69-20,931

SHAFFER, Bernard Leroy, 1935-
PALYNOLOGY OF THE MICHIGAN "RED BEDS".

Michigan State University, Ph.D., 1969
Paleontology

University Microfilms, Inc., Ann Arbor, Michigan

PALYNOLOGY OF THE MICHIGAN "RED BEDS"

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Geology

1969

ABSTRACT

PALYNOLOGY OF THE MICHIGAN "RED BEDS"

BY

BERNARD L. SHAFFER

A palynological study of the problematic "Red Beds" in the subsurface Michigan Basin has been undertaken primarily to establish their time-stratigraphic position, and to develop information on the geographic, floral, ecologic, and climatic history of the basin and adjacent areas for the time interval represented.

A comparison of the "Red Beds" spore/pollen assemblage with established time ranges of diagnostic species from Canada, Europe, and Australia, indicates a Jurassic age between early Bathonian and late Oxfordian. Previously, these deposits have been considered "Permo-Carboniferous". This is the first documentation of Jurassic rocks east of the Mississippi River, except in the subsurface Gulf and Atlantic Coastal Provinces. A similar age is established for the Fort Dodge Formation of central Iowa.

Sixty-four spore and pollen species assigned to 31 genera are described and illustrated. In all samples examined, the genus Classopollis invariably accounts for more than 70 percent (relative abundance) of the entire assemblage. Pteridophyte spore species, all of which have low relative frequencies, comprise 39 percent of the flora. They have been assigned to the Equisetaceae, Lycopodiaceae,

Selaginellaceae, Osmundaceae, Hymenophyllaceae, and Cyatheaceae. Sixty-one percent of the species are assigned to the gymnosperm families Cycadaceae, Ginkgoaceae, Pinaceae, Podocarpaceae, Araucariaceae, Cupressaceae, and Chlamydospermales. One pteridosperm species was recorded. No angiosperm pollen or marine biota were identifed.

It is concluded that deposition of the "Red Beds" occurred in fluviatile and shallow, oxidizing lacustrine environments subsequent to structural subsidence of the Michigan Basin. A marine transgression of Western Interior Jurassic seas into the Michigan Basin is possible, but is not necessary as a source for the calcium sulphate. Warm arid to subarid climates are indicated by the position of the Michigan Basin within a global Jurassic evaporite belt, by the closely associated and widespread gypsum and the redbed facies, and by the inferred xerophytic aspect of local floras. Extensive plains peripheral to the "Red Beds" basin were probably inhabited by a desert-like flora dominated by the plant which produced Classopollis. Coniferous communities might have occurred on uplands to the north and northwest. The less common mesic tropical to subtropical constituents of the palynological assemblage conceivably were derived from riverline associations in stream valleys penetrating the uplands.

ACKNOWLEDGMENTS

This study was instigated and carried through under the direction of Dr. Aureal T. Cross. For his keen personal interest in the study, for untiring offer of his time for the field collection of reference materials, and for the genial atmosphere provided, the author extends a deep sense of gratitude.

Dr. J. E. Smith, Dr. J. E. Cantlon, Dr. C. E. Prouty, and Dr. B. T Sandefur offered many suggestions which are incorporated in the text. Dr. Stanley A. Pocock generously made available an unpublished manuscript of his comprehensive palynological study of the western Canadian Jurassic. Numerous "Red Beds" thickness data were supplied by Dr. J. A. Dorr, University of Michigan.

Acknowledgments are also extended to the Michigan Geological Survey and the Subsurface Laboratory of the University of Michigan for making available their repositories of subsurface samples. Equipment and supplies were provided by the Department of Geology, Michigan State University.

The writer is especially grateful to Dr. Napier S. Aldrich for his genuine interest and constant encouragement.

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INTRODUCTION

The time-stratigraphic position of the so-called "Red Beds" of Michigan has remained, since their discovery in 1908, an enigmatic and controversial chapter in the geologic history of the Michigan Basin. This redbed and evaporite sequence, centrally located in the subsurface of the Michigan Basin, lies between Late Paleozoic strata and Pleistocene drift. This inconclusive physical stratigraphic relationship, and the fact that no paleontologic evidence had been discovered previously, have been the principal causes for the uncertainty regarding the age of these strata. In the past they have generally been considered to be "Permo-Carboniferous".

Preliminary investigation of the palynomorphs provided evidence that they are neither Pennsylvanian nor Permian, as presumed, but rather of medial Mesozoic age. Strata of this age have not been previously recognized in the United States and southern Canada east of the Mississippi River, except in the subsurface Atlantic and Gulf Coastal Provinces. Therefore, discovery of Mesozoic sediments in the Michigan Basin is significant and warrants a re-evaluation of the stratigraphic, paleogeographic, paleoclimatic, and floral history of Michigan and adjacent areas of the northeast central United States.

The scope and purpose of this study is to make a detailed taxonomic and systematic assessment of the palynological assemblage recovered from the "Red Beds", and from the derived data, to develop information on the following objectives:

1) To establish for the "Red Beds" a reasonable geochronology and to correlate these strata with those of similar age deposited in areas outside the Michigan Basin.

2) To consider the geology and paleogeography relative to the history of the structural configuration of the Michigan Basin and adjacent areas for the time interval represented by the "Red Beds". It is hoped some contribution can be made toward resolving questions concerning the origin and deposition of these rocks, <u>e.g.</u>, were they deposited in an intracratonic freshwater basin, or by an epeiric sea which transgressed from outside the Michigan Basin?

3) To demonstrate, whenever possible, genetic consanguinity between members of the spore/pollen flora and natural phyletic categories, and to reconstruct the terrestrial floras which inhabited areas peripheral to the depositional site of the "Red Beds". Preliminary examinations revealed that gymnospermous pollen are far more abundant that pteridophyte spores, both in terms of relative percentage and species diversity. Because of the uniqueness of strata of this age in the northeast central United States, a thorough inventory of the flora represented by the palynomorphs should contribute to future syntheses of North American Mesozoic floristic and vegetation zones.

4) To employ both biological and physical criteria to determine the environmental and climatic regimes in which these sediments were deposited. An attempt will also be made to place the "Red Beds" in proper perspective relative to global Mesozoic climatic and floral zones.

Palynology is employed in this study first and foremost to approach a longstanding geochronologic problem. The determination of the biostratigraphic position of these deposits is therefore of paramount importance. The other objectives will have maximum meaning only when interpreted within the context of an adequate time stratigraphy. A palynologic study of the "Red Beds" provides, for the first time, an opportunity to elucidate the geologic and floral history of a previously unrecognized segment of time represented in the stratigraphic succession of the Great Lakes region.

PALYNOLOGICAL MATERIALS AND METHODS OF STUDY

SOURCE OF SAMPLES

As the "Red Beds" are unknown from surface exposures, it was necessary to exploit sources of subsurface samples. Core samples would have been preferable, but a search for such proved futile. Cable tool cuttings are more reliable than and superior to rotary cuttings, but only a few suites were available. Suites of samples from wells drilled with rotary tools are abundant, and were the source of the bulk of samples studied.

Repositories from which materials were obtained included the Michigan Geological Survey, Michigan State University, and the Subsurface Laboratory at the University of Michigan. A listing of all samples studied, with their location and depth interval, is included in the Appendix. The geographic locations of the wells from which samples were taken are shown in Fig. 1.

Samples of representative lithologies from the "Red Beds" interval were selected from wells over a wide geographic distribution. Cuttings from each depth interval were examined under a binocular microscope, and rock chips believed to represent that particular interval were hand-picked with tweezers. The possibility of incorporating contaminants resulting from down-hole caving was thus minimized. In addition, samples of strata underlying the "Red Beds" were selected for analysis.

For comparative purposes, samples were also obtained from the Lower Cretaceous Mattagami Series of the James Bay region of northern Ontario, from the Jurassic Morrison, Sundance, and "Ralston Creek" Formations of the western United States, from the Jurassic and early Cretaceous of the Gulf Coastal Province, and from the Jurassic Fort Dodge Formation of north central Iowa.

SAMPLE PREPARATION

A few grams of material from each sample was washed in water or dilute hydrochloric acid to remove caked drilling muds and other possible sources of surficial contamination. Carbonates were then removed by treatment with hydrochloric acid and, after washing, silicates were digested for 24 hours in 48% hydrofluoric acid. Fluorosilicates and silica gels remaining in the residue were dissolved in hot dilute hydrochloric acid. Minor amounts of comminuted organic detritus remaining in the residue were usually readily oxidized and dispersed by brief treatment in five percent sodium hypochlorite (commercial Clorox). The opacity of the characteristically deep brown to amber colored palynomorphs was reduced by this brief oxidation to a point where they were sufficiently transparent. Staining was rarely necessary to increase contrast. The swirling technique was sometimes used to remove excessive particulate mineral matter and larger organic detritus.

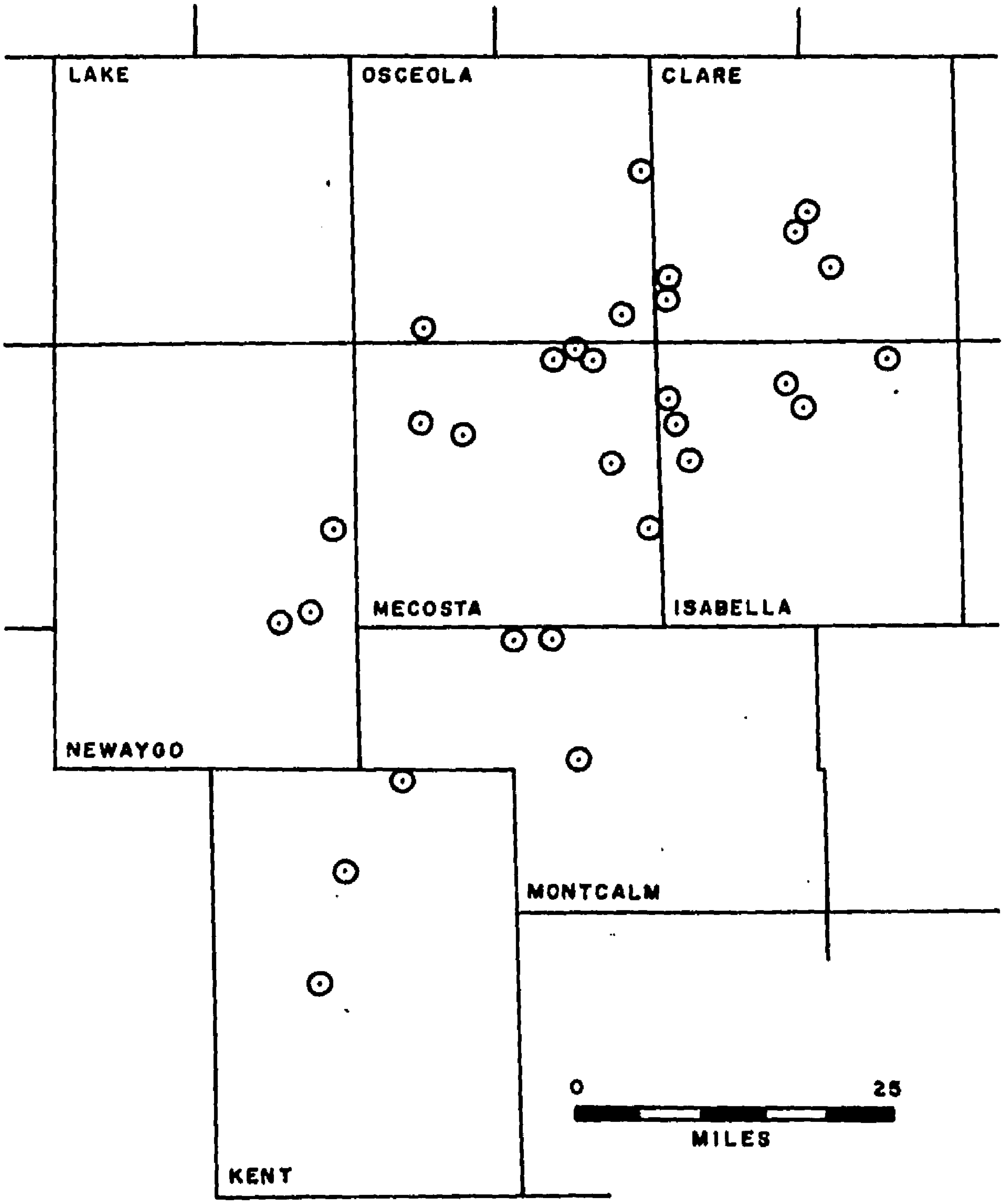


Figure 1. - Locations of wells in central Michigan from which "Red Beds" were sampled for palynologic analysis.

Microslides of the residues were prepared by the double layered mounting medium method. A thin film of hydroxyethyl cellulose containing the residue was spread uniformly over a coverslip, and when this film was dry, the coverslip was inverted on, and thereby affixed to the slide by, a drop of Canada Balsam placed in the center of the slide.

SOME PRELIMINARY RESULTS AND OBSERVATIONS

A total of 113 samples taken from 29 wells spread over seven counties in central Michigan were prepared. Palynomorphs were recovered from 74 of these samples. The most productive lithologies were light gray to greenish-gray shales and siltstones. These lithologic units also usually yielded better preserved specimens. Spores and pollen were also found in bedded gypsum, and reddish-brown claystones, shales, and siltstones. Late Paleozoic gray to black shales and siltstones underlying the "Red Beds" were frequently quite productive.

Redeposited palynomorphs derived from the erosion of Paleozoic strata during "Red Beds" deposition were present in a few samples, but they were always rare. Pennsylvanian and perhaps Mississippian spores and pollen noted in the "Red Beds" include species of _Calamospora_, _Florinites_, _Laevigatosporites_, _Densosporites_, and _Verrucososporites_. Probable Devonian spores and microplankton observed were _Emphanisporites_, _Baltisphaeridium_, _Veryhachium_, _Leiosphaeridium_, _Leiofusa_, and _Tasmanites_. Chitinozoa, probably of Devonian age, and scolecodonts were also recorded. Several of these redeposited Paleozoic forms are illustrated on Plate 22.

DESCRIPTIVE GEOLOGY OF THE "RED BEDS"

Pre-Pleistocene strata comprising the Michigan "Red Beds" are apparently restricted to the subsurface of the Central Michigan Basin. Evidence of their very existence, as well as their distribution, thickness, lithology, and stratigraphic position was unavailable until the advent of bedrock water well and deeper exploratory drilling in the central portion of the Southern Peninsula.

Prior to 1930, there were but few casual references to this stratigraphic unit, which volumetrically represents less than one percent of the sedimentary record of Michigan, and it is uncertain just when the existence of the "Red Beds" became documented. Probably the earliest written accounts was by Lane, et al (1909), in the 1908 annual report of the Geologic Survey of Michigan. Smith (1917), reported apparent "Red Beds" gypsum overlying Pennsylvanian red sandstones at a depth of 93 feet in a well in central Ionia County. Strictly on the basis of stratigraphic superposition and lithologic similarity, these earlier accounts understandably included the "Red Beds" in a sequence of Pennsylvanian sandstones now recognized as the Grand River Group.

The derivation and early usage of the name "Red Beds" is likewise obscure, although Newcombe (1931, 1933) is credited with introducing the term into the Michigan stratigraphic nomenclature, in addition to describing and incorporating these strata onto the geologic map of Michigan. Kelly (1936) discussed the sequence in his study of Pennsylvanian deposits of Michigan. Two unpublished Master of Science theses have contributed to the knowledge of the "Red Beds". One, by Swartz (1951), resulted in a distributional map which also illustrated the nature of the topographic surface on which the "Red Beds" were deposited. The other (Sander, 1959) applied mineralogic, sedimentologic, and thickness distribution analyses to paleogeographic considerations. Up to the present the "Red Beds", for lack of biochronologic evidence, have been provisionally considered "Permo-Pennsylvanian".

From the time of the first major expression of the Michigan Basin, probably in the Late Silurian, sedimentary distribution patterns have born some genetic relationship with this structural complex. The "Red Beds" are no exception, being confined to the central portion of the Southern Peninsula where they are present over all or most of Clare, Osceola, Mecosta, Isabella, Gratiot, and Montcalm Counties. Peripheral deposits and outlying erosional remnants occur in parts of Ogemaw, Roscommon, Missaukee, Wexford, Lake, Newaygo, Kent, Ionia, Clinton, Saginaw, Midland, Gladwin, and possibly Oceana Counties. This irregularly oval distribution pattern(Fig. 2) includes an areal extent of approximately 5,500 square miles.

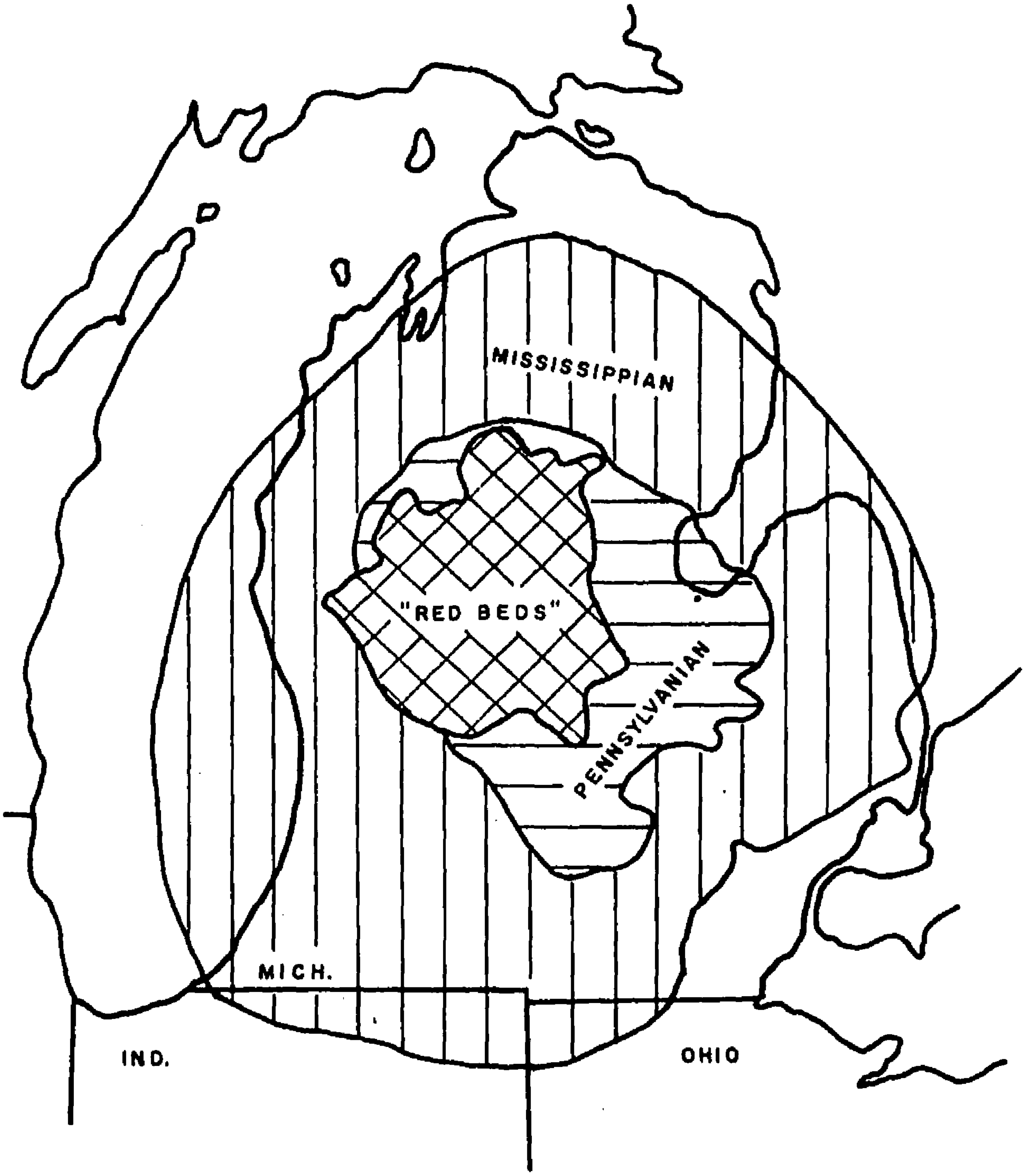


Figure 2. - Distribution of the Michigan "Red Beds".

The bulk of the total volume of "Red Beds", which may or may not represent its depocenter, lies somewhat west of the center of the present Michigan Basin configuration, as illustrated by structural contours on the Trenton Limestone (Cohee, 1965, Fig. 2). Throughout most of their known distribution, the "Red Beds" are superjacent to various lithofacies belonging mainly to the Pennsylvanian Grand River Group. In some peripheral areas of Kent, Newaygo, and Ogemaw Counties, they overlie Mississippian strata. When sample quality in any particular suite of well cuttings is adequate, the unconformable base of the "Red Beds" can be picked physically and paleontologically without difficulty. Lithologically, sandstones of the Grand River Group are sometimes micaceous and slightly feldspathic, and those having hematitic pigmentation are often stained a much deeper reddish-brown to purplish color than the non-micaceous and non-feldspathic basal "Red Beds". Underlying sandstones are also often coarser grained, better cemented, and less friable than the basal "Red Beds", which locally are slightly gypsiferous. Unknown from the "Red Beds" are gray to black shales, and gray, micaceous, sometimes carbonaceous siltstones and sandstones which are characteristic of underlying Mississippian and Pennsylvanian strata. Favorable lithologies on opposite sides of the unconformity between the "Red Beds" and Paleozoic rocks can be readily differentiated palynologically. The Late Paleozoic strata dip toward the center of the Michigan Basin, and the updip edges of these strata, beveled by erosion, intersect the unconformity at the base of the "Red Beds" at an angle. Technically, the erosional surface could therefore be considered an angular unconformity. The angle of intersection is slight, however, and some of the dip of the late Paleozoic strata may be attributable to the paleoslope of the surface on which they were deposited, rather than to structural downwarping entirely.

Thickness of the "Red Beds" ranges from a few feet at the periphery of their distribution to a maximum of slightly over 200 feet in Mecosta County. While Cohee (1965) reported thicknesses of 300 to 400 feet, an examination of samples from numerous wells failed to confirm thicknesses of that magnitude. Thickness varies considerably within the area of distribution, having been extensively modified by irregularities of the pre-"Red Beds" topography, by post-"Red Beds" and pre-Pleistocene erosion, and by Pleistocene glaciation.

An isopach map (Fig. 3), incorporating data from over 2,000 wells, shows in a generalized manner the "Red Beds" thickness trends. Because of extremely disparate thicknesses within very short distances, which may be only apparent because of poor data quality, the mean thickness per township was determined. This probably tended to average out unreal thickness disparities, and provided data more appropriate for the map scale being used and for the intended purpose of the isopach map. The area in central

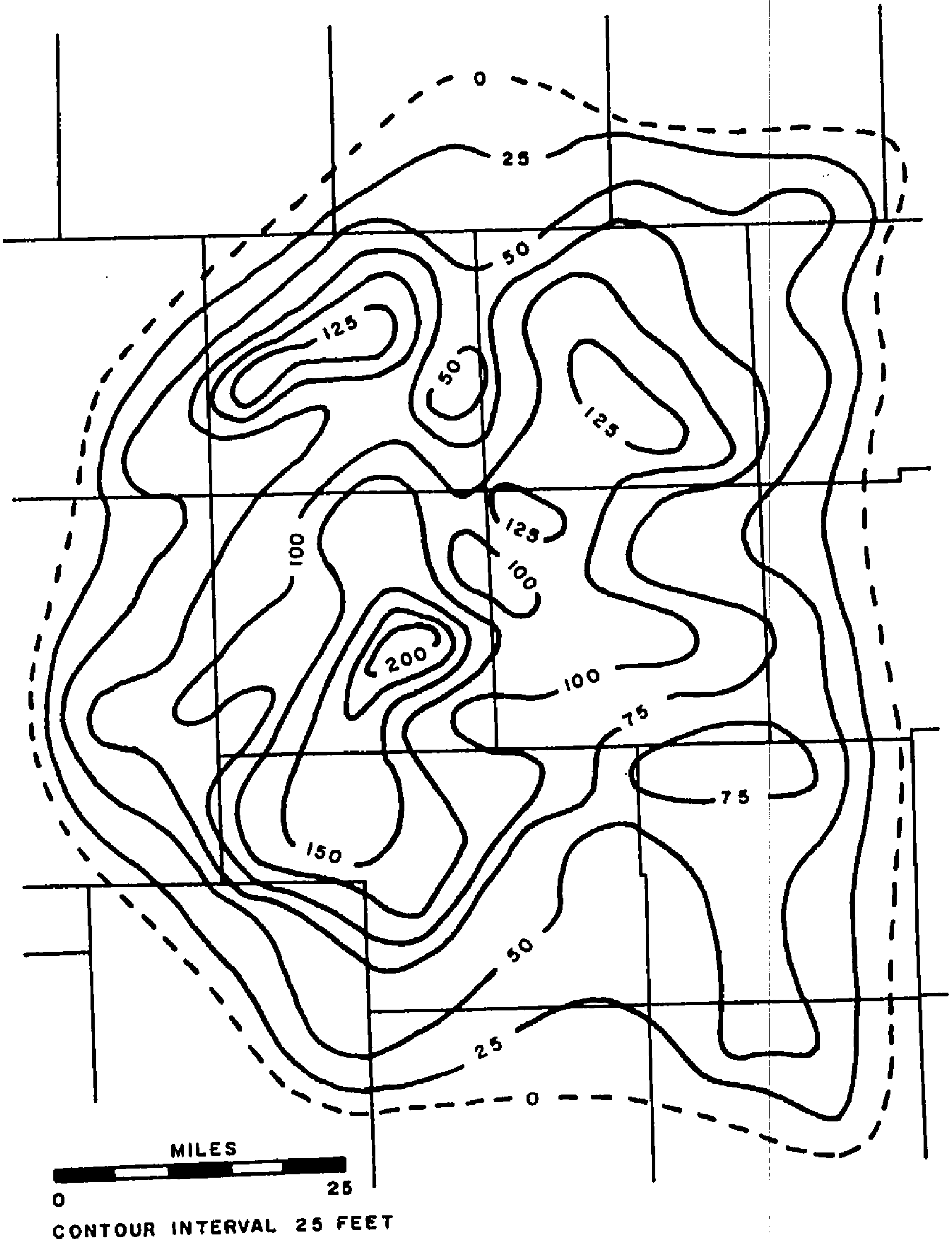


Figure 3. - Isopach map of the Michigan "Red Beds"

Mecosta County, where an excess of 200 feet occur, is part of a more or less north-south trending maximum represented by thicknesses greater than 150 feet in central and southern Mecosta and northwestern Montcalm Counties. Isolated areas exceeding 125 feet in thickness occur in Osceola, Clare, and Isabella Counties.

The "Red Beds" thin progressively from these areas of maximum thickness in the central region to the periphery of their areal distribution, and no major thickness trends, which may have represented axes of the "Red Beds" depositional basin, are apparent. However, the greatest proportion of the thicker areas is situated slightly west of the center of the present distributional pattern. This unequal distribution imparts an asymmetrical aspect to the "Red Beds" basin. Whether this reflects an originally asymmetrical structural basin receiving "Red Beds" sediments, or whether it simply reflects more intense glacial abrasion on the eastern side of the basin, especially by the Saginaw Lobe, would be difficult to ascertain.

Gypsum and dominantly reddish-brown colored shale, siltstone, and sandstone constitute the major lithologic types occurring in the "Red Beds". Attempts to assess quantitatively the relative proportions of these sediments are faced with the inherent difficulties of working with rotary cutting samples, chief among which are sample mixing attributed to down hole caving, and the questionable reliability of sampling procedures at the well site. In addition, soft, poorly indurated shales and friable, weakly cemented sandstones are often washed out and thus are under-represented, while gypsum, being less susceptible to disagregation during the drilling process, would tend to be relatively over-represented.

Utilizing the most complete sets of samples available, lithologic logs from 56 wells were prepared, and a structural three-dimensional panel diagram (Fig. 4) was constructed from those sample logs containing the thickest and most complete representation of the "Red Beds" interval, and from those providing a maximum geographic distribution.

The structural profiles illustrated provide some indication of the present attitude of the unconformable surface lying beneath the "Red Beds". From the northeast sector of the "Red Beds" distribution in southeast Ogemaw County, where the base of the "Red Beds" is approximately 700 feet above sea level, the unconformity slopes progressively downward in a southwesterly direction. In southwestern Osceola County this surface has plunged to almost 400 feet above sea level, whereupon the slope is reversed in a direction toward the western limits of the "Red Beds", rising to about 460 feet above sea level in south-central Lake County. In north-central Midland the basal unconformity is 430 feet above sea level, and from the northwestern part of the county, where it is 20 feet higher, it slopes uniformly westward, reaches a maximum depth of 350 feet above sea level in northwestern Isabella County, and then ascends very gradually

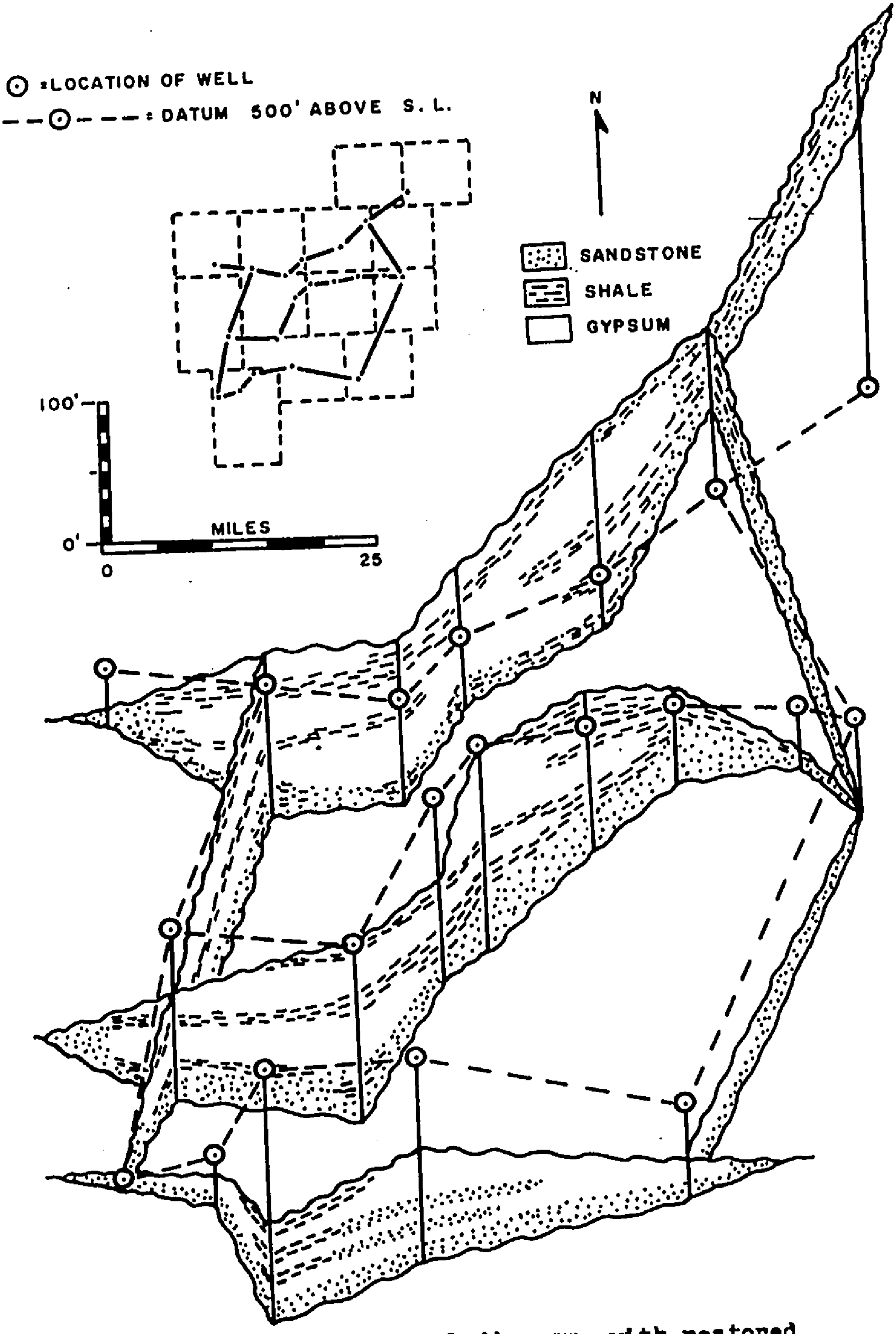


Figure 4. - Structural panel diagram, with restored "Red Beds" lithofacies.

southwesterly to an elevation of near 380 feet in east-central Newaygo County. The unconformity likewise dips uniformly westward from an elevation of 430 feet in north-western Gratiot County to a depth of 320 feet in north-central Kent County, and from this point southwestwardly, it reverts sharply upward to a height of almost 500 feet in west-central Kent County.

In a general sense, the surface marking the base of the "Red Beds" slopes basinward at a somewhat more gentle angle on the eastern flanks of the basin than on the west. The resulting asymmetry, though imperfectly defined because of the limited quantity and quality of data, roughly coincides with the asymmetrical thickness patterns discussed previously.

Restored lithofacies, constructed from superimposed lithologic data for each well, are extremely localized in development, and as variable in lateral continuity as thickness distributions. One of the most persistent lithofacies is a basal fine to medium grained sandstone resting unconformably upon the Paleozoic surface. This facies is present almost throughout the entirety of the "Red Beds" areal extent. This quartzose sandstone sometimes grades laterally into and is interbedded with siltstones and shales. A maximum thickness of approximately 60 feet has been recorded for this unit in several wells, but it is usually less than 30 feet thick. Reddish-brown hues are the rule, but the variable intensity of the hematitic pigmentation is largely a function of the proportion of silt and clay matrices. Clean and well sorted sands often have only a faint light red tint, while silty and clayey sands have a deeper reddish-brown color. Greenish mottling has been rarely observed in thin peripheral sands that presumably represent updip equivalents of this unit. The well- to poorly-sorted sands range from an unconsolidated and friable state to one of moderate cementation. White gypsiferous cement is a characteristic feature observed in numerous wells, and, together with the reddish pigmentation of the sand, produces a white and red mottled appearance. In many samples the quartz sand grains are completely isolated in the gypsiferous matrix. Conceivably this gypsum cement represents the trace of localized autochthonous sedimentary patterns which have been modified and almost obliterated by a dominating allochthonous clastic influx. Associated reddish-brown shales and siltstones of the basal unit are soft and usually have an earthy texture.

Gypsum is the only representative of an autochthonous sedimentary pattern known. Salt, other evaporites, and carbonates, are lacking. Volumetrically, gypsum may be the most abundant constituent, although as previously noted, true proportions of the various lithologies cannot be precisely assessed. Minor occurrences include, in addition to gypsiferous cement which may be either primary or secondary, interlaminated gypsum and reddish siltstones. Most of the gypsum occurs as bedded evaporite bodies possibly exceeding 80 feet in maximum thickness. In comparison to clastics, these gypsum facies tend to be concentrated more toward the north- and west-central portion of the "Red Beds" basin, and the inconstancy of their thickness and relative stratigraphic position between closely adjacent wells suggests geographically and temporally shifting loci of evaporite deposition.

Most commonly, the bedded gypsum is in a soft, white, chalky, opaque form almost totally free of impurities. It is most probably highly weathered and leached by ground water. Well-cuttings of this type commonly display cleavage faces, and transparent selenite (?) may be present either as minute inclusions within the chalky fragments, or as isolated crystalline fragments. Bedded gypsum also occurs in a harder, denser, less weathered form having a light grayish color due to detrital impurities in the form of silt, clay, and fine organic debris.

Bedded gypsum has not been observed in direct contact with the underlying erosional Paleozoic surface, from which it is separated by the silty and sandy basal unit. Reddish-colored shales, siltstones, and silty sandstones of varying thicknesses are interbedded with the gypsum facies, and laterally the gypsiferous bodies phase into similar siltstones and sandstones toward the perimeter of the "Red Beds" subcrop.

Several very thin light greenish to greenish-gray shale layers occur in the middle to upper portions of the "Red Beds" where they are interbedded with red silts and shales and are in many places closely associated with thick gypsum bodies. While they are generally quite localized in development, one greenish shale bed at the base of a massive gypsum has been identified in approximately the same stratigraphic position in several wells spanning a distance of over ten miles. Judging by the very restricted vertical occurrence of greenish shale cuttings within a particular set of well samples, along with their infrequency relative to other lithologies at those intervals where they are present, a maximum thickness of less than 10 feet is estimated, and most of these beds are undoubtedly less than five feet thick. Nevertheless, the greenish shale beds are of particular interest palynologically, for they have almost invariably contained abundant and well preserved spore and pollen complement.

In summary the "Red Beds" are a sequence of clastic and gypsiferous sediments lying unconformably above Pennsylvanian and Mississippian strata and below Pleistocene drift. Their present distribution and thickness conform to and were probably controlled by the configuration of the Michigan Basin. Lithologic patterns include a basal allocthonous facies comprised of dominantly reddish colored sands and shales. This basal clastic facies is replaced by an overlying autochthonous facies comprised of isolated bedded gypsum deposits of variable thickness and distribution.

Bedded gypsum is centrally confined within the "Red Beds" basin, and is interbedded with reddish silts, shales, and occasional thin greenish shales.

AGE OF THE "RED BEDS"

Stratigraphic synthesis involving interpretations of depositional environments, ecology, climate, geography, and organic evolution must of necessity be soundly predicated on either relative or absolute geochronology. It is futile to position geologic events outside the context of a temporal framework. Because of an absence of conventional paleontologic evidence, and because of their noncommittal stratigraphic position between Pennsylvanian and Pleistocene deposits, the "Red Beds" have not previously been amenable to considerations that are dependent for their credibility upon an adequate time-stratigraphy. Prior assumptions and interpretations derived from erroneous age determinations, especially paleogeographic inferences, are regarded as weak. It is thus the fundamental concern of this study to develop a reasonably accurate chronostratigraphic assessment with which other previously outlined objectives can be coordinated.

Motivated by the unique potential of palynological applications to such chronostratigraphic problems, preliminary investigations ascertained without question that neither a Pennsylvanian nor a Permian age can be assumed for the "Red Beds". On the strength of both positive and negative criteria, a Middle Mesozoic age is now evident. With the exception of obviously redeposited Paleozoic spores, phytoplankton, and chitinozoa, no indigenous palynomorphs were recovered that commonly occur in or are entirely restricted to Late Paleozoic strata. Even a cursory comparison of the "Red Beds" plant microfossil complement with that of any Pennsylvanian sediment inside or outside the Michigan Basin readily and unequivocally supports that fact. Strikingly significant is the virtual absence of proximally-striated saccate pollen of gymnospermous and pteridospermous affinity, such as the genera <u>Striatites</u>, <u>Lueckisporites</u> and <u>Taeniaesporites</u>, which so ubiquitously characterize Permian and Lower Mesozoic sediments, and whose stratigraphic ranges do not extend above the Triassic period.

Without exception, the pollen genus <u>Classopollis</u> is the dominant element in all "Red Beds" assemblages thus far observed. Relative abundance peaks for this genus typify many Jurassic and lower Cretaceous strata. Species of <u>Eucommiidites</u>, <u>Exesipollenites</u>, and some primitive tsugoid pollen, here included in the genus <u>Zonalapollenites</u>, are present in most samples, and together with <u>Classopollis</u> abundances indicate a Middle to Late Mesozoic age. These are long ranging taxa within the Mesozoic, and their upper range is especially ambiguous. However, the first appearance of each in the stratigraphic record is considerably more definitive. Pollen of <u>Classopollis</u> and <u>Eucommiidites</u> have been reported from European Rhaeto-Liassic deposits (Nilsson, 1958; Chaloner, 1962), and may therefore extend into the Upper Triassic.

Tetrads figured by Klaus (1959, 1960) from the Upper Triassic of Austria are also probably those of *Classopollis*. McGregor (1965) has identified *Eucommiidites* from uppermost Triassic (Norian or Rhaetian) deposits of Arctic Canada. The widely occurring genus *Exesipollenites* has not been reported below the Jurassic. Ancestral tsugoid pollen may extend into the Upper Triassic. These preliminary observations, including the lack of multistriated saccate pollen, enable a maximum age for the "Red Beds" to be placed with some degree of confidence at uppermost Triassic or Lower Jurassic.

The conspicuous absence of angiosperm pollen serves to establish a minimum age. At present there are no fully documented accounts of pre-Cretaceous pollen of this type (Scott *et al*, 1960; Hughes, 1961). In North America pre-Albian Lower Cretaceous angiosperm pollen have not been recorded from the Potomac Group of the Atlantic Coast (Brenner, 1963), from western Canada (Pocock, 1962; Singh, 1964), from Artic Canada (McGregor, 1965) or from Nova Scotia (Stevenson and McGregor, 1963). The writer has not observed angiosperm pollen in similarly aged sediments of the central Gulf Coast region.

In most of Europe, unquestioned angiosperms likewise make their first appearance in Lower Albian or possibly Upper Aptian sediments. The monocolpate genus *Clavatipollenites*, which may be either gymnospermous or angiospermous, has been reported in the Wealden and Aptian of Britain by Couper (1958).

This problematic pollen has also been reported by Brenner (1963) from Aptian sediments of the Potomac group. Clavatipollenites, whatever its affinity, is not known from the Jurassic. Burger (1966) has identified angiospermous tricolporate pollen of the "Castanea" type from Early Cretaceous sediments near the Jurassic-Cretaceous boundary in the Netherlands. Groot and Groot (1962) note an absence of angiosperm pollen in pre-Albian Cretaceous sediments of Portugal. Pre-Albian angiosperm pollen are likewise missing in Australia (Dettmann 1964).

Although the foliage genus Sanmiguelia is regarded by some as a possible Triassic palm frond, the pollen record does not as yet support speculation on pre-Cretaceous angiosperm ancestry. The apparent cosmopolitan absence of pre-Cretaceous angiosperm pollen lends strong if not incontrovertible evidence for a minimum age for the "Red Beds". The relevance of the absence of certain schizaeaceous spores, especially Appendicisporites, and other fern spores which first appear at or near the Jurassic-Cretaceous boundary, will be discussed later. The palynologic assemblage is of unquestionable mid-Mesozoic aspect, and the evidence thus far presented brackets the "Red Beds" between uppermost Triassic and lowermost Cretaceous ages. At this point it would be difficult to challenge the conclusion that the "Red Beds" are exclusively Jurassic in age.

Attempts at a more precise geochrononology, for instance at the stage level, are placed at a disadvantage by several difficulties, any or all of which could restrict or at least delay the ultimate in refinement of age determination. First there are but a few published accounts of North American Jurassic palynology, and some of these have limited applicability or bearing on the "Red Beds" problem. The study by Jux (1961), for instance, is stratigraphically restricted to the Louann Formation and diapiric salt of the Gulf Coast; his taxonomic treatment and conclusions are not considered adequately documented for consideration here. A report by Rouse (1959) is stratigraphically and geographically confined to the problematic Jurassic and/or Cretaceous Kootenay coal of British Columbia, and Pocock (1962) presents an exhaustive palynologic treatment of strata at the Jurassic-Cretaceous boundary in Western Canada. These studies are germane to the present investigation only insofar as they bear on the possible minimum age of the "Red Beds". The illustrated spore and pollen assemblages from selected Triassic, Jurassic, and Lower Cretaceous samples from Arctic Canada (McGregor, 1965) are useful for comparative purposes, but only Lower and Upper Jurassic assemblages are illustrated, there is no formal systematic treatment, and there are no statements concerning ranges or abundances of illustrated forms.

Because there is a dearth of published monographic treatments of North American Jurassic spores and pollen, as well as an inventory of their stratigraphic distribution, especially for the vast Jurassic deposits in the Western and Gulf Coast region of the United States, it is therefore necessary to compare the "Red Beds" assemblage with extra-continental data sources, principally from Britain, Western Europe and Australia. Intercontinental time correlations founded on palynology are affected and rendered difficult by problems of homotaxis, which may or may not play a significant role, and by dynamic time-space phytogeographic and climatic patterns on a global scale.

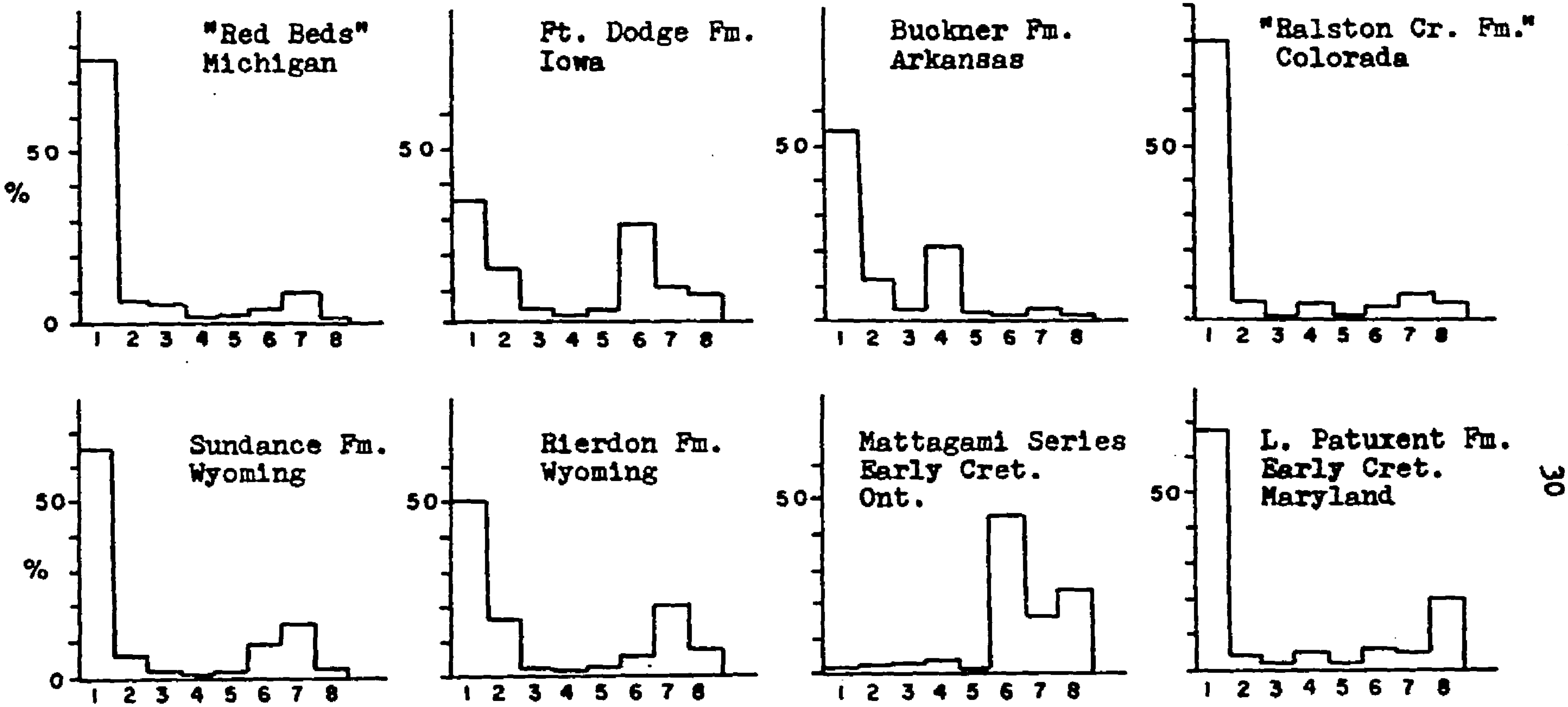
It is this set of circumstances, together with the fact that the "Red Beds" assemblage cannot be "plugged" into a local palynological Jurassic zonation, which produces the second major difficulty, namely the problem of correlation methodology.

Traditionally, three approaches have more or less common usage in biostratigraphy. These include (1) some form of the zonal or "index fossil" concept, (2) the total knowable range of a taxon, and (3) various degrees and methods of quantification. The preference of any one method usually reflects the biochronological philosophy adhered to be a particular paleontologist. Proponents of the use of the index or guide fossil as the characteristic species of a zone include, of course, such notables as Arkell and Schindewolf. Jeletzky (1965), a recent spokesman of this fundamentally qualitative approach, has condemned quantified biochronological methods on the grounds that such statistical methods erroneously assume that all members of a biota have equal biochronological value. Some of Jeletzky's views no doubt are justified. However, his total rejection of quantified correlation methods has been challenged in a most provacative manner by Cockbain (1966), who has demonstrated that the degree of biochronological usefulness of a fossil can possibly be expressed numerically with the application of an information function. Shaw (1964) has also developed a unique and intriguing quantified correlation technique based on sound biostratigraphic principles. This method, which employs the known range of a taxon as the basis for correlation, is not entirely if at all subject to the criticisms leveled by Jeletzky (1965).

The overwhelming relative abundance of Classopollis in practically all "Red Beds" samples makes worthy a consideration of the possible use of such abundance data in geochronology. If it could be demonstrated that the "Red Beds" abundance peak of Classopollis represented an evolutionary acme, or, in zonal perlance, its hemera or epibole, then conceivably, a theoretically sound basis for correlation could be established. This is not the case, however, because numerous and practically cosmopolitan abundance peaks of this genus are found throughout the mid-Mesozoic. They occur not only throughout the Jurassic, but in the Lower Cretaceous as well. In the British Jurassic, Couper (1958) records Classopollis abundances greater than fifty per cent in the Liassic, Bajocian, and Purbeckian stages. Similar peaks occur in the Lias, Bathonian, and Purbeckian of Southern England (Lantz, 1958). A Lower Jurassic maximum occurs in Australia (Balme, 1957). At least six regularly spaced abundance peaks have been identified in the Late Jurassic and Early Cretaceous of the Netherlands (Burger, 1966). Brenner (1963) indicates several sometimes regularly spaced peaks from the Lower Cretaceous Potomac Group of Maryland. In addition, the author has observed a dominance of Classopollis in several Jurassic samples from the western United States, notably in the Rierdon, Sundance, Morrison, and "Ralston Creek" Formations. Similar abundances have likewise been observed in the Jurassic Buckner Anhydrite and certain Lower Cretaceous samples of the Gulf Coast Province. These data are graphically summarized in fig. 5.

Because of the dispersal mechanisms of certain spores and pollen, the hemera of some plant species should be more readily detectable than that of practically any other organism. However, it would be impossible to determine if any one of the above mentioned Classopollis dominances is hemeric in nature, and it is amply clear that such maxima are not amenable to hemeral correlation. More probable, the multiple and sometimes rhythmical abundances of this pollen are a manifestation of a complex of ecological and sedimentological phenomena, and as such are completely inadequate criteria for time correlations, except perhaps on a very local basis. Probably the only biochronologic significance such maxima have, other than on a local basis, is that they are confined within the total stratigraphic range of Classopollis.

Index fossils, either as characteristic of formations or zones, and various zonal concepts, are among the most



1 - Classopollis
2 - Exesipollenites
7 - Inaperturopollenites
3 - Spheripollenites
4 - Cycadopites
8 - trilete spores
5 - Zonalapollenites
6 - Bisaccates

Figure 5. - Histograms of selected palynomorphs in "Red Beds" and other North American Jurassic and Early Cretaceous formations.

widely accepted and commonly used correlation methods. The biozone (biochron) is actually an abstract concept recently discredited by Shaw (1964) on grounds of impracticality because the true stratigraphic range of an index fossil, upon which a biozone is defined, is generally unknowable and unattainable. Shaw further regards the biozone simply as a theoretical concept from which a more practical approach to the utility of fossil ranges can be derived. The concept developed by Shaw is based on the knowable and establishable stratigraphic range. This, the "total stratigraphic range", is the stratigraphic interval delineated by the first and last recoverable specimens of a particular taxon.

Jurassic palynology has not progressed to the establishment of spore/pollen zones correlatable intercontinentally, and as previously discussed, relative abundances are totally inadequate for long range correlation. Regarding the "Red Beds", the most plausible approach would be an age determination from the currently known total stratigraphic ranges of selected palynomorphs established from published literature.

In order to summarize stratigraphic ranges on a comparative geographic basis, a range chart (Fig. 6) of selected taxa was compiled for each of four regions. These regions, including Western Canada, Arctic Canada, Western Europe (chiefly British Isles and Netherlands) and Australia, were chosen because they represent areas where the Jurassic has been more thoroughly investigated palynologically, and, as in the case of Western and Arctic Canada, because of their geographic proximity to the Michigan Basin.

In reviewing literature pertaining to Jurassic palynology, a number of papers were encountered which provided insufficiently documented stratigraphic data; in others the quality of illustrations and taxonomic treatment was such that they were of limited usefulness. It was felt necessary either to disregard such papers, or to utilize their data selectively. The principal references incorporated into the range chart were; for Western Europe, Couper (1958, 1964), Couper and Hughes (1963), Lantz (1958), Delcourt and Sprumont (1955), and Burger (1966); for Australia, Balme (1957, 1964), and Dettmann (1963); for Western and Arctic Canada, Pocock (1962), Rouse (1959), Singh (1964), and McGregor (1965). In addition, Dr. Stanley Pocock has kindly made available a manuscript of a palynologic study on the Western Canadian Jurassic. This study, soon to be published, is unquestionably the most comprehensive analysis of the Jurassic in the Western Hemisphere, and was of indispensible value throughout the course of this study.

An analysis of the stratigraphic ranges of previously described species occurring in the "Red Beds" focuses attention on several issues. A heterochronism of the first recorded appearance of these species in the various regions begs the validity of intercontinental correlations with such distant regions as Australia. For example, <u>Exesipollenites tumulus</u> is restricted to the Lias of Australia, while in

Western Canada it does not appear until the uppermost Lias and extends into the Cretaceous. It is not reported from Arctic Canada and its presence in Western Europe is not fully documented. Otherwise practically cosmopolitan species such as Eucommiidites troedssonii, Zonalapollenites mesozoicus, and Spheripollenites scabratus are notably absent from Australia. The record of Zonalapollenites trilobatus commences in the upper Lias in Western Canada, in the Bajocian or Bathonian of Western Europe, and in the Oxfordian of Australia; that of Zonalapollenites mesozoicus begins in the middle Lias of Western Europe, and in the Bajocian of Western Canada. These and other heterochronous first appearances are the result of climatic and phytogeographic patterns, migration rates, etc., as well as inadequate data, at least in some cases. Whatever the cause, they stress the desirability of a North American Jurassic standard of reference, incorporating stratigraphic ranges from the Gulf Coast and Western United States in addition to Canada.

The long stratigraphic range of most of the forms that can be identified with previously described taxa has already been mentioned. As previously discussed, a consideration of those species present only in the "Red Beds" has the limitation of not providing a precise minimum age limit. The youngest species present are Zonalapollenites dampieri, and Zonalapollenites trilobatus. If the entrance level of the youngest species is used as a determinant, then a maximum age for the "Red Beds" could be placed in the uppermost

Liassic (Toarcian). *Zonalapollenites mesozoicus* is very similar, having an entrance level in the Pliensbachian.

Considering further only those species present, a Lower to Middle Cretaceous minimum age would be suggested. Again the use of negative evidence, *i. e.* the use of well established ranges for taxa not present in the "Red Beds", is necessitated. There is a prodigious number of such taxa, and taken together they would not contribute significantly to the resolution of the problem because ranges of the respective taxa would overlap throughout the Jurassic. A possible approach would be to select arbitrarily a group of species confined more or less to the Lower Jurassic, and another group having entrance levels in the Upper Jurassic. If *Calamospora mesozoica* and *Concavisporites subgranulosus* are considered, a lower limit to the "Red Beds" could be placed at the base of the Bathonian or the base of the Callovian. Another possibly significant absence is the genus *Latensina*, which does not extend above the Lower Jurassic of Western Canada (Pocock 1964).

The absence of *Appendicisporites*, *Trilobosporites bernissartensis*, and *Pilosisporites trichopapillosus* indicate a pre-Purbeckian age, and that of *Concavissimisporites verrucosus* would suggest a pre-Kimmeridgian age. The entrance of *Concavissimisporites punctatus* and *Staplinisporites caminus* occurs in the Oxfordian. *Cicatricosisporites* has not been reported below the Portlandian of Canada, but may occur rarely in the Middle Jurassic of Europe and Australia.

If the upper range limits of *Calamospora mesozoica* and *Concavisporites subgranulosus* are considered along with the lower range limits of *Concavissimisporites punctatus*, *C. verrucosus*, and *Staplinisporites caminus*, then an age between the base of the Bathonian and the top of the Oxfordian can be assigned to the "Red Beds". The acceptance of this age determination largely depends on the credence on wishes to place on the negative evidence presented. Any refinement of this determination will hopefully come about through future data accumulation for the Jurassic of the Western Hemisphere in general and for North America in particular. At this stage it is probably reasonable to regard the "Red Beds" as being of middle to lower Upper Jurassic in age.

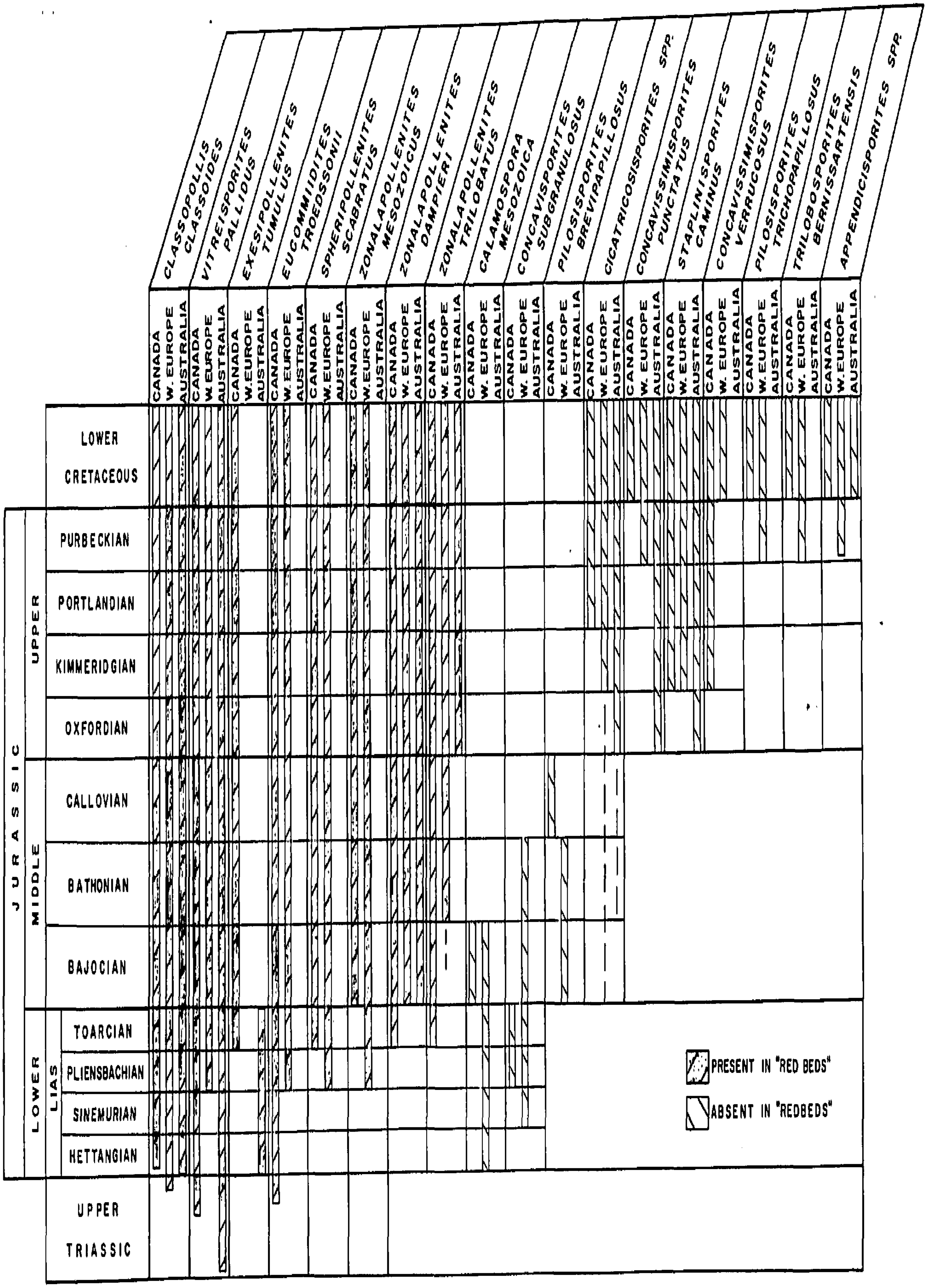


FIGURE 6.- RANGES OF SELECTED MESOZOIC PALYNOMORPH SPECIES.

FLORA OF THE "RED BEDS"

Comparative spore and pollen morphology of extant taxa, or of dispersed fossil palynomorphs and those recovered from fructifications attached to or otherwise known to be related to identifiable magafloral remains, provide the only possible means of paleofloristic reconstruction for the Jurassic of Michigan and adjacent areas.

By the mid-Mesozoic, most of the present families of gymnosperms, as well as pteridophytes, were already in existence. Direct morphological comparisons between forms found in the "Red Beds" and their living generic and supra-generic counterparts can thus be made, limited of course, to the extent that various taxonomic levels within and between extant plant families can themselves be readily distinguished on the basis of spore/pollen characters.

It is well known that closely related genera and species within a plant family are sometimes markedly eurypalynous, while other families tend to be more stenopalynous. Both of these conditions exist in the families represented by plant microfossils in the "Red Beds".

Only a few Jurassic spores and pollen have been related to their parent plants by virtue of their presence in fruiting bodies. The botanical affinities of fewer still have been demonstrated for North America, where few rich Jurassic macrofloras have been described and where very little information on Jurassic palynology is yet available. Because of the dearth of known relationships between extinct spore and pollen types and their parent plants, as well as the eurypalynous condition among extant families, attempts at the reconstruction of ancient floras must be considered speculative. Great caution must be exercised in assuming genetic consanguinity for sporae dispersae in sediments other than perhaps Pleistocene or Late Tertiary.

Approximately 64 spore and pollen species are described or illustrated from the "Red Beds". Of this total figure, 25 (39 percent) are spores of pteridophytes, while 39 (61 percent) are pollen of gymnospermous aspect. This latter figure includes one species of known pteridospermous affinity. Pteridophyte spores are extremely rare and all but a few species of this group are known only from single specimens. Many of these spores have been only tentatively identified from the published reports on Mesozoic palynology. It is likely that several uncertain taxa may be recycled from nearby Paleozoic source areas. Recycled palynomorphs of Devonian, Mississippian and Pennsylvanian age have, in fact, been recognized. The extreme rarity of spores, compared to gymnospermous pollen, may indicate derivation from plants nonindigenous to the regional Jurassic flora. When these singly occurring species, except those certainly known to be at least as young as mid-Mesozoic age, are deleted from floristic considerations, a flora comprised of 23 percent pteridophytes and 77 percent gymnosperms is indicated. Either way it is inventoried, a dominantly gymnospermous flora is evident.

All of the pteridophyte spores whose botanical affinity can be ascertained, at least at the family level, are known only from single occurrences in the "Red Beds". Possible lycopsids are represented in this group by Lycopodiumsporites, a spore morphologically resembling those produced by living and fossil lycopodiales, and Densoisporites, whose suggested relationship is with the Selaginellales. A peculiar spore, here identified as Lundbladispora willmotti Balme, previously recorded from the Triassic of Australia, may also be related to the Selaginellales (Balme, 1963).

Calamospora is related to the Late Paleozoic calamarians, and the "Red Beds" specimen could have been recycled from nearby Pennsylvanian strata, where it is quite common. It is also somewhat similar to a species which is commonly associated with and may have been produced by Mesozoic equisetaleans in Great Britain (Couper, 1958).

The Filicales are represented by two species of Todisporites, of possible osmundaceous affinity, and one species of Cyathidites, which may be related to cyatheaceous or dicksoniaceous ferns. The specimen of this latter genus is not well preserved and the genus itself is practically indistinguishable from, and considered by some to be synonymous with, the Paleozoic genus Leiotriletes. It is suspected that the "Red Beds" specimen is recycled. A grain very similar to some identified by Burger (1966) as *Matonisporites* may have been produced by matoniaceous or perhaps even schizaeaceous ferns. Rouse (1957) suggests an affinity of spores similar to *Biretisporites* with *Hymenophyllum* of the family Hymenophyllaceae.

In addition, a group of 16 fern type spore species which cannot be related at the family level have been described and illustrated. Included in this group are *Cingulatisporites distaverrucosus*, *Converrucosisporites*, *Convolutisporites*, *Undulatisporites*, *Verrucosisporites*, and 11 other species not assignable to existing genera. Of this group *Cingulatisporites distaverrucosus* and Spore Types "A" and "F" are the only taxa represented by multiple specimens in the samples observed. No spore types which can be definitely related to non-vascular plants are known from the "Red Beds" assemblage.

For the most part, there is no particular difficulty in distinguishing Mesozoic pteridosperm and gymnosperm pollen from pteridophyte spores or angiosperm pollen. Among the gymnospermous types, four distinct pollen morphological groupings can be recognized; these include (1) an apparently inaperturate group, (2) a porate or leptomate group, (3) a sulcate, non-saccate group and (4) a sulcate or leptomate bisaccate group.

The first group is comprised of morphologically simple, spherical to subspherical pollen having two exinal layers of more or less uniform thickness which may or may not be closely appressed and which may or may not have extra- or infra-sexinal ornamentation. The salient feature of pollen in this group is that they bear no visible pores, leptoma, or any other organized germinal mechanism. Possibly several species of this pollen type are present in the "Red Beds", but because of its extremely variable size, ornamentation, and wall structure, they have all been lumped together under Inaperturopollenites sp. "A". It most strongly resembles araucarian pollen, but may well be polyphyletic in origin.

The second group encompasses porate and leptomate pollen having radial symmetry and a circular amb. On some members of this group the leptoma is weakly or inconsistently developed, and often undetectable except under phase contrast. The exine of this group is usually two-layered, and ranges from those forms in which the sexine is either tightly or loosely appressed, to those in which it is separated equatorially to produce a monosaccate condition. Pollen of the genera Spheripollenites, Exesipollenites, Zonalapollenites, and Classopollis are incorporated in this group. Couper (1958) has illustrated and discussed a comparison between Spheripollenites scabratus, as well as other species of the genus, and the pollen of certain extant members of the Cupressaceae and Taxaceae. Exesipollenites tumulus is a similar form also probably produced by fossil members of these gymnospermous families. Pollen of the genus Zonalapollenites possess many of the morphological attributes of Tsuga, including the distally pendant saccus and the leptomate germinal area centered at the distal pole. The proximal triradiate tetrad mark which characterizes many of the fossil grains has likewise been observed on modern *Tsuga* pollen. Six species of this highly variable pollen genus are recognized in the "Red Beds", indicating a considerably diverse tsugoid representation in the regional flora. The genus *Classopollis*, having a distal leptomate pore, a distal ring tenuitas, an infra-sexinal striated equatorial band, and a trilete or triangular tetrad mark at the proximal pole, is among the most morphologically complex of all gymnosperm and most angiosperm pollen. Fortunately its botanical affiliation is also well documented by its presence in staminate cones of *Cheirolepis* and less certainly in those of the closely related conifers *Brachyphyllum* and *Pagiophyllum*. Dispersed grains of *Classopollis* are frequently associated with the foliage of these three genera, which are considered more closely allied with the araucarians than any other coniferous family. Four species of this unique pollen are herein recognized from the Michigan deposits.

Eleven species distributed among the pollen genera *Cycadopites*, *Ginkgoretectina*, *Chasmatosporites*, and *Eucommiidites* make up a non-saccate morphological grouping characterized by a single distal sulcus or sulcate leptoma. Those species of *Cycadopites* having a straight, simple sulcus with somewhat irregular margins and without thickened lips flanking the sulcus resemble the pollen of the Ginkgoales.

One such species, designated *Cycadopites* *sp*. "*A*", was noted. Forms of this genus with either a straight or "keyhole-shaped" sulcus flanked by thickened lips appear to be more closely related to the cycadales. Two species of this type were present. The genera *Ginkgoretectina* and *Chasmatosporites* also bear semblance to some modern cycad pollen. Because of the similarity of the monosulcate pollen type to several pteridospermous as well as gymnospermous groups, including the Bennettitales, the mid-Mesozoic forms are probably best considered as having affinity with a Ginkgoales-Bennettitales-Cycadales complex.

Five species of the peculiar and complex pollen *Eucommiidites* are described from the "Red Beds", and this constitutes a greater species diversity for this genus than previously recorded from a single stratigraphic unit. The pollen differs from most monosulcate pollen in having a pair of proximal sulcoid tenuitates flanking the distal sulcus. So great is its resemblance to tricolpate pollen that it was originally considered angiospermous. However, Highes (1961) found numerous specimens of *E*. *delcourtii* in the micropyle and pollen chamber of the gymnosperm seed *Spermatites* *pettensis* from the British early Cretaceous, and Brenner (1963) has reported *E*. *troedssonii* in the micropylar tube of similar seeds from the early Cretaceous of Maryland. On the basis of its structure, Hughes (1961) suggests a relationship between *Spermatites* and the *Chlamydospermales*. At the present, it is more appropriate to consider *Eucommiidites* simply as a gymnosperm pollen.

Distally sulcate and leptomate bisaccate pollen are known to have been produced in the past by a number of pteridosperms and other gymnosperms alike. Currently, just two families, the Pinaceae and Podocarpaceae, produce such pollen, but it is certainly not possible to ascribe all Late Paleozoic and Mesozoic bisaccate grains to these two families. In a few cases it is possible to differentiate pteridosperm and gymnosperm pollen of this type. One cosmopolitan Mesozoic pteridosperm pollen which occurs rarely in the "Red Beds" is *Vitreisporites pallidus*. It has been found in male fructifications of *Caytonanthus*, belonging to the Caytoniales. The genera *Pityosporites* and *Alisporites*, with one and three "Red Beds" species respectively, most likely have taxonomic affiliations within the family Pinaceae, although some species presently assignable to these genera may well be pteridospermous. The family Podocarpaceae is represented by two species of *Podocarpidites*, a pollen morphologically similar to those produced by Podocarpus, and by six species of *Phyllocladidites*, which particularly resembles the pollen of *Dacrydium*.

Two specimens of *Aumancisporites cretaceus*, a form actually belonging in a morphological group comprised of proximally multi-striated pollen which are prominent in Permian and Triassic sediments, were observed. This whole group has been thought to be related to primitive or ancestral Chlamydospermales, and Pocock (1964) discusses in detail the similarity of *A. cretaceus* to the pollen of

Welwitschia. Those multi-striated forms which have a transverse sulcus, as does *A*. *cretaceus*, appear to be more closely related to the Coniferales than to the Chlamydospermales (Wilson, 1962). The botanical affiliations of the "Red Beds" spore/pollen assemblage are summarized in Table 1.

Table 1 - Botanical affinities of the "Red Beds" palynomorphs.

PTERIDOPHYTES	Equisetaceae	_Calamospora_ *
	Lycopodiaceae	_Lycopodiumsporites_
	Selaginellaceae	_Densoisporites_ _Lundbladispora willmotti_
	Osmundaceae	_Todisporites_
	Hymenophyllaceae	_Biretisporites_ *
	Cyatheaceae	_Cyathidites_ *
	Matoniaceae	_Matonisporites_ *
GYMNOSPERMS	Pteridospermae Caytoniales	_Vitreisporites pallidus_
	Cycadales - Bennettitales - Ginkgoales	_Cycadopites_ _Ginkgoretectina_ _Chasmatosporites_
	Taxaceae - Cupressaceae	_Exesipollenites tumulus_ * _Spheripollenites scabratus_ *
	Podocarpaceae	_Podocarpidites_ _Phyllocladidites_
	Araucariaceae	_Inaperturopollenites_ * _Classopollis_
	Pinaceae	_Pityosporites_ _Alisporites_ _Zonalapollenites_
	Chlamydospermidae	_Aumancisporites cretaceus_ *

* Indicates provisional assignment.

PALEOGEOGRAPHIC CONSIDERATIONS

In considering the Michigan Basin in spatial relation to the Jurassic geography of North America, it would be helpful to know the position of strand lines during deposition of the "Red Beds". Knowing this, the maximum extent of this Jurassic depositional site could be estimated. Subsurface sample quality and post-depositional erosion are again factors limiting reasonable speculation on these matters. It is certain that post-Jurassic erosion and Pleistocene glacial abrasion reduced, by an undeterminable amount, the original areal distribution of these deposits. They do thin and wedge-out toward the updip limits of their distribution, but this thinning may reflect either proximity to a former shoreline, or post-depositional erosional truncation, or both. A lateral projection of erosionally truncated strata (see restored lithofacies profiles, Fig. 4) along the unconformity between the "Red Beds" and Pleistocene drift implies a maximum extent of the shoreline beyond the present limits of areal distribution.

Available paleontologic information does not support a marine genesis for the "Red Beds", but the absence of marine phytoplankton from the palynological assemblage does not necessarily rule out speculations of a marine influence, which may have been a source for the evaporites. The possibility of a shoreline extending beyond the Michigan Basin, coupled with the unclear relationship of the "Red Beds" to the post-Paleozoic structural history of the basin, begs the question whether they were deposited in an intracratonic basin, or by a transgression from outside the basin. They may have been deposited by a shallow epeiric sea transgressing over a flat or gently sloping eroded Paleozoic surface that was, subsequent to deposition, downwarped to form a structural basin in which the "Red Beds" are preserved as an erosional remnant. Deposition could also have occurred during an epeiric transgression into a pre-existing basin where sedimentation would thus be bathymetrically controlled. Or, they may have been deposited by an epeiric sea where basinal downwarping and sedimentation were concurrent and tectonically controlled.

The stratigraphic and sedimentologic evidence provides no clues pertaining to either the point of origin or the route taken by any such transgression. Because of post-Jurassic erosion, sediment thickness patterns do not indicate the source of sediment influx into the Michigan Basin. The very presence of the "Red Beds", considered in relation to the distribution pattern of North American sedimentary rocks (Fig. 7), poses several paleogeographic possibilities.

One possible source for an epeiric transgression would be from the south in the Gulf Coast Province. This postulate specifically implies a brief extension of Gulf Coast Jurassic

Figure 7. - Jurassic paleogeography of North America (after Eardley, 1962). Arrows indicate courses of possible epeiric transgressions into the Michigan Basin.

seas through the Mississippi embayment, up the Mississippi Valley, and into the Michigan Basin, a distance of some 700 miles. The Michigan "Red Beds" do have several common attributes with the Gulf Coast Jurassic. In particular, evaporite and red bed facies (Louann, Norphlet, Buckner, and Shuler formations) are an important component of the Gulf Coast Jurassic, and chronological equivalents of the Michigan Jurassic are likely to be represented in the Gulf Coast. While lithologic and as yet undetermined temporal similarities exist, there is no evidence whatsoever to commend the postulate of a genetic continuity between these widely disjunct regions during the Jurassic.

Most if not all sedimentary facies of the Central Gulf Coast Jurassic have clastic, often conglomeratic equivalents in an updip northward idrection. This strongly suggests that their present distributional limits approximately coincides with the nothernmost Jurassic limit. The Mississippi Embayment is of course overlain by early Cretaceous sediments, with later Cretaceous extending into southeast or perhaps east central Illinois. Throughout the Mississippi Embayment itself, north of the Jurassic limit, there likewise is no record of Jurassic sediments underlying the Cretaceous overlap. Finally, the Mississippi Embayment itself did not actually come into existence until early Cretaceous, although a drainage system was present somewhere in the vicinity of the Embayment which supplies a considerable volume of clastics to the central Gulf Coast Jurassic depositional sites.

Epeiric connections could also be postulated toward the north, northeast or east, but again the present distribution of Jurassic sediments lend virtually no support. The nearest Jurassic in a northward and northeastward direction is in the Canadian Arctic and Eastern Greenland. Jurassic sediments have been encountered deep in the subsurface off Cape Hatteras, and conceivably they extend offshore throughout the entirety of the Atlantic Coastal and Maritime Provinces. The Appalachian system no doubt imposed an effective barrier against transgressions from the East, with the possible exception of the St. Lawrence Valley. A distance of approximately 1,100 miles separates the Michigan Basin from the Gulf of St. Lawrence, and no mid-Mesozoic sediments, except Lower Cretaceous in Nova Scotia (Stevenson & McGregor 1963) are present in the intervening distance.

A small exposure of non-marine, lignite-bearing sediments located at the southern tip of James Bay has been and still is referred to as Jurassic in age. The megaflora of this sequence, the Mattagami Series, suggests an early Cretaceous age (Bell, 1928), and the palynologic assemblage of this series clearly indicates a pre-Aptian Cretaceous age. There is no reason to suspect that Jurassic strata may underlie the Mattagami Series, which is roughly 500 miles distant from the Michigan Basin, and there are no reported Jurassic occurrences beneath Hudson's Bay.

The Mesozoic history of the Canadian Shield, and the amount of such history removed by Pleistocene glacial erosion, are two great intangibles vitiating any postulates involving a Jurassic transgression across the Canadian Shield into Michigan. Paleozoic seaways at times apparently traversed at least part of this vast expanse, and it is certainly not inconceivable that a veneer of Jurassic or other Mesozoic strata was completely stripped from the Shield by continental ice sheets. This imponderable must remain so until the fragmentary Mesozoic record on and peripheral to the Shield area, and the paleogeographic conclusions presently deduced from it, is supplemented by additional discoveries.

Jurassic strata of the Western Interior extend almost as far east as the western margin of Minnesota, and this relatively close proximity to the Michigan Basin has appeal as a possible paleogeographic relationship between the "Red Beds" and the Western Interior Jurassic. As in the case of the Gulf Coast, however, little more than a postulate can be advanced. There is no tangible evidence of an eastward transgression of that magnitude, with the exception of one notable occurrence which does strengthen the postulate. In Webster County, Iowa, located in the north-central portion of the state, a sequence of gypsum and dominantly reddish colored shales, sandstones, and conglomerates occurs. This deposit, the Fort Dodge Formation, is restricted to the northern half of Webster County where it occurs as isolated erosional remnants spread over an area of approximately 125 square miles. An original distribution covering a considerably larger area has no doubt been diminished by pre-Pleistocene erosion and Pleistocene glacial abrasion. A maximum thickness not in excess of 80 feet has been recorded (Hale, 1955). Bedded gypsum in commercial quantities reach thicknesses of about 30 feet. The gypsum thins radially toward the periphery of its distribution limits, as do also the clastic facies of the formation. Overlying red shale and sandstone facies extend laterally beyond the gypsum beds, at least in a north and west direction. A thin basal conglomerate composed largely of locally derived Paleozoic limestone pebbles is present in some exposures in the southern area of occurrence. The Fort Dodge Formation unconformably overlies Pennsylvanian and, locally, Mississippian strata. Pleistocene glacial deposits overly the formation in most places, although Cretaceous sediments may overlap the extreme western extremities. No fossils other than obviously recycled Pennsylvanian invertebrates in the basal conglomerate have previously been found. For this reason, together with its stratigraphic position, the Fort Dodge Formation has usually been regarded as Permian or perhaps Pennsylvanian in age.

Palynologic evidence from an abundant spore-pollen flora recovered from the gypsum as well as the associated shales clearly indicates a Jurassic age for this Iowa deposit. In fact a striking compositional resemblance exists between the Jurassic deposits of Michigan and those of Iowa, and preliminary investigation on the latter indicates almost a species-for-species comparison is possible. Classopollis is by far the most abundant form in the Fort Dodge Formation, but it is not always the overwhelming dominant that is in the "Red Beds". Pteridophyte spores and bisaccate pollen are somewhat more abundant in the Fort Dodge. The Fort Dodge Formation is tentatively regarded as late middle to early Upper Jurassic in age, and a synchronism between the Michigan "Red Beds" and the Fort Dodge is implied.

In addition to this probable synchronous relationship, several other noteworthy points in comparison are possible between the two deposits in question. Both exhibit comparable lithologic, stratigraphic and paleoclimatologic patterns which indicate a history of similar successions of sedimentary environments. Both appear to have been deposited in, though now restricted to and preserved in, or in some other way related to, a structural basin. The structural configuration of the Fort Dodge area is somewhat more subtle than that of the Michigan Basin, owing to the disjunct distribution of the isolated remnants of the formation, but it definitely is reflected by the structural attitude of the base of the Fort Dodge Formation itself as well as by underlying Paleozoic formations (Hale, 1955). The structural configuration has been modified by the Fort Dodge Fault, a graben structure up to three miles in width trending approximately 20 miles east-northeast through the area of occurrence of the Fort Dodge Formation. The time of faulting relative to the deposition of the Fort Dodge Formation has long been a controversy, but there now seems to be little question that the faulting, which does involve the Fort Dodge Formation, was a post-depositional event. The preservation of much of the Fort Dodge Formation can be attributed in part to the presense of this graben.

If indeed the Fort Dodge Formation is chronologically equivalent to the Michigan "Red Beds", it plays a prominent role insofar as a paleographic interpretation of the "Red Beds" and adjacent areas is concerned. The Iowa deposit itself presents several unsolved problems, and any interpretation must account for the source of the gypsum present there. There are no extensive surface exposures of pre-Jurassic evaporites in the vicinity of north central Iowa which, upon chemical weathering and erosion, could have supplied calcium sulfate to the Fort Dodge basin where it could have been re-precipitated at a later time. A more likely mechanism, which would also more adequately explain the volume of gypsum present there, would be through the evaporation of hypersaline marine water flowing into central Iowa during the brief geologic time period required for the deposition of the Fort Dodge Formation. A shallow connection with the Jurassic seas of the Western Interior only 200 miles distant, having a restricted circulation pattern and existing in an arid climatic regime, would ultimately develop the requisite conditions for evaporite deposition. Could it be that the Fort Dodge Formation and the Michigan "Red Beds" are the sole known erosional remnants of a Jurassic epieric transgression extending at least as far east as Michigan?

Substantiating evidence might be revealed in a search for new, and a re-examination of known, deposits of uncertain age in adjacent areas. Inadequately dated deposits occur in the "Driftless Area" of Wisconsin. Many of these are probably Pleistocene sediments, but they do merit a re-examination, especially by palynological techniques. Similarly, Illinois contains deposits which mostly are considered either Pleistocene or as remnants of the late Cretaceous overlap. Others may be Tertiary in age. A considerable post-Paleozoic and pre-Pleistocene record may be represented by these and other mostly unfossiliferous and presently inadequately dated deposits.

The possible paleogeographic influence of the Lake Superior Basin should also be considered in the context of a postulate for a direct epeiric connection between the Michigan Basin and the Western Interior. Unlike other Great Lakes basins, that of Lake Superior is a structural basin of great geologic antiquity, and in part could have provided an avenue for an eastward transgression into the Michigan area during the mid- to late-Jurassic. The origin and history of the Superior basin is not well known at present, and its relation to the "Red Beds" problem can only be listed among a multitude of others based on speculation. If the "Red Beds" were deposited by an epeiric transgression from outside the Michigan Basin, the most engaging postulate would be a genetic linkage with the Jurassic Seas of the Western Interior.

A final postulate demanding consideration is that the "Red Bed's" depositional history has no direct or genetic relationship with Jurassic events, especially transgressions, outside the Michigan Basin. Throughout most of the Paleozoic, the Michigan Basin has undergone episodic crustal downwarping to accommodate the great thickness and volume of sediment that has accumulated there. There is thus no particular difficulty envisioning a Jurassic reactivation of the Michigan Basin, resulting in a structural, intracratonic sedimentary basin where the "Red Beds" could be deposited. Unlike the paleogeologic setting at the Fort Dodge area, Silurian, Devonian, and Mississippian strata fringing the basin, if exposed, would have been an ample potential source of evaporties. Chemical weathering of these evaporites and re-precipitation could readily account for the "Red Beds" gypsiferous facies, without invoking a linkage with a marine body. The absence of marine microplankton in the "Red Beds" supports this thesis, although hypersaline conditions in an epeiric connection with the Western Interior conceivably could have created an effective barrier preventing migrations of marine organisms from the west.

Weathering products of adjacent Paleozoic sediments, especially sandstones of the Grand River Group, would have also provided a likely source for clastics deposited in the "Red Beds" basin. Upland areas no doubt existed toward the northwest in the Upper Peninsula, but lithologic and thickness distribution patterns do not indicate a provenance for sediments from any particular direction.

By the above mentioned postulate, the post-Pennsylvanian and pre-late Mesozoic paleogeographic history of the

Michigan Basin might be summarized as follows: The area experienced a long period of non-deposition and erosion between late Pennsylvanian and Early to Mid-Jurassic; any intervening sedimentary record was either decimated by pre-"Red Beds" erosion, or has yet to be discovered. With the formation, in Mid- to Late-Jurassic, of a structural basin, more or less coincident with the well established structural configuration of the Michigan Basin, a pluvial lake of considerable but unknown extent developed. Initially, a basal clastic facies was deposited on the old erosional Paleozoic surface. Neither the initial nor maximum bathymetric limits allowed by the structural activity is known, but the lake must have been fairly shallow. Total downwarping did not exceed total sediment accumulation; the basin filled with sediment and thus underwent a geomorphic cycle typical of basins characterized by internal drainage. This latter stage was also accompanied by a climatic regime where evaporation exceeded precipitation. Localized gypsum facies might have been deposited in isolated temporally and spatially shifting playa lakes over the surface of the shrinking "Red Beds" basin. The paleoclimatic and depositional environment of the "Red Beds" will be discussed in greater detail later. If deposition continued into latest Jurassic or even early Cretaceous, the record has again been stripped by erosion and glacial abrasion.

The postulate of an intracratonic structural basin having no direct physical relationship to exterior Jurassic events is an entirely logical conclusion, when the past structural history of the Michigan Basin is considered. It is also the simplest one; it can be formulated without excessive unfounded supposition or transcendence of the limits of existing evidence, and it stands as the most probable paleogeographic postulate that can presently be advanced. The second most plausible explanation involves an epeiric transgression from the Western Interior. This is a less engaging postulate but is still within the realm of possibility.

DEPOSITIONAL ENVIRONMENTS, CLIMATE, AND ECOLOGY OF THE "RED BEDS"

Any detailed interpretation of depositional environments operating in and adjacent to the "Red Beds" basin must be speculative for several reasons. For one, these deposits are accessible only through subsurface samples of limited quality and quantity. For another, the paleogeographic improbability of a marine or marginal marine influence cannot be completely discounted. No indigenous marine fossils have been found, but as previously discussed, a narrow, shallow, hypersaline connection with a marine source could impose an effective barrier against migration into the Michigan Basin. The fossil record of limited biotic invasion that might have occurred conceivably could remain undetected in the limited subsurface samples available for examination. While future studies must be open to the possibility of at least marginal marine influence, the available evidence does not warrant further consideration.

The absence of all except terrestrial biota, in the form of spores and pollen, necessitates heavy reliance on physical criteria in the reconstruction of environments within the basin itself. Red clastics and their component detrital particles are of course indicative of no single environment but many. There is probably a varied array of environments represented by the Michigan deposits. Most red pigmented clastics do however reflect nonmarine conditions. Among the clay mineral constituents, illite is the most commonly occurring, and this has been given as evidence to indicate deposition under marine conditions (Sander, 1959). Illite predominates in the clay fraction of most red sediments, but such ubiquity can be accounted for by several factors, including the one that under prolonged diagenesis of red beds many clays, such as amorphous and kaolinitic clays, will be converted to illite. Clays, of course, may either be weathered detritus inherited from source areas, or result from depositional and/or diagenetic environments. The commonness of illite, in particular, in red beds is no specific indicator of environments in source areas or depositional sites (Van Houten, 1964). Finally, the gypsum facies of the "Red Beds" do not require a marine connection as a source for the calcium sulphate.

An interpretation of the depositional history within a nonmarine paleogeographic setting is the simplest and most logical approach. After a long period of Late Paleozoic and Early Mesozoic erosion, a structural downwarping would have provided favorable conditions for deposition of the dominantly sandy, basal "Red Beds" facies. These initial sediments, deposited on an eroded Paleozoic surface, might have consisted of valley and channel fills and similar fluvial deposits.

At least seasonal pluvial conditions would have been required during deposition of clastic facies to provide erosional runoff in the source areas and to produce streams for the transportation of detritus to the depositional sites. No extensive conglomeratic sediments have been observed which would signify steep stream gradients and torrential stream flow.

The combination of postulated internal drainage in the Jurassic structural basin and the pluvial conditions would lead ultimately to the formation of a lacustrine environment. Whether this existed as a large lake completely filling the central portion of the Michigan Basin, or as several smaller, isolated playa scattered over the plain of alluviation in the central basin area, cannot be determined. The localized development of gypsiferous facies suggest the latter, but they may simply represent the shrunken remnants of a former lake of greater extent and continuity. Shaly and clayey facies would indicate comparatively quiet water deposition in the lacustrine environment. Other sedimentary regimes concommitent with the lacustrine phase might have included subaerial alluvial plains grading into nearshore deposits such as beaches, bars, and deltaic areas. Aeolian deposits might have accumulated on the adjacent plains.

It is reasonable to assume that the lake, or lakes, which were originally fresh water, became increasingly saline as streams supplied dissolved salts derived from chemical weathering of adjacent Paleozoic evaporites. With the advent of climatic conditions where evaporation exceeded precipitation plus runoff, this fresh water environment was superceded by one saturated with calcium sulphate, and gypsum or anhydrite which later became hydrated, was deposited. Red clastics and minor amounts of greenish shales, were deposited in close association with the evaporites, but apparently no carbonates preceded the gypsum deposition. It is not known if the water was also saturated with sodium chloride and other salts, and it is likewise unknown if the precipitation of gypsum was an early phase of a succession of evaporites leading to the deposition of halite. The stratigraphic position of the gypsum bodies indicates that several evaporite episodes occurred, but any associated halite facies have been removed by subsequent erosion or ground water solution.

Regardless of the derivation of the ferric oxides, oxidizing conditions must have prevailed at the depositional sites in order to preserve the hematite which imparts the characteristic color. Such conditions would have been aptly met in shallow, well-oxygenated aqueous environments lacking appreciable organic detritus, and in those parts of the basin exposed continuously or periodically to subaerial oxidative weathering. Oxidation was the dominant process throughout the duration of sedimentation, with the exception of several brief periods when greenish and greenish-gray shales and siltstones were developed in at least moderately reducing environments. The relatively finer-grained aspect of these greenish sediments indicates deposition in deeper water farther offshore.

The pollen genus *Classopollis* is widespread in Jurassic and lower Cretaceous sediments, but its mode of abundant occurrence and its morphology indicates it was not particularly amenable to long distance transport by the agencies of either wind or water. Pocock and Jansonius (1961), note that great abundances of this genus in marine facies occur in assemblages where phytoplankton are very rare or absent altogether, and that strata dominated by this genus frequently grade laterally into strata where its abundance is diminished and in its stead marine assemblages predominate. This inverse abundance relationship is well documented in the Late Jurassic Upper Vanguard Formation of southwestern Saskatchewan, where shallow near shore deposits flanking the then emergent Sweetgrass Arch contain an abundance of *Classopollis* far in excess of equivalent strata deposited farther offshore (Pocock, 1962). A similar situation occurs in Upper Jurassic and Lower Cretaceous sediments of the Netherlands, where Burger (1966) has related cyclical abundance peaks of *Classopollis* to near shore regressive phases.

According to Pocock and Jansonius (1961), extreme abundances of this pollen are usually associated with sediments of the type deposited under shallow water conditions in close proximity to shore lines. These abundances are also commonly associated with evaporites. The combined palynologic and lithologic associations have led these and other authors to conclude that the parent plants of

Classopollis favored dry or well drained coastal environments. The "Red Beds" data are in accord with this repeatedly observed pattern.

Because of unestimable post-depositional erosion, only conjecture can be made regarding the final phases and ultimate fate of the "Red Beds" sedimentary basin. If sedimentation rates exceeded rates of structural downwarping, fluvial and subaqueous sedimentation would cease as the basin became filled with sediments. Aqueous environments would have been supplanted by an aeolian regime on a plain of alluviation, in the event of aridity during the final phase. Cessation of sedimentation could also have been effected by mild structural uplift of the Michigan Basin area.

Climatologically, the Jurassic Period was part of an overall warming trend beginning in the Triassic or earlier and continuing well into the Cretaceous, followed by a cooling trend toward the end of the Mesozoic. Latitudinal climatic, floral, and faunal zonations approximating present latitudes can be defined for the Jurassic, though the zones were much broader with much less distinct boundaries than those of today. In general these zones, which are more clearly defined in the northern hemisphere, were characterized by expanded tropic, subtropic, and especially temperate zones, and a much compressed boreal zone at higher latitudes. The conclusion to be drawn from paleoclimatic and paleogeographic data is that a high degree of temperateness (Bailey, 1960, 1964) accented the Jurassic. Factors contributing to this temperate condition include the moderating effect of epeiric seas, and the lower relief and altitude of the continents which would permit a more equable heat exchange.

Evidence for Jurassic floral zones and their climatic significance is discussed by Seward (1931), Arkell (1956), Axelrod (1963, 1966), Vakhrameev (1964), and Smiley (1967). The synthesis of Eurasian Mesozoic floras by Vakhrameev (1964) is a particularly noteworthy demonstration of floral zones during the Jurassic and Cretaceous periods. For the Eurasian continent, Vakhrameev recognizes a southern "Indo-European Paleofloristic Province" and a northern "Siberian Paleofloristic Province". The boundary between these two vegetation zones migrated northward steadily throughout the interval from Early Jurassic through Middle Cretaceous, thus indicating a corresponding global warming trend for this period. Smiley (1967) has noted a similarity between these Eurasian Mesozoic floral boundaries and the Tertiary isoflors of Chaney (1940), which in turn coincide with the present-day isotherms. If the northward deflections of the Jurassic floral boundaries (Fig. 8) near the continental margin can be accounted for by the ameliorating effects of warm currents in the Atlantic and Pacific basins, as well as by the Prevailing Westerly winds, then it can be assumed that the Jurassic floral zones did not depart significantly, if at all, from present lines of latitude.

Jurassic macrofloras of North America are not nearly as numerous or widespread as those of Eurasia, and it may never be possible to treat them in the comprehensive manner of Vakhrameev (1964). There is some palynological indication of latitudinal floral and climatic zonation. For North America, principally in the Canadian Jurassic, Pocock (1964) records marked north to south increases in the abundances of Classopollis, Zonalapollenites, and Cycadopites. Conversely, bisaccate conifer-type pollen increase in abundance towards higher northern latitudes. Similar north-south abundance trends have been observed in the Russian Jurassic (Kara-Murza, 1960). Climates no more rigorous than cool temperate, possibly accented by coniferous forests, apparently characterized the Arctic region. Although Jurassic floras are generally considered cosmopolitan and uniform in nature, there is substantial basis for implying latitudinally controlled floral and climatic zones. By comparison to modern vegetation, these zones were not nearly as narrow or as well-defined. This no doubt can be attributed to the widespread temperateness of Jurassic climates.

The position of the evaporite belt for the northern hemisphere Jurassic, as mapped by Lotze (1957), infers a latitudinally controlled arid to subarid homoclimate belt with a distribution approximately between 25 and 50 degrees north latitude (Green, 1961). The Jurassic evaporites of Michigan and Iowa are within this belt (Fig. 8). This belt is considerably north of the present zone of significant evaporite deposition, which owes its presence primarily to the subtropical high pressure belts confined approximately between the latitudes 20 to 30 degrees north and south. The Jurassic warm arid homoclimate belt can best be explained by a northward expansion of the subtropical high pressure belt.

The boundary between the warmer "Indo-European Paleofloristic Province" and the cooler "Siberian Paleofloristic Province" lies just to the north of an, except for the northward deflection of the floral boundary at the continental margin, roughly parallel to the northern margin of the Jurassic evaporite belt. If a similar relationship existed in North America, then the Michigan Basin was not only situated within the northern margin of an arid belt inhabited by a warm-arid to semi-arid flora, but may also have been in close proximity to a floral transition zone a short distance northward.

Among the physical criteria, the "Red Beds" gypsum facies rank as the most reliable primary indicator of climate, and confirm the placement of the Michigan Basin within a Jurassic warm, arid, evaporite belt. Associated red clastics are the most voluminous and widespread of all the clastics comprising the "Red Beds", and may be a manifestation of the prevalent climatic conditions existing during their deposition. Any interpretation of these red clastics unavoidably leads to the longstanding controversy

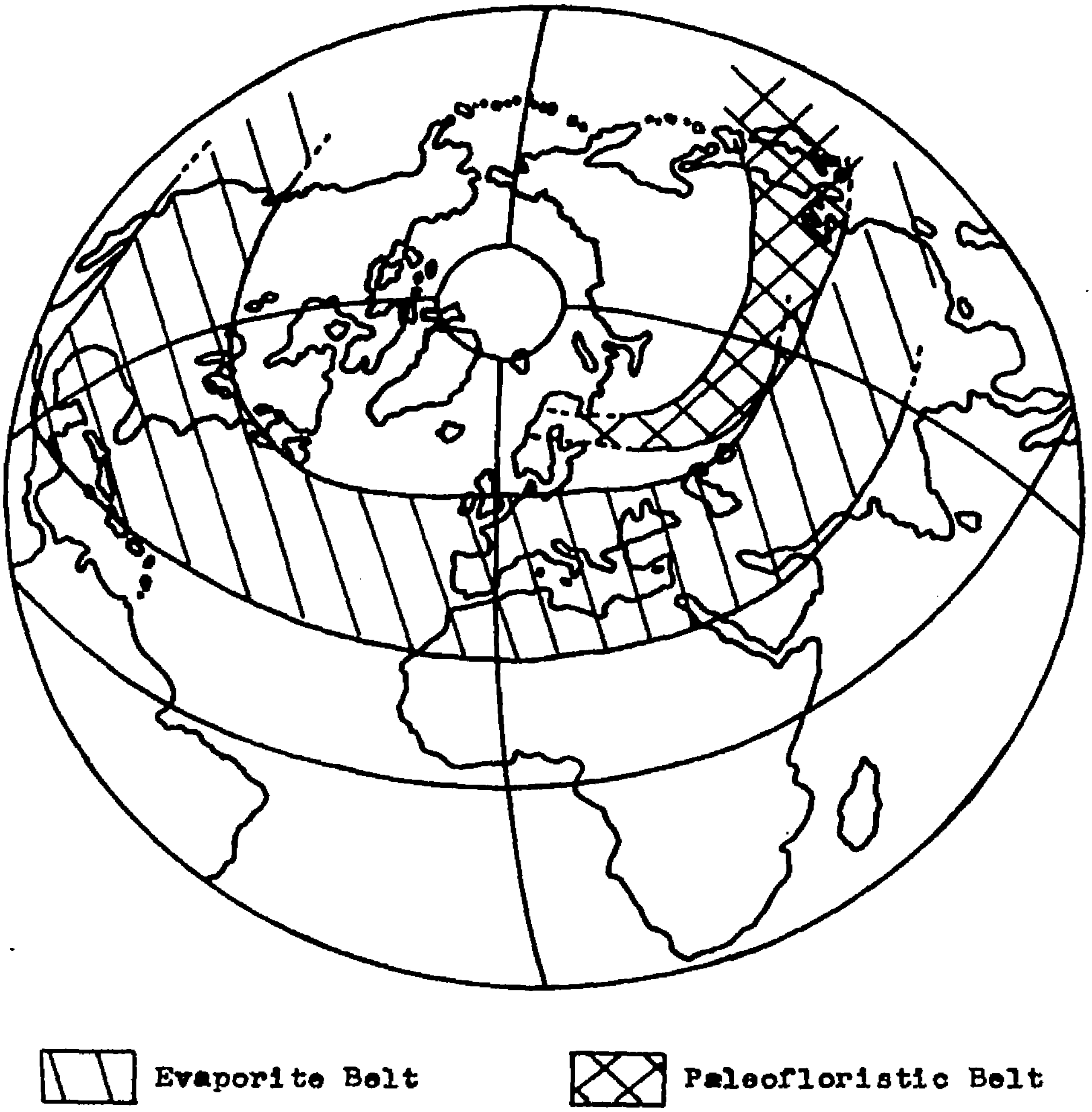


Figure 8. - Map showing distribution of Jurassic belt of evaporites for the northern hemisphere (after Lotze, 1957), and transition belt in which the boundary between the Siberian and the Indo-European paleofloristic provinces migrated in the Jurassic in Eurasia (after Vakhrameev, 1964).

and confusion concerning the climatic significance of redbeds. No unified interpretation of redbed genesis can be employed. They must be regarded as a lithofacies that formed under various geographic, tectonic, and climatic complexes.

Current trends of thought on the climatic conditions in which redbeds form are aptly summarized by Van Houten (1961, 1964, 1968,), McKee (1964), and Walker (1967). Two opposing viewpoints can be cited, and the controversy centers upon the origin of the hematitic pigment. These two points of view have undergone an interesting cycle of popularity in recent decades. Prior to the 1940's, the common association of redbeds and evaporites led to a hypothesis that the hematite formed during and/or after deposition by the alteration of iron-bearing minerals in a hot, arid to semi-arid climate. This school of thought was later disavowed by those who believed the hematite to be derived from laterites developed in and transported from warm, humid, upland areas. The hematite would thus be allogenic, and the sediments would be red at the time of deposition. A further condition would be the preservation of hematite in oxidizing environs at depositional loci. The influence of Krynine's (1935, 1949, 1950) studies on redbeds and their purported modern analogues sustained the acceptance of this popular hypothesis for over 20 years.

The former hypothesis, favoring _in situ_ formation of hematite in desert-like climates, is coming back into vogue. This revival is partly attributable to Walker (1967), who was unable to document the existence of Recent red, fluvial sediments deriving their hematite pigment from erosion of laterites in warm, humid uplands of tropical Mexico, as claimed by Krynine. On the other hand, Walker (1967), has documented the generation of redbeds in modern desert environments of the Sonoran desert of northeastern Baja, California. There, Pliocene, Pleistocene, and Recent fluvial and fluvial-marine facies are being stained red by hematite through progressive intrastratal alteration of iron bearing silicates. Numerous evaporite facies in this region confirm continuous or at least periodic aridity from the Pliocene to Recent. Walker also cites evidence for a similar origin for Late Paleozoic redbeds in Colorado.

The Michigan Jurassic redbeds are not consistent with laterization of humid uplands in tropical or subtropical climates as a mechanism supplying hematite to the depositional basin. Within the limited geographic extent of the Michigan Basin drainage area, it is difficult to reconcile the high rainfall requirements for laterization in postulated Pre-Cambrian uplands to the north and northwest occurring simultaneously with evaporite deposition in the basin. While these uplands of the Upper Penninsula and Wisconsin would have been an ample source for iron bearing detritus, any red pigmented detritus supplied from these sources probably would have been diluted and masked by non-red detritus, just as modern alluvium derived from lateritic uplands is (Van Houten, 1964; Wealker, 1967). Considering the close association of evaporite and redbed facies in the Michigan Jurassic, it is more tenable to conclude that they formed under warm, arid climatic conditions comparable to those operating to produce similar facies described by Walker (1967), in the Sonoran Desert of northeastern Baja, California.

The inherent bias in all palynological samples restricts conclusions regarding any ecologic and climatic history chronicled within strata. A limiting factor in assemblages as old as Jurassic is the inability to relate spores and pollen to their parent plants at taxonomic levels permitting close ecologic and climatic analogy with modern counterparts. Most of the "Red Beds" spores and pollen can be related only at the family or generic level. Many of them are extremely rare and may represent long distance transport. Therefore, only sweeping ecologic and climatic generalities based on botanical evidence are possible.

Pteridophyte spores in the assemblage are so rare that they contribute little to climatic interpretation. Without exception they can only be identified at the family level, and most of these families are not diagnostic of any particular climate. Living Lycopodiales are generally absent from arid regions, but are otherwise cosmopolitan. They are more abundant in the tropics and subtropics than in temperate and subarctic regions. Members of the

Selaginellales are presently confined mostly to the tropics but are widespread throughout temperate North America. The Equisetales, questionable members of the "Red Beds" flora, are cosmopolitan except for New Zealand and Australia. Extant species inhabit primarily aquatic sites, and the majority of the species live in tropical and subtropical climates, although some are widely distributed over temperate realms.

The Osmundaceae, possibly represented in the Michigan Jurassic by two species, are ferns occupying subaquatic and terrestrial habitats in tropic to temperate regions. Delicate ferns belonging to the Hymenophyllaceae favor shady environs in warm humid regions. Species of this family occur throughout the tropics and extend into warm temperate zones. The existence of this family in the "Red Beds" is not well documented. Another family of doubtful presence is the Cyatheaceae, which includes tree ferns of tropical, subtropical, and warm temperate regions where they are often a conspicuous element of montane vegetation.

Living species of the Cycadales are confined to tropical and subtropical regions where they prefer drier, well-drained habitats usually in upland areas. Presumably the extinct Bennettitales were adapted to similar environments. The single living species of the Ginkgoales is a temperate plant restricted, in historical times, to small isolated areas of China.

Species belonging to the Taxaceae and Cupressaceae are mostly temperate; a few species extend into the subtropics. Some species of these two groups are xerophytic, while some species of the Cupressaceae are of aquatic to subaquatic habit. Members of the Podocarpaceae are largely southern hemispheric in distribution. A few species extend into the northern hemisphere, but none are native to North America. Representatives of this family are common in temperate to subtropical forests. Pollen similar to those of the living genera *Podocarpus* and *Dacrydium* are present in the "Red Beds". Present-day Araucariaceae are entirely endemic to the southern hemisphere where they inhabit temperate to warm temperate regions. It is generally perilous to presuppose the environmental requirements of extinct plants, but in the case of *Cheirolepis*, the gymnospermous plant that produced the pollen *Classopollis*, there is sufficient evidence from palynologic and lithologic associations to enable reasonable speculation. According to Pocock and Jansonius (1961), and Pocock (1962, 1964), *Cheirolepis*, a presumed araucarian, favored dry or well-drained coastal areas in at least semi-arid, warm, climatic conditions.

The Pinaceae are undoubtedly represented in the "Red Beds" by non-podocarpoid and non-pteridospermous bisaccate pollen, resembling that produced by extant pines, as well as by monosaccate pollen of tsugoid aspect. The pines commonly range throughout temperate to cool temperate regions of the northern hemisphere; they are also found in subarctic and subtropical extremes. Extant species of Tsuga are common to cooler temperate forests. They also inhabit montane areas and, in North America, extend into the southern Appalachians.

Since most of the palynomorphs can be assigned only at the familial, and rarely at the generic, level, an interpretation of ecologic and climatic conditions based on physiognomy rather than on floristic analogy is unavoidable. Several generalized life form categories can be inferred for the Michigan Jurassic flora. A xeric association is represented in part by the Cycadales, Pinaceae, Podocarpaceae, Auaucariaceae, and Cupressaceae (juniper-type pollen). More mesic constituents include Lycopodiales, Selaginellales, Osmundaceae, Cyatheaceae, Hymenophyllaceae (?), Caytoniales, and Ginkgoales. An estuarine or marsh assemblage is questionably represented by the Equisetales and perhaps in part by the Cupressaceae. In terms of relative abundance, pollen assigned to the xeric association consistently comprise more than 90 percent of the assemblage. Xerophytic species may account for as much as 70 percent of the flora.

The "Red Beds" assemblage is typical of Classopollis-dominated assemblages in the sense described by Pocock and Jansonius (1961); that is, in addition to the overwhelming abundance of Classopollis, there is moderate but subordinate amounts of inaperturate pollen (Spheripollenites, Exesipollenites, Inaperturopollenites), and monosulcate pollen (Cycadopites) of the type produced by cycads. Pteridophyte spores and saccate conifer pollen are almost invariably rare and sometimes absent, as are marine microplankton. While the entire flora contains components indicative of climates varying from such extremes as arid and subarid to humid and dry subtropical or even tropical, xerophytes are the dominants. Xeric dominance is especially accented when considering that many of the more mesophytic to aquatic forms are either extremely rare or even of questionable presence. Most of the rare and/or questionable forms are pteridophytes, and their sparcity may be a matter of their abundance being masked as a consequence of the greater pollen production and more effective dispersal of many of the gymnosperms. The rare forms may also indicate long distance transport from outside the Michigan Basin area.

The seemingly incongruous association of tropical to temperate mesic elements in a dominantly arid to subarid climate can be explained by the presence of localized or micro-habitats on the Jurassic landscape of the Michigan Basin area. Broad lakeshore plains of very little relief undoubtedly extended for considerable distances, especially on the eastern, southern, and western perimeters of the basin. A desert to semi-desert association, possibly characterized principally by _Cheirolepis_ and minor cycads, might have occupied well drained, droughty sites along these plains. The dominance of _Classopollis_ suggests extensive distribution of the parent and associated plants in close proximity to the basin.

Upland regions to the north and northwest were near enough to have supplied some pollen to the central basin area. In the Upper Peninsula, the Porcupine Mountains and the Arvon Hills rise almost 2,000 feet above sea level, and the Huron Mountains exceed 1,600 feet in elevation. A considerable amount of elevation was probably lost from these areas through Pleistocene glacial erosion. By contrast, the maximum elevation of the top of the "Red Beds" is just over 700 feet. The topographic relief of these uplands in the Jurassic certainly was sufficient to have effected altitudinal vegetational zonations. In modern desert regions of the southwestern United States, considerably less than 1,000 feet of relief is needed to separate desert shrub and grasslands from piñyon-juniper and other higher altitude life zones. Similarly, the Jurassic uplands could have separated localized low to middle altitude coniferous communities from a more extensive desert association on the plains adjacent to the "Red Beds" basin.

In many modern arid regions of the world, narrow, protected stream valleys provide local habitats for sharply contrasting ecological arrays. This is well known in parts of the arid Southwest and the Sonoran desert, where palms and mixed mesophytic communities with cypress, sycamore, ash, maple, and cottonwood occur in narrow stream valleys or in lowland areas where phreatic water is available. Such sites may be the refugia in which these Tertiary-like assemblages still persist. These mesic riverine communities often lie in close justaposition to arid piñyon-juniper uplands and even drier playas downstream. Local riverine and/or phreatic assemblages would be expected to have occurred in stream valleys draining into the Michigan basin from upland sources to the north and northwest. Palynomorphs transported from these sites could account for the minor mesic to aquatic constituents of the "Red Beds" spore/pollen flora.

A synoptic view of the Michigan Jurassic landscape conceivably would include a lowland desert Cheirolepis-assemblage inhabiting a terrain of low relief extending to the east, south, and west of the basin, a dominantly coniferous life zone on dry to mesic localized uplands to the north and northwest, and restricted riverine communities in stream valleys out into the uplands. Though there is a considerable degree of speculation in these interpretations, the environmental, climatic, and ecological inferences drawn are reasonably compatible with both the botanical and physical criteria currently available.

SUMMARY AND CONCLUSIONS

Although the "Red Beds" represent less than one percent of the total sedimentary volume of the Michigan Basin, they are the most recent of pre-Pleistocene events known from the area. They thus play a critical role in augmenting our understanding of the geologic history of the basin. Knowledge of this phase of basinal history has remained obscure pending a geochronology more adequate than that offered by a nondefinitive physical stratigraphic position between late Paleozoic and Pleistocene. The primary objective of this study was to establish the time-stratigraphic relations of the "Red Beds", as an antecedent to geographic, environmental, climatic, and ecologic considerations.

Palynological methods were used to attain some of the outlined objectives. A thorough palynologic study of 113 samples from subsurface sources yielded 64 spore and pollen species, in addition to several palynomorphs recycled from Paleozoic strata. When several singly occurring and unidentified spores of uncertain origin are deleted from floristic consideration, a flora comprised of 77 percent gymnospermous and 23 percent pteridophytic species, is indicated. No angiosperm pollen was recorded.

Possible pteridophytic representatives of the flora include the Equisetaceae, Lycopodiaceae, Selaginellaceae, Osmundaceae, Hymenophyllaceae, and Cyatheaceae. Most of these families are not well documented by the spore assemblage. One pteridospermous pollen species belonging to the Caytoniales is present. Gymnosperm pollen can be assigned to the Cycadales and/or Bennettitales, Ginkgoales, Taxaceae and/or Cupressaceae, Podocarpaceae, Araucariaceae, Pinaceae, and provisionally the Chlamydospermae.

The notable absence of indigenous spores and pollen characteristic of Late Paleozoic and Early Mesozoic strata, together with the equally notable absence of angiosperm pollen and a number of characteristic Early Cretaceous spores, precludes all except a mid-Mesozoic age for the "Red Beds." A comparison of the "Red Beds" assemblage with established time ranges of diagnostic species from Canada, Western Europe, and Australia indicates a Jurassic age between earliest Bathonian and latest Oxfordian. Many of the "Red Beds" species are long-ranging throughout the Jurassic and early Cretaceous, and the above age assessment relies in part upon negative evidence, that is, absence of certain species. Such evidence was utilized particularly in establishing an upper age limit.

Problems of intercontinental palynological correlations stress the need for a North American standard of reference. Until palynologic data, especially for the Western and Gulf Coastal provinces of the United States are forthcoming, the "Red Beds" can be regarded with some degree of confidence as being of lower to middle Late Jurassic in age. A similar age can be assigned to the Fort Dodge Formation, a local gypsum and redbeds deposit in north central Iowa.

No clear genetic relationship exists between the "Red Beds" and the distribution of North American Jurassic strata, but the very presence of deposits of this age in Michigan warrants consideration of possible marine transgression into the area. The postulate of an epeiric connection with either the Gulf Coastal Province through the Mississippi embayment, or the Atlantic Coastal and Maritime Provinces by way of an ancestral St. Lawrence valley, or the Canadian Arctic by way of the Hudson's Bay-James Bay region, is largely speculative and without support. A narrow and brief eastward transgression of Western Interior Jurassic seas is rendered somewhat more tenable by the shorter distance involved, and especially by the presence of the Fort Dodge Formation of Iowa. Localized gypsum facies in the Devonian and Mississippian of Iowa are mostly if not entirely in the subsurface, and are a doubtful source for the calcium sulphate. The considerable volume of gypsum in the Fort Dodge may have required a marine source. Conceivably the Iowa and Michigan deposits are mere structurally preserved remnants of an eastward extension of Jurassic Western Interior seas.

Marine biota are lacking from both of these deposits, but none would necessarily accompany a brief, narrow, hypersaline transgression. Chemical weathering of exposed Paleozoic evaporites in the Michigan Basin could account for the "Red Beds" gypsum without invoking a marine source. Sedimentary distribution patterns, especially for the evaporite facies and perhaps some peripheral coarser clastics, appear to bear some relation to, and to some extent were controlled by, the structural configuration of the Michigan Basin. Since the biota, sediment source, and lithofacies distributions are genetically explicable without reference to outside Jurassic events, a gentle mid-Jurassic reactivation of the Michigan Basin, resulting in a structural, intracratonic sedimentary basin, is the most plausible paleogeographic postulate that can be advanced. The downwarping essentially conformed to the oft repeated structural pattern established in the Paleozoic.

Commencing with the establishment of a structural basin, a basal sandy facies was deposited upon a Paleozoic surface comprised mostly of Pennsylvanian sediments. Postulated interior drainage and pluvial conditions resulted in a fresh water lake which later became saturated with calcium sulfate and perhaps other salts derived from chemical weathering of exposed Paleozoic evaporites. Gypsum was deposited as localized facies in temporally and spatially shifting saline playa within the central Michigan Basin when total evaporation exceeded precipitation plus runoff. Interbedded gypsum and redbed facies indicate several evaporite episodes. The widespread distribution of red clastics indicates dominantly oxidizing conditions during the "Red Beds" depositional period. Mildly reducing environments were present during the deposition of thin, localized, green shales.

Structural downwarping did not greatly exceed sediment accumulation rates, as both lithologic and palynologic data suggests deposition in shallow, near shore environments. Any record of downwarping and sedimentation continuing into latest Jurassic or even Cretaceous has been eroded away. Cessation of deposition could have been caused by structural uplift of the basin, or by discontinued subsidence accompanied by sedimentary filling of the basin.

A postulate of a warm arid to subarid climate is supported by the geographic position of the Michigan Basin within a global Jurassic evaporite belt, by the close association of gypsum and redbed facies, by the Classopollis-dominated spore/pollen flora, and by the inferred xerophytic aspect of the dominantly gymnospermous flora. A lowland desert flora, probably dominated by Cheirolepis, inhabited dry or well-drained sites on lakeshore plains extending for considerable distances to the east, south, and west of the "Red Beds" basin. Uplands to the north and northwest would have had sufficient relief to separate this desert association from restricted low to mid-altitude coniferous communities. The relatively less common mesic, tropical to subtropical forms might represent a riverine association occurring along stream valleys penetrating the uplands.

The uniqueness of a Jurassic flora in the Michigan Basin should, by dint of its isolated and somewhat central geographic position, serve as a focal point for future floristic, phytogeographic, and climatic comparisons of Jurassic deposits of the Western Interior and Gulf Coast Provinces with those of the Atlantic Coastal province, the Canadian Arctic, and Greenland. The significance of the "Red Beds" flora will undoubtedly be realized when enough North American Jurassic palynological data become available for such syntheses.

SYSTEMATIC DESCRIPTIONS

INTRODUCTION

In this study, 64 spore and pollen species are described from the "Red Beds", and they are photographically illustrated on Plates 1 - 22. All identifiable palynomorphs are referred to form generic epithets, and the principles of priority and typification, as governed by the International Code of Botanical Nomenclature, are adhered to. Each species is formally described morphologically, as an aid to anyone referring to the "Red Beds" palynological assemblage in the future.

Of the 24 pteridophyte spore species recorded, most are known only from single specimens, and it has been possible to assign but a few to existing genera. Since in most cases the number of specimens was totally inadequate as a basis for the circumscription of new taxa, it was necessary to encompass these unidentified forms in provisional and artificial taxonomic designates. To a lesser degree, this practice was also applied to some of the rare and/or unidentified gymnosperm pollen.

Because of the provisional and uncertain assignment of many of the "Red Beds" palynomorphs at the generic level, it was not particularly convenient to employ a morphographic classification system, such as that of

Potonié. While a natural classification is desirable, the botanical affinities of many *sporae dispersae* are not well enough established to permit the use of such a system, except at high taxonomic levels. Morphologically, pteridophyte spores and gymnosperm pollen are sufficiently distinguishable to enable a broad and simple grouping. The species described here are arranged approximately in order of increasing morphologic complexity within these two higher taxonomic ranks.

GLOSSARY OF DESCRIPTIVE TERMS

The following list of morphological terms employed in the systematic descriptions have been adopted, with little or no modification, primarily from the previous definitions given by Erdtman (1952), Harris (1955), and Potonie & Kremp (1955). A much more comprehensive treatment of the history and various interpretations, definitions, and illustrations of palynologic terms can be found in the glossary of Kremp (1965).

Alete: Spores or pollen lacking tetrad marks or apertures.

Amb: Shape of the equatorial outline of a spore or pollen when viewed with the polar axis directed toward the observer.

Aperture: An opening, or weakly developed opening, of the exine surface, usually functioning in the germinal exit of intraexinous cellular contents.

Apiculae: Small conical processes of the surface of the exine.

Auriculae: Thickened or vesiculate extensions of the exine (or sexine), usually equatorially disposed at the radial region of trilete spores and the longitudinal extremities of bilaterally symmetrical spores or pollen.

Baculate: Exine ornamentation comprised of straight-sided, flat-topped, rod-shaped projections (Baculae) without expanded or modified tips and whose length is greater than their diameter.

Canaliculate: Exine ornamented with parallel or concentric narrow grooves. The intervening areas are narrow and flat. Canaliculae may be extra- or infra-sexinous.

Cappa: On the central body of saccate pollen, the proximally situated sexinal cap. It is delineated laterally by the proximal saccus bases.

Capula: On saccate pollen, the distal area of the central body between the distal saccus bases and including the germinal aperture.

Central body: The inner spherical to sub-spherical portion of a spore or pollen comprised of nexine either entirely or partially surrounded by loosely appressed sexine.

Clavate: Exine ornamented with rod-shaped projections with expanded tips; length greater than basal diameter.

Commissure: The line of weakness or dehiscence on monolete or trilete rays of spores. It refers only to the trace of the slit on the sexine and excludes lips, margo, or contact areas.

Distal: That portion of a spore or pollen surface which is directed outwards from the center of its tetrad. Apertures and colpi of gymnospermous pollen are commonly distal.

Exine: The main, outer, usually resistant layer of a sporoderm. Simple exine stratification, if present, consists of an inner nexine and an outer sexine.

Foveolate: Exine ornamentation comprised of pits up to 2.0 micra in diameter or, if larger, are too widely separated to form a reticulum.

Gemmate: Exine ornamented with subspherical, usually relatively large, projections (gemmae) with constricted bases.

Granulate: Small exinal sculptural projections from 1.0 to 2.0 microns in diameter. Individual granulae with circular bases, either isodiametric or with height slightly less than basal diameter.

Inaperturate: A spore or pollen devoid of apparent exinous apertures.

Interradial: The region of a trilete spore between adjacent commissures and the amb. Synonym: interapical.

Laesurae: Trilete or monolete tetrad marks of spores, including commissures, lips, margo, etc. when present.

Leptoma: An exinal thinning, with or without clearly delineated margins, which may serve as a germinal aperture on the distal face of pollen grains. A leptoma may be porate to sulcate in shape.

Lips: Thickened and frequently raised exinal margins flanking trilete or monolete commissures. Synonym: labra.

Marginal crest: Thickened exine at the equatorial region of the cappa on the central body of saccate pollen.

Margo: An area marginal to commissures or apertures distinguished by differential exinal thickening, or by the absence or reduction of surface sculpture in that area. The margo may or may not correspond to the contact area.

Nexine: The inner, usually unsculptured layer of stratified exines. Synonyms: intexine; endexine.

Perine: An outermost, usually loosely enveloping, extra-exinous sporoderm layer. Synonyms: perium; perispore.

Polar axis: A perpendicular line connecting the proximal and distal poles of a spore or pollen.

Pore: A distal circular to sub-circular germinal aperture usually having a distinct margin. Such an aperture with a poorly defined margin, or an aperturoid structure comprised of thinned exine, would be termed a leptomate pore or leptoma.

Proximal: That portion of a spore or pollen surface which is inwardly directed in its tetrad. Trilete and monolete tetrad marks are proximal.

Psilate: Exine surface smooth and essentially devoid of sculptural elements. Synonym: Laevigate.

Radial: The region in the immediate vicinity of the proximal commissures of trilete spores and the corresponding distal region. Synonym: apical

Reticulum: Extra- or infra-sexinal sculpture pattern consisting of a network of well-defined elevated ridges (muri) which surround regular or irregular depressions (lumina).

Rugulate: Surface ornamentation of exine consisting of elongate, narrow, wrinkled and irregularly distributed, raised sculptural elements (rugulae). Rugulae are irregular in basal outline, often with converging or diverging sides, and with flat or rounded crests.

Saccus: A sac-like structure, with varying degrees of inflation, comprised of separated or loosely appressed sexine which either partially or completely envelops the nexinal central body at the equatorial region of principally gymnospermous or pteridospermous pollen.

Saccus bases: The area or areas of attachment of saccus sexine to the sexine which surrounds and is usually tightly appressed to the nexine of the central body. Bisaccate pollen grains may possess a pair of proximal saccus bases flanking the cappa, and a pair of distal saccus bases flanking the distal surface of the central body.

Scabrate: Surface of exine sculptured with minute pits or granulae less than 1.0 micron in diameter.

Sexine: The outer, frequently sculptured layer of stratified exines. Synonyms: Exoexine; ektexine.

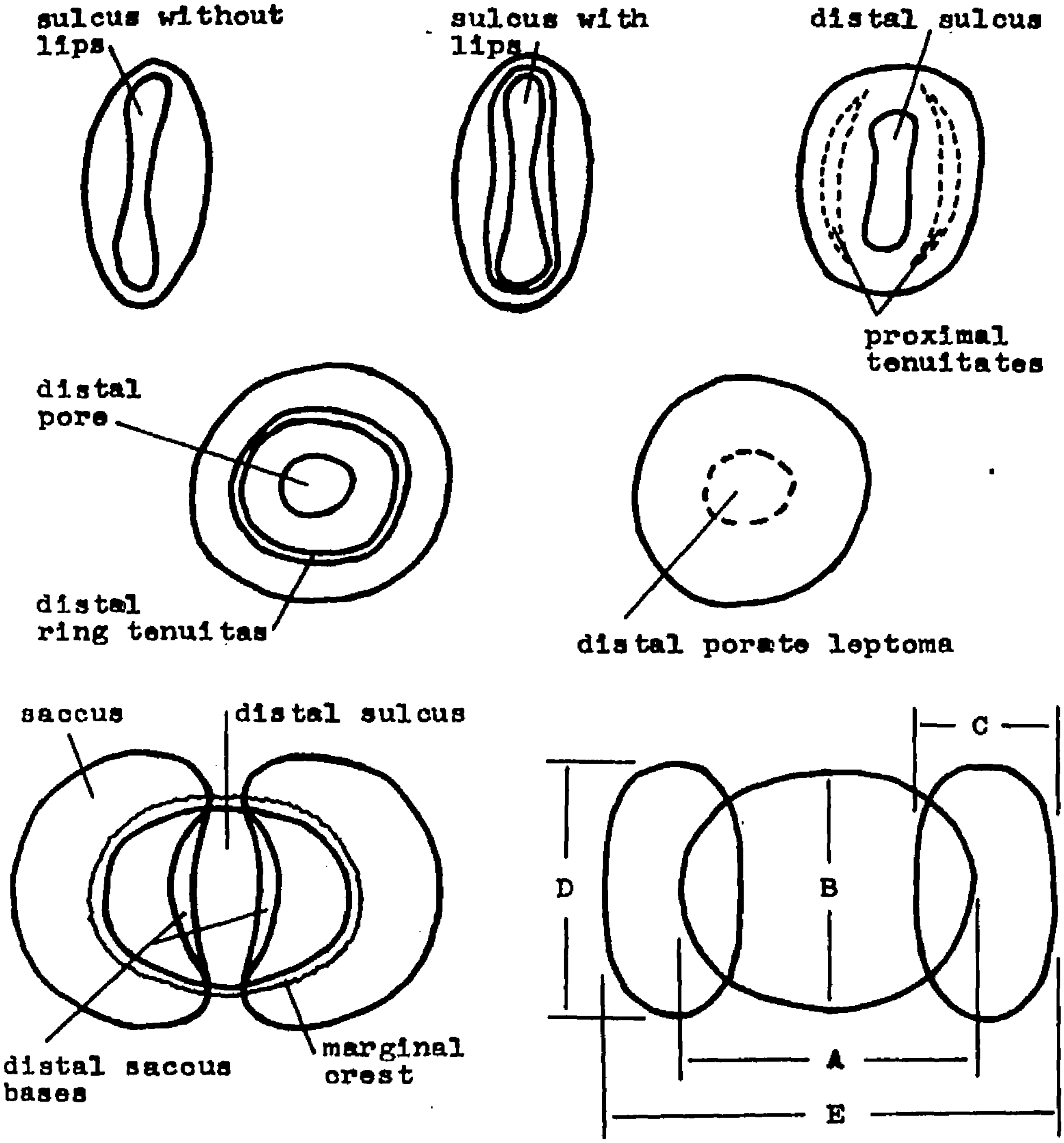
Spinose: Exine ornamentation comprised of narrow, tapering projections, with pointed apices, whose height is greater than twice their basal diameter. Synonym: echinate.

Striate: Surface ornamented with elongate, parallel to subparallel, straight or slightly sinuous, lines or grooves that are separated by raised sexinal ribs or bands.

Sulcus: On the distal face of pollen grains, an elongate aperture, with distinct margins, having a length considerably greater than width. The term sulcoid leptoma is applied when the aperture margins are poorly delineated.

Tenuitas: (plur. tenuitates) Exinal thinning probably not functioning as a germinal aperture. Tenuitates may be present either proximally or distally, and may appear as elongate or ring-like furrows.

Verrucate: Exine sculpture comprised of large, more or less irregular, broadly rounded to flat-topped protuberances having a height slightly less than width.



A - Width of central body
B - Length of central body
C - Width of saccus
D - Length of saccus
E - Total width of grain

Figure 9. - Morphology of some selected gymnosperm pollen.

DESCRIPTIONS OF PTERIDOPHYTE SPORES

Genus *CALAMOSPORA* Schopf

1944 *Calamospora hartungiana* Schopf; pp. 51 - 52.

DIAGNOSIS:

Trilete microspores; amb circular; laesurae short, simple slits; granulose contact areas sometimes developed; exine single-layered, very thin, psilate, and characteristically folded.

Calamospora sp. "A"

Plate 1; Figs. 16, 17

DESCRIPTION:

Trilete microspores; amb circular, probably originally spherical. Laesurae 8.0 - 10 micra in length, simple; commissures narrow slits with slightly thickened margins. Contact area slightly thickened, darkened, and faintly granulate. Exine hyaline, single-layered, about 1.0 micron thick, showing little tendency to fold; ornamented by scattered, fine, granules.

Dimension: diameter 48 micra

DISCUSSION:

This spore is very similar to *Calamospora mesozoica* Couper, a characteristic spore of the British Lower and Middle Jurassic. The single specimen described here has a slightly thicker exine, and thus shows less susceptibility to the characteristic folding of most species of Calamospora. In the Paleozoic, Calamospora has been related to the Calamarians, and may have been produced by those Mesozoic equisetaleans morphologically comparable to the Paleozoic Calamarians.

Genus CINGULATISPORITES Thomson

1953 Cingulatisporites Thomson (*in* Thomson & Pflug; p. 58)

DIAGNOSIS:

Trilete microspores; amb rounded triangular; exine single-layered, smooth to variously ornamented; narrow cingulum equatorially disposed; laesurae simple, extending towards but not onto the cingulum.

Cingulatisporites distaverrucosus Brenner

Plate 3; figs. 3, 4, 8, 9, 10, 15, 16

1963 Cingulatisporites distaverrucosus Brenner; p. 58,
pl. 13, figs. 6, 7; pl. 14, fig. 1.

DESCRIPTION:

Trilete microspores; amb convexly triangular to subtriangular. Exine two-layered. Laesurae extending to apical extremities of convexly triangular nexinal layer; commissures flanked by dark, raised lips 1.0 - 2.0 micra wide. Raised lips slightly sinuous, comprised of thickened sexine (?). Nexine about 0.5 micron thick, psilate; surface of proximal sexine thin, psilate to scrabrate; thick distal sexine bearing densely spaced, irregularly shaped verrucae having a maximum diameter ranging from 2 - 5 micra.

Verrucae sometimes coalesce, and, at least in optical section at the equator, they sometimes appear to have basal constrictions. Verrucate sexine thickens equatorially to form a cingulum 2 - 4 micra wide. Cingulum comprised for the most part of distinct verrucae which are not completely coalesced, resulting in a highly dissected cingulum.

Dimensions: Diameter 32 (34) 37 micra (3 specimens)

DISCUSSION:

The forms described here are similar in every respect to those described by Brenner (1963) from the Lower Cretaceous of Maryland, where it occurs rarely throughout the Potomac Group. It is extremely rare in the Michigan "Red Beds", being recorded from only three samples.

Botanical affinity unknown.

Genus CONVERRUCOSISPORITES Pot. & Kremp

1933 Verrucosi-sporites triquetrus Ibrahim; p. 26, pl. 7, fig. 61, type species.

1955 Converrucosisporites triquetrus (Ibr.) Pot. & Kremp; p. 65, pl. 13, fig. 191.

DIAGNOSIS:

Trilete microspores; triangular to subtriangular in equatorial outline. One- or two-layered exine densely ornamented with warts or verrucae of irregular size and shape.

Converrucosisporites sp. "A"

Plate 3; figs. 5, 6, 7

DESCRIPTION:

Trilete microspores; amb convexly subtriangular, apices broadly rounded. Exine two-layered. Laesurae 10 - 12 micra long, extend to apical extremities of subtriangular nexinal layer. Commissures flanked by slightly sinuous raised lips which are 1.0 - 2.0 micra wide. Proximal surface of sexine psilate to scabrate; thickened sexine of distal surface marked by large (2 - 7 micra), circular or irregularly shaped verrucae. Verrucae closely packed, sometimes coalescing. Verrucate sexine up to 5.0 micra thick at equator. Nexine thin, of indeterminate thickness.

Dimensions: Diameter 32 micra

DISCUSSION:

Only one specimen of this morphologically distinct spore has been recovered from the "Red Beds.".

Botanical affinity unknown.

Genus CYATHIDITES Couper

1935 Deltoidospora Miner; p. 618

1937 Leiotriletes Naumova (in part)

1953 Cyathidites australis Couper; p. 27, pl. 2, fig. 11 (type species)

1955 Leiotriletes (Naum) Pot. & Kremp; p. 36 (assignment of type species)

1956 Deltoidospora (Miner) Potonie; p. 13, pl. 1, fig. 1. (Assignment of type species "D". hallii Miner)

DIAGNOSIS:

Trilete microspores; amb triangular to subtriangular; sides straight to concave; apical angles rounded to bluntly pointed. Commissures simple, straight slits, without raised lips, extending over half of spore radius but not reaching apical extremities. Exine single layered; psilate to infrapunctate.

DISCUSSION:

The valid publication of the morphographic genus Cyathidites by Couper (1953), predated the validation of Naumova's (1937) genus Leiotriletes by Potonie and Kremp in 1955. Although Leiotriletes is presently a widely used generic name well ensconced in literature, especially that pertaining to Paleozoic spores, it is thus technically a junior synonym of Cyathidites.

The extant fern genus Cyathea produces morphologically simple spores similar to those of Cyathidites.

Cyathidites sp. "A"

Plate 1, fig. 1

DESCRIPTION:

Trilete microspores; amb triangular to subtriangular, apices rounded, sides concave. Laesurae extend almost to apical extremities, simple, comissures straight, without flanking raised lips, but margins may be slightly thickened. Exine one-layered, thin (1.0 micron), uniformly thick, psilate to faintly scabrate.

Dimensions: diameter 30 micra (one specimen)

DISCUSSION:

While morphologically simple spores similar to the one described here are one of the most ubiquitous spores of the Mesozoic, it is represented in the "Red Beds" by only a single poorly preserved specimen.

DENSOISPORITES (Weyland & Krieger) Dettmann

1953 Densoisporites Weyland & Krieger, p. 12.

1963 Densoisporites (Weyland & Krieger) Dettmann, p. 83, 84.

DIAGNOSIS:

Trilete microspores; amb triangular to subtriangular or subcircular; exine two-layered, cavate, sexine equatorially and distally separated from nexine. Sexine may be equatorially thickened; nexine thin, smooth, and with interradial proximal papillae.

DISCUSSION:

A lycopodiaceous, possibly selaginellid affinity has been suggested for Densoisporites, as well as some similar spores belonging to the genera Endosporites Wilson & Coe and Lundbladispora Balme, (see Dettmann [1963] for detailed discussion).

Densoisporites sp. "A"

Plate 2; figs. 17, 18

DESCRIPTION:

Trilete microspores; amb circular, polar outline probably biconvex. Laesurae straight, extend to inner margin of cingulum; commissures flanked by very narrow

(2.0 micra wide), low, weakly developed raised lips. Exine two-layered; sexine equatorially thickened to form a hyaline cingulum, 3.0 micra wide, sexine loosely appressed to nexine, bearing a microrugulate to microverrucate ornamentation on the cingulum and extending poleward for about 10 micra from the inner margin of cingulum. Sexine at proximal polar region with irregular granulate sculpture which may be the result of corrosion. Nexine thin (about 0.5 micron), psilate to finely scabrate.

Dimension: diameter 53 micra (one specimen)

DISCUSSION:

According to the emendation by Dettmann (1963), species belonging to the genus Densoisporites are characterized by interapical papillae situated on the nexine at the proximal polar area. The interapical papillae are not apparent on the type species, Densoisporites velatus, illustrated by Weyland & Krieger (1953), or on Densoisporites perinatus illustrated by Couper (1958) and by Brenner (1963). These papillae may thus not be a constant structural feature of the genus. They are not present on the single specimen observed in this study, which otherwise conforms to the circumscription of the genus.

Genus LUNDBLADISPORA Balme

1963 Lundbladispora willmotti Balme; p. 21, 22, pl. 5, figs. 1 - 3. (type species)

DIAGNOSIS:

Trilete microspores; circular to subcircular to subtriangular in equatorial outline. Exine cavate with ornamented sexine enclosing a thin-walled nexine. Sexine thinner on the proximal than on the distal side, thickened equatorially. Surface of sexine scabrate; distal surface may or may not bear small cones, spines, or grana. Proximal surface of sexine smooth or with considerably reduced ornamentation. Nexine smooth, with three interradial papillae at proximal polar area. Nexinal body often not centrally disposed.

DISCUSSION:

Spores of the genus *Lundbladispora* possess several morphological attributes frequently occurring in both the micro-and mega-spores of modern and fossil lycopiaceous, especially selaginellid, plants (Balme, 1963). The genus may be at least in part synonymous with *Aculeisporites* Artüz 1957.

Lundbladispora willmotti Balme

Plate 3; fig. 19

1963 *Lundbladispora willmotti Balme*; p. 22, pl. 5, figs. 1 - 3

DESCRIPTION:

Trilete microspores; amb circular to slightly subtriangular. Laesurae indistinct, especially at proximal polar area where exine appears to be ruptured; laesurae extend over three-fourths of spore radius, bifurcate irregularly at their apical extremities, and may be flanked by very narrow, slightly sinuous lips. Exine cavate; nexine thin, psilate, and forms an eccentrically disposed central body approximately 35 micra in diameter. Interradial papillae on proximal polar area of nexine, if present, not readily visible. Sexine relatively thin and psilate to scabrate on proximal surface; distal sexine thick, about 2 to 3 micra, ornamented with pointed to rounded spines; spines up to 3 micra in length, usually about 2 micra in basal diameter, spaced 3 to 8 micra apart, and project beyond the equatorial periphery. An equatorial band of sexinal thickening appears to be present.

Dimensions: Total diameter 59 micra

DISCUSSION

The single specimen observed is in a somewhat less than optimum state of preservation, but, other than being slightly smaller than the indicated minimum size range, conforms reasonably well with the description and illustrations of *Lundbladispora willmotti* Balme. The species has previously been recorded only from Lower Triassic sediments of Western Australia.

Genus *LYCOPODIUMSPORITES* Thiergart

1934 *Sporites agathoecus* Pot.; p. 43, pl. 1, fig. 25,
type species.

1938 *Lycopodiumsporites agathoecus* (Pot.) Thierg.; p. 293,
pl. 22, figs. 9 - 10.

DIAGNOSIS:

Trilete microspores with triangular to subtriangular amb. Laesurae usually extend to apical extremities. Exine two-layered. Proximal surface psilate to granulate; distal surface bearing regular to irregular reticulum.

Lycopodiumsporites sp. "A"

Plate 2; figs. 12, 13

DESCRIPTION:

Trilete microspores; amb triangular, apices rounded, sides convex; Exine two-layered. Laesurae extend to apices of subtriangular nexinal body. Commissures flanked by narrow raised lips up to 2.0 micra in width. Nexine thin (0.5 micron), closely appressed to sexine, which is 1.0 - 1.5 micra thick. Distal surface characterized by irregular, open-mesh reticulum comprised of convolute, sinuous, membraneous muri up to 4.0 micra high and 1.0 - 1.5 micra wide, which rarely enclose lumina. Proximal surface psilate.

Dimensions: diameter 32 micra (one specimen)

DISCUSSION:

One specimen of this spore, having possible affinity with the Lycopodiaceae, was observed in the Michigan "Red-Beds".

Genus TODISPORITES Couper

1958 Todisporites major Couper; pp. 134-135, pl. 16, Figs. 6-8.

DIAGNOSIS:

Trilete microspores. Amb circular. Laesurae simple slits without raised lips, relatively long, usually extending more than half of spore radius. Exine single-layered, more or less psilate.

DISCUSSION:

Todisporites is very similar to and possibly synonymous with the genus *Punctatisporites* (Ibr.) Pot. & Kremp (1954).

Todisporites *sp*. "*A*"

Plate 1; fig. 8

DESCRIPTION:

Trilete microspores; amb circular to subcircular; probably originally spherical. Laesurae simple, extend almost entire spore radius, commissures without thickened raised lips. Exine two-layered (?), 1.5 - 2.0 micra thick, uniform in thickness, psilate.

Dimensions: diameter 36 micra

DISCUSSION:

This morphologically simple spore is known from a single occurrence in the Michigan "Red Beds". Spores of this type may have been produced by fossil members of the Osmundaceae.

Todisporites *sp*. "*B*"

Plate 1; figs. 12, 13

DESCRIPTION:

Trilete microspores; amb circular, spore probably originally spherical. Laesurae comprised of simple commissures without flanking lips, 13 micra long. Exine single-layered, uniformly thick (2.0 micra), scabrate.

Dimensions: diameter 39 micra

DISCUSSION:

Only one specimen of this possible osmundaceous spore was observed in the Michigan "Red Beds".

Genus *UNDULATISPORITES* Pflug

1953 *Undulatisporites microcutis* Pflug; p. 52, pl. 1, fig. 18.

DIAGNOSIS:

Trilete microspores. Amb triangular to subtriangular, sides straight to convex, apices rounded, Laesurae extend almost to equatorial margin, frequently bifurcating near their tips. Exine two-layered, psilate to granulate.

Undulatisporites sp. "*A*"

Plate 2, fig. 16

DESCRIPTION:

Trilete microspores; amb triangular, sides convex, apices slightly rounded. Commissures indistinct, flanked by parallel-sided raised lips extending 0.5 to 0.75 micron on each side of commissures. Raised lips strongly undulate, especially for about one-half the radius from the proximal pole. Raised lips extend almost to apical extremities and bifurcate irregularly 2.0 to 3.0 micra from apices. Exine stratification indeterminate; exine about 1.0 micron thick. Surface psilate to faintly scabrate, with small granules scattered infrequently.

Dimensions: Total diameter 28 micra

DISCUSSION:

Only one specimen was observed. This spore, of unknown botanical affinity, is very similar, if not identical, to

Undulatisporites undulapolus Brenner 1963, which occurs infrequently in the Lower Cretaceous Potomac Group of Maryland.

Genus *VERRUCOSISPORITES* (Ibrahim) Pot. & Kremp

1932 *Sporonites verrucosus* in Pot., Ibr. & Klaus; p. 448, pl. 15, fig. 17, type species.

1933 *Verrucosi-sporites verrucosus* Ibr.; p. 25, pl. 2, fig. 17.

1954 *Verrucosisporites verrucosus* (Ibr.) Pot. & Kremp; p. 69, pl. 13, figs. 196-199.

DIAGNOSIS:

Trilete microspores; circular to subcircular in equatorial outline. Exine one- or two-layered, densely ornamented with warts or verrucae of irregular size and shape.

Verrucosisporites sp. "*A*"

Plate 3; figs. 1, 2

DESCRIPTION:

Trilete microspores; amb circular to subcircular; distal face more convex than proximal. Exine two-layered. Laesurae straight, extend to margin of nexinous central body; commissures flanked by narrow (1.5 micra), raised lips which become slightly wider at radial extremities. Nexine thin, about 0.5 micron; Sexine differentially thickened, up to 5.0 micra on distal surface, considerably thinner on proximal surface. Proximal surface scabrate to finely granulate; distal surface with large, closely crowded, circular to slightly elongate, verrucae ranging in size from 3.0 to 8.0 micra in diameter.

Dimensions: diameter 37 micra

DISCUSSION:

One specimen of this spore was observed in the Michigan "Red Beds".

Trilete Spore "A"

Plate 2; figs. 1 - 9

DESCRIPTION:

Trilete microspores; amb triangular to subtriangular, apices rounded and sometimes folded, sides straight to slightly concave or convex. Polar outline probably biconvex. Laesurae variable in length, extending from three-fourths the radius of spore to the apical extremities; commissures straight to slightly sinuous, flanked by narrow, raised lips ranging from 1.0 to 3.0 micra wide; raised lips darkened, comprised of thickened exine, and sometimes exhibit a slight sinuosity. A hint of kyrtome development has been observed at the apical extremities of the laesurae of some specimens. Exine apparently single-layered, about 1.0 to 2.0 micra thick, essentially sculptureless, except on proximal face, which is conspicuously punctate.

Dimensions: diameter 22 (26) 30 micra

DISCUSSION:

Forms assigned to this species vary in size, shape, and morphology of their raised lips, and the apical folding sometimes obscures the nature of the apical extremities of the spores and their laesurae, and distorts the shape. All proximally punctate spores encompassed within the above description are included in this temporary specific designate. The precise botanical affinity of these spores is unknown.

Trilete spore "B"

Plate 3; figs. 17, 18

DESCRIPTION:

Trilete microspores; amb triangular to subtriangular, apices rounded, sides convex. Laesurae sinuous, extend almost to inner margin of cingulum; commissures flanked by narrow (1.0 - 1.5 micra), raised lips. Exine two-layered; sexine differentially thickened, forming a thickened equatorial belt 3.0 - 3.5 micra wide completely encircling spore. Distal face marked by a circumpolar, subtriangular, sexinal elevation 22 micra in diameter which is separated from the equatorially thickened belt by a zone of considerably thinned sexine. Sexine of distal surface coarsely rugulate. Nexine less than 1.0 micron thick, psilate, forming a nexinous central body more or less of same shape and diameter of distal sexinal elevation. Exine of proximal surface psilate.

Dimensions: diameter 32 micra (one specimen)

DISCUSSION:

This spore, in having only an equatorial circular belt of sexine thickening, differs from Taurocusporites

Stover and *Distalanulisporites* Klaus, which are characterized by two or more concentric circular belts of sexinal thickening on the distal face. It differs from *Coronatispora* Dettmann in lacking interapical crassitudes. Only one specimen observed.

Trilete spore "C"

Plate 1; figs. 6, 7

DESCRIPTION:

Trilete microspores; amb triangular to subtriangular, apices rounded; sides slightly convex. Laesurae extending almost to apical extremities, simple, with very slightly thickened margins flanking the slightly agape commissures. Exine single-layered, scabrate or faintly punctate.

Dimensions: diameter 25 micra

DISCUSSION:

Only one specimen of this morphologically simple spore of unknown botanical affinity was observed in the Michigan "Red Beds".

Trilete spore "D"

Plate 2; figs. 14, 15

DESCRIPTION:

Trilete microspores; amb circular to subcircular. Commissures simple, straight slits extending approximately one-half spore radius, flanked by narrow, highly undulate raised lips which extend about two-thirds of spore radius. Raised lips befurcate near their extremities, the individual limbs becoming less pronounced as they approach the equator.

Exine 2.0 micra thick, apparently single-layered; surface of exine psilate to faintly scabrate.

Dimensions: Total diameter 37 micra

DISCUSSION:

Only one specimen of this distinct spore was observed. With the exception of its circular amb, it is morphologically similar to the genus Undulatisporites Pflug. The precise botanical affinity of this spore is unknown.

Trilete spore "E"

Plate 1; fig. 5

DESCRIPTION:

Trilete microspores; amb circular to subcircular. Laesurae extend almost to equatorial margin; simple, straight commissures flanked by raised lips which may be exine thickening or only artifacts of preservation produced by exine folding along commissures. Exine thin, less than 1.0 micron thick; surface faintly scabrate.

Dimensions: Total diameter 30 micra

DISCUSSION:

Only one rather poorly preserved specimen was observed. The spore is morphologically similar to and may belong to the genus Todisporites. Its botanical relationships are unknown.

Trilete spore "F"

Plate 3; fig. 11 - 14

DESCRIPTION:

Trilete microspores; amb triangular to subtriangular, apices well rounded, sides straight to slightly convex. Laesurae extending to apical extremities; commissures flanked by raised lips 1.5 - 2.0 micra wide. Exine stratification indeterminate. Distal surface densely covered with circular to irregularly shaped verrucae 2 - 4 micra across. Verrucae larger and more densely packed at distal polar region. Large granulae and fine verrucae are scattered sparsely on the proximal surface. Exine 1.0 - 2.0 micra thick.

Dimensions: diameter 23 micra

DISCUSSION:

Several rarely occurring spores of this type have been observed in the Michigan "Red Beds". Its botanical affiliations are unknown.

Trilete spore "G"

Plate 1; figs. 9, 10

DESCRIPTION:

Trilete microspores; amb subtriangular to subcircular, apices broadly rounded, sides convex. Laesurae straight, extend to apical extremities; commissures flanked by raised lips 2.0 - 2.5 micra wide. Exine single-layered, of uniform width, 1.0 - 1.5 micra thick, psilate to faintly scabrate.

Dimensions: diameter 36 micra

DISCUSSION:

Only one specimen of this spore of unknown affinity has been observed in the Michigan "Red Beds".

Trilete spore "H"

Plate 1; fig. 4

DESCRIPTION:

Trilete microspores; amb subtriangular, apices broadly rounded, sides convex. Laesurae extend to apical extremities; commissures slightly agape at proximal polar area, flanked by raised lips which may be formed by upturned sexinal extensions. Lips 4.0 - 5.- micra wide at proximal polar region, taper toward apices. Exine 1.0 - 1.5 micra thick, two-layered, surface psilate; sexine infrapunctate, less than 1.0 micron thick, closely appressed to thin nexine (about 0.5 micron).

Dimensions: diameter 26 micra

DISCUSSION:

This spore type is known from a single occurrence in the Michigan "Red Beds". Its botanical relationships are unknown.

Trilete spore "I"

Plate 1; figs. 2, 3

DESCRIPTION:

Trilete microspores; amb subtriangular, apices broadly rounded, sides slightly convex. Laesurae extend to apical extremities, commissures flanked by narrow (1.0 micron wide), lips comprised of upturned extensions of proximal exine. Exine single-layered, thin (less than 1.0 micron thick), uniform in thickness, very faintly scabrate.

Dimensions: diameter 25 micra

DISCUSSION:

This spore is very similar to Biretisporites potoniaei Delcourt & Sprumont, from which it differs in having a thinner exine and a somewhat smaller size. Only one specimen was observed in the Michigan "Red Beds". Its botanical affinity is uncertain; Rouse (1957) suggests an affinity of similar forms with Hymenophyllum L.

Trilete spore "J"

Plate 4; figs. 1, 2

DESCRIPTION:

Trilete microspores; amb circular to subcircular; shape probably originally spherical to subspherical. Commissures indistinct, apparently simple, open slits about 2.0 micra wide, extending to equatorial extremities. Exine thick, up to 2.0 micra in thickness, single-layered. Proximal surface ornamented with small, irregular, sinuous verrucae; distal surface uniformly covered by large clavae. Individual clavae up to 5.0 micra long, spaced at intervals of 2.0 to 5.0 micra from each other, expanded at their tips to form a rounded terminal knob up to 2.0 micra in diameter. The maximum constriction occurs just beneath the bulbous tip, and each clavae is expanded at its base where it merges with the exine.

Dimensions: Total diameter about 60 micra

DISCUSSION:

Only one broken specimen of this distinctive spore was observed. The botanical affinites are not known.

Trilete spore "K"

Plate 1; figs. 14, 15

DESCRIPTION:

Trilete microspores; amb subtriangular to subcircular, apices slightly angular, sides convex. Laesurae straight, simple, extend over three-fourths the radius of spore; commissures without flanking raised lips, margins faintly jagged. Exine thick, measuring 2.5 - 3.0 micra at equatorial optical section, two-layered, sexine only slightly thicker than nexine; sexine finely infrapunctate; infrapunctation more prominent on proximal surface.

Dimensions: diameter 48 micra

DISCUSSION:

This distinct, two-layered spore is known from a single specimen. Its botanical relationships are unknown.

Trilete Spore "L"

Plate 2; figs. 10, 11

DESCRIPTION:

Trilete microspores; amb triangular to subtriangular, sides straight to slightly convex, apices rounded or bluntly pointed. Laesurae extend to apical extremities; commissures flanked by narrow raised lips 1.0 to 2.0 micra in width. Exine thick, dense; exine stratification, if present, indeterminate. Distal surface densely ornamented with sinuous, vermiculate convolutions which appear to cross each other; individual convolutions about 2 micra wide. Proximal surface more or less smooth with minor, radially disposed folds or crenulations.

Dimensions: total diameter 28 micra

DISCUSSION:

Only one specimen was recorded. This spore, of unknown botanical relations, may belong in the genus Convolutisporites.

Trilete spore "M"

Plate 1; fig. 11

DESCRIPTION:

Trilete microspore; probably originally spherical, amb circular to subcircular. Laesurae straight, extending about three-fourths the spore radius; margins of commissures slightly thickened. Exine 0.5 - 1.0 micron thick, folded, scabrate or punctate.

Dimensions: diameter 27 micra

DISCUSSION:

One specimen of this spore of unknown affinity was observed from the Michigan "Red Beds".

DESCRIPTION OF GYMNOSPERM POLLEN

Genus *CYCADOPITES* (Wodehouse) ex Wilson & Webster

1933 *Cycadopites* Wodehouse; p. 483.

1946 *Cycadopites folliculari*s Wilson & Webster; p. 274,
fig. 7, type species

1947 *Monosulcites* Cookson; p. 134

1953 *Monosulcites* (Cookson) Couper; p. 65

1958 *Monosulcites* (Cookson) Potonié; p. 95 (citation of
holotype)

DIAGNOSIS:

Monosulcate pollen, oval to fusiform in equatorial outline. Elongate sulcus traversing the entire length, or nearly the entire length, of the pollen grain. Sulcus may be elongate-oval in outline, or it may be wider at the longitudinal extremities than at the distal polar region. Raised exinal lips may or may not flank the sulcus. Exine usually two layered. Surface ornament may be psilate to scabrate.

DISCUSSION:

Included in this genus are monosulcate grains which may or may not have lips flanking the sulcus, and which lack infrasculptural elements in the exine. Because of the similarity of this pollen type to several pteridospermous and gymnospermous groups, species referred to Cycadopites are best considered as having affinity with a Ginkgoales-Bennettitales- Cycadales complex.

Cycadopites sp. "A"

Plate 4; Figs. 3 - 5

DESCRIPTION:

Monosulcate pollen, elongate-oval in equatorial outline, longitudinal ends rounded. Sulcus centered on distal face and traverses the entire length of the grain. Sulcus not flanked by raised lips, widest (3 - 5 micra) at longitudinal extremities, margins often overlapping in region of distal pole. Two-layered exine 1.0 - 1.5 micra thick, surface psilate to very faintly scabrate; sexine closely appressed to and thicker than nexine.

Dimensions:					
	length	34	(37)	39	micra
	width	19	(22)	25	micra

DISCUSSION:

This is a rarely occurring species in the "Red Beds".

Cycadopites Sp. "B"

Plate 4; figs. 6 - 11

DESCRIPTION:

Monosulcate pollen, fusiform to elongate-oval in equatorial outline, sides nearly straight to slightly convex, ends sharply rounded. Sulcus extending entire length of distal face, usually slightly wider (2 - 4 micra) at longitudinal extremities than at the central distal polar region, where it is closed by overlap of the margins or forms a more or less uniformly narrow slit 0.5 - 2.0 micra in width. Sometimes sulcus gapes widely at only one end. Sulcus flanked by more or less biconvex, darkened, well developed lips which attain a maximum width of 6 micra at the distal polar region and taper towards longitudinal extremities of the sulcus where they merge with exine of normal thickness. Exine two-layered, psilate, 1.0 - 2.0 micra in thickness. Sexine and nexine closely appressed.

Dimensions:					
	length	26	(33)	47	micra
	width	10	(14)	19	micra

DISCUSSION:

This species is rare but is present in all samples of the "Red Beds".

Cycadopites subgranulosus (Couper) Pocock

Plate 5; Figs. 1 - 3

1958 *Monosulcites subgranulosus* Couper, p. 158, pl. 26, fig. 28-30

1965 *Cycadopites subgranulosus* (Couper) Pocock (in press)

DESCRIPTION:

Monosulcate pollen, oval in equatorial outline, ends pointed. Sulcus extending entire length of distal face, slightly wider at longitudinal extremities (3.0 micra) than at distal polar region. Sulcus flanked by weakly developed raised lips 2 - 3 micra wide. Raised lips infrapunctate or infragranulate, tapering gently to longitudinal extremities. Exine two-layered; nexine thin, of indeterminable thickness; sexine 1 - 1.5 micra thick, infragranulate (tegillate); infragranulation of proximal side much finer than that of distal side. Surface of exine psilate to faintly scabrate.

Dimensions: length 49 micra
width 23 micra

DISCUSSION:

Only one specimen of this distinct pollen has been found which compares closely with the holotype (Couper, 1958, pl, 26, fig. 28). In that my specimen and the holotype both have infrasexinal ornamentation, perhaps *Cycadopites subgranulosus* should be transferred to the genus *Ginkgoretectina*.

Genus *CHASMATOSPORITES* Nilsson

1958 *Chasmatosporites major* Nilsson; p. 54, pl. 3, figs. 10 - 15

DIAGNOSIS:

Monosulcate pollen grains with a single longitudinal sulcus or leptoma. Outline circular to oval. Sulcus usually relatively wide and of verying length, frequently extending about three-fourths of length of grain. Exine generally two-layered. Sulcus or leptoma may or may not be flanked by sexinal lips.

DISCUSSION:

This genus is distinguished from *Cycadopites* and *Ginkgoretectina* by its more or less circular to rounded-oval shape and its relatively short and wide sulcus.

Chasmatosporites *sp.* "*A*"

Plate 4; fig. 19

DESCRIPTION:

Oval pollen grains; length only slightly greater than width. Distal surface traversed by parallel-sided sulcus or sulcoid leptoma which extends almost entire length of grain. Sulcus (or leptoma) flanked by weakly developed exinal thickenings. Sulcus about 35 micra long, of uniform width throughout (5 - 6 micra wide). Exine about 2 micra thick; sexine only slightly thicker than and closely appressed to nexine. Surface of sexine rugulate to irregularly verrucate.

Dimensions:			
	Total length	40	micra
	Total width	34	micra

DISCUSSION:

Only one specimen was observed. This form is morphologically similar to the pollen of some cycads, but it is conceivably an aberrant bisaccate pollen, possibly of podocarp affinity, whose sacci have failed to develop.

Genus *GINKGORETECTINA* Maljawkina

1953 *Ginkgoretectina* *punctata* Mal.; p. 136, pl. 1, fig. 20, type species

DIAGNOSIS:

Pollen grains monosulcate, oval to fusiform in equatorial outline. Distal sulcus may be well developed, extending the full length of the grain, either wider or narrower at longitudinal extremities than at central distal polar area, or may be an elongate leptoma. Sulcus (or leptoma) flanked by sexinal lips. Exine two-layered, infrapunctate or infrareticulate (tegillate).

DISCUSSION:

This genus, of probable gymnospermous affinity, differs from Cycadopites in encompassing only those species with infrapunctate or infrareticulate sexines.

Ginkgoretectina sp. "A"

Plate 5; Figs. 4 - 7

DESCRIPTION:

Monosulcate pollen, oval in equatorial outline, ends sharply rounded. Sulcus extending almost the full length of distal face, wider (5.0 micra) at longitudinal extremities than at distal polar area. Sulcus flanked by irregularly developed raised lips which are more prominent at the distal polar region. Lips have maximum width of 5.0 micra, coarsely infrapunctate. Exine two-layered, nexine approximately 0.5 micron thick; sexine 1.0 - 2.0 micra thick, distinctly infrapunctate (tegillate).

Dimensions:	length	59	micra
	width	31	micra

DISCUSSION:

Only one specimen of this distinctive pollen has been found in the Michigan "Red Beds". It probably bears affinity with the cycadales.

Ginkgoretectina sp. "B"

Plate 4; figs. 13, 14, 17, 18

DESCRIPTION:

Monosulcate pollen grains; oval in equatorial outline. Distal surface traversed by a sulcus extending almost the entire length of the pollen grain; sulcus 1 to 3 micra wide, more or less parallel-sided, except at extremities where it tapers somewhat. Sulcus usually flanked by thickened exinal lips up to 3.0 micra wide on each side of sulcus. Exine 1.0 to 1.5 micra thick, two-layered; sexine infrapunctate to finely infragranulate, closely appressed to nexine; nexine may be slightly thinner than sexine. Surface of exine may bear scattered punctae or granulae.

Dimensions: Total length 26 (31) 34 micra
Total width 14 (16) 17 micra

DISCUSSION:

Only four grains of this rare species of possible cycadeoid affiliation have been observed. It resembles some species of Cycadopites with the exception of infrasexinal ornamentation. The granulate or punctate surface may be a result of exine corrosion.

Genus EUCOMMIIDITES (Erdtman) Hughes

1948 Tricolpites (Eucommiidites) troedssonii Erdtman; p. 267, type species
1957 Trifossopollenites (in part) Rouse; p. 372
1958 Eucommiidites (Erdtman) Couper; p. 160
1961 Eucommiidites (Erdtman) Hughes; p. 293

DIAGNOSIS:

Complex pollen grains bearing one conspicuous sulcus on the somewhat flattened distal face, and a pair of tenuitates, or sometimes a ring tenuitas, on the more convex proximal surface. Grains are elongated-elliptical to subcircular in equatorial outline, and sulcus and tenuitates parallel the longer axis. Two-layered exine may be smooth, scabrate, punctate, pitted, or tegillate (infrapunctate).

DISCUSSION:

Originally, Erdtman (1948) interpreted these grains as tricolpate pollen, and thus possible evidence for pre-Cretaceous angiosperms. Later examination revealed, however, that the more fully developed "colpus" was of gymnospermous aspect, and that the other two "colpi" were crescentic or circular exinal thinnings with jagged edges (tenuitates) on the proximal side of the equator. Not only do the sulcus and tenuitates differ in structure but they are not symmetrically disposed with respect to each other in a radial manner, as is the case in most angiospermous tricolpate pollen.

Hughes (1961) found numerous specimens of *Eucommiidites delcourtii* in the micropyle and pollen chamber of several specimens of the gymnospermous seed *Spermatites pettensis* Hughes from the Lower Cretaceous of England, and Brenner (1963) has reported *Eucommiidites troedssonii* Erdtman in the micropylar tube of 12 specimens of a similar gymnospermous seed from the Lower Cretaceous Potomac Group of Maryland. *Eucommiidites* is thus without doubt a pollen with gymnospermous affinity, but it is not possible at present to definitely state to which group it belongs. On the basis of the structure of *Spermatites*, Highes (1961) suggests the Chlamydospermales as the most likely group.

The known stratigraphic range of forms assignable to this genus is from Lower Jurassic to Lower Cretaceous.

Eucommiidites troedssonii Erdtman

Plate 8; Figs. 14 - 17

1948 *Tricolpites* (*Eucommiidites*) *troedssonii* Erdtman; p. 267

DESCRIPTION:

Monosulcate pollen, oval in equatorial outline, with sulcus paralleling the long axis and traversing almost the entire length of the distal face. Sulcus 24 to 35 micra in length, usually widest at the terminal extremities (2 - 5 micra) and narrowest in the region of the distal pole (1 - 3 micra). On the proximal face, a pair of crescentic tenuitates flank the distal sulcus and are disposed just proximal to the equator. Tenuitates more or less parallel the equator, vary in width from 2 - 4 micra, and taper towards the longitudinal extremities. Margins of tenuitates usually irregularly serrate. Exine two-layered; sexine averages 1.0 micron in thickness and is tightly appressed to nexine which is approximately

0.5 micron thick. Exine psilate to faintly scabrate, and of uniform thickness except over tenuitates where it is considerably thinned.

Dimensions: length 34 (39) 43 micra
width 23 (26) 36 micra

DISCUSSION:

This species is of rare occurrence in all "Red Beds" samples. No specimens were observed in which a proximal ring tenuitas had developed by the merger of the tenuitates extending completely around the longitudinal extremities of the pollen grain. *Eucommiidites troedssonii* is distinguished from *E. minor* by its decidedly oval shape, larger size, and generally uniform thickness of the exine.

Eucommiidites minor Groot & Penny 1960

Plate 8; Figs. 18 - 22

DESCRIPTION:

Monosulcate pollen, circular to subcircular in equatorial outline; with sulcus extending almost the entire length of the distal face. Sulcus 18 to 25 micra in length, variable in shape and width with some specimens having a sulcus wider at longitudinal extremities than at distal polar area, and others wider at the distal polar area than at extremities. Maximum width of sulcus 3 - 5 micra. Sulcus flanked by a distinct, usually darkened, zone of distal exinal thickening, 3 - 8 micra wide at polar area, which tapers toward the longitudinal extremities. Exine two-layered, psilate to faintly scabrate, uniform in thickness, except for thinning over tenuitates, and thickening marginal to distal sulcus. At the equatorial region, the nexine ranges up to 0.5 micron in thickness, and the sexine is approximately 1.0 micron thick.

Dimensions: length 22 (26) 29 micra
width 20 (23) 28 micra

<u>DISCUSSION</u>:

The brief description of this species by Grout and Penny (1960) does not mention the broad, thickened lips bordering the sulcus, and the orientation, state of perservation, and quality of illustration of the holotype renders it difficult to determine whether this potentially diagnostic feature is present or not. The specimen designated as <u>E</u>. <u>minor</u> by Groot and Penny (1962) from the Lower Cretaceous of Portugal seems to suggest the presence of broad, thickened lips flanking the sulcus.

This species occurs rarely in the "Red Beds".

<u>Eucommiidites</u> <u>sp</u>. "<u>A</u>"

Plate 9: Figs. 1 - 6, 10

<u>DESCRIPTION</u>:

Monosulcate pollen, oval to sub-circular in equatorial outline, grains often assume sub-rectangular outline due to lateral exine folding parallel to the long axis. Sulcus extending almost entire length of distal face, 18 - 27 micra in length, more or less uniform in width, or wider at longitudinal extremities than at distal polar area. Two weakly developed tenuitates placed near equator on proximal face, not extending around the longitudinal extremities of the pollen to form a ring tenuitas. Details of tenuitates generally obscured by lateral folding of exine. Exine two-layered, 0.5 - 1.0 micra thick; nexine less than 0.5 micron thick; sexine up to 1.0 micron in thickness, externally smooth, tegillate (infrapunctate), columellae small, iso-diametric, less than 0.5 micron in height, dense, uniformly spaced. Sexine closely appressed to nexine, becoming slightly loose on less well preserved grains. Exine of uniform thickness, except at longitudinal extremities, where it thickens slightly.

Dimensions: length 26 (30) 35 micra
width 16 (22) 26 micra

DISCUSSION:

The thin exine apparently renders this form susceptible to pronounced, complex, arcuate folding which is invariably present along the lateral extremities of the grain. These folds parallel the long axis of the grain, symmetrically flank the sulcus, and involve the tenuitates. It is suggested that the tenuitates create a zone of weakness where infolding of the exine may have occurred during compression of an originally asymmetrically biconvex pollen grain. This would explain the generally obscure nature of the tenuitates.

Forms assigned to this taxa differ from *E. troedssonii* and *E. minor* in having a slightly thinner exine whose sexine is distinctly tegillate or infrapunctate. This species bears some semblance to several specimens briefly described as scabrate by Saad (1963) from the Sinai Region. Careful re-examination of his material may reveal a tegillate (infrapunctate) sexine. Saad did not give his forms a specific name, and no holotype was designated.

Eucommiidites _sp_. "_B_"

Plate 9; Figs. 7 - 9, 11 - 20

Plate 16; Figs. 14, 15

DESCRIPTION:

Monosulcate pollen; lateral extremities of equatorial outline gently convex; longitudinal extremities of equatorial outline angular to sharply convex or pointed. Sulcus 17 to 23 micra in length, traversing nearly entire length of distal face; nearly uniform in width (1.0 to 3.0 micra) throughout, or only slightly wider at longitudinal extremities. Sulcus margins flanked by narrow lips. Characteristics of proximal tenuitates obscured by minor exine folding along lateral equatorial regions. Tenuitates do not extend completely around proximal face to form ring tenuitas. Exine two-layered, sexine about 1.0 micron thick, tightly appressed to nexine (less than 0.5 micron thick). Distal surface psilate; proximal surface conspicuously marked by pits apparently penetrating both nexine and sexine; pits variable in size from less than 0.5 micron to 2.0 micra in diameter, randomly scattered over and confined to proximal surface, but can be observed along equatorial outline.

Dimensions: length 20 (24) 28 micra
width 11 (15) 17 micra

DISCUSSION:

The most diagnostic characters of this species are the pitting of the proximal exine and the angular aspect of the longitudinal extremities. Whether or not the pitting is a genetically controlled feature, or whether it is a spurious product of differential corrosion, cannot be ascertained, but it is a constant feature on all specimens observed and appears to be a valid taxonomic criterion. The angular longitudinal extremities may be the result of folding confined to and possibly controlled by the tenuitates flanking the distal sulcus.

This species is quite similar to Eucommiidites delcourtii Hughes, which, according to Hughes (1961), bears two distinct sizes of pittings confined to the proximal face. The quality of illustrations of E. delcourtii prohibit a close comparison. The "Red Beds" material does not possess a bimodal size distribution of the pits.

This species is extremely rare and has only been observed in a few samples of the "Red Beds".

Eucommiidites sp. "C"

Plate 9; Figs. 21 - 30

DESCRIPTION:

Monosulcate pollen grains; rounded oval to subcircular in equatorial outline. Gaping sulcus extending almost entire length of distal face, widest at the distal polar region and tapering toward, and becoming pointed to sharply rounded at, the longitudinal sulcus extremities. Sulcus not flanked by thickened exinal lips. Sulcus 16 - 22 micra in length, and 7 - 9 micra in maximum width at the distal polar region. Proximal surface bears a pair of arcuate tenuitates just proximal to the equator and symmetrically disposed on each side of the distal sulcus. Tenuitates are narrow, less than 2.0 micra wide, of more or less uniform width throughout, parallel the lateral equatorial margin of the pollen, and extend almost to the longitudinal extremities of the pollen grain, but do not appear to merge to form a ring tenuitas. A small, auriculate-like process, comprised of a thickened extension of equatorial exine is present at the longitudinal extremities of the pollen grain. The blunt auriculate-like processes are attached across the ends of the sulcus, range in width from 6.0 - 9.0 micra, and are 2.0 - 3.0 micra long. Lateral infolding of the exine along the position of the tenuitates sometimes accentuates the auriculate-like processes. Exine two-layered, of more or less uniform thickness throughout (about 1.0 micron thick), except at thickened longitudinal extremities; sexine and nexine closely appressed and of indeterminate thickness. Exine frequently densely pitted; pitting more pronounced on, but not restricted to, the proximal surface. Pits average about 1.0 micron in diameter.

Dimensions: Length 23 (26) 28 micra
Width 18 (20) 21 micra

DISCUSSION:

The above interpretation is based on observations on four specimens. This rare species is readily distinguished from other species of the genus by the gaping, elliptical sulcus, the broadly oval equatorial outline, and the auriculate-like terminal exinal thickenings, which apparently are a unique morphologic feature of the genus. The exine pitting so common on the proximal surface may be an artifact of corrosion of the perhaps more susceptible proximal exine.

Genus *INAPERTUROPOLLENITES* Thomson & Pflug, 1953

DIAGNOSIS:

Pollen grains lacking, or apparently lacking, apertures; originally spherical or subspherical. Exine either one- or two-layered; surface psilate, scabrate, to granulate. Nexine and sexine of two-layered forms may be tightly or loosely appressed. Sexine may have infra-ornamentation.

DISCUSSION:

Strictly a morphologic genus, *Inaperturopollenites* is similar to pollen produced by a number of plant taxa, and as such has practically no botanical connotation. Some species have been compared to araucarian pollen. Most pollen included in this genus are probably of gymnospermous affinity.

Inaperturopollenites Sp. "A"

Plate 21; Figs. 1 - 4

DESCRIPTION:

Inaperturate pollen; oval to subcircular in outline; grains probably originally spherical in shape. No germinal mechanism or exine thinning (leptoma) observed. Exine two-layered; smooth nexine thin, about 0.5 micron thick; sexine up to 1.5 micra thick, very finely infrapunctate or infra-granulate, surface of exine scabrate to finely granulate. Sexine may be tightly or loosely appressed to nexine. Exine commonly intensely folded and sometimes ruptured. Surface of exine sometimes has roughened appearance, probably due to corrosion.

Dimensions: Total diameter 35 (56) 78 micra

DISCUSSION:

Size, ornamentation, exine thickness, and the relative degree of sexine attachment to the nexine are considered salient taxonomic criteria at the species level. The numerous specimens closely examined here exhibit complete intergradation of all these aspects, and the differentiation of more than one species was considered unwarranted. It appears that both exine ornamentation and the degree to which the sexine may be appressed to the nexine can be a product of differential preservation. This gymnospermous pollen occurred commonly in the Michigan "Red Beds". It has little stratigraphic significance, and a possible araucarian affinity can only be conjectural.

Genus *SPHERIPOLLENITES* Couper

1953 *Inaperturopollenites* Thoms, & Pflug (in part); p. 66.
1958 *Spheripollenites scabratus* Couper; p. 158, pl. 31,
Figs. 12 - 14, type species.

DIAGNOSIS:

Originally spherical to subspherical pollen grains with a distal germinal aperture comprised of either a distinct to scarcely discernible pore, or a leptoma. Exine thin, readily folded, two-layered; sexine may be uniformly infrapunctate, or infragranulate, infracanaliculate, throughout, being absent at the pore or leptoma. Surface of sexine may be psilate, scabrate or granulate.

DISCUSSION:

A comparison between species of *Spheripollenites* and certain extant members of the Cupressaceae and Taxaceae has been discussed and illustrated by Couper (1958). The pore or leptoma is often detectable under phase contrast.

Spheripollenites scabratus Couper

Plate 5; Figs. 15, 16. Plate 6; Figs. 1 - 4

1958 *Spheripollenites scabratus* Couper; p. 158, pl. 31,
Figs. 12 - 14.

DESCRIPTION:

Probably leptomate pollen, originally spherical or subspherical in shape. Indistinct leptoma centered at distal pole, formed by differential sexinal (?) thinning over a circular to subcircular area averaging 6 micra in diameter. Two-layered exine 1.0 - 2.0 micra thick, often folded; nexine thin (less than 0.5 micron thick); sexine usually about 1.0 micron thick, infrapunctate or infragranulate, closely appressed to nexine, surface of exine psilate.

Dimensions: Diameter 27 (34) 37 micra

DISCUSSION:

Couper (1958) described this species as having a scabrate ornamentation, but noted that the surface of the exine was smooth in optical section. The sculpture of his figured specimen (pl. 31, fig. 14) appears to be infrasexinal, and are thus comparable to those found in the "Red Beds". The leptoma is rarely observed by normal microscopy, but can usually be detected under phase contrast. *Spheripollenites scabratus* is rare to common in occurrence, and is present in almost all samples of the "Red Beds" examined.

Genus *EXESIPOLLENITES* Balme

1953 *Inaperturopollenites* Thoms. & Pflug (in part); p. 66.
1957 *Exesipollenites tumulus* Balme; p. 39, pl. 11, Fig. 123, type species.

DIAGNOSIS:

Pollen grains originally spherical or subspherical in shape; distal pole marked by a weakly developed circular pore or a circular area of exine thinning forming a leptoma. Pore or leptoma may be surrounded by a circular zone of thickened and/or darkened exine. Exine two-layered, psilate, scabrate, or granulate. Infra-sexinal ornamentation, if present at all, is usually confined to the area surrounding the distal germinal area.

DISCUSSION:

This monotypic genus is morphologically similar to *Spheripollenites* Couper, from which it can be distinguished by its general lack of uniform infra-sexinal ornamentation, and by the structure of the distal germinal aperture and adjacent area. Like *Spheripollenites* and other similar pollen, it is probably related to some members of the Cupressaceae and Taxaceae.

Exesipollenites tumulus Balme

Plate 5; Figs. 9 - 14

1957 *Exesipollenites tumulus* Balme; p. 39, pl. 11, fig. 123.

DESCRIPTION:

Monoporate or leptomate pollen grains; probably originally spherical to subspherical in shape. Pore or leptoma situated centrally on distal face, delineated by a circular zone of exinal thinning averaging 6 micra in diameter, which is enclosed by a characteristic dark, thickened (?), circular area of exine averaging 18 micra in diameter. This darkened zone merges equatorially with exine of normal thickness. Two-layered exine up to 1.5 micra thick, surface scabrate to finely granulate. In addition, the surface is often ornamented with small, spherical "orbicules", averaging slightly less than 1.0

micron in diameter, randomly attached, either singly or in clusters, to the exine. Sexine, when present, loosely appressed to nexine, except over the distal polar area where they are in close contact.

Dimensions: Diameter 23 (29) 38 micra

DISCUSSION:

Pocock (1965) has convincingly demonstrated the two-layered exine in this species, and noted further that specimens complete with the enveloping sexine are rare. In fact, the nexinous central body, bearing the darkened circular area encircling the pore is the most common state of preservation. Brenner (1963) noted an occasional feature on the proximal face which he interpreted as a triradiate tetrad mark. This is believed by Pocock (1965) to be a spurious feature on the sexine resulting from folding of the nexinous central body.

Exesipollenites tumulus is without doubt a distinct pollen entity in its own right, and the suggestion of Venkatachala and Goczan (1964), that it probably represents an "operculate body" separated from Corollina, is without basis.

This species is common in all "Red Beds" samples observed, and is almost always represented by the nexinous central body.

Genus *CLASSOPOLLIS* (Pflug) Pocock & Jansonius

1950 Conifer Pollen, Reissinger; p. 114, pl. 14, Figs. 15 - 16.
1953 *Classopollis classoides* Pflug; p. 91, pl. 16, Figs. 29 - 31, type species.
1961 *Classopollis classoides* (Pflug) P. & J.; p. 443, pl. 1, Figs. 1 - 9.

DIAGNOSIS:

Complex pollen grains; distally monoporate or leptomate; spherical to ovoid in shape and circular, oval, or subtriangular in equatorial outline. Exine two-layered; nexine forming a continuous layer of variable thickness beneath sexine. Nexine essentially sculptureless, sometimes bearing a vestigial trilete tetrad mark at proximal pole, and is usually thinned at distal pole. Sexine tightly or loosely appressed to nexine, and may be infrapunctate or infragranualte to infrabaculate. At the equator, the inwardly directed rods or baculae of the sexine are usually well developed, and are laterally fused in an orderly manner to produce a pronounced equatorial band of striae on the internal surface of the sexine. Sexine is usually thickened at the equatorial striated band, and is reduced or absent at the distal pole to form a pore. A triangular opening is present in the sexine at the proxinal pole opposite the nexinal tetrad mark. Just distal and parallel to the equatorial striated band, the sexine is attenuated or absent to form a narrow ring tenuitas. The surface of the exine is smooth to psilate or faintly granulate.

DISCUSSION:

Pollen of the genus Classopollis are among the most structurally and morphollogically complex pollen known, and they undoubtally outrank all gymnospermous pollen, living or fossil, in complexity. Considering the various manifestations these pollen can assume, due to states of preservation, orientation, and maturity, it is not surprising that the original diagnosis of the genus by Pflug (1953), was grossly inaccourate. It wasn't until the more astute observations of Harris (1957), Couper (1958), Klaus (1960), Pocock & Jansonius (1961), and Chaloner (1962), that the details of the structure of Classopollis were elucidated. More recently, the electron microscopic examinations of ultra-thin sections by Pettitt and Chaloner (1964), have enabled a far more accurate interpretation of the wall structure of Classopollis grains found in the pollen sacs of Cheirolepidium muensteri (Schenk) Takhtajan.

Although the pollen of Classopollis have been found closely associated with, and may have been produced by, the closely related conifer genera Brachyphyllum, Pagiophyllum, and Cheirolepis, they have only been observed within the male cones of the latter (Cheirolepidium muensteri), (see Pettitt & Chaloner, 1964, for further discussion).

There is considerable difference of opinion concerning the taxonomic treatment of this elaborate pollen. Couper

(1958), and Chaloner (1962), favor the recognition of only one species, while Balme (1957) recognized two species, and Pocock & Jansonius (1961) recognized four species.

In this study, four species have been recognized, only one of which has been ascribed to existing species. Principal morphologic criteria employed include size, shape, exine sculpture, size of distal pore, and degree of separation of sexine and nexine.

Classopollis is the most abundant form in all the Michigan "Red-Beds" samples studied, and the many hundreds of specimens observed have enabled specific determinations to be founded on multiple observations.

Classopollis classoides Pflug

Plate 7; figs. 2 - 12, 14, 15

1953 *Classopollis classoides* Pflug; p. 91, pl. 16, figs. 29 - 31

DESCRIPTION:

Originally spherical or ovoid pollen grains usually slightly shorter along the polar axis than along equatorial axis; grains circular to subcircular in equatorial outline. Distal pore or leptoma circular, 5 to 11 micra in diameter. Exine two-layered; nexine laevigate, about 1.0 micron thick, more or less uniform in thickness, and apparently forms a continuous nexinous body beneath sexine, except at proximal pole where a vestigial trilete mark may occur, and at the position of the distal pore where it may be thinned or absent. Sexine variable in thickness, ranging from 0.5 to 2.5 micra thick; the sexine of proximal hemisphere is separated from the sexine of the distal hemisphere by a narrow (1 - 2 micra wide) band of sexinal thinning forming a ring tenuitas parallel to and just distal to the equator. A thin band of sexinal thickening is often observed flanking the distal border of the ring tenuitas. A narrow belt of sexine, 5 to 8 micra wide, surrounds the distal pore. At the proximal polar region, a triangular area of sexine reduction or absence is a common feature. The surface of exine is smooth and without visible ornament; sexine between the equatorial band and the polar regions bears an infrapunctate to infragranulate sculpture which is sometimes so weakly developed as to be scarcely perceptible. Approaching the equatorial region from a poleward direction, the infrasexinal ornament grades into weakly developed, radially directed "rods" or infrabaculae, which fuse laterally at an equatorial zone of sexinal thickening to produce an internal band of annular striae. Up to 9 striae may comprise this equatorial band. The color is usually pale yellow.

Dimensions: Equatorial diameter 16 (29) 34 micra

DISCUSSION:

The specimens described and illustrated here, which conform reasonably well with the emended concept of C. classoides by Pocock and Jansonius, occur in abundance in all Michigan "Red Beds" samples.

Classopollis *sp.* "*A*"

Plate 6; figs. 5 - 18. Plate 7; fig. 1

DESCRIPTION:

Pollen grains originally subspherical to ovoid in shape, frequently subtriangular in equatorial outline. Subtriangular aspect of equatorial outline apparently the result of regularly spaced exinal thickening at equatorial region. Distal pore or leptoma circular, 7 to 17 micra in diameter. Exine two-layered; nexine laevigate, closely appressed to sexine, of indeterminate thickness and apparently forms a continuous layer beneath sexine, except at proxinal pole where a vestigial trilete tetrad mark may occur. Nexine may be thinned or absent at the position of the distal pore. Sexine ranges in thickness up to about 4 micra; distal and proximal sexine separated by well developed ring tenuitas disposed on the distal side of the equator. A conspicuous band of sexinal thickening flanks the distal border of the ring tenuitas. Both proximal and distal sexine display a well developed infrapunctation or infragranulation and the infrabaculate sculpture at the equatorial region is a particularly salient feature. On some specimens these inwardly directed sexinal rods are about 2 micra in length. The precise nature of the equatorial internally striated band is obscure, because no tetrads of this species have been observed, and the dispersed grains invariably occur in proximodistal orientation. The outline of the triangular opening in the sexine at the proximal pole may be straight sided or strongly concave. The color is usually a dark amber.

Dimensions: Equatorial diameter 30 (38) 50 micra

DISCUSSION:

The relatively large overall equatorial diameter and the diameter of the distal pore, the subtriangular amb, and the well developed infra-sexinal ornamentation, serve to distinguish this species from others encountered in the Michigan "Red Beds". It is present in all samples, but is always uncommon.

Classopollis sp. "B"

Plate 7; figs. 13, 16 - 21

DESCRIPTION:

Originally spherical or ovoid pollen grains. Usually slightly shorter along the polar axis; grains circular to subcircular in equatorial outline. Distal pore or leptoma 5 to 9 micra in diameter. Exine two-layered; nexine laevigate, thin, closely appressed to sexine and forms a more or less continuous layer beneath sexine, except at the proximal pole where a vestigial trilete tetrad mark may occur, or at the distal pole where it may be thinned or absent. Sexine of variable thickness and may be as much as 2 micra thick at equatorial region. Infrasexinal sculpture consists of a conspicuous infrapunctation or infragranulation, on both distal and proximal hemispheres, which becomes strongly infrabaculate at the equatorial region. The infrabaculae fuse at the equatorial region to produce as many as ten annular internal striae. The ring tenuitas, located just distal to the equator is often weakly developed, as is the band of sexinal thickening flanking its distal border. Proximal pole marked by a straight sided or concave triangular opening in the sexine. Color is usually a pale yellow.

Dimensions: Equatorial diameter 24 (26) 27 micra

DISCUSSION:

The relatively small equatorial diameter, the strong infrasexinal ornamentation on both hemispheres, and the conspicuously developed, radially disposed infra-baculae near the equatorial region are the distinguishing features of this species. It is present in all "Red Beds" samples, and is common in most.

Classopollis sp. "C"

Plate 8; figs. 1 - 8

DESCRIPTION:

Originally spherical to ovoid pollen grains; subcircular to oval in equatorial outline. Exine two-layered; nexine thick, of indeterminate thickness, always opaque or nearly so, and forms a distinct smooth nexinal central body beneath the very loosely appressed sexine. At the distal pole the nexine is reduced or absent over a circular area 3 to 8 micra in diameter which apparently corresponds to the distal pore of the sexine. The loosely appressed sexine is often transparent, thin, usually less than 2 micra thick at the equatorial region, and may possess a triangular opening at the proximal polar region. Infrasexinal ornamentation is reduced to almost absent, and the ring tenuitas and the equatorial internally striated band is likewise weakly developed. Up to six equatorial striae have been observed. The thin sexine is externally smooth and often folded and wrinkled.

Dimensions: Diameter of nexinal body 14 (18) 25 micra
Total equatorial diameter 22 (27) 34 micra

DISCUSSION:

The thin, loosely appressed sexine is the readily distinguishable feature of this species. It is similar to, but differs from, *C. pflugii* Pocock & Jansonius in having a thick, opaque nexinal central body. This species is present in most Michigan "Red Beds" samples, and is common in many.

Genus *ZONALAPOLLENITES* Pflug (in Thomson & Pflug)

1931 *Sporonites igniculus* Potonie; p. 556, fig. 2.
1934 *Tsuagae-pollenites igniculus* Pot. & Ven.; p. 17, pl. 1.
1938 *Tsuga-pollenites* Raatz; p. 15.
1953 *Zonalapollenites igniculus* Potonié ex Pflug (in Thomson & Pflug); p. 66.
1958 *Tsugaepollenites* Pot. & Ven. ex Potonie; p. 48.
1958 *Cerebropollenites* Nilsson; p. 72.
1961 *Callialasporites* Dev; p. 48.
1962 *Pflugipollenites* Pocock; p. 72.

DIAGNOSIS:

Monosaccate, radially symmetrical pollen grains; inaperturate or possibly distally leptomate. Proximal surface may or may not be marked by a triradiate tetrad mark. When present, the three radial ridges may be distinct or only faintly represented. Exine two-layered, more or less closely appressed about the polar region, separating at equatorial region to form a monosaccate condition comprised of either a simple, radially folded or crenulate saccus, or of numerous highly convolute vesiculae. Saccus usually distally pendant. Exine psilate, punctate, granulate, or convolute, usually considerably thinned over the distal polar area.

Type species: Zonalapollenites igniculus Potonie ex Pflug
(in Thomson & Pflug).

DISCUSSION:

Confusion regarding the validity of Zonalapollenites and Tsugaepollenites has recently been cleared up by Pocock (1968).In the "Red'Beds" assemblage, the strongly convolute aspect of some grains appear gradational with less convolute forms. On this basis, it is felt desirable to place Cerebropollenites in synonymy with Zonalapollenites. These fossil pollen grains possess many of the morphological attributes of those of modern Tsuga, including the distally pendant saccus and the assumed leptomate germinal mechanism produced by exinal thinning at the distal pole.

A proximal triradiate tetrad mark has even been observed on modern *Tsuga* pollen.

Zonalapollenites trilobatus Balme

Plate 14; figs. 5 - 11

1957 *Zonalapollenites trilobatus* Balme; p. 33, pl. 8, fig. 91, 92.
1961 *Callialasporites trilobatus* (Balme) Dev; p. 48, pl. 4, fig. 28, 29.
1961 *Triangulopsis trilobatus* (Balme) Döring; p. 114, pl. 17, fig. 4 - 8.
1962 *Pflugipollenites trilobatus* (Balme) Pocock; p. 73, pl. 12, fig. 186, 187.
1963 *Tsugaepollenites trilobatus* (Balme) Dettmann; p. 100, pl. 24, fig. 6 - 10.

DESCRIPTION:

Monosaccate pollen, encircling saccus produced by equatorial separation of sexine and nexine. A trilete tetrad mark may be present on proximal face, with laesurae extending almost to outer margin of saccus. A commissure is faintly represented between narrow, slightly raised, sexinal lips. Equatorial outline of saccus circular, subcircular, or subtriangular. Sexine thin, about 1.0 micron thick, scabrate to faintly granulate, completely enclosing a thicker (about 1.5 micra thick), biconvex or distally concave, nexinous central body which is convexly subtriangular in equatorial outline. Saccus extends from 5 to 16 micra beyond the equatorial margin of nexine, may or may not be radially folded, and saccus constrictions at the apical regions aften impart a trilobate outline to the grains.

Dimensions:	Diameter of central body	36	(43)	49	micra
	Total diameter	43	(57)	66	micra

DISCUSSION:

When present, the triradiate laesurae on specimens observed from the "Red Beds" clearly extends onto the saccus beyond the equatorial margin of the nexinous central body, and I believe that the tetrad mark involves only the sexine. Several isolated central bodies have been observed, all of which lack any trace of a proximal tetrad mark.

All specimens observed in this study, and most previously published illustrations, exhibit orderly folding of the central body, the folds occurring at the interapical regions and joining at the apices of the central body. This folding accounts for the subtriangular outline of the central body, and is probably related to and controls the apical constrictions of the saccus which results in the tri-lobate outline of the saccus.

This species is never abundant but is present in most "Red Beds" preparations.

Zonalapollenites dampieri Balme

Plate 12; figs. 3 - 12 Plate 13; figs. 1, 4, 6 - 8
Plate 14; fig. 4

1957 *Zonalapollenites dampieri* Balme; p. 32, pl. 8, fig. 88 - 90.
1961 *Callialasporites dampieri* (Balme) Dev; p. 48, pl. 4, fig. 26, 27.
1961 *Applanopsis dampieri* (Balme) Döring; p. 113, pl. 16, fig. 11 - 15.
1962 *Pflugipollenites dampieri* (Balme) Pocock; p. 72, pl. 12, fig. 183, 184.
1963 *Tsugaepollenites dampieri* (Balme) Dettmann; p. 100, pl. 24 fig. 1 - 5.

DESCRIPTION:

Monosaccate pollen equatorial outline of saccus and central body circular to rounded sub-triangular; saccus outline sometimes undulate or crenulate due to radial folding. Exine two-layered; nexine thin, 0.5 to 1.5 micra thick, psilate to scabrate, forming a central body completely enclosed by the enveloping sexine; sexine 1.0 to 2.0 micra thick, tightly appressed to nexine at both distal and proximal polar regions; sexine and nexine separated at equatorial region to produce a narrow, slightly inflated, frequently distally pendant saccus 3.0 to 11.0 micra wide. A circular to subcircular area of thinned sexine, and possibly nexine, forms a leptoma 13 to 35 micra in diameter at the distal pole. The proximal surface may or may not bear a trilete tetrad mark. Commissures rarely developed; laesurae, when present, are in the form of raised sexinal ridges about 2.0 micra wide which may extend full radius of nexinal central body. Sexine may be granulate, scabrate, or punctate, and weak convolutions may sometimes be developed on the proximal surface, especially near the periphery. In addition, convolutions may also be present on the distal surface flanking the leptoma.

Dimensions:	Diameter of central body	27	(42)	58	micra
	Total diameter	30	(51)	65	micra

DISCUSSION:

The overall size, width and intensity of crenulate folding of the equatorial saccus, and the thickness of sexine are extremely variable among specimens described above, and the gradational nature of these morphological criteria among the "Red Beds" specimens appear to contradict a distinction between *T. dampieri* (Balme) Dettmann and *T. segmentatus* (Balme) Dettmann. The forms here assigned to *T. dampieri* are present throughout the "Red-Beds" samples examined, but are never abundant.

ZONALAPOLLENITES sp. "A"

Plate 11; Figs. 10 - 12, Plate 12; Figs. 1, 2,
Plate 13; Figs. 3, 5.

DESCRIPTION:

Monosaccate pollen; equatorial outline of saccus and central body circular to broadly subtriangular. Exine two-layered; nexine thin, 1.0 to 1.5 micra thick, psilate to scabrate; sexine 1.0 to 2.0 micra thick, completely envelops nexinal central body, and is closely appressed to nexine at proximal and distal polar regions, becoming separated equatorially to produce a narrow (2 to 7 micra wide), weakly inflated, distally pendant saccus whose outline is often highly undulate or crenulate due to intense convolution and radial folding of the saccus sexine. Proximal surface of sexine often profusely convolute, rugulate, or verrucate. These sculptural features are usually, but not always, more intensely developed around the periphery of the pollen grain. A circular to subcircular leptoma, 9 to 26 micra in diameter, comprised of unornamented, thinned exine, is centered at the distal pole. Leptoma is frequently surrounded by highly convolute sexine. Trilete tetrad mark, usually lacking apparent commissures, may or may not exist on proximal surface. When present, laesurae are present at raised sexinal ridges about 2.0 micra wide which may extend to equatorial margin of central body.

Dimensions:	Diameter of central body	33	(40)	49	micra
	Total diameter	38	(48)	57	micra

DISCUSSION:

The frequently intense rugulate to verrucate sexinal convolutions, present on the proximal surface, and also the distal surface where they surround and clearly define a generally smaller leptoma, serve to distinguish this species from Z. dampieri Balme. This species is present in most "Red Beds" samples but is never abundant.

Zonalapollenites *sp.* "*B*"

Plate 13; Figs. 9 - 16

DESCRIPTION:

Monosaccate pollen, relatively small; amb circular to subcircular; outline at equator smooth to slightly crenulate. Exine two-layered; nexine thin, 0.5 to 1.0 micron thick, completely envelops nexinal central body, and is tightly appressed over the entire area of the nexine except equatorially where it is only slightly separated to produce a somewhat rudimentary saccus 1.0 to 4.0 micra wide. Saccus has little or no distal inclination. The exact width of saccus, which is usually about 2.0 micra or less, is often obscured by the dense, faintly inflated, and convolute aspect of the sexine at the equatorial region, but a circular to subcircular area of thinned exine 5 to 23 micra in diameter delineates a leptoma centered at the distal pole. Sexine delicately convolute to regulate over entire surface except at leptomate area where ornamentation is greatly reduced or lacking. The convolute to rugulate ornament is also frequently reduced over the proximal polar area, and in general tends to be more developed on the proximal and distal equatorial regions. Proximal tetrad mark rarely detectable; but when present, is comprised of raised, thickened, more or less crenulate sexinal ridges up to 3.0 micra wide which may extend almost to equatorial margin of the pollen grain. Commissures have not been observed in this species.

Dimensions: Diameter of central body 26 (31) 37 micra
Total diameter 28 (34) 40 micra

DISCUSSION:

The relatively small size and the slight equatorial separation of sexine to produce a very narrow and sometimes scarcely discernible saccus are the distinguishing features of this species. It is present in most "Red Beds" samples, but is never abundant.

Zonalapollenites mesozoicus (Couper) n. comb.
Plate 10; Figs. 11 - 18, Plate 11; Figs. 1 - 7

1954 *Pollenites macroserratus* Thierg.; in Rogalska; p. 20, pl. 9, figs. 5, 6.

1958 *Tsugaepollenites mesozoicus* Couper; p. 155, pl. 30, fig. 8, holotype.

1958 *Cerebropollenites mesozoicus* (Couper) Nilsson; p. 72, pl. 6, figs. 10, 12.

DESCRIPTION:

Monosaccate pollen grains; equatorial outline circular to subcircular, grains probably originally spherical to subspherical. Exine two-layered; nexine about 1.0 micron thick, smooth, without apparent ornamentation, forming an obscure central body completely enveloped by dense, highly convolute sexine; degree of sexinal inflation, and compactness and intensity of convolutions, highly variable; sexine punctate, generally more inflated equatorially to produce an irregular saccus comprised of numerous, densely spaced, vesiculate convolutions, which extend distal to the equator. Convolutions tend to be reduced in size and more loosely spaced on the proximal surface, and generally absent over a leptomate area centered at the distal pole. Circular to subcircular leptoma 12 to 33 micra in diameter, marked by thinned, comparatively smooth exine, and is surrounded by a zone of convolute sexine. Weakly developed proximal tetrad marks are extremely rare. Ornamentation ranges from compactly spaced convolutions having a circular to subcircular outline, to loosely spaced convolutions that are narrow, elongate, and irregularly sinuous. These extremes in sculptural elements are completely gradational in aspect, and correlate with overall size variations, the pollen grains with the compact, circular convolutions tending to be associated with smaller grains.

Dimensions: Total diamter 37 (46) 59 micra

DISCUSSION:

Corresponding to a gradual increase in diameter is a reduction in intensity and density of sexine convolutions, expecially on the proximal surface, a progression from convolutions having more or less circular outlines to those having narrow, elongate outlines, an enlargement of the distal leptomate area, and a greater separation of the equatorial sexine to produce a more clearly defined, continuous, though highly folded and crenulate, saccus than present on the typical Z. mesozoicus morphology. The above outlined trends are successively illustrated on Pl. 10, figs. 11 - 18, and Pl. 11, figs. 1 - 9. The extreme development of these trends results in a form similar to *Z. dampieri* and related forms. Such a transition is suggested by the specimens illustrated in Pl. 11, figs. 8, 9. *Z. mesozoicus* is present in most "Red Beds" samples, but is usually rare.

Zonalapollenites sp. "*C*"

Plate 10; Figs. 1 - 10

DESCRIPTION:

Monosaccate pollen grains, relatively small; amb circular to subcircular or subtriangular, grains probably originally spherical to subspherical. Exine two-layered; thin, psilate nexine about 1.0 micron thick or less, forming a smooth central body enclosed completely by sexine which is closely appressed to, or only locally separated from, the nexine on the proximal and distal surfaces. Sexine is slightly more inflated at the equatorial region where sometimes compactly spaced, small vesiculate convolutions may form a saccus. Density of convolutions on proximal surface variable. Convolutions usually extend distal to the equator and surround a smooth, more or less unornamented, circular to subcircular leptoma which ranges from 6 th 22 micra in diameter. Sexine ornamentation gradational from densely spaced, circular to subcircular convolutions, to loosely spaced, narrow and elongate sinuous convolutions. Raised trilete laesurae are rarely present on the proximal sexine.

Dimensions: Total diameter 27 (31) 36 micra

DISCUSSION:

This species is structurally indistinguishable from *T. mesozoicus*. It even exhibits the same morphological trends cited above *T. mesozoicus*, with the exception that the trends do not appear to correspond to a size gradient. A strongly bimodal size distribution pattern exists between this species and *Z. mesozoicus*, and is thus the primary criterion for recognizing the two species. The species is present in many "Red Beds" samples but is invariably relatively rare.

Genus *VITREISPORITES* (Leschik) Jansonius

1950 *Pityopollenites* Reissinger.

1955 *Vitreisporites signatus* Leschik; p. 53, pl. 8, fig. 10, type species.

1958 *Caytonipollenites* Couper; p. 149.

1962 *Vitreisporites* (Leschik) Jansonius; p. 55.

DIAGNOSIS:

Bisaccate pollen grains, small, equatorial outline oval. Exine two-layered. Distal surface of oval to subcircular central body bears wide sulcus or leptoma flanked by nexinal lips. Proximal cappa infrapunctate; marginal crests may or may not be present. Sacci large relative to central body, generally semi-circular, inflated, equatorially attached, finely infrareticulate, only slightly distally pendant.

DISCUSSION:

The genus Caytonipollenites was erected by Couper (1958) to encompass pollen grains of the type found in male fructifications of the Mesozoic pteridosperm Caytonanthus. It is a junior synonym of Vitreisporites. Although morphologically distinguishable from the pollen of the Abietineae and Podocarpaceae, it possibly may have been produced by pteridosperms other than the Caytoniales.

Vitreisporites pallidus (Reiss.) Nilsson

Plate 15; Figs. 1, 2

1938 Pityosporites pallidus Reiss; p. 14
1950 Pityopollenites pallidus Reiss.; p. 115, figs. 1 - 5.
1955 Pollen of Masculostrobus E. Carp. in Delc. & Sprum.; p. 51, fig. 6.
1958 Caytonipollenites pallidus (Reiss.) Couper; pp. 149-150, pl. 26, figs. 7, 8.
1958 Vitreisporites pallidus (Reiss.) Nilsson; pp. 77-78.

DESCRIPTION:

Bisaccate pollen; equatorial outline oval. Central body oval to subcircular, slightly longer than it is wide; nexine of central body very thin; sexine of proximal cap thin and finely infrapunctate. Central body marked by a parallel-sided or laterally concave sulcoid leptoma, 3.0 - 7.0 micra wide, extending entire length of central body. Sacci semi-circular in polar view, attaining a maximum length equal to length of central body, slightly distally pendant, distal saccous bases laterally bound the sulcoid leptoma. Sacci finely infrareticulate, reticulum exhibiting tendency toward radial linearity; sacci merge proximally with sexine of cappa.

Dimensions:					
	Total width	24	(28)	35	micra
	Length central body	14	(17)	20	micra
	Width central body	10	(12)	13	micra
	Length saccus	14	(17)	21	micra
	Width saccus	10	(13)	15	micra

DISCUSSION:

This comparatively small, probably pteridospermous pollen occurs rarely in the Michigan "Red Beds".

Genus ALISPORITES Daugherty, 1941;
restr. Potonié & Kremp, 1956

1941 *Alisporites opii* Daugherty; p. 98, pl. 34, fig. 2, (type species).

1956 *Alisporites opii* Daugherty; restr. Pot. & Kremp, p. 176 - 177, fig. 82.

1959 *Alisporites* Daugherty, emend. Rouse; p. 314, pl. 1, figs. 10 - 16.

DIAGNOSIS:

Bisaccate pollen grains; equatorial outline, including sacci, more or less oval. Central body usually not clearly defined; length of central body equal to that of sacci. Sacci thin, infrareticulate, only slightly distally pendant, occasionally equatorially connected. Distal face marked by narrow sulcus or leptoma which is flanked by parallel-sided distal saccus bases. Proximal saccus bases merge with relatively thin sexine of cappa.

DISCUSSION:

The more definitive generic diagnosis of Potonié and Kremp, 1956, is here favored over the emendation of Rouse, 1959. Pollen of the genus *Alisporites* may have taxonomic affiliations with the family Pinaceae.

Alisporites sp. "*A*"

Plate 15; figs. 5 - 7

DESCRIPTION:

Bisaccate pollen grains; broadly oval in equatorial outline; ends of sacci somewhat blunt; central body oval to subcircular, its length being longer than its width. Nexine very thin, of indeterminate thickness, psilate; sexine of cappa thin, less than 1.0 micron thick, finely infrapunctate; a faint marginal crest may sometimes be developed only at the proximal saccus bases. A wide, more or less oval-shaped sulcoid leptoma occupies most of distal surface of central body; exine of leptoma very thin, hyaline, psilate; leptoma bordered laterally by thin, indistinct distal saccus bases. Sacci slightly distally pendant, length equal to or only slightly less than that of central body, moderately inflated, somewhat flattened distalo-proximally, infrareticulate, with lumina up to 3.0 micra in diameter. Proximal saccus bases attached approximately at equatorial margin of cappa. Saccus bases not constricted at point of attachment to central body.

Dimensions:	Total width	50	(55)	61	micra
	Length central body	42	(46)	52	micra
	Width central body	27	(30)	34	micra

Length saccus	40	(44)	48	micra
Width saccus	17	(21)	24	micra

DISCUSSION:

This species occurs infrequently in the Michigan "Red Beds".

Alisporites sp. "B"

Plate 15; figs. 8, 9

DESCRIPTION:

Bisaccate pollen grains; broadly oval to subcircular in equatorial outline, ends of grains uniformly rounded. Central body oval to subcircular, only slightly longer than it is wide; outline of central body and cappa indistinct due to thin exine and lack of marginal crest development. Exine two-layered; nexine very thin, of indeterminate thickness, psilate; sexine of cappa less than 1.0 micron thick, finely infrapunctate. An oval-shaped sulcus, having a maximum width up to 15 micra at distal polar area, traverses almost entire length of central body. Sulcus flanked by thin, concave distal saccus bases. Strongly crescentic sacci equal to length of central body; proximal saccus bases attached approximately at equatorial region of cappa; sexine of sacci merges with sexine of cappa without constriction of saccus bases, thus imparting the uniformly oval equatorial contour of the entire grain. Sacci relatively narrow, proximal saccus bases more strongly concave than distal saccus bases. Sacci infrareticulate, only slightly distally pendant. Sacci nearly but not quite continuously united at equatorial margin.

Dimensions:	Total width	41	(49)	56	micra
	Length central body	45	(47)	51	micra
	Width central body	30	(36)	39	micra
	Length saccus	44	(46)	48	micra
	Width saccus	17	(19)	22	micra

DISCUSSION:

The rounded equatorial outline and crescent shape of the sacci distinguishes this very rare species from *Alisporites* *sp*. "*A*".

Alisporites *sp*. "*C*"

Plate 16; figs. 1 - 3

DESCRIPTION:

Bisaccate pollen grains; elongate oval in equatorial outline, ends of sacci uniformly rounded to bluntly pointed. Central body oval in equatorial outline, width greater than length. Exine two-layered; nexine of central body thin, of indeterminate thickness, psilate; sexine of cappa infrapunctate, less than 1.0 micron thick, and of uniform thickness except for apparent marginal thickenings occurring between the cappa and the proximal saccus bases. Distal sulcus traverses more or less entire length of central body, up to 17 micra wide at distal polar area, tapers toward longitudinal extremities, flanked by thin, straight to slightly concave, distal saccus bases. Sacci semicircular to crescentic in equatorial outline, moderately inflated, slightly distally pendant; proximal saccus bases attached at or just proximal to the equatorial margin.

Sacci equal to or slightly longer than length of central body; sacci almost but not quite continuous around equatorial margin of central body, and cover most of the distal surface of grain except for the area occupied by distal sulcus. Sacci infrareticulate, reticulum up to 2.0 micra in diameter. Saccus bases not constricted at area of attachment with sexine of central body.

Dimensions:	Total width	56	(63)	69	micra
	Length central body	32	(37)	40	micra
	Width central body	37	(42)	48	micra
	Length saccus	36	(40)	44	micra
	Width saccus	23	(25)	26	micra

DISCUSSION:

This species, which may belong in the genus Podocarpidites, occurs rarely in the Michigan "Red Beds", having been observed only a few times.

Genus PITYOSPORITES (Seward, 1914) emend. Manum, 1960

1914 Pityosporites antarcticus Seward; p. 23, pl. 8, fig. 45, type species.

1954 Pityopsorites (Seward) Potonié & Klaus; p. 534.

1958 Pinuspollenites Raatz ex Potonié; p. 62.

1960 Pityosporites (Seward) Manum; pp. 11 - 15, pl. 1, figs. 1 - 4.

DIAGNOSIS:

Bisaccate pollen grains; exine two-layered; sacci inflated, infrareticulate, distally pendant, constricted at their bases of attachment and set off from central body.

Sacci extend onto distal surface and distal saccus bases are separated by a narrow sulcus or leptoma; proximal saccus bases attached equatorially or may extend proximally onto cappa where they merge with sexine of cappa. Nexine thin and smooth; sexine of cappa may be infrapunctate; surface of cappa usually smooth or only finely sculptured. Exine of cappa of moderate thickness and without conspicuous thickening toward roots of sacci.

DISCUSSION:

Unlike that of Potonié and Klaus (1954), the emended diagnosis of the genus Pityosporites by Manum (1960) was founded on a re-examination of Seward's holotype. Manum found that the generic diagnosis of Potonié and Klaus excluded the type species. His restricted diagnosis eliminates some of the confusion pertaining to the taxonomic treatment of fossil bisaccate pollen, especially those of the Paleozoic and Mesozoic. Pollen included in the genus are morphologically similar to those of the Pinaceae, but the relation is equivocal, and some species may even be of pteridospermous affinity.

Pityosporites sp. "A"

Plate 15; figs. 10 - 14

DESCRIPTION:

Bisaccate pollen; outline broadly oval; central body oval to subcircular in equatorial outline, slightly longer than it is wide. Psilate nexine less than 0.5 micron thick; sexine of cappa thin, finely micro-convolute to micro-rugulate;

weakly developed marginal crests present at lateral extremities of cappa. A sulcoid leptoma, comprised of thinned distal exine, is flanked by thin, slightly concave, distal saccus bases; sulcoid leptoma traverses almost entire length of central body, is more or less oval in outline, averaging 17 micra at its greatest width at the distal polar region. Sacci somewhat inflated, distally pendant, crescentic to almost semicircular in polar outline; enveloping the central body distalo-equatorially; proximal saccus bases join central body slightly distal to the equator, merging with sexine of cappa. Saccus bases very slightly constricted at area of attachment to central body. Saccus length equal to or only slightly less than length of central body.

Dimensions:	Total width	38	(44)	52	micra
	Length central body	34	(37)	48	micra
	Width central body	31	(35)	43	micra
	Length individual saccus	32	(36)	46	micra
	Width individual saccus	15	(17)	23	micra

DISCUSSION:

This distinct pollen is always rare in the Michigan "Red Beds", but has been observed in a number of samples.

Genus *PODOCARPIDITES* Cookson & Potonié, 1958

1947 *Podocarpidites ellipticus* Cookson; p. 131, pl. 13, fig. 9; type species.

1958 *Podocarpidites ellipticus* Cookson; in Potonié; p. 68; designation of type species.

DIAGNOSIS:

Bisaccate pollen grains; distinct central body circular to oval in equatorial outline. Sacci inflated, distally pendant, extend onto distal surface where they flank a broad sulcoid leptoma; sacci infrareticulate; reticulum sometimes exhibiting a radial alignment. Sacci usually but not always longer than central body. Cappa relatively thick, may be infrapunctate, and surface may be roughened, granulose, rugulate, or convolute; cappa frequently with thickened sexinal marginal crest which may completely surround cappa or may be restricted to the area between the cappa and the proximal saccus bases.

DISCUSSION:

The above diagnosis is intended to encompass fossil pollen similar to those of the modern family Podocarpaceae. The form-genus *Podocarpidites* does not however include pollen of podocarpaceous affinity having more than two sacci, as proposed by the unacceptable emendation of Couper, (1953).

Podocarpidites sp. "A"

Plate 16; fig. 4

DESCRIPTION:

Bisaccate pollen; central body oval to subcircular in equatorial outline, slightly longer than wide. Nexine thin, about 0.5 micron; sexine of cappa thin and finely infrapunctate. Marginal crests narrow, much more pronounced at lateral margins of cappa. Exine of distal face of central body psilate, considerably thinned over most of the distal surface to form a leptoma flanked by narrow (up to 4.0 micra wide), concave, crescentic lips, which also form distal saccus bases. Individual sacci well inflated, distally pendant, more or less semi-circular to crescentic in polar view, with length considerably longer than that of central body. Sacci infrareticulate, with lumina up to 2.0 micra in diameter; sacci joined by a narrow sexinal band about 2.0 micra wide around the longitudinal equatorial margin of cappa; proximally the sacci merge with sexine of cappa.

Dimensions:	Total width of pollen	66	micra
	Length central body	34	micra
	Width central body	30	micra
	Length sacci	41	micra
	Width sacci	26	micra

DISCUSSION:

The above interpretation is based on a single specimen observed from the Michigan "Red Beds".

Podocarpidites sp. "B"

Plate 16; figs. 8 - 11

DESCRIPTION:

Bisaccate pollen grains; broadly oval in outline; central body subcircular to subrectangular, frequently slightly wider than it is long. Nexine less than 0.5 micron thick, psilate; sexine of cappa finely convolute, convolutions becoming more intense toward equatorial margins of cappa. Along longitudinal equatorial margin of central body, the convolutions form a conspicuous, somewhat distally disposed, marginal frill about 3.0 - 4.0 micra wide. This highly convolute marginal frill joins with and connects the sacci around the margin of the cappa. Exine thinned and psilate almost over entire area of distal face of central body to form a leptoma flanked by parallel-sided, thickened lips which apparently are coincident with distal saccus bases. Leptoma oval to subrectangular in outline, averages 24 micra in length and 17 micra in width. Sacci more or less semicircular in polar outline, moderately inflated, slightly longer than or equal to length of central body, sexine of sacci tends to be radially folded and the infrareticulum is also somewhat radially aligned. Proximal bases of sacci attached at margin or just distal to margin of cappa; sexine of sacci merges with sexine of cappa.

Dimensions:	Total width	50	(55)	65	micra
	Length central body	26	(30)	39	micra
	Width central body	26	(28)	32	micra
	Length saccus	28	(32)	40	micra
	Width saccus	19	(21)	25	micra

DISCUSSION:

The comparatively wide central body with straight-sided longitudinal cappa margins bearing a frill-like marginal crest connecting the sacci, are the most diagnostic features of this rarely occurring species.

Genus PHYLLOCLADIDITES Cookson, 1947 ex Couper, 1953

1947 Disaccites (Phyllocladidites) mawsonii Cookson; p. 133, pl. 14, figs. 22 - 28.

1953 Dacrydiumites mawsonii (Cookson) Cookson; p. 38, pl. 9, fig. 135 (type species).

1953 Dacrydiumites mawsonii (Cookson) Cookson; p. 66, pl. 1, figs. 9 - 26.

1957 Dacrydium mawsonii (Cookson) Cookson; p. 53.

1960 Dacrydiumites mawsonii Cookson; Couper, p. 43, pl. 3, figs. 7, 8.

DIAGNOSIS:

Bisaccate pollen grains; equatorial outline of distinct central body circular to oval. Sacci generally small, sometimes only slightly inflated, with indistinct infrareticulation, strongly distally pendant and may be disposed entirely on distal surface. Distal saccus bases flank a well defined sulcus. Sexine of sacci commonly thick and rigid. Sexine of cappa usually thick, may be infrapunctate, granulate, rugulate, or convolute. Cappa frequently extends beyond equator onto distal surface.

DISCUSSION:

Fossil pollen belonging to the form-genus *Phyllocladidites* are probably of podocarpaceous affinity, and particularly resemble the pollen of *Dacrydium*. In denoting this probable taxonomic affinity with *Dacrydium*, Cookson (1953) changed the name to *Dacrydiumites*, and later (Cookson, 1957) referred these fossil pollen to the natural genus *Dacrydium*. In that *Phyllocladidites* is a valid form-genus, the erection of the genus *Dacrydiumites* by Cookson is unwarrented, and the use of natural plant taxa for *sporae dispersae* is unacceptable.

Phyllocladidites *sp.* "*A*"

Plate 18; figs. 1 - 5

DESCRIPTION:

Bisaccate pollen grains; central body and distinct, thickened cappa oval in equatorial outline; central body wider than it is long; sacci may or may not extend beyond the equatorial outline of central body in polar view. Exine two-layered; nexine thin, about 0.5 micron thick, psilate; sexine of cappa 1.0 to 1.5 micra thick, conspicuous ornamentation coarsely granulate to verrucate. At each lateral extremity of the cappa, a thickened, rounded, sexinal protrusion up to 4.0 micra long and 8.0 micra wide at the base, has been observed on some grains. These protuberances are formed at the equatorial margin of the cappa and are located just proximally to the proximal saccus bases. Sacci relatively small, more or less fully inflated, rounded, somewhat bulbous, and greatly constricted at their roots; maximum length of sacci sometimes slightly greater than length of central body. Both unthickened saccus bases attached on distal surface of central body; maximum length of saccus bases considerably less than length of central body. Infrareticulum of sacci indistinct; radial sexinal folds sometimes developed near distal saccus bases. A poorly delimited leptoma occupies the area of the distal surface between the thin, indistinct, distal saccus bases. Distal leptoma comprised of thin, psilate exine, averages about 7.0 micra wide at distal polar region.

Dimensions:	Total width	34	(39)	43	micra
	Length central body	28	(31)	34	micra
	Width central body	33	(37)	39	micra
	Length saccus (maximum)	23	(27)	31	micra
	Width saccus	13	(16)	18	micra

DISCUSSION:

The lack of well developed thickened saccus bases, and the presence of a thickened exinal protrusion at the equatorial lateral extremities of the cappa on some specimens, are the diagnostic features of this rarely occurring species.

Phyllocladidites sp. "B"

Plate 18; figs. 6, 7, 9, 10

DESCRIPTION:

Bisaccate pollen grains; central body oval in equatorial outline; width of central body greater than length; in polar view, sacci have an irregular outline, and usually extend beyond equatorial outline of central body at its lateral extremities. Exine two-layered; psilate nexine thin, about 0.5 micron thick; thick sexine of cappa up to 2.0 micra in thickness, surface verrucate to rugulate or convolute. Distinct cappa and its ornamentation barely extend onto the distal side of the equator, and surface ornamentation of cappa can be observed in optical section projecting at the equatorial margin of the cappa. Sacci distally pendant, moderately inflated, often collapsed, relatively wide and sharply rounded to somewhat pointed at their lateral extremities. Infrareticulum of sacci indistinct; sexine of sacci often radially folded; radial folds particularly noticable on distal surface of sacci. Length of sacci almost as great as that of central body; sacci little if at all constricted at their roots, and maximum length of sacci occurs at or near the distal saccus bases. Proximal saccus bases attached distal to the equator of cappa, and sometimes may be marked by sexinal thickenings. A well defined sulcus or sulcoid leptoma is flanked by thickened, parallel-sided sexinal lips which correspond to the distal saccus bases. Conspicuous distal saccus bases up to 4.0 micra wide at their center and generally taper toward their longitudinal extremities; length of distal saccus bases equal to or only slightly less than length of central body. Sulcus traverses more or less entire length of central body, uniform in width 5.0 to 8.0 micra wide, and terminates abruptly at its longitudinal extremities against the thickened equatorial margin of the cappa. The sulcus thus assumes a somewhat rectangular shape.

Dimensions:	Total width	41	(44)	49	micra
	Length central body	27	(29)	31	micra
	Width central body	33	(33)	35	micra
	Length-saccus	25	(27)	32	micra
	Width saccus	17	(22)	24	micra

DISCUSSION:

Distinguishing features of this rare species are the frequently collapsed, relatively wide sacci having an irregular outline and more or less pointed ends, as well as the pronounced thickened distal saccus bases which flank the rectangular shaped sulcus. The cappa ornamentation is variable but always comparatively coarse.

Phyllocladidites sp. "C"

Plate 18; figs. 11 - 14

Plate 20; figs. 9 - 12

DESCRIPTION:

Bisaccate pollen grains; central body oval in equatorial outline; width of distinct central body greater than length; in polar view, sacci do not extend far, if at all, beyond equatorial outline of lateral extremities of central body. Exine two-layered; nexine about 0.5 micron thick, psilate; sexine of cappa 0.5 to 1.0 micron thick, finely infrapunctate, surface of cappa granulate to finely verrucate or convolute. Sacci narrow, moderately inflated, strongly distally pendant, attached on distal side of central body; distal and proximal saccus bases not widely spaced, and the sacci tend to be somewhat flattened proximodistally. Sexine of sacci thick and dense, particularly at their lateral extremities, and with indistinct infrareticulum. Lateral extremities of sacci bluntly rounded; sacci sometimes bear radial folds near their roots, and the blunt, lateral terminations are often convolute. Length of sacci equal to or slightly less than length of central body. Proximal saccus bases attached distal to equator, and are little if at all thickened; distal saccus bases much thickened, extend almost full length of central body to form parallel-sided lips up to 3.0 micra thick flanking distal sulcus. Distal sulcus 7.0 to 10.0 micra wide, of more or less uniform width, extends almost full length of central body, and abuts at its longitudinal extremities against the thickened sexine at the equator of the cappa to give a rectangular outline to the sulcus.

Dimensions:	Total width	27	(32)	38	micra
	Length central body	22	(26)	29	micra
	Width central body	24	(29)	35	micra

Length saccus	23	(25)	28	micra
Width saccus	9	(12)	14	micra

DISCUSSION:

This species is similar to but differs from *Phyllocladidites* *sp*. "*B*" in possessing more narrow, flattened, strongly distally pendant sacci having blunt to broadly rounded ends, and a less pronounced ornamentation of the cappa. The species is always rare.

Phyllocladidites *sp*. "*D*"

Plate 19; figs. 1 - 3

DESCRIPTION:

Bisaccate pollen grains; central body elongate oval in equatorial outline, width greater than length; lateral extremities of central body sometimes somewhat sharply rounded. Exine two-layered; nexine of cappa thin, of indeterminate thickness; sexine of cappa relatively thin, less than 1.0 micron thick, infrapunctate, surface of cappa granulate to punctate. At lateral extremities of central body, cappa extends onto distal side of equator. Reduced sacci weakly inflated, collapsed, thin, narrow, with length slightly less than that of central body. Sacci strongly distally pendant, attached entirely on distal surface; proximal and distal saccus bases closely spaced; in polar view, sacci do not extend beyond equator of central body. Sexine of cappa faintly infrareticulate to infrapunctate, thickened and with convolute folding at lateral extremities of sacci. Distinct distal saccus bases thickened, up to 2.0 micra thick, extend almost entire length of central body, and flank a wide sulcus or leptoma 11 to 15 micra in width. Proximal saccus bases considerably less thickened than distal saccus bases.

Dimensions:					
	Total width	34	(36)	38	micra
	Length central body	26	(29)	32	micra
	Width central body	34	(36)	38	micra
	Length saccus	24	(26)	28	micra
	Width saccus	11	(13)	14	micra

DISCUSSION:

Only a few specimens of this rare species have been observed from the Michigan "Red Beds".

Phyllocladidites *sp.* "*E*"

Plate 19; figs. 6 - 11

DESCRIPTION:

Bisaccate pollen grains; central body oval to subcircular in equatorial outline; length of central body usually slightly greater than width; in polar view, sacci do not usually extend beyond equatorial outline of central body. Exine two-layered; thin nexine of indeterminate thickness; sexine of distinct cappa 1.0 to 1.5 micra thick, surface of cappa finely granulate, punctate to micro-convolute. A band of thickened sexine up to 3.0 micra wide is often present at the equatorial margin of cappa. Cappa extends onto the distal side of equator at its lateral extremities. Sacci thin, narrow, weakly inflated, frequently collapsed, attached entirely on distal surface of central body, strongly distally pendant, length of sacci usually less than, but sometimes equal to, length of central body. Outline of sacci rounded. Sacci thickened, dense, and often convolutely folded at their lateral extremities. Sacci finely infrareticulate to infrapunctate. Proximal and distal saccus bases moderately thickened, closely spaced, and both on distal surface of central body. Distal saccus bases more thickened than proximal saccus bases, extend approximately three-fourths length of central body, and form more or less parallel-sided lips about 2.0 micra wide flanking distal sulcus or leptoma which ranges from 7.0 to 11.0 micra in width. Sulcus extends almost full length of central body, may be slightly wider at longitudinal extremities.

Dimensions:	Total width	29	(34)	38	micra
	Length central body	30	(33)	35	micra
	Width central body	28	(30)	31	micra
	Length saccus	25	(28)	30	micra
	Width saccus	11	(15)	20	micra

DISCUSSION:

The almost circular equatorial outline of the central body having a length slightly greater than its width, and the rim-like marginal crest, are among the distinguishing features of this rarely occurring species.

Phyllocladidites sp. "F"

Plate 19; figs. 12, 13, 15 - 18

DESCRIPTION:

Bisaccate pollen grains; central body oval to subcircular in equatorial outline, usually slightly longer than wide. Exine two-layered; psilate nexine of indeterminate thickness; sexine of cappa up to 2.0 micra thick, somewhat inflated, surface of cappa rugulate to convolute. A marginal crest comprised of inflated, convolute sexine may be present. Sacci strongly distally pendant, thin, moderately inflated, length equal to or greater than length of central body, infrareticulum very fine and sometimes indistinct; sacci sometimes bear radially convolute folding near the distal saccus bases; terminal extremities of sacci rounded. Both distal and proximal saccus bases are on distal side of cappa. Proximal and distal saccus bases conspicuously thickened, more or less parallel to each other, and are comprised of rounded, sub-cylindrical bars of thickened, dense, opaque exine. The distal saccus bases are almost as long as maximum length of central body; proximal saccus bases are approximately half as long as distal saccus bases. Both saccus bases merge at their longitudinal extremities with a similar, sometimes incompletely oval band of thickened exine which encircles the cappa at the equatorial region. The saccus bases and the equatorial band are more or less in a single plane. The oval shape of the equatorial band may be disrupted at the lateral extremities of the central body where it is sometimes recessed and merges with the proximal saccus bases. The parallel-sided distal saccus bases are 2 to 3 micra thick, and flank an elongate oval sulcus, which extends almost the entire length of central body. Sulcus averages 29 micra in length, 9 micra in width, and is delimited laterally by the distal saccus bases and longitudinally by the equatorially thickened band of exine.

Dimensions:	Total width	31	(36)	42	micra
	Length central body	34	(37)	40	micra
	Width central body	27	(31)	34	micra
	Length saccus	34	(38)	41	micra
	Width saccus	14	(17)	18	micra

DISCUSSION:

The structure and configuration of the thickened saccus bases and the thickened exinal band at the equatorial region of the central body is the diagnostic aspect of this species. It occurs rarely in the Michigan "Red Beds". The above interpretation is based on five specimens.

Genus *AUMANCISPORITES* (Alpern) Jansonius

1958 *Aumancisporites* *striatus* Alpern, p. 84, pl. 2, fig. 53 (type species).

1962 *Aumancisporites* (Alpern) Jansonius, p. 76.

DIAGNOSIS:

Bilateral pollen grains; oval in equatorial outline; non-saccate or possessing rudimentary terminal sacci. Proximal surface longitudinally striate; ribs (taeniae) occasionally befurcating; equatorial rib usually continuous.

A transverse sulcus, bordered by thickened parallel-sided sexinal lips, traverses the distal pole.

DISCUSSION:

This genus bears a striking morphological similarity to the genus Vittatina, from which it differs in possessing a distal transverse sulcus flanked by thickened lips. Pocock, (1964), considers Aumancisporites to be related to the chlamydospermae, and discusses in detail its similarity to the pollen of Welwitschia.

Aumancisporites cretaceus (Pocock) Pocock

Plate 16; figs. 12, 13

1962 Vittatina cretacea Pocock; p. 70; pl. 12; figs. 181, 182.

1964 Aumancisporites cretaceus (Pocock) Pocock; p. 139 - 141; pl. 1, figs. 3 - 5.

DESCRIPTION:

Pollen grains lacking sacci or with two very rudimentary sacci disposed at the longitudinal extremities of the grain just distal to the equator. Pollen bilaterally symmetrical, oval in equatorial outline with broadly rounded to blunt ends, width greater than length. Exine two-layered; nexine transparent and hyaline, smooth, and thinner than sexine. Sexine variable in thickness, up to 2.0 micra thick on proximal surface. Proximal surface ribbed with approximately 7 to 10 longitudinal striae; individual ribs 2.0 to 5.0 micra wide, taper towards ends and occasionally branch; ribs separated by grooves about 0.5 micron wide.

An apparently continuous rib encircles the proximal face equatorially and merges with the thickened and slightly inflated sexine of the rudimentary sacci at the longitudinal extremities of the grain. Distal surface smooth, traversed by a transverse sulcus which passes through the distal polar area. Sulcus almost as long as length of grain, original width of sulcus indeterminate due to collapse and compression of the grain; sulcus flanked by two conspicuous, thickened sexinal lips, each about 2.0 to 3.0 micra wide. Sexine of proximal striae and of rudimentary sacci finely infrapunctate.

Dimensions: Total length approximately 31 micra
Total width approximately 40 micra

DISCUSSION:

Two specimens of this species were observed, one of which was in a poor state of preservation. The figured specimen is compressed, somewhat distorted, and the distal sulcus is collapsed, but the diagnostic thickened sexinal lips are distinguishable. The "Red Beds" specimen conforms to the description of Pocock (1964). Pollen of similar aspect are common in Permian and some Lower Mesozoic strata and, according to Pocock (1964), *Aumancisporites cretaceus* is widespread in western Canadian Lower Cretaceous sediments.

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PLATES

PLATE 1

(All figures X 1000)

Fig. 1	*Cyathidites sp.* "*A*". Pb 5312, sl. 1, coord. 37 - 126, diam. @ 28 micra.
Figs. 2, 3	*Trilete spore* "*I*" (cf. *Biretisporites*). Pb 3684, sl. 1, coord. 47.7 - 119.5, diam. 25 micra. Fig. 2 - Focus on equator. Fig. 3 - Focus on laesurae.
Fig. 4	*Trilete spore* "*H*". Pb 3684, sl. 1, coord. - 50 - 128.6, diam. 26 micra.
Fig. 5	*Trilete spore* "*E*". Pb 5330, sl. 8, coord. - 33.9 - 120.4, diam. @ 30 micra.
Figs. 6, 7	*Trilete spore* "*C*". Pb 5315, sl. 1, coord. - 43.8 - 116.8, diam. 25 micra. Fig. 6 - Focus on equator. Fig. 7 - Focus on commissures.
Fig. 8	*Todisporites sp.* "*A*". Pb 5330, sl. 4, coord. 35.2 - 118.7, diam. 37 micra.
Figs. 9, 10	*Trilete spore* "*G*". Pb 5319, sl. 6, coord. - 41.9 - 123.4, diam. 36 micra. Fig. 9 - Focus on equator. Fig. 10 - Focus on laesurae.
Fig. 11	*Trilete spore* "*M*". Pb 5319, sl. 6, coord. - 41 - 127.1, diam. 26 micra.
Figs. 12, 13	*Todisporites sp.* "*B*". Pb 5330, sl. 8, coord. 33.4 - 125.3, diam. 37 micra. Fig. 12 - Focus on equator. Fig. 13 - Focus on laesurae and exine ornament.
Figs. 14, 15	*Trilete spore* "*K*", Pb 5330, sl. 6, coord. 39.6 - 124.4 diam. 46 micra. Fig. 14 - Focus on laesurae and proximal surface showing fine infrapunctation. Fig. 15 - Focus on equator showing two-layered exine.
Figs. 16, 17	*Calamospora sp.* "*A*". Pb 5330, sl. 7, coord. - 40.7 - 127.6, diam. 47 micra. Fig. 16 - Focus on equator. Fig. 17 - Focus on commissures.
Fig. 18	Undetermined trilete spore. Pb 5330, sl. 8, coord. 34.2 - 114.1, diam. 40 micra.

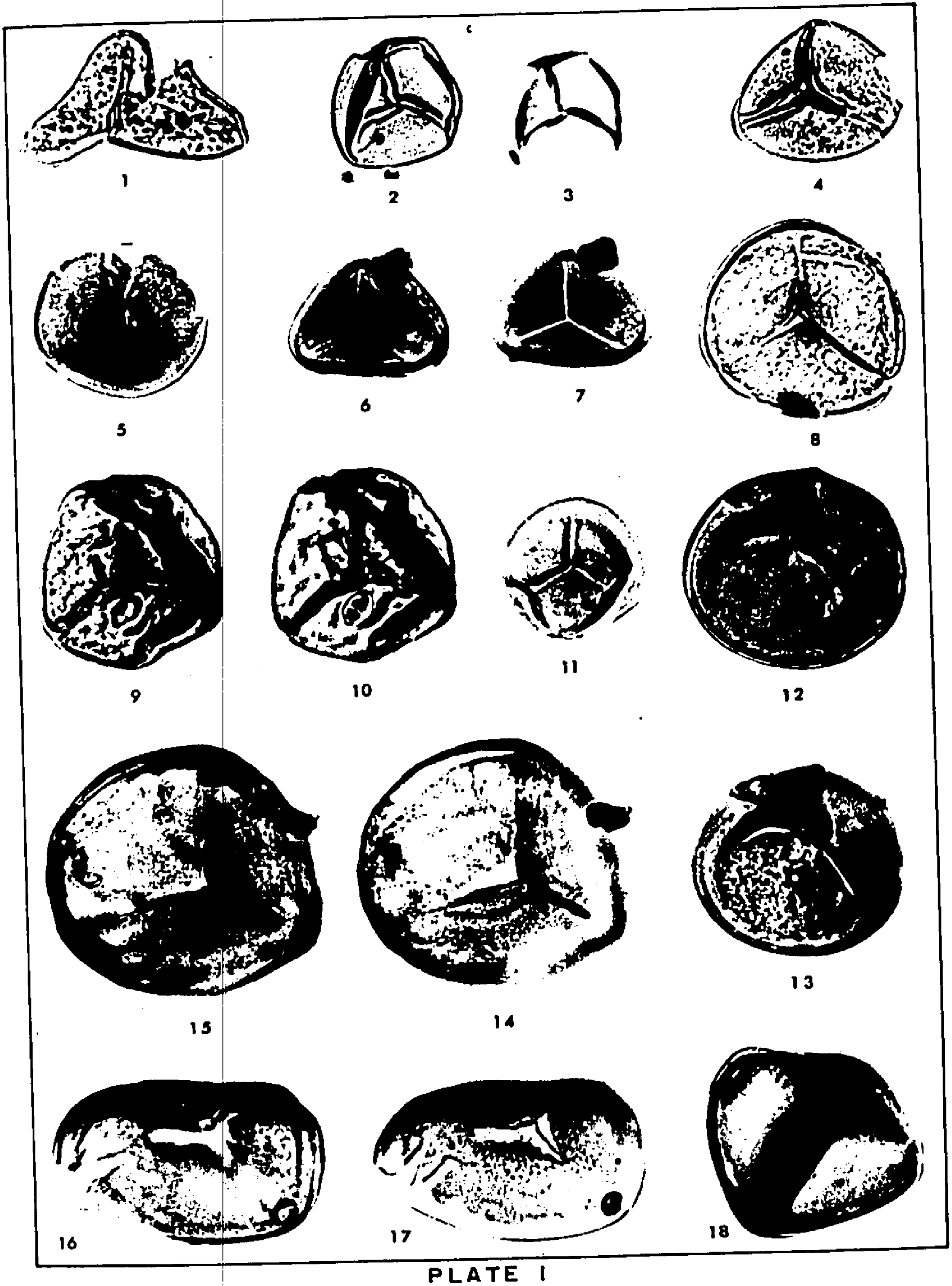


PLATE I

PLATE 2

(All figures X 1000)

Fig. 1, 2	*Trilete spore "A"*. Pb 5330, sl. 6, coord. - 46.8 - 113.4, diam. 28 micra. Fig. 1 - Focus on equator. Fig. 2 - Focus on laesurae.
Fig. 3	*Trilete spore "A"*. Pb 5315, sl. 4, coord. - 40.3 - 125.5, diam. 28 micra. Focus on laesurae and punctate proximal surface.
Figs. 4, 5	*Trilete spore "A"*. Pb 5315, sl. 2, coord. - 35.2 - 121.4, diam. @ 30 micra. Fig. 4 - Focus on equator. Fig. 5 - Focus on laesurae.
Figs. 6, 7	*Trilete spore "A"*. Pb 5319, sl. 4, coord. - 35.5 - 121.3, diam. 22 micra. Fig. 6 - Focus on equator. Fig. 7 - Focus on laesurae.
Figs. 8, 9	*Trilete spore "A"*. Pb 5315, sl. 4, coord. - 49.7 - 125.8, diam. 23 micra. Fig. 8 - Focus on equator and punctate surface. Fig. 9 - Focus on laesurae.
Figs. 10, 11	*Trilete spore "L"* (cf. *Convolutisporites*). Pb 5319, sl. 1, coord. - 33.9 - 127.6, diam. 28 micra. Fig. 10 - Focus on convolute distal surface. Fig. 11 - Focus on laesurae and proximal surface.
Figs. 12, 13	*Lycopodiumsporites sp.* "A". Pb 3679, sl. 1, coord. 32.4 - 120.8, diam. 32 micra. Fig. 12 - Focus on equator and distal surface. Fig. 13 - Focus on laesurae.
Figs. 14, 15	*Trilete spore "D"*. Pb 5330, sl. 12, coord. - 37.8 - 125.8, diam. 36 micra. Fig. 14 - Focus on sinuous raised lips. Fig. 15 - Focus on straight commissures.
Fig. 16	*Undulatisporites sp.* "A". Pb 5330, sl. 8, coord. 29.8 - 119.2, diam. 27 micra.
Figs. 17, 18	*Densoisporites sp.* "A". Pb 3653, sl. 2, coord. 40.5 - 115.4, diam. 53 micra. Fig. 17 - Focus on proximal surface and equator, showing equatorial separation of sexine and nexine. Fig. 18 - Focus on opposite equatorial outline, showing equatorial separation of sexine and nexine.

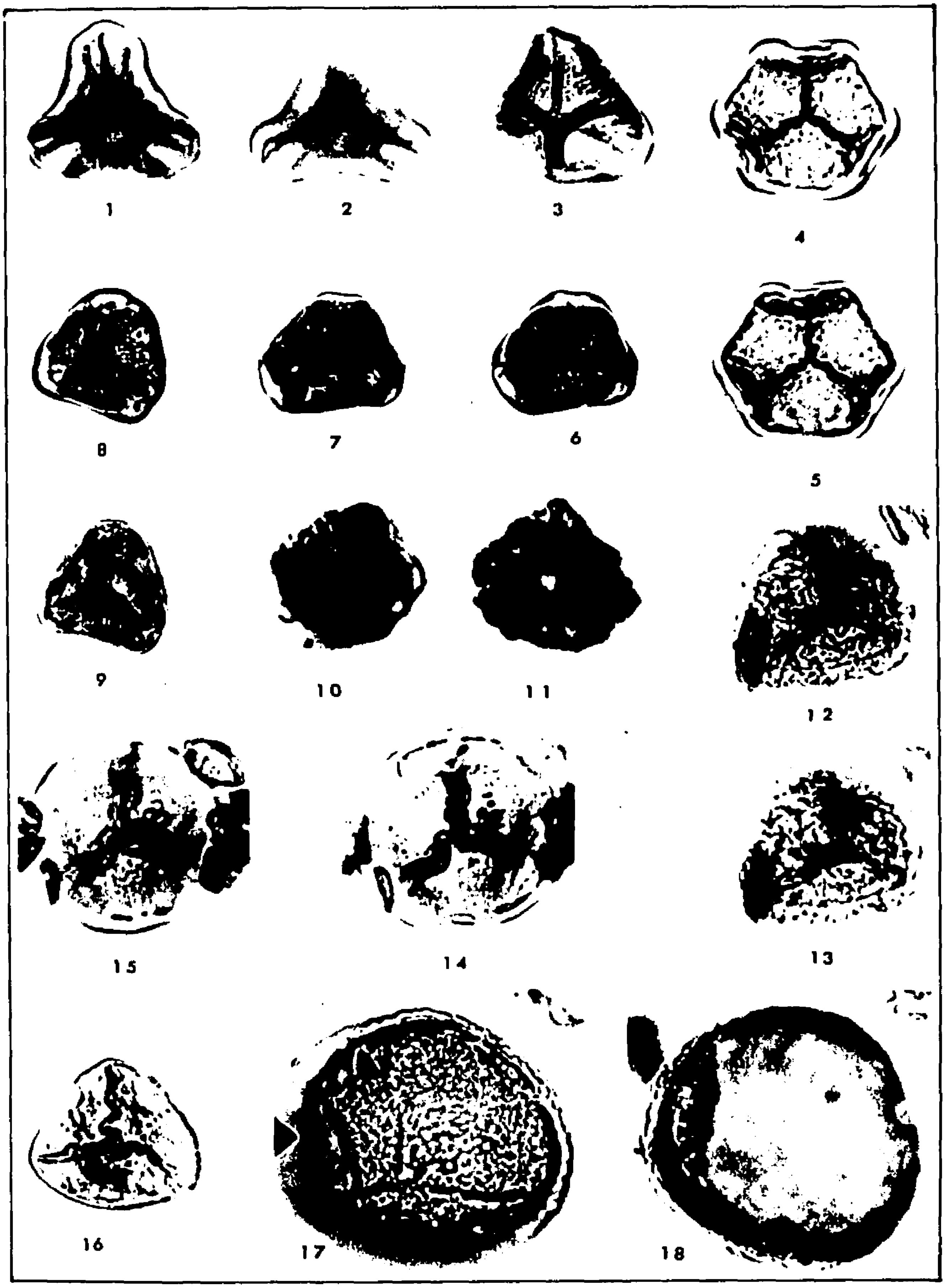


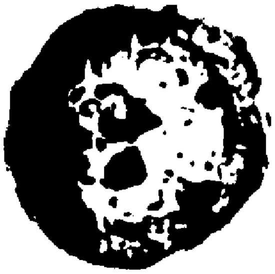
PLATE 2

PLATE 3

(All figures X 1000)

Figs. 1, 2	Verrucosisporites sp. "A". Pb 5330, sl. 1, coord. - 43.5 - 124.3, diam. 35 micra. Fig. 1 - Focus on coarse verrucae of distal surface. Fig. 2 - Focus on laesurae.
Figs. 3, 4	Cingulatisporites cf. C. distaverrucosus Brenner. Pb 5330, sl. 8, coord. - 39.1 - 120.4, diam. 29 micra. Fig. 3 - Focus on verrucate distal surface and equator. Fig. 4 - Focus on laesurae and proximal surface.
Figs. 5, 6, 7	Converrucosisporites sp. "A". Pb 5319, sl. 4, coord. - 46.7 - 111.3, diam. 32 micra. Figs. 5, 6 - Two focus levels showing nature of distal verrucae. Fig. 7 - Focus on laesurae.
Fig. 8	Cingulatisporites cf. C. distaverrucosus Brenner Pb. 5330, sl. 6, coord. 45.2 - 117.8, diam. 29 micra.
Figs. 9, 10	Cingulatisporites distaverrucosus Brenner. Pb 5315, sl. 2, coord. 49.6 - 109.1, diam. 34 micra. Fig. 9 - Focus on equator and distal verrucae. Fig. 10 - Focus on laesurae.
Figs. 11, 12	Trilete spore "F". Pb 5315, sl. 4, coord. 40.7 - 123, diam. 23 micra. Fig. 11 - Focus on distal verrucae. Fig. 12 - Focus on proximal surface and laesurae.
Figs. 13, 14	Trilete spore "F". Pb 5315, sl. 3, coord. 38.4 - 121, diam. 24 micra. Fig. 13 - Focus on distal surface. Fig. 14 - Focus on laesurae.
Figs. 15, 16	Cingulatisporites cf. C. distaverrucosus Brenner. Pb 5330, sl. 5, coord. 38.2 - 122.2, diam. 30 micra. Fig. 15 - Focus on equator and laesurae. Fig. 16 - Focus on verrucate to convolute distal surface.
Figs. 17, 18	Trilete spore "B". Pb 5315, sl. 2, coord. 35.7 - 110.9, diam. 32 micra. Fig. 17 - Focus on distal surface and equator. Fig. 18 - Focus on laesurae.

Fig. 19 *Lundbladispora. willmotti* Balme; Pb 5330, sl. 8, coord. 31.6 - 116.7, diam. 60 micra. Overall aspect of spore showing distal ornamentation, cavate nexinous central body, and radial extremity of one laesura.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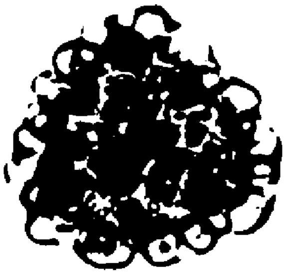
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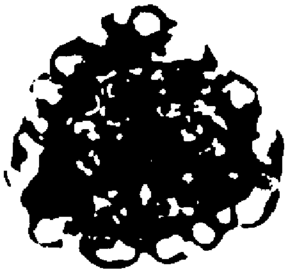
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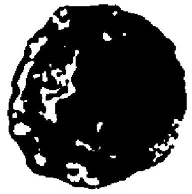
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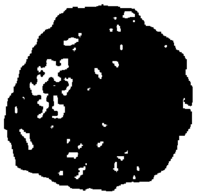
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PLATE 3

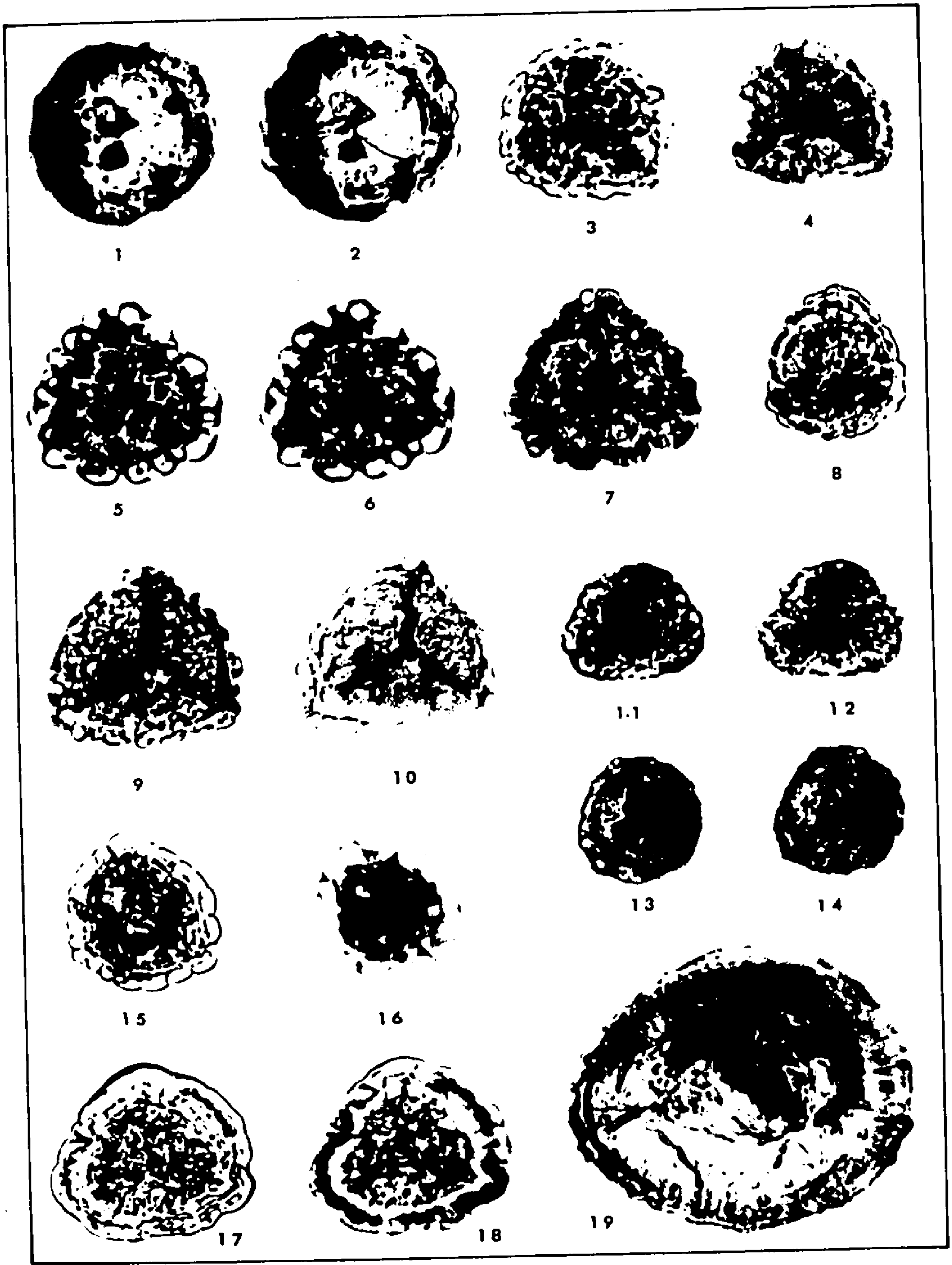


PLATE 3

PLATE 4

(All figures X 1000)

Figs. 1, 2	*Trilete spore* "J", Pb 3679, sl. 2, coord. 40.3 - 113.7, diam. 65 micra. Fig. 1 - Focus on equator showing clavate ornament and proximal tetrad mark. Fig. 2 - Focus on distal surface showing distribution of clavate processes.
Fig. 3	*Cycadopites sp.* "A". Pb 5330, sl. 11, coord. 45 - 118.4, length 39 micra.
Fig. 4	*Cycadopites sp.* "A". Pb 3653, sl. 3, coord. 39.3 - 122.8, length 38 micra.
Fig. 5	*Cycadopites sp.* "A". Pb 5330, sl. 9, coord. 41.7 - 114.5, length 42 micra.
Fig. 6	*Cycadopites sp.* "B". Pb 5319, sl. 6, coord. 41.2 - 125,6, length 33 micra.
Fig. 7	*Cycadopites sp.* "B". Pb 5315, sl. 4, coord. 49.9 - 108.5, length 34 micra.
Fig. 8	*Cycadopites sp.* "B". Pb 5330, sl. 4, coord. 42.2 - 125, length 35 micra.
Fig. 9	*Cycadopites sp.* "B". Pb 5330, sl. 4, coord. 47.7 - 115.5, length 28 micra. Specimen with well developed thickened sexinal lips flanking sulcus.
Fig. 10	*Cycadopites sp.* "B". Pb 5315, sl. 4, coord. 51.3 - 122.6, length 29 micra. Specimen with well-developed thickened lips flanking sulcus.
Fig. 11	*Cycadopites sp.* "B". Pb 3653, sl. 3, coord. 42.1 - 128.6, length 29 micra.
Fig. 12	*Cycadopites sp.* Pb 5315, sl. 4, coord. 37 - 113.6, length 21 micra.
Figs. 13, 14	*Ginkgoretectina sp.* "B". Pb 5319, sl. 5, coord. 49.7 - 113.8, length 26 micra. Fig. 13 - Focus on distal side showing sulcus and punctate (corroded?) exine. Fig. 14 - Focus on equatorial outline showing exine structure.
Fig. 15	*Cycadopites sp.* Pb 5329, sl. 6, coord. 38.5 - 126.4 micra, length 42 micra.

Fig. 16	*Cycadopites sp.* Pb 5319, sl. 1, coord. 45.2 - 120.5, length 35 micra. This specimen appears to be infragranulate, and may belong to *C. subgranulosus* Couper.
Fig. 17	*Ginkgoretectina sp.* "B". Pb 3684, sl. 1, coord. 54.4 - 127.4, length 34 micra. Specimen exhibits infrasexinal ornamentation.
Fig. 18	*Ginkgoretectina sp.* "B". Pb 5330, sl. 4, coord. 34.2 - 112.3, length 30 micra.
Fig. 19	*Chasmatosporites sp.* "*A*". Pb 5330, sl. 1, coord. 46 - 111.8, length 40 micra. Focus on distal surface and sulcus. This may be an aberrant or immature bisaccate pollen grain with sacci.

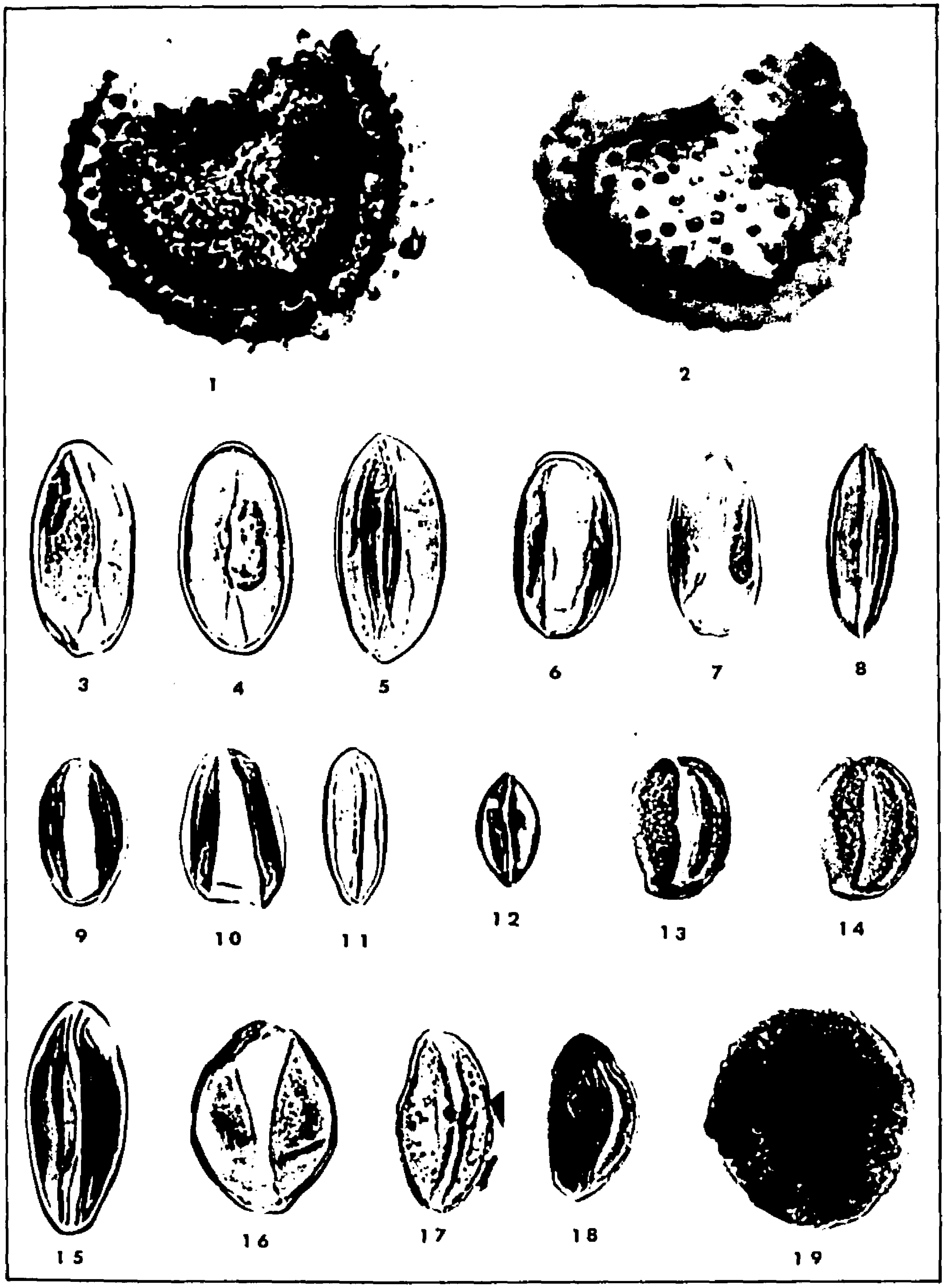
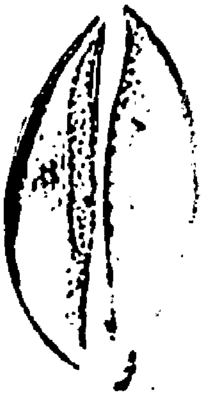


PLATE 4

PLATE 5

(All figures X 1000 unless otherwise indicated)

Fig. 1, 2, 3	*Cycadopites subgranulosus* (Couper) Pocock. Pb 5319, sl. 2, coord. 30 - 128.6, length 49 micra. Figs. 1 and 2 - Two focus levels showing overall aspect of grain. Fig. 3 (X 2000) - Focus levels showing infragranulate nature of sexine. Arrows point to infragranulation.
Figs. 4, 5, 6, 7	*Ginkgoretectina sp.* "A". Pb 5319, sl. 2, coord. 32.5 - 128.9, length 59 micra. Figs. 4 and 5 - Two focus levels showing overall aspect of grain. Fig. 6 - Focus on Tegillate sexine. Fig. 7 - (X 2000) Same view as Fig. 6. Arrows indicating tegillate sexine.
Fig. 8	*Ginkgoretectina* cf. *G. sp.* "A". Pb 5330, sl. 9, coord. 40.7 - 114.2, length 46 micra.
Fig. 9	*Exesipollenites tumulus* Balme. Pb 5319, sl. 1, coord. 40 - 122.5, diam. 21 micra.
Fig. 10	*Exesipollenites tumulus* Balme. Pb 5315, sl. 2, coord. 34.5 - 121.3, diam. 26 micra.
Figs. 11, 12	*Exesipollenites tumulus* Balme. Pb 5315, sl. 1, coord. 40.7 - 118.6, diam. 34 micra. Fig. 11 - Focus on equator, showing projecting granules. Fig. 12 - Focus on exine surface, showing scattered granules.
Fig. 13	*Exesipollenites tumulus* Balme. Pb 5319, sl. 1, coord. 48.4 - 128.6, diam. 25 micra. Specimen with granules clustered over distal leptoma.
Fig. 14	*Exesipollenites tumulus* Balme. Pb 5319, sl. 3, coord. 34.6 - 122, diam. 28 micra. Specimen with granules scattered over exine surface.
Figs. 15, 16	*Spheripollenites scabratus* Couper. Pb 5315, sl. 1, coord. 40 - 129, diam. 36 micra. Fig. 15 - Focus on equator, showing smooth surface of exine. Fig. 16 - Focus on infrasexinal ornamentation.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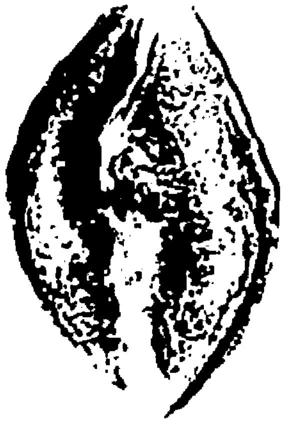
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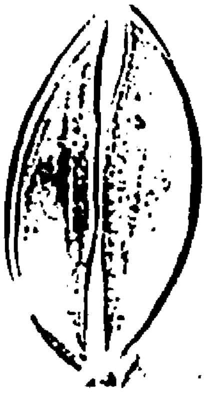
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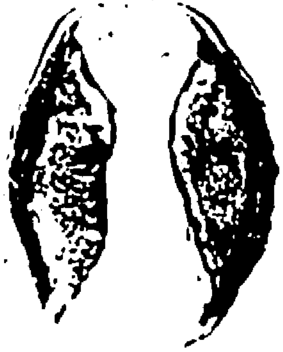
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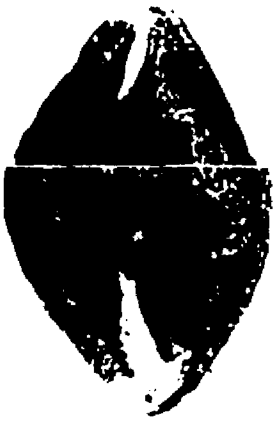
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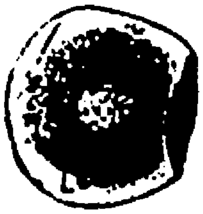
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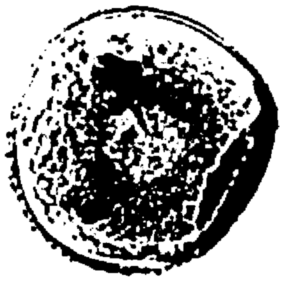
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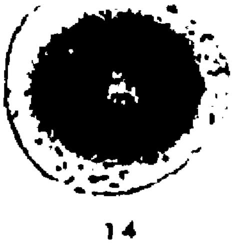
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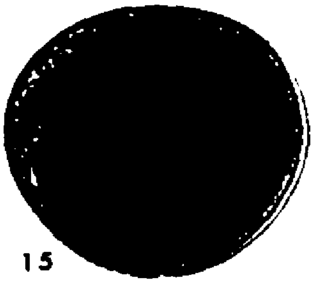
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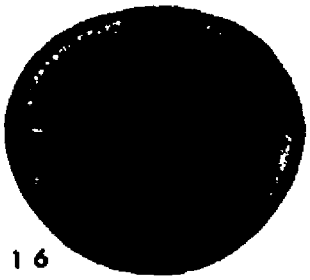
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PLATE 5

PLATE 6

(All figures X 1000)

Fig. 1	*Spheripollenites scabratus* Couper. Pb 3653, sl. 3, coord. 37.6 - 115.7, diam. 36 micra. Broken specimen revealing infrasexinal nature of ornamentation.
Fig. 2	*Spheripollenites scabratus* Couper. Pb 5319, sl. 1, coord. 37.3 - 126.4, diam. 30 micra. Specimen showing small leptoma (?) or pit.
Fig. 3	*Spheripollenites scabratus* Couper. Pb 3653, sl. 3, coord. 32.7 - 122.1, diam. 36 micra. Focus on distal surface showing faint leptomate pore.
Fig. 4	*Spheripollenites scabratus* Couper. Pb 3684, sl. 1, coord. 50.1 - 109.4, diam. 34 micra. Phase contrast showing leptomate pore on distal surface.
Figs. 5, 6, 7	*Classopollis sp.* "*A*". Pb 5319, sl. 2, coord. 43.1 - 125, diam. 42 micra. Fig. 5 - Focus on equator showing infrabaculate "rods". Fig. 6 - Focus on thickened sexinal band distally bordering ring tenuitas. Fig. 7 - Focus on distal polar region showing pore and coarse infrasexinal ornamentation.
Figs. 8, 9, 10	*Classopollis sp.* "*A*". Pb 3679, sl. 2, coord. 37.8 - 118.7, diam. 44 micra. Fig. 8 - Focus on equator and infrabaculate "rods". Fig. 9 - Focus on ring tenuitas and distally flanking, thickened sexinal band. Fig. 10 - Focus on distal polar area, showing coarse infrasexinal ornamentation.
Figs. 11, 12, 13, 14	*Classopollis sp.* "*A*". Pb 3653, sl. 3, coord. 41.8 - 114.7, diam. 36 micra. Fig. 11 - Focus on equator. Fig. 12 - Focus on ring tenuitas and distally flanking sexinal band. Fig. 13 - Focus on proximal polar region showing triangular tetrad mark. Fig. 14 - Focus on distal polar region showing leptomate pore.
Fig. 15	*Classopollis sp.* "*A*". Pb 5319, sl. 5, coord. 37 - 123, diam. 33 micra.
Fig. 16	*Classopollis sp.* "*A*". Pb 5319, sl. 1, coord. 43.4 - 124.8, diam. 39 micra. Specimen with conspicuous equatorial infrabaculate "rods".

Fig. 17	Classopollis sp. "A". Pb 5319, sl. 1, coord. 39 - 110.2, diam. 32 micra. Focus on triangular exinal thinning at proximal pole, and on equatorial infrabaculate "rods."
Fig. 18	Classopollis sp. "A". Pb 3684, sl. 1, coord. 47.8 - 124.4, diam. 34 micra.

PLATE 6

PLATE 7

(All figures X 1000 unless indicated otherwise)

Fig. 1	*Classopollis sp.* "A". Pb 5313, sl. 7, coord. 42.3 - 123.1, diam. 51 micra. An abnormally large individual.
Fig. 2	*Classopollis classoides* Pflug. Pb 5330, sl. 8, coord. 32.7 - 115, diam. of individual grains @ 30 micra. A rarely occurring tetrad.
Figs. 3, 4	*Classopollis classoides* Pflug. Pb 5319, sl. 1, coord. 46.1 - 118.7, diam. 33 micra. Fig. 3 - Side view of broken specimen with portion of proximal hemisphere missing, showing sexine, nexine, infra-sexinal nature of equatorial striated band, ring tenuitas, and distal pore lacking sexine. Fig. 4 - Same specimen X 2000. Note that ring tenuitas (indicated by arrow) is a thinned, indentation of sexine which apparently does not effect thickness of nexine.
Fig. 5	*Classopollis classoides* Pflug. Pb 3712, sl. 2, coord. 45.5 - 113.1, diam. 33 micra. Compressed specimen showing distal pore and proximal triradiate tetrad mark.
Fig. 6	*Classopollis classoides* Pflug. Pb 5319, sl. 1, coord. 44 - 119.4, diam. 30 micra. Side view showing thickened equatorial band, ring tenuitas, thickened sexinal band distally flanking tenuitas, and distal pore.
Figs. 7, 8	*Classopollis classoides* Pflug. Pb 5319, sl. 2, coord. 35 - 120.9, diam. 27 micra. Fig. 7 - Focus on equator. Fig. 8 - Focus on proximal polar region showing triangular tetrad mark comprised of thinned or absent sexine.
Figs. 9, 10	*Classopollis classoides* Pflug. Pb 3653, sl. 2, coord. 34.6 - 117.2, diam. 28 micra. Fig. 9 - Side view showing thickened equatorial sexinal band with infra-striae, and ring tenuitas formed by sexine thinning. Fig. 10 - Same specimen X 2000.
Figs. 11, 12	*Classopollis classoides* Pflug. Pb 3653, sl. 3, coord. 33.4 - 115.1, diam. 27 micra. Fig. 11 - Focus on equator. Fig. 12- Focus on ring tenuitas and distally flanking thickened band.

Fig. 13	*Classopollis sp.* "*B*". Pb 3684, sl. 1, coord. 46.9 - 119.4, diam. 25 micra. Focus on coarse infragranulation of sexine.
Fig. 14	*Classopollis classoides* Pflug. Pb 3712, sl. 2, coord. 35.8 - 120, diam. 26 micra.
Fig. 15	*Classopollis classoides* Pflug. Pb 3712, sl. 2, coord. 39.7 - 112.1, diam. 29 micra.
Fig. 16	*Classopollis sp.* "*B*". Pb 3688, sl. 1, coord. 32.5 - 127.3, diam. 29 micra. Lateral view, showing coarse infrasexinal ornamentation, especially near equatorial region, and equatorial striae.
Fig. 17	*Classopollis sp.* "*B*". Pb 3653, sl. 3, coord. 29.4 - 118.9, diam. 30 micra. Specimen shows coarse infrasexinal ornamentation.
Figs. 18, 19	*Classopollis sp.* "*B*". Pb 3679, sl. 2, coord. 40.8 - 121.8, diam. 31 micra. Fig. 18 - Focus on equator, showing pronounced, radially disposed infrabaculate "rods". Fig. 19 - Focus on coarse infragranulation of sexine.
Figs. 20, 21	*Classopollis sp.* "*B*". Pb 3653, sl. 2, coord. 45.8 - 112.2, diam. 27 micra. Fig. 20 - Focus on equator and infrabaculate "rods". Fig. 21 - Focus on coarsely infragranulate sexine.

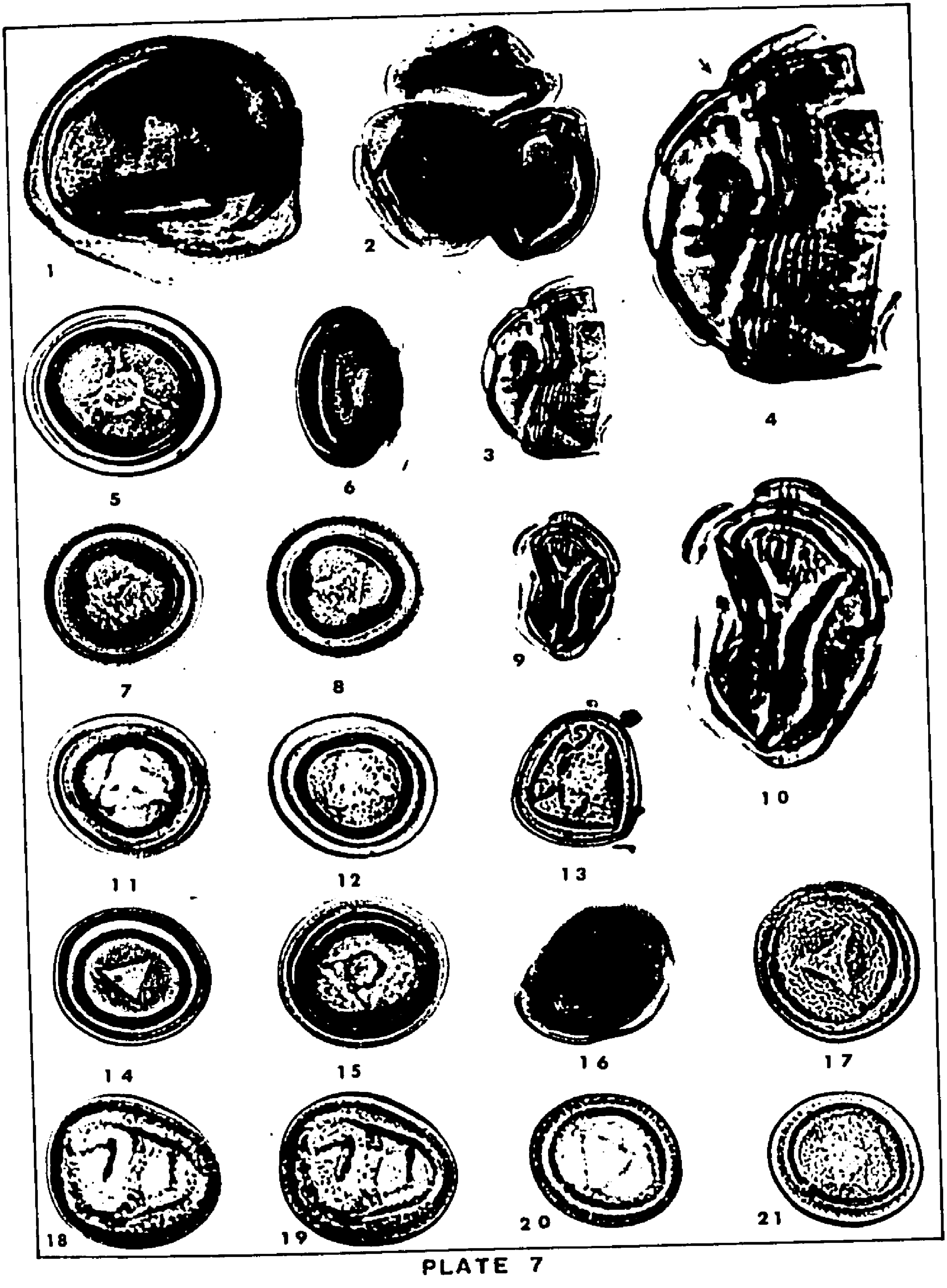


PLATE 7

PLATE 8

(All figures X 1000)

Fig. 1	*Classopollis sp.* "*C*". Pb 3679, sl. 2, coord. 35.1 - 121.1, diam. 35 micra. Note dense, opaque nexinal body enveloped by loosely appressed, equatorially striated sexine. Light area in center of nexinal body represents distal leptomate pore, proximal tetrad mark, or both.
Fig. 2	*Classopollis sp.* "*C*". Pb 5313, sl. 7, coord. 43 - 113.1, diam. 37 micra.
Fig. 3	*Classopollis sp.* "*C*". Pb 5330, sl. 9, coord. 41.5 - 119, diam. 30 micra.
Fig. 4	*Classopollis sp.* "*C*". Pb 5330, sl. 4, coord. 46.7 - 110.8, diam. 28 micra. The light area in center of opaque nexinal body corresponds to the distal deptomate pore comprised of thinned or absent nexine and sexine (?).
Fig. 5	*Classopollis sp.* "*C*". Pb 5330, sl. 8, coord. 36.7 - 122.3, diam. 23 micra.
Figs. 6, 7	*Classopollis sp.* "*C*". Pb 5315, sl. 4, coord. 43.1 - 124.2, diam. 24 micra. Fig. 6 - Overall aspect showing opaque nexine and loose, hyaline sexine. Fig. 7 - Focus on light area (distal leptomate pore?) in center of nexine.
Fig. 8	*Classopollis sp.* "*C*". Pb 5312, sl. 3, coord. 46.7 - 111.2, diam. 26 micra.
Fig. 9	*Classopollis sp.* Pb 3688, sl. 1, coord. 31.2 - 123.6, diam. 42 micra. Specimen with sexine loosely appressed to nexinal central body. Note arcuate equatorially striated band of sexine.
Fig. 10	*Classopollis sp.* Pb 5330, sl. 6, coord. 39.4 - 121.7, diam. 34 micra. Specimen apparently lacking either extra- or infrasexinous ornamentation of any kind. Note well developed distal leptomate pore and conspicuous dark thickened sexine band distally flanking ring tenuitas.
Fig. 11, 12	*Classopollis sp.* Pb 3653, sl. 2, coord. 43.3 - 127.3, diam. 19 micra. A very small, immature grain, possibly of *C. classoides*.

Fig. 11 - Focus equatorial outline. Fig. 12 - Focus on proximal surface, showing triradiate tetrad mark.

Fig. 13 Cf. *Corollina meyeriana* (Klaus) Venkatachala and Góczán. Pb 5310, sl. 4, coord. 39.9 - 116.1, diam. of individual grains @ 28 micra. This may be a tetrad of *Classopollis* in which the sexine has been corroded or not preserved.

Fig. 14 *Eucommiidites troedssonii* Erdtman. Pb 5319, sl. 2, coord. 42 - 124.8, length 38 micra. Proximal-distal orientation of compressed grain showing "key-hole"-shaped distal sulcus flanked by a pair of proximally disposed arcuate tenuitates.

Fig. 15 *Eucommiidites troedssonii* Erdtman. Pb 5315, sl. 4, coord. 44.1 - 116.6, length 43 micra.

Fig. 16 *Eucommiidites troedssonii* Erdtman. Pb 5330, sl. 6, coord. 37.4 - 122.4, length 35 micra.

Fig. 17 *Eucommiidites troedssonii* Erdtman. Pb 5319, sl. 2, coord. 42.6 - 121.4, length 38 micra.

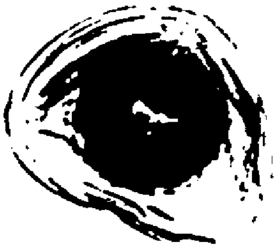
Fig. 18 *Eucommiidites minor* Groot and Penny. Pb 5319, sl. 2, coord. 31.8 - 118.3, length 27 micra. Note dark, thickened sexinal lips flanking distal sulcus. A pair of arcuate tenuitates are present near the equator on the proximal surface.

Fig. 19 *Eucommiidites minor* Groot and Penny. Pb 5330, sl. 6, coord. 42.8 - 118.7, length 26 micra.

Fig. 20 *Eucommiidites minor* Groot and Penny. Pb 5319, sl. 2, coord. 34 - 110.9, length 26 micra.

Fig. 21 *Eucommiidites minor* Groot and Penny. Pb 5319, sl. 2, coord. 45.8 - 111.6, length 24 micra.

Fig. 22 *Eucommiidites minor* Groot and Penny. Pb 5330, sl. 4, coord. 47.4 - 120, length 22 micra.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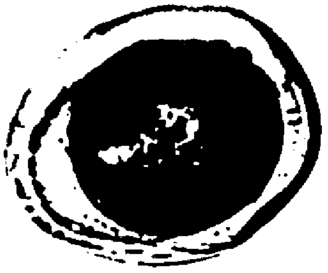
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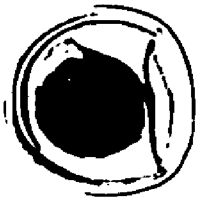
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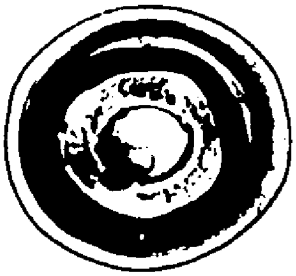
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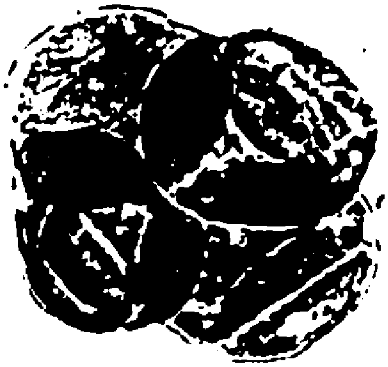
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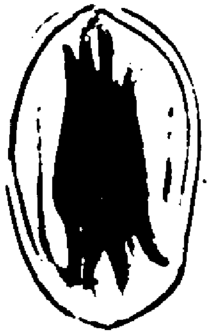
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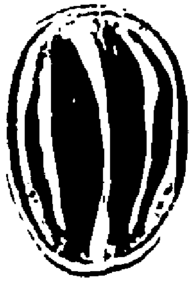
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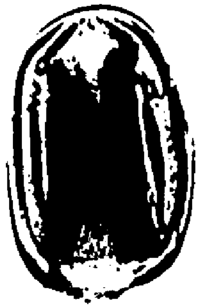
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PLATE 8

PLATE 9

(all figures X 1000 unless indicated otherwise)

Figs. 1, 10	*Eucommiidites* sp. "A". Pb 5319, sl. 2, coord. 42.5 - 127.9, length 30 micra. Fig. 1 - Overall aspect showing lateral symmetrical folding at position of tenuitates just proximal to equator. Fig. 10 - Same specimen X 2000. Arrows point to infrapunctate (tegillate?) sexine, and to infolded tenuitates flanking distal sulcus.
Figs. 2, 3	*Eucommiidites* sp. "A". Pb 5319, sl. 1, coord. 32.4 - 113.5, length 31 micra. Fig. 2 - Focus on equator and distal face. Arrow points to infrapunctate (tegillate?) sexine. Fig. 3 - Focus on pitted proximal surface.
Figs. 4, 5	*Eucommiidites* sp. "A". Pb 5319, sl. 5, coord. 44.6 - 120.5, length 29 micra. Fig. 4 - Focus on distal face and sulcus. Fig. 5 - Focus on pitted proximal surface.
Fig. 6	*Eucommiidites* cf. sp. "A". Pb 5319, sl. 1, coord. 48.2 - 116, length 28 micra.
Figs. 7, 8, 9	*Eucommiidites* sp. "B". Pb 5319, sl. 5, coord. 47.1 - 111.3, length 24 micra. Fig. 7 - Focus on distal face and sulcus. Fig. 8 - Focus on pitted proximal face. Fig. 9 - Phase contrast. Focus on proximal face showing large pits in exine.
Figs. 11, 12 13, 14	*Eucommiidites* sp. "B". Pb 3684, sl. 1, coord. 40.9 - 117.3, length 22 micra. Fig. 11 - Focus on distal surface and sulcus. Fig. 12- Phase contrast. Focus on distal surface and sulcus. Fig. 13 - Focus on pitted proximal surface. Fig. 14 - Phase contrast. Focus on pitted proximal surface.
Figs. 15, 16	*Eucommiidites* sp. "B". Pb 5315, sl. 1, coord. 41 - 125.8, length 26 micra. Fig. 15 - Focus on distal face. Fig. 16 - Focus on pitted proximal face.
Figs. 17, 18	*Eucommiidites* sp. "B". Pb 5330, sl. 5, coord. 37.5 - 116, length 23 micra. Fig. 17 - Focus on distal face. Fig. 18 - Focus on pitted proximal face.
Figs. 19, 20	*Eucommiidites* sp. "B". Pb 3712, sl. 1, coord. 36.4 - 127. 8, length 25 micra.

	Fig. 19 - Focus on distal face. Fig. 20 - Phase contrast. Focus on pitted proximal face.
Figs. 21, 22, 23, 24	*Eucommiidites sp.* "*C*". Pb 3653, sl. 3, coord. 30.6 - 117.7, length 23 micra. Fig. 21 - Focus on equator, showing terminal auriculate processes. Fig. 22 - Focus on pitted proximal face. Fig. 23 - Phase contrast. Focus on pitted proximal surface. Fig. 24 - Phase contrast, showing nature of terminal auriculate processes and outlines of oval distal sulcus and arcuate proximal tenuitates near equator.
Figs. 25, 26	*Eucommiidites sp.* "*C*". Pb 5310, sl. 11, coord. 41.6 - 112.3, length 28 micra. Fig. 25 - Overall aspect of grain. Fig. 26 - Phase contrast, showing outlines of terminal auriculate processes, oval distal sulcus, and flanking proximal tenuitates.
Figs. 27, 28 29, 30	*Eucommiidites sp.* "*C*". Pb 5330, sl. 6, coord. 34 - 122.9, length 26 micra. Fig. 27 - Focus on distal sulcus and terminal auriculate processes. Fig. 28 - Focus on pitted proximal surface. Fig. 29 - Phase contrast. Focus on distal sulcus and terminal auriculate process. Fig. 30 - Phase contrast. Focus on pitted proximal surface.

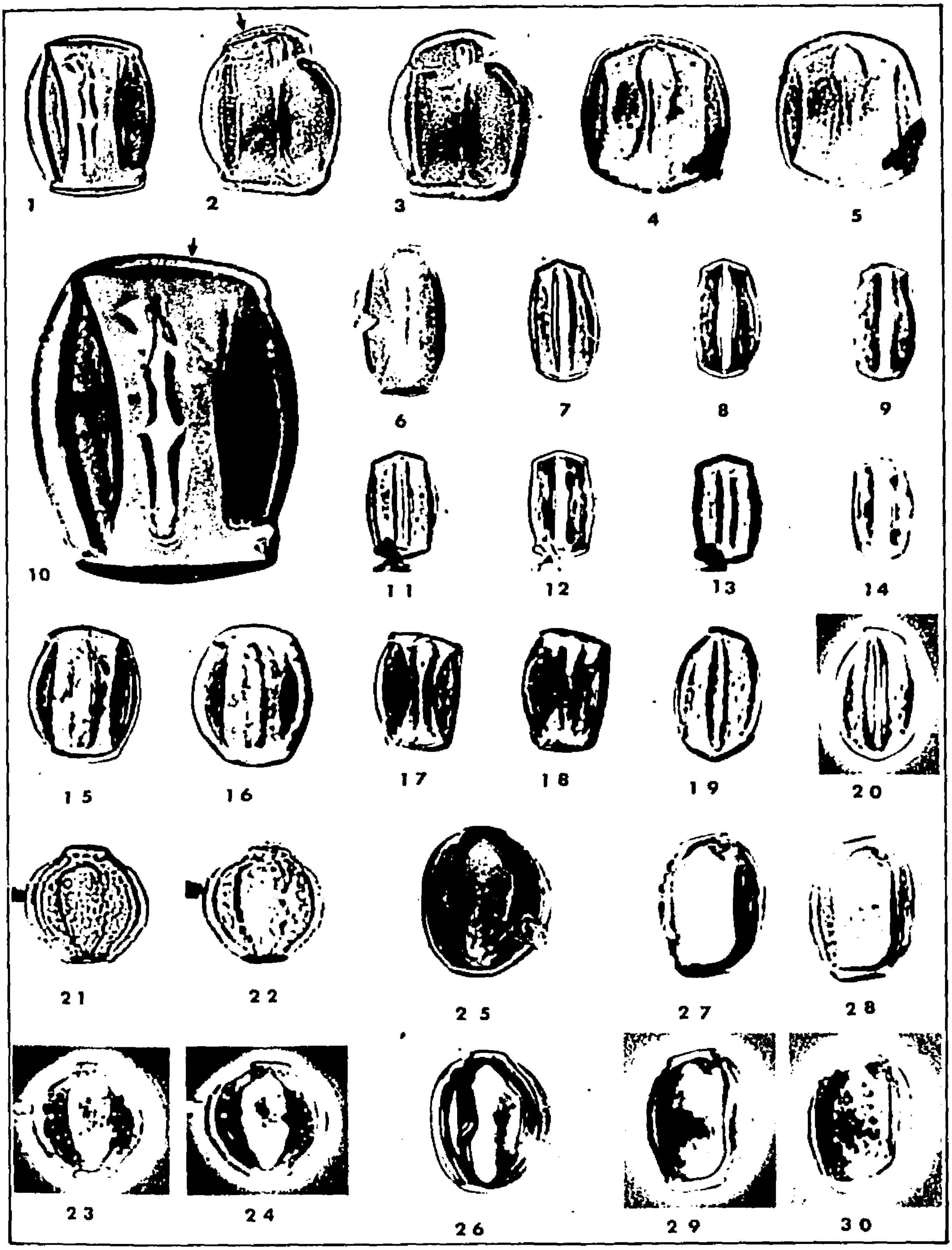
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PLATE 9

PLATE 10

(All figures X 1000)

Figs. 1, 2	Zonalapollenites sp. "C". Pb 5315, sl. 4, coord. 44.5 - 116.2, diam. 33 micra. Fig. 1 - Focus on equator and distal face showing extension of compact convolutions of sexine onto the distal face where they surround the small, circular leptomate pore. Fig. 2 - Focus on proximal face showing closely spaced, circular to oval shaped sexinal convolutions.
Figs. 3, 4	Zonalapollenites sp. "C". Pb 5319, sl. 1, coord. 48 - 117.8, diam. 32 micra. Fig. 3 - Focus on equator and distal face. Note small leptomate pore, surrounded by distal extensions of compactly spaced sexinal convolutions. Fig. 4 - Focus on proximal polar region showing distribution of densely spaced sexinal convolutions.
Figs. 5, 6	Zonalapollenites sp. "C". Pb 5330, sl. 8, coord. 33.5 - 120.6, diam. 31 micra. Fig. 5 - Focus on equator and distal face, showing relatively larger leptomate pore and less intensely convolute sexine. Fig. 6 - Focus on proximal face, showing comparatively loosely spaced convolutions having elongate, sinous outline, rather than a circular outline as in Fig. 2. Note triradiate laesurae.
Figs. 7, 8	Zonalapollenites sp. "C". Pb 5319, sl. 5, coord. 50.7 - 112.8, diam. 32 micra. Fig. 7 - Focus on equator and distal face. Note relatively large leptomate pore surrounded by less intensely convolute sexine. Fig. 8 - Focus on proximal face, showing loosely spaced, elongate and sinuous sexinal convolutions.
Figs. 9, 10	Zonalapollenites sp. "C". Pb 5319, sl. 1, coord. 46.4 - 111.5, diam. 31 micra. Figs. 9 - Focus on equator and distal face. Leptomate pore, covering much of distal face, is poorly delineated by weakly convolute sexine. Fig. 10 - Focus on extremely elongate, narrow, sinuous, and loosely packed sexinal convolutions of proximal face. Contrast with the convolutions as developed in Figs. 2, 4, 6, and 8.

Figs. 11, 12	*Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5315, sl. 1, coord. 45.1, - 126.8, diam. 41 micra. Fig. 11 - Focus on equator and distal face, showing intensely convolute sexine extending distally from the equator and surrounding small leptomate pore. Fig. 12 - Focus on compactly spaced proximal sexinal convolutions. Individual convolutions subcircular to oval in outline.
Figs. 13, 14	*Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5315, sl. 4, coord. 40.9 - 123.4, diam. 46 micra. Fig. 13 - Focus on equator and distal face bearing leptomate pore surrounded by tightly convolute sexine. Fig. 14 - Focus on proximal face. Convolutions somewhat less densely spaced and more elongate in outline than those shown in Fig. 12.
Figs. 15, 16	*Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5315, sl. 2, coord. 48.4 - 126.4, diam. 44 micra. Fig. 15 - Focus on equator and distal face. Note larger leptomate pore and less intensely convolute sexine than that shown in Fig. 11. Fig. 16 - Focus on convolutions of proximal sexine.
Figs. 17, 18	*Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5319, sl. 6, coord. 34.9 - 113.1, diam. 46 micra. Fig. 17 - Focus on equator and distal leptomate pore. Fig. 18 - Focus on comparatively loosely packed sexinal convolutions of proximal face. Note the narrow, elongate outline of sinuous convolutions as compared to those in Fig. 12.

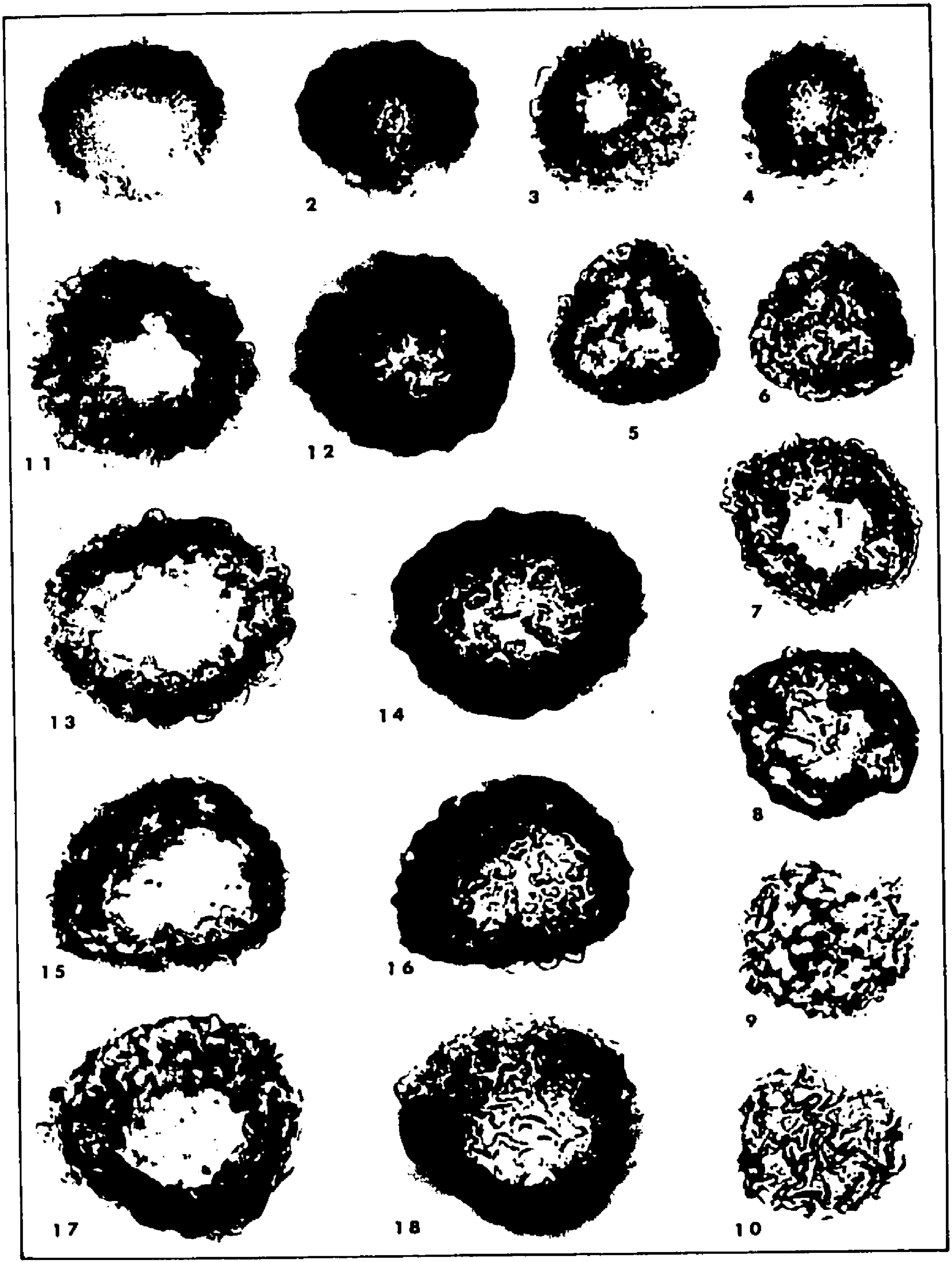

PLATE 10

PLATE 11

(All figures X 1000)

Figs. 1, 2 *Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5330, sl. 11, coord. 31 - 115.8, diam. 47 micra. Fig. 1 - Focus on equator and distal face, showing relatively large leptomate pore and less intensely convolute sexine surrounding leptomate pore. Fig. 2 - Focus on loosely spaced, narrow, elongate and sinuous convolutions of proximal sexine.

Figs. 3, 4 *Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5319, sl. 1, coord. 44.6 - 124.6, diam. 51 micra. Fig. 3 - Focus on comparatively weakly convolute sexine at equatorial region, and on leptomate pore occupying much of distal face. Fig. 4 - Focus on very loosely spaced, extremely elongate, narrow and sinuous proximal convolutions.

Figs. 5, 6 *Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5319, sl. 3, coord. 35.3 - 116.4, diam. 52 micra. Fig. 5 - Focus on equator and leptomate pore occupying most of distal surface. Convolutions occupying most of distal surface. Convolutions of equatorial and distal regions greatly reduced. Fig. 6 - Focus on proximal surface. Ornamentation reduced to a few narrow, elongate, sinuous convolutions.

Fig. 7 *Zonalapollenites mesozoicus* (Couper) n. comb. Pb 5319, sl. 1, coord. 42.3 - 115.1, diam. 46 micra. Focus on proximal convolutions.

Fig. 8 *Zonalapollenites cf. Z. mesozoicus* (Couper) n. comb. Pb 3712, sl. 1, coord. 43.7 - 122.5, diam. 55 micra. Focus on equatorial outline showing large leptomate pore surrounded by moderately convolute sexine. Specimen bears triradiate tetrad mark on proximal surface.

Fig. 9 *Zonalapollenites sp.* Pb 5319, sl. 1, coord. 48.2 - 123.4, diam. 58 micra. This specimen, similar to the *T. mesozoicus* type, exhibits a degree of equatorial separation of sexine and nexine common to the *T. dampieri* type.

Figs. 10, 11	*Zonalapollenites sp.* "*A*". Pb 5330, sl. 5, coord. 33 - 127.8, diam. 48 micra. Fig. 10 - Focus on equator and distal face. Note equatorial separation of nexine and sexine, and moderate to strong convolutions extending distally from equator to surround leptomate pore. Fig. 11 - Focus on proximal sexinal convolutions.
Fig. 12	*Zonalapollenites sp.* "*A*". Pb 5319, sl. 2, coord. 44.8 - 115.3, diam. 48 micra. Focus level depicting narrow, crenulate equatorial saccus and distal sexinal convolutions surrounding small leptomate pore.

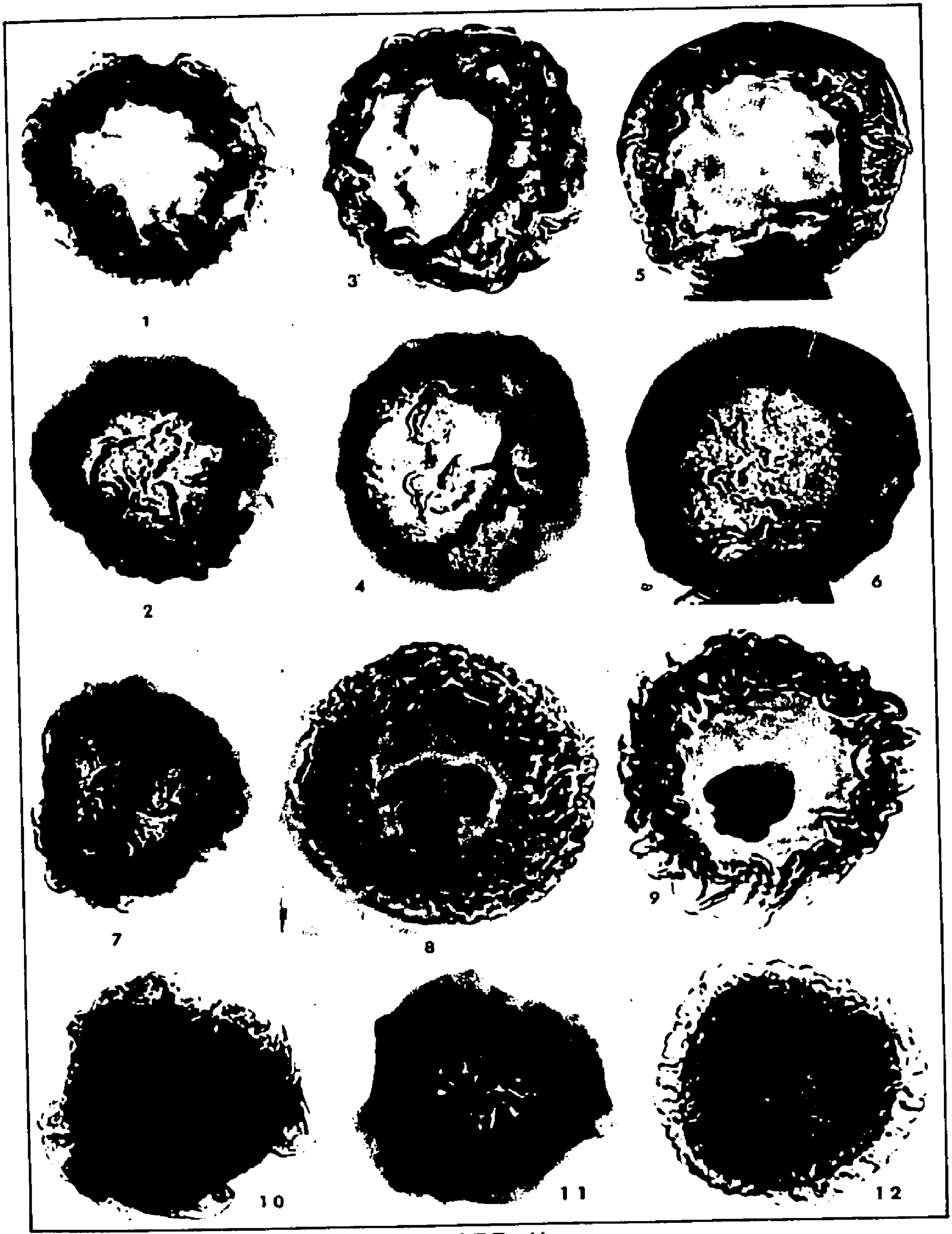

PLATE II

PLATE 12

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Figs. 1, 2	*Zonalapollenites sp. "A".* Pb 5315, sl. 1, coord. 47.6 - 127.7, diam. 53 micra. Fig. 1 - Focus on equatorial saccus and distal sexinal convolutions surrounding leptomate pore. Fig. 2 - Focus on proximal triradiate tetrad mark.
Figs. 3, 4	*Zonalapollenites dampieri* Balme. Pb 5315, sl. 3, coord. 40 - 119.7, diam. 45 micra. Fig. 3 - Focus on equator and distal surface. Fig. 4 - Focus on proximal tetrad mark comprised of raised sexinal laesurae.
Fig. 5	*Zonalapollenites dampieri* Balme. Pb 3679, sl. 2, coord. 48.7 - 112, diam. 50 micra.
Fig. 6	*Zonalapollenites dampieri* Balme. Pb 5319, sl. 3, coord. 32.2 - 126.5, diam. 52 micra. Only a faint trace of a proximal trilete tetrad mark is present on this grain.
Fig. 7	*Zonalapollenites dampieri* Balme. Pb 5319, sl. 1, coord. 34.7 - 126.6, diam. 48 micra. No hint of a proximal tetrad mark is apparent on this specimen.
Fig. 8	*Zonalapollenites dampieri* Balme. Pb 5330, sl. 6, coord. 40.7 - 122.8, diam. 48 micra. Overall aspect showing equatorial saccus and proximal trilete mark.
Fig. 9	*Zonalapollenites dampieri* Balme. Pb 3679, sl. 1, coord. 29.2 - 115, diam. 48 micra.
Fig. 10	*Zonalapollenites dampieri* Balme. Pb 3712, sl. 1, coord. 43 - 117.3, diam. 54 micra. Specimen with well-developed proximal tetrad mark and very narrow equatorial saccus. Punctate sexine without crenulations or convolutions.
Fig. 11	*Zonalapollenites dampieri* Balme. Pb 5315, sl. 3, coord. 49.3 - 110, diam. 41 micra.
Fig. 12	*Zonalapollenites dampieri* Balme. Pb 3679, sl. 2, coord. 40 - 122, diam. 57 micra.

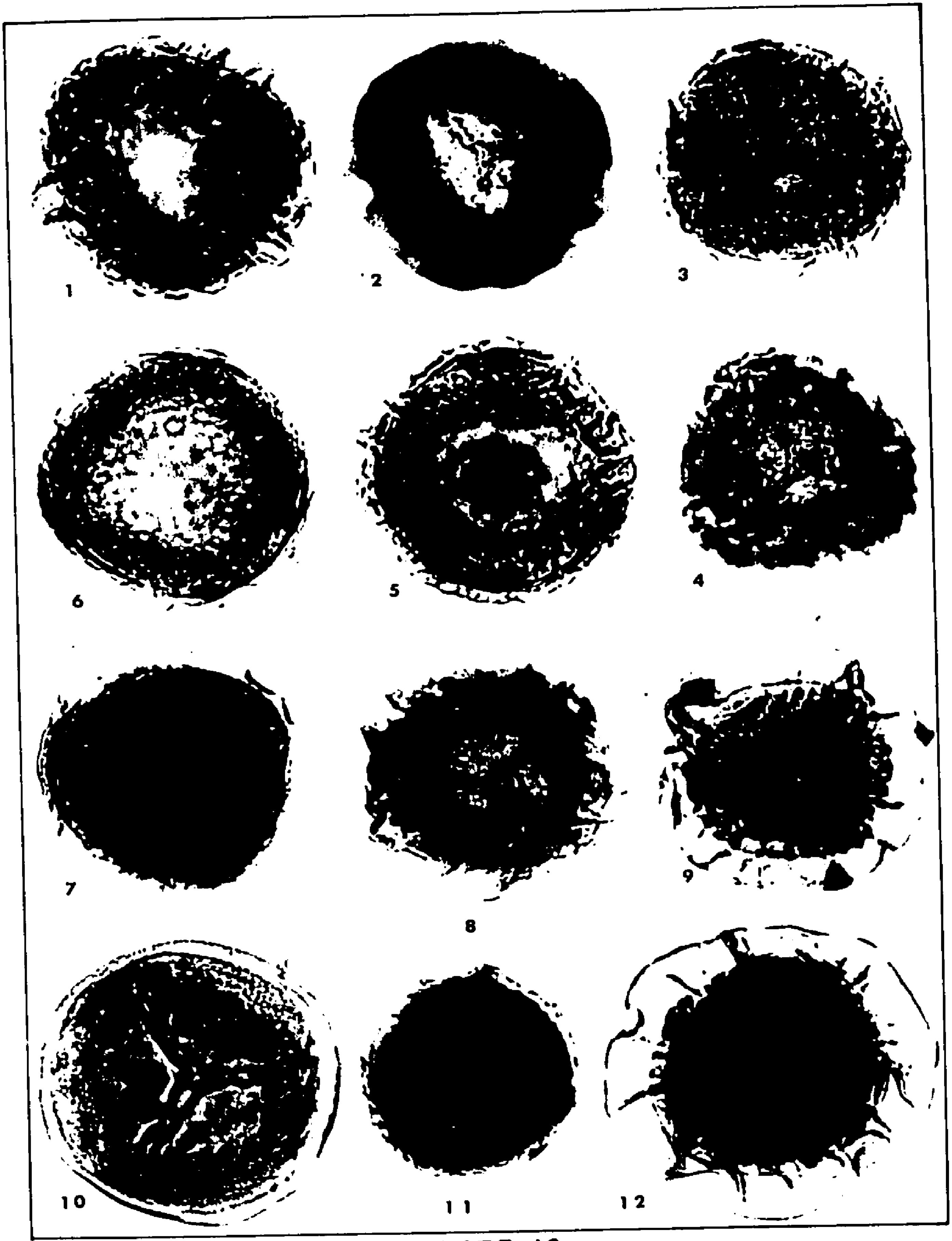

PLATE 12

PLATE 13

(All figures X 1000)

Fig. 1	*Zonalapollenites dampieri* Balme. Pb 3712, sl. 2, coord. 37.8 - 115.3, diam. 57 micra.
Fig. 2	*Zonalapollenites* cf. *Z.* sp. "A". Pb 5315, sl. 1, coord. 46 - 121.2, diam. 62 micra. Focus on proximal surface showing conspicuous sexinal convolutions.
Fig. 3	*Zonalapollenites* sp. "A". Pb 5315, sl. 1, coord. 40.9 - 118.6, diam. 58 micra. Focus on proximal sexinal convolutions.
Fig. 4	*Zonalapollenites dampieri* Balme. Pb 3653, sl. 2, coord. 33.5 - 117.5, diam. 61 micra.
Fig. 5	*Zonalapollenites* sp. "A". Pb 5330, sl. 10, coord. 37.3 - 115.8, diam. 51 micra. Focus on equator and distally extending sexinal convolutions surrounding small leptomate pore.
Figs. 6, 7	*Zonalapollenites* cf. *Z. dampieri* Balme. Pb 5330, sl. 3, coord. 41.1 - 111.1, diam. 28 micra. A very small or immature (?) grain. Fig. 6 - Focus on narrow equatorial saccus. Sexine bears moderate convolutions. Fig. 7 - Focus on proximal trilete mark.
Fig. 8	*Zonalapollenites* cf. *Z. dampieri* Balme. Pb 5315, sl. 4, coord. 42.6 - 128.6, diam. 32 micra. Focus on narrow, crenulate, equatorial saccus.
Fig. 9	*Zonalapollenites* sp. "B". Pb 5315, sl. 4, coord. 33.8 - 119, diam. 32 micra. Specimen with very little equatorial separation of sexine and nexine, resulting in reduced or absent saccus.
Figs. 10, 11	*Zonalapollenites* sp. "B". Pb 3712, sl. 2, coord. 41.3 - 127.4, diam. 36 micra. Fig. 10 - Focus on equatorial region lacking well defined saccus. Note delicate sexinal convolutions on distal surface. Fig. 11 - Focus on faint proximal tetrad mark.
Fig. 12	*Zonalapollenites* sp. "B". Pb 3712, sl. 1, coord. 38.5 - 116.3, diam. 38 micra. Focus on equatorial region almost entirely lacking separation of sexine and nexine.

Fig. 13	*Zonalapollenites sp.* "B". Pb 5315, sl. 1, coord. 45.2 - 110.7, diam. 33 micra. Specimen without well defined saccus and with delicate convolutions surrounding distal leptoma.
Figs. 14, 15	*Zonalapollenites sp.* "B". Pb 5330, sl. 6, coord. 32.9 - 111.8, diam. 35 micra. Fig. 14 - Focus on equator and distal convolutions of sexine. Fig. 15 - Focus on faint proximal tetrad mark.
Fig. 16	*Zonalapollenites sp.* "B". Pb 5315, sl. 1, coord. 34.6 - 117.3, diam. 40 micra. Folded grain with very narrow saccus.


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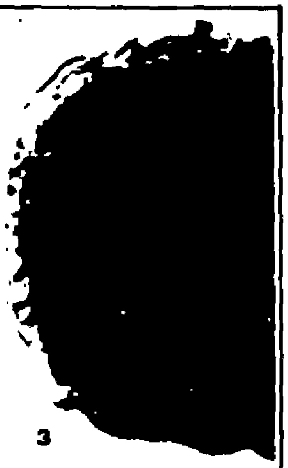
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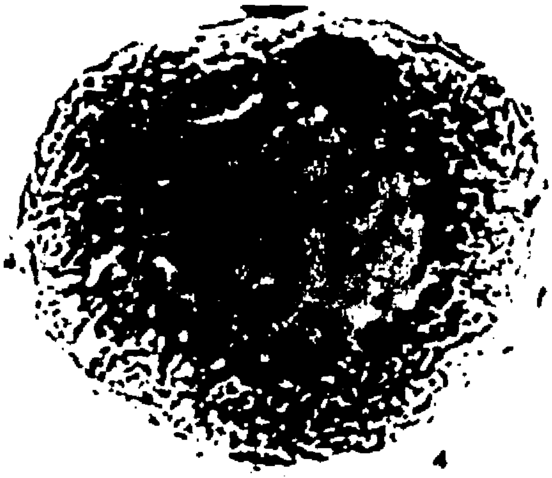
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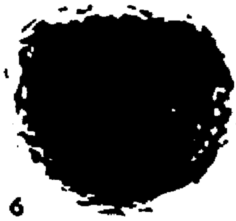
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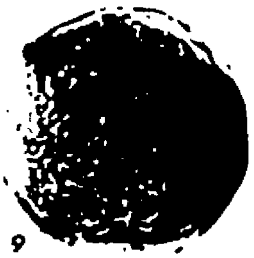
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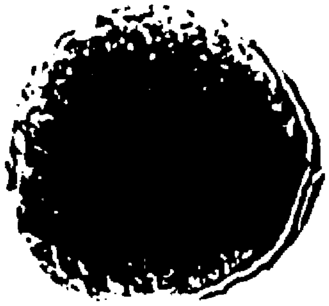
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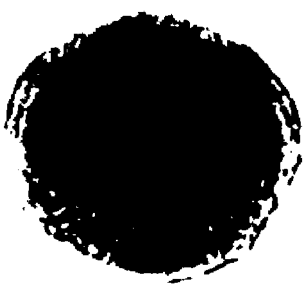
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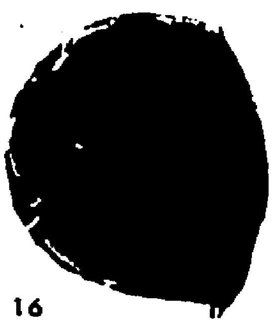
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PLATE 13

PLATE 14

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Figs. 1, 2	*Zonalapollenites sp.* Pb 5330, sl. 8, coord. 44.8 - 120.6, diam. 43 micra. Fig. 1 - Focus on narrow equatorial saccus lacking crenulations or convolutions. Fig. 2 - Focus on proximal surface densely ornamented with verrucate sculptural elements on sexine. Only one such specimen was observed.
Fig. 3	*Zonalapollenites sp.* Pb 3712, sl. 2, coord. 34.3 - 113.1, diam. 42 micra. Specimen with narrow saccus, crenulate sexinal margin delineating large distal leptomate pore, and well-developed proximal tetrad mark.
Fig. 4	*Zonalapollenites dampieri* Balme. Pb 5330, sl. 3, coord. 46.4 - 127, diam. 41 micra.
Figs. 5, 6	*Zonalapollenites trilobatus* Balme. Pb 5319, sl. 2, coord. 33.5 - 123.7, diam. 63 micra. Fig. 5 - Focus on equatorial saccus. Fig. 6 - Focus on proximal tetrad mark.
Fig. 7	*Zonalapollenites trilobatus* Balme. Pb 5319, sl. 1, coord. 40.1 - 115.7, diam. 63 micra. Specimen with circular saccus outline and irregularly folded and distorted nexinal central body.
Fig. 8	*Zonalapollenites trilobatus* Balme. Pb 5315, sl. 1, coord. 47.5 - 122.8, diam. @ 50 micra. Note symmetrical nexinal folding to produce triangular aspect of central body.
Fig. 9	*Zonalapollenites trilobatus* Balme. Pb 5330, sl. 5, coord. 39.1 - 121, diam. @ 55 micra.
Fig. 10	*Zonalapollenites trilobatus* Balme. Pb 5319, sl. 2, coord. 47.5 - 119.5, diam. 43 micra. Triangular outline of central body due to symmetrical folding of nexine.
Fig. 11	*Zonalapollenites trilobatus* Balme. Pb 5319, sl. 1, coord. 37.8 - 120.3, diam. 36 micra. Nexinal central body completely separated from sexine. Note symmetrical folding resulting in triangular outline.

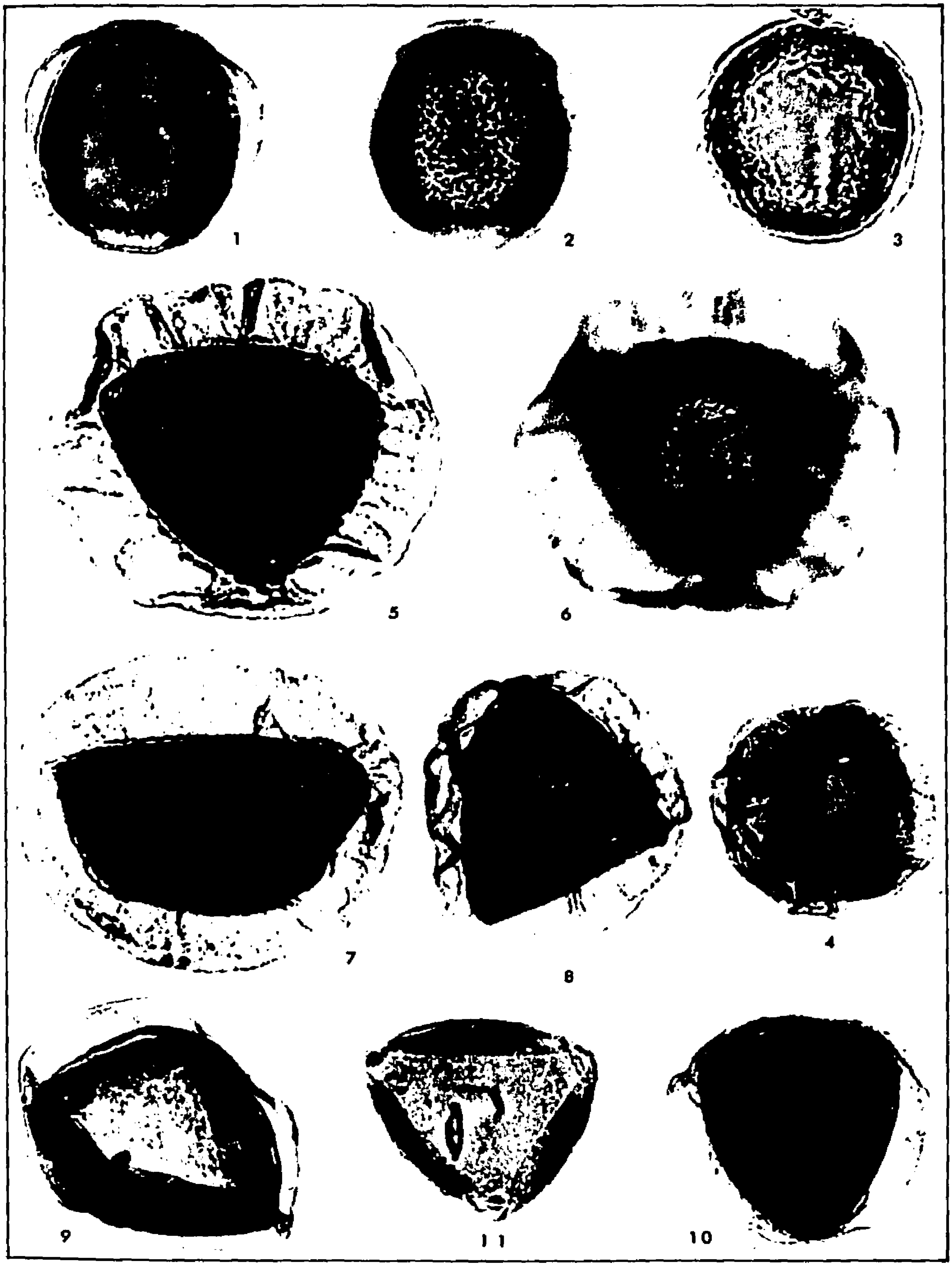

PLATE 14

PLATE 15

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Fig. 1	*Vitreisporites pallidus* (Reiss) Nilsson. Pb 5329, sl. 8, coord. 42.1 - 126,4, total width 35 micra.
Fig. 2	*Vitreisporites pallidus* (Reiss) Nilsson. Pb 5319, sl. 6, coord. 36.7 - 117, total width 25 micra.
Fig. 3	*Vitreisporites sp.* Pb 3679, sl. 1, coord. 41.4 - 128.8, total width 31 micra.
Fig. 4	*Pityosporites sp.* Pb 5312, sl. 2, coord. 41.8 - 121.9, total width 42 micra. Lateral view.
Fig. 5	*Alisporites sp.* "*A*". Pb 5313, sl. 8, coord. 31.9 - 121.4, total width 54 micra. Overall aspect showing equatorial outlines of sacci and central body, and infrareticulum of sacci and infrapunctation of cappa.
Figs. 6, 7	*Alisporites sp.* "*A*". Pb 3712, sl. 1, coord. 51.3 - 118.3, total width 50 micra. Fig. 6 - Focus on sacci and equatorial outline of central body. Fig. 7 - Focus on cappa showing delicately infrapunctate sexine.
Fig. 8	*Alisporites sp.* "*B*". Pb 5330, sl. 13, coord. 46.4 - 124, total width 36 micra.
Fig. 9	*Alisporites sp.* "*B*". Pb 5330, sl. 2, coord. 33.4 - 121.9, total width 54 micra.
Figs. 10, 11	*Pityosporites sp.* "*A*". Pb 5319, sl. 1, coord. 49.5 - 120.3, total width @ 50 micra, actual 42 micra. Fig. 10 - Focus on sacci with slightly constricted bases, and on equatorial outline of central body. Fig. 11 - Focus on infrapunctation of cappa sexine.
Figs. 12, 13	*Pityosporites sp.* "*A*". Pb 5319, sl. 3, coord. 34.4 - 112.4, total width 42 micra, extrapolated width @ 46 micra. Fig. 12 - Focus on sacci. Fig. 13 - Focus on cappa showing sexinal infrapunctation.
Fig. 14	*Pityosporites sp.* "*A*". Pb 5319, sl. 4, coord. 40.5 - 117.1, total width 44 micra. Aberrant grain showing unequal saccus development.

Fig. 15 *Podocarpidites sp.* Pb 5315, sl. 3, coord. 48.5 - 109.4, total width 53 micra. Overall aspect of grain. Note marginal crest developed at equatorial lateral extremities of cappa.

Fig. 16 *Alisporites* (?) *sp.* Pb 5313, sl. 3, coord. 40.9 - 120.3, total width 40 micra.

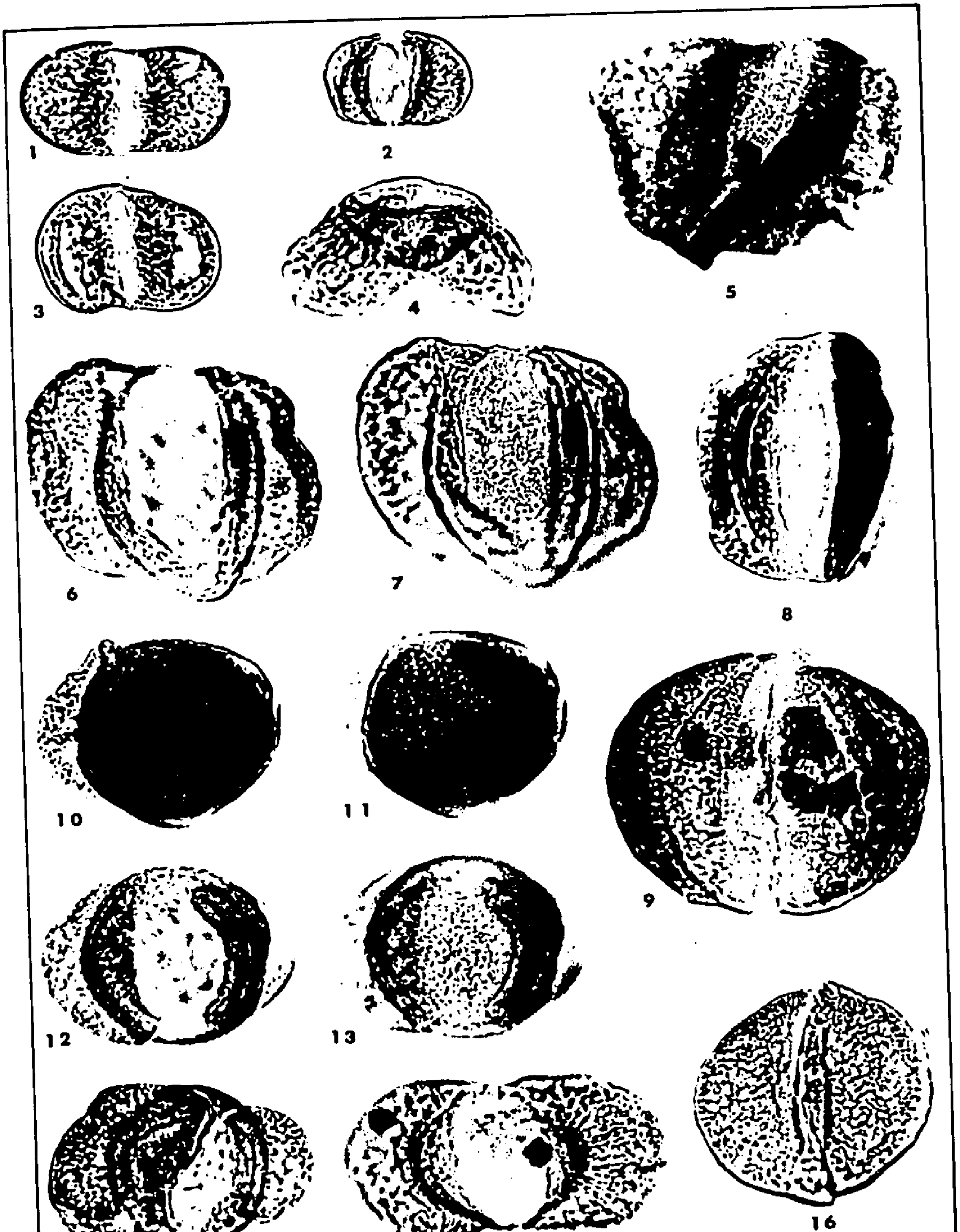

PLATE 15

PLATE 16

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Fig. 1	*Alisporites sp.* "*C*". Pb 5330, sl. 10, coord. 41.2 - 117.1, total width 58 micra.
Figs. 2, 3	*Alisporites sp.* "*C*". Pb 3679, sl. 1, coord. 38.9 - 113, total width 68 micra. Fig. 2 - Focus on equatorial outline. Fig. 3 - Focus on infrapunctate sexine of cappa.
Fig. 4	*Podocarpidites sp.* "*A*". Pb 5319, sl. 2, coord. 35.4 - 113.9, total width extrapolated @ 66 micra.
Fig. 5	*Pityosporites* (?) *sp.* Pb 3712, sl. 2, coord. 40.5 - 124.3, total width 34 micra.
Figs. 6, 7	*Podocarpidites sp.* Pb 5330, sl. 8, coord. 41.2 - 114.9, total width 58 micra. Fig. 6 - Focus on sacci and on distal surface of central body showing outline of sulcus. Fig. 7 - Focus on equatorial outline of central body and on proximal surface of cappa.
Figs. 8, 9	*Podocarpidites sp.* "*B*". Pb 5319, sl. 1, coord. 44.7 - 119.4, total width 56 micra. Fig. 8 - Focus on sacci. Note connection of sexine of sacci across longitudinal extremities of central body at equatorial region. Sulcus occupies most of distal face. Fig. 9 - Focus on ornamentation of cappa.
Fig. 10	*Podocarpidites sp.* "*B*". Pb 5330, sl. 2, coord. 40.3 - 126, total width 44 micra.
Fig. 11	*Podocarpidites sp.* "*B*". Pb 5315, sl. 3, coord. 38.9 - 112.3, total width 43 micra, extrapolated width @ 50 micra.
Figs. 12, 13	*Aumancisporites cretaceus* Pocock. Pb 5315, sl. 4, coord. 43.9 - 115.2, total width @ 40 micra. Fig. 12 - Focus on striated sexine of proximal surface. Fig. 13 - Focus on collapsed thickened lips flanking distal sulcus, and on rudimentary saccus at lateral extremities of grain.
Figs. 14, 15	*Eucommiidites sp.* "*B*". Pb 5330, sl. 11, coord. 35 - 120.5, total length 26 micra. Fig. 14 - Focus on distal face and sulcus.

Fig. 15 - Focus on pitted proximal surface. A pair of arcuate tenuitates are present near equatorial lateral margins.


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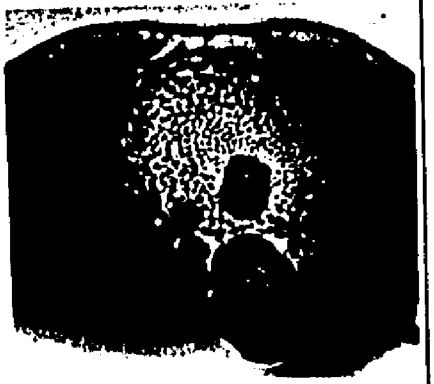
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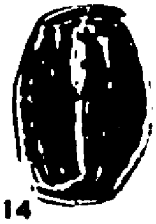
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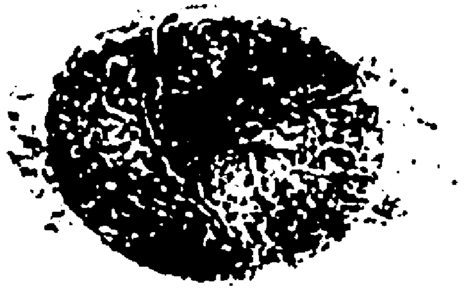
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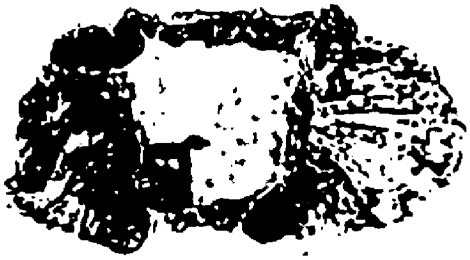
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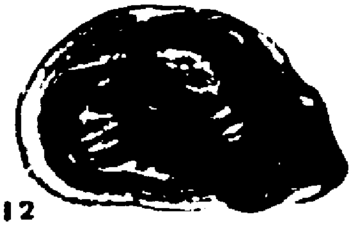
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PLATE 16

PLATE 17

(All figures X 1000)

Figs. 1, 2	*Podocarpidites sp.* Pb 5330, sl. 1, coord. 39 - 127.9, total width 79 micra. Fig. 1 - Focus on sacci and on exine stratification at polar region of proximal cappa. Fig. 2 - Focus on sexinal ornamentation of cappa.
Figs. 3, 4	*Podocarpidites sp.* Pb 5319, sl. 1, coord. 38.7 - 118.8, total width 74 micra. Fig. 3 - Focus on cappa and equatorial outline of central body. Fig. 4 - Focus on ornamentation of cappa.
Figs. 5, 6	*Podocarpidites sp.* Pb 5319, sl. 4, coord. 37 - 114.7, total width 65 micra. Fig. 5 - Focus on sacci and on equatorial outline of central body. Note marginal crest at equator of central body. Fig. 6 - Focus on ornamentation of cappa.
Figs. 7, 8	*Podocarpidites sp.* Pb 5330, sl. 5, coord. 49.5 - 112.9, total width 57 micra. Fig. 7 - Focus on sacci and on equatorial marginal crest of central body. Fig. 8 - Focus on sexinal ornamentation of cappa.
Fig. 9	*Podocarpidites sp.* Pb 5330, sl. 2, coord. 48 - 116.6, total width 42 micra.

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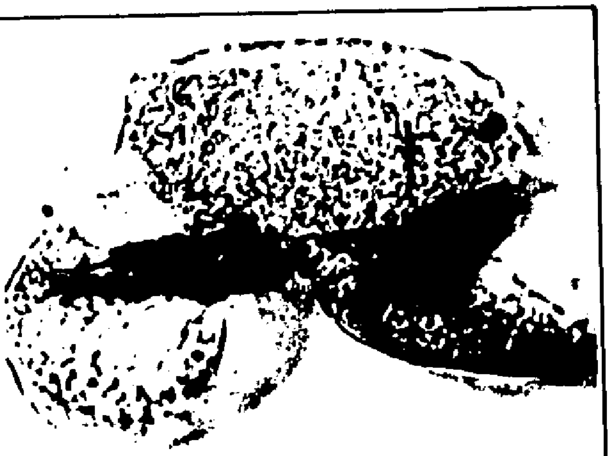

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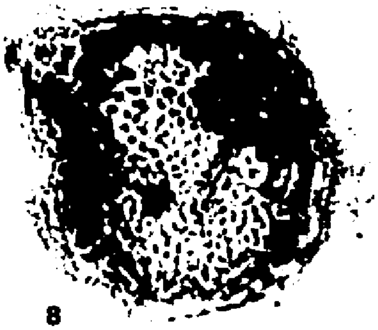

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PLATE 17

PLATE 18

(All figures X 1000 unless indicated otherwise)

Figs. 1, 2, 3	*Phyllocladidites sp.* "*A*". Pb 5319, sl. 1, coord. 41.2 - 111.4, total width 43 micra. Fig. 1 - Focus on sacci, showing radial folding near distal bases, and indistinct infrareticulum. Fig. 2 - Focus on equatorial outline of central body. Note lack of thickened distal saccus bases flanking distal sulcus. Fig. 3 - (X 2000) Focus on thickened, sexinal protuberance at equatorial lateral extremities of cappa, and on verrucate ornamentation of proximal surface.
Figs. 4, 5	*Phyllocladidites sp.* "*A*". Pb 5330, sl. 9, coord. 31.4 - 110.2, total width 38 micra. Fig. 4 - Focus on bulbous sacci with constricted bases and lacking thickened distal bases flanking sulcus. Fig. 5 - Focus on verrucate sexine of cappa.
Figs. 6, 7	*Phyllocladidites sp.* "*B*". Pb 5319, sl. 1, coord. 35.9 - 118.8, total width 49 micra. Fig. 6 - Focus on relatively wide, womewhat pointed sacci bearing well-developed thickened bases flanking distal sulcus. Fig. 7 - Focus on verrucate proximal sexine of cappa and on thick distal saccus bases flanking sulcus.
Fig. 8	*Phyllocladidites sp.* Pb 3653, sl. 1, coord. 34.3 - 125, total width 30 micra. Specimen shows narrow, elongate-oval distal sulcus.
Figs. 9, 10	*Phyllocladidites sp.* "*B*". Pb 5319, sl. 2, coord. 46.1 - 128.9, total width 46 micra. Fig. 9 - Focus on sacci and thickened distal saccus bases flanking rectangular sulcus. Fig. 10 - Focus on coarse, verrucate sexine of cappa.
Figs. 11, 12	*Phyllocladidites sp.* "*C*". Pb 5319, sl. 1, coord. 39.7 - 127.7, total width 32 micra. Fig. 11 - Focus on thin, weakly inflated sacci. Fig. 12 - Focus on equatorial outline of central body and on cappa.
Figs. 13, 14	*Phyllocladidites sp.* "*C*". Pb 5315, sl. 3, coord. 43.1 - 109.2, total width 39 micra. Fig. 13 - Focus on sacci. Fig. 14 - Focus on central body.

Figs. 15, 16, 17 *Phyllocladidites sp.* Pb 5330, sl. 8, coord. 39.5 - 112.6, total width 42 micra. Fig. 15 - Focus on sacci. Fig. 16 - Focus on equatorial outline of central body, and on sulcus flanked by thickened distal saccus bases. Fig. 17 - Focus on ornamentation of cappa sexine.

PLATE 18

(All figures X 1000 unless indicated otherwise)

Figs. 1, 2, 3	*Phyllocladidites sp. "A"*. Pb 5319, sl. 1, coord. 41.2 - 111.4, total width 43 micra. Fig. 1 - Focus on sacci, showing radial folding near distal bases, and indistinct infrareticulum. Fig. 2 - Focus on equatorial outline of central body. Note lack of thickened distal saccus bases flanking distal sulcus. Fig. 3 - (X 2000) Focus on thickened, sexinal protuberance at equatorial lateral extremities of cappa, and on verrucate ornamentation of proximal surface.
Figs. 4, 5	*Phyllocladidites sp. "A"*. Pb 5330, sl. 9, coord. 31.4 - 110.2, total width 38 micra. Fig. 4 - Focus on bulbous sacci with constricted bases and lacking thickened distal bases flanking sulcus. Fig. 5 - Focus on verrucate sexine of cappa.
Figs. 6, 7	*Phyllocladidites sp. "B"*. Pb 5319, sl. 1, coord. 35.9 - 118.8, total width 49 micra. Fig. 6 - Focus on relatively wide, somewhat pointed sacci bearing well-developed thickened bases flanking distal sulcus. Fig. 7 - Focus on verrucate proximal sexine of cappa and on thick distal saccus bases flanking sulcus.
Fig. 8	*Phyllocladidites sp.* Pb 3653, sl. 1, coord. 34.3 - 125, total width 30 micra. Specimen shows narrow, elongate-oval distal sulcus.
Figs. 9, 10	*Phyllocladidites sp. "B"*. Pb 5319, sl. 2, coord. 46.1 - 128.9, total width 46 micra. Fig. 9 - Focus on sacci and thickened distal saccus bases flanking rectangular sulcus. Fig. 10 - Focus on coarse, verrucate sexine of cappa.
Figs. 11, 12	*Phyllocladidites sp. "C"*. Pb 5319, sl. 1, coord. 39.7 - 127.7, total width 32 micra. Fig. 11 - Focus on thin, weakly inflated sacci. Fig. 12 - Focus on equatorial outline of central body and on cappa.
Figs. 13, 14	*Phyllocladidites sp. "C"*. Pb 5315, sl. 3, coord. 43.1 - 109.2, total width 39 micra. Fig. 13 - Focus on sacci. Fig. 14 - Focus on central body.

Figs. 15, 16, 17 *Phyllocladidites sp.* Pb 5330, sl. 8, coord. 39.5 - 112.6, total width 42 micra. Fig. 15 - Focus on sacci. Fig. 16 - Focus on equatorial outline of central body, and on sulcus flanked by thickened distal saccus bases. Fig. 17 - Focus on ornamentation of cappa sexine.

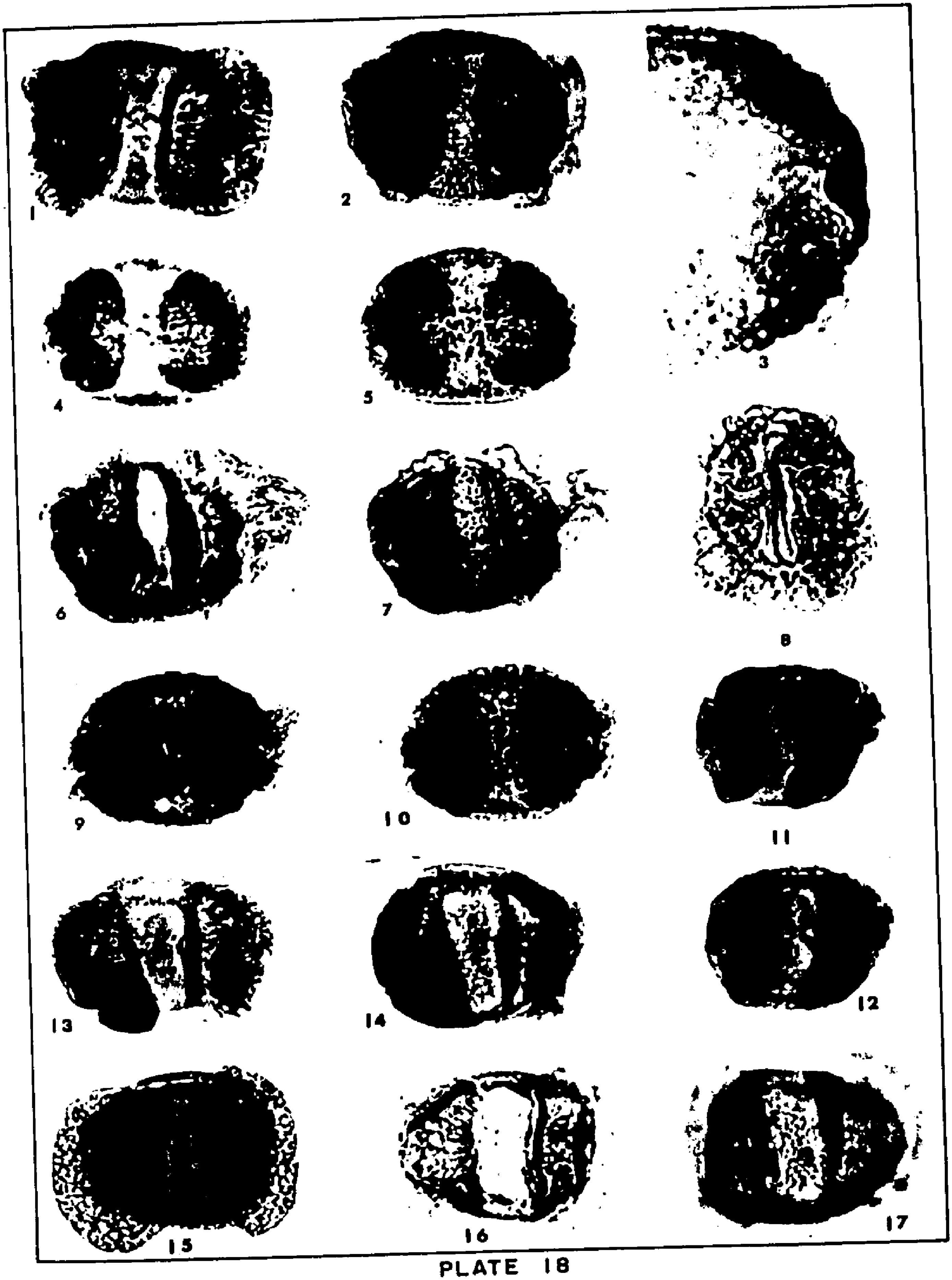


PLATE 18

PLATE 19

(All figures X 1000)

Figs. 1, 2	*Phyllocladidites sp.* "*D*". Pb 3653, sl. 1, *coord. 33.5 - 127.1*, total width 36 micra. Fig. 1 - Focus on thin, weakly inflated sacci. Fig. 2 - Focus on oval-shaped central body.
Fig. 3	*Phyllocladidites sp.* "*D*". Pb 5330, sl. 6, *coord. 39.6 - 123.8*, total width 33 micra. Overall aspect, showing small, thin, weakly inflated sacci distally attached to oval central body.
Figs. 4, 5	*Phyllocladidites sp.* Pb 5330, sl. 6, coord. *41.9 - 124.4, total* width 35 micra. Fig. 4 - Focus on sacci. Fig. 5 - focus on equatorial outline of central body.
Figs. 6, 7	*Phyllocladidites sp.* "*E*". Pb 5315, sl. 2, *coord. 40.2 - 112, total* width 29 micra. Fig. 6 - Focus on small sacci and on slightly thickened sexinal margin at equator of central body. Fig. 7 - Focus on ornamentation of sexine of cappa.
Figs. 8, 9	*Phyllocladidites sp.* "*E*". Pb 5315, sl. 2, *coord. 36.6 - 120.9*, total width 30 micra. Fig. 8 - Focus on sacci. Fig. 9 - Focus on equatorial outline of central body and on sexinal ornamentation of cappa.
Figs. 10, 11	*Phyllocladidites sp.* "*E*". Pb 3653, sl. 2, *coord. 41.9 - 122.7*, total width 36 micra. Fig. 10 - Focus on sacci. Fig. 11 - Focus on thickened equatorial margin of central body and on ornamentation of cappa.
Figs. 12, 13	*Phyllocladidites sp.* "*F*". Pb 5319, sl. 1, *coord. 31.4 - 116.3*, total width 42 micra. Fig. 12 - Focus on relatively large sacci with delicate infrareticulum. Fig. 13 - Focus on distinct, thickened distal saccus bases flanking sulcus, and on similar exinal thickenings at equatorial region of central body.
Fig. 14	*Phyllocladidites sp.* Pb 5315, sl. 3, coord. *42 - 127.1, total* width 34 micra.

Figs. 15, 16 *Phyllocladidites sp.* "*F*". Pb 5319, sl. 1, coord. 30.5 - 119.3, total width 30 micra. Fig. 15 - Focus on sacci. Fig. 16 - Focus at equatorial plane, showing conspicuous thickened distal saccus bases extending full length of central body, and considerably shorter proximal saccus bases recessed in from equatorial outline of central body. A peripheral circular band of similarly thickened exine connects distal and proximal saccus bases.

Figs. 17, 18 *Phyllocladidites sp.* "*F*". Pb 5315, sl. 4, coord. 38 - 119.8, total width 34 micra. Fig. 17 - Focus on sacci. Fig. 18 - Focus on equatorial plane showing long, thickened, distal saccus bases, and shorter, recessed, proximal saccus bases connected by circular band of thick exine at equatorial margin of central body.

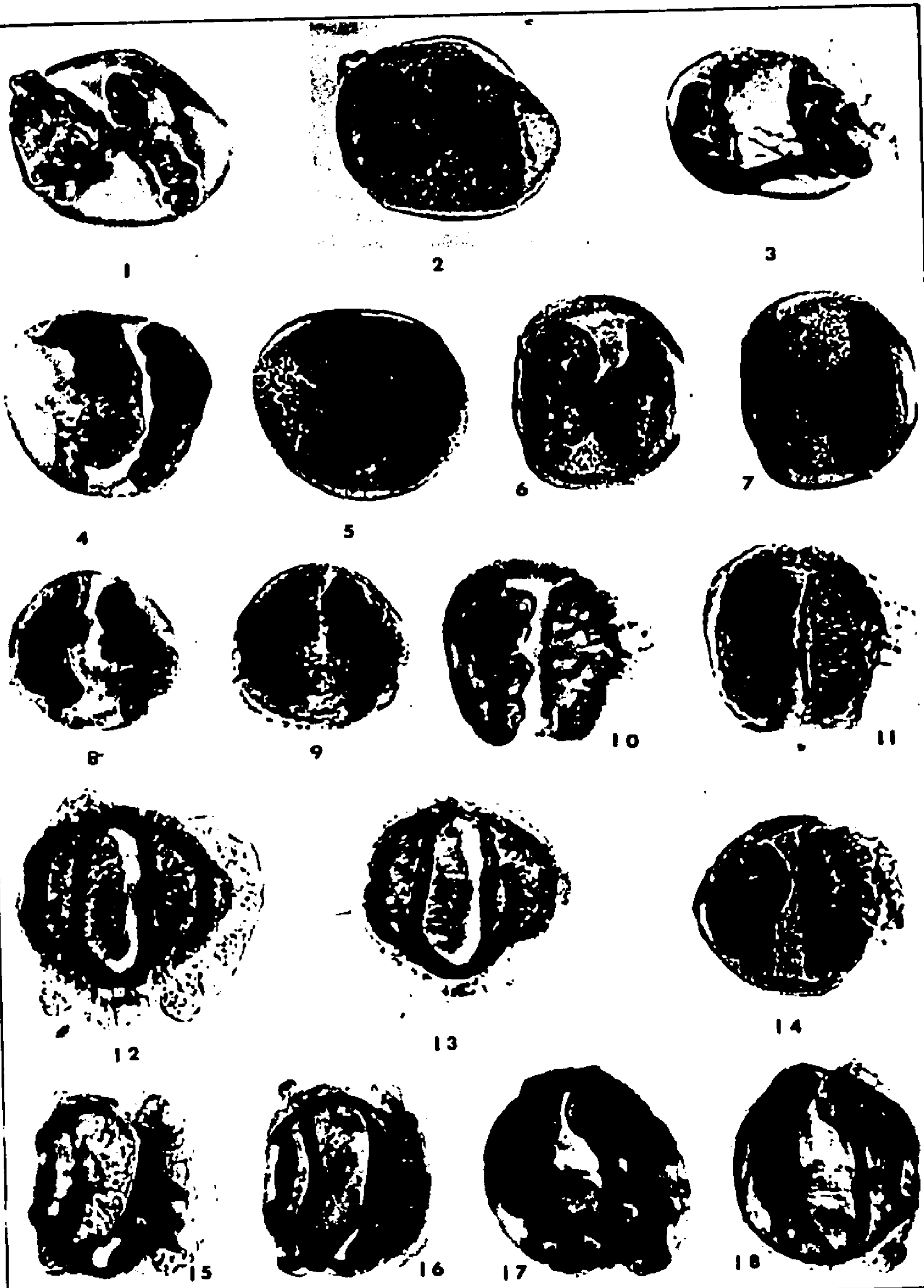


PLATE 19

PLATE 20

(All figures X 1000)

Figs. 1, 2	*Phyllocladidites sp.* Pb 3679, sl. 2, coord. 33.7 - 117.2, total width 44 micra. Fig. 1 - Focus on sacci. Fig. 2 - Focus on equatorial outline of oval central body.
Figs. 3, 4	*Phyllocladidites sp.* Pb 5315, sl. 4, coord. 47.1 - 126.1, total width 25 micra. Fig. 3 - Focus on equatorial outline and verrucate sexine of cappa. Fig. 4 - Focus on distal surface showing narrow sulcus flanked by rudimentary or underdeveloped frill-like sacci.
Fig. 5	*Podocarpidites* (?) *sp.* Pb 5328, sl. 5, coord. 34.6 - 119.8, total width 70 micra. Two focus levels showing nature of sacci and ornamentation of cappa sexine. Sacci are connected equatorially across longitudinal extremities of central body.
Figs. 6, 7	*Phyllocladidites sp.* Pb 5330, sl. 8, coord. 46 - 111.4, total width 20 micra. Fig. 6 - Focus on small thin sacci of an extremely small pollen grain. Fig. 7 - Focus on ornamentation of cappa.
Fig. 8	*Phyllocladidites sp.* Pb 5330, sl. 6, coord. 45.6 - 113.7, total width 26 micra.
Figs. 9, 10	*Phyllocladidites sp.* "*C*". Pb 3653, sl. 3, coord. 28.1 - 121.9, total width 28 micra. Fig. 9 - Focus on thin, weakly inflated sacci. Fig. 10 - Focus on sexine ornamentation of cappa.
Figs. 11, 12	*Phyllocladidites sp.* "*C*". Pb 5315, sl. 2, coord. 41.9 - 122.5, total width 27 micra. Fig. 11 - Focus on sacci. Fig. 12 - Focus on sexine ornamentation of cappa.
Fig. 13	*Phyllocladidites* (?) *sp.* Pb 5330, sl. 3, coord. 30.5 - 123.8, total width 30 micra.
Fig. 14	*Phyllocladidites sp.* Pb 5330, sl. 3, coord. 45.7 - 122.1, total width 30 micra.
Fig. 15	*Phyllocladidites* (?) *sp.* Pb 5330, sl. 6, coord. 43.4 - 121.4, total width 32 micra.

Fig. 16	*Phyllocladidites sp.* Pb 3712, sl. 1, coord. 42.5 - 126.3, total width 33 micra.
Fig. 17	*Phyllocladidites sp.* Pb 5315, sl. 2, coord. 36.4 - 114, total width 41 micra.
Figs. 18, 19	Unknown monosaccate (?) pollen. Pb 5319, sl. 1, coord. 33.2 - 126.6, total width 38 micra. Fig. 18 - Focus on distal face showing oval sulcus completely surrounded by convolute saccus attached entirely distally. This may be an aberrant bisaccate grain of the genus *Phyllocladidites*. Fig. 19 - Focus on circular equatorial outline of central body and on verrucate sexine of cappa.
Figs. 20, 21	Unknown monosaccate (?) pollen. Pb 5319, sl. 1, coord. 38.4 - 125.9, total diam. 33 micra. Fig. 20 - Focus on distal face showing subcircular sulcus completely surrounded by weakly inflated saccus. This may be an aberrant bisaccate grain of the genus *Phyllocladidites*. Fig. 21 - Focus on equatorial outline of circular central body.
Figs. 22, 23	Unknown monosaccate (?) pollen. Pb 5319, sl. 1, coord. 44.7 - 123.1, total width 31 micra. Fig. 22 - Focus on sacci almost completely surrounding irregularly shaped distal sulcus. Fig. 23 - Focus on equatorial outline of central body.

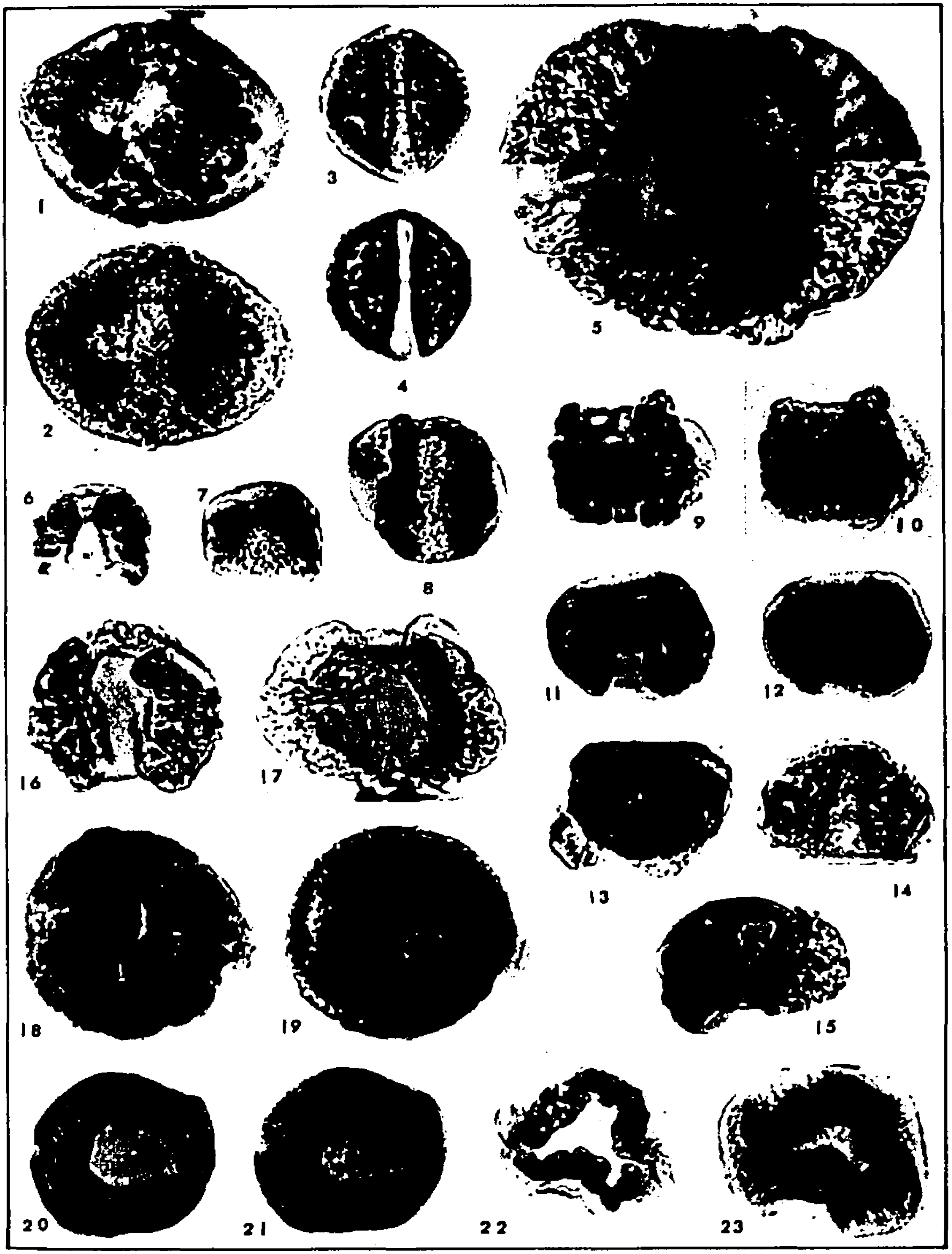
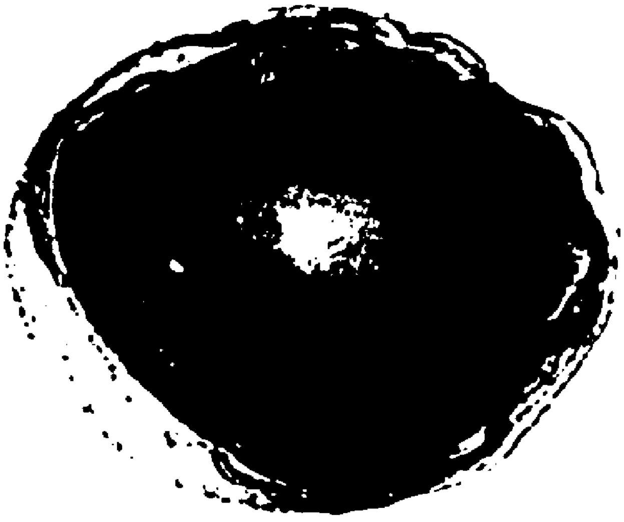


PLATE 20

PLATE 21

(All figures X 1000)

Fig. 1	*Inaperturopollenites* sp. "A". Pb 5319, sl. 1, coord. 34.9 - 116.1, diam. 72 micra. Specimen shows considerable separation of sexine and nexine.
Fig. 2	*Inaperturopollenites* sp. "A". Pb 5319, sl. 1, coord. 34.1 - 109.8, diam. 65 micra.
Fig. 3	*Inaperturopollenites* sp. "A". Pb 5330, sl. 5, coord. 33 - 114.7, diam. 55 micra.
Fig. 4	*Inaperturopollenites* sp. "A". Pb 5313, sl. 6, coord. 49.8 - 122.2, diam. 44 micra.
Fig. 5	*Pityosporites* sp. Pb 5330, sl. 7, coord. 36.1 - 116.3, total width 42 micra.
Figs. 6, 7	Undetermined Pollen Genus "A". Pb 5329, sl. 8, coord. 34 - 120.9, length 51 micra. Fig. 6 - Focus on possible sulcate structure and on terminal saccate (?) projections. Fig. 7 - Focus on pitted exine.
Fig. 8	Undetermined Pollen Genus "A". Pb 5319, sl. 1, coord. 41.5 - 118.3, length 44 micra. Specimen showing characteristic rupture splitting grain in two halves.
Fig. 9	Undetermined Pollen Genus "A". Pb 5319, sl. 1, coord. 46.2 - 118.7, length 42 micra.
Fig. 10	Undetermined Pollen Genus "A". Pb 5313, sl. 1, coord. 43.2 - 117.7, length 46 micra.
Fig. 11	Undetermined Pollen Genus "A". Pb 5319, sl. 1, coord. 35.5 - 126.4, length 39 micra.
Fig. 12	Undetermined Pollen Genus "A". Pb 5329, sl. 9, coord. 33.5 - 127, length 36 micra.
Fig. 13	Undetermined Pollen Genus "A". Pb 5315, sl. 2, coord. 38 - 117.7, length 32 micra.
Fig. 14	Undetermined Pollen Genus "A". Pb 5313, sl. 3, coord. 36 - 121.9, length 34 micra.
Figs. 15, 16	Undetermined Pollen Genus "A". Pb 5330, sl. 6, coord. 45.4 - 118, length 40 micra. Fig. 15 - Focus on possible sulcate structure. Fig. 16 - Focus on pitting of exine.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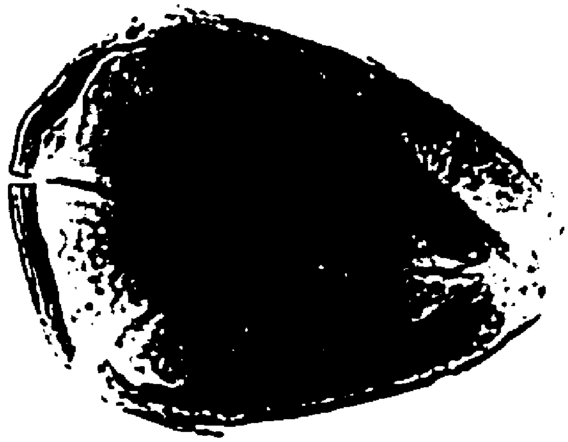
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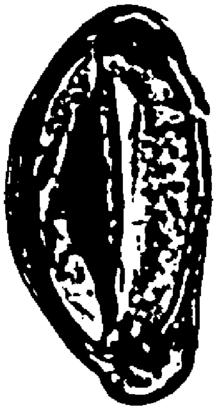
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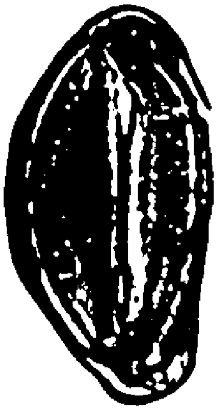
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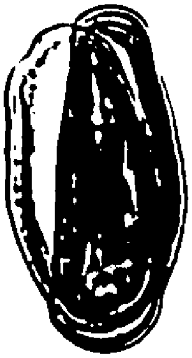
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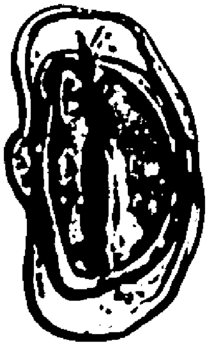
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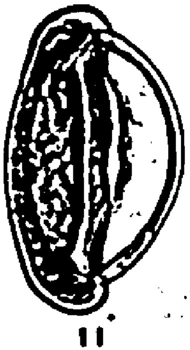
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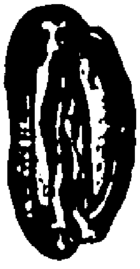
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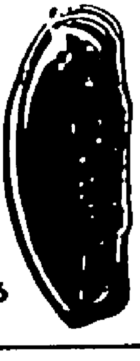
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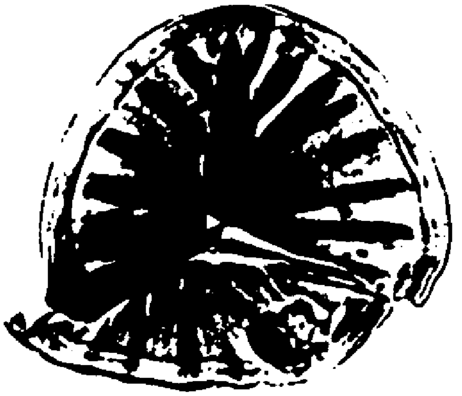
PLATE 21

PLATE 22

(All figures X 1000 unless indicated otherwise)

Fig. 1	*Emphanisporites sp.* (Reworked). Pb 5330, sl. 9, coord. 30.5 - 114.5, diam. 50 micra. A characteristic Devonian spore with radial exinal thickenings.
Fig. 2	*Verrucososporites* (?) *sp.* (Reworked?). Pb 5319, sl. 6, coord. 38.2 - 117.3, length 34 micra. This may be a reworked Pennsylvanian monolete spore.
Fig. 3	*Baltisphaeridium sp.* (Reworked?). Pb 5330, sl. 7, coord. 30.4 - 118.6, diam. 47 micra.
Fig. 4	*Baltisphaeridium sp.* (Reworked). Pb 5330, sl. 7, coord. 28 - 126.4, diam. 45 micra.
Fig. 5	*Veryhachium sp.* (Reworked) (Phase contrast). Pb 5330, sl. 6, coord. 33.1 - 122.1, diam. @ 37 micra. Probably reworked from Devonian or older strata.
Fig. 6	*Tasmanites sp.* (X 500) (Reworked). Pb 5330, sl. 5, coord. 44 - 111.5, diam. @ 110 micra. Similar to frequently occurring forms in Devonian sediments.
Fig. 7	*Leiofusa sp.* (X 250) (Reworked). Pb 5330, sl. 8, coord. 28 - 124.7, length 256 micra. Similar forms are common in some Devonian sediments of Michigan.
Fig. 8	*Baltisphaeridium* (?) *sp.* (Reworked?). Pb 5330, sl. 11, coord. 47.7 - 117.1, total diam. @ 80 micra.
Fig. 9	*Leiosphaeridia sp.* (Reworked). Pb 5330, sl. 9, coord. 36.5 - 112.5, diam. 62 micra. A commonly occurring palynomorph in Devonian strata of Michigan.
Fig. 10	Scolecodont (X 500) (Reworked?). Pb 5330, sl. 7, coord. 43.6 - 115.2, length 126 micra. Probably a reworked Paleozoic annelid worm jaw.



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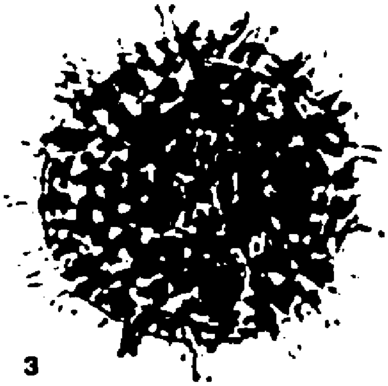

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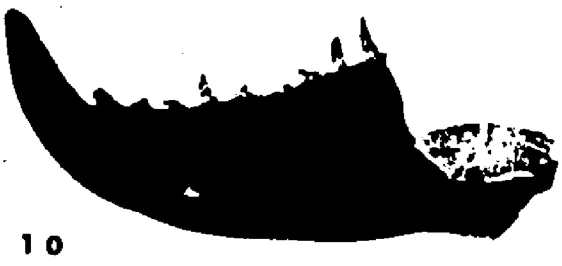

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PLATE 22

APPENDIX

APPENDIX

List of wells from which samples were obtained for palynological analyses. Listings include company and well name, location, permit number, repository catalogue number, and depth interval and Michigan State University maceration number for each sample studied. Sources of samples included repositories at Michigan State University (MSU), the University of Michigan (MU), and the Michigan Geologic Survey (MGS).

Table 2 - List and Location of Wells Sampled

Well	Location	Permit	Catalogue No.	Depth	MSU Mac. No.
		Clare County			
Sohio #1 Loker	sec. 7-17N-6W	10687	MSU 3945	570-585'	Pb 3717
Bauer #1 Loker	sec. 7-17N-6W	16914	MSU 5739	560-570'	Pb 3713
				595-600'	Pb 3719
				600-610'	Pb 3705
				640-650'	Pb 3695
				690-695'	Pb 3696
Pure #1 Root	sec. 7-18N-4W	12236	MGS 17-7-C	650-660'	Pb 5319
Sohio #1 McKay	sec. 33-18N-4W	13364	MGS 23-1-R	500-510'	Pb 5331
				570-580'	Pb 5316
Burton #1 Thompson	sec. 13-18N-5W	10380	MSU 4355	645-656'	Pb 3551
				656-665'	Pb 3679
				665-674'	Pb 3662
				674-688'	Pb 3680
				688-694'	Pb 3663
				720-722'	Pb 3666
				738-762'	Pb 3664
				836-842'	Pb 3665
		Isabella County			
Mogul #1A Dent	sec. 5-15N-6W	13018	MGS 22-6-L	490-500'	Pb 5332
				580-590'	Pb 5318
Brazos #1 State-Sherman	sec. 21-15N-6W	19842	MGS 40-3-C	440-500'	Pb 5311
Mich. O. & G. #1 Parker	sec. 7-16N-3W	1149	MGS 21-7-L	300-305'	Pb 5320
				325-330'	Pb 5321
				370-375'	Pb 5314

Well	Location	Permit	Catalogue No.	Depth	MSU Mac. No.
Wickland #1 Gamble	sec. 23-16N-5W	12635	MGS 18-6-R	420-440'	Pb 5324
				490-510'	Pb 5325
				510-520'	Pb 5326
Sohio #1 Gilmore	sec. 25-16N-5W	11849	MSU 4496	330-340'	Pb 3693
				340-350'	Pb 3686
				390-400'	Pb 3691
				420-430'	Pb 3692
				510-520'	Pb 3729
				560-570'	Pb 3685
				680-690'	Pb 3721
				700-710'	Pb 3694A
				750-760'	Pb 3720
Sohio #1 Chapman	sec. 30-16N-6W	12182	MGS 17-6-C	580-590'	Pb 5315
				610-620'	Pb 5333
		Kent County			
McGerry #1 Vanderhyde	sec. 14-9N-11W	12966	MGS 15-3-R	303-312'	Pb 5328
Mich. Consol. #1 Phillips	sec. 3-10N-10W	11288	MSU 4218	520-530'	Pb 5310
		Mecosta County			
Gulf #1 Warner	sec. 21-15N-7W	9841	MSU 3516	600-610'	Pb 3698
				670-680'	Pb 3676
				680-690'	Pb 3675
				700-710'	Pb 3723
				710-720'	Pb 3724
				730-740'	Pb 3672
				780-790'	Pb 3673
				780-790'	Pb 3697
				790-800'	Pb 3674

Well	Location	Permit	Catalogue No.	Depth	MSU Mac. No.
Gulf #1 Colfax Project	sec. 9-15N-9W	--	MSU 3819	520-525'	Pb 3507
				550-555'	Pb 3684
				555-560'	Pb 3508
				610-615'	Pb 3722
				625-630'	Pb 3510
Gulf #2 Colfax Project	sec. 1-15N-10W	--	MSU 3825	400-405'	Pb 3656
				405-410'	Pb 3677
				415-420'	Pb 3657
				455-460'	Pb 3661
				480-485'	Pb 3660
				490-495'	Pb 3653
				495-500'	Pb 3655
				560-565'	Pb 3678
				590-595'	Pb 3658
				600-605'	Pb 3659
				670-675'	Pb 3654
Gulf #2 Compson	sec. 6-16N-7W	10630	MSU 3890	565-570'	Pb 3513
				580-585'	Pb 3514
				595-600'	Pb 3725
				615-620'	Pb 3515
				630-635'	Pb 3726
				660-665'	Pb 3516
				665-670'	Pb 3727
				670-675'	Pb 3728
				675-680'	Pb 3517
				695-700'	Pb 3518
Gulf #3 Bottoroff	sec. 1-16N-8W	11260	MSU 4075	590-600'	Pb 3716
				635-640'	Pb 3715
				680-685'	Pb 3714
				680-685'	Pb 3714A
				700-705'	Pb 3701

Well	Location	Permit	Catalogue No.	Depth	MSU Mac. No.
Gulf #2 Daggy	sec. 1-16N-8W	11154	MSU 4046	605-610'	Pb 3667A
				605-630'	Pb 3667
				610'615'	Pb 3668
				620-625'	Pb 3671
				630-635'	Pb 3702
				645-650'	Pb 3670
				670-675'	Pb 3703
				720-725'	Pb 3669
				730-735'	Pb 3700
	Montcalm County				
Sun #1 Martens	sec. 36-11N-8W	11099	MU 17-H	490-500'	Pb 5309
Union #1 Douglas	sec. 3-12N-8W	11919	MSU 4424	435-440'	Pb 3683
				530-535'	Pb 3712
				540-550'	Pb 3682
				580-590'	Pb 3706
				600-610'	Pb 3707
				620-630'	Pb 3708
				630-640'	Pb 3681
Gordon #1 Paris	sec. 6-12N-8W	10922	MSU 4223	510-520'	Pb 3688
			"	560-570'	Pb 3689
			"	600-610'	Pb 3687
			"	680-690'	Pb 3690
			MU 24-A	460-500'	Pb 5312
			"	510-520'	Pb 5313
	Newaygo County				
Sun #1 Woodard-Brown	sec. 29-12N-11W	17132	MGS 25-3-C	445-450'	Pb 5323
				490-495'	Pb 5334

Well	Location	Permit	Catalogue No.	Depth	MSU Mac. No.
Sun #5 Cons. Power	sec. 28-13N-11W	14886	MGS 27-1-C	490-495'	Pb 5322
Cordell #1 Gorman	sec. 31-13N-11W	16361	MGS 10-2-L	387-390'	Pb 5329
Pure #1-A Miller	sec. 23-14N-11W	15127	MGS 17-4-R	591-599'	Pb 5330
		Osceola County			
Slusser #1 Wood	sec. 22-17N-7W	16192	MGS 27-7-C	585-590'	Pb 5327
Pure #1-A Haist	sec. 25-17N-10W	11282	MSU 4108	630-640'	Pb 3718
				670-680'	Pb 3699
Pure #1-A Jones	sec. 24-19N-7W	10009	MSU 3640	580-585'	Pb 5305
				570-575'	Pb 5306
				560'565'	Pb 5307