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PLANT MICROFOSSILS OF THE LAMINATED SEDIMENTS OF THE LOWER EOCENE WILCOX GROUP IN SOUTH-CENTRAL ARKANSAS

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PLANT MICROFOSSILS OF THE LAMINATED SEDIMENTS OF THE

LOWER EOCENE WILCOX GROUP IN SOUTH-CENTRAL ARKANSAS

by Eugene L.averne Jones

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A total of 62 spore and pollen genera are described from the laminated sediments of the Wilcox group in south-central Arkansas. Of these, 40 are assigned to natural plant genera and the remainder to form genera. Angiospermous pollen dominates the microflora, and a small, tricolporate type, identified as *Castanea*, is the most abundant. The spores *Anemia* and *Lygodium* are common. The gymnosperms are represented by *Pinus*, *Taxodium*, *Cryptomeria*, *Podocarpus* and *Ephedra* (?).

The microflora and the megaflora of the Wilcox group have few genera in common. The same situation has been described for other well-known fossil floras. The Wilcox microflora like the megaflora is a mixture of temperate and tropical plant genera. An area like that of present day eastern Mexico, with highlands adjacent to a warm, low coastal plain, is postulated as the lower Eocene environment of the Gulf Coastal Plain. The absence of detrital feldspar in the Wilcox sands, despite the presence of a local igneous source, supports this interpretation. The deltaic origin of the Wilcox group in Arkansas, indicated by sedimentary features, is also suggested by the presence of small numbers of Dinoflagellata and Hystrichosphaeridae throughout the section.

The microflora is relatively uniform in composition through much of the section. This is expectable because the nature of the sediments indicates little or no change in the environmental conditions. A distinctive change, an abrupt decrease in tricolporate pollen, does

occur in the upper part of the section and possibly is of regional stratigraphic significance. Two other floristic anomalies, an increase in *Pinus* pollen and an increase in dinoflagellates, are also possibly stratigraphically important for regional correlation. A comparison of the Wilcox microflora with other Tertiary spore and pollen floras reveals a close similarity with the Eocene microfloras of Europe.

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INTRODUCTION

Nature of the Investigation

The investigation of the spore and pollen flora of the laminated sediments of the lower Eocene Wilcox section in south-central Arkansas was undertaken with a number of objectives in view. The primary goal was the enumeration and description of the microflora. The investigation was conducted so as to show any vertical change in the flora that would serve for the zonation of the section. The nature of the flora was evaluated in order to determine the environmental conditions of the area at the time of the deposition of the Wilcox sediments. The indications of the depositional environment as shown by the flora were compared with those obtained through a study of the sediments.

The results of previous studies of the nature of the Wilcox flora of the Coastal Plain as represented primarily by leaf impressions were available for comparison with the spore and pollen flora.

Finally, through comparison of the Wilcox flora with the Tertiary floras of other areas, the possibility of using the plant microfossils for purposes of correlation of the Wilcox group was evaluated.

Geography of the Area Studied

The material used in the investigation was collected from outcroppings of sediments of the Wilcox group in Saline County, Arkansas. The location of the area is shown by the map in figure 1.

This area is a part of the Gulf Coastal Plain in Arkansas and is near the boundary of that region with the Interior Highlands.

The Coastal Plain is a region of low relief. The maximum change in elevation in the area of study is less than 300 feet, with elevations ranging from a minimum of some 250 feet above sea level to a maximum of slightly more than 500 feet. This situation, coupled with the poorly indurated nature of the Wilcox sediments, resulted in a paucity of exposures suitable for study. Artificial exposures including road cuts, open pit mines and railroad cuts were utilized, as well as natural exposures along streams.

The major drainage feature in the area is the Saline River. It is along this stream that the most extensive sections of the laminated sediments of the Wilcox group are exposed. Outcroppings along the Saline River are shown in figures 2 and 3.

General Geology

The surface rocks of the area are predominantly of the Tertiary system. A small exposure of nepheline syenite, possibly Cretaceous in age, is present to the east of the town of Benton. To the north of the area of study, Paleozoic rocks of the Ouachitas crop out and mark the beginning of the Interior Highlands.

The Tertiary system is represented by the Paleocene Midway group and the Eocene Wilcox group. Locally, these rocks are overlain by alluvial materials and by terrace sands and gravels of post-Eocene age.

The Tertiary rocks seem to be essentially flat lying in the area. A study of the information derived from test holes drilled in exploration for bauxite deposits in Saline County and from electric logs of wells drilled for oil and gas in adjacent counties indicates a gentle, somewhat irregular dip to the southeast.

Methods of Investigation

Sampling Technique

After suitable exposures were located in the field, a series of channel samples were collected in 18-inch units from each. The exposures were selected and the sampling conducted so as to give as complete a section of the laminated sediments as possible, despite the lack of extensive exposures. The first series of samples were from a section just above the Wilcox-Midway contact. The last series included a section of laminated sediments just below the massive silts and clays which overlie the laminated zone.

Method of Processing

The sediments were processed in the Palynological Laboratory of the Oklahoma Geological Survey. The flow sheet in figure 4 summarizes the processing schedule.

Disaggregation was accomplished by crushing with mortar and pestle. The siliceous fraction of each sample was removed by treatment with commercial grade hydrofluoric acid for a period of 48 hours. After washing with distilled water to remove excess acid, the samples were then treated for 10 minutes with concentrated ammonium hydroxide. Further washing with distilled water was then carried out to remove the excess ammonium hydroxide.

Figure 2. Wilcox sediments of sample interval 4 which crop out along the Saline River near Benton, Arkansas

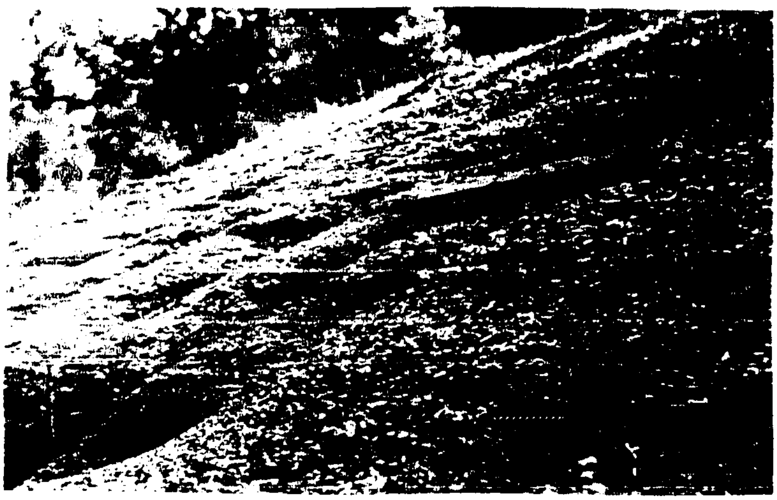

Figure 3. Wilcox sediments of sample interval 5 exposed along Saline River in Saline County, Arkansas

1. Crush sample to coarse sand or fine gravel sized fragments.

2. Treat with 52 percent hydrofluoric acid for 48 hours.

3. Wash residue with distilled water.

4. Treat with concentrated ammonium hydroxide for 10 minutes.

5. Wash residue with distilled water.

6. Centrifuge residue in zinc chloride solution.

7. Wash floating fraction with distilled water.

8. Stain with saffranin "O".

9. Mount residue on microscope slides and store surplus in labeled vials.

Figure 9. A flow sheet of processing procedures.

To remove additional inorganic detritus, each sample was then centrifuged for five minutes in a zinc chloride solution having a specific gravity of 1.48, slightly greater than the spores and pollen grains contained in the sample and less than the inorganic detritus. Spores and pollen could then be decanted from the centrifuge tube in the upper part of the solution. Additional washing with distilled water removed the zinc chloride.

A portion of the resulting concentrate of plant microfossils from each sample was then stained with safranin "O" and mounted on microscope slides with clearcol as the mounting medium. A minimum of 10 slides was made for each sample to insure an adequate number of specimens for study.

Of the more than 100 samples processed, 60 contained an identifiable flora and the others were apparently devoid of plant microfossils. Many of the barren sections were sands, but in some instances the laminated sands and clays failed to yield a flora. There is no obvious explanation for these barren zones. Lithologically, these sections were not anomalous. They appeared to be identical in every respect to the sediments that yielded abundant plant microfossils.

Personal communications from other investigators who have processed Tertiary sediments from other parts of the Coastal Plain mention barren sections in those areas also.

Examination of Slides

The plant microfossils on the slides were then identified and counted using an American Optical Company Microstar binocular microscope with a mechanical stage. To insure that a sufficient number of individual grains were counted to give a valid representation of the flora, a species stratum curve was constructed for each level using the method described by Wilson (1959, p. 91-93). Data showing the relative abundance of genera making up the flora were plotted as histograms.

Examination of Sediments

A study was also conducted to determine the nature of the sediments making up the sections examined for spores and pollen.

The size distribution of the laminated sediments were determined by using standard methods of sieving for the coarse fraction, sand sizes, and by pipette and hydrometer methods for the fine fraction, grains smaller than 0.062 millimeters in diameter. The result of this study was also plotted as histograms.

Massive sand bodies were also examined as to the size distribution of the grains and as to mineral composition. Size distribution was determined by sieving. Mineral composition was determined by study with binocular and polarizing microscopes. The quartz-feldspar ratio was investigated and the amount and nature of the heavy minerals present was determined. Heavy and light minerals were separated through the use of tetrabromethane. Fractions of each group were then mounted on microscope slides in Canada balsam. The light minerals were examined with a polarizing microscope for the quartz-feldspar ratio and the heavy minerals were studied to determine the nature and distribution of the heavy mineral suite present in the Wilcox sands.

STRATIGRAPHY OF THE WILCOX GROUP

History of Nomenclature

The term Wilcox was officially adopted by the United States Geological Survey on March 23, 1905, according to Wilmarth (1938, p. 2333). The type locality was selected as Wilcox County, Alabama, not the town of Wilcox, Alabama, as has since been asserted by some authors. The name was published in the following year in reports by Crider and Johnson (1906, p. 5, 9) and by Crider (1906, p. 25) to describe the section overlying the Midway group and underlying the Claiborne group. Since that time the term has been in general use in descriptions of Coastal Plain Tertiary geology.

Prior to 1906 a variety of terms had been used in reference to this part of the Tertiary section. Some of these include the equivalent of the Wilcox, some only a part of the present Wilcox, and others include parts of other Tertiary stratigraphic units and even portions of the Cretaceous system. Among the terms used are the following: Lignitic by Stafford (1856), Northern Lignitic by Hilgard (1860), La Grange by Safford (1864), Mansfield by Hilgard (1869), Camden series by Hill (1888), Chickasawan by Dall (1898), and Sabine by Penrose (1890) and by Veatch (1906).

For a time Sabine was acceptable west of the Mississippi River, but in 1910 the United States Geological Survey dropped the term as a

Figure 10A. Cross-bedded sands of the Wilcox group in sample interval 4 in Saline County, Arkansas.

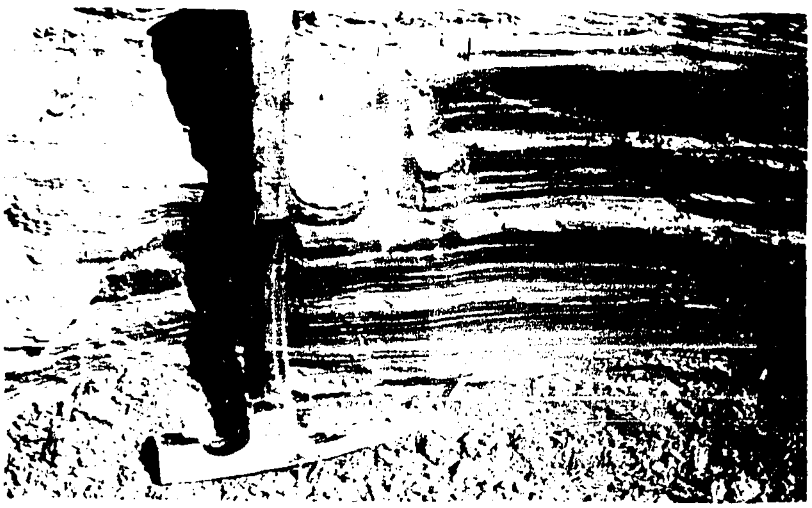

Figure 10B. Laminated Wilcox sediments in sample interval 5 in Saline County, Arkansas.

junior synonym of Wilcox. Howe (1933, p. 617) proposed that the name Wilcox be supressed in favor of Sabine. Murray (1955, p. 685) proposed that Wilcox be retained as a rock unit name and that Sabine be adopted as the name of the lower Eocene stage. This system of nomenclature proposed by Murray is used by many Gulf Coast geologists.

Regional Stratigraphy

The Wilcox group is subdivided into formations in most of the Gulf Coastal Plain. Many of these units, described in areas of outcrop of the Wilcox group, cannot be recognized in the subsurface. Few of them are carried from state to state. As a result the literature concerning Wilcox stratigraphy is complicated by an extensive, complex nomenclature. Attempts to correlate the units within the Wilcox group have been made despite the abrupt vertical and lateral changes in lithology and the prevalence of non-marine sediments. Barry and LeBlanc (1942) were able to correlate certain faunal zones from Alabama to Louisiana and Texas.

Throughout much of the Coastal Plain sediments of the Wilcox group rest upon the Midway group of Paleocene age. The determination of this boundary is, in most areas and particularly in the subsurface, a difficult problem.

A general practice among petroleum geologists is that of considering the base of the Wilcox group to be at the base of the last prominent sand development shown on electric logs of wells drilled in an area. This method of determination of the boundary is mentioned by Jung and Malkin (1948, p. 17). They pointed out that the boundary is possibly transitional, as is indicated by the absence of a marked unconformity both in the subsurface and in many areas of outcrop. They considered it to be quite possible that many shales referred to as Midway are actually part of the Wilcox group and that many sands called Wilcox are actually Midway in age.

In his study of the northern part of the Mississippi Embayment, Stearns (1957, p. 1082) found that as much as 200 feet of sandy sediments are present below the last definite Wilcox sand body and the top of the Porters Creek clay of the Midway group. He considered this section to be Midway because it appeared to grade laterally into the Porters Creek clay. He marked the base of the Wilcox at the base of the "1400 foot sand", a prominent sand body which serves as an aquifer in a part of the embayment.

Murray and Thomas (1945, p. 60) described what they considered to be Midway sediments above the Porters Creek clay and below the *Ostrea thirsae* zone in the lower part of the Wilcox group in Louisiana.

Lowe (1933, p. 131), in writing of the Midway-Wilcox contact in Mississippi, pointed out that there was no apparent break in deposition in that area and that "...the plane marking the division between the two is physically rather arbitary than exact" and that there appeared to be a transitional zone of considerable thickness.

The upper boundary of the Wilcox group is also problematical in many parts of the Coastal Plain. The Claiborne group of Middle Eocene age overlies the Wilcox in much of the Coastal Plain.

Stearns (1957, p. 1082) considered the Wilcox-Claiborne contact to be the base of the "500 foot sand", a prominent sand body shown by electric logs of wells drilled in the upper part of the Mississippi embayment.

Murray (1955, p. 688) defined the Wilcox-Claiborne boundary lithologically as being the point of the "...first occurence of clays and silts, commonly lignitic or carbonaceous, and/or dirty sands, below the marine greensands of the Claiborne Stage".

Lowe (1933) reported an unconformity separating the Wilcox and Claiborne sediments in Mississippi. In view of later work which redefined the two upper formations of the Wilcox as being Claiborne in age, (Brown 1947, p. 34), the contact in that area has become problematical.

Local Stratigraphy

The Wilcox section is shown on the State Geological Map of Arkansas, edited by H. D. Miser and G. W. Stose in 1929, as a single formation. More recent publications of the Arkansas Geological Survey also consider it in this respect. However, a sample log from a well drilled in Clay County, Arkansas, and compiled by the Missouri Geological Survey was published in a report by Renfroe (1940) showed the Ackerman and Holly Springs formations.

Gordon, Tracey and Ellis (1958, p. 38) subdivided the Wilcox section in the bauxite-producing areas of Pulaski and Saline Counties into three formations based upon lithologic criteria.

The basal unit is the Berger formation, which received its name from the Berger siding on the Rock Island and Pacific railroad where the section is exposed in railroad and highway cuts. The siding is in Pulaski County, four miles south of Little Rock. Lithologically, the formation is described as consisting of greenish-gray sands and clay as well as lignites, lignitic clays, kaolinitic clay, bauxitic clay and bauxite. Its thickness in outcrop is limited to 25 feet. Drill-hole data indicate a maximum thickness of 90 feet. It is absent in at least part of the area.

Resting with unconformity upon the Berger formation is the Saline formation, named for exposures along the Saline River near Benton, Arkansas. The formation, reaching a maximum thickness of almost 500 feet according to drill-hole information, consists of sands, interlaminated brown, lignitic clay and sands, lignites and clay. C don, Tracey and Ellis also consider the coarse sands and gravels underlying the town of Benton to be a part of the Saline formation.

The Dentoni sand, named for the small settlement of Dentoni on the Missouri Pacific railroad in southern Saline County, is the uppermost unit in the Wilcox group in the bauxite producing area. It consists of several hundred feet of homogenous sands. Some clay and a basal lignite are also included in the formation. The Dentoni sand rests conformably upon the Saline formation. Drill-hole information indicates a thickness of more than 400 feet for the Dentoni sand.

The formations described by Gordon, Tracey and Ellis (1958, p. 38) are restricted in their areal distribution to parts of Saline and Pulaski Counties in central Arkansas. The relationship of these formations to the Wilcox sections in the other parts of the Coastal Plain in Arkansas, both surface exposures and subsurface sections, is unknown. There is little justification to attempt to correlate them with the Wilcox formations in other states.

Berry (1930, p. 37) stated that "...the floras preserved are sufficient to render conclusive the statement that Wilcox deposits of the western Gulf area are either of Holly Springs (middle Wilcox) or Grenada (Wilcox) age. In other words, the Ackerman, or lower Wilcox, of the eastern Gulf area does not outcrop west of the Mississippi River". Although the work by Barry and LeBlanc on Wilcox faunas in Texas and Louisiana disproves Berry's contention as to the age of the Wilcox in those areas, it remains that, so far as Arkansas is concerned, fossil evidence based primarily on a study of leaf impressions places the Wilcox sediments well up in the type section.

There is a strong lithologic similarity between the upper 200 to 250 feet of the Wilcox section in Alabama as described by Crider (1906, p. 28) and the Saline formation of central Arkansas. Both sections consist of highly laminated, chocolate-colored clays. The lower boundary of the Wilcox sediments in the subsurface of eastern and southern Arkansas is, at many places, of the transitional type as shown by electric logs of wells drilled in those areas. Renfroe (1949, p. 12) reported that he was able to detect a lithologic change from silty sandstone to a dark-gray or blue silty shale that marked the base of the Wilcox in eastern Arkansas. He also reported that commonly there were hard, sideritic layers occurring at this point. He stated that the contact as marked by the lithologic change was considerably below the last porosity curve on the electric log, the usual basis for the determination of the boundary.

In the area in central Arkansas in which the Wilcox crops out the lower boundary is more definite. In most of the area it rests with distinct unconformity upon the eroded surface of the dark, blue-gray Midway clay. Wilcox sediments rest locally upon the folded Paleozoic rocks of the Ouachitas and upon syenites of possible Cretaceous age.

In central Arkansas the Wilcox is commonly overlain by the Middle Eocene Claiborne. Locally, however, it is covered by alluvium deposited by the Saline River or by gravels, post-Eocene in age.

In this area the Wilcox-Claiborne contact is nebulous. Gordon, Tracey and Ellis (1958, p. 58) considered the possibility that a part of the section considered as Wilcox in their report was actually Claiborne. In view of the reassignment of a part of the Wilcox section in Mississippi to the Claiborne group, such a possibility must certainly be considered.

Wilbert (1953, p. 51) assigned a section mapped as Claiborne on the Geologic Map of Arkansas to the Jackson group. The Claiborne-Wilcox boundary is shown by the State Map to be some four miles to the east. Unless the Claiborne section is unusually thin in the area, this boundary is also in error if Wilbert's assertion is correct.

Field work by the author has failed to produce any real justification for changing the boundary shown on the State geologic map.

SEDIMENTS OF THE WILCOX GROUP

Depositional Environment

Sediments of the Wilcox group have been the subject of extensive investigation, both as to the nature of the sediments and the conditions under which they were deposited. The investigators generally agree that the deltaic environment with its diverse conditions such as water depth and salinity can satisfactorily explain the extensive lateral and vertical variations in the nature of Wilcox sediments.

Murray (1945) suggested that the three subdivisions of the deltaic environment, the shallow water marine, the coastal marsh and the fluviatile deposits of river channels and flood plains, are each represented in the Wilcox section of the Gulf Coastal Plain.

Echols and Malkin (1948, p. 13) recognized two great deltaic masses as comprising the sediments of the Wilcox group. They referred to one of these as the Rockdale delta and the other deltaic mass as the Holly Springs delta. From a study of isopachous maps of Lower Eocene sediments, they inferred that the greatest period of delta building was in Middle Wilcox time. Non-marine sediments of this age extend far down dip.

Culbertson (1940), as did Echols and Malkin, noted that the thick non-marine section of the Middle Wilcox is generally overlain by a thin, shallow-water marine Upper Wilcox section.

Borings made through modern deltas support the concept of a deltaic origin for Wilcox sediments. Shepard and Lankford (1959, p. 2058) reported finding zones of laminated sediments which alternated with massive zones of clay, with sandy silts and sandy clays in cores taken from the lower Mississippi delta. Shepard (1956) stated that the sediments in cores taken from the delta platform are almost always distinctly laminated but the laminated sediments do not extend much, if any, beyond the delta platform. Sediments from deeper water are structureless. He also reported finding cross-bedded zones present in the laminated sections.

The modern delta sediments closely resemble the laminated brown, lignitic clays which contain zones of silty sands in the Saline formation near Benton, Arkansas. Such an alternation of laminated and massive sediments is shown in the measured section in figure 7 which is in the area of the type locality of the formation. A cross-bedded sand interval is also present.

Shepard and Lankford described individual laminae as normally less than one centimeter in thickness. Their illustrations indicated that the boundaries between coarse and fine laminae are distinct.

Laminated sediments from the Mississippi delta were also described by Scruton (1955, p. 35-37). He classed them as delta-front silts and clays. The thickness of individual laminae range up to ten centimeters. He considered the delta front sediments to be shallow water in origin. Because of continuous reworking, sorting and transportation, well-sorted coarse sediments alternate with laminae of well sorted sandy clays and clayey silts.

A histogram of a sample of the laminated sediments from the Saline formation, shown in figure 11, illustrates the nature of the textural boundary between the fine and coarse laminae.

Grain Size Distribution

Histograms of the size distribution of sands from the Saline formation of the Wilcox group are shown in figures 12A - 12D. The histograms in figure 12A are of sand from the massive, sandy zone in the measured section in figure 9, and the histogram in figure 12B is of the cross-bedded sand overlying that zone.

A more extensive study of the grain sizes of Wilcox sands of central Arkansas by Jones (1959) indicated that the degree of sorting was extremely variable. This is expectable as the result of the variation in depositional conditions of the deltaic environment. The results of this study showed the diameters of the bulk of the sand in the Wilcox group in Arkansas to range from 0.5 to 0.062 millimeters.

Analyses of the fine laminae of the Saline formation showed a concentration of material with diameters below 0.00138 millimeters. The analyses were carried out using the pipette method described by Rittenhouse (1939). Results were checked using a Bouyoucos hydrometer.

Grim (1936) conducted a survey of the Tertiary sands of Mississippi. Histograms of sands from the Wilcox group showed the bulk of the material to have diameters ranging from 0.89 millimeters downward and with much of the material smaller than 0.45 millimeters in diameter.

Shepard (1956) reported that sediments deposited in open water in the Mississippi delta area are dominantly fine sand and silt-sized materials with diameters ranging from 0.125 to 0.016 millimeters.

Mineral Composition of Sediments

Grim (1936), in his analysis of Tertiary sediments of Mississippi, described mineral composition as well as grain-size distribution of the sands. He reported finding quartz as the dominant mineral constituent of the sands from the Wilcox group. A mica, apparently muscovite, was also common in the coarse fractions of the sands. Grains of chert were rare. Feldspar was essentially absent.

He reported heavy minerals to constitute an average of from three to four percent by weight of the total volume. The range was from a trace to as much as nine percent of the total. The higher percentages appeared to be "pay zones" of heavy minerals concentrated by depositional processes.

Kyanite was reported as the dominant heavy mineral in most of the sands. Staurolite was commonly found but nowhere in large amounts. Zircon was normally abundant. Tourmaline was present in most sands, but in varying amounts. Rutile, ilmenite and sillimanite were generally present in small quantities. Leucoxene was found as an alteration product of ilmenite. Shapes of the grains included both angular and well-rounded types for most of the minerals.

Todd and Folk (1957) described the petrology of the Carrizo sand in Texas. They considered it to have been formed from reworked Wilcox sediments and to be earliest Claiborne in age. Many others assign the Carrizo to the Wilcox group. Todd and Fold found the dominant mineral in the Carrizo sand to be quartz. Potash feldspar grains constituted from five to ten percent of the total volume by weight. Heavy minerals present in the Carrizo included kyanite, staurolite, zircon and tourmaline, with small amounts of garnet and rutile.

The dominant mineral of the sands from the Wilcox group in Arkansas is also quartz. Chert is rare and feldspar is essentially absent. Muscovite is common in the coarser factions.

The percentage of the total volume of Wilcox sands made up of heavy minerals ranges from a trace to as much as 4.5 (Jones, 1959). That from the Saline formation is well within these limits.

Heavy minerals present in these sands include zircon and tourmaline as the more abundant constituents. Kyanite, rutile, ilmenite and magnetite are also common. Bramlette (1938) reported finding garnet as well. Zircon is present as angular grains, rounded grains and also as euhedral, doubly terminated prisms. Tourmaline, both brown and blue varieties, is present as both rounded and angular grains. Kyanite and rutile grains are angular while the opaque minerals are well rounded.

Source Area for Sediments

Grim (1936) interpreted the lack of variation, either vertical or lateral, in the heavy minerals of the Wilcox sands of Mississippi to be indicative of a single source area for these sediments. He suggested that the most probable source area was a combination of the southern Appalachians and the older rocks of the Coastal Plain.

Todd and Folk (1957, p. 2564) also considered the southern Appalachians to be the ultimate source area for the sediments forming the Carrizo sand. They suggested that the Tertiary sediments of the Coastal Plain reflect tectonism which began in the southern Appalachians in the Midway or Sabine stage.

If these postulations as to the source area for Eocene sediments in Texas and Mississippi are acceptable, it can be assumed that the same area supplied at least a part of the sediments of the Wilcox group in Arkansas. The strong degree of similarity of the heavy mineral suites of the three areas supports such an inference as to a genetic relationship.

The Paleozoic sedimentary rocks of the Ouachita and Ozark uplifts could also have supplied sediments to the central Arkansas area during Wilcox time. Local sources of sediments also included the syenite outcroppings near Benton in Saline County and near Little Rock in Pulaski County. The extensive bauxite deposits in the area, derived from weathering of the syenites, indicates they were a source of sediments.

Cyclical Deposition

It has been noted by a number of investigators of Upper Cretaceous and Tertiary sediments of the Coastal Plain that they appear to be cyclical in their nature.

Bornhauser (1947, p. 621) recognized four and possibly five major cycles of marine deposition in Tertiary sediments of the Coastal Plain. Each cycle consists of a transgressive phase, an inundative phase and closes with a regressive phase. The cycles are characterized by the relatively poor development of the transgressive phase, illustrated by the Clayton formation of the Midway group, by the impressive nature of the regressive phase, shown by the entire Wilcox group, and by the considerable lithologic variation in the types of sediments. He considered these cycles to be initiated by epeirogenic movements. A table showing the cycles is given in figure 13.

Only cycle I of the cycles described by Bornhauser can be recognized with certainty. Claiborne sediments in Arkansas are undifferentiated. This precludes the possibility of the recognition of cycles II and III. Wilbert (1953) described three distinct marine facies in the Jackson of Arkansas. He interpreted them as representing a transgressive and inundative phase of a cycle of deposition. This apparently correlates with cycle IV of Bornhauser. Oligocene sediments have not been identified in Arkansas.

A different type of cyclical deposition was described by Murray and Thomas (1945, p. 54). They described cycles in Tertiary sediments which consists of (1) a basal unit which is a massive to broken sand; overlying this is (2) a carbonaceous shale with lignite zones. This, in turn, is overlain by (3) a calcareous silt and shale unit that may also have lignites. The cycle is completed by (4) another "massive to broken" sand member. Cycles are often incomplete, and, where possible, each member is considered as a separate formation.

They postulated that each cycle was initiated by a sharp increase in the gradient of the streams that were depositing their loads on a broad, low, coastal plain. This change in gradient caused the streams to transport the fine components of their loads far out into the depositional area and permitted the deposition of coarser materials on the coastal plain itself. This situation is reflected by the upward change in the section from fine to coarse clastic sediments. As equilibrium was established in the gradient of the streams, their competence decreased, and the next unit, the carbonaceous shale and lignite, was deposited. Still further decreases in the competence of the streams led to the deposition of the calcareous unit. A rejuvenation of the streams brought about the renewed deposition of coarse sediments, a "massive to broken" sand member, thus completing the cycle.

The formations of the Wilcox group as defined by Gordon, Tracey and Ellis (1958) illustrated the cycle in an incompleted form. The Berger formation possibly represents the first member of the cycle. The Saline formation, with its lignitic clays, could be equivalent to the second unit, the carbonaceous shale. The calcareous unit is not present in the Saline formation. The Dentoni sand possibly correlates with the final, massive sand member of the cycle.

Stearns (1957) considered Tertiary and Upper Cretaceous rocks of the upper part of the Mississippi Embayment to have been deposited in a single depositional cycle which had five advances and regressions of the sea. This interpretation of depositional conditions is apparently like that described by Bernhauser.

Seasonal Lamination

The alternation of white, micaceous sand laminae with those of dark, lignitic clay prompted an investigation as to this being evidence of seasonal lamination. The common occurrence of laminated deposits in the deltaic environment indicates that the possibility of the laminated sediments of the Saline formation being seasonal in nature is unlikely.

Trowbridge (1923) suggested that laminated sediments of the Mississippi delta are not of seasonal origin. Wood (1947) gave additional examples of non-seasonally laminated sediments. He cited an example of three pairs of laminae being formed during a two weeks

LITHOLOGY	FORMATION Miss.	La.	GROUP	PHASE	CYCLE
Sand, shale lignite	Catahoula - Post Catahoula		Pliocene	Regression	
Dark shale	?	?	Miocene	Inundation	
Limestone, marl, shale	Chickasahay Byram marl Marianna Forest Hill Red Bluff	Vicksburg	Vicksburg (Oligocene)	Transgression	V
Gray shale, marl	Yazoo	Jackson shale	Jackson (Eocene)	Inundation	
Glauconitic sand, marl	Moodys Branch	Moodys Branch		Transgression	IV
Gray shale, sand, lignite	Cockfield	Cookfield		Regression	
Dark shale	Cook Mtn	Cook Mtn		Inundation	III
Limestone, shale, sand	(Wautubee)	Cook Mtn	Claiborne (Eocene)	Transgression	
Sand, shale lignite	Sparta	Sparta		Regression	
Dark shale	Zilpha	Cane River		Inundation	II
Glauconitic sand, marl	Winona Tallahatta	Cane River		Transgression	
Sand, shale lignite	Wilcox	Wilcox	Wilcox (Eocene)	Regression	
Dark shale	Porters Creek	Midway		Inundation	
Calcareous	Clayton		Midway (Paleocene)	Transgression	I

Figure 13. Sedimentary cycles in Gulf Coastal Plain sediments of Tertiary age, after Bornhauser (1947).

period in which streams flowing into a reservoir were swollen by heavy rains.

An explanation such as this seems plausible in the case of the laminated zones of the Saline formation. The competence of streams flowing into the depositional area was periodically increased by heavy rains. During these periods the sand laminae were deposited. During the intervening period when the competence of the streams was decreased, the thicker, finer-grained laminae of clay were deposited. The lateral and vertical variations in individual laminae support this explanation. The possibility that the winnowing action of waves and currents, limited to shallow water, produces the lamination of the sediments must also be considered.

Indication of Lower Eocene Climate

The paucity of feldspar in the Eocene sediments of Mississippi was pointed out by Grim (1936, p. 150) as "...perhaps the most conspicuous feature of the mineralogy". His explanation of the low feldspar content included a combination of a source area with rocks having a composition poor in feldspar and a warm, moist climate which would eliminate grains of feldspar through chemical weathering.

Pettijohn (1949, p. 124) also pointed out that a high quartz to feldspar ratio can be explained in terms of deposition of sediments in a warm, humid climate in an area of low relief.

The low feldspar content of the Saline formation sands is a conspicuous feature of their mineralogy. In this area it cannot be satisfactorily explained by the absence of feldspar in the source rocks. Exposures of nepheline syenite near Little Rock in Pulaski

County and near Benton in Saline County were exposed to erosion at the beginning of the Eocene. These syenite outcroppings are accepted as the sources from which the bauxite deposits of these areas were derived, Bramlette (1938)

The climatic conditions under which bauxite forms are generally accepted to include both high temperatures and considerable moisture. Gordon, Tracy and Ellis (1958, p. 145) have suggested that temperatures exceeding 77 degrees F. for much of the time are essential to the formation of bauxite.

If the climatic conditions under which the bauxite deposits were formed persisted throughout the Eocene, it explains the destruction of feldspar derived from the syenite outcroppings through chemical weathering and, thus, the small amount of that mineral in Wilcox sediments of central Arkansas.

PALEONTOLOGY

Previous Work

Because of the abundance of well preserved plant remains in the Wilcox sediments, the flora has been the object of considerable study. One of the first to examine the Wilcox fossil flora was Leo Lesquereux who came to Arkansas at the invitation of David Dale Owen, State Geologist, to study the Arkansas plant fossils. Three genera, Magnolia, Rhamnus and Quercus, were identified from leaf impressions in Eocene sediments and reported by him in Owen (1960). Call (1891, p. 97) mentioned the presence of Magnolia in the Tertiary rocks of Crowley's Ridge.

The most extensive investigation of the Eocene flora of the Gulf Coastal Plain was conducted by E. W. Berry (1916, 1917, 1930). Berry identified 543 species of fossil plants representing 180 genera and 82 families from Wilcox sediments of the Coastal Plain states, including Arkansas. Identifications were made primarily from remains preserved as leaf impressions.

R. W. Brown (1940, 1944, 1946) revised and corrected some of the identifications made by Berry and others. He also identified additional material from Saline County, Arkansas, for Gordon, Tracey and Ellis (1958).

Ball (1931) published the results of his study of plant fossils from the Wilcox section in Texas. His work, like that of Berry, was

Spore and Pollen Studies

In contrast to the considerable work done on the Wilcox leaf flora, there have been no published reports on palynological studies of this section. There are, however, a number of published reports of investigations of other Tertiary spore and pollen floras. Wodehouse (1933) described the pollen flora of the Green River formation of Colorado. Wilson and Webster (1946) described fossil pollen and spores from the Fort Union formation in Montana. Traverse (1955) published the results of a study of spores and pollen from the Brandon Lignite of Vermont.

Extensive investigations of Tertiary spore and pollen floras have been carried on in other countries. Potonie (1934) and Thompson and Pflug (1953) are among those who have investigated the Eocene of Germany. Simpson (1936) described plant microfossils from Tertiary coals in Scotland. Other countries where Tertiary spore and pollen floras have been investigated include Russia, Japan, Australia, New Zealand, India, Canada and Venezuela.

Taxonomy

A major problem in the use of fossil spores and pollen as a stratigraphic or paleoecological tool is the lack of a uniform, universally accepted system of classification. Classification schemes used by many investigators are completely artificial, ignoring the biological aspects of spore and pollen affinities, and are based on such physical features as germinal apparatus, ornamentation, or shape without regard to the phylogenetic significance of these structures.

Other systems are natural, attempting to relate the spores and pollen grains to their modern affinities.

Wodehouse (1935), in discussing the history of pollen studies, noted that investigators in the 19th century such as Fritzsche, Von Mohl and Fischer evolved classification of pollen grains based on features such as number of layers in cell wall, type of germinal apparatus and surface ornamentation.

Most investigators agree that the most important point in the development of a method of classification is the adherence to the systematic principles of the International Rules of Botanical Nomenclature. Many violations of these rules can be cited in palynological literature. Schopf, Wilson and Bentall (1944) pointed out that the purpose of giving a name to a taxonomic group is simply a matter of convenience for further reference. They noted that names that are taxonomically valid and pertinent to recognized groups should be continued even though they are in poor form or lack euphony. Faegri (1956, p. 650) states that "...if a pollen grain can be identified as belonging to a known taxon, living or fossil, no special name need be or can be attached to it".

Classification schemes that are being used or have been used in the past are illustrated by the following examples. Ibrahim (1933) evolved a binomial system in which the suffix "sporites" was attached to the name of the form genus to indicate that the taxon was a spore. This system was patterned after that used for fossil wood or fossil leaves in which a suffix denotes the nature of the taxon. Raistrick (1934) used a system based on letters and numbers rather than names.

Thomson and Pflug (1953) set up a system using morphologically descriptive root names combined with a suffix of "sporites" or "pollenites" to designate the identity of the taxon as a spore or pollen grain. Rouse (1957) proposed a classification system in which spores and pollen grains known to belong to modern genera are assigned the generic name of the modern taxon and a specific name composed of a morphologically descriptive root plus a suffix of "-sporites" or "-pollenites". He proposed that a pollen grain or spore that shows family characteristics should be given the name of the genus of that family to which the pollen appears to be most closely related, plus a suffix of "-sporites" or "-pollenites". If no family relationship can be established, the spore or pollen grain is given a morphologically descriptive root name plus a suffix of "-sporites" or "-pollenites". This is essentially the system proposed earlier by Wodehouse (1933).

In reference to classifications such as that of Wodehouse, R. Potonie (1959) suggested that the placing of a spore (or pollen grain) in a recent genus using as a basis only a few identifiable characteristics can only cause confusion in stratigraphy and taxonomy. Erdtman (1952) noted that a single anther has yielded as many as eight distinctly different pollen forms in terms of shape, symmetry and aperature types of the grains. Such a condition further complicates the placement of a fossil spore or pollen grain into a recent genus.

Despite the problems in the employment of a natural system of spore and pollen classification, such a system has been used in this investigation because it bests serves the objectives of the study. Spore and pollen genera found in the Wilcox sediments were, where possible, assigned to the modern genera to which they appear to belong. No specific names of extant plants have been used. Those that could not be assigned to modern genera were assigned to existing form genera such as those of Thomson and Pflug (1953). The use of modern genera in describing the fossil flora facilitates the comparison of the microflora with the megaflora. It also simplifies the interpretation of environmental conditions of lower Eocene time in south-central Arkansas. A major disadvantage of this system of nomenclature is that a comparison of the Wilcox spore and pollen flora with that of some other areas is difficult because a lack of conformity in taxonomy.

It is the policy of the University of Oklahoma's School of Geology not to erect new generic or specific names in theses or dissertations. These are to be erected at time of valid publication. The Wilcox plant microfossil species are referred to by number.

Wilcox Spore and Pollen Flora

During the investigation of the spore and pollen flora present in the laminated sediments of the Wilcox group, 40 genera from 27 families were identified. In addition, 22 other spore and pollen types were found which could not be associated with modern plant genera and were assigned to form genera. Associated with the flora are species of the Hystrichosphaeridae and the Dinoflagellata.

Fifteen of the plant microfossil genera are spores of cryptogams, but these do not exceed 10 percent of the total assemblage in any sample.

Five gymnosperm genera are present in the flora. Pollen of the genus Pinus was found at most levels and in amounts up to 10 percent of the total. Taxodium, Podocarpus, Ephedra and Cryptomeria were also identified. These four genera are not common in the microflora.

Angiosperm pollen was found to be the dominant element of the spore and pollen flora both in number of genera and number of individual grains. Only three of the angiosperm genera are monocots. The dicotyledons comprise the bulk of the flora. They are represented by 39 genera. A single genus, Castanea, is more abundant in terms of the individual grains present in many levels than those of all other pollen and spore genera combined.

Description of Genera

THALLOPHYTA

FUNGI

Fungus species 1

Plate 9 Figure 121

Description: Elongated, multicellular body; exine psilate, dark brown; prominent cross walls, tapering body; cell diameter 10-14 microns.

Discussion: Fungus spores are common in Wilcox sediments, but not in large numbers.

Slide 4-1-4.

Fungus species 2

Plate 9 figure 122

Description: Dark brown, multicellular body; exine psilate, outline ovate; size 14 X 26 microns.

Discussion: Fungus spores of this type are not common in the Wilcox spore and pollen flora.

Slide 4-1-5.

Fungus species 3

Plate 9 figure 123

Description: Elongate, multicellular bodies; exine dark brown, psilate; prominent cross walls, diameter varies 10 to 14 microns.

Discussion: This is a common, but not abundant, constituent of the Wilcox microflora.

Slide 4-1-9

BRYOPHYTA

Genus SPHAGNUMSPORITES Raatz, 1937

Genotype: Sphagnumsporites stereoides

(Potonie and Venetiz, 1934) Raatz, 1937

Sphagnumsporites species 1

Plate 1 figure 6

Description: Spores radial, trilete; trilete distinct, rays extend to spore margin; exine levigate, 1.5 microns thick; outline deltoid to ovate, diameter 20-26 microns.

Discussion: Spores of this type are rare in the Wilcox section. They are probably spores of the genus Sphagnum of the Bryophyta.

Slide 4-1-5.

EMBRYOPHYTA

Family LYCOPODIACEAE

Genus LYCOPODIUM Linne', 1753

Lycopodium species 1

Plate 1 figure 12

Description: Spores trilete, radial to ovate; trilete often indistinct, rays extend to margin; exine reticulate, diameter of grains 35 to 45 microns.

Discussion: Spores of this type appear to be similar to those described as *Sporites vegetus* by Potonie (1934). The ornamentation is like that of the *Lycopodium complanatum* group. Spores of *Lycopodium* are rare in the Wilcox sediments.

Slide 6-6-M-1.

Family SCHIZAEACEAE

Genus ANEMIA Smith

Anemia species 1

Plate 1 figures 1, 2

Description: Spores trilete, radial to ovate; trilete rays extend three-fourths distance to margin; exine is strongly ribbed, nonparallelism of ribs on proximal and distal surface creates cross-hatched pattern; size range 45 to 70 microns.

Discussion: This is *Sporites dorogensis* of Potonie (1934) and *Cicatricosisporites* of later authors. Spores of this type are common in the Wilcox sediments.

Slides 6-12-M-1 and 6-12-M-3

Genus LYGODIUM Swartz

Lygodium species 1

Plate 1 figures 3, 4

Description: Spores trilete, deltoid; rays prominent, extend three-fourth distance to margin; exine psilate, thin; size range 45 to 90 microns.

Discussion: This is the most common spore type in the Wilcox sediments. Spores of this type are produced by many plant genera in several families.

Slides 6-6-M-3 and 6-6-M-5.

Genus SCHIZAEA Smith

Schizaea species 1

Plate 2 figures 23, 24

Description: Spores monolete, ovate; exine prominently ribbed, less than 2 microns thick; size range 75 to 90 microns.

Discussion: Spores of this type are rare in the Wilcox sediments studied. They are apparently the same as those referred to by Potonie (1931) as *Sporites dorogensis* and as *Schizaeosporites* in 1933.

Slides 6-6-M-1 and 4-1-9.

Family POLYPODIACEAE

Genus ATHYRIUM Roth

Athyrium (?) species 1

Plate 2 figures 21, 22

Description: Spores monolete, ovate; exine psilate, microns thick; size range 50 to 65 microns.

Discussion: Spores of this type are found in most of the samples analyzed but not in large numbers. Spores of many genera lose their exosporium and have the same general appearance as *Athyrium*.

Slides 6-6-M-3 and 4-1-4.

Genus GYMNOGRAMMA Desvaux

Gymnogramma species 1

Plate 2 figure 8

Description: Spores trilete, deltoid, cingulate; trilete distinct with rays extending to margin of cingulum; exine rugulate, with irregular ridges and knobs; diameter 52 microns, width of cingulum variable, approximately 5 microns.

Discussion: A single speciman of this spore type was found during the investigation.

Slide 2-5-T-1.

SPOREAE DISPERSAE

Genus DELTOIDOSPORA (Miner, 1935) Potonie, 1956

Genotype: Deltoidospora hallii Miner, 1935

Deltoidospora species 1

Plate 1 figure 5

Description: Spores radial, trilete; trilete distinct, rays extend to margin; exine levigate; outline deltoid, diameter 20 microns.

Discussion: This spore type is rare in the Wilcox microflora.

Slide 6-7-13-7.

Genus CORRUGATISPORITES (Thomson and Pflug, 1953, non Ibrahim) Weyland and Greifeld, 1953

Genotype: Corrugatisporites toratus Weyland and Greifeld, 1953

Corrugatisporites species 1

Plate 1 figures 9, 10

Description: Spores radial, trilete; rays extend one-half to two-thirds distance to margin; exine with low, irregular, branching ridges;

margin thickened and crenulated; size range 40 to 65 microns.

Discussion: Spores of this type are present in most of the samples investigated but not numerous.

Slides 4-1-5 and 3-5-8.

Genus RUGULATISPORITES Thomson and Pflug, 1953

Genotype: Rugulatisporites quintos Thomson and Pflug, 1953

Rugulatisporites species 1

Plate 1 figure 7

Description: Spores radial, trilete; rays extend two-thirds distance to margin; trilete distinct, lips of commisora thickened; exine rough, rugulate; outline circular, diameter 30 to 35 microns.

Discussion: This spore type is rare in sediments of the Wilcox section studied. No affinity with an extant genus has been established. The spores resemble Sporites caelatus vibralilis of Potonie (1934)

Slide 2-8-13-7.

Rugulatisporites species 2

Plate 1 figure 8

Description: Spores radial, trilete; rays extend three-fourths distance to margin; trilete distinct, lips of commisura slightly thickened; exine rugulate, approximately 2 microns thick; outline deltoid, diameter 40 to 50 microns.

Discussion: Spores of this type are common, but not abundant, in the Wilcox sediments studied.

Slide 3-1-5.

Genus LYGODIOISPORITES Potonie, 1951

Genotype: Lygodioisporites solidus (Potonie, 1934)

Potonie, 1951

Lygodioisporites species 1

Plate 1 figure 11

Description: Spores radial, trilete; rays extend to spore margin; lips of commisura thickened; exine covered with coarse, closely spaced bacculae; outline deltoid, diameter 50 microns.

Discussion: A single speciman of this spore type was found in the Wilcox sediments studied.

Slide 6-12-M-5.

Genus PUNCTATISPORITES (Ibrahim, 1933) Schopf, Wilson, and Bentall, 1944

Genotype: Punctatisporites punctatus Ibrahim, 1933

Punctatisporites species 1

Plate 2 figure 13

Description: Spores radial, trilete; rays extend to spore margin; exine coarsely punctate, variable in thickness; outline deltoid; diameter 63 microns.

Discussion: A single speciman of this spore type was found in the Wilcox sediments. Because of the poor state of preservation, it is considered to be a redeposited Paleozoic spore.

Slide 2-5-T-10.

Genus CINGULATISPORITES Thomson and Pflug, 1953

Genotype: *Cingulatisporites levispecious* Pflug, 1953

Cingulatisporites species 1

Plate 2 figure 15

Description: Spores radial, trilete, cingulate; trilete distinct, rays broad, open, extending to spore margin; outline deltoid, exine coarsely granular; diameter 46 microns, cingulum 5 microns wide.

Discussion: A single specimen of this type was found in the Wilcox sediments. It is possibly a reworked Paleozoic spore.

Slide 4-1-4.

Cingulatisporites species 2

Plate 2 figure 16

Description: Spores radial, trilete, cingulate; trilete distinct, rays extend to margin of central body; exine of central body faintly granular, cingulum psilate, thick; grain diameter 39.5, width of cingulum 7 microns.

Discussion: Spores of this type are rare in the Wilcox sediments.

Slide 3-5-8.

Cingulatisporites species 3

Plate 2 figure 17

Description: Spores radial, trilete, cingulate; trilete distinct, rays extend to margin of central body; exine psilate; outline deltoid, diameter 35 to 45 microns, cingulum 5 microns in width.

Discussion: Spores of this type are not abundant in the samples studied.

Slide 2-4-4.

Cingulatisporites species 4

Plate 2 figure 19

Description: Spores radial, trilete, cingulate; rays of trilete extend to margin of central body; lips of commisura thickened; exine psilate, thick; outline deltoid to ovate; diameter 68 microns, width of cingulum 12.5 microns.

Discussion: A single speciman of this species was found during the investigation

Slide 6-7-T-6.

Cingulatisporites species 5

Plate 2 figure 14

Description: Spores radial, trilete; cingulate; trilete prominent, rays extend to margin of central body; exine verrucate with prominent, irregular ridges; cingulum approximately 5 microns wide, appears to break away from central body; outline deltoid, diameter 43.5 microns.

Discussion: A single individual of this spore type was found during the study. It is possibly a reworked Paleozoic spore.

Slide 4-1-9.

Genus VERRUCATOSPORITES Thomson and Pflug, 1953

Genotype: Verrucatosporites alienus (R. Potonie, 1931) Thomson and Pflug, 1953

Verrucatosporites species 1

Plate 2 figure 22

Description: Spores monolete, bean-shaped; exine rough, verrucate; size range 50 to 70 microns.

Discussion: Spores of this type are rare in the sediments studied. The genus probably is a member of the Palypodiaceae.

Slide 6-9-M-3.

SPERMATOPHYTA

GYMNOSPERMAE

Family PINACEAE

Genus PINUS Linnaeus, 1735

Pinus species 1

Plate 4 figures 41, 42

Description: Pollen grains with two broadly attached, reticulate, ovate bladders approximately the same size as the central body; Reticulation on bladders occasionally indistinct; Central body faintly granular, ovate, with proximal cap; size range from 90 to 110 microns.

Discussion: Pollen of this type varies in abundance in the section studied from absent to as much as 10 percent of the total microflora. It is similar to Pollenites labdacus of Potonie (1931) and Pityosporites labdacus of Pflug and Thomson (1953).

Slides 6-6-M-1 and 6-10-B-1.

Genus CRYPTOMERIA Dodonaeus

Cryptomeria species 1

Plate 4 figure 43

Description: Pollen grains monoporate (?) with pore (?) at hyaline tip of prominent conical projection; round central body; exine smooth, levigate; size range from 35 to 45 microns.

Discussion: Pollen of this type is rare in the Wilcox microflora.

It is considered by many to be inaperaturate. Thomson and Pflug (1953) described pollen similar to *Cryptomeria* as *Inaperaturopollenites polyformus*.
Slide 4-1-10

Family TAXACEAE

Genus TAXODIUM Richard

Taxodium species 1

Plate 4 figure 40

Description: Inaperaturate pollen grains; exine smooth, levigate; grains characteristically split, collapsed, wrinkled; size range 30 to 40 microns.
Discussion: *Taxodium* pollen is not abundant in the Wilcox microflora, but it is present in most samples.
Slide 4-1-5

Family PODOCARPACEAE

Genus PODOCARPUS Persoon

Podocarpus species 1

Plate 4 figure 44

Description: Bivesiculate pollen; bladders ovate, reticulate, broadly attached, 35 microns in diameter; central body granular, ovate in outline, 25 microns in diameter.
Discussion: A few *Podocarpus* pollen grains were found in one sample of the Wilcox sediments studied.
Slide 6-6-M-1

Family EPHEDRACEAE

Genus EPHEDRA (Tournefort) Linnaeus, 1737

Ephedra (?) species 1

Plate 7 figure 91

Description: Polycolpate pollen, 10 to 15 alternate ridges and furrows; exine psilate, less than one micron in thickness; outline prolate, grains flattened, twisted; grain size 24 X 42 microns.

Discussion: Pollen of this type is rare in the Wilcox microflora.

Slide 5-1-1.

ANGIOSPERMAE

MONOCOTYLEDONEAE

Family RESTIONACEAE

Genus STABERHOA Kunth

Staberhoa (?) species 1

Plate 6 figure 77

Description: Monoporate pollen with pore surrounded by a distinct annulus; outline circular, exine granular; size range 45 to 55 microns; diameter of pores from 5 to 8 microns.

Discussion: Pollen of this type is quite rare in the Wilcox microflora of south-central Arkansas. It is present in only a few samples and as a few grains.

Slide 6-9-T-5.

Family LILIACEAE

Genus LILIUM Linnaeus, 1735

Lilium (?) species 1

Plate 3 figure 38

Description: Large, ovate, inaperaturate pollen grains with verrucate ornamentation; size range of grains in longest diameter is from 120 to 165 microns.

Discussion: Pollen of this type is only provisionally assigned to the genus Lilium. Erdtman (1952) pointed out that a number of monocotyledonous families including Iridaceae and Amaryllidaceae have pollen with similar characteristics. This pollen type is not common in the Wilcox microflora described from the laminated sediments of south-central Arkansas.

Slide 3-9-B-2.

Family PALMAE

Genus MAURITIA Linnaeus, 1735

Mauritia (?) species 1

Plate 3 figures 27, 28

Description: Monocolpate pollen with an echinate exine; spines broad at the base and taper sharply to tips; scattered sparsely over surface of grain, average 2 microns in length; grains round to ovate in outline, size range 35 to 45 microns.

Discussion: Mauritia pollen is found in practically every sample in the section studied. It is nowhere abundant, however.

Slides 3-9-B-9 and 2-8-B-6.

DICOTYLEDONEAE

Family SALICACEAE

Genus SALIX Linnaeus, 1735

Salix species 1

Plate 6 figures 83, 84

Description: Tricolpate grains; finely reticulate surface, reticulations sharp, distinct; prolate in shape, trilobate in polar view; size range 25 to 35 microns.

Discussion: *Salix* pollen is a common constituent of the Wilcox microflora. It closely resembles the *Salix* pollen described by Erdtman (1954) and Wodehouse (1935).

Slides 6-6-M-10 and 3-9-B.

Family MYRICACEAE

Genus MYRICA Linnaeus, 1735

Myrica species 1

Plate 4 figures 48, 50

Description: Triporate pollen grains, rounded-triangular outline; pores at apices of triangle, slightly protruding; exine not thickened around pores, finely granular to levigate; size range from 32 to 38 microns.

Discussion: Pollen of this type is common in the section studied. Identification is difficult because of similar pollen in other families, such as the Corylaceae.

Slides 6-12-M-2 and 6-6-M-4.

Family JUGLANDACEAE

Genus PTEROCARYA Kunth, 1824

<u>Pterocarya species 1</u>

Plate 6 figures 72, 73

Description: Polyporate grains, pores in equatorial position, tending to be in one hemisphere; five pores normally present; grains rounded-polyhedral, levigate exine; size range 35 to 45 microns.

Discussion: Pterocarya pollen is nowhere abundant but is scattered throughout the section.

Slides 4-1-10 and 2-8-B-2.

Genus CARYA Nuttall, 1818

<u>Carya species 1</u>

Plate 5 figures 64, 65 and 66

Description: Triporate, rarely tetraporate pollen grains; pores at equator, in one hemisphere; grains circular in outline, distinctly thin central area in the exine of the pore-bearing hemisphere; exine levigate to faintly granular, the size range 35 to 45 microns.

Discussion: <u>Carya</u> pollen is found throughout the section but is never abundant.

Slides 6-6-M-8, 6-6-M-4 and 3-2-2.

Genus ENGELHARDTIA Leschen, 1825

<u>Engelhardtia species 1</u>

Plate 5 figures 62, 63

Description: Triporate pollen grains, pores equatorial; exine faintly granular to levigate, not thickened around the pores; exine thin in polar areas, folded in many specimens; size range 35 to 40 microns; shape round to rounded-triangular.

Discussion: Grains of this type are common but not abundant in the Wilcox microflora of south-central Arkansas. They appear similar to grains described as <u>Pollenites plicatus</u> by Potonie (1931). They are much like <u>Eucalyptus</u> as described by Wodehouse (1932) and <u>Momipites</u> of Wodehouse (1933) and Wilson and Webster (1946).

Slides 6-12-M-1 and 6-6-M-1.

Family CORYLACEAE

Genus CORYLUS Linnaeus, 1735

<u>Corylus species 1</u>

Plate 4 figures 49, 51

Description: Triporate pollen; exine granular, not thickened at pores; grains rounded-triangular, pores at apices; size range from 25 to 35 microns.

Discussion: <u>Corylus</u> pollen is a common constituent of the Wilcox microflora. It is present in most samples but is nowhere more than two or three percent of the total number of grains.

Slides 6-12-M-6 and 6-6-M-4.

Genus CARPINUS Linnaeus, 1735

<u>Carpinus species 1</u>

Plate 6 figure 68

Description: Pollen grains with four, rarely five, pores surrounded by prominent rims; exine faintly granular, thickened at pores; pores equatorial, evenly spaced; outline circular, size range 35 to 40 microns.

Discussion: Pollen of this type is present in small numbers and in only a few of the samples studied.

Slide 2-5-T-1.

Genus BETULA Linnaeus, 1735

Betula species 1

Plate 4 figure 47

Description: Triporate pollen grains, outline rounded-triangular; exine faintly granular, thickens at pores; size range of grains from 35 to 45 microns.

Discussion: Pollen of this type is present in practically all of the samples analyzed. It is not an abundant constituent of the Wilcox microflora. Although the construction of the pores is not identical to that described for Betula pollen by Wodehouse (1933) and by Erdtman (1954), comparison with modern Betula pollen appears to justify the assignment to that genus. It also resembles Pollenites granifer bituitus in Potonie (1931).

Slide 6-6-M-7

Family FAGACEAE

Genus CASTANEA Linnaeus, 1735

Castanea species 1

Plate 7 figures 92, 93

Description: Tricolporate pollen grains, colpi extending to poles; pores distinct, equatorial, surrounded by thickened exine; outline of grains prolate, often blunt; exine levigate, size range from 12 to 24 microns.

Discussion: This is the dominant pollen type of the Wilcox microflora, in many samples more numerous than all other types combined.

It closely resembles the _Castanea_ pollen described by Traverse (1955) from the Brandon lignite.

Slides 6-9-T-3 and 6-6-M-1.

Genus QUERCUS Linnaeus, 1753

Quercus species 1

Plate 7 figures 89, 90

Description: Tricolpate pollen with colpi extending to poles; exine medium to coarsely granular, does not thicken around colpi; outline prolate; size range 30 to 45 microns.

Discussion: Pollen of this type is found in most samples but is most abundant in the sediments of sample interval five.

Slides 3-9-B-5 and 3-9-B-8.

Genus NOTHOFAGUS Blume, 1825

Nothofagus (?) species 1

Plate 8 figures 112, 113

Description: Polycolporate pollen with four or five colpi and pores; pores equatorial, colpi extend two-thirds the distance to poles; exine faintly granular, less than one micron in thickness; outline of grains ovate to circular, size range from 35 to 45 microns.

Discussion: _Nothofagus_ pollen is not a common constituent of the Wilcox microflora. It is represented by a few grains present in a few of the samples studied.

Slides 5-1-2 and 3-4-T-6.

Family ULMACEAE

Genus ULMUS Linnaeus, 1735

Ulmus species 1

Plate 6 figure 69

Description: Tetraporate pollen; shape rectangular, pores at the corners of the rectangle; exine is moderately rugose, not thickened at the pores; size range 35 to 45 microns.

Discussion: Pollen of this type was found at few levels in the section studied and was not numerous in those. It resembles Pollenites megadolium tetraexituum of Potonie (1931).

Slide 2-4-4.

Genus CELTIS Linnaeus, 1735

Celtis (?) species 1

Plate 5 figure 59

Description: Triporate grains with thick, levigate exine; exine not thickened at pores, shape of grains rounded-triangular, size range 20 to 35 microns.

Discussion: Pollen of this type, tenatively identified as Celtis, is present in most levels of the section in small numbers.

Slide 6-9-3.

Family CHENOPODIACEAE

Genus CHENOPODIUM Linnaeus, 1735

Chenopodium species 1

Plate 6 figure 71

Description: Polyporate pollen grains, pores distributed over entire grain; pores 15 to 20 in number; exine levigate; outline of grains circular, size range 24 to 35 microns.

Discussion: Chenopodium pollen is a minor constituent of the microflora and is present in only a few of the samples.

Slide 6-9-T-1.

Family MAGNOLIACEAE

Genus MAGNOLIA Linnaeus, 1735

Magnolia (?) species 1

Plate 3 figure 29

Description: Monocolpate pollen grains; exine distinctly reticulate; outline of grains ovate to round, size range 55 to 65 microns.

Discussion: Pollen of this type is not abundant in any of the samples that were studied, but it is present in many of them.

Slide: 6-12-M-1.

Genus ILLICIUM Linnaeus, 1735

Illicium (?) species 1

Plate 6 figure 82

Description: Tricolpate pollen grains, verrucate exine; colpi prominent, extending to poles; outline of grains circular, size range from 70 to 80 microns.

Discussion: Pollen grains of this type are present in most of the samples that were studied. Although the size range is greater than that given by Erdtman (1952) for modern species of Illicium, the general description of that genus fits this pollen type.

Slide 6-6-M-9

Family SAXIFRAGACEAE

Genus ITEA Linnaeus, 1735

Itea (?) species 1

Plate 6 figure 76

Description: Pollen grains ovate, diporate; pores opposite, equatorial, four microns in diameter; exine fine-granular, 1.5 microns thick; longest diameter of grain 35 microns.

Discussion: Pollen of this type is very rare in the Wilcox sediments.

Slide 3-9-B-6.

Family POLYGALACEAE

Genus POLYGALA Linnaeus, 1735

Polygala species 1

Plate 8 figure 110

Description: Polycolporate pollen, pores and colpi numbering 12 to 16; colpi extend to poles, pores in equatorial position; exine not thickened around germinal apparatus, levigate; grains bluntly prolate, size range 30 to 40 microns.

Discussion: This distinctive pollen type is rare in the Wilcox microflora from south-central Arkansas.

Slide 2-9-1.

Family ANACARDIACEAE

Genus RHUS Linnaeus, 1735

Rhus species 1

Plate 7 figures 94, 95

Description: Tricolporate pollen, colpi extending to poles; pores equatorial, surrounded by rims; exine punctate; grains prolate, size 40 to 45 microns.

Discussion: Pollen of this type is a common constituent of the microflora. It is present at most levels and in amounts up to 5 percent of the total.

Slides 6-6-M-3 and 6-6-M-6.

Family AQUIFOLIACEAE

Genus ILEX Linnaeus, 1735

Ilex species 1

Plate 6 figure 40

Description: Tricolpate pollen, tapering colpi extend to poles; exine clavate with closely spaced club-like processes: grains ovate, size 40 to 55 microns.

Discussion: *Ilex* pollen is a common, but not abundant, constituent of the microflora.

Slide 6-6-M-3.

Family RHAMNACEAE

Genus RHAMNUS Linnaeus, 1735

Rhamnus (?) species 1

Plate 7 figure 98

Description: Tricolporate pollen, colpi extend three-fourths of distance to poles; grains blunt-triangular, pores at the blunted apices; exine smooth; size range 35 to 40 microns.

Discussion: *Rhamnus* pollen is rare in the microflora and is absent at many sample levels. Traverse (1955) described similar pollen from the Brandon lignite.

Slide 2-8-B-1.

Family TILIACEAE

Genus TILIA Linnaeus, 1735

Tilia species 1

Plate 6 figure 79

Description: Tribrevicolpate pollen, finely granular exine; grains trilobate in outline, size range 40 to 50 microns.

Discussion: *Tilia* pollen of this type is a distinctive but minor constituent of the microflora.

Slide 6-6-M-2.

Tilia (?) species 2

Plate 6 figure 78

Description: Pollen grains tribrevicolpate; colpi short, pore-like; exine distinctly reticulate, 1.6 microns thick; outline trilobate, diameter 30 microns.

Discussion: A single pollen grain of this type was found in the Wilcox sediments. Pollen resembling this is produced by other plants including the Bombacaceae.

Slide 5-1-6.

Family NYSSACEAE

Genus NYSSA Linnaeus, 1735

Nyssa species 1

Plate 7 figure 99

Description: Pollen tricolporate, tapering colpi extend to poles;

pores equatorial, with transverse furrows; exine punctate, grains circular in outline; size range 45 to 55 microns.

Discussion: Pollen of this type is present throughout the section in amounts up to 5 percent of the total.

Slide 6-6-M-4.

<u>Nyssa species 2</u>

Plate 7 figure 101

Description: Tricolporate pollen, colpi extend to poles; pores are equatorial; exine thick, levigate; grains circular in outline, range in size 35 to 42 microns.

Discussion: Pollen of this type is a common but not a numerous constituent of the microflora. It differs from species 1 in that the exine is not punctate and the pores do not have transverse furrows.

Slide 6-12-M-5.

<u>Nyssa species 3</u>

Plate 7 figure 100

Description: Tricolporate grains, colpi extend two-thirds distance to poles; grains triangular, pores at apices; exine faintly granular; pores prominent, exine thickens slightly around them; size range 20 to 32 microns.

Discussion: Pollen of this type is found at most levels in the section but in small numbers. It differs from species 1 and 2 in terms of size range, nature of the pores, shape and exine.

Slide 6-12-M-2.

PLEASE NOTE: Page 56 is lacking in page numbering only.

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Family ERICACEAE

Genus RHODODENDRON Linnaeus, 1735

Rhododendron species 1

Plate 8 figure 114

Description: Tricolporate pollen grains in tetrads; exine psilate; grains ovate; tetrads range in size 45 to 55 microns, individual grains 35 microns.

Discussion: Tetrads were found at only a few levels. It is possible that many crushed, unidentified individual grains present in the microflora are Rhododendron pollen.

Slide 2-6-T-3.

Family SAPOTACEAE

Genus MANILKARA Adanson, 1763

Manilkara (?) species 1

Plate 8 figures 108, 109

Description: Tetracolporate pollen, colpi normally indistinct; pores large, prominent, equatorial in position; exine levigate, thickened at the pores; grains are prolate, range in size 45 to 55 microns; pores 5 to 8 microns in diameter.

Discussion: Manilkara pollen is found at many levels of the section and ranges from a trace to one or two percent of the total.

Slides 3-2-8 and 2-9-1.

Manilkara species 2

Plate 8 figure 107

Description: Pollen grains tetracolporate; pores equatorial, 5 microns in diameter; colpi extend to poles; exine psilate, one micron in thickness; outline round to ovate, 20-30 microns in diameter.

Discussion: This pollen is common but not abundant in the Wilcox sediments.

Slide 6-6-M-1.

Family SYMPLOCACEAE

Genus SYMPLOCOS Jacquin, 1760

Symplocos species 1

Plate 8 figure 102

Description: Tricolporate pollen, narrow colpi extending two-thirds distance to poles; grains triangular, pores present at the apices; exine granular; size range 45 to 50 microns.

Discussion: Although it is distinctive in appearance, pollen of this type is rare in the microflora.

Slide 6-12-M-5.

Family OLACACEAE

Genus ANACOLOSA Blume, 1825

Anacolosa (?) species 1

Plate 5 figure 67

Description: Pollen grains rounded-triangular; six arcuate pores, three proximal, three distal, approximately three microns from margin of grain; exine psilate, 0.5 microns in thickness; diameter of grains 18 to 25 microns.

Discussion: Pollen of this type is rare in the Wilcox microflora.

Slide 4-1-10.

POLLEN DISPERSAE

Genus MONOCOLPOPOLLENITES Pflug and Thomson, 1953

Monocolpopollenites species 1

Genotype: Monocolpopollenites tranquillus (R. Potonie) Thomson and Pflug, 1953

Plate 3 figure 26

Description: Monocolpate pollen, colpus extending across grain; exine psilate, thickened around colpus; shape of grains prolate, size range 20 to 30 microns.

Discussion: Grains of this type are scattered throughout the section but are nowhere abundant. They are possibly of cycadaceous origin.

Slide 2-18-1.

Monocolpopollenites species 2

Plate 3 figure 25

Description: Monocolpate pollen, punctate exine; colpus prominent, extending across the grain; exine slightly thickened around it; grains prolate, size range 50 to 60 microns.

Discussion: This pollen type is present at many levels as a few, scattered grains. It differs from species 1 in that it is larger and has a punctate exine.

Slide 2-18-3.

Genus INAPERTUROPOLLENITES Thomson and Pflug, 1953

Inaperaturopollenites species 1

Genotype: Inaperaturopollenites dubius (R. Potonie) Thompson and Pflug, 1953

Plate 3 figures 33, 34

Description: Pollen grains inaperaturate (?), exine is punctate, sparsely covered with coarse spines; spines up to 15 microns in length, in some cases bifurcated; grains ovate, range in size 55 to 70 microns.

Discussion: This type of pollen is rare in the microflora and is known from only a few levels. It possibly belongs to the family Nympaceae.

Slides 3-9-B-5 and 3-9-B-6.

Inaperaturopollenites species 2

Plate 3 figure 32

Description: Inaperaturate pollen; coarse, somewhat vague, reticulum; grains bluntly prolate, flat; size range 65 to 75 microns.

Discussion: Pollen of this type is found at many levels in the section but is not a numerically important constituent. Its modern affinity is not known.

Slide 3-9-13-4.

Inaperaturopollenites species 3

Plate 3 figure 30

Description: Inaperaturate pollen, verrucate exine; grains circular in outline, size range 50 to 60 microns.

Discussion: Pollen of this type is present in most sample levels as a few grains. Its modern affinites are not known.

Slide 6-6-M-7.

Inaperaturopollenites species 4

Plate 3 figure 39

Description: Pollen grains inaperaturate; exine psilate, 0.5 microns thick; grains collapsed, folded, oblate; diameter 40 to 60 microns.

Discussion: Pollen of this type is common in the Wilcox sediments but is not numerous.

Slide 4-1-6.

Inaperaturopollenites species 5

Plate 3 figure 36

Description: Pollen grains inaperaturate; exine gemmate, gemmae 2.5 microns in diameter; grain outline circular, 20.5 microns in diameter.

Discussion: A single speciman of this pollen type was found in the Wilcox sediments.

Slide 4-1-4.

Inaperturopollenites species 6

Plate 3 figure 35

Description: Pollen inaperaturate; exine echinate; spines 3 microns in length, slightly tapered; outline circular, diameter 35 to 40 microns.

Discussion: Pollen of this type is present in most of the samples of Wilcox sediments, but is not abundant.

Slide 3-9-13-2.

Inaperaturopollenites species 7

Plate 3 figure 31

Description: Pollen grains inaperaturate; exine verrucate, verrucae indistinct at grain margin; outline circular, diameter 50 microns.

Discussion: This pollen type is rare in the Wilcox microflora.

Slide 6-6-M-2.

Inaperaturopollenites species 8

Plate 3 figure 37

Description: Pollen grains inaperaturate; exine echinate, spines with bulbous base, tapered sharply to tip, 3 microns in length; outline circular, 30 microns in diameter.

Discussion: A single grain of this pollen type was found during the investigation.

Slide 3-9-B-9.

Genus PROTEACIDITES (Cookson, 1950) Couper 1953

Genotype: Proteacidites adenanthoides Cookson, 1950

Proteacidites species 1

Plate 5 figure 56

Description: Pollen grains triporate; outline triangular-triquette, pores at apices; pores ragged, six microns in diameter; exine verrucate, one micron thick; grain size 40 to 48 microns.

Discussion: Pollen of this type is rare in the Wilcox microflora.

Slide 5-1-3.

Proteacidites species 2

Plate 5 figure 55

Description: Pollen grains triporate, 25 microns in diameter; exine verrucate, less than one micron thick; outline rounded-triangular, pores ragged, seven microns in diameter, at apices of grain.
Discussion: This pollen type is not common in the sediments studied. Slide 6-6-M-6.

Genus EXTRATRIPOROPOLLENITES Pflug, 1953

Genotype: Extratriporopollenites fractus Pflug, 1953

Extratriporopollenites species 1

Plate 4 figures 45, 46

Description: Triporate pollen, exine thickened at pores; pores at apices of triangular grains, surrounded by prominent conical rims; exine is finely granular to smooth; size range 40 to 48 microns.
Discussion: Grains of this type are known from almost every sample. They are not numerically abundant. The unique germinal apparatus has been described as tricolporate by Kuyl, Muller and Waterbolk (1955) rather than triporate with outer pore, pore canal and endopore. The affinity to modern taxa is not known.
Slides 6-6-M-6 and 6-12-M-1.

Genus TRIATRIOPOLLENITES Pflug, 1953

Genotype: Triatriopollenites rurensis Thomson and Pflug, 1953

Triatriopollenites species 1

Plate 5 figure 58

Description: Triporate pollen, pores at apices of triangular grains; pores slightly recessed, exine smooth to faintly granular; size range

40 to 55 microns.

Discussion: A common but not abundant pollen type, these grains are found at most levels in the section.

Slide 6-7-T-10.

<u>Triatriopollenites species 2</u>

Plate 5 figure 57

Description: Triporate pollen; pores at apices of the rounded-triangular grains, surrounded by exincus pad; exine verrucate, size range 30 to 40 microns.

Discussion: This pollen type is rare in the Wilcox microflora and was found in only a few samples.

Slide 6-7-T-4.

Genus INTRATRIPOROPOLLENITES Thomson and Pflug, 1953

Genotype: <u>Intratriporopollenites instructus</u> (R.Potonie) Thomson Pflug, 1953

<u>Intratriporopollenites species 1</u>

Plate 5 figure 54

Description: Triporate pollen grains, prominent pores; exine finely reticulate, not thickened at pores; grains circular, range in size 25 to 30 microns; pores round, 4 to 6 microns in diameter.

Discussion: The grains are scattered through the section in small numbers.

Slide 6-12-M-2.

Genus TRIPOROPOLLENITES Thomson and Pflug, 1953

Genotype: Triporopollenites coryloides Pflug, 1953

Triporopollenites species 1

Plate 5 figure 53

Description: Pollen triporate; pores prominent, 2.5 microns in diameter; exine 1.5 microns thick, striate; striae narrow, discontinuous; outline of grain rounded-triangular, diameter 29.5 microns.

Discussion: A single grain of this type was found during the investigation.

Slide 6-6-M-1.

Triporopollenites species 2

Plate 5 figures 60, 61

Description: Pollen grains triporate; exine psilate, variable thickness; pores equatorial, thin areas in exine appear to be incipient pores; outline ovate, diameters 35-40 microns.

Discussion: Pollen of this type is common in many of the samples. It is possibly related to the Juglandaceae.

Slides 2-8-B-8 and 2-8-B-2.

Triporopollenites species 3

Plate 4 figure 52

Description: Pollen grains triporate; pores 2.5 microns in diameter, at apices of triangular grains; exine punctate, 2 microns thick; grain size range 50-60 microns.

Discussion: This pollen type is not common in the Wilcox microflora.

Slide 6-6-M-2.

Genus POLYPOROPOLLENITES Pflug, 1953

Genotype: Polyporopollenites undulosus (Wolff) Thomson and Pflug, 1953

Polyporopollenites species 1

Plate 6 figures 74, 75

Description: Polyporate pollen, pores in equatorial area, number from 6 to 8; exine covered with short, sharp spines, 2 microns in length, tapering sharply from broad bases; grains circular in outline, 40 to 45 microns in diameter.

Discussion: These distinctive pollen grains are found only occasionally in the samples. Their relationship with modern taxa has not been established.

Slides 2-8-B-2 and 6-9-3.

Polyporopollenites species 2

Plate 6 figure 70

Description: Tetraporate grains, pores equatorial, exine finely granular; grains circular in outline, pores equally spaced around equator; size range 35 to 45 microns.

Discussion: This pollen type is found at only a few sample levels in the Wilcox section in south-central Arkansas.

Slide 6-10-B-1.

Genus TRICOLPOPOLLENITES Thomson and Pflug, 1953

Genotype: Tricolpopollenites parmularis (R. Potonie) Thomson and Pflug

Tricolpopollenites species 1

Plate 7 figure 87

Description: Tricolpate pollen, colpi extending to poles; exine thick, levigate; grains bluntly prolate in outline, range in size 15 to 22 microns.

Discussion: This pollen type is present in almost every sample level and often in considerable numbers. It is most abundant in the upper part of sample interval five. It is similar to Pollenites oviformis parmularis of Potonie (1931) and to Tricolpopollenites parmularis of Thomson and Pflug (1953)

Slide 6-6-M-2.

Tricolpopollenites species 2

Plate 7 figure 88

Description: Tricolpate pollen, colpi extending one-half the distance to poles; exine finely granular; grains circular in outline, diameter 30 to 40 microns.

Discussion: This pollen type is found at many levels in the section. It appears similar to Clethera (?) of Traverse (1955) and to Pollenites ventosus of Potonie (1931)

Slide 6-12-M-7.

Tricolpopollenites species 3

Plate 7 figures 85, 86

Description: Pollen grains tricolpate, colpi extending two-thirds of distance to poles; exine punctate; grains circular in outline, split along colpi with trilobate effect; size range is 40 to 45 microns.

Discussion: This pollen type is found at many levels in small numbers. It resembles Pollenites ortholaesus lasinus of Potonie (1931)

Slides 6-12-M-7 and 6-6-M-1.

Tricolpopollenites species 4

Plate 6 figure 80

Description: Pollen tricolpate, colpi 6.25 microns long; exine fine - granular, one micron thick; outline circular, diameter 30-35 microns.

Discussion: This pollen type is not common in the Wilcox spore and pollen flora. It is similar to pollen of the Tiliaceae.

Slide 5-1-6.

Genus TRICOLPOROPOLLENITES Thomson and Pflug, 1953

Genotype: Tricolporopollenites dolium (R. Potonie) Thomson and Pflug, 1953

Tricolporopollenites species 1

Plate 8 figures 104, 105

Description: Tricolporate pollen, broad colpi taper sharply to poles; pores equatorial; exine coarsely recticulate, slightly thicker at margins of colpi; grains trilobate in outline, range in size 60 to 70 microns.

Discussion: Only a few grains of this type were found scattered through the section. It appears to be similar to Pollenites margaritatus of Potonie (1931).

Slides 2-8-B-2 and 2-8-B-4.

Tricolporopollenites species 2

Plate 7 figure 97

Description: Tricolporate pollen, colpi extend to poles; pores are equatorial in position, surrounded by thickened rims; exine coarsely reticulate; shape of grains bluntly prolate, size range 55 to 60 microns.

Discussion: This is a minor constituent of the microflora and is found at only a few levels.

Slide 3-4-T-7.

Tricolporopollenites species 3

Plate 7 figure 96

Description: Tricolporate pollen, colpi extend to poles; pores in equatorial position; exine coarsely granular; grains prolate, range in size 30 to 38 microns.

Discussion: Pollen of this type is present at many levels in the section but only as small numbers of grains.

Slide 6-9-T-5.

Tricolporopollenites species 4

Plate 8 figure 103

Description: Pollen grains tricolporate; pores prominent, equatorial, vestibulate; colpi faint, extend to poles; exine fine-granular, 2.5 microns thick; outline rounded-triangular, diameter 25 microns.

Discussion: This pollen type is not common in the Wilcox microflora.

Slide 5-1-1.

Genus TETRACOLPOROPOLLENITES Thomson and Pflug, 1953

Genotype: Tetracolporopollenites sapotoides Thomson and Pflug, 1953

Tetracolporopollenites species 1

Plate 8 figure 106

Description: Tetracolporate pollen: broad, untapered colpi, large, oval pores; exine thin, faintly reticulate; grains ovate, normally folded; range in size 75 to 80 microns; pores 8 microns in diameter.

Discussion: This pollen type, limited to a single level, is probably a member of the family Malpighiaceae.

Slide 2-8-B-6.

Pollen type A

Plate 8 figure 111

Description: Polycolporate pollen, 8 pores and colpi; pores equatorial, colpi extend to poles; exine striate (?); outline prolate, size range longest axis 25-35 microns.

Discussion: This type is not common in the spore and pollen flora. It could not be assigned to existing genera.

Slide 2-8-B-7.

DINOFLAGELLATA

Genus WETZELIELLA Eisenack, 1938

Genotype: Wetzeliella articulate (D. Wetzel) Eisenack, 1938

Wetzeliella articulata

Plate 9 figure 119

Discussion: This dinoflagellate genus is most numerous in samples from interval two.

Slide 5-1-1

Genus GONYAULAX

Gonyaulax (?) species 1

Plate 9 figure 124

Description: Collapsed, wrinkled, psilate grains; plate margins indistinct; size range 40-50 microns.

Discussion: This microfossil type is rare in the sediments studied.

Slide 2-8-B-7.

HYSTRICHOSPHAERIDEA

Genus HYSTRICHOSPHAERIDIUM (Erhenberg)

Deflandre, 1937

Hystrichosphaeridium species 1

Plate 9 figure 115

Description: Symmetry radial; shape, ovate; vesicle size 50 microns; surface psilate, ornamented with funnel-shaped processes with frilled margins; processes 10 to 15 in number, 10 microns in length.

Discussion: This microfossil type is present in small numbers in the Wilcox samples.

Slide 6-7-B-8.

Hystrichosphaeridium species 2

Plate 9 figure 116

Description: Symmetry radial; shape, ovate; surface smooth; size of vesicle 45 microns; numerous spine-like processes with blunt tips.

Discussion: These microfossils are rare in the sediments studied.

Slide 6-8-B-1.

Hystrichosphaeridium species 3

Plate 9 figure 117

Description: Radial, ovate body ornamented with scattered, short, polyfurcated processes; vesicule size, 48 microns.

Discussion: A rare element in the microfossil assemblage.

Slide 6-10-B-8.

INCERTAE SEDIS

Species 1

Plate 9 figure 120

Description: Psilate, ovate central body, 60 microns in diameter; thin, transparent flange, 15 microns wide.

Discussion: A single speciman of this type was found.

Slide 2-1-4.

Distribution of the Spore and Pollen Flora

The distributon of the components of the Wilcox spore and pollen flora is shown by two methods. The first is by histograms showing abundance of spore and pollen types in various levels of the intervals sampled and the second with tables showing the stratigraphic distribution of genera. The data for the first presentation were obtained by the counting of spores and pollen grains on the micro-slides and calculating the relative abundance of each type with relation to the total microflora of the level. These results are presented as histograms in figures 14 to 28. Only those levels which seemed significant are presented. Because of the large number of spore and pollen types present, it was necessary to group similar morphological genera into single units in order to present the information graphically. The groups selected are as follows:

group 1 - monolete spores

group 2 - trilete spores

group 3 - vesiculate pollen

group 4 - monoporate pollen

group 5 - monocolpate pollen

group 6 - tricolpate pollen

group 7 - tricolporate pollen

group 8 - triporate pollen

group 9 - polycolpate pollen

group 10 - polyporate pollen

group 11 - polycolporate pollen

group 12 - alete spores and pollen

group 13 - Dinoflagellata

group 14 - Hystrichosphaeridae

The result of this method of grouping of genera is that groups 1 and 2 include the pteridophytes, group 3 most of the gymnosperms, group 4 and part of 5 the monocotlyedons, groups 6 through 11 are primarily dicotyledons, and the other groups are as designated.

The stratigraphic distribution of genera is shown in table 1. Each interval is divided into lower, middle and upper units.

Comparison of the Wilcox Microflora with the Megaflora

Berry (1930) reported a megaflora of 543 species representing 180 genera and 82 families from the Wilcox group in the Coastal Plains states, including Arkansas. As the result of additions and corrections by Brown (1940, 1944, 1946), Sharp (1951) placed the number of genera in the Wilcox flora at 137. Additional genera have been identified by Ball (1931) from the Wilcox group in Texas. The exactness of these numbers is questionable inasmuch as some of the fossils are organ genera which possibly duplicate natural genera.

Of the 180 genera listed by Berry, only 12, representing nine families, were from localities in central Arkansas. These are as follows:

AREACEAE - *Chamaedorea*, *Sabalites*

JUGLANDACEAE - *Engelhardtia*

MORACEAE - *Artocarpus*

CAESALPINIACEAE - *Cassia*, *Caesalpinites*

SAPINDACEAE - *Sapindus*

LAURACEAE - *Oreodaphne*, *Nectandra*

MYRTACEAE - *Myrica*

ARALIACEAE - *Oreopanax*

APOCYNACEAE - *Apocynophyllum*

Additions to the flora from central Arkansas were made recently by Gordon, Tracey and Ellis (1958) based on identification of fossil leaves by R. W. Brown. They reported the presence of the following genera and species - *Anemia eocenica*, *Ficus mississippiensis*, *Ficus myrtifolia*, *Ceridiphyllum arcticum*, *Artocarpus pungens* and *Menispermites wilcoxensis*.

The entire Wilcox flora as represented by fossil leaves, fruits and wood includes representatives of the Thallophyta, Bryophyta, Pteridophyta, Gymnospermae and Angiospermae. The dominant element is the angiosperms. Of the 543 species that Berry listed, only 33 are not angiosperms. Ball described a like condition in the Texas Wilcox flora.

The pteridophyte families listed by Berry and by Ball include the three that were identified in the spore flora. These are the Lycopodiaceae, Polypodiaceae and Schizaeaceae. Only two genera, *Anemia* and *Lygodium*, were found both as spores and as megafossils.

Of the gymnosperms, the families Pinaceae and Taxaceae were found both as microfossils and megafossils. The genus Taxodium is common to both but Pinus is found only as pollen.

The number of the monocotyledonous plants represented both by pollen and megafossils is small. No genera or families are identified as being present in both. This is not unexpected because this group is a minor constituent of both floras.

The dual representation of the dicotyledonous families is greater in numbers. Of the families found to be represented by pollen, only the Polygalaceae and the Symplocaceae are not reported as being in the megaflora. Eight genera are common to both. These are Carya, Engelhardtia, Ilex, Magnolia, Myrica, Betula, Nyssa and Rhamnus. The numerically dominant pollen type, Castanea, is not reported in the megaflora. The most abundant genus in the megaflora, Ficus, has not been identified in the pollen flora.

The degree of difference between the megaflora and microflora of a stratigraphic unit was found to be much the same in the case of the Wilcox group as was found by Wodehouse (1933) for the Green River shales. Because of differences in opportunity for preservation, of transportation and resistance to destruction it is not expected that there should be a strong similarity between megafloras and microfloras.

Comparison with Other Spore and Pollen Floras

Eocene of Germany

Potonie (1934), Pflug (1952), and Thompson and Pflug (1953) described Eocene spore and pollen floras from Germany. A comparison of these floras with that of the Wilcox is complicated by the fact that each used a different system of nomenclature which was, in each case, based on form genera. For example, Pollenites labdacus of Potonie appears to be identical to the genus Pinus of the Wilcox flora. His taxon Sporites dorogensis includes both monolete and trilete ribbed spores of the family Schizaceae.

A general comparison of the Wilcox spore and pollen and that of the German Eocene indicates that the following families are present in both: Polypodiaceae, Schizaceae, Lygopodiaceae, Pinaceae, Taxaceae, Salicaceae, Fagaceae, Myricaceae, Aquifoliaceae, Sapindaceae, Tiliaceae, Ericaceae, Sapotaceae and Nyssaceae. The same genera of these families appear to be present in both areas. It appears, therefore, that the Eocene of the Gulf Coastal Plain of the United States is similar to that of the Eocene of Germany.

Green River Flora

The spore and pollen flora present in the Green River shales was described in part by Wodehouse (1933). Although he listed only those genera that he could relate to modern forms, Wodehouse described 43 species from 34 genera and 22 families. Taxa found in both the Green River and Wilcox sediments include: Pinaceae - Pinus, Juglandaceae, Myricaceae - Myrica, Corylaceae - Carpinus, Salicaceae - Salix, Ulmaceae, Anacardiaceae - Rhus, Tiliaceae - Tilia, Ericaceae and Magnoliaceae.

Brandon Lignite Flora

Traverse (1955) investigated the spore and pollen flora present in the Brandon lignite and related sediments in Vermont. In its gross aspects this flora is much like that in the Wilcox sediments of south-central Arkansas. It was described by Traverse as an "overwhelmingly dicotyledonous flora". The followin; taxonomic units are present in both the Wilcox and Brandon floras: "Polypodiaceous spores", Juglandaceae Engelhardtia, Fagaceae - Castanea, Quercus, Ulmaceae - Ulmus, Magnoliaceae Magnolia, Illicum, Anacardiaceae - Rhus, Aquifoliaceae - Ilex, Rhamnaceae Rhamnus, Tiliaceae - Tilia, Nyssaceae - Nyssa, Ericaceae - Rhododendron, Sapotaceae - Manilkara and Symplocaceae - Symplocos.

Quercus is a dominant constituent of the Brandon microflora. It is a minor constituent in the Wilcox sediments. Castanea, the dominant feature of much of the Wilcox section, is present in the Brandon lignite, but only as a small percentage of the total. The ribbed spores of the Schizaeaceae were not found in the Brandon flora. There is, however, as shown by many features in common, a similarity between the two floras.

Other Floras

Of the 20 genera reported from the Tertiary of Scotland by Simpson (1936) only four, Pinus, Corylus, Magnolia and Engelhardtia, are known from the Wilcox. The Eocene flora of New Zealand described by Couper (1956) and of India by Rao and Vimal (1952) also has little in common with the spore and pollen flora of the Wilcox group of south-central Arkansas.

A statistical comparison of the Wilcox flora with that of the lower Eocene of France as reported by Jekhowsky and Varma (1959) indicates a strong degree of similarity. Tricolporate pollen is the most abundant type in the French flora, becoming almost fifty percent of the total at some levels. It decreases sharply in the upper part of the section. No generic names or descriptions were given in the report.

TABLE I - STRATIGRAPHIC DISTRIBUTION OF GENERA															
	Int. 1			Int. 2			Int. 3			Int. 4			Int. 5		
GENUS	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
LYCOPODIUM			x							x	x				
ANEMIA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
LYGODIUM	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SCHIZAEA		x	x	x						x				x	
ATHYRIUM (?)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
GYMNOGRAMME			x												
CORRUGATISPORITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RUGULATISPORITES											x				
PUNCTATISPORITES								x							
VERRUCATOSPORITES	x			x					x				x		
DELTOIDOSPORA								x							
LYGODIOISPORITES									x						
CINGULATISPORITES	x							x			x				
PINUS	x	x	x	x	x	x		x	x	x	x	x	x	x	x
TAXODIUM	x		x		x				x		x	x	x		x
CRYPTOMERIA	x														
PODOCARPUS								x							
EPHEDRA (?)				x											
STABERHOA (?)							x	x					x		
LILIUM (?)	x			x								x			
MAURITIA (?)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SALIX	x		x	x	x	x	x	x	x	x	x	x	x	x	x
MYRICA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
PTEROCARYA	x	x	x	x				x		x	x	x		x	x

TABLE I - STRATIGRAPHIC DISTRIBUTION OF GENERA

GENUS	Int. 1			Int. 2			Int. 3			Int. 4			Int. 5		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
CARYA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ENGELHARDTIA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CORYLUS	x	x	x	x	x		x	x				x		x	
CARPINUS		x	x	x			x	x			x				
BETULA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CASTANEA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
QUERCUS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ULMUS			x	x		x		x	x			x	x		
CELTIS (?)			x	x	x	x	x	x	x	x	x	x	x		
CHENOPODIUM								x	x			x		x	
MAGNOLIA (?)	x			x						x		x	x	x	x
ILLICUM (?)				x	x			x							
ITEA (?)														x	
POLYGALA			x					x	x					x	x
RHUS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ILEX	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RHAMNUS (?)			x												
TILIA		x		x	x	x	x	x	x	x	x		x	x	x
NYSSA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RHODODENDRON	x			x											
MANILKARA	x	x		x		x	x	x	x		x	x		x	x
SYMPLOCOS	x			x					x		x		x	x	x
ANACOLOSA (?)	x														
MONOCOLPOPOLLENITES	x	x				x				x			x		

TABLE I - STRATIGRAPHIC DISTRIBUTION OF GENERA															
GENUS	Int. 1			Int. 2			Int. 3			Int. 4			Int. 5		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
INAPERTUROPOLLENITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
EXTRATRIPOROPOLLENITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TRIATRIOPOLLENITES								x	x						
INTRATRIPOROPOLLENITES		x	x		x		x	x	x	x	x	x		x	
POLYPOROPOLLENITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TRICOLPOPOLLENITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TRICOLPOROPOLLENITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TETRACOLPOROPOLLENITES												x			
TRIPOROPOLLENITES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

DISCUSSION

The study of the spore and pollen flora of the Wilcox section in south-central Arkansas and the sediments in which they are contained has suggested conclusions as to Wilcox paleoecology and stratigraphy. Such conclusions are based in part on the assumption that the spore and pollen flora is representative of the actual lower Eocene vegetation. Work by several investigators including recent work by Davis and Goodlett (1960) indicates that this is a valid assumption. In discussing this factor, Kuyl, Muller and Waterbolk (1955) noted that limnic and brackish water sediments are relatively free from the influence of local vegetation. Terrestrial bog deposits, to the contrary, can contain a pollen flora dominated by the local vegetation. As is shown by the lithology of the sections used in this study, the sediments are fine-grained, clastics and should, therefore, reflect the nature of the regional vegetation.

There are factors which can affect the accuracy with which spores and pollen grains reflect the fossil flora of a unit of time in the geologic past for an area. One such factor is differential weathering of plant microfossils. Godwin (1956) mentioned examples in which high *Tilia* values in pollen spectra were the result of the remarkable resistence to decay of that genus and not the result of a prolific local source of *Tilia* pollen. The spores and pollen of the Wilcox show a remarkable state of preservation which appears to be quite uniform for most taxonomic units. It appears that differential weathering has not affected the nature of the microflora.

Pollen grains are affected by sedimentation processes just as are the inorganic materials in which they are preserved. The general absence of plant microfossils in coarse clastic sediments reflects their reaction to the energy level of the environment of deposition. Muller (1957) described the effects of currents in pollen distribution in the Orinoco delta sediments. The laminated clays and sands of the Wilcox sections sampled in this investigation indicate a low-energy depositional environment which would not have affected the nature of the spore and pollen flora deposited in the area by differential sedimentation.

Still another factor which can affect the composition of fossil microfloras is the addition of spores and pollen from other sediments undergoing erosion contemporaneously and in the general area as the site of deposition of the sediments containing the flora under study. This is of particular importance in the poorly consolidated Tertiary sediments of the Gulf Coastal Plain. The Berger formation, the basal unit in the Wilcox group in the area of the investigation, undoubtedly does contain reworked Midway sediments and the flora that they contain. The overlying laminated section that was sampled for this investigation should be composed of sediments derived from the Paleozoic highlands and the exposed syenite plugs. At least two of the trilete spore types present in the Wilcox spore and pollen flora are probably reworked Paleozoic types.

Paleoecology

The use of pollen and spores in the interpretation of paleoecological conditions is well established. Wodehouse, as early as 1933, used the microflora of the Green River shales to interpret the nature of the depositional environment of those sediments. More recently Traverse (1955) made interpretations as to climate and other physical conditions of the area in which the Brandon lignite was deposited based on the spore and pollen flora contained in the lignite and associated sediments.

E. S. Barghoorn stated (Shapley, 1953) that "...land plants are probably the most valid biological indicators of past physical conditions - especially climate". It is assumed that the pollen spectra obtained from the Wilcox sediments of south-central Arkansas can likewise be used as a basis for environmental interpretations.

Climate

The lower Eocene climate as suggested by the megaflora present has been discussed by Berry (1916, 1930), Brown (1944) and Sharp (1950). Berry contended that the flora was tropical in nature and that none of the genera were "strictly temperate" types. Brown and, later, Sharp interpreted the flora as being more temperate in nature. This difference in opinion as to climate was largely the result of differences as to the identity of several genera.

Sharp noted that some sixty percent of the genera present as megafossils can still be found in the southeastern states. Many of these are present only in Florida. Approximately fifty-three percent of the genera are present today in central and eastern China and sixty-eight percent in eastern Mexico. Even after considering the possibility of errors in identification of the fossil genera, these are impressive statistics. Despite the close similarity of the Eocene Wilcox and the present day eastern Mexico floras, Sharp did note that two important elements of the Mexican flora, Quercus and Pinus, were not reported from the Wilcox megaflora.

An examination of the spore and pollen flora reveals a number of "temperate" genera that were also found as megafossils. These include Carya, Engelhardtia, Magnolia, Nyssa and Myrica. Other plant microfossils have a more tropical aspect. These include the several spore genera of the family SCHIZACEAE which are conspicuous elements of the microflora. Also indicative of tropical to subtropical climate are the genera Manilkara, Symplocos, Anacolosa and Mauritia.

A possible interpretation as to the Wilcox climate based on this mixed tropical and temperate spore and pollen flora is that of a tropical coastal plain with neighboring temperate highlands. Such a condition is present in eastern Mexico where cool escarpments and a warm coastal plain produce a combined flora which Sharp pointed out as being much like the Wilcox megaflora. The presence of Pinus and Quercus in the pollen flora is further evidence of the similarity. The coastal and highland pollen floras could be, as the result of wind and water transport, mixed in the area of deposition of the Wilcox sediments. Muller (1957) found such a mixture of highland and coastal pollen types in the recent sediments of the Orinoco delta.

As was previously noted, the high quartz to feldspar ratio of the sediments, despite the presence of a source of detrital feldspar in the area, supports the concept of deposition in a warm, humid environment.

Depositional Environment

The nature of the Wilcox sediments has generally been interpreted as being indicative of a deltaic environment of deposition. Shepard (1960) listed the following among the criteria for the recognition of the sediments of ancient deltas: abundance of plant remains, abundance of mica, scarcity of invertebrates, well developed laminations and elongate sand bodies. The character of the Wilcox sediments in the sections sampled meet these requirements.

The microfossils found in the sediments add additional evidence for the deltaic environment interpretation. The presence of representatives of the HYSTRICHOSPHAERIDEA in many of the levels sampled for this investigation is an indication of environment. These problematic fossils forms are restricted, so far as is known, to marine and brackish water environments. Because they are only a minor constituent of the microfossil assemblage, it is concluded that the environment was not marine, but brackish. Berry (1930) described brackish water lagoons along a low coastal plain in his interpretation of environmental conditions for the megaflora.

The variation in abundance of hystrichosphaerids and dinoflagellates in the sections studied is possibly related to the salinity of the water in the depositional areas. Such variations could be the result of variation in amounts of rainfall and, thus, fresh water inflow. The methods used in this study were not such as would indicate whether or not this was a cyclical phenomenon related to climatic cycles such as have been recognized in tree rings and varved sediments.

Stratigraphic Significance of the Microflora

When viewed as a whole, the spore and pollen flora found in the Wilcox sediments show a remarkable similarity to those found in the Eocene section in Germany. This was expectable because the early Eocene age of the Wilcox of the Gulf Coastal Plain had been established through the use of other fossil groups.

Even without the comparison with the Eocene microflora of Germany, the spores and pollen found in the Wilcox sediments give an indication as to their stratigraphic position. The flora, dominated by the angiosperms, is distinctly Tertiary in nature. It does not have the grass and composite pollen which characterize the middle and upper Tertiary section of the Gulf Coastal Plain. A number of elements are known from Cretaceous rocks. This is the case of the spores of the family SCHIZACEAE which reached its maximum development during that period. Many of the triporate grains as well as the winged grain of the genus _Pinus_ have been described from Cretaceous rocks. An Eocene age is indicated by the flora.

The histograms showing distribution of spore and pollen types in the various sample levels do show variations which appear to be significant stratigraphically for correlation of zones within the Wilcox group of the Coastal Plain. The most striking of these is the sharp reduction in tricolporate pollen in the upper part of the section. This reflects the disappearance of the small, tricolporate pollen genus, identified as _Castanea_, which had dominated the microflora to this point. The change was abrupt, as the histograms of levels five and seven of section five show. It possibly represents a floral change in response to a change in climate. The general aspect of the flora did not noticeably change, however. Davis and Goodlett (1960) concluded that even large local variations in plant life are not reflected in the pollen spectrum, but that the spectrum remains uniform throughout large areas. This indicates that this change in the Wilcox microflora should be reflected throughout the Gulf Coast and would be of value in correlation within the Wilcox group.

Other units within the flora also show apparently significant variation. The increase of *Pinus* in level three of the third section sampled appears to have a magnitude that can be detected without question. Further, it does not reach such a magnitude again in any level. Dinoflagellates increase distinctly in section two.

Many of the genera, such as *Carya*, are present in the entire section but show no significant changes in density. Others, such as *Tilia*, are found scattered through the section, but their presence or absence cannot be given stratigraphic significance because they are represented by only a few individuals where they are found.

Of the spores, *Lygodium* is most abundant and also shows the greatest variation in density. The pattern of variation is not such that it appears suitable for correlation. The HYSTRICHOSPHAERIDAE show the same type of variation from level to level and, despite their environmental significance, are of questionable use for correlation of zones within the Wilcox.

Need for Additional Work

This investigation was concerned with the vertical distribution of the Wilcox spore and pollen flora in a composite section in a limited area. The stratigraphic importance of the results, if any, can be realized only when other sections along the strike and down the dip of the Wilcox group have been examined and compared. The application of palynology to stratigraphic problems in the Gulf Coast Tertiary depends upon such additional investigations.

Summary

A total of 62 genera of pollen and spores are described in the laminated clays and sands of the Wilcox group in south-central Arkansas. In addition to these plant microfossils, representatives of the Dinoflagellata and of the Hystrichosphaeridae are identified. The flora is dominated by the angiosperms and is characteristic of the lower Tertiary. It is similar to that described from the Eocene of Germany.

The flora remains uniform in composition throughout much of the section. This was to be expected because the uniformity of the sediments indicated that the depositional environment did not change greatly. The lower part of the section is characterized by an abundance of the pollen of *Castanea*, which made up as much as three-fourths of the total of grains counted in many sample levels. The abrupt disappearance of this pollen type in the upper part of the section is considered to have regional stratigraphic significance for correlation within the Wilcox group of the Gulf Coastal Plain. An increase in the pollen of *Pinus* and an increase in dinoflagellates possibly has stratigraphic value.

The flora is a mixture of temperate and tropical to subtropical genera and is interpreted as being the result of the mixing of the pollen from plants on a low, warm coastal plain with that from plants in neighboring highlands. A high ratio of quartz to feldspar in the Wilcox sediments, despite a source for detrital feldspar in the area, supports this concept of the Wilcox climate.

The presence of the representatives of the Hystrichosphaeridae and the Dinoflagellata indicate that the sediments were deposited in a brackish or marine environment. Because of the limited numbers of these two groups present as microfossils in the section studied, and because of the nature of the sediments, the depositional environment is interpreted as being brackish water lagoons or lakes along the great delta forming in the Coastal Plain area during the lower Eocene.

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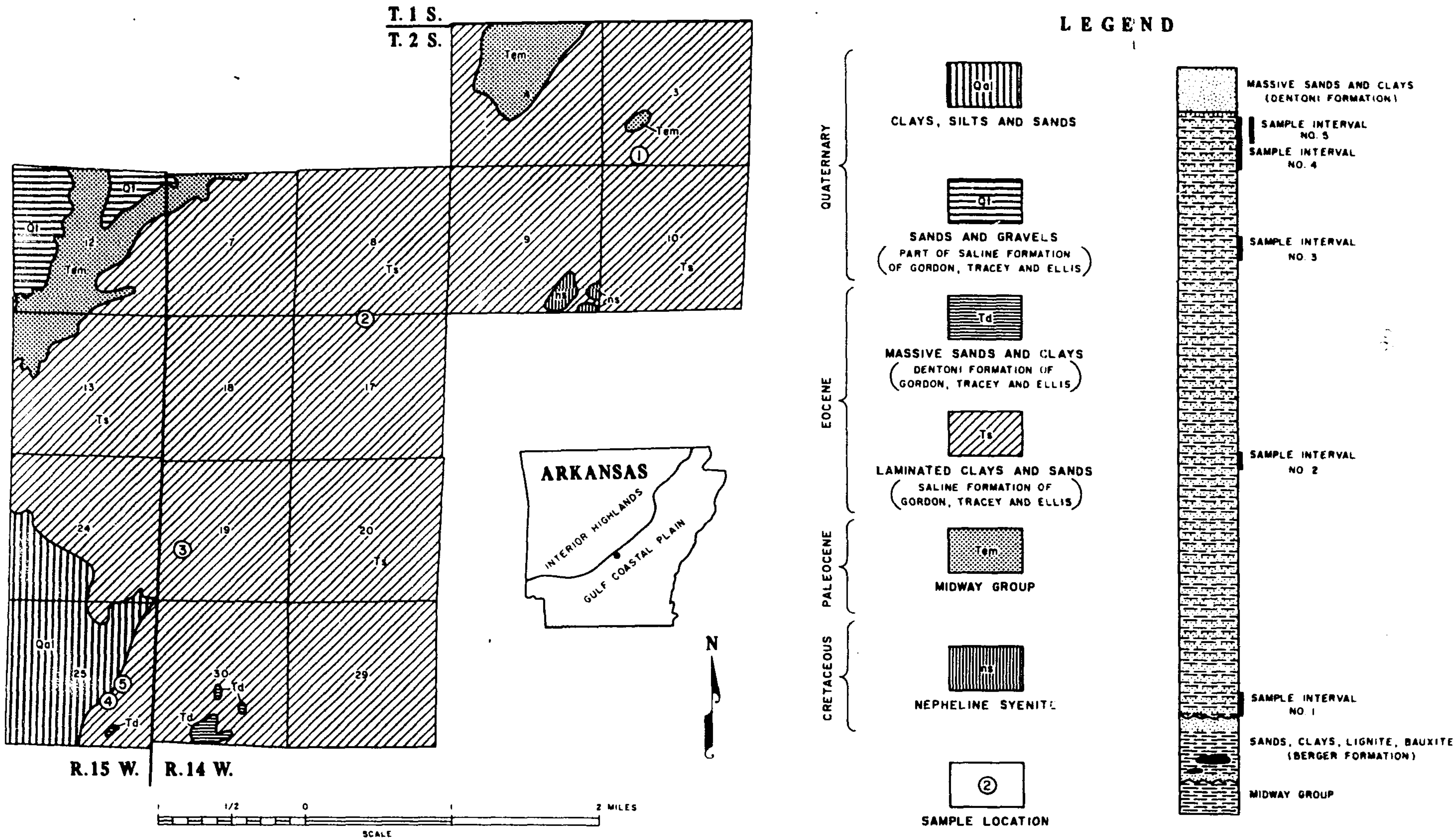
FIGURE 1

GEOLOGIC MAP OF SAMPLE LOCATIONS



SAMPLE INTERVAL I

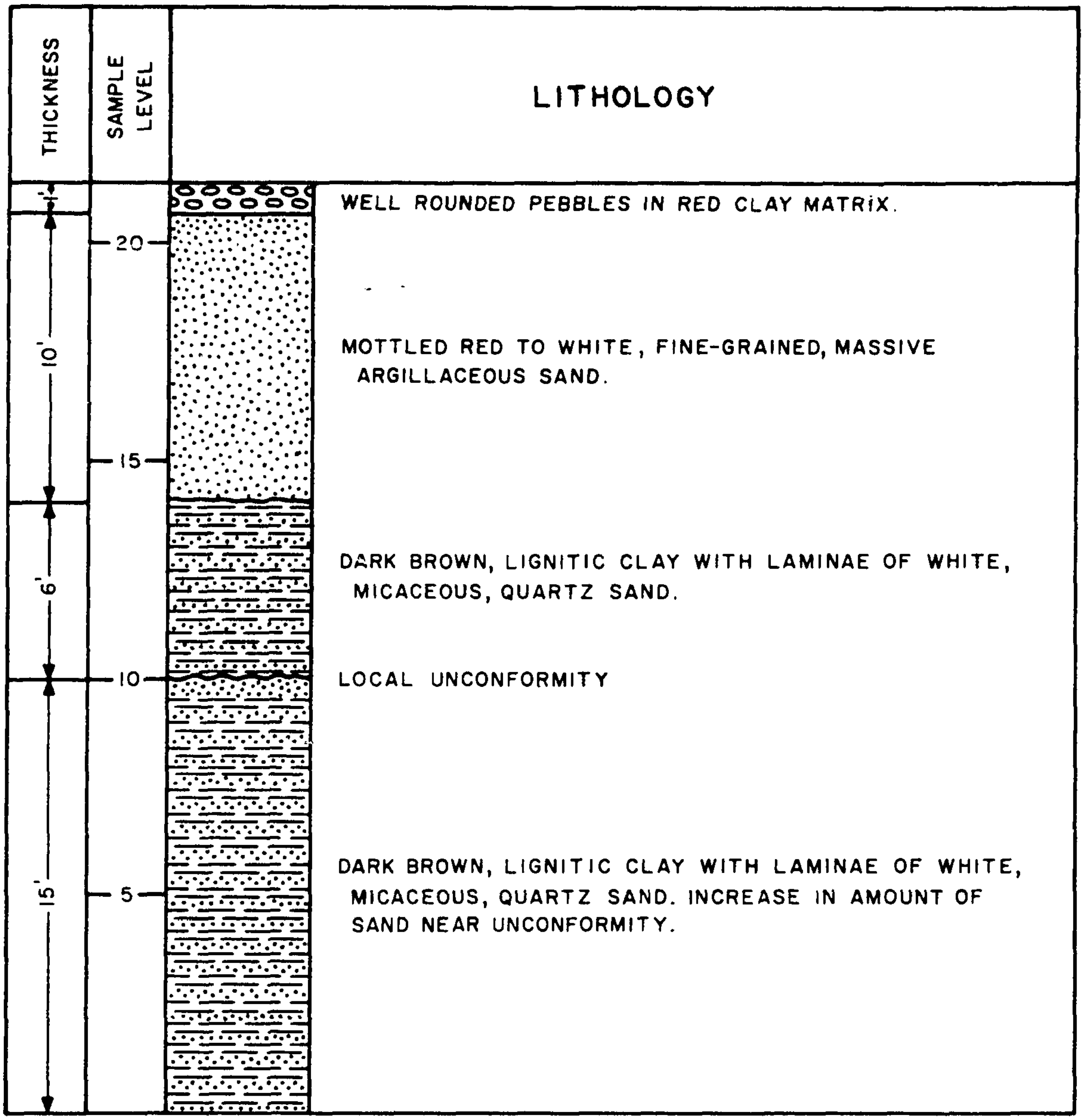


FIGURE 4. EXPOSURE OF LAMINATED SEDIMENTS OF WILCOX GROUP OVERLAIN BY QUATERNARY SAND AND GRAVEL IN RAILROAD CUT IN SECTION 5 T. 2 S. R. 14 W.

SAMPLE INTERVAL 2

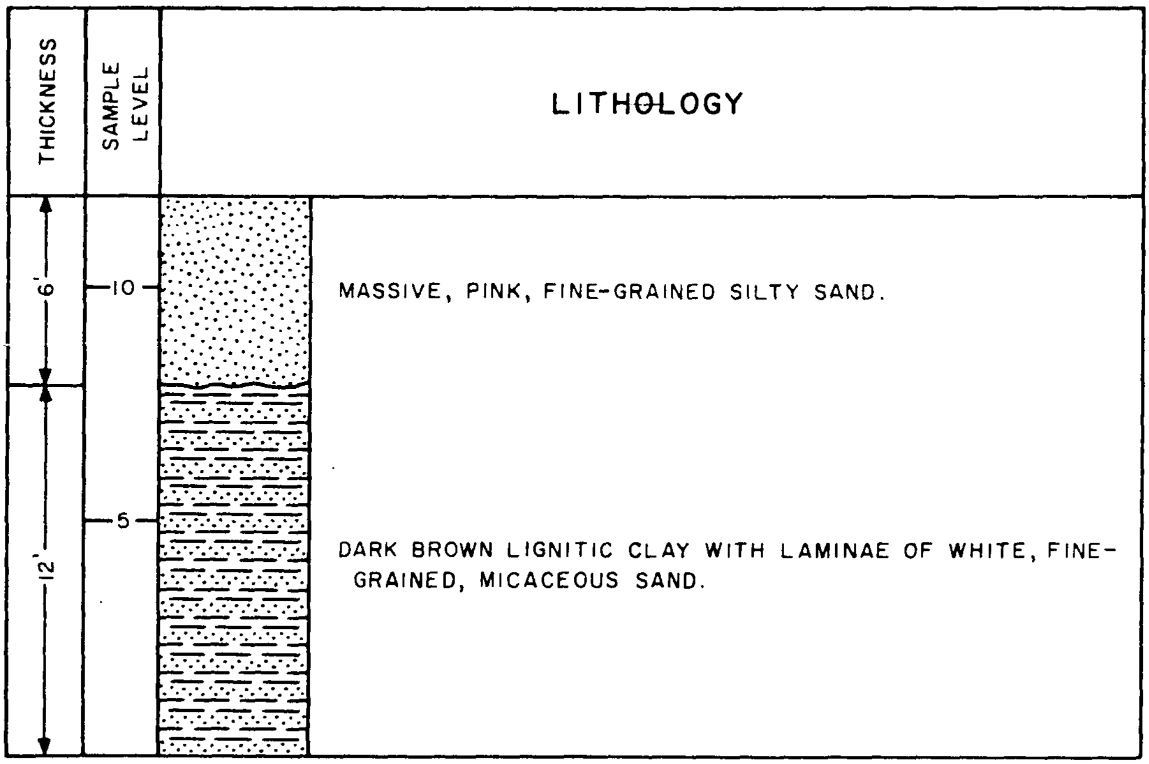


FIGURE 5. WILCOX SEDIMENTS EXPOSED IN ROAD CUT ALONG BENTON-BAUXITE HIGHWAY IN SECTION 17 T. 2 S. R. 14 W.

SAMPLE INTERVAL 3

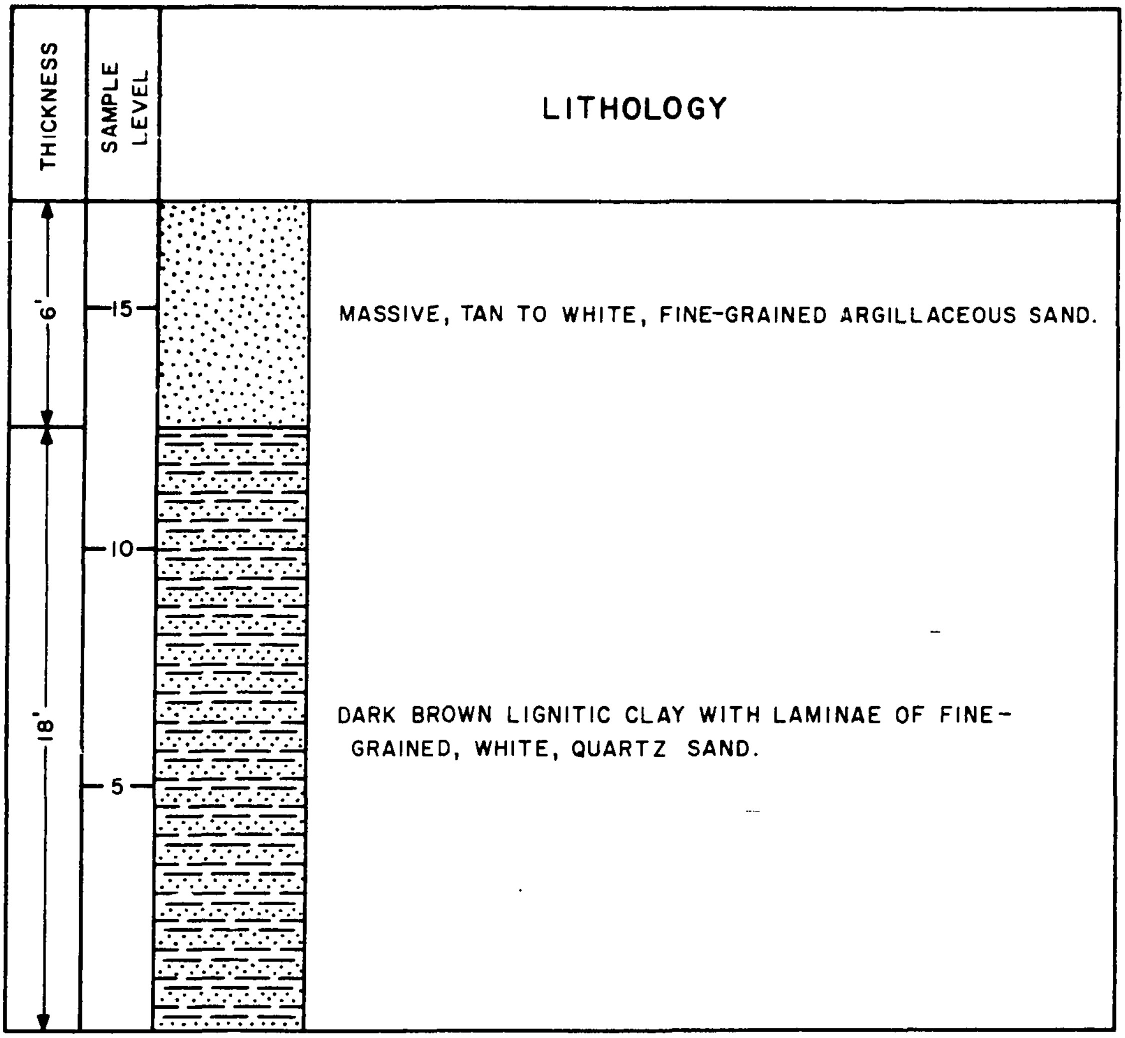


FIGURE 6. ROAD CUT ON STATE HIGHWAY 35, TWO MILES SOUTH OF BENTON IN SECTION 19 T. 2 S. R. 14 W.

SAMPLE INTERVAL 4

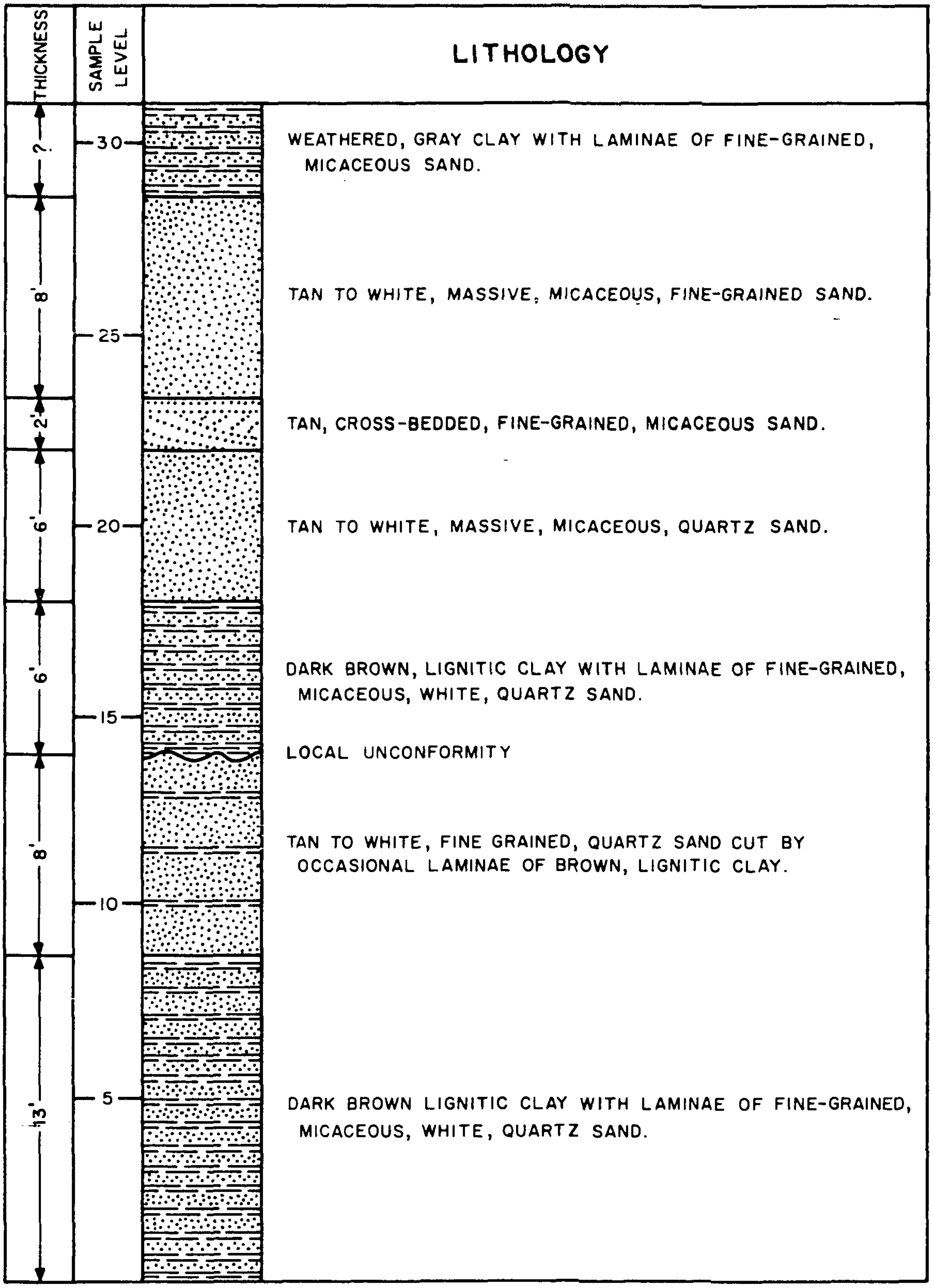


FIGURE 7. WILCOX OUTCROP IN SECTION 25 T.2S. R.14W. IN AREA OF TYPE LOCALITY OF SALINE FORMATION ALONG SALINE RIVER.

SAMPLE INTERVAL 5

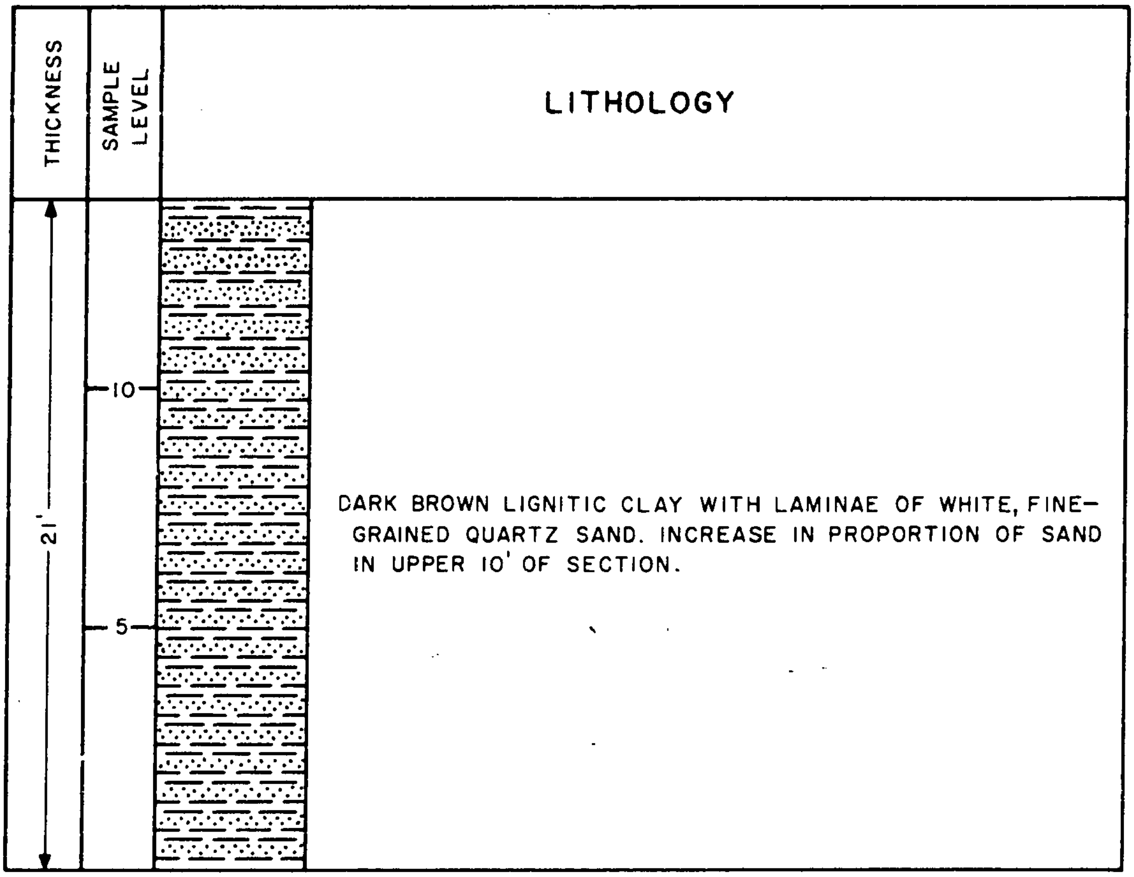


FIGURE 8. EXPOSURE OF WILCOX SEDIMENTS ON GRAVEL ROAD IN SECTION 25 T. 2 S. R. 14 W.

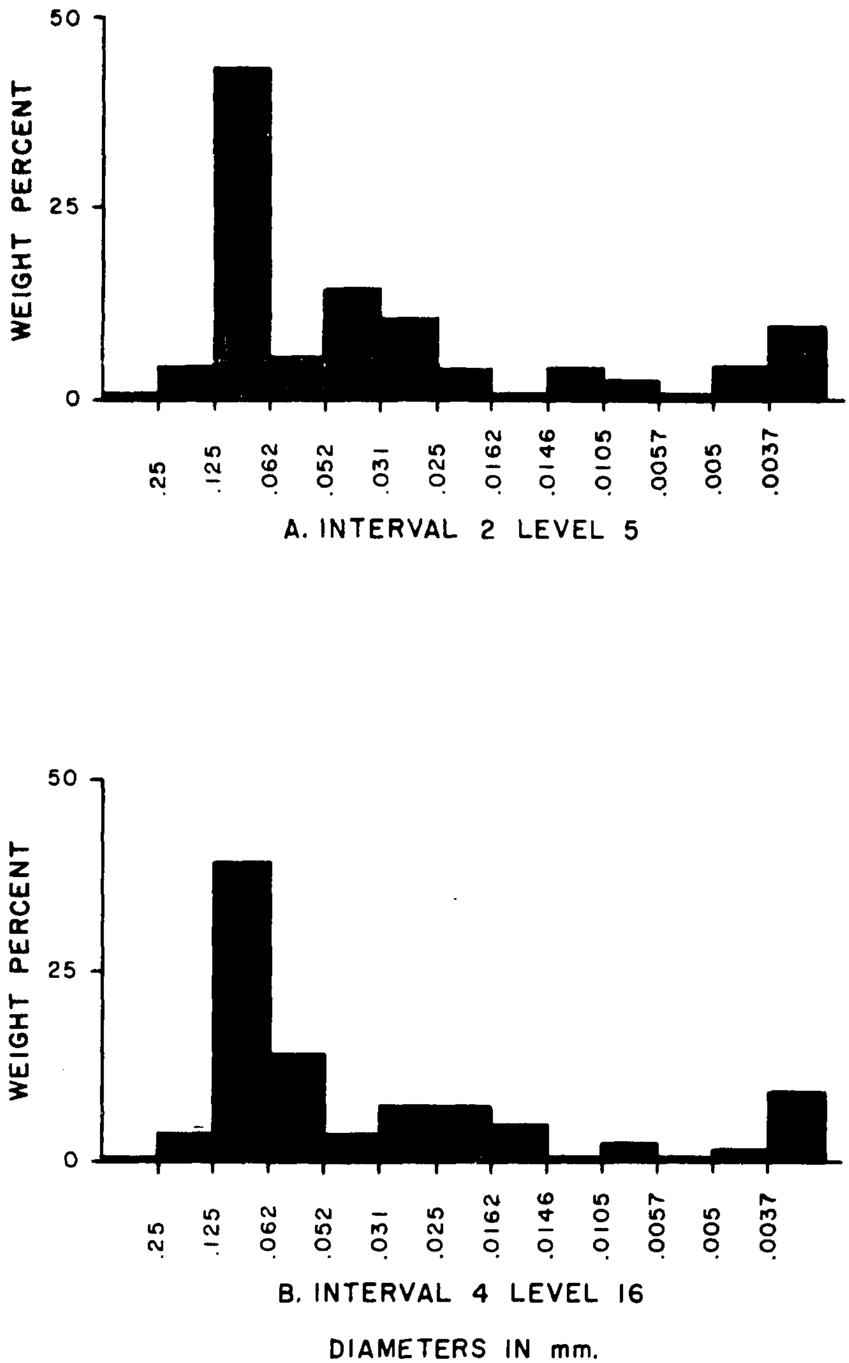


FIGURE 11. HISTOGRAMS SHOWING GRAIN SIZE DISTRIBUTION OF LAMINATED SANDS AND CLAYS OF WILCOX GROUP.

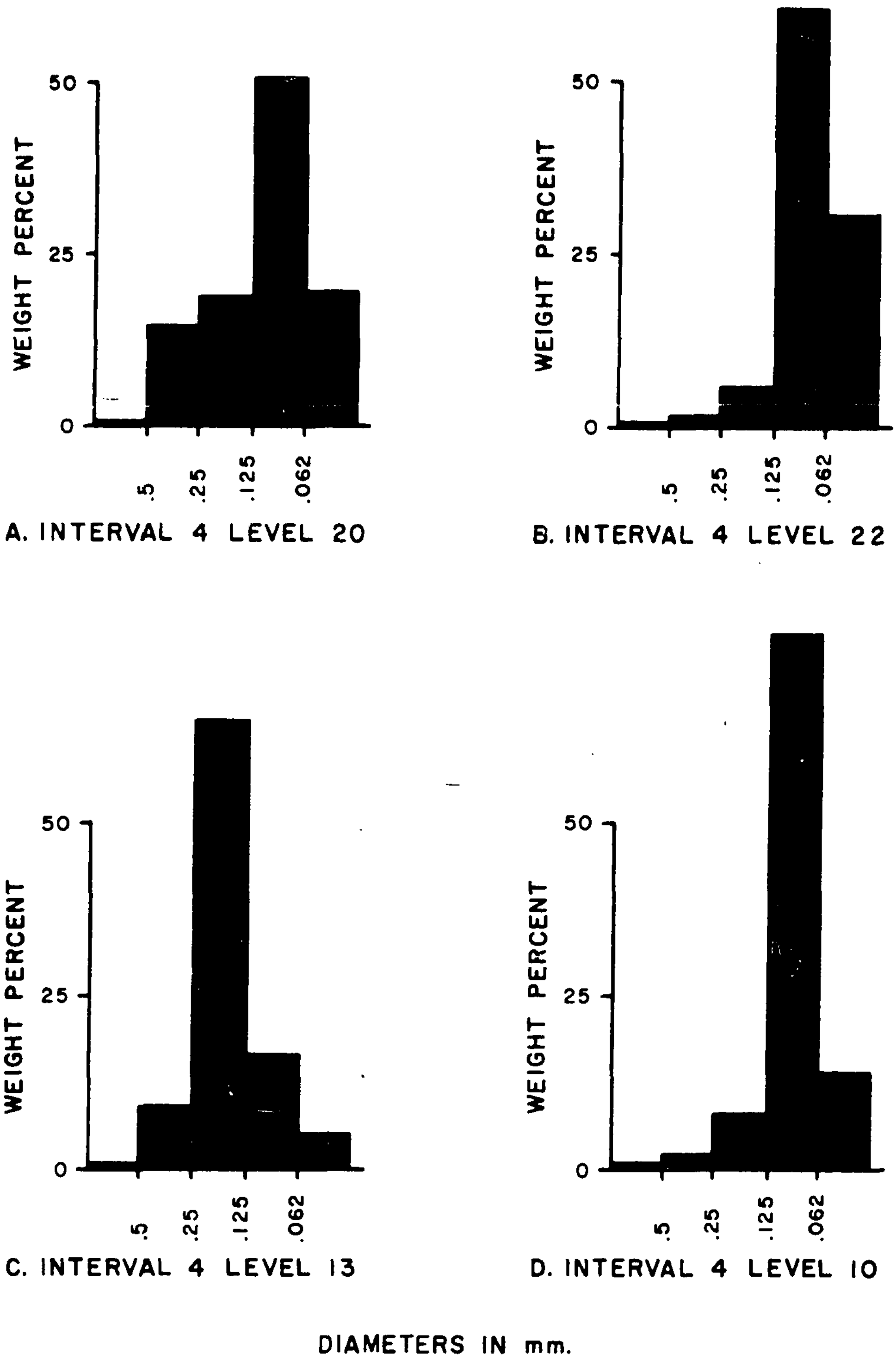


FIGURE 12. HISTOGRAMS SHOWING GRAIN SIZE DISTRIBUTION OF WILCOX SANDS.

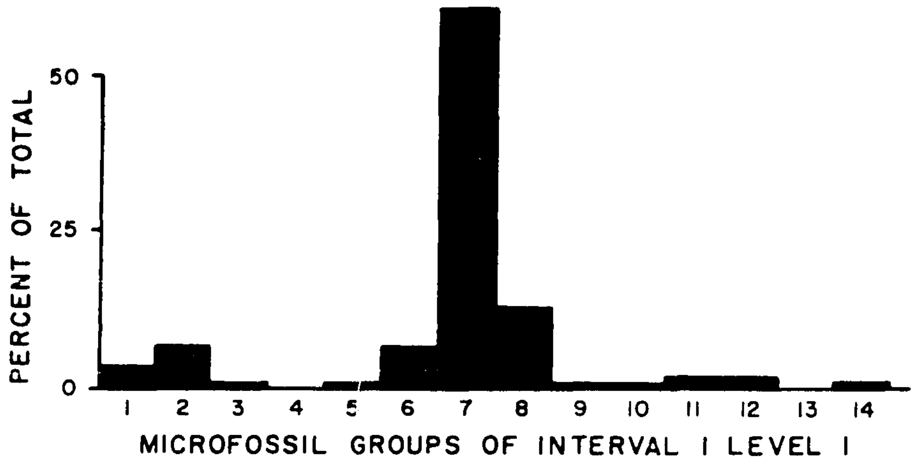


FIGURE 14

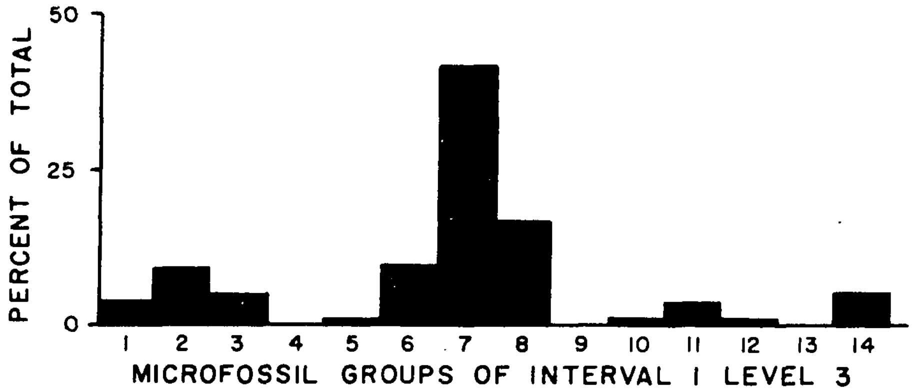


FIGURE 15

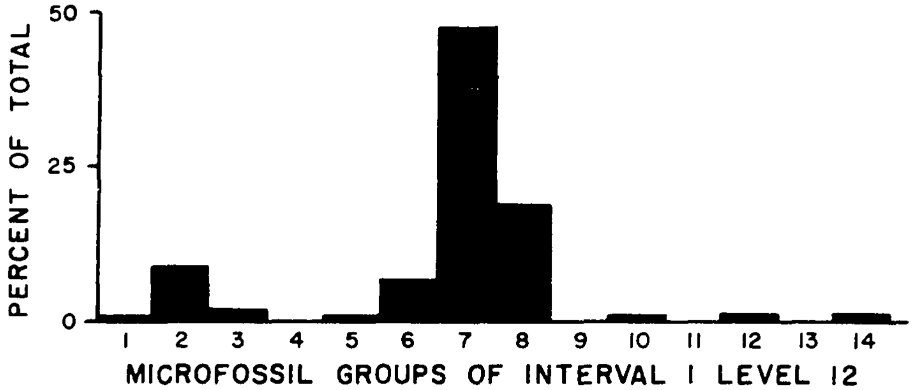


FIGURE 16

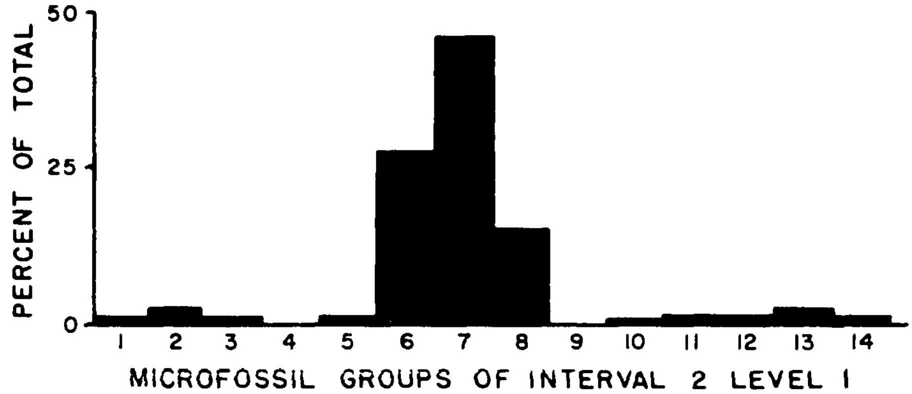


FIGURE 17

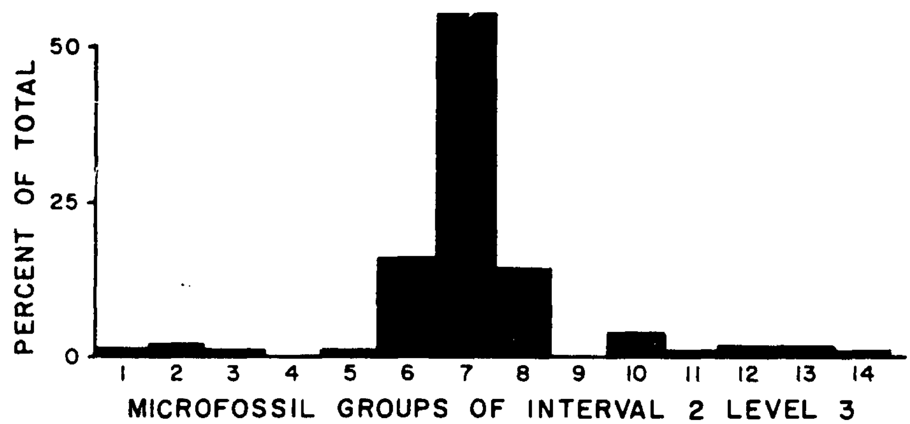


FIGURE 18

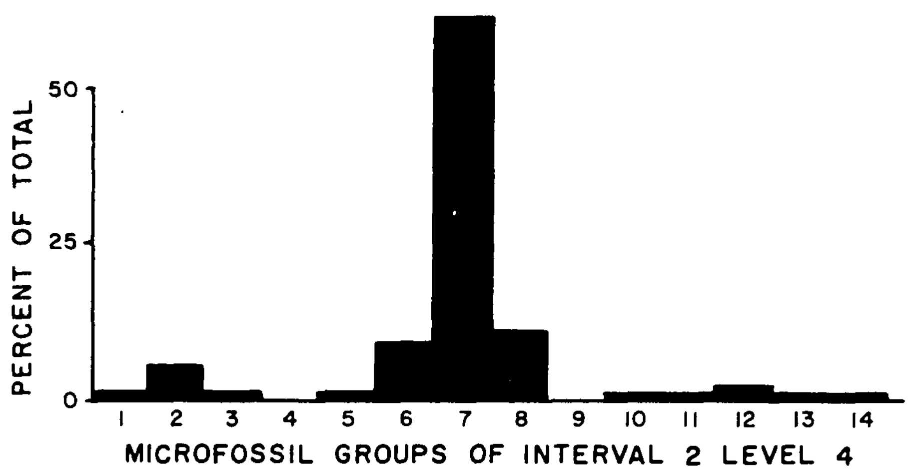
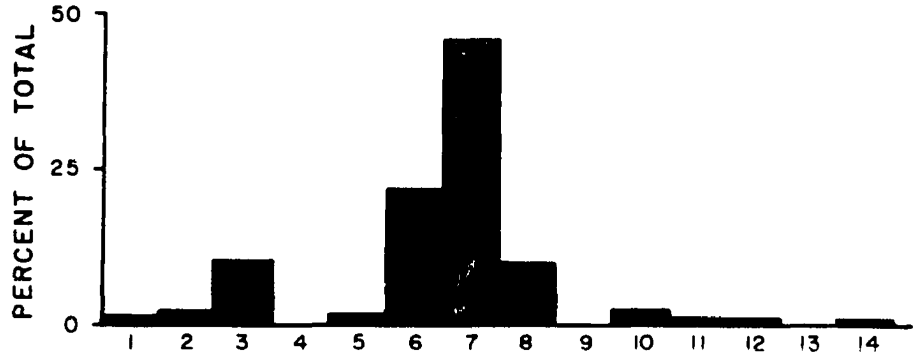
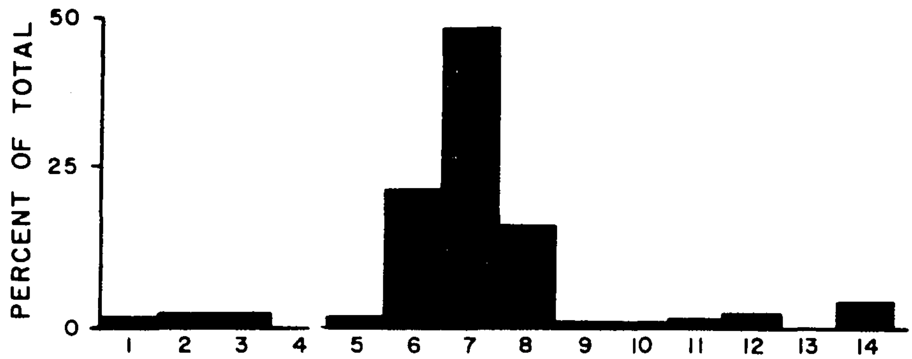


FIGURE 19



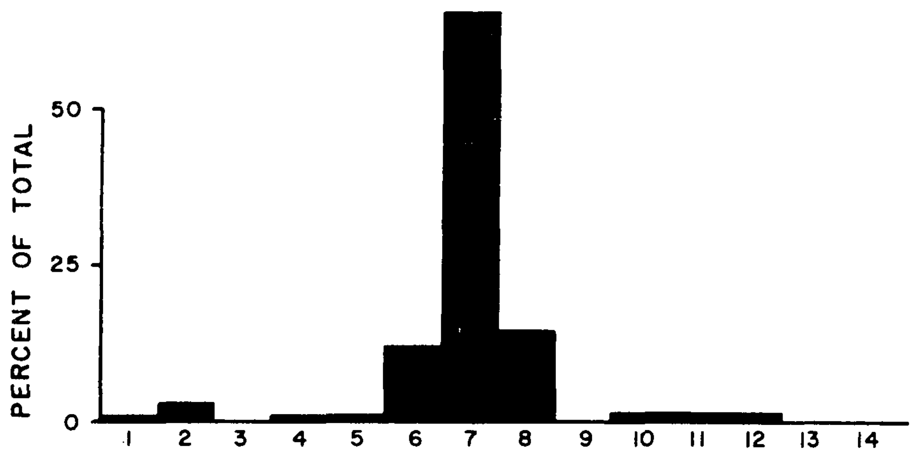
MICROFOSSIL GROUPS OF INTERVAL 3 LEVEL 3

FIGURE 20



MICROFOSSIL GROUPS OF INTERVAL 3 LEVEL 7

FIGURE 21



MICROFOSSIL GROUPS OF INTERVAL 3 LEVEL 12

FIGURE 22

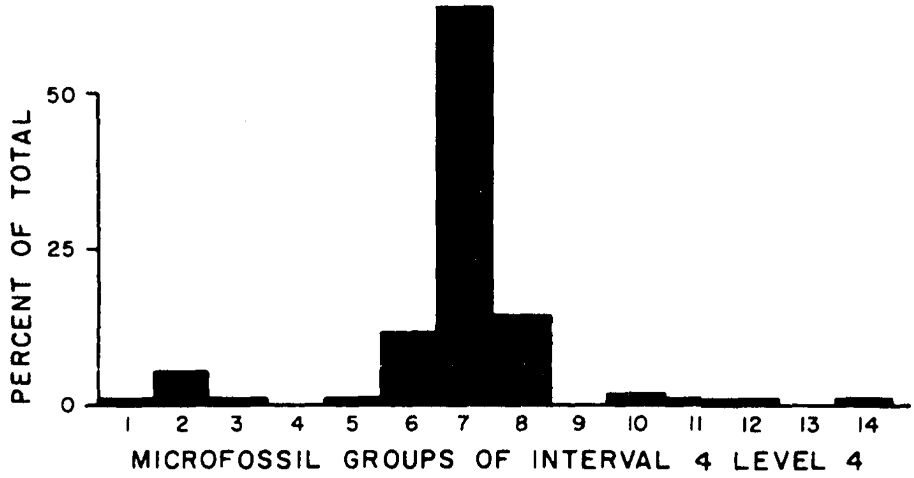


FIGURE 23

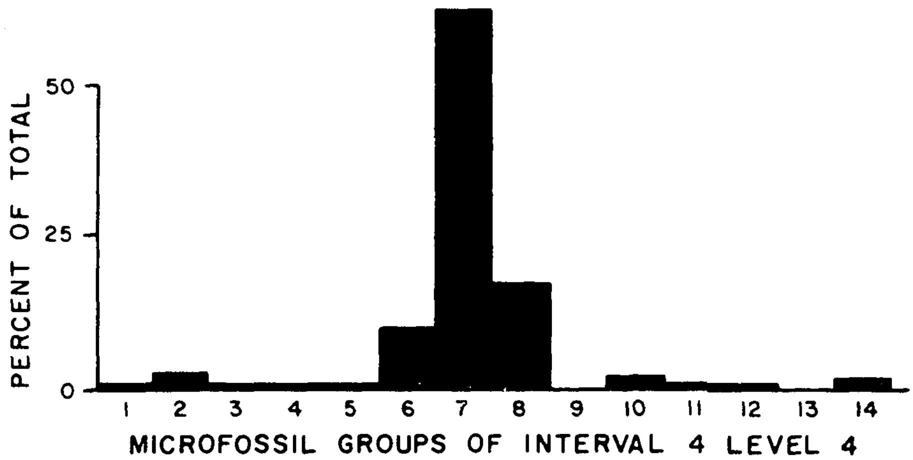


FIGURE 24

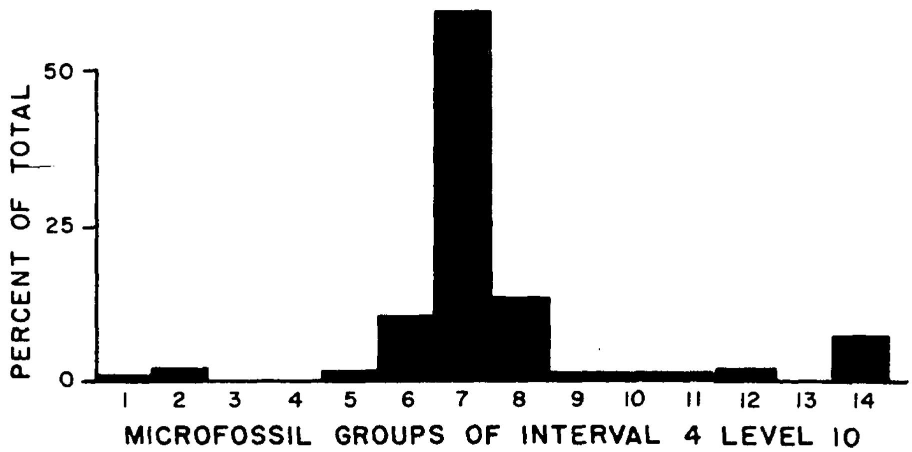
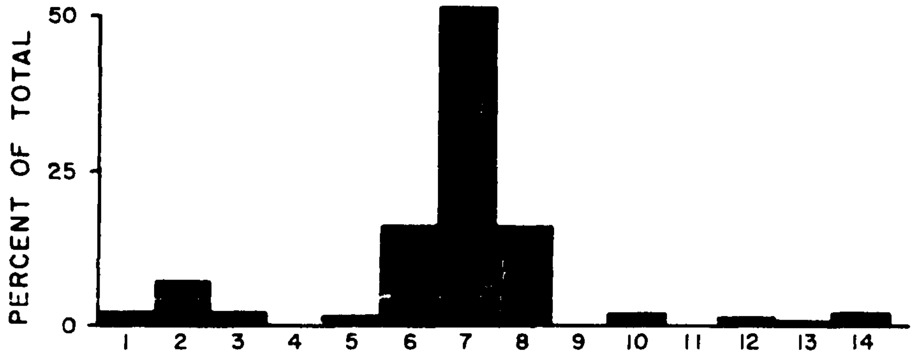
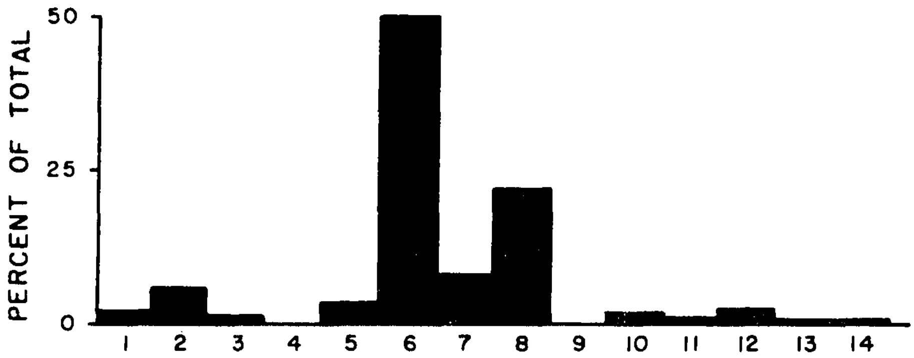


FIGURE 25



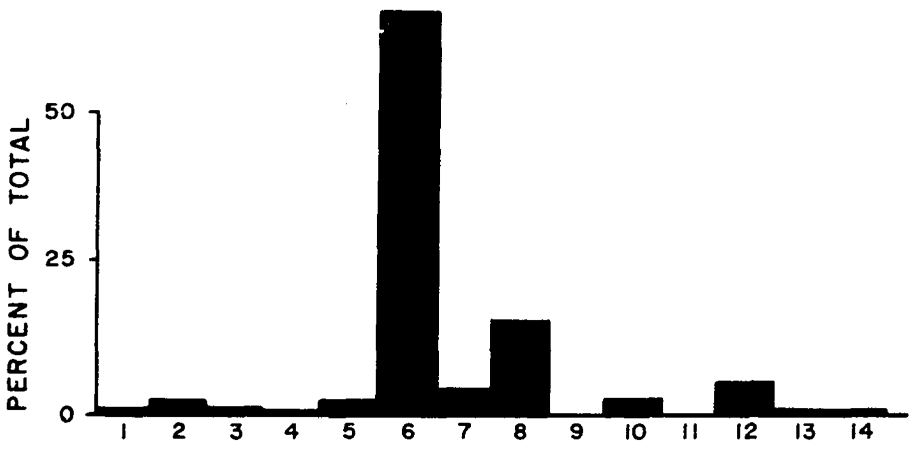
MICROFOSSIL GROUPS OF INTERVAL 5 LEVEL 5

FIGURE 26



MICROFOSSIL GROUPS OF INTERVAL 5 LEVEL 7

FIGURE 27



MICROFOSSIL GROUPS OF INTERVAL 5 LEVEL 9

FIGURE 28

PLATE 1

Figure	
1,2	<u>Anemia sp. 1</u> (1) 47 microns Slide no. 6-12-M-1 (2) 45 microns Slide no. 6-12-M-3
3,4	<u>Lygodium sp. 1</u> (3) 68.6 microns Slide no. 6-6-M-3 (4) 72 microns Slide no. 6-6-M-5
5	<u>Deltoidospora sp. 1</u> 20 microns Slide no. 6-7-B-7
6	<u>Sphagnumsporites sp. 1</u> 26 microns Slide 4-1-5
7	<u>Rugulatisporites sp. 1</u> 32 microns Slide no. 2-8-B-7
8	<u>Rugulatisporites sp. 2</u> 41 microns Slide no. 3-1-5
9,10	<u>Corrugatisporites sp. 1</u> (9) 57.8 microns Slide no. 3-5-8 (10) 68 microns Slide no. 4-1-5
11	<u>Lygodioisporites sp. 1</u> 50 microns Slide no. 6-12-M-5
12	<u>Lycopodium sp. 1</u> 40 microns Slide no. 6-12-M-1

Wilcox

Plate 1

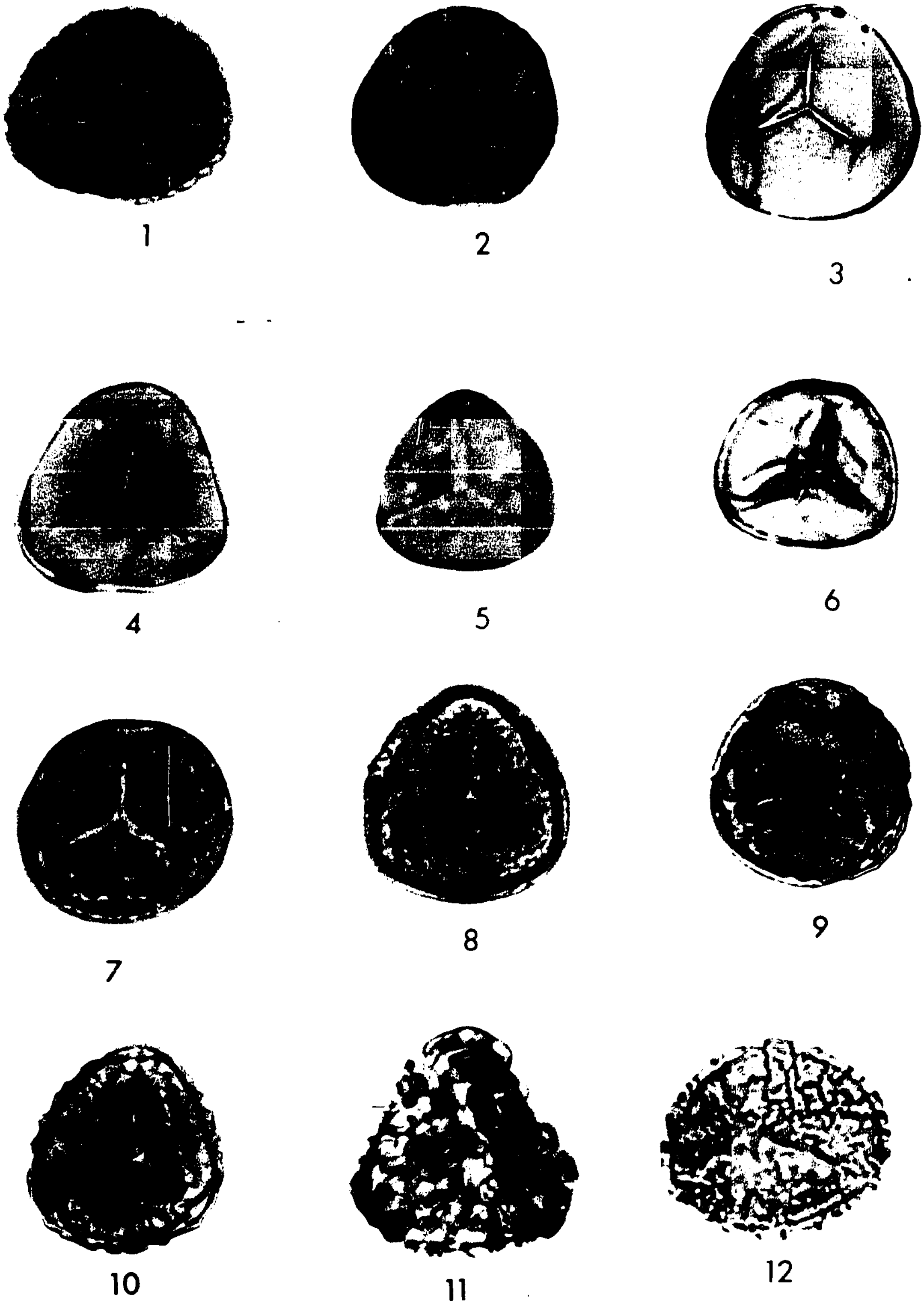


PLATE 2

Figure	
13	<u>Punctatisporites sp. 1</u> 63 microns Slide no. 2-5-T-10
14	<u>Cingulatisporites sp. 5</u> 43.5 microns Slide no. 4-1-9
15	<u>Cingulatisporites sp. 1</u> 46 microns Slide no. 4-1-4
16	<u>Cingulatisporites sp. 2</u> 39.5 microns Slide no. 3-5-8
17	<u>Cingulatisporites sp. 3</u> 41 microns Slide no. 2-4-4
18	<u>Gymnogramma sp. 1</u> 52 microns Slide no. 2-5-T-1
19	<u>Cingulatisporites sp. 4</u> 69 microns Slide no. 6-7-T-6
20,21	<u>Athyrium (?) sp. 1</u> (20) 40 x 64 microns Slide no. 4-1-4 (21) 45 x 63 microns Slide no. 6-6-M-3
22	<u>Verrucatosporites sp. 1</u> 50 x 60 microns Slide no. 6-9-M-3
23,24	<u>Schizaea sp. 1</u> (23) 52.6 x 73.4 microns Slide no. 6-6-M-1 (24) 64 x 82.5 microns Slide no. 4-1-9

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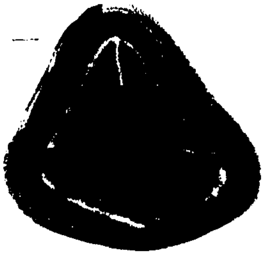

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PLATE 3

Figure	
25	Monocolpopollenites sp. 2 31.5 x 52 microns Slide no. 2-18-3
26	Monocolpopollenites sp. 1 18 x 27 microns Slide no. 2-18-1
27,28	Mauritia (?) sp. 1 (27) 39 microns Slide no. 3-9-B-9 (28) 35 microns Slide no. 2-8-B-6
29	Magnolia (?) sp. 1 58 microns Slide no. 6-12-M-1
30	Inaperturopollenites sp. 3 56 microns Slide no. 6-6-M-7
31	Inaperturopollenites sp. 7 50 microns Slide no. 6-6-M-2
32	Inaperturopollenites sp. 2 45 x 77 microns Slide no. 3-9-B-4
33,34	Inaperturopollenites sp. 1 (33) 52 x 68 microns Slide no. 3-9-B-6 (34) 56 microns Slide no. 3-9-B-5
35	Inaperturopollenites sp. 6 38 microns Slide no. 3-9-B-2
36	Inaperturopollenites sp. 5 20.5 microns Slide no. 4-1-4
37	Inaperturopollenites sp. 8 30 microns Slide no. 3-9-B-9
38	Lilium (?) sp. 1 143 microns Slide no. 3-9-B-2
39	Inaperturopollenites sp. 4 45 microns Slide no. 4-1-6

Wilcox Plate 3

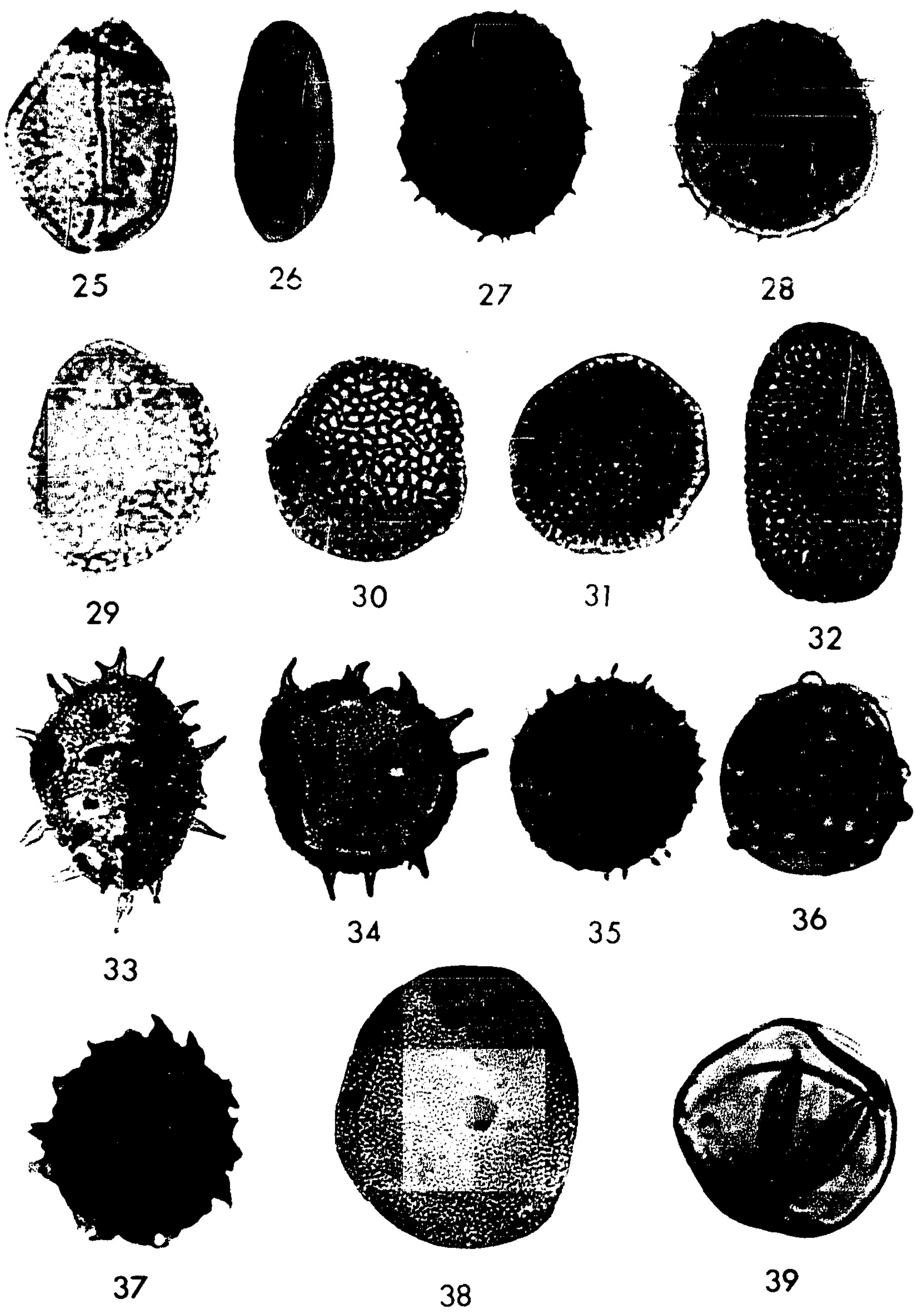

PLATE 4

Figure	
40	Taxodium sp. 1 33 microns Slide no. 4-1-5
41,42	Pinus sp. 1 (41) 78 x 92 microns Slide no. 6-10-B-1 (42) 67 x 90 microns Slide no. 6-6-M-1
43	Cryptomeria sp. 1 35 microns Slide no. 4-1-10
44	Podocarpus sp. 1 40 x 75 microns Slide no. 6-6-M-1
45,46	Extratriporopollenites sp. 1 (45) 43 microns Slide no. 6-6-M-6 (46) 40 microns Slide no. 6-12-M-1
47	Betula sp. 1 42 microns Slide no. 6-6-M-7
48,50	Myrica sp. 1 (48) 35 microns Slide no. 6-12-M-2 (50) 32 microns Slide no. 6-6-M-4
49,51	Corylus sp. 1 (49) 25 microns Slide no. 6-6-M-4 (51) 28 microns Slide no. 6-12-M-6
52	Triporopollenites sp. 3 52 microns Slide no. 6-6-M-2

Wilcox

Plate 4

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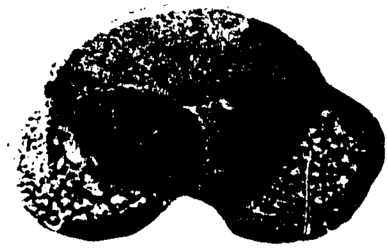

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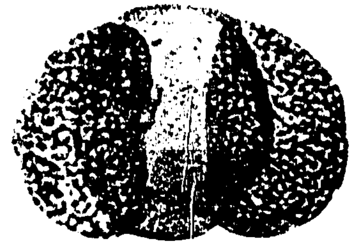

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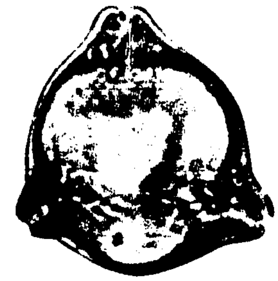

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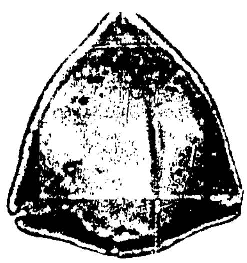

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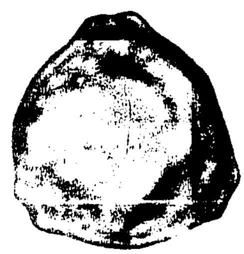

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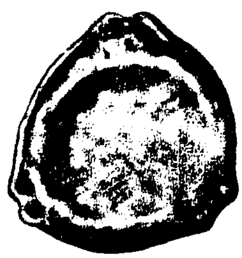

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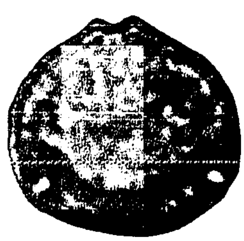

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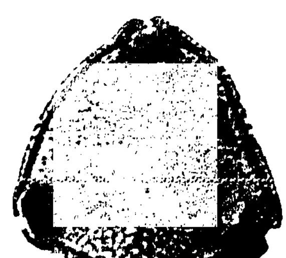

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PLATE 5

Figure	
53	Triporopollenites sp. 1 29.5 microns Slide no. 6-6-M-1
54	Intratriporopollenites sp. 1 29 microns Slide no. 6-12-M-2
55	Proteacidites sp. 2 25 microns Slide no. 6-6-M-6
56	Proteacidites sp. 1 45.3 microns Slide no. 5-1-3
57	Triatriopollenites sp. 2 30 microns Slide no. 6-7-T-4
58	Triatriopollenites sp. 1 40 microns 6-7-T-10
59	Celtis (?) sp. 1 21 microns Slide no. 6-9-3
60,61	Triporopollenites sp. 2 (60) 38 microns Slide no. 2-8-B-8 (61) 36 microns Slide no. 2-8-B-2
62,63	Engelhardtia sp. 1 (62) 38 microns Slide no. 6-12-M-1 (63) 39 microns Slide no. 6-6-M-1
64,65,66	Carya sp. 1 (64) 38.5 microns Slide no. 6-6-M-8 (65) 42 microns Slide no. 6-6-M-4 (66) 42 microns Slide no. 3-2-2
67	Anacolosa (?) sp. 1 22 microns Slide no. 4-1-10
68	Carpinus sp. 1 42 microns Slide no. 2-5-T-1

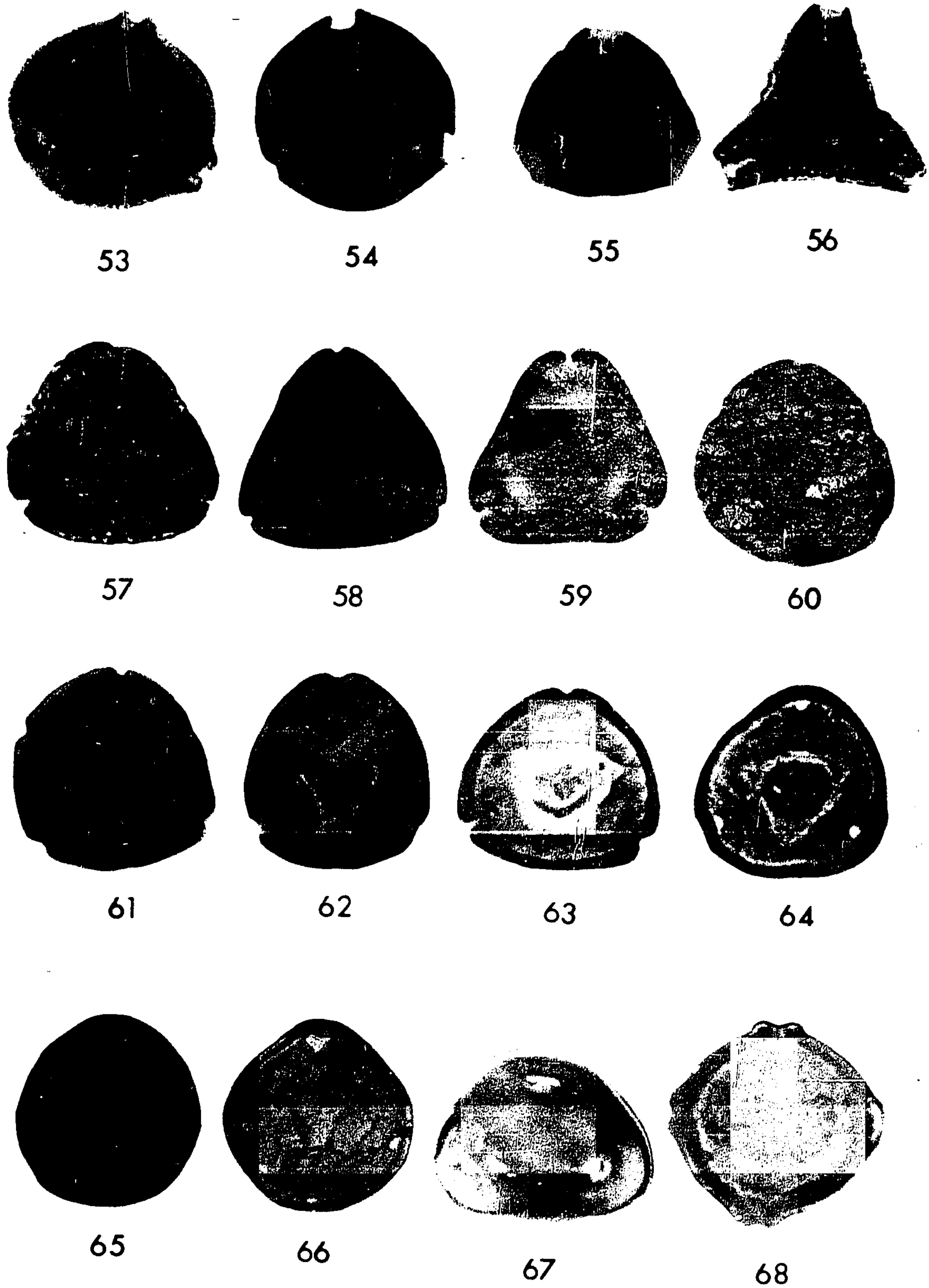
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PLATE 6

Figure	
69	Ulmus sp. 1 37 microns Slide no. 2-4-4
70	Polyporopollenites sp. 2 38.5 microns Slide no. 6-1-B-1
71	Chenopodium sp. 1 32 microns Slide no. 6-9-T-1
72,73	Pterocarya sp. 1 (72) 36 microns Slide no. 4-1-10 (73) 35 microns Slide no. 2-8-B-2
74,75	Polyporopollenites sp. 1 (74) 42 microns Slide no. 2-8-B-2 (75) 42 microns Slide no. 6-9-3
76	Itea (?) sp. 1 35 microns Slide no. 3-9-B-5
77	Staberhoa (?) sp. 1 48 microns Slide no. 6-9-T-5
78	Tilia (?) sp. 2 30 microns Slide no. 5-1-6
79	Tilia sp. 1 48 microns Slide no. 6-6-M-2
80	Tricolpopollenites sp. 4 33 microns Slide no. 5-1-6
81	Ilex sp. 1 42 microns Slide no. 6-6-M-3
82	Illicum (?) sp. 1 73 microns Slide no. 6-6-M-9
83,84	Salix sp. 1 (83) 31.5 microns Slide no. 6-6-M-10 (84) 28 microns Slide no. 3-9-B

Wilcox Plate 6

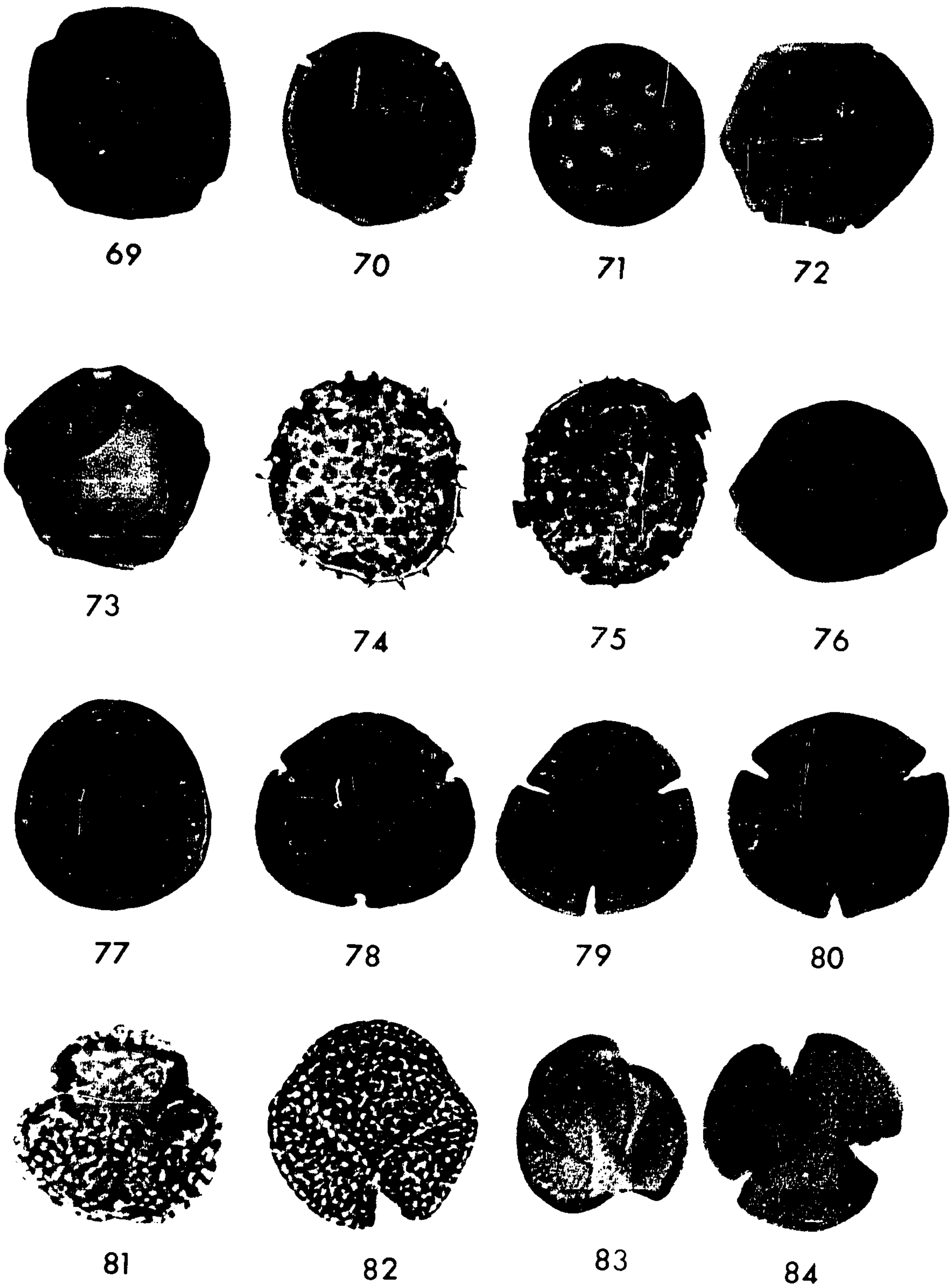

PLATE 7

Figure	
85,86	Tricolpopollenites sp. 3 (85) 42 microns Slide no. 6-12-M-7 (86) 40 x 56 microns Slide no. 6-6-M-1
87	Tricolpopollenites sp. 1 15 x 20 microns Slide no. 6-6-M-2
88	Tricolpopollenites sp. 2 34 microns Slide no. 6-12-M-7
89,90	Quercus sp. 1 (89) 20 x 35 microns Slide no. 3-9-B-5 (90) 23 x 34 microns Slide no. 3-9-B-8
91	Ephedra (?) sp. 1 24 x 40 microns Slide no. 5-1-1
92,93	Castanea sp. 1 (92) 16 x 20 microns Slide no. 6-6-M-1 (93) 16 x 22 microns Slide no. 6-9-T-3
94,95	Rhus sp. 1 (94) 31 x 40 microns Slide no. 6-6-M-6 (95) 32 x 39 microns Slide no. 6-6-M-3
96	Tricolporopollenites sp. 3 25 x 35 microns Slide no. 6-9-T-5
97	Tricolporopollenites sp. 2 35 x 55 microns Slide no. 3-4-T-7
98	Rhamnus (?) sp. 1 37 microns Slide no. 2-8-B-1
99	Nyssa sp. 1 49 microns Slide no. 6-6-M-4
100	Nyssa sp. 3 22 microns Slide no. 6-12-M-2
101	Nyssa sp. 2 40 microns Slide no. 6-12-M-5

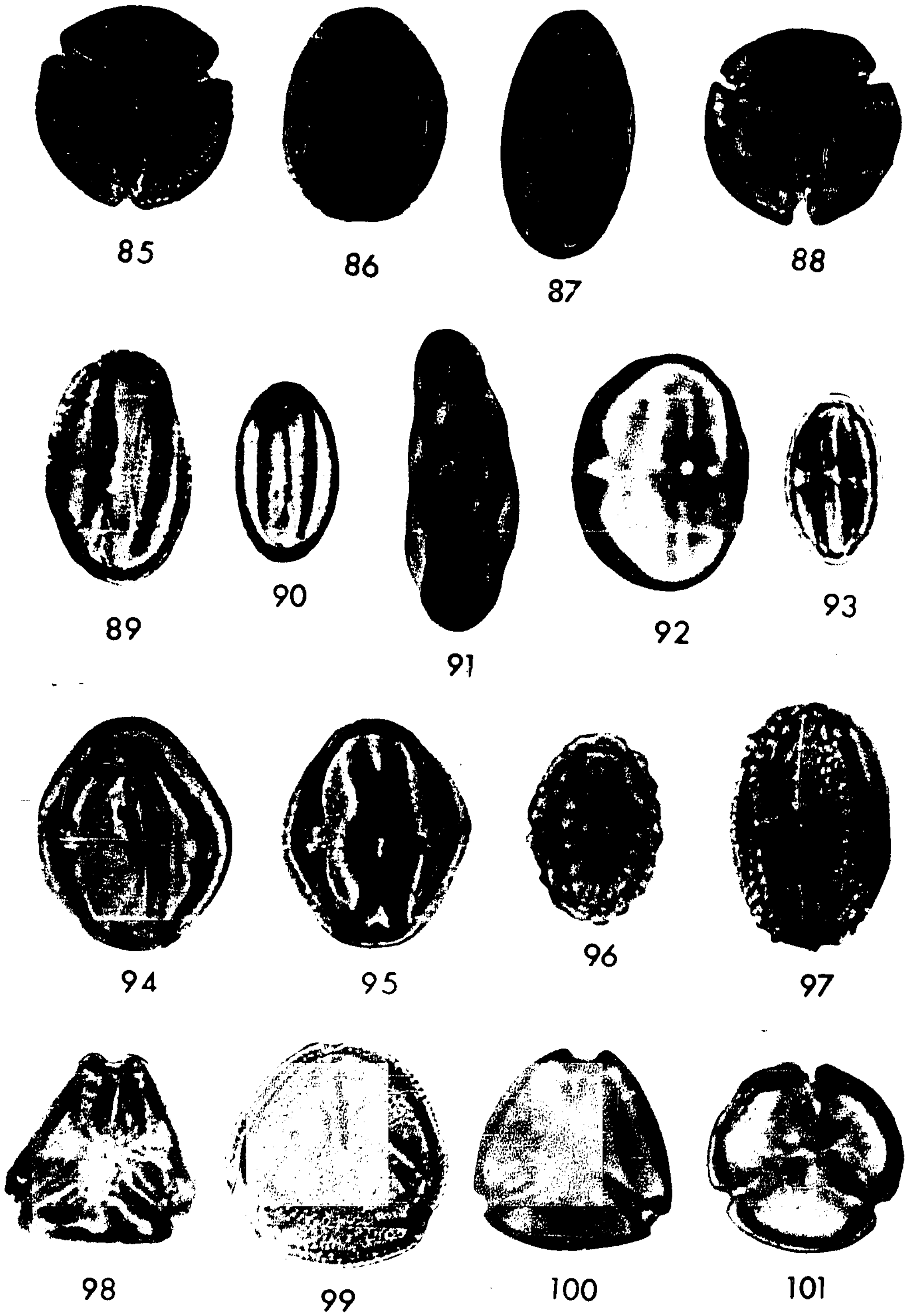
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PLATE 8

Figure	
102	Symplocos sp. 1 50 microns Slide no. 6-12-M-5
103	Tricolporopollenites sp. 4 25 microns Slide no. 5-1-1
104,105	Tricolporopollenites sp. 1 (104) 63 microns Slide no. 2-8-B-2 (105) 70 microns Slide no. 2-8-B-4
106	Tetracolporopollenites sp. 1 78 microns Slide no. 2-8-B-6
107	Manilkara sp. 2 25 microns Slide no. 6-6-M-1
108,109	Manilkara sp. 1 (108) 38.5 x 50 microns Slide no. 3-2-8 (109) 37 x 48 microns Slide no. 2-9-1
110	Polygala sp. 1 31 x 38.5 microns Slide no. 2-9-1
111	Pollen type A 20 x 28 microns Slide no. 2-8-B-7
112,113	Nothofagus (?) sp. 1 (112) 40 microns Slide no. 5-1-2 (113) 36 microns Slide no. 3-4-T-6
114	Rhododendron sp. 1 50 microns Slide no. 2-5-T-3


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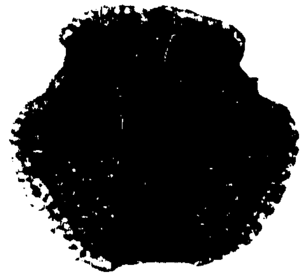
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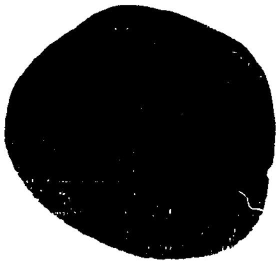
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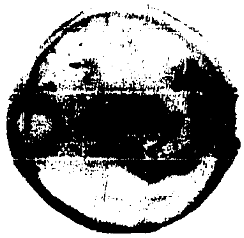
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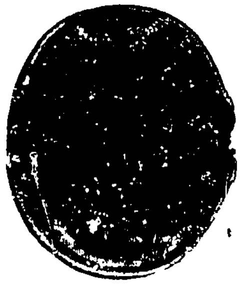
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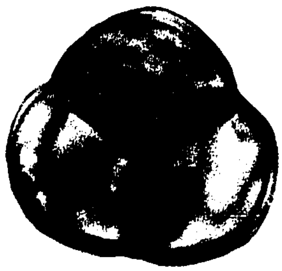
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PLATE 9

Figure	
115	<u>Hystrichosphaeridium sp. 1</u> 60 microns Slide no. 6-7-B-8
116,118	<u>Hystrichosphaeridium sp. 2</u> (116) 52 microns Slide no. 6-8-B-1 (118) 47 microns Slide no. 6-7-B-8
117	<u>Hystrichosphaeridium sp. 3</u> 51 microns Slide no. 6-10-B-8
119	<u>Wetzeliella articulata</u> 98 x 106 microns Slide no. 5-1-1
120	<u>Incertae Sedis sp. 1</u> 90 microns Slide no. 2-1-4
121	<u>Fungus sp. 1</u> 10 x 65 microns Slide no. 4-1-4
122	<u>Fungus sp. 2</u> 14 x 26 microns Slide no. 4-1-5
123	<u>Fungus sp. 3</u> 12 x 58 microns Slide no. 4-1-9
124	<u>Gonyaulax (?) sp. 1</u> 42 microns Slide no. 2-8-B-7

Plate 9

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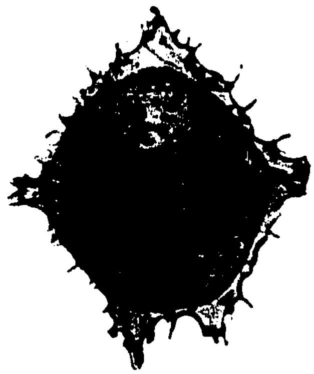

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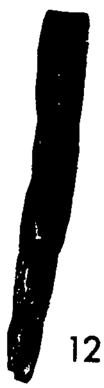

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