THE PALYNOLOGY AND PALEOECOLOGY OF THE PIERRE SHALE (CAMPANIAN-MAESTRICHTIAN) OF NORTHWESTERN KANSAS AND ENVIRONS

THESIS FOR THE DEGREE OF Ph.D.

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JAMES MONROE LAMMONS

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This is to certify that the

thesis entitled

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ABSTRACT

THE PALYNOLOGY AND PALEOECOLOGY
OF THE PIERRE SHALE (CAMPANIAN - MAESTRICHTIAN)
OF NORTHWESTERN KANSAS AND ENVIRONS

By

James Monroe Lammons

The Pierre Shale of northwestern Kansas and environs has been subdivided into four palynological zones. In ascending order these are: Palynologic Zone I, characterized by various species of the genera *Proteacidites*, *Tricolpites*, *Triporites* and the dinoflagellate *Gillinia*; Palynologic Zone II, with a microfossil flora that includes species of the genera *Sphagnum*, *Undulatisporites*, and *Acanthotriletes*; Palynologic Zone III, dominated by the marked development and diversification of the genera *Aquilapollenites*, *Proteacidites*, and *Osmundasporites*, and Palynologic Zone IV, characterized by a heterogeneous assemblage of numerous fern spores, dicotyledonous pollen, fungal spores and dinoflagellates. Based on the distribution patterns of each of five selected palynomorph groups during each of the four time divisions of the Pierre Shale (Palynologic Zones, I, II, III and IV), inferences are made concerning the paleoecology, bottom conditions and source areas during the deposition of the Pierre Shale in northwestern Kansas and environs.

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James Monroe Lammons

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CHAPTER I

INTRODUCTION

This study of the palynomorphs separated from the Pierre Shale by chemico-mechanical maceration was undertaken with the following objectives in view:

(1) to identify and describe the principal types of spores and pollen, acritarchs, dinoflagellates and other palynomorphs present;

(2) to establish and define any discernible floral changes during Pierre time;

(3) to relate the assemblages of the various entities in the microfossil flora to the ecologic and climatic conditions at various time levels within the Pierre;

(4) to demonstrate that the accepted zonation of the Pierre Shale in surface exposures can be successfully projected to the subsurface sections.

Published descriptions of the megafossil floras of units elsewhere in North America that are correlative in time with the Pierre are compared with the palynomorph assemblages reported here.

Palynological studies of the Upper Cretaceous in North America are increasing in number. Published and unpublished studies have been summarized (Table 1) and also illustrated (Figure 1).

The area originally considered (and sampled) for inclusion in this thesis included several additional subsurface sections in

Washington and Lincoln counties (Colorado) and surface sections in northeastern Nebraska, southeastern South Dakota and central South Dakota. Because of various factors, these sections were deleted from the present study.

The present study is primarily concerned with the utilization of the palynological method in the zonation and correlation of the Pierre Shale. The palynological data thus derived were coordinated with previously published paleontological, paleobotanical and sedimentological data. The principal result of this effort is a better understanding of a portion of the eastern shelf of the epicontinental seas of Pierre time. Inferences concerning the composition of the plant cover in areas believed to have been the source of both the Pierre sediments and the enclosed plant microfossils, are based on the composition of the acid-resistant residues derived from the lithified Pierre sediments.

All sample material, reserve residues and prepared microslides are stored in the Palynological Collection, Michigan State University, East Lansing, Michigan.

Table 1.--Published and unpublished palynological studies of the Upper Cretaceous and related sequences in North America

Author(s)	Date	Location	Remarks[1]
Agasie, J. M.	1969	Coconino County, Arizona	Cenomanian (1)
Ames, H. T.	1951	Central Colorado	Campanian (2)
Anderson, R. Y.	1960	Eastern San Juan Basin, N. M.	Campanian-Maestrich. (3)
Binda, P. L. & S. K. Srivastava	1968	Southern Alberta, Canada	Upper Cretaceous (4)
Brenner, G. J.	1963	Northcentral Maryland	Lower Cretaceous (5)
Brown, C. W. & R. L. Pierce	1962	Northeast Texas	Turonian (6)
Cahoon, E. J.	1964	Northwestern South Dakota	Lower Cretaceous (7)
Clarke, R. T.	1963	Canyon City Area, Colorado	Maestrich.-Danian (8)
________	1965	Central Colorado	Late Cretaceous (9)
Crickmay, C. H. & S. A. J. Pocock	1963	Vancouver, B. C., Canada	Campanian-Eocene (10)
Dickinson, R. G., E. G. Leopold & R. F. Marvin	1968	San Juan Mountains, Colorado	Campanian-Maestrich. (11)
Drugg, W. B.	1967	West of Fresno, California	Late Cret.-early Tert. (12)
Ellis, C. H. & R. H. Tschudy	1964	Denver Basin, Colorado	Albian-Cenomanian (13)

[1]Numbers following each entry (in parentheses) denote its designation on Figure 1 (page

Table 1.--Continued

Author(s)	Date	Location	Remarks
Funkhouser, J. W.	1961	Rawlins Uplift, Wyoming	Maestrichtian (14)
Gartner, S.	1968	Texas and Arkansas	Late Cretaceous (15)
Gerhard, J. E.	1958	Harding City, South Dakota	Paleocene (16)
Gray, T. C. & J. J. Groot	1966	Delaware and New Jersey	Senonian (17)
Gray, R. J., R. M. Pataski & N. Schapiro	1966	Central Utah	Upper Cretaceous (18)
Grayson, J. F. & R. L. Pierce	1959	Central Texas	Upper Cretaceous (19)
Griesbach, F. R.	1956	Southwestern Wyoming	Late Cretaceous (20)
Groot, J. J. & J. S. Penny	1960	Maryland and Delaware	Lower & Upper Cret. (21)
Groot, J. J., J. S. Penny & C. R. Groot	1961	Eastern United States	Cenomanian-Santonian (22)
Habib, D.	1969	Bahama Islands, W.I.	Albian-early Cenom. (23)
Hail, W. J. Jr. & E. B. Leopold	1960	North Park, Colorado	Paleocene-Eocene (24)
Hall, J. W.	1963	Western Iowa	Cenomanian (25)
______	1967	Northeastern Maryland	Turonian (26)
______ & N. J. Norton	1967	Garfield, McCone Counties Montana	Late Cret.- early Tert. (27)

Table 1.--Continued

Author(s)	Date	Location	Remarks
______ & N. M. Peake	1968	Springfield, Minnesota	Cenomanian (28)
______ & N. P. Swanson	1968	Dawson County, Montana	Maestrichtian (29)
______ & ______	1968	Springfield, Minnesota	Cenomanian (30)
Hedlund, R. W.	1963	Bryan County, Oklahoma	Cenomanian (31)
______	1966	Bryan County, Oklahoma	Cenomanian (32)
______	1967	Bryan County, Oklahoma	Cenomanian (33)
Hills, L. & E. Jensen	1966	Olds area, Alberta, Canada	Campanian (34)
______ & J. Weiner	1965	Princeton, B.C., Canada	Upper Cretaceous (35)
Hoff, J. H.	1960	Central South Dakota	Campanian-Maestrich. (36)
Howell, R. H. Jr.	1954	Central Colorado	Maestrichtian (37)
Kimyai, A.	1964	New Jersey, Long Island	Early Late Cret. (38)
______	1966	New Jersey, Long Island	Early Late Cret. (39)
Leffingwell, H. A.	1962	Eastern Wyoming	Maestrichtian (40)
______	1966	Lance area, Wyoming	Late Cretaceous (41)
Leopold, E. B. & H. M. Pakiser	1964	Western Alabama	Cenoman.-Coniacian (42)
______ & B. Tschudy	1965	Eastern Wyoming	Campanian-Maestrich. (43)

Table 1.--Continued

Author(s)	Date	Location	Remarks
McGregor, D. C.	1959	Northern Canada	Mesozoic (44)
———	1965	Arctic Canada	Triassic-Low. Cret. (45)
McLaughlin, R. E.	1957	Western Tennessee	Late Cretaceous (46)
Miner, E. L.	1935	Cascade, Carbon Counties, Montana	Cretaceous-Tertiary (47)
Newman, K. R.	1961	Northwest Colorado	Paleocene-Lage Cret. (48)
———	1964	Northwestern Colorado	Late Cret.-Paleocene (49)
———	1965	Rio Blanco City, Colorado	Late Cret.-Paleocene (50)
Norton, N. J.	1963	Hell Creek, Montana	Campanian-Maestrich. (51)
———	1965	Garfield County, Montana	Late Cretaceous (52)
———	1966	Montana, Great Plains	Late Cretaceous (53)
———	1966	Montana, Great Plains	Late Cretaceous (54)
——— & J. W. Hall	1967	Eastern Montana	Danian (55)
Pierce, R. L.	1961	Minnesota	Lower Upper Cret. (56)
———	1962	Minnesota	Lower Upper Cert. (57)
Potter, D. R.	1963	Cimarron County, Oklahoma	Lower Cretaceous (58)

Table 1.--Continued

Author(s)	Date	Location	Remarks
Radforth, N. W. & G. E. Rouse	1954	Western Canada	Late Cretaceous (59)
Rouse, G. E.	1956	Canada	Cretaceous (60)
________	1957	Western Canada	Upper Cretaceous (61)
________	1959	British Columbia	Early Tertiary (62)
________	1962	Vancouver, B.C., Canada	Late Cret.-Tertiary (63)
Sarmiento, R.	1957	Eastern Utah, Western Colorado	Cenoman.-Campanian (64)
Saulnier, H. S.	1950	Red Lodge, Montana	Paleocene (65)
Schemel, M. P.	1950	Western Iowa	Cenomanian (66)
Shoemaker, R. E.	1966	Central Montana	Campanian (67)
Slean, R. E.	1964	Garfield, McCone Counties Montana	Late Cret.-Paleocene (68)
Srivastava, S. K.	1965	Scollard, Alberta, Canada	Maestrichtian (69)
________	1966	Scollard, Alberta, Canada	Maestrichtian (70)
________	1967	Scollard, Alberta, Canada	Maestrichtian (71)
________	1967	Scollard-Drumheller area, Alberta, Canada	Maestrichtian (72)

Table 1.--Continued

Author(s)	Date	Location	Remarks
________	1967	Scollard, Alberta, Canada	Maestrichtian (73)
________ & P. L. Binda	1967	Alberta and Saskatchewan	Late Cretaceous (74)
Srivastava, S. K.	1968	Scollard, Alberta, Canada	Maestrichtian (75)
________	1968	East Coulee, Alberta, Canada	Maestrichtian (76)
Stanley, E. A.	1960	Northwestern South Dakota	Maestrichtian (77)
________	1961	Northwestern South Dakota	Maestrichtian (78)
________	1961	Northwestern South Dakota	Maestrichtian (79)
________	1965	Northwestern South Dakota	Maestrich.-Tert. (80)
Steeves, M.	1959	Long Island, New York	Cenoman.-Santonian (81)
Stone, J. F.	1967	Central Texas	Turonian (82)
Stover, L. E.	1964	Near Baltimore, Maryland	Lower and Upper Cret. (83)
Tabbert, R. L.	1966	Eastern Alaska	Upper Cretaceous (84)
Tasch, P., K. McClure & O. Oftedahl	1964	Clarke County, Kansas	Albian (85)
Trotter, C. E.	1963	Harding County, South Dakota	Paleocene (86)
Tschudy, R. H.	1961	Colorado-Wyoming Rickies	Late Cret.-Tert. (87)

Table 1.--Continued

Author(s)	Date	Location	Remarks
________	1965	Near Chambersburg, Pennsylvania	Turonian-Campanian (88)
________	1966	Colbert County, Alabama	Late Cretaceous (89)
________	1966	Mississippi Embayment & northern Rocky Mountains	Late Cretaceous.- Tert. (90)
________ & H. M. Pakiser	1967	Calloway County, Kentucky	Maestrichtian (91)
Upshaw, C. F.	1959	Near Dubois, Wyoming	Upper Cretaceous (92)
________	1963	Fremont County, Wyoming	Upper Cretaceous (93)
________	1964	Near Dubois, Wyoming	Upper Cretaceous (94)
Wheelwright, M. V.	1958	Northeastern Utah & southwestern Wyoming	Late Cretaceous (95)
Zaitzeff, J. B.	1967	South central Texas	Campanian-Maestrich. (96)

es of Upper Cretaceous
h America
) March, 1969

Figure 1
Published & Unpublished Palynological Studies of Upper Cretaceous
& Related Sequences in North America
J.M. Lammons *(Numbers refer to TABLE 1)* March, 1969

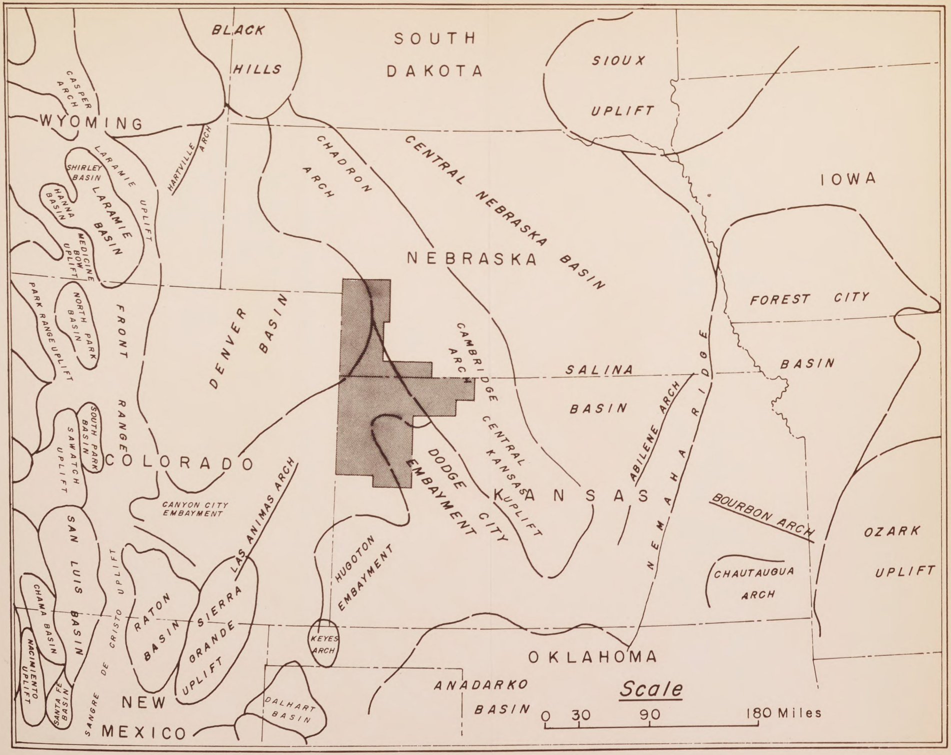

Figure 2
Setting of Study Area Relative to Major Geologic Features
(Based on geological map provided by J. H. Fisher, M.S.U.)

J.M. Lammons March, 1969

CHAPTER II

STRATIGRAPHY OF STUDY AREA

Regional Stratigraphy

Lewis and Clark referred to the prominent bluffs of Pierre Shale along the Missouri River (Coues, 1893, p. 113-130) and secured fossil collections in the vicinity of Fort Pierre that provided the first verification of the existence of Cretaceous rocks in that region (Meek and Hayden, 1858, p. 117). Nuttall (1821, p. 26) examined the Pierre on his trip of 1810 and noted the pyrite rich basal unit of the Pierre (the Sharon Springs Member). The top and base of the Pierre were designated in the sections measured by Meek and Hayden in 1853. Hall and Meek (1855, p. 405) subdivided the section into units designated by numbers only. This system prevailed until 1862 when Meek and Hayden (1862, p. 419) applied the name Fort Pierre to a portion of the previously delineated section ("Formation No. 4"). Meek and Hayden noted that the Fort Pierre Group, as originally defined (1862, p. 424-425), ". . . composes all the hills on both sides of the Missouri at Fort Pierre, and much of the country between there and the Badlands". The same authors noted that the Pierre reappears on the upper Missouri in the Milk and Muscle [sic] Shell River region. It has also been identified in Saskatchewan (Dawson, 1859, p. 18). Shumard (1860) described Cretaceous strata in Texas that contain

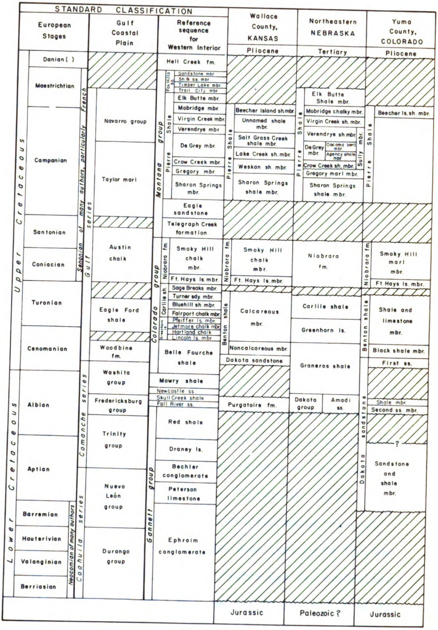

Figure 3

Terminology of Cretaceous Units

N.W. Kansas, E. Colorado & N.E. Nebraska

(adapted from Cobban and Reeside, 1952)

fauna similar to that described by Meek and Hayden. Williston (1897) recognized the Pierre in Kansas by its vertebrate content. Elias (1931) studied the Pierre Shale of Wallace County, Kansas, and differentiated six members based on lithologic characteristics and fossil content. The members[1], as established by Elias, are still recognized and are useful for subdividing the surface exposure of the Pierre Shale in Kansas (Moore and others, 1951). Correlation between the subdivisions (members) of the Pierre in surface exposures and subsurface sections is difficult because of the lack of distinctive lithologic characteristics discernible by the available geophysical well-logging methods. The lowermost unit, the Sharon Springs Member, is commonly recognized in drilling operations in northwestern Kansas by its distinctive lithological characteristics. Merriam (1963, fig. 17) does not attempt to subdivide the Pierre in the subsurface of Kansas.

The Pierre Shale and strata approximately equivalent in age cover an area of approximately 600,000 square miles in the Western Interior of the United States (Reeside, 1944). The original extent of this unit must have been much greater, perhaps as great as postulated by Reeside (1957, fig. 16-20). Tourtelot (1962, p. 3-4) estimated that the original volume of Pierre sediments must have been about 225,000 cubic miles. This has been reduced to 175,000 cubic miles by erosion and uplift. The Pierre and its equivalents are now exposed over a total of approximately 90,000 square miles

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[1] "The 'zones' in the Pierre formation are established, not on a paleontological basis, but on a lithologic basis, and hence should be called members" (Hayes, 1950, p. 19).

Formation	Member	Characteristic Fauna Wallace County, Kansas Elias, 1931, 1933	Suggested Zonal Indices Western Interior of U.S. Cobban & Reeside, 1952	Zonal Indices - Pierre Shale Jarre Creek-Loveland, Colorado Scott & Cobban, 1965	Front Range, Colorado LeRoy & Schieltz, 1958	Palynologic Zones Northwest Kansas & Environs (This study)
Ogallala fm.	Ogallala fm.					No palynomorphs recovered from surface samples of this unit.
Pierre Shale	Beecher Island Shale Member	Tardinacara (Pseudoptera) fibrosa[1] Inoceramus sagensis[2] Baculites grandis Hall & Meek[3] Discoscaphites abyssinus (Morton)[5] Anchura americana[4] Baculites clinolobatus Elias[3] Discoscaphites conradi (Morton)[5]	Discoscaphites nicolletii Baculites grandis B. baculus			PALYNOLOGIC ZONE IV Engelhardtia cf. microfoveolata Aquilapollenites cf. pulvinus Osmundacidites comaumensis Fungal spores Selaginella sp. Leptolepidites sp. Reticuloidosporites dentatus Dinoflagellates (various species) Eisenackia sp.
Pierre Shale	Undifferentiated Shale Member	Baculites grandis Hall & Meek[3]		Baculites clinolobatus B. grandis B. baculus B. eliasi B. jenseni B. reesidei		
Pierre Shale	Salt Grass Creek Shale Member	Discoscaphites nicolleti var. saltgrassensis[5] Pteria cf. linguiformis[2] Baculites pseudovatus var. A Elias[3] B. compressus var. reesidei Elias[3] Acanthoscaphites nodosus s.s. (Owen)[5] A. nodosus var. brevis Meek[5] Scaphites reesidei Elias[3] S. plenus Meek[3] Baculites compressus var. reesidei Elias[3] B. pseudovatus var. A Elias[3]	Baculites compressus	Baculites cuneatus		
Pierre Shale	Lake Creek Shale Member	Scales & bones of small fishes Lingula[6] Baculites compressus var. reesidei Elias[3] B. compressus var. corrugatus Elias[3] None Serpula ( ) wallacensis Elias[7] Baculites compressus s.s.[3] Acanthoscaphites nodosus var. quadrangularis[5] Pholadomia hodgii[8] Anisomyon centrale[9] Baculites cf. ovatus[3]		B. compressus Didymoceras cheyennense Exiteloceras jenneyi		PALYNOLOGIC ZONE III Triporopollenites sp. Aquilapollenites sp. A A. cf. reticulatus A. polaris Proteacidites retusus Aquilapollenites sp. B A. reticulatus A. cf. pulvinus Trilites comaumensis
Pierre Shale	Weskan Shale Member — Upper	Fragments of Inoceramus sp. Serpula ( ) wallacensis Elias[7] Acanthoscaphites nodosus var. [5] Baculites compressus s.s.[3] Anomia subtrigonalis[10] Ostrea aff. lugubris[2] Crassatella evansi[2] Baculites compressus s.s.[3] B. pseudovatus[3] None Crassatella evansi[2]	Baculites gregoryensis	Didymoceras stevensoni D. nebrascence		
Pierre Shale	Weskan Shale Member — Lower	Anomia subtrigonalis[10] Amauropsis cf. punctatus[11]		Baculites scotti B. gregoryensis		PALYNOLOGIC ZONE II Sphagnum punctaesporites Acanthotriletes varispinosus Undulatisporites cf. sinuosis U. sinuosis
Pierre Shale	Sharon Springs Shale Member	Bones & scales of small fishes cf. Pteris haydeni[2] Heteroceras cf. tortum[3] Baculites aquilaensis[3] Protosphyroena gigas[12] Polycotylus latipinnis[13] Elasmosaurus platyurus[13] Tylosaurus sp.[14] Toxochelys lateremis[15]	Baculites asperiformis	B. perplexus B. asperiformis B. mclearni B. obtusus	Microsphere Zone Globigerina subcretacea Lomnicki[C] Bathysiphon arenacea Cushman[A] Fish teeth Haplophragmoides collyra Nauss[A] H. rugosa Cushman & Waters[A] Bathysiphon aff. B. carapitanus Hedberg[A] B. eocenica Cushman & Hanna[A] Anomalina sp.[C]	PALYNOLOGIC ZONE I Proteacidites thalmannii Tricolpites sp. A T. sp. B Corylus sp. Tricolpites sp. (=Sabbatia sp.) Gillinia cf. hymenophora
Niobrara fm.	Niobrara fm.	(No data given by Elias)	Desmoscaphites erdmanni Clioscaphites chateauensis C. vermiformis Scaphites depressus S. ventricosus	(No data given by Scott & Cobban)	Calcareous planktonic foraminifera (e.g., Globigerina, Gümbelina	No palynomorphs recovered from surface & subsurface samples of this formation.

KEY:
(1) Pseudoptera
(2) Dysodont pelecypod
(3) Ammonoid
(4) Strombaceoid gastropod
(5) Nautiloid
(6) Atremate brachiopod
(7) Annelid worm
(8) Desmodont pelecypod
(9) Pulmonate gastropod
(10) Isodont pelecypod
(11) Prosobranch gastropod
(12) Large fish
(13) Plesiosaur
(14) Mosasaur
(15) Marine turtle

KEY:
All forms listed are ammonoids.

KEY:
All forms listed are ammonoids.

KEY:
(A) Arenaceous foraminifera
(C) Calcareous foraminifera

NOTE:
Forms listed are not restricted to the palynologic zone in which they are noted.

Figure 4
Synthesis of Zonation of the Pierre Shale
(Compiled from various sources)

J.M. Lammons March, 1969

in the states of Montana, Wyoming, North Dakota, South Dakota, Nebraska, Kansas, Colorado, Utah and New Mexico. Tourtelot (op. cit.) also infers that a seaway connection between this area of Pierre and its equivalents and the Gulf Coast of Texas was present through eastern New Mexico and western Texas. This agrees with Schuchert's interpretation of the distribution of Campanian sediments (1955, p. 75). Reeside (1957) and Merriam (1963, p. 42) agree that the eastern shoreline of the Pierre Sea crossed Kansas in a northeast-southwest direction. There is, however, little agreement on the exact position of this boundary because of the unknown amount of post-Pierre erosion. Merriam (loc. cit.) suggests that the Pierre once covered a more extensive area of Kansas than at the present. The outliers of Pierre Shale east of the principal outcrop area in Kansas, as interpreted by Merriam (op. cit., fig. 18), include only the oldest portion of the formation (the Sharon Springs Member). Such sections are preserved by local structural adjustments (e.g., along Prairie Dog Creek, Phillips County, Kansas).

The area considered in the present dissertation represents a portion of the eastern shelf of the Pierre Sea. This interpretation was suggested by Tourtelot (1962, p. 10) and evidence for such an interpretation is in part obtained from a consideration of the thicknesses of the Pierre that can be measured today. The origin of the basal member of the Pierre (the highly organic, low-grade oil shales of the Sharon Springs Member) is somewhat enigmatic; possibly representing sedimentation in deeper waters some distance from the shelf. Reeside (1957, p. 530) suggests that black soils formed during the Santonian (Smoky Hills portion of the Niobrara) provided, through normal erosional processes, the black muds that later lithified as the black shales of the Sharon Springs. The character of the insoluble organic residues, recovered from the Sharon Springs Member during the present study, tends to refute Reeside's hypthesis. Morrow (1941, p. 93) believed that the area of Upper Cretaceous outcrops in Kansas is toward the eastern edge of the Montanan (Pierre) seaway. The eastern boundary cannot be placed on the basis of sedimentary characteristics because coarsening of the sediments toward the east is not clearly demonstrable. McLaughlin (1957, p. 5) also experienced difficulty in placing the eastern limit of the Cretaceous seas and noted that ". . . the eastern limit of the coastal plain in the Tennessee section of the Mississippi Embayment has been drawn by various authors at the western margin of the Highland Rim section of the Interior Low Plateau, at the Tennessee River, or at the innermost edge of Cretaceous sediments. Locally, all of these criteria break down, and commingling of coastal plain and plateau topographies and soils adds to the problem of distinguishing such a boundary."

The land area east of the seaway, as proposed by Reeside (1957), was probably quite low in relief and probably contributed very small amounts of detrital material to the Pierre seaway. The size of this positive feature, as shown by Reeside (1944, 1957, fig. 16-20), must have exerted great influence over the floras of the time. The effects of this lowland can be demonstrated by the floral elements present in the microfossil flora of the Pierre. Local, detailed studies of the Pierre have been made where potential oil and gas reserves are present (Lavington, 1933, Mather and others, 1928, Ball, 1924). Studies of this nature have never included a consideration of the plant microfossils. Osborne (1932) attempted to zone the Pierre, on a local basis, through the use of arenaceous foraminifera. LeRoy and Schieltz (1958) recorded the occurrence of arenaceous foraminifera in the Sharon Springs Member of the Pierre along the Front Range of Colorado. As far as can be ascertained, regional correlation of the members established by Elias (1931) has been made in limited areas only. The true relationship of the Pierre, from its indicated maximum thickness of 10,000 feet, near Fort Collins, Colorado, to its feather edge in northwestern Kansas, has not been resolved. There are at least three possible relationships, (1) progressive off-lap conditions so that sediments that were accumulating for a longer time are now represented by younger beds to the west, each member maintaining a more or less constant thickness eastward, (2) consistent thinning of each unit eastward so that the thinner sections in Kansas actually represent the same time interval as the thicker sections in eastern Colorado and southwestern Nebraska, (3) progressively greater erosion to the east. A combination of these conditions is entirely possible.

The regional dip at the end Cretaceous time was northwest, into the Denver Basin. This situation, according to Merriam and Frye (1954, p. 61), was possibly accentuated during Cenozoic time. Merriam (1963, p. 219 and Fig. 121) has demonstrated through isopachous mapping of the Dakota-Ogallala interval that significant movement took place in post-Niobrara time. Lee and Merriam

(1954, pp. 9-10) elaborate on the minor structures that may have been developed during late Cretaceous time in the area of the present study. These include a northward plunging syncline in eastern Thomas and western Gove counties and several other less-distinct folds, all of which maintain a northwestward trend and plunge into the Denver Basin. All of these features are discernible on Merriam's isopachous map of the Dakota-Ogallala ("Algal Limestone") interval (Merriam, 1963, fig. 121). Early tilting ". . . both before and after deposition of the "Algal limestone" . . ." (Merriam, loc. cit.) may be additional evidence for minor movements during the deposition of Palynologic Zone II time (during the deposition of the lower part of the Weskan Shale Member) as suggested elsewhere in the present study.

The accepted position of the Pierre in the Montana Group of the Gulfian Series (Upper Cretaceous) in the Mid-Continent region of the United States has been substantiated by the work of Elias (1931, 1933) and Cobban (1951, 1958). The Pierre Shale is the sole representative of the Montana Group in Kansas and is the uppermost Cretaceous section present in Kansas. Well-defined zones based primarily on ammonites (generally Baculites) have been successfully correlated with the European stages. Figure 4 summarizes the known paleontological data of the Pierre and/or its equivalents in the area considered in this dissertation. Because of its voluminous nature, the geochemical data gathered by Tourtelot and others from units correlatable with the Pierre in Montana and the Dakotas is not included here. Detailed geochemical studies similar to those conducted by Tourtelot, have

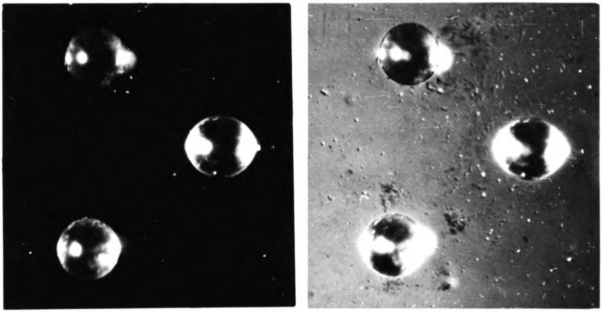

Figure 5.--Typical microspherules from the lower part of the Upper Sharon Springs Member of the Pierre Shale, outcrop section 5, Wallace County, Kansas. Diameters range from 482 to 498 microns. Left photo taken with reflected light only; right photo taken with combination of reflected and transmitted light.

not been undertaken on the Pierre of Kansas. LeRoy and Schieltz (1958) noted the occurrence of "microspheres" in the Sharon Springs Member of the Pierre Formation from various localities along the Front Range of the Rockies in Colorado. Spherules were also found in the Pierre of Kansas during the course of the present investigation, but are completely unlike those reported by LeRoy and Schieltz. Figure 5 illustrates the spherules recovered from samples of the Sharon Springs Member in Wallace County, Kansas. The Wallace County specimens are nearly spherical, although several exhibit pointed extensions that suggest features of cooling while in flight. Definite crystalline structures have not been observed in the Wallace County specimens. The occurrence of spherules in the Pierre of Kansas is limited to surface locality Wallace 5 (SE$\frac{1}{4}$ sec. 2, T. 13S.,R. 42 W.) where they occur in the lower part of the upper Sharon Springs Member.

Local Stratigraphy

Figure 6 summarizes the local stratigraphic relationships of the members of the Pierre in the area studied. The Pierre conformably overlies the Niobrara Formation in Wallace County, Kansas (Hodson, 1963, p. 47) but is apparently unconformable with the underlying formations elsewhere. Meek and Hayden (1862, p. 424) noted that the Pierre occupies sinkholes in the Niobrara, but failed to list localities where this relationship could be observed. LeRoy and Schieltz (1958) utilized micro-paleontological and geochemical methods to establish the presence of an unconformable contact between the Pierre (the Sharon Springs Member) and the

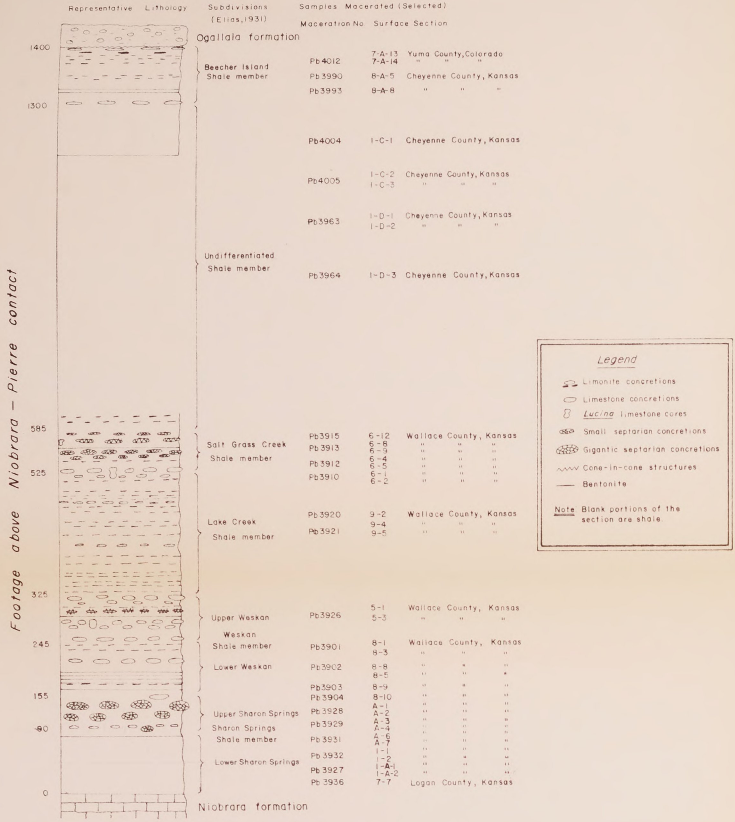

Figure 6

Generalized Composite Section of the Pierre Shale of Northwestern Kansas (modified from Elias, 1931)

J.M. Lammons March, 1969

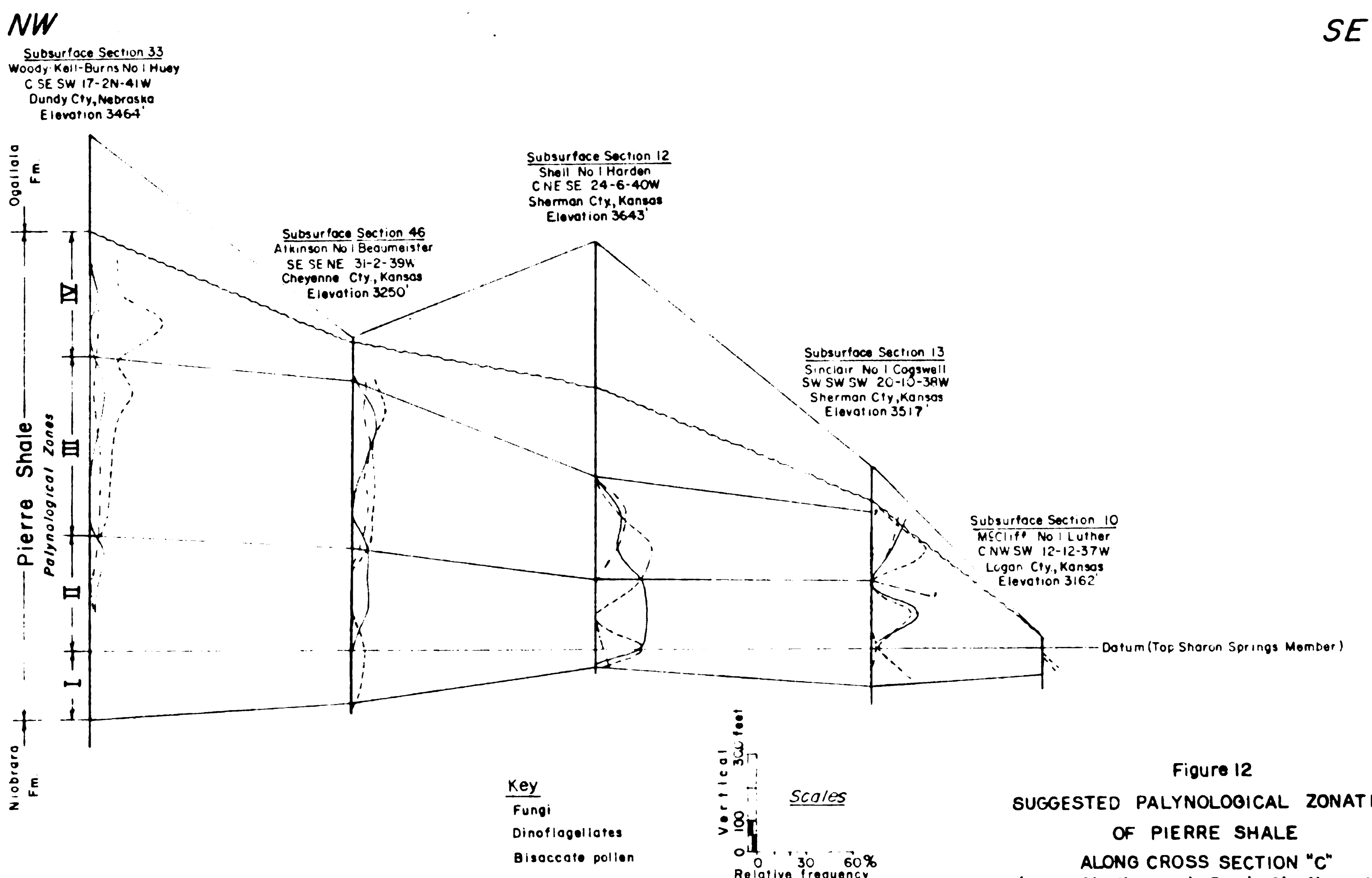

Figure 12
SUGGESTED PALYNOLOGICAL ZONATION
OF PIERRE SHALE
ALONG CROSS SECTION "C"
(Logan Cty., Kansas to Dundy Cty., Nebraska)
J.M.Lammons March, 1969

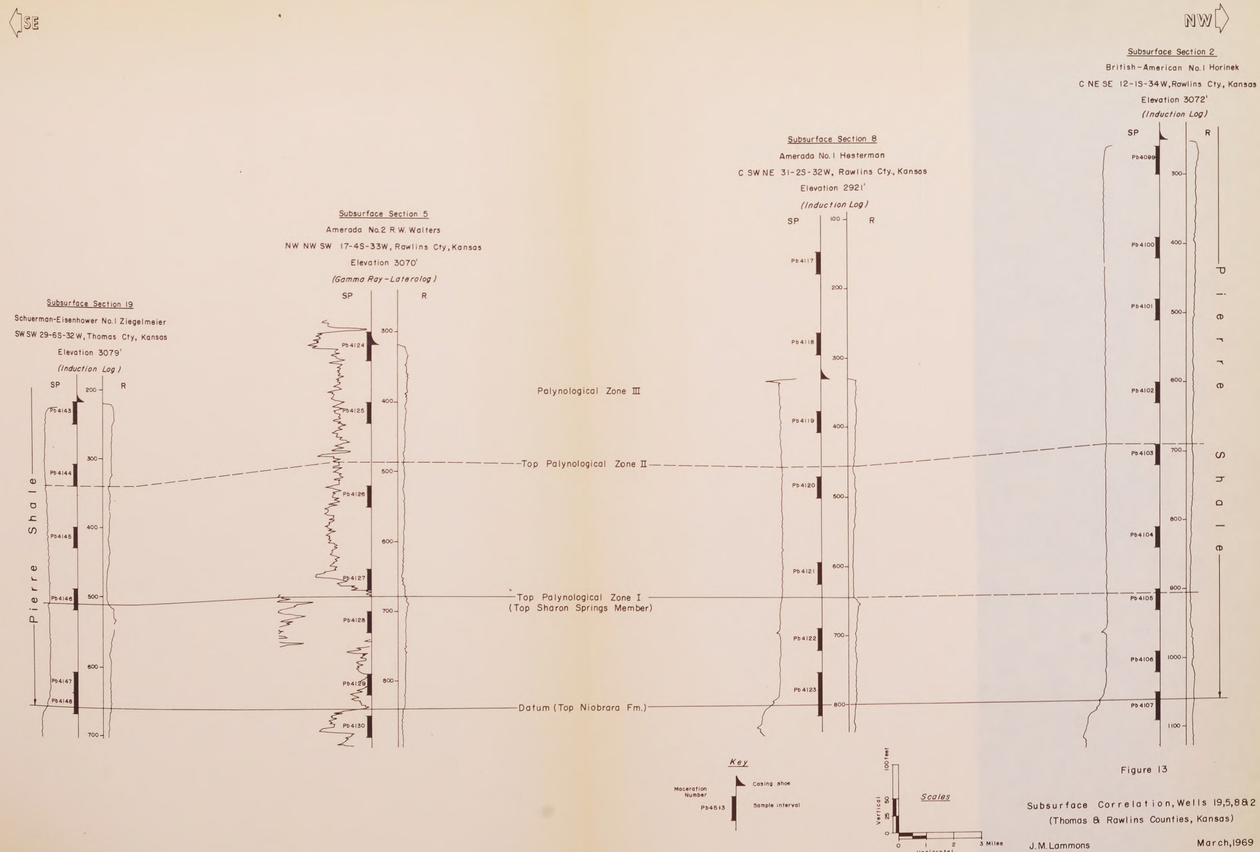

Figure 13

Subsurface Correlation, Wells 19,5,8&2
(Thomas & Rawlins Counties, Kansas)

J.M. Lammons March, 1969

Smoky Hills Member of the Niobrara in six sections along the Front Range of Colorado. The amount of time represented by this unconformity (if present in the area of the present study) could not be determined by a comparison of the plant microfossils of the Pierre and those of the underlying Niobrara. The Niobrara sediments and/or their environment of deposition, provided very unfavorable conditions for the preservation of spores and pollen. None of the thirty samples from the Niobrara yielded workable palynomorphs. The Pierre-Niobrara contact is difficult to discern in the field in many areas. Surface exposures of the contact typically include the gray, shaly limestones of the Smoky Hills Member of the Niobrara and the gray shales of the Pierre. The contact can usually be determined by testing for carbonates with dilute hydrochloric acid. The Smoky Hills Member is generally strongly calcareous and the overlying Pierre is rarely calcareous. The occurence of a calcareous Pierre section is many times closely related to the presence of calcareous concretions embedded in an otherwise noncalcareous matrix. In many areas, the Niobrara is a bench-former, contrasting sharply with the slope-forming Pierre. The placement of a group boundary at such an obscure contact has been challenged by several workers, but has been supported by Stanton (1893, p. 17) and Morrow (1941, p. 93). The widespread differences in the invertebrate remains of the Colorado and Montana Groups (i.e., between the faunas of the Niobrara and Pierre) are significant and are believed to constitute valid grounds for separating these two groups. The complex structural and facies relationships found by Tourtelot (1962) in the Pierre equivalents of Montana and

North Dakota are not apparent in the Pierre Shale of the area included in the present study.

The Pierre is unconformably overlain by Pliocene, Pleistocene or Recent sediments in the area studied. The overlying unit in much of northwestern Kansas, the Pliocene Ogallala Formation, is fluvial in nature and is composed of sand, gravel, silt and clay, with varying amounts of calcareous cement. The only rock types in the Ogallala that are favorable for the preservation of plant microfossils, the various clayey silt beds, are generally very calcareous, having been penetrated by ground waters carrying high concentrations of calcium carbonate from the interbedded limestone lentils. Occasional layers of volcanic ash and diatomaceous marl apparently do not contain plant remains other than algae.

The Pierre Shale has been subdivided by Elias (1931) as follows:

Beecher Island Shale Member (about 100 feet thick):

This unit is composed primarily of gray shale with some *Lucina-* bearing limestones near its upper boundary. Numerous limonite concretions and occasional cone-in-cone streaks are found in the upper and middle parts of this member. Thin beds of bentonite and large concretions of limestone occur near the base. The characteristic invertebrate fauna of this unit includes the following:

Tardinacara (Pseudoptera) fibrosa
Inoceramus sagensis
Baculites grandis
B. clinolobatus
Discoscaphites abyssinus
D. conradi
Anchura americana

Undifferentiated Shale Member (500 to 600 feet thick):

Elias studied only the upper 80 feet and the lower 30 feet of this unit. This member has been described by Elias (*op. cit.*) as a monotonous sequence of gray and black shales with occasional streaks of rusty limonite at its base.

Salt Grass Creek Shale Member (60 feet thick):

This unit consists of gray clay-shale with occasional thin bentonite beds. Abundant streaks of limonite concretions and many limestone concretions with cone-in-cone structures have been noted in this member. The characteristic invertebrate fauna of this unit includes the following:

Baculites pseudovatus var. *A*
B. compressus var. *reesidei*
Acanthoscaphites nodosus[1]
Discoscaphites nicolleti var. *saltgrassensis*
Pteris cf. *linguiformis*
Scaphites reesidei
S. olenus

Lake Creek Shale Member (200 feet thick):

This unit is composed of dark gray and black shales. Rare bentonite bands have been noted. Limestone and limonite concretions are common in this member. Gypsum bands are common, and at times abundant. The characteristic fauna of this unit includes the following:

Lingula sp.
Baculites compressus var. *reesidei*

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[1]The genus *Acanthoscaphites* was cited by Elias as "*Acantoscaphites*" [sic] twenty-six times in Bulletin 18 of the Kansas Geological Survey (1931). In a later publication (1933), Elias used the term "*Acantoscaphites*" at least once (p. 289). Insofar as I have been able to determine, these apparent typographical errors have not been corrected in later publications.

Baculites compressus var. corrugatus
Serpula (?) wallacensis
Baculites compressus s.s.
Acanthoscaphites nodosus var. quadrangularis
Scales and bones of small fishes.

Upper Weskan Shale Member (170 feet thick):

This unit consists of gray clay-shales containing several thin beds of bentonite. Large concretions of gray, unfossiliferous limestone have been noted. Occasional thin streaks of concretionary limonite and cone-in-cone limestone occur throughout this unit. The characteristic fauna of this unit includes the following:

Serpula (?) wallacensis n.sp.
Acanthoscaphites nodosus var. ?
Anomia subtrigonalis
Ostrea aff. lugubris
Crassatella evansi

Lower Weskan Shale Member (90 feet thick):

This unit is composed of gray clay-shales and commonly contains large limonite concretions. The upper portion of the Lower Weskan Shale commonly contains smaller concretions of limonite. The characteristic invertebrate fauna of this unit includes the following:

Anomia subtrigonalis
Anauropsis cf. punctatus

Sharon Springs Shale Member (155 feet thick):

This unit is a sequence of bituminous, black, low grade oil shales, occasionally interbedded with thin beds of light gray shale. Bentonite streaks have rarely been noted in this unit. The characteristic fauna of the Sharon Springs includes the following:

Pteris haydeni
Heteroceras cf. tortum
Baculites aquilaensis
Protosphyraena gigas
Polycotylus latipinnis
Elasmosaurus platyurus
Tylosaurus sp.
Toxochelys latiremis

CHAPTER III

FIELD DATA

Details concerning the location of surface and subsurface sections from which the rock samples were selected for the present study are included in Appendix A. A search of the oil, gas and water-well records, provided by the Kansas Geological Survey, has revealed that few samples of the Pierre have been preserved. Of the hundreds of oil and gas wells which have been drilled in the area considered in this dissertation, the samples of only thirty were available for examination. Some of the wells selected penetrated the Pierre at the surface. Some first penetrated thin soil layers or various thicknesses of the Pliocene Ogallala Formation before reaching the Pierre. The maximum known thickness of post-Pierre sediments found in any of the sections considered is approximately 100 feet.

Cursory examination of macerations of Ogallala sediments, in the well-sections studied, showed that the Ogallala is essentially barren of plant microfossils. This fact is possibly due to deep oxidation or aeration of the calcareous and conglomeratic Ogallala Formation. Additional examinations of surface exposures of the Ogallala were also barren. Because of this circumstance, contamination of the drill cuttings of the Pierre from overlying strata has been greatly minimized.

A similar condition of oxidation was found in the underlying Niobrara Formation. Only the uppermost part of the Niobrara was examined.

A check on the contemporary pollen contamination of the Pierre exposures was made in Logan County, Kansas. In this case, the pollen and spores in the sediments that had accumulated in a cattle watering tank after its first month of service were checked against the recovery from the outcrop samples less than a mile away. Bottom sediments contained in the Jake Reisler cattle tank in sec. 20, T. 15 S., R. 33 W., were prepared for study (Maceration No. Pb 4024). The contemporary pollen suite found in these sediments was comprised primarily of grains assignable to the families Gramineae and Compositae. The pollen of three closely allied genera of thistles, *Carduus*, *Cnicus* and *Cirsium* were especially common in the residue, but this abundance is probably due to the fact that these plants flourish in the disturbed area surrounding the water tank.

CHAPTER IV

SAMPLE PREPARATION AND STUDY PROCEDURES

All rock samples were crushed to coarse size, washed and dried overnight at 90°F., then crushed to fine size and weighed. A five gram fraction of the processed material was used from all surface samples; a weighed sample not exceeding two grams was used from all subsurface samples. The samples were placed in large urine tubes and covered with 50 milliliters of "Calgon"[1] solution. These were then clamped to a modified ball-mill and slowly rotated for a period of four to twenty-four hours. The entire sample and the Calgon solution were then transferred to 90 milliliter, round-bottom centrifuge tubes and thoroughly washed at least two times in distilled water. Centrifugation followed each wash. A short wash in dilute HCl (10%) was given the calcareous samples after the Calgon solution was discarded. All Pierre samples were subjected to 30 minutes of Schulze treatment after dissolution of the carbonates. The sample was washed free of the Schulze solution and centrifuged in a saturated solution of $ZnCl_2$ (sp. gr. 1.96) for 14 minutes at 1850 r.p.m. The float material (or light fraction) was decanted into another 90 milliliter tube. The amount of $ZnCl_2$

---

[1]"Calgon" is a mixture of sodium phosphate, soda ash and other carbonates of soda and is manufactured by the Calgon Corporation, Pittxburgh, Pa., under U.S. Patent 2494828.

decanted with the float material was replaced with an equal amount of fresh $ZnCl_2$ having the same specific gravity (1.96). A second crop of float material was secured by centrifugation and added to the first crop. The total amount of organic material that floated in the $ZnCl_2$ solution was then washed with distilled water three times. The residues were then checked microscopically to ascertain the condition of the extracted organic material, and were then bleached in a 1:5 mixture of household "Clorox" (0.525% sodium hypochlorite) for approximately one minute. A short treatment in NH_4OH (10%) or, in the cases of obviously oxidized samples, in K_2CO_3 (5%) followed. After several washes in distilled water, all samples were stained with a basic Safranin O solution. Depending upon the condition of the residue after separation, occasional samples necessitated overnight treatment in cold HF (47%) to remove silt-size silicates. A measured portion of each residue was mounted by the film method in "HEC" (hydroxyethyl cellulose) on cover glasses. After overnight drying, the cover glasses with the residues embedded in HEC, were inverted on Canada balsam. The finished slides were allowed to dry at room temperature for several days.

Microscopic examination of the prepared slides was performed using a Leitz Orthlux microscope. Detailed examination, expecially low contrast forms, was performed using a Zeiss GFL Phase Contrast microscope. In all cases, all addresses are those of the Leitz instrument. Traverses of the prepared slides began at the upper left hand corner of the cover glass and proceeded from left to right, until the residue beneath the entire lower surface of the cover glass of one slide was examined. In some cases more than one slide was counted and, in a few cases, the count terminated when 200 palynomorphs had been counted. Photomicrographs of selected entities were made using a Leica camera attachment.

CHAPTER V

DISCUSSION

The Use of Palynology in General, and the Results Obtained Through Its Use in the Present Study

Palynology has been applied by numerous workers to a variety of problems in the field of geologic exploration. Such applications have been summarized by Cross (1965, p. 12) and include the use of the method in the resolution of problems involving the identification of stratigraphic units, both intra- and inter-basinal correlations, determination of ancient environments and distribution of sediments. The present study includes the application of palynology, to a greater or lesser degree, in the resolution of similar problems in the Pierre Shale of northwestern Kansas and environs. Each of the applications now included in the literature, as well as the present application, have inherent limiting factors. In most cases the factors limiting the acceptibility obtained through the use of palynology are outweighed by lack of any other acceptable criteria for zonation or stratigraphic determination (foraminifers, ostracods, geophysical results made uncertain by facies changes, etc.).

The factors controlling the quantity of palynomorphs now available from stratigraphic units such as the Pierre Shale have been summarized by Cross (1965, p. 11). These include: 1) the rate of production and dissemination of spores and pollen by the various plant types, 2) the seasonal variations in spore and pollen production, 3) the nature and efficiency of transporting media, 4) the sedimentation of the spores and pollen at

the site of deposition, and 5) the degree or nature of preservation after deposition and post-depositional factors of weathering and re-working. The first two factors have been treated by numerous investigators (e.g., Davis and Goodlett, 1960; Cain, 1939; Wodehouse, 1935) utilizing a variety methods and approaches. The third factor has been treated by Faegri and Iversen (1964), Erdtman (1943), Kuyl and other (1955) and Leopold and Scott (1957). The fourth has received the least amount of attention. Erdtman (1943, p. 177) and Sussman and Halvorson (1966, pp. 332-339) have summarized several investigations on the rate of sinking pollen and spores in air. The rate of sedimentation (or sinking) of spores and pollen in water has also been investigated by Federova (1952), Muller (1959) and others.

The preservation or selective destruction of spores and pollen after deposition has been investigated by Havinga (1962, 1964, 1967, Sangster and Dale (1961, 1964) and others. Re-working and stratigraphic leakage of palynomorphs have been reported by Wilson (1964). In addition, there is a considerable amount of literature relating to the destruction and consequent biasing of palynomorph recovery in the laboratory (Wilson, 1964); McIntyre and Norris, 1964; Funkhouser and Evitt, 1959).

One of the principal uses of the palynologic method in the present study is to establish the location of the source areas that contributed the various palynomorphs recovered from the Pierre Shale. The use of relating spores and pollen, recovered some distance from their source area, to their parent plant is somewhat tenuous. It is, however, no riskier than accepting or suggesting a direct relationship between a single leaf recovered at some distance from its source and the parent plant responsible for its production. McLaughlin (1957) quoting Odell, 1932 and Arnold, 1947, stated that ". . . from the botanical point of view, the identification of fossil plants based on a single criterion of leaf morphology, as has been attempted in many cases, has serious limitations." In the present study, recognizable leaves and other macro-size fragments of the parent plants were not found, but fossil spores and pollen are abundant. The very meager leaf flora reported by Elias (1951) from the Beecher Island Shale Member attest to the paucity of such remains in the section. A concerted effort to establish a leaf flora for the Pierre Shale in the area of this study would be worthwhile and would aid greatly in deciphering the paleogeography (i.e., the location of land masses) of the Pierre Sea.

Figures 7 through 11 (in pocket) demonstrate the spatial relationships of the various palynomorphs considered in the present study along selected subsurface sections. The lateral distribution patterns of the name groups are discussed under the heading "Areal distribution of selected palynomorph groups in the Pierre Shale".

Fungal Spores (Figure 7)

The most abundant occurrences of fungal spores are found in the upper portion of the Pierre (i.e., 10 of 18 Pierre sections included in this study[1] contain an abundance of fungal spores in their upper portions). Seven of the same 18 sections also have an abundance of fungal spores in the middle portion of the Pierre and 6 of 18 in the lower portion. Samples of the upper portion of the Pierre Shale in Subsurface Section 49 were not available for study. Special significance cannot be attached to this disparate distribution through the Pierre. A distinct

[1]Sections studied listed in Table 7, Appendix A.

reduction in the abundance of fungal spores in an easterly direction is demonstrated by Figure 21. Fungal hyphae were never observed in more than minimal numbers and, in the case of the Pierre, cannot serve as indicators of quiet, undisturbed conditions in the manner cited by Trotter (1962, p. 196). Trotter (op. cit.) referred to a personal communication with Dr. Alfred Traverse who stated that fungal entities recovered from his (Trotter) samples may be ". . . the result of either post-macerative contamination and subsequent growth within the sample, or pre-macerative development while samples are being stored" (Trotter, op. cit., p. 28). Trotter chose to regard the fungal entities that he recovered as indigenous to his samples. In the case of the Pierre of the Great Plains there would seem to be little doubt, because of the present-day conditions, that the entities herein referred to as fungal spores or hyphae are truly Pierre in age. Other authors, such as Muller (1959) and Neuy-Stolz (1958) have regarded fungal spores and hyphae as important constituents of the microfossil flora assemblage. In the present study, samples were split on the outcrop, one fraction in Nalgene bottles with HAC (5%) added and the other fraction in a dry plastic sack failed to demonstrate a discernible difference in fungal entities. It is therefore concluded that the entities considered to be of fungal origin (in the present paper) did indeed originate during Pierre time.

Bisaccate Pollen (Figure 8)

Thirteen of 18 Pierre sections considered contain an abundance of bisaccate pollen in the upper portion of the Pierre. Ten of the same sections also contain relatively high percentages of the same palynomorph group in their middle portions, while eight exhibit relatively high percentages in their lower portions. The samples barren of bisaccate pollen (such as the lower 2/5 of section 46) may have been subjected to extreme conditions of oxidation, corrosive attack by bacteria and microorganisms, winnowing action of marine currents or changes in the drainage patterns of the streams in the source areas. Similarly, the same factors may have been responsible for the absence of other palynomorphs in other portions of the Pierre Shale.

Acritarchs (Figure 9)

Eleven of the 18 Pierre sections considered in the present study exhibit relatively high percentages of acritarchs in their middle portions. Eight sections contain an abundance of acritarchs in their lower portions and seven contain an abundance in their upper portions.

The oldest portion of the Pierre (Palynologic Zone I) yielded the greatest relative percentages of acritarchs. Subsequently, the average relative percentage of this palynomorph group remained nearly constant through Palynologic Zones II, III and IV. Relatively high percentages of acritarchs are present throughout the Pierre in subsurface sections 46, 33, 24 and 50, all of which are located in the northwestern part of the study area.

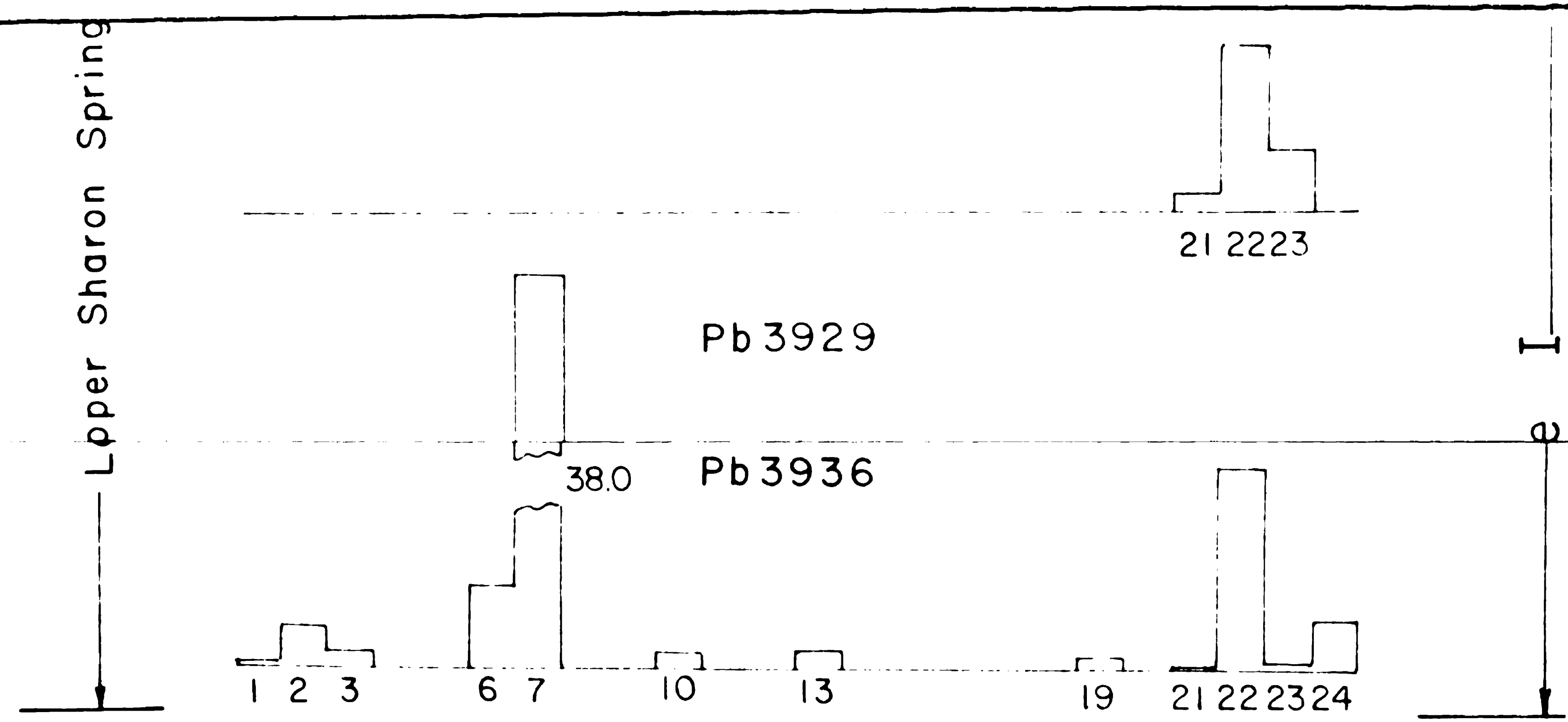
Dinoflagellates (Figure 10)

Dinoflagellates are generally abundant throughout the Pierre Shale. This palynomorph group is not, however, represented in the upper portion of the Pierre in subsurface sections 34, 10 and 12 or in the lower portion of the Pierre in subsurface sections 19 and 13. Dinoflagellates occur in relatively high percentages in the upper portions of 13 sections, in the middle portion of 15 sections and in the lower portion of 12 sections of the total of 18 subsurface sections considered. The three lowermost Palynologic Zones are characterized by high percentages of dinoflagellates over most of the area studied. A significant decrease is evident in the uppermost portion of the Pierre. Only one section, subsurface section 12, Sherman County, Kansas, is barren of dinoflagellates in the uppermost portion.

Classopollis spp. (Figure 11)

Various species of Classopollis are found in all sections studied except subsurface section 19 (northeast Thomas County, Kansas). Occurrences of relatively high percentages of Classopollis are found in 9 of 18 sections (upper portion), 10 of 18 sections (middle portion) and 14 of 18 (lower portion). A marked decrease in the occurrence of Classopollis in Palynologic Zones III and IV (see Figure 21) may be the result of locally severe conditions of oxidation (note the thin Pierre sequences in subsurface sections 31, 34 and 10).

As discussed elsewhere in this thesis, the Pierre Shale has been divided into four Palynologic Zones. The limits of each zone have been plotted on Figures 7 through 11 and 15 through 19.



Note: Refer to Figure 15 for listing of palynomorphs utilized in this illustration.

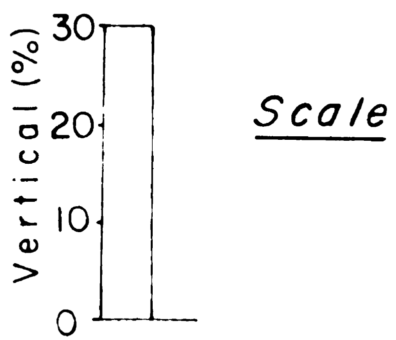
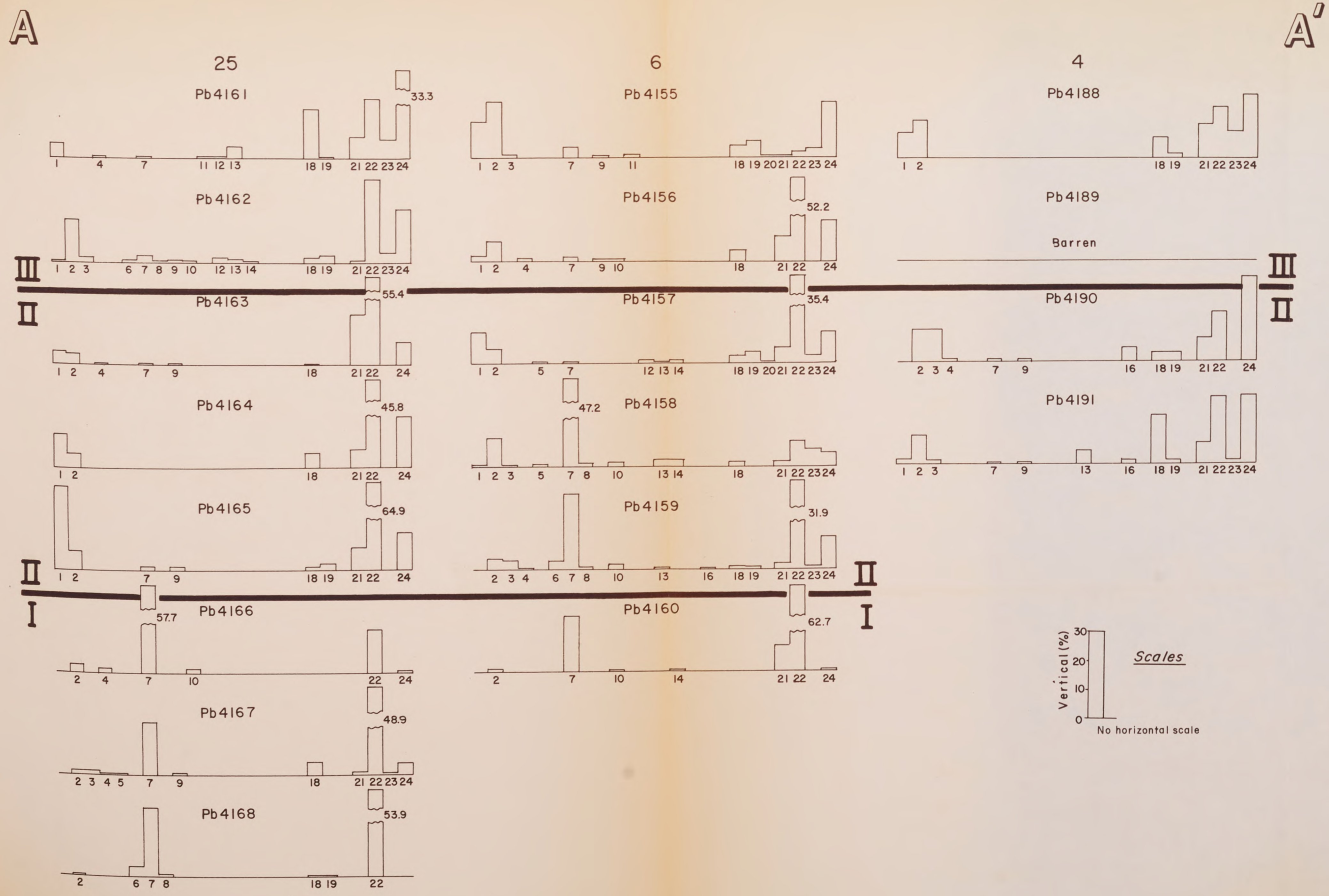


Figure 14

Histograms of Selected Palynomorphs
from
Representative Outcrop Samples
of
The Pierre Shale

J. M. Lammons

March, 1969



Palynomorphs Utilized

Reference No. (on each histogram)	Palynomorph	Reference Plate	Photo Figure
1	Fungal spores	15	4-7
2	Bisaccate pollen	6	7-16
3	Triporopollenites sp. D	7	6
4	Tricolpites sp. D	7	7
5	T. sp. E	n.f.[a]	
6	Triporate pollen A	n.f.	
7	Triporate pollen B	n.f.	
8	Tetraporate pollen A	n.f.	
9	Momipites coryloides	7	16
10	Conclavipollis sp.	n.f.	
11	Proteacidites retusus	Fig.20	15
12	P. cf. retusus	n.f.	
13	P. sp. A	n.f.	
14	P. sp. B	n.f.	
15	Cicatricosisporites dorogensis	2	8
16	Sphagnumsporites cf. antiguasporites	n.f.	
17	Undulatisporites sp.	1	1,10
18	Osmundacidites comaumensis	2	2
19	Perotriletes sp.	4	2,3
20	Osmunda-sporites primarius	n.f.	
21	Acritarchs	14	all
		15	1-3
22	Dinoflagellates	12,13	all
23	Taxodiaceae, Cupressaceae, Taxaceae ("TCT")	7	3,4
24	Classopollis spp.	6	1-4

[a] n.f. = not figured

Figure 15

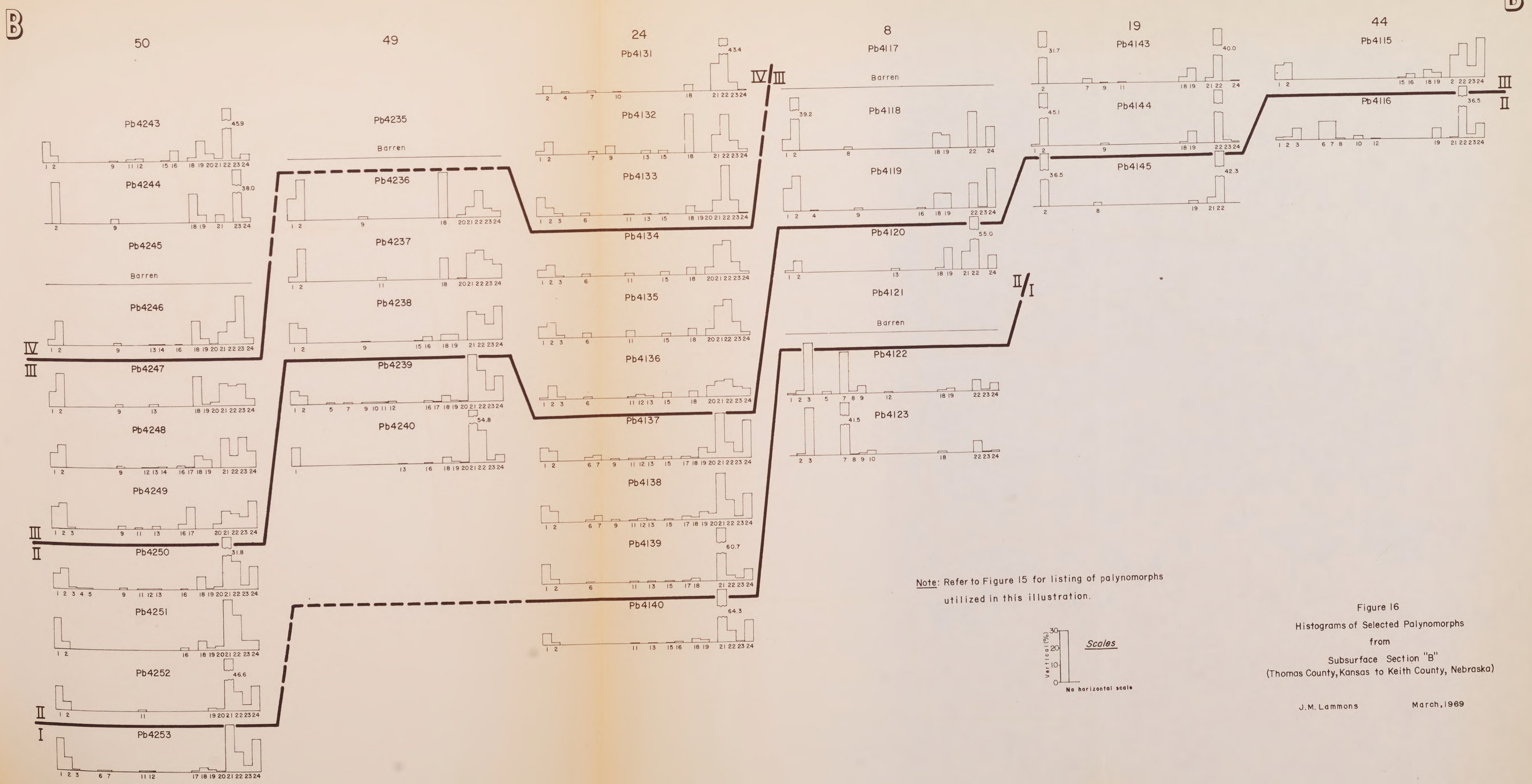
Histograms of Selected Palynomorphs

from

Subsurface Section "A"

(Decatur County, Kansas to Hitchcock County, Nebraska)

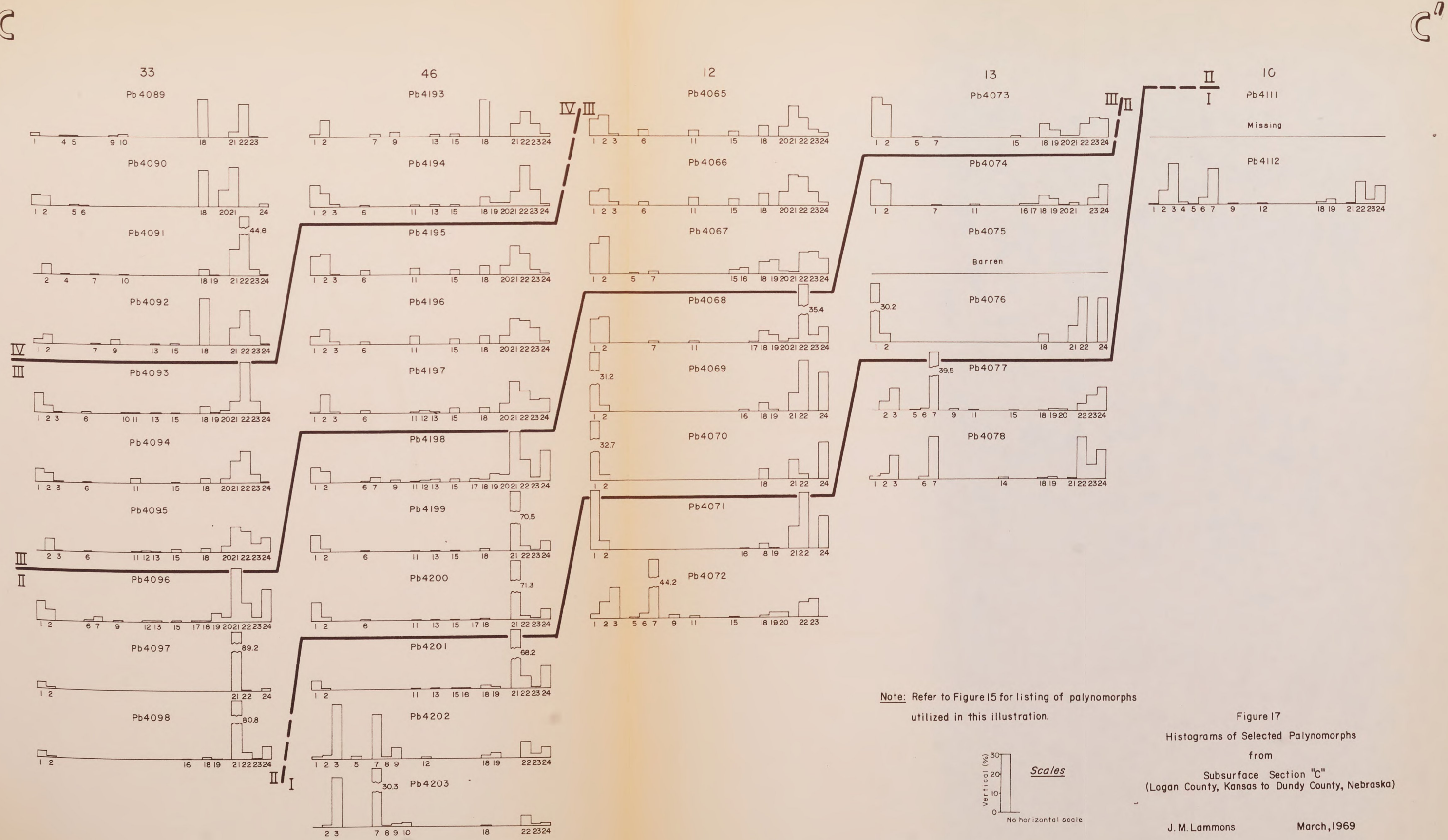
J.M. Lammons   March, 1969



Note: Refer to Figure 15 for listing of palynomorphs utilized in this illustration.

Figure 16
Histograms of Selected Palynomorphs
from
Subsurface Section "B"
(Thomas County, Kansas to Keith County, Nebraska)

J. M. Lammons March, 1969



Note: Refer to Figure 15 for listing of palynomorphs utilized in this illustration.

Figure 17

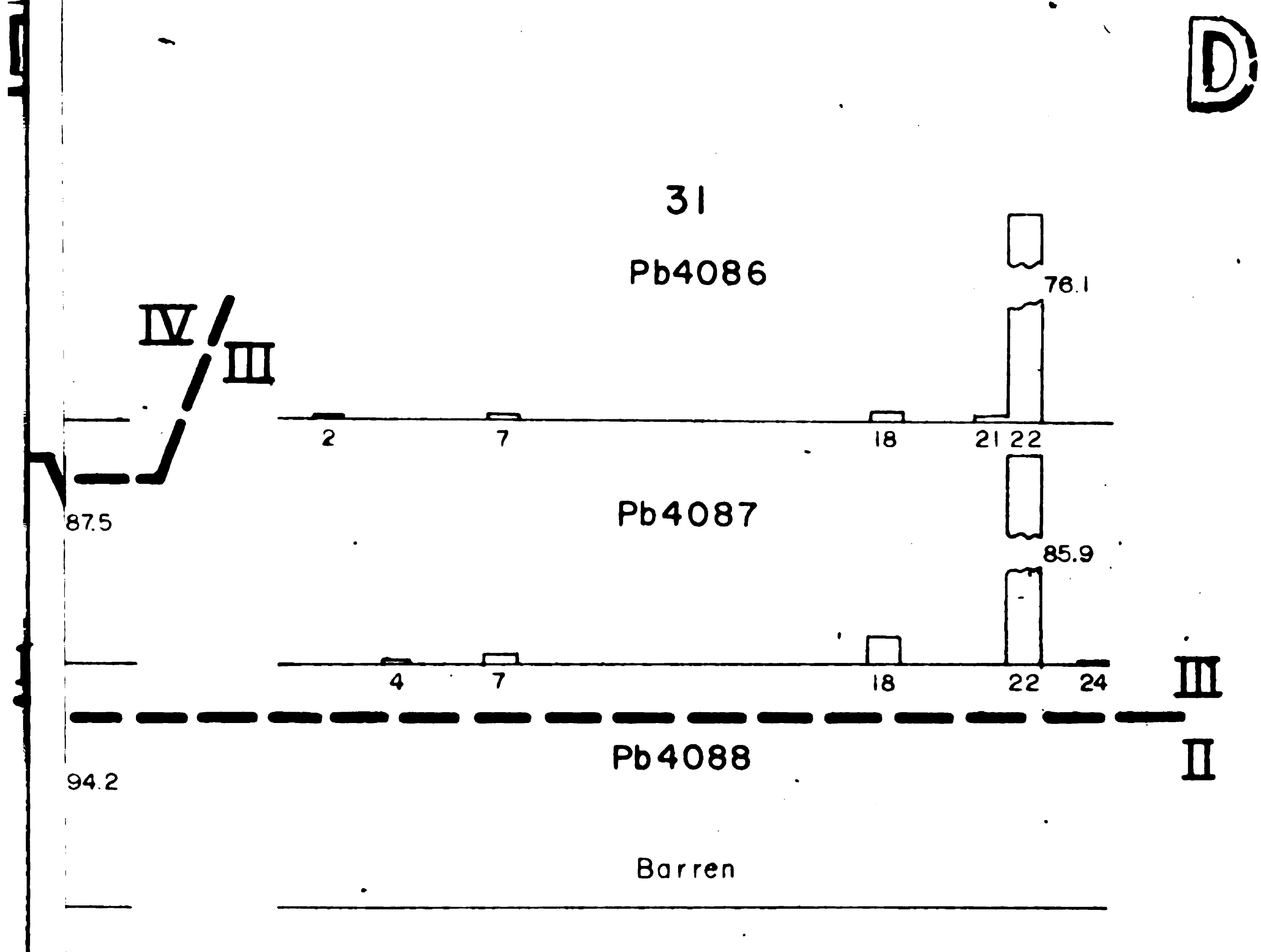
Histograms of Selected Palynomorphs

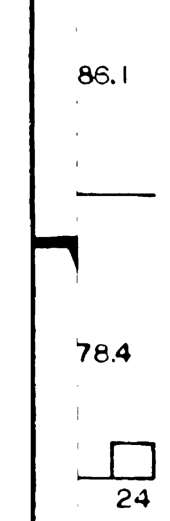
from

Subsurface Section "C"

(Logan County, Kansas to Dundy County, Nebraska)

J. M. Lammons March, 1969





Note: Refer to Figure 15 for listing of palynomorphs utilized in this illustration.

Figure 18

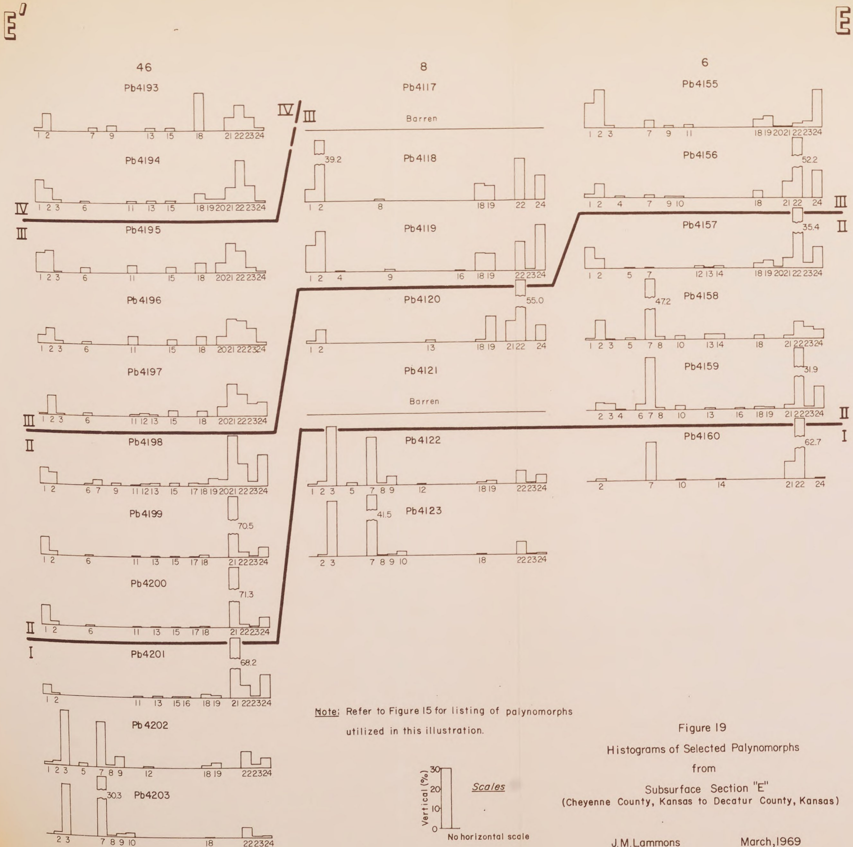
Histograms of Selected Palynomorphs

from

Subsurface Section "D"

(Norton County, Kansas to Wallace County, Kansas)

J. M. Lammons March, 1969



Note: Refer to Figure 15 for listing of palynomorphs utilized in this illustration.

Figure 19

Histograms of Selected Palynomorphs

from

Subsurface Section "E"

(Cheyenne County, Kansas to Decatur County, Kansas)

J. M. Lammons March, 1969

Palynological Associations

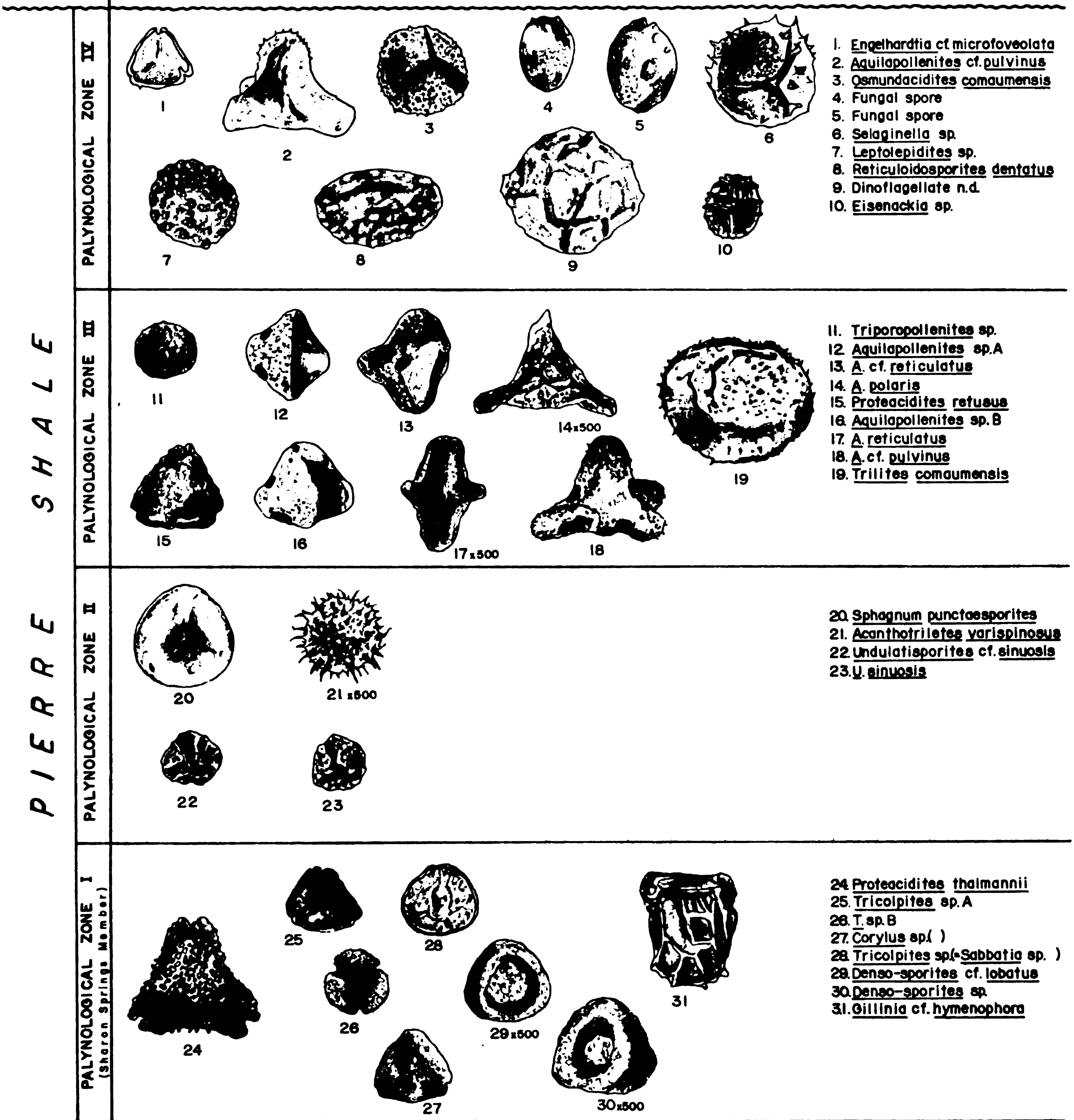
The relative percentages of a selected group of palynomorphs that occur throughout the Pierre Shale are illustrated in various ways. Histograms of each sample included in the present study (Figs. 18-19) are used to demonstrate vertical and horizontal (or lateral) changes in the relative abundance of selected entities along certain traverses (A-A', B-B', etc. see Figs. 7-11). The geographic distribution of five of the component groups (Acritarchs, Dinoflagellates, fungal spores, Classopollis spp., and bisaccate pollen) is illustrated by the panel diagrams (Figs. 7-11) to show more clearly the geographic distribution of each group during various parts of Pierre time. A characteristic electric log feature (designated "Top Sharon Springs Member") has been noted on each subsurface section where it has been identified (see Fig. 13). The relative percentage of each of the same five groups of palynomorphs is mapped at the time represented at the top of each palynologic zone (Fig. 21). Conclusions reached after considering the various approaches are included under "Paleoecological Considerations".

Palynological Zone I

This zone is essentially equivalent to the Sharon Springs Member. It is characterized by various species of Proteacidites, Tricolpites and Triporites. These forms are associated with at least two species of Denso-sporites (probably reworked from Pennsylvanian rocks or their weathered residuum being eroded or recycled at the time of deposition of sediments in this zone) and the dinoflagellate Gillinia. The concentration of Denso-sporites in Zone I is significant and is possibly a reflection of extensive erosion or/and of extensive exposure of Upper

Ogallala Fm.

-No palynomorphs recovered from surface samples of this formation-



Niobrara Fm.

-No palynomorphs recovered from surface or subsurface samples of this formation-

Note:
All figures x1000 except where noted.

Figure 20

SUMMARY OF PALYNOMORPHS CHARACTERISTIC OF EACH PALYNOLOGICAL ZONE IN THE PIERRE SHALE

NORTHWEST KANSAS–SOUTHWEST NEBRASKA

J.M. Lammons March, 1969

Paleozoic rocks in the source area. The occurrence of Gillinia in the low-grade oil shales of the Sharon Springs Member probably indicates a marine environment and may suggest that the land areas were far removed from the site of deposition. The true significance of this palynomorph has not yet been determined although additional occurrences have been reported from the Senonian of western Australia (Cookson and Eisenack, 1960b, p. 12). A postulated deeper water condition is partially substantiated by the relatively low pollen count in the same stratigraphic unit. This interpretation does not support the suggestion by Reeside (1957, p. 530) that the black shales of the Sharon Springs Member were derived from black soils of an earlier (Santonian) age. Dark soils sometimes contain large quantities of plant microfossils which may be recycled to different depositional basins, but the number of spores present is greatly modified by corrosion susceptibility and other factors such as the pH of the original soil (calcareous soils are not good for optimum preservation of plant remains; and the total amount of organic material available for preservation. Elias (1931, p. 56) noted the great abundance of small fish remains and the almost complete lack of invertebrates in the Sharon Springs Member. Elias (op. cit., p. 58) also suggested that the decomposition of the small fishes might account for the bituminous material in the same member. Kline (1942, p. 354) found abundant fish scales in the Sharon Springs Member in North Dakota.

Palynologic Zone II

This zone is characterized by the spores of Aphagnum, Undulatisporites and Acanthotriletes, in association with Lariocoidites magnus. The family Sphagnaceae and the class Filicineae are therefore well represented in the organic residues from Zone II. Palynologic Z one II time may represent a rapid development of, or a closer proximity to, coastal swamp conditions.

Palynologic Zone III

This zone is dominated by a marked development and diversification of pollen assignable to the genus Aquilapollenites. This diversification agrees with the earlier observation by Funkhouser (1961, p. 193). If it is assumed that the Aquilapollenites- producing plants are closely related to the extant genus Arjona (Santalaceae), as suggested by Funkhouser (loc. cit.), then the climate during Zone III time may have been temperate and possibly even sub-tropical. The genus Proteacidites is represented principally by the species P. retusus Anderson (1960). Both P. retusus and Aquilapollenites spp. have been reported from the Cretaceous of northern Alaska. The ferns are represented by the form-genus Osmunda-sporites.

Palynologic Zone IV

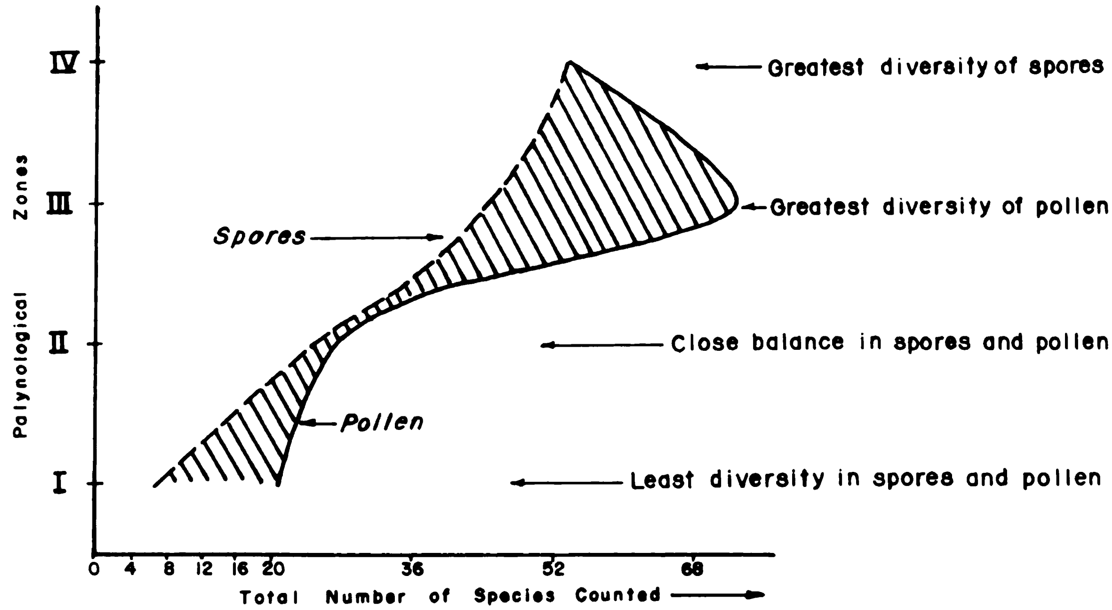
This zone is characterized by four spore types, at least two pollen types, two fungal spore types and two types of dinoflagellates, is perhaps the most heterogeneous (in the number of form-species) of the proposed palynologic zones. The presence of Selaginella in Zone IV suggest a temperate to sub-tropical condition with attendant high rainfall. A predominantly moist condition in the source areas during Zone IV time would have favored the development and proliferation of the terrestrial fungal types. The large number of definite fungal spores observed in the residues from this zone may include both terrestrial and marine forms. Detailed examination of the entities, placed under the broad heading

"Fungal Spores", was not possible because extensive bleaching preferentially destroyed other, equally important, spores, pollen and marine phytoplankton. There is a general correspondence between the occurrence of significantly high percentages of fungal spores and equally high percentages of dinoflagellates. An even more striking relationship though possibly fortuitous, between the same two groups was found by Cross in his studies of the bottom sediments of the Gulf of California (personal communication). The significant numbers of dinoflagellates recovered from Zone IV can be explained by sporadic improvement in circulation during the deposition of Zone IV sediments in localized areas.

The general relationship between the number of pollen and spore species within each palynologic zone of the Pierre is summarized in Text-figure 1. Cousminer (1961) attempted to analyze palynological data in terms of biotic diversity. The method used in the present study follows closely that employed by Cousminer. Obvious limitations of the technique are cited by Cousminer (loc. cit.).

It is possible to gain at least a partial understanding of the floral and physiographic changes that occurred during the deposition of the Pierre Shale in northwestern Kansas through the use of the palynological method. The period of least floral diversity in the source area (or areas) during the deposition of the Pierre Shale is demonstrated (Text-fig. 1) to have been during Palynologic Zone I time. Some of the factors that could account for the interpreted diversification of plant types (or form species) from Zone I time to an indicated maximum during Zone III time include 1), variations in distance between the source areas and the site of deposition during a given period of time within the Pierre,

2) localized areas of optimum growth conditions that would support more diversified plant communities, 3) unequal distribution systems and 4), vertical and lateral variations in the conditions of preservation. The influence of the first factor is reflected by the distribution of the acritarchs and dinoflagellates (see Figure 18). The distribution of the



Text-fig. 1 - Total number of pollen and spore species identified from each proposed palynologic zone within the Pierre Shale of northwestern Kansas and environs.

dinoflagellates, in particular, suggests that significant changes in the positions of the shorelines occurred at, or between, each of the proposed palynological subdivisions of the Pierre. The effect of the second factor is not discernible since most of the sediments derived from the same areas that produced the spores and pollen have been stripped away by post-Pierre erosion. The third factor may have included variations in debouchment patterns and stream capacity of the component drainage patterns at various time levels within the Pierre. The fourth factor involves a large number of variables such as the Eh-pH condition at the site of deposition, the type and intensity of bacterial activity during and after burial of the palynomorphs and the geochemical nature of the enclosing sediments. None of the factors mentioned are regarded as objective and none can be resolved with the data on hand.

The varying degrees of diversification, expressed in numbers of form-species in Text-figure 1, probably resulted from the interaction of all of the previously cited factors. The variations in the number of form-species within each palynologic zone are most probably not the result of a singular factor such as distance from shore. Muller (1959, Cross (1965), Woods (1955) and others have shown that the distribution of palynomorphs under marine conditions is not generally dependent upon a singular factor. Although her data were sparse and the number of palynomorphs low, Ressignol (1961) demonstrated that significant variations in distribution should be expected over a relatively small area. When present-day distribution patterns, based on closely spaced sampling points, are known, it should be possible to project the statistical data into the fossil record. The present study involves samples that are relatively widely spaced, both vertically and horizontally.

Palynological Comparisons

Studies concerning the palynology of the Upper Cretaceous sediments of North America are increasing in number at a rapid rate. At least twenty-eight articles that describe and illustrate palynomorphs from the Upper Cretaceous of North America have been published since Miner's work on the Late Cretaceous-Tertiary coals of Montana (Miner, 1935). A comparison of the microfossil flora of the Pierre and three of the published assemblages follows. A comparison with Clarke's work in the Vermejo, although it is unpublished, is also included.

Anderson (1960) reported the microfossil floral assemblages of Late Cretaceous age along the eastern side of the San Juan Basin, New Mexico. One of the florules described by Anderson, the Kirtland Shale Florule, is similar to that of the Pierre. Anderson (op. cit., p. 5) noted that the proteaceous pollen types were the most common dicotyledonous type present. Polypodiaceous spores and spores of Lycopodium are common to the Kirtland and Pierre assemblages. Anderson also noted the almost complete absence of coniferalean pollen. This is also in agreement with the results obtained in the present study. Anderson proposed that the Kirtland Shale was deposited in an area slosely associated with vegetation of low, swampy source areas to the south of area studies. ". . . the influx of new material was slight and the florule must represent mostly the vegetation in the immediate area." (op. cit., p. 5)

Clarke (1963) found many similarities between the Kirtland Florule as reported by Anderson and the microfossil flora of the Vermejo Coals of Fremont County, Colorado. Clarke recognised that the two units considered had probably been deposited under quite different conditions but, in general contain similar microfossil floras. Many of the palynomorphs reported by Clarke from the Vermejo Coals also occur in the Pierre Shale. The great differences in relative percentages of a given form, e.g., Proteacidites, are probably the result of 1), different source area-site of deposition relationships, 2) great differences in the depositional area itself (coal was deposited in the Vermejo; marine shales in the Pierre), and 3) much more favorable conditions for preservation of the plant microfossils in the Vermejo than in the Pierre.

Rouse (1962) described the microfossil flora of the Burrard Formation (Campanian) of western Canada. Many of the morphological types described and fi

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described and figured by Rouse are present in the Pierre Shale of the study area.

Ames (1951) reported on the microfossil flora of the Como Coal of South Park, Colorado. The assemblage described by Ames agrees with Clarke's analysis of the Vermejo Coal and is in general agreement with the assemblage from the Pierre Shale. Some of the aplynomorphs included in Ames' thesis are congeneric with those of the Pierre (e.g., Aquilapollenites).

The microfossil flora of the Pierre Shale also agrees quite well with the assemblage reported by Stanley from the Hell Creek Formation of the Crow Butte section (Stanley, 1965, table 4). Stanley (op. cit., p. 216) states that ". . . the Crow Butte section is late Upper Cretaceous in age . . . and most closely resembles the Upper Cretaceous assemblage described by Samoilovitch, et al., from western Siberia."

Elias (19

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the Pierre Shale

<u>Salix</u> cf.
cf. <u>Ficus</u>
cf. <u>Celast</u>
<u>Cinnamomu</u>
<u>Eucalyptus</u>

Elias note

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1917, p. 54-55)

Vermejo shales a

TABLE 2.--
City Coal
p. 223-435

Genus
<u>Halymenites</u>
<u>Acrostichum</u>
<u>Polystichum</u>
<u>Pteris</u>
<u>Asplenium</u>
<u>Stenopteris</u> ?
<u>Osmunda</u>
<u>Gleichenia</u>
<u>Anemia</u>
<u>Sequoia</u>
<u>Cupressinoxlon</u>
<u>Sabal</u>
<u>Canna</u>
<u>Juglans</u>
<u>Myrica</u>
<u>Salix</u>
<u>Quercus</u>
<u>Dryophyllum</u>
<u>Ficus</u>

Plant Megafossil Comparisons

Elias (1931, p. 130) identified fragments of the following dicotyledonous plants from surface exposures of the Beecher Island Member of the Pierre Shale in Sec. 3, T. 22 S., R. 42 W., Yuma County, Colorado:

Salix cf. *S. gardneri* Knowlton
cf. *Ficus minima* Knowlton
cf. *Celastrus arctica* Heer
Cinnamomum
Eucalyptus

Elias noted that the forms found in the Beecher Island Member were imperfectly preserved, but appeared to compare favorably with the Vermejo flora described earlier by Knowlton (1917). Knowlton (in Lee and Knowlton, 1917, p. 54-55) listed the following genera of plant megafossils from the Vermejo shales and sandstones of the Canon City Coal Field:

TABLE 2.--Plant megafossils from the Vermejo Shale of the Canon City Coal Field (after Knowlton, in Lee and Knowlton, 1917, p. 223-435.)

Genus	Family or larger group	Palynomorphae[1]
Halymenites	Algae	
Acrostichum	Polypodiaceae	
Polystichum	Polypodiaceae	
Pteris	Polypodiaceae	
Asplenium	Polypodiaceae	
Stenopteris ?	Polypodiaceae	
Osmunda	Osmundaceae	*Osmundacidites*, *Osmunda*
Gleichenia	Gleicheniaceae	*Gleicheniidites*
Anemia	Schizaeaceae	*Cicatricosisporites*
Sequoia	Pinaceae	
Cupressinoxlon	Pinaceae	
Sabal	Palmae	*Sabalpollenites*
Canna	Cannaceae	
Juglans	Juglandaceae	
Myrica	Myricaceae	
Salix	Salicaceae	*Tricolpites* cf. *T. reticulatus*
Quercus	Fagaceae	
Dryophyllum	Fagaceae	
Ficus	Moraceae	

Laurus
Platanus
Amelanchier
Phaseolites
Celastrus
Rhamnus
Pterospermites
Viburnum
Palaeoster
Phyllites

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Table 2--continued

Laurus	Lauraceae
Platanus	Platanaceae
Amelanchier	Rosaceae
Phaseolites	Papilionaceae
Celastrus	Celastraceae
Rhamnus	Rhamnaceae
Pterospermites	Sterculiaceae
Viburnum	Caprioliaceae
Palaeoster	Incertae sedis
Phyllites	Incertae sedis

Knowlton (1896, p. 472) noted that the Laramie flora (=Laramie Formation, Maestrichtian) of the Denver Basin includes about 15 species of Ficus, abundant ferns, Quercus and Rhamnus. The same author found a single species of Artocarpus and at least two palms. The conifers were noted as being rare. Knowlton (1922, p. 95-96) listed the following plant megafossils from the Laramie Formation of the Denver Basin:

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[1]The palynomorphae listed in Table 2 (above) are based on the work of Clarke (1963). Clarke (op. cit., p. 118) found that palynormorphs of five of the twenty-nine genera described by Knowlton are present in the Vermejo Coals. Three other plant megafossils listed by Knowlton (Myrica, Ficus and Rhamnus) are believed by Clarke to be represented by Palynomorphs of the Vermejo that are assigned to form genera only. In addition, two plant megafossils (Taxodium) and (Brachyphyllum)reported by Knowlton from the Vermejo of the Raton Mesa region, are believed to have palynologic representation in the Vermejo of the Canon City Coal Field (Clarke, p. 119). Clarke also recognized that the lack of agreement between the Vermejo floras of the Raton Mesa and Canon City Coal Field areas is due primarily to sampling techniques, but may also be a reflection of paleoecological conditions during deposition.

TABLE 3--
Denver Ba

Laramie Fm., *Denver Basin*
Delesseria
Onoclea
Dryopteris (4 sp
Phanerophlebites
Asplenium
Pteris (2 spp.)
Anemia (2 spp.)
Lygodium
Equisetum
Dammara
Sequoia (2 spp.)
Cycadeoides
Cyperacites ? (3
Phragmites
Smilax
Sabal
Juglans (5 spp.)
Hicoria (2 spp.)
Myrica (3 spp.)
Salix (3 spp.)
Populus ?
Quercus (4 spp.)
Artocarpus (2 sp
Ficus (21 spp.)
Aristolochia
Nelumbo
Magnolia (2 spp.)
Anona (2 spp.)
Laurus (3 spp.)
Malapoenna
Cinnamomum (2 sp
Platanus
Leguminosites (3
Mimosites
Cassia
Cercis
Celastrinites (3
Negundo
Pistacia (2 spp.)
Ilex
Ceanothus (2 spp.
Rhamnus (8 spp.)
Paliurus
Zizyphus (4 spp.)
Apeibopsis

TABLE 3--Plant megafossils from the Laramie Formation of the Denver Basin (after Knowlton, 1922)

	Areas where similar forms are noted			
Laramie Fm., Denver Basin	Canon City Coal Field	Raton Mesa Region	Mesaverde Fm.	Beecher Is. Sh.
Delesseria				
Onoclea				
Dryopteris (4 spp.)				
Phanerophlebites				
Asplenium	x			
Pteris (2 spp.)	x			
Anemia (2 spp.)				
Lygodium				
Equisetum				
Dammara				
Sequoia (2 spp.)	x	x	x	
Cycadeoides				
Cyperacites ? (3 spp.)				
Phragmites				
Smilax				
Sabal	x	x		
Juglans (5 spp.)	x			
Hicoria (2 spp.)				
Myrica (3 spp.)	x	x	x	
Salix (3 spp.)	x	x		x
Populus ?				
Quercus (4 spp.)	x	x		
Artocarpus (2 spp.)		x		
Ficus (21 spp.)	x	x		x
Aristolochia				
Nelumbo				
Magnolia (2 spp.)				
Anona (2 spp.)				
Laurus (3 spp.)	x			
Malapoenna				
Cinnamomum (2 spp.)				x
Platanus	x			
Leguminosites (3 spp.)				
Mimosites				
Cassia				
Cercis				
Celastrinites (3 spp.)	x	x		x
Negundo				
Pistacia (2 spp.)				
Ilex				
Ceanothus (2 spp.)				
Rhamnus (8 spp.)	x	x		
Paliurus				
Zizyphus (4 spp.)		x		
Apeibopsis				

Cornus (3 spp.)
Hedera
Diospyros
Fraxinus
Apocynophyllum
Lonicerópsis (4 s
Carpites (3 spp.
Phyllites (7 spp
Palaeoaster

The meager

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Table 3--continued

Cornus (3 spp.)		
Hedera		x
Diospyros		x
Fraxinus		x
Apocynophyllum		
Dombeyopsis (4 spp.)		
Carpites (3 spp.)		
Phyllites (7 spp.)	x	x
Palaeoaster	x	x

The meager megafossil flora reported from the Pierre Shale of the area studied does not permit direct comparison with other floras. Table 5 suggests that, at least on the generic level, the Beecher Island flora is most comparable with the Lance, Medicine Bow and Hell Creek floras. It is of interest to note that Dorf (1942, p. 106) regarded the identification of three of the genera listed by Elias from the Beecher Island and by others from various other Cretaceous floras, as questionable. These include *Celastrus*, *Cinnamomum* and *Ficus*. One genus, *Eucalyptus*, reported by Elias, is not included in Dorf's summary of the Lance, Medicine Bow and equivalent floras.

TABLE 4.--Comparison of Beecher Island megafossil

TABLE 4.--Comparison of Beecher Island megafossil flora with other late Cretaceous-early Tertiary flores[1]

Beecher Island[2]	Lance[3]	Medicine Bow[3]	Vermejo[3]	Hell Creek[3]	Mesaverde[3]	Laramie[3]	Wilcox[3]	Raton[3]
cf. *Celastrus arctica*	x	x	x	x		x	x	
Cinnamomum sp.	x	x			x			
Eucalyptus ? sp.								
Ficus minima	x	x	x	x		x		x
Salix cf. *gardneri*	x			x				

[1]At generic level only.

[2]From Elias (1931, p. 130).

[3]As summarized by Dorf (1942, pp. 32, 106).

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Present Distribution of Plant Families Represented in the Pierre Assemblages

A brief discussion of the present distribution of some of the plant families that are represented by spores and pollen in the Pierre assemblages is pertinent to a consideration of their paleoecological significance. Present distribution and ranges of the various families cannot be equated exactly to the supposed distribution of the same families during Pierre time since several unknown factors must be considered. A principal factor that may have been of major importance in the distribution of the same plant families include greater or lesser tolerance to different edaphic conditions. The same families during Pierre time probably included numerous genera that are not represented in the present day flora.

Phycomycetae

The Phycomycetae include 130 genera comprising 1500 species. Species assignable to this division produce more than one type of spore. Most species have non-septate, multinucleate mycelia, but some have mycelia that are regularly tranversely septate. Representatives of the Phycomycetae have been reported from every continent under a wide range of environments.

Fungi Imperfectae

The composition of this large fungal group is not circumscribed at the present time. Many forms previously assigned to the Fungi Imperfectae have now been placed in the Phycomycetae, the Ascomycetae or the Basidiomycetae. The geographical distribution of the Fungi Imperfectae is undoubtedly world-wide, for examples have been repo

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Division Bryophyta

Order Sphagnales

Family Sphagnaceae

Several hundred species comprise the single genus *Sphagnum* and represent this family on a world-wide basis. Present distribution of the Sphagnaceae is mostly limited to moist areas, usually associated with ponds or lakes.

Division Pteridophyta

Class Lycopodiaceae

Family Lycopodiaceae

Two genera, *Lycopodium* and *Phylloglossum*, comprising approximately 100 species, represent this family in the present day flora. *Lycopodium* has been reported on a world-wide basis, except in the most arid regions. It is abundant in subtropical and tropical forests, where it is generally epiphytic. *Phylloglossum* is now restricted to various parts of Australia.

Family Selaginellaceae

This family is composed of a single genus, *Selaginella*. Of the 600 extant species, less than 40 occur in the United States. The remainder are widely distributed, occuring on all continents, and are mostly tropical.

Class Articulatae

Order Equisetales

Family Equisetaceae

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The single genus *Equisetum*, comprised of 25 species, represents the Equisetaceae in all of the large land areas of the world except Australia and New Zealand. *Equisetum* occurs primarily in wet places but at least one species has been found under the driest of conditions. The majority of the species are tropical or subtropical, but 12 species are widely distributed over temperate North America.

Class Filicinae

Subclass Leptosporangiatae

Order Eufilicales

Family Osmundaceae

The family Osmundaceae is composed of 3 genera containing 20 species. *Osmunda*, with 12 species, is found in swampy areas of the temperate and tropic zones. Three species of the same genus extend (in aggregate) from Newfoundland to Florida and westward to the Northwest Territories of Canada, south-eastward to Texas and into Mexico. *Todea* has a disjunctive distribution pattern, having been reported from Africa, Australia and New Zealand. *Leptopteris* is distributed over New Zealand, Polynesia and Malaysia.

Family Schizaeaceae

Four genera comprised of 160 species represent the Schizaeaceae. The present distribution of this family is largely confined to tropical areas and has rarely been reported in temperate regions. Three species, *Lygodium palmatum*, *Schizaea pusilla* and *Lygodium japonicum* occur sporadically in the United States. Two species of *Anemia* are indigenous to southern United States.

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Family Gleicheniaceae

A maximum of 6 genera comprised of 130 species have been assigned to the Gleicheniaceae. Representatives of this family occur mostly in drier habitats in the tropics and subtropics of the south temperate regions. Two species occur in Japan and a few species have been reported from Hawaii. One species is disjunctive between Brazil and the West Indies.

Family Cyatheaceae

Members of the Cyatheaceae are restricted to tropical mountain forests from Mexico to Chile, Malaysia to Australia and New Zealand, and Africa. This family is composed of 7 genera with 800 species.

Family Dicksoniaceae

Five genera composed of 30 species represent the Dicksoniaceae in a disjunctive distribution that includes occurrences in eastern Asia, Malaysia, Hawaii, Central America and the Juan Fernandez Islands.

Family Polypodiaceae

Approximately 170 genera and 7000 species are included in this, the largest fern family. Members of this family are widely distributed over most of the major land areas of the world. They are especially common in forests and humid areas, but occur in almost all floristic zones from rain forests to deserts and from the tropics to the arctic and antarctic regions.

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Division Pteridophyta

Class Filicinae

Subclass Eusporangiatae

Order Marattiales

Family Marattiaceae

Seven genera and 55 species are presently assigned to the Marattiaceae. The present distribution of this family is almost exclusively tropical. The largest genus, *Angiopteris*, is found only in the eastern hemisphere. The genus *Marattia* occurs in tropical regions throughout the world. *Danaea*, another important genus, is confined to tropical America. Four other monotypic genera are confined to southern Asia.

Family Matoniaceae

This family, represented by the single genus *Matonia*, is restricted to the East Indies. Seward (1933, p. 312, 543) noted that this family was once more widespread.

Division Spermatophyta

Subdivision Gymnospermae

Order Coniferae

Family Podocarpaceae

Seven genera of 100 species represent the Podocarpaceae in the southern hemisphere; none have been reported as being native to North America.

Family Pinaceae

This family, composed of 9 genera and about 210 species, is of wide distribution, especially in the temperate regions of the northern

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northern hemisphere. The distribution of seven of the genera comprising this family can be summarized as follows:

Pseudotsuga, *Tsuga* - occur in both North America and eastern Asia.

Cedrus - occurs in the Mediterranean region of Europe and North Africa and the western Himalayas of Asia.

Abies, *Picea*, *Larix*, *Pinus* - widely dispersed over Eurasia and North America.

Family Taxadiaceae

Ten genera composed of 16 species represent the Taxodiaceae. Three genera (*Cryptomeria*, *Sciadopitys* and *Taiwania*) are endemic to Japan. Two genera (*Glyptostrobus* and *Metasequoia*) are endemic to China. Two genera (*Sequoia* and *Sequoiadendron*) are endemic to southern Oregon and California. *Athrotaxis* is the sole representative of the Taxodiaceae in the southern hemisphere with three species in western Tasmania. *Taxodium* occurs in North America from Delaware to Florida and Mexico, extending into Illinois, Missouri and Texas.

Division Spermatophyta

Subdivision Angiospermae

Class Dicotyledoneae

Order Salicales

Family Salicaceae

The family Salicaceae is comprised of two genera and more than 300 species. It is almost world-wide in distribution being absent only in Australia and the Malayan Archipelago. The most primitive species occur in the tropics but present centers of distribution are in the temperate and subarctic regions.

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Order Santalales

Family Santalaceae

This predominantly southern hemisphere family is comprised of 26 genera and 250 species. Present distribution of the Santalaceae is limited to temperate South America.

Family Loranthaceae

Thirty genera of more than 1100 species comprise the family Loranthaceae. This family is primarily tropical, but extends into the temperate zones of both the northern and southern hemispheres. The primarily American genus Arceuthobium, which is parasitic on conifers, and the evergreen Phoradendron, which is parasitic on numerous genera, represent the Loranthaceae in North America.

Order Sapindales

Family Aquifoliaceae

The genera Ilex, Nemopanthus and Byronia, with a total of approximately 300 species, comprise the Aquifoliaceae. This family is widespread, occurring in North America, Asia and Polynesia. According to Lawrence (1951, p. 576), the chief center of world distribution of the Aquifoliaceae is in Central and South America.

Order Fagales

Family Betulaceae

The tribes Betuleae and Corlyeae with a total of 6 genera and over 100 species comprise the family Betulaceae. Most of the family is now restricted to the northern hemisphere. Five genera (Betula, Alnus, Corylus, Ostya and Carpinus) are indigenous to North America.

Order Urticales

Family Ulmaceae

Fifteen genera composed of 150 species comprise the Ulmaceae. This family is distributed throughout much of the northern hemisphere and more particularly in the tropics and subtropics.

Order Sapindales

Family Buxaceae

The family Buxaceae is indigenous to the tropics and subtropics, especially of the Old World. One species, *Pachysandra procumbens*, is indigenous to West Virginia, western Florida and Louisiana. The monotypic genus *Simmondsia* occurs in northern Mexico and southwestern United States.

Order Rosales

Family Hamamelidaceae

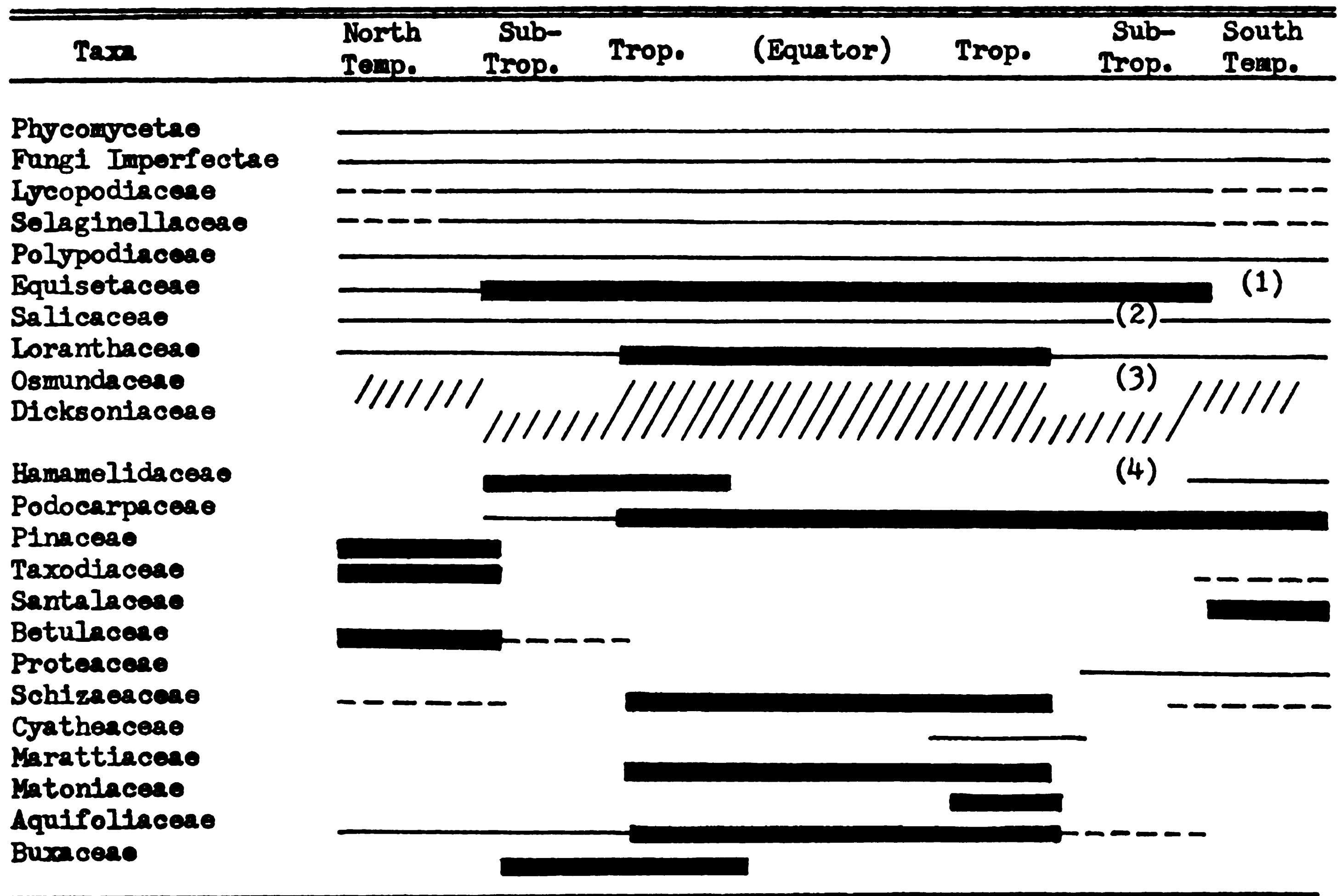
Twenty-three genera composed of approximately 100 species comprise the family Hamamelidaceae. Seventeen genera occur in Asia, two genera occur in Africa and one genus has been reported from Australia. Three genera (*Hamamelis*, *Liquidambar* and *Fothergilla*) have species indigenous to eastern North America.

Order Proteales

Family Proteaceae

The family Proteaceae occurs mainly in the more arid regions of the southern hemisphere. It is composed of 55 genera with a total of 1200 species. Approximately 15 genera and 475 species are found in South Africa and many genera and approximately 700 species are native to Australia.

TABLE 5.--Present distribution of plant families represented by spores and pollen in the Pierre Shale of northwestern Kansas and environs



(1) Not reported from Australia or New Zealand.
(2) Not reported from Australia or the Malayan Archipelago.
(3) Disjunctive distribution.
(4) One genus reported from Australia.

Discussion

Table 5 indicates that the greater number of extant plant families whose fossil counterparts are represented in the microfossil flora of the Pierre Shale, are primarily subtropical and tropical in habitat. Several taxa have been reported from a majority of the earth's land surface and cannot, therefore, be regarded as indicative of any given climatic region (e.g., Phycomycetae, Fungi Imperfectae and Polypodiaceae). The inference is therefore drawn that the Pierre flora of the area studied was primarily subtropical and tropical in composition. The minor contributions of pollen from the families Pinaceae, Taxodiaceae and Betulaceae could have been fortuitously supplied by wind or water from land areas east or west of the study area for they are readily transported by both wind and water. Because they are in low relative frequency, despite their adaptability to long distance transportation, plants of these families probably did not comprise a large percentage of the total vegetation in the source areas.

Areal Distribution of Selected Palynomorph Groups in the Pierre Shale

The palynomorph groups considered in the present study are not unique nor limited to the Pierre. All those identified here have earlier representatives in older rocks and many have been observed in the younger rock sequences of the Tertiary. Because of various factors, palynomorphs were not recovered from the stratigraphic units above and below the Pierre Shale in the area of study. It is quite possible that, given sufficient time and greater sampling density, representatives of the various palynomorph groups noted in the Pierre, could be found in the Niobrara and Ogallala formations. The overall preservation of plant microfossils in the Pierre is strikingly better than that of the earlier and later rocks deposited in this area. This may be attributed to penecontemporaneous or post-depositional oxidation or other factors of preservation rather than lack of source areas or primary deposition in these rocks. The areal distribution of each of the selected palynomorph groups during the accumulation of the sediment are illustrated on Figure 21 and will be discussed in ascending order for Palynologic Zones I-IV.

Palynologic Zone I:

Fungal spores of the Pierre are limited to certain areas of northwest Kansas and southwest Nebraska. A distinct area of high concentration (over 30% in relative frequency) in Sherman County, Kansas (the maximum value is present in Subsurface Section 12) is unique and is not repeated later in the Pierre. An inferred increase north and west of Subsurface Section 49 (Chase County, Nebraska) is, however, also found in Palynologic Zone IV.

The area distinguished by relatively high percentages of fungal spores is roughly coincidental with areas high in acritarchs, and Classopollis pollen. The best correspondence, or fit, is between various fungal spores and the pollen of Classopollis spp. This apparent correspondence may be a function of physical similarities between the two palynomorph types, i.e., entities in each group are small, many are subspherical-oblate and most are comparatively dense. Both types could respond to the forces of transport in essentially the same manner and their distribution patterns might be expected to

Shale Zones IV

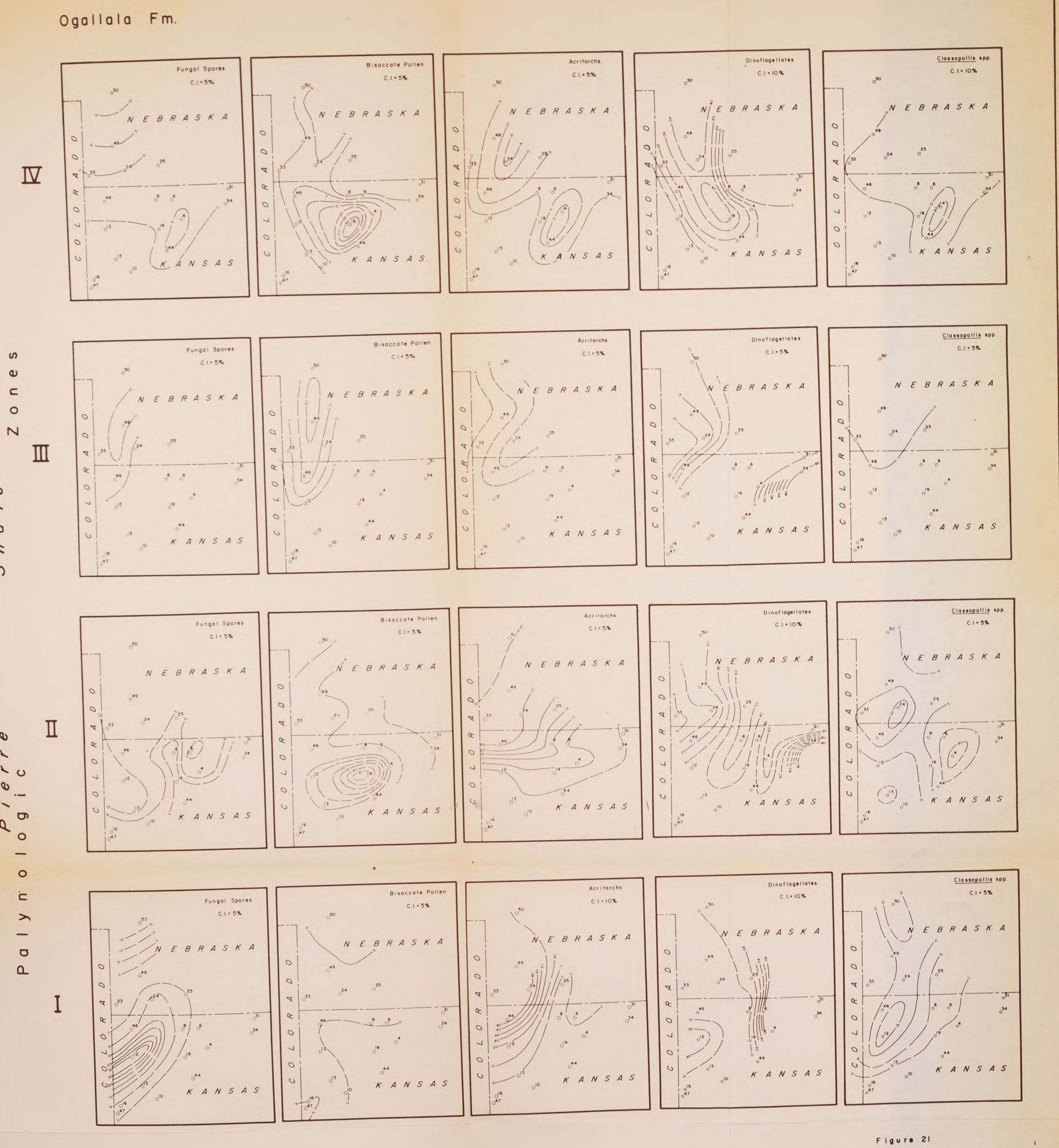


Figure 21

Areal Distribution of Selected Palynomorph Groups in The Pierre Shale

(Contours in relative percentage of each group)

Scale

0 18 36 60 90 miles

J.M.Lammons

March, 1969

coincide quite well. This relationship is repeated again in Palynologic Zone IV.

The apparent discrepancy between the inferred direction of increase in the relative percentages of acritarchs and dinoflagellates (the former apparently increasing north-westward, the latter eastward and westward) is not unique to Palynologic Zone I. The same relationship is repeated in Palynologic Zone II.

The extremely low percentages of the bisaccate pollen types in Palynologic Zone I precludes any inference of direction of increase in relative percentage. There is a weak anomaly based on Subsurface Section 47 (Wallace County, Kansas). This scarcely exceeds 5% relative frequency and is not regarded as a significant feature.

In summary, the distribution of the selected palynomorphs of Palynologic Zone I indicates that both fungal spores and Classopollis pollen responded in similar ways to a common mechanism such as water transport. The areas of highest concentration of both groups correspond, in general, to areas of concentration of the acritarchs. It is possible, although not proven by the present study, that the configuration of the sea floor may have influenced the distribution of the acritarchs after their demise during Palynologic Zone I time. A similar control was found by Rossignol (1961) in the distribution of spores and pollen in the Quaternary sediments of off-shore Israel. It is acknowledged that the factors controlling the distribution of the acritarchs are different than those controlling the distribution of spores and pollen. The almost diametrically opposed directions of relative increase in the acritarchs and dinoflagellates may be related to distribution of these forms during life.

Palynologic Zone II

A more subtle relationship between fungal spores and *Classopollis* pollen is shown in Palynologic Zone II. The areas of apparently high concentration of these palynomorph groups do not coincide with those previously discussed under Palynologic Zone I. The distinctively anomalous concentration of fungal spores in northwest Kansas in Palynologic Zone I time had largely disappeared before the inception of Palynologic Zone II.

The inferred directions of increase in the concentrations of acritarchs and dinoflagellates remained the same during Palynologic Zone II as in Palynologic Zone I. Greater concentrations of dinoflagellates in Subsurface Sections 31 and 34 (Norton County, Kansas) are possibly due, in part, to local bottom conditions resulting from minor structural changes in the Cambridge Arch (see Fig. 2 for the location of this feature).

A well-defined area of abnormally high concentration of bisaccate pollen is evident in Palynologic Zone II. A modified version of this same feature reappears in Palynologic Zone IV after having been strongly modified in Palynologic Zone III time.

In summary, the greatest changes in Palynologic Zone II involve the distribution of fungal spores, bisaccate pollen and *Classopollis* pollen.

Palynologic Zone III:

The relative percentages of fungal spores recovered from Palynologic Zone III sediments are too small and scattered for a significant interpretation. There is, nevertheless, a suggested increase in the relative percentages of fungal spores in the area of Subsurface Section 49 (Chase County, Nebraska).

Pollen of the bisaccate type are found in significant percentages in a north-south trending area that is almost coincidental with the earlier mentioned area of fungal spore concentration. The parent plants of some of the fungal spores may have been conspecific with some of the parent plants of the bisaccate pollen. A relationship such as this in extant plants has been reported for *Fomes pini* (Thore) Llyd. and *Tsuga mertensiana* (Bong.) Sarg. by Graham (1963, p. 65), but, of course, no evidence to support such a postulation was established in this study. Dilcher (1965, Table 1) summarized the epiphyllous and probably epiphyllous fungi known from the fossil record, including the following cases from Cretaceous sequences:

Fungi	Host	Location	Author[1]
Petrosphaeria	Outside cortical cells of *Saururopsis*	Japan	Stopes & Fujii, 1909
Pleosporites	*Cryptomeriopsis*	Japan	Suzuki, 1910
Sphaeriopsis	various	Bohemia, Italy and France	Geyler, 1887
Phacidium	*Pyrus*, *Eugenia* *Populus*	Germany, Bohemia	Ludwig, 1959
Xylomides	*Pistacia*, *Rhus*, *Acer*	Italy, Switzerland	Schimper, 1869
Excipula	*Pecopteris*, *Macrostachya*	Prussia	Schimper, 1869
Aecidites	*Dryophyllum*, *Rhamnus*	Prussia, Bohemia	Debey & Ettingshausen, 1859

[1]References as given by Dilcher (1965, p. 46-49).

Fungi	Host	Location	Author
Puccinites	none given	Austria, Nebraska	Ettingshausen, 1853
Ovularites	none given	Nebraska	Whitford, 1916
Torula	none given	Prussia	Caspary, 1907
Himantia	Dryophyllum	Bohemia	Debey & Ettingshausen, 1859

The distribution patterns of the marine phytoplankton in Palynologic Zone III time are inconsistent. Figure 21 illustrates the fact that the acritarchs increase in relative abundance to the northeast and are somewhat localized in their distribution. The same illustration shows that a wide area barren of dinoflagellates is flanked on its east and west by areas of moderate to high percentages of the same palynomorph group.

The occurrence of Classopollis pollen in Palynologic Zone III is too sketchy for analysis. The single contour shown is based on the occurrence of Classopollis pollen (less than 5% relative percentage) in sections north and south of the same contour.

In summary, the most significant changes in, or continuations of, Palynologic Zone II distribution patterns in Palynologic Zone III are, 1) the subtle relationship between the fungal spores and bisaccate pollen types and 2), the interpreted, diametrically opposed increases in the relative percentages of the dinoflagellates in Palynologic Zone III time.

Palynologic Zone IV:

There is a possible relationship between the distribution patterns of the fungal spores, bisaccate pollen types and

Classopollis pollen in Palynologic Zone IV.

A correspondence between the two areas of above-average concentration of acritarchs and the two areas of above-average concentration of dinoflagellates may indicate that conditions during Palynologic Zone IV time were uniquely favorable for the proliferation of both palynomorph groups. The above-average concentrations of acritarchs and dinoflagellates in localized, coincidental areas, may also have been governed by optimum conditions of preservation. The fact that greater numbers of each group are present in Palynologic Zone IV coincides with the earlier observation that greater numbers of palynomorph species were also present in the same Palynologic Zone (see p. 52) for further discussion of this point).

Areal Distribution of Palynological Zones in the Pierre Directly Beneath the Post-Pierre Unconformity

Figure 22 (in pocket) summarizes the data derived from the preceding analysis. Assignment of the youngest portion of the Pierre, sampled directly beneath the post-Pierre (pre-Ogallala) unconformity, to a corresponding Palynologic Zone is supported by data found elsewhere in this thesis (see Figures 15 through 19). The assignment of the first Pierre sediments penetrated below the post-Pierre unconformity in Subsurface Section 34 (central Norton County, Kansas) to a specific palynologic zone is conjectural; repeated attempts failed to yield workable quantities of plant microfossils from that portion of the Pierre. In this case, the assignment is based on the results obtained in the stratigraphically lower portions in the same section. A similar situation is apparent in Subsurface Section 4 (southwest Decatur County, Kansas) where a barren sample occurs at or near the boundary between the proposed Palynologic Z ones (see Figure 18).

The distribution of the oldest Palynologic Zone occurring directly beneath the post-Pierre unconformity, Zone I, is limited to southern Wallace and central Logan counties, Kansas.

The next higher unit, Palynologic Zone II, occurs in a narrow subcrop[1] belt across central Wallace and northern Logan counties, Kansas. The eastern limit of this unit can not be placed on the basis of the data currently available.

Palynologic Zone III occupies a northwest-southeast subcrop belt across northwestern Kansas. The width of the subcrop varies from 36 to 78 miles. Two major variations in the distribution of this zone can be noted; 1) the exceptionally wide area of Zone III subcrop in the Rawlins-Thomas counties area and 2), the re-entrant of Palynologic Zone IV material in Decatur and Norton counties, Kansas. The first-named anomaly may be a reflection of an intermittently positive area in the same region (to be discussed under "Paleoecological Considerations", p. 83 or simply the result of the thickness of the zone itself. The last-named anomaly may represent a local downwarping in post-Palynologic Zone III time which permitted deposition of Zone IV sediments east of the previously mentioned Rawlins-Thomas county area.

Z one IV occurs directly beneath the post-Pierre unconformity north and west of the geographical limit of Zone III. Subsurface

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[1]"A paleogeographic map illustrates the distribution of rock units exposed at a paleotopographic surface in the same way that a geologic map illustrates the position of outcrops at the present surface. Such maps are also called subcrop maps because they show where the rocks previously cropped out at a surface that is now covered." Bishop, 1960, p. 136.

Section 50 (Keith County, Nebraska), the northernmost section studied, contains a Palynological Zone IV assemblage directly beneath the same unconformity. Zone IV, which includes the Lake Creek Shale Member, is not present directly beneath the post-Pierre unconformity in Wallace County, Kansas. Palynologic Zones I, II and III are believed to comprise the entire Pierre sequence in Wallace County and to include the Sharon Springs, Weskan and Salt Grass Creek Shale members. Hodson (1963, p. 47) stated that ". . . only the lower four members [the Sharon Springs, Weskan Shale, Salt Grass Creek Shale and Lake Creek Shale members] which make up about the lower half of the Pierre, are present in Wallace County, the upper half having been removed by pre-Ogallala erosion". Hodson does not, however, discuss in detail the lithologic character of any of the Pierre that he believes to be present in Wallace County, Kansas. The apparent discrepancy between Hodson's interpretation and that of the present study (where Palynologic Zone IV, the main part of which is the Lake Creek Shale Member, is not believed to be represented in the palynologic analysis of the Pierre of Wallace County) may be due to the distribution of the samples available to the present study. An attempt to secure samples from the type section of the Lake Creek Shale Member was unsuccessful principally because of the vagueness of Elias' original designation (". . . a stream in the northwest part of Wallace County . . ." Elias, 1931, p. 93).

The width of the subcrop belt of Palynologic Zone II sediments shown, though perhaps a function of zone thickness, may not depict its true distribution. More sampling in Gove, Sheridan and Graham counties might reveal an eastern extension of this zone. The

interpreted distribution of Palynologic Zone III probably reflects a localized positive physiographic feature in Thomas and Rawlins counties which may be a minor extension of the Cambridge Arch (discussed by Fuenning, 1942, p. 1536). Merriam and Atkinson (1955, p. 25) suggested that ". . . there was slight movement on the southern end of the Cambridge Arch during that [Niobrara] time". Merriam and Atkinson found, through the use of structure maps, that the structure of the Pierre Shale is the same as the older Cretaceous beds and assumed that folding occurred in post-Niobrara time. This folding probably resulted from movements associated with the Laramide Revolution of the Rocky Mountain region. The same authors concluded that the last major movement of the Cambridge Arch occurred near the end of Cretaceous (Pierre) time and prior to the deposition of the earliest Tertiary sediments. It is probably presumptious to suggest that this movement occurred during the deposition of Palynologic Zone III, but it is reasonable to expect some expression of such an event in the distribution of the various proposed zones within the Pierre.

The anomalous area shown in Decatur and Norton counties, Kansas (Figure 22) coincides with a thinner area of the interval from the Dakota to the base of the Fort Hays Limestone Member of the Niobrara Formation (the southern end of the Cambridge Arch of Merriam and Atkinson, 1955, Figure 12).

As previously mentioned, an assignment of the last major structural movement in northwestern Kansas to the time of deposition of a specific member of the Pierre Shale does not seem to be warranted at this time. It is suggested from the data available in the present study, however, that the movement is expressed in the distribution pattern of Palynologic Zone III, thus suggesting that movement occurred in Weskan and Lake Creek times.

The interpreted succession of the palynologic zones of the Pierre in subcrop beneath the post-Pierre unconformity suggests, therefore, that slight movements of the Cambridge Arch are expressed in the distribution of the various palynologic zones of the Pierre. The anomalous areal distribution of Palynologic Zone III sediments (as shown in Figure 22) is believed to be an expression of a structurally sensitive portion of the Pierre.

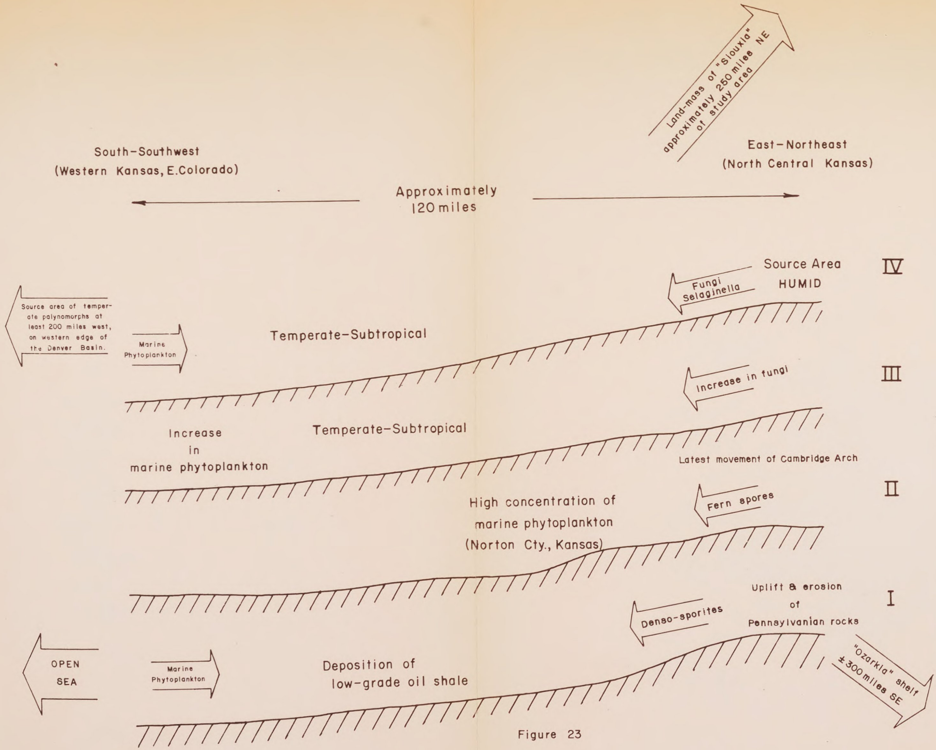

Figure 23

Diagrammatic Reconstruction of Sea Floor Configuration
Along a General Line of Section Normal to the Inferred Eastern Limit of the Pierre Sea

(No vertical or horizontal scale)

J. M. Lammons — March, 1969

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Paleoecological Considerations

Several of the general conclusions regarding the paleoecology of the Pierre are summarized by Figure 23. The palynological data derived from the present study are related to the published paleontological data as follows:

Palynologic Zone I (essentially the Sharon Springs Shale Member of the Pierre Shale):

The deposition of low-grade oil shales relatively rich in marine phytoplankton distinguishes this zone (lithologically) from succeeding zones. An apparently high percentage of the typical Pennsylvanian form, Denso-sporites sp., suggests that Paleozoic sediments were exposed to erosion in the source areas. The first group, the marine phytoplankton, indicate more or less open marine conditions and moderately shallow waters. This interpretation is supported by the recovery of Elasmosaurus platyurus and Tylosaurus sp., both of which were probably inhabitants of the near-shore zone. The recovery of the ammonites Heteroceras cf. tortum and Baculites aquilaensis from the Sharon Springs Member by Elias (1931, op. cit.) would also indicate open marine conditions. The rare occurrences of bentonite bands in this zone infer only minor vulcanism in the upwind areas. The possibility of major changes in meteorological conditions between the area of volcanic activity and northwestern Kansas can not be discounted.

Palynologic Zone II (lower Weskan Shale Member of the Pierre Shale):

The entry of significant numbers of fern spores during the deposition of this zone suggests greater stability and less erosion due to lower relief in the source areas that had previously supplied

numerous spores of Pennsylvanian age. Anomalous conditions did exist in Norton County, Kansas, where large populations of marine phytoplankton were incorporated in sediments of Palynologic Zone II. The comparably meager fauna of this zone, together with the common occurrence of limonite concretions, would indicate near-shore, shallow water, swampy conditions. A general warming trend and development of broad, low coastal plains and swamps are suggested, somewhat tenuously, by the influx of fern spores. Such an interpretation is tenuous because of the known durability (in transport, preservation and re-cycling) of fern spores in general. The possibility that the source area for the ferns in question may have been a considerable distance northeast of the site of deposition can not be discounted.

Palynologic Zone III (Upper Weskan Shale and Lake Creek Shale members of the Pierre Shale):

A significant increase in fungal entities in this zone may be interpreted as an indication of sustained swampy conditions in the source areas or possibly variations in the discharge patterns of the drainage system. The increased percentages of marine phytoplankton indicate that more open marine conditions existed in the area of deposition. Faunal evidence that includes *Serpula* (?) *wallacensis* n. sp., *Ostrea* aff. *lugubris* and *Lingula* sp. indicates shallow water conditions in the same area. Relatively free water circulation is necessary for survival of the bottom-dwelling forms mentioned. The water must have been sufficiently streng to support small fishes (noted by Elias in the Lake Creek section), *Baculites compressus* var. *reesidei*, *B. compressus* var. *corrugatus* and *B. compressus* s.s. Abundant bands of gypsum in the upper part of Palynologic Zone III indicate significant changes in

water circulation. The spores and pollen produced and transported to the depositional basin during this time indicate a subtropical and perhaps almost tropical, condition in the source areas.

Palynologic Zone IV (Salt Grass Creek Shale, Undifferentiated and Beecher Island Shale members of the Pierre Shale):

More humid conditions (in the source areas) are indicated by the increase in spores assignable to the family Selaginellaceae and an increase in fungal entities of probable terrestrial origin. The presence of marine phytoplankton in significant numbers and varieties indicates open marine conditions in the area of deposition. This interpretation is supported by the occurrence of *Baculites pseudovatus* var. *A*, *B. compressus* var. *reesidei*, *B. grandis*, *B. clinolobatus*, *Acanthoscaphites nodosus*, *Discoscaphites nicolleti* var. *saltgrassensis*, *D. abyssinus*, *D. conradi*, *Scaphites reesidei* and *S. olenus*. The *Lucina*-bearing limestones of the upper part of the Beecher Island Shale Member suggest that open marine waters of shallow depth existed in the area of deposition at the close of Pierre time.

A general reduction in the total microfossil floral assemblage, from west to east, is suggested by Figure 21 to have occurred during Palynologic Zone IV time. Such a reduction would further substantiate the postulation of a source area (for the temperate palynomorphs) along the western edge of the Denver Basin. In contrast, Cross (personal communication) suggests that the coastal plains of Pierre time were probably located near, or perhaps even coincidental with, the more firmly established edge of the Dakota Formation (see also Merriam, 1963, Figure 23). Additional support for the postulated coastal swamp conditions are the late Cretaceous coals of northwest Iowa and Minnesota.

CHAPTER VI

SYSTEMATIC PALYNOLOGY

Introduction

A generally conservative approach to the systematic taxonomy of the microfossil flora of the Pierre Shale is utilized in the present dissertation. A "cf" designation alluding to previously established taxa is freely employed because the author did not have the opportunity to compare the species of Pierre palynomorphs with the type specimens of those species. An attempt is made, however, to place each significant palynomorph in its proper taxon[1]. A natural system of classification, such as the one employed in the present study, has numerous inherent weaknesses. Perhaps the most significant of these is the relative lack of morphological information on spores and pollen of extant species. In a study such as the present one, it is believed that a sincere attempt to assign the palynomorphs recovered from the Pierre Shale to extant forms is warranted. Palynomorphs that are apparently distinct from any described extant spore or pollen are included under the general heading "incertae sedis". All spores and pollen included in this study are in a dispersed state and neither sori nor pollen-producing

[1]The systematic taxonomy used will be up-dated prior to publication of this dissertation. Such a procedure is necessitated by the fact that very recent (or in-press) publications have modified certain of the taxa included in the present study.

structures were observed.

The systematic treatment of the dinoflagellates and acritarchs follows that recommended by Downie, Evitt and Sarjeant (1963) and more extensively elaborated upon by Downie and Sarjeant (1964), and modified by Staplin, Jansonius and Pocock (1965).

All addresses included are from the Leitz Ortholux instrument with the lateral stage movement (right hand side of slide holder) locked in the 76 position. The value of a reference mark scratched on each slide near its upper left hand corner is recorded in Appendix A. The location of each significant palynomorph is given (in millimeters) vertically and laterally from this mark.

A. Sporae Dispersae

Division PHYCOMYCOTA[1]

Phycopeltis sp.

Plate 16, Fig. 4

Description:

Fungal (?) entity, subtriangular in outline. Walls very dense and without any apparent stratification. Three sulcus-like reentrants from the peripheral outline are separated by three pronounced indentations. Size: 15 to 16 μ (overall diameter).

Discussion:

Cranwell (1964, p. 46) included an example of Phycopeltis sp. from Rapa Island, which she placed in the algae. Similar forms have also been referred to the Phycomycotae (Bold, 1957) and are either parasitic or saprophytic in habit. Cranwell (loc. cit.) also noted the association of Phycopeltis sp. with representatives of the Microthyriaceae. A similar association of Phycopeltis sp. and fungal spores is present in the Pierre. Dilcher (1965, pl. 4, figs. 18-29) figures forms very similar to Phycopeltis sp. which he terms ". . . microthyriaceous germlings, fossil, reconstructed developmental series progressing to the stomata . . .". Phycopeltis sp. is extremely rare in the Pierre samples and is not limited to any particular portion of the formation.

Figured specimen:

Surface section Phillips 1A (Pb 4013)(41.1 x 127.8).

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[1]Division 11 of Bold (1957), synonymous (according to Bold) with Class 1. Phycomycetes of Tippo (1942).

FUNGI IMPERFECTAE

Fungal Spore sp. A

Plate 15, Fig. 4

Description:

Spores linear, individuals consisting of from six to eight cells; terminal cells outwardly convex with or without visible aperture. Septa planar to very slightly convex. Cell walls smooth and without stratification. Average diameter at approximate mid-point, 30μ ; average overall length, 88 μ.

Discussion:

Fungal Spore sp. A occurs infrequently throughout the Pierre Formation. The most distinguishing characteristic of this form is the common "branching" of the apical cell.

Figured specimen:

Subsurface section 44, slide 2X (Pb 4115A)(32.8 x 122.8).

Fungal Spore sp. B

Plate 15, Fig. 5

Description:

Spores linear, individuals consist of five to six cells. The apical cell is convex outward; the basal cell (at the opposite termination of the spore) is conical. Cell walls thick (average 2 μ) and without stratification. Septa planar and regularly distributed along the longitudinal dimension of the spore. Average diameter at approximate mid-point, 9μ ; average overall length, 35μ .

Figured specimen:

Subsurface section 46, slide 8F (Pb 4200F)(38.3 x 126.6).

Fungal Spore sp. C

Plate 15, Fig. 6

Description:

Spores linear, individuals consist of sixteen to twenty cells. The apical cell is convex outward and is occasionally subdivided by a subordinate wall that is oriented parallel to the longitudinal axis of the spore. The cell (at the opposite termination of the spore) is conical and is not subdivided. Cell walls average 1μ in thickness and are without stratification. Septa irregularly planar and at times join the main wall at angles up to 20°. Average diameter of spore at approximate mid-point, 11μ; average length, 44μ.

Discussion:

Fungal Spore sp. C differs from Fungal Spore sp. B by its much thinner cell walls and the irregular septal spacing. Fungal Spore sp. C occurs sporadically throughout the Pierre Formation.

Figured specimen:

Subsurface section 25, slide 8A (Pb 4168A)(39.0 x 127.7).

Fungal Spore sp. D

Plate 15, Fig. 7

Description:

Spores irregularly one-ranked; individuals consist of six or seven cells. Terminal cells are spherical and lack apertures. Cell walls smooth and unstratified. Overall diameter from 17 to 22 μ; overall dimension from 53 to 56 μ.

Discussion:

The individual cells comprising Fungal Spore sp. D were apparently spherical in the live state and are now collapsed. The overall appearance of this form is similar to a group of thin-walled inaperturate spores. Fungal Spore sp. D recurs throughout the Pierre Formation.

Figured specimen:

Subsurface section 7 (Logan)(Pb 3936)(43.1 x 122.8).

Division BRYOPHYTA

Family SPHAGNACEAE

Genus Sphagnum (Dillenius) Ehrh.

Genotype: none designated

Sphagnum punctaesporites Rouse (1959)

Plate 1, Fig. 16

1959 Sphagnum punctaesporites Rouse, p. 308, pl. 1, figs 25, 26.

Description:

Trilete spore, sub-triangular to sub-circular in equatorial outline. Laesurae extending approximately 2/3 of the equatorial radius. Exine smooth, 1.1 to 1.7μ in thickness. Broadly punctate ornamentation. Exine thickenings in the polar areas between the laesurae. Equatorial diameter from 24 to 37 μ.

Figured specimen:

Subsurface section 33, slide 5A (Pb 4093A)(43.3 x 114.9).

Discussion:

Members of the family Sphagnaceae are cosmopolitan in distribution but are confined to boggy or aquatic habitats. The presence of spores assignable to the genus Sphagnum in the microfossil flora of the Pierre infers that wet lowland terrain formed a part of the source area for the organic remains recovered from the Pierre.

Division PTEROPHYTA

Family LYCOPODIACEAE

Genus *Lycopodium* Linn.

Genotype: none designated

Lycopodium cf. *fastigioides* Couper (1953)

Plate 3, Figs. 12-13

1953 *L. fastigioides* Couper, p. 19, pl. 1, fig. 3.

Description:

Trilete spore; long, distinct laesurae; sub-triangular in equatorial outline. Exine 1.6 to 2.0 μ in thickness. Distal surface clearly reticulate, muri from 0.3 to 1.0μ thick, projecting 2.5 to 3.3 μ into the perispore layer. Lumen of reticulum from 4.5 to 8.0μ in width. Equatorial diameter (overall), from 31 to 51 μ.

Discussion:

The figured specimen is similar to *Lycopodium fastigiatum* and *L. volubile*, but is larger than both.

Figured specimen:

Subsurface section 46, slide 1 (Pb 4193)(44.3 x 110.9).

Lycopodium sp. (*fastiatum*-*volubile* group) Couper (1953)

Plate 3, Fig. 11

Description:

Subtriangular spore; weak trilete mark extending nearly to periphery; exine 1.0 to 2.5 μ in thickness. Distal surface reticulate, muri less than 1 μ thick, projecting 3.0 to 5.0μ into the perispore (?) layer. Equatorial diameter, 68 to 79 μ.

Discussion:

Couper (1953, p. 19) noted that the two species, L. fastigiatum R. Br. and L. volubile Forst. f., cannot be consistently seprated. He therefore considered the forms found in the Ohika beda within a "fastigiatum-volubile group".

Figured specimen:

Subsurface section 46, slide 8F (Pb 4200F)(43.1 x 121.4).

Lycopodium cf. papillaesporites Rouse (1957)

Plate 3, Figs. 6-7

1957 L. papillaesporites Rouse, p. 361, pl. 3, figs. 50-52.

Description:

Trilete spore; sub-triangular in equatorial outline. Trilete scar with somewhat wavy laesurae extending to periphery. Some examples exhibit thin perisporial layer. Reticulate ornamentation with thin papillae. Equatorial diameter, 34μ .

Discussion:

Rouse (1957, p. 361) noted that this form compares well with the modern Lycopodium spores described by Jonas (1952, p. 37).

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(40.0 x 112.0).

Genus Lycopodiumsporites Thiergart (1938)

Lectogenotype: Lycopodiumsporites agathoecus (R. Potonie, 1934) Thiergart 1938

1934 Lycopodiumsporites agathoecus R. Potonie, p. 43, pl. 1, fig. 25.

1938 L. agathoecus (R. Potonie 1934) Thiergart, p. 293.

<u>Lycopodiumsporites</u> <u>tri-arcuatus</u> Delcourt & Sprumont (1955)

Plate 2, Fig. 10

1955 <u>L.</u> <u>tri-arcuatus</u> Delcourt & Sprumont, p. 32, pl. 3, fig. 1.

Description:

Trilete spore; trilete scar (not shown in the specimen figured) nearly reaches the periphery of the spore; triangular to slightly concave in equatorial outline; apices rounded; exine 3.6 μ thick, distinctly ornamented with more or less regularly spaced openings 3.5 to 5.0 μ in diameter. Equatorial diameter, 59 μ.

Figured specimen:

Surface section Logan 7 (Pb 3936)(34.4 x 126.4).

Family SELAGINELLACEAE

Genus <u>Acanthotriletes</u> (Naumova, 1937) R. Potonie and Kremp (1954)

Genotype: <u>Acanthotriletes</u> <u>ciliatus</u> (Knox) Potonie and Kremp (1954)

1937 <u>Acanthotriletes</u> <u>Naumova</u>, p. 60-61.

1950 <u>Spino-sporites</u> <u>ciliatus</u> Knox, p. 313, pl. 17, fig. 206.

1954 <u>Acanthotriletes</u> <u>ciliatus</u> (Knox) Potonie and Kremp, p. 83, pl. 14, fig. 257.

<u>Acanthotriletes</u> <u>varispinosus</u> Pocock (1962)

Plate 1, Fig. 11

1962 <u>A.</u> <u>varispinosus</u> Pocock, p. 36, pl. 1, figs. 18-20.

Description:

Trilete spore; laesurae (observed in a single specimen) over 3/4 of the equatorial radius; circular to sub-circular in equatorial outline; proximal face flat to slightly concave; distal face convex. Exine 1.5 to 1.7 μ thick, spinose with pointed spines from 3 to 6 μ in length and with bases from 1.0 to 2.5 μ in diameter, Spine

Holotype:

Subsurface section 13, slide 2C (Pb 4074C)(37.0 x 117.5).

Figured specimen:

Subsurface section 13, slide 2C (Pb 4074C)(37.0 x 117.5).

Cingulatisporites callosus Weyland & Greifeld (1953)

Plate 4, Fig. 5

1953 *C. callosus* Weyland & Greifeld, p. 42, pl. 11, fig. 60.

Description:

Trilete spore; sub-triangular in equatorial outline; laesurae extend to inner margin of the cingulum. Cingulum 3.6μ wide in interradial areas, thinning to 1.2μ in apical areas and somewhat hyaline in nature. Equatorial diameter; 32 μ.

Figured specimen:

Subsurface section 50, slide 6 (Pb 4246)(42.9 x 120.2).

Cingulatisporites levispeciosus Pflug (1953),
emend. R. Potonie (1956)

Plate 4, Fig. 10

Description:

Trilete spore; almost circular in compressed equatorial outline; outline slightly indented due to preservation; thickened central body and flange with granular exine. Diameter of central body, 27 to 35 μ. Width of flange, 7 to 9 μ. Trilete scar extends to periphery. Overall diameter, 40 μ.

Figured specimen:

Subsurface section 46, slide 7F (Pb 4199F)(31.2 x 119.0).

Holotype:

Subsurface section 13, slide 2C (Pb 4074C)(37.0 x 117.5).

Figured specimen:

Subsurface section 13, slide 2C (Pb 4074C)(37.0 x 117.5).

Cingulatisporites callosus Weyland & Greifeld (1953)

Plate 4, Fig. 5

1953 C. callosus Weyland & Greifeld, p. 42, pl. 11, fig. 60.

Description:

Trilete spore; sub-triangular in equatorial outline; laesurae extend to inner margin of the cingulum. Cingulum 3.6μ wide in interradial areas, thinning to 1.2μ in apical areas and somewhat hyaline in nature. Equatorial diameter; 32 μ.

Figured specimen:

Subsurface section 50, slide 6 (Pb 4246)(42.9 x 120.2).

Cingulatisporites levispeciosus Pflug (1953), emend. R. Potonie (1956)

Plate 4, Fig. 10

Description:

Trilete spore; almost circular in compressed equatorial outline; outline slightly indented due to preservation; thickened central body and flange with granular exine. Diameter of central body, 27 to 35 μ. Width of flange, 7 to 9 μ. Trilete scar extends to periphery. Overall diameter, 40 μ.

Figured specimen:

Subsurface section 46, slide 7F (Pb 4199F)(31.2 x 119.0).

Discussion:

Living representatives of the family Selaginellaceae are cosmopolitan in distribution but are developed most abundantly in tropical regions with heavy rainfall.

Order EQUISETALES

Family EQUISETACEAE

Genus Equisetosporites Daugherty (1941), emend. Singh (1964)

Genotype: Equisetosporites chinleana Daugherty (1941)

1941 Equisetosporites chinleana Daugherty, p. 63, pl. 14, fig. 4.

1964 Equisetosporites Daugherty, emend. Singh, p. 129-131.

Equisetosporites sp.

Plate 4, Fig. 4

Description:

Acolpate pollen grain, ellipsoidal and apparently twisted during fossilization. Exine ornamented with unbranched, strongly twisted ridges, approximately 2 μ in width and separated by 10 to 12 furrows. Furrows less than 1μ in width. Ridges coalesce immediately before reaching the longitudinal ends. Longitudinal end areas unsculptured and slightly thicker than the individual ridges. Size range (9 specimens), 22 to 25 μ in width; 34 to 37 μ in length.

Discussion:

The Ephedraceae have developed adaptations for almost every type of environment. They are limited, requiring both climatic and edaphic dryness.

Figured specimen:

Subsurface section 13, slide 2A (Pb 4074)(34.4 x 114.1).

Order FILICALES

Family OSMUNDACEAE

Genus Osmundacidites Couper (1953)

Genotype: Osmundacidites wellmanii Couper (1953)

1953 Osmundacidites wellmanii Couper, p. 20, pl. 1, fig. 5.

Osmundacidites wellmanii Couper (1953)

Plate 2, Fig. 1

Description:

Trilete spore; laesurae distinct, extending at least 3/4 of the equatorial radius, occasionally reaching the periphery; circular to subcircular in equatorial outline. Exine less than 1μ in thickness, granulate-papillate, sculpture somewhat reduced near the trilete mark. Equatorial diameter from 42 to 46μ .

Discussion:

Couper (1953, p. 20) noted that the spores of Todea barbara (Thumb.) Moore, an extant member of the Osmundaceae in New Zealand, are similar to, but smaller than, the spores of Osmundacidites wellmanii. The same author also noted that the former is more lightly sculptured. Members of the family Osmundaceae are, at the present time, cosmopolitan in distribution; mainly in temperate and tropical moist woodlands.

Figured specimen:

Subsurface section 46, slide 1 (Pb 4193)(33.7 x 113.8).

Family SCHIZAECEAE

Genus *Appendicisporites* Weyland & Krieger (1953) ex Weyland & Greifeld 1953

Genotype: *Appendicisporites tricuspidatus* Weyland & Griefeld (1953)

1953 *Appendicisporites tricuspidatus* Weyland & Krieger, p. 42, pl. 11, fig. 54.

Appendicisporites tricornitatus Weyland & Greifeld (1953)

Plate 4, Fig. 6

1953 *A. tricornitatus* Weyland & Greifeld, p. 43, pl. 11, fig. 52.

Description:

Trilete spore; laesurae about 3/4 of the radius; commissures raised; outline rounded-triangular; proximal surface unsculptured; distal surface ribbed (ribs 1.6 to 2.2 μ in width, spaced 1.6 to 2.8 μ apart). Apical protrusions 7.3 μ in length. Equatorial diameter, from 42 to 63μ .

Figured specimen:

Subsurface section 46, slide 11F (Pb 4203F)(38.6 x 110.4).

Genus *Chomotriletes* Naumova (1937 ? 1939) ex Naumova (1953)

Lectogenotype: *Chomotriletes vedugensis* Naumova (1953)

1937 *Chometriletes* Naumova, p. 60-61.

1953 *Chomotriletes vedugensis* Naumova, p. 39, pl. 7, fig. 21.

Chomotriletes fragilis Pocock (1962)

Plate 3, Fig. 5

1962 *C. fragilis* Pocock, p. 39, pl. 3, figs. 30-32.

Description:

Alete spore; circular in equatorial outline. Exine thin (less than 1 μ), ornamented with ridges about 1 μ apart. The ridges shown on the illustrated specimen are concentric and parallel to the equatorial outline. Size (equatorial outline), 41 x 49 μ.

Discussion:

The specimens recovered from the Pierre are considerably larger than the specimens of the type species. *Chomotriletes* was placed in the family Schizaeceae by Singh (1964, p. 61). Singh (*loc. cit.*) also restricted the genus to ". . . those forms which have numerous circular and concentric ridges, and a faint or no trilete mark. To avoid further confusion, it seems necessary to place in the genus *Chomotriletes* only those forms which have numerous circular and concentric ridges, and to exclude trizonate forms with distinct trilete marks."

Figured specimen:

Subsurface section 33, slide 5A (Pb 4093A)(30.8 x 118.8).

Genus *Cicatricosisporites* R. Potonie & Gelletich (1933)

Genotype: *Cicatricosisporites dorogensis* R. Potonie and Gelletich (1933)

1933 *C. dorogensis* R. Potonie and Gelletich, p. 522, pl. 1, fig. 1.

Cicatricosisporites dorogensis R. Potonie & Gelletich (1933)

Plate 2, Fig. 8

Description:

Trilete spore; laesurae long with raised commissures; subtriangular in equatorial outline; commonly with sides slightly concave; distal surface sculptured with slightly raised ribs measuring

1.1 to 1.6 μ in width and spaced 0.5 μ apart; proximal surface not sculptured. Exine approximately 1.5 μ in thickness (proximal surface). Size, 35 x 29 μ.

Discussion:

Couper (1958, p. 110) found that the spores of Anemia colwellensis Chandler taken from a fertile pinnule were comparable to the fossil spore Cicatricosisporites dorogensis. On the basis of this, Couper suggested that C. dorogensis is a dispersed from of Anemia.

Figured specimen:

Surface section Cheyenne 1C (Pb 4004)(40.5 x 115.3).

Cicatricosisporites mohrioides Delcourt & Sprumont (1955)

Plate 2, Fig. 6

1955 C. mohrioides Delcourt & Sprumont, p. 20, pl. a, fig. 2.

Description:

Trilete spore; circular to triangular in equatorial outline; caniculate sculpture; equatorial diameter from 32 to 33 μ.

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(45.0 x 121.2).

Genus Lygodioisporites R. Potonie (1951)

Lectogenotype: Lygodioisporites solidus R. Potonie (1951)

1951 L. solidus R. Potonie, p. 144.

Lygodioisporites sp.

Plate 3, Fig. 9

Description:

Trilete spore; laesurae almost reaching periphery and

bordered by distinct margo; equatorial outline sub-triangular with well rounded apices; both the proximal and distal faces ornamented with large verrucae; verrucae measure approximately 2.6 μ at their base and are approximately 2.7 μ in height. Equatorial diameter from 31 to 36 μ.

Discussion:

This form is similar to the Lygodioisporites species described by Couper (1958, p. 144) and included by Upshaw (1964, pl. 1, fig. 5). The species described here is smaller than previously described species.

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(31.2 x 126.7).

Genus Undulatisporites Pflug (1953)

Genotype: Undulatisporites microcutis Pflug (1953)

1953 Undulatisporites microcutis Pflug, p. 52, pl. 1, fig. 81.

Undulatisporites sinuosis Groot and Groot (1962)

Plate 1, Fig. 1

1962 Undulatisporites sinuosis Groot and Groot, p. 154, pl. 6, fig. 3.

Description:

Spore trilete, triangular-convex in equatorial outline; laesurae extending to the periphery, undulating; bordered by a narrow margo. Exine faintly scabrate. Equatorial diameter, 19 to 25 μ.

Discussion:

Groot and Groot (loc. cit.) have stated that the genus Undulatisporites is a "catch-all" taxon for immature spores of

several genera. The same authors cite the work of Couper (1958, p. 111, pl. 16, figs. 11-13) with recent Anemia phyllitidis (Linn.) Swartz in which immature spores of at least one species (A. phyllitidis (Linn.) Swartz) are very similar, morphologically, with Undulatisporites.

Figures specimen:

Subsurface section 33, slide 9A (Pb 4097A)(33.1 x 117.0).

Undulatisporites sp.

Plate 1, Fig. 10

Description:

Trilete spore; triangular-rounded in equatorial outline; laesurae extending to the periphery, undulating. Exine very thin (possibly eroded in the figured specimen), strongly scabrate. Equatorial diameter, 18μ.

Figured specimen:

Subsurface section 46, slide 2 (Pb 4194)(35.3 x 124.8).

Family GLEICHENIACEAE

Genus Gleicheniidites Ross (1949) ex Delcourt and Sprumont (1955)

Genotype: Gleicheniidites senonicus Ross ex Delcourt and Sprumont 1955

1949 G. senonicus Ross, p. 31, pl. 1, figs. 3-4.

1955 G. senonicus Ross ex Delcourt and Sprumont, p. 26.

Gleicheniidites cf. circinidites (Cookson) Singh (1964)

Plate 1, Figs 2-3

1953 Gleichenia circinidites Cookson, p. 464, pl. 1, figs. 5-6.

1957 Gleichenia cf. G. circinidites Cookson, in Balme, p. 23, pl. 3, figs. 42-44.

1964 Gleicheniidites cf. G. circiniidites (Cookson) Singh, p. 69-70, pl. 8, figs. 10-11.

Description:

Trilete spore; laesurae with very thin lips, reaching the periphery; triangular in equatorial outline; apices pointed and somewhat rhombic. Singh (op. cit., p. 69-70) suggests that the dark lines, normal to the laesurae in the apical areas, may be due to a diffraction pattern related to the thickened zones. Size range (equatorial diameter), from 23 to 32 μ.

Figured specimen:

Subsurface section 13, slide 2A (Pb 4074A)(35.6 x 114.1).

Genus Gleichenia Smith 1793

Genotype:

Gleichenia concavisporites Rouse (1957)

Plate 1, Fig. 7

1957 Gleichenia concavisporites Rouse, p. 363, pl. 2, figs. 36, 48; pl. 3, fig. 49.

Description:

Trilete spore; sub-triangular in equatorial outline; laesurae invaginated and surrounding the tetrad scar. Exine laevigate; somewhat translucent; frequently folded. Size (equatorial diameter), 38μ.

Discussion:

Selling (1946, Pt. 1, p. 32-33) described Gleichenia emarginata, the spores of which correspond very well with the spores named Gleichenia concavisporites by Rouse (1957).

Figured specimen:

Subsurface section 46, slide 11E (Pb 4203E)(34.3 x 116.0).

Genus Leiotriletes Naumova (1937) emend.
R. Potonie and Kremp (1954)

Genotype: Leiotriletes sphaerotriangulus Loose (1952, in R. Potonie, Ibrahim and Loose, pl. 18, fig. 15) ex R. Potonie and Kremp (1954)

Leiotriletes dorogensis (Kedves, 1960)Kedves (1961)

Plate 1, Fig. 13

1960 Laevigatisporites dorogensis Kedves (1960), Kedves, p. 98, pl. 3, figs. 1, 2, 5 & 7.

1961 L. dorogensis (Kedves, 1960) Kedves, p. 120-122, pl. 4, figs. 14-19; pl. 5, figs. 1,2,5,6,8,9,12 & 13.

Description:

Trilete spore; subcircular in polar view with well rounded apices; laesurae extending over 3/4 of the radius. Exine from 1.8 to 2.1μ in thickness, intrapunctate to intragranulate. Bifurcation of distal portions of laesurae distinct. Equatorial diameter, 74μ.

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(38.2 x 125.7).

Family CYATHEACEAE

Genus Cyathidites Couper (1953)

Genotype: Cyathidites australis Couper (1953)

Cyathidites concavus (Bolk.) Dettmann (1963)

Plate 1, Fig. 7

1953 Stenozonotriletes concavus Bolkhovitina, p. 46, pl. 6, fig. 7.

1963 Cyathidites concavus (Bolk.) Dettmann, p. 24, pl. 1, figs. 17-19.

Description:

Trilete spore; biconvex; outline concavely triangular with somewhat pointed apices; laesurae straight, convex (on proximal surface), extending to the periphery. Exine smooth, 1 to 2μ in thickness. Equatorial diameter, 22μ.

Figured specimen:

Subsurface section 25, slide 2A (Pb 4162A)(40.7 x 112.8).

Family DICKSONIACEAE

Genus *Trilites* Erdtman (1947) ex Couper 1953

Lectogenotype: *Trilites tuberculiformis* Cookson 1947

1947 *Trilites* Erdtman, p. 110.

1947 *Trilites tuberculiformis* Cookson, p. 136, pl. 16, figs. 61-62.

1953 *Trilites tuberculiformis* Cookson, in Couper, p. 29.

Trilites comaumensis Cookson (1953)

Plate 2, Fig. 3

1953 *T. comaumensis* Cookson, p. 470, pl. 2, figs. 27-28.

Description:

Trilete spore; sub-triangular to sub-circular in flattened outline. Conspicuous tetrad mark; laesurae extending to periphery. Exine approximately 1μ in thickness, covered with small conical spinules or rod-like processes (ca. 1.8μ in length). Equatorial diameter, from 25 to 48μ.

Figured specimen:

Subsurface section 33, slide 4 (Pb 4092)(32.4 x 116.7).

Family POLYPODIACEAE

Genus Polypodiidites Ross (1949) ex Couper (1953)

Genotype: Polypodiidites senonicus Ross (1949) ex Couper

1949 Polypodiidites senonicus Ross, p. 33, pl. 1, figs. 8-9.

1953 Polypodiidites senonicus Ross ex Couper, p. 28.

Polypodiidites sp.

Plate 5, Fig. 13

Description:

Monolete spore; exine 3.3 to 3.8 μ thick, covered with warty projections. A somewhat reticulated appearance is given by the furrows separating the projections. Size, 34 to 38 μ x 44 to 58 μ.

Discussion:

Ross (1949, p. 33) referred to the forms Polypodium pellucidum illustrated by Selling (1946, pl. 7, fig. 158). The principal difference between the Hawaiian forms and the Pierre forms would seem to be their size; spores from the extant forms are larger.

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(34.0 x 119.8).

Genus Laevigato-sporites Ibrahim (1933) emend. Schopf, Wilson and Bentall 1944

Genotype: Laevigatosporites vulgaris (Ibrahim, 1932) Ibrahim (1933) emend. Schopf, Wilson & Bentall (1944)

1932 Sporonites vulgaris Ibrahim, p. 448, pl. 15, fig. 16.

1933 Laevigato-sporites vulgaris (Ibrahim) Ibrahim, p. 39-40, pl. 2, fig. 16; pl. 5, figs. 37-39.

1944 Laevigato-sporites (Ibrahim 1933) emend. Schopf, Wilson and Bentall, p. 36-37, pl. 1, figs. 5-5b.

Discussion:

Singh (1964, p. 99) has stated that ". . . the monolete bean-shaped form indicates a close affinity with the families Polypodiaceae and Dennstaedtiaceae."

<u>Laevigato-sporites</u> <u>albertensis</u> Rouse (1957)

Plate 5, Fig. 4

1957 <u>L.</u> <u>albertensis</u> Rouse, p. 363, pl. 2, figs. 17-18.

Description:

Monolete spore; kidney or bean-shaped in lateral compression; ovate in compression normal to suture; suture extends 2/3 of the total length of the spore. Wall thin, less than 1 μ in thickness, weakly punctate. Size, 22 x 36 μ.

Figured specimen:

Subsurface section 33, slide 3 (Pb 4091)(35.4 x 115.9).

<u>Laevigatosporites</u> cf. <u>ovatus</u> Wilson & Webster (1946)

Plate 5, Fig. 8

1946 <u>L.</u> <u>ovatus</u> Wilson & Webster, p. 273, fig. 5.

Description:

Monolete spore; bilateral, bean-shaped in flattened outline; suture extends almost full length of spore; exine smooth, somewhat folded along longitudinal dimension. Exine from 1 to 4 μ in thickness. Size, 32 x 55 μ.

Figured specimen:

Subsurface section 46, slide 4 (Pb 4196)(30.3 x 128.1).

Family MARATTIACEAE

Genus *Marattisporites* Couper (1958)

Genotype: Maratisporites scabratus Couper (1958)

1958 Marattisporites scabratus Couper, p. 133-134, pl. 15, figs. 20-23.

Marattisporites scabratus Couper (1958)

Plate 5, Fig. 14

Description:

Monolete spore; narrow laesurae extending the length of the spore; bean-shaped to ellipsoidal in laterally compressed specimens. Exine from less than 1μ to 1.2μ in thickness, granulate. Size, 24 x 39μ.

Discussion:

Couper (1958, p. 106) calls attention to the forms described earlier by Knox (1938), Harris (1955), Brown and Brown (1931) and Selling (1946) and assigns *M. scabratus* Couper to the Marattiaceae.

Figured specimen:

Subsurface section 46, slide 10F (Pb4202F)(38.2 x 119.8).

Family MATONIACEAE

Genus *Matonisporites* Couper (1958)

Genotype: *Matonisporites phlebopteroides* Couper (1958)

1958 *Matonisporites phlebopteroides* Couper, p. 139-140, pl. 20, figs. 15-17.

Matonisporites cf. *equiexinus* Couper (1958)

Plate 1, Figs. 5-6

1958 *M. equiexinus* Couper, p. 140, pl. 20, figs. 13-14.

Description:

The description of the holotype, as given by Couper (*loc. cit.*) is ". . . trilete, laesurae reaching to equator, commissures raised and flanked by a margo; equatorial contour triangular, sides usually slightly convex; exine unsculptured to finely scabrate, 2.5 to 3.5 μ thick, not greatly thickened at apices". The Pierre specimens conform to Couper's description. Size range, from 40 to 68 μ (8 specimens).

Discussion:

Members of the family Matoniaceae are at present limited to Borneo and the Malayan Peninsula. The family is represented by a single genus, *Matonia* R. Brown.

Figured specimen:

Subsurface section 13, slide 2A (Pb 4074A)(28.7 x 113.7).

Order FILICALES

INCERTAE SEDIS

Genus *Concavisporites* (Pflug 1952) Delcourt and Sprumont 1955

Genotype: *Concavisporites rugulatus* Pflug (1953)

1953 *Concavisporites rugulatus* Pflug, in Thomson and Pflug, p. 49, p. 1, fig. 22.

1955 *Concavisporites rugulatus* Pflug emend. Delcourt and Sprumont.

Concavisporites sp.

Plate 1, Fig. 9

Description:

Trilete spore; triangular in equatorial view, strongly concave in interapical areas; laesurae straight or weakly undulating and extending to the periphery; laesurae bounded by margo. Exine psilate, less than 1 μ in thickness. Equatorial diameter, from 20 to 29 μ.

Figured specimen:

Subsurface section 46, slide 5A (Pb 4197A)(45.9 x 121.4).

Genus Concavissimisporites Delcourt and Sprumont (1955) emend. Delcourt, Dettmann & Hughes 1963

Genotype: Concavissimisporites verrucosus Delcourt and Sprumont 1955

1955 Concavissimisporites verrucosus Delcourt and Sprumont, p. 25, pl. 2, fig. 1.

1963 Concavissimisporites verrucosus Delcourt and Sprumont emend. Delcourt, Dettmann and Hughes, p. 285, pl. 42, figs. 5-7.

Concavissimisporites variverrucatus (Couper) Singh (1964)

Plate 2, Fig. 4

1964 C. variverrucatus (Couper) Singh, p. 78, pl. 9, figs. 9-11.

Description:

Trilete spore; triangular in equatorial outline; sides concave; apices well rounded; both surfaces verrucate; laesurae approximately 3/4 of the equatorial radius. Exine 2.5 to 3.0 μ in thickness. Equatorial diameter, 50 μ .

Discussion:

Singh (loc. cit.) has proposed that several forms (species) of Concavisporites should be transferred to the genus Concavissimisporites as emended by Singh (loc. cit.). It is argued that earlier workers based their assignments on such criteria as surface ornamentation and the presenceeor absence of kyrtomes. Singh emended the genus Concavissimisporites by more fully recognizing the other

discernible attributes of the two genera which are particularly ". . . the shape of the spore; the position, shape, length, and number of the germinal apertures; the nature of the exine adjoining the laesurae; and the pattern of ornamentation or the complete lack of it . . .".

Figured specimen:

Subsurface section 46, slide 11G (Pb 4203G)(32.8 x 128.3).

Genus Kuylisporites Potonie (1956)

Genotype: Kuylisporites waterbolki R. Potonie (1956)

1956 Kuylisporites waterbolki R. Potonie, p. 38, pl. 4, fig. 39.

Kuylisporites waterbolki R. Potonie (1956)

Plate 3, Fig. 3

Description:

Trilete spore; sub-triangular to sub-circular in equatorial outline; trilete scar does not reach periphery. Exine up to 1 μ in thickness, finely reticulate. Equatorial diameter (8 specimens), from 25 to 34 μ.

Discussion:

The specimens recovered from the Pierre correspond specifically with Potonie's description of the type. The only significant difference is in the overall size, which is ca. 45 μ in the type specimen.

Figured specimen:

Subsurface section 13, slide 5X (Pb 4077X)(43.4 x 111.8).

Genus *Perotriletes* Couper (1953)

Genotype: *Perotriletes granulatus* Couper (1953)

1953 *Perotriletes granulatus* Couper, p. 31, pl. 3, figs. 28-29.

Perotriletes pseudoreticulatus Couper (1953)

Plate 4, Fig. 2

1953 *P. pseudoreticulatus* Couper, p. 32, pl. 3, fig. 30.

Description:

Trilete spore; subtriangular in polar view; laesurae indistinct, but long; both proximal and distal surfaces sculptured with irregular ridges 1.1 to 1.4μ in height. Indistinct narrow perispore observed in some specimens. Equatorial diameter from 35 to 39μ.

Figured specimen:

Subsurface section 46, slide 1 (Pb 4193)(34.5 x 112.9).

Perotriletes rugulatus Couper (1958)

Plate 4, Figs. 11-12

1958 *P. rugulatus* Couper, p. 147, pl. 25, figs. 7-8.

Description:

Trilete spore; sub-round to sub-triangular in equatorial outline; laesurae flanked by weak margo and extending more than 3/4 of the distance to the periphery; both proximal and distal surfaces ornamented with low, rounded, anastomosing rugae 2.0 to 3.5μ in width and averaging 1 μ in height. Equatorial diameter, 55μ.

Figured specimen:

Subsurface section 13, slide 6X (Pb 4078X)(40.6 x 121.6).

Perotriletes sp.

Plate 4, Fig. 3

Description:

Trilete spore. Laesurae extending almost to the periphery; equatorial outline circular to sub-circular; weakly developed margo; proximal and distal surfaces sculptured with low, well-rounded rugulae from 1.0 to 2.0μ in width and which form a distinct rugulate pattern. Equatorial diameter (7 specimens), 28 to 35μ.

Figured specimen:

Subsurface section 6, slide 1X (Pb 4155X)(31.1 x 115.3).

Genus Aequitriradites Delcourt and Sprumont (1955) emend. Cookson and Dettmann (1961)

Genotype: Aequitriradites dubius Delcourt and Sprumont (1955)

1955 A. dubius Delcourt and Sprumont, p. 44-45, pl. 3, fig. 7.

1961 Aequitriradites Delcourt and Sprumont (1955) emend. Cookson and Dettmann, p. 426, pl. 52, figs. 1-12.

Aequitriradites sp.

Plate 5, Fig. 2

Description:

Radial, trilete, zonate spore; sub-triangular in equatorial outline; zona granulate, varying from 2.4μ in width in the inner apical areas to 6.0μ in width in the apical areas; zona finely serrate along periphery. Laesurae accompanied by a thin muri along its entire length. Overall diameter of spore, from 38 to 53μ; diameter of central body, from 21 to 23μ; width of zona, from 2.4 to 6.0μ; wall thickness, less than 1μ.

Figured specimen:

Subsurface section 46, slide 5A (Pb 4197A)(32.9 x 111.8).

Genus Umbosporites Newman (1965)

Genotype: Umbosporites callosus Newman (1965)

1965 Umbosporites callosus Newman, p. 10, pl. 1, fig. 2.

Umbosporites callosus Newman (1965)

Plate 5, Figs. 5-7

Description:

Monolete spore; laesurae approximately 1/2 the amb axis; unornamented exine distinctly thickened at longitudinal extremities (up to 6 μ thick). Overall length of spore from 32 to 39 μ; overall breadth of spore from 14 to 20 μ; length of laesurae from 13 to 25μ.

Figured specimens:

Pl. 5, Fig. 5, Subsurface section A (Wallace) (Pb 3929) (35.2 x 116.2); Pl. 5, Fig. 6, Subsurface section A (Wallace) (Pb 3931)(46.3 x 123.7); Pl. 5, Fig. 7, Subsurface section A (Wallace)(Pb 3929)(29.1 x 129.0).

UNASSIGNED SPORES

INCERTAE SEDIS

Genus Murospora Somers (1952)

Genotype: Murospora kosankei Somers (1952)

1952 Murospora kosankei Somers, p. 20, fig. 13a.

Murospora mesozoica Pocock (1961)

Plate 4, Fig. 7

1961 Murospora mesozoica Pocock, p. 1233, text-figs. 1,3-5.

Description:

Trilete spore; irregularly sub-triangular in equatorial outline; cingulum from 5.0 to 9.4 μ in width. Exine single layered, approximately 1 μ thick in polar areas, 2.3 μ thick near the equator. Laesurae straight to weakly undulate, extending to periphery of inner spore body; laesurae flanked by lips (1.0 to 1.2 μ in height). Diameter of inner body, 29 μ; overall diameter (including cingulum), 41 μ.

Figured specimen:

Subsurface section 33, slide 4 (Pb 4092)(37.3 x 119.4).

Genus Triplanosporites Pflug (1953)

Genotype: Triplanosporites sinuosus Pflug (1953)

1953 Triplanosporites sinuosus Pflug, in Thomson and Pflug, p. 58, pl. 3, fig. 7.

Triplanosporites cf. sinuosus Pflug (1953)

Plate 1, Fig. 12

Description:

Trilete spore; oval in equatorial outline; usual polar compression results in a flattened proximal face; a characteristic three-leafed outline (normal to polar axis) results from lateral compression; length of polar axis, from 33 to 45μ ; width at equator, from 30 to 49μ . Exine psilate to slightly granulate.

Figured specimen:

Subsurface section 46, slide 2 (Pb 4194)(34.4 x 116.7).

Genus Cyclosporites (Cookson & Dettmann, 1958)
Cookson and Dettmann (1959)

Genotype: Cyclosporites hughesi (Cookson and Dettmann 1958) Cookson and Dettmann 1959

1958 Radiatisporites hughesi Cookson and Dettmann, p. 103, pl. 15, figs. 4-6.

1959 Cyclosporites hughesi Cookson and Dettmann, v. 21, p. 8.

Cyclosporites radiatus Krutzsch (1959)

Plate 1, Figs. 14-15

1959 Cyclosporites radiatus Krutsch, v. 8, p.

Description:

Trilete spore; radial, triangular to sub-triangular in equatorial outline; laesurae deeply entrenched, extending to periphery. Exine covered with ridges 2.2 to 2.8μ in width, separated by linearly branched furrows. Equatorial diameter, from 32 to 42μ .

Figured specimen:

Subsurface section 6, slide 1X (Pb 4155X)(31.7 x 124.7).

Genus *Densosporites* Berry (1937) emend. Schopf, Wilson and Bentall (1944)

Genotype: *Densosporites* *covensis* Berry (1937)

1937 *Densosporites* *covensis* Berry, p. 157, fig. 11.

1944 *Denso-sporites* (Berry 1937) emend. Schopf, Wilson and Bentall, p. 39, pl. 1, figs, 9-9c.

Densosporites sp.

Plate 4, Fig. 8

Discussion:

Because of the eroded nature of the specimens of *Densosporites* found in the Pierre and its accepted stratigraphic range, it is believed that the examples of this spore found during the present study are the results of reworking and re-cycling of older (probably Pennsylvanian) rocks.

Figured specimen:

Subsurface section 33, slide 7 (Pb 4095)(35.2 x 117.8).

Genus *Camarozonosporites* Pant (1954) ex R. Potonie (1956) emend. Klaus (1960)

Genotype: *Camarozonosporites* *cretaceus* (Weyland and Krieger, 1953) R. Potonie (1956)

1953 *Rotaspora* *cretacea* Weyland and Krieger, p. 12, pl. 3, fig. 27.

1956 *Camarozonosporites* *cretaceus* (Weyland and Krieger 1953) R. Potonie, p. 65, pl. 9, fig. 85.

Camarozonosporites *rudis* (Leschik, 1955) Klaus 1960

Plate 5, Fig. 1

1955 *Verrucosisporites* *rudis* Leschik in Krausel and Leschik, v. 72, p. 15, pl. 1, fig. 15.

1960 *Camarozonosporites* *rudis* (Leschik, 1955) Klaus, p. 136, pl. 29, figs. 12, 14.

Description:

Trilete, radial spore; equatorial outline sub-circular; trilete mark distinct; deeply set in proximal face; laesurae extending to equatorial flange; distal face broadly reticulate, proximal face laevigate; interapical flange from less than 1 μ to approximately 1.2 μ in width. Equatorial diameter, 35 to 37 μ.

Figured specimen:

Subsurface section 46, slide 8F (Pb 4200F)(40.8 x 113.0).

Genus Taschites gen. nov.

Genotype: Taschites primum

Generic description:

Spore, overall circular in polar view; consisting of central body surrounded by thin flange or structure composed of fused wing-like modifications.

Taschites primum gen. et sp. nov.

Plate 11, Figs. 1-4

Description:

Spore, trilete (?); overall diameter including flange, 140.4 μ; diameter of central body, 61 μ. Flange composed of from 11 to 15 wing-like projections that are apparently fused. Areas of fusion are equally spaced around the central body in the equatorial plane. Exine of central body granulate, up to 2 μ in thickness. Flange finely granulate, diaphanous, venation or striation pattern not apparent.

Discussion:

Taschites primum differs from any described Mesozoic spore thus far noted in the literature. Two previously described spores or spore-bearing structures, Pteroretis and Tetrapterites, are superficially similar to the presently described entity. Comparisons between the form described here and those two previously published forms are as follows:

Taschites primum differs from Pteroretia primum Felix and Burbridge (1961) in the following respects:

1.) Non-veined wing-like flange as opposed to prominently bifurcative venation of the wings of P. primum.

2.) Central body non-striated or ribbed as in P. primum.

Taschitex primum agrees with Pteroretis primum Felix and Burbridge (1961) in the following respects:

1.) Twelve wing-like structures in P. primum compares with 11 to 15 in T. primum.

2.) Overall size: Taschites primum 140.4 μ
Pteroretis primum 100 to 130 μ

3.) Central body diameter: T. primum 60.8 μ
P. primum 55 to 72 μ

4.) Wing-like projections are single thickness, thus separating both forms considered from Alatisporites as discussed by Felix and Burbridge (op. cit., p. 492).

Taschites primum differs from Tetrapterites visensis Sullivan and Hibbert (1964) in the following respects:

1.) Distinct separation between the wing-like projections as opposed to complete flange in Tetrapterites visensis.

2.) Twelve wing-like projections as opposed to seven to nine "parallel-sided folds . . . located on the outer rim of the cupule . . ." in Tetrapterites visensis.

3.) Very thin, granulate wall of the central body as opposed to a thick, opaque wall of the cupule of Tetrapterites visensis.

4.) Central body of Taschites primum is circular as opposed to a basic tetrahedral shape of the cupule of Tetrapterites visensis.

Taschites primum agrees with Tetrapterites visensis Sullivan and Hibbert (1964) in the following respects:

1.) Overall size: Taschites primum 140.4 μ

Tetrapterites visensis 190μ

Central body or cupule diameter:

Taschites primum 60.8 μ

Tetrapterites visensis (cupule[1] about half the total radius of the skiadion[2], or from 52.5 to 77.5 μ).

2.) The superficial geometry of Taschites primum resembles that of a single skiadion as figured by Sullivan and Hibbert (1964) (see Pl. 13, Fig. 3 and Pl. 14, Figs. 1, 4 and 5).

The interesting association of Tetrapterites visensis Sullivan and Hibbert with up to 26% of the microspores observed in the Drybrook sample assigned to the species Punctatisporites platirugosus (Waltz) was noted by Sullivan and Hibbert (op. cit., p. 69). A

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[1]"The darker-appearing, originally bowl-shaped, central area is called the cupule and this encloses the distal hemisphere of the spore" (op. cit., p. 66).

[2]"The apical portions of the capsule . . ." (op. cit., p. 66).

similar association was noted between Pteroretis primum Felix and Burbridge (1961) where 8.0 to 13.5% of the microspores recovered from the Upper Chester sediments are assigned to the genus Punctatisporites. The occurrence of Taschites primum is not associated with spores assignable to the genus Punctatisporites.

Adequate separation between the only known, superficially similar, plant microfossils and the presently described spore has been demonstrated. Sullivan and Hibbert (loc. cit.) also mention the similarity between Tetrapterites visensis and the acritarch Pterospermopsis Wetzel (1952) and Cymatiosphaera (Wetzel, 1933) Deflandre (1954). Species assignable to both of the mentioned genera have been found in the Pierre samples; none of the forms found, however, possess wing-like flanges. This fact, together with the great disagreement of size ranges between Taschites primum and the acritarchs considered is believed to be sufficient for adequate separation.

Genus Peromonolites Erdtman (1947) ex Couper (1953)

Genotype: Peromonolites bowenii Couper 1953

1947 Peromonolites Erdtman, p. 111.

1953 Peromonolites bowenii Couper, p. 32, pl. 3, figs. 31-32.

Peromonolites cf. problematicus Couper (1953)

Plate 5, Fig. 15

1953 Peromonolites problematicus Couper, p. 32, pl. 3, fig. 33.

Description:

Monolete spore; ellipsoidal in polar (?) view. No laesurae observed. Exine less than 1μ in thickness, psilate. Central body surrounded by perispore 2.2 to 2.4 μ in width. The perispore is composed of closely spaced or fused setae. Size, 22 to 29μ .

Discussion:

Couper (1953, p. 33) observed that Peromonolites problematicus superficially resembles the microspores of the water fern Pilularia novae-zealandiae T. Kirk. The perine layer in the latter, however, is not setaceous but is rather dense and minutely rugulate. Harris (1955, p. 144) also noted that spores identical to and inseparable from those of Pilularia novae-zealandiae have been recovered from Jurassic sediments by Couper (see Couper, 1953, p. 33).

Figured specimen:

Surface section Phillips 1-A-L (Pb 4013)(42.6 x 110.7).

Genus Reticuloidosporites Pflug in Thomson & Pflug (1953)

Genotype: Reticuloidosporites dentatus (Pflug 1952) Thomson and Pflug 1953

1952 R. dentatus Pflug, p. 136, pl. 7, fig. 7.

1953 R. dentatus (Pflug 1952) Thomson and Pflug, p. 60, pl. 4, fig. 11.

Reticuloidosporites dentatus Pflug in Thomson & Pflug 1953

Plate 5, Figs. 10-12

Description:

Bilateral, monolete spore; sub-ellipsoidal in equatorial outline, broadly ellipsoidal in compressed outline. Laesurae straight, slightly more than 1/2 the length of the amb axis. Exine thick, foveolate with irregularly spaced foveolae measuring approximately 1 μ in diameter. Size range, length of amb axis, from 27 to 40 μ; length of short axis, from 25 to 29μ .

Discussion:

Similar spore types are found in the Polypodiaceae and the Schizaeceae. The polypodiaceous types are nearly cosmopolitan in present day distribution. The schizeaceous types are typical tropical with only rare occurrences in the temperate zones.

Figured specimen:

Subsurface section 13, slide 2A (Pb 4074A)(36.4 x 116.5).

Reticuloidosporites sp.

Plate 5, Fig. 12

Description:

Monolete spore; reniform to ovoid in lateral equatorial outline; monolete scar distinct and approximately 1/2 the length of the major dimension (not visible on the specimen figured). Exine 1.6 μ in thickness with network or reticulum of conical projections 1.2 μ in height. Size, 55 x 72 μ.

Figured specimen:

Subsurface section 13, slide 2A (Pb 4074A)(36.4 x 116.5).

Division SPERMATOPHYTA

Class PTERIDOSPERMAE

Family CAYTONIACEAE

Genus Caytonipollenites Couper (1958)

Genotype: Caytonipollenites pallidus (Reissinger, 1950) Couper (1958)

1950 Pityosporites pallidus Reissinger, p. 109, pl. 15, figs. 1-5.

1958 Caytonipollenites pallidus (Reissinger) Couper, p. 150, pl. 26, figs. 7-8.

Caytonipollenites cf. pallidus (Reissinger) Couper (1958)

Plate 6, Fig. 6

Description:

Bisaccate pollen grain; specimen figured has slightly folded sacci; restored configuration of sacci demonstrates oval shape in polar view. Exine of central body less than 1.0 μ in thickness, scabrate to smooth. Sacci are finely reticulate and are attached to the distal face. Size, length of central body, 20 μ; length of sacci, 11 μ; breadth of sacci, 22μ; overall length of grain, 24μ.

Discussion:

Only a single specimen assignable to the genus Caytonipollenites was recovered from the Pierre. Singh (1964, p. 33) observed that the family Caytoniaceae apparently became extinct in the Late Cretaceous.

Figured specimen:

Subsurface section 46, slide 6A (Pb 4198A)(40.3 x 117.0).

Order CONIFERALES

Family PODOCARPACEAE

Genus Phyllocladidites (Cookson, 1947) Couper (1958)

Genotype: Phyllocladidites mawsonii (Cookson, 1947) Couper (1958)

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

1958 Phyllocladidites mawsonii Cookson in Couper, p. 38, pl. 9, fig. 135.

Phyllocladidites sp.

Plate 6, Fig. 9

Description:

Bisaccate pollen grain; circular to ovate in equatorial outline. Exine finely granulate. Sacci elongated, narrow, attached to distal face and apparently not reaching the periphery. Sacci attached along their entire length. Size: breadth of central body, 34 μ; length of central body, 43 μ; length of sacci, 22 μ; width of sacci (folded), 8.5 μ.

Figured specimen:

Subsurface section 50, slide 4 (Pb 4244)(38.2 x 116.0).

Genus Phyllocladus Rich.

Genotype: none designated

1940 Pollen of Phyllocladus, Cranwell, p. 4-5, figs. 7e, 7f.

1947 Pollen of Phyllocladus, Cookson, p. 133, pl. 14, figs. 38-40.

1953 Phyllocladus sp., Couper, p. 38.

1954 Fossil pollen of Phyllocladus, Cookson and Pike, p. 63-64, pl. 2, figs. 1-6.

1958 Phyllocladus sp., Couper, p. 44.

Phyllocladus sp.

Plate 6, Fig. 16

Description:

Bisaccate pollen grain; central body exine scabrate and without distinct cap. Sacci small, loosely frilled and reticulate. Size: length of central body, 37μ ; breadth of central body, 52μ ; length of sacci, 17 μ ; breadth of sacci, 34 μ ; overall length of grain, 51 μ.

Figured specimen:

Subsurface section 46, slide 5A (Pb 4197A)(42.2 x 116.0).

Genus Podocarpidites Cookson (1947) emend. R. Potonie (1958)

Genotype: Podocarpidites ellipticus Cookson 1947

1947 Disaccites (Podocarpidites) elliptica Cookson, p. 131, pl. 13, figs. 5-7.

1958 Podocarpidites ellipticus (Cookson, 1947) emend. R. Potonie, p. 68, pl. 8, fig. 85.

Podocarpidites cf. biformis Rouse (1957)

Plate 6, Fig. 15

1957 P. biformis Rouse, p. 267, pl. 2, fig. 13.

Description:

Bisaccate pollen grain; circular central body measuring 25μ in length and 28 μ in breadth; central body more coarsely reticulate than the sacci; sacci measuring 31μ in length are attached distally. Exine cap on proximal of the central body is approximately 6 μ thick. Overall length of grain, 66μ .

Discussion:

The specimens found in the Pierre material are slightly

smaller than Rouse's holotype.

Figured specimen:

Subsurface section 33, slide 4 (Pb 4092)(42.5 x 121.4)

Genus *Pityosporites* Seward (1914)

Genotype: *Pityosporites antarcticus* Seward (1914)

1914 *Pitysporites antarcticus* Seward, p. 23, pl. 8, fig. 15

Pityosporites cf. *similis* Balme (1957)

Plate 6, Fig. 11

1957 *Pityosporites similis* Balme, p. 36, pl. 10, figs. 108-109.

Description:

Bisaccate pollen grain; overall equatorial outline oval; central body circular to sub-circular. Exine 1.5 μ thick. Sacci symmetrically located on either side of a well-defined furrow. Sculpture of central body finely reticulate; that of the sacci clearly reticulate. Size: length of central body, 39 μ; breadth of central body, 42 μ; length of sacci, 45 μ; breadth of sacci, 24 to 28 μ; overall length of grain, 64μ .

Figured specimen:

Subsurface section 33, slide 7 (Pb 4095)(39.8 x 117.4).

Discussion:

Seward (1914) suggested that *Pityosporites* has an affinity with the family Pinaceae. He also admitted that "on geographical grounds it would seem more probable that the spores *Pityosporites* belonged to some plant allied to *Podocarpus*, *Dacrydium* or *Microcachrys*".

Family PINACEAE

Genus Tsugapollenites (Potonie & Venitz 1934) emend. R. Potonie 1958

Genotype: Tsugaepollenites igniculus (Potonie, 1931) Potonie and Venitz (1934)

1931 Sporonites igniculus Potonie, p. 556, Abb. 2.

1934 Tsugaepollenites igniculus (Potonie, 1931) Potonie and Venitz, p. 17, pl. 1, fig. 8.

Tsugaepollenites cf. segmentatus Balme (1957)

Plate 3, Fig. 10

1957 T. segmentatus Balme, p. 33, pl. 9, figs. 93-94.

Description:

Circular pollen grain, consisting of circular central body surrounded by a much folded, narrow bladder; rugose central body with exine from 1.2 to 1.8 μ in thickness. Bladder width (average) 5 μ. Overall diameter, 50 μ.

Figured specimen:

Subsurface section 46, slide 8F (Pb 4200F)(39.8 x 113.8).

Tsugaepollenites sp.

Plate 3, Fig. 8

Description:

Monosaccate pollen grain; proximal tetrad mark distinct; extending to near the periphery; well-developed equatorial fringe of saccate protrusions; saccate or interconnected vesiculae approximately 2 to 4 μ in height. Exine 1.2 μ thick, two-layered; exine is apparently thinner in the polar area than in the proximal polar area. Overall equatorial diameter, 44 μ.

Figured specimen:

Subsurface section 10, slide 10X (Pb 4112X)(29.9 x 122.6).

Genus Pinuspollenites Raatz (1937)

Lectogenotype: Pinuspollenites labdacus (R. Potonie, 1931) Raatz (1937)

1931 Pollenites labdacus R. Potonie, p. 5, fig. 32.

1937 Pinuspollenites labdacus (R. Potonie, 1931) Raatz, p. 16.

Pinuspollenites sp.

Plate 6, Fig. 7

Description:

Bisaccate pollen grain; central body (corpus) reticulate, ovate in equatorial outline. Sacci strongly reticulate, attached to distal face. Size: length of central body, 47 μ; breadth of central body, 40 μ; length of sacci, 36 μ; breadth of sacci, 22 μ.

Figured specimen:

Subsurface section 46, slide 1 (Pb 4193)(33.9 x 117.1).

Genus Abiespollenites Thiergart in Raatz (1937)

Genotype: Abiespollenites absolutus Thiergart in Raatz (1937)

1937 Abiespollenites absolutus Thiergart, in Raatz, p. 16, pl. 1, fig. 11; pl. 8, fig. 77.

Abiespollenites sp.

Plate 6, Fig. 8

Description:

Bisaccate pollen grain; distal cap clear on most specimens observed and approximately 30μ in thickness; central body (corpus) granulate; sacci surfaces reticulate. Size: length of central

body, 121 μ ; breadth of central body, 58 μ ; length of sacci, 53 μ ; breadth of sacci, 49 μ.

Figured specimen:

Subsurface section 33, slide 3 (Pb 4091)(32.2 x 115.0).

Genus Piceaepollenites R. Potonie (1931)

Genotype: Piceaepollenites alatus R. Potonie (1931)

1931 Piceaepollenites alatus R. Potonie, p. 28, pl. 2.

Piceaepollenites sp.

Plate 6, Fig. 14

Description:

Bisaccate pollen grain; central body finely granulate, measuring 52 μ in height and 73 μ in breadth. Sacci finely reticulate, measuring 45 to 47 μ in length and 28 to 33 μ in breadth. Sacci attached distally.

Figured specimen:

Subsurface section 33, slide 2 (PB 4090)(28.0 x 121.2).

Genus Cedripites Wodehouse (1933)

Genotype: Cedripites eocenicus Wodehouse (1933)

1933 Cedripites eocenicus Wodehouse, p. 489-490, fig. 13.

Cedripites eocenicus Wodehouse (1933)

Plate 6, Fig. 10

Description:

Bisaccate pollen grain; exine of central body 1.0 to 2.0 μ thick; distal cap distinct, approximately 5 μ in thickness; sacci large. Size: length of central body, 39 μ ; breadth of central

body, 28 μ; breadth of sacci, 25 μ; overall length of grain, 62μ .

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(37.1 x 123.1).

Family TAXODIACEAE

Genus Sequoiapollenites (Thiergart, 1937)
ex Thiergart (1938)

Lectogenotype: Sequoiapollenites polyformosus Thiergart (1938)
ex Potonie (1958)

1938 Sequoiapollenites polyformosus Thiergart, p. 301, pl. 23, fig. 6.

1958 Sequoiapollenites polyformosus Thiergart (1938) ex Potonie, p. 79.

Sequoiapollenites sp.

Plate 4, Fig. 1

Description:

Oblate, almost spherical pollen grain. Exine psilate, folded, less than 1 μ thick. Distinct germinal papillae, slightly curved and 5 μ in length. Equatorial diameter, 22 μ.

Figured specimen:

Subsurface section 13, slide 2A (Pb 4074A)(44.4 x 111.9).

INCERTAE SEDIS

Genus Eucommidites Erdtman (1948) emend. Hughes (1961)

Genotype: Eucommidites troedssonii Erdtman (1948)

1948 Eucommodites troedssonii Erdtman, p. 267, fig. 15.

1961 Eucommidites troedssonii Erdtman (1948) emend. Hughes, p. 293, pl. 37, figs. 1-16; text-figs. 1a-1f.

Eucommidites minor Groot and Penny (1960)

Plate 7, Fig. 2

1960 E. Minor Groot and Penny, p. 234, pl. 2, fig. 14.

Description:

Grain circular in equatorial outline; central furrow approximately 1/2 the total length of grain; ring furrows narrow, incomplete in both ends of grain. Exine psilate, 1.3 μ in thickness. Size: equatorial diameter, from 23 to 25μ .

Discussion:

Hughes (1961) found Eucommidites- type grains in the micropyle and pollen chamber of a Lower Cretaceous seed, Spermatites pettensis Hughes (1961). This is clearly a gymnospermous ovule. Singh (1964, p. 128) interpreted the morphology of Eucommidites and concluded that ". . . the genus Eucommidites tends to show its affinity with cycadophytes, Ginkgoales, and perhaps Chlamydospermales".

Genus Classopollis Pflug (1953) emend. Pocock & Jansonius (1961)

Genotype: Classopollis classoides Pflug (1953)

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

1961 Classopollis classoides Pflug, emend. Pocock and Jansonius, p. 439-449, pl. 1.

Classopollis classoides Pflug (1953) emend. Pocock and Jansonius (1961)

Plate 6, Figs. 1,2 and 4

Description:

Circular pollen grain (in polar view), monoporate; trilete mark small, at proximal pole; rays of trilete extend approximately 2.5 μ outward from center of trilete mark. Exine finely granulate. Striated equatorial band ca. 4 μ in width, at times interrupted (e.g., Pl. 6, Figs. 1 and 4). Size range: from 21 to 32 μ (overall equatorial diameter, flattened).

Figured specimens:

Pl. 6, Fig. 1, Subsurface section 33, slide 1, (Pb 4089) (39.3 x 121.0); Pl. 6, Fig. 2, Subsurface section 19, slide 2C (Pb 4144C)(30.7 x 121.7); Pl. 6, Fig. 4, Subsurface section 33, slide 2 (Pb 4090)(32.4 x 124.6).

Classopollis obidosensis Groot and Groot (1962)

Plate 6, Fig. 3

Description:

The figured specimen agrees with the description given by Groot and Groot (1962). The Pierre specimens, however, exhibit a more distinct subdivision of the equatorial band. In this case, the outermost portion (approximately 1/2 of the band is either micro-reticulate or laevigate while the remainder of the grain is granulose. A very small, weak trilete scar can be noted in the figured specimen. Size: from 21 to 32 μ (equatorial diameter).

Figured specimen:

Subsurface section 13, slide 5D (Pb 4077D)(29.5 x 118.8).

Genus Callialasporites Dev (1961)

Genotype: Callialasporites trilobatus (Balme) Dev 1961

1953 Zonalapollenites Pflug in Thomson and Pflug, p. 66.

1953 Euryzonotriletes Sah, pl. 1, photo 14.

1961 Callialasporites Dev, p. 48, pl. 4, figs. 28-29.

1961 Applanopsis Doring, p. 110-114.

Callialasporites dampieri (Balme) Dev, 1961

Plate 4, Fig. 13

1957 Zonalapollenites dampieri Balme, p. 32-33.

1961 Callialasporites dampieri (Balme) Dev, p. 48, pl. 4, Figs. 26-27.

Description:

Complex pollen grain, circular in outline; composed of circular central body (22 to 24μ) surrounded by narrow folded bladder (4 to 7μ in width); central body finely granulate; bladder very finely granulate. Exine of central body less than 1 μ in thickness. Overall equatorial diameter from 30 to 37μ.

Discussion:

Goubin, Taugourdeau and Balme (1965, p. 226-227) state that Pflug (Pflug, 1953, p. 66) failed to establish a genotype for the genus Zonalapollenites Pflug. In a later publication, Balme (1957, p. 32-33) described two new species, Z. dampieri Balme and Z. trilobatus Balme, which, following Article 42 of the International Code of Botanic Nomenclature, are not considered valid. Goubin, Taugourdeau and Balme (loc. cit.) emended the genus Applanopsis Doring to include the forms previously placed in the genus Zonalapollenites by Pflug (1953) and Balme (1957). Hughes and Couper (1958)

reported *Z. campieri* Balme and *Z.* cf. *trilobatus* Balme from the middle Jurassic Brora Coal of Scotland. The Brora specimens are in conformity with the emendation of *Applanopsis* by Goubin, Taugourdeau and Balme (1965, p. 227). Dev (1961, p. 48) pointed out the fact that the form genus *Callialasporites* which he proposed included forms with many variations in the form of the body and the number of bladders. The new combination proposed by Dev includes all the different species of *Callialasporites* that in turn show a spectrum of variation from one form to the other. The form genus *Callialasporites* Dev is presently regarded as valid.

Figured specimen:

Surface section Wallace A (Pb 3931)(30.3 x 125.5).

Genus *Corallina* Maljawkina (1949) emend.
Venkatachala and Goczan (1964)

Genotype: *Corallina funifera* Maljawkina (1949)

1949 *Corallina funifera* Maljawkina, p. 124.

1964 *Corallina funifera* Maljawkina, emend. Venkatachala and Goczan, p. 217.

Corallina sp.

Plate 6, Fig. 5

Description:

Oval to subcircular pollen grain; occasionally folded near the equator; distal face (as in Pl. 6, Fig. 5) has a weak area or centrally located pore. Pore measures 6 to 7 μ in diameter and is circumscribed by a weakened ridge (ring tenuitas of Venkatachala and Goczan). Size: 23μ (overall diameter).

Discussion:

Maljawkina's original description of Corallina funifera is as follows:

"The contour of the pollen grain round, edge separated from the body clearly, the outer edge thickened, wide and somewhat swollen, its colour being darker than that of the body. Exine thick, body and edge punctate with pattern of fine network."

Venkatachala and Goczan (1964, p. 219) indicate that Maljawkina intended to include Classopollis-type grains in his description of Corallina.

Figured specimen:

Subsurface section 25, slide 2A (Pb 4162A)(41.7 x 123.2).

Genus Inaperturopollenites Pflug (1952) ex Thomson & Pflug (1953) emend. R. Potonie (1958)

Genotype: Inaperturopollenites dubius (R. Potonie and Venitz, 1934) Thomson and Pflug, 1953

1934 Pollenites magnus dubius R. Potonie and Venitz, p. 17, pl. 2, fig. 21.

1953 Inaperturopollenites dubius R. Potonie and Venitz (1934) ex Thomson and Pflug, p. 65, pl. 4, fig. 89; pl. 5, figs. 1-13.

Inaperturopollenites sp.

Plate 7, Fig. 3

Description:

Oval, inaperturate pollen grain; characteristic split usually present. Exine granular to finely granular. Overall equatorial diameter, 22 μ.

Figured specimen:

Subsurface section 46, slide 2 (Pb 4194)(31.2 x 127.4).

Inaperturopollenites hiatus (R. Potonie) Pflug (1953)

Plate 7, Fig. 4

1953 I. hiatus (R. Potonie) Pflug, p. 65, pl. 5, figs. 14-20.

Description:

Inaperturate pollen grain, almost circular in polar compression; characteristically split as in figured specimen; exine granulate to coarsely granulate with a suggestion of lineation of the sculptural elements. Size: 33μ (estimated restored equatorial diameter, flattened).

Figured specimen:

Subsurface section 6, slide 4X (Pb 4158X)(37.5 x 110.0).

Genus Pollenites R. Potonie (1934)

Genotype: Pollenites ortholaesus R. Potonie (1934)

1934 P. ortholaesus R. Potonie, p. 76, pl. 6, figs. 17-18.

Pollenites ortholaesus R. Potonie (1934)

Plate 7, Fig. 1

Description:

Tricolpate pollen grain, sub-triangular to near circular in equatorial outline; sulci deep, bordered; exine punctate to granulate. Exine 2.4 μ in thickness with well-defined stratification. Equatorial diameter from 25 to 36 μ.

Figured specimen:

Subsurface section 46, slide 11E (Pb 4203E)(30.8 x 113.2).

Division ANGIOSPERMAE

Order SALICALES

Family SALICACEAE

Genus Tricolpites Erdtman (1947) ex Couper (1953)

Lectogenotype: Tricolpites reticulatus Cookson 1947

1947 Tricolpites Erdtman, p. 109.

1947 Tricolpites reticulatus Cookson, p. 134, pl. 15, fig. 45.

1953 Tricolpites reticulatus Cookson (generic validation by) Couper, p. 61.

Tricolpites sp.

Plate 7, Fig. 7

Description:

Tricolpate pollen grain, concave triangular in equatorial outline. Colpi 4μ in depth. Exine laevigate. Equatorial diameter, 29μ.

Discussion:

Tricolpites, as defined by Couper (1953, p. 61), includes oblate tricolpate grains. Tricolpites bears a strong resemblance to the grains of living Aceraceae.

Figured specimen:

Surface section Cheyenne 1C (Pb 4005)(39.3 x 112.2).

Tricolpites thomasii Cookson & Pike (1954)

Plate 7, Fig. 18

1954 T. thomasii Cookson & Pike, p. 214, pl. 2, figs. 92-94.

Description:

Triangular, tricolpate pollen grain, slightly concave in the interpolar areas. Equatorial diameter, 29μ .

Figured specimen:

Subsurface section 33, slide 2, (Pb 4090)(39.3 x 122.2).

Order FAGALES

Family BETULACEAE

Genus Corylus L.

First fossil record of pollen of this genus:

Corylus punctatipollenites Rouse (1957)

1957 Corylus punctatipollenites Rouse, p. 368, pl. 2, figs. 31-32.

Corylus punctatipollenites Rouse (1957)

Plate 7, Fig. 21

Description:

Triporate pollen grain. Pores appear as notches with weak to strong lips. Grain slightly convex in equatorial outline. Ornamentation punctate. Equatorial diameter, 20 to 22μ .

Figured specimen:

Subsurface section 46, slide 4 (Pb 4196)(41.5 x 123.6).

Genus Triporopollenites Pflug (1952) ex Pflug in Thomson and Pflug (1953)

Genotype: Triporopollenites coryloides Pflug in Thomson and Pflug (1953)

1952 Triporopollenites Pflug.

1953 Triporopollenites coryloides Pflug, p. 84, pl. 9, figs. 20-24.

Triporopollenites sp.

Plate 7, Fig. 6

Description:

Triporate, occasionally tetraporate, pollen grain; rounded triangular in equatorial outline. Exine less than 1 μ in thickness in interpolar areas but thickens near the pores; exines laevigate or finely granulate. Size: from 21 to 26μ (triporate forms); from 17 to 29 μ (tetraporate forms).

Discussion:

According to Thomson and Pflug (1953, p. 44) Triporopollenites is closely similar to Corylus and should be assigned to the Betulaceae.

Figured specimen:

Subsurface section 46, slide 11E (Pb 4203E)(32.9 x 128.9).

Order URTICALES

Family ULMACEAE

Genus Momipites Wodehouse (1933)

Genotype: Momipites coryloides Wodehouse (1933)

1933 Momipites coryloides Wodehouse, p. 511, fig. 43.

Momipites coryloides Wodehouse (1933)

Plate 7, Fig. 16

Description:

Triporate pollen grain, sub-triangular in flattened outline. Pores equatorial, not protruding above the surface of the grain. Equatorial diameter, 14 μ.

Figured specimen:

Subsurface section 46, slide 5A (Pb 4197A)(29.3 x 117.1).

Momipites inaequalis Anderson (1962)

Plate 7, Fig. 20

1962 M. inaequalis Anderson, p. 25, pl. 6, figs. 7-10; pl. 7, fig. 13.

Description:

Oblate, triporate pollen grain; unequally triangular in equatorial outline, interapical areas convex; pores very slightly protruding and slightly thickened. Exine scabrate, less than 1μ in thickness. Equatorial diameter, 17 to 24 μ.

Discussion:

Anderson (1962, p. 25) based the differentiation of M. inaequalis Anderson (1962) from M. coryloides Wodehouse (1933) on its unequally triangular outline. It is possible that the imperfectly triangular outline of this grain is due to the manner of preservation and is not a haptotypic feature.

Figured specimen:

Subsurface section 46, slide 6A (Pb 4198A)(41.6 x 120.2).

Order PROTEALES

Family PROTEACEAE

Genus Proteacidites Cookson (1950)

Genotype: Proteacidites adenanthoides Cookson (1950)

1950 Proteacidites adenanthoides Cookson, p. 172, pl. 2, fig. 21.

Proteacidites thalmanni Anderson (1960)

Plate 8, Figs. 5, 12

1960 P. thalmanni Anderson, p. 21, pl. 2, figs. 1-4; pl. 10, figs. 9-13.

Description:

Triporate pollen grain; triangular, sometimes slightly convex

in equatorial outline; pores may be circular, notched, lolongate, notch-like or elongate; endannulus present around each pore. Sculpture irregularly reticulate in the pore areas and finer in the polar areas. Exine approximately 2 μ thick. Equatorial diameter, from 29 to 31 μ.

Discussion:

Anderson (1960, p. 21) suggests that a transitional series between P. thalmanni Anderson (1960) with "notched" pores, and P. thalmanni with circular pores (as found in the Kirkland and Lewis florules) does not warrant the erection of two new species. P. thalmanni resembles P. granulatus Cookson (1953), but is smaller, more definitely reticulate, and often has "notched" pores.

Figured specimen:

Subsurface section 44, slide 2X (Pb 4116X)(34.5 x 114.7).

Proteacidites sp. A

Plate 8, Fig. 6

Description:

Triporate pollen grain; triangular in equatorial outline, somewhat convex, but commonly straight. Inter-oral areas more coarsely reticulate than the oral (apical) areas. Exine 1.2 μ thick in inter-oral areas, 1.6 μ thick in apical areas. Overall diameter, 32 μ.

Figured specimen:

Subsurface section 13, slide 1D (Pb 4073D)(35.5 x 119.2).

Proteacidites annularis Cookson (1950)

Plate 8, Figs. 7-8

1950 *P. annularis* Cookson, p. 170-171, fig. 2a; pl. 1, fig. 15.

Description:

Triangular triporate pollen grain with prominent apertural areas; sides slightly concave. Apertures 3.4 μ in diameter. Equatorial diameter, 23 to 28 μ. Exine 1.3 μ thick. Collars, as described by Cookson (*loc. cit.*) are clearly visible.

Discussion:

Cookson (loc. cit.) demonstrated that a close agreement exists between *P. annularis* Cookson (1950) and the pollen of *Xylomelum occidentale* R. Br., a living representative of the Proteaceae.

Figured specimen:

Subsurface section 46, slide 2 (Pb 4194)(38.0 x 112.2).

Proteacidites sp. B

Plate 8, Fig. 4

Description:

The specimen figured agrees with the description of *P. auricularis* (Stanley, 1960, unpublished thesis). As far as can be ascertained, this species has not been validated.

Figured specimen:

Subsurface section 4, slide 1A (Pb 4188A)(42.0 x 117.2).

Order SANTALALES

Family SANTALACEAE (?)

Genus Aquilapollenites Rouse (1957)
emend. Funkhouser (1961)

Genotype: Aquilapollenites quadrilobus Rouse (1957)

1957 Aquilapollenites qudrilobus Rouse, p. 370, pl. 2, figs. 8-9.

1961 Aquilapollenites Rouse, emend. Funkhouser, p. 193-194, pls. 1-2, text-fig. 1.

Aquilapollenites cf. trialatus Rouse (1957)

Plate 9, Figs. 4-5

1957 A. trialatus Rouse, p. 371, pl. 2, figs. 14-15.

Description:

The specimen figured is apparently distorted normal to the polar axis. Restored configuration would probably result in a bilaterally symmetrical form. The three laevigate, equatorial protrusions also exhibit minor damage. Ornamentation of the central body is punctate. Length of polar axis, 44 μ, length of equatorial protrusions (distal tip to polar axis of grain), approximately 21μ; diameter of central body, approximately 25μ.

Discussion:

The specimens considered here are somewhat smaller than Rouse's holotype, but otherwise compare closely with the description which he gave.

Figured specimen:

Surface section Wallace 6, slide 1 (Pb 3912)(29.8 x 122.7).

Aquilapollenites pulcher Funkhouser (1961)

Plate 10, Fig. 1

1961 A. pulcher Funkhouser, p. 198, pl. 1, figs. 7a-7c.

Description:

The examples of A. pulcher Funkhouser (1961), found in the Pierre Shale compare favorably with the description of the holotype as given by Funkhouser (loc. cit.). Length of polar axis, 34 µ; length of equatorial protrusions, 23µ (distal tip to polar axis of grain).

Figured specimen:

Subsurface section 13, slide 1C (PB 4073C)(36.4 x 123.1).

Aquilapollenites reticulatus Stanley (1961)

Plate 9, Figs. 7-9

1961 A. reticulatus Stanley, p. 315, pl. 49, figs. 10-14.

Description:

Isopolar tridemicolpoidate pollen grain. Length of polar axis, 36 µ; length of equatorial protrusions (distal tip to polar axis of grain), 18µ. Endexine of central body 1.2 µ thick; ektexine sculptured with a reticulum of coarse luminae in the equatorial region which becomes finer in the polar regions. Endexine in the equatorial protrusions less than 1 µ in thickness; ektexine striated with muri. Colpoids are distinct on many specimens and are located along the polar edges of the equatorial protrusions. Colpoids extend from the distal tip of the equatorial protrusions to points well up on the central body.

Figured specimen:

Surface section Wallace A (Pb 3931)(40.4 x 121.7).

Aquilapollenites belos sp. nov.

Plate 10, Figs. 2-3

Description:

Heteropolar pollen grain; one pole very slightly extended outward (along the polar axis); opposite pole essentially flat. Three equatorial protrusions extend approximately 30μ outward from the main body of grain at angle of 45°. One edge of the equatorial protrusions convex; the opposite concave. Tips of protrusions ornamented with small, equally spaced spinules; remainder of grain granulose with irregularly distributed, smaller spinules. Tricolpate; colpi indistinct, probably restricted to the distal extremity of each equatorial protrusion. Thickened exinous areas along either edge of each protrusion extend 2/3 to 3/4 the distance from the main body to the distal extremity of each protrusion. Size: diameter of main body, from 8 to 10 μ; length of polar axis of main body, 23 μ; overall major breadth of grain, 46 μ; overall major length of grain, 34μ.

Figured specimen (holotype):

Subsurface section 13, slide 1D (Pb 4073D)(36.1 x 123.0).

Family LORANTHACEAE

Genus Elytranthe Blume

First fossil record of pollen of this genus:

Elytranthe aff. colensoi (Hook. f.) Engl., in Cranwell, 1942

1942 Elytranthe Cranwell, p. 305.

Elytranthe striatus Couper (1953)

Plate 8, Figs. 9, 11

1953 Elytranthe striatus Couper, p. 51-52, pl. 6, fig. 85.

Description:

Tricolporate pollen grain; colpi short to medium in length, narrow; triangular to sub-triangular in equatorial outline; areas between ora straight or very faintly convex. Exine 1 to 1.5 µ thick, finely granulate with granulae linearly arranged, thus producing a striated appearance. Equatorial diameter, 23 to 29µ .

Figured specimens:

Pl. 8, Fig. 9, Surface section Wallace 6 (Pb 3913)(29.1 x 122.3); Pl. 8, Fig. 11, Subsurface section 33, slide 5A (Pb 4093A)(28.4 x 115.8).

Order ROSALES

Family HAMAMELIDACEAE

Genus Liquidambar L.

First fossil record of pollen of this genus:

Liquidambar brandonensis Traverse (1955)

1955 L. brandonensis Traverse, p. 53, fig. 10, (60-61).

Liquidambar cf. brandonensis Traverse (1955)

Plate 8, Fig. 2

1955 Liquidambar brandonensis Traverse, p. 53, fig. 10, (60-61).

Description:

Approximately 16 pore pollen grain with nearly circular pores 1.6 to 2.4µ in diameter. Ektexine and endexine clearly visible. Sculpture finely reticulate. Maximum equatorial diameter, 21µ .

Discussion:

Kuprianova (1960, p. 85) assigns the two specimens figured by Traverse (loc. cit.) to two different species: L. styraciflus L. and L. parviporata mihi. Kuprianova does not, however, formally

emend or restrict the forms previously included by Traverse.

Figured specimen:

Surface section Wallace 6 (Pb 3915)(30.4 x 124.7).

Order SAPINDALES

Family AQUIFOLIACEAE

Genus *Ilexpollenites* R. Potonie (1931) Thiergart (1937)

Genotype: *Ilexpollenites iliacus* (R. Potonie, 1931) Thiergart (1937)

1931 *Pollenites iliacus* R. Potonie, p. 556, fig. 5.

1937 *Ilexpollenites iliacus* (R. Potonie, 1931) Thiergart, p. 321, pl. 25, fig. 30.

Discussion:

Potonie (1960, p. 99), in an effort to clear the considerable confusion inherent in the name *Ilexpollenites*, stated that ". . . the name of the taxon *Ilexpollenites* has to be ascribed to Thiergart (1937, p. 321). Raatz (1937, p. 25) used it on the advise of Thiergart (see remark of Raatz, 1937, p. 7 above)". Potonie's original statement in German is as follows:

"Der Name des Taxons '*Ilexpollenites*' ist Thiergart 1937, S. 321, zuzuschreiben. Raatz 1937, S. 25, benutzte ihn auf Anraten von Thiergart (s. die Bemerkung von Raatz 1937, S. 7, oben)."

It is evident to the author that the genus *Ilexpollenites* is attributable to Thiergart (*loc. cit.*).

Ilexpollenites parvus Groot and Groot (1962)

Plate 7, Fig. 9

1962 *I. parvus* Groot and Groot, p. 168, pl. 30, figs. 26-30.

Description:

Tricolpate pollen grain; colpi long, with very distinct pores;

equatorial outline oval with broadly rounded polar areas. Exine stratification easily distinguished; ektexine with closely spaced clavate processes measuring ca. 1 μ in length. Size: 27 x 17 μ (flattened).

Figured specimen:

Subsurface section 44, slide A (Pb 4115A)(35.9 x 117.0).

Family BUXACEAE

Genus Pachysandra Micheaux (1803)

First fossil record of pollen of this genus:

Pachysandra procumbentiformis Samoilovich (1961)

A very complete treatment of Pachysandra and Sarcococca can be found in Amer. Jour. Sci., v. 262, p. 1159-1197.

Pachysandra sp.

Plate 8, Fig. 1

Description:

Periporate pollen, circular in overall outline, approximately 56 pore (28 are visible on the surface shown in figured specimen) arranged in pentagonal groups. Exine highly sculptured. Size: 35 μ (equatorial diameter).

Discussion:

Pachysandra procumbentiformis Samoilovich (1961) is apparently analogous to the modern species Pachysandra procumbens Micheaux (1803).

Figured specimen:

Subsurface section 8, slide 2X (Pb 4118X)(31.4 x 122.9).

INCERTAE FAMILAE

Genus Extratriporopollenites Pflug (1952) ex Pflug in Thomson and Pflug (1953)

Genotype: Extratriporopollenites fractus Pflug 1952 ex Pflug in Thomson and Pflug (1953)

1952

1953 Extratriporopollenites fractus Pflug, in Thomson and Pflug, p. 69, pl. 6, fig. 2.

Extratriporopollenites audax Pflug (1953)

Plate 7, Fig. 17

1953 E. audax Pflug, p. 106, pl. 21, figs. 26, 29-30.

Description:

Triporate pollen grain; pores equatorial, strongly protruding and with annulus; equatorial outline triangular-convex. Exine psilate to faintly scabrate. Equatorial diameter, 17 to 22 μ.

Figured specimen:

Subsurface section 25, slide 7A (Pb 4167A)(28.3 x 112.0).

Extratriporopollenites atumescens Pflug (1953)

Plate 7, Fig. 15

1953 E. atumescens subsp. amplus Pflug, p. 73, pl. 6, figs. 65-66.

1953 E. atumescens subsp. ornatus Pflug, p. 73, pl. 6, figs. 67-68.

Description:

E. atumescens Pflug (1953), as found in the Pierre, compares favorably with the original description of E. atumescens subsp. ornatus Pflug. It differs from E. atumescens subsp. amplus Pflug in size, being much smaller than the latter subspecies.

Figured specimen:

Subsurface section 46, slide 11E (Pb 4203E)(32.4 x 116.9).

Extratriporopollenites sp.

Plate 7, Fig. 14; Plate 8, Fig. 3

Description:

Oblate, triporate pollen grain; equatorial outline triangular with projecting (aspidate) apices; equatorial diameter, 24 to 31μ. Exine 1.2 to 2.4 μ in thickness, psilate. Pores slit-like with small vestibulum.

Figured specimens:

Pl. 7, Fig. 14, Subsurface section 46, slide 11F (Pb 4203F) (35.2 x 126.6); Pl. 8, Fig. 3, Subsurface section 13, slide 6X (Pb 4078X)(40.4 x 118.4).

Genus Subtriporopollenites Pflug in Thomson and Pflug (2953)

Genotype: Subtriporopollenites anulatus Thomson and Pflug (1953)

1953 Subtriporopollenites anulatus subsp. notus Thomson and Pflug, p. 86, pl. 9, figs. 42-53.

Subtriporopollenites cf. anulatus subsp. notus Thomson and Pflug (1953)

Plate 7, Fig. 13

Description:

The specimen figured is very poorly preserved. Observation using a phase contrast system, demonstrates that the pore position compares to some extent with the description of Thomson and Pflug. Size: 25 to 27 μ (equatorial diameter).

Figured specimen:

Subsurface section 46, slide 11F (Pb 4203F)(32.1 x 125.3).

Genus Oculopollis Pflug (1953)

Genotype: Oculopollis concentus Pflug (1953)

1953 Oculopollis concentus Pflug, p. 110, pl. 19, figs. 28-31 and 35-49.

Oculopollis cardinalis Weyland & Krieger (1953)

Plate 7, Fig. 12

1953 O. cardinalis Weyland & Krieger, p. 18, pl. 2, figs. 10-11.

Description:

Triporate pollen grain; prominently thickened pore areas, somewhat rounded. Oculus weak. Endannulus present. Exine faintly intrarugulates. Size: 25μ (equatorial diameter).

Figured specimen:

Subsurface section 34, slide 5X (Pb 4215X)(38.5 x 118.2).

B. Incertae Sedis

Group ACRITARCHA Evitt (1963)[1]

Subgroup ACANTHOMORPHITAE Evitt (1963)

Genus Operculodinium centrocarpum (Deflandre & Cookson) Wall 1967

Genotype: Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall

1953 Hystrichosphaeridium sp. a Cookson, p. 115, pl. 2, figs. 26, 27.

1953 Hystrichosphaeridium sp. b Cookson, p. 115, pl. 2, fig. 28.

1955 Hystrichosphaeridium centrocarpum Deflandre and Cookson, p. 272, pl. 8, figs. 3, 4.

1959 Hystrichosphaeridium centrocarpum Defl. and Cooks.; Maier, p. 314, pl. 28, fig. 9.

1961 Baltisphaeridium centrocarpum Defl. and Cooks.; Gerlach, p. 192, pl. 28, fig. 9.

1963 Baltisphaeridium centrocarpum Defl. and Cooks.; Brosius, p. 44, pl. 6, fig. 6, text-fig. 8a,b.

1967 Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall, p. 111, pl. 16, figs. 1, 2, 5.

Operculodinium cf. centrocarpum (Deflandre & Cookson) Wall 1967

Plate 14, Fig. 4

1967 O. centrocarpum (Deflandre & Cookson) Wall, p. 111, pl. 16, Figs. 1, 2, 5.

Diagnosis:

The specimen figured compares favorably with the specimens reported by Wall (1967) in deep-sea cores from the Caribbean Sea. Additional, more favorably preserved, specimens may demonstrate the intratabular arrangement of the spines more clearly. Size: diameter

[1]Suprageneric categories of the Acritarcha follow Downie, Evitt and Sarjeant (1963) and Staplin, Jansonius and Pocock (1965).

of shell, 48 to 50 μ; length of processes, 4 to 10μ ; overall diameter, 65 to 70 μ.

Figured specimen:

Subsurface section 33, slide 9A (Pb 4097A)(30.4 x 121.6).

Genus *Micrhystridium* Deflandre (1937)

Genotype: *Micrhystridium* (al. *Hystrichosphaera*) *inconspicum* Deflandre (1935)

Micrhystridium sp.

Plate 13, Fig. 12

Diagnosis:

Spherical to subspherical; spinose, spines simple, less than 1 μ in length, more or less regularly spaced on vesicle. Size: 8 to 10 μ (overall diameter).

Discussion:

The position taken by Downie and Sarjeant (1963) is accepted here; separation is made between *Baltisphaeridium* and *Micrhystridium* principally on size mode differences. The nature of the distal tips of the Pierre specimens is not discernible.

Figured specimen:

Surface section Phillips 1A (Pb 4013)(31.1 x 126.1).

Subgroup SPHAEROMORPHITAE Downie, Evitt & Sarjeant (1963)

Genus *Leiosphaeridia* Eisenack (1958)

Genotype: *Leiosphaeridia baltica* Eisenack (1958)

1958 *Leiosphaeridia baltica* Eisenack, p. 8, pl. 2, fig. 5.

1963 *Leiosphaeridia* Eisenack (1958) emend. Downie and Sarjeant, p. 94.

Generic diagnosis:

"Spherical, hollow, thin-walled forms consisting of a very resistant light yellow to dark reddish-brown, translucent organic substance, which is often in a compressed disc-shaped state or also may be preserved irregularly folded. Membrane, also in the adult state, always without pores (distinction from Tasmanites). Pylome present." (Norris and Sarjeant, 1965, p. 36).

Downie (1963, p. 94) emended Eisenack's diagnosis to include "spherical to ellipsoidal bodies without processes, often collapsed or folded, with or without pylome. Walls granular, punctate or ornamented; thin. Without division into fields and without transverse or longitudinal furrows or girdles".

Leiosphaeridia sp.

Plate 13, Fig. 15

Diagnosis:

The figured specimen is in conformity with the generic description of Leiosphaeridia Eisenack (1958). The color of the shell has been altered by staining, but, as Downie and Sarjeant observed (1963, p. 94), "this is considered to reflect the degree of staining by humic substances rather than any intrinsic differences . . .". The Pierre specimen closely resembles Evitt's "Forma P" (Evitt, 1967, pl. 3, figs. 10-15). The archeopyle, however, is not discernible in the specimen figured and the specimen can not, therefor, be assigned to "Forma P". Size: diameter of test, 45 to 50 μ (approximate because of folding).

Figured specimen:

Subsurface section 25, slide 3A (Pb 4163A)(39.2 x 117.2).

Subgroup HERKONMORPHITAE Evitt (1963)

Genus Cymatiosphaera (O. Wetzel, 1933) emend. Deflandre (1954)

Genotype: Cymatiosphaera radiata O. Wetzel (1933)

1933 Cymatiosphaera radiata O. Wetzel, p. 27, pl. 4, fig. 8.

1954 C. radiata (O. Wetzel, 1933) emend. Deflandre, p. 257.

Generic description:

"The forms belonging to this genus are distinguished mostly by means of the possession of a lamellar skin, which is supported by means of irregularly distributed but nearly radially arranged rods (thickenings of the edges of the fields). With its meshwork it suggests in part the radiolarian Dictyospyris angilica Rust 1955, formerly found by Rust in the English fling." (Norris and Sarjeant 1965, p. 22).

Deflandre (1954, p. 257) emended the generic description of Cymatiosphaera to include forms with a ". . . shell of organic material, often brown, globular (spherical or ellipsoidal) whose external surfaces are divided into polygonal fields by membranes perpendicular to the surface. Points of junctions of membranes perpendicular to the surface. Points of junctions of membranes (angles of polygons) usually thickened, and giving in lateral view the impression of small sticks or columns. No system of equatorial differentiation of the fields. No points or spines. Margin of the membrane often distinct and parallel to the shell surface, sometimes a little concave to torn and eroded. Shell surface smooth or punctate or supplied with granules. Size from a few to several dozen microns. Sometimes 100 micra, crests included". (Norris and Sarjeant, P. 22).

Cymatiosphaera cf. punctifera Deflandre and Cookson (1955)

Plate 13, Figs. 9-10

Diagnosis:

The figured specimen is in conformity with the generic description given above. Size; diameter of test, 19 x 23 μ; individual fields, 4 x 6 μ.

Figured specimen:

Subsurface section 31, slide 1A (Pb 4086A)(41.3 x 115.3).

Subgroup PTEROMORPHITAE Downie, Evitt & Sarjeant (1963)

Genus Pterospermopsis W. Wetzel (1952)

Genotype: Pterospermopsis danica W. Wetzel (1952)

1952 P. danica W. Wetzel, p. 411, pl. A, Fig. 26.

Generic diagnosis:

Deflandre and Cookson (1955, p. 286) have noted that "the diagnosis given by W. Wetzel (1952) is both precise and comprehensive: capsule of organic matter, globular and provided with an equatorial flange. The name of the genus indicates a resemblance to the genus Pterosperma Pochet, a component of living plankton of which the systematic position still remains enigmatical".

Pterospermopsis cf. australiensis
Deflandre and Cookson (1955)

Plate 13, Fig. 4

1955 P. australiensis Deflandre and Cookson, p. 286, pl. 3, fig. 4, text-figs. 52-53.

Diagnosis:

Test circular with undulating, folded equatorial wing-like flange. Size: diameter of test, 11 to 13μ; overall diameter, 35 to 37μ; ratio of test diameter to flange width, 1:1 to 1:1.1.

Figured specimen:

Surface section Phillips 1A (Pb 4013)(43.3 x 123.2).

Pterospermopsis cf. *aureolata*
Cookson and Eisenack (1958)

Plate 13, Fig. 2

1958 *P. aureolata* Cookson and Eisenack, p. 49, pl. 9, figs. 10-12.

Diagnosis:

Thick-walled body; circular in overall outline; thin equatorial wing. Size: diameter of body, 87μ ; overall diameter, 143μ .

Figured specimen:

Subsurface section 46, slide 8F (Pb 4200)(42.4 x 112.1)

Subgroup TASMANITITAE (Sommer)
Staplin, Jansonius and Pocock (1965)

Genus *Crassosphaera* Cookson and Manum (1960)

Genotype: *Crassosphaera concinna* Cookson and Manum (1960)

1960 *C. concinna* Cookson and Manum, p. 6, pl. 1, figs. 1-3, 7-10, text-fig. 1.

Generic diagnosis:

Somewhat compressed microscopic round bodies (evidently originally spherical) with a wall about 1/20th to 1/16th of the diameter of the body. The wall is ornamented with prominences or projections which may or may not form a regular pattern, and is perforated by minute radial tabules, one to each prominence. When a tubule enters the wall from a prominence it may subdivide into a few smaller branches or remain unbranched throughout its course.

Crassosphaera cf. *concinna* Cookson & Manum (1960)

Plate 16, Fig. 8

Diagnosis:

The specimens recovered from the Pierre Shale were not sufficiently clear to allow detailed examination of the wall. They are assigned to Crassosphaera cf. concinna Cookson and Manum (1960) because of their agreement in all discernible features. The Pierre forms are sufficiently clear as to follow separation from such similar forms as Tytthodiscus chondrotus Norem (1955) and Hungarodiscus fragilis Krivan-Hutter (1963). Size: overall diameter, 74 to 75 μ; wall thickness, 3 to 4 μ.

Figured specimen:

Surface section Cheyenne 1 (Pb 4004)(29.0 x 122.1).

INCERTAE FAMILIAE

Genus Oodnattia Eisenack and Cookson (1960)

Genotype: Oodnattia tuberculata Eisenack and Cookson (1960)

1960 O. tuberculata Eisenack and Cookson, pp. 6-7, pl. 2, figs. 10-14, text-fig. 1.

Oodnattia sp.

Plate 13, Fig. 14

Diagnosis:

The figured specimen is referred to the genus Oodnattia solely on its gross morphology since tabulation is not visible. The Pierre specimens are much smaller than the holotype and may represent a separate and valid species. Size: 29 μ (overall diameter).

Discussion:

Deflandre (in Norris and Sarjeant, 1965, p. 44) concluded that

Oodnattia is a junior synonym of Dinopterygium Deflandre (1935). The difference between the two genera, as proposed by Eisenack and Cookson (loc. cit.), were not resolved by Deflandre.

Figured specimen:

Subsurface section 8, slide 6A (Pb 4122A)(42.9 x 125.9).

Division PYRRHOPHYTA Pascher (1914)

Class DINOPHYCEAE Pascher (1914)

Subclass DINOPHYCIDAE (Bergh 1881) Graham (1951)

Order DINOPHYSIALES Lindemann (1928)

Family HYSTRICHOSPHAERIDIACEAE Evitt (1963)

Genus Hystrichosphaeridium Deflandre (1937)

Genotype: Hystrichosphaeridium (al. Xanthidium) tubiferum (Ehrenberg, 1838) Deflandre, p. 69, pl. 13, figs. 2,4,5.

Generic diagnosis:

"This genus comprises all the hystrichospheres totally destitute of an equatorial system of elongate plates and whose shell, in general, does not bear fields or plates limited by sutures. The shell, of dimensions greater than 20 micra, is most often spherical or less elongate". (Norris and Sarjeant, 1965, p. 33).

Eisenack (1958, p. 399) emended the generic diagnosis as follows: "Hystrichospheres with spherical to oval, non-tabulate central shell and with more or less numerous, mostly well separated and in general similar appendages, the ends being open and often expanded in funnel-like fashion".

Hystrichosphaeridium tubiferum (Ehrenberg, 1838,) emend. Deflandre (1937)

Plate 14, Fig. 3

1937 H. tubiferum (Ehrenberg, 1838) emend. Deflandre, p. 69, pl. 13, figs. 2,4,5.

Diagnosis:

The figured specimen is in conformity with the specific diagnosis given by Deflandre (loc. cit.). Size: diameter of shell, 33 to 35 μ; length of processes, 15 to 22μ; diameter of processes, 1 to 3 μ.

Figured specimen:

Subsurface section 46, slide 7F (Pb 4199F)(27.6 x 118.2).

Hystrichosphaeridium complex (White, 1842)
emend. Deflandre (1946), emend. Deflandre and Cookson (1955)

Plate 14, Fig. 1

1942 *Xanthicium tubiferum complex* White, p. 39, pl. 4, div. 3, fig. 11.

1946 *Hystrichosphaeridium complex* (White, 1842) Deflandre, p. 11.

1955 *H. complex* (White, 1842) emend. Deflandre (1946) emend. Deflandre and Cookson, p. 270, pl. 1, figs. 9-10.

Diagnosis:

Similar to *H. tubiferum* (Ehrenberg, 1838) Deflandre (1937), but does not possess equatorial processes. The inferred tabulation of *H. complex* (White, 1842) Deflandre (1946) would be as determined from the number of processes: 4', 6'', 5''', 1_s (sulcal), 1_{pi} (posterior intercalary) and 1'''', (personal communication, G. Williams). Size: diameter of shell, 24 to 30μ ; length of processes, 20 to 22 μ ; diameter of processes, 1 to 2.5 μ.

Figured specimen:

Subsurface section 49, slide 4 (Pb 4238)(32.5 x 112.2).

Genus *Cordosphaeridium* Eisenack (1963)

Genotype: *Cordosphaeridium* (al. *Hystrichosphaeridium*) *inodes* Klumpp (1953)

1953 *Hystrichosphaeridium inodes* Klumpp, p. 391-392, pl. 18, figs. 1-2.

1963 *Cordosphaeridium* (al. *Hystrichosphaeridium*) *inodes* (Klumpp, 1953) emend. Eisenack, p. 261.

Generic diagnosis:

"Hystrichospheres with spherical to (usually weakly) ellipsoidal shells, which are bedecked with approximately homogeneneous and approximately symmetrically distributed radial appendages, which appear cord-like, i.e., are formed by numerous thin, closely set fibres. A hollow space is generally not discernible (in them), can however in particular cases be present in relic fashion. Frequently the shell consists of two layers, of which the outer has a fibrous structure and (in all probability) allows the processes to go forth as converging fibres. At the tips the fibres diverge in paintbrush-like fashion, however may also unite together in net-like fashion". (Norris and Sarjeant, 1965, p. 20).

Cordosphaeridium sp.

Plate 15, Fig. 1

Diagnosis:

The figured specimen is in conformity with the generic description given above. Size: diameter of shell, 42 to 48 μ ; length of processes, 10 to 13 μ.

Figured specimens:

Subsurface section 33, slide 9A (Pb 4097A)(40.3 x 11.7 and 26.0 x 124.2).

Genus *Hystrichosphaera* O. Wetzel (1933)

Genotype: *Hystrichosphaera* (al. *Xanthidium*) *furcata* Ehrenberg (1838)

1838 *Hystrichosphaera* (al. *Xanthidium*) *furcata* Ehrenberg, p. 109-136, pl. 1, fig. 14.

1933 *Hystrichosphaera furcata* (Ehrenberg, 1838) O. Wetzel, p. 34-35.

1937 *Hystrichosphaera furcata* (Ehrenberg, 1838) O. Wetzel, 1933, emend. Eisenack, p. 61.

Generic diagnosis:

"Spherical shell with pointed appendages in the form given as characteristic for the family, however without threefold metametric division of the body and without a complete aliform lamella, an outer shell membrane, or an outer tressil work". (Norris and Sarjeant, 1965, p. 33).

Eisenack (*loc. cit.*) emended the generic diagnosis as follows:

"Spherical, sub-spherical, or ovoid shells, divided into polygonal fields by projecting suture lines. There are always present a series of equatorially elongated fields, disposed in a helicoid girdle and ending more often near a triangular field, more or less well defined. The processes or appendages always arise from the points or junctions of the suture lines, the latter strongly projecting or not". (Norris and Sarjeant, 1965, p. 33).

Hystrichosphaera sp.

Plate 14, Fig. 5

Diagnosis:

The figured specimen is in conformity with the generic diagnosis given above. Size: diameter of shell, 34 to 37 μ ; length of processes, 7 to 12 μ.

Figured specimen:

Subsurface section 46, slide 10F (Pb 4202F)(32.0 x 118.2).

INCERTAE FAMILAE

Genus Dinogymnium Evitt, Clarke, and Verdier (1967)
Gymnodinium Stein (1878)

Genotype: Dinogymnium acuminatum Evitt, Clarke and Verdier (1967)

1878 Gymnodinium Stein, p. 89-91, pl. 2, figs. 14-21; pl. 3, figs. 1-4.

1921 Gymnodinium (Stein, 1878) emend. Kofoid and Swezy, p. 158, figs. A,B,I,M,V-BB and T.

1967 Dinogymnium acuminatum Evitt, Clarke and Verdier, p. 8-16, text-fig. 11-22, fig. 21-23, pl. 1.

Generic diagnosis:

"Tests of variable size and shape, commonly exhibiting a strong superficial similarity to motile cells of the modern genus Gymnodinium Stein; without indications of tabulation and without an inner body. Some species are characterized by a few to numerous longitudinal folds or ribs, but in other species these folds may be feebly developed or wholly lacking. Cingulum usually, but not always, distinct and moderately to deeply incised; circular to spiral with a ventral offset of about one cingulum width; not crossed by septa or other projections. Sulcus, when clearly developed, apparently confined to the hypotract, but a fold in the epitract often lies in a line with the sulcus and may appear to be a simple continuation of it. Surface smooth or ornamented with small features (e.g., scabrae, granules, or pustules); normally without spines and large projections. Wall partially or completely penetrated by many wall-canals which vary in diameter, inclination, and distribution although they are usually under 0.5 microns in diameter and about perpendicular to the surface. Apex occupied by a small, but usually distinct, archeopyle." (Evitt, Clarke & Verdier, 1967, p. 4).

Dinogymnium ? nelsonense (Cookson) Evitt, Clarke and Verdier (1967)

Plate 12, Fig. 6

1956 Gymnodinium nelsonense Cookson, p. 183-184, pl. 1, fig. 10-11.

Diagnosis:

The specimen figured agrees closely with D. nelsonense (Cookson) Evitt, Clarke and Verdier 1967, but differs slightly in the extent of the folds. It agrees well with the diagnosis by Cookson (1956, p. 183, pl. 1, fig. 10). Size of the holotype: length, 70 μ; width, 38 μ. Size of the Pierre specimen: length, 62 to 69 μ; width, 25 to 28 μ.

Figured specimen:

Subsurface section 46, slide 11F (Pb 4203F)(26.5 x 122.1).

Dinogymnium westralium Cookson and Eisenack (1958)

Plate 12, Fig. 3

1958 Gymnodinium westralium Cookson & Eisenack, p. 25-26, pl. 1, fig. 9.

1967 Dinogymnium westralium (Cookson & Eisenack, 1958) Evitt, Clarke and Verdier, p. 23-24.

Diagnosis:

The Pierre specimen (figured) agrees with the discussion of D. westralium by Evitt, Clarke and Verdier (1967, p. 24). The specific features differentiating D. westralium from D. acuminatum (small

conspicuous pustules on the longitudinal ribs, graded increase in length of the ribs on the ventral surface and convergence of the ribs toward the antapex) are not discernible in Plate 12, Figure 3, but can be seen by direct observation of the specimen. Size: length, 65-68 μ; breadth, 45-50 μ.

Figured specimen:

Subsurface section 46, slide 11F (Pb 4164B)(41.2 x 117.1).

Family DEFLANDREACEAE Eisenack

Genus Deflandrea Eisenack (1938)

Genotype: Deflandrea phosphoritica Eisenack (1938)

1938 Deflandre phosphoritica Eisenack, p. 187, text-fig. 6.

Generic diagnosis:

"Deflandrea phosphoritica n.g. is rendered recognizable through its circular apical view, oval inner body in cross section, furnished with a transverse band within its characteristically three-pointed, compressed outer shell". (Norris and Sarjeant, 1965, p. 23).

Eisenack (1954, p. 52) gave a restated diagnoses of Deflandrea:

"Shell elongated pentagonal, with apical horn and two antapical horns, without tabulation, smooth (without spines), with a wide but very shallow horizontally trending transverse girdle, which is displayed on the front only; a longitiudinal furrow is absent. Flagellar pore on the back between the apical horns. Spherical".

The archeopyle of Deflandrea is anterior intercalary as the result of the loss of plate 2_a (Graham Williams, personal communication).

Deflandrea cooksoni Alberti (1959)

Plate 12, Fig. 5

1959 D. cooksoni Alberti, p. 97-98, pl. 9, figs. 1-6.

Diagnosis:

The figured specimen conforms with the specific diagnosis as given by Alberti (loc. cit.). D. cooksoni Alberti (1959) is distinguished from the other species of Deflandrea by its distinctive outline (of the epi- and hypotheca) and the oblique angle that the antapical horn makes with the longitudinal axis. Size: length, 86 to 90 μ; breadth, 42 to 46μ.

Figured specimen:

Subsurface section 25, slide 3A (Pb 4163A)(30.5 x 116.0)

Deflandrea piraensis Alberti (1959)

Plate 12, Fig. 7

1959 D. piraensis Alberti, p. 100, pl. 8, figs. 1-15.

Diagnosis:

The figured specimen conforms with the specific diagnosis given by Alberti (loc. cit.). This species can be differentiated from other species within the genus through the ratio of the larger hypotheca (42 to 45 μ in diameter), the acutely angled triangular epitheca, the outline of the body and the structure of the differentiated membrane. Size: length, 80μ; breadth, 48 μ; length of antapical horns, 22μ.

Figured specimen:

Subsurface section 46, slide 8F (Pb 4200F)(39.4 x 122.3).

Deflandrea echinoides Cookson & Eisenack (1960)

Plate 12, Fig. 1

1960 D. echinoidea Cookson & Eisenack, p. 2, pl. 1, figs. 5-6.

Diagnosis:

The figured specimen is in conformity with the specific diagnosis by Cookson and Eisenack (loc. cit.). Size: length, 67 μ; breadth, 55 μ.

Figured specimen:

Subsurface section 6, slide 6X (Pb 4160X)(33.4 x 115.9)

Family PAREODINIACEAE Gocht

Genus Pareodinia Deflandre (1947)

Genotype: Pareodinia ceratophora Deflandre (1947)

1947 P. ceratophora Deflandre, p. 4, text-figs. 1-3.

Diagnosis:

"Microfossil with an apparently cellulosic membrane, deprived of all traces of tabulation and furrows. General form ellipsoidal or oval, drawn out at one of the poles into a strong horn. Transverse section circular". (Norris and Sarjeant, 1965, p. 47).

Discussion:

The archeopyle in Pareodinia is apparently intercalary and may result from the loss of plates 1a, 2a and 3a (Graham Williams, personal communication).

Pareodinia cf. ceratophora var. pachyceras Sarjeant (1959)

Plate 13, Figure 13

1947 P. ceratophora Deflandre, p. 4-5, text-figs. 1-3.

1959 P. ceratophora var. pachyceras Sarjeant (1959)

Diagnosis:

The specimen figured agrees most closely with Sarjeant's description differentiating P. ceratophora, P. aphelia and P. prolongata and establishing P. ceratophora var. pachyceras. The Pierre specimen is probably more coarsely granulate than Sarjeant's specimens but agrees well with his description of a more massive, less-tapered horn. Size: overall length, 69 μ; breadth, 57 μ; length of apical horn, 15 μ.

Figured specimen:

Subsurface section 33, slide 10A (Pb 4098)(28.2 x 127.2).

Pareodinia sp.

Plate 12, Figure 9

Diagnosis:

The figured specimen resembles P. aphelia Cookson and Eisenack 1958, having an acuminate apex, a short closed neck and a granulate to almost smooth thecal wall. It differs from P. aphelia in size (the holotype measures 88 x 50 μ; the Pierre specimen 41 x 68 μ). The Pierre specimen (Plate 12, Figure 9) is closer, in size, to P. ceratophora Deflandre 1947, but has a slightly less granulate wall. The author is hesitant to assign the subject specimen to either P. ceratophora, P. ceratophora var. pachyceras or to P. aphelia until additional specimens are available for study.

Figured specimen:

Subsurface section 10, slide 2X (31.5 x 119.0).

Family MUDERONGIACEAE Neale & Sarjeant

Genus Muderongia Cookson & Eisenack (1958)

Genotype: Muderongia mcwhaei Cookson & Eisenack (1958)

1958 Muderongia mcwhaei Cookson & Eisenack, p. 41, pl. 6, figs. 1-5.

Generic diagnosis:

Test flattened, bilaterally symmetrical, composed of a thin outer membrane and an internal body or capsule. The outer membrane prolonged into four equidistant horns and crossed by a narrow shallow girdle. A longitudinal furrow is not developed.

Muderongia sp.

Plate 12, Fig. 2

Diagnosis:

The specimen figured is not in conformity with the genotype (*M. mcwhaei* Cookson and Eisenack 1958) but does agree with at least one species now included in the genus (*M. crucis* Neale and Sarjeant 1962). The girdle is absent in both the Pierre specimen and in *M. crucis*. The specimen figured differs sufficiently from *M. crucis* Neale and Sarjeant 1962 in morphological features such as overall size, size and character of the apical, antapical and lateral horns to justify the erection of a new species. Further searching of the Pierre material for corroborative specimens must be done before a new species can be proposed.

Figured specimen:

Subsurface section 33, slide 3 (Pb 4091)(37.9 x 114.9).

Genus *Gillinia* Cookson and Eisenack (1960)

Genotype: *Gillinia hymenosphora* Cookson and Eisenack (1960)

1960 *Gillinia hymenophora* Cookson and Eisenack, p. 12, pl. 3, figs. 4-6, text-fig. 5.

Generic diagnosis:

"Shell circular to oval in outline, bearing fine surface ridges which partly or wholly delimit fields of varying shape and size and form two more or less spherical, hollow, membraneous structures with a net-like appearance on either side of the anterior surface". (Cookson and Eisenack, *loc. cit.*).

Gillinia cf. hymenophora Cookson & Eisenack (1960)

Plate 13, Fig. 3

Diagnosis:

The figured specimen is in conformity with the specific diagnosis as given by Cookson and Eisenack (loc. cit.). Size: overall length, 37 to 39μ ; overall breadth, 28 to 29μ .

Figured specimen:

Subsurface section 33, slide 9A (Pb 4097A)(44.6 x 126.3).

Genus Horologinella Cookson & Eisenack (1962)

Genotype: Horologinella lineata Cookson & Eisenack (1962)

1962 H. lineata Cookson & Eisenack, p. 272, pl. 37, figs. 1-3.

Generic diagnosis:

Shell small, slightly biconvex, roughly hour-glass shaped with or without an opening at one end, surface with or without fields, smooth or sculptured.

Horologinella apiculata Cookson & Eisenack (1962)

Plate 16, Fig. 1

1962 H. apiculata Cookson & Eisenack, p. 272, pl. 37, fig. 4.

Diagnosis:

The figured specimens agree quite well with the specific description given by Cookson and Eisenack (loc. cit.) for the holotype. Because Cookson and Eisenack proposed Horologinella as a form genus, the placement of the Pierre specimens is based primarily on morphological similarities. Size: measurements (taken normal to each other) range from 12 x 14μ to 13 x 15μ.

Figured specimen:

Surface section Phillips 1 (Pb 4013)(44.7 x 123.2).

Horologinella sp. and H. cf. apiculata

Plate 16, Figs. 2 and 5

Diagnosis:

All specimens figured (Plate 16, Figs. 2 and 5) agree, morphologically, with the descriptions given by Cookson and Eisenack (1962, p. 272). The author is hesitant to assign the subject specimens to H. apiculata because of the preservation of the specimens. Insofar as can be ascertained at this time, the subject specimens must be referred to the genus Horologinella solely on the basis of their gross morphology since criteris that would permit definite speciation is not present. The figured specimens measure from 13 x 17 to 13 x 15 microns.

Figured specimens:

Plate 16, Fig. 2, Subsurface section 25, slide 3A (37.8 x 111.0) and Plate 16, Fig. 5, Surface section Phillips 1A (41.4 x 127.8).

Genus Svalbardella Manum 1960

Genotype: Svalbardella cooksoniae Manum (1960)

1960 S. cooksoniae Manum, p. 17-24, pl. 1.

Generic diagnosis:

"Shells of planktonic microorganisms. Shape fusiform with somewhat swollen middle part and blunt ends. No appendages. Girdle approximately equatorial. Middle part of shell entirely filled with a thin-walled ellipsoidal body" (Manum, op. cit.).

Svalbardella sp.

Plate 13, Fig. 1

Diagnosis:

The specimen figured agrees most closely with S. australina Cookson. It differs somewhat from the genotype (S. cooksoniae Manum 1960) in the character of its apical and antapical horns which, in the Pierre specimen, appear to have suffered greatly in preservation and are consequently strongly flattened and distorted. Plate 13, Figure 1 demonstrates a longitudinal furrow and vestiges of plates on the thecal walls; both of which are characteristics of S. cooksoniae. Size: length, 149 to 152 μ ; breadth, 27 to 29 μ; length of horns, from 38 to 50 μ .

Figured specimen:

Subsurface section 33, slide 3 (Pb 4091)(36.0 x 122.7).

Genus Microdinium Cookson and Eisenack (1960)

Genotype: Microdinium ornatum Cookson and Eisenack (1960)

1960 M. ornatum Cookson and Eisenack, p. 6, pl. 2, figs. 3-4

Generic diagnosis:

"Shell ovoidal, narrower end anterior, divided unequally by the relatively broad girdle; epitheca shorter than hypotheca. Plates bordered by low but distinct ledges, which frequently are perforated by a single row of holes and look like strings of beads in surface view. Sometimes the outer edge of the ledges may be missing, in which case the portions of the wall originally separating the perforations appear as isolated 'beads'. The surface of the plates may be ornamented by a varying number of small tubercles" (Cookson and Eisenack, loc. cit.).

Microdinium sp.

Plate 13, Figs. 5-8, 11

Diagnosis:

The five specimens figured agree, on the generic level, with the description given by Cookson and Eisenack (loc. cit.). Plate 13,

Figures 5-6, demonstrate the loss of the outer edge of the ledges as noted by Cookson and Eisenack, while Plate 13, Figures 7, 8 and 11 possess well-preserved ledges. Size of holotype: length, 28 to 38 μ; breadth, 27 to 36μ. Size of Pierre specimens: length, 20 to 21 μ; breadth, 18 to 20μ.

Figured specimens:

Pl. 13, figs. 5,6, Subsurface section 46, slide 2 (Pb 4194) (38.2 x 119.8); Pl. 13, figs. 7,8, Subsurface section 46, slide 2 (Pb 4194)(38.2 x 129.8); Pl. 13, fig. 11, Subsurface section 46, slide 2 (Pb 4194)(32.4 x 111.7).

C. Microforaminifera

"Microforaminifer"

Microforaminifera sp. A

Plate 16, Fig. 7

Description:

Microforaminifer, planispiral, chambers lobate, umbilicus open. Overall size: 86μ; diameter of proloculus, 17μ.

Discussion:

Very rarely observed in the Pierre samples. Possibly a megalospheric form of a member of the family Anomalinidae.

Figured specimen:

Subsurface section 33, slide 6X (35.8 x 124.8).

D. Unassigned Sporomorphae

Genus *Wodehouseia* Stanley (1961)

Genotype: *Wodehouseia spinata* Stanley (1961)

1961 *W. spinata* Stanley, p. 157, pl. 1, figs. 1-12.

Wodehouseia spinata Stanley (1961)

Plate 16, Fig. 6

Diagnosis:

The figured specimen from the Pierre is in agreement with the specific diagnosis as given by Stanley (*loc. cit.*). Size: overall length, 50μ ; length of central body, 48μ ; width of central body, 17 μ; width of flange (maximum), 9 μ.

Figured specimen:

Subsurface section 50, slide 10 (Pb 4250)(27.0 x 124.3).

CHAPTER VII

Summary and Conclusions

The present study demonstrates that the palynologic zonation of lithologically monotonous sequence of marine shales is valid and practical. Application of the palynologic method to the Pierre Shale of northwest Kansas and environs provided the following conclusions:

1.) The sources areas for the plant microfossils of the Pierre were located northeast and southeast of the study area. The source areas for the marine phytoplankton (open marine waters) were located northwest and southwest of the study area.

2.) Variations in the biotic diversity of the floras of the source areas during the deposition of the Pierre Shale are reflected in the palynomorphs produced by the parent plants and later deposited in the basins that existed at the time. The levels of discernible variations in biotic diversity are roughly synchronous over the area studied. Greater sample density will be necessary for more detailed or accurate correlations.

3.) The Pierre Shale has been divided into four palynologic zones. Only the stratigraphically lowest unit (Palynologic Zone I) is a correlatable lithologic unit in the subsurface sections of the Pierre. The three younger palynologic zones (II, III and IV) do not exhibit reliable or distinctive geophysical characteristics. However, the four proposed zones can be characterized by groups of palynomorphs, but apparently not by true index forms.

4.) The areal distribution of the proposed palynologic zones of the Pierre support the thesis that the present day distribution of Pierre strata of different ages which forms the pre-Tertiary surface, resulted from post-Pierre uplift and erosion. Minor localized structural adjustments in the Cambridge Arch are reflected in the distribution of several of the palynomorph groups considered. Regional thinning of individual palynologic zones can not be discounted or proven because of the lateral and vertical spacing of the samples available for study.

5.) A large proportion of the extant plant families represented in the microfossil flora of the Pierre Shale are subtropical and tropical in their present day distribution. The conclusion is drawn that the floras of the source areas were essentially comparable to extant floristic groups present in the subtropic and tropic zones of the present. It is inferred that the minor contributions of pollen referable to the families Pinaceae, Taxodiaceae and Betulaceae could have been produced in higher, more temperate areas north and northwest of the study area.

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Appendices A and B

Appendix A

Table 6.--Surface exposures of the Pierre Shale sampled and studied in the present dissertation

Section Number	Location	Thickness (feet)	Samples Macerated
Wallace County, Kansas:			
A	SW SE 35-13S-40W	29.8	Pb 3927-3931
1	NE 2-14S-40W	52.2	Pb 3932-3937
2	SW SW 1-14S-40W	26.0	Pb 3922-3925
3	E/2 33-13S-39W	25.0	Pb 3918-3919
4	NE NE NE 12-14S-39W	49.5	Pb 3906-3909
5	SE 2-13S-42W	18.5	Pb 3926
6	SW SW 36-11S-42W	57.3	Pb 3910-3915
7	NE NE 12-12S-42W	12.0	Pb 3916-3917
8	SW 4-13S-40W	52.0	Pb 3901-3905
9	NW 15-12S-38W	14.0	Pb 3920-3921
Logan County, Kansas:			
1	N/2 NW 36-11S-37W	14.7	Pb 3944-3947
2	NE 20-11S-37W	48.0	Pb 3960-3962
3	NE NW 35-11S-37W	32.5	Pb 3950-3952
4	5-14S-36W	31.0	Pb 3953-3954
5	NE 4-15S35W	35.0	Pb 3941-3943
6	SW NW 35-13S-32W	7.5	Pb 3946-3949
7	NE 20-15S-32W	78.0	Pb 3933-3940

Table 6.--Continued

Section Number	Location	Thickness (feet)	Samples Macerated
8	13-12S-37W	56.8	Pb 3955-3959
1	C W/2 22- 2S-40W	6.0	Pb 3982-3985
1A	SE NW SW 22- 2S-40W	6.0	Pb 3996-3998
1B	SW SE SE 22- 2S-40W	9.0	Pb 3979-3981
1C	SW NW NW 26- 2S-40W	9.0	Pb 4004-4005
1D	SW SW NW 26- 2S-40W	9.0	Pb 3963-3964
2A	C NW 32- 1S-39W	7.5	Pb 3969
2B	NEc 5- 2S-39W	4.5	Pb 3971
3A	NEc 4- 2S-38W	11.5	Pb 3974
3B	C N/2 SE 33- 2S-38W	11.5	Pb 3999
3C	C N/2 NE 33- 2S-38W	7.5	Pb 3970
3D	C NE NE 28- 2S-38W	15.0	Pb 4000-4002
3E	NE NE NE 28- 2S-38W	6.0	Pb 4003
4A	NE NW NE 11- 1S-41W	13.0	Pb 3977-3978
4B	NE SE SE 11- 1S-41W	18.5	Pb 3994-3995
5A	SE SE NW 22- 1S-37W	3.5	Pb 3968
5B	NE SW NW 22- 1S-37W	11.0	Pb 3972-3973
6A	C W/2 22- 1S-37W	10.5	Pb 3975-3976
6B	SE SE SW 6- 1S-40W	24.0	Pb 3986-3987
8A	C N/2 SW 22- 1S-42W	44.2	Pb 3988-3993
9A	NEc 3- 2S-40W	19.5	Pb 3965-3967
Yuma County, Colorado:			
7A		49.5	Pb 4006-4012

Table 6.--Continued

Section Number	Location	Thickness (feet)	Samples Macerated
Phillips County, Kansas:			
1A	NE SE 24- 1S-20W		Pb 4012-4016
Rawlins County, Kansas:			
1A	NW NW SW 9- 1S-36W	2.5	Pb 4017
1B	SW NW 9- 1S-36W	7.5	Pb 4018
1C	NW 9- 1S-36W	19.5	Pb 4019-4021
2A	SW SW 1- 3S-33W	17.7	Pb 4022-4023

Table 7.--Subsurface section of the Pierre Shale sampled and studied in the present dissertation

Well Number	Well Location	Pierre Interval (drill depth, feet)	Samples macerated and studied
2	C NE SE 12- 1S-34W Rawlins County, Kansas	250-1050	Pb 4099 to 4107
3	C SE SE 24-11S-37W Logan County, Kansas	315-375	Pb 4108 to 4110
4	NWc NE 16- 5S-29W Decatur County, Kansas	220-590	Pb 4188 to 4192
5	NWc SW 17- 4S-33W Rawlins County, Kansas	303-860	Pb 4124 to 4130
6	C NW SW 32- 2S-30W Decatur County, Kansas	276-755	Pb 4155 to 4160
7	C SE NW 23- 8S-39W Sherman County, Kansas	390-920	Pb 4079 to 4085
8	C SW NE 31- 2S-32W Rawlins County, Kansas	170-800	Pb 4117 to 4123
10	C NW SW 12-12S-37W Logan County, Kansas	0-90	Pb 4111 to 4112
12	C NE SE 24- 6S-40W Sherman County, Kansas	460-1306	Pb 4065 to 4072
13	SWc SW 20-10S-38W Sherman County, Kansas	120-680	Pb 4073 to 4078
16	SE SW NE 11-13S-42W Wallace County, Kansas	150-420	Pb 4207 to 4210
19	C SW SW 29- 6S-32W Thomas County, Kansas	220-660	Pb 4143 to 4148
20	C SE NE 34- 6S-32W Thomas County, Kansas	344-775	Pb 4149 to 4154
22	23- 2N-30W Red Willow City, Nebraska	260-650	Pb 4170 to 4174

Table 7.--Continued

Well Number	Well Location	Pierre Interval (drill depth, feet)	Samples macerated and studied
24	C N/2 SW 32- 3N-36W Dundy City, Nebraska	300-1350	Pb 4131 to 4142
25	C SE SE 12- 3N-32W Hitchcock City, Nebraska	130-960	Pb 4161 to 4169
31	SE NE 20- 1S-22W Norton City, Kansas	350-610	Pb 4086 to 4088
33	C SE SW 17- 2N-41W Dundy City, Nebraska	300-1790	Pb 4089 to 4098
34	SWc NW 22- 3S-23W Norton City, Kansas	106-455	Pb 4211 to 4215
41	C 13-12S-37W Logan City, Kansas	0-210	Pb 4113 to 4115
44	NEc NW 19- 9S-31W Thomas City, Kansas	190-310	Pb 4115A- 4116
46	SE SE NE 31- 2S-39W Cheyenne City, Kansas	30-1120	Pb 4193 to 4203
47	9-14S-42W Wallace City, Kansas	260-450	Pb 4204 to 4206
49	C NE 24- 6N-38W Chase City, Nebraska	340-1630	Pb 4235 to 4240
50	C NW NW 21-13N-37W Keith City, Nebraska	?	Pb 4241 to 4255

APPENDIX B

Table 8.--Summary list of palynomorphs from the Pierre Shale

Division Phycomycota

Phycopeltis sp.

Fungi Imperfectae

Fungal spore sp. A
Fungal spore sp. B
Fungal spore sp. C
Fungal spore sp. D

Division Bryophyta

Family Sphagnaceae

Sphagnum punctaesporites Rouse 1959

Division Pterophyta

Family Lycopodiaceae

Lycopodium cf. *fastigioides* Couper 1953
Lycopodium sp. (*fastiatum-volubile group*) Couper 1953
Lycopodium cf. *papillaesporites* Rouse 1957
Lycopodiumsporites tri-arcuatus Delcourt & Sprumont 1955

Family Selaginellaceae

Acanthotriletes varispinosus Pocock 1962
Cingulatisporites pierrensis sp.nov.
Cingulatisporites callosus Weyland and Greifeld 1953
Cingulatisporites levispeciosus Pflug 1953, emend.R. Potonie 1956

Order Equisetales

Family Equisetaceae

Equisetosporites sp.

Order Filicales

Table 8.--Continued

Aequitriradites sp.
Umbosporites callosus Newman 1965

UNASSIGNED SPORES

Murospora mesozoica Pocock 1961
Triplanosporites cf. sinuosus Pflug 1953
Cyclosporites radiatus Krutzsch 1959
Densosporites sp.
Camarozonosporites rudis (Leschik 1955) Klaus 1960
Taschites primum gen. et sp. nov.
Peromonolites cf. problematicus Couper 1953
Reticuloidosporites dentatus Pflug, in Thomson and Pflug 1953
Reticuloidosporites sp.

Division Spermatophyta

Class Pteridospermae

Family Caytoniaceae

Caytonipollenites cf. pallidus (Reissinger) Couper 1958

Order Coniferales

Family Podocarpaceae

Phyllocladidites sp.
Phyllocladus sp.
Podocarpidites cf. biformis Rouse 1957
Pityosporites cf. similis Balme 1957

Family Pinaceae

Tsugaepollenites cf. segmentatus Balme 1957
Tsugaepollenites sp.
Pinuspollenites sp.
Abiespollenites sp.
Piceaepollenites sp.
Cedripites eocenicus Wodehouse 1933

Family Taxodiaceae

Sequoiapollenites sp.

Incertae Sedis

Eucommidites minor Groot and Penny 1960
Classopollis obidosensis Groot and Groot 1962
Classopollis classoides Pflug (1953) emend. Pocock and Jansonius 1961

Table 8.--Continued

Family Osmundaceae

Osmundacidites wellmanii Couper 1953

Family Schizaeceae

Appendicisporites tricornitatus Weyland and Greifeld 1953
Chomotriletes fragilis Pocock 1962
Cicatricosisporites dorogensis R. Potonie and Gelletich 1933
Cicatricosisporites mohrioides Delcourt and Sprumont 1955
Lygodioisporites sp.
Undulatisporites sinuosis Groot and Groot 1962
Undulatisporites sp.

Family Gleicheniaceae

Gleicheniidites circinidites (Cookson) Singh 1964
Gleichenia concavisporites Rouse 1957
Leiotriletes dorogensis (Kedves 1961

Family Cyatheaceae

Cyathidites concavus (Bolk.) Dettmann 1963

Family Dicksoniaceae

Trilites comaumensis Cookson 1953

Family Polypediaceae

Polypodiidites sp.
Laevigatosporites cf. ovatus Wilson and Webster 1946

Family Marattiaceae

Marattisporites scabratus Couper 1958

Family Matoniaceae

Matonisporites cf. equiexinus Couper 1958

Incertae Sedis

Concavisporites sp.
Concavissimisporites variverrucatus (Couper) Singh 1964
Kuylisporites waterbokli R. Potonie 1956
Perotriletes pseudoreticulatus Couper 1953
Perotriletes rugulatus Couper 1958

Table 8.--Continued

Aequitriradites sp.
Umbosporites callosus Newman 1965

UNASSIGNED SPORES

Murospora mesozoica Pocock 1961
Triplanosporites cf. *sinuosus* Pflug 1953
Cyclosporites radiatus Krutzsch 1959
Densosporites sp.
Camarozonosporites rudis (Leschik 1955) Klaus 1960
Taschites primum gen. et sp.nov.
Peromonolites cf. *problematicus* Couper 1953
Reticuloidosporites dentatus Pflug, in Thomson and Pflug 1953
Reticuloidosporites sp.

Division Spermatophyta

Class Pteridospermae

Family Caytoniaceae

Caytonipollenites cf. *pallidus* (Reissinger) Couper 1958

Order Coniferales

Family Podocarpaceae

Phyllocladidites sp.
Phyllocladus sp.
Podocarpidites cf. *biformis* Rouse 1957
Pityosporites cf. *similis* Balme 1957

Family Pinaceae

Tsugaepollenites cf. *segmentatus* Balme 1957
Tsugaepollenites sp.
Pinuspollenites sp.
Abiespollenites sp.
Piceaepollenites sp.
Cedripites eocenicus Wodehouse 1933

Family Taxodiaceae

Sequoiapollenites sp.

Incertae Sedis

Eucommiidites minor Groot and Penny 1960
Classopollis obidosensis Groot and Groot 1962
Classopollis classoides Pflug (1953) emend. Pocock and Jansonius 1961

Table 8.--Continued

Callialasporites dampieri (Balme) Dev 1961
Corallina sp.
Inaperturopollenites sp.
Inaperturopollenites hiatus (R. Potonie) Pflug 1953
Pollenites ortholaesus R. Potonie 1934

Family Salicaceae

Tricolpites sp.
Tricolpites thomasii Cookson and Pike 1954

Family Santalacea (?)

Aquilapollenites cf. *trialatus* Rouse 1957
Aquilapollenites pulcher Funkhouser 1961
Aquilapollenites reticulatus Stanley 1961
Aquilapollenites belos sp.nov.

Family Aquifoliaceae

Ilexpollenites parvus Groot and Groot 1962

Family Betulaceae

Corylus punctatipollenites Rouse 1957
Triporopollenites sp.

Family Ulmaceae

Momipites coryloides Wodehouse 1933
Momipites inaequalis Anderson 1962

Family Loranthaceae

Elytranthe striatus Couper 1953

Family Buxaceae

Pachysandra sp.

Family Hamamelidaceae

Liquidambar brandonensis Traverse 1955

Family Proteaceae

Proteachdites thalmanni Anderson 1960
Proteacidites annularis Cookson 1950
Proteacidites sp. A
Proteacidites sp. B

Table 8.--Continued

Incertae Familae

Extratriporopollenites audax Pflug 1953
Extratriporopollenites atumescens Pflug 1953
Extratriporopollenites sp.
Subtriporopollenites cf. anulatus subsp. notus Thomson and Pflug 1953
Oculopollis cardinalis Weyland and Krieger 1953

Group ACRITARCHA Evitt 1963

Subgroup Acanthomorphitae Evitt 1963

Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Micrhystridium sp.

Subgroup Sphaeromorphitae Downie, Evitt and Sarjeant 1963

Leiosphaeridia sp.
Cymatiosphaera cf. punctifera Deflandre and Cookson 1955

Subgroup Pteromorphitae Downie, Evitt and Sarjeant 1963

Pterospermopsis cf. australiensis Deflandre and Cookson 1953
Pterospermopsis cf. aureolata Cookson and Eisenack 1958

Subgroup Tasmanititae (Sommer) Staplin, Jansonius and Pocock 1965

Crassosphaera cf. concinna Cookson and Manum 1960

Incertae Sedic

Oodnattia sp.

Class Dinophyceae Pascher

Subclass Dinoferophycidae Bergh

Order Dinophysiales Lindemann

Family Hystrichosphaeridiaceae Evitt

Hystrichosphaeridium tubiferum (Ehrenberg 1838) emend. Deflandre 1936
Oligosphaeridium complex (White 1842) emend. Deflandre and Cookson 1955
Cordosphaeridium sp.
Hystrichosphaera sp.

Table 8.--Continued

Dinogymnium ? *nelsonense* (Cookson) Evitt 1967
Dinogymnium westralium (Cookson and Eisenack 1958) Evitt 1967
Dinogymnium sp.

Family Deflandreaceae

Deflandrea cooksoni Alberti 1959
Deflandrea piraensis Alberti 1959
Deflandrea echinoidea Cookson and Eisenack 1960

Family Pareodiniacea Gocht

Pareodinia sp.
Pareodinia cf. *certatophora* var. *pachyceras* Sarjeant 1959

Family Muderongiaceae Neale and Sarjeant

Muderongia sp.
Gillinia cf. *hymenophora* Cookson and Eisenack 1960
Horologinella apiculata Cookson and Eisenack 1962
Svalbardella sp.
Microdinium sp.

Microforaminifera

Microforaminifera sp. A

Unassigned Sporomorphae

Wodehouseia spinata Stanley 1961

Plates 1 through 16

PLATE 1

Figure

1. Undulatisporites sinuosis Groot & Groot 1962, 19 to 25 μ; 33-9A (33.1 x 117.0)

2, 3. Gleicheniidites cf. G. circinidites (Cookson) Singh 1964, 23 32 μ; 13-2A (35.6 x 114.1). Figure 2: high focus; Figure 3 low focus.

4. Cyathidites concavus (Bolkhovitina) Dettmann 1963, 22 μ; 25-2A (40.7 x 112.8)

5, 6. Matonisporites cf. M equiexinus Couper 1958, 40 to 68 μ; 13-2A (28.7 x 113.7). Figure 5: high focus; Figure 6: low focus.

7. Gleichenia concavisporites Rouse 1957, 38 μ; 46-11E (34.3 x 116.0)

8. Leiotriletes cf. L. adriennis (R. Potonie & Gelletich 1933) Krutzsch 1959, 34 μ; 10-2X (34.1 x 114.6)

9. Concavisporites sp., 20 to 29 μ; 46-5A (45.9 x 121.4)

10. Undulatisporites sp., 18 μ; 46-2 (35.3 x 124.8)

11. Acanthotriletes varispinosus Pocock 1962, 25 to 42 μ; 33-9A (36.5 x 120.7)

12. Triplanosporites cf. T. sinuosus Pflug 1953, 33 to 45 μ (length polar axis) x 30.2 to 48.7 μ (equatorial diameter compressed); 46-2 (34.4 x 116.7)

13. Leiotriletes dorogensis Kedves 1960, 74 μ; 13-1D (38.2 x 125.7)

14, 15. Cyclosporites radiatus Krutzsch 1959, 32 to 43 μ; 6-1X (31.7 x 124.7). Figure 14: proximal focus; Figure 15: distal focus.

16. Sphagnum punctaesporites Rouse 1959, 24 to 37 μ; 33-5A (43.3 x 114.9)

PLATE I

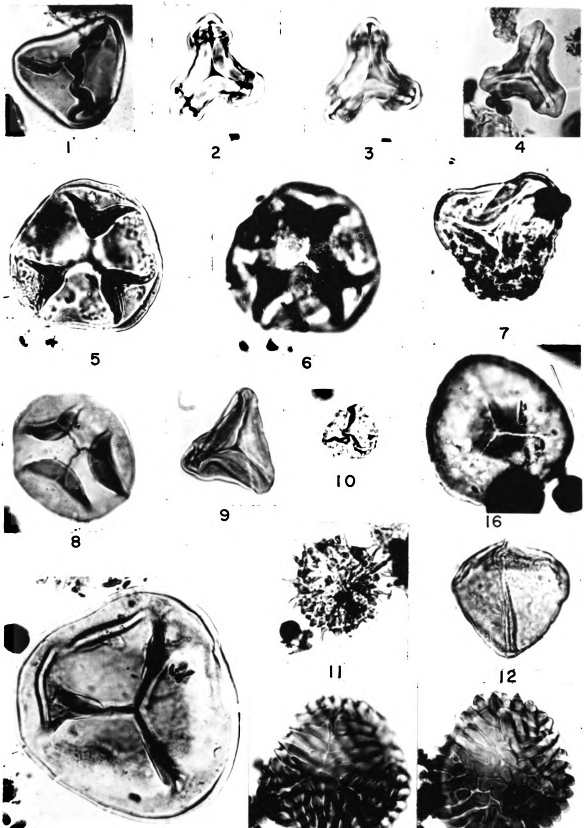


PLATE 2

Figure

1. <u>Osmundacidites</u> <u>wellmanii</u> Couper 1953, 42 to 46μ ; 46-1 (33.7 x 113.8)

2. <u>Osmundacidites</u> <u>comaumensis</u> (Cookson) Cookson 1947, 31 x 33μ ; 46-6A (35.5 x 122.2)

3. <u>Trilites</u> <u>comaumensis</u> Cookson 1953, 25 to 48 μ; 33-4 (32.4 x 116.7)

4. <u>Concavissimisporites</u> <u>variverrucatus</u> (Couper) Singh 1964, 50μ ; 46-11G (32.8 x 128.3)

5. <u>Cicatricosisporites</u> sp., 38μ ; 13-2C (35.7 x 120.7)

6. <u>Cicatricosisporites</u> <u>mohrioides</u> Delcourt & Sprumont 1955, 32 to 33 μ; 13-1D (45.0 x 121.2)

7. <u>Cicatricosisporites</u> sp., 37 μ; 33-5X (29.7 x 110.9)

8. <u>Cicatricosisporites</u> <u>dorogensis</u> R. Potonie & Gelletich 1933, 35 x 29 μ; Cheyenne 1C (40.5 x 115.3)

9. <u>Selaginella</u> <u>deflexa</u> Br. 1854, 42 μ; 13-1C (27.8 x 126.0)

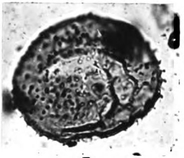
10. <u>Lycopodiumsporites</u> <u>tri-arcuatus</u> Delcourt & Sprumont 1955, 59μ ; Logan 7 (34.4 x 126.4)

11. <u>Selaginella</u> <u>deflexa</u> Br. 1854, overall tetrad diameter, 56 μ; diameter, 56μ ; diameter of individual spores, 28μ ; 19-1B (37.6 x 110.7)

PLATE 2

1

2



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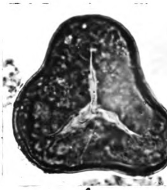

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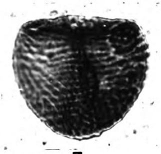

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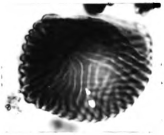

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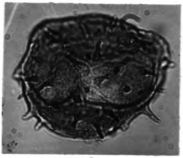

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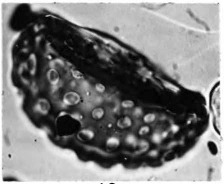

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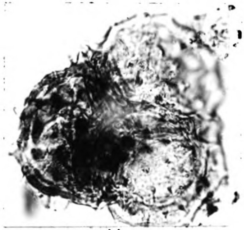


11

PLATE 3

Figure

1, 2. Cingulatisporites sp., 32 µ; 50-1124 (30.9 x 127.6). Figure 1: proximal focus; Figure 2: distal focus.

3. Kuylisporites waterbolki R. Potonie 1956, 25 to 34 µ; 13-5A (43.4 x 111.8)

4. Cingulatsporites pierrensis sp. nov., 23 µ (central body diameter); 13-2C (37.0 x 117.5)

5. Chomotriletes cf. C. fragilis Pocock 1962, 41 x 49 µ; 33-5A (30.8 x 118.8)

6, 7. Lycopodium cf. L. papillaesporites Rouse 1957, 34 µ; 13-1D (40.0 x 112.0). Figure 6; proximal focus; Figure 7: distal focus.

8. Tsugapollenites sp., 44µ ; 10-2X (29.9 x 122.6)

9 Lygodiosporites sp., 31 to 36µ ; 13-1D (31.2 x 126.7)

10. Tsugapollenites cf. T. segmentatus Balme 1957, 50 µ (overall diameter); 46-8F (39.8 x 113.8)

11. Lycopodium cf. L. sp. (fastigiatum-volubile group) Couper 1958, 41 to 48 µ; 46-8F (43.1 x 121.4)

12, 13. Lycopodium cf. L. fastigioides Couper, 1958, 31 to 51µ ; 46-1 (44.3 x 110.9)

PLATE 3

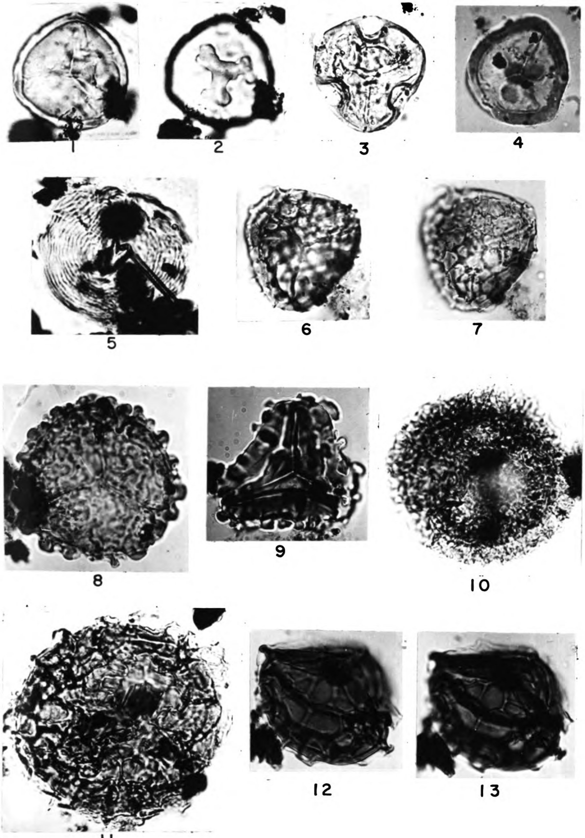


PLATE 4

Figure

1. *Sequoiapollenites* sp., 22 μ; 13-2A (44.4 x 111.9)

2. *Perotriletes pseudoreticulatus* Couper 1953, 41μ ; 46-1

3. *Perotriletes* sp., 28 to 35 μ; 6-1X (31.1 x 115.3)

4. *Ephedra* cf. *E. voluta* Stanley 1965, 22 to 25 x 34 to 37 μ; 13-2A)34.4 x 114.1)

5. *Cingulatisporites callosus* Weyland and Greifeld 1953, 32 μ; 50-1124 (42.9 x 120.2)

6. *Appendicisporites tricornitatus* Weyland and Greifeld 1953, 42 to 63μ ; 46-11F (38.6 x 110.4)

7. *Murospora mesozoica* Pocock 1961, 41μ ; 33-4 (37.3 x 119.4)

8. *Densosporites* sp., 80 μ; 33-7 (35.2 x 117.8)

9. *Appendicisporites* sp., 69 μ; 33-5X (38.0 x 111.0)

10. *Cingulatisporites levispeciosus* Pflug 1953, 40μ ; 46-7F (31.2 x 119.0)

11, 12. *Perotriletes rugulatus* Couper 1958, 55 μ; 13-6X (40.6 x 121.6). Figure 11: proximal focus; Figure 12: distal focus.

13. *Zonalapollenites* cf. *Z. dampieri* Balme 1957, 30 to 37μ ; Pb 3931 (30.3 x 125.5)

PLATE 4

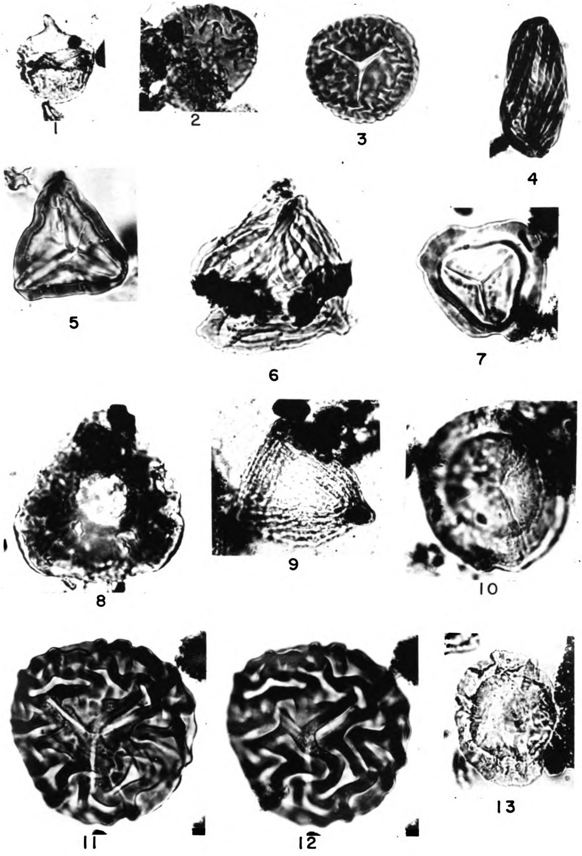


PLATE 5

Figure

1. Camarozonosporites rudis (Leschik 1955) Klaus 1960, 35 to 37 μ; 46-8F (40.8 x 113.0)

2. Aequitriradites sp., 38 to 53 μ ; 46-5A (32.9 x 111.8)

3. Aequitriradites sp., 73 μ ; 33-7 (29.5 x 110.0)

4. Laevigato-sporites albertensis Rouse 1957, 22 x 36 μ; 33-3 (35.4 x 115.9)

5, 6, 7. Umbosporites callosus Newman 1965, 32 to 39 x 14 to 20 μ ; Surface section (Wallace) (Pb 3929 and Pb 3931)

8. Laevigatosporites cf. L. ovatus Wilson & Webster 1946, 32 x 55 μ; 46-4 (30.3 x 128.1)

9, 10, 11. Reticuloidosporites dentatus Pflug 1953, 27 x 46 μ ; 46-11F (29.1 x 126.8). Figure 9: high focus; Figure 10: intermediate focus; Figure 11: low focus.

12. Reticuloidosporites sp., 55 x 72 μ; 13-2A (36.4 x 116.5)

13. Polypodiidites sp., 34 to 38 x 44 to 58 μ; 13-1D (34.0 x 119.8)

14. Marattisporites scabratus Couper 1958, 24 x 39μ ; 46-10F (38.2 x 119.8)

15. Peromonolites cf. P. problematicus Couper 1953, 22 to 29 μ; Phillips 1A (42.6 x 110.7)

PLATE 5

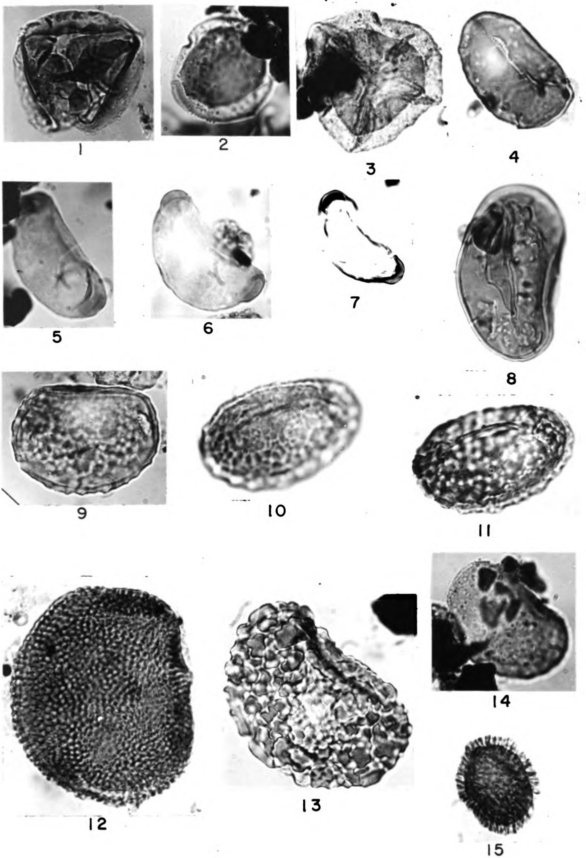


PLATE 6

Figure

1. Classopollis classoides (Pflug 1953) Pocock & Jansonius 1961, 29 μ ; 33-1 (39.3 x 121.0)

2. Classopollis classoides (Pflug 1953) Pocock & Jansonius 1961, diameter of individual grains, 27μ ; 19-20 (30.7 x 121.7)

3. Classopollis obidosensis Groot & Groot 1962, 21 to 32 μ ; 13-5D (29.5 x 118.8). Distal polar view.

4. Classopollis classoides (Pflug 1953) Pocock & Jansonius 1961, 21 μ ; 33-2 (32.4 x 124.6). Proximal polar view.

5. Corallina sp., 23 μ ; 25-2A (41.7 x 123.2)

6. Caytonipollenites cf. C. pallidus (Reissinger) Couper 1958, overall length, 24 μ ; 46-6A (40.3 x 117.0)

7. Pinuspollenites sp., length of central body, 47 μ ; breadth of central body, 40 μ ; 46-1 (33.9 x 117.2)

8. Abiespollenites sp., length of central body, 121 μ ; breadth of central body 58 μ ; length of sacci, 53 μ ; breadth of sacci, 44 μ ; 33-3 (32.2 x 115.0)

9. Phyllocladidites sp., breadth of central body, 34 μ ; length of central body 43 μ ; length of sacci, 22 μ ; 50-778 (38.2 x 116.0)

10. Cedripites eocenicus Wodehouse 1933, overall length 62 μ ; length of central body, 39 μ ; 13-1D (37.1 x 123.1)

11. Pityosporites cf. P. similis Balme 1957, length of central body, 38 μ ; breadth of central body, 42μ ; length of sacci, 54 μ ; overall length, 64μ ; 33-7 (39.8 x 117.4)

12. Podocarpidites sp., length of central body, 17μ ; breadth of central body, 14 μ ; overall length of grain 34 μ ; 25-2A (30.4 x 115.9)

13. Abiespollenites sp., overall length 220 μ ; Subsurface section 33, slide 4 (37.2 x 124.7)

14. Piceaepollenites sp., breadth of central body, 73 μ ; length of central body, 52 μ ; 33-2 (28.0 x 121.2)

PLATE 6

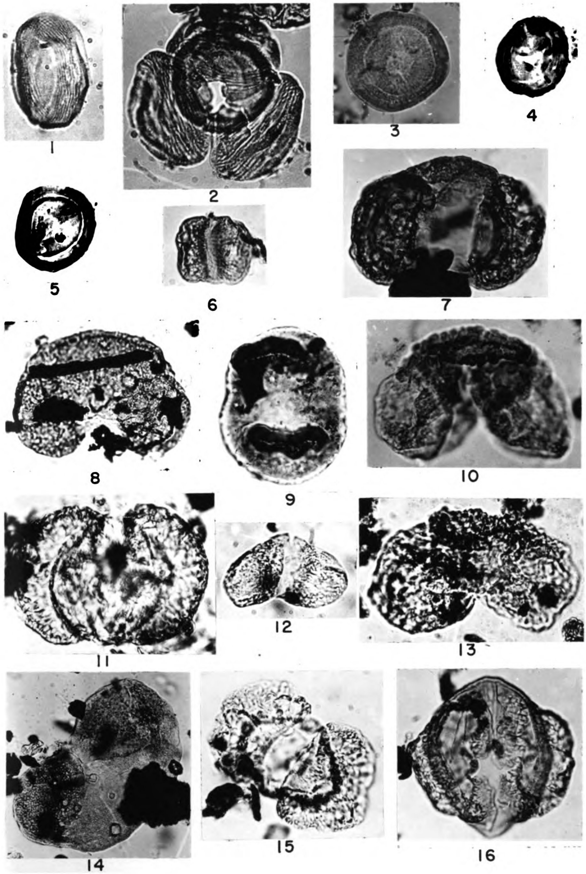


PLATE 6.--Continued

Figure

15. Podocarpidites cf. P. biformis Rouse 1957. Breadth of central body, 28 µ; length of central body, 25 µ; 33-4 (42.5 x 121.4).

16. Phyllocladus sp., length of central body, 37 µ; breadth of central body, 52 µ; 46-5A (42.2 x 116.0).

PLATE 7

Figure

1. Pollenites ortholaesus Potonie 1934, 25 to 36μ ; 46-11E (30.8 x 113.2)

2. Eucommiidites minor Groot & Penny 1962, 23 x 25 μ ; 6-5X (26.8 x 123.9)

3. Inaperturopollenites sp., 22 μ ; 46-2 (31.2 x 127.4)

4. Inaperturopollenites hiatus (R. Potonie) Pflug 1953, 33 μ; 6-4X (37.5 x 110.0)

5. Tricoloporopollenites cf. T. dolium (R. Potonie) Pflug & Thomson 1953, 23 x 53 μ; 46-2 (38.3 x 117.2)

6. Triporopollenites cf. T. sp. D Clarke 1963, 21 to 26μ (triporate forms), 17 to 29μ ; (tetraporate forms); 46-11E (32.9 x 128.9)

7. Tricolpites sp., 29 μ, Cheyenne IC (39.3 x 112.2)

8. Ilexpollenites sp., 20 x 22μ ; 44-1X (32.4 x 122.4)

9. Ilexpollenites parvus Groot & Groot 1962, 27 x 17 μ; 44-1X 35.9 x 117.1)

10. Ilexpollenites sp., 21 x 17 μ; 44-2X (37.2 x 124.7)

11. Sporopollis sp., 20 μ, 13-6X (39.8 x 124.4)

12. Oculopollis cardinalis Weyland & Kreiger 1953, 25 μ; 34-5X 38.5 x 118.2)

13. Subtriporopollenites cf. S. anulatus Thomson & Pflug 1953, 25 to 27 μ; 46-11F (32.1 x 125.3)

14. Extratriporopollenites sp., A, 24 to 31μ ; 46-11F (35.2 x 126.6)

15. Extratriporopollenites atumescens Pflug 1953, 20 μ ; 46-11E 32.4 x 116.9)

PLATE 7

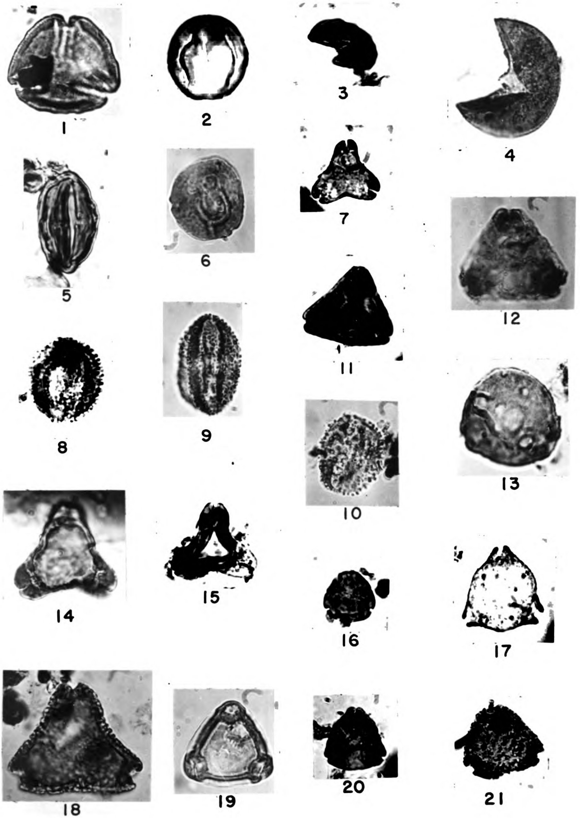


PLATE 7.--Continued

Figure

16. Momipites coryloides Wodehouse 1933, 14 μ; 46-5A (29.3 x 117.1)

17. Extratriporopollenites sp., 17 to 22μ ; 25-7A (28.3 x 112.0)

18. Tricolpites thomasii Cookson & Pike 1954, 29 μ; 33-2 (39.3 x 122.2)

19. Trivestibulopollenites sp., 21 to 24μ ; Cheyenne 1C (33.4 x 117.3)

20. Momipites inaequalis Anderson 1962, 17 to 24 μ ; 46-6A (41.6 x 120.2)

21. Corylus punctatipollenites Rouse 1957, 20 to 22μ ; 46-4 (41.5 x 123.6)

PLATE 8

Figure

1. Pachysandra sp., 35 μ; 8-2X (31.4 x 122.9)

2. Liquidambar cf. L. brandonensis Traverse 1955, 21 μ; Wallace 6 (30.4 x 124.7)

3. Extratriporopollenites sp., 21 μ; 13-6X (40.4 x 118.4)

4. Proteacidites sp., 20μ ; 4-1A (42.0 x 117.2)

5. Proteacidites thalmanni Anderson 1960, 27μ ; 46-1 (44.7 x 117.3)

6. Proteacidites sp. C, 32μ ; 13-1D (35.5 x 119.2)

7, 8. Proteacidites annularis Cookson 1950, 23 to 28μ ; 46-2 (38.0 x 112.2)

9. Elytranthe striatus Couper 1953, 23μ ; Pb 3913 (29.1 x 122.3)

10. Elytranthe sp., 28μ ; 33-5A (34.7 x 118.6)

11. Elytranthe striatus Couper 1953, 24μ ; 33-5A (28.4 x 115.8)

12. Proteacidites thalmanni Anderson 1960, 29 x 32 μ; 44-2X (34.5 x 114.7)

13. Aquilapollenites sp. A, 30 x 32μ ; Wallace 6 (43.0 x 119.9)

14. Aquilapollenites cf. A. attenuatus Funkhouser 1961, 32 x 40μ ; Cheyenne 1D (29.3 x 121.5)

15. Aquilapollenites sp., overall diameter 50μ ; Cheyenne 1C (37.0 x 124.3)

16. Aquilapollenites cf. A. amplus Stanley 1961, Wallace 6 (46.1 x 129.1)

17. Aquilapollenites sp. A, 30 x 33μ ; 6-1X (43.1 x 126.9)

PLATE 8

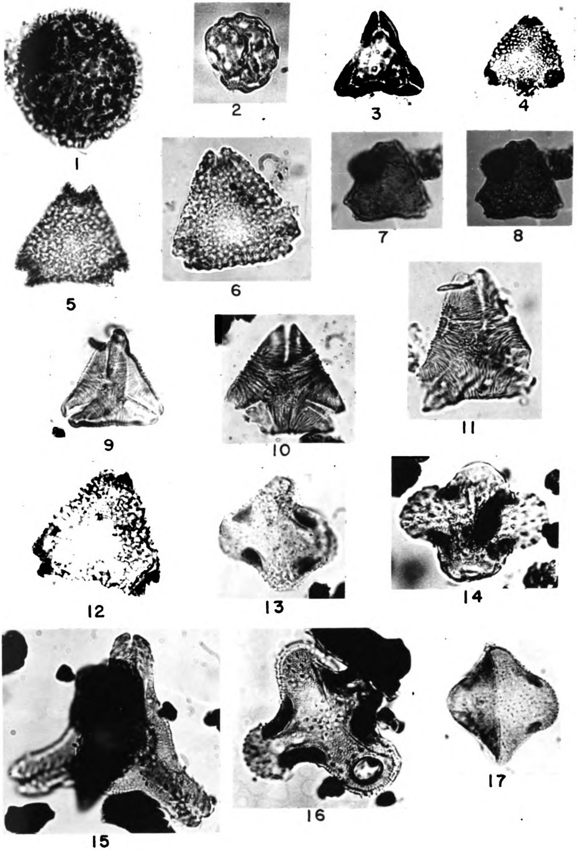


PLATE 9

Figure

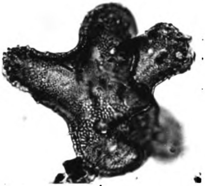
1, 2, 3. Aquilapollenites amplus Stanley 1961, length of polar axis, 53μ ; 46-2 (37.8 x 119.0). Figure 1: high focus; Figure 2: intermediate focus; Figure 3: low focus.

4, 5. Aquilapollenites cf. A. trialatus Rouse 1957, overall size 50μ ; Pb 3912 (29.8 x 122.7). Figure 4: high focus; Figure 5: intermediate focus.

6. Aquilapollenites cf. A. trialatus Rouse 1957, length of polar axis, 44μ ; 13.1C (29.9 x 121.2)

7, 8, 9. Aquilapollenites reticulatus Stanley 1961, length of polar axis, 36μ ; Pb 3931 (40.4 x 121.7)

PLATE 9



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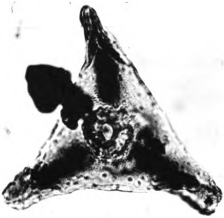

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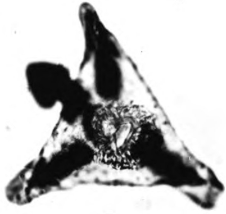

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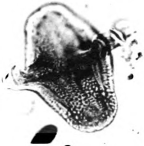

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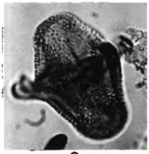

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PLATE 10

Figure

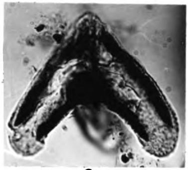
1. <u>Aquilapollenites</u> <u>pulcher</u> Funkhouser 1961, length of polar axis, 34 μ ; 13-1C (36.4 x 123.1)

2, 3. <u>Aquilapollenites</u> <u>belos</u> sp. nov., overall size, 34 x 46μ ; 13-1D (36.1 x 123.0). Figure 2: high focus; Figure 3: low focus.

4, 5, 6, 7. <u>Aquilapollenites</u> cf. <u>A.</u> <u>quadrilobus</u> Rouse 1957, overall size 50 x 50μ ; 33-4 (44.0 x 116.8). Figure 4: high focus; Figure 5: high intermediate focus; Figure 6: low intermediate focus; Figure 7: low focus.

PLATE 10


1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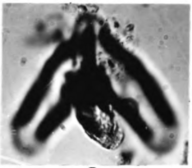
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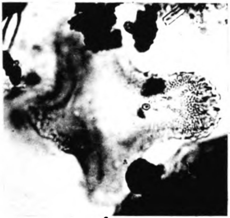
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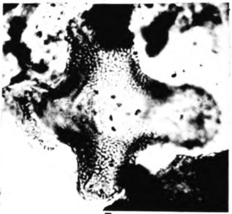
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PLATE 11

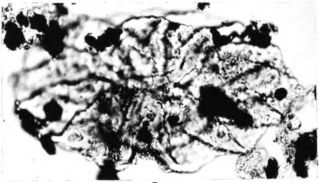
Figure

1, 2. Taschites primum gen et sp. nov., overall diameter 140 μ; diameter of central body, 61μ; 33-5X (34.6 x 116.5). Figure 1: high focus; Figure 2: low focus.

3, 4. Taschites primum, overall diameter, 131μ; diameter of central body, 47 μ; 13-4D (40.7 x 112.9). Figure 3: low focus; Figure 4: detail of peripheral area (x 1200).

PLATE II

1



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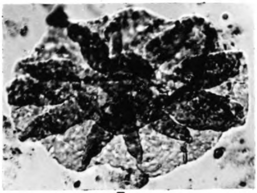

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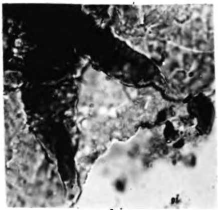

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PLATE 12

Figure

1. Deflandrea echinoidea Cookson & Eisenack 1960, 55 x 67 μ; 6-6X (33.4 x 115.9)

2. Muderongia sp., 68 μ; (overall length of test); 85 μ (overall breadth); 33-3 (37.9 x 114.9)

3. Dinogymnium westralium (Cookson & Eisenack) Evitt 1967, 50 x 68μ; 25-4B (41.2 x 117.1)

4. Dinogymnium sp., 28 x 32 μ; 19-1B (35.5 x 128.1)

5. Deflandrea cooksoni Alberti 1961, 46 x 86 μ; 25-3A (30.5 x 116.0)

6. Dinogymnium ? nelsonense (Cookson) Evitt 1967, 62 to 69 x 25 to 28 μ; 40-11F (36.5 x 122.3)

7. Deflandrea pirnaensis Alberti 1959, 48 x 80μ; 46-8F (39.4 x 122.3)

8. Dinogymnium ? nelsonense (Cookson) Evitt 1967, 45 x 65 μ; 46-11F (39.0 x 113.0)

9. Pareodina sp., 41 x 67μ; 10-2X (31.5 x 119.0)

PLATE 12

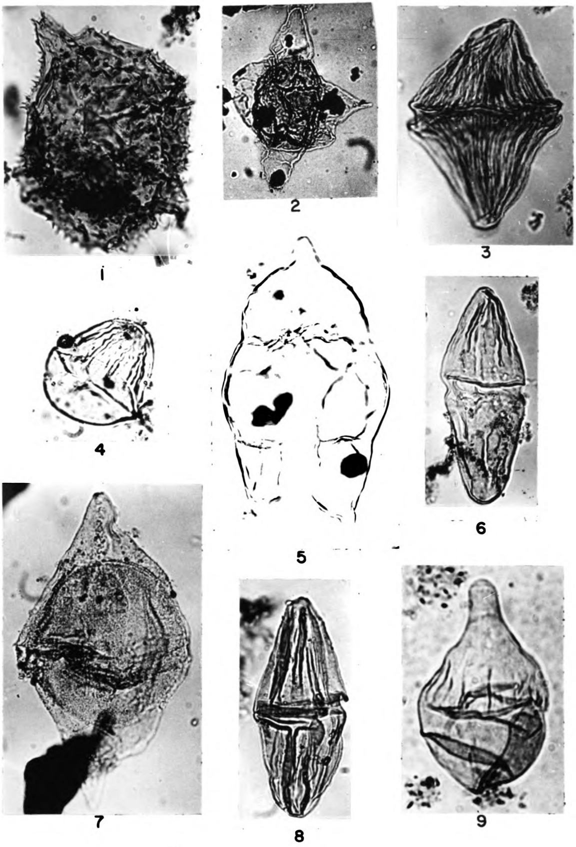


PLATE 13

Figure

1. *Svalbardella* sp., overall length, 152 μ; diameter at midpoint, 29 μ; 33-3 (36.0 x 122.7)

2. *Pterospermopsis* cf. *aureolata* Cookson & Eisenack 1958, diameter central body, 87μ; overall diameter, 143μ; 46-8F (42.4 x 112.1)

3. *Gillinia* cf. *G. hymenophora* Cookson & Eisenack 1960, overall breadth, 29μ; 33-9A (44.6 x 126.3)

4. *Pterospermopsis* cf. *australiensis* Deflandre and Cookson 1955, 37 μ; Phillips 1A (43.3 x 123.2)

5, 6. *Microdinium* sp., length, 21μ; breadth 20μ; 46-2 (38.2 x 119.8). Figure 5: high focus; Figure 6: low focus.

7, 8. *Microdinium* sp., length, 20 μ; breadth 20μ; 46-2 (38.2 x 129.8). Figure 7: high focus; Figure 8: low focus.

9, 10. *Cymatiosphaera* cf. *punctifera* Deflandre and Cookson 1955, 19 x 23 μ; 31-1A (41.3 x 115.3). Figure 9: high focus; Figure 10: low focus.

11. *Microdinium* sp., length, 20 μ; breadth 18μ; 46-2 (32.4 x 111.7)

12. *Micrhystridium* sp., 8 μ; Phillips 1A (31.1 x 126.1)

13. *Pareodinia ceratophora* var. *pachyceras* Sarjeant 1959, overall length, 69 μ; breadth, 57μ, length of apical horn, 15μ; 33-10A (28.2 x 125.9)

14. *Oodnadattia* sp., 33μ; 8-6A (42.9 x 125.9)

15. *Leiosphaeridia* sp., 45 x 50 μ; 25-3A (39.2 x 117.2)

PLATE 13

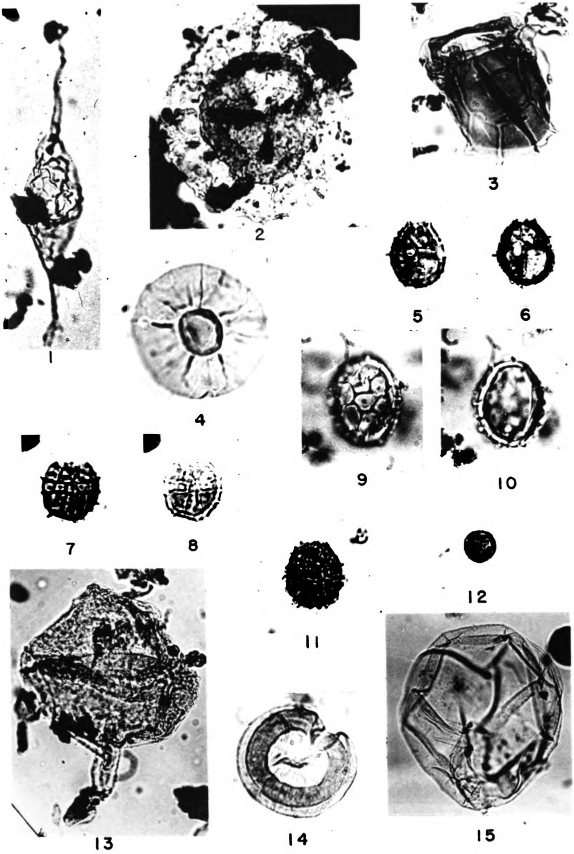


PLATE 14

Figure

1. Oligosphaeridium complex (White) Davey, Downie, Sarjeant & Williams, 1966, overall diameter, 83μ ; diameter of shell, 24 to 30 μ ; length of processes, 20 to 22 μ; 49-1080/1360 (32.5 x 112.2)

2. Dinoflagellate cyst (Forma F of Evitt, 1961, pl. 7, figs. 1-2), overall diameter, 62 to 70 μ ; length of processes, 14 to 20 μ; 13-C (30.7 x 125.8)

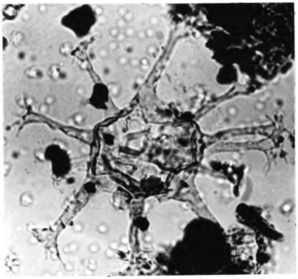
3. Hystrichosphaeridium tubiferum (Ehrenberg) Deflandre 1937, diameter of shell, 33 to 35μ ; length of processes, 15 to 22 μ ; 46-7F (27.6 x 118.2)

4. Operculodinium centrocarpum (Deflandre & Cookson) Wall 1967, overall diameter, 65 to 70 μ ; diameter of shell, 48 to 50 μ; length of processes, 4 to 10μ ; 33-9A (30.4 x 121.6)

5. Hystrichosphaera sp., diameter of shell, 34 to 37μ ; length of processes, 7 to 12 μ ; 46-10F (32.0 x 118.2)

6. Micrhystridium cf. stellatum Deflandre 1945, overall diameter, 70 μ; diameter of central body, 19 μ; 13-2A (31.7 x 115.8)

PLATE 14



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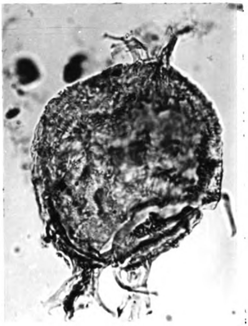

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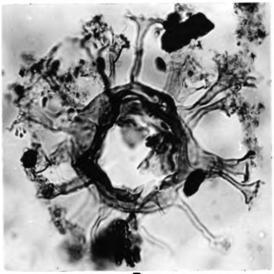

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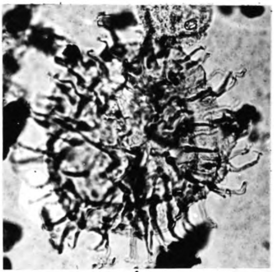

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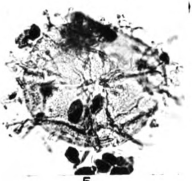

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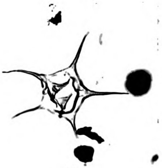

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PLATE 15

Figure

1. *Cordosphaeridium* sp., diameter of shell, 42 to 48μ ; length of processes, 10 to 13μ ; 33-9A (40.3 x 111.7)

2. *Veryhachium reductum* (Deunff) Jekhowsky 1961, 27μ ; Wallace A (32.6 x 125.1)

3. *Cordosphaeridium* sp., 90 μ; 33-9A (26.0 x 124.2)

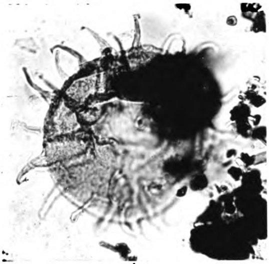
4. Fungal spore, sp. A, 25 x 75 μ ; 44-2X (32.8 x 122.8)

5. Fungal spore, sp. B (*Alternaria* sp. ?), 0 x 36 μ ; 46-8F (38.3 x 126.6)

6. Fungal spore, sp. C, 11 x 44 μ ; 25-8A (39.0 x 127.7)

7. Fungal spore, sp. D, 17 to 22 x 53 to 56 μ ; Logan 7 (43.1 x 122.8)

PLATE 15



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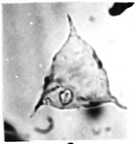

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PLATE 16

Figure

1. Horologinella apiculata Cookson and Eisenack 1961, 13 x 15 μ ; Phillips 1A (44.7 x 123.2)

2. Horologinella sp., 13 x 17μ ; 25-3A (37.8 x 111.0)

3. Fungal spore (?), length, 29 μ ; breadth, 20 μ; 46-7F (28.9 x 117.7)

4. Phycopeltis sp., 13 x 16 μ; Phillips 1A (41.4 x 127.8).

5. Upper specimen: Horologinella cf. apiculata Cookson & Eisenack 1961; lower specimen: Horologinella sp., 13 x 15 μ; Phillips 1A (29.9 x 124.3)

6. Wodehouseia spinata Stanley 1961, overall length, 50 μ ; length of central body, 48 μ ; width of flange, 9μ ; 50-1528 (27.0 x 124.3)

7. Microforaminifer, overall diameter, 86μ ; diameter of proloculus, 17 μ; 33-6X (35.8 x 124.8)

8. Crassosphaera concinna Cookson & Manum 1960, 75 μ ; Cheyenne 1 (29.0 x 122.1)

PLATE 16