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NEW DIRECTIONS OF PALYNOLOGY IN ETHNOBIOLOGY

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ABSTRACT.—Archaeological palynology, fairly new as a discipline, originated in studies conducted less than 50 years ago. During this early developmental stage, it suffered because of: (1) inadequate communication between botanically-oriented palynologists and field archaeologists, (2) differences in conceptual orientation between archaeologists and archaeological palynologists, (3) fossil pollen studies of archaeological sites often had been incorporated into final reports only as appendices, (4) a growing number of studies on the fossil pollen remains of archaeological sites were published almost exclusively in "contract-type" reports where the number of printed copies was limited and distribution is restricted, and (5) sophisticated, statistical techniques had not been applied to fossil pollen data from archaeological sites. Our article, after a brief history of archaeological palynology, discusses some of the applications of fossil pollen data in archaeology, and offers suggestions and concerns about the course of the discipline in the years to come.

INTRODUCTION

Palynology, broadly defined as the study of pollen and spores from both living and fossil seed plants (Hyde and Williams 1944), includes research in such various areas as pollen production and dispersal, composition and morphology of the exine (outer pollen wall), applications in stratigraphy and paleoecology, preservation, and in explaining man-plant interactions. Even though the field has a history of over 70 years, only during the past several decades has significant emphasis been placed on analysis of fossil pollen from archaeological materials. Although most archaeologists know of the basics of palynology, many of them are still unaware of the full range of data which palynology can provide.

As a discipline, palynology is relatively young and its applications to archaeology are still being developed and refined. Thus, we feel that the full comprehension and appreciation of the impact and importance of archaeological palynology, requires a review of its historical development, an examination of its data base and specific techniques, a survey of the range of research questions which are currently arising, and finally, an exploration of the potentials of this discipline for future research needs in archaeology.

HISTORICAL REVIEW

Pollen analysis, initially defined as the calculation of pollen percentages, appears first to have been attempted on Swedish peat deposits by Gustav Lagerheim (in Witte 1905). In 1916, at a convention of Scandinavian naturalists (Davis and Faegri 1967), von

Post explained the potential of this technique by presenting the first percentage calculations of fossil pollen. As Faegri (1981) observed, von Post regarded pollen analysis primarily as a method for dating Quaternary-aged sediments from northern Europe, although later he acknowledged the technique also could be a useful tool in paleoecology. The initial development of pollen analysis can therefore be viewed as a continuation or extension of the original palaeophysiognomic school which was exemplified by Blytt (1876). According to Faegri (1981:45) von Post's pollen analysis was, "pure palaeofloristics: the registration of the occurrence and (what was new) relative frequency of taxa . . .". The results and interpretation of von Post's analyses were not based on pollen analysis *per se* but on the techniques and data base associated with the palaeophysiognomic school (Faegri 1981).

The influences of the palaeophysiognomic school can be clearly seen in the construction of the early pollen diagrams. The palaeophysiognomic school accentuated its emphasis upon the arboreal (tree) component of the forests. Thus, pollen from plants confined to the understory levels in the environment (non-arboreal plants) often were ignored or were calculated only as a function of arboreal pollen. Unfortunately, this limited approach to the study of fossil pollen became the standard during the early part of the twentieth century.

During the early 1900s, the field of pollen analysis did not produce the types of comprehensive fossil pollen studies which would become standard in later years. This problem was created initially by three main factors: (1) a poor understanding of pollen morphology; (2) the use, not the lack of availability, of poor quality optical equipment and (3) the use of inadequate laboratory extraction techniques for separating fossil pollen from matrix materials such as peat, soil, sand, and coprolites (Faegri 1981).

The concept of using an ecological approach in pollen analysis was first introduced by Auer (1927) and later by Sears (1930a, 1930b) in their studies of North American sediments. In Europe, similar concepts were first introduced at the 1933 meeting of the Baltic Committee (Faegri 1981).

Once the ecological approach was introduced as a proper avenue of investigation, the directions and potential benefits derived from the field of pollen analysis were changed forever. However, in spite of the demonstration of the new ecological approach to solve problems in fossil pollen studies, the influence of the older, synecological (palaeophysiognomic) school, was still evident in North American fossil pollen analyses up through the 1950s. This is evidenced by the reliance of palynologists such as Hansen and Potzger, upon arboreal pollen counts as the primary basis for their interpretations and constructing of pollen diagrams. Thus, as in the initial studies by von Post and others, these later North American palynologists tended to consider non-arboreal fossil pollen counts as representing unimportant information in the interpretation of paleoenvironmental data.

Almost immediately after the acceptance of an ecological perspective emphasizing ecological questions, palynology expanded to incorporate information related to the influence that man may have had upon prehistoric plant communities. In what seems to be the first pollen analysis of an archaeological site, Jessen (1935) reported on the fossil pollen analysis of sediments in North Jutland, Denmark. Later, Iversen (1941) again demonstrated the importance of using fossil pollen data in archaeology when he successfully dated the beginning of the Neolithic period in Denmark. He based his findings on the decline of local *Ulmus* (elm) pollen in sediments, which showed the appearance of herbs and weedy plant pollen normally associated with human disturbance. The first appearance of agriculture in southern Denmark was again documented by the later fossil pollen studies of Faegri (1944).

Iversen's and Faegri's studies not only defined with fair precision the first arrival of agriculture into northern Europe and evidence that cereals of Middle Eastern origin were planted, but they also noted how cultures had altered the environment by clearing the forested areas using slash and burn techniques. Some of the later fossil pollen studies related to origins of agriculture in other regions of the world include Donner (1962), Durno (1965), Godwin (1944a, 1944b, and 1956), Iversen (1949), Mitchell (1951, 1956), and Morrison (1959).

Following Iversen's (1944) example, other palynologists began using fossil pollen to clarify and interpret archaeological data. Troels-Smith (1960) examined pollen and seed remains from the Muldbjerg archaeological site located in West Zealand, Denmark. Based on pollen and plant macrofossil analysis of deposits from that Neolithic-age site, he reconstructed aspects of the past environment and showed how the overgrazing of domestic animals in that region of Denmark had created dramatic changes in the local plant composition. Dimbleby (1960) showed how the fossil pollen record from a Mesolithic site in England demonstrated changes in prehistoric forest composition caused by early man's shift from a hunting and gathering economy to one which focused upon agriculture and pastoralism. Dimbleby (1963) conducted another fossil pollen study near Addington, England where he introduced a technique for calculating the concentration of fossil pollen in soils. He then used those pollen concentration values to show how Mesolithic cultures had modified the local vegetation.

Applications of pollen analysis in North American archaeological sites was also progressing. Paul B. Sears was one of the first researchers in North America to apply pollen analytical techniques to solving archaeological problems. In an early article, Sears (1932) suggested that a possible cause for the Hopewell expansion into areas of the eastern United States may have been a climatic shift that favored the growth of maize. Later, Sears (1937) conducted some of the pioneering pollen investigations of archaeological and non-archaeological sediments in the American Southwest. Although Sears' initial attempts in the Southwest (Sears 1937) resulted in only limited success, he and others (Sears and Clisby 1952; Clisby and Sears 1956) continued examining open sites in the American Southwest while Roger Anderson (1955) began trying to recover fossil pollen from cave sediments. The work of these early palynologists demonstrated that fossil pollen was often difficult to recover but that it was present in many Southwestern sediments. In the late 1950s Paul S. Martin and his graduate students began a detailed look at the fossil pollen in lakes, peat bogs, and archaeological sites in the Southwest. Their studies convinced others that even though some deposits in the Southwestern United States were barren of fossil pollen, other areas yielded good records (Martin 1963).

The next two decades saw new developments in archaeological palynology. First, during the 1960s fossil pollen studies of archaeological sites became more common (Cox and Lewis 1965; Godwin 1967; Tsukada and Deevey 1967; van Ziest 1967); and secondly, the 1970s saw a dramatic rise in contract archaeology. The development of contract archaeology programs throughout the United States was caused by increased federal funding and resulted in a large quantity of archaeological fossil pollen studies, especially in the American Southwest. Unfortunately, most of these reports (both palynological and archaeological) were never published, and the data recovered lie buried in the offices of many federal and state agencies. Since there is no central clearing house for palynological contract reports, for all practical purposes, the majority of these reports are not available as reference sources in most major libraries. Hall (1985) has provided some help by compiling a bibliography of southwestern palynology which includes many of the contract studies.

VALIDITY OF POLLEN ANALYSIS

Pollen analysis is a useful research technique in paleoenvironmental reconstruction and archaeology because of two important criteria: (1) preservation and (2) recognition.

Most pollen grains and spores produced by terrestrial plants have a chemically stable outer wall, called the exine which preserves well in many sediments because it is composed of a mixture of cellulose and a more durable compound called sporopollenin. Sporopollenin is composed of oxidative co-polymers of carotenoid and carotenoid esters (Shaw 1971) which are highly resistant to decay and have enabled ancient pollen and spores to remain preserved for millions of years. In addition to its preservation quality, extensive research has demonstrated that pollen grain characteristics and wall morphology are consistent within a plant species, but vary from the pollen morphology of other plant taxa. These differences permit the pollen of one genus, or species, to be recognized from types produced by other plant taxa.

The utility of pollen analysis is based upon two major assumptions: (1) any particular fossil pollen assemblage is indicative of the original pollen contributing flora; and (2) the recontructed fossil vegetational communities can be used to infer paleoecologic and paleoclimatic parameters. The first assumption appears warranted subject to certain limitations. Plants produce varying amounts of pollen or spores which are dispersed and are carried by wind currents (anemophilous), water currents (hydrophyllous), or by different types of animals (zoophilous). Several researchers (Andersen, 1967; Erdtman, 1969) have estimated relative pollen productivity rates and attempted to correlate these with the mode of pollination, i.e. anemophily, etc.

After being dispersed, pollen falls to the earth's surface in the form of a pollen rain which is influenced by a number of factors such as the rate of fall (Wright 1953); the method of transport (Janssen 1970); the effects of atmospheric and climatic conditions (Tauber 1965, 1967); and the effects of pollen recruitment into lake-type sediments (Bonny and Allen 1985; Davis *et al.* 1985). Once deposited, pollen and spores are subject to various types of degregation which selectively destroy certain pollen types and leave other types uneffected (Bryant and Holloway 1983).

Numerous studies have also been conducted which address the presumed relationship between the recovered fossil pollen assemblage and the plant community from which it was derived (King and Kapp 1964; Andrews 1967; O'Sullivan 1973; Adam and Mehringer 1975; Birks *et al.* 1975; Webb and McAndrews 1976; Webb *et al.* 1981; Heide and Bradshaw 1982; Holloway 1984). Recent numerical techniques, which are presented in a later section, have been very successful in elucidating this relationship. The successful application of these techniques notwithstanding, the lack of discrimination of exine morphological characters which would permit taxonomic identification of these pollen grains to the species level, has been a major obstacle in defining the precise relationship between the paleovegetational community and the fossil pollen assemblage.

The second major assumption used by palynologists involves the interpretation of the accumulated pollen data. In each study, the ultimate goal is to infer paleoecologic and ultimately, paleoclimatic conditions; yet to do this we just assume a valid relationship between the reconstructed vegetational community and the paleoenvironment. Both biotic and abiotic factors influence the distribution of certain plants. These pollen and abiotic factors influence the distribution of certain plants. These pollen and spore producing plants are restricted (today) to specific ecological habitats in which they survive, and in their optimum environments, are most abundant. Drawing on modern ecological studies as analogues to paleovegetational communities, enables the palynologist to effectively test this second assumption.

From the information gained by modern ecological studies, the palynologist can begin to assign ecological parameters to the paleovegetational communities based on the presence of a few characteristic pollen types. This "indicator species" approach (Birks and Birks 1982) is usually successful enough to infer paleoenvironmental conditions. This procedure cannot rely solely on the modern ecological data as many other factors are involved in determining plant biogeographical distributions. As an alternative to the indicator species approach, Conolly (1961) stressed the importance of including all taxa present, rather than a few "indicator species", prior to interpreting the pollen assemblages paleoecologically. This procedure may be cumbersome, especially with long temporal records consisting of many levels, but the numerical treatment of these data in terms of recognizing co-occurring and co-varying groups of taxa may provide the necessary information to demonstrate the validity of the relationship between the paleovegetational community and the paleoenvironment.

DISCUSSION

During the past several decades, pollen analysis has become a standard procedure during many archaeological excavations. The major problem remaining is that much of the palynological and botanical data has not been completely synthesized with the archaeological data for the purpose of interpretation. Most often, palynological and other types of botanical data are included at the end of an archaeological report in appendix form. There may be an historical precedent for this, yet we suspect that a major cause may lie in the philosophical development of the two disciplines.

Quaternary palynology, as an historically based descriptive science, has a long history of strict inductionist thought. Palynology, as an empirical science depends upon inductive reasoning which proceeds from one observation to the next in an attempt to provide generalities about the environment (Birks and Birks 1981). Edwards (1983) has suggested that this philosophical position may not be intellectually stimulating for some researchers. Although this may, or may not, be the case, the history and tradition of inductive reasoning in this field is strongly entrenched due, in large part, to the influence of historical geology on the field of palynology.

Archaeological palynology is not only tied to both the historically based geological precepts of biostratigraphy and environmental reconstruction, but also to those concepts inherent to the fields of anthropology and archaeology. During the past two decades, much of the emphasis in archaeology has been away from the descriptive techniques of the earlier "culture history" approach (Flannery 1968). thus, the "new" archaeology, which emerged in the late 1960s, concentrated upon analysis, synthesis, and hypothesis testing, emphasizing instead of descriptive work, a processual approach (Binford 1971, 1977; Watson *et al.* 1971; Morgan 1973; Schiffer 1981). This, however, was by no means a universal shift in theoretical orientation, for much archaeological activity during this period was directed, as in palynology, toward data collection using primarily inductive approaches. But we do see among many archaeologists a shift towards incorporation of deductive principles within the archaeologists' research design. As Binford (1983) notes, this does not imply the rejection of an inductive approach, but rather the integration of alternative research strategies in order to arrive at explanation.

We see current archaeology as moving in a direction of scientifically testing explicitly stated hypotheses. Most palynologists, on the other hand, have not yet made this shift and thus continue in their collection of new data (Edwards 1983). This aspect, however, may not be all that unfortunate since many geographical areas are still lacking an adequate, comprehensive data base. For example, much of Texas (Bryant and Holloway 1985), California (Adams 1985), and the Great Plains (Baker and Waln 1985) are known palynologically only from a limited number of sites which in many cases lack adequate geological chronologies.

A secondary problem in archaeological palynology has stemmed from the development of contract archaeology during the last several decades. Often there is too little time alloted for botanical analysis and interpretation, yet many federal and state regulations proscribe paleoenvironmental testing in the initial scope of work. Thus, because of time constraints, the vegetational and environmental data often are not effectively incorporated into the archaeological analysis. With careful planning, however, this need not be the case. The paleoenvironmental data provided by palynology, even when presented in appendix form, can be incorporated within the interpretation of the archaeological data as in the case along the Yazoo River drainage system in central Mississippi (Thorne and Curry 1983). More of this type of integration is desperately needed in the field of archaeology.

As a first step toward integration between palynological and archaeological data, palynologists need to utilize a rigorous scientific approach. As Edwards (1983) observed, only one paper (Garbett 1981) published in six major journals during 1981, dealt with testing an explicitly stated hypothesis and then discussed the level at which the hypothesis would be rejected. Although in many cases, the acquisition of new palynological data is necessary, in many geographical regions such as the Northeastern U.S. (Gaudreau and Webb 1985), the Great Lakes Region (Holloway and Bryant 1985), the Southeastern U.S. (Delcourt and Delcourt 1985), and the American Southwest (Hall 1985a, 1985b) palynological data are available to afford researchers the opportunity to test models and hypotheses of climatic and vegetational dynamics (Delcourt and Delcourt 1984). It is in this direction that palynology will have its most beneficial effect upon the understanding of the human impact on vegetation and the full utilization of the botanical and archaeological data. Without this, palynologically data will be forever relegated to the appendix.

ANTHROPOGENIC STUDIES

Human cultures modify the natural environment in which they live and thus often alter the ecological balance of the plant taxa which, in turn, are reflected in the local pollen rain. Learning to recognize ancient man's alterations of the environment through analysis of the fossil pollen record is one of the important goals of the discipline of palynology.

There are a number of studies which have focused upon anthropogenic factors as reflected by pollen analysis. Dyakowska (1958) was able to correlate two decreases of forest tree pollen in the fossil records of Poland to known historic events. Studies of cultivated plants, on the other hand, are often the best indicators of human plant modification (Behre 1981) and have generated the majority of archaeological interest (Martin 1963; Hill and Hevly 1968; Leroi-Gourhan 1969; Lytle-Webb 1978). One of the biggest problems with these types of studies has been the lack of adequate pollen morphological characters with which to separate the cultivated from the wild forms of the plant (Behre 1981). Much effort has been spent on the analysis and identification of these crop plant remains at archaeological sites and these studies demonstrate that the best evidence of prehistoric cultivation of plants still comes from plant macrofossils rather than from the fossil pollen record.

The pollen of some non-cultivated plant species are often good indicators of disturbance and thus, by extension, useful in interpreting anthropogenic plant use. For example, Burrichter (1969) recognized the importance of *Plantago* sp. as an indication of rotational cultivation systems and the historic increases in pollen of *Ambrosia* and other weedy species following the advent of European agriculture, especially in the Upper Midwest U.S.A., are well documented (Birks *et al.* 1976; Webb *et al.* 1983; Holloway and Bryant 1985). In each of these cases, identification and interpretation of anthropogenic factors relies heavily upon the ecological and edaphic parameters of the plant species in question (Behre 1981). Because of the differences between prehistoric and modern agricultural practices, modern analogues of pollen recovered from agricultural fields are not necessarily applicable to these types of studies.

Additionally, pollen analysis is useful in the investigation of economic land use criteria. Edwards (1982) has discussed several methodologies for investigating the economic use of ancient ecotone regions between forest and "prairie" areas. However, as Edwards (1982) cautions, using anthropogenic interpretations of vegetational change during the Early Postglacial times often cannot be documented with any degree of certainty. In fact, during these periods, a natural rather than a cultural explanation is more likely to be correct.

The fossil pollen analysis of ancient floor surfaces in architectural dwellings is yet another way that palynologists can help the archaeologist to understand past environmental and cultural phenomena. One of the first applications of this technique was demonstrated by Schoenwetter (1962) when he used soil scraping from peublo dwelling in eastern Arizona to date the periods of site occupation and infer past climatic conditions. Hevly (1964) attempted a similar study of ancient floor surfaces in abandoned pueblo dwellings located in the Colorado Plateau area of the American Southwest. Hill and Hevly (1968) later attempted to determine room function through the application of fossil pollen analysis in their investigation of the sediments recovered from Broken K Pueblo, Arizona. Unfortunately, these earlier studies did not employ multiple pinch sampling as later suggested by Cully (1979). In addition to occupational floor levels found in structures, agricultural fields are also being examined. Dimbleby (1985) discussed the fossil pollen evidence of Goodburn, at Winterton, Hamberside, England, in which he used palynology to identify possible associated agricultural fields. Wiseman (1983) likewise has recovered fossil pollen data from possible agricultural fields in Lowland Central America.

Under ideal circumstances pollen analyses from archaeological sites can also be used to determine a wide range of other cultural phenomena including: prehistoric diets, possible graveside rituals, subsistence patterns, use of native or cultivated plants, use of certain types of artifacts (*e.g.* grinding stones, pottery, and baskets), probable use of areas within architectural structures, intersite and intrasite dating, and preexcavation recognition of potentially important archaeological sites.

Pollen analyses of archaeological sites are now serving as a useful technique for determining the probable function of certain types of baskets, ceramic vessels, bedrock mortars, and milling stones. Experiments have demonstrated (Bohrer 1968) that pollen can be inadvetently included during the gathering and later storage of certain types of foods such as *Zea* (maize), *Typha* (cattail), *Cleome* (beeweed), *Chenopodium* (goosefoot), and *Amaranthus* (amaranth). Pollen from these plants often adheres to the inside surfaces of baskets and ceramic vessels. Later, when recovered by the archaeologist, these same vessels can be analyzed for their fossil pollen contents and the resulting data can be used to determine probable functional use. Others have noted that the pollen contents on the surfaces of grinding stones often are reflective of the plants utilized (Hevly 1964; Bryant and Morris n.d.).

Under certain circumstances, bedrock mortars can also be examined for their fossil pollen contents. Careful removal of dirt and the subsequent analysis of the fossil pollen trapped at the bottom of these mortars sometimes indicates which plant foods were ground in these mortars. On the other hand, an unfavorable aspect of this type of analysis is that bedrock mortars also may contain modern pollen that was deposited after the mortars were actually in use. Therefore, it is rare that a palynologist is able to determine with certainty the precise food plants which may have been originally processed in bedrock mortars.

Basketry and other woven artifacts sometimes provides important clues to the types of plant material which they carried. Often the dirt trapped between the weaves contains fossil pollen grains that became embedded while the basket was still in use. Like the pollen recovered from the inside surfaces of ceramic vessels, these fossil pollen grains can be used to determine which plant materials were collected and/or stored in basket containers. Many ceramic vessels made during aboriginal times were used to store food, as cooking pots, and as food containers for meals. If the foods in the vessels contained pollen, then often some of that pollen became trapped along the inside surfaces of these vessels during their use and can be utilized as clues to prehistoric uses of the vessels. Unfortunately, the archaeologist is not always able to test this sampling technique at archaeological sites since many ceramic vessels are recovered only as broken sherds. Hevly (1970), for example, recovered fossil pollen from a mid-Pueblo III age, sealed, ceramic storage jar excavated from a site in northern Arizona. His analysis revealed very high percentages of fossil pine pollen and fungal spores, which he believed represented a post-depositional phenomenon rather than the jar's original juse. In a related study by Bryant and Morris (n.d.) the inside bottom portions of 42 complete ceramic vessels recovered from rooms and burials at the Antelope House Pueblo were scraped carefully to recover fossil pollen that was deposited when the vessels were in use. The fossil pollen spectrum recovered from the bottommost vessel scrapings were statistically compared with the fossil pollen spectrum in the dirt matrix of each vessel. In cases where chi-square tests revealed that the two pollen spectra from the same vessel were of different origin, Bryant and Morris (n.d.) were able to assign probable functional use categories to over 30 corrugated, wide-mouthed vessels dating from the Late Pueblo III period as well as one Late Pueblo III plainware open bowl.

Pollen analysis of soils recovered directly underneath a Neanderthal burial (Leroi-Gourhan 1975) at Shanidar Cave, Iraq, revealed unusually high percentages of pollen from tiny, insect-pollinated alpine flowers. Because of the low pollen productivity of zoophilous plants, it was assumed that the high percentages of those pollen types in the burial soils must have resulted from cultural, not natural introduction. Therefore, Leroi-Gorhan (1975) concluded that a large number of small, alpine flowers must have been collected from the nearby hillsides and then carefully placed in the Neanderthal grave at the time of internment. The significance of this research has had a profound effect upon our understanding of Neanderthal's cultural activities and the possibility that they were the first group to adopt a basic philosophy about religion and the afterlife.

At Broken K Pueblo in Arizona, Hill and Hevly (1968) noted the probable ceremonial use of *Sphaeralcea* (mallow) and pine pollen in an infant's burial. In a nearby region of Arizona, Bryant and Morris (n.d.) noted what they suspected was a similar use of maize pollen as part of a graveside ritual at Antelope House Pueblo during the internment of a young child. These two studies, each from different pueblo sites, suggest that in some Southwestern groups flowers and pollen may have been thrown into the graves of the dead as some type of mortuary ritual accompanying internment. More importantly, at each of these burial sites, it was the fossil pollen data that helped establish new cultural insights into our understanding of prehistoric rites.

The pollen analysis of preserved human coprolites is one of the most useful methods for determining prehistoric diet and certain types of cultural patterns. Pollen data recovered from human coprolites can, under ideal circumstances yield information as to: (1) the use and source of economic and background pollen types; (2) the seasonality of site usage; (3) diet; and (4) certain aspects concerning paleoenvironmental conditions (Bryant 1974). However, like other forms of pollen data, the best and most reliable records come from studies at a given site in which the data base consists of many coprolites all dating to the same time period, rather than from only a few or even a single specimen representing one stratum or one time period. Single coprolite specimens, like a single lithic artifact, may or may not be an accurate reflection of the entire time period represented by the stratum.

Pollen studies of coprolites have shown that not all of the pollen found in coprolites reflect aspects of human diet. Within each human coprolite there are two distinct groups of pollen: economic pollen and background pollen. Economic pollen, as a specific category, is recognized by palynologists to include those pollen types that were probably ingested directly as part of the diet. Most of these economic pollen types are easily recognized because they come from plant species having pollen that is rarely, if ever, found as part of the normal atmospheric pollen rain. Economic pollen grains from zoophilous plant such as *Cleome*, *Yucca* (yucca), *Opuntia* (cactus), *Agave* (agave), *Dasylirion* (sotol), *Cucurbita* (squash), and *Prosopis* (mesquite) are transported from flower to flower by insects and thus rarely become airborne in the atmosphere as do the wind pollinated background grains of *Ambrosia* (ragweed), *Pinus* (pine), or *Quercus* (oak). Therefore, when significant quantities of zoophilous economic pollen types are found in human coprolite specimens, they are generally interpreted to reflect the direct consumption of the plant, flowers, or honey made from those plants rather than representing the accidental ingestion of these pollen grains from atmospheric sources. Some wind pollinated types of pollen such as *Chenopodium*, *Zea mays*, *Iva* (marsh elder), *Ephedra* (mormon tea), *Typha* and *Helianthus* (sunflower) may or may not be included as economic types depending upon the circumstances under which they are found. Since these types come from edible plants whose pollen often adheres to the collected seeds of these plants or to other plant parts which are known ethnographically to have been utilized, the presence of these pollen types can often be associated with economic use rather than representing deposition from strictly natural pollen rain sources.

The preserved pollen in human coprolites sometimes may offer clues as to the probable seasonality of site occupation and insights concerning the paleoenvironment at the time when the coprolite was produced. When human coprolites contain high percentages of economic pollen from one or more plants that generally bloom during the spring and/or summer, then that information can be used to offer tentative evidence for seasonal usage of the site. Ethnobotanical reports of many subsistence-level protohistoric cultures in North America have noted that in most instances, flowers were eaten fresh and that honey was rarely, if ever, found or eaten (Barrows 1900; Castettler and Bell 1941; Curtin 1949; Newberry 1887; Palmer 1887) thereby confirming that flower pollen can generally be attributed to seasonality when recovered in coprolites. In a similar way, the presence of coprolitic pollen from plants which no longer inhabit the region may suggest that environmental changes have occurred which caused the extinction or out migration of certain plant taxa.

From this somewhat cursory overview, it is evident that palynological investigations of anthropogenic issues require asking specific types of questions dealing with both cultural and botanical science and the understanding of both anthropological and botanical research methodologies (King 1985). Furthermore, we believe that one of the major stumbling blocks that discourages the incorporation of palynological data into archaeological research has been the use of techniques which are generally employed in stratigraphic palynology to answer non-stratigraphic types of culturally important questions. Many times, this type of palynological approach is just not applicable to solving anthropogenic issues. In attempting to formulate testable hypotheses concerning anthropological questions, palynologists must be prepared to discard precepts which are almost inviolate in biostratigraphy. For example, in some cases valuable information can be obtained solely by the use of presence/absence criteria in archaeological palynology. In such instances, these arguments may provide a better basis for data explanation and synthesis within the framework of archaeological concepts.

DATA ANLYSIS AND STATISTICS

Data analysis and interpretation are two aspects that have become rapidly more sophisticated during the past two decades. More than 60 years ago, von Post (Davis and Faegri 1967) based his initial pollen analysis on calculated, relative pollen frequencies.

Although in many cases this type of statistic is still useful, it lacks the needed precision for most of today's studies.

Throughout the first half of the twentieth century, relative pollen frequencies were used exclusviely by palynologists both in the reconstruction of paleoenvironmental conditions and in the interpretation of palynological data from archaeological sites. After the introduction of radiocarbon dating and the availability of tightly controlled temporal chronologies, Benninghoff (1962), and later Davis (1963, 1966, 1969), Jorgensen (1967), and Matthews (1969) helped to develop new methods for the calculation of fossil pollen ratios through the use of pollen concentration and pollen influx values. Although pollen influx data provide needed additional information used in paleoenvironmental reconstructions, the lack of precise stratigraphic and temporal control within an archaeological site often precludes the use of pollen influx values in these sediments. Therefore, in order to provide more meaningful results from the analysis of pollen data recovered from archaeological sites, palynologists have begun to use pollen concentration values which can be expressed in terms of the number of fossil grains per unit weight or volume, and then those ratios can be compared between levels of the same site or between similar cultural strata from different sites. This type of comparison has proven useful for demonstrating smilarities and/or differences in the fossil pollen record. Although concentration values can be computed using either sample weight or volume, we have found that the volume method is more reliable for comparing both intrasite and intersite pollen variability (Bryant and Holloway 1983).

While multivariate statistical analysis of palynological data from archaeological sites can provide a wealth of information, the major utility of statistical analyses has been realized within the framework of biostratigraphic and paleoecological problems. Initially, much of the work was, and still is, concerned with statistically analyzing modern pollen assemblages and using these data to infer paleoecological changes. Initially, multivariate statistics were utilized quite effectively to quantify the relationship between surface pollen and vegetation (Webb and Bryson 1972; O'Sullivan and Riley 1974; Birks *et al.* 1975; Webb and McAndrews 1976; Bernabo and Webb 1977; among others). Much of this research was aimed at obtaining modern analogues to fossil pollen assemblages. However, as many of these authors noted, some assemblages, especially those from late-glacial/Holocene times, lacked modern analogues and thus were outside the purvue of these techniques. Recently, Liu and Lam (1985) using discriminat analysis were able to statistically quantify these anomalous assemblages.

In an attempt to reconcile surface pollen spectra with the extant vegetation, Davis and Goodlett (1960), earlier had devised the concept of R-values. Although a valid attempt at solving these problems, the model was never universally accepted primarily because, as noted by Livingstone (1968, 1969), of the model's failure to accurately reflect over-representation of arboreal pollen types. Recently, Parsons and Prentice (1981:127) demonstrated the utility of Davis and Goodlett's (1960) model "subject to certain caveats." Parsons and Prentice (1981) developed three mathematical models to account for the observed discrepancies. These mathematical models involved the use of principal components analysis and regression equations which provide a good basis for inferring vegetational compositon from surface pollen data.

Regression analysis has likewise been utilized recently (Webb *et al.* 1981; Heide and Bradshaw 1982) to estimate directly the plant abundance of vegetational stands based on their surface pollen rain. Delcourt and Delcourt (1984) investigated the distribution of 24 major tree taxa and produced paired maps showing the percentage of growing stock volume (isophyte maps) and arboreal pollen percentages (isopool maps). These data were produced using a geometric-mean linear regression and have proved valuable in the quantitative reconstruction of vegetational change in eastern North America.

These attempts to correlate vegetational composition with surface pollen rain have been supported largely by the impetus of research projects such as CLIMAP (1976, 1981) which have utilized paleoenvironmental data to reconstruct ancient landscapes. Almost from the beginning of these studies, palynologists recognized the importance of ultimately relating the pollen/plant relationships to the interpretation of climatic data (Webb and Bryson 1972; Webb and Clark 1977; Kay 1979; Andrews *et al.* 1980; Webb 1980; Heusser and Streeter 1980). More recently, Howe and Webb (1983) have effectively discussed the methodologies employed in calibrating palynological data in terms of quantitatively derived climate estimates. These procedures can be combined with certain mapping techniques (Webb 1983) to provide measurements of changes in paleovegetational communities.

These types of paleoenvironmental data, although derived from differing sources, have been utilized by Delcourt and Delcourt for the production of statistical models reflecting biotic responses to climatic patterns occurring throughout the Holocene. Drawing upon the established data base, Delcourt and Delcourt (1983) have additionally provided a model designed to test vegetational responses to climate changes occurring at various periods within the Holocene. The model is exactly what is needed as it provides mechanisms to predict future modifications of the biota in response to those climate changes induced by man (*i.e.*, the estimated global warming trend caused by increased CO_2 concentrations in the atmosphere). These types of quantitative models serve as generalized hypotheses for empirical testing.

These techniques and approaches cannot, at this stage, be applied universally. The quantitative measurements have been derived primarily from sites located within the Upper Midwest, or southeastern U.S. The work in these geographical areas has been conducted for several decades. Not only are a large number of palynological sites available for study (Holloway and Bryant 1985; Delcourt and Delcourt 1985) from these areas, but extremely large numbers of surface samples and the corresponding vegetational data have been collected. It is only in those regions where a large accumulated data base is available that multivariate statistical analyses of data can provide both the models and the empirical tests for vegetational responses to climate.

The ultimate goal of paleoenvironmental reconstruction is, of course, to draw on as much data as possible and then use those data for determining comparisons between adjacent geographical areas. Gordon and Birks (1974) attempted to statistically delimit pollen zones (*i.e.* a series of adjacent levels with similar pollen assemblages) and then use those zones for chronological purposes within a given geographical region. The advantage of using such pollen zones is that they permit comparisons of two or more pollen records from different locations within a given geographical locale. The main disadvantage of using pollen zones is that their selection must be unbiased which argues for a numerical approach rather than an intuitive approach to the problem.

Numerous statistical techniques are presently available for numerical analysis and zonation of pollen data. Birks and Gordon (1985) recently have summarized many of these techniques and have provided computer programs for general dissemination. While these analytical techniques are readily available, few palynologists routinely use them. What is important to remember is that these numerical techniques were not designed to replace the interpretation of the palynologist, but rather to insure that the observed changes are real (not biased), and that a significant amount of variation is present before interpreting drastic changes.

Although as a general rule paleoenvironmental reconstructions from archaeological sites pose severe conceptual restrictions due to the biased nature of the data base, a numerical approach has been demonstrated which may alleviate this problem. Fall *et al.* (1981) have utilized principal components analysis to extract paleoenvironmental data from Antelope House in Arizona. Based on over 100 pollen samples, the numerical method reflected changes in vegetation patterns through time which were correlated with environmental indices reflecting temperature and moisture. These were likewise interpreted in light of known cultural activity patterns and population movements (Fall *et al.* 1981).

As Fall *et al.* (1981) correctly observed, in many archaeological sites, especially in the American Southwest, most palynologists have difficulty in distinguishing which pollen represents the naturally occurring regional pollen rain and which types reflect the cultural activities of man. In their study, the authors, using multi-variate statistical techniques, were able to successfully separate these two components. Once assured of the composition of the regional pollen rain, they demonstrated the effectiveness of these numerical techniques for the interpretation of paleoenvironmental conditions and in some cases, the human response to these conditions.

SUMMARY

During the past fifty years the fields of archaeology and palynology have begun to establish a working relationship in which the scientists of each discipline have tried to help the other understand what is needed in archaeological palynology. In some cases this has succeeded quite well, but in others it remains a problem. Over the years the primary problem between workers in these two disciplines has been effective communication. Archaeologists have moved into the area of hypothesis testing at many of their sites while most of the palynologists working with archaeologists are still in the data collection stage. Other problems have developed when archaeologists have unrealistic expectations from the palynological data and have become disappointed when fossil pollen information was unable to solve some major hypothesis or problem confronting the archaeologist. Additionally, there has been a great deal of misunderstanding on the part of both archaeologists and palynologists as to exactly what information is needed from the fossil pollen data at a site. One example of this should serve as an illustration of what we mean.

During the recent excavation and fossil pollen study of an archaeological site, a palynologist presented a wide array of interpretations as to what the prehistoric inhabitants may have been using as food, the types of plant materials they carried into the site and later used in the making of matting, clothing, and other items of their material culture. It was a carefully researched study and presented the types of information that most archaeologists would be pleased to obtain from fossil pollen studies of their site sediments. However, at this particular site, the sediment samples which had been examined and interpreted by the palynologist all came from culturally sterile strata which contained no artifacts or any other evidence suggesting that the site was even occupied by prehistoric groups during the deposition of those strata.

Another area in which communications between palynologists and archaeologists have been lacking is in the application and use of statistics. During the past several decades archaeologists have been quick to apply the use of statistical methods to studies of the cultural remains from their sites; however, until very recently most fossil pollen studies of archaeological sediments have not made effective use of new methodology in statistics. Hopefully, in the decades to come we will see an increased emphasis placed upon the use of statistical methods such as multivariate statistical-, principal component-, and regression-analysis when working with the pollen data from archaeological sites. In the past these statistical methods have been used in the analysis of pollen data from a few archaeological sites and have proved to be an effective method of interpreting information. These methods of data analysis and statistical approaches represent some of the currently utilized techniques in studies of archaeological palynology. However, there are many other alternative approaches from the wider field of palynology which currently have limited application. Perhaps, as archaeological palynologists become more comfortable with the use of statistics as they apply directly to problems in archaeological palynology, then new avenues of data integration will develop which will provide a wide range of new information on which to base interpretations.

Also, further studies are needed in the area of pollen degradation and in the better understanding of pollen sources which become trapped in archaeological sites. Unlike most peat bogs, lakes, and other terrestrial deposits where the activities of mankind are not a factor, the pollen in archaeological sites comes from both natural sources and from the activities of cultural groups. As shown earlier, there are many ways in which the activities of cultural groups can alter the natural vegetation through burning, agricultural or pastoral practices, through the selective use of certain firewoods or plants while others are not disturbed, and through the collection and use of certain plants to make their shelters or clothing. Degradation of fossil pollen in archaeological deposits is also an important issue. It is well to remember there are many factors which will lead to the destruction of pollen. In addition, experiments have shown that not all types of pollen grains degrade at the same rate, therefore, selective destruction of fossil pollen types can occur. That, in turn, will create a preserved pollen record that may be quite different from the actual pollen rain that was originally deposited. Knowledge of these differences are critical to the preparation of meaningful pollen analyses pertaining to archaeological sediments.

Finally, one aspect which we hope will be corrected in the years to come is the wide variety and range of archaeological fossil pollen records which currently are being buried in various "contract-type" reports. What makes this problem especially troublesome is that all too often they are printed in very limited numbers and are not widely distributed. If this procedure continues during the next decades, it will contribute to the unintentional duplication of fossil pollen research and will hinder researchers in a given area from being able to utilize the full range of fossil pollen data which may be available only in numerous contract-type reports. What is desperately needed in the field of archaeological palynology is a national or regional clearing house for these types of reports. In this way, the results of completed research will be available to the entire field.

The union of archaeology and palynology has been accomplished and now most archaeologists consider fossil pollen data from their sites as being an important aspect for them to consider. Furthermore, during the past several decades more and more palynologists with strong backgrounds in both botany and archaeology are entering the profession and are now in a position to communicate effectively with archaeologists. In addition, more and more pollen analyses are now becoming available from archaeological deposits in a wide variety of geographical areas. In other words, the data base is expanding rapidly. Soon, it is hoped that the archaeological palynologist will be able to turn his or her attention more toward research involving the testing of specific hypotheses, and away from the simple data collection.

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