

May 21, 1957

To the Graduate Council:

I am submitting herewith a thesis written by Robert E. McLaughlin entitled "Plant Microfossils from the Bruhn Lignite." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Botany.

E. J. Sharp
Major Professor

We have read this thesis and
recommend its acceptance:

Royal E. Shanks

Gordon E. Hunt

Harry J. Klepper

George W. Swingle

Accepted for the Council:

Charles P. White for
Dean of the Graduate School

PLANT MICROFOSSILS FROM THE BRUHN LIGNITE

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Doctor of Philosophy

by

Robert E. McLaughlin

June 1957

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INTRODUCTION

The collection and preliminary examination of fossiliferous materials from West Tennessee, begun in the fall of 1952 with the aid and encouragement of Dr. A. J. Sharp, convinced the writer that the opportunity to extend present knowledge of early vegetational history in the area was substantial. Despite the fact that the region west of the Tennessee River has yielded a considerable amount of plant fossil evidence, mainly in the form of leaf impressions, many unsolved problems remain.

From the botanical point of view, the identification of fossil plants based on the single criterion of leaf morphology, as has been attempted in many cases, has serious limitations (Odell, 1932; Arnold, 1947, pp. 338-339). Furthermore, the restricted representation inherent with this mode of fossilization, and the special set of conditions under which it is operative have led to qualitative and quantitative interpretations that are questionable.

In recent years, the vulnerability of time-honored correlation procedures has been recognized by many geologists. Paleontology developed as a stratigraphic tool with little regard for the biological aspects of the plants and animals involved. The inevitable consequence of this stereotyped approach, which led ultimately to fallacious deductions, has been a general distrust of paleontological data. The need for re-evaluation of time-stratigraphic concepts involving paleontology has been recently stressed by Allan (1948) and Newell (1953).

The increase in knowledge provided by modern geologic methods has brought about a realization that the simple stratigraphy envisioned by earlier workers such as Berry (1920, p. 333) in West Tennessee and other parts of the embayment region is not consistent with the facts. More recent geologic investigations have further emphasized the necessity for re-examining and implementing where possible the paleobotanical evidence on hand.

With these problems in mind, the writer undertook a study of fossil pollen and spores isolated from lignites and lignitic clays from West Tennessee. The wealth of such materials available for collection, and their widespread geologic occurrence made systematic organization of the total study essential. Consequently, the decision was made to select material from a particular geologic horizon that would provide a logical frame of reference upon which to establish definite geological and botanical relationships. The initial investigation is described in this thesis.

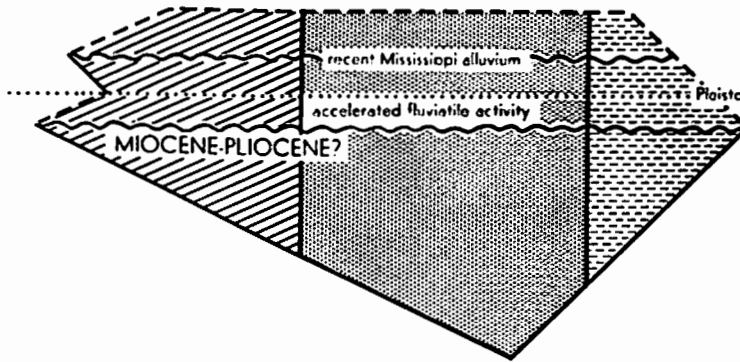
GEOLOGICAL SETTING

Geologically, the materials obtained for this study are associated with other sediments forming a part of the great coastal plain complex deposited during the Mesozoic and Cenozoic eras, and extending from Newfoundland to Texas and southward to nearly enclose the Gulf of Mexico if its submerged portions be included. While typically expressed landward along the margins of the Atlantic Ocean and the Gulf of Mexico, a northward projection, the Mississippi Embayment, extends inland beyond the 37th parallel at least to Cape Girardeau, Missouri. Evidence of further extension of the embayment beyond the latter point may be masked by subsequent geologic events.

The Mississippi Embayment region is bisected by the main channel of the Mississippi River whose sinuous course roughly parallels the axis of a structural trough pitching gently toward the Gulf and floored with Paleozoic rocks. Most of the present alluvial plain, with the exception of the Yazoo Basin, lies west of the main trunk of the river system and, along with the flanking loess deposits, is a development of the Pleistocene. However, the structural deformity responsible for its fundamental alignment was an event of the Late Cretaceous. The major geomorphologic phenomena during the last 125 million years or so of embayment history are summarized in Figure 1 based principally on the interpretation of Fisk (1944, pp. 67-68) but with certain modifications.

East of the river, in the western parts of Mississippi, Tennessee, and Kentucky, belted older deposits of Cretaceous and Tertiary age crop

RECENT



Ponded north-flowing streams diverted southward and westward merge eventually into present Mississippi drainage system.

Pleistocene glaciation temporarily interrupts cycle

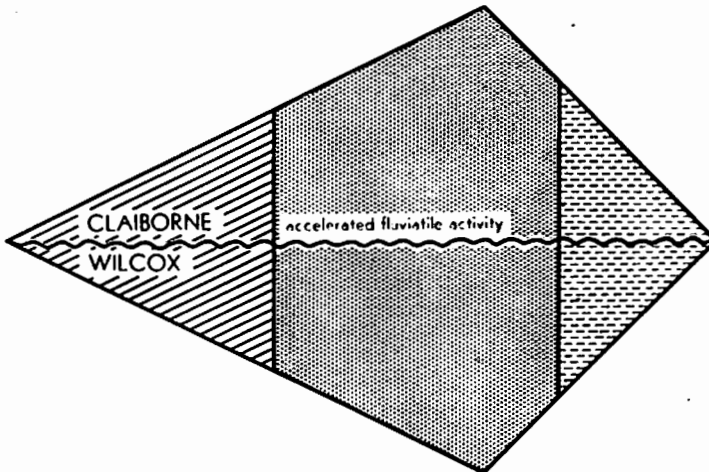
Uplift throughout the Embayment region institutes widespread erosion responsible for present belted topography and for maximum delta growth.

OLIGOCENE

widespread marine conditions but limited to Central Coastal Plain outside the Mississippi Embayment.

JACKSON

fluctuating shore lines of shallow seas.



Gulf Coast Geosyncline continues to deepen, its axis having reached the maximum outboard extent parallel to the present shoreline.

Major sedimentary history in the Mississippi Structural Trough terminates

EOCENE

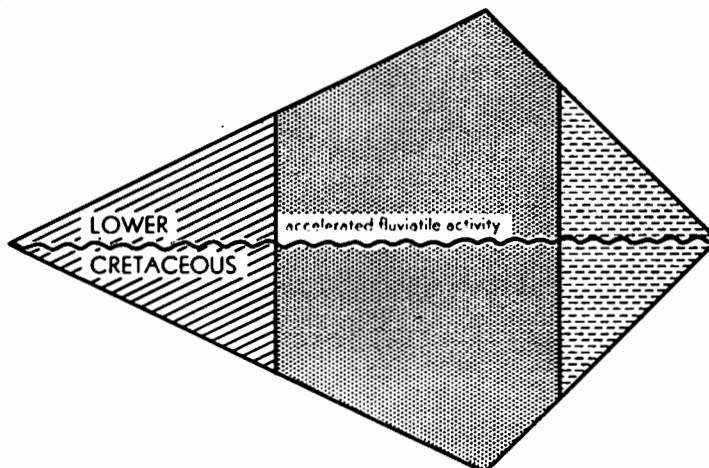
Uplifted borderlands supply sediments in quantity to the Mississippi Structural Trough and the Central Gulf Coastal Plain as deltaic masses progress seaward.

PALEOCENE

widespread marine conditions reach inland to the head of the Embayment.

UPPER CRETACEOUS

fluctuating shore lines of shallow seas.



Mississippi Structural Trough initiated through inland faulting.

Gulf Coast geosynclinal downwarp begins.

Paleozoic uplands supply great quantities of sediments from two main sources: the Appalachians on the south and east; the Ouachitas on the south and west.

JURASSIC

widespread marine conditions.

ELEVATED LAND MASSES



REDUCED LAND MASSES



DELTAIC DEVELOPMENT



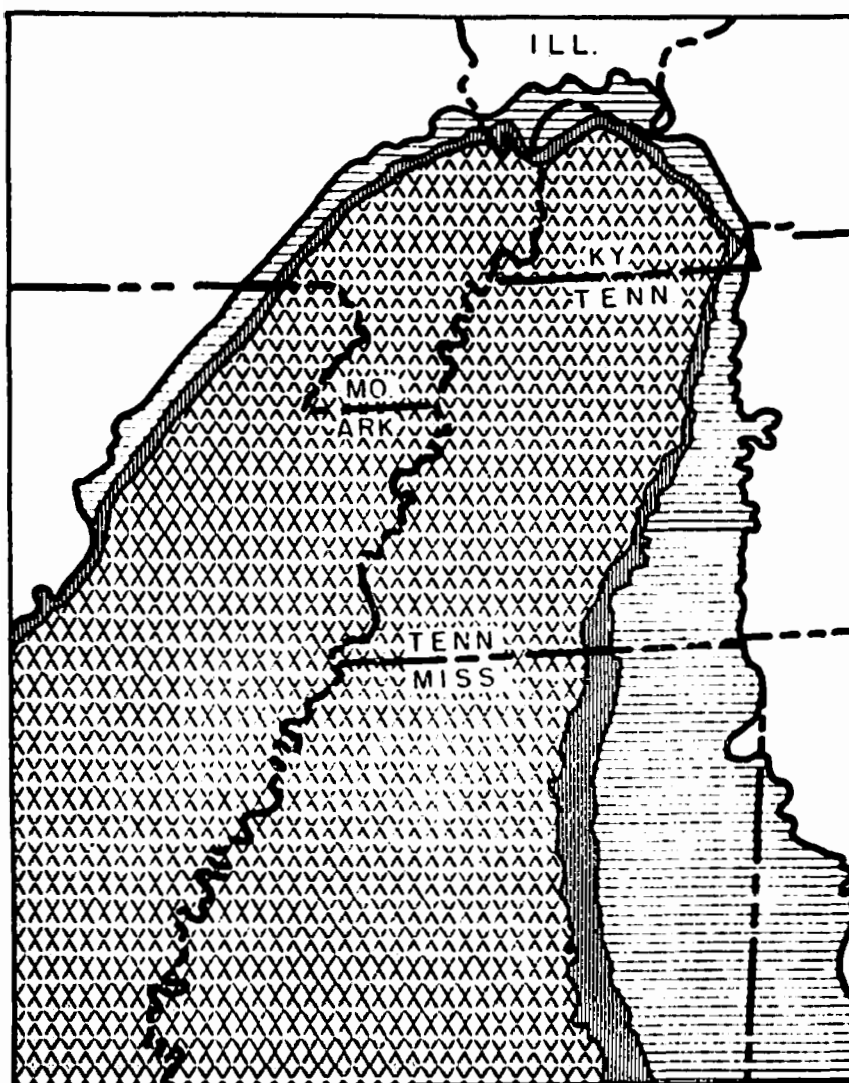
Figure 1. Cyclic interpretation of geomorphological development in the Mississippi Embayment Region.

out in a north-south direction; and from the inner margin of the embayment these beds disappear beneath successively younger deposits toward the axis of the trough. Near their easternmost exposures these deposits dip to the west and southwest at an average rate of 30 feet to the mile although this may be reduced to a minimum of 15 feet to the mile farther westward (Wells, 1933, p. 27).

The eastern limit of the coastal plain in the Tennessee section of the Mississippi Embayment has been drawn by various authors at the western margin of the Highland Rim section of the Interior Low Plateau, at the Tennessee River, or at the innermost edge of Cretaceous sediments. Locally, all of these criteria break down, and commingling of coastal plain and plateau topographies and soils adds to the problem of distinguishing such a boundary.

The oldest and easternmost deposits in West Tennessee related to coastal plain sedimentation are Late Cretaceous in age. The earliest account recognizing basic stratigraphical features is that of Safford (1864). Lower Cretaceous sediments are not recorded in the Mississippi Embayment region but, with the development of the structural trough previously noted, Late Mesozoic seas transgressed inland and Upper Cretaceous deposits, the earliest of which lie unconformably on Paleozoic rocks, mark the boundaries of this advance (Figure 2).

The Tuscaloosa formation, the first of the embayment deposits, was considered in some of the earlier reports (e.g., Stephenson, 1914, p. 14) to disappear in the vicinity of the Tennessee-Mississippi line. However, Miser (in Drake, 1913, p. 107) and Wade (1914, p. 173; 1917, pp.



Eocene and later



Cretaceous



Paleocene



Undifferentiated
pre-Cretaceous

Figure 2. Generalized areal geology of the Upper Mississippi Embayment (after Stearns and Armstrong, 1955).

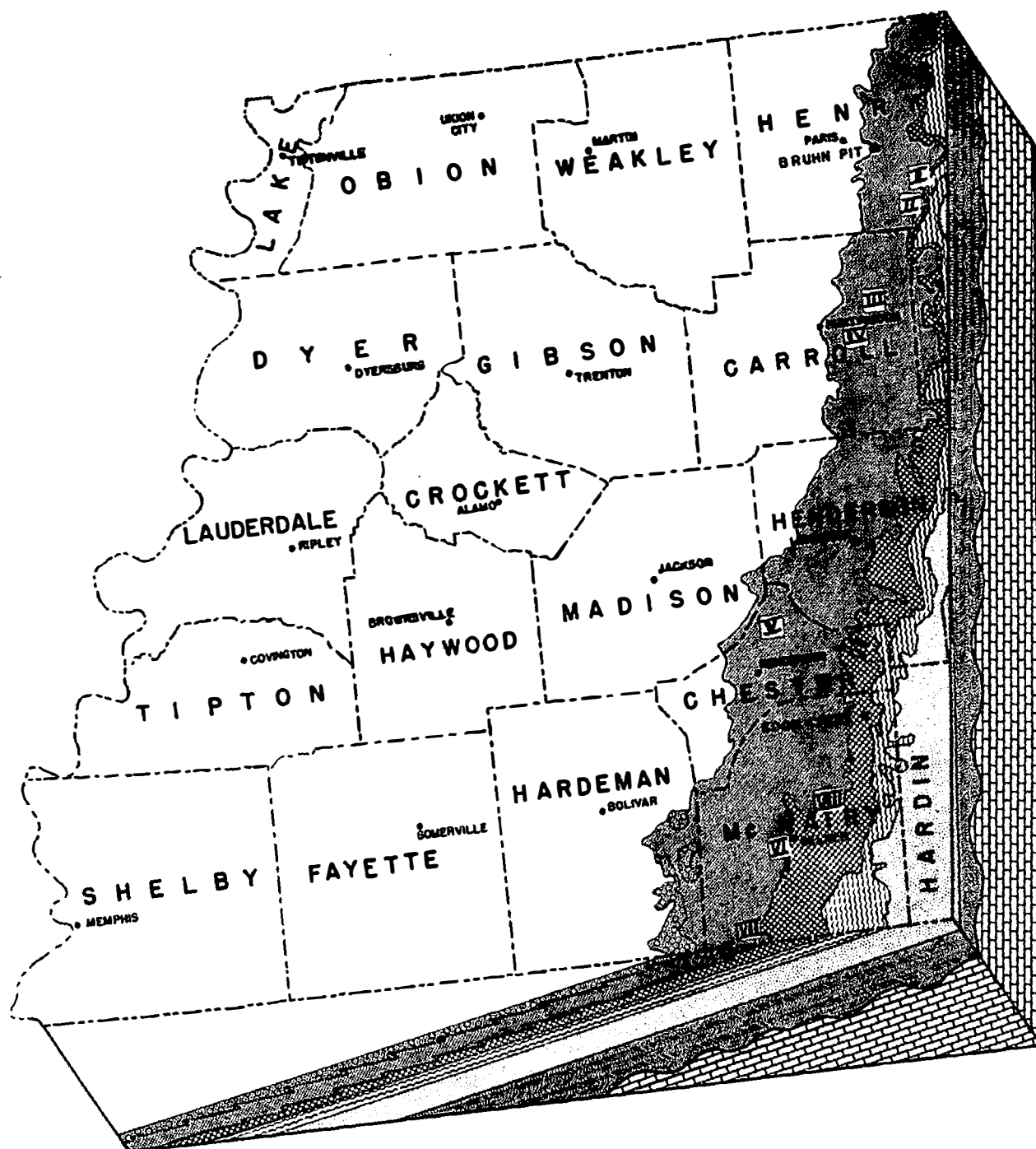
102-106) described occurrences of Tuscaloosa gravel in Tennessee, and the latter's extension of a basal gravel in the Upper Cretaceous series north into Kentucky has been confirmed recently by Lamar and Sutton (1930, pp. 850-851), Roberts and Gildersleeve (1950, pp. 38-39), and Moneymaker and Grant (1954, p. 1743) although the last named authors do not regard these occurrences as exact time equivalents.

The Tuscaloosa gravels are normally overlain by members of the Eutaw formation but the latter, due to overlap, may lie directly on the Paleozoic rocks to the north and northwest. The sands and clays of the Eutaw in Tennessee, like most of the once-extensive Tuscaloosa formation, have been removed by erosion so that occurrences are spotty.

West of the Tennessee River, the Upper Cretaceous series is represented by the Selma and Ripley formations in westward sequence. The prominent Black Belt lowland to the south has been developed on the Selma chalk but this formation is not present on the surface north of Henderson County in Tennessee according to Wells (1933, p. 75).

Parallel to and west of the Selma formation or the Eutaw formation, depending on the persistence of these beds, or, lying directly on Paleozoic rocks, if the older Mesozoic formations are missing, is the Ripley formation. These uppermost and hence youngest Upper Cretaceous deposits in the embayment region are the greatest in areal distribution (Figure 3).

In West Tennessee the Ripley formation extends completely across the state in a broad band that ranges in width from 18 miles at the southern boundary to 8 miles at the Kentucky line. A maximum thickness



CENOZOIC



MESOZOIC

CRETACEOUS

SELMA fm

EUTAW fm

TUSCALOOSA fm

RIPLEY fm

OWLE CREEK mbr

MURKIN SAND mbr

COCK CREEK mbr

PALEOZOIC



Figure 3. Distribution of Upper Cretaceous deposits in West Tennessee with generalized stratigraphical relationships based on Wade (1926). Roman numerals refer to plant megafossil localities described in Appendix B.

of 600 feet has been determined in the south where it comprises most of the surface outcrop in McNairy County. To the north in Henry County, the formation thins to approximately 350 feet. In general, the Ripley outcrop belt occupies a position on or near the divide between the Tennessee and Mississippi rivers and a hilly scarp region is developed along the outcrop. However, the physiographic distinction that characterizes the Ripley cuesta in the more obviously belted coastal plain to the South is generally not observed in western Kentucky and Tennessee. In the latter region, the intervening lowlands are poorly developed or absent and thus the contrasts are less pronounced (Fenneman, 1938, p. 74). Glenn (1906, p. 28) attributed the ridge-like elevation maintained throughout a considerable part of the Ripley outcrop belt to the peculiar ironstone or sandstone layers and masses that typify the formation.

Higher areas, particularly on the uplands bordering the Tennessee River, and south and northeast of Buchanan in Henry County, are formed by local deposits of chert gravel and sand that overlies the Ripley beds to thicknesses of thirty feet or more. These highly weathered superficial deposits, which have been assigned to the Lafayette formation, have long been the subject of controversy as to age and origin, and several authors (e.g., Roberts, 1928, p. 436) have adopted the arbitrary age classification of Plio-Pleistocene. Recently, Potter (1955, p. 122), following the most extensive study of these deposits to date, has marshalled evidence in support of a Pliocene age.

Wade (1926, pp. 7-9) subdivided the Ripley formation into three units: the Coon Creek tongue, the McNairy sand member with which it

merges to the north, and the Owl Creek tongue (Figure 3). Later, Stephenson and Monroe (1937, p. 808; 1938, p. 1631) found the Owl Creek unit in Mississippi to merge with the Prairie Bluff chalk. These authors, however, raised the Owl Creek to formational status, interpreting its relationship to the underlying McNairy sand to be unconformable.

The greenish to black, glauconitic, micaceous, sandy marl or clays of the Coon Creek and Owl Creek members appear to intertongue at their upper or lower limits respectively into the irregularly bedded, mainly nonglauconitic sands and subordinate clays of the McNairy sand member. Such an association has been interpreted as indicating the oscillatory nature of the Ripley sea as shallow marine conditions were interrupted by nonmarine or near-shore deposition of the McNairy beds (Wade, 1926, p. 9; Wells, 1933, p. 81).

Classic Owl Creek marine fossil localities occur in Tippah County, Mississippi, and on Muddy Creek in Hardeman County where the tongue reaches its northernmost limit in Tennessee. In contrast, the Coon Creek tongue, which borders the McNairy sand on the east across the state, becomes a ferruginous sand with few or no fossils as it extends northward. The type locality at the Dave Weeks place on Coon Creek in northeastern McNairy County was made famous through the description of a large and beautifully preserved marine fauna by Wade (1926). W. Berry and Kelley (1929) published an account of the Coon Creek Foraminifera largely invalidated later by Cushman (1931).

The McNairy sand member was differentiated from the more typical

marine facies of the Ripley formation by Stephenson (1914, pp. 17-18).

A description of the general lithology of this member is as follows:

Fine to coarse-grained sands consisting chiefly of subrounded quartz grains with some mica and glauconite although largely nonglauconitic in the main. Sands exhibit a variety of color including white, yellow, brown, pink, red, and purple but are characteristically deep red or brown on surface outcrop due to precipitation of ferric oxide when exposed to oxidation. The high iron content of these sands is further indicated by local columnar or tabular masses of ironstone or ferruginous sandstone formed particularly in the lower part of the unit. Bedding may be more or less regular or parallel but very often the sands are crossbedded.

Distinctly bedded subordinate clays occur in interlaminated layers of a few to several inches in thickness but lenses extending from 1 to 20 feet or more occur throughout the outcrop belt. The clays are light or varicolored, or exhibit different shades of gray to black owing to high organic content. These clays, which are usually fine-grained and moderately siliceous, can be assigned to the ball, wad, and sagger type designations of the ceramic industry. Lignite in beds a few feet thick often overlies the clay although not as commonly as in the Eocene deposits farther west.

Compared with the Owl Creek and Coon Creek tongues, the McNairy sand member of the Ripley is relatively unfossiliferous. However, plant megafossils, leaf impressions for the most part, have been recorded from Tennessee localities in McNairy, Chester, Carroll, Benton, and Henry counties (see Figure 3). These fossils, along with a few specimens collected several hundred miles away in Georgia and Alabama, have been described and interpreted by E. W. Berry (1910, 1916, 1919, 1920, 1921, 1925, 1928) and constitute the Ripley Flora of that author. A complete list of localities and species is included in the appendix, and elements of this fossil flora will be discussed later in connection with the present study.

Tertiary Deposits

West of the Ripley surface exposures, largely unconsolidated Tertiary deposits consisting chiefly of gravels, sands, and clays, crop out in similar parallel bands over a distance of 60 to 70 miles. The youngest of these dips beneath the Pleistocene loess that ultimately limits at the Mississippi Bluffs the physiographic division that Safford (1869, p. 110) described as "the Plateau or Slope of West Tennessee."

The earliest Tertiary sediments exposed are assigned to the Midway Group of Paleocene age. A basal unit, the Clayton formation, has been correlated with beds containing impure limestones in Mississippi. This member is not considered to extend into Tennessee farther than 35 miles north of the state line (Roberts, 1928, p. 436). Stratigraphically above the Clayton is the Porters Creek formation which represents the major part of the Midway Group present in West Tennessee. The formation extends across the state in a narrow band from eight miles to less than a mile in width. Near the axis of the embayment, thicknesses greater than 360 feet have been recorded in well logs (Whitlatch, 1940, p. 52), but at the outcrop near Paris the clay measures 140 feet (Wells, 1933, p. 88). Locally known as "soapstone" because of its greasy feel when wet, the fine-textured Porters Creek clay is well characterized by peculiar conchoidal or cubical fractures on the weathered surface. These properties, along with the homogeneity of its dark to light gray color, makes the clay one of the most easily recognized lithologic units in West Tennessee. The clay is mined as a bleaching earth near the southeastern limits of Paris in Henry County.

Roberts and Collins (1926, p. 236) and Wells (1933, p. 86) are among the authors who regard the Midway Group as distinctly marine. Allen (1934, pp. 590-598) and others have subscribed to a bentonitic origin for the Porters Creek clays. The latter view is not shared by Grim (1936, pp. 42-48) who believes that these clays are deltaic deposits. Cushman (1931, p. 7) concludes that the Porters Creek fauna indicates that the clays, in part at least, are of freshwater origin. Imperfect leaf impressions have been reported from the glauconitic clay overlying the impure limestone of the Clayton formation (Roberts, 1928, p. 437).¹

Whitlatch (1940, p. 14, p. 53) observes that unlike the clays of other Tertiary deposits in West Tennessee, those of the Porters Creek formation do not occur in lenses, tend to be massive, and are ceramically distinct from all others regardless of age. As far as the present writer has been able to determine, associated lignites such as those which typify the later Tertiary deposits above and the Ripley beds below are conspicuously absent.

The Porters Creek formation is overlapped on the west by Eocene sediments. Immediately to the west of the Porters Creek outcrop are deposits that have been assigned to the Wilcox group or formation. However, since these beds bear no direct relationship to the present investigation, they will not be discussed further at this point. Moreover, these deposits are being re-mapped at the present time and major

¹Glenn (1906, p. 32) found similar fossils that he felt identifiable in the greensand of the Porters Creek about a mile east of Middleton. Unfortunately, no collections were made.

nomenclatural changes are in prospect. Up to the present time, only a preliminary report outlining the general results obtained from an electric log survey of post-Paleozoic sediments has been published by Stearns and Armstrong (1955).

THE BRUHN PIT

Location

The lignite sampled in this study is exposed in a pit opened on the property of Mrs. Ethel Bruhn, Route 5, Paris, Henry County, Tennessee [Figure 4(A)]. Directions for reaching the pit are as follows:

At the junction of U. S. Highway 79 (State Highway 76) and State Highway 69 near the eastern margin of Paris, turn left on State Highway 69 (the Big Sandy Highway) and continue southeast then due east for a distance of 2.5 miles. Turn left (northeast) onto an unimproved dirt road and proceed approximately 1000 feet to the first farmhouse on the left. On foot, continue left of the farmhouse on a farm road that leads in a northwesterly direction to the pit at a distance of 1800 feet. The surface above the pit opening lies close to the 400-foot contour line that skirts the broad hill sloping down to the site.

Lithology

The excavation (Figure 5) reveals ten to fifteen feet of medium-grained ferruginous sand, orange to buff in color and poorly bedded, overlying approximately two and one-half feet of lignite. The lignite, which contains scattered pieces of fusain, is, in turn, underlain by a fine, slightly micaceous, kaolinitic, gray clay. At the time of the first visit to the site, in the Fall of 1952, mining operations had exposed about four feet of clay. Since that time, the pit has filled with water to the level of the lignite bed as indicated in the photograph.

Officials of the Kentucky-Tennessee Clay Company, which mines the clay under lease, do not consider the clay to be top quality because of

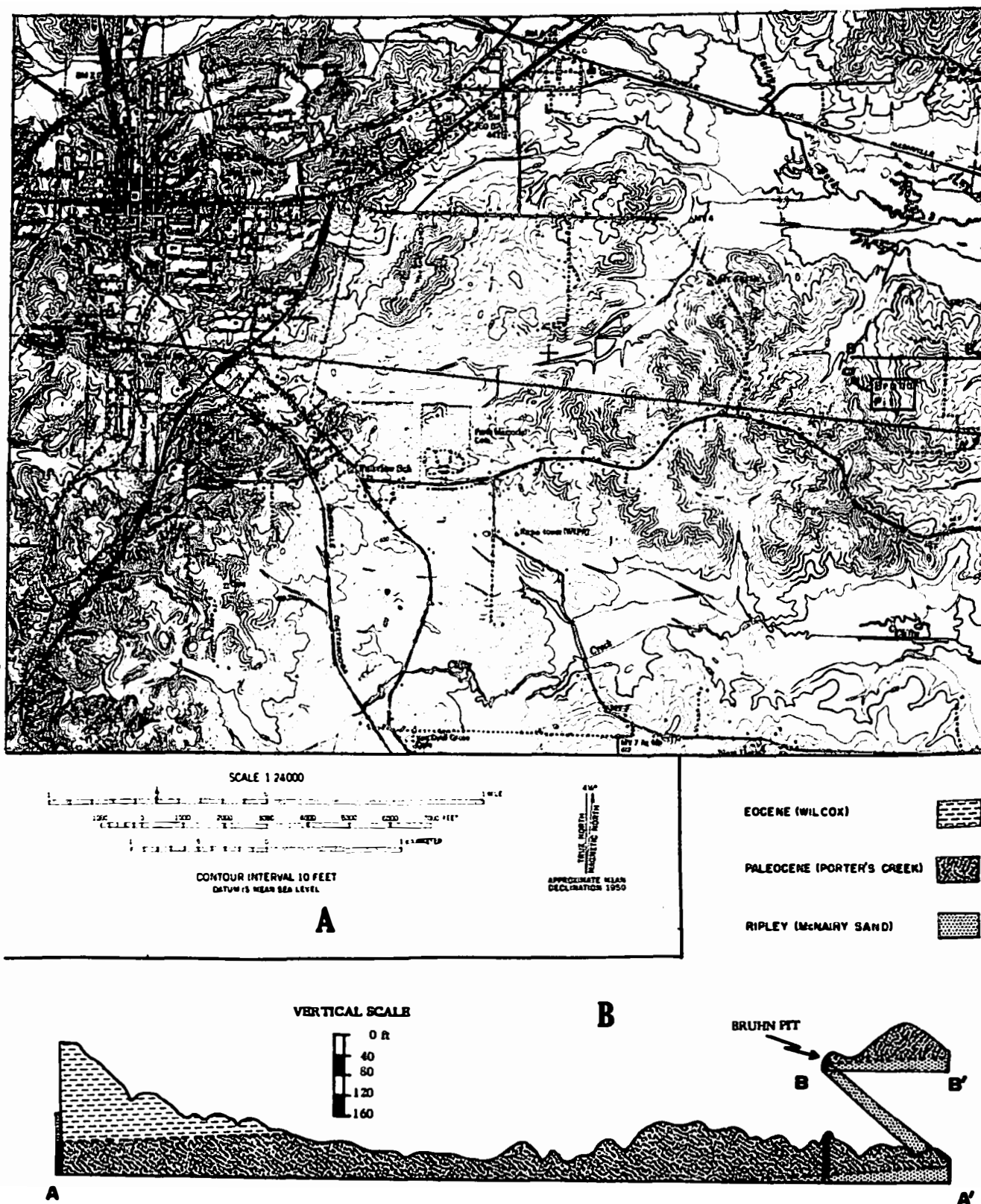


Figure 4. Location and stratigraphical position of the Bruhm lignite.



Figure 5. Photograph of the Bruhn pit.

its high iron content; consequently, operations have virtually ceased at the time of this writing. It has been determined through borings that the clay extends to a depth of several feet, and occupies a considerable area.¹

Sampling

Samples were taken from four points along the vertical section: two feet down in the gray clay; at the contact between the clay and the lignite; about a foot down in the lignite; and at the contact between the lignite and the overlying sand. In addition, better preserved wood fragments were collected from the lignite and stored for possible identification later. However, up to the present time, no attempt has been made to establish botanical relationships of the wood specimens and further consideration of them will not be included in this report.

Later, in the laboratory, preliminary treatment of the samples disclosed that those taken from the clay and sand were largely unfossiliferous and further investigation would be unrewarding. Consequently, major emphasis was placed on the samples removed from the lignite and from the zone of contact between the lignite and clay.

During the process described in a later section by which the microfossils were separated from the matrix, the roman numeral I was used to designate the samples taken from the lignite-clay contact, and

¹Mr. James H. Wilson, Kentucky-Tennessee Clay Co., Paris, personal communication.

the numerals II and IV were assigned to the lignite samples. These numerals were carried over to labels on stoppered vials used to store the fossiliferous material concentrated from the samples. When slides were prepared from the latter, the sample numerals became prefixes in the number-letter combinations written on the slides for cataloging purposes and reference.

Stratigraphic Considerations

The present state of knowledge pertaining to West Tennessee stratigraphy permits only a tentative age assignment to the Bruhn lignite. Boundaries of surface outcrops shown in the several geologic maps covering this region cannot be regarded as completely reliable, and, at best, are drawn on such a scale as to make local identification of particular beds difficult. The scarcity or absence of characteristic fossils in this portion of the embayment region has been the main source of difficulty in the past.

However, within a reasonable range of accuracy it is possible through stratigraphic and lithologic observations to arrive at a relative chronology for the region that can be used to advantage in establishing paleobotanical relationships and interpreting results. The necessity for delimiting the scope of the problem in this manner will become quite obvious in later chapters dealing with the identification of the microfossils.

Wells (1933, p. 202) records the log of Well No. 4, drilled for

the Louisville and Nashville Railroad at Paris, in which the Porters Creek clay was reached at a depth of 63.5 feet through an overburden of Eocene sands. This formation had a total thickness of 147 feet and was underlain by the Ripley formation at a depth of 210.5 feet. Assuming that the altitude of the well collar, given at 489 feet, is relatively close to the surface, the top of the Porters Creek clay was located at an elevation of 425.5 feet while the top of the Ripley formation occurs 147 feet below at an elevation of 278.5 feet.

The regional dip of the Ripley formation has been determined to be thirty feet to the mile (Wells, 1933, p. 76) and, in Henry County, the Porters Creek clay dips from twenty to thirty feet to the mile in a similar westward direction (Wells, 1933, p. 200).

Figure 4(B) shows approximate stratigraphical relationships deduced from these data plotted along physiographic profiles drawn at A-A' and B-B' on the map in Figure 4(A). The writer, selecting an average dip of twenty-five feet to the mile, projected the upper surfaces of the Porters Creek and Ripley formations to points of intersection with the present landscape.

By the calculation above, the western margin of the Porters Creek formation outcrop belt should appear a little less than a mile west of Grove School in Paris at a point $3/10$ of a mile east of the junction of U. S. Highway 79 (State Highway 76) and State Highway 69. That this assumption is very nearly correct is indicated by the fact that Porters Creek clay is mined relatively close to the surface just east of State Highway 69 in the Fairview section of Paris by the Tennessee Bleaching

Clay Corporation. This characteristic clay, described previously, can be seen in road and railroad cuts within a quarter mile west of these clay pits as well.

The Ripley formation might be expected to outcrop about three-fifths of a mile east of the Bruhn pit where elevations fall below the 400-foot contour. Considering the amount of overburden (10-15 feet) above the lignite, it seems reasonable to conclude that the latter is stratigraphically related to the Ripley formation which, in this area, is represented by the McNairy sand member. It does not appear likely that a marked shift in the strike of these beds might have occurred within the small area under discussion to jeopardize this premise.

No account of Porters Creek lithology, or, in fact, that of any other Midway formation in this part of the Embayment Region that has come to the writer's attention contains any reference to lignite. In fact, there is almost general agreement that these sediments are marine in origin, for the most part at least. On the other hand, lignite in the Ripley formation is somewhat common.

Mining operations in the past and present have exposed Ripley clays near the surface within a relatively short distance east of the Bruhn pit. Among these are: the Porter's Switch pit of the Kentucky-Tennessee Clay Company, one and two-fifths miles to the northeast; the McCall Mining Company operation on the west side of Roark Hill about one-half mile east of the Porter's Switch pit; the J. G. Jackson prospect in the same vicinity; the Russell Pottery Company excavation one and three-tenths miles to the southeast; and sites near India, two and

seven-tenths miles north of the Bruhn pit (e.g., the Mandle-Sant "No. 3" pit and the Jackson Clay Mining Company's "Black Diamond" pit, both about a mile east of India). These pits have a relatively consistent profile that is strikingly similar to that previously described for the Bruhn pit. A generalized profile based on data from Nelson (1911, pp. 89-90), Ries, Bayley, et al. (1922, p. 226), Schroeder (1919, p. 130), and Whitlatch (1940, pp. 74, 92, 133, 151, 182-183), and on personal observation is represented by the following sequence:

Sandy overburden, clayey in places	12-18'
Lignite or black lignitic clay	1-2'
Clay: grey, brown, blue, or black	2-16'

Material from the above sites may prove useful in establishing a definite age correlation for the Bruhn lignite based on paleontological grounds. However, in view of the rather convincing stratigraphical position of the lignite, there seems to be little argument against assigning the deposit to the Ripley formation, McNairy sand member, at least tentatively.

Paleobotanical Relationships

Of more consequence, insofar as the present thesis is concerned, is the paleobotanical position of the flora represented in the lignite. Localities that provided a high percentage of the plant megafossils, upon which current concepts of Late Cretaceous and Early Tertiary vegetation in southeastern North America are largely based, occur within a few miles of the lignite site. The opportunity for comparing fossil

evidence is unique.

The Ripley Flora, previously mentioned, was described by E. W. Berry from collections made principally by Wade in Tennessee, although a few specimens were collected by L. W. Stephenson and Professor Berry near Byron and Buena Vista, Houston County, Georgia, and on Cowikee Creek, Barbour County, Alabama. Stephenson also collected three species along the Camden-Paris road in southeastern Henry County, Tennessee. A total of 135 species were described in all but whether they comprise a single floristic unit as the name implies (and as has been inferred by subsequent writers) might be questioned.

Almost 75 per cent of the Ripley megafossil localities occur in West Tennessee, and except for a Coon Creek site on the John Boyd place five miles northeast of Selmer, McNairy County, all are regarded as belonging to the McNairy sand member (Figure 3). Wade (1926, p. 4) shows the stratigraphic position of most of the Ripley fossil occurrences, an exception being the site on the Camden-Paris road, 13 miles northwest of Camden, visited by Stephenson. However, the latter informs the writer that he considers this site to be in the McNairy as well.²

On the West Tennessee McNairy sand localities, the Cooper pit, $1\frac{1}{2}$ miles south of Hollow Rock, Carroll County, and the gully exposure on the Dr. J. R. Perry farm, 10 miles southeast of Paris, Henry County, on the Manlyville road are particularly significant. These two sites yielded 117 or about 87 per cent of the Ripley species. Fifty-eight or 82 per cent

²L. W. Stephenson, personal communication, 1956.

of the 71 genera were found only at these two localities, and ten other genera are represented by a single species elsewhere.

A few miles to the west of the Bruhn pit, across the Tennessee-Mississippi drainage divide, are the clay pits near Puryear, Whitlock, Paris, and Henry that provided a high percentage of the fossil species assigned by Berry (1916, 1930) to the Wilcox Flora of Early Eocene age. The Puryear locality alone contributed 205 species or roughly 38 per cent of those constituting the flora described from the fossils.

It is of considerable interest to note that all of these major fossil localities, both of Eocene Tertiary and Ripley Cretaceous ages, can be reached within a radius of sixteen miles centered at the Bruhn pit (Figure 3). Furthermore, since the latter is situated near the western margin of the Ripley outcrop belt, it seems justifiable to assume that the botanical materials obtained from the lignite certainly represent pre-Eocene and hence pre-Wilcox deposition, while the degree of contemporaneity with the Ripley Flora as described by Berry, or the more northerly elements of it, remains to be established. The juxtaposition of extensive Early Eocene floristic evidence also invites further comparisons.

METHODOLOGY

Previous Applications

The particular research method employed in this investigation is one aspect of a relatively new botanical discipline for which Hyde and Williams in 1944 proposed the term palynology - "the study of pollen and other spores and their dispersal, and applications thereof." The development of palynology has gained momentum in recent years following the work of European pioneers in the field such as Reinsch, Fröh, Weber, and Lagerheim who first recognized the wider potentiality of such studies. For an account of the early history of the science, the monographs of Erdtman (1943) and Wodehouse (1935) may be consulted.

While the impetus responsible for current interest in palynology was generated by the formalization of pollen analysis by Von Post (1918), it should be emphasized that studies of this type represent but one application of palynology and the terms are not synonymous. More fundamental to the development of the science has been the work of anatomists and morphologists, beginning with Grew and Malpighi, who have studied and recorded the structural characteristics of pollen and spores and their differences. In this connection, the researches of von Mohl (1835), Fritzsche (1837), Fischer (1890), Lindau (1895), Servettaz (1909), Pope (1925), Jentys-Szafer (1928), Wodehouse (1935), Florin (1936, 1937), Cramwell (1939, 1940, 1942, 1953), Erdtman (1943, 1952), Heimsch (1940, 1944), Selling (1944, 1946, 1947), Hedberg (1946), Kurtz (1948),

Mueller-Stoll (1948), Knox (1950), Rao (1950), Van Campo-Duplan (1950, 1951, 1953), Ueno (1951), Straka (1952, 1954), Dahl (1952), Zinderen-Bakker (1953), Masa (1954), Coetzee (1955), Baker (1955, 1956), Pike (1956), and the exhaustive studies of I. W. Bailey and students (1943a, 1943b, 1945, 1948, 1949), (Money, Bailey, and Swampy, 1950), (Swampy, 1949), (Swampy and Bailey, 1949), (Canright, 1953), (Reed, 1955) over the past several years, may be cited particularly. It is unfortunate that such basic research upon which palynology must build or remain infantile has not kept pace with the more popular interpretative aspects of the science.

Analysis of postglacial peats, especially in northern Europe around the turn of the century, focussed attention on the micropaleontological significance of pollen and spores although, prior to that time, paleobotanists had been reporting on Carboniferous spores for several years. As plant microfossils these reproductive bodies are now known to occur in sedimentary deposits over a wide range of geologic time. Adaptability to preservation is provided by the peculiar chemical nature of the outer integument (exine, exosporium) which resists degradation, although exceptions are known to exist.

Peat studies in this country, stimulated to a great extent by the efforts of Erdtman through bibliographic compilations and the monographs previously noted, have dealt primarily with the problems of Quaternary forest succession and climatic shifts. A discussion of basic assumptions, methodology, and earlier investigations may be found in Cain (1939, 1944, pp. 122-144), while Deevey (1949) has summarized the results of the

several American workers who have contributed to the growing literature of pollen analysis.

Spores and pollen in Carboniferous deposits have received a considerable amount of attention in recent years, and their use in the correlation of coal deposits has been exploited in many areas. Wilson (1944, 1946) discusses the utilization of plant microfossils in this manner rather fully and suggests further applications in other sedimentary deposits as well. A summary of taxonomically valid Paleozoic spore genera scattered throughout the literature has been undertaken by Schopf, Wilson, and Bentall (1944). Arnold (1950), Kosanke (1950) and Potonié and Kremp (1954, 1955) have made recent contributions to this field.

Compared with palynological studies of Paleozoic and Cenozoic materials, similar investigations of Mesozoic deposits in the main have not been extensive, either through lack of economic stimulus or, perhaps, due to scientific apathy. A survey of the literature reveals a large number of papers reporting isolated occurrences of pollen and spores showing pteridophyte, gymnosperm, or angiosperm affinities but there are few detailed studies. However, there is evidence of increased activity, particularly in Europe, which promises to add to present knowledge concerning this most important era in the development of modern vegetation. As will be shown in detail in subsequent chapters in this thesis, there is no dearth of material available for study and it seems reasonable to suggest that present concepts of plant evolution and distribution should be regarded as tentative until more information of this nature is assembled.

A relatively complete bibliography of Mesozoic palynology has been included in this report as Appendix C. Just (1951) points out the significance of Mesozoic microfossils and discusses the results of several of the pollen and spore studies included in the bibliography. After reviewing this literature one is impressed not only with the paucity of information concerning fundamental developments in the plant kingdom beyond the lower groups but also with the general incompatibility of the results of these investigations with other published paleobotanical data. Because of related inferences and conclusions to be drawn later in connection with the results obtained by the present author, it is of interest, at this point, to review several of the more important papers on Mesozoic palynology.¹

Triassic

While winged pollen characteristic of the gymnosperms is reported from the Triassic, no definite relationships to extant groups have been indicated by most authors. From the Triassic in this country, Daugherty (1941) has described among other microfossils isolated from Petrified Forest material, a winged spore, Alisporites opii, of undetermined affinities. Most workers have resorted to the artificial classification embodied by the form genera, Pollenites and Sporites, when dealing with

¹The inclusion of summaries of the more recent Russian investigations, several of which have been indicated by translated titles in the bibliography in Appendix C, would have added much to this review. However, full reports are unavailable at the present time.

microfossils of this age.

The Alpine salt beds in Austria investigated by Klaus (1953a, 1953b) show a characteristic Upper Triassic to Liassic assemblage of plant microfossils, dominated by Triletes, and including 2-winged pollen. An angiospermous (?) pollen grain assigned to Tricolporites is found occasionally. Several of these microfossils have been described and classified by Potonié and Klaus (1954).

Jurassic

In the Jurassic, conifer pollen grains, in some instances assigned to the Abietaceae and Podocarpaceae, have been described from several localities in Europe, Asia, India, Australia, and New Zealand. Lycopod and fern spores, however, form the basis of most Jurassic microfossil reports although angiospermous pollen has been reported from Sweden (Erdtman, 1948), Russia (Naumova, 1939), and Scotland (Simpson, 1937, 1938). In the first instance, a tricolpate grain resembling a structural type found only in the angiosperms was found in the Palsjö beds in northwest Scania. A monosulcate grain bearing magnolioid features but believed to be more definitely related to the Bennettitales was reported from the same deposit. The dicotyledonous nature of Erdtman's tricolpate grain, Tricolpites (Eucommiidites) Troedssonii has been challenged recently by Kuyt, Muller, and Waterbolk (1955) in reference to almost identical grains from the Upper Jurassic of the Netherlands. It is suggested by these authors that the relationship should be sought among the

Chlamydospermae (Ephedra, Welwitschia) although the resemblance to dicotyledonous pollen types indicates that the fossil may indeed represent a forerunner.

Naumova (1939), in a survey of plant microfossils found in Russian coals, observes that angiosperm-type pollen occurs earliest in the Jurassic in the region of the Caucasus, but does not appear prior to the Upper Cretaceous in coals of Asiatic Russia. In another early Russian palynological study, Tchigouriaeva (1938) discovered podocarpaceous pollen in the Jurassic of Kasakstan.

From the Jurassic coals of Brora, Sutherlandshire, in Scotland, Simpson isolated several pollen grains that constitute the "first indubitable angiosperm evidence" often cited in the literature. Certain forms were assigned to the Abietineae and Nymphaeaceae, in the latter to the genera, Nelumbium and Castalia. Another type appears to be similar to Magnolia but definite identification appears to be questionable.

Thiergart (1949) has reported on spores and pollen from Jurassic beds in Germany but they are grouped into the form genera Sporites and Pollenites for the most part. Among the gymnosperms, Pinus, Picea?, a Cycas-type, and a podocarpaceous grain were found, however, along with spore types referable to Lycopodium and the fern families Schizaeaceae (Lygodium, Mohria) and Osmundaceae. Recently, Rogalska (1954) obtained somewhat similar results from the Lias deposits in Upper Silesia. Forty-three per cent of the microfossils were gymnospermous types with winged and unwinged pollen about equally divided. Fifty per cent of the

total was made up of pteridophyte spores, the ferns constituting the majority. Among the unknowns are a few pollen forms of indefinite relationship.

A large number of Jurassic spores and pollen grains have been described by Sah (1953) from materials collected at Andigama, Ceylon. These include winged pollen, and spores of several morphological types. No modern affinities are suggested by Sah. Earlier, Rao (1936, 1943) reported similarly nonassigned sporomorphs² from the Rajmahal Hills, India.

Several investigations by English workers in Yorkshire are cited in the bibliography. Harris (1948) has assigned one pollen type to the genus Ginkgo. Otherwise, the Jurassic microfossils from that area have been megaspores for the most part, many of which have been placed in the form genus Triletes.

The Lower Coal Measure Ohika, Hawks Crag, and Breccia beds of New Zealand, considered to be Upper Jurassic in a larger stratigraphic work by Couper (1953), revealed no angiosperm pollen upon analysis. Moss and pteridophyte spores were present as were araucariaceous, podocarpaceous and monosulcate grains similar to those found in Ginkgo.

Cookson (1953) and Cookson and Pike (1954) have called attention

²The term sporomorph (an abbreviation for sporomorpha (pl., sporomorphae) as suggested by Erdtman (1947) is used here and throughout this report in an abstract as well as concrete sense to designate a pollen or spore type or individuals belonging to these types, not necessarily related except morphologically. This is a useful term in fossil palynology although a purist might prefer a term such as palynomorph to apply to both spores and pollen in the abstract.

to the occurrence of podocarpaceous sporomorphs in Jurassic sediments of Australia. One of the sporomorphs appears to be similar to the microfossil described by Rao in the study of the Rajmahal Hills Jurassic cited above.

Except for the work of Harris (1931-1932, 1935, 1937) who isolated fourteen megaspores and coniferous pollen from Scoresby Sound, Greenland, Lias material, Jurassic beds in North America have not been investigated. The major obstacle--the paucity of favorable superficial deposits--may be offset in the future by subsurface material obtained through petroleum exploration.

Cretaceous

Among deposits of Cretaceous age, materials such as lignite, sub-bituminous coal, and carbonaceous shales have considerable geographical distribution. This widespread feature of Cretaceous sedimentation can be correlated with the number and areal extent of the palynological reports to be found in the literature dealing with this period of time.

To date, one of the most extensive investigations of Mesozoic pollen and spores has been made at several sites in Germany and Austria by Thiergart (1949). In addition to Triassic microfossils, and the Jurassic spores and pollen mentioned previously, Cretaceous sporomorphs were obtained from samples ranging from Wealden coals to transitional beds extending into the Paleocene. Thiergart found no angiospermous pollen in any pre-Cretaceous sample. Furthermore, monocotyledonous types

were practically absent and none appeared prior to his most recent samples. Pteridophyte and gymnosperm types were the most abundantly represented.

In this study, Thiergart reported several resemblances to modern pollen and spores. In the lowermost Wealden beds, gymnosperm pollen suggesting the genera Picea, Pinus (haploxydon-type), Podocarpus, and Cycas were observed, along with spores possibly referable to Lygodium, Mohria, and Pteridium. In Upper Cretaceous and transitional beds, Thiergart found, in addition, pollen of Taxodiaceae, Pinus of the sylvestris type and grains resembling Ephedra. In these last-named beds, angiosperms were represented by palmaceous, nymphaeaceous, myrtaceous, and ericaceous pollen along with more specifically identified Castanopsis, Carya, Engelhardtia, and Eucalyptus types. Other spores and pollen were separated into generalized pollen and spore groups on the basis of an interesting stain technique.

In a later study of assorted samples from the Perutzer (Cenomanian) clays of Bohemia, Thiergart (1953) reported an almost exclusively fern and gymnosperm composition in the lower beds. Near Altendorf, in Moravia, the clays contained pteridophyte spores in abundance, with bladderless gymnosperm pollen (some possibly belonging to Cupressaceae and Taxaceae) relatively numerous. On the whole, conifer pollen was poorly represented with the Pinus haploxydon-type the only winged form observed. Of all the sporomorph groups, least common was angiosperm pollen. Three dicotyledonous forms were particularly noted: a quercoid type (cf. Pollenites henrici R. Potonié); a Castanopsis-type, sensu lato; and one displaying the form of Pollenites laesus R. Potonié, a

prominent Tertiary type which may have quercoid, nysoid, or rhamnoid affinities.

According to Thiergart, no sample revealed any definite monocotyledonous pollen although certain forms were present which might conceivably belong to the Palmaceae. These, however, are not distinguishable from certain cycadophyte pollen and the author is thus reluctant to suggest any positive relationship.

Other major contributions to Cretaceous palynology by German workers are contained in the recent publications by Weyland and Krieger (1953), Weyland and Greifeld (1953), and Pflug (1953). These reports are complementary and nomenclaturally synchronized. In addition, certain conclusions reached by these authors, particularly Pflug, take into account earlier results of Thomson and Pflug (1953).

Weyland and Krieger studied material from the Middle Senonian Cretaceous at Aachen. The lower Basiston was found to contain relatively more spores than the overlying Aachen Sand although in both beds pollen forms predominated. Altogether, gymnosperms were only weakly represented. Among the spores, those belonging to the Schizaeaceae were particularly noticeable.

The angiosperm pollen from Aachen was dominated by a group of triangular forms (Dreieckspollen) of undetermined generic or family relationship. These possess certain morphological similarities to recent myrtaceous pollen and hence are designated "myrteoid" although no definite taxonomic assignment is implied. The roots of such families as Myricaceae,

Betulaceae, and Juglandaceae are believed to be present among the complex group of more or less morphologically related types that seem to represent a period of rapid evolution within the dicotyledons. Associated epidermal studies failed to produce any systematic evidence to aid the investigators in classifying the microfossils.

More recently, Vangerow (1954) has added seventeen species of megaspores, all within the generic limits of Triletes and Chrysotheca, to the sporomorph count at Aachen. Megaspores from stratigraphically comparable deposits in the Netherlands have been described by Dijkstra (1949). This same author (1951) has surveyed the stratigraphic importance of Wealden megaspores as well.

In the microfossil investigation made by Weyland and Greifeld (1953) of the Lower Senonian clays at Quedlinburg, quite a large number of spores and pollen forms were found along with the remains of leaves. The latter were assigned to a new cycadalean genus, Pleiotrichium, and to the genera, Myrica and Crednaria. The spores and pollen were placed in previously established morphological taxa.

The contribution of Pflug (1953) is an attempt to establish the morphologic and systematic relationships of angiospermous pollen through time. Summarizing the evidence compiled by the German workers, certain structural elements are associated with morphological types. In connection with these types, the evolution of the angiosperm (or "angiospermid") germinating apparatus is traced theoretically in a series of morphogenetic changes extending from a simple trilete type in the Carboniferous through convergent and divergent steps to the heterogeneous assortment of pollen

types found in the present flora. As an example, the pollen of Myricales, Juglandales, Betulaceae and Urticales is traced by an assumed morphogenetic order of development to a common root in the Senonian Cretaceous.

According to Pflug, in agreement with his associates, the evidence compiled from the palynological investigations of Cretaceous and older deposits has led to the conclusion that, due to the inherent heterogeneity manifested by transitional forms during the earlier stages of angiosperm evolution, the great majority of sporomorphs cannot be assigned with certainty to the recognized higher taxa utilized by neontologists. As a means for alleviating this difficulty, a system of fourteen morphogenetically contrived taxonomic units called "stemma" are suggested by Pflug. Into these largest taxa are placed smaller morphologically defined units, fixed by types, and corresponding to subspecies, species, and genera, but with greater latitude than is normally implied by these categories.

The intent of Pflug's classification scheme is to provide a flexible taxonomic framework upon which present knowledge can be organized and yet allow for subsequent changes to be made whenever warranted by new phylogenetic information. The erection of such "collecting groups," consisting of heterogeneous units possessing convergent and hence rank-unspecific characteristics, is a reflection on our still fragmentary insight into phylogenetic relationships.

Sporomorphs within certain of the taxa erected by Pflug perhaps are without hope of further clarification but others, established on morphological grounds also, approach the conditions of natural relationship.

The latter situation is illustrated, for example, within the "Post-normapolles," one of the stemma proposed. The genera, Triporo-pollenites, Trivestibulo-pollenites, Subtriporo-pollenites, Multiporo-pollenites, and Polyatrio-pollenites contain the Ostrya- and Corylus-, Betula-, Carya-, Juglans-, and Pterocarya-types, respectively. The remaining four genera of the group, however, are more complex.

Whether or not the taxonomic practices employed by Pflug and his associates are accepted, in the present writer's view the important observation to be made at this point is the obvious inadequacy of any current scheme of plant classification in the light of palynological evidence from the older deposits. Cretaceous and Early Tertiary paleobotanists using leaf impressions, on the other hand, do not appear to have experienced such difficulties.

In contrast with the sterile, stratigraphic-index approach employed by a number of European palynologists, Ross (1949) made a genuine effort to establish botanical relations in studying plant microfossils isolated from Senonian clays in southern Sweden. Both pollen grains and spores were found but only the latter could be identified with any certainty. The comparatively more rapid evolution among pollen-bearing plants, and the current poor state of knowledge concerning tropic and subtropic vegetation are possibilities submitted to explain the failure to associate the pollen with extant taxa.

Ross added the suffix "-idites" to names applied to sporomorphs bearing a resemblance to modern genera. Spores suggesting Lycopodium, Gleichenia, Aneimia, Cibotium, and Polypodium fell into this category.

The majority of the microfossils, however, including all pollen grains, were placed in morphological taxa with the assigned binomial enclosed in quotations to emphasize its tentative nature. Such a "working name" is to be kept until natural relations can be ascertained where possible.

Two obvious gymnosperm pollen grains are listed by Ross, and reference is made to a "sylvestris" type and a "haploxylon" type which previous authors have associated with Pinus. Monosulcate, triorate, tricolporate, and tricolpate angiosperm pollen grains are described.

Certain of the unknown pollen grains with angiospermous characteristics, particularly the tricolporate group which dominates all other types, are especially noteworthy. The perplexing "Dreieckspollen" of the German workers, mentioned previously as being a dominant floristic element in the Upper Cretaceous, and which also forms a significant part of the "older" Tertiary brown coal flora as well (Thomson, 1949; Thomson and Pflug, 1952) appears to be established in the clays investigated by Ross. One member of the striking tricolporate group, Tricolporites protrudens, has been discussed recently by Erdtman (1951) and reference is made to the discovery of allochthonous grains redeposited in Late Glacial sediments (Fries and Ross, 1950).

Another European palynological investigation was conducted by Hofmann (1948) in an attempt to establish the mode of formation of the flysch deposits on the outer margin of the Alps-Carpathian arc. Material regarded as Upper Cretaceous was collected in Muntigl near Salzburg, and pollen and spores as well as tissue remains were isolated and studied.

Pollen believed to be Rhizophora, Xylocarpus, Avicennia, and Pterocarya led Hofmann to the conclusion that the flysch was deposited in a mangrove swamp. Pinus of both haploxyton and silvestris types were identified by this investigator, along with spores referred to Lycopodium and Platycerium. Several characteristic forms, however, could not be identified. In the case of Rhizophora and Platycerium, the pollen identifications were substantiated in the mind of the author by epidermal remains present in the deposit.

In total aspect, Hofmann concludes that the predominance of certain pollen forms typically found in the Upper Cretaceous as noted earlier by Thiergart (1940) is confirmed by this investigation. However, the lack of precise morphological descriptions and the inadequacy of the illustrations make acceptance of the positive identifications accorded some of them extremely difficult.

An Upper Cretaceous deposit from Namaqualand, South Africa, was analyzed for pollen and spores by Kirchheimer (1932). Two gymnosperms appearing to belong to the Pinaceae were noted in addition to four different angiosperm types. The angiosperm pollen resembled that found in Betulaceae and Myricaceae, with the genera Corylus and Myrica mentioned specifically. However, the statement made by the author that exact botanical identification of the pollen was impossible implies a degree of uncertainty regarding these suggestions.

In Australia, Cookson (1953) has been able to follow the changing vegetation from the Jurassic through the Cretaceous to the Early Tertiary in a single bore at Comaun, South Australia. Pteridophyte spores

dominate the pre-Tertiary clays with pollen grains of podocarpaceous gymnosperms occurring in smaller numbers. In particular, the spores of Schizaeaceae (cf. Mohria and Lygodium) are characteristic and have no further range. Monosulcate grains similar to those in Cycadales and Ginkgoales were present but could not be differentiated with certainty. No angiosperm pollen was detected below the Tertiary-Cretaceous contact.

Similar results were obtained by the same investigator (Cookson, 1954) from analysis of a bore at Birregurra, Victoria, where, again, dicotyledonous types of uncertain affinities do not make an appearance until the Paleocene section is reached.

In a comprehensive stratigraphic study of the fossil pollen and spores from over a hundred localities in New Zealand, Couper (1953a) found the first angiosperm-type pollen in Lower Cretaceous beds. In the Upper Cretaceous, dicotyledonous pollen referable to Proteaceae and Fagaceae (cf. Nothofagus) and a liliaceous monocot were recognized among several tricolpate, tricolpate, polycolpate and monosulcate sporomorphs of questionable identity.

A number of fern genera, such as Gleichenia, Cyathea, Pteris, and Adiantum were identified by Couper from the Upper Cretaceous material as were the podocarps, Dacrydium and Phyllocladus. The discovery of the latter, along with members of the Proteaceae and Fagaceae in Southern Hemisphere localities is summarized by Couper (1953b) in relation to the restricted present distribution of the same floristic elements.

The recent monograph by van der Hammen (1954a) describing fossil pollen and spores from Colombia is the first major palynological report

from South America. Previously, Thiergart (1940) had listed Selaginella-like spores, a monolete spore similar to Sporites primarius R. Potonie, and fern spores belonging to either Schizaeaceae or Cyatheaceae from an Upper Cretaceous sample collected in the Rio Marahu valley in Brazil.

The stratigraphic range of van der Hammen's study extends from the Upper Cretaceous (Maestrichtian) to the Early Tertiary. In the lowermost Cretaceous samples, a number of angiosperm-type pollen grains are present but trilete spores dominate the microfossils. The aspect of the total flora at this point is described as somewhat primitive. In a middle zone, palmaceous pollen assumes a position of numerical dominance as a floristic change takes place that is ascribed by the author to climatic shift. As the Cretaceous is brought to a close, a final zone is recognized wherein many new species of dicotyledonous plants seem to make an appearance, with spore-bearing plants reduced, at the same time, to a minor role.

The Early Tertiary (Paleocene) in Colombia is marked by a reduction in the "primitive species" present in the Cretaceous. According to van der Hammen, the development of the modern and typically South American characteristics of the vegetation appears to have taken place some time after the Early Tertiary.

The system of classification presented by van der Hammen in this work is largely based on the definitions of morphological types of Iversen and Troels-Smith (1950), although there are certain unique and interesting features. In a separate publication, van der Hammen (1954b) has summarized his system and the nomenclatural procedure employed. While

essentially utilizing an artificial form classification for stratigraphic purposes, the author does refer occasionally to natural taxa bearing morphological resemblance to particular microfossils. There is a considered effort, as well, to relate stratigraphic findings to evolutionary development. However, in this connection, the apparent difficulty in associating the Mesozoic and Early Tertiary forms with definite modern taxa has restricted the author, in the main, to general observations.

More recently, Kuyl, Muller, and Waterbolk (1955), in an excellent summary of the application of palynological research to petroleum exploration, especially in Venezuela, have included scattered references to Cretaceous plant microfossils from Nigeria and Iraq as well as South America. Several unknown sporomorphs are illustrated along with Ephedra (strobilacea-type) positively identified from several Middle and Upper Cretaceous localities. Referring to the latter occurrences, these authors observe that winged coniferous types found elsewhere in the younger Mesozoic are entirely absent in such tropical regions as Venezuela, Colombia, and Nigeria, having been replaced at this time by the Chlamydospermae. Of interest also is the fossil pollen record of Podocarpus-type grains in Venezuela. First sporadic appearances occur in the Eocene but the type becomes strikingly abundant in Oligocene-Miocene sediments.

For the most part, the contribution to knowledge made by the few restricted palynological investigations of Cretaceous sediments in North America is rather insignificant when compared to developments elsewhere.

Arnold (1932) studied several kinds of Late Cretaceous microfossils macerated from material collected along the southeast coast of Nugsuak Peninsula and the eastern coast of Disko Island, in Greenland. Angiospermous and gymnospermous foliar fragments made up the bulk of plant remains, and, along with thallophytic and bryophytic vegetative structures formed the principal bases for the paleobotanical interpretations given. Two specimens only resembled pollen grains rather than cryptogamic spores, and, as a group, pollen was extremely rare. Beyond this observation, however, no further identification was attempted.

Arnold was able to distinguish filicinean and lycopodiaceous spores while other more diagnostic spores were believed to be related to Iscetes. Other megaspores, also from Upper Cretaceous coals of Greenland, and which appear to fall within the range of Triletes, have been described by Miner (1932, 1935). The second report by Miner includes, in addition, several pteridophyte spores from Cretaceous and Tertiary coals of Montana.

Schemel (1950) has described a spore-like form, Molaspora rugosa, as the most common among other plant microfossils isolated from the Upper Cretaceous Grall coal of Iowa. Doubt as to the true nature of the object is expressed by the author, however, and the generic name Sporites is consequently avoided. No further palynological evidence is reported.

Ideal palynological procedure, seldom possible to achieve, was performed by Andrews and Pearsall (1941) in a study of plant structures from the Upper Cretaceous Frontier formation in Wyoming. Spores of the genera, Aneimia and Microtaenia were isolated from detached fructifications

found associated with foliage previously described, as well as from others that had not become separated.

Plant microfossils from the Upper Cretaceous Brazeau formation in western Alberta, Canada, are the subject of a recent report by Radforth and Rouse (1954). In the most extensive study of such material yet attempted in North America, nearly a hundred distinct microfossils, representing all the major plant groups except the Algae, were discovered by these investigators. Thirty-four of the microfossils were chosen as most typical and important stratigraphically.

The classification of spores and pollen used by Radforth and Rouse follows the scheme developed by Raistrick and Simpson (1933). Where certain pollen grains and spores appeared similar to previously reported forms, this resemblance was noted. On the other hand, binomial designation of new types was avoided as neither appropriate nor expedient due to present inadequate knowledge of ranges. This approach is entirely commendable in the present author's view.

Several general considerations of the results obtained by Radforth and Rouse are worthy of statement. Statistically, the microfossils were dominated by pteridophyte spores and monosulcate cycadalean and ginkgoalean gymnosperm pollen. Outstanding were fern spores of the Laevigatosporites type, which has been related to the fern genera, Aspidium, Asplenium, Athyrium, and Thelypteris. Schizaeaceous fern spores, particularly Senftenbergia- and Mohria-types, while not abundant, were especially noteworthy. The coniferous pollen present showed pinaceous and podocarpaceous affinities.

Among the angiospermous pollen, subtriangular betulaceous and myricaceous types dominate. The predominance of similar pollen grains in the Middle and North European Cretaceous and Early Tertiary deposits has been established. Of considerable interest also is the presence of the family Juglandaceae, with the genus Carya definitely represented. Although the genera, Betula, Carpinus, and Corylus are suggested, certain morphological differences must be regarded as phylogenetically significant, at least. In contrast with a comparatively large number of dicotyledonous pollen types, only one sporomorph showed monocotyledonous affinity and it was represented by a single specimen.

Considerable importance may be attached to the recognition by these authors of a number of related types reported by Wilson and Webster (1946) and Wodehouse (1953) from the geographically related although stratigraphically higher Fort Union coal of Montana and the Green River oil shales. Furthermore, Radforth and Rouse, with few exceptions, found that neither the variety nor the generic composition of the fossil flora established for the area on megafossil evidence could be correlated directly. The possible geological as well as botanical significance of a more extensive exploitation of palynological techniques throughout this area is clearly indicated. An indication of increased palynological activity along these lines has been the recent report by Pierce (1957) of pine pollen from Cretaceous deposits in Minnesota.

Tertiary

It is beyond the scope of the present discourse to examine at length the wealth of literature available on pollen and spores from Tertiary deposits. Extensive bibliographic compilations may be consulted with profit in a series of collocations published by Erdtman in the pages of Geologiska Foreningens i Stockholm Forhandlingar since 1927.

Plant microfossils of Tertiary age have been known for over a hundred years. However, the potential importance of such pollen and spores as micropaleontological tools was not fully realized until after 1930. Since that time, the interest stimulated by the pioneer investigations of Robert Potonie and Kirchheimer in Germany has spread to many sections of the globe.

Ironically, the rapid expansion of Tertiary palynology in recent years has resulted in a concomitant increase in problems. These problems bear a close similarity to those encountered in the developmental history of other microfossil research, particularly that involving the Foraminifera.

Glaessner (1945, p. 5), in a retrospective analysis of the causes for the limited value of the accumulated results in foraminiferal research after a century of development, makes several observations that should strike a familiar ring among palynologists today. By way of illustrating the parallel, the following quotations from Glaessner's summary are submitted as being appropriate in reviewing Tertiary palynology as it has developed up to the present time.

The abundance of microfossils compared with other organic remains of the past necessitates well planned and organised (sic) work. This abundance brought forth a flood of micropalaeontological literature which in the course of time became more difficult to handle than the material itself.

. . . Even specialists experienced in the study of foraminifera, carrying out research work on the age of faunal assemblages and accepting current views on the delimitations of species, were often unable to distinguish correctly between major stratigraphic periods or between fossils of widely different age in mixed assemblages. The great majority of microfossils from oil-bearing areas had never been studied or described and were new to science. Descriptions of faunas from rock samples collected at random in other areas were plentiful but identification of species was not only made difficult by loose application of nomenclature, but proved to be little use, as the stratigraphic ranges of species had not been clearly established.

The difficulties encountered in the practical application of micropalaeontology had a twofold effect. In practical work the use of scientific names for species was often avoided and private systems of index numbers or letters were used instead, "type"-specimens being kept for reference in private collections. At the same time an intensive campaign of description and publication of microfaunal assemblages from important areas began

Micropalaeontology, stimulated by early successes in oilfield stratigraphy, was mainly concerned with finding "marker horizons" in oilfields. As long as these markers could be based on the presence of certain distinctive fossils in one part of the local or regional stratigraphic sequence and on their absence in another part, little significance was attached, even in research work, to the factors which had caused the limited ranges of these species, to their distribution outside the area under investigation, or to their nomenclature The extent of the areas of occurrence of local faunal sequences was a secondary consideration in the practical application of micropalaeontology, and as correlation was generally required only within the limits of a single oil-bearing structure or oilfield, regional correlation appeared mostly as a by-product of local work rather than as a result of independent research.

At the present writing, Tertiary palynology is fraught with nomenclatural problems and inhibited by attempts to legalize artificial, arbitrary, or "semi-natural" systems of classification. Rather complete summaries and criticisms of the various taxonomic methods employed by the principal workers in this field are given by Schopf (1949) and Traverse

(1955, 1956).

While this chaotic situation might be viewed with alarm, similar experiences in other areas of micropaleontological research, as noted previously, would seem to indicate that such problems are characteristic of a juvenile stage of development and quite normal. Nevertheless, by recognizing fruitless trends that have developed in the past, palynologists may be able to avoid the confusion that has blocked progress elsewhere.

A consideration of the taxonomic problems confronting palynologists concerned with pre-Quaternary material, and a discussion of the various approaches that have been made toward their solution is given in a later section.

Quaternary

No attempt will be made here to review plant microfossil studies within the province of Quaternary pollen analysis, or pollen statistics, to be more precise. Aside from an historical account of studies that first directed attention in this country to the utility of pollen and spores, including those of Sears, Cain, Potzger, Wilson, and Hansen, nothing would be added to the present discussion. Objectives, methods, and problems when dealing with more recent sediments are considerably different, in most cases, from those involved in palynological studies of older deposits.

Separatory Technique

It is necessary to separate the microfossils from the enclosing matrix to the extent that critical analysis of the individual pollen grain or spore can be made. The main problems in effecting the separation can be traced back to factors operative in the original sedimentary environment, and to the diagenetic changes that have occurred. Principally involved are the nature and extent of clastic sedimentation and the accumulation of bituminous end members in the deposit. Consequently, the techniques employed by palynologists are variously concerned with the removal of extraneous inorganic and organic matter, and the concentration of the microfossils for examination.

After extensive experimentation, a technique was adopted by the writer to cover the whole range of samples collected in the preliminary reconnaissance described earlier in this report. With the larger project in mind, it was felt that a standardized procedure requiring only slight variations would tend to minimize the distortion of results arising from the technique itself, and would lead to greater accuracy as different samples are compared.

The procedure found widely applicable for the lignite and lignitic clay samples collected by the writer actually combines several features adapted from techniques previously described by Assarson and Granlund (1924), Barghoorn and Bailey (1940), Erdtman (1943), Barghoorn (1948), and Wilson (1949), while the sequence of operations, in general, is similar to that followed by Traverse (1955). Purposes and details of the several treatments to which the Bruhn lignite was subjected are outlined below in

chronological order.

1. Disaggregation. About a cubic inch of material with fresh surfaces exposed on all sides is removed from the sample and broken up mechanically with the aid of a mortar and pestle. Since reducing the material to particles below 1 mm in diameter may result in crushing larger microfossils, excessive powdering should be avoided.

2. Demineralization. A. Siliceous matter is broken down by a hydrofluoric acid (ca. 50 per cent) treatment lasting 4-5 days, carried out in a hood using a 500 ml polyethylene container. Frequent stirring and renewal of the acid is necessary. Transfer to a Pyrex beaker follows the several changes of distilled water and decantations needed to elutriate as much of the acid as possible.

B. Hydrochloric acid (10 per cent) is added to dissolve calcium carbonate, and heating the suspension without boiling removes colloidal SiO_2 and silicofluorides. Decanting and washing with distilled water completes this stage of the treatment.

3. Deflocculation. Maceration in potassium hydroxide (10 per cent) for a period of 48 hours with frequent stirring removes humic acids to some degree but, more importantly, flocculating substances are dissolved in order to prepare the sample for the subsequent treatments. The material is then transferred to Pyrex glass centrifuge tubes and washed three times with distilled water, separating the solids (which are saved) each time by centrifugation.³

³Centrifugation during this stage and those following was carried out in an International Clinical table model centrifuge set at top speed for two minutes approximately.

4. Delignification. Lignin is removed and humic acids and cellulosic substances are bleached through an oxidation process using acidified sodium chlorite (10 per cent aqueous solution). After adding the sodium chlorite solution to the sample, the reaction is begun by adding a few drops of slightly dilute HCl, the speed of the reaction depending upon the degree of acidity. Corrosive chlorine dioxide is evolved so that this treatment must be carried on in a hood. A yellow to gray residue denotes success of this treatment. Three washings with distilled water, centrifuging between each wash, complete this stage.

5. Dehydration. The removal of water is necessary to prepare the sample for subsequent treatment. This is accomplished by dehydrating the sample with two changes of glacial acetic acid, and centrifuging each time.

6. Acetylation. The residue is acetylated by a chemical treatment, commonly referred to as acetolysis but more properly called acetylation, which is designed to remove cellulose and related compounds. An acetylation mixture consisting of one part concentrated sulphuric acid added to nine parts acetic anhydride is prepared slowly and carefully beforehand. The material in each centrifuge tube is covered adequately with the acetylation mixture, and the tubes are placed in a water bath with stirring rods of proper length inserted. While stirring the tubes regularly, the water bath is brought to a boil, then allowed to cool. Since the fumes are particularly vicious, the acetylation treatment is carried out under a hood. After centrifuging, the fuming supernatant fluid is decanted into running water, otherwise the reaction is violently explosive. Three washings with

distilled water along with centrifuging follow this step.

7. Concentration and storage. Cellulosic substances are further removed and greater concentration of pollen and spores is achieved by adding Cellosolve (Ethylene-glycol-monoethyl-ether) to the sample and centrifuging. Cellosolve is also an efficient storage medium after the sample has been transferred to stoppered vials. Permanent slides can be made by placing a drop of the material on a slide, allowing the drop to evaporate, and mixing in a drop of Diaphane without any prior treatment.

If staining is desired, it can be inserted in the procedure following the acetylation treatment and after thorough washing with distilled water. However, the writer found that the technique described above provided the sporomorphs with adequate and highly satisfactory optical properties without staining.

Although the reagents used are powerful and certain reactions are violent, they will not affect the majority of pollen grains and spores due to the chemical nature of the sporoderm, a fact that constantly amazes the observer. On the other hand, this technique in the hands of a careless or inexperienced operator could be extremely dangerous to himself or others.

It is further recommended that covered receptacles be used throughout and all steps be carried out with dispatch in order to avoid contamination, the bane of all palynologists. Furthermore, the palynologist, no less than the bacteriologist, must maintain laboratory cleanliness at all times.

Comparison of Results

1. Reference Collection

As Wodehouse (1933, pp. 480-481) has stated,

In the last analysis, the identification of fossil pollen must always be based upon comparison with living species, or with previously recorded fossil forms, as is the identification of leaves, stems, seeds, and various other parts of plants.

Furthermore, he continues,

. . . the fossil-pollen botanist must build up and interpret his own reference collections to meet his needs as the work of identification progresses, and the degree of reliability of his identifications will depend largely upon the extent of his collections and his understanding of them.

There are various manuals illustrating and describing pollen and spores, notably by Meinke (1927), Zander (1935, 1937), Wodehouse (1935), Bertsch (1942), Erdtman (1943, 1952) and Jonas (1952), which render valuable assistance to the fossil palynologist, in some degree or other. However, even the best of these publications are inadequate either in scope or in detail, and their use for the purpose of identifying unknown forms, not to mention living pollen and spores in many instances, is highly questionable to say the least. Only the study of reference slides of extant pollen and spores can provide the investigator with the necessary background to recognize the salient features of fossil forms, which, in turn, serve as a sound basis for making comparisons and accurate botanical identifications.

In the actual organization of a reference collection, the palynologist is faced with several difficulties. According to the estimate of Merrill (1943), more than one third of a million species of plants are

now known. Of this vast number, more than two thirds are vascular plants, any species of which, potentially, might contribute significantly to the pollen and spore rain that continually falls from the atmosphere. A reference collection of this magnitude is quite obviously outside the realm of practicality and beyond the limits of human cognition. Hence, the design of the reference collection involves judicious selection on the part of the palynologist, and is directly related, in a large measure, to the aims of his investigation.

The fossil palynologist, in erecting a reference collection in order to seek affinities for the microfossils under investigation, is confronted with the additional problems of discontinuity that are inherent in any reconstruction of Earth history. It is apparent that both physical and organic changes have introduced complications that place a limitation on the success with which a comparison with the present can be made, the oft-repeated Huttonian precept notwithstanding.

On the basis of evidence from many sources it is clear that floristic distribution has been altered consistently throughout geologic time in response to geomorphologic changes. Consequently, a reference collection embracing species in the present flora cannot be delimited by discrete geographical boundaries. Moreover, through the impress of plant evolution, the relationship between elements in the modern flora and those comprising the floras of the past becomes progressively more obscure with advancing geologic age.

There are other limitations connected with basic problems in plant taxonomy that present obstacles perhaps greater than those cited above.

These restrictions stem from the inadequacy of knowledge concerning modern plants in general. First of all, a vast segment of the present flora, particularly in the tropical and subtropical regions of both hemispheres, is yet little known.

Secondly, the inconsistency of pollen types within discrete taxonomic units established by systematists on the basis of variable criteria makes the task of sampling the known flora for comparative purposes extremely difficult. While it is true that certain taxa are characterized by specific pollen or spore types, the same cannot be said for the majority. This fact, to which even the tyro will attest, makes assembling an adequate reference collection difficult at best. Some degree of uncertainty always attends the use of the reference collection that might be compiled by the individual palynologist.

It is to be hoped that assistance will be forthcoming from within the area of plant taxonomy itself. In the past it has often been the custom to dismiss pollen and spore morphology entirely even in the more exhaustive plant monographs, although welcome exceptions were noted in an earlier section. Pollen and spore diagnoses included in the description of taxa would lighten the burden of the palynologist immensely, and, in the opinion of the writer, would prove to be a valuable aid in plant systematics heretofore utilized only to a limited degree.

In order to carry out objectives of the present investigation, discussed at length heretofore, the reference collection used as a basis for comparing the fossil spores and pollen isolated from the Bruhn lignite was organized specifically in accordance with the paleobotanical

relationships of the floristic evidence present in the deposit. The published reports of the megafossil floras, particularly the Ripley Flora, established for the immediate area of the deposit were consulted and generic lists compiled.

Where extant material was available, reference slides were made using a technique designed to reduce the discrepancies between living and fossil forms through fossilization and reaction to the chemical treatment involved in the preparation of the slides. This technique, outlined by Traverse (1955, pp. 97-99), is primarily the acetylation treatment described earlier. Previously dried material requires little initial preparation other than removal of extraneous matter. Freshly cut parts, however, should be placed in glacial acetic acid to remove moisture prior to acetylation.

Pollen grains of certain families, e.g., Cannaceae, Juncaceae, Lauraceae, Marantaceae, Musaceae, and Zingiberaceae, do not respond favorably to acetylation and must be treated by an alternative method (cf. Erdtman, 1943, pp. 30-31). Other pollen grains may become too dark through acetylation but may be recovered by bleaching with sodium chlorite activated with a few drops of HCl for as long as deemed necessary.

The reference collection of the writer contains twelve hundred and forty-one species of vascular plants distributed among major groups as follows:

	<u>Numbers of Taxa Represented</u>		
	<u>Families*</u>	<u>Genera</u>	<u>Species</u>
Lycopsida, Sphenopsida, & Psilopsida....	3(5).....	3.....	16
Pteropsida			
Filicineae.....	8(12).....	24.....	36
Gymnospermae.....	9(10).....	40.....	122
Angiospermae			
Monocotyledoneae.....	25(35).....	60.....	72
Dicotyledoneae.....	141(240).....	645.....	995

*For numerical comparison with the writer's collection, the figure in parentheses indicates the number of families listed by Gundersen (1950) for the Dicotyledoneae, and by Lawrence (1951) for the balance of the Tracheophyta.

Several hundred additional slides in the collection at the Harvard Biological Laboratories were studied by the writer through the courtesy of Dr. Elso Barghoorn during the academic year 1955-1956.

2. Literature

Supplementing the information derived from the comparison of living and fossil material directly, a considerable number of publications reporting on fossil pollen and spores from Cretaceous and Tertiary deposits were reviewed by the writer. These papers, many of which were discussed in a previous section, enabled the writer to make further comparisons, and to obtain a general comprehension of results from investigations of a similar nature.

Unfortunately, the presentation of such results is extremely variable and, in many instances, the stated evidence is far from convincing. Moreover, insofar as the comparison of results is concerned, the dearth of palynological intelligence in this country presents an additional handicap. However, it is to be hoped that this situation will be

rectified as interest in plant microfossils from the older deposits increases. The recent monograph on the pollen and spores from the Brandon lignite by Traverse (1955) has been a tremendous step forward, both in the advancement of palynology in this country and in the delineation of results.

SYSTEMATIC DESCRIPTION

Systematic Methods

It is generally agreed that (a) some sort of nomenclatural system is necessary for plant microfossils as a means for reference, for systematization of results, and for communication, and (b) that no systematic procedure should be in conflict with existing rules. Disagreements among workers have arisen over personal philosophies concerning the form such a system should take and the extent to which the system can or should be applied.

The underlying cause of the whole conflict of ideas is nothing new. The bane of paleobotanists from the time of initial discoveries of plant fossils to the present is the problem of the detached plant part. In the past, fossil systematists have incorporated specimens into a previously established system embracing reconstructed fossil plants or, unable to do this, have erected form or organ genera against the time that additional knowledge might permit a conception of the entire plant. In most instances, there has been an effort to relate this material to taxa established for the Recent flora at some level or another. The matter of judgment involved in any of these dispositions introduces a highly subjective element.

Obviously, the approach used by the paleobotanist will depend to a large extent on the relative age of the deposit, and the hierarchy of plants represented. For example, many well-established paleobotanical

procedures have been developed around the more widely studied Paleozoic fossils, which, in the vast majority, represent extinct taxa below the class level if placed in a single system with modern representatives.

In many respects, problems in Paleozoic plant taxonomy have not been as perplexing as those encountered in dealing with the subsequent Mesozoic and Cenozoic, despite the increasing modernization of floras. The prospect of reassembling detached parts, especially from the autochthonous plant-bearing deposits of the Carboniferous, has had the effect of stabilizing much Paleozoic taxonomy, and the same can be said for the use of large taxonomic units that have been extinct for millions of years.

Concerning Paleozoic plant fossils particularly, it should be pointed out that, down through the years, it has been the firm conviction of most paleobotanists that isolated parts should be treated taxonomically as separate entities until organic connection could be established. Several examples could be cited to illustrate the wisdom of this course of action, if the developmental history of paleobotany be reviewed a posteriori.

In the main, similar conservatism has been the guiding principle employed by investigators of Mesozoic plant fossils. However, as angiospermous types became more numerous in the later deposits of that era, they came to the attention of workers whose primary object was stratigraphic correlation rather than an increase in knowledge concerning the developmental history of plants. These workers were impressed by the rather sudden emergence of leaf types comparable to those found in the modern flora, particularly among the Dicotyledonae. As Arnold (1950)

has remarked, much of this fossil evidence was fragmentary, and interpreted in the absence of adequate botanical training by some, and with a narrowly restricted familiarity with modern plants at best.

It must be remembered, as well, that stratigraphers of this period were under the influence of the catastrophic hypothesis that has dominated geologic thinking until relatively recent times. The requirement that universal and periodic biologic changes match periods of diastrophism led to the confusion of time units with rock units. This indiscriminate mingling of geologic concepts continues to crop out in the literature, particularly among neontologists. Many stratigraphers and paleontologists, e.g., Schenck and Muller (1941), Hedberg (1948), and Gilluly (1949), have recognized the need for re-examination and re-evaluation of the doctrine of episodic diastrophism and evolution. Failure to recognize the lateral variation in the biologic aspect of a stratigraphic unit (the biofacies, as defined by Krumbein and Sloss (1951, pp. 231, 268) has led undoubtedly to other false conclusions.

The voluminous literature resulting from the extensive collections and descriptions of the leaf impressions discovered in the Late Mesozoic deposits, and in the overlying Tertiary beds as well, has contributed very little toward an understanding of angiospermic evolution. Rather, it has added to the "abominable mystery" early noted by Darwin. Struck by the resemblance to modern leaf types, these investigators, in contrast to the caution exercised by the majority of paleobotanists, were quick to place the detached leaf organs into recognized taxa within the modern flora, especially on the generic level. Whether this procedure was justified in

view of the fact that the angiosperms as they are known today had another 50,000,000 years to evolve remains a moot question. Without doubt, many misconceptions have arisen from these widely quoted results. Furthermore, the identifications made by these workers are largely unsupported by supplementary evidence that, in many instances, might have been sought.

As to the question of evolution, particularly among the dicotyledons, it would appear that the underlying assumption that the foliar organs of plants have been so conservative as to permit such early identification requires further proof. While it has been established by Bailey and Howard (1941) that rates of development in the various parts and organs of a plant may differ in contrast with the evolution of other regions in the same plant or group of plants, the identity of a fossil leaf with a ~~taxon~~ taxon that represents the net result of evolution in the entire plant is highly questionable. Not only must the single organ have remained static but the remainder of the plant along with it.

As Simpson (1943, 1945) has keenly observed, the classification of paleontologic objects is a classification of inferences. The characters displayed by the specimens on hand support the basic inference as to the nature of the morphological group from which the sample was taken. Evaluation of these characters at the same time is made in the hope that the inferred morphologic group will approximate a genetic group. The "taxonomic entity" actually classified is an inference, a purely subjective concept, approximating a real, but unobservable morphological unit. The latter, in turn, approximates an equally real but even less observable genetic unit.

Throughout neontologic systematics runs an undercurrent of disagreements on matters of definition stemming from the same source of difficulty plaguing the paleontologist. Despite the fact that genetics, cytology, anatomy, phytogeography, physiology, and ecology have made extensive contributions, external morphological comparisons continue to be the primary bases for classification. The net result has been the maintenance of systems embracing the modern flora that are no more natural than the paleontologist has been able to erect with far greater circumscription.

Attempts to introduce specialized data derived from outside the scope of strictly morphological studies into such systems for purposes of correlation have resulted in frustration in many instances. Although the more perspicacious investigators in other fields [e.g., Bailey (1951), and Metcalf and Chalk (1950), in anatomy] have recognized the limitations in basing classification solely on their respective evidence, taxonomists, in general, minimizing the same limitations of morphological characters, have chosen rather to treat conflicting data with mistrust or to ignore it. The result has been the development of increasingly divergent courses of study leading to the overspecialization that characterizes natural sciences today. Around the margin of a given problem, bodies of data arise but move farther apart from each other and the central objective as the periphery is distended by continued specialization.

Already severely limited, the paleontologist is expected to place his discoveries into a system of "modern" classification based on a heterogeneous assortment of criteria, many of which are untenable. Even

the basic units, the genus and the species, defy definition.

In an attempt to include forms based on a minimum of taxonomic evidence, and to seek a common class of criteria to group all forms not otherwise comparable, morphological taxonomy has produced a firmly entrenched system that does lip service only to matters of evolution and phylogeny. Lawrence (1951, p. 5) typifies this myopia when he defines phylogeny as the classification of taxa.

Until it is recognized that a taxon is a spatial and temporal delimitation of phyletic lines, and as such must be established through the correct recognition and grouping of these lines according to natural affinities, one must question the utility of modern systems of classification available to the paleontologist, convenient though they may be in cataloguing the biota of the present. In an excellent review of the taxonomic dilemma, Cain (1956) points out that use of the same criteria and the establishment of discrete units in space and time, as applied in current taxonomy, are relicts of Aristotelian logic and Linnaean systematics past which we have progressed little. Lam (1951) has discussed the same problems from the standpoint of paleobotany and concludes that even the use of the term, "angiosperm," is not without reservation.

Viewing current plant taxonomy in particular, the task confronting the palynologist is to relate a single organ, primarily discriminated on the basis of morphological characters, to a taxonomic system that is, at best, only superficially natural. Two major attempts to do this by Wodehouse (1935) and Erdtman (1952) have fallen short of expectations. Taxa displaying a great array of morphological types (eurypalynous) are

far more frequent than those exhibiting reasonably similar pollen morphology (stenopalynous). It seems especially significant, however, that among the latter are taxa considered to be most natural on other grounds.

If the foregoing is a correct appraisal of the present situation in neontology, consider the dilemma of the fossil palynologist. He must take isolated, single organs and seek affinities in the modern flora, the taxonomic arrangement of which is based on suspect criteria in many cases. Above all, the modern taxa to which relationships are sought have been formulated in many instances on the combined characters of several organs.

The varying degrees of success rewarding palynologists' endeavors along the lines just mentioned have resulted in a veritable hodge-podge of proposals as to how the fossil sporomorphs should be treated taxonomically. In Table I is an annotated summary of systems proposed or in current usage. Listed also are two objective and somewhat synonomous systems that must represent, in the writer's view, the ultimate objectives of any classification of fossil pollen and spores, otherwise the current chaotic state of fossil palynology will persist. Only Wodehouse (1928, 1936) and Pflug (1953) have made any overtures toward phylogenetic analysis of pollen and spores.

The systems listed or combinations of them that are to be found in palynological literature up to the present time fall into three main categories. These range from the strictly and admittedly practical to the strictly and purposefully botanical. At fluctuating intermediate positions between the two extremes are hybrid combinations that attempt to be both practical and botanical. The whole lot, in the opinion of the writer, is

TABLE I

CLASSIFICATION OF PALEOPHYTOLOGICAL SYSTEMS

A. SUBJECTIVE

Geological
 ↑
 Transitional
 ↓
 Botanical

1. Stratigraphic

Forms are related to geologic horizons and their associated lithologies. Correlation is the main objective and botanical affinities or relationships are not sought primarily. Hence, systems employing letters and/or numerals serve as well as latinized binomials that are simply pseudoscientific window-dressing.

2. Organic

With few exceptions, detached roots, stems, leaves, seeds, pollen and spores constitute the material to be classified. The trend has been one of elaboration beyond the Pollenites, Sporites, Phyllites, etc., stage of classification, although these terms or variations of them have been retained as suffixes in some cases. Taxonomy is based on morphological characters, the more pronounced of which are alluded to in the name assigned.

3. Morphogenetic

Morphological features, considered to be of sufficient magnitude to imply genetic basis, are treated in an evolutionary manner out of context or otherwise separated from the plant or plant organ with which they are connected.

4. Semi-Neontologic

Similarity to extant species, genera, or a higher category is implied by adding a suffix to root of modern name. In certain instances, the author has insisted that this implication does not mean identity or even true relationship, while in other cases, no such warning is given.

5. Neontologic

Fossil material is placed in Recent taxa at some categorical level without change in name. Varying degrees of confidence are shown by presence or absence of question marks.

B. OBJECTIVE

1. Phylogenetic

The ultimate aim of classification is to reflect phylogeny, to establish the degree of relationship not similarity, although the latter may be caused by the former. Taxonomic characters must be differentiated as to homologies and analogies. Since evolution in time and space is involved, paleontology and comparative morphology provide the logical bases for such a system.

TABLE I

CLASSIFICATION OF PALEOPHYTOLOGICAL SYSTEMS
(CONCLUDED)2. Biostratigraphic

The ultimate basis for correlation must be a phylogenetic system combined with information supplied by the various geological disciplines that constitute stratigraphy. Ideally, an orderly sequence of time-rock units will emerge with lateral facies changes ascertained through the application of paleoecological techniques.

steeped in artificiality to greater or lesser degree, whether it is admitted, implied, or unconsciously rendered by the proponent.

In the main, the differences of opinion among palynological systematists, concerning the use of one system or another, center around the degree to which such a system is acceptable or applicable rather than the validity of the system itself, except in matters where established taxonomic procedure has been circumvented. Consequently, the group of "hybrid" or transitional systems noted in Table I have arisen largely through compromise, and differ only in the degree of deviation from the purely artificial on the one hand and an approximation of a "natural" system on the other.

In the writer's opinion, the question of the degree of artificiality or the degree of naturalness represents a moot point that may forever remain elusive. However, certain current arguments relating to such matters require comment.

First of all, disputes have arisen over the geological horizon beyond which organ genera are justified, assuming that, at such a point in time, connections with modern taxa become so obscure that assignment to a particular one of them cannot be made. Depending on the range of experience of the author involved, different horizons have been selected in the Tertiary and beyond. To the present author, such an approach is wholly unimaginative, if not fundamentally erroneous.

In the first place, the modern flora, separated as it is into various categories, based on arbitrarily selected characters, exists only because the human species has felt obliged to catalogue it as such. The

taxa making up this flora did not evolve against the backdrop of time but rather the characters that constitute them by definition. Consequently, to select a point in time at which a taxonomic category came into being cannot miss being entirely speculative, particularly if the evidence is derived from a single organ such as a leaf or a pollen grain.

It must be admitted, however, that the inability to relate characters displayed by fossil material to homologues in the modern flora may result from lack of familiarity with the latter rather than the evolutionary disjunction obscuring the former. The end result would be the same, the cause entirely different. On the one hand, the extent of the reference collection for comparative purposes is the limiting factor while on the other, time and evolution are involved.

Other points of controversy stem from the dual responsibility of the fossil palynologist that is related to the hybrid nature of his interests. He must provide botanists with information that can be applied to problems of taxonomy, evolution, and phylogeny. At the same time, he possesses a micropaleontological tool that may assist geologists in problems of stratigraphy. In several cases, it is quite obvious that palynologists consciously or unconsciously have emphasized one aspect of this dual role at the expense of the other. As has been pointed out previously, it is vital to the development of both that they be complementary. Nevertheless, such unilateral development has resulted in the two extremes shown in Table I.

No one can object to the erection of artificial systems for private use whether they are composed of numbers, letters, organ genera, or some

combination of these. It must be recognized, however, that the utility of such systems in matters of stratigraphy are obviously limited. But legalization of such names, which are in effect no more than laboratory "nick-names" applicable within a restricted area must certainly be opposed or treated provisionally. Otherwise, the real objectives of fossil palynology will be lost in a nomenclatural tangle beyond all recognition.

At the same time, the promiscuous application of modern taxonomic names without some method of qualification is equally inhibitive to the development of botanical science. It is quite possible that the over-zealousness of some investigators to create a "natural" system has led to the use of modern names or modifications of them without justification. The probability of confusing genetic identity with morphological similarity is made abundantly clear by even a cursory examination of the pollen and spores of modern taxa. In this connection, it should be pointed out that a precedent for indulging in such practices that has been established in other phases of paleobotany does not justify application in palynology. As a matter of fact, it might well serve as a warning.

In general, it must be concluded that no present system of classification and nomenclature proposed for fossil pollen and spores beyond the Quaternary is completely adequate. In a large measure, this is due, principally, to the immaturity of fossil palynology itself. The adoption of a formalized system before sufficient collections are made, and before problems of nomenclature at the "alpha" level are solved, is premature. Nor could proposals based on a greater understanding of geological and geographical ranges of plant microfossils in one area be expected to gain

support in another region where the study of such materials has hardly begun, as for example, in this country.

In the present work, the writer has followed the general descriptive practices employed by most palynologists but has refrained from introducing any precise system of nomenclature and classification for the time being. Until the stratigraphical ranges of the Bruhn microfossils are better understood through intensive sampling over a larger area than embraced by the present report, nothing would be gained by using a system that would be temporary and highly artificial at best.

To the extent that the reference collection and other means of comparison assembled by the writer have permitted, suggestions as to botanical relationships at the lower taxonomic level are incorporated in the descriptive analyses of the microfossils that follow in the next section.

Sporomorphs From the Bruhn Lignite

1. Terminology

Descriptive terminology applicable to the various features of sporederm morphology has become somewhat unmanageable, largely through the attempts of certain investigators to introduce terms unnecessarily, or to emphasize minor variations that have no general utility. One can agree with Traverse (1955) that a standardization of terms would be desirable, and with Erdtman (1943) that a less elaborate terminology not based on special techniques is more reasonable.

Terminology used to describe pollen and spores is to be found in Potonié (1934), Wodehouse (1935), Erdtman (1943, 1952a, 1952b), Iversen and Troels-Smith (1950), Faegri and Iversen (1950), and Traverse (1955). The last three publications have been followed principally in the descriptive phase of the present work, although general features represent a compilation from the several sources noted above. Most of these features are illustrated in the literature and of particular merit are the drawings of Christensen in Iversen and Troels-Smith (1950) and Faegri and Iversen (1950). An excellent summary of terminology is given by Kuyl, Muller, and Walterbolk (1955).

Origin of Basic Form. A most consistent phenomena in the ontogeny of sexually reproduced plants is the formation of pollen and spores in tetrad groups following successive or simultaneous divisions of the sporocyte. The geometric arrangement of the tetrad members in contact determines the basic form and symmetry of the individual, and is responsible for fundamental and often conspicuous characters that relate the higher categories of plants and hence have phylogenetic significance.

According to Wodehouse (1935), who has approached the form of the pollen grain and spore both mathematically and phylogenetically, the fundamental features are governed by cellular inter-relationships in the tetrad that are determined by the assumption of specific geometric configurations incident to reduction division. This has resulted in isotachynic (equilateral) stresses being directed toward faces of contact that activate a basic tendency or capacity to respond to stimuli. Characteristic features are thus produced, which, in turn, control the developmental pattern of still others.

Boundaries of faces of contact may be involved in this response, as in the case of the scars found in certain pteridophytes, primitive gymnosperms and angiosperms, or the point of contact may be directly or indirectly responsible for the more advanced apertures (openings or thinner areas on the surface) found on the sporoderm. These are elongate, somewhat elliptical furrows (colpi, sulci), and isodiametric pores, which serve as germinal passageways as well as mechanisms to accommodate changes in volume, which Wodehouse has termed harmomegathi. The last named function appears to have phylogenetic precedence (Wodehouse, 1936). However, as Wodehouse (1935) points out clearly, while the form and characteristic position of the furrows and pores are hereditary and phyletic, alterations in the basic number and arrangement may be brought about through some modification of internal environmental conditions at the time of tetrad formation.

Orientation. For descriptive purposes, it is customary to refer to the orientation of the individual pollen grain or spore with respect to position in the original tetrad. Consequently, each pollen grain or spore possesses a polar axis directed toward the center of the tetrad. This axis passes from a distal (outer) pole through a proximal (inner) pole being intersected perpendicularly at the midpoint by an equatorial plane.

Surface features can be located, then, in relation to polar hemispheres and an equator, and referred to longitudinal (vertical) meridians parallel to the polar axis and latitudinal (transverse) areas parallel to the equatorial plane. However, with few exceptions, such as single-furrowed

pollen grains, and spores with scars or fissures, the distinction between polar areas is not possible after the members of the tetrad have been separated. There are, of course, some instances in which tetrad separation does not normally take place, a notable example being the family Ericaceae.

The shape of pollen grains and spores as viewed from a polar position is quite distinct from that seen in the plane of the equator (equatorial view). In reference to the latter, geometric terminology can be applied to radially symmetrical pollen and spores, e.g., spherical, prolate spheroidal, subprolate, prolate, and perprolate. In the case of bilaterally symmetrical types, similar configurations, but with the polar axis the minor one, are called spherical, oblate spheroidal, suboblate oblate, and peroblate. Limits for these shape classes, based on the ratio of the equatorial diameter to the length of the polar axis, follow those proposed by Erdtman (1953, p. 45) where used in this report.

The polar outline (amb) of pollen grains or spores may be circular, angular, lobate, etc., and descriptions from this view usually include reference to the position of equatorial apertures (e.g., angulaperturate, planaperturate, semi-aperturate, fossaperturate, indicating apertures at the angles, midpoints on straight sides, midpoints on concave sides, and at indentations between lobes, respectively). Other types may be completely irregular without a definite shape, or the body of the grain may be masked by bladder-like extensions of the exine, a condition termed vesiculate.

In the case of bilaterally symmetrical pollen and spores, the equatorial axis is the major axis and a variation of a curved ellipse is the usual shape seen in polar (longitudinal, transverse) view. More

prosaic terms (e.g., boat-shaped) are often applied to such pollen and spores, and the description of the apical outline is sometimes included.

Symmetry, Type, Number, and Position of Apertures. With few exceptions, the number and arrangement of the apertural features, determined to a large extent by the position of individuals in the tetrad, serve to organize pollen grains and spores into two major symmetry groups and a number of apertural classes as follows:

- I. Bilaterally symmetrical: These result from successive nuclear divisions and bi-partitioning of the sporocyte in a single plane with a consequent tetragonal or rhomboidal arrangement. The polar axis is the minor axis. A single aperture or none (inaperturate, alete) is present.

- A. Aperture distal (pollen):

1. Monosulcate - with a single furrow (sulcus).
2. Monoporate - with a single pore.

- B. Aperture proximal (spores):

1. Monolete - with a single longitudinal fissure (laesura).

- II. Radially symmetrical (radiosymmetrical): These result from almost simultaneous nuclear divisions at right angles with a consequent tetrahedral arrangement. The polar axis is the major axis. Three (rarely two) or more apertures or scars are present.

- A. Furrows or spores, or combinations (pollen):

1. Furrows and pores free (not combined).

- a. Furrows free.

- (1) Furrow or furrows on meridians:

- (a) Monocolpate - one furrow (colpus) present in this position.
- (b) Dicolpate - two furrows present.
- (c) Tricolpate - three furrows present.
- (d) Stephanocolpate - more than three furrows present.

(2) Furrows not all on meridians:

- (a) Pericolpate - furrows distributed over whole surface (global).

b. Pores free.

(1) Pores on equatorial area:

- (a) Diporate - two pores present in this position.
- (b) Triporate - three pores present.
- (c) Stephanoporate - more than three pores present.

(2) Pores outside equatorial area:

- (a) Periporate - pores distributed over whole surface (global).
- (b) Extraporate - pores located outside furrows (pseudocolpi).

2. Furrows with pores or transverse furrows (ora) in composite structures at the equator.

a. Combinations on meridians:

- (1) Tricolpate - three combinations present.
- (2) Tetracolporate - four combinations present.
- (3) Stephanocolporate - more than four combinations present.

b. Combinations not on meridians:

- (1) Pericolporate - combinations distributed over whole surface (global).

c. Variable combinations:

- (1) Heterocolpate - Combinations of furrows (pseudocolpi) with pores distributed along with furrows (pseudo-colpi) without pores.

3. Furrows fused to spirals, rings, etc.:

- a. Syncolpate (Spiraperturate) - two or more furrows combined into rings or spirals surrounding the whole or parts of grain, anastomosing at the poles.

B. Triradiate crest or scar (spores especially but not exclusively):

1. Trilete - three radially directed fissures (laesurae) flanked by parallel crests meeting at the proximal pole and marking the boundaries of contact areas in the tetrad. Found also among fossil gymnosperm and pteridosperm pollen grains, and, in rare instances, among angiosperms.

Stratification, Structure, and Sculpture of the Sporoderm. Excluding the membrane of the living cell (which bounds the pollen tube in the case of pollen), the majority of pollen grains and spores have two wall (sporoderm) layers, an outer exine (exosporium), and an inner intine (endosporium). The intine and subdivisions need not be considered further here for they are not found in the fossil state, or after the "fossilizing" conditions created by the previously described technique have been introduced.

Typically, the exine consists of two layers, an outer ektexine, and an inner endexine. The endexine is a continuous, homogeneous layer upon which the various structural and sculptural patterns making up the ektexine are constructed by the external deposition of great diagnostic value within the larger categories of plants. The more important terms used to describe these features are listed below.

I. Structural and sculptural terminology.

A. Surface without radial elements (granula).

1. Psilate - surface more or less smooth.
2. Foveolate (scrobiculate) - surface pitted.
3. Fossulate - surface grooved.

B. Ektexine composed of small radial elements.

1. Intectate - elements not forming a membrane (tectum)

outside the endexine.

a. Elements more or less free and isolated consisting of the following discernible morphologic types:

- (1) Small protuberances less than 1 micron in any dimension - scabrate.
- (2) Small rounded protuberances greater than 1 micron and constricted at the base - gemmate.
- (3) Larger protuberances greater than 1 micron and rounded at the top - verrucate.
- (4) Elements in the form of rods the same diameter throughout - baculate.
- (5) Club-shaped rods with rounded ends constricted below the top - clavate.
- (6) Elements pointed, spine-like - echinate.

Note: A mixture of the morphologic types above may be described as polymorphic. The term granulate can be used where the morphology of the elements is obscure.

b. Elements fused laterally to form ridges with or without a sculpture pattern clearly developed.

(1) Sculpture pattern definitely established:

- (a) Reticulate - reticulum or network composed of walls (muri) and openings (lumina) formed, the breadth of the muri more or less equal to the diameter of the lumina.
- (b) Lophate - large, regularly spaced openings (lacunae) are enclosed by high anastomosing ridges, often bearing spines.

(2) Sculpture irregular, consisting mainly of laterally disposed bands:

- (a) Rugulate - unevenly distributed bands, not consistently parallel.
- (b) Striate - bands more or less parallel with grooves between.

2. Tectate - elements forming an outer membrane (tectum) derived from lateral fusion of intectate types, at the tips or at the tips and bases of granula.

a. Spaces visible in optical section beneath solid or nearly solid tectum:

- (1) Columellate - small columns appear to bear tectum at their tips, the columns, in some cases, forming patterns such as reticula.
- (2) Perforate - small columns bear tectum perforated by holes.

b. Tectum broken up by a number of large, symmetrically arranged openings (lacunae, pseudopores):

- (1) Fenestrate - a special, highly developed type derived from a complete tectum.

Note: Tectum may bear elements on the surface of the morphological types listed under the intectate ektexine. It is necessary to distinguish between the sculpture pattern, i.e., the external geometric features viewed at high focus, and the structural composition, i.e., the arrangement of radial elements, since the latter may be distributed differently beneath a tectum and thus can be observed only at lower focus.

II. Special features.

A zone (margo) bordering a furrow, or a rim (annulus) surrounding a pore may be distinguished from the rest of the surface by differences in thickness and sculpture of the ektexine. Furrow or pore membranes may be differentiated similarly if present. A membrane of this type may be modified into an operculum.

Thickened edges of internal furrows or pores in the endexine are called costae. Endexinous bands (arci) are occasionally found extending between pore areas.

A cavity (vestibulum) directly beneath the external pore opening, bounded on the inside by a low rim or formed by the separation of exine layers, is a feature of aspidate pollen grains, those in which the pore areas protrude as rounded domes.

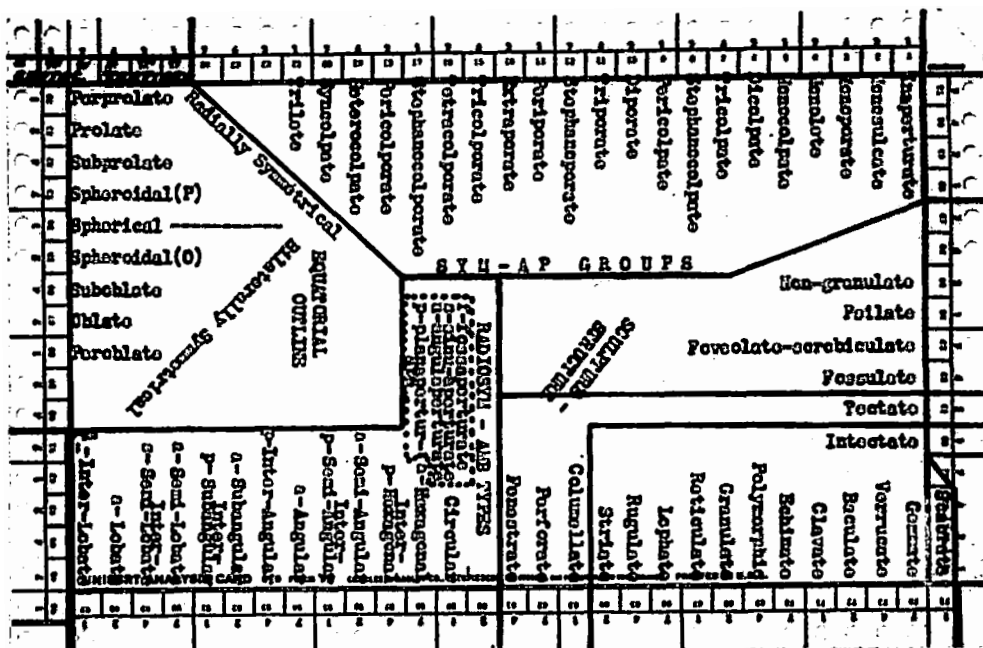
In order to facilitate systematic description and organization of the fossil sporomorphs obtained from the Bruhn lignite, much of the terminology outlined and defined above was organized into a master key to be used in connection with a series of "Unisort" analysis cards. The morphological information obtained from the microscopic study of the sporomorphs

was recorded along the margins of the cards in the customary manner. The master key employed by the writer and a sample card are shown in Figure 6.

In addition to other pertinent data, such as the particular slide location, size statistics, reference numbers, and special remarks where necessary, a photographic record of the microfossil, taken at high, median, and low focus levels, was placed on each card concerned. Duplicates of these photographs make up the plates that are included in Appendix A of this report. All photographs were made with a Bausch and Lomb Model N Eyepiece Camera attached to an American Optical Company standard monocular microscope using an oil immersion objective. Lighting for both the ordinary microscopic work and the photomicrography was provided by a Bausch and Lomb tungsten ribbon filament illuminator. Adox KB-14 35mm film was used, and the original prints were made on Kodabromide F-4 paper. The illustrations of microfossils on the plates accompanying this report (Appendix A) represent total magnification of 1000X or 1150X. Magnification has been indicated for each microfossil in the plate caption.

2. Itemization

As a basis for the study and enumeration of the pollen and spores described in the following paragraphs from the Bruhn deposit, a total of 100 permanent slides were made using 25mm square cover slips sealed with Tuf-On #74, a phenolic resin recommended by Barghoorn (1947). The number of slides prepared is admittedly arbitrary but believed by the writer to be an adequate sample for statistical purposes.



A

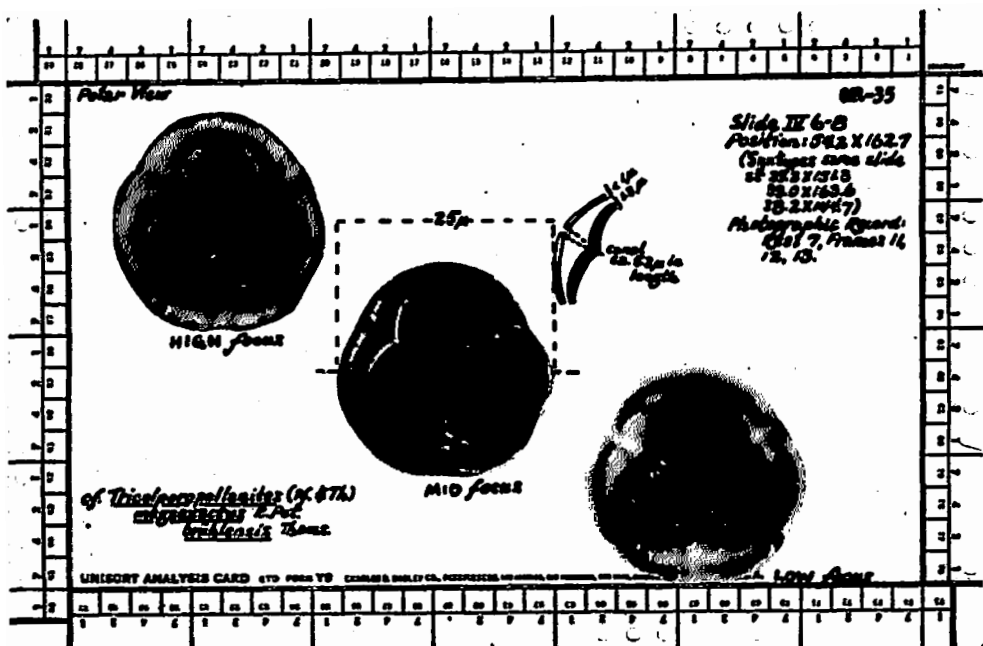
**B**

Figure 6. Illustration of master key and sample analysis card used to systematize morphological data.

Since permanent slides were made, a means of relocating the spore or pollen grain, whenever the occasion demands, could be used. A method suggested by Traverse (1955, p. 35) based on readings from a mechanical stage graduated to tenths of millimeters was employed by the writer. An "X" has been scratched with a glass marking pencil on the underneath side of the opposite end of the slide from the label. The center of the "X" on each slide has been calculated in tenths of millimeters and serves as a reference point. Each pollen grain or spore described has a location in terms of "latitude" and "longitude" (with the former stated first) as does the reference point. In order to find the microfossil with any other mechanical stage, it is only a matter of locating the center of the reference point and converting the readings given.

The total number of microfossil types in the Bruhn lignite is probably close to a hundred. Many of these were either too poorly preserved for recognition of critical details or were not significantly represented beyond a single occurrence. It became necessary therefore, for practical purposes, to limit the descriptive phase of this report to around fifty microfossils types, which, in the opinion of the writer, were representative elements in the flora responsible for the deposit, or, were otherwise worthy of special recognition.

Each plant microfossil has been assigned a catalog number prefixed with the letters MR (McLaughlin-Ripley) as a means for further reference. For the same reason, the photographic record of the microfossil, referring to location of the original negative in the writer's files, has been supplied. The description of the microfossils includes a diagnosis of

shape, apertures, exine structure and sculpture, and size. The latter is based on the dimensions of the spore or pollen grain of the supporting illustration since these individuals were selected as typical specimens of the group to which they belong.

As a means for indicating the frequency with which individual microfossils were encountered in a statistical analysis to be discussed in a later section, a set of terms pertaining to relative abundance of the microfossils was used in the descriptive paragraphs below, and standardized as follows: Abundant - greater than 10 per cent; Common - between 5 and 10 per cent; Frequent - between 2.5 and 5 per cent; Scarce - between 1.25 and 2.5 per cent; and Rare - less than 1.25 per cent.

Study of the samples taken from the contact zone between the lignite and the underlying clay disclosed a paucity of describable sporomorphs but did reveal, perhaps, an interesting chapter in the early history of the Bruhn pit. However, since special handling not covered in this investigation is required, discussion of these samples will be limited to the brief account that follows.

Despite the intense demineralization to which all samples were subjected, innumerable translucent bodies presumed to be siliceous characterize the slides made from samples taken at the zone of contact between the clay and lignite. These objects (of variable length and widths, the larger averaging ca. 50 X 15 microns) are elliptical in outline, distinctly valvate and ornamented. The writer believes that these objects represent diatoms that inhabited the basin prior to the accumulation

of peat now transformed into lignite. If diatoms, they are best described as naviculoid in reference to the shape of the diatom genus Navicula. None of these microfossils has been found on slides made from the lignite. Furthermore, the common types of microfossils described below from the lignite were not found in the contact zone samples. In the latter samples, the sporomorphs were largely nondescript and added little to the results of the investigation.

In the paragraphs below are itemized, according to cataloguing number, the principal plant microfossils from the Bruhn lignite. They are assumed to represent a fairly adequate record of the vegetational history developing at or within the general vicinity of the pit during the depositional period represented by the lignite.

MR-1. Illustration: Plate I (A)
Photographic record: Reel 1, Frame 6.
Slide: IV-6-C (Reference point: 69.2 X 155.5).
Location: 46.5 X 156.4.

Diagnosis: A colony or portion of a colonial mass consisting of several cup-shaped chambers arranged in a branching system. Size of individual cups ca. 7 microns in diameter with a wall ca. 1.75 microns in thickness; colony or portion of colony measures 35 microns in its longest dimension. Frequency: Rare.

Affinity: In arrangement and form, this microfossil closely resembles algal colonies of the Chlorophyceae, especially those of Botryococcus.

MR-2. Illustration: Plate I (D).
Photographic record: Reel 2, Frame 18.
Slide: IV-6-C (Reference point: 69.2 X 155.5).
Location: 56.7 X 162.6.

Diagnosis: Tetrahedral spore, semiangular with rounded angles and one side tending to be straight. Pronounced trilete marking on the proximal polar surface, each arm approximately 20.8 microns long. Exosporium ca. 3.5 microns in thickness, foveolate, with the pits distributed uniformly. Dimensions: 41.5 X 50.2 microns in polar view. Frequency: Rare.

Affinity: A filicinean spore probably referable to the Polypodiaceae.

MR-3. Illustration: Plate I (E).
Photographic record: Reel 3, Frames 28, 29, 30.
Slide: IV-6-B (Reference point: 69.1 X 154.0).
Location: 57.2 X 154.1.

Diagnosis: Tetrahedral spore, semiangular with rounded angles. Exosporium ca. 3.5 microns in thickness and distinctly two-layered. Easily the largest sporomorph isolated from the lignite, measuring ca. 65 microns in polar diameter. Exosporium without ornamentation, psilate. Frequency: Rare.

Affinity: A filicinean spore of a type found in the Polypodiaceae.

MR-4. Illustration: Plate I (F).
Photographic record: Reel 3, Frame 18.
Slide: IV-6-B (Reference point: 69.1 X 154.0).
Location: 39.8 X 151.2.

Diagnosis: Subangular sporomorph with sides tending to be concave between the rounded angles. The arms of a triradiate furrow is flanked on both sides by a relatively thick border appearing to be of uniform width (ca. 2.2 microns) and continuous. Exosporium (?) ca. 1.2 microns

in thickness. Dimensions: 20 microns in diameter. Frequency: Rare.

Affinity: Obscure, presumably pteridophytic.

MR-5. Illustration: Plate I (G).
Photographic record: Reel 1, Frame 7.
Slide: IV-6-C (Reference point: 69.2 X 155.5).
Location: 36.1 X 156.7.

Diagnosis: Monosulcate (?) pollen grain, circular in polar view. Ektexine tectate or nearly so, columellate in optical section. Rod-shaped radial elements ca. 3.5 microns long. Surface reticulate at high focus. Aperture appears only as an indistinct shadow in proximal view. Dimensions: 3.5 microns in diameter. Frequency: Rare.

Affinity: Undetermined at present. May be a non-vesiculate gymnospermous type. In some aspects, this sporomorph resembles highly ornamented forms frequently encountered in the Liliaceae.

MR-6. Illustration: Plate I (H).
Photographic record: Reel 2, Frames 14, 15.
Slide: IV-6-C (Reference point: 69.2 X 155.5).
Location: 38.7 X 160.5.

Diagnosis: Monosulcate pollen grain, circular in polar view but often compressed as illustrated. Exine tectate, or nearly so, columellate, ektexine elements ca. 3.5 microns long and forming a reticulum. At high focus the central aperture appears to be fringed by an inwardly projecting margin similar in structure to the exine and perhaps a part of it. The aperture may mark the distal hemisphere of the pollen grain. Dimensions: 33 microns in diameter. Frequency: Rare.

Affinity: Undetermined at present. Although smaller, this pollen type may be closely related to MR-5.

MR-7. Illustration: Plate II (A).
Photographic record: Reel 6, Frame 6.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 43.3 X 162.8.

Diagnosis: Monosulcate (monocolpate or monolete?) pollen grain or spore. Perprolate or peroblate in lateral view but tending to gape open as illustrated. Exine or exosporium very thin (ca. 1 micron) and psilate. With aperture closed, an ellipse 14 X 38 microns is formed. This type remains almost colorless after acetylation and is seen only with difficulty. Frequency: Rare.

Affinity: Undetermined. May be a filicinean spore although a monocotyledonous origin is also possible.

MR-8. Illustration: Plate II (B).
Photographic record: Reel 4, Frames 6, 8.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 57.2 X 162.8.

Diagnosis: Apparently monosulcate pollen grain. Oblate in the plane of the aperture but sides often concave or pinched. Dimensions: 6.9 X 13.8 microns with exine thickness less than a micron (ca. .65 micron average). Psilate. As in MR-7 does not respond to acetylation. Pollen grains often found in pairs as photographed. Frequency: Scarce.

Affinity: Monocotyledonous, the Palmaceae most strongly suggested.

MR-9. Illustration: Plate II (C).
Photographic record: Reel 4, Frames 10, 16.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 56.8 X 162.8.

Diagnosis: Monocolpate (?) pollen grain. Prolate in equatorial view. Distinctive flap-like thickening runs parallel to the polar (?) axis, bulging laterally just above the equatorial plane. Dimensions: 13.8 X 7.8 microns. Exine .865 microns thick, psilate. Another type

that is unaffected by acetylation. Frequency: Rare.

Affinity: Undetermined, possibly monocotyledonous.

MR-10. Illustration: Plate II (D).
Photographic record: Reel 2, Frames 23, 24.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 37.0 X 164.5.

Diagnosis: Large, tricolporate pollen grain. Subprolate in equatorial view, circular to interhexagonal in polar view. Strongly developed, wide furrows narrow sharply at the equator. Distinctive costae are angular and invaginated at their midpoints along the equator, suggesting development toward the tricolporate condition. Exine tectate, columellate, with a loosely reticulate surface sculpture formed by the ends of the radial elements in bead-like fashion. Radial elements ca. 3.5 microns in length. Dimensions: 34.6 X 41.5 microns. Frequency: Scarce.

Affinity: Dicotyledonous type of undetermined relationship.

MR-11. Illustration: Plate II (E).
Photographic record: Reel 8b, Frame 1.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 54.0 X 164.0.

Diagnosis: Tetrad of tricolporate pollen grains in a compact tetrahedral arrangement. Each pore region is underlain by thickened costae marking the position of transverse furrows. Individual grain ca. 21 microns in diameter. Exine ca. 3 microns thick, psilate. Tetrad dimensions: 38.1 X 20.8 microns but probably isodiametric when undistorted. Characteristically darkens to a deep brown through acetylation. Frequency: Rare.

Affinity: A dicotyledonous type that appears to belong to the

Ericaceae without question.

MR-12. Illustration: Plate II (F).
 Photographic record: Reel 10, Frame 22.
 Slide: IV-6-A. (Reference point: 69.9 X 154.4).
 Location: 48.5 X 157.8.

Diagnosis: Monosulcate (or inaperturate according to some authors) pollen grain, the open side probably representing the distal surface. Spherical, echinate, the irregularly disposed spines up to 5.5 microns in length measured from the rounded base to the point. In median optical section, a rim ca. 4.6 microns in width encloses the large central opening. A discrete layer, ca. 1.2 microns thick, is formed to the outside, supporting the spines at the inner margin, the base of each spine appearing to be sunken. Dimension: 33 microns in diameter. Frequency: Rare.

Affinity: Assignment to the dicotyledonous family Nymphaeaceae seems reasonably certain. The genera Nymphaea and Nuphar are suggested.

MR-13. Illustration: Plate II (G).
 Photographic record: Reel 11, Frame 5.
 Slide: IV-6-C. (Reference point: 69.2 X 155.5).
 Location: 47.9 X 163.9.

Diagnosis: Triporate, aspidate pollen grain, the amb subangular in outline, ca. 34 microns in diameter. Exine psilate, 2.2 microns thick and composed of two distinct and similar layers of equal thickness. Endexinous arci swing from pore to pore merging with annuli at the angles to the amb. One arcus between two pores is seen completely at a given focus level, the shadow of the second crossing the first at right angles near the center of the grain. Bringing the second arcus into focus

causes the first to disappear except for a faint shadow. Frequency: Rare.

Affinity: The genus Platycarya of the dicotyledonous family Juglandaceae seems certain to be represented by this type.

MR-14. Illustration: Plate II (H).
Photographic record: Reel 9, Frame 8.
Slide: IV-6-A. (Reference point: 69.9 X 154.4).
Location: 51.5 X 146.2.

Diagnosis: Triporate, aspidate pollen grain, the aspides measuring ca. 3.5 microns across. One pore is characteristically not precisely on the equatorial plane. Exine thickness ca. 1.2 microns. Surface of exine granulate. Dimension: 33 microns in polar view. Frequency: Scarce.

Affinity: This dicotyledonous type resembles pollen of the juglandaceous genus Engelhardtia very closely. It appears to be related as well to the sporomorph MR-16 with which it has been combined in statistical treatments described elsewhere in these pages.

MR-15. Illustration: Plate II (I).
Photographic record: Reel 9, Frames 3, 4.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 43.9 X 152.8.

Diagnosis: Triporate pollen grain with a subangular amb. Exine in two distinct layers, together ca. 1.2 microns thick. Pores 2.6 microns wide, somewhat rectangular in optical outline. A continuous subendexinous (?) arcus, often in two distinct layers sets off a circular area comprising a large part of the transverse section as seen in polar view at midfocus. Sculpture of exine granular. Dimension: 25 microns in diameter. Frequency: Scarce.

Affinity: Another dicotyledonous sporomorph probably referable to the Juglandaceae, although the genus Artocarpus of the Moraceae is a possibility.

MR-16. Illustration: Plate II (J).
 Photographic record: Reel 3, Frames 3, 4, 6.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 43.5 X 151.3.

Diagnosis: Triporate pollen grain, similar to MR-14 in size (ca. 33 microns in diameter) and outline but less aspidate. This sporomorph resembles MR-15 in having a large circular central area defined by a continuous band quite apart from the exine. In the central area the membrane appears to be much thinner, reminiscent of certain juglandaceous pollen grains as in Carya. Subequatorial distribution of pores, also characteristic of juglandaceous pollen, is shared by MR-14, MR-15, and this type. The pore outline, as in MR-15, is angular, measuring 3.5 microns by 1.7 microns, the latter dimension the same as the thickness of the exine. Frequency: See MR-14.

Affinity: As in the case of MR-14, this sporomorph resembles the juglandaceous pollen type found in Engelhardtia.

MR-17. Illustration: Plate III (A-G).
 Photographic record: Reel 4, Frames 30, 31, 32 (A);
 Reel 1, Frame 27 (B), Frames 1, 2, 3 (G);
 Reel 6, Frame 18 (C), Frames 14, 15 (E);
 Reel 3, Frame 8 (D);
 Reel 5c, Frame 19 (F).
 Slide IV-6-B. (Reference point: 69.1 X 154.0).
 Locations: 48.5 X 162.8 (A); 40.0 X 162.8 (C);
 43.6 X 151.1 (D); 42.9 X 162.8 (E); 56.4 X 162.8 (F).
 Slide IV-6-C. (Reference point: 69.2 X 155.5).
 Locations: 51.1 X 158.3 (B); 46.7 X 155.8 (G).

Diagnosis: Large triporate pollen grain found in several configurations formed by infolding at the margins of the grain, which might be circular or nearly so in polar view if found in a flattened condition not yet observed by the writer. Most consistently a somewhat oblate outline is achieved in the manner described above, the folded margins often enclosing an elliptical area superficially resembling a sulcus or colpus. When the latter configuration obtains and the pores are out of focus, the over-all appearance is deceptively magnolioid. The isodiametric pores are ca. 3.5 microns in average diameter and made distinctive by well-developed annuli. Elongate thickened bands extending either longitudinally or transversely are often present and in some cases resemble costae. Dimensions range from ca. 38 microns in diameter, for the more nearly circular configurations, to 48-54 micron lengths and 31-38 micron widths for the more elliptical forms. The tectate ectexine is columellate, the elements increasing in length near the pores. Frequency: Common.

Affinity: A dicotyledonous type of uncertain relationships. Preparations of modern Juglans pollen often show a range of configurations similar to those assumed by this sporomorph and in other ways the family Juglandaceae is suggested. However, direct reference to living genera is as yet undetermined.

MR-18. Illustration: Plate IV (A).
Photographic record: Reel 8a, Frame 14.
Slide IV-6-A. (Reference point: 69.9 X 154.4).
Location: 40.0 X 157.9.

Diagnosis: Triporate pollen grain, semiangular and slightly aspidate in polar view. Angulaperturate, operculate (?). The pores

measure 1.7 microns by 2.5 microns and are subequatorial in distribution. Exine ca. 1.7 microns thick but near the pores it thickens to ca. 2.6 microns. The slightly granulate ectexine is usually ruptured around the center of the grain when viewed from the polar position. Dimension: 24 microns in polar diameter. Larger grains ca. 30 microns have been found. Frequency: Scarce.

Affinity: Morphological features of this sporomorph are reminiscent of the pollen found in Myricaceae, Betulaceae, and Juglandaceae, but as yet no direct relationship has been established.

MR-19. Illustration: Plate IV (B).
Photographic record: Reel 1, Frame 21.
Slide IV-6-C. (Reference point: 69.2 X 155.5).
Location: 35.4 X 158.2.

Diagnosis: Triporate pollen grain, semiangular, angulaperturate, and aspidate in polar view. Diameter of the amb ca. 33 microns. The exine, ca. 1.2 microns wide at its narrowest point, thickens toward the margin of the pores, which are ca. 3.5 microns in width and depth. The prominent pore areas protrude 3.5 microns beyond the general margin of the pollen grain and measure almost 7 microns across. Separated from the exine at a distance of 1.2 microns is a striking, continuous, circular band about 1.2 microns wide. A central area measuring 21 microns in diameter is included by the band. Frequency: Rare.

Affinity: This sporomorph appears to be related to the Amentiferae since it exhibits general features found in different members of that order. Identity with a particular family, however, is uncertain.

MR-20. Illustration: Plate IV (C).
 Photographic record: Reel 3, Frame 15.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 50.7 X 151.2.

Diagnosis: Triporate, semiangular, angulaperturate pollen grain. Rounded, aspidate protrusions rise from the general surface rather abruptly and measure 7.8 microns across. Annuli are pronounced features bordering each of the circular pores. The latter measure ca. 2.2 microns across and 3.5 microns in depth. In the interpore areas the exine is ca. 2.2 microns thick, equally divided into a distinct ectexine and endexine. The ectexine, without surface ornamentation (psilate), thickens somewhat near the pores. Diameter of the amb: 30 microns. Frequency: Scarce.

Affinity: A dicotyledonous type that can be assigned to the Betulaceae with reasonable certainty. Features of the extant genera Carpinus and Ostrya are exhibited by this sporomorph.

MR-21. Illustration: Plate IV (D).
 Photographic record: Reel 7, Frames 3, 4.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 48.4 X 162.7.

Diagnosis: Triporate, semiangular, angulaperturate pollen grain. Strongly aspidate with sides of the amb distinctly convex at midpoints between pores, becoming concave near the angles. Each elongate pore canal situated at an angle leads into a vestibulum formed by arching ectexine knobs, the later with roughened inner margins [cf. the "tarsus" pattern described by Wodehouse (1935), p. 363]. A mesexinous development between the ectexine and endexine fills the vestibulum except in specimens such as that shown at IV (H) where the apertures gape open. Exine ca.

1.73 microns in thickness increasing to ca. 8.5 microns in the pore areas. A distinctive feature seen in polar view is a large, central, circular area with an inwardly directed membranous fringe showing varying degrees of degradation. In certain closely related types such as that shown at Plate IV (E) the extent of the somewhat granular fringe suggests that the membrane may have been continuous. Since the apertures are not equidistant, one side of the amb is always longer than the other two, the latter being the same length. Dimensions: 42 X 38 microns in undistorted specimens. Frequency: Common.

Affinity: This sporomorph and related forms constitute the most striking microfossil element in the Bruhn lignite. Pollen from the family Myricaceae among extant dicotyledonous plants most nearly approaches this type in form although generic relationships are obscure. Pollen grains from members of the Elaeagnaceae and Onagraceae show superficial resemblance. Interesting occurrences of very similar sporomorphs in other deposits will be noted in a later section.

MR-22. Illustration: Plate IV (F).
Photographic record: Reel 3, Frames 11, 12.
Slide: IV-6-B (Reference point: 69.1 X 154.0).
Location: 38.0 X 151.5.

Diagnosis: Triporate, semiangular, angulaperturate pollen grain. Pronounced aspides rise from the general margin more or less gradually, being wider and more angular than in MR-21 which appears to be closely related. Tangent lines projected along the sides of the typical aspis form an equilateral triangle ca. 10 microns high with the endexine as a base. The distinctly convex amb margin between the aspides serves to delineate a subendexinous region, deltoid in shape but with truncated

angles. The over-all outline of undistorted specimens is distinctly shield-shaped as in the lower right hand figure shown at IV (H). Characteristically, the central region bears one or two elongate sub-endexinous thickenings (or folds?). The exine along the interaspide margin measures 2 microns thick but becomes considerably thicker near the pore area as the ectexine separates and arcs toward the pore from opposite sides. The pore measures 3.5 microns across and extends (by means of a canal ca. 7 microns long) into a partially filled vestibulum that is rectangular in outline as shown at IV (G). A membranous fringe lines the central region in a fashion similar to MR-21. As in the latter, apertures not equidistant. Dimensions: 32 X 35 microns. Frequency: Scarce.

Affinity: This sporomorph is undoubtedly related to the more commonly encountered MR-21 but is clearly separated from the latter on morphological grounds. As in the case of MR-21, this type may be myricaceous in origin.

MR-23. Illustration: Plate V (A).
Photographic record: Reel 2, Frames 26, 27.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 57.8 X 150.2.

Diagnosis: Triporate (or vaguely tricolporate), angular, angulaperturate pollen grain. At each angle the inwardly curving endexine forms a shallow transverse furrow ca. 3.5 microns wide subtending the pore. This feature causes the otherwise equilaterally triangular amb to appear truncated. Exine ca. 1.75 microns in thickness and faintly granular. Dimension: 24 microns in diameter. A possibly related larger specimen

(ca. 44 microns in diameter) on the same slide (Location: 39.5 X 146.4) but not figured in this report has distinct furrow clefts. Frequency: Rare.

Affinity: A dicotyledonous type resembling pollen of certain members of the Moraceae, Nyssaceae, and Symplocaceae, but as yet no direct generic relationship has been established.

MR-24. Illustration: Plate V (B).
Photographic record: Reel 3, Frames 21, 22.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 43.0 X 150.7.

Diagnosis: Stephanocolpate (colporate?) (polycolporate of Erdtman, 1943) pollen grain, prolate spheroidal in equatorial view. About sixteen meridionally arranged furrows are separated by parallel raised areas of thickened exine ca. 3.5 microns wide at the equator but narrowing toward the poles where they converge to form polar caps. Psilate exine ca. 1 micron thick. Dimension: 22 microns in diameter. Frequency: Rare.

Affinity: A dicotyledonous type that resembles pollen of the genus Polygala rather closely. Specimens found up to the present time lack sufficient detail for precise identification.

MR-25. Illustration: Plate V (C).
Photographic record: Reel 5c, Frames 21, 22, 23.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 46.4 X 162.8.

Diagnosis: Tricolporate pollen grain, prolate in equatorial view, fossaperturate in polar view. Three long individual furrows with thickened rims (costae) tapering toward the poles from the equatorial region where

they enclose the pores. A narrow transverse furrow with a thickened rim is a distinctive feature. Exine 1.2 microns in thickness, psilate.

Dimensions: 11 X 20 microns. Frequency: Abundant.

Affinity: This sporomorph is considered to be identical with pollen grains of the genus Castanea. Specimens of this type form one of the largest groups represented in the Bruhn lignite.

MR-26. Illustration: Plate V (E).
Photographic record: Reel 10, Frames 14, 15.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 49.3 X 144.2.

Diagnosis: Tricolporate pollen grain, oblate spheroidal to almost spherical in equatorial view. Near the equator the uniformly thickened furrows invaginate sharply to form a wide angle centered on the equator. Above and below the equatorial angles the furrows arc toward the poles where they appear to converge. Exine measures 1.75 microns in thickness and is clearly psilate. Dimension: 14 microns in diameter. Frequency: Rare.

Affinity: A dicotyledonous type perhaps referable to the extant genus Ternstroemia.

MR-27. Illustration: Plate V (F).
Photographic record: Reel 1, Frames 22, 23, 24.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 36.2 X 158.2.

Diagnosis: Tricolpate (colporate) pollen grain, circular in equatorial view when expanded. A partly expanded grain is shown at Plate V (J). The meridional furrows incise deeply and gape widely when expanded. In an unexpanded condition the furrows divide the polar area

into three equal sections as at Plate V (G). Furrow membranes are psilate in sharp contrast to the reticulate ornamentation elsewhere. Exine tectate, columellate, ca. 1.75 microns in thickness. Dimension: 25 microns in diameter. Frequency: See MR-28.

Affinity: This particular sporomorph may represent Dalbergia or some related genus in the Leguminosae. Other types catalogued as MR-28 and MR-29 seem to be related and may represent the same family. Similar characteristics are shown by MR-39.

MR-28. Illustration: Plate V (I).
Photographic record: Reel 5c, Frames 25, 26.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 46.1 X 162.8.

Diagnosis: Tricolpate (colporate?) pollen grain, circular in outline. The commonly encountered orientation shown in the illustration represents an oblique equatorial view with the columellate exine, ca. 1.3 microns in thickness, revealed in optical section. Surface of exine uniformly reticulate. Dimension: 25 microns in diameter. Frequency: Frequent.

Affinity: In several respects not especially distinct from MR-27 and MR-28, two leguminoid types with which this sporomorph may share a common relationship. For this reason all of these types were treated together in statistical studies connected with this investigation.

MR-29. Illustration: Plate V (K).
Photographic record: Reel 10, Frame 9.
Slide: IV-6-A. (Reference point: 69.9 X 154.0).
Location: 36.5 X 150.6.

Diagnosis: Tricolpate (colporate?) pollen grain, circular in

unexpanded outline. Meridional furrows deeply cleft. The furrow regions are psilate in contrast to the reticulate surface elsewhere. Exine tectate, columellate, ca. 1 micron in thickness. Dimension: 21 microns in diameter. Frequency: See MR-28.

Affinity: A type perhaps referable to the Leguminosae and thus may be related to MR-27 and MR-28. This type is smaller than the latter sporomorphs, however, but is otherwise very similar.

MR-30. Illustration: Plate V (L).
Photographic record: Reel 3, Frames 33, 34.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 57.3 X 154.0.

Diagnosis: Stephanoporate, slightly aspidate pollen grain. Circular in outline but tending to be hexagonal in a much flattened polar view. Four or five rounded pores are arranged equatorially or subequatorially, each ca. 1.75 microns wide and deep. Slight transverse furrows appear to subtend the pore areas. Elongate, subendexinous thickenings are characterically developed and appear in some instances to be branched. Psilate exine ca. 1.75 microns in thickness and distinctly two-layered. Dimension: 34 microns in diameter. Frequency: Rare.

Affinity: This sporomorph bears certain resemblances to pollen found in the families Ulmaceae, Haloragaceae, Fagaceae, and Casuarinaceae. However, no definite relationship has as yet been established within any of these families.

MR-31. Illustration: Plate VI (A).
Photographic record: Reel 2, Frames 2, 3.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 44.2 X 158.9.

Diagnosis: Triporate pollen grain. Circular in undistorted polar view. Short and long transverse thickenings, in some cases resembling furrows, are a consistent feature. Occasionally the elongate markings appear to be associated with pores but the relationship is vague. Pores ca. 1.75 microns in diameter are generally arranged subequatorially. Exine ca. 1.75 microns in thickness, granulate. Dimension: ca. 28 microns in diameter. Frequency: Rare.

Affinity: This sporomorph may be another juglandaceous type, in this case approaching the morphological characteristics of Carya pollen in a general way.

MR-32. Illustration: Plate VI (B).
Photographic record: Reel 2, Frames 5, 6.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 36.6 X 159.3.

Diagnosis: Tricolporate pollen grain, circular, intruding at the apertures in polar view, prolate in equatorial view. Longitudinal furrows flanked by thick costae interrupted at the equator by distinctive, narrow, transverse furrows. Near the poles the costae appear to fuse. The intectate exine measures ca. 3 microns in thickness, the gemmate ectexine composed of closely spaced protuberances not of equal height producing a rugulate sculpture pattern. Dimensions: ca. 17 microns in polar diameter; 21 X 35 microns measured in equatorial view. Frequency: Rare.

Affinity: A dicotyledonous type of undetermined relationship to extant taxa.

MR-33. Illustration: Plate VI (D).
Photographic record: Reel 2, Frames 11, 12, 13.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 50.2 X 160.0.

Diagnosis: Tricolporate pollen grain, perprolate to prolate in equatorial view but appearing to be slightly depressed midway along the sides. Longitudinal costae curve toward the polar axis from the margin of the wide transverse furrows located at the equator. The transverse furrows appear to fuse forming a continuous band, a condition referred to as zonorate. The longitudinal costae are flanked by distinct margoes. The tectate ectexine forms a distinct reticulum with circular lumina and pronounced muri. Total thickness of the exine: 1.2 microns. Frequency: Rare.

Affinity: A dicotyledonous type as yet unrelated to any extant group.

MR-34. Illustration: Plate VI (E).
Photographic record: Reel 1, Frame 14.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 50.2 X 157.6.

Diagnosis: Tricolporate (colpate) pollen grain, subangular, with furrows flat in polar view. Furrows project from the amb margin almost to the pole, dividing the polar region into three equal, angular parts. A characteristic feature seen in polar view is the presence of curved endexinous thickenings (costae?) extending transversely across the furrows at right angles. Surface of the exine psilate or slightly granulate. Thickness of exine ca. 1 micron. Dimension: 17 microns in diameter with the furrows closed. Frequency: Rare.

Affinity: A dicotyledonous type resembling pollen grains found in the Araliaceae, Anacardiaceae, Cornaceae, and Rhamnaceae. However, reference to a particular family or genus has not been possible up to the

present time.

MR-35. Illustration: Plate VI (F).
Photographic record: Reel 7, Frame 12.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 54.2 X 162.7.

Diagnosis: Tricolporate pollen grain with a generally circular amb that is flattened perpendicular to the line of intersection formed by the pore canal and furrow axis. The latter is a sharply indented channel with sides curving gently toward the margin of the pollen grain midway between colpa, where they appear to fuse with the sides of adjacent furrows similarly directed. Thick (ca. 1.3 microns) endexinous costae underlying the furrows almost form a fossaperturate configuration enclosing a darker central area quite distinct in optical properties from the rest of the grain. Between the thin (less than 1 micron) ectexine and the endexine, the circular amb formed to the outside is produced by a lighter mesexinous layer that fills in the furrow valleys. The indented channel of each furrow is connected to the outside by a pore canal ca. 5.2 microns in length. Surface of ectexine psilate. Dimension: 28 microns in polar diameter. Frequency: Rare.

Affinity: Relationship to extant dicotyledonous taxa is yet to be established for this sporomorph. Of interest are types referred to Tricolporopollenites described from the German brown coals, particularly T. megaexactus subspecies bruhlensis Thomson (Thomson and Pflug, 1953), a form that appears identical with MR-35.

MR-36. Illustration: Plate VI (G).
Photographic record: Reel 2, Frame 9.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 56.6 X 159.3.

Diagnosis: Tricolporate, circular pollen grain. Similar to MR-35 except for a slightly thicker (ca. 1.7 microns) ectexine, a general crenulation of the endexinous costae, and the absence of the mesexinous filling. However, the outer layer continues to be a discrete unit apart from the interior, as in the case of MR-35. In the main, this sporomorph gives the appearance of a somewhat relaxed version of MR-35. Psilate. Dimension: 25 microns in diameter. Frequency: Rare.

Affinity: Undetermined except for probable relationship in some degree or other to MR-35.

MR-37. Illustration: Plate VI (H).
Photographic record: Reel 11, Frame 15.
Slide: IV-6-A. (Reference point: 69.9 X 154.4).
Location: 56.8 X 155.0.

Diagnosis: Tricolporate pollen grain, probably circular in amb outline but quadrilateral flattening is characteristic. Very thick (ca. 3.5 microns), dark, endexinous or subendexinous bands describe a roughly three-lobed central area outside of which is a less dense region separating the former from a distinctive outer wall (ektexine?) that is ca. 1.75 microns in thickness. Psilate. Dimension: 33 microns in diameter. Frequency: Rare.

Affinity: Undetermined at present, probably angiospermous.

MR-38. Illustration: Plate VI (I).
Photographic record: Reel 4, Frame 2.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 57.2 X 162.8.

Diagnosis: Triporate (tricolpate or tricolporate?), angular sporomorph. An enigmatic type with a triangular amb except at the angles

where loop-like connections are formed by the converging margins. A triangular, featureless, central area is set off by the apparently folded margins. Psilate. Exine (or exosporium) ca. 1 micron in thickness. Dimension: 25 microns in diameter. Frequency: Rare.

Affinity: As yet it has not been possible to place this sporomorph in one of the higher categories with certainty. At the present time it is assigned provisionally to the Angiospermae.

MR-39. Illustration: Plate VI (J).
Photographic record: Reel 9, Frame 31.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 37.9 X 149.8.

Diagnosis: Tricolpate (colporate) pollen grain. Circular in polar view with furrows rather narrow and angular in cross section. As seen in polar view, the shape of the sporomorph seems to be formed by the linking of three boat-shaped parts around a central triangular area, the furrows forming at the junctions of any two ends. This configuration might be considered as resembling superficially a common myrtaceous arrangement except that the arches forming to the outside are reversed. Closer study reveals a similarity to pollen grains of the MR-29 type, direct comparison being obscured by oblique turning away from precise polar orientation in the case of MR-39. The exine, with tectate columellate structure and reticulate sculpture on the surface of the ectexine, has a total thickness of ca. 1.75 microns. Dimension: ca. 36 microns in diameter. Frequency: Rare.

Affinity: Unknown at present, possibly related to MR-29 and other leguminoid types.

MR-40. Illustration: Plate VI (K).
Photographic record: Reel 12, Frames 31, 32, 33.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 48.8 X 151.1.

Diagnosis: Tricolporate, inter-subangular, planaperturate pollen grain. The most prominent feature seen in polar view as shown is the very thick exine composed of no fewer than four distinct, continuous layers, together measuring 2.6 microns in thickness. A darker endexinous layer outlines a lobate central region, the interlobal indentations being sharpened by endexinous or subendexinous thickenings. Directly overlying the latter along the outer endexinous surface, mesexinous fillings restore the entire margin that is continued to the outside by the ectexine.

Psilate. Dimension: ca. 14 microns in diameter. Frequency: Rare.

Affinity: Undetermined at present although definitely dicotyledonous.

MR-41. Illustration: Plate VI (L).
Photographic record: Reel 5, Frames 27, 28, 29.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 45.8 X 162.8.

Diagnosis: Tricolporate pollen grain, prolate in equatorial view but with a tendency toward being slipper-shaped. This type is characteristically little affected by acetylation. Longitudinal costae flank the furrows except where interrupted in the equatorial region by a relatively wide but laterally short transverse furrow. Pore margins rounded. Exine ca. 1 micron thick, intectate, psilate. Dimensions: 10 X 16.5 microns. Frequency: See note under MR-43.

Affinity: In most respects this sporomorph resembles MR-43, a sapotaceous pollen grain. These two types, along with MR-44, were placed

together in the statistical evaluation of the Bruhn microfossils.

MR-42. Illustration: Plate VI (M).
 Photographic record: Reel 7, Frames 7, 8, 9, 10.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 50.0 X 162.6.

Diagnosis: Tricolporate pollen grain, prolate in equatorial view. Longitudinal furrows with costae extend to the poles or nearly so, the costae possessing optical properties different from those of the parallel regions. In size, shape, and general aspect this sporomorph resembles MR-25 but lacks the distinct transverse furrow of the latter. Exine ca. 1.2 microns thick and consisting of two distinct layers. Psilate. Dimensions: 12 X 22 microns. Frequency: Common.

Affinity: A dicotyledonous type possibly related to MR-25.

MR-43. Illustration: Plate VII (A).
 Photographic record: Reel 5a, Frames 1, 2, 3.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 51.1 X 162.7.

Diagnosis: Tricolporate pollen grain, prolate in equatorial view. Furrows flanked by costae and somewhat straight (i.e., not distinctly bow-shaped). These elongate structures are intersected sharply at the equator by a wide transverse furrow that appears to circumscribe the exine internally or nearly so. The latter furrow is seen most pronounced in polar view at midfocus. Exine is around 1 micron thick and psilate. Dimensions: 10 X 17 microns. Frequency: Abundant.

Affinity: This sporomorph resembles pollen grains produced by certain genera in the Sapotaceae, particularly Bumelia, but not Mimusops or Chrysophyllum. For statistical purposes this type was considered along

with MR-41 and MR-44, as a single unit because of the close similarity that exists among them.

MR-44. Illustration: Plate VII (C).
 Photographic record: Reel 3, Frames 24, 25, 26.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 54.9 X 150.8.

Diagnosis: Tricolporate pollen grain, subprolate in equatorial view. Longitudinal costae narrow. Pore small (ca. 1 micron in diameter). Exine thin (ca. .87 microns) and psilate. In most respects, this sporomorph resembles MR-41 and MR-43, especially the pollen grains of the latter that have not been acetylated. Dimensions: 15 X 12 microns. Frequency: See MR-43.

Affinity: A sapotaceous type that is closely related morphologically to MR-41 and MR-43.

MR-45. Illustration: Plate VII (D).
 Photographic record: Reel 6, Frames 29, 31.
 Slide: IV-6-B. (Reference point: 69.1 X 154.0).
 Location: 37.8 X 162.7.

Diagnosis: Tricolporate pollen grain, prolate, in equatorial view. Thick, curved, longitudinal furrows and costae tapering toward the poles, are crossed at right angles by an elliptical transverse colpus that measures around two microns at its widest point. Longitudinal furrows have distinct margo. Exine structure intectate, scabrate, 1.3 microns in total thickness. The surface of the ectexine bears a fine reticulum, the origin of which is obscure. Dimensions: 22.5 X 14 microns. Frequency: Scarce.

Affinity: The relationship of this sporomorph to modern dicotyledonous

taxa is not clear but certain characteristics are reminiscent of the Fagaceae.

MR-46. Illustration: Plate VII (E).
Photographic record: Reel 4, Frames 19, 20, 21.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 53.9 X 162.8.

Diagnosis: Tricolporate pollen grain, subprolate in equatorial view. Costae furrows extending nearly to the poles, sharply intersected at the equator by large rectangular pore areas similarly bounded by costae. The intectate exine is scabrate with closely packed radial elements less than a micron in length and of unequal lengths giving a roughened, foveolate appearance to the outer surface. Exine thickness ca. 1.73 microns. Dimensions: 25 X 18 microns. Frequency: Rare.

Affinity: This sporomorph shows some similarity of pollen grains found in the Fagaceae.

MR-47. Illustration: Plate VII (F).
Photographic record: Reel 5b, Frames 10, 11, 12, 13.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 54.9 X 162.8.

Diagnosis: Monocolpate (?) pollen grain or spore, prolate (or oblate) in longitudinal view with sides somewhat flattened parallel to the major axis. A single, long, and narrow furrow with roughened edges extends along the sporomorph for nearly the whole length, parallel to but to the side of the longitudinal axis. Exine psilate, ca. 1.3 microns in thickness. Dimensions: 18 X 10 microns. Frequency: Scarce.

Affinity: Undetermined at present.

MR-48. Illustration: Plate VII (G).
Photographic record. Reel 2, Frames 29, 30.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 55.4 X 151.0.

Diagnosis: Monocolpate (or monocolporate?) pollen grain, prolate (or oblate) in longitudinal view. An elongate, slit-like opening is seen to gape slightly midway between the ends. At high to midfocus, a continuous, thick, endexinous or subendexinous band encloses an elliptical area bisected by the furrow. Exine intectate, psilate, thin (ca. .7 micron in thickness). Dimensions: 19 X 10 microns. Frequency: Frequent.

Affinity: Unknown at present.

MR-49. Illustration: VII (H).
Photographic record: Reel 9, Frame 18.
Slide: IV-6-C. (Reference point: 69.2 X 155.5).
Location: 36.6 X 146.3.

Diagnosis: Monocolpate pollen grain, prolate in equatorial (?) view. A widely gaping furrow with a distinct margin extends nearly to the poles. Exine is distinctly baculate with surface sculpture finely reticulate. Thickness of the exine ca. 1 micron. Dimensions: 32 X 18 microns. Frequency: Rare.

Affinity: Undetermined at the present time, probably angiospermous.

MR-50. Illustration: Plate VII (I).
Photographic record: Reel 10, Frame 8.
Slide: IV-6-B. (Reference point: 69.1 X 154.0).
Location: 42.1 X 157.1.

Diagnosis: Dyad spore or sporangial mass, each segment circular or nearly so except at the margin of contact where the sides tend to be flattened. A thin wall, less than a micron in thickness and simple in

structure, encloses a dense, central region that appears to contain small, loosely packed spherical objects less than a micron in diameter. Dimensions of dyad: 31 X 50 microns; individual segments measure ca. 24 microns in diameter. Frequency: Rare.

Affinity: An occasionally found microfossil of uncertain relationship. Many highly degraded but still discrete blebs permeating every preparation may have originated with this microfossil.

Addenda. Three additional sporomorphs have been illustrated in this report but are uncatalogued as yet, either pending further investigation or due to difficulties in establishing contemporaneity with the microfossils described above. None has been found in the lignite beyond a rare occurrence.

At Plate I (B) and (C) two reproductive structures of fungi have been included but no attempt has been made up to the present time to identify them further. A dicotyledonous sporomorph is illustrated at Plate I (I) that strongly suggests the genus Ilex because of the distinctive clavate nature of the exine. However, a single specimen only of this type has been noted among the several hundred microfossils examined and the writer has elected to withhold cataloguing and description at this time.

3. Statistical Analysis

In order to compare relative abundance of the pollen and spore types recovered from the Bruhn lignite, slides were selected at random from among the one hundred initial slides that had been prepared. These slides represented all portions into which the processed material had been split for storage purposes.

By means of the mechanical stage a single horizontal traverse was made across the 25 mm wide coverslip region on each slide. On successive slides different positions on the vertical graduated scale were used in an attempt to avoid statistical errors that might arise from uneven distribution due to concentration of pollen and spores in particular areas. In all, twenty-eight slides were analyzed in the above fashion, resulting in a total pollen and spore count of 1450 individuals. It was found that frequency percentages did not become stabilized until after ten slides had been traversed, at which point a total of 305 individuals had been reached.

Due to problems of identification, counts of certain morphologically similar types, not easily separated during rapid surveys of this kind, were combined and entered under the catalogue number of the type considered to be the most representative. These types have been noted in the preceding section and are connected by arrows in the frequency graph shown in Figure 7.

The general characteristics of the flora represented by the fossil sporomorphs are illustrated by the sectorial diagrams also in Figure 7. Separation of types into the larger categories presented no great difficulty except in assigning the questionable forms of possible gymnospermous origin and in differentiating the monocotyledons among the angiosperms. However, in neither case could the total vegetational aspect be altered appreciably by any decision made pertaining to these two groups since both represent minor constituents of the sporomorph sample.

In the angiospermous group, the largest category represented, the

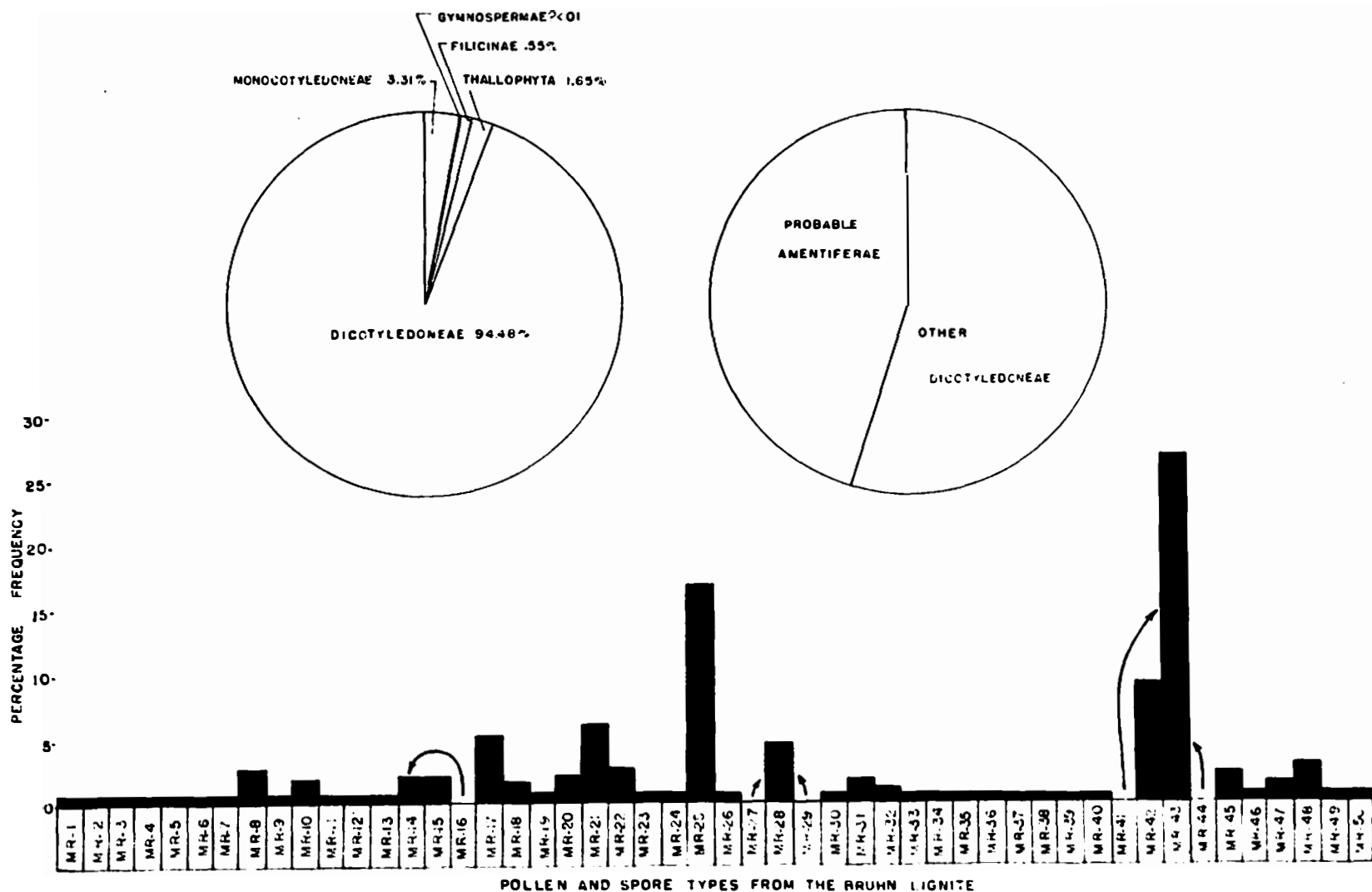


Figure 7. Frequency distribution of plant microfossils in the Bruhn lignite and comparative representation of higher taxonomic categories.

especially noteworthy predominance of pollen from types referable in greater or less degree to families often placed in the order Amentiferae, is illustrated diagrammatically as well. This has been accomplished by combining percentages recorded for such types.

No types not catalogued in this report were encountered in sufficient numbers in making the statistical survey to regard them as being important elements in the total flora. Hence, the writer believes that the results presented in the graphical summary provide an adequate basis for drawing fairly sound inferences regarding the nature of the flora as is done in the following section.

DISCUSSION OF RESULTS

The most obvious first impression obtained from surveying the pollen and spores in the Bruhn lignite is the dominance of pollen from dicotyledonous angiosperms (ca. 95 per cent) and the reduced amount assignable to all other groups of plants. Based on the number of individual pollen types, the dicotyledonous element in terms of separate entities far exceeds any other since 74 per cent of the types can be placed among the Dicotyledoneae with reasonable certainty. In comparison, the absence of gymnosperms or only a faint suggestion of them stands out in sharp contrast.

On the basis of presumed family or generic relationships of the dicotyledonous types, a second observation is similarly inescapable. Almost 50 per cent of the pollen, if relative abundance is compared, was produced by plants that could be assigned to the Amentiferae providing morphological similarities have been properly interpreted. Nor could the dominance of such pollen be dismissed on the grounds of over-representation in numbers, generally considered to be characteristic of plants from amentiferous families. Morphologically and, perhaps, taxonomically, distinct types of possible or probable relationship to the Amentiferae constitute nearly a third of the sporomorph total.

Again, assuming the writer's judgment regarding affinities of the principal angiosperm pollen types to be nearly correct, certain ecologic observations can be made. Two definite elements, considered by the writer to be environmental in nature, appear to be represented by the Bruhn

lignite sporomorphs. On the other hand, an autochthonous element apparently grew within the basin of accumulation or along the margin during the sedimentary period represented by the lignite sample. This was essentially a non-arboreal group that included the thallophytes, pteridophytes, small herbaceous plants, and shrubs represented by at least half of the sporomorph types itemized in the previous section of this report. Of special interest among this group is the alga, Botryococcus, Nymphaea or Nuphar of the Nymphaeaceae, the ferns, the ericad, in all probability those members of the Leguminosae, Myricaceae, and Ternstroemiaceae believed to have been present. In addition, the sapotaceous type or types resembling Bumelia that contributed better than 25 per cent of the sporomorph specimens may represent the same element.

A second element comprising plants that might be regarded as arboreal probably grew at some distance from the margin of the basin of accumulation. Greater or lesser quantities of pollen accumulating in the deposit from such plants may have depended on relative proximity or some less obvious factor. Indications of such plants are provided by the several juglandaceous, betulaceous, and fagaceous types among others, and, in particular, this allochthonous element would have included the pollen type referable to Castanea that was responsible for better than 16 per cent of the pollen total.

One of the main objectives of this investigation was to compare the published account of the Ripley Flora based on megafossil evidence (see Appendix B) with the local development of this flora as expressed by the plant microfossils obtained from the Bruhn lignite. The comparison below

follows the systematic sequence employed by Berry in listing the Ripley megafossils.

1. Bryophyta

No evidence of mosses or other bryophytes was found in the Bruhn lignite.

2. Pteridophyta

Among the ferns, Asplenium and Gleichenia along with several extinct genera have been recorded for the Ripley Flora. Neither of these living genera was indicated in the Bruhn lignite. At least three fern genera are represented, two of these probably belonging to the Polypodiaceae.

3. Coniferophyta

Gymnosperm pollen is significantly absent or rare in the Bruhn lignite. An exception may be two forms possibly referable to Cupressaceae and Araucariaceae. No podocarpaceous pollen was noted. Phyllocladus and other members of the family were not observed although Berry suggests the possibility of such affinities in erecting the form genus Proto-phyllocladus.

4. Angiospermophyta

a. Class Monocotyledonae

Certain forms in the Bruhn lignite show affinities in the direction of the Palmaceae and Alismataceae. However, like the gymnosperms, the monocots are but slightly represented, if at all. Pollen from none of the

monocotyledons mentioned or suggested by Berry (e.g., Sabal, Potamogeton) is present in the Bruhn material.

b. Class Dicotyledonae

In terms of species representation in the Ripley Flora as revealed by megafossil identification, the major families of dicotyledons were the Leguminosae, Lauraceae, Myricaceae, Moraceae, Celastraceae, Apocynaceae, Euphorbiaceae, Rhamnaceae, Myrtaceae, Juglandaceae, Fagaceae, Ternstroemaceae and Sapotaceae in that order. All other families had no more than two representatives in the total flora. A discussion of the pollen assignable to these families along the lines of comparative dominance seems reasonable.

(1) Leguminosae. Among the legume genera identified or implied by Berry are Bauhinia, Caesalpinia, Acacia, Mimosa, Dalbergia and Gleditsia. There are a few suggestions of pollen from this family in the Bruhn lignite but none of the above genera is present with any degree of certainty except, perhaps, Dalbergia. Other possibilities are Baptisia, Robinia, and Sophora.

(2) Lauraceae. Berry records 12 species from this family, most of which he places in the genera Laurus, Cinnamomeum, Nectandra and Malapocenna. No pollen referable to this family is indicated in the Bruhn lignite. This may be due to the characteristically delicate nature of the pollen produced by members of this family, rather than to their total absence.

(3) Myricaceae. Only one genus, Myrica, is listed by Berry for this family but eleven species were assigned to it. He makes special note of the fact that the differentiation within this genus was extraordinary at

this time.

There is no indication of the genus Myrica in the Bruhn lignite. On the other hand, there are at least two pollen types that indicate a family or perhaps an ordinal relationship to the genus. If one combines certain characteristics of Myrica pollen with the features of the colpa as found in the pollen of such genera as Epilobium and Elaeagnus, the general aspect of these apparently extinct types can be approximated. By a reduction of the colpa, the pollen grain of Myrica could be derived rather easily. Consequently, the present writer believes that the family is clearly present but not to the generic extent envisioned by Berry. The myricaceous microfossils, one of the most interesting and numerically significant elements in the Bruhn lignite, will be referred to later in a discussion of other fossil pollen and spore studies in nearly contemporaneous deposits elsewhere.

(4) Moraceae. Listed among the Ripley megafossils are 10 species assigned to this family, nine of which are presumed to belong to the controversial Ficus (the several thousand fossil species described for this genus have plagued paleobotanists for years). Two pollen types, one suggesting Ficus slightly, the other resembling Artocarpus, a second genus believed to be present in the Ripley Flora, are among the Bruhn microfossils.

(5) Celastraceae. Despite the high representation of megafossils assigned to this family by Berry, the present writer was not able to find any supporting microfossil evidence. However, due to the limitations of reference material available from this family only a few genera were

investigated thoroughly. Pollen from the genus Celastrus, implied by Berry, was compared but was not found in the lignite.

(6) Apocynaceae. Fossil pollen from this family appears to be completely absent at the Bruhn locality.

(7) Euphorbiaceae. This family may be represented among the microfossils but not the Croton-Euphorbia group. Affinities appear to be in the direction of Drypetes.

(8) Rhamnaceae. There appears to be no clear evidence of pollen types characteristic of Rhamnus, Zizyphus or other genera in this family.

(9) Myrtaceae. Except for a single specimen, in which the resemblance is remote at best, this family is not represented.

(10) Juglandaceae. Sharing, with the myricaceous pollen noted previously, the role of prominence among the apparently related amentiferous pollen groups found in the Bruhn lignite are at least four microfossil types that are unmistakable members of this family. However, none of the types is directly referable to Juglans, the only genus listed by Berry.

The genera indicated by the fossil juglandaceous pollen are of considerable interest due to the present restricted range of certain of them, and because of the evolutionary implications involved in the early differentiation of members of this family.

Pollen similar to that of the genus Platycarya is present in the Bruhn lignite along with forms referable to Engelhardtia and possibly Carya. The first genus is represented in the modern flora by one species in China. However, fossil evidence indicates a much wider distribution in the past. Recently, Ingwersen (1954) found Platycarya pollen among

other microfossils in Tertiary lignite from Denmark.

The presence of Engelhardtia pollen in the Bruhn lignite is of particular interest due to the remarks of Berry (1925, p. 40) in reference to the megafossil species Juglans wadii Berry.

The smaller leaves are rather suggestive of lower Eocene forms referred to the allied genus Engelhardtia, but in the absence of the characteristic winged fruits of that genus such a determination can not be substantiated, nor is the species certainly a Juglans, although it appears to be a member of the Juglandaceae.

(11) Fagaceae. This family is apparently represented by Castanea and possibly Fagus and Quercus although the latter are only vaguely suggested. Perhaps present among these questionable forms is pollen from the supposed ancestral type called Dryophyllum although this, of course, can only be conjecture.

(12) Ternstroemiaceae. Berry lists one form genus for leaf impressions that indicate relationship to this family. One pollen type in the Bruhn lignite appears to be similar to Ternstroemia but additional reference material is required.

(13) Sapotaceae. Three genera from this family, Bumelia, Chrysophyllum, and Mimusops, are reported by Berry from Ripley sites. The writer found Bumelia-type pollen to be abundant in the Bruhn lignite but Mimusops and Chrysophyllum pollen was completely absent.

Among the families having only minor representation among the megafossils, the Cornaceae, Magnoliaceae, Platanaceae, Meliaceae, Tiliaceae, and Vitaceae have no definite members that contributed to the microfossil record displayed by the Bruhn lignite. Other families, such

as Aceraceae, Asclepidaceae, and Ranunculaceae, may be present in certain forms but the relationships are somewhat obscure at this writing.

Berry recorded the genus Capparis in the Ripley Flora but the present author was unable to find any type referable to this genus. On the other hand, an uncatalogued form showing affinities toward Polanisia of the Capparidaceae is present.

Other possibilities for genera and families listed by Berry are Aralia (Araliaceae), Salix (Salicaceae), and Sterculia (Sterculiaceae). Other family relationships are indicated by forms more or less referable to Dilleniaceae, Menispermaceae, and Ericaceae. In the latter instance, a definite ericad is present in a type very similar to Oxydendrum.

A very common pollen type that assumes a variety of shapes and configurations either through fossilization or the technique used to isolate the microfossils is one that may represent the genus Carya or some member of the Juglandaceae. This particular pollen type through folding, occasionally assumes a form superficially like Magnolia and if finer details of the wall are overlooked, the unwary might be deceived.

Three striking dicotyledonous sporomorphs that apparently belong to the Nymphaeaceae, Polygalaceae, and Betulaceae are present in the Bruhn lignite although none of these families has been established in the Ripley Flora on the basis of megafossil evidence. In the case of Nymphaeaceae and Polygalaceae the genera Nymphaea and Polygala are suggested, while the betulaceous grain resembles Corylus and Carpinus but not Betula.

Other Plant Microfossils

Fungal spores are abundant in the Bruhn lignite but they are undistinguished for the most part. However, the occurrence of occasional colonies of an alga that appears identical with published reports of Botryococcus is noteworthy.

Organic sediments rich in Botryococcus remains extend back to the Mississippian. A form called Epipolaia by Bradley (1924) may be a previous Cretaceous record for the genus while Traverse (1955) has recently described an occurrence of the alga in the Brandon (Vermont) lignite of presumed Oligocene age.

Comparison With Other Cretaceous Microfossil Studies

In the review of palynological studies of Cretaceous material from various parts of the world undertaken in a preceding section, the general character of Late Cretaceous vegetation established by the principal contributors is, in certain respects, remarkably uniform. This is particularly true of the dominant angiospermous elements in the Northern Hemisphere deposits. Almost consistent reference to betulaceous, myricaceous, and juglandaceous types is made to the point that one might suspect a rather cosmopolitan flora for the time, and one which had developed to a similar, somewhat uniform evolutionary level. Not until the succeeding Tertiary were essential details altered and even then many of these types persist in the earlier beds.

In general, the results obtained from the investigation of the Bruhn lignite by the writer compare favorably with studies of similar

Upper Cretaceous deposits. Furthermore, there are some interesting coincidences. In the reports of the several investigations of the German brown coals [e.g., Pflug (1952), Weyland and Krieger (1953), Thomson and Pflug (1953), and Pflug (1953)] sporomorphs assigned to the form genera Extratropopollenites, Tropopollenites, and Triatri-pollenites are strikingly similar to some of the prominent Bruhn microfossils. A sporomorph referred to Pollenites vestibulum R. Potonié' (cf. Betula) described and illustrated by Pastiels (1948, p. 58 and Pl. VI, fig. 17) from Eocene sediments in Belgium appears to follow this same general category.

A certain amount of correspondence exists between the results of the present investigation and those obtained by Radforth and Rouse (1954) discussed in a previous section. In the absence of more detailed information, however, it is not yet possible to compare the Bruhn microfossils and the Canadian spores and pollen fully. There can be little doubt that, taken together, both investigations demonstrate the need for additional studies of a similar nature while disclosing the opportunity for extending knowledge.

In the opinion of the writer, the absence of any significant gymnospermous record in the Bruhn lignite, in contrast to other deposits containing Cretaceous plant microfossils, is best explained on ecological grounds. A comparable dearth of such evidence in the megafossil collections of Berry seems to support this view. The general under-representation of gymnosperm megafossils due solely to difficulties involved in the fossilization process itself does not appear to be a valid argument since the pollen evidence is similarly absent.

SUMMARY AND CONCLUSIONS

The palynological investigation of the Bruhn lignite has disclosed a distinctive group of microfossils of considerable variety and extent. When compared with the modern flora across time and space, it is clear that the pollen and spores preserved as microfossils represent a strange assortment of plants composed of many extinct types in association with others that show definite relationships and perhaps direct connections with living taxa.

While a certain number of extant genera appear to have been differentiated, the overall character of the flora is produced by synthetic types that indicate lines of evolution yet to culminate in recognizable forms. The latter types along with the absence of typical ferns, cycadophytes, and conifers that dominated earlier Mesozoic floras, place this group of plants in an intermediate position in the phylogenetic development of the modern flora. The extent to which systematic methods applicable on the present horizon can be employed in the delineation of an ancient flora such as this remains an open question.

It is abundantly clear that, numerically, the flora of the segment of geologic time represented by the Ripley deposits is only partially known. From eight localities, Berry was able to compile a list of slightly over a hundred species. On the other hand, the Bruhn lignite, a single source, has produced at least that many discrete pollen and spore types. It is apparent that further investigations should uncover a highly varied and remarkable flora of sizable dimensions.

The similarities that exist between the Ripley megafossil record and the microfossils from the Bruhn locality are primarily on the family, or higher, level. Several taxa established on megafossil grounds are absent and, conversely, others that have not been previously indicated by other evidence are suggested by the sporomorphs. That a wider application of the methods used in this investigation will permit other comparisons in the future can be predicted without reservation.

Concerning particular inferences in regard to plant evolution, the writer believes that the close association of myricaceous forms along with those assigned to the Juglandaceae, Betulaceae, and other amentiferous plants cannot be ignored, especially since this evidence is in accord with the observations made by other investigators in dealing with a considerable amount of nearly contemporaneous material. Moreover, in all matters of evolution, the inadequacy of the megafossil record no longer provides a convenient means for disposing of conflicting arguments since palynological evidence is not subject to the same limitations.

The stratigraphic value of the microfossils described in this report is obvious but further observations along this line must await the assembly of additional information as to ranges of individual taxa as more extensive sampling is undertaken. The results obtained in this study serve to underline the inadequacy of paleobotanical criteria used as a basis for correlation and provide an insight into the potential importance of the micropaleontological methods employed.

It must be emphasized in closing that certain observations should be considered tentative since they are limited by the extent of botanical and geological comparisons that have been possible up to this point.

However, regarding the main conclusions drawn from the investigation, there appears to be little reasonable doubt as to their validity. In general, they point up the enormous gaps in knowledge that exist in our understanding of past events that shaped the development of the present biological spectrum.

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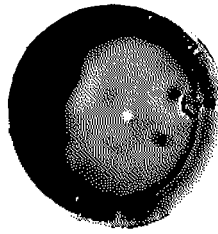
APPENDIX A

CAPTION FOR PLATE I

- A. MR-1. Page 84. Focus on top margin of colony. 1150X.
- B. Uncatalogued fungal spore, midfocus. Page 111. 1150X.
- C. Uncatalogued fungal spore, midfocus. Page 111. 1150X.
- D. MR-2. Page 85. Midfocus. Proximal polar view. 1150X.
- E. MR-3. Page 85. Mid- to upper focus. Oblique lateral view. 1150X.
- F. MR-4. Page 85. Midfocus. Polar view. 1150X.
- G. MR-5. Page 86. Midfocus. Polar view. 1150X.
- H. MR-6. Page 86. Low to midfocus at left, high focus at right. Polar view. 1150X.
- I. Uncatalogued angiosperm pollen grain. Page 111. High focus at left, midfocus at center, low focus at right. Equatorial view. 1150X.



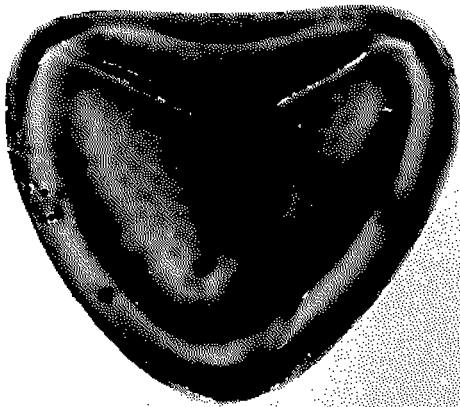
A



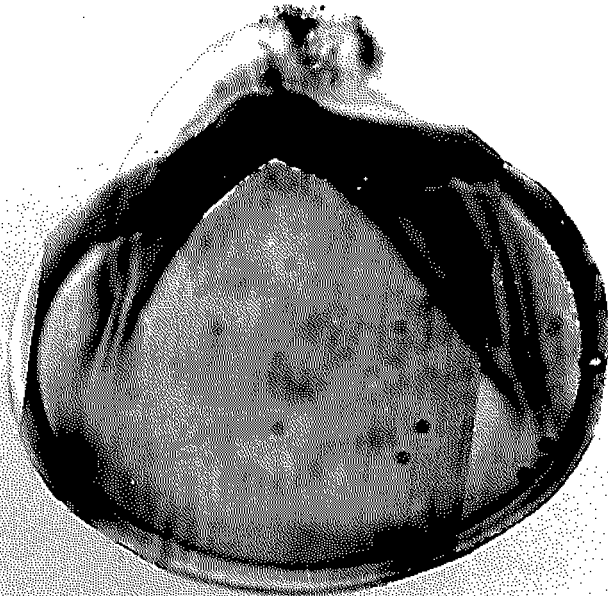
B



C



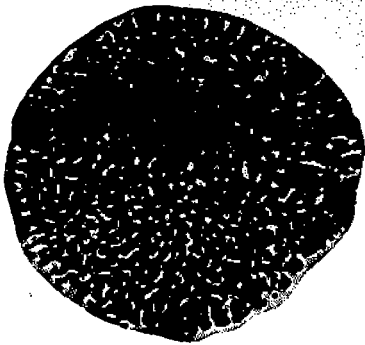
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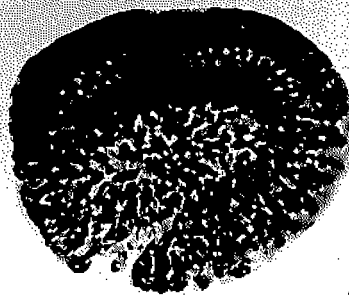
E



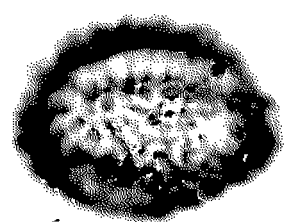
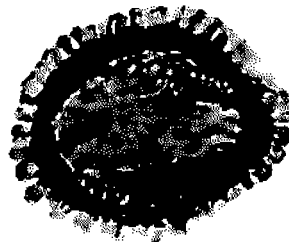
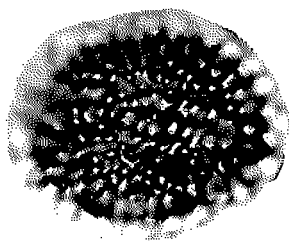
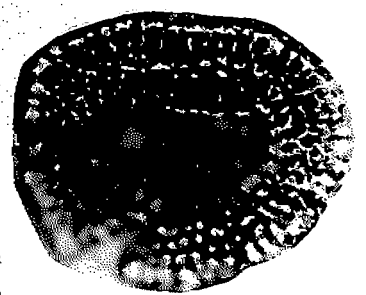
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G



H



I

PLATE I

CAPTION FOR PLATE II

- A. MR-7. Page 87. Midfocus with blue filter. Lateral view. 1150X.
- B. MR-8. Page 87. Midfocus with blue filter at left, low focus and no filter at right. Lateral views. 1150X.
- C. MR-9. Page 87. High focus with blue filter at left, no filter at right. Lateral view. 1150X.
- D. MR-10. Page 88. Midfocus at left, high focus at right. Equatorial view. 1150X.
- E. MR-11. Page 88. Midfocus on "top" of tetrad. 1000X.
- F. MR-12. Page 89. Midfocus. Polar view. 1000X.
- G. MR-13. Page 89. Midfocus. Polar view. 1000X.
- H. MR-14. Page 90. Midfocus. Polar view. 1000X.
- I. MR-15. Page 90. High to midfocus at left, midfocus to low focus at right. Polar view. 1000X.
- J. MR-16. Page 91. High focus at upper left, midfocus at center right, midfocus with blue filter at lower right. Polar view. 1150X.



A



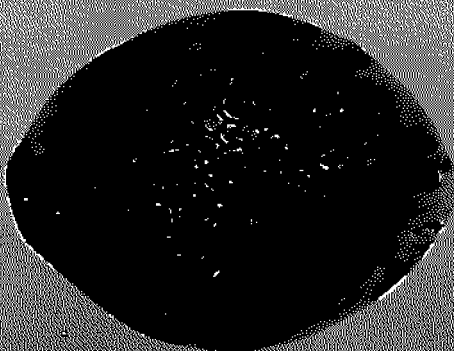
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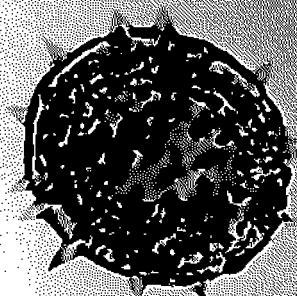
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D



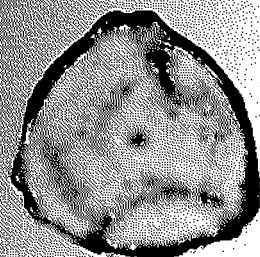
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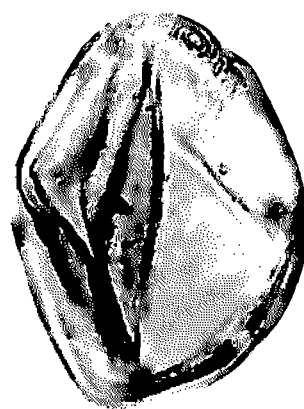
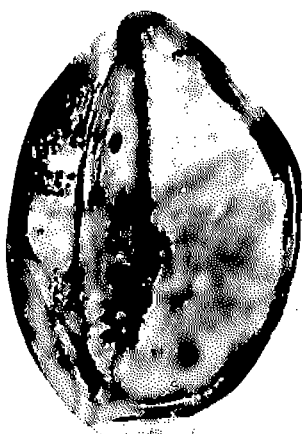
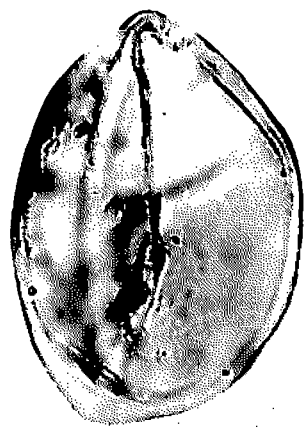
I



J

CAPTION FOR PLATE III

- A. MR-17. Page 91. High focus at left, midfocus at center, low focus at right. Distorted polar view? 1150X.
- B. Same. Furrow? in focus.
- C. Same. Pore in side view at top right.
- D. Same. Optical view of wall structure at right margin.
- E. Same. Midfocus at upper left, mid- to high focus at lower right. Elongate folds partially in focus.
- F. Same. Mid- to low focus. Pore annulus in focus on left flap.
- G. Same. Low focus upper left, mid- to high focus at center, high focus at lower right. Sculpture on exine surface faintly visible. Central figure illustrates common "magnolioid" configuration.
- H. Perhaps same as above but distinctly circular in this uncommon view.



B

A



C



D



E



G



H

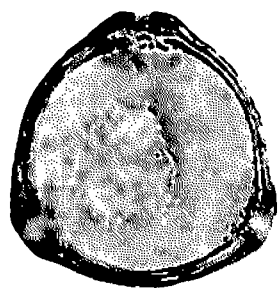


F

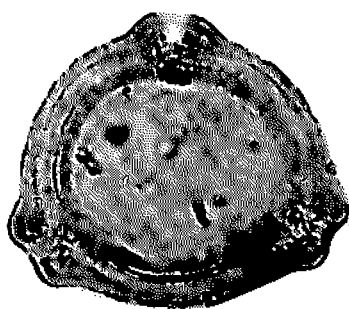


CAPTION FOR PLATE IV

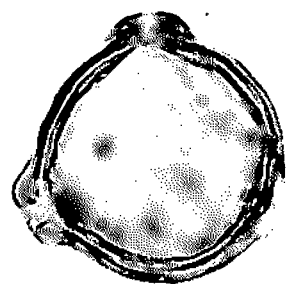
- A. MR-18. Page 92. Midfocus. Polar view. 1000X.
- B. MR-19. Page 93. Low to midfocus. Polar view. 1150X.
- C. MR-20. Page 94. Midfocus, one pore area slightly off the equator and out of focus. Polar view. 1150X.
- D. MR-21. Page 94. Midfocus above left, mid- to low focus at right. Polar view. 1150X.
- E. Same. Much larger specimen showing remnant of central membrane at high focus. Polar view. 1150X.
- F. MR-22. Page 95. Midfocus on left, low focus on right. Polar view. 1150X.
- G. MR-22. Another specimen with open pore canal in focus at upper left angle of amb. Left figure at high focus, right figure at midfocus. Polar view. 1150X.
- H. MR-21, MR-22. Typical undistorted views. 1000X.



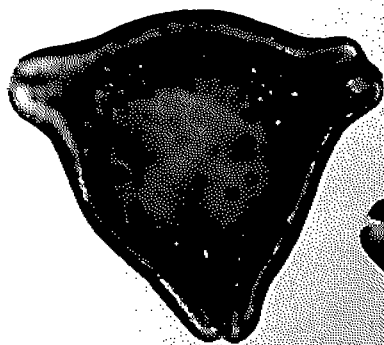
A



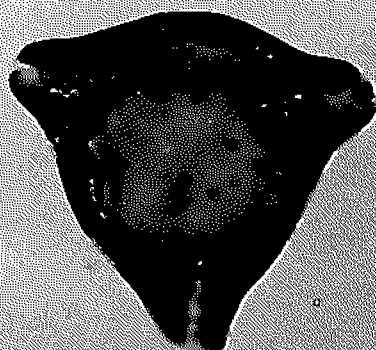
B



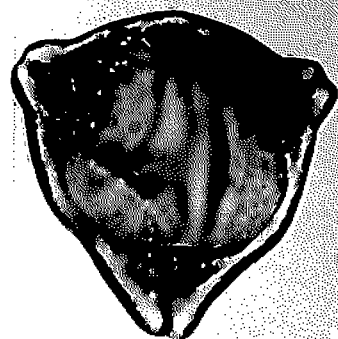
C



D



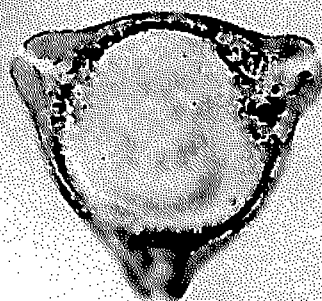
E



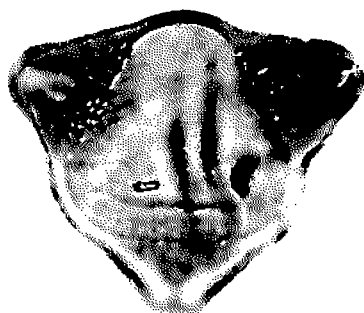
F



G

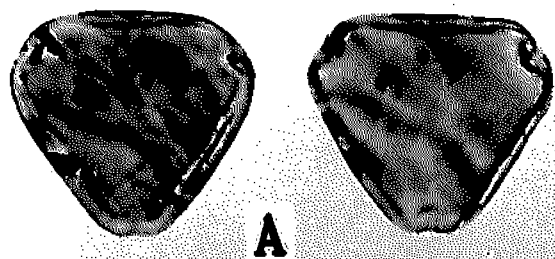


H

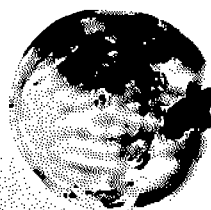


CAPTION FOR PLATE V

- A. MR-23. Page 96. High focus at left, midfocus at right. Polar view. 1150X.
- B. MR-24. Page 97. Midfocus at left, low focus at right. Lateral view. 1150X.
- C. MR-25. Page 97. High focus at left, midfocus at center, low focus at right. Equatorial view. 1150X.
- D. MR-25. Another view. Midfocus at left, low focus at right. Polar view. 1150X.
- E. MR-26. Page 98. Midfocus at left, mid- to low focus at right. Equatorial view. 1000X.
- F. MR-27. Page 98. High focus at upper left, midfocus at middle right, low focus at lower right. Oblique polar to lateral view. 1150X.
- G. MR-27. Another view. High focus at left, midfocus at center, low focus at right. Unexpanded polar view. 1150X.
- H. MR-27? High focus with filter at left, midfocus with filter above center, low focus without filter at right. Equatorial view. 1150X.
- I. MR-28. Page 99. Mid focus at left, low focus at right. Oblique lateral view. 1150X.
- J. MR-27 or MR-28. Mid to high focus. Oblique, expanded, polar view. 1000X.
- K. MR-29. Page 99. High focus. Expanded polar view slightly oblique. 1000X.
- L. MR-30. Page 100. High focus at upper left showing pore in optical section on left margin. Lower right shows other pores at midfocus. Polar view. 1150X.



A



B



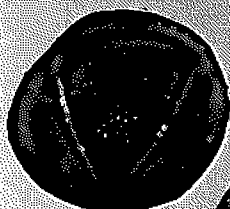
C



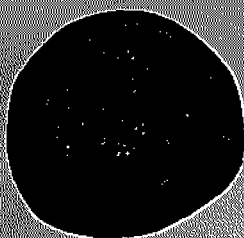
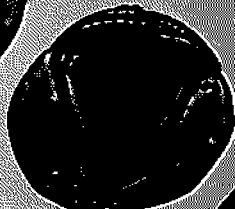
D



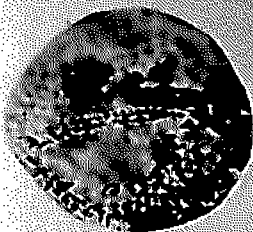
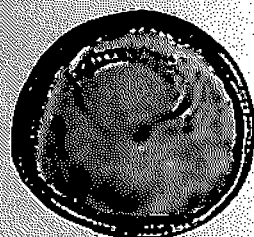
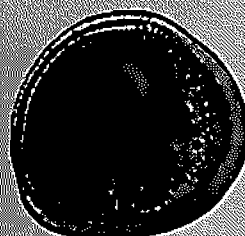
E



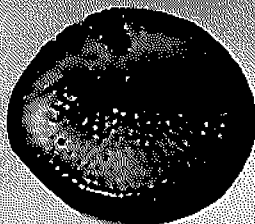
F



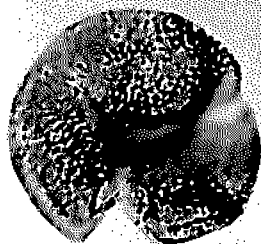
G



I



H



J



K



L

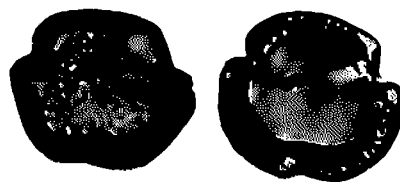


CAPTION FOR PLATE VI

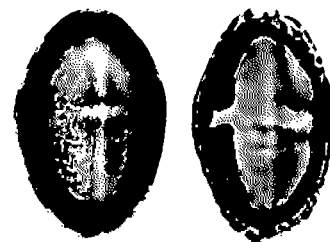
- A. MR-31. Page 100. High focus at left, midfocus at right. Slightly distorted polar view. 1150X.
- B. MR-32. Page 101. High focus at left, midfocus at right. Polar view. 1150X.
- C. MR-32. Another view. Low to midfocus on left, midfocus on right. Equatorial view. 1000X.
- D. MR-33. Page 101. High focus at left, midfocus above center, low focus at right. Equatorial view. 1150X.
- E. MR-34. Page 102. Mid- to high focus with blue filter. Polar view. 1150X.
- F. MR-35. Page 103. Midfocus. Polar view. 1150X.
- G. MR-36. Page 103. Midfocus. Polar view. 1150X.
- H. MR-37. Page 104. Midfocus. Polar? view. 1000X.
- I. MR-38. Page 104. Midfocus. Polar? view. 1150X.
- J. MR-39. Page 105. Midfocus. Polar view. 1000X.
- K. MR-40. Page 106. High focus at the left, midfocus above center, low focus at right. Polar view. 1150X.
- L. MR-41. Page 106. High focus at upper left, midfocus at middle right, low focus at lower right. Slightly oblique equatorial view. 1150X.
- M. MR-42. Page 107. High focus at extreme left, midfocus with blue filter at center left, midfocus without filter at center right, low focus at extreme right. Equatorial view. 1150X.



A



B



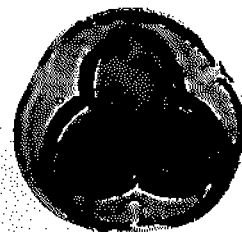
C



D



E



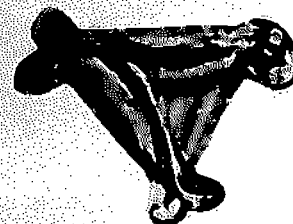
F



G



H



I



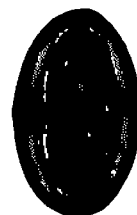
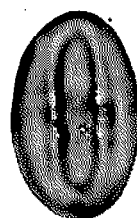
J



K



N



T

CAPTION FOR PLATE VII

- A. MR-43. Page 107. High focus at left, midfocus in center, low focus at right. Equatorial view. 1150X.
- B. MR-43. Another specimen. High focus at left, midfocus in center, low focus at right. Equatorial view. 1150X.
- C. MR-44. Page 108. High focus at upper left, midfocus at top center, low focus at upper right. Oblique equatorial view. 1150X.
- D. MR-45. Page 108. High focus at left, low focus at right. Equatorial view. 1150X.
- E. MR-46. Page 109. High focus at left, midfocus above center, low focus upper right. Equatorial view. 1150X.
- F. MR-47. Page 109. High focus extreme left, midfocus center left, midfocus with filter center right, low focus extreme right. Longitudinal view. 1150X.
- G. MR-48. Page 110. Midfocus on left, high focus on right. Longitudinal (or lateral?) view. 1150X.
- H. MR-49. Page 110. Midfocus. Lateral? view. 1000X.
- I. MR-50. Page 110. Midfocus. "Top" view of dyad. 1000X.



A

B



C



D



E



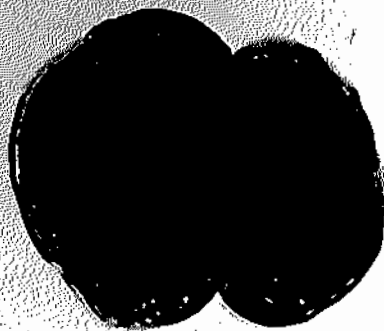
F



G



H



I

APPENDIX B

APPENDIX B

PLANT MEGAFOSSIL LOCALITIES AND SPECIES FROM THE RIPLEY FORMATION IN WEST TENNESSEE

The following list of Ripley localities in West Tennessee and the plant megafossils collected and described from them has been compiled largely from the publications of E. W. Berry (1925, 1928). Systematic arrangement used by that author has been retained except where synonymy has made alterations necessary. Synonyms indicated are those arising through 1937 as cited by LaMotte (1944).

Additional information concerning several of the sites was obtained from Wade (1926) although some doubt exists in regard to two of them. The Chester County locality described by Berry (1925) as $2\frac{1}{2}$ miles south of Mifflin was subsequently listed by Wade (1926, pp. 4, 8) first at 3 miles south of Mifflin, then later at 4 miles south of the town, on Jacks Creek road.

Another minor fossil plant locality whose location shows inconsistency is that listed by Berry (1925) as "Coon Creek, McNairy County." The two fossils are described as occurring in "the shell marl at Coon Creek" and assignment was made to the McNairy sand member of the Ripley formation. The name of the collector is not given. However, Wade (1926, p. 4) lists a plant locality in the Coon Creek tongue of the Ripley at "the John Boyd place, 5 miles northeast of Selmer, McNairy County" and, although no specific plant fossils are mentioned in this connection, it is probable that this is the locality implied by Berry. This assumption is further strengthened by Berry's reference to the shell marl which would seem to indicate the Coon Creek tongue rather than the McNairy sand member.

On the other hand, confusion in the literature surrounding another Ripley plant locality has been straightened out. Berry (1919, p. 38) first published on the occurrence of three species of fossil plants along the Camden-Paris public road in "the northwestern part of Benton County." Later, however, these three species are handled by Berry (1925) as separate collections made at two localities, 13 miles northwest of Camden, Henry County, and near Camden, Benton County. The collector, L. W. Stephenson, informs the writer¹ that only one collection of fossil plants was made by him along the Camden-Paris road and these were from a site 13 miles from Camden, Benton County, a distance that would place the locality well into Henry County. As a consequence, these fossils are listed below as from a single locality, Camden-Paris road, Henry County.

¹Personal communication, 1956.

LOCALITY I

Dr. J. R. Perry place, 10 miles
east of Paris, Henry County, on
the Manlyville Road. Occurrence:
McNairy sand member, Ripley forma-
tion.

PHYLUM PTERIDOPHYTA

Sphenopteris jorgenseni (Heer) Seward. Seward, 1926, p. 86.
Raphaelia neuropteroides Debey & Ettingshausen. Berry, 1925, p.
26, pl. 1, fig. 8.
Taeniopteris sp. (Many leaf specimens referred to this genus are
considered to be cycadophyte foliage by most paleobotanists.)

PHYLUM CONIFEROPHYTA

Protophyllocladus lobatus Berry
Moriconia cyclotoxon Debey and Ettingshausen. Seward and Conway,
1935a, p. 10, fig. 1.
Moriconia americana Berry. Berry, 1925, p. 31, pl. 3, figs. 3, 4.

PHYLUM ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order LILIALES

Family DIOSCOREACEAE

Dioscorites cretaceus Berry

Order ARECALES

Family ARECACEAE

Geonomites schimperii Lesquereux

Class DICOTYLEDONAE

-Series Choripetalae

Order JUGLANDALES

Family JUGLANDACEAE

Juglans similis Knowlton

Juglans tennesseensis Berry

Juglans wadlii Berry

Order MYRICALES

Family MYRICACEAE

Myrica wadii Berry
Myrica wadii minor Berry
Myrica minor Berry
Myrica brittoniana Berry
Myrica brittoniana obtusata Berry

Order SALICALES

Family SALICACEAE

Salix gardneri Knowlton?

Order URTICALES

Family MORACEAE

Artocarpus cretacea Berry
Ficus obtusa-sessilia Berry
Ficus crassipes (Heer) Heer
Ficus georgiana Berry

Order PLATANALES

Family PLATANACEAE

Platanophyllum insigne (Heer) Seward. Seward and Conway, 1935b, p. 29,
 fig. 27.
Cissites panduratus Knowlton. Berry, 1925, p. 70, pl. 14.

Order RANALES

Family MAGNOLIACEAE

Liriodendron laramiense Ward

Family MENISPERMACEAE

Menispermites variabilis Berry

Order PAPAVERALES

Family CAPPARIDACEAE

Capparis proeocenica Berry

Order ROSALES

Family MIMOSACEAE

Acaciaphyllites cretaceum Berry
Mimosites cooperensis Berry

Family CAESALPINIACEAE

Caesalpinites perryensis Berry
Caesalpinites ripleyensis Berry

Family PAPILIONACEAE

Dalbergia cretacea Berry
Dalbergia perryana Berry
Dalbergia prewilcoxiana Berry

Leguminosae (position uncertain)

Leguminosites canavalioides Berry
Leguminosites perryensis Berry
Gleditsiophyllum preovatum Berry
Gleditsiophyllum proecenicum Berry

Order GERANIALES

Family EUPHORBIACEAE

Euphorbiophyllum cretaceum Berry
Euphorbiophyllum petiolatum Berry
Euphorbiophyllum tennesseensis Berry

Order SAPINDALES

Family CELASTRACEAE

Celastrorhynchium cassinoides Berry
Celastrorhynchium minimum Berry
Celastrorhynchium perryi Berry
Celastrorhynchium ripleyanum Berry
Celastrorhynchium variabilis Berry
Pachystima? cretacea Berry

Order RHAMNALES

Family RHAMNACEAE

Rhamnus ripleyensis Berry
Zizyphus ripleyensis Berry
Zizyphus perryi Berry

Order MALVALES

Family TILIACEAE

Grewiopsis inequilateralis Berry

Order PARIETALES

Family TERNSTROEMIACEAE

Ternstroemites ripleyensis Berry
Ternstroemites cretaceus Berry

Order THYMELEALES

Family LAURACEAE

Laurus asiminoides Berry
Laurus atanensis Berry
Laurus coloradensis Knowlton
Laurus ripleyensis Berry
Laurophyllum ripleyensis Berry

Order MYRTALES

Family MYRTACEAE

Myrtophyllum angustum (Velenovsky) Berry

Order UMBELLALES

Family ARALIACEAE

Aralia problematica Berry
Aralia wellingtoniana minor Berry

-Series Gamopetalae

Order ERICALES?

Family ERICACEAE?

Andromeda anceps Berry

Order EBENALES

Family SAPOTACEAE

Bumelia prewilcoxiana Berry
Bumelia ripleyana Berry

Order GENTIANALES

Family APOCYNACEAE

Apocynophyllum perryensis Berry
Apocynophyllum alatum Berry

Position uncertain

Calycites ripleyensis Berry
Carpolithus perryensis Berry
Phyllites hydrilloides Berry

LOCALITY II

13 miles northwest of Camden, Benton
 County, on the Camden-Paris road in

Henry County. Occurrence: McNairy
sand member, Ripley formation.

PHYLUM ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order ARECALES

Family ARECACEAE

Sabalites sp.

Class DICOTYLEDONAE

-Series Choripetalae

Order MYRICALES

Family MYRICACEAE

Myrica ripleyensis Berry

Order MYRTALES

Family MYRTACEAE

Myrica havanensis Berry

LOCALITY III

Cooper pit, $1\frac{1}{2}$ miles south of Hollow
Rock, Carroll County. Occurrence:
McNairy sand member, Ripley formation.

PHYLUM BRYOPHYTA

Muscites? lesquereuxi Berry. Berry, 1928, p. 442, pl. 11, figs. 1-3.
Selaginella laciniata Berry not Lesquereux. Berry, 1925, p. 25.

PHYLUM PTERIDOPHYTA

Asplenium calopteris (Debey & Ettingshausen) Heer

Gleichenia delicatula Heer. (LaMotte, 1944, p. 165, follows species
name with a question mark.)

Monheimia aquisgranensis Debey & Ettingshausen

Raphaelia minuta Berry

Sphenopteris jorgenseni (Heer) Seward. Seward, 1926, p. 86.

Raphaelia neuropteroides Debey & Ettingshausen. Berry, 1925, p. 26,
pl. 1, fig. 8.

Taeniopteris sp. (See Locality I listing.)

PHYLUM CONIFEROPHYTA

Widdringtonites reichii (Ettingshausen) Heer
Moriconia cyclotoxon Debey and Ettingshausen
Geinitzia formosa Heer

PHYLUM ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order NAIADALES

Family NAIADACEAE

Potamogeton hydrocharitoides (Berry) Berry. Berry, 1928, p. 446, pl. 12.
Phyllites hydrocharitoides Berry. Berry, 1925, p. 88, pl. 22, fig. 9.
Potamogeton ripleyensis Berry
Alismaphyllum cretaceum Berry

Class DICOTYLEDONAE

-Series Choripetalae

Order MYRICALES

Family MYRICACEAE

Myrica cooperensis Berry
Myrica johnstrupi (Heer) Berry
Myrica ornata Berry
Myrica torreyi Lesquereux
Myrica torreyi obtusata Berry
Myrica wadii minor Berry

Order FAGALES

Family FAGACEAE

Dryophyllum gracile Debey
Dryophyllum protofagus Berry
Fagus ripleyensis Berry

Order URTICALES

Family ULMACEAE

Celtis cretacea Berry

Family MORACEAE

Artocarpus cretacea Berry
Ficus carrollensis Berry
Ficus celtifolius Berry
Ficus cooperensis Berry
Ficus krausiana Heer
Ficus ripleyana Berry
Ficus speciosissima Ward. Berry, 1935, p. 30.
Ficus leei Knowlton. Berry, 1925, p. 52.

Order RANALES

Family RANUNCULACEAE

Antholithes ranaliformis Berry

Order PAPAVERALES

Family CAPPARIDACEAE

Capparis proecenica Berry

Order ROSALES

Family MIMOSACEAE

Mimosites cooperensis Berry

Leguminosae (position uncertain)

Gleditsiophyllum aristatum BerryLeguminosites canavalioides BerryLeguminosites carrollensis Berry

Order GERANIALES

Family MELIACEAE

Cedrela prewilcoxiana Berry

Family EUPHORBIACEAE

Euphorbiophyllum antiquum Saporta and MarionEuphorbiophyllum petiolatum Berry

Order SAPINDALES

Family CELASTRACEAE

Celastrrophyllum carolinensis BerryCelastrrophyllum ripleyanum Berry

Family ACERACEAE

Acer cretaceum Berry

Order RHAMNALES

Family RHAMNACEAE

Zizyphus laurifolius BerryZizyphus ripleyensis Berry

Order MALVALES

Family TILIACEAE

Grewiopsis inequilateralis Berry
Grewiopsis ripleyensis Berry

Order PARIETALES

Family DILLENACEAE

Dillenia cretacea Berry

Family TERNSTROEMACEAE

Ternstroemia cretacea Berry
Ternstroemia tennesseensis Berry

Order THYMELALES

Family LAURACEAE

Cinnamomum newberryi ellipticum Berry
Cinnamomum newberryi lanceolatum Berry
Cinnamomum newberryi minimum Berry
Cinnamomum praespectabile Berry
Laurophyllum ripleyensis Berry
Laurus atanensis Berry
Nectandra prolifica Berry

Order MYRTALES

Family MYRTACEAE

Myrcia dubia Berry
Myrcia havanensis Berry
Myrtophyllum angustum (Velenovsky) Berry
Eugenia? anceps Berry

Order UMBELLALES

Family ARALIACEAE

Aralia problematica Berry

Family CORNACEAE?

Cornophyllum minimum Berry

-Series Gamopetalae

Order EBENALES

Family SAPOTACEAE

Chrysophyllum parvum Berry
Mimusops collinsi Berry

Order GENTIANALES

Family ASCLEPIADACEAE

Acerates cretacea Berry

Family APOCYNACEAE

Apocynophyllum giganteum BerryApocynophyllum sumterensis (Berry) BerryApocynophyllum ripleyensis Berry

Position uncertain

Carpolithus carrollensis BerryPhyllites ripleyensis Berry

LOCALITY IV

$\frac{1}{4}$ mile southwest of Buena Vista,
Carroll County, on the Huntingdon
road. Occurrence: McNairy sand
member of the Ripley formation.

PHYLUM CONIFEROPHYTA

Dammara acicularis KnowltonWiddringtonites reichii (Ettingshausen) Heer

PHYLUM ANGIOSPERMOPHYTA

Class DICOTYLEDONAE

-Series Choripetalae

Order THYMELEALES

Family LAURACEAE

Cinnamomoides newberryi (Berry) Seward. Seward, 1925, p. 253, pl. 100, fig. 29.Cinnamomum newberryi Berry. Berry, 1925, p. 75, pl. 16, fig. 5.

Order MYRTALES

Family MYRTACEAE

Myrtophyllum angustum (Velenovsky) Berry

LOCALITY V

2½ - 4 miles south of Mifflin,
Chester County, on Jacks Creek
road. Occurrence: McNairy sand
member of the Ripley formation.

PHYLUM ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order ARECALES

Family ARECACEAE

Geonomites schimperi Lesquereux

Class DICOTYLEDONAE

-Series Choripetalae

Order ROSALES

Family MIMOSACEAE

Mimosites cooperensis Berry

Order GERANIALES

Family EUPHORBIACEAE

Euphorbiophyllum petiolatum Berry

Order THYMELEALES

Family LAURACEAE

Cinnamomoides newberryi (Berry) Seward. Seward, 1925, p. 253, pl.
100, fig. 29.

Cinnamomum newberryi Berry. Berry, 1925, p. 75, pl. 16, fig. 5.

Order MYRTALES

Family MYRTACEAE

Myrtophyllum angustum (Velenovsky) Berry

LOCALITY VI

2½ miles southwest of Selmer,
McNairy County, on New Bethel
road. Occurrence: McNairy sand
member of the Ripley formation.

PHYLUM ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order ARECALES

Family ARECACEAE

Sabalites sp.

Class DICOTYLEDONAE

-Series Choripetalae

Order MYRICALES

Family MYRICACEAE

Myrica ripleyensis Berry

Order FAGALES

Family FAGACEAE

Dryophyllum gracile Debey

Order RANALES

Family MAGNOLIACEAE

Magnoliaephyllum thomsenianum (Heer) Shotton. Seward and Conway,
1935b, p. 19, figs. 15, 16.

Magnolia capellinii Heer. Berry, 1925, p. 55.

Order ROSALES

Family CAESALPINIACEAE

Bauhinia ripleyensis Berry

Order GERANIALES

Family EUPHORBIACEAE

Manihotites georgiana Berry

Order RHAMNALES

Family VITACEAE

Cissites crispus Velenovsky

Order MALVALES

Family STERCULIACEAE

Sterculia snowii tennesseensis Berry

Order THYMELALES

Family LAURACEAE

Cinnamomoides newberryi (Berry) Seward. Seward, 1925, p. 253, pl.
100, fig. 29.

Cinnamomum newberryi Berry. Berry, 1925, p. 75, pl. 16, fig. 5.
Malapoenna horrellensis Berry

Order MYRTALES
 Family MYRTACEAE

Eugenia? anceps Berry
Myrcia havanensis Berry

Position uncertain

Halymenites major Lesquereux

LOCALITY VII

Big cut, Southern RR., $1\frac{1}{2}$ miles
 west of Cypress, McNairy County.
 Occurrence: McNairy sand member
 of the Ripley formation.

PHYLUM ANGIOSPERMOPHYTA
 Class DICOTYLEDONAE
 -Series Choripetalae
 Order FAGALES
 Family FAGACEAE

Dryophyllum gracile Debey

Order THYMELEALES
 Family LAURACEAE

Malapoenna horrellensis Berry

Order MYRTALES
 Family MYRTACEAE

Myrcia havanensis Berry

LOCALITY VIII

Assumed to be John Boyd place, 5
 miles northeast of Selmer, McNairy
 County. Occurrence: Coon Creek
 tongue? of the Ripley formation.

PHYLUM ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order ARECALES

Family ARECACEAE

Geonomites schimperi Lesquereux

Position uncertain

Carpolithus ripleyensis

APPENDIX C

APPENDIX C

BIBLIOGRAPHY OF MESOZOIC PALYNOLOGY

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