PALYNOLOGY AND GEOPHOTOMETRY OF THE MIDDLE CRETACEOUS ROCKS IN ELLSWORTH AND RUSSELL COUNTIES, KANSAS

by

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INTRODUCTION

Purpose of Investigation

The purpose of this investigation was to determine the values of photometric measurements and palynological techniques as correlation methods in Middle Cretaceous rocks of Central Kansas. The extremely varied lithology presented an ideal test for these methods and yielded a wide variety of spores, pollen grains, and marine organisms. An attempt was made to relate these results to the Middle Cretaceous regional paleogeography of the investigated area.

General Stratigraphy of the Investigated Area

The lithologic units investigated included, in descending order, the Lincoln limestone member of the Greenhorn limestone, the Graneros shale, the Janssen member of the Dakota formation, and the upper part of the Terra Cotta member of the Dakota formation. The position of these units in the rock column has been summarized according to Moore et al. (1951) in table 1.

Table 1. Cretaceous strata in Kansas.

Cretaceous System
- Gulfian Series
  - Montana Group
  - Colorado Group
    - Niobrara formation
    - Carlile shale
    - Greenhorn limestone
      - Pfeifer shale member
      - Jetmore chalk member
      - Hartland shale member
      - Lincoln limestone member

Table 1 (cont.)

Graneros shale
Dakota formation
Janssen member
Terra Cotta member
Comanchean Series
Kiowa shale
Cheyenne sandstone

Previous Work

Previous investigations of this area include Hatfield's (1961) study of the paleoecology of the Graneros shale and an investigation by Schoewe (1951) on the coal resources of the Dakota formation. Other related studies include a bulletin on the stratigraphy of Pre-Greenhorn Cretaceous rocks of Kansas by Plummer, Norman, and Romary (1942), a bulletin on the geology of Russell County by Rubey and Bass (1925), an investigation of the depositional environment of the Graneros shale by Hattin and Hatfield (1962), a bulletin on lower Upper Cretaceous plant microfossils of Minnesota by Pierce (1961), and several investigations of Cretaceous plant microfossils in other areas of the world (see references).

FIELD INVESTIGATIONS

Location of Area Investigated

The area included in this investigation lies in Ellsworth and Russell Counties of Central Kansas as shown in figure 1. The description of the two locations where samples were collected and rock units described is as follows. Vertical rock interval A is located in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 14, Township 15 South, Range 11 West

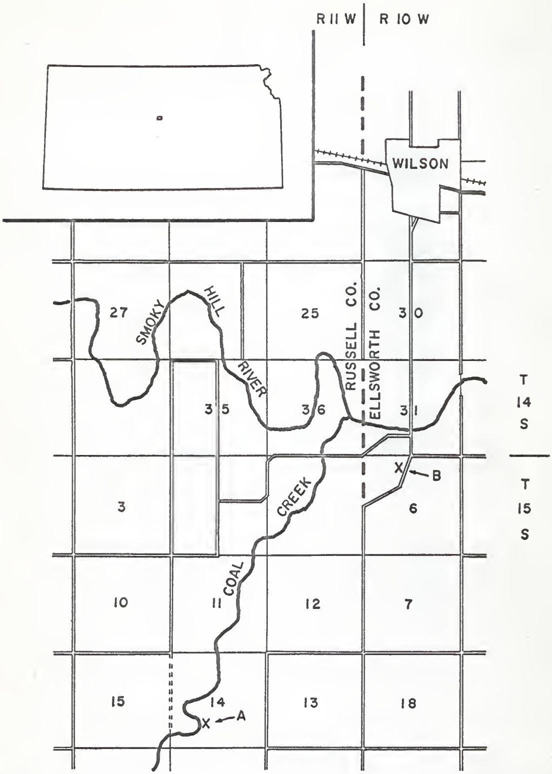

Figure 1. Map of area investigated showing locations A and B. Inset (upper left) shows area in Kansas.

and rock interval B in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 6, Township 15 South, Range 10 West (fig. 1).

The exposures were bluffs on the south side of Coal Creek and the Smoky Hill River respectively. Relief in excess of 200 feet was present at each location, making possible a collection of vertically related samples.

Field Procedure

A series of samples representing each lithologic zone was collected at each of the two locations. The stratigraphic position of each sample was measured and noted. Only fresh, unweathered samples were collected. The lithology of the two vertical rock exposures is given in tables 2 and 3 and diagramed in figure 3 (p. 41).

In addition, the surface outcrops connecting the two locations were traced by walking out the exposures through the area.

Table 2. Lithologic descriptions of rock exposure A.

Sample No.	Description	Distance in feet above previous sample
Dakota formation		
	Terra Cotta member (upper 34 feet):	
1.	Siltstone; gray	
2.	Sandstone; buff	.8
3.	Siltstone; light gray	1.3
4.	Sandstone; light gray, argillaceous	1.3
5.	Siltstone; light gray	.8
6.	Sandstone; light brown with clay layers	2.2

Table 2 (cont.)

Sample No.	Description	Distance in feet above previous sample
7.	Siltstone; light gray	.3
8.	Siltstone; light gray, same as no. 7	4.3
9.	Sandstone; tan, weathersred	1.7
10.	Siltstone; light gray	.3
11.	Siltstone; gray	6.3
12.	Sandstone; light gray, massive	2.2
13.	Siltstone; gray, coarse	.9
14.	Sandstone; light gray-pink, massive	.7
15.	Sandstone; light gray-white, massive	5.3
16.	Mudstone; light gray, arenaceous	1.5
17.	Siltstone; light gray, carbonaceous	3.9
	Janssen member:	
18.	Lignite	.6
19.	Lignite; same as no. 18	2.6
20.	Shale; light and dark gray banded, thin lignite and limonite seams	.3
21.	Shale; light and dark gray banded, limonite seams up to $\frac{1}{2}$" thick	4.5
22.	Shale; dark gray	1.2
23.	Shale; dark gray, same as no. 22	3.3
24.	Sandstone; light gray banded, weathers red	1.8
25.	Shale; dark gray	.6
26.	Shale; gray, iron stains	2.4
27.	Sandstone; red-brown, high iron content, clay	2.4

Table 2 (cont.)

Sample No.	Description	Distance in feet above previous sample
28.	Shale; gray, iron stains	1.1
29.	Shale; light gray, bentonite	.3
30.	Shale; dark gray	.4
31.	Shale; dark gray, same as no. 30	1.8
32.	Shale; gray, sand lenses, gypsum	2.1
33.	Sandstone; gray	.6
34.	Shale; dark gray	1.1
35.	Sandstone; gray, limonite seams, gypsum	2.4
36.	Shale; dark gray	10.2
37.	Shale; black, thin sand layers	3.6
38.	Mudstone; light gray, bentonite	1.6
39.	Shale; black, arenaceous	1.2
40.	Shale; brown, silty	1.6
41.	Limestone; gray, arenaceous	.4
42.	Shale; gray, calcareous	2.7
43.	Shale; black, calcareous	1.3
44.	Shale; dark gray, calcareous	2.1
45.	Mudstone; light gray, bentonite	.2
46.	Shale; dark gray, calcareous	2.2
47.	Mudstone; light gray, bentonite	.6
48.	Shale; gray, calcareous	.5
49.	Siltstone; gray, calcareous	1.8
50.	Shale; dark gray, calcareous	3.9
51.	Limestone; light brown, argillaceous	2.6

Table 2 (cont.)

Sample No.	Description	Distance in feet above previous sample
52.	Limestone; gray, arenaceous, abundant pelecypods (Inoceramus)	3.0
Graneros shale		
53.	Shale; dark brown, calcareous	3.1
54.	Shale; dark brown, calcareous, same as no. 53	3.9
55.	Shale; dark gray, silty, calcareous	3.9
56.	Limestone; gray	.6
57.	Shale; brown, massive, calcareous	.9
58.	Shale; dark gray, fissile, calcareous	3.4
59.	Limestone; white, arenaceous	1.2
60.	Shale; dark gray, arenaceous	1.1
61.	Limestone; brown, argillaceous	3.6
62.	Limestone; white, arenaceous	1.7
63.	Limestone; gray, argillaceous	.7
64.	Limestone; brown, argillaceous	3.7
65.	Limestone; gray	.5
66.	Shale; gray, very calcareous	.9
Greenhorn limestone (lower 3 feet):		
67.	Limestone; buff, argillaceous	2.4
68.	Limestone; tan, abundant pelecypods (Inoceramus)	.8

Table 3. Lithologic descriptions of rock exposure B.

Sample No.	Description	Distance in feet above previous sample
Dakota formation		
	Terra Cotta member (upper 22 feet):	
1.	Sandstone; tan, massive	
2.	Mudstone; light gray, arenaceous	1.3
3.	Sandstone; orange, iron stains, limonite concretions	1.5
4.	Shale; dark gray	1.1
5.	Sandstone; light gray-orange, banded	2.1
6.	Sandstone; orange, iron stains	3.2
7.	Sandstone; light gray-orange, thin layered	1.5
8.	Shale; dark gray-yellow layers, arenaceous	.4
9.	Sandstone; gray-orange, thin layered	.5
10.	Sandstone; orange, iron stains, argillaceous	.6
11.	Sandstone; light gray, argillaceous	.3
12.	Mudstone; gray, arenaceous	3.3
13.	Sandstone; orange, iron stains	.8
14.	Sandstone; gray, thin layered, argillaceous	.8
15.	Sandstone; orange, iron stains	.1
16.	Mudstone; gray, arenaceous	1.1
Janssen member:		
17.	Sandstone; orange, massive, iron stains	1.8
18.	Sandstone; brown-orange, thin bedded, limonite concretions	.7
19.	Sandstone; dark gray, thin bedded, argillaceous	.7
20.	Sandstone; light gray, argillaceous	.8
21.	Sandstone-Shale; dark gray, thin interlayers	1.4

Table 3 (cont.)

Sample No.	Description	Distance in feet above previous sample
22.	Sandstone; light gray, limonite in thin beds, argillaceous	.4
23.	Shale; very dark gray, fissile, arenaceous	.8
24.	Shale; dark gray, carbonaceous, arenaceous	.7
25.	Sandstone; gray, thin bedded, argillaceous	.8
26.	Sandstone; light gray, argillaceous, limonite in thin layers	.8
27.	Shale; gray, iron stains, arenaceous	1.8
28.	Shale; dark gray, iron stains, arenaceous	1.1
29.	Sandstone; light red-orange	.4
30.	Sandstone; dark gray-orange, iron stains, argillaceous	.2
31.	Sandstone; gray-orange, thin layered	.4
32.	Sandstone; gray-brown, iron stains argillaceous	.5
33.	Mudstone; light gray, thin limonite layers	1.1
34.	Mudstone; blue-gray, arenaceous	3.4
35.	Mudstone; dark gray, iron stains	1.5
36.	Mudstone; dark gray, iron stains	2.2
37.	Shale; brown-gray, iron stains	1.7
38.	Shale; brown-gray, iron stains	2.5
39.	Shale; light gray, bentonite	2.9
40.	Shale; gray, fissile	1.2
41.	Shale; black, rich in organic material	2.1
42.	Shale; gray, silty, gypsum	.8

Table 3 (cont.)

Sample No.	Description	Distance in feet above previous sample
43.	Shale; dark gray, carbonaceous	2.1
44.	Shale; dark gray, gypsum, carbonaceous	.4
45.	Lignite; black	1.1
46.	Siltstone; light gray, organic material	.5
47.	Siltstone; gray, banded with gypsum layers	1.3
48.	Mudstone; light gray, silty	1.6
49.	Lignite; black	1.6
50.	Shale; black, carbonaceous	1.0
51.	Shale; gray-black, compact, bentonite	.2
52.	Siltstone; light gray	.9
53.	Shale; dark gray, gypsum	.1
54.	Lignite; black	1.1
55.	Shale; dark gray	.5
56.	Lignite; black	2.2
57.	Shale; very black	.9
58.	Shale; brown-gray, silty	.5
59.	Shale; dark gray, fissile	2.5
60.	Sandstone; brown-gray, gypsum, iron stains, argillaceous	2.7
61.	Sandstone; brown-gray, iron stains	2.9
62.	Mudstone; brown-yellow, arenaceous, bentonite	.7

Table 3 (cont.)

Sample No.	Description	Distance in feet above previous sample
Graneros shale:		
63.	Mudstone; gray	2.4
64.	Shale; gray-brown, iron stains	3.0
65.	Sandstone; brown, gypsum, argillaceous	4.1
66.	Shale; orange-gray	1.7
67.	Shale; gray	3.0
68.	Shale; gray, banded	3.0
69.	Shale; dark gray	4.5
70.	Mudstone; gray-yellow	1.6
71.	Shale; yellow	1.4
72.	Shale; gray-yellow	1.1
73.	Sandstone; yellow, calcareous	1.5
74.	Shale; yellow-gray, thin bedded, calcareous	.2
Greenhorn limestone (lower 10 feet):		
75.	Limestone; brown, arenaceous	1.2
76.	Limestone; buff, abundant pelecypod shells (Inoceramus)	1.1
77.	Shale; gray, arenaceous, very calcareous	1.5
78.	Limestone; buff, thin bedded, abundant Inoceramus shells	2.0
79.	Shale; light gray-white, calcareous	1.5
80.	Shale; tan-brown, calcareous	3.0

PHOTOMETRIC INVESTIGATION

Introduction

A Zeiss Elrepho photoelectric reflection photometer was utilized for this investigation. The instrument was equipped with a mercury lamp which yields a high proportion of ultra violet light and a set of seven different filters distributed nearly evenly over the visible light spectrum (see table 4).

Table 4. Wave length values in angstroms (maximum transmittance).

Filter	Wave length (±20 A)
1.	6800 A
2.	6200 A
3.	5700 A
4.	5340 A
5.	4920 A
6.	4610 A
7.	4220 A

The photometer produces reflection percentage values relative to a specific standard. The standard used with this instrument is calibrated against magnesium oxide. Thus the standard becomes 100 percent reflection and the measurements obtained are relative percentages of the standard.

The part played by fluorescence in the total effective reflectance is determined by two successive measurements with each selected reflectance filter. The normal measuring procedure yields reflectance alone and by removing the ultra violet barrier filter, the reflectance plus the excited fluorescence which in turn may yield an added correlation tool.

The measuring accuracy of the instrument amounts to about 0.3 percent under the special conditions used and the fluorescence accuracy is generally about 0.2 according to the Zeiss operation manual.

Preparation and Graph Technique

The rock samples were individually crushed in a jaw crusher to an approximate grain size of one millimeter or finer and placed in shallow three-quarter inch deep cardboard containers. The prepared material was then photometrically analyzed on its natural rock reflection and fluorescence characteristics according to the principles published by Pflug (1962a, 1962 b).

Early in the investigation, it was apparent that the results needed for correlation work could be obtained by using only the red and violet reflection values which represent the limits of the visible spectrum. The intermediate values were recorded and graphed originally but were discarded when all values fell between the limits of red and violet and thus added no additional value for correlation. The values for red and violet reflections were graphed by the curve bands in figure 2. The ordinates of the diagram represent the columnar sections, A at left and B at the right. The absissi are scaled to the reflection values; the left line of each curve band shows the change in the violet reflection over the rock sequence as does the line to the right for the red reflection. The left curve refers to the rock column A, the right to column B. The sample numbers are plotted to scale vertically at the outer margins of the diagram.

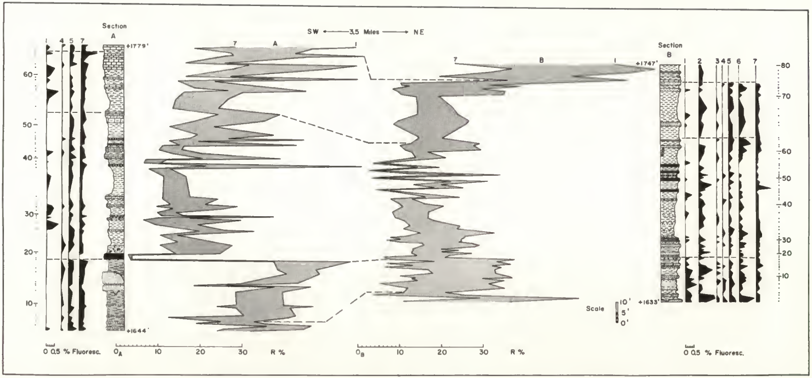

Figure 2. Graphic results of the photometric analysis.

Results of Photometric Analysis

The similar patterns displayed by both curve bands seem to yield good correlation criteria between the columns even though the lithology of the rock units changed significantly in this distance. This may be observed by comparing the two columns. The similarity of the curve bands may be attributed to the presence of some of the same elements in the sediments at the time of deposition. The field studies indicated that the photometric correlation such as demonstrated by the interrupted lines in figure 2 is correct. This leads to the conclusion that the photometric curves are a helpful tool for correlation work, especially as the preparation and measuring procedure does not require more than about five minutes time per sample.

The average value of the curve for column B is about 12 percent lower than that of column A. In this behavior, facies differences are shown which are further expressed by the palynological results.

The higher content of highly oxidized iron coating the sand grains and the dark organic matter lowers the average reflection values of column B (see Patnode, 1941). The higher calcareous and shaly proportions in column A are expressed by the higher reflection values. When combined with the palynological results, the photometric investigation indicates that column B is more influenced by a continental facies while column A exhibits more influence by a marine environment. However, reflection values can not specifically indicate whether a layer is of limnic or marine origin.

Fluorescence Measurements

The relative fluorescence of the samples is depicted graphically on figure 2 outside of the rock columns. Only the spectral areas showing high fluorescence intensities have been considered. The following observations can be noted from these curves: First, contact planes of formations and members are marked by distinct breaks in the fluorescence intensities. This phenomenon can be explained only by lithologic breaks which can be associated with a change of the source area. According to the literature (Daniels, 1961), the natural rock fluorescence can be partially attributed to small amounts of radioactive substance enclosed in some minerals.

Secondly, analysis of the graphs indicated that the fluorescence characteristics of the sedimentary rock columns differed. For instance column A has its fluorescence maximum in violet light while column B exhibited a maximum in orange light. Similar phenomena from other rock columns have already been reported by Pflug (1962b). The reasons are still obscure but are probably related to variations in sediments from different source areas.

INVESTIGATION OF MACERATION RESIDUE

Palynological Separation and Preparation Technique

The samples collected in the field were first crushed with mortar and pestle into particles of approximately one millimeter in diameter. Approximately 5 cc. of this material was then treated with 2.5 percent HCl and heated to 150° F in a water bath for 15 minutes to destroy the carbonate content. After decanting the top liquid, the material was centrifuged and washed twice with distilled water. The material was then placed in covered plastic cups and treated with 24 percent HF acid in order to chemically destroy the silicates present. This mixture was stirred daily for one week and the acid changed once midway through the week. The material was then poured through a paper filter and washed with water. After returning the material to the plastic cups about one-third full of water, the residue was centrifuged and washed once with water. The water was then decanted and $KClO_3$ was then added and the mixture warmed for 30 minutes in the water bath to oxidize the organic matter. One week later, the samples were reheated for 40 minutes, centrifuged and washed twice with water. The samples were then treated with 5 percent NaOH and heated for 15 minutes to neutralize the mixture. Twenty four hours later, the samples were again centrifuged and washed with water. The residue was then placed in small glass fusion tubes. The material was again centrifuged in these small tubes and water decanted. A drop of the residuum was then placed on a glass slide and using glycerine gelatin as a mounting medium, a cover glass was placed over the material to permit examination and preservation of the maceration residue.

Examination of Slides

The results obtained from the examination of the slides is listed in tables 5 and 6 and summarized on figure 3, which shows the qualitative and quantitative position of spores, pollen grains, and plankton organisms in relation to the rock columns.

Descriptions of the Pollen and Spore Types Found in this Investigation

The various pollen and spore types found in this investigation were placed into groups for convenience. After each group, a comparison of similar types identified by various authors is given. The comparison information is listed in the following manner: fossil name, fossil author, date, reference author (if different), date of publication, page, plate, figure, age and locality.

Group 1: Sphagnoid Types (Plate 1, fig. 18-22)

This group contains all specimens marked by features which are characteristic for spores of the sphagnales. Morphological definitions and descriptions are especially given by Thomson and Pflug (1953) and by Krutzsch (1959). For isolated spores mostly the form genera Stereisporites Pflug 1953, Sphagnites Cookson 1953, and Sphagnum-sporites Thiergart 1937 are used.

Sphagnum spores are abundant in the Pleistocene and Tertiary rocks and have been identified in Cretaceous sedimentary rocks. Several different form species have been described, but it is difficult to distinguish between them. Therefore sphagnum spores have little correlation value, but can be important for facies studies, as sphagnum moss is a representative for the ombrogene bog type.

Comparisons for Group 1:

Cingutriletes densocingulatus n. sp., Pierce, 1961, p. 26, Pl. 1, fig. 2, lower Upper Cretaceous, Minnesota.

Liliacidites hyalacinatus n. sp., Anderson, 1960, p. 38, Pl. 1, fig. 14, Cretaceous, N. Mexico.

"Microlepiidites psilatus", Ross, 1949, p. 43, Upper Cretaceous, Scania.

Sphagnites australis f. crassa f. nov., Cookson, 1953 (no. 3), p. 464, Pl. 1, fig. 2-4, Upper Mesozoic, Australia.

Sphagnites australis f. parva f. nov., Cookson, 1953 (no.3), p. 464, Pl. 1, fig. 1, Upper Mesozoic, Australia.

Stenozontriletes pumilus Naumova, Bolchovitina, 1953, p. 161, Pl. 5, fig. 13, Cretaceous, USSR.

Stereisporites divisisteroides n. sp., Krutzsch, 1959, p. 339, Pl. 6, fig. 40, Eocene, Mid. Europe.

Stereisporites megasteriooides n. sp. (Pf.), Thomson & Pflug, 1953, p. 119, Pl. 1, fig. 74, Tertiary, M. Europe.

Stereisporites stereiodes (R. Pot. & Ven. 1934) Th. & Pf. 1953, Krutzsch, 1959, p. 339, Pl. 6, fig. 36-38, Eocene, M. Europe.

Stereisporites cf. stictus (Wolff 1934) n. comb., Krutzsch, 1959, p. 339, Pl. 6, fig. 39, Eocene, M. Europe.

"Triletes psilatus", Ross, 1949, p. 43, Pl. 1, fig. 12, Upper Cretaceous, Scania.

Group 2: Lycopodoid Type
(Plate 1, fig. 1-9)

Botanical assignments of most spores of this group probably belong to the order Lycopodales but may signify different genera and species. Hamulate sculptural elements (term after Krutzsch, 1959) predominate. The cross section of sculpture elements is mostly rounded with very small furrows. The exospore is not remarkably thickened in the equatorial regions and does not show any differentiation like zones or cingulum. On the proximal pole side, the sculptural elements are directed radially towards the pole. On the distal pole side, the sculptural elements form an irregular pattern.

Comparisons for Group 2:

Camerozonosporites heskemensis (Pflanzl 1955) n. comb., Krutzsch, 1959, p. 403, Pl 38, fig. 413-421, Eocene, M. Europe.

Lycopodium cerniidites n. sp., Ross, 1949, p. 29, Pl. 1, fig.1, Upper Cretaceous, Scania.

Retitriletes varius n. sp., Pierce, 1961, p. 29, Pl. 1, fig. 15, lower Upper Cretaceous, Minnesota.

Rugutriletes regularis n. sp., Pierce, 1961, p. 30, Pl. 1, fig. 19, lower Upper Cretaceous, Minnesota.

Sporites, Pacltova', 1961, p. 97, Pl. 4, fig. 7-9, Senonian, Czech.

Group 3: Intergranulate Type
(Plate 1, fig. 10, 11)

The botanical assignment of this type is not certain. The sculpture consists of small granular to fiberous elements separating the thick, smooth exospore and a very small endospore. Some of the specimens show duplospore arrangements. Small tori can be observed near the upsilon lines.

Group 4: Parvotrilete Types
(Plate 1, fig. 12,13)

This type may be compared with representatives of the fern family Osmundales. These spores have only a small indistinct upsilon mark. The bodies are globular in shape with the equator contour rounded. The exospore is thin and easily deformable. The surface shows a pattern consisting of small worm shaped fossula.

Group 5: Salinoid Type
(Plate 1, fig. 14, 23)

The morphology of these spores is similar to that of the fern families Cyatheaceae and Gleicheniaceae. The equator contour is triangular or weakly concave. The upsilon lines are straight and touch the equator region. A weak sculpture can be observed consisting of flat foveae.

Group 6: Wichitoid Type
(Plate 1, fig. 15)

This type is similar to the formgenus Leiotriletes (Naumova 1937) R. Pot. & Krp. 1954, with the exception that the face of the exospore has a very weak, wavy contour. The morphology is not completely studied to date.

Group 7: Tesselatoid Type
(Plate 1, fig. 16,17)

The equator contour is triangular or weakly concave. Sculpture consists of a nut shaped element only flatly prominant. Upsilon lines are straight and long, touching the equator area and having small tori.

Group 8: Foveasporoid Type
(Plate 1, fig. 24-26)

The equator contour is convex triangular. The equator has a broad flange like zone consisting of different laminae and descreasing in thickness toward the edges or corners of the triangular contours. Upsilon lines are thin, straight and long, touching the equator. They are occasionally split at the ends and have small tori. The distal pole area is patterned by the fine perforations. Sculpture of the proximal pole is not exactly known, but is probably smooth.

Group 9: Cicatricosoid Type
(Plate 2, fig. 1-17)

From the increasing abundance of trilete spores with striped sculpture patterns in the cross section, three subgroups have been distinguished to date.

Subgroup A (fig. 1-6) shows very thick ridges of some irregular contour. The forrows are smaller than the ridges. At the proximal pole, the ridges extend parallel to the upsilon lines and have knot like thickenings near the edges of the triangular equator.

Subgroup B (fig. 7-9) normally also has thicker ridges than furrows, but the contours of the ridges are more straight. No knot like thickenings can be observed on the ridges which again parallel the upsilon lines at the proximal pole.

Subgroup C (fig. 10-17) shows a more delicate pattern with smaller straight flowing ridges. On the proximal pole side, the pattern is arranged radially to the upsilon mark.

Comparisons for Group 9:

Cicatricosisporites dorogensis R. Pot., Th. & Pf., 1953, p. 119, Pl. 1, fig. 1-12, Tertiary, M. Europe.

Cingulatisporites psilatus n. sp., Groot & Penny, 1960, p. 235, Pl. 2, fig. 21, Lower Cretaceous, Maryland & Delaware.

Mohria-Typ., Theirgart, 1949, p. 33, Pl. 4, fig. 6-8, 15-17, Wealden, M. Europe.

"Group 3", Krutzsch, 1957, p. 526, Pl. 1, fig. 12, Upper Cretaceous, Germany.

Comparisons for Subgroup 9A:

Anagamma leptophylla (L.) Link, Bolchovitina, 1953, p. 157, Pl. 3, fig. 34, Cretaceous, USSR.

Cicatricosisporites dorogensis R. Pot. & Gell., Couper, 1958, p. 175, Pl. 17, fig. 10-12, Lower Cretaceous, British Isles.

Mohrioisporites australiensis n. sp., Cookson, 1953 (no. 3), p. 470, Pl. 2, fig. 31, 34, Upper Cretaceous, Australia.

Striatriletes striatus n. sp., Pierce, 1961, p. 31, Pl. 1, fig. 24, 25, lower Upper Cretaceous, Minnesota.

Comparisons for Subgroup 9B:

Aneima aurita Sw., Bolchovitina, 1953, p. 159, Pl. 4, fig. 22, Cretaceous, USSR.

A imbricata Sturm. (E. Knox), Bolchovitina, 1953, p. 159, Pl 4, fig. 20, Cretaceous, USSR.

A pastinacaria Prantl., Bolchovitina, 1953, p. 159, Pl. 4, fig. 23, Cretaceous, USSR.

A tomentosa (Sav.) Sw. (E. Knox), Bolchovitina, 1953, p. 159, Pl. 4, fig. 21, Cretaceous, USSR.

Ceratopteris thalictroides (L.) Brong., Bolchovitina, 1953, p. 157, Pl. 3, fig. 35, Cretaceous, USSR.

Cicatricosisporites goepperti n. sp., Groot & Penny, 1960, p. 235, Pl. 2, fig. 20, 22, Lower Cret., Maryland & Delaware.

Chromotriletes exiliodes (Mal.), Bolchovitina, 1953, p. 159, Pl. 4, fig. 7-8, Cretaceous, USSR.

C macrorhyzus (Mal.), Bolchovitina, 1953, p. 159, Pl. 4, fig, 16, Cretaceous, USSR.

C mutabilis sp. nov., Bolchovitina, 1953, p. 159, Pl. 4, fig. 6, Cretaceous, USSR.

C pseudauriferus sp. nov., Bolchovitina, 1953, p. 159, Pl. 4, fig. 13, Cretaceous, USSR.

C tricostatus sp. nov., Bolchovitina, 1953, p. 159, Pl. 4, fig. 9-12, Cretaceous, USSR.

Comparisons for Subgroup 9C:

Cicatricosisporites cicatricosoides n. fsp., Krutzsch, 1959, p. 395, Pl.34, fig. 361-365, Eocene, M. Europe.

C dorogensis Pot. & Gell., Groot & Penny, 1960, p. 233, Pl. 1, fig. 2, Lower Cret., Maryland & Delaware.

C cf. paradorogensis n. fsp., Krutzsch, 1959, p. 391, Pl. 32, fig. 351-353, Eocene, M. Europe.

C pseudotertiarius n. fsp., Krutzsch, 1959, p. 391, Pl. 32, fig. 346-348, Eocene, M. Europe.

C regulatearis n. fsp., Krutzsch, 1959, p. 391, Pl. 32, fig. 349-350, Eocene, M. Europe.

Chromotriletes striatus Naumova, Bolchovitina, 1953, p. 159, Pl. 4, fig. 1-5, Cretaceous, USSR.

Mohria (Thiergart), Bolchovitina, 1953, p. 159, Pl. 4, fig. 19, Cretaceous, USSR.

Group 10: Concavoid Type
(Plate 3, fig. 1-29)

Spores exhibiting a smooth or nearly smooth spore wall and a concave or triangular equator contour are abundant in the investigated cross section. Different forms can be recognized, some examples of which are given on Plate 3. It was not possible to distinguish between species by defined morphological characteristics. Differentiation is possible for the typical representatives, but during the quantitative examinations, many specimens were found which did not show these characteristics clearly or which exhibited features of two different groups defined. Therefore only three special subgroups have been separated from the variety of this group. Many of the forms included in this group might belong to the fern families Gleicheniaceae and Cyathenceae.

Subgroup A (fig. 15) seems to be the most characteristic one signified by a distinct fiber structure inside of the spore wall in the area of the corners of the extreme concave triangular equator. An analogous structure is characteristic for some Upper Cretaceous angiosperms of the Normapolles stemma (Pflug 1953b).

Subgroup B (fig. 16, 17) is defined by its equatorial thickenings restricted to the sides and absent around the corners. This subgroup appears related to the genus Gleicheniidites (Ross 1949) Krutzsch 1959. Indications of similar thickenings are exhibited by the specimens pictured in figures 11, 12, 18, and 19.

Very delicate spores with extreme concave equator contours and sometimes having small openings in the edges of the equator corners, mark the subgroup C (fig. 10, 13). Occasionally small or indistinct appendices can be observed.

Comparisons for Group 10:

Concavisporites acutus n. sp. (Pf.), Th. & Pf., 1953, p. 119, Pl. 1, fig. 25-29, Tertiary, M. Europe.

Concavisporites discites n. sp. (Pf.), Th. & Pf., 1953, p. 119, Pl. 1, fig. 24, Tertiary, M. Europe.

Duplosporis Pflug (cf. Gleichenia concavisporites Rouse) cf. Gleicheniaceae, Pacltova', 1961, p. 97, Pl. 1, fig. 5-7, Senonian, Czech.

Toroisporis (Toroisporis) aneddeni n. fsp., Krutzsch, 1959, p. 347, Pl. 10, fig. 75, 78, Eocene, M. Europe.

Toroisporis (Toroisporis) postregularis n. fsp., Krutzsch, 1959, p. 347, Pl. 10, fig. 77, 78, Eocene, M. Europe.

"Group 9", Krutzsch, 1957, p. 526, Pl. 1, fig. 24-26, Upper Cret.-Tertiary, Germany.

"Group 23", Krutzsch, 1957, p. 526, Pl. 2, fig. 45-52, Upper Cret.-Tertiary, Germany.

Comparisons for Subgroup 10A:

Gleichenidites sp.-cf. Gleicheniaceae, Pacltova', 1961, p. 98, Pl. 10, fig. 4,5, Senonian, Czech.

Comparisons for Subgroup 10B:

Cingutriletes interruptus n. sp., Pierce, 1961, p. 26, Pl. 1, fig. 5, lower Upper Cretaceous, Minnesota.

C trijugatus n. sp., Pierce, 1961, p. 26, Pl. 1, fig. 4, lower Upper Cretaceous, Minnesota.

Gleichenia circinata, Cookson, 1953 (no. 3), p. 364, Pl. 1, fig. 7, Upper Mesozoic, Australia.

G circinidites n. sp. Cookson, 1953 (no. 3), p. 364, Pl. 1, fig. 5,6, Cretaceous, Scania.

Gleicheniidites senonicus n. sp., Ross, 1949, p. 43, Pl. 1, fig. 3, Upper Cretaceous, Scania.

G s Ross 1949, Delcourt & Sprumont, 1959, p. 33, Pl. 7, fig. 37, Wealden, France.

Schizaeoisporites cretacius (Krutzsch) Pot. 1956, Del. & Spr., 1959, p. 43, Pl. 3, fig. 5, Wealden, France.

Comparisons for Subgroup 10C:

Concavisporites regulatus n. sp. (Pf.), Th. & Pf., 1953, p. 119, Pl. 1, fig. 22, 23, Tertiary, M. Europe.

Toroisporis (cf. Toroisporis), Krutzsch, 1959, p. 349, Pl. 11, fig. 91-93, Eocene, M. Europe.

Toroisporis (Duplototoisporis) distalitoris n. fsp., Krutzsch, 1959, p. 351, Pl. 12, fig. 99-101, Eocene, M. Europe.

Group 11: Laevigatoid Type
(Plate 4, fig. 1-28)
(Plate 5, fig. 1-6)

Another very abundant group of spores, connected with the previous one by many transitions of specimen, is the one here designated as Laevigatoid Type. The representatives usually lack sculpture and structure. Sometimes the wall can be delicately pointed as shown in figures 3-5. The equator contour is typically convex or rounded, but equator contours exhibiting both concave and convex sides can be observed. Undoubtedly this group also contains a variety of different genera and species which cannot be distinguished to date.

Comparisons for Group 11:

Cyathidites minor Couper 1953, Del. & Spr., 1959, p. 33, Pl. 6, fig. 26, Wealden, France.

Deltoidospora hallii Miner 1935, Del. & Spr., 1959, p. 32, Pl. 3, fig. 2, Wealden, France.

Duplosporis cf. comitatus n. sp., Pflug, 1953, p. 159, Pl. 18, fig. 39, 40, Cretaceous, M. Europe.

D__________ convulsus n. sp., Pflug, 1953, p. 159, Pl. 18, fig. 37, 44, Cretaceous, M. Europe.

D__________ spasticus n. sp., Pflug, 1953, p. 159, Pl. 18, fig. 41-43, Cretaceous, M. Europe.

D__________ stipator subsp. lacina n. sp. & n. subsp., Pflug, 1953, p. 159, Pl. 18, fig. 29-36, Cretaceous, M. Europe.

Gleichenia angulata Naumova, Bolchovitina, 1953, p. 167, Pl. 8, fig. 1-3, Cretaceous, USSR.

G_________ umbonata sp. nov., Bolchovitina, 1953, p. 167, Pl. 8, fig. 4-7, Cretaceous, USSR.

Gleicheniidites senonicus Ross 1949, Del. & Spr., 1959, p. 33, Pl. 3, fig. 5, Wealden, France.

Laevigatisporites neddeni R. Pot. subsp. irregularis n. subsp. (Pf.), Th. & Pf., 1953, p. 120, Pl. 2, fig. 2-7, Tertiary, M. Europe.

L_______________ n______ R. Pot. subsp. regularis n. subsp. (Pf.), Th. & Pf., 1953, p. 120, Pl. 2, fig. 1, Tertiary, M. Europe.

L_______________ n______ R. Pot. subsp. torus n. subsp. (Pf.), Th. & Pf., 1953, p. 120, Pl. 2, fig. 8-17, Tertiary, M. Europe.

Leiotriletes adriennis fvar. pseudodivisus n. fvar, Krutzsch, 1959, p. 331, Pl. 2, fig. 8, 9, Eocene, M. Europe.

Leiotriletes adriennis pseudomaximus (Th. & Pf. 1953) n. comb., Krutzsch, 1959, p. 329, Pl. 1, fig. 1,2, Eocene, M. Europe.

L__________ a__________ fvar. pseudotorus n. fvar., Kretzsch, 1959, p. 331, Pl. 2, fig. 10, 11, Eocene, M. Europe.

L__________ a__________ fvar. pseudoundulus n. fvar, Krutzsch, 1959, p. 331, Pl. 2, fig. 12, 13, Eocene, M. Europe.

L__________ laetus sp. nov., Bolchovitina, 1953, p. 155, Pl. 2, fig. 6, Cretaceous, USSR.

L__________ microadriennis n. fsp., Krutzsch, 1959, p. 329, Pl. 1, fig. 3-7 , Eocene, M.Europe.

L__________ selectus Naumova, Bolchovitina, 1953, p. 153, Pl.1, fig. 24-28, Cretaceous, USSR.

L__________ stellatus sp. nov., Bolchovitina, 1953, p. 155, Pl. 2, fig. 8, Cretaceous, USSR.

Pollenites triangulatus n. sp., Thiergart, 1949, p. 33, Pl. 4, fig. 13, Wealden, M. Europe.

Psilatriletes excelsus n. sp., Pierce, 1961, p. 28, Pl. 1, fig. 8, lower Upper Cretaceous, Minnesota.

P__________ vitreus n. sp., Pierce, 1961, p. 28, Pl. 1, fig. 8, lower Upper Cretaceous, Minnesota.

Stereisporites stereoids R. Pot. & Ven., Th. & Pf., 1953, p.119, Pl. 10, fig. 82-84, Eocene, M. Europe.

Torisporis (Torisporis) longitorus n. fsp., Krutzsch, 1959, p. 347, Pl.10, fig. 82-84, Eocene, M. Europe.

Toripunctisporis punctineddeni n. fsp., Krutzsch, 1959, p. 345, Pl. 9, fig. 63-65, Eocene, M. Europe.

Group 12: Maximoid Type
(Plate 5, fig. 8)

These are very large trilete spores and are mostly dark brown in color. The smooth or nearly smooth equator contour is concave with rounded edges. An upsilon mark is present without tori.

Comparisons for Group 12:

Concavisporites antweilerensis n. sp. (Th.), Th. & Pf., 1953, p. 119, Pl. 1, fig. 43, Tertiary, M. Europe.

Cyathidites cf. australis Couper -cf. Cyatheaceae, Pacltova', 1961, p. 97, Pl. 1, fig. 1, Senonian, Czech.

Lygodiosporites adriennis Pot. & Gell. f. mesozoicus Thiergart, Cookson, 1953, (no. 3) p. 470, Pl. 2, fig. 29, Upper Mesozoic, Australia.

Matonisporites equiexinus Couper 1958, Del. & Spr., 1959, p. 35, Pl. 4, fig. 8, Wealden, France.

Sporites adriennis R. Pot. mesozicus n. f., Thiergart, 1949, p. 33, Pl. 4, fig. 9, Wealden, M. Europe.

Group 13: Osmundoid Type
(Plate 5, fig. 7)

This type is normally globe shaped with circular equator contours, but the specimens are usually found flattened and folded. The upsilon mark is small and indistinct. Characteristic sculpture consists of small wart like elements partially lengthened in the ground plane and forming an irregular pattern. Similarly structured spores occur in the fern family Osmundales.

Comparisons for Group 13:

Baculatisproites gemmatus n. fsp., Krutzsch, 1959, p. 377, Pl. 25, fig. 268-271, Eocene, M. Europe.

B____________ gemmiclavatus n. fsp., Krutzsch, 1959, p. 377, Pl. 25, fig. 272, Eocene, M. Europe.

Rugulatisporites quintus n. sp., Th. & Pf., 1953, p. 120, Pl. 2, fig. 44, Tertiary, M. Europe

Group 14: Dakotoid Type
(Plate 5, fig. 9-15, 19, 20)

This type is similar to pollen grains occurring in the genus Sciadopitys. The monocolpate pollen grains are lens shaped with a colpus extending across the entire proximal hemisphere and sometimes the distal hemisphere. Structure consists of long thin fibers wavily bent and irregularly interweaved.

Group 15: Tsugoid Type
(Plate 5, fig. 16-18)

This type consists of flat, disc shaped inaperaturate pollen grains with a circular equator contour and a wart like sculpture. The warts are short and irregular. The equatorial zone is indistinct. These pollen grains can be compared with the modern genus Tsuga canadensis.

Comparisons for Group 15:

Verrumonoporites verrucatus n. sp., Pierce, 1961, p. 46, Pl. 3, fig. 84, lower Upper Cretaceous, Minnesota.

Zonalapollenites (Tsuga) viridifluminipites Wodeh. (Tsuga-canadensis-Typus Rudolph), Th. & Pf., 1953, p. 121, Pl. 4, fig. 80-82, Tertiary, M. Europe.

"Group 26", Krutzsch, 1957, p. 527, Pl. 4, fig. 20-30, Upper Cretaceous-Tertiary, Germany.

Group 16: Megadakotoid Type
(Plate 5, fig. 23,24)

These are large egg shaped monocolpate pollen grains with a very thick wall consisting of a thin endexine and a thick fiber structured ektexine. Both layers are spaced in the polar regions. The ektexine exhibits a few flat warts which are very large in the ground plane.

Group 17: Kansoid Type
(Plate 5, fig. 21, 22)
(Plate 6, fig. 2-11, 14)

The characteristic feature of this group is the reduced sacs which form a wavy thickened band at the line of attachment. A great variety exists within the group, sometimes a colpus like opening is developed between the two sacs which are completely reduced (Plate 5, fig. 21,22) or blister like protrusions may be present (Plate 6, fig. 10,11).

Comparisons for Group 17:

Bacubivesiculites inchoatus n. sp., Pierce, 1961, p. 34, Pl. 2, fig. 35, lower Upper Cretaceous, Minnesota.

Clavabivesiculites inchoatus n. sp., Pierce, 1961, p. 34, Pl. 2, fig. 36, lower Upper Cretaceous, Minnesota.

C__________ pannosus n. sp., Pierce, 1961, p. 35, Pl. 2, fig. 37, lower Upper Cretaceous, Minnesota.

Dacrydiumites mawsonii Cookson, Cookson, 1953 (no. 3), p. 465, Pl. 1, fig. 10, Upper Mesozoic, Australia.

D__________ m______ Cookson, Cookson, 1953 (no. 1), p. 66, Pl. 1, fig. 23-26, Upper Mesozoic, Australia.

D__________ ruei Cookson, Cookson, 1953 (no. 1), p. 66, Pl. 1, fig. 27, Upper Mesozoic, Australia.

Granabivesiculites inchoatus n. sp., Pierce, 1961, p. 35, Pl. 2, fig. 38, lower Upper Cretaceous, Minnesota.

Punctamultivesiculites inchoatus n. sp., Pierce, 1961, p. 42, Pl. 3, fig. 68, lower Upper Cretaceous, Minnesota.

Group 18: Pinoid Type
(Plate 6, fig. 1, 4, 9, 13)

These pollen grains represent the Pinus haploxylom type and are commonly observed in Mesozoic to Recent sediments.

Comparisons for Group 18:

Abietineae, Pacltova', 1961, p. 98, Pl. 12, fig. 1, 3, Senonian, Czech.

Abietineaepollenites grandialatus n. sp., Groot & Penny, 1960, p. 233, Pl. 1, fig. 7, Lower Cretaceous, Maryland & Delaware.

A_______________ Microalatus R. Pot. -cf. Pinus haploxylon, Pacltova', 1961, p. 98, Pl. 11, fig. 1-3, Senonian, Czech.

A_______________ M_________ R. Pot., Couper, 1958, p. 179, Pl. 28, fig. 11-13, Lower Cretaceous, British Isle.

A_______________ microreticulatus n. sp., Groot & Penny, 1960, p. 233, Pl. 1, fig. 8, Lower Cretaceous, Maryland & Delaware.

Cedripites sp.-cf. Cedrus, Pacltova', 1961, p. 98, Pl. 11, fig. 4, 5, Senonian, Czech.

Granabivesiculites constrictus n. sp., Pierce, 1961, p. 36, Pl. 2, fig. 42, lower Upper Cretaceous, Minnesota.

G_______________ latus n. sp., Pierce, 1961, p. 36, Pl. 2, fig. 42, lower Upper Cretaceous, Minnesota.

Pinuspollenites sp., Pacltova', 1961, p. 98, Pl. 12, fig. 2,4, Senonian, Czech.

Group 19: Tetradoid Type
(Plate 6, fig. 16-19)

This group represents tricolporate angiosperms which are usually found in tetrade units. The exine has a fiber structure which rises above the surface and forms a fine baculate sculpture. The type closely resembles recent Salicales.

Comparisons for Group 19:

Retitetradites monocolpatus n. sp., Pierce, 1961, p. 34, Pl. 2, fig. 34, lower Upper Cretaceous, Minnesota.

Group 20: Wilsonoid Type
(Plate 7, fig. 1-7)

These very large tricolpate and tricolporate angiosperms show a distinct stick like structure between endexine and ektexine. They are unsculptured with an indistinct endospore like figures 1, 5, and 6; or with a notched surface like figures 2, 3, 4, and 7. Specimens pictured in figures 1, 5, and 6 are similar to pollen grains of the angiosperm family Cornaceae and those of figures 2, 3, and 4 closely resemble the family Araliaceae.

Comparisons for Group 20:

Bacutricolpites constrictus n. sp., Pierce, 1961, p. 48, Pl. 3, fig. 91, 92, lower Upper Cretaceous, Minnesota.

Group 22: Quercoid Type
(Plate 7, fig. 11, 29)

The members of this group all exhibit the morphological features characteristic of Quercus pollen.

Comparisons for Group 22:

Eucommiidites minor n. sp., Groot & Penny, 1960, p. 235, Pl. 2, fig. 14, Lower Cretaceous, Maryland & Delaware.

Punctatricolpites brevis n. sp., Pierce, 1961, p. 50, Pl. 3, fig. 100, lower Upper Cretaceous, Minnesota.

Tricolpopollenites crassimurus n. sp., Groot & Penny, 1960, p. 235, Pl. 2, fig. 4, 5, Lower Cretaceous, Maryland & Delaware.

Group 23: Smaller Tricolpate and Tricolporate Types
(Plate 7, fig. 15-28)

It was not possible to make distinction among the variety of forms summarized in this group. Specimens as shown by figures

15-21 and 26-28 might belong to Cupuliferae. Figures 22-25 resemble Araliaceae, Mastixiaceae, Symplocaceae, and others.

Comparisons for Group 23:

Clavatricolpites firmus n. sp., Pierce, 1961, p. 48, Pl. 3, fig. 94, lower Upper Cretaceous, Minnesota.

C ____________ *prolatus* n. sp., Pierce, 1961, p. 48, Pl. 3, fig. 93, lower Upper Cretaceous, Minnesota.

cf. *Complexiopollis* Krutzsch, Pacltova', 1961, p. 99, Pl. 15, fig. 15-23, Senonian, Czech.

Foveotricolpites sphaeroides n. sp., Pierce, 1961, p. 49, Pl. 3, fig. 95, lower Upper Cretaceous, Minnesota.

Gemmatricolpites gemmatus n. sp., Pierce, 1961, p. 49, Pl. 3, fig. 96, 97, lower Upper Cretaceous, Minnesota.

Plicapollis silicatus Pflug, Pacltova', 1961, p. 99, Pl. 15, fig. 11-14, Senonian, Czech.

Retitricolpites oblatoides n. sp., Pierce, 1961, p. 51, Pl. 3, fig. 104, lower Upper Cretaceous, Minnesota.

R ____________ *pannosus* n. sp., Pierce, 1961, p. 51, Pl. 3, fig. 105, lower Upper Cretaceous, Minnesota.

R ____________ *patens* n. sp., Pierce, 1961, p. 51, Pl. 3, fig. 108, lower Upper Cretaceous, Minnesota.

R ____________ *prolatus* n. sp., Pierce, 1961, p. 51, Pl. 3, fig. 106, lower Upper Cretaceous, Minnesota.

R ____________ *sphaeroides* n. sp., Pierce, 1961, p. 50, Pl. 3, fig. 103, lower Upper Cretaceous, Minnesota.

Sporopollis peneserta Pflug, Pacltova', 1961, p. 99, Pl. 15, fig. 6-10, Senonian, Czech.

Tricolpopollenites distinctus n. sp., Groot & Penny, 1960, p. 235, Pl. 2, fig. 10, Lower Cretaceous, Maryland & Delaware.

T ____________ *parvulus* n. sp., Groot & Penny, 1960, p. 235, Pl. 2, fig. 8, 9, Lower Cretaceous, Maryland & Delaware.

Tricolporites psilatus, Ross, 1949, p. 43, Pl. 3, fig. 46, Upper Cretaceous, Scania.

Group 24: Smooth Monocolpate Type

This group consists primarily of Ginkgoiae and Cyadinae. It is possible, however, that some monocolpates of the angiosperm groups Magnoliaceae, Helobiae, and Spadiciflorae are also included.

Group 25: Taxodium

The Taxodium pollen grains are characterized by their split condition and the indistinct ligula. The occurrence is usually combined with conifer wood and resin of the Taxodium type.

Group 26: Selaginella

Typical trilete grains united in tetrades and equiped with spines on the surface were observed several times in the examination of the slides.

Pollen Grains - Incertae Sedis:

The type shown on Plate 7, figures 30, 31, resembles a monocolpate grain. Plate 7, figure 36 shows a trilete spore with a very indistinct upsilon mark. The fossil pictured on Plate 7, figure 35, might be close to the Kansoid Group (17).

Fungi and Algae:

Fungi spores and fungi hyphae were observed in relatively abundant numbers. The fungi are usually recognized easily by their dark brown chitinous walls (Plate 7, fig. 37). The assignment of the specimens pictured on Plate 7, figures 32, 33, is doubtful, though possibly belonging to the algae.

Hystrichosphaerids:

As a great part of the cross section investigated consisted of marine beds, a few Hystrichosphaeridium types were found. They were not in great abundance however.

Comparisons for Hystrichosphaerids:

Hystrichosphaera sp., Evitt, 1961, p. 408, Pl. 4, fig. 15, 16, Lower Eocene, New Jersey.

Hystrichosphaera cf. H. furcata (Ehrenburg) o. Wetzel 1933, Anderson, 1960, p. 54, Pl. 9, fig. 6, Cretaceous, New Mexico.

Hystrichosphaeridium sp., Cookson, 1953 (no. 18), p. 115, Pl. 2, fig. 26, 27, Cainozoic, Australia.

Age of the Rocks Investigated

The previous comparisons show that similar forms of the spore and pollen types have already been described from other Cretaceous occurrences in North America and Europe. Some types, especially those listed as groups 2, 3, 9, 10, 11, 12, 18, 19, 23, and 24, indicate a Cenomanian age as most probable, but a Upper Albian age could also be possible.

Plant Associations

The following plant associations can be distinguished from the maceration residuum; 1) ombrogene moss associations with Sphagnum and Pinus, 2) fern swamps with Schizaeaceae, Gleichen-iaceae and fungi spores, 3) Taxodium pollen, fusite, and conifer wood of Taxodiaceae type, 4) limnic facies with fresh water plankton and wind transported pollen grains from forests outside the sedimentation area and 5) marine facies characterized by Hystrichosphaerids, Dinoflagellates, and other plankton remains.

Inferred Climatic Conditions

The presence of tropical and subtropical fern families like Gleicheniaceae, Schizaeaceae, and Cyatheaceae indicates a climate similar to the present climate of Southern Florida.

Table 5. Examination of slides from column A.

Slide No.	Observations
1a.	No spores or pollen grains; black organic bodies with a dark shell and poorly preserved tissue fragments in the interior.
4a.	Well preserved pollen and spores of groups 9, 10, 12, and 18; poorly preserved tissues; dark dark organic bodies.
5a.	Well preserved pollen and spores of groups 10 and 12, also some pollen and spore fragments; irregular grains of yellow resin.
8a.	No pollen or spores; dark organic bodies.
11a.	No pollen or spores; badly destroyed plant tissues; egg shaped organic bodies which look much like plankton.
18a.	A few spores and pollen grains of groups 1, 10, and 18; fungi spores; resin; abundant fiber like pieces of fusite; indications of a swamp like environment with evidence of a fire.
19a.	Rich in pollen and spores of groups 1, 2, 10, and 12; abundant wood material, poorly preserved; large brown resin grain.
23a.	A few poorly preserved spores and pollen grains of group 18; Teleutospores of Ustilaginales and other well preserved fungi spores; fine grained organic material; well preserved epidermis.
28a.	No spores, pollen grains or organic remains.

Table 5. (cont.)

Slide No.	Observations
29a.	No spores or pollen grains; very badly destroyed plant tissues.
30a.	No spores or pollen grains; disc shaped bodies, probably plankton remains; badly destroyed organic matter.
31a.	A few pollen grains of the monocolpate type; fungi spores; very fine detritus.
34a.	No spores or pollen grains; pieces of black material appearing burned; fine detritus.
36a.	No spores or pollen grains; very fine organic detritus.
37a.	A few corroded pollen grains of group 11.
39a.	A few faint, corroded pollen grains of groups 11 and 14; fine detritus.
40a.	No spores or pollen grains; poorly preserved plant tissues.
43a.	A few small monocolpate pollen grains; rich in other microfossils, large inaperaturate plankton forms, small delicate inaperaturate plankton forms; abundant large dinoflagellates with rough surfaces and another unidentified plankton organism; all evidence indicates a marine bed.
44a.	Pollen grains destroyed beyond recognition; fine detritus.
46a.	Small monocolpate pollen grains and a trilete spore; smooth circular plankton; Hystrichosphaerid with a net like structure; small; smooth plankton types.
49a.	A few spores and pollen grains of groups 11, 20, 23, and 24; fungi spores; large plankton; a Hystrichosphaerid; first observed angiosperm grain; dark detritus.

Table 5 (cont.)

Slide No.	Observations
50a.	Rich in spores and pollen grains of groups 11, 23, and 24, poorly preserved in most cases; dark wood material and fusite; fungi spores; plankton bodies consisting of a sculptured spiny globe and small inaperaturate plankton.
53a.	A smooth monocolpate pollen grain and some poorly preserved spores; plankton; fine detritus.
54a.	A few corroded spores of group 1; wood fragments; coalified dark material.
57a.	A few spores and inaperaturate pollen grains of the genus <u>Taxodium</u> appearing as split globes; poorly preserved plant tissues; indications of a swamp environment.
58a.	A few poorly preserved pollen grains; inaperaturate plankton; badly destroyed organic material; other dark substance.
60a.	Very badly destroyed organic material; dinoflagellates.
61a.	Dinoflagellates; dark substance.
63a.	No spores, pollen grains or plankton; dark substance.
66a.	No organic material.
68a.	A few spores of group 11; plant tissues.

Table 6. Examination of slides from column B.

Slide No.	Observations
2b.	No spores or pollen grains; badly destroyed organic material.
4b.	A few spores and pollen grains of groups 9, 10, 11, and 12; fungi spores; plant tissues; leaf epidermis.
12b.	Spores of <u>Selaginella</u>, showing spines; fungi spores; well preserved plant tissues; cork tissues.

Table 6 (cont.)

Slide No.	Observations
19b.	Very rich in spores and pollen grains of groups 1, 2, 10, 11, 12, and 24; brown resin.
21b.	Very rich in spores and pollen grains of groups 1, 2, 9, 10, 11, 12, and 24; small peices of well preserved tissue.
22b.	Rich in spores and pollen grains of groups 1, 2, 9, 10, 11, 24;and well preserved tissues and leaf epidermis.
23b.	Rich in spores and pollen grains of groups 1, 2, 9, 10, 11, 12, 18, 24, and monolete spores.
24b.	Rich in spores and pollen grains of groups 9, 10, 11, 18, and 24.
27b.	Spores of groups 1, 9, and 11; plant tissues.
36b.	Spores and pollen grains of groups 9, 10, 11, and 18; plant tissues; fluorite crystals.
37b.	Spores and pollen grains of groups 10, 11, and 24; pollen of <u>Taxodium</u>, compressed and folded; poorly preserved plant tissues; fine detritus.
38b.	Well preserved spores and pollen grains of groups 1, 9, 10, 11, 18, and 25; fungi spores; plant tissues.
39b.	Spores and pollen grains of groups 2, 10, 11, 18, 24, and 25; resin; well preserved tissues; dark substance.
40b.	No spores or pollen grains; dark substance abundant.
42b.	A few pollen grains of groups 24, 25; abundant plankton but no definite marine forms, indicates a limnic or brackish environment; badly destroyed tissues; resin; dark material.
43b.	Inaperaturate <u>Taxodium</u> grains; poorly preserved leaf epidermis.
45b.	Spores and pollen grains of groups 11, 18, and 23, the first angiosperms; plankton like large granular bodies; well preserved tissues; resin.

Table 6 (cont.)

Slide No.	Observations
47b.	Poorly preserved plankton similar to Hystrichosphaerids, indicating marine to brackish conditions; poorly preserved plant tissues; dark substance.
49b.	Mostly marine plankton; dark bodies.
50b.	Large egg shaped plankton, dinoflagellates; well preserved leaf epidermis; plant tissues; yellow resin grains.
51b.	Identical to slide 50b.
53b.	Rich in spores and pollen grains of groups 2, 10, 11, 18, 19, and 23.
54b.	Spores and pollen grains of groups 1, 2, 10, 11, 17, 19, 20, 23, and 24; abundant fungi spores; plant tissues; large pieces of wood, probably conifers.
56b.	Rich in poorly preserved spores and pollen grains of groups 1, 5, 8, 9, 10, 11, 19, 23, 24, and 25; badly preserved detritus.
57b.	Rich in well preserved spores and pollen grains of groups 1, 2, 3, 9, 10, 11, 19, 23, and 24; brown resin grains; very badly destroyed humic material.
59b.	Very rich in spores and pollen grains of groups 1, 2, 9, 10, 11, 20, 23, and 24.
64b.	No spores or pollen grains; fine detritus.
69b.	No spores or pollen grains; fine detritus.

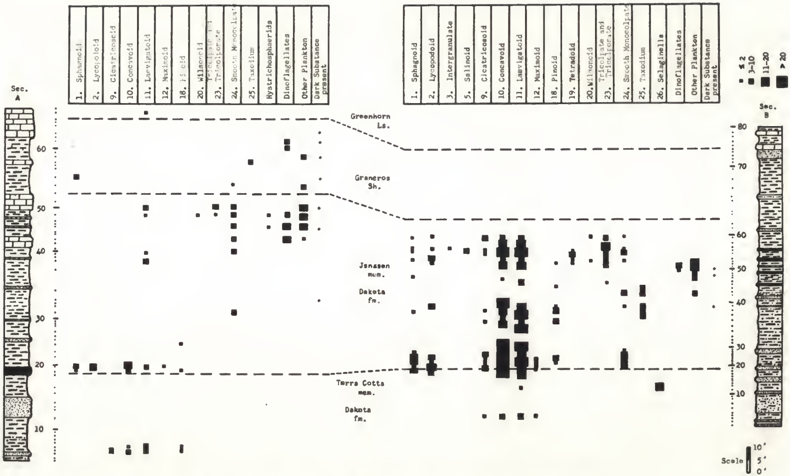

Figure 3. Position of spores, pollen grains, and plankton organisms in relation to the rock sequences.

SUMMARY AND CONCLUSIONS

The two rock columns investigated, approximately 3.5 miles apart, are in Ellsworth and Russell Counties of Central Kansas. Both rock columns comprise the upper part of the Terra Cotta member of the Dakota formation, the Janssen member of the Dakota formation, the overlying Graneros shale, and the lower part of the Greenhorn limestone.

The stratigraphic units of each vertical section were correlated by tracing the outcropping horizons through the area separating the two columns. Samples were taken in an interrupted sequence through each column. The samples were examined by photometric and fluorescence analysis and were macerated for pollen and spore analysis. The investigation was directed toward the evaluation of these methods for stratigraphic correlation, facies analysis, paleoecology, and paleoclimatic determinations.

The photometric values obtained from the photometer in reflected light were produced for seven areas of the visible light spectrum. It was shown that the reflection values for red (6800 A) and violet (4200 A) gave sufficient correlation information about the reflection characteristics of the different facies types. The values are shown in graphic form in figure 2 in relation to the stratigraphic sequence.

The information obtained can be summarized in the following manner:

I. Reflection Measurements. The curves for the two columns exhibited such great similarities that the layers and members could be correlated without difficulty. The member and formation boundaries were marked by major variations in intensity. The reflection technique seems to be applicable for correlation work as it yields an accurate, detailed correlation and is extremely rapid. It was found that for the cross section studied, the correlation could not be made by lithologic features of the rock sequence. The coal seams appear to represent lenses deposited within a restricted area and interfingering with shales or sandstones. In a similar way, limestone layers at column A can grade into shales in column B and shales of column A are tied by correlation to sandstone facies at column B. The most reliable marker beds seem to be the bentonite layers. Photometry seems to provide a reliable basis for correlations as the photometric characteristics of the lithologic units usually are more consistent than the lithologic features.

Significant differences do exist between the curves of the two rock columns however; the average values of column B, to the northeast, are about 12 percent lower than those of column A. Comparing this peculiarity with the results of field and palynological studies, it appears that the difference is probably due to a more continental facies at column B while column A seems to be more influenced by a marine environment.

II. <u>Fluorescence Measurements</u>. Variations in fluorescence, measured by the same photometer, yielded the following results. The boundaries of formations and members are often marked by fluorescence breaks in both vertical sections. This phenomenon seems to indicate lithologic breaks which can be related to changes in the source areas. The fluorescence characteristics of the two columns analyzed are remarkably different. While column A has its maximum fluorescence in violet light, column B has its maximum in orange light. Therefore, the fluorescence seems to have only a limited importance for correlation work, moreover the fluorescence intensities are generally small.

III. Palynological Analysis. The examination of the vertical sections on pollen and spore analysis yielded the following results:

A. A considerably high number of different lithologies, not only coals, but clays, shales, and sometimes sandstones yielded spores, pollen grains, and plankton organisms, often in good concentrations.

B. Many of the same or related specimens of the spores and pollen grains found, have already been detected by other investigators in Middle Cretaceous sedimentary rocks of North America and Europe. Comparisons indicate that the age of the cross section is Cenomanian or slightly earlier.

C. As the maceration technique is time consuming and some rock layers do not contain microfossils, the correlation by photometric techniques seems to be quicker and easier. However, valuable additional information could be obtained from the palynological diagram (fig. 3).

1. Modern angiosperms appear suddenly in the same horizon of both columns. This horizon is in the upper part of the Janssen member above a distinct bentonite layer. Numerous specimens of about a dozen different genera are present, most of them representing the

tricolpate and tricolporate types (Group 23) with some tetrade types (Group 19). This first appearance of the angiosperms seems to be of stratigraphic significance for correlation.

2. The striped Schizaeaceae of Group 10A are restricted to the Terra Cotta member of both columns.

3. The delicately striped Schizaeaceae (Group 10C) occur predominately in the upper part of the Janssen member. The smooth monocolpate types (Group 24) are also present in the Upper Janssen but continue on into the Graneros shale.

4. The large Maximoid spores (Group 12) occur mainly in the Terra Cotta member, but extend into the lower part of the Janssen member.

D. The presence of tropical and subtropical ferns indicates a warmer climate than exists today.

E. The pollen and spore assemblages yield some information about the plant associations present at, or close, to the deposition locality. They could be classified as ombrogene _Sphagnum_ facies, fern swamp facies, _Taxodium_ swamp facies, subaquatic fresh water facies, and marine facies.

F. Column B shows a considerably higher pollen and spore content than does column A. The spores of herbs and other short statured plants are particularly well represented in column B and the proportion of plankton, especially those of marine origin, is higher in column A. This confirms other evidence indicating that column B was nearer the shoreline than column A.

G. In both rock columns, the beginning of the marine facies is indicated by the occurrence of marine plankton organisms. The point of the first appearance is near the middle of the Janssen member. This fact is evidence that the upper part of the Dakota formation represents marine sediments or at least sediments influenced by a marine environment.

H. Some of the maceration residue exhibits dark bodies consisting of plant tissue fragments surrounded by a highly charred shell. These samples normally are completely free of pollen and spores but contain abundant plankton, thereby a sub-aquatic origin is indicated for these sedimentary rocks. A heating or burning effect seems to be the best explanation of the dark, highly charred material. The beds marked by this phenomenon are above the bentonite layers. The absence of pollen grains may be due to an absence of vegetation at the time or to a far from shore depositional environment. It has already been suggested by other investigators (Hatfield, 1961; Hattin & Hatfield, 1962) that the bentonite layers represent horizons of volcanic ash. The occurrences of this dark substance and the absence of abundant vegetation could be easily explained by the effect of heat or volcanic ash fall in the source area. The sudden appearance of the angiosperms above a bentonite layer would seem to be a logical sequence provided by a barren volcanic ash covered landscape.

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I would like to express my deepest appreciation to Dr. Hans D. Pflug for his constant guidance and suggestions throughout this investigation and also for the use of his personal equipment which was utilized during the period of research. Without his assistance, the preparation of this paper would have been impossible.

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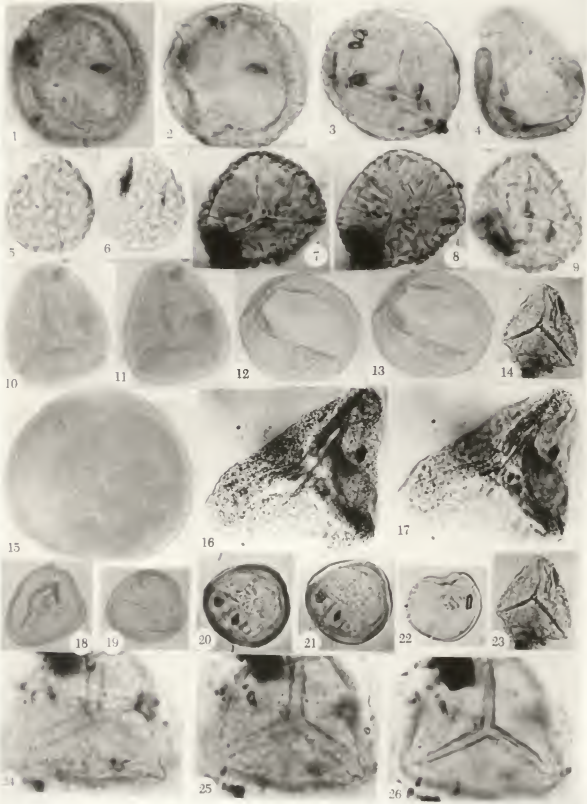
EXPLANATION OF PLATE I

Fig. 1-9.	Group 2:	Lycopodoid. Type.
Fig. 10, 11.	Group 3:	Intergranulate Type.
Fig. 12, 13.	Group 4:	Parvotrilete Type.
Fig. 14, 23.	Group 5:	Salinoid Type.
Fig. 15.	Group 6:	Wichitoid Type.
Fig. 16, 17.	Group 7:	Tesselatoid Type.
Fig. 18-22.	Group 1:	Sphagnoid Type.
Fig. 24-26.	Group 8:	Foveasporoid Type.

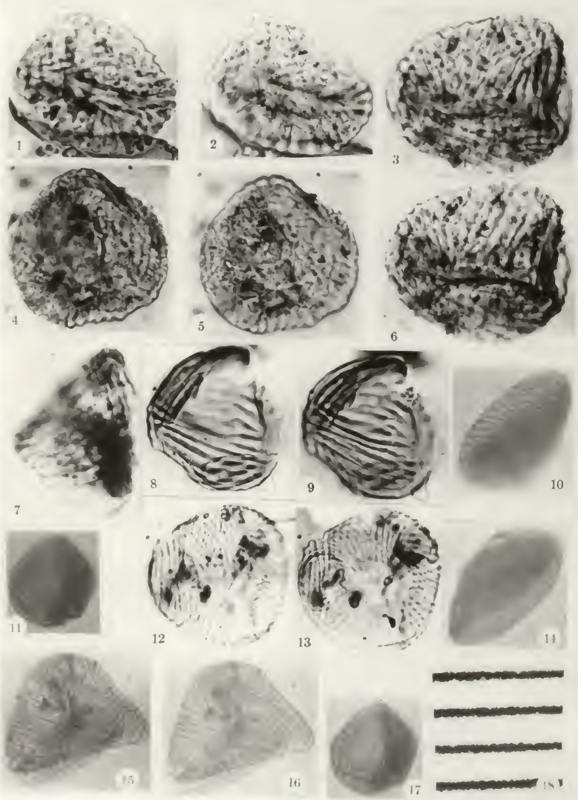
PLATE I



EXPLANATION OF PLATE II

Fig. 1-17.	Group 9: Cicatricosoid Type.
(1-6).	Subgroup 9A: Cicatricosoid Type A.
(7-9).	Subgroup 9B: Cicatricosoid Type B.
(10-17).	Subgroup 9C: Cicatricosoid Type C.
Fig. 18.	Measuring scale (10 microns between marks).

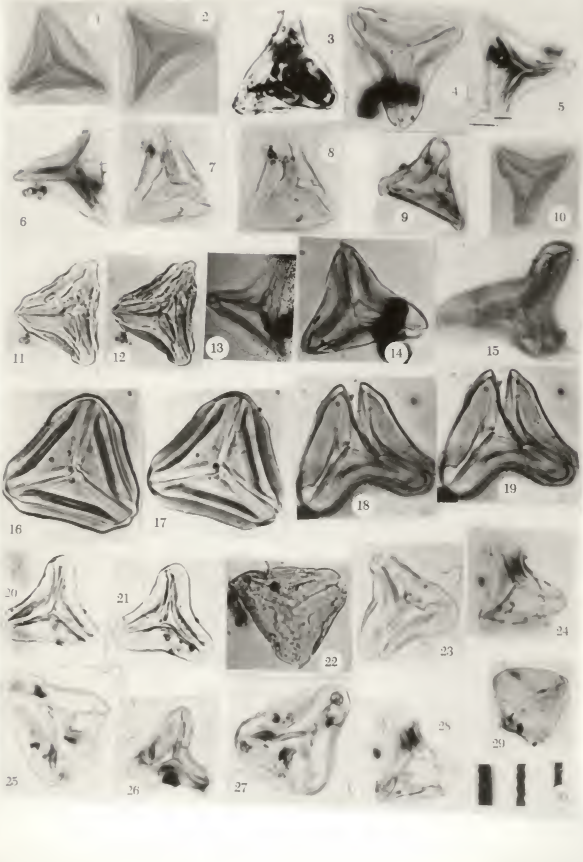
PLATE II



EXPLANATION OF PLATE III

Fig. 1-29.	Group 10: Concavoid Type.
(15).	Subgroup 10A: Concavoid Type A.
(16, 17).	Subgroup 10B: Concavoid Type B.
(10, 13).	Subgroup 10C: Concavoid Type C.
Fig. 30.	Measuring scale (10 microns between marks).

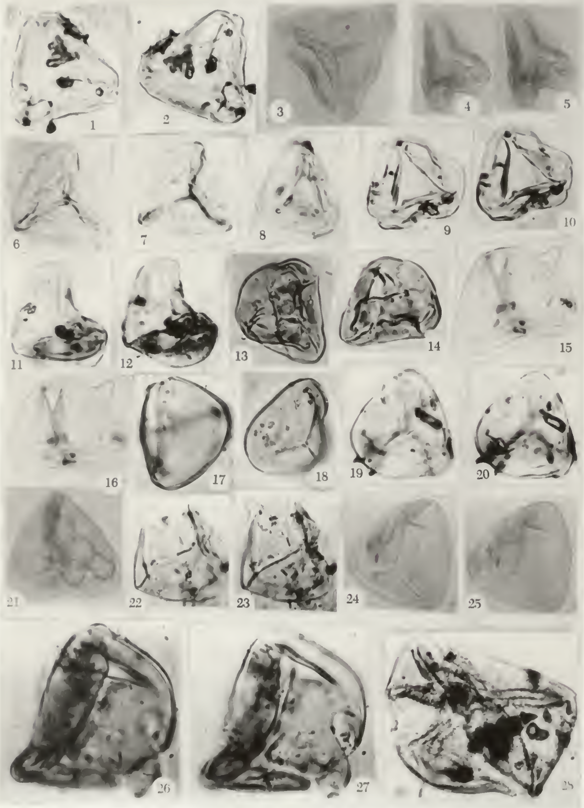
PLATE III



EXPLANATION OF PLATE IV

Fig. 1-28.   Group 11: Laevigatoid Type.

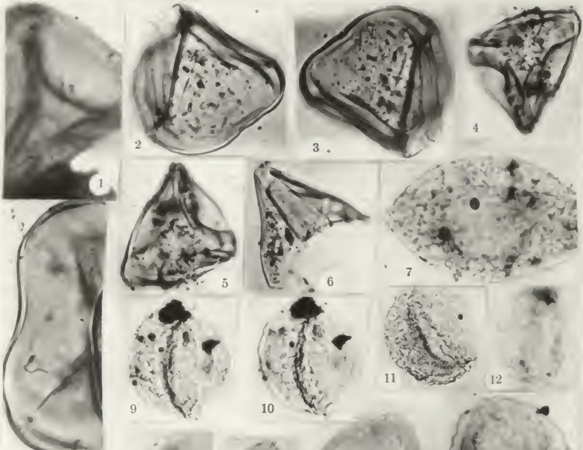
PLATE IV



EXPLANATION OF PLATE V

Fig. 1-6.	Group 11: Laevigatoid Type.
Fig. 7.	Group 13: Osmundoid Type.
Fig. 8.	Group 12: Maximoid Type.
Fig. 9-15, 19, 20.	Group 14: Dakotoid Type.
Fig. 16-18.	Group 15: Tsugoid Type.
Fig. 21, 22.	Group 17: Kansoid Type.
Fig. 23, 24.	Group 16: Megadakotoid Type.

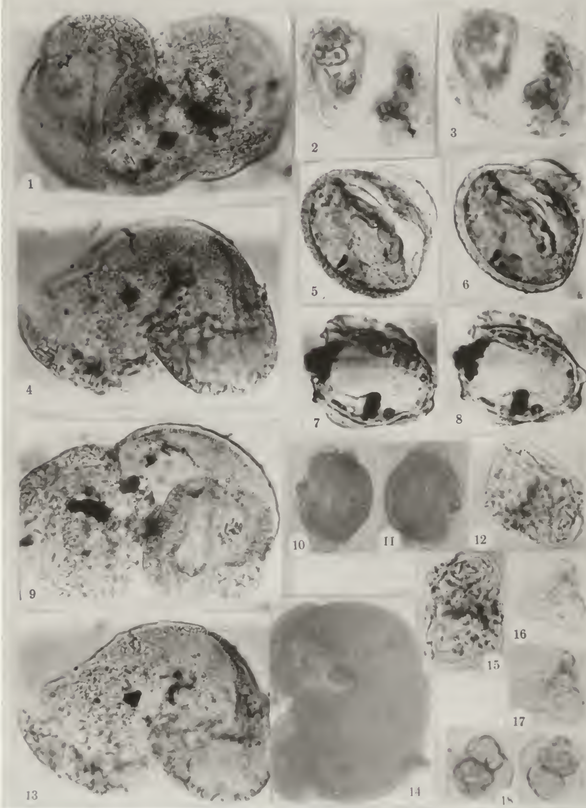
PLATE V



EXPLANATION OF PLATE VI

Fig. 1, 4, 9, 13.	Group 18: Pinoid Type.
Fig. 2, 3, 5-8, 10, 11, 14.	Group 17: Kansoid Type.
Fig. 12, 15.	Questionable.
Fig. 16-19.	Group 19: Tetradoid Type.

PLATE VI



EXPLANATION OF PLATE VII

Fig. 17.	Group 20: Wilsonoid Type.
Fig. 8-10, 12, 13.	Group 21: Russeloid Type.
Fig. 11, 29.	Group 22: Quercoid Type.
Fig. 15-28.	Group 23: Smaller Tricolpate and Tricolporate Types.
Fig. 14, 30, 31, 35, 36.	Questionable.
Fig. 32, 33, 37.	Fungi Spores.
Fig. 34.	Hystrichosphaeroide.
Fig. 38.	Measuring scale (10 microns between marks).

PLATE VII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PALYNOLOGY AND GEOPHOTOMETRY OF THE MIDDLE CRETACEOUS ROCKS IN ELLSWORTH AND RUSSELL COUNTIES, KANSAS

by

DONALD LEROY SNYDER

B. S., Kansas State University, 1961

AN ABSTRACT OF A THESIS

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requirements for the degree

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1963

This investigation is directed toward detailed field and laboratory analysis of two stratigraphic sedimentary rock sections in Middle Cretaceous rocks of Central Kansas. The two rock columns are approximately 3.5 miles apart and the rock units exposed have been correlated by tracing outcrops in the field. Both rock columns have been analyzed by field study, examination of samples by means of photometric methods including reflectance and fluorescence measurements, and by palynological examinations. These analyses may be useful in determining the palynological characteristics which should indicate the approximate geologic age, climatic conditions and other ecological factors of deposition, and also provide new correlation methods that can be applied to Cretaceous rocks elsewhere.

A comparison of these analysis methods indicates that reflectance measurements yield the most detailed and rapid correlation method; although sudden facies changes occurred between the two rock columns. The distribution of spores, pollen grains, and plankton organisms seems to provide a basis for assignment of some additional guide horizons. The age of the sediments as determined by palynological comparisons is Cenomanian and characteristic pollen and spore elements suggest a tropical to subtropical climate at the time of deposition. Different facies types and plant assemblages are associated with the distinct pollen and spore assemblage. The first occurrence of marine plankton organisms is assumed to mark the earliest Cretaceous appearance of marine facies in the area investigated. The rock column in the southwest exhibits a stronger marine influence than the area in the northeast as revealed by the results of field, photometric, and palynological examinations. The fluorescence intensities measured were generally too low for use as an effective correlation tool, however, distinct and effective correlation "breaks" can be noted near some of the contact planes of the formations and members.