAEOLOGICAL SEDIMENT POLLEN STUDIES  
IN THE MAMMOTH CAVE NATIONAL PARK STUDY AREA:  
A METHODOLOGICAL AND INTERPRETIVE REPORT

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#### ACKNOWLEDGEMENTS

I wish to express my debt to Mr. Robert J. Burton, for without his assistance and advice this report could never have been prepared in its present form. Bob's expertise in the areas of statistical analysis and the applications of computer technology to archaeology has been, successively, a source of wonderment and education for me. When our association first began I, like many of my academic generation, had been assiduously working to avoid involvement in any use of inferential statistics for many years. I neither knew nor wished to know much of the variety of statistical tools available for my use, and I had experienced just about as much frustration with our idiot savant friend, the computer, as I felt was tolerable for a lifetime. Bob was the first to guide me, quietly and with a gentle hand, into the maze of multivariant techniques and statistical models. He also has given more than moral support over the years. He has happily helped out frequently as a combination keypunch operator, statistics-computer consultant and sounding board and has gone so far as to learn a good deal of the technology and methodology of pollen analysis as a means of assisting me more fully. Bob has rejected junior authorship of this report on the grounds that his contribution to it was technical rather than creative. But I find that distinction too finely drawn in this case to let pass unregarded. Hopefully, this paragraph expresses not only the character of his contribution but my respect for its significance.

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## 1. PREFACE

Pollen analysis is traditionally undertaken on sediment samples collected from swamps, bogs and lakes. Practical experience, experimental results and theories of the dispersal and distribution of pollen grains combine to indicate that sediment samples of such locations contain an essentially randomized sample of the pollen dispersed within the basin of deposition at the time the particular sediment collected was laid down. Exceptions to this generalization are recognized, particularly when the basin is extensive or inflowing streams create water circulation patterns which encourage differential sediment deposition in different areas. But as a general rule it is understood that the pollen types one observes in samples of such sediments, and their relative frequencies, are a reliable index to the nature and proportions of vegetation patterns in the general vicinity at the horizon of deposition.

The fact that the pollen of such deposits is transported to the locus of deposition in an aqueous medium is significant. Pollen grains are grazed and destroyed by a wide variety of herbivores and saprophytes, many of which are microscopic. These organisms are normally terrestrial and require aerobic conditions for survival. Aqueous environments of deposition thus accommodate the preservation of large numbers of pollen grains per unit volume of sediment through exclusion of destructive agents. Another significant factor is the fairly slow rate of deposition under aqueous conditions. If a given volume of deposit represents a greater number of seasons of pollen production, it offers more opportunity for the accumulation of large numbers of pollen grains.

Sediments accumulated in the context of archaeological sites are normally exposed to atmospheric pollen rain, and so also normally trap pollen grains. But these sediments are deposited under wholly terrestrial conditions, since man does not function habitually in an aquatic environment, and sediment accumulation may be very rapid and directly influenced by a myriad of human

activities. Further, such sediments are not exposed to the atmospheric pollen rain of an entire depositional basin. Normally, they are principally exposed only to the pollen dispersed by plants at or immediately proximate to the location of sediment accumulation, involving distances measured only in tens or scores of meters. These qualities encourage the degradation and destruction of the pollen trapped, and tend to reduce the amount of pollen recoverable from a given volume of deposit. To complicate the matter further, human activities may introduce pollen into site deposits. This may be pollen of exotic plants brought to the site from distant locations by its occupants, cultivated near the site, or traded to the site. Even if the intrusive pollen is of local plants, human actions may influence the relative frequencies of pollen types in site context deposits.

The net effect is that pollen records recovered from the context of archaeological sites cannot be considered directly comparable to those recovered from the deposits traditionally investigated by pollen analysts. Site context deposits must be assumed to contain not only less pollen per unit volume, but pollen which has been subject to different processes of destruction and preservation, pollen types which have been subject to a greater potential human influence in regard to both production and dispersal mechanisms, and pollen frequency values highly influenced by very localized behavioral and ecological conditions. In light of these complications, some pollen analysts (e.g. Wright 1974) argue that the study of pollen records of archaeological sites is not worthwhile if one's objectives are those of traditional pollen analysis: establishment of relative chronology through biostratigraphic correlation; reconstruction of paleovegetational patterns; paleoecological reconstruction; and paleoclimatic analysis.

The issue is, however, methodological rather than theoretical or practical. From a practical perspective it is apparent that at least some sediments accumulated in archaeological sites contain reasonably large numbers of pollen grains which are sufficiently preserved to be identified. Samples from such deposits produce pollen records experiments have documented are replicable among different workers and are comparable to each other. They are thus subject to scientific study. From a theoretical perspective, such pollen records are interpretable as reflections of prior ecological and vegetational events irrespective of whether those events were extensively subject to human influence. Because pollen records are statistical in form, it is theoretically possible to differentiate those statistical values of a given pollen record which result from human influence and treat them separate from the remaining values. Even if the remaining values are highly conditioned by quite localized ecological conditions they are still related in some particular and specific fashions to regional vegetational and ecological patterns which may be deduced through sufficiently detailed study. The question is not whether the pollen records of archaeological sites can be used to achieve the traditional objectives of pollen analysis. It is how this can be accomplished. Clearly, it cannot be accomplished by the procedures pollen analysts traditionally employ for study of aquatic deposits.

A similar problem was faced by Martin (1963; Martin, Schoenwetter and Arms 1961) in his study of pollen records from alluvial deposits in Southern Arizona. In that case the sediments were water laid, but the pollen they contained could not be assumed to provide records comparable to those recovered from lacustrine or swamp deposits since alluvial and lacustrine depositional process and basin parameters are so distinctive. Martin developed a distinctive method for interpretation which has gradually been adopted by pollen analysts concerned with the study of lacustrine desopits as well.

rain records representing known conditions of vegetation pattern, ecology and climate. But there are two assumptions which must be made if one is to employ this method, and neither can be conclusively demonstrated through experimental evidence. First, one must assume that the effect of human activities upon a fossil pollen record of archaeological context can never exactly (within statistical parameters) mimic the effect of natural processes resulting in the formation of modern pollen rains. Thus, if a modern pollen record and a fossil pollen record from an archaeological context are statistically identical, that identity is not a human artifact. This assumption is hotly debated among archaeological palynologists. Some take the position that the assumption is normally valid since human actions are far less consistent than natural processes and there is little probability that human behavior could effect pollen rain mimicry. Others argue that since the natural processes which cause pollen records to occur in particular forms are essentially unknown, mimicry is not unexpected. Yet others argue that though mimicry might occur in a given pollen record it is not likely to be the explanation for the occurrence of consistent pollen records from different samples assignable to the same temporal horizon.

The second assumption is that modern pollen rain traps may be identified which are essentially comparable to the fossil pollen rain traps of sediments from archaeological context. Without such comparability the principle of uniformitarianism cannot be applied at all, so this assumption is of critical significance. Modern pollen rain traps used as a control for the interpretation of lacustrine fossil pollen records are normally the surficial deposits at the mud-water interface of lakes and swamps (McAndrews, 1968). Moss polsters collected from the forest floor or the surficial levels of the mat vegetation of bogs are also used (Webb, 1974). Martin (1963) gathered samples



from a number of different types of recent deposits in an attempt to identify those which produced pollen records most similar to the fossil pollen spectra of alluvial sediments in Southern Arizona, ranging from cattle dung to flood waters and freshly deposited alluvium. He concluded that the sediments laid down in open water storage facilities (both earthen and metal cattle tanks) were probably best because such deposits integrated the pollen rain of a controlled number of years. But other forms of modern deposits, including samples of surficial sediment collected from the terrestrial surface, produced quite similar pollen spectra. Martin was able to document that terrestrial surface samples produced somewhat distinctive forms of pollen spectra, however, relative to surface samples from aquatic context. Terrestrial surface samples are much more influenced by very local floristic patterns.

Subsequent study of terrestrial surface sediment pollen spectra by a number of Martin's students (e.g. Hevly, Mehringer and Yocum 1965; Hevly 1968; Mehringer 1967, Schoenwetter and Doerschlag 1970) have regularly confirmed this early observation, and a series of experiments on pollen dispersal patterns (summarized in Faegri and Iverson 1975) have produced a body of data which tends to explain this effect. As a rule, the vast majority of pollen grains dispersed from any given plant "rain" onto the surface in the immediate vicinity with modal dispersal distance primarily influenced by the height at which the pollen is released and the pollen productivity of the plant. Taller very productive plants disperse the majority of their pollen most widely; smaller equally productive plants disperse most of their pollen an appreciably smaller distance; the pollen of small plants dispersing little pollen falls to the surface very near the plant. Thus the pollen rain of terrestrial surface samples is essentially composed of pollen dispersed within and quite close to the sampled plot. Those of lacustrine sediment surfaces are essentially composed of pollen transported to the sampling location by wind and water from all sources in the

basin of deposition. The tendency of terrestrial sediment modern pollen spectra is to reflect local ecological patterns and floristic distributions. The tendency of lacustrine surficial sediment pollen spectra is to record regional patterns of floristic dominance and pollen productivity.

Because the pollen of terrestrial surficial sediments is exposed to similar degradational and decay processes, and tends to similarly trap local rather than regional pollen rain, some pollen analysts have assumed that they produce pollen records essentially comparable to those recovered from archaeological contexts. These workers have used terrestrial surface pollen records as controls for the interpretation of archaeological context pollen spectra in a wide variety of locations in the arid portions of the Southwestern United States (Schoenwetter 1962a; Mehringer 1967; Hill and Hevly 1968; McLaughlin 1977), Mexico (Schoenwetter 1972, Flannery and Schoenwetter, 1970) and South America (Schoenwetter 1973).

Very little use of the method, however, has been made for the investigation of archaeological pollen records in areas of temperate climate where coniferous and/or deciduous forest vegetation patterns occur historically. Schoenwetter attempted to apply the method in investigations of archaeological context pollen records from North Central Wisconsin (1966) and the Mississippi River floodplain (1962b, 1964). Gish (1976) elaborated on the earlier Wisconsin work with apparent success. She was able to document that intra-site biostratigraphic correlations generated through pollen analyses controlled by surface sample records are consistent with sedimentological and archaeological stratigraphic correlations of the sampled contexts. Fish (1973) utilized the method for paleovegetation interpretation of archaeological pollen records of Powers Phase sites in Missouri. Schoenwetter (1974a) applied the method to the study

of pollen of Archaic, Early Woodland and Late Woodland contexts at the Koster Site in Southwestern Illinois. The vegetational reconstructions produced were completely consistent with those independently derived from geomorphological-sedimentological evidence (Butzer, in press) and malacological studies (Jaehnig, in press).

Thus the assumptions which subtend the method, while recognizably debatable, are not so little evidenced that they have obviated the development of productive research. A few pollen analysts have been encouraged to produce interpretations of archaeological context pollen records from a variety of geographical locations which have the same objectives as traditional pollen analyses. In a number of cases these interpretations are consistent with those developed independently on the basis of geological, paleontological and artifactual evidence. It is still arguable that the interpretations produced by the method are erroneous, of course, and it is true that the assumption that a pollen spectrum from an archaeological context is not an artifact of human behavior cannot be tested experimentally. The relatively poor quality of pollen preservation under such conditions also disturbs experienced workers (King 1975, Bryant 1976a). Interpretations developed through application of the method, however, seem sufficiently vindicated by theory and experience to be granted the status of evidenced hypotheses.

## 2. INTRODUCTION

Archaeological pollen studies initiated in the area of Mammoth Cave National Park seem potentially open to interpretation through the method of surface sample comparison. Work accomplished to date (Schoenwetter 1974b) has demonstrated that small quantities of pollen can be extracted from large volumes of archaeological context sediments at some sites in the area. The pollen was so poorly preserved, however, and constituted such a minute fraction of the volume of any given sample of the deposits, that analysis of only 10-15% of

the submitted samples was reasonably profitable. While this is surely a small amount of information to recover considering the requirements of original investment, it appeared significant because of its unique character and potential archaeological utility. Also, of course, the 38 samples investigated did not accurately reflect the total range of archaeological contexts which exist in the MCRP study area. We could at least hope that if other contexts were subjected to palynological investigation a pattern might emerge which would allow identification of types of contexts where study would be more productive, or alternative extraction procedures which would allow greater recovery of data.

These investigations also documented the occurrence of sequentially ordered variations in the pollen records of such contexts. Such variations demonstrated the potential utility of the pollen analysis of archaeological context sediments in the study area for the construction of relative chronologies and the identification of changes in the paleoenvironmental settings of prehistoric cultural events.

These studies were complemented by palynological investigations of human paleofeces from Mammoth and Salts Caves (Bryant, 1974; Schoenwetter, 1974c). This body of work evaluated certain palynological results as reflections of seasonality and others as artifacts of the behaviors attendant upon menu preparation, medication, and food redistribution systems of the occupants of the study area 1500-4000 years ago. Though such research complements many aspects of the present study, and may be continued as opportunity develops, it should be recognized as a separate form of study. It pursues investigation of matters of archaeological pertinence, but is not concerned with the traditional objectives of pollen analysis.

This report presents the results of initial investigations of the modern pollen rain of Mammoth Cave National Park and applies that information to the interpretation of archaeological context pollen records recovered from the deposits

of three sites. I wish to begin this discussion, however, with a statement of my recognition that its outcome is in no way considered conclusive. Much of the interpretive value of the pollen records of the 22 surface samples investigated is severely limited by the relatively small number of samples involved. As Faegri and Iversen have repeatedly cautioned (1950, 1964, 1975), pollen analysis is a statistical procedure. The record of a single sample cannot be assumed to be representative of the population from which it is drawn, and the fewer samples one has drawn from any given population the more role chance may play in conditioning the pollen frequency values observed. The surface samples investigated have been drawn from six different vegetational patterns and therefore it is necessary to recognize they are unlikely to adequately reflect the range of pollen rain variation which actually occurs in the park. In order to proceed with the investigation efficiently I have made the assumption that the samples are sufficiently numerous for present purposes. I have used statistical procedures for evaluating this assumption wherever possible, as well. But the assumption is only defended on the basis of a lack of contradictory information. The conclusions arrived at, then, must be accepted with a measure of skepticism.

As should be evident from my prefatory remarks, the method of surface sample control for interpreting fossil pollen records depends upon two qualities in the data base: replicability and comparability. Two or more surface samples of atmospheric pollen rain ostensibly drawn from the same population should be statistically identical. The presumption is that such a population of pollen grains is formed by a particular and exclusive set of natural processes operating in a uniform fashion. If the samples are not statistically identical replicates, they must be recognized as products of different formation processes even if this is not apparent from inspection of the sampled plot. However, the

samples need not replicate each other in all attributes. That is, they need not be identical in respect to each and every particular of variety and number of pollen types and relative pollen frequencies. All that is required is that the samples replicate each other in some respect which is unique to the samples of that population and therefore diagnostic of their relationship to the specific population of pollen grains from which the samples were drawn.

To function as controls, the surface samples must also produce pollen statistics comparable to those of the fossil pollen records under consideration. In particular it must be demonstrable that the unique attribute or set of attributes which relates a particular set of surface pollen records to a particular vegetational, ecological or climatic pattern is observed in comparable form in the fossil pollen record. The problem of comparability is a sticky one, as both qualitative and quantitative mechanisms of evaluation and judgement must be employed. Traditional forms of pollen analysis similarly utilize both mechanisms to evaluate the comparability of pollen records, so the problem is not unique to this methodology. But in archaeological pollen analysis anthropological judgements are as crucial as biological ones, and this complicates matters. In the present case, the basis for quantitative evaluation is weak because so few samples of modern pollen rain have yet been subjected to analysis. Similarly, the basis for qualitative judgement is reduced because we presently know only a little of the habitual behavior patterns of the occupants of sites in the study area. Thus we are unable to make demonstrably sound judgements of the probable effect of human activities on the pollen records recovered from the sites.

Study of the modern pollen record of MCNP was initiated in the Spring of 1974 in co-operation with Dr. Adolf Faller, then of Cleveland State University. At that time Faller was completing the final draft of a study of the plant

ecology of MCNP (Faller 1975). As a means of assessing the range of variation in vegetation patterns occurring in the area, Faller had established a series of 44 vegetation stand stations through areal photographic analysis. Thirty-two of these were locations of representative wooded stands which were assessed quantitatively; the remainder were plots where trees were absent or rare. Seventeen of the surface pollen samples were collected within the confines of forest stands established and evaluated in Faller's study. One surface sample was collected from the surface of a rockshelter archaeological site within a studied stand, one sample was collected from a treeless location Faller had not studied, and one was collected from a plot (50 x 100 feet) established for the purpose.

Faller employed quantitative study procedures which emphasized stand basal area using a variable-radius plotless method (Bitterlich sampling method of Shanks 1954). This procedure yields plots of distinctive size. Where the density of trees is low and the basal area of the trees of a stand is small, the plot may encompass a number of hectares; where the stand is quite dense and the trees have a great basal diameter the plot may encompass only a few tens of square meters. Because Faller's analysis serves as an assessment of the ecology of the study area, the procedure used by Faller to identify a sample within a stand was used to identify the geographic space from which a surface sediment pollen sample was normally collected. Faller collected a series of samples within each forest stand station for his analysis, however. In this study only one sample was collected at a stand location with one exception, where that used in other forest areas (Schoenwetter 1966, in prep.). Within the geographic area identified by the Bitterlich method, twenty "pinch" (Hevly 1968) subsamples of sediment were collected from the base of the leaf litter at the

point mineralization was first evident (the A<sub>0</sub> soil horizon) at random positions. It is thought that this sort of sampling recovers atmospheric pollen rain of the sampled area which has been concentrated over a number of seasons by down-wash through the leaf litter and has been degraded and reduced by most of the destructive processes likely to affect archaeological sediment contexts (Schoenwetter, in prep.). Records were kept of the number of mature trees of each species and the variety of shrubs at each sampled area.

In theory, the surface samples have trapped modern pollen rains which are principally derived from the local floras of the sampled stations. They therefore are expected to produce pollen records which are palynological reflections of local vegetation patterns. Since they were collected to maximize the influence of natural processes destructive of the modern pollen and to minimize the effects of pollen rain seasonality, they are (at least in theory) reasonably comparable to the sorts of pollen records that could occur in an archaeological context if those fossil records were not more influenced by human behavior than the modern surface samples. Because the samples were collected from six different vegetation types, and because each location was distinctive as regards dominance, subdominance, coverage, sociability and other characteristics of vegetation patterns, the series should provide effective information on the variability of pollen rains in Mammoth Cave National Park.

It should be emphasized, however, that the number of surface samples recovered is not statistically adequate for characterization of either the modern pollen rain of MNCNP or the range of variation in pollen rain of any given vegetation type occurring in the park. The geographic range of the park has not been sampled as yet, and only 1-5 samples have been recovered from any given of vegetation type. For purposes of this study I have assumed that the



samples are adequate but no statistical defense of that assumption can be offered. Presumably, future research will resolve this issue.

### 3. VEGETATION OF THE PARK

Faller's investigations (1975) led to the recognition of seven forest types within the MCNP boundaries: Mixed Mesophytic Forest, Western Mesophytic Forest, <sup>Relict Tertiary Forest,</sup> Oak-Chestnut Forest, Oak-Hickory Forest, Floodplain Forest and Successional Forest. Stands were classified into six ecologically significant categories: Beech Woods, Mixed Woods, Oak Woods, Hemlock Woods, Riparian Woods and Successional Woods. These categories are interpreted as those grouping stand variations responsive to ecological factors conditioning the dominance and coverage values of the most important plant species of the study area. Faller concluded that a good deal of the variation observed in the vegetation of the park is the result of historic human influences and consequent successional changes. Such influences range from introduction of chestnut blight and planting of exotics to land clearance and selective lumbering. But some of the variation is certainly due to the substrate, topographic and hydrographic variations which characterize the MCNP area. Had historic human activity never occurred in the park, it is possible that the six forms of woods now observed would have been integrated into one forest type in which oak, maple, hickory and tulip tree would have formed a complex of dominant elements. But it is more probable that four forest types would occur conditioned, respectively, by the distribution of floodplains, outcrops of Mississippian bedrock (limestone), outcrops of Pennsylvanian bedrock (sandstone), and the deep, level soils of solution valleys and plateaus. Modern Riparian Woods, modern Oak Woods, and modern Mixed Woods and Beech Woods stands evidencing little human influence probably approximate the vegetational characteristics, respectively, of the forest types that could be "normal" to the floodplains, limestone outcrops and

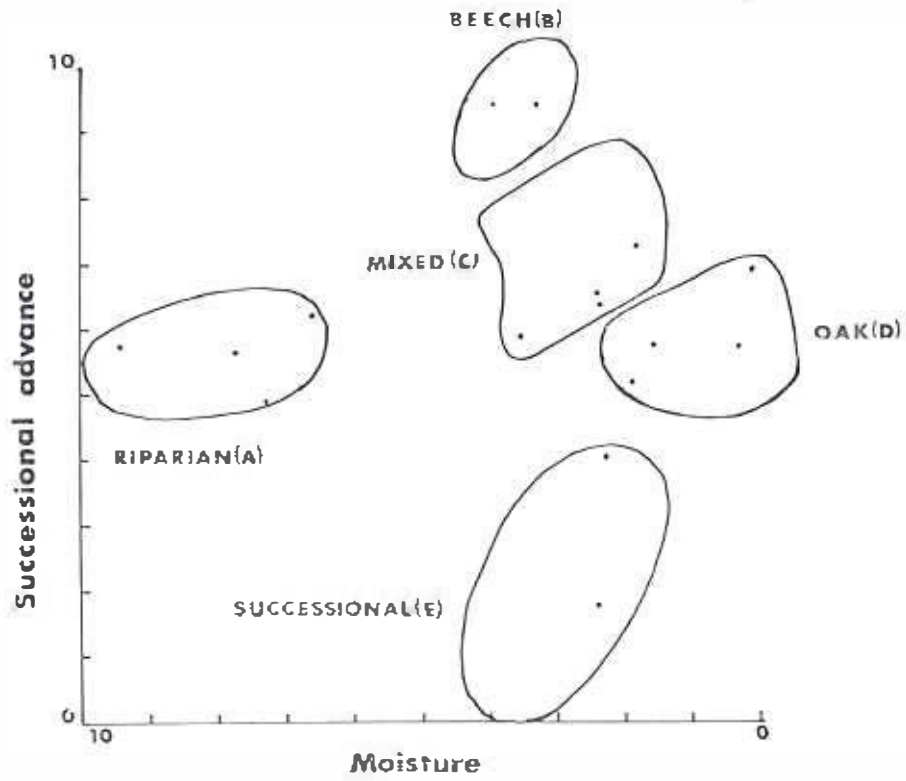


Figure 1. Ecological positions of the seventeen surface samples controlled by Bitterlich records in MCNP.

sandstone outcrops of the park. The deep soil districts, however, were favored by historical farmers. The Successional Woods which now occur in such locations are probably poor indices of their original floras.

Faller used the Bitterlich sampling procedure to provide quantitative estimates of the importance of different species in a stand. This was employed to produce cluster analyses based on indices of stand similarity for identification of the six categories of woods. Such analysis also allows placement of any location-specific body of vegetation data collected in the park by Bitterlich sampling upon a graph plotting the successional character of the observed vegetation against relative degree of xericity (Faller 1975: 87 and 89), so it offers a means of identifying the ecological significance of the vegetation of particular locations. Where the Bitterlich method was used to establish the geographical boundaries of the locations sampled for modern pollen rain study, we are able to plot the ecological position of each of the sampling stations in reference to moisture and successional parameters (Fig. 1).

It may be noted that the Hemlock Woods vegetation pattern is not expressed on Figure 1. This occurs as a result of the distribution of associations in which hemlock is a dominant or subdominant element and the character of Faller's sampling procedure. Hemlock is a highly localized as a dominant or sub-dominant element in the park at the present time, to the degree that Hemlock Woods plant associations have a markedly smaller geographic extent than the other five vegetation types. Since Hemlock Woods could not be isolated as a geographical unit from areal photographs like the others, it could not be internally sampled within a single stand. Faller identified Hemlock Woods as a segregate vegetation type on the basis of several Bitterlich samples in a number of stand locations which he then grouped into a composite set. As this set represents

only one stand, it is not amenable to the cluster analysis procedure used to establish the ecological parameters graphed on Figure 1.

#### 4. OBSERVATIONS

Observation of the pollen extracted from the surface sediment samples was controlled by attempts to insure comparability with the fossil pollen records of archaeological sites. Experience has demonstrated that the site context deposits are not polliniferous. Generally, an extract of the pollen-bearing fraction of ca. 100 cc. of sediment yields so little pollen that less than 10 grains are observed per drop of extract. In some cases, however, 30-100 pollen grains occur per drop and in a very few cases 1000-3000 pollen grains occur. To avoid inordinate investment of labor in the analysis of the fossil pollen only those samples of the last two categories are investigated. In these cases, all the pollen of a single drop of extract or 100 pollen grains are tabulated, whichever occurs first as observation proceeds. We have been concerned, of course, about the statistical quality of pollen counts of 30-100 grains. Two hundred grain counts are the traditional accepted minimal standard for pollen analysis (see Faegri and Iversen 1975:187) though experimental evidence may be presented which indicates that the value of smaller counts is not impaired if fewer than 20 pollen types are encountered in each pollen record (Schoenwetter, in prep.). A pollen sum of 200 grains was utilized for observation of the controlled modern surface samples as it was felt that a larger number would reduce their comparability to the fossil records and a smaller number might be suspect.

Because fossil pollen is not generally as well preserved as the pollen of the modern surface sediments, fine details of pollen morphology are adversely affected by the more corroded, eroded, broken and distorted characteristics of the fossil grains. Certain taxonomic distinctions which can be made in

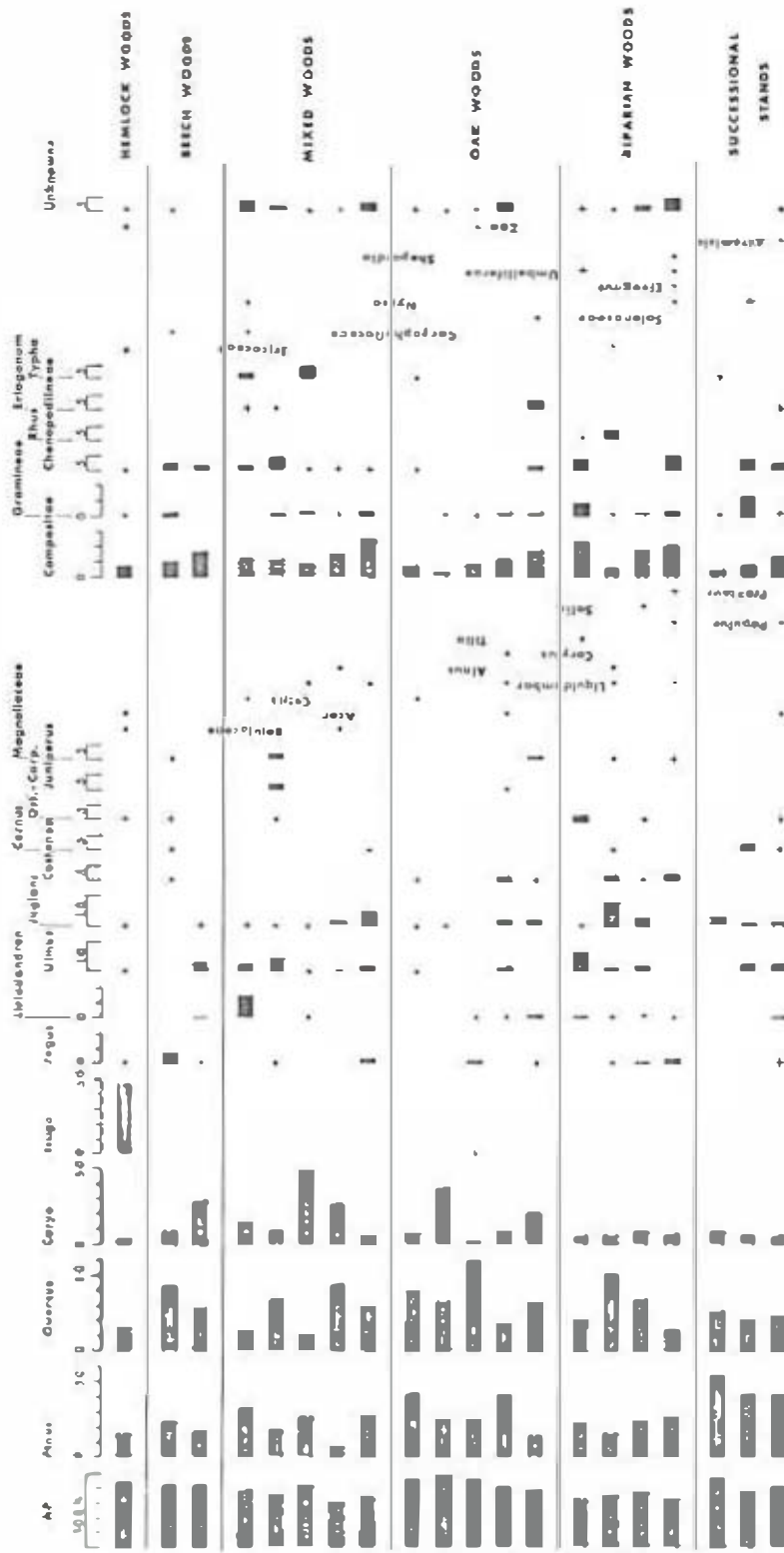


Figure 2. Pollen frequency values of the 20 controlled surface samples. "+" indicates 1.0% frequency; "." indicates 0.5% frequency.

identification of the pollen of the surface samples were therefore disregarded during observation, to effect closer comparability with the fossil record. For example, size variations of pollen of the genus Quercus, which could potentially be an index of species distinctions, were not recorded. Similarly, morphological distinctions among pollen types of the Ambrosieae and Tubuliflorae tribes of Compositae were not recorded.

##### 5. ANALYSIS: CONTROLLED POLLEN RECORDS

The first analytic design employed for assessment of the twenty 200-grain pollen records was that normally and traditionally used in pollen analyses attempting identification of comparable pollen records. This involves graphing pollen type frequency values to allow visual comparison of the data within and between vegetational categories (Fig. 2). Simple inspection of the frequency values is normally thought sufficient to document comparability, though localized conditions fostering the overrepresentation of particular pollen taxa or the long-distance transport of particular taxa might require adjustments of the pollen sum upon which frequency values are calculated.

All of the surface sample pollen records were collected at localities subjected to the same climatic conditions, but edaphic conditions vary and the degree of successional advancement is not uniform among the sampling stations. It was therefore anticipated that the analysis might have one of two results. If the primary condition controlling pollen frequency values was a regional phenomenon, such as climate, inspection should document comparability among all the samples. If the primary condition affecting the pollen record was floristic, those samples collected from each type of woods should be comparable but not comparable to the samples collected from another woods type. This would occur because each type of woods responds to local combinations of edaphic and

biotic conditions.

It may be observed that all the records of Figure 1 are comparable in regard to the frequency of arboreal pollen (AP). This is true irrespective of arboreal density at the sampling locality, for some loci supported no trees at all and others supported large numbers of trees. Apparently, modern regional conditions of the MCNP area are best identified palynologically by the occurrence of AP values having a mean of 80.9% and a 95% confidence interval of 76% to 86%. However, inspection does not provide documentation for the proposition that pollen records of different types of woods are normally comparable among themselves but non-comparable with each other. The single pollen record from a Hemlock Woods station contains a distinctive frequency value for hemlock pollen, but we cannot presently know if this is characteristic of the population of Hemlock Woods samples as there is no mechanism for statistical evaluation. Successional stands are more consistently characterized by the occurrence of pine pollen at a frequency value exceeding 40%, but half of the Mixed Woods samples and 40% of the Oak Woods samples are statistically comparable in this regard. Judging on the basis of this procedure of analysis, it appears fairly clear that the type of vegetation occurring at a sampling location cannot be recognized through inspection of the frequency values of 200-grain pollen counts recovered from deposits occurring at that locus. There is neither sufficient comparability among samples known to be derived from the same vegetation type, nor sufficient lack of comparability among samples known to be derived from distinctive vegetation types.

But simple inspection of pollen frequency values is not the only analytic procedure which may be used to measure the comparability of pollen records. Though they are not traditionally employed, a variety of statistical procedures for analysis of variance are applicable to pollen data as a result of its expression as frequency values. Mosimann (1965), Webb (1974a), and Birks, et al (1975) have explored the value of univariate and multivariate procedures such as homogeneity chi square analysis, principal components analysis, and canonical correlations analysis. Burton (1973) and Smith (1976) have explored the application of multivariate discriminant function analysis as yet another avenue.

Because the low number of samples recovered from a given type of woods make the application of any statistical procedure suspect, it is evident that no statistical procedure should be used which requires acceptance of many complex assumptions about the data that can neither be accepted or rejected. It is also evident, however, that if any statistical procedure is to be used it should be of the category statisticians call "robust." The term robustness refers to the sensitivity of a test to distortions of various kinds. Such sensitivity allows more cause for acceptance of null hypotheses; for example, the hypothesis that two pollen records are not comparable. Since multivariate procedures of analysis of variance are generally more robust than univariate procedures, use of a multivariate examination of these pollen records is the more conservative approach. If distortions occur as the result of such factors as differential pollen preservation, long-distance transport of pollen or local overrepresentation of particular pollen types, a multivariate analysis--being more sensitive to such distortions--would tend to identify them and recognize two pollen records as non-comparable that could be identified as comparable if a univariate analysis was employed.

Among the various multivariate procedures pollen analysts have employed, discriminant functions analysis seems most suited to the specific needs of this study.



Webb and Clark (1977) have recently demonstrated that multiple regression analysis is the least complex and most effective among five multivariate procedures used to establish calibration functions that allow interpretation of pollen records in terms of meteorological parameters. Webb and McAndrews (1976) show the value of a combination of trend surface and principle components analysis for the assessment of broad scale features of modern pollen rain records to allow illustration of the relationship of pollen rain to regional forest types by use of isopoll maps of northeastern North America. Bernabo and Webb (1977) have used these isopoll maps in conjunction with a variety of other data forms (isochrome maps and difference maps) as a means of tracing the changing location and composition of four major vegetational regions during the Holocene in northeastern North America. In view of these successes, why was discriminant function analysis selected?

The procedures used by Webb and his colleagues are, like discriminant functions analysis, based upon a linear empirical model of the relationship between pollen rain and the set of conditions (climatic, edaphic and biotic) which cause it to be formed as observed. Principal components analysis, multiple regression analysis and forms of correlation analyses justified by the model assume the occurrence of a continuous distribution of the independent variables which influence the pollen rain. These forms of analysis recognize, then, a range of biological expressions for various forest types. The flora observed at a sampling location may, for example, have all the attributes of a plant association characteristic of the Boreal Forest vegetation type. But that flora's map position and its relationship to adjacent plant associations in the region unequivocally would demonstrate that the plant association is properly classified as one of the variants of the Mixed Forest vegetation type.

Discriminant functions analysis is specifically designed for analysis of data which may be unequivocally assigned to discrete groups. That is, a data base in which the independent variables are demonstrably non-continuous. This is precisely

the situation of the samples collected from MCNP. Thanks to the prior work of Faller, it is possible unequivocally to assign each sample to one of six categories of woods and to recognize its relationship to particular samples of the same or different categories in terms of degree of successional advance and degree of xericity. To ignore the value of such information in selecting the appropriate format of analysis of the pollen records would be foolish. Discriminant functions analysis was therefore elected over other procedures justified by the same mathematical model of the relation of pollen rains to ecological factors.

The first discriminant function analysis employed<sup>1</sup> was a step-wise analysis which utilized almost all of the palynological information available. In essence, the computer was asked to calculate the set of mathematical statements necessary to discriminate the pollen frequency values for each of five vegetation types as widely as possible. Then it was required to statistically test the hypothesis that the group mean values for each of 38 pollen types<sup>2</sup>, taken together, were not likely to be the result of chance. Since inspection of the pollen frequency values indicated there was little comparability among the spectra of a given vegetation type, it was anticipated that the discriminant function analysis would indicate the same result. That is, the discriminant analysis would document the proposition that the pollen records of various types of woods were so much like each other that statistically significant discrimination of each or any group was not possible.

The analysis identified two mathematical statements (discriminant functions or "roots") which, respectively, account for 95.5% and .03% of the variation in the data. That is, applying these two functions to the pollen frequency values allows

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<sup>1</sup>BIOMED Program 7M, Health Sciences Computer Facility, UCLA, Version of September 1, 1965.

<sup>2</sup>*Zea* was excluded from consideration and *Ambrosieae* and *Tubiliflorae* were collapsed to the single category "Compositae."

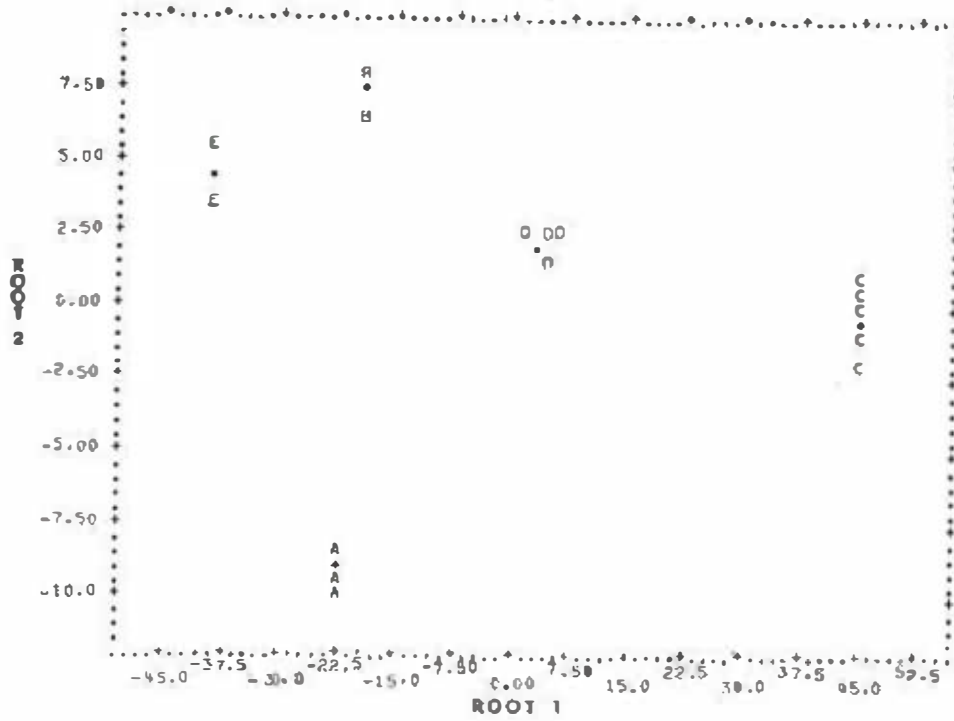


Figure 3. Distribution of sample discriminant scores using 38 independent variables.

discrimination of pollen records from the five vegetation types (Hemlock Woods was excluded because it is represented only by a single sample) 95.53% of the time. An F test indicates that the probability that these functions could be achieved by chance distribution of the data is less than 1 chance in 10,000. The distribution of records when graphed after application of these functions is illustrated in Figure 3. The multivariant mean value of pollen frequencies for each of the types of woods (the "centroid value") is graphed as an asterisk; the range of discriminant score values of the most divergent pollen spectra in each forest type group is also represented.

This analysis indicates that though inspection of pollen spectra does not provide a basis for determining the vegetation pattern at a sampling locus, discriminant function analysis might provide such a basis. The word might is used advisedly because it is clear that one of the basic assumptions of the statistical procedure is not demonstrable.

The procedure assumes the range of palynological variation that might be observed in the population of pollen grains from each type of woods is adequately reflected in the available data. We cannot know that this is true. Therefore we can only say at this juncture that discriminant function analysis allows a means of identifying the vegetation type associated with a 200-grain pollen record if the assumption holds up upon statistical testing.

In any case, this discriminant function analysis does not adequately serve to control the archaeological pollen records of MCNP. This analysis took 38 pollen taxa into consideration in the calculation of mean pollen frequency values of the vegetation type groups. Because of poor preservation, fossil pollen records contain fewer pollen types. Also, all of the pollen types of the modern pollen rain are not produced by plant taxa which are conditioned by the ecological factors which account for similarities and differences among the vegetation types of MCNP.

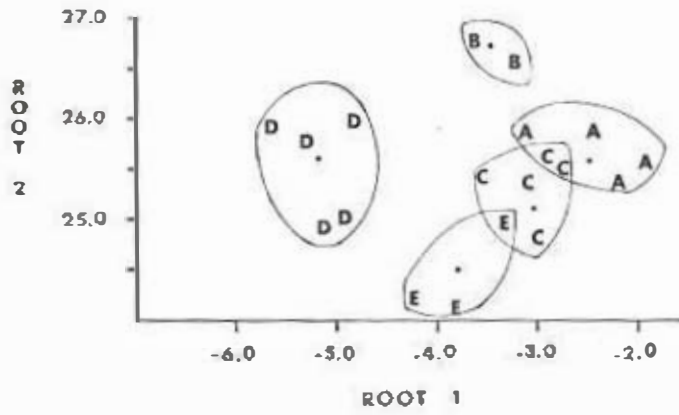


Figure 4. Distribution of sample discriminant scores using 11 pollen types.

For example, pine pollen occurs regularly in appreciable quantities in the surface samples but pine trees in the park are all introduced since the beginning of this century. They reflect only the systematic human behavior pattern of planting pine trees to beautify roadsides and/or prevent surface erosion. The degree to which pine pollen frequency values aid in the discrimination of forest type pollen records is, then, an artifact of human behavior or long-distance transport of pine pollen and not an expression of ecological factors conditioning vegetation pattern characteristics.

With these facts in mind, and guided by Faller's identification of the plant taxa of the park which characterize the types of woods, a second discriminant function analysis was undertaken.<sup>3</sup> This time only the frequency values of 11 pollen types were considered, and frequency calculations of each sample were based upon the sum of the observed pollen of those types. It was recognized that we here treaded very heavily upon the assumption that the number of pollen grains observed in the 11 pollen categories in each sample is adequate for statistical analysis. But it is impractical to attempt to observe more than 100 pollen grains in the fossil samples. If rigorous controls cannot be identified for such pollen counts then they simply cannot. Conversely, if there is some indication that it is possible to work within such constraints it is obviously profitable to attempt to do so.

The discriminant function analysis undertaken using 11 variables produced the results illustrated as Figure 4. The two functions account for only 84.6% of the observed variance (a notable contrast to the results of the first analysis) and of that amount only 64.3% is not likely to be a result of chance ( $p = .03$ ). Essentially, this analysis informs us that samples from Oak Woods can be recognized as having very distinct mean pollen values from those of other vegetation types and that

<sup>3</sup>DISCRIM program, ASU Statistical Library. This program does not graph the results of the analysis, but it prints the discriminant weights for each variable and the discriminant scores of each pollen record.

samples from Successional Woods can very likely be separately recognized. Considering all the individual sources of distortion potentially inherent in this data base, though, it is a marvel that any discrimination of vegetation types was achieved in which a measure of statistical confidence can be established. Again, the expectation was that all of the vegetation patterns would be assessed as palynologically comparable with a probability of .05. The result obtained indicates that the pollen records of Oak Woods are sufficiently distinct from the others that the odds are about 4 to 1 that this is not due to chance.

One of the 11 pollen types used in this second discriminant function analysis was Pinus. It was included because it appears in abundance in the surface pollen record and may have some particular relation to the Successional Woods samples group. But when the results of the second analysis were in, I felt it might be useful to see what would happen if the discriminant functions were developed only on the basis of the 10 pollen types which are produced by the most ecologically significant taxa in the park and are most commonly represented in the fossil pollen record: Quercus, Carya, Ulmus, Juglans, Liriodendron, Fagus, Chenopodiineae, Gramineae, Magnoliaceae, and Compositae.

In this third analysis the number of pollen grains observed in some samples was below the minimum number a statistician would consider usable - or even reasonable. But I was curious to learn whether or not any discriminations could be generated which had statistical credibility. If not, this analysis would finally document the extreme limitations of the fossil pollen record by demonstrating that if one utilized only those few pollen grains of ecologically significant taxa observed in a small pollen count one could not identify vegetation types from their pollen spectra. To my surprise, the analysis indicated such expectations were not fulfilled. Not only did the third analysis allow discrimination of as many

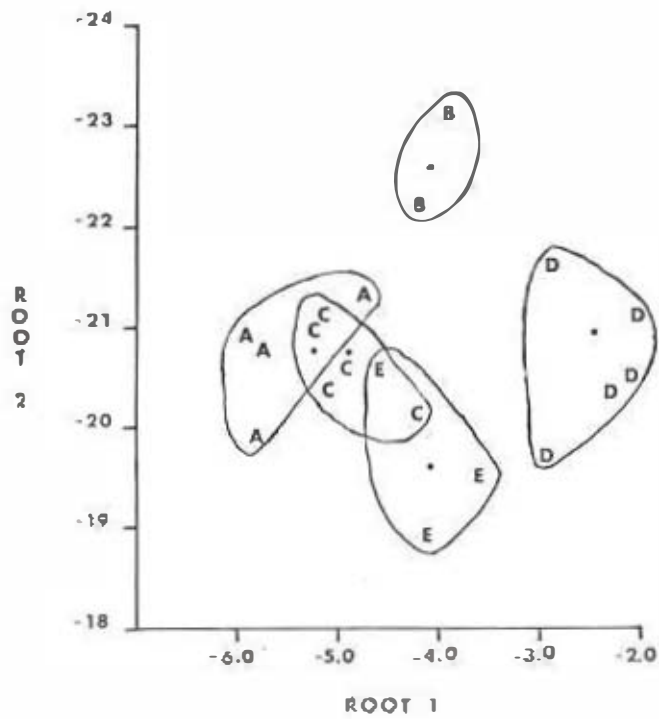


Figure 5. Distribution of sample discriminant scores in the third discriminant function analysis. 10 pollen types.



vegetation types as the second analysis, it actually accomplished this task better than the second analysis. That is, it offered a more secure statistical basis for confidence in the proposition that the discriminations are not due to chance.

The results of the third analysis are illustrated as Figure 5. The two discriminant functions account for 86.5% of the variance in the data, of which 72.4% is not likely to be a result of chance ( $p = .016$ ). In this analysis, pollen records of Oak Woods are very strongly discriminated from Riparian Woods records. The odds are about 99 to 1 that a pollen record from one of these vegetation types will not be comparable to a record from the other. Discrimination of pollen records of the Beech Woods vegetation type is less secure in this analysis, however. The odds only are 3:2 that a pollen record from a Beech Woods location will be non-comparable to one from any location other than Oak Woods.

Since no statistical argument is more credible than the assumptions upon which it is based, the fact that palynological discrimination of vegetation type groups was achieved through the third discriminant function analysis cannot be assessed as convincing. It is certainly suggestive, however, and it could be confirmed or denied if a statistically large number of surface pollen sample records were to be analyzed of each vegetation pattern. A reliable minimum would be approximately 30 samples from each type of woods, though larger numbers would provide greater confidence in the statistical argument. Fortunately, there is another argument which reinforces the credibility of the outcome of the third discriminant function analysis. Since it is independent of the statistical argument, it strongly supports the hypothesis that discriminant function analysis based on ten pollen types in pollen counts of 100 grains or less in fact offers a means of identifying the vegetation type occurring at the sampling location.

Faller's ecological analysis of the vegetation of MCNP drew the conclusion that

two ecological conditions are most directly responsible for the vegetation type variations observed in the area today: the degree of successional advancement and the degree of xericity. The former is strongly influenced by historic human behavior, the latter by topographic, hydrographic and substrate factors. Presumably, these two ecological conditions affect the modern pollen rain of the park as well, since the pollen rain is produced by the modern vegetation. Those ecological conditions which affect the competitive vigor of a plant taxon should also affect that taxon's reproductive capability and thus its capability to produce and disseminate quantities of its pollen into the local environment.

All of the ten pollen taxa of the third discriminant function analysis are produced by plants highly adapted to the factors which condition the occurrence of the various vegetation types of MCNP. The Riparian Woods type is adapted to deep, water-lain, oft-flooded substrates. Ulmus, Chenopodiineae and Compositae pollen are produced by plants frequently occurring under such conditions. Successional Woods are adapted to disturbed areas in which high light levels occur and soils are not conditioned by the decomposing wood and leaves of mature stands of vegetation. Compositae, Gramineae and Chenopodiineae pollen derive from plant forms characteristic of the early successional stage in such situations and Liriodendron and Magnoliaceae pollen derive from plant forms characteristic of a later successional stage. Beech Woods vegetation is adapted to moderately xeric conditions and the rich soils which result from a long successional advance. Fagus pollen is produced by a plant taxon adapted so stringently to such conditions that the tree survives as a dominant or subdominant element only where they occur. Mixed Woods are adapted to the same moisture parameters as Beech Woods but to less rich substrates. It is well represented today in the solution valleys of the limestone karst portion of MCNP. Juglans, Liriodendron, and Magnoliaceae pollen derive from

plant forms very well adapted to such conditions. Oak Woods are adapted to the most xeric environments of the park. Carya and Quercus pollen derive from plant genera observable in all of the vegetation types of the park and adapted through species diversity to almost all habitats as successful dominant or subdominant forms. But the reproductive competitive advantages of these genera are best expressed in the Oak Woods vegetation type. Since pollination is a reproduction mechanism, one would anticipate greater mean quantities of Quercus and Carya pollen in the pollen rain of Oak Woods than in the others even though Quercus and Carya species occur in all the vegetation types.

There should, then, be a fairly clear relationship between the results of the discriminant function analysis based upon these ten pollen types and the ecological conditions which foster development of the vegetation types represented differentially by their pollen rains. That is to say, we would anticipate that the ecological variations which encourage the sample plots to support different floras would be exactly those which encourage them to develop different pollen rains. A correspondence should be observable, then, between the discriminant functions which separate the pollen rains of the woods types and the ecological conditions which condition their floristic characteristics.

Faller's cluster analysis of the floristic similarity of the park's vegetation types, based upon a two dimensional ordination along moisture and successional gradients, was illustrated as Figure 3. The discriminant function analysis based upon the 10 pollen taxa is illustrated as Figure 5. The similarity of relative position of vegetation types on these figures is readily apparent. At this juncture, or course, it cannot be demonstrated that the correspondence is "real." A statistical test of correlation would require assumptions about the data base which are not demonstrable. But it seems hardly likely, irrespective of what a statistical test

might indicate, that such a correspondence of two independently generated sets of data could occur if the two were not actually independently measuring the same natural processes. It would appear that the first discriminant function of the 3rd analysis (Root 1), which accounts for 72.4% of the variation among the samples ( $p = .016$ ), measures the degree of xericity Faller identified as the primary axis of dissimilarity among the vegetation types of MCNP. The second discriminant function (Root 2), which accounts for another 14.1% of the variation among the samples ( $p = .402$ ) appears to measure the degree of successional advance Faller identified as the secondary axis of dissimilarity among the vegetation types. The correspondence of the results of the discriminant function analysis and Faller's analysis of similarity lends, I believe, convincingly strong support to the proposition that this form of discriminant function analysis is usable as a control. Application of the discriminant scores for each of the ten pollen types to a pollen spectrum recovered as a fossil record should allow reliable diagnosis of the vegetation type which produced that fossil spectrum. At least, this should be true if the fossil pollen record refers to one of the five vegetation patterns controlled by these data.

#### 6. ANALYSIS: UNCONTROLLED POLLEN RECORDS

There are two forms of uncontrolled pollen records to which the analysis of the control data may be applied for purposes of interpretation. The first of these consists of surface sample pollen records which are not assignable to positions on Figure 1. The second consists of fossil pollen records.

One of the 20 surface samples collected could not be assigned a position on Figure 1 because it derived from a plot representing the Hemlock Woods vegetation type. Two other surface samples have also produced pollen records, as a result of sampling undertaken subsequent to the initial work in 1974. These are uncontrolled

Discriminant Weight x Pollen Frequency

LOCALITY	Specimen No.	Sample N	Root	Quercus	Carya	Ulmus	Juglans	Liriodendr.	Fagus	Cheno-pod.	Gramin.	Magnoliac.	Compositae	Spectrum Discrim. Score	Vegetation Pattern
Blue Springs hollow	Hemlock Plot	67	1	.8063	.2543	.6789	1.0352	0.0	.5383	.4657	.1294	0.0	-.0112	-3.1779	Hemlock
			2	-11.2712	2.7451	.8083	-.0976	0.0	-.9703	.2589	-.2952	0.0	-.4.1552	-20.0840	Woods
Owl Cave	Surface	75	1	1.4421	.0852	0.0	1.6496	1.325	0.0	.8320	.8092	0.0	-.0200	-3.5067	Success.
			2	7.0755	.9196	0.0	1.744	-.2797	0.0	.4627	1.8461	0.0	-.7.4240	-17.2566	Woods
Blue Springs hollow Shelter	Talus Surface	85	1	.7557	.1001	0.0	.8138	0.0	0.0	1.0982	.2037	0.0	-.0165	-0.7916	Hemlock
			2	-10.5642	1.0805	0.0	-.0767	0.0	0.0	.6107	-.4648	0.0	-.6.1137	-17.5358	Woods
Blue Springs hollow Shelter Profile	OK, OK	70	1	.7717	.2130	4.2064	.6606	-.2830	0.0	.4457	-.2477	-.4.2507	-.0064	-10.1948	Riparian
			2	-10.7881	2.9900	3.8685	-.0623	-.5594	0.0	.2478	-.5651	1.4528	-2.3863	-21.7345	Woods
Blue Springs hollow Shelter Profile	OK, OK	79	1	.7577	.2427	.7454	0.0	-.7539	0.0	.7899	.6390	0.0	-.0101	-2.1602	Oak
			2	-10.5925	2.6191	-.6856	0.0	1.5934	0.0	.4392	1.0015	0.0	-.3.7590	-19.8119	Woods
Blue Springs hollow Shelter Profile	OK, OK	60	1	1.1437	-.0710	.9815	-.3853	0.0	0.0	0.0	-.5780	0.0	-.0042	-3.1637	Oak
			2	-15.9678	.7663	-.9026	-.0363	0.0	0.0	0.0	1.3187	0.0	-.1.5467	-20.5584	Woods
Crump's Cave Test A		25	1	.5256	-.2556	2.3656	-.9248	0.0	0.0	1.2480	1.0404	0.0	-.0140	-3.8680	Success.
			2	7.3476	2.7588	2.1664	-.0872	0.0	0.0	.6940	-2.3736	0.0	-.5.1968	-19.2364	Woods
Crump's Cave Test A		74	1	.6788	-.5469	2.3874	-.9373	1.343	0.0	.8432	-.4686	0.0	-.0061	-4.3082	Mixed
			2	9.3776	5.9028	2.1956	-.0884	-.2835	0.0	.4689	1.0592	0.0	-.2.2573	-20.7055	Woods
Crump's Cave Test A		56	1	.6779	-.3904	2.1032	3.3029	1.775	0.0	.6441	0.0	-.6193	1.0627	-8.9707	Riparian
			2	9.4761	4.1053	1.9343	-.3114	-.3745	1.609	0.0	4.1207	1.3087	0.0	-.0151	-1.6616
Crump's Cave Test A		53	1	.3106	-.1600	2.222	1.7449	0.0	0.0	2.2915	2.9857	0.0	-.5.6030	-14.8616	Woods
			2	4.6211	1.7351	-.0437	1.645	0.0	0.0	2.0571	-.9527	0.0	-.0099	-2.9217	Woods
Crump's Cave Test A		91	1	.4974	-.3277	0.0	2.7947	0.0	0.0	1.1440	2.1736	0.0	-.3.6712	-15.9885	Woods
			2	6.9529	3.5369	0.0	-.2635	0.0	0.0	2.7690	-.3805	0.0	-.2308	2.6052	Woods
Crump's Cave Test A		93	1	.5294	-.0230	0.0	0.0	0.0	0.0	2.0959	-.8683	0.0	-.8.5654	-14.9691	Woods
			2	7.4007	2.566	0.0	0.0	0.0	0.0	.6708	-.1864	0.0	-.0204	-0.4013	Woods
Crump's Cave Test A		94	1	.6593	-.2060	0.0	0.0	0.0	0.0	.3730	-.4253	0.0	-.7.5836	-19.0762	Woods
			2	9.2172	2.2231	0.0	0.0	0.0	0.0	4.6457	-.4604	0.0	-.0207	2.8719	Woods
Crump's Cave Test A		16	1	.4193	1.359	0.0	-.7375	0.0	0.0	2.5834	1.0503	0.0	-.7.6987	-13.5637	Woods
			2	5.0618	1.4668	0.0	-.0095	0.0	0.0	10.1712	-.3763	0.1	-.0217	9.4150	Woods
Crump's Cave Test A		46	1	.1269	-.2313	0.0	0.0	0.0	0.0	5.6561	-.8685	0.0	-.8.0680	-7.5409	Woods
			2	1.7736	2.4967	0.0	0.0	0.0	0.0	8.2774	4.9012	0.0	-.0189	3.2244	Woods
Crump's Cave Test A		98	1	.0894	-.0435	0.0	0.0	0.0	0.0	4.6030	5.2476	0.0	-.7.0064	-9.3691	Woods
			2	1.2491	-.6990	0.0	0.0	0.0	0.0	19.2972	-.5358	0.0	-.0124	18.6311	Woods
Crump's Cave Test A		97	1	.0301	-.0878	0.0	0.0	0.0	0.0	12.2339	1.2570	0.0	-.4.5917	5.0176	Woods
			2	4.204	-.9472	0.0	0.0	0.0	0.0	2.5272	-.7023	0.0	-.0230	-0.6478	Woods
Crump's Cave Test A		37	1	.1183	-.1150	1.5900	-.6242	0.0	0.0	1.4054	1.6022	0.0	-.8.5265	-13.1392	Woods
			2	1.6532	1.2415	1.4623	-.0369	0.0	0.0	1.6224	1.1739	0.0	-.0104	-3.5558	Woods
Crump's Cave Test A		96	1	.5322	-.3994	3.0623	0.0	0.0	0.0	.9022	2.6782	0.0	-.3.8660	-20.2083	Woods
			2	7.4394	4.3106	2.8163	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

because the archaeologist who collected them did not record the vegetation occurring at the collection locus. In theory, however, these surface sample pollen records can be interpreted through application of the discriminant function analysis plotted as Figure 5. If the analysis provides an accurate reflection of vegetation types and the ecological parameters which condition their existence, knowledge of either the ecology or the flora of a surface sampling locus should allow prediction of the position of its discriminant scores on that graph.

The Hemlock Woods sample, for example, was collected at a plot having moisture and successional characteristics well expressed by its floristic and substrate attributes. The plot is located in the sandstone substrate district north of the Green River on the terrace of a seasonally active stream draining Blue Springs Hollow. Within the 50 x 100 foot area sampled, Tsuga is the dominant tree (14 specimens) and various species of oak make up the subdominant taxon (4 specimens). The basal area of these 18 individuals is large enough to exclude all but eight other trees from the plot. This, and the fact that none of the trees of the plot are well adapted to successional habitats, documents the relatively high position the plot holds on the successional scale of Figure 1. Both the adaptations of the flora and its topographic-edaphic situation document the plot as representing a moderately low position on the scale of xericity. One would predict that application of the discriminant function analysis would locate the pollen record of this plot between the positions of Mixed Woods and Oak Woods records on the horizontal scale of Figure 5 and between the positions of Beech Woods and Successional Woods records on the vertical. In fact, this is the case; its calculated co-ordinate on the horizontal scale (Root 1) is -3.18 and its co-ordinate on the vertical scale (Root 2) is -20.08 (Table I).

The second surface sample was collected from the surface of the archaeological site named Owl Cave (GRS-19). This is a solution cavern locality in the northwest corner of Cedar Sink, which occurs in the southwest corner of MCNP. Cedar Sink derives its name from the prominence of Juniperus virginiana at the locus, which is recognized as a characterizing taxon of Successional Woods. One would predict that this surface sample would yield a pollen record attributable to Successional Woods through application of the discriminant functions analysis. Indeed, this is the case. The surface pollen record from Owl Cave is located at -3.51 on the horizontal scale of Figure 5 and -17.26 on the vertical scale as a result of such analysis.

The third surface sample was collected from the surface of the talus slope external to the archaeological site named Blue Springs Hollow Shelter (GRS-12). This is a sandstone rockshelter locality situated above the terrace of Blue Springs Hollow. It lies only a few scores of meters downstream and opposite one of the Oak Woods locations sampled in the original surface series, and is situated about one kilometer upstream of the Hemlock Woods location discussed above. Though no vegetation data were collected at the sampling location, its map position in relationship to controlled data and its topographic-edaphic situation are sufficiently well known to allow minimal predictions. If discriminant function analysis were applied, the sample should reflect habitat xericity on the order of an Oak Woods pattern. Its relationship to the successional scale is more obscure. There are two reasons for this. On the one hand, the statistical probability of accuracy of interpretation which results from use of this scale of measurement is only .402. On the other hand, the sample was collected from a geographic area of less than  $20 \text{ m}^2$ . It is thus not comparable to the controlled surface pollen records. Even if the vegetation of this small plot were recorded, it would not produce data comparable to the vegetation records of the control series. In fact, the prediction of indications of xeric conditions is borne out by the analysis but in a fashion

which could not have been anticipated from available information. The pollen record of the Blue Springs Hollow Shelter talus is positioned at co-ordinate -0.79 on the horizontal scale and co-ordinate -17.54 on the vertical scale of Figure 5. This would indicate the xericity level at the talus locus is lower than any sampled in the original series and the degree of successional advance is not appreciably greater than that represented by the flora of Cedar Sink.

Fossil pollen records presently available from the three archaeological locales (Table III) represent a series of temporal horizons. One of the records from Blue Springs Hollow Shelter was removed from midden deposits containing artifactual materials diagnostic of Late Woodland occupation of the park, which is estimated to date between 500-1000 BP.<sup>4</sup> The sediments of Crump's Cave which were polliferous were of the upper strata examined archaeologically. These produced artifacts attributable to Middle Woodland occupation of the general area and probably date between 1400 and 2400 BP. The pollen records of Salts Cave Vestibule are earliest in the series. The sequence of sampled deposits incorporates a series of strata that presumably were developed over a relatively long interval. The best available approximation is that at least part of the sequence covers the 3500-1900 BP horizon of vestibule occupancy, and part may be earlier.

Comparison of discriminant score values of the fossil pollen records with those of the controlled modern surface samples produces different results at each site. Presumably these reflect paleoenvironmental changes through time.

The Late Woodland midden sample from Blue Springs Hollow Shelter (spec. 3 of Table) produced a pollen record classifiable to the Riparian Woods group. Though this indicates the occurrence of a much wetter paleoenvironment during occupation, it could well have been very localized in Blue Springs Hollow. Establishment of a beaver dam or

<sup>4</sup>Estimates of antiquity are expressed in terms of uncorrected radiocarbon years.



other obstruction adequate to flood that portion of the hollow below the shelter would account for such a pollen record without invoking climatic change, and would explain the prominence of box turtle remains in the occupational area as well. The pollen records of the pre-occupational deposits (specimens 4 and 5) are both classifiable to the Oak Woods group. They ostensibly represent the occurrence of a vegetation pattern in the immediate vicinity of the shelter which is more or less like that generally supported today in this area of MCNP just prior to Late Woodland occupation.

The pollen records of Crump's Cave ostensibly date more or less to the horizon of the pre-occupation pollen records from Blue Springs Hollow Shelter. They do not appear to document the same local vegetation type, but this is not to be expected since the two sites are located in different substrate provinces of the MCNP study area. Crump's Cave is, in fact, located about six miles southwest of the park in a district of limestone substrate.

The pollen record of the uppermost stratum tested at Crump's Cave (spec. 1) is classifiable to the Successional Woods group. Though this stratum incorporates prehistoric materials it is described as very loosely compacted, disturbed and probably deposited subsequent to occupation. I believe the pollen it contains is, a reflection of historic conditions. The pollen record of the second stratum is classifiable to the Mixed Woods group, and that of specimen 3 - which was associated with ash and charcoal sealed by a lens of limestone breakdown - is assignable to the Riparian Woods group. Taken together, the two reflect the sort of mesic local environment one would anticipate for the Crump's Cave location today.

The pollen records of specimens 4 and 5 derive from occupational strata also, but are not classifiable in terms of vegetation patterns known in the MCNP area at the present time. They most closely approximate the surface sediment sample pollen record from the talus at Blue Springs Hollow Shelter, which has been evaluated as

reflecting very xeric conditions of local ecology. The Crump's Cave sequence, then, appears to reflect the occurrence of local, if not regional, modification of ecological conditions from an earlier xeric to a subsequent mesic situation during the horizon of Middle Woodland occupancy of Crump's Cave.

The fossil pollen records of profile JIV at Salts Cave Vestibule have been previously interpreted in terms of forest type variations through time (Schoenwetter 1974b). Here we are concerned with vegetation type variation, as this is the level of abstraction controlled by the surface sample data now available.

The four recognized temporal horizons represented stratigraphically in the excavated portions of the site (Watson 1974a:82) are represented, sequentially, by pollen sample 18 (upper breakdown debris and clay horizon); samples 17 and 16 (midden among breakdown horizon); samples 15, 14 and 13 (midden-bearing brown clay horizon); and samples 10 and 5 (lower breakdown debris interfingering with sand and gravel horizon). There is no exact correlation between these horizons and the character of sequential variations in the pollen record, however. The pollen records of the upper two horizons are comparable to each other, and the pollen records of the two samples of the earliest horizon are not comparable to each other. The pollen records of samples 17 and 16 date to the latest Early Woodland occupancy of the cave. Sample 18 presumably dates just subsequent to this interval. At present there is no obvious way the absolute antiquity of sample 18 may be precisely estimated, but it is probably accurate to assume that it reflects environmental conditions occurring at Salts Cave approximately two to four centuries prior to the paleoenvironmental conditions represented by the earliest pollen records of the Middle Woodland horizon at Crump's Cave.

Sample 18 yields a pollen record which, when assessed in reference to the controlled surface samples, indicates the local occurrence at Salts Cave of the same paleovegetation pattern and ecological conditions which occurred at Crump's

Cave during the early part of the Middle Woodland horizon sampled. This should not be taken as an indication that the pollen record of the two sites allows their biostratigraphic correlation, however. It is unlikely that the same vegetation pattern would have been locally prominent at each of the two locations at any given time under equivalent conditions of climate since each is distinctive in regard to local hydrography and edaphology. Today the Crump's Cave location supports a more mesic vegetation pattern though it is influenced by the same climatic condition which occurs at Salts Cave. If uniformitarian principles apply, this obviates the likelihood that the occurrence of the same vegetation pattern at both locations--at least as evidenced by the pollen of archaeological context sediments--is a reflection of contemporaneity through biostratigraphic correlation.

It is significant to note that the pollen records of samples 17 and 16, which date to the late Early Woodland occupation of Salts Cave, apparently reflect the same local paleoenvironmental conditions as sample 18. The inferences to be drawn are, on the one hand, that local conditions at the extreme of variation of the xericity scale yet sampled in the modern vegetation patterns of MCNP were maintained before and after the interval of late limestone breakdown at Salts Cave. In light of this it becomes difficult to assess that breakdown as a consequence of regional climatic change. On the other hand, the inference may be drawn that modification of the biological environment of the Salts Cave locality was not coincident with the termination of late Early Woodland residency of the site. Some of the anthropological and archaeological implications of this inference are discussed in section 8. Suffice it to say here that the continuity of ecological conditions from pre- through post-abandonment time seems to obviate the prospect that the behavior of abandonment was strongly influenced by environmental change.

The pollen records of the Salts Cave Vestibule midden horizon are comparable to each other in this analysis but not comparable to those from the superimposed

deposits. Their position on the scales expressed on Figure 5 indicates they derive from a vegetation pattern significantly more xeric, and perhaps also evidencing significantly less successional advance, than any of the vegetation patterns occurring in MCNP at the present time. The inference to be drawn is that during the principle period of Early Woodland residency of the site, local vegetation was adapted to such xeric conditions of paleoenvironment that--relative to the present--the character, quality and distributions of biotic resources in the area were modified in major fashions.

The likelihood that the xericity of the paleoenvironment was climatically induced is not evaluable from the MCNP pollen data now available because it references local conditions. The date of this environmental interval at Salts Cave, however, is estimated to lie in the 3500-2500 BP range on the basis of three radiocarbon assays (Gak 2622, 2765 and 2766). Wendland and Bryson (1974) date the transition from the sub-Boreal to sub-Atlantic climatic "episodes" (Bryson et al 1970) ca. 2760 BP. There is thus general information derived from the palynological record of the northern hemisphere to indicate that both the local maximally xeric and the local relatively xeric conditions expressed in the pollen records of Salts Cave were climatically conditioned and do not reflect strictly localized paleoenvironmental modification.

The two pollen records of the earliest stratigraphic horizon of sediment accumulation are not comparable to those of the midden horizon nor are they comparable to each other. The sample from stratum 13 (specimen 10) is comparable to the records obtained in the upper stratigraphic units of this site and those referencing the earlier part of the Middle Woodland period at Crump's Cave. Taken at face value, it seems to reflect the local occurrence of relatively xeric conditions and vegetation of a type not now observable in the MCNP area. There are two problems, however, which reflect strongly on the prospect of accurate analysis in this case. First, the

number of pollen grains observed in this sample is low and the number upon which frequency values of the significant pollen types is calculated is lower still. The probability that the population of pollen grains sampled in this case derives from some other vegetation pattern than the one evidenced is thus higher than occurs in the other Salts Cave vestibule records. The occurrence of single pollen grains of walnut and elm, in this instance, strongly influences the analysis. Second, no pollen records are yet available from temporally equivalent or temporally similar deposits at the site which would offer a means of evaluating the replicability of this record. In combination, these problems justify recognition that--at present--the analysis of this pollen record must be considered sufficiently insecure to obviate reliance on any interpretive statement which might be advanced.

The record of pollen sample 5, derived from the basal sands of the section, is comparable to that of the modern surface sediment of the Hemlock Woods plot. Taken at face value it indicates the local occurrence of a vegetation pattern adapted to conditions which are more xeric than those occurring today at Salts Cave but not more xeric than occur today within the boundaries of MCNP. If the Salts Cave area supported human populations at the time, they would presumably have had access to the resources of one type of vegetation pattern which does not now occur there. But the distribution (and possibly quality) of other vegetation patterns would probably have been quite different from that we observe today.

These inferences also must be regarded with some skepticism, however. Again, we are dealing with the evidence provided by a single pollen record. The problem is compounded by the fact that we have only a single surface sample of Hemlock Woods vegetation to guide the analysis and no quantitative evaluation of the degree of xericity that vegetation type might express. The comparability of this record and the modern surface record from the Hemlock Woods plot is statistically adequate, but lack of replicability must be taken into account in assessing the accuracy of the reconstruction advanced as a result of analysis.

## 7. INTERPRETATION OF THE FOSSIL RECORD

The earliest archaeological context pollen records of the MCNP can be analyzed in terms of the vegetation patterns evidenced, but such inferences are not yet sufficiently well supported to serve as a firm basis for interpretative remarks. When these pollen records can be controlled through replications and expanded surface sample studies, it is likely they will reflect paleoenvironmental conditions in the study area during the Atlantic climatic episode.

Reasonably firm evidence referent to the Early Woodland period allows recognition of an interval of very xeric paleoenvironment that probably ended ca. 2760 BP and a succeeding interval of relatively xeric paleoenvironment. Little modification of Early Woodland resource extractive strategy seems to have been conditioned by this paleoenvironmental change even though the change itself is likely to have been climatically induced and therefore regionally effective. Modification of hunting strategy is evidenced subsequent to the change, but the available record would indicate that hunting was not a significant resource extraction pattern used by the Early Woodland residents of Salts Cave Vestibule at any time (Duffield 1974:133). Though modification of the resource extraction pattern which involved cultigens and exotic plants (e.g. Cucurbita) did occur during the Early Woodland, this behavioral modification preceded local paleoenvironmental change by some centuries.

Relatively xeric conditions of paleoenvironment appear to have been maintained without local modification through and after the period of termination of Early Woodland culture in the study area. Local vegetation pattern changes had occurred by the time our pollen sequence picks up again in the Middle Woodland period, but these may not reflect regional modifications of paleoenvironment. The record offers no indication that the modification of cultural systems from that we identify as Early Woodland to that we identify as Middle Woodland was influenced by paleoenvironment changes occurring in the study area.

During the course of Middle Woodland occupation of the MCNP district another paleoenvironmental change took place. Relatively xeric conditions which supported vegetation patterns not now observable in the park were replaced by more mesic ones. At Crump's Cave local vegetation of the sort that was probably present at the time of American pioneer entry to the study area became established. The same is probably true for the Blue Springs Hollow Shelter locale. The date of this transition is not known, but it is not unreasonable to suggest it took place between 1700 and 1600 BP and marks the termination of the sub-Atlantic climatic episode and the initiation of modern (Neo-Boreal) climatic conditions.

Though the characteristics of the local and regional resource base must have been profoundly affected by this paleoenvironmental change we presently have no evidence of behavioral or cultural modifications that may have occurred as a result of, or been conditioned by, the change. Partly, of course, we may account for this by our rather limited understanding of the nature of Middle Woodland culture in the park area. Presently, most of what we know only allows recognition of the temporal placement of Middle Woodland populations.

The regional paleoenvironment conditions initiated during Middle Woodland times appear to have persisted until the present. Local paleoenvironment modifications are recorded for the Late Woodland period, but could be explained without recourse to consideration of regional scale factors. Presently available cultural information supports this interpretation to a degree, since it provides no evidence of significant change in resource extraction strategies from Middle to Late Woodland times.

There are two issues of some significance which require resolution for acceptance of these interpretations. One is the issue of the potential influence of human behavior on the pollen records. The other is the relationship of prehistoric resource extraction technology to the characteristics and distributions of the paleovegetation patterns.

The discriminant function analysis utilized is highly influenced by frequency values of two pollen types likely to have been introduced to the site area as a result of plant harvesting and storage activities: Chenopodiaceae and Compositae pollen. Chenopodiaceae and Compositae pollen also are produced by species adapted to disturbed soil conditions, so may have been locally prominent as a result of human traffic and waste disposal near the sites. Thus high frequency values of these taxa may be artifacts of human activity patterns in fossil records which, if they occur, would bias an analysis based on the comparability of fossil and modern pollen values.

The problem is greatest in the case of the Salts Cave Vestibule records referable to the Early Woodland horizon, for a wealth of available evidence (Watson 1974b) documents the harvesting and storage of species producing both pollen types by the cave occupants. Is it likely that the palynological indices of xericity in samples of this age are artifacts of man-induced variation in pollen frequency? Though I grant the possibility, I believe the probability of such an inference to be lower than the inference that the fossil pollen records are true indices of the local vegetation.

If the pollen record were influenced to a significant degree by human disturbance of the local environment, one would expect that as occupation proceeded this disturbance would be progressively more pronounced. Presumably, it would rise from a minimal to a maximal level and be maintained more or less at that position until occupation ceased. Then it would fall off to a lesser level subsequent to occupation. Neither the Chenopodiaceae nor the Compositae pollen discriminant score values pattern sequentially as expected by this reconstruction. Root 1 discriminant scores for Compositae (Table I) are not significantly different prior to cave occupancy (sample 10), during cave occupancy (samples 14, 16) and subsequent to cave occupancy (sample 18). Root 1 discriminant scores for Chenopodiaceae are



maximal early in the period of cave occupancy (sample 13) but show a pattern of decline there after until the terminus of occupation and then increase significantly. If occupation of the cave created disturbed conditions in the immediate area supporting stands of Chenopodiaceae and Compositae pollen producers, these pollen records leave no clue to their existence.

If the pollen record were influenced to a significant degree by pollen harvested with the seeds of Chenopodiaceae and Compositae pollen producers, we would expect to observe an increase in that pollen if harvesting was increased. Yarnell (1974) provides clear evidence from the JIV profile of an increase in the harvest of Chenopodium and Iva in level 4 relative to levels 5-7. The Root 1 discriminant scores of Chenopodiaceae and Compositae pollen, however, decrease in level 4 relative to levels 5-7. The apparent xericity of paleoenvironment during the Early Woodland, then, is not as easily interpreted as an artifact as it is interpreted as a natural phenomenon.

Though far less is known of the patterns of prehistoric resource extraction strategies in MCNP than we would prefer, flotation of archaeological context deposits offers a substantial body of evidence relating to this matter. Present indications are that the subsistence strategy of Early Woodland populations centered upon seed and nut harvests supplemented by game and collection of wild native fruits and pot herbs. At least two of the seed crops were cultivated. During the later phase of Early Woodland occupation at least one exotic cultigen (Cucurbita) was added as a resource and subsistence dependence on seed and nut harvests was intensified. In the Middle Woodland period nut harvests and game resources seem to have been more emphasized than was the case earlier, though cultivation of exotic species was maintained. This pattern is also evidenced for Late Woodland populations, but there are some indications that by this time cultivation of native seed crops had

been abandoned as an extractive strategy.

Throughout the sequence, reliance upon species adapted to floodplain and disturbed soils habitats is emphasized. The primary seed crops--sumpweed, chenopod, amaranth, knotweed, pokeweed, sunflower, maygrass and panic grass--flourish as a natural association on seasonally disturbed and replenished floodplain soils. The primary nut crops--hickory and oak during the Early Woodland and hickory and walnut during the Middle and Late Woodland periods--also may be attributed to the floodplain habitat. Hickory and oak species are well adapted to more xeric habitats as well, and walnut is not uncommon in Mixed Woods stands, but there is no reason to require reconstructions of plant food extraction strategy beyond the floodplain margin.

Interestingly, in the study area floodplains constitute the most stable form of habitat available. The major streams are supported by underground reservoirs, as are many minor creeks which flow as a result of the discharge of springs. Thus the principle flow of many floodplains is maintained through periods of drought, while seasonally increased flow occurs as a result of the release of winter precipitation. Climatic fluctuations, particularly in the degree of xericity, thus have much more pronounced effect on other vegetation patterns than on Riparian Woods. Subsistence strategies oriented towards the harvest of Riparian Woods and floodplain resources, then, could maintain a high level of consistency in this area irrespective of climatic change. At least, it would be relatively easier to maintain a subsistence strategy which was floodplain-oriented without technological modification over many millenia than one oriented towards the resources of other vegetation patterns.

The evidence of the archaeological record, of course, is that subsistence strategy did undergo variation through time. On the one hand, the palynological record indicates that these changes bear no temporal relationship to paleoenvironmental changes which occurred in the area during the period of occupancy. On the

other hand, assessment of the habitat requirements of the vegetation pattern from which the major subsistence resources were extracted indicates that this habitat would have been least affected by the sorts of paleoenvironmental changes which took place.

#### 8. ANTHROPOLOGICAL IMPLICATIONS

The interpretations drawn in the prior section threaten to some degree two widely accepted positions of modern anthropological theory as it is applied to archaeological research. Though it is premature to assess this threat as grounds upon which that theory should be seriously questioned, it is worthwhile at this juncture to elucidate the issues involved and to examine the relevance of this situation to the question of its influence on plans for future archaeological investigation in the MCNP area.

As characterized by Leone (1972), modern archaeological work relies upon an evolutionary theory of cultural change which accepts a systems perspective and a cultural ecological approach to the analysis of prehistoric patterns of behavior. The role of environmental factors in conditioning and influencing the nature of habitual behavior patterns is recognized as crucially significant in this theory. Any major modification in the bio-physical or the socio-cultural environmental context in which a behavior pattern functions is thought to operate to select positively certain ranges of behavioral variation and negatively select against other ranges. Thus, by a process the anthropologist calls adaptation, habitual behavior patterns are modified to function more efficiently or effectively in the new environmental context and culture change is effected.

Modification of environmental parameters should, if the theory is accurate, create conditions stimulating the establishment of new functionally effective relationships between environmental context and the behavior of a population. The

major paleoenvironmental variations which occurred in the MCNP area late in the Early Woodland and during the Middle Woodland periods, then, should have had a clear and immediate effect upon the behavioral patterns of MCNP populations. We presently have no archaeological evidence that this is the case. Similarly, the major behavioral change involving late Early Woodland intensification of extractive strategy should, theoretically, have resulted in adaptive restructuring of relationships between habitual patterns of behavior and the socio-cultural context in which they occurred. No archaeological evidence of this has yet been recognized.

A second theoretical proposition of modern archaeology is that the subsistence strategy of any given prehistoric population functioned either to maximally exploit the food resources of its territory with a minimum of energy investment ("mini-max" model of Plog and Hill 1971) or to fulfill minimal food requirements by selecting the least cost options among alternative courses of economic action ("satisficer" model of Joachim 1976). Though other economic models having strong parallels with ecological models are recognized (Rappaport and Turner 1977), archaeologists have not yet found them applicable.

Neither model, however, seems suitable or appropriate to the MCNP archaeological record. MCNP populations appear not to have maximized the extractive strategy most consistent with paleoenvironmental conditions occurring at any given time. If they had done so, one would anticipate the recovery of archaeological evidence of extractive strategy modification coincident with, or lagging shortly behind, paleoenvironmental modification. In fact, the record indicates that those changes which were made in extractive strategy preceded paleoenvironmental changes and were not modified further when paleoecological variations then occurred. Nor does evidence of satisficer behavior show up in the MCNP record. If this were the economic pattern employed one would expect a very consistent suite of extraction strategy activities to have been employed throughout the occupational history of

MCNP since the resource zone exploited is a very stable one not much subject to modification as a result of paleoclimatic change. But this is not what is indicated. At one point in the sequence a pre-existing extractive strategy is intensified in the direction of more seed cultivation and harvesting and later it is modified in the direction of more intensive nut harvesting. If one of these variations is the least cost alternative, the other cannot be.

I am not proposing that the lack of congruence between the archaeological record predicted by accepted theory and that observed calls the credibility of accepted theories into serious question. I am concerned more to point out that it raises serious doubts about our ability to recognize behavioral modifications of the sorts significant to our theoretical propositions on the basis of the data forms normally recovered and traditionally considered significant for the interpretation of prehistory. It would appear that if we are to make research progress in our study of the archaeology of this area we must come to grips with the issue of the effectiveness of the research design that has been employed to date. New directions for research seem to be demanded, as those we've been following appear to be leading us ever deeper into areas of confusion some rather basic theory informs us should be reasonably clear.

I am quite unsure of the research directions likely to prove profitable in future study of the archaeological record of the MCNP area. Because a great number of logistical and methodological problems impinge on any form of archaeological study, that matter should most properly be addressed by archaeologists far more familiar with the particulars of archaeological work in the area. In general terms, I think two alternative research orientations--or a combination of both--might be effective, however. One of these is research into the question of the character of archaeological data already accumulated which has been largely ignored or studied only in traditional fashions until now. Our theory predicts that

certain behavioral changes of an adaptive character are recognizable in the data we have. Perhaps our principle problem is that we've not realized the significance of certain information now available or not identified analytic procedures to extract it properly.

The other orientation is research into the question of the appropriateness of identifying prehistoric behavior patterns in the ways we have done until now. Our research tendency to date has been principally oriented towards identification of prehistoric activity patterns as members of a given class: horticultural activity, mining activity, hunting activity, disposal of the dead activity, ceramic manufacturing activity, stone tool manufacturing activity, settlement location activity, etc. We have tended to leave examination of the behavioral boundaries of such classes either unstated or unresolved as a general rule. We have looked into the question of how one class of activities may serve to amplify and re-enforce a deviation from the behavioral norm of another class, but our methods are more oriented to assessments of the distinctions between the classes than to their overlaps and similarities.

I am quite well aware of the difficulties even the most knowledgeable, skilled and creative scientific archaeologist faces when confronted with the challenge of identifying and implementing new research orientations for the study of a mass of archaeological records. I have no idea if such a challenge is even worthy of serious consideration and commitment in the study area at present. But the implication of the results of research to date is that some very real and very significant problems remain to be resolved and the research orientations that have been used do not seem to be adequate to the purpose.

It may be true, when taken in perspective, that it is yet necessary to pursue existing research strategies for an undefinable period. Those problems that can be identified as requiring resolution are yet only conflicts between what theory predicts we should expect as a general rule and what we actually observe. Before

a significant commitment is made to specific new research designs, it may be most profitable to attempt to better clarify the specifics of predicted expectations and use existing research designs as means of assessing more exactly the discrepancies that seem to exist. The point of this portion of the report is not that of attacking either the anthropological theory or the archaeological methods presently used. The point has been to establish a reference position from which one may evaluate problems and consider the advantages and disadvantages of the pursuit of present orientations. Whether or not a new tack is chosen is really not at issue, as I understand the situation. What is important is that the matter is not ignored when it is necessary to formulate programs for additional archaeological work in the MCNP district.

## APPENDIX: TECHNICAL INFORMATION

1. Pollen Extraction Procedure

The extraction procedure in general use in this laboratory (Schoenwetter 1975) is a modification of that designed by Mehringer (1967) for extraction of pollen from sediment samples of large volume. The normal procedure was modified for this sample series to involve (a) boiling the extract in HF in a nickel crucible for 20 minutes as a means of further reducing its inorganic fraction, and (b) subjecting the extract to acetylation (acetolysis procedure of Erdtman 1943) as a means of reducing its organic fraction. These modifications were also used by Gish (1975) when extracting pollen from surface and archaeological context samples from Wisconsin.

2. Tabulation of Results

Table II: Pollen observed in the controlled surface samples. Locality designations follow the system employed by Faller (1975) where possible. Field records identify UTM co-ordinates of the sampled location on the U.S.G.S. Rhoda and Mammoth Cave 7.5' quadrangles.

Table III: Pollen observed in the uncontrolled surface samples and the fossil samples of Blue Springs Hollow Shelter and Crump's Cave. Pollen observations of Salts Cave Vestibule deposits are already published (Schoenwetter 1974b:100-101).

Table IV: Discriminant weights of the taxa of the third discriminant function analysis. Discriminant scores for a pollen taxon are calculated through multiplication of each pollen frequency by its discriminant weight value and addition of all values obtained.



Stand Name	APF	Pinus	Quercus	Carya	Tsuga	Fagus	Liriodendron	Ulmus	Juglans	Cespedes	Cornus	Ostrya-Carpinus	Juniperus	Betulaceae	Acer	Celastrus	Teucrium	Aster	Lythrum	Amorpha	Tubiflora	Ligustrum	Anemone	Geranium	Chenopodium	Rhus	C. Erigeron	Typha	Erythraea	Caryophyllaceae	Solanaceae	Nyssa	Cf. Eleagnus	Cf. Shepherdia	Zea	Unknowns
Big Hollow	83.5	47	83	20	13						1	1	1	1						20	1	1	4	5											1	
Stoan's Crossing N.	81.5	33	58	59	1	3	7	2												33	1	3														
Salts Sink	79.0	67	27	28		29	4	2												25			5		5		2	3	1	1						7
Hunt's Sink S.	71.0	37	68	19	1		9	1				1	3	3						41	1	1	5	4	1											3
Cromp's Knob N.	84.0	43	21	99			1	2												14	1	1	3	1				8							2	
3 Springs (below shelter)	82.0	14	89	54			2	3				1								28	2	2	2	2											2	
3 Springs (shelter)	88.5	45	59	11	7		3	10	1											43	5	6	2	6											6	
Lee Ridge	91.0	82	80	16			1	1	2											14			1					1							2	
Crump's Knob Crest	96.0	77	66	75					2											5	1														1	
Blue Springs (shelter)	90.5	60	117	5	2	4	1	1	1											17		1													1	
3 Springs (above shelter)	80.0	83	36	19			1	6	5	0										23	2	2	3	3											6	
Deer Park Hollow	75.5	29	65	48			3	5	1											36		2	3	6												
River Styx	61.5	45	43	12			7	13	2											42	6	16	7	1											2	
Dennison Ferry	90.0	32	102	15			2	3	16	4	1									11		1	1	6											1	
New Ferry	77.5	48	70	19			3	4	6	1	1									33	3	5													4	
Mammoth Ferry	64.5	54	29	15			7	1	7	4	3	1								36	7	6	10													8
Cedar Grove	94.0	110	53	19					6											10			1													
Flint Ridge (N)	75.5	83	42	13			5	3	5											13	2	35	7												2	
Brook's Knob Flat	82.0	83	48	13			3	6	4	1	1	1	1	1						25	1	1	2	5	1										1	

Table II. Pollen observed in the uncontrolled samples of this study.



Variable	Root 1	Root 2
Quercus	-.0146	-.2041
Carya	-.0213	-.2299
Ulmus	-.5889	-.5416
Juglans	-.2312	-.0218
Liriodendron	-.0994	-.2098
Fagus	-.3607	-.6501
Chenopodiineae	.3120	.1735
Gramineae	-.0867	-.1978
Magnoliaceae	-.5951	-.2034
Ambrosieae & Tubuliflorae	-.0005	-.1856

Table IV. Discriminant weights of the third discriminant functions analysis

### 3. Efficiency of the Palynological Investigation

All of the 20 controlled surface sample collections made by Schoenwetter and Faller in April 1974 yielded polleniferous extracts. One of the three uncontrolled surface samples collected by Carstens in November of 1974 was not polleniferous. My suspicion in that instance is that too small a geographic territory was sampled and that highly localized conditions adverse to pollen preservation led to low productivity of the sample. The controlled samples were collected from plots of varying size, but never less than 100 m<sup>2</sup>. This should be kept in mind when additional surface sampling is undertaken.

The five uppermost samples collected from Crump's Cave Test A were polleniferous; the three samples collected at greater depth - also associated with Middle Woodland artifacts - were not. The extracts of samples 6 and 7 were very inorganic and difficult to observe because of the occurrence of colloid. The extract of sample 8 contained an abundance of such organic detritus as leaf epidermal and parenchyma cells and fungal spores. It seems likely that geomorphological processes have adversely affected pollen preservation in samples 6 and 7. I suspect that sample 8, however, was collected from a deposit which formed relatively slowly. This may have encouraged the destruction of pollen falling on its surface by herbivores and saprophytes.

Of the nine samples submitted from Owl Cave, only the surface sample was polleniferous. Test pit D, source of the non-polleniferous sediments, may have been located at a position where sediments are too protected to trap adequate quantities of atmospheric pollen rain. The slope of the deposits of the vestibule chamber of Salts Cave allowed in-wash of pollen with rainwaters running off the surface of the solution sink. At the location of Test D

in Owl Cave, the slope of deposits is such that only atmospheric pollen could accumulate on their surfaces as deposition proceeded, or pollen introduced by human agency.

At Blue Springs Hollow Shelter two sediment profiles were sampled for pollen analysis and one sample was collected from the fill of a pit feature. At profile <sup>0</sup>PN, OW the two samples of sediments superimposed on the main midden deposit were not polleniferous; in fact very little organic material of any sort was found in the extract. The midden sample, in contrast, is extraordinarily productive of excellently preserved pollen; a drop of extract allows examination of ca. 2000 pollen grains. The two samples collected from submidden deposits in this profile are similar to modern surface samples as regards productivity and preservation. At profile <sup>6</sup>PN, OW - another very protected locus which surface runoff waters could never have affected significantly - none of the 12 samples collected proved polleniferous. Inorganic detritus dominates the extracts in all cases. The garbage pit fill sample was of the same character.

Efficiency of modern surface sample pollen study thus is quite high (95.5%), as expected, but that of archaeological context samples (32%) remains low. This efficiency value is yet lower if the shell midden deposit samples from sites east of the park are considered. It would appear most judicious at this time to maintain palynological research investment at about the same level as has been done, rather than increase it very dramatically. Sampling programs for recovery of both surface and archaeological context deposits can and should be elaborated as normal activities of archaeological work in the area. But until patterns emerge which may indicate which samples have maximal probability for producing pollen records, it would seem appropriate to proceed

cautiously as regards the investment of significantly larger amounts of time and money than has been done so far on the archaeological pollen analysis of Mammoth Cave National Park.

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