ABSTRACT

PALYNOLOGY OF SEDIMENTS
BORDERING SOME
UPPER CRETACEOUS STRAND LINES
IN NORTHWESTERN COLORADO

By

Theodore F. Gies

Sixty samples from three subordinate sections and one composite reference section of the upper part of the Mancos Shale and the lower part of the Mesaverde Group in northwestern Colorado were analyzed palynologically. A flora of 214 different palynomorph types was differentiated. These are reviewed, illustrated, and compared to other palynomorphs from related floras. No new species were described, as the critical comparison necessary to establish new species was beyond the scope of this study.

A composite section for the Grand Junction area was constructed to include the stratigraphic units studied and sampled from four localities in the vicinity. Rocks of this composite section were compared palynologically with the equivalent strata exposed in the Rifle Gap, Colorado, area. This comparison revealed the time equivalence of certain strata in the two sections. The comparison included data derived from palynomorph ranges, relative abundance, and ratios of land-derived palynomorphs to microplankton. These data, especially the Land-derived/Microplankton ratios (LD/M ratios), also provided a basis for paleoenvironmental interpretations.

The West Salt Creek section of Kidson, 1971, 40 miles west of Grand Junction, was also compared to the Grand Junction Area Composite section. The former section contains the Buck Tongue of the Mancos Shale and associated rocks of the Mesaverde Group. To the west of the Grand Junction area, the Buck Tongue is a well-defined transgressive unit which is differentiated from the main body of the Mancos Shale by sandstones, but it is not lithologically differentiated in the Grand Junction area. This marine unit, which was studied palynologically by Kidson in 1971, was found to be recognizable in the main body of the Mancos Shale near Grand Junction as a more offshore marine sediment than the rest of the Mancos there on the basis of LD/M ratios and other palynologic criteria. A time correlation was also established between these two sections on the basis of palynomorph range data.

During comparison of the Buck Tongue with the Mancos near Grand Junction, it was discovered that LD/M ratios presented a different model of paleoenvironmental relationships in the Buck Tongue than the model resulting from a factor analysis study of that unit by Kidson (1971).

A section at Wilson Ranch, south of Craig, Colorado, was correlated with the Grand Junction Area Composite section within broad limits.

Six coal samples were compared by means of relative abundance percentage histograms. No correlation was noted between any of these coals, although some were from the same stratigraphic intervals. This lack of correlation is thought to be the result of the discontinuous, lensing nature of these coals.

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and Dr. Cross provided two suites of samples collected and processed earlier.

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Finally, my sincere appreciation goes to my wife, Aloma, who in addition to giving her patience and encouragement, also typed the manuscript and aided in various manipulations of the data.

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INTRODUCTION

Statement of Problem

The following were the goals of this study:

1. Determine and describe the types of fossil pollen, spores, dinoflagellates and acritarchs preserved in the Upper Cretaceous rocks sampled for this study.

2. Determine the time ranges and relative abundances of the palynomorphs and attempt to make time correlations of the various stratigraphic sections studied.

3. Note any correlation of the occurrences of specific palynomorphs with specific rock types or other environmental indicators. Apply this information to the correlation of rock units, interpretation of environments of deposition, etc.

4. Using the information gained from the above studies, determine whether or not the Buck Tongue of the Mancos Shale, studied in detail to the west of the study area by Kidson (1971), can be recognized on the basis of palynology in the Mount Garfield section of this study, where it can no longer be distinguished lithologically as a separate unit of the Mancos because of the disappearance of its enclosing sandstones by gradation into the shale.

5. Determine whether the six coals analyzed in this study can be distinguished and/or correlated on the basis of their palynomorph content.

Previous Work

The palynological literature of the Upper Cretaceous of the Rocky Mountain region up to 1971 as well as much of the geological literature pertinent to this thesis area has been reviewed by Kidson (1971).

An additional reference which was useful in the preparation of this report is the sedimentological study of the Mesaverde Group and upper Mancos Shale in northwestern Colorado done by Masters (1965).

Three other pertinent palynological references are Leffingwell (1971), Tschudy and Leopold (1971), and Singh (1971). The first two deal with Upper Cretaceous palynology in the Rocky Mountain region of the United States; the latter is a study of the Lower Cretaceous in northwestern Alberta.

This thesis is one part of a total project of "Palynological Analysis and the Determination of Environments of Deposition in the Rocky Mountain Cretaceous," supported in part by National Science Foundation Grant GA429, Dr. A. T. Cross, principal investigator. Other units of this project which were particularly pertinent to my thesis are the theses of Zaitzeff (1967), Thompson (1969), Griggs (1970), Kidson (1971), and Stone (1971).

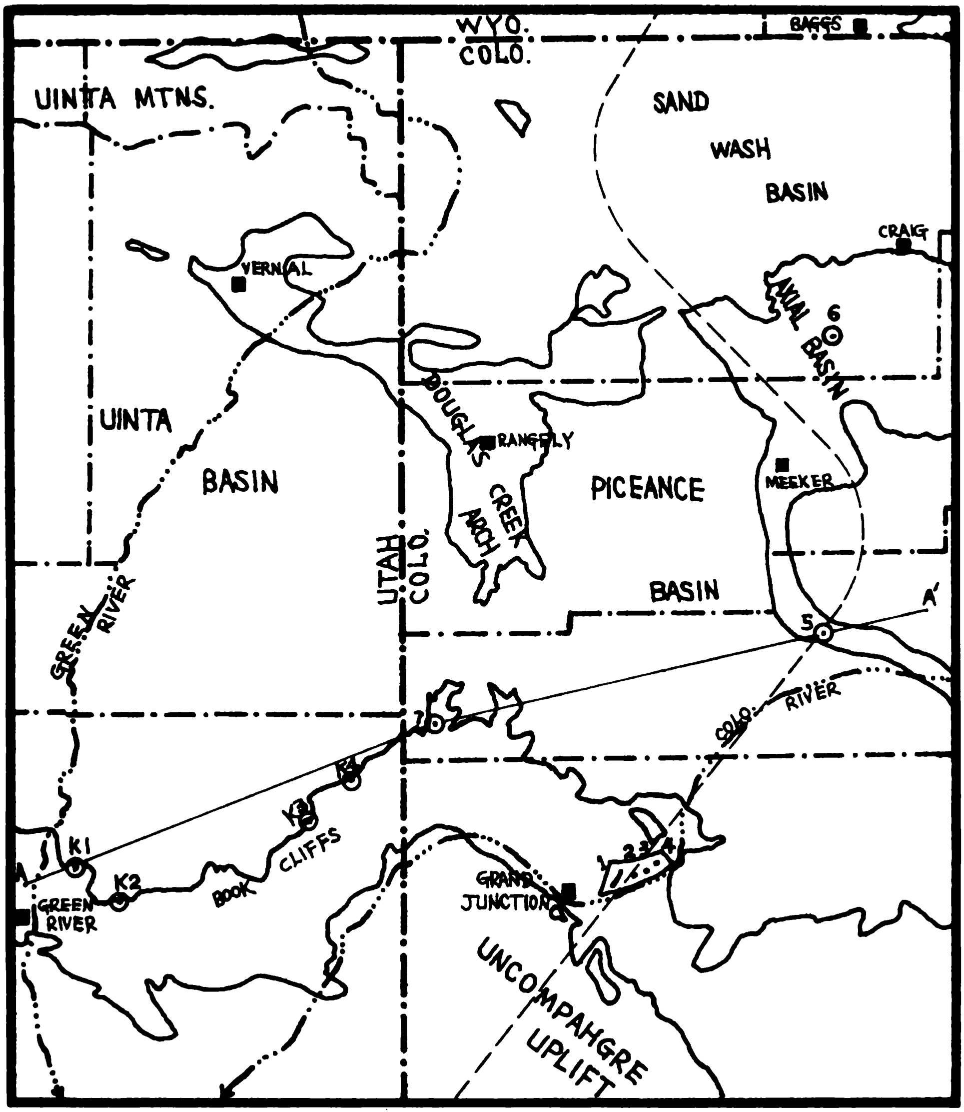
GEOLOGY

Structural and Geomorphic Setting

The thesis area lies in a region dominated by structural basins which formed during the Laramide Orogeny in early Tertiary time (Osmund, 1965), and which lie to the north of the Colorado Plateau.

Five of the seven sections collected for this study are situated along the margins of the Piceance Basin (see Figure 1). The Wilson Ranch section, number 6, is in a flat-lying sequence along the north edge of the Axial Basin, which is separated from the Piceance Basin by the Danforth Hills. The seventh section of this study is also the West Salt Creek section of Kidson (1971), and it lies on the southeast margin of the Uinta Basin. This basin is partially separated from the Piceance Basin by the Douglas Creek Arch, a north-south trending positive feature which began to uplift in the late Cretaceous but did not develop fully until the early Tertiary (Hale and Van de Graaf, 1964).

Sections 1-4 and 7 (and also sections K1-K4, the designation used here for the first four sections in Kidson [1971]) lie along the Book Cliffs escarpment, which forms the northern rim of the Grand Valley of the Colorado River. These cliffs consist of barren slopes of Mancos Shale, capped by the sandstones and interbedded shales and coals of the Mesaverde Group, all of which dip gently into the basins to the north. The trend of the Book Cliffs in this area is determined mainly by the Uncompahgre Uplift to the south, a structurally positive feature which had its major development during the Pennsylvanian period.



Grand Junction Area Composite Section

0 6 12 24 Miles

⊙ Other sections

A ——— A' Cross-section (see Figure 2)

1 Mount Garfield section
2 Palisade section
3 Colorado River section
4 Cameo section
5 Rifle Gap section
6 Wilson Ranch section
7 West Salt Creek section
K4 Westwater Wash section of Kidson (1971)
K3 Cottonwood Creek section of " "
K2 Crescent Wash section of " "
K1 Tuscher Wash section of " "

Political boundaries

Cretaceous outcrops

Approximate Lower Mesaverde strand line trend

Figure 1: Index map, showing structural setting, Lower Mesaverde strand line trend, Cretaceous outcrops, and location of sections.

Quigley (1965, p. 1974) reports a period of renewed uplift of this feature during the Late Cretaceous, and Osmund (1965, p. 1971) mentions another rejuvenation in post-Green River time.

Section 5 lies along the steeply southwest-dipping Grand Hogback, which is a prominent topographic feature forming the northeast rim of the Piceance Basin.

Late Cretaceous Paleogeography and Strand Lines

The basic paleogeographic features of the area in late Cretaceous time were a shallow epicontinental sea in the east, and a land area to the west. The marine basin of deposition was subsiding during the first part of late Cretaceous time (as it had done also in the early Cretaceous), thus providing an area for the accommodation of a very thick wedge of clastic sediments.

The source area for these sediments was in western Utah, which was undergoing continual uplift accompanied by an eastward shift throughout the Cretaceous, thus keeping the subsiding basin amply supplied with sediment. The subsidence of the basin allowed widespread marine transgressions of the adjacent lowlands until the middle of the late Cretaceous, when the dominant trend of sedimentation became regressive (Hale and Van de Graaf, 1964, p. 117). During the time of deposition of the rocks involved in this study (middle and late Campanian, according to Young, 1966, p. 11), the sedimentary regime was thus mainly regressive, punctuated occasionally by transgressive episodes of short duration, resulting in complex intertonguing of continental marine sediments along the western margin of the eastwardly regressing sea. The sections collected for this study all include rocks from this zone of intertonguing upper Mancos and lower Mesaverde Group sediments.

The strand line of the late Cretaceous regressive sea has a northeast-southwest trend in the southern part of the study area. It is a northwest-southeast trend in the northern part of the area (see Figure 1). These statements are based on the work of Hale and Van de Graaf (1964). However, Zapp and Cobban (1960) do not show this reversal in strand line trend to the north. Results of this study make it seem likely that this reversal did indeed exist, possibly because of the presence of a large deltaic system near Rifle Gap. Sedimentary units are thicker and less marine (having higher land derived/microplankton ratios) in the Rifle Gap section than in the Grand Junction area, even though both areas lie approximately along the same strand line (see below). Such a situation could have been caused by faster sedimentation and fresher water associated with a delta near Rifle Gap. The strand line marking the margin of this delta may have thus bulged eastward in a deltaic shape.

The regressive strand line passed through the areas of the Grand Junction Area and Rifle Gap sections at approximately the same time, so that any given lithologic horizon (such as the Cameo-Trout Creek Coal for example) is about the same age in each of these two sections. The strand line passed through the West Salt Creek area earlier than in the cases of the other sections, thus any given lithologic unit which may be recognizable in both this section and those farther east would be older in the West Salt Creek section. The reverse is true for units in the Wilson Ranch section, since any particular strand line did not pass through this area until after it had passed through the others. In other words, the lithologic units laid down by the dominantly

regressive late Cretaceous (late Gulfian) sea in the area of this study transgress upward across timelines in an easterly direction.

For discussion of the facies relationships and paleo-environments adjacent to these strand lines, see Masters (1965).

Stratigraphy

1. Brief Stratigraphy of Collecting Localities

The four localities in the vicinity of Grand Junction, Colorado (see Figure 1), were collected as the Grand Junction Area Composite Section, the major reference section for the thesis, and all other sections were correlated or compared with this composite section. The base of this section is within the Mancos Shale near the base of the Book Cliffs, about 1,700 feet, stratigraphically, below the top of the Corcoran Sandstone. This section extends upward to the top of the Cameo Coal zone. The Cameo Coal lies above the Cameo (Rollins) Sandstone, the youngest sandstone in the Neslen facies of the Price River Formation in the eastern Book Cliffs (see Young, 1955). This composite section includes the stratigraphic equivalents of the strata studied in the other four sections.

The Rifle Gap collection, locality 5, includes the upper part of the Mancos as well as most of the Iles Formation (up through the coals overlying the Trout Creek Sandstone). These samples were collected along the road on the west side of Rifle Gap Reservoir, along a freshly exposed near-vertical surface.

The Wilson Ranch locality, number 6, was a collection from the uppermost Mancos and lower Iles Formations.

In addition to the analyses of the samples from the above collections, this study includes a comparison of the Mount Garfield section

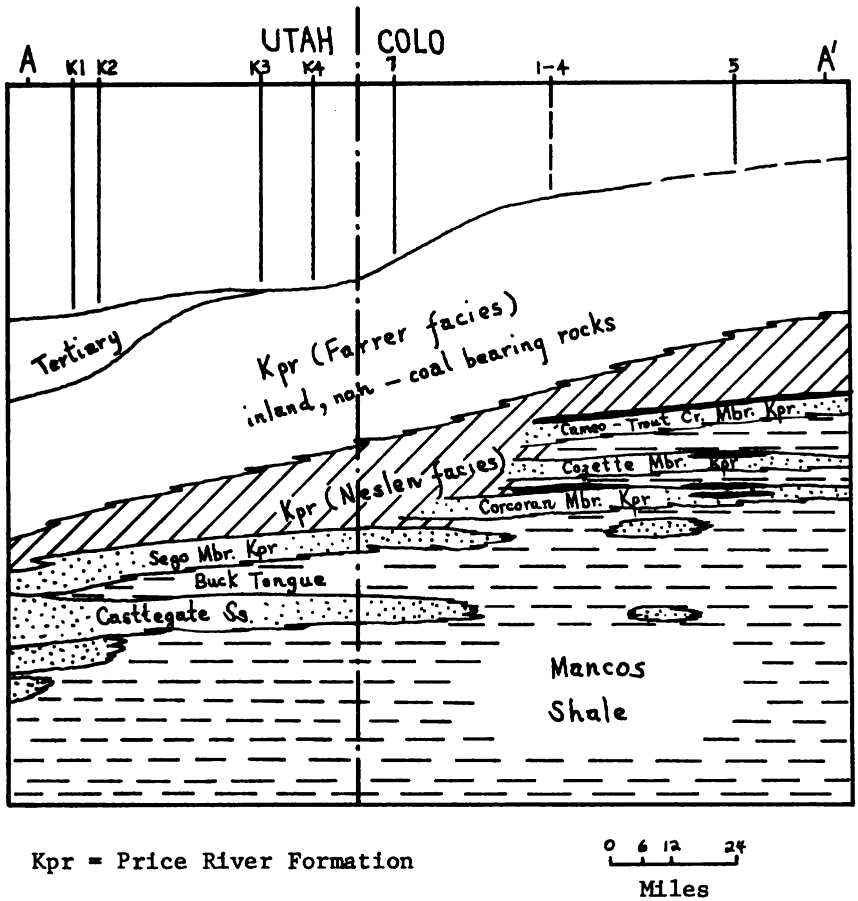
with the easternmost of the sections studied by Evan Kidson and reported in his Ph.D. dissertation (Michigan State University, 1971) on the palynology of the Buck Tongue of the Mancos Shale. The Buck Tongue lies to the west of the present study area, in western Colorado and east-central Utah. Thus, Kidson's easternmost locality (West Salt Creek, locality 7 of this study) is also included in the localities map (Figure 1), and five productive samples from it were studied. Some comparisons were also made with Kidson's other four sections, and they are included on the map of localities for this study as sections K1-K4.

A detailed description of each of the sections used (except for K1-K4) is given in the Appendix.

2. General Stratigraphy of Area

The thesis study involves the upper part of the Mancos Shale, and the lower Mesaverde Group up through most of the thickness of the Cameo Member of the Price River Formation (Young, 1955), and equivalent units. Figure 2, an east-west diagrammatic cross-section of the area, shows the relationships of these units in the sections studied. See Figure 1 for the exact location of the cross-section.

Mancos Shale--The Mancos Shale, named by Cross (1899) from exposures of drab gray marine shale in southwestern Colorado, is the name currently applied to this shale between the Dakota Formation and the lowest sandstone of the Mesaverde Group over a large area of the Western Interior west of the Rocky Mountains. The name is generally restricted to the area south of the Uinta Mountains, but its usage extends to the vicinity of the Wyoming border in the area of northwest Colorado east of the Uintas.



Kpr = Price River Formation

Vertical scale
greatly exaggerated

Figure 2: Diagrammatic cross section of units discussed in this study. See Figure 1 for location of sections. Adapted from Young (1955) and Warner (1964).

The shale is usually monotonously uniform, but is occasionally interrupted by thin limestones, sandstones and concretionary zones. In places the shale is gypsiferous, sometimes forming a white "bloom" on the weathered surface; it is also often calcareous, with occasional zones of calcite crystals. Fossils are rare, but the limestone zones sometimes contain occasional ammonoids, and numerous gastropods and pelecypods. Thin bentonite zones are fairly common, and a 30 foot zone with five bentonites up to three inches thick was sampled by Dr. A. T. Cross and by me on Mount Garfield during the collection of samples for this study. This zone is about 1,200 feet below the Corcoran Sandstone.

The formation is generally from 3,450 to 4,150 feet thick, but locally exceeds 5,000 feet in thickness; the upper 1,660 feet was sampled at Mount Garfield, to the base of the Corcoran Sandstone.

In the thesis area, the top of the main body of the Mancos terminates at the base of the Castlegate Sandstone to the west, and at the base of the Corcoran Sandstone (or approximately equivalent units of the Iles Formation) to the east. Spieker (1949) reports a 2,700 foot stratigraphic rise in this upper contact in the 135 miles between Castlegate, Utah, and Palisade, Colorado. Young (1966) reports the age of the contact as middle Campanian near Helper, Utah, and late Campanian near Palisade, Colorado.

Castlegate Sandstone--This unit has been regarded as a member of the Price River Formation by some authors (Cobban and Reeside, 1952; Young, 1955) and as a separate formation by others (Fisher, Erdmann and Reeside, 1960; Hale and Van de Graaf, 1964). The latter usage is followed here.

The Castlegate extends from the Wasatch Plateau in Utah to the vicinity of West Salt Creek, Colorado. It is about 500 feet at its thickest point in the west. Near the source area it merges into conglomerate beds, and it feathers into the marine Mancos Shale at its easternmost exposure.

Lithologically, the Castlegate is a light gray to light brown, coarse-grained, often cross-bedded, cliff-forming sandstone. It is a marine unit in the West Salt Creek section, the only section of this study in which it occurs.

The top of the Castlegate is a relatively smooth surface which is thought to have been "smeared out" by the rapidly transgressing Buck Tongue sea (see Kidson, 1971, p. 32). The widespread, abrupt contact between the Castlegate Sandstone and the shales of the Buck Tongue is probably the closest approximation to a lithologically recognizable time marker in this region of diachronous Upper Cretaceous strata.

Buck Tongue of the Mancos Shale--The Buck Tongue represents the last major transgression of the Mancos sea in this area, covering at least 90 miles of the western edge of the widespread Castlegate Sandstone. The shale of the Buck Tongue is generally indistinguishable (in lithologic characteristics) from the main body of the Mancos. It is a lithologically separate stratigraphic interval in the West Salt Creek section where it clearly overlies the greatly-thinned Castlegate Sandstone. The possibility of distinguishing this unit palynologically farther east, beyond where it passes into the main body of the Mancos, was one of the topics of investigation of this study. The results of that investigation are reported on page 251.

Price River Formation--This unit was named by Spieker and Reeside in 1925 for a series of noncoal-bearing rocks above the Blackhawk Formation (Young, 1955, p. 186). It is the name now applied to the entire complex of littoral sandstones intertonguing with the upper Mancos in the Book Cliffs region (with the Castlegate being excluded, as noted above) as well as to the continental deposits above them to the base of the Tuscher-North Horn sediments. The names Iles Formation and Williams Fork Formation apply to these sediments along the Grand Hogback (Warner, 1964). Farther west, Price River Formation is the name applied as far north as the Rangely, Colorado, region.

Earlier authors had named two separate formations, the Neslen and Farrer Formations, for Price River beds lying above the Sego Sandstone. However, Young (1955, p. 187-192) correctly recognized the diachronous nature of these units, and renamed them as the Neslen (or coal-bearing) and Farrer (noncoal-bearing) facies of the Price River Formation. The members of the Price River which intertongue with the Mancos all belong to the Neslen facies, but the Castlegate, regarded as such a member by Young (1955), contains sediments of the Farrer facies in its western exposures. This is one of the reasons the Castlegate is here regarded as a separate formation.

Sego Member--The Sego Member of the Price River Formation occurs in this study only in the West Salt Creek section. It grades into the Mancos Shale between that locality and Mount Garfield. The description of the Sego Member given here will suffice in general as a description of the other overlying members of the Price River, and the descriptions of the other members will thus be more brief. The descriptions are largely based on the work of Young (1955) and Hale and Van de Graaf (1964).

The lowest unit of the Sego Member is a basal sandstone, probably representing an offshore bar, perhaps a beach in some areas, which intergrades at the base with the underlying Buck Tongue of the Mancos Shale. In addition to other evidence of their origin as offshore bars, discussed by Young (1955), Masters (1965) and others, this study has revealed a few marine microplanktonic entities and microforaminifera in the sediments just above these sandstones, suggesting the presence of brackish (or perhaps occasionally marine) waters behind the bars. For an extensive discussion of the origin of these sandstones, and of the other depositional environments represented in the sediments of this study, the reader is referred to the work of C. D. Masters (1965).

The sandstone grades from massive, medium-grained, buff sandstone to thin-bedded, fine-grained silty gray sandstones with shale partings and attains a thickness of up to 50 feet. The upper portion of the sandstone is commonly pure white where overlain by coal deposits, probably due to leaching of ferruginous cement by acid swamp waters (Young, 1955, p. 190). This phenomenon is even better developed in the sandstones of the overlying members. Both Masters (1965, p. 26) and Young (ibid.) note that these "white caps" may be found occasionally where there was no overlying coal, but Young refers to such occurrences as giving "the false appearance of white capping as is typical of littoral marine sandstone under coal."

There are several minor littoral marine sandstone tongues in the Sego Member, but only two of importance. The Anchor Tongue of the Mancos Shale lies between these two tongues, which are called the upper

and lower Sego sandstones. Above the upper marine sandstone tongue, coal-bearing rocks were deposited representing a lagoon behind the off-shore bar. These rocks consist of interbedded marine and brackish water sandstones, siltstones, shales and coals. The main coal bed above the upper Sego Sandstone is the Anchor Coal, mined at the Anchor No. 1 Mine northwest of Grand Junction, Colorado (Young, 1955, p. 190). The coal-bearing interval attains thickness of up to 60 feet, and its upper contact is disconformable with the overlying marine shale tongue. This type of contact is also characteristic of the coal-bearing intervals investigated in this study.

Corcoran Member--This member is separated from the underlying Sego Member by a thin tongue of Mancos Shale. It is named for exposures near the old Corcoran Mine north of Palisade, Colorado. It extends from Big Salt Wash, near the Colorado-Utah border, eastward at least as far as Newcastle, Colorado. It is recognizable at least as far north as Rifle Gap, where these Price River members are usually referred to as part of the Iles Formation. The Palisade Coal zone lies atop the main sandstone of the Corcoran Member in the Grand Junction Area Composite section and coal units also appear in the Corcoran Sandstone equivalent in the Rifle Gap section. (See page 263 and Figure 8 for palynological correlation of these two sections.)

The lithology of the Corcoran Member, and its relationships to its enclosing units is the same as for the Sego Member described above.

Cozette Member--This member was named for coal-bearing exposures near the old Cozette Mine north of Palisade, Colorado (Young, 1955). However, in a locality east of Palisade, which was sampled for this study (Colorado River section, see Appendix for detailed lithologic

descriptions), the member does not contain any true coal, although plant-bearing lignitic zones were noted, suggesting that the lagoonal environment (as defined by Masters, 1965) was present, even though an actual coal swamp did not develop at this location.

The Cozette Member extends as far north as Piceance Creek, where it is 200 feet thick, and at least as far south along the Grand Hogback as North Thompson Creek, where it is only 21 feet thick (Warner, 1964, p. 1099). The interval between the top of the Corcoran and the top of the Cozette is much thicker in the Rifle Gap section of the present study than in the Grand Junction Area Composite section. The two sections are along approximately the same strand line, as inferred from Zapp and Cobban (1960), and the Cozette Member should thus represent rocks of the same age in both sections. Palynological analysis indicates that they are of the same age, and that, therefore, the thicker section at Rifle Gap is the result of a higher sedimentation rate rather than representing a longer time interval (see page 263 for further discussion relating to this matter). Several coal zones are present within the Cozette Member at Rifle Gap.

Cameo Member--The Cameo Member is the youngest unit of Mesaverde group rocks included in this study. It is a widespread, thick sequence of coal-bearing rocks underlain by a thick white-capped massive sandstone. The entire interval is about 350 feet thick near Mount Garfield.

First appearing near Hunter Canyon, north of Grand Junction, the member can be traced at least 50 miles southeastward, and 80 to 90 miles northeastward (Young, 1966, p. 17). The basal sandstone of this unit has been called the Rollins by some authors. Young and others disagree with this terminology, saying that the true Rollins is

stratigraphically much higher (Young, 1955, p. 191). The Rollins of the type area of Lee; near Delta, Colorado (W. T. Lee, 1909, cited in Wilmarth, 1938, p. 1839) is the base of the Mesaverde Group at that location, and is no doubt both stratigraphically higher and younger in age due to the southeastward regression of the sea from which it was deposited. The name Rollins (and Trout Creek further north) has been applied to the next sandstone above the Cozette Member in the Grand Hogback at Newcastle, Colorado, by Warner (1964). This sandstone is in the correct stratigraphic position to be equivalent to the basal Cameo sandstone of the Book Cliffs, and is here so regarded. Palynologic analysis indicates that the coal above the basal sandstone of the Trout Creek Member of the Iles Formation at Rifle Gap, which is the lithologic equivalent of the Rollins Sandstone of Warner (1964) at Newcastle, may be the same age as the Cameo Coal, which lies along approximately the same strand line in the Grand Junction area (see page 266 and Figure 8). The Rollins and Cameo Members are also correlated by Quigley (1965, p. 1986). Thus, the Rollins and Trout Creek sandstones as used by Warner, and the basal sandstone of Young's Cameo Member represent the same lithologic unit. Whether they are continuous with the Rollins of the type area near Delta has yet to be proven.

Iles Formation--This formation was named by Hancock (1925) for exposures of interbedded sandstones, shales and coals in Iles Mountain and vicinity, northwestern Colorado. These sediments represent a complex intertonguing of various marine, brackish and fresh water depositional environments, the nature of which are described in detail by Masters (1965). The top of the formation is the Trout Creek Sandstone member, according to Hancock (1925), who assigns the overlying

coal beds to the base of the Williams Fork Formation. According to the practice of dealing with these sandstone-coal sequences followed by Young (1955, 1966) and others in the Book Cliffs region, these coals should be regarded as belonging to the Trout Creek Member of the Iles Formation. This study uses the latter approach in dealing with these coals.

The lower member of the Iles Formation is a thin sandstone, according to Hancock (1925), which is underlain by the Mancos Shale. Masters (1965) names the Caster Member as a basal unit of the Iles Formation in the type area. This member consists primarily of flood plain deposits. At the type area, the basal unit is a coal, the Wilson Ranch Coal (sample number Pb8957-60) of this study. The coal is underlain by a marine sandstone which Masters assigns to the Mancos Shale. The correlation of this sandstone with those of the Book Cliffs and Grand Hogback is apparently unknown, but palynological analysis of the coal above it indicates that the coal could be no higher than the Palisade Coal (see page 269). Further work needs to be done in order to more precisely determine the stratigraphic position of this coal in relation to the Book Cliff coals.

The members of the Price River Formation of the Book Cliffs, the Corcoran, Cozette and Cameo Members, are recognizable in the Iles Formation of the study area. The names used for these three members in the Book Cliffs are used throughout this report wherever these units are recognized irrespective of the fact that different formation names than Price River Formation are used elsewhere.

METHODS OF STUDY

Collection of Samples

The stratigraphic sections sampled for this study were measured using, as needed, a hand level, a Brunton compass, and a carpenter's rule.

Thick, homogenous shale intervals were sampled every 22 feet (four eye heights). A trench approximately three feet long was dug into the shale with a mattock to a depth at which a relatively fresh, unweathered sample could be obtained (usually about one foot deep). A composite sample was taken from the total thickness of unweathered shale so exposed, which varied from one to three feet, depending on such factors as depth of weathering, steepness of slope, and hardness.

Each variation in lithology was sampled separately regardless of the distance to the last sample. Lithologic units less than six feet thick were sampled across their total thickness.

Samples were placed in tightly-woven cloth bags. At the end of each day, samples collected that day were wrapped in newspaper to protect them from contaminating each other during shipment. Two hundred eleven samples were collected and macerated, but only 55, which yielded sufficient palynomorphs for study, were used. This does not include the samples collected and processed by Kidson (1971) as part of his study, five of which were also studied by me. Thus, this study is based on a total of 60 productive samples.

Preparation of Samples

The samples were first crushed in a mortar until the largest pieces were approximately one-fourth inch in diameter. Only a small amount of rock was placed in the mortar at a time and finer portions were removed intermittently in order to reduce destruction of the palynomorphs.

A five gram aliquot of each sample was weighed out. (Some samples had to be re-prepared using 10 grams in order to obtain sufficient palynomorphs for study.)

The weighed aliquots of samples were placed in 10 percent hydrochloric acid for 24 to 72 hours, then washed to neutrality. After this, they were treated with a mild Schulze solution (seven parts concentrated nitric acid to one part saturated potassium chlorate solution) for five to 30 minutes in a hot water bath. Coal samples required about three hours treatment in saturated Schulze solution made by dissolving potassium chlorate powder in concentrated nitric acid.

Following Schulze treatment, the samples were washed three or four times and then treated with five percent potassium hydroxide solution for five minutes in a hot water bath. Then the samples were washed several times, until the supernatant liquid was clear.

After this, a specific gravity separation of the organic fraction, including the palynomorphs, from the inorganic residue was done using zinc chloride solution with a specific gravity of 1.93. The float fraction from this step was diluted with 10 percent hydrochloric acid and distilled water (resulting HCl solution about five percent) in order to reduce the specific gravity enough to permit the residue to be centrifuged down. The residues were then washed with distilled water until neutral. The material which settled to the bottom during heavy liquid separation was discarded, after it was determined that no significant number of palynomorphs remained in it.

The residues were then checked microscopically and, if satisfactory, were stained and mounted.

Unsatisfactory residues were given special treatment. Various minor techniques were used to improve these residues. These included removal of clays by use of glassware detergent solution as a suspending agent, short retreatment with HF to remove fine mineral matter, short additional Schulze treatment, and screening with a 250 micron screen to remove large material. The few samples treated in this manner were checked for megaspores before discarding the large fraction. None were found. Examination of the residues before and after treatment with these special processes indicated negligible loss of palynomorphs. Where appreciable losses were observed, the sample in question was remacerated from a fresh aliquot of material or was eliminated from the study.

Following specific gravity separation and/or the special steps just described, the residues were stained for five minutes with two percent Safranin-O solution, and stored in distilled water to which was added a mixture of hydroxyethyl cellulose (HEC) and phenol, both in two percent solution. The amount of this mixture added was 1/4 to 1/3 of the volume of the residue. Residues were placed in one- or two-dram size, screw-top vials at the proper dilution for making slides. After slides were made, the vials were sealed with paraffin and filed.

Slide-making Technique

Slides for this study were made using a known quantity of residue. Using a known quantity of residue obtained from a known quantity of sediment allows the possibility of estimating numbers of palynomorphs per unit volume of sediment.

Before making slides, the number of drops of residue was counted by dropping them at a moderate, constant rate from a thin-tipped glass pipette equipped with a rubber bulb. The number of drops removed for slides were recorded on the vial's label as the numerator of a fraction, the denominator of which was the total number of drops in the vial. The fraction of the residue used on each slide was written on the slide label.

Four slides were made of each residue, as follows. One drop of residue (in dilute HEC and phenol solution, as described above) was placed on a 22 mm coverslip, and distributed as evenly as possible over its entire surface. The liquid was allowed to evaporate, thus attaching the palynomorphs to the coverslip surface. Then the coverslip was inverted over a drop of HSR (Harleco Synthetic Resin, made by Hartman-Leddon Company, of Philadelphia) on a regular 1"x3" slide.

Counting Procedure

The sum of 500 palynomorphs was selected for counting from each sample used in this study. This sum was chosen by plotting a curve of new taxa encountered versus total palynomorphs counted for several samples which contained the most diverse assemblages in the study. In all of these samples, the sum of 500 fell well to the right of the point at which the curve exhibited a sharp change in slope and began to level off. Usually the curve began to level off at a count of 300 to 400, but 500 was chosen to be certain to collect all the significant information possible within a reasonable length of time and also for ease of computations.

All samples contained a few more taxa than were included in the 500 sum; this would be true in most cases unless all the specimens on the slides were counted. Therefore, after the initial 500 recorded and categorized counts, 1,000 additional specimens were counted for each sample by use of a hand-tally. Only those taxa not previously encountered in the sample were recorded, with a statement that they were not included in the 500 sum. Such reporting of taxa present in very small relative amounts is useful for the purpose of accurately determining ranges of taxa, but is not statistically valid in a rigorous sense. Any taxa noted in addition to those in the 500 count and the 1,000 non-recorded count, such as may have been seen in preliminary scanning, were also included as present but not in the 500 sum.

The counting was carried out using basically the same system of traverses as used by Kidson (1971). The first six traverses were assigned certain definite distances (10 mm, 1 mm, 15 mm, 12 mm, 6 mm and 20 mm respectively) in from the edge of the coverslip farthest from the investigator. This was to ensure that a sampling of most "geographical" areas of the coverslip would be made, and is admittedly non-random. The remainder of the traverses up to a total of 25, were drawn by lot from a total of 100 possible traverses (the original six were omitted from the drawing, and the two outermost traverses per coverslip were omitted to eliminate a region of drying cracks which had developed near the edge in some samples). The same sequence of traverses was followed for each sample.

No more than 100 entities were counted per traverse. Upon reaching 100 counts on a traverse, the location and traversing direction were noted, in order to enable determination of number of palynomorphs per gram of sediment, if desired. In the event that 100 palynomorphs were counted before reaching the center of the coverslip, the count was extended above 100 until the center was reached, in order to overcome any bias due to a centering effect of certain sizes or types of palynomorphs.

In order to avoid possible biases from one slide of a residue to the next, at least two slides were studied for each sample. The sequence of traverses outlined above was followed on the first slide until either the whole 25 traverses were exhausted or until 250 palynomorphs were counted. The position of the 250th entity was recorded, and the next traverse in the regular sequence was begun on the second slide. Thus, at least six different traverses were counted, at least in part, per sample, and at least two slides per sample were examined. If 500 entities could not be counted in the 50 traverses of the first two slides, the third and, if necessary, the fourth slide per sample were examined, using the same 25 traverses per slide.

Not all the samples macerated contained sufficient well-preserved palynomorphs to be useful. Before counting was begun, the slides from all the samples were subjectively judged to be useable or non-useable. Those judged useable were counted. Upon reaching a count of 100 (or fewer for obviously very poor samples), the relative percentage of entities in unknown (unidentifiable to genus, see below) categories was calculated. If over 30% of the entities counted in a sample were unknowns, the sample was judged to be too poorly preserved to be reliable, and no further counting was done. Samples were also regarded as unreliable if the Unknown Palynomorph (not identifiable even to division level) category exceeded 12%.

In addition to the 214 palynomorph types identifiable to approximately generic level, the following "unknown" categories were also included in the counts: unknown angiosperm (these had angiospermous wall structure but were too folded or corroded for further identification), unknown tricolpate, unknown triporate, unknown tricolporate, unknown bisaccate, unknown pollen (obviously pollen but not possible to distinguish positively whether gymnospermous or angiospermous, tricolpate or monosulcate, etc.), unknown trilete spore, unknown monolete spore, unknown spore, unknown land-derived (this was a rather subjective category, rarely used in cases where wall structure and other characteristics did not seem to fit any microplankton group but it was impossible to tell for sure if the entity in question was a spore or a pollen grain; the same type of reasoning, but in a reverse direction, applies to the next category, unknown microplankton), unknown dinoflagellate, unknown hystrichosphere (chorate dinoflagellate cyst) and unknown acritarch.

Even though other studies have excluded such unknowns from the sum counted, I felt that to exclude them would eliminate the possibility of considering all potentially useful data inherent in the samples. Their elimination also tends to minimize the restrictions imposed on the reliability of the data by poor preservation and other factors. Every complete or nearly complete palynomorph, regardless of its further identifiability, was counted, thus preserving all the data which could possibly be extracted from the samples, as well as building an "index of reliability" or "index of preservation" into the data. (No quantitative index was attempted, but obviously a sample with a high percentage of unknown categories would indicate lower reliability of relative abundance figures and poorer preservation than one with a low percentage of unknowns. A high percentage of unknowns allows the possibility that certain palynomorph types were rendered unrecognizable more easily than others and that, therefore, all the relative abundance figures in such samples may be biased to a greater or lesser degree by this possibly selective degradation. This factor is not considered fully, if at all, by studies which exclude poorly preserved entities from counts.)

In addition to giving an exact, potentially quantifiable idea of the preservation and reliability of the samples, counting in this manner may reveal that preservation varies with paleoenvironmental parameters such as distance from shore, water depth, salinity, temperature, and presence of other organisms, if these parameters can be determined.

SYSTEMATICS

Taxonomic Listing

Two-hundred fourteen separate kinds of palynomorphs, mostly of specific rank, are reported here. Initially, I had planned to classify the palynomorphs in this study according to their formal taxonomic position in a natural system. However, so many forms are of uncertain origin that I decided to merely list the land-derived forms in alphabetical order under the following categories: TRILETE SPORES, MONOLETE SPORES, SPORES INCERTAE SEDIS, GYMNOSPERMOUS POLLEN (with the exception of monosulcate forms), NON-RETICULATE MONOSULCATE POLLEN (this category probably includes mostly gymnospermous forms, but may include some non-reticulate angiospermous pollen, such as palm pollen), and ANGIOSPERMOUS POLLEN (with the exception of any which may be unrecognized angiosperms included in the preceding category).

Clavatipollenites cf. *C. minutus* Brenner is included with the non-reticulate monosulcates, even though it is more or less reticulate, because it shares the questionable status of many members of that group; i.e., it is not possible to say with certainty whether it shares closest affinities with the gymnosperms or the angiosperms.

GYMNOSPERMOUS POLLEN is separated into the sub-categories Bisaccate Pollen, Monosaccate Pollen, Perinate Pollen, Inaperturate Pollen, Polyplicate Pollen and Eucommiiditean Pollen.

ANGIOSPERMOUS POLLEN is separated into the subcategories Inaperturate Pollen, Reticulate Monosulcate Pollen, Tricolpate Pollen,

Aquilate Pollen, Tricolporate Pollen, Triporate Pollen and Polyporate Pollen.

The microplankton was classified according to the artificial taxonomic system recommended by Downie, Evitt and Sarjeant (1963) and later extended and modified by these and other authors.

As many forms were assigned to previously published species as possible. However, several were cited using question marks or the "cf." designation, and many forms were identified to the generic level, with species being designated, if at all, by the use of sp.-1, sp.-2, and so on. A few palynomorph types could not be assigned beyond a major heading, and are cited with the title of that heading, as for example Bisaccate-1, Unknown Dinoflagellate-4, and so on.

The reasons for each of the varied citations above is given under the discussion of each species or, in some cases, in a commentary section under a higher category. The most common reasons for not assigning these palynomorphs to recognized species were unavailability of type materials for comparison, poor preservation (many specimens were corroded, punctured by pyrite crystals, or obscured by adhering materials), and inadequacy of the original description and/or illustration of a species to allow confident assignment of specimens to that species.

A few of the species reported here may never have been previously described, but it is my judgment that a disservice is done to the science of palynology by defining new species without having seen the type materials of all similar taxa; and I further believe that an international moratorium on the describing of new species should be declared until the complex synonymy and errors in taxonomy up to the

present can be worked out monographically. Perhaps an exception could be made for taxa obviously grossly different from any in the literature; such a taxon would not be validly published during the period of the moratorium unless approved by an international review board.

Too many "new" species are so similar to already published forms as to be indistinguishable on the bases of descriptions and photographs. There is a need for many palynologists to turn to the difficult and lengthy task of correcting the deleterious effects of past taxonomic abuses by detailed, careful, thorough monographic revisions of all taxa of palynomorphs. Here again some type of international coordination would be desirable to set standards and avoid duplication of effort; the beginning of the work should not await the formation of such a body, however.

Stratigraphic workers in new areas who discover apparently new taxa could report them as is done in the present study, or undertake to completely and carefully compare all similar type materials and essentially monograph the new taxon as it is first reported. Alternatively, number-letter combinations as proposed by Tschudy (1957) could be used for local stratigraphic work, or studies of depositional environments, with no necessity for cluttering the literature with "new" incompletely compared, illustrated and described formal taxa.

Method of Description and Discussion of Palynomorphs

The palynomorphs reported herein are formally described only if they are not definitely referred to a published species.

All reported species include the size range as observed in this study and the number of specimens measured, followed by an "occurrence"

section discussing the number of occurrences in the study, any trends observed in the distribution, and the stratigraphic range of the taxon as per the literature for those forms assigned to published species. Next, the suggested affinity is given (for land-derived forms), if known. Finally, a "discussion" section is given, including various topics such as reasons for the taxonomic placement of the species, characters which distinguish the species from similar forms, and comments on the affinities of the species.

The location of reference specimens is given in the plate descriptions. Microscope coordinates are listed for each specimen illustrated. These coordinates are from a Zeiss GFL Microscope. An "X" is scratched into the upper left-hand corner of each slide containing reference specimens, with the coordinates of the center of the "X," as determined using the same microscope, being recorded on the slide label. This enables calculation of the position of the reference specimen for location of the specimen using other microscopes.

The sample numbers referred to in the descriptions are the access numbers by which the slides and samples are filed in the paleobotany collection of Michigan State University.

The paleoenvironmental conclusions regarding the probable depositional environments of samples mentioned in discussing the palynomorphs were arrived at by study of Land Derived/Microplankton ratio curves (see Figure 7) and relating this information to the lithology, and to the paleoenvironments determined by Masters (1965) in his study of the sedimentology of Mancos-Mesaverde sediments in northwestern Colorado.

TRILETE SPORES

Genus Acanthotriletes Naumova ex Potonie and Kremp, 1954

Type species: Acanthotriletes ciliatus Potonie and Kremp, 1954

Acanthotriletes cf. A. levidensis Balme, 1957

Plate 1, Figure 1

1957 Acanthotriletes levidensis Balme, p. 18, pl. 1, figs. 18-19.

Description: Trilete, laesurae indistinct, extending to equator; equatorial outline circular or rounded triangular; exine ornamented by spines ca. 1 micron long, spaced 2 to 4 microns apart on distal surface; proximal side has a few spines near the equator, remainder of proximal side is unornamented.

Size range: 19-27 microns; three specimens measured.

Occurrence: Acanthotriletes levidensis has been reported from the Lower Cretaceous (Balme, 1957) to Upper Cretaceous (Norton and Hall, 1969) in various parts of the world. The species considered here is scattered throughout the sections of the present study (30 samples) in very low numbers (up to 0.8%) with no discernible pattern of distribution. A. levidensis has been reported from the Buck Tongue of the Mancos Shale in Utah by Kidson (1971).

Suggested affinity: Selaginella? (Balme relates his specimens to the Selaginella subarborescens group of Knox (1950).

Discussion: This species is tentatively assigned to A. levidensis because it has indistinct laesurae, which is not generally the case in A. levidensis, and also because the spines are sparser than on Balme's specimens.

A. varispinosus Pocock, 1962, has much larger, longer spines than this species.

Genus Appendicisporites Weyland and Krieger, 1953

Type species: Appendicisporites tricuspidatus Weyland and Krieger, 1953

Appendicisporites potomacensis Brenner, 1963

Plate 1, Figure 2

1963 Appendicisporites potomacensis Brenner, p. 46, pl. 6, figs. 4-5.

Size range: One specimen found, 50 microns diameter.

Occurrence: Various Lower Cretaceous horizons in many areas. Reported from the Buck Tongue of the Mancos Shale by Kidson (1971). The only occurrence in the present study is a single specimen, also on one of Kidson's Buck Tongue slides (sample Pb4741a).

Suggested affinity: Schizeaceae.

Discussion: No attempt was made to trace the synonomy of this species because only one specimen was encountered, and because this genus is characterized by a proliferation of species not clearly separated from each another. A monographic treatment is needed for this group, but is beyond the scope of this paper. See Brenner (1963, p. 46) for description, etc.

Appendicisporites sp.

Plate 1, Figure 3

1971 Appendicisporites cf. A. dentimarginatus Brenner, 1963, in Stone, p. 83, pl. 11, fig. 63.

Description: Trilete, laesurae reach margin; equatorial outline triangular; sides straight to slightly concave; ornamentation cicatricose; muri robust, 2-1/2 to 4 microns wide and high, with fairly rough, wavy appearance, extending beyond spore margin as separate projections from the apices; 5 to 6 muri per side of spore, paralleling the equator; top 2 or 3 muri per side fuse at apices to form appendici which extend 3-1/2 to 5 microns beyond margin.

Size range: 40 to 55 microns, three specimens measured.

Occurrence: Present in abundances of 0.4% or less in four marine shale samples irregularly distributed in the sections studied. Stone (1971) reports these spores from one sample in the Lower Almond Formation (Upper Cretaceous) of southwestern Wyoming. Clarke (1963) has reported a similar species (species A, p. 47) from the Upper Cretaceous of Fremont County, Colorado.

Suggested affinity: Schizeaceae.

Discussion: Stone (1971) considered these spores as being similar to A. dentimarginatus Brenner except for their larger size. My specimens, which are probably conspecific with Stone's, differ from Brenner's in equatorial outline and do not have an equatorial dentate zone, although the muri often exhibit a rough, wavy appearance. As far as I was able to determine, this "species" is not described in the literature. However, because of the already chaotic taxonomy of this group and because too few specimens were available for proper characterization of a new species, no new species is erected for these forms here.

Genus Camarozonosporites Pant ex. Potonie,
emend. Klaus, 1960

Type species: Camarozonosporites cretaceous (Weyland and Krieger) Potonie, 1956

Camarozonosporites hamulatis (Krutzsch, 1959) Krutzsch, 1963

Plate 1, Figures 4-5

1959 Hamulatisporis hamulatis Krutzsch, p. 157, pl. 29, figs. 326-328.

1963 Lycopodiacidites cerniidites auct. non Ross: BRENNER, p. 43, pl. 5, fig. 2.

1963 Camarozonosporites (H.) hamulatis (Krutzsch, 1959) Krutzsch, p. 23.

1967 Camarozonosporites insignis Norris, p. 96-97, pl. 13, figs. 12-16.

1969 Perotriletes sp., auct. non: LAMMONS, p. 115, pl. 4, fig. 3.

Description: As given for C. insignis in Norris (1967, p. 97), with this exception: The interradial crassitudes are usually, but not always, present, and considerable variability is exhibited in their development, even from one interradial area to another on the same specimen. See discussion below.

Size range: 26-35 microns diameter, several specimens measured (literature size range: 25-55 microns).

Occurrence: Albian to M. Eocene (see Norris, 1967, Oltz, 1969, and Krutzsch, 1959). Irregularly distributed through the sections of the present study (22 samples); sample abundance of 0.8% or less. Other occurrences from the Upper Cretaceous of the western interior of the U. S. are reported in Thompson (1969), Stone (1971), Kidson (1971), and Lammons (1969, reported there as Perotriletes sp.).

Suggested affinity: Lycopodiaceae.

Discussion: The spores of this species (and genus) have been the subject of considerable confusion in the literature, so an attempt at clarification is in order.

Krutzsch (1959) set up the genus Hamulatisporis for Camarozonosporites-like spores which lacked the apical thinning of the equatorial exine mentioned in Klaus' (1960) emendation of Camarozonosporites. Krutzsch (1959) recognized variability in this feature, however, as well as transitional forms between the two genera. Dettmann and Playford (1968, p. 79) report that Krutzsch later (1963) recognized that his Hamulatisporis was synonymous with Camarozonosporites as emended by Klaus. Thus, the genus Hamulatisporis is invalid.

It should be noted that variability in the "interradial crassitudes" of Camarozonosporites is allowed for by the fact that Hamulatisporis, originally set up for spores lacking such crassitudes, was combined with Camarozonosporites as a junior synonym. Indeed, careful reading of the original German in Klaus' emendation of Camarozonosporites reveals that Klaus does not say all spores of that genus must be thickened interradially. What Klaus says is that the spores characteristically have the exine thinner in the apical regions of the equator, which IN THOSE CASES WHERE THE EXINE IS SO THINNED, (my emphasis), creates an appearance in polar view of convexly arched equatorial interradial margins.

It is, therefore, obvious that authors are not justified in describing Camarozonosporites as consisting of spores with prominent equatorial interradial crassitudes (as does, for instance, Singh (1971, p. 110). Dettmann and Playford (1968, p. 79) recognize this, as they assign to the genus spores which have only slight equatorial thickenings. This feature is variable, even from one interradial region to the next on the same specimen. (See Norris' illustrations of C. insignis, for example; Norris, 1967, pl. 13, fig. 12-16.) The condition may even be a folding or crushing phenomenon rather than an actual thinning or thickening. The generic description of Camarozonosporites should possibly be re-emended to make it clear to all that the equatorial thickening is variable and may even be absent.

The species encountered in the present study fits the description of Camarozonosporites insignis Norris and Hamulatisporis hamulatis Krutzsch, which are essentially the same except for the fact that H.

hamulatis is supposed to lack the equatorial "crassitudes" exhibited by C. insignis. Actually, Krutzsch's holotype of H. hamulatis shows a definite thinning of the exine at the apices in the equatorial region (see Krutzsch, 1959, pl. 29, fig. 326-328). Krutzsch mentions variability in this feature, and Norris' illustrations of C. insignis show some variability, as mentioned earlier. This variability was also observed in my specimens.

Since the name Hamulatisporis is invalid as a generic name, these specimens must be assigned to Camarozonosporites, as Krutzsch (1963) did. The specific epithet from H. hamulatis was retained because of priority; and C. insignis Norris becomes a junior synonym of C. hamulatis (Krutzsch, 1959) Krutzsch, 1963.

Genus Chomotriletes (Naumova) ex. Naumova, 1953

Type species: Chomotriletes vedugensis Naumova, 1953

Chomotriletes fragilis Pocock, 1962

Plate 1, Figure 6

1962 Chomotriletes fragilis Pocock, p. 39, pl. 2, figs. 30-32.

Size range: 19-23 microns, three specimens.

Occurrence: Lower Cretaceous (see Pocock) to Upper Cretaceous (present study). Found in two samples (one specimen in sample Pb6741, two specimens in sample Pb4972) from the Mancos Shale of Mount Garfield.

Suggested affinity: Possibly schizeaceous.

Discussion: Lammons (1969, pl. 3, fig. 5) illustrates a similar form, from the Upper Cretaceous of northwestern Kansas, using the designation Chomotriletes cf. C. fragilis Pocock. However, Lammons' specimens are much larger than Pocock's. (Lammons' illustrated specimen is 41 x 49 microns, while Pocock's stated size range for _C. fragilis_ is 23-27 microns.)

Genus _Cicatricosisporites_ Potonie and Gelletich, 1933

Type species: _Cicatricosisporites dorogensis_ Potonie and Gelletich, 1933

Cicatricosisporites spp.

Plate 1, Figure 7

Description: No description is given, as this category includes spores which probably represent several species of _Cicatricosisporites_. For genetic description, see Potonie and Gelletich, 1933, p. 522.

Size range: ca. 30 to ca. 55 microns diameter; several specimens measured.

Occurrence: Widespread in Upper Jurassic to Lower Tertiary deposits, worldwide. Occurs sparsely scattered throughout the present study in percentages of 0.6% or less.

Suggested affinity: Schizeaceae.

Discussion: Initially, an attempt was made to separate the species of _Cicatricosisporites_ encountered, but it was later decided to combine them. This was done because of the poor preservation of most specimens observed, the scarcity of the occurrences, and the notoriously confused state of the taxonomy of this group. The scarcity and poor quality of most specimens may indicate recycling from older deposits.

The specimen illustrated, one of the best preserved examples found, may be a representative of *Cicatricosisporites potomacensis* Brenner, 1963.

Genus *Cingulatisporites* Pflug, emend. Potonie, 1956

Type species: *Cingulatisporites levispeciosus* Pflug, 1953

Cingulatisporites dakotaensis Stanley, 1965

Plate 1, Figures 8-9

1965 *Cingulatisporites dakotaensis* Stanley, p. 243-244, pl. 30, figs. 1-8.

1969 *Cingulatisporites pierrensis* Lammons, manuscript name, p. 96-97, pl. 3, fig. 4.

Size range: 25-32 microns diameter, including cingulum; six specimens measured.

Occurrence: Uppermost Cretaceous and lowest Paleocene, western interior of North America (Stanley, 1965, and Snead, 1969). Scattered through the present study (12 samples) in sample percentages of 0.6% or less, no discernible pattern of distribution. Other Upper Cretaceous occurrences reported by Lammons (1969) from northwestern Kansas (see synonomy above) and by Stone (1971) from southwestern Wyoming.

Suggested affinity: *Selaginella*? Bryophyta?

Discussion: Stanley assigns these spores tentatively to *Selaginella*. However, these spores also resemble spores of the genus *Stereisporites*, which are usually referred to the Bryophyta. One of Stanley's figured specimens (figure 5, plate 30, Stanley, 1965) may be a specimen of *Stereisporites antiquasporites*. I observed many spores of the latter species during the course of work in the summer of 1971 for Amoco Production Company in Tulsa, Oklahoma, as well as during the present study. A feature resembling the distal "Y"-mark of *C*.

dakotaensis is often present, which, coupled with the equatorial stereozone, create a strong resemblance to C. dakotaensis. Thus, these two species may sometimes have been confused in the literature, and they may have been produced by similar plants. In any case, no strong statement can be made as to their botanical position.

Griggs (1970, pl. 7, fig. 11) illustrates a spore designated as S. antiquasporites, which strongly resembles, and may indeed be, a representative of C. dakotaensis.

C. radiatus Stanley can be differentiated from C. dakotaensis by its striate cingulum, but it is otherwise quite similar.

Genus Cyathidites Couper, 1953

Type species: Cyathidites australis Couper, 1953

Cyathidites minor Couper, 1953

Plate 1, Figure 10

1953 Cyathidites minor Couper, p. 28, pl. 2, fig. 13.

Size range: 23-32 microns, several specimens measured.

Occurrence: Jurassic and Cretaceous rocks of diverse areas of the world (see Couper, 1953 and 1958, Hedlund, 1966, etc.). Found in a high percentage of the samples of this study (43 samples) in low relative frequency (highest: 1.4%), with no discernible pattern. Another western interior Upper Cretaceous occurrence is reported in Griggs (1970). Stone (1971, pl. 10, fig. 52) illustrates a specimen which fits into C. minor, using the name Deltoidospora diaphana Wilson and Webster, 1946. Stone's photograph shows longer rays than normal for D. diaphana, and the size range (28-48 microns) is much broader than Wilson and Webster's (42-46 microns).

Suggested affinity: Filicinae. Couper (1958) relates these spores to the Cyathaceae and Dicksoniaceae. Hedlund (1966) relates them to the Schizeaceous genus *Lygodium*. Some members of the Gleicheniaceae are also similar.

Discussion: Species similar to *C. minor* Couper are *C. australis* Couper, *Deltoidospora diaphana* Wilson and Webster, 1946, and *Cardioangulina diaphana* (Wilson and Webster) Stanley, 1965.

C. australis has a mean diameter roughly 25 microns greater than the mean for *C. minor*, though there is some overlap.

D. diaphana has shorter rays (roughly 1/2 spore radius vs. over 2/3) than *C. minor*. Wilson and Webster (1946) gave a size range of 42-46 microns for *D. diaphana*, while *C. minor* has a range of 26-56 microns (Couper, 1958, p. 139).

Stanley (1965, p. 248), in transferring *D. diaphana* to the genus *Cardioangulina*, also markedly extended the size range of the species in a downward direction, giving a range of 25-40 microns for *Cardioangulina diaphana*, while Wilson and Webster (1946) gave a size range of 42-46 microns (as already mentioned). Thus, since Stanley's specimens were of markedly differing size and don't even include the size range of the type material for the species, Stanley may have been unjustified in placing his specimens in the same species as Wilson and Webster's, and in so changing the size range of that species. As *C. diaphana* now stands, the only difference between it and *Cyathidites minor* is a slight and not always constant difference in the length of the rays. Thus, there is a certain amount of overlap between these two species, creating potential confusion in identification, especially where specimens are not plentiful. This problem merits more study in order to more clearly establish exactly how many truly different groups are involved.

Genus Dictyophyllidites Couper, 1958

Type species: Dictyophyllidites harrisii Couper, 1958

Dictyophyllidites? sp.

Plate 1, Figure 11

Description: Trilete spores laesurae almost reaching margin; laesurae bounded for their entire length by thickenings 2-3 microns thick, which may be interpreted as a wide margo, or as tori; outline in polar view triangular with straight to slightly concave sides; exine smooth, dense, ca. 1/2-1 micron thick.

Size range: 20-23 microns; three specimens measured.

Occurrence: Found in 16 marine shale samples scattered through the sections studied. Sample percentage never over 0.6%.

Suggested affinity: Couper relates Dictyophyllidites tentatively to the Cheiropleuriaceae; however, these specimens also resemble members of the Gleicheniaceae.

Discussion: These specimens somewhat resemble a spore illustrated as Dictyophyllites sp. in Brenner (1963, pl. 12, fig. 4). Couper (1958, p. 140) defines that genus as having a margo, although his illustrations of the type species, D. harrisii (ibid, pl. 21, fig. 5-6), shows what would better be referred to as tori rather than a margo. The specimens found in this study possess thickenings which strain the definition of the term "margo," but could be regarded as tori.

It is not certain whether these specimens should be regarded as belonging to Dictyophyllidites, although they fit the definition of the genus fairly well. They also resemble certain variant spores produced in the same sporangia as typical *Gleicheniidites senonicus* spores, and should perhaps be regarded as belonging to that species (see Skarby, 1964).

Genus *Foraminisporis* Krutzsch, 1959

Type species: *Foraminisporis foraminis* Krutzsch, 1959

Foraminisporis wonthaggiensis (Cookson and Dettmann)
Dettmann, 1963

Plate 1, Figures 12-13

1963 *Foraminisporis wonthaggiensis* (Cookson and Dettmann) Dettmann, p. 71-72, pl. 14, figs. 19-23.

1971 *Foraminisporis undulatus* Leffingwell, p. 25, pl. 4, fig. 5.

1971 *Conbaculatisporites undulatus* (Leffingwell) Stone, manuscript name, p. 80-81, pl. 11, figs. 58-59.

Size range: 38-45 microns, five specimens.

Occurrence: Barremian to Maestrichtian strata, widespread localities (see Dettmann, 1963, and Leffingwell, 1971). This species is scattered throughout the sections of the present study (21 samples, up to 0.8% per sample) and was reported from the Upper Cretaceous Almond formation of southwestern Wyoming by Stone (1971).

Suggested affinity: Dettmann notes its similarity to the living anthocerotid liverwort *Notothylas*, but it is also similar to several types of osmundaceous spores (see discussion below).

Discussion: Leffingwell gives the following diagnosis as a basis for distinguishing his specimens from those of Dettmann: "This species is distinguished from *Foraminisporis wonthaggiensis* Dettmann, 1963, in having less densely spaced spines on its proximal surface and larger sculptured elements on its distal surface."

However, comparison of Leffingwell's and Dettmann's photographs of their respective taxa does not reveal any obvious differences of sufficient magnitude to allow consistent differentiation of the two. It is my opinion that these slight, rather subjective differences are not sufficient nor consistent enough to justify addition of another new taxon to the palynological literature, and Leffingwell's species is here regarded as a junior synonym of *F. wonthaggiensis*.

F. foraminis Krutzsch differs in that the rays of the laesurae split into two branches as they approach the equator. *Baculatisporites comaumensis* (Cookson) Potonie, 1956, differs in having more abundant and closely spaced baculae.

As to the affinities of this species, in addition to its resemblance to the liverwort *Notothylas*, Dettman mentions its similarity to several fern spore taxa. It also has gross similarities to other osmundaceous spores, and may indeed be a fern spore. It is found in this study in samples presumed to be far from shore as well as in near-shore samples. The "taxon" Unknown Trilete Spore-1, of unknown but possibly hepatic affinities, is restricted to coals, which may indicate that liverwort spores don't travel far. If this is the case, it argues against *F. wonthaggiensis*' being a liverwort spore. However, both taxa occur in such low numbers that it is unwise to derive definite conclusions based on their distributions.

Genus *Gleicheniidites* Ross ex. Delcourt and Sprumont, 1955

Type species: *Gleicheniidites senonicus* Ross, 1949

Gleicheniidites senonicus Ross, 1949

Plate 1, Figures 14-15

1949 Gleicheniidites senonicus Ross.

1964 Gleicheniidites senonicus Ross in Skarby, pp. 60-77, pls. 1-3.

Size range: 19-32 microns, many specimens.

Occurrence: Widespread in Jurassic and Cretaceous strate, world-wide.

Found in most samples (52 samples) of the present study in widely varying abundance, up to 3.2%.

Suggested affinity: Gleicheniaceae.

Discussion: Skarby (1964) gives an excellent account of the extensive synonymy of this species. She shows, by study of sporangia of fossil ferns producing the G. senonicus type of spores, that what had been previously regarded as being several different species and even genera of spores could all be found within a single sporangium. Much of the literature regarding this species and similar forms shows confusion and inconsistent identification, both before and after Skarby's work appeared.

Genus Klukisporites Couper, 1958

Type species: Klukisporites variegatus Couper, 1958

Klukisporites pseudoreticulatus Couper, 1958

Plate 1, Figure 16

1958 Klukisporites pseudoreticulatus Couper, p. 138, pl. 19, figs. 8-10.

1962 Dictyotriletes pseudoreticulatus (Couper) Pocock, p. 6, pl. 3, figs. 46-47.

Size range: 33-35 microns, two specimens measured.

Occurrence: Occurs once in each of eight samples with no recognizable pattern of distribution. Reported from Jurassic and Cretaceous formations of diverse areas.

Suggested affinity: Couper set up the genus for spores of the type produced by the Jurassic schizeaceous ferns Klukia exilis and Stachypteris hallii.

Discussion: I apologize for the poor quality of the photograph of this species. All specimens were poorly preserved, and no better picture was available at the time the plates were completed.

Pocock (1962) assigned this species to Dictyotriletes without citing his reasons. The generic diagnosis for Dictyotriletes, as it appears in Pocock (1962, p. 41), says spores of that genus have smooth to scabrate proximal sculpture. Couper (1958, p. 138) describes the proximal surface of K. pseudoreticulatus as "smooth around laesurae, distal sculpture encroaches on to the proximal surface between arms of the triradiate scar." This would seem to exclude it from the genus Dictyotriletes. Also, the latter genus is supposed to have low, flattened muri. I consider the muri of K. pseudoreticulatus to be fairly robust and not particularly flattened. Pocock's specimens seem to be the same as the ones considered here.

Griggs (1970, pl. 4, fig. 10) illustrates a spore which he calls K. pseudoreticulatus, but which appears to be different from Couper's species, and should more likely be assigned to Corrugatisporites solidus (Potonie) Pflug, 1953.

This species is very similar to Ischyosporites punctatus Dettmann, 1963; the main difference being the presence of apical valvae in the latter, which are not always well developed.

The sparse occurrence and poor condition of these spores and the normal range for the genus being older may indicate reworking.

Genus Kuylisporites Potonie, 1956

Type species: Kuylisporites waterbolki Potonie, 1956

Kuylisporites scutatus Newman, 1965

Plate 2, Figures 1-2

1965 Kuylisporites scutatus Newman, p. 9-10, pl. 1, fig. 1.

1971 Camarozonosporites insignis auct. non Norris: KIDSON, p. 59, pl. 1, fig. 9.

Size range: 24-30 microns; three specimens measured.

Occurrence: Was found once in each of three samples from the lower part of the Mount Garfield section.

Suggested affinity: Hemitelia.

Discussion: The spore Kidson (1971, pl. 1, fig. 9) illustrates as Camarozonosporites insignis Norris is a specimen of Kuylisporites scutatus which is unusually rugulate. The prominent interradial scutulae clearly identify it as a member of K. scutatus, however, and Newman (1965, p. 10) allows for a rugulate distal surface in the description of K. scutatus. Kidson appears to have mistaken the scutulae for the interradial crassitudes mentioned in the specific description of C. insignis Norris (see also Camarozonosporites hamulatis (Krutzsch) Krutzsch, 1963, above, for discussion of the "interradial crassitudes" of that species).

Lammons (1969, pl. 3, fig. 3) illustrates a spore which he calls Kuylisporites waterbolki Potonie, but which is probably K. scutatus.

Hemitelites laevis Romanovskaya, 1960, which is an invalid name since no generic description has been published, is similar to K. scutatus, but has a smoother surface and shorter laesurae (see Catalog of Fossil Spores and Pollen, vol. 16, p. 62).

Genus Leiotriletes Naumova ex Potonie and Kremp, 1954

Type species: Leiotriletes sphaerotriangulus (Loose) Potonie and Kremp, 1954

Leiotriletes varius Bolkhovitina, 1953

Plate 2, Figure 3

1953 Leiotriletes varius Bolkhovitina, in Catalog of Fossil Spores and Pollen, vol. 8, p. 5.

Size range: 26-28 microns diameter; two specimens measured.

Occurrence: Occurs in three samples in percentages up to 0.2% per sample. One is a coal sample (Pb8929-31), and another (Pb5591) is a carbonaceous shale. The third occurrence (Pb5578) is in a marine shale parting in the Corcoran Sandstone.

Bolkhovitina's specimens are from the Lower Cretaceous of the U.S.S.R.

Suggested affinity: Unknown.

Discussion: I decided to ally these specimens with L. varius rather than the similar Deltoidospora cascadensis Miner, 1935, mainly because they are slightly below the size range of 30-41 microns which Miner gave for his specimens. The two species, as described and illustrated by their respective authors, are essentially the same except for the size range. However, the size range of L. varius, given by Bolkhovitina as 15-25-31-35 microns, seems to have been based on only four specimens and may, thus, not represent the full range of the species. It is not known how many specimens were measured in determination of the size range of D. cascadensis. The two species may be synonymous, in which case the older name, Deltoidospora cascadensis Miner, 1935, would apply. However, comparison of type material and examination of more specimens is needed in order to resolve the problem.

As it stands now, it would seem that populations of these spores with a mean diameter of substantially over 30 microns should be assigned to D. cascadensis and those with a mean diameter of substantially below 30 microns be assigned to L. varius. This would, however, still leave an unresolvable "twilight zone" of situations in which the mean fell close to 30 microns, or where single specimens are found.

Another related problem is the fact that many, perhaps over 50%, of occurrences of Deltoidospora hallii Miner reported in the literature actually represent occurrences of D. cascadensis or Leiotriletes varius.

An example of this is D. hallii Miner as reported in Hedlund (1966, pl. 1, fig. 4). This spore plainly has convex sides, and following the rough guideline of size range described above, it should be assigned to D. cascadensis. A quick search of the literature will reveal many more examples, by diverse authors.

These erroneous assignments are due to the common mistake of assigning spores with convex equatorial outlines to D. hallii Miner. Miner (1935, p. 618) clearly states that the spores of D. hallii have "sides straight or slightly curved inwards;" no exception is made to allow for specimens with convex sides in that species, but on the very same page, Miner describes D. cascadensis as having "sides rounded." Possibly Miner was amiss in defining two species separated by such a small and possibly variable difference. The type materials should be compared, and perhaps D. hallii should be retained as the only name for the group if it were combined, since that name has by far the wider usage. However, until such a combination is effected, there is no justification for continuing to use the name D. hallii for specimens with convex sides.

Genus Osmundacidites Couper, 1953

Type species: Osmundacidites wellmanii Couper, 1953

Osmundacidites wellmanii Couper, 1953

Plate 2, Figure 4

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

1953 Triletes comaumensis Cookson, in Catalog of Fossil Spores and Pollen, vol. 15, p. 50.

1957 Osmunda-sporites elongatus Rouse, p. 362, pl. 3, figs. 59-60.

1956 Baculatisporites comaumensis (Cookson) Potonie, p. 23.

1957 Osmundacidites comaumensis (Cookson) Balme, p. 25, pl. 4, figs. 54-56.

1962 Osmundacidites wellmanii Couper, in Pocock, p. 35, pl. 1, fig. 15.

1963 Osmundacidites wellmanii Couper, in Dettmann, p. 32, pl. III, fig. 22, 23.

1965 Osmunda comaumensis (Cookson) Stanley.

Size range: ca. 40 to ca. 55 microns in diameter, five specimens measured. (Measurements approximate because all specimens observed were somewhat crushed.)

Occurrence: Reported from many Jurassic and Cretaceous horizons from many areas of the earth. Found in nine samples scattered through all the sections of the present study with no recognizable pattern of distribution, and in very low abundance (not exceeding 0.4% of any sample).

Suggested affinity: Osmundaceae. Couper (1958, p. 134) states that this species is "a good example of the 'broadness' of spore species compared with most plant macrofossil species. They are comparable with the spores of the Greenland Liassic species Osmundopsis plectophora Harris and Todites hartzi Harris, and with the spores of Todites undans from the Yorkshire Jurassic."

Discussion: I have followed the species concept of O. wellmanii as put forth in Pocock (1962), who combined Osmundacidites comaumensis Cookson (Baculatisporites comaumensis (Cookson) Potonie, 1956) and similar forms as synonymous with O. wellmanii Couper. However, since Dettmann (1963) in a rather important paper chose not to follow Pocock and re-separated the species, I feel that an expanded justification for combining the two species is necessary.

The reason these other species are usually excluded from O. wellmanii seems to be that Couper, in his original description of the species, used the unusual term "granulate-papillate" to describe the ornamentation, whereas Baculatisporites comaumensis is described as baculate. (Actually, Cookson's first description of the latter species, as Triletes comaumensis Cookson, 1953, described the ornamentation as "blunt rodlike processes, about 1.2 microns long.")

Couper (1958, p. 102) in a "glossary of terminology" as used by him, describes papillate projections as not less than 1 micron in height and with "apex more or less rounded to truncate, trunk not markedly tapering." This is essentially the same condition as Cookson described for T. comaumensis. In a description of O. wellmanii, Couper (1958, p. 134) describes the projections as being "up to 1.5 microns above general surface." Thompson and Pflug (1953) use the term "baculate" in their descriptions, which they define (ibid, p. 22) as "rodlet sculpture."

Thus, the "papillae" of Couper and the "baculae" of other authors as applied to this species seem to be the same type of sculptural element.

Dettman (1963, p. 33-35) ignores the papillae mentioned by Couper and describes O. wellmanii as granulate. She then describes B. comaumensis as "covered with short, equidimensional bacula together with a few setae and clavae. Sculpture elements 1-1.5 microns long and 1-1.5 microns in diameter." However, an "equidimensional" baculum ca. 1 micron in diameter and height is a granum (see Kremp's Morphologic Encyclopedia of Palynology); thus, we have the granulate-papillate ornamentation of Couper and the baculate ornamentation of Dettmann and others differing mainly because of a difference in wording rather than because of actual difference in form. A connotation seems to have developed of O. wellmanii as being less robustly ornamented than B. comaumensis, but actually there is a continuum between the less highly ornamented forms and the more densely ornamented, robust forms. This realization was a product of my own experience, partly in summer work for Amoco Production Company in Tulsa, Oklahoma, in which many of these spores from all parts of the continuum were observed; partly in the present study; and partly from extensive review of occurrences of both species as reported in the literature. Pocock (1962) obviously reached a similar conclusion which led him to combine several formerly separate species as O. wellmanii.

Thus, since much of the difference in descriptions of the two species in question can be attributed to usage of different technical terminology and to the presence of a continuum of ornamentation, as described above, there does not seem to be room for more than one name for this group. There are probably several natural species included here, but until a method is found of consistently separating them (as is not now the case) it seems prudent to combine them all under the name of O. wellmanii.

Osmunda-sporites elongatus Rouse seems to be conspecific with O. wellmanii as used here (see Pocock, 1962, p. 35).

The specimen of Monosulcites sp. illustrated in Norton and Hall (1969, p. 35, pl. 3, fig. 7) may also be a specimen of O. wellmanii.

Besides the forms considered here, Krutzsch (1959) names several new species of Baculatisporites from the Tertiary of Germany which appear to be possibly conspecific with O. wellmanii. More study needs to be done in order to determine for sure whether or not this is the case.

Genus Perotrilites Couper, 1953

Type species: Perotrilites granulatus Couper, 1953

Perotrilites sp.

Plate 2, Figures 5-6

Description: Trilete spore; laesurae ± indistinct, simple, extend ca. 2/3 spore radius; exine smooth, thickness indeterminate, enclosed in perisporium; perisporium reticulate, with the luminae ca. 2 microns across in the equatorial regions, decreasing in size toward poles, with only scattered microfoveolae in the polar regions; equatorial outline rounded triangular.

Size range: 18-22 microns; four specimens measured.

Occurrence: See Discussion below.

Suggested affinity: Unknown.

Discussion: One specimen was found in sample Pb8929-31, from the lower bench of the Trout Creek Coal at the top of the Rifle Gap section. The sample of the shale parting between the two coals (sample Pb8932) contained 2.6% of this species. The calcareous shale (sample

Pb8934), also in the parting, just above Pb8932, contained none of these spores. Both shale samples were from brackish lagoonal environments, as deduced from the well-developed land plant palynoflora in these samples, plus the presence of a very few presumably marine microplankton.

Thus, this spore seems to have been produced by a plant which lived near (but possibly not actually in) coal swamps along low coast lines. Possibly the sea had re-invaded slightly by the time sample Pb8934 was deposited thus eliminating the plant's habitat, or pushing it shoreward beyond the range of transport of the spores.

The upper bench of the Trout Creek Coal was not examined, and above it is a sandstone, which was not sampled, which marked the top of the section, so further trends could not be observed.

Genus *Retitriletes* Pierce, 1961

Type species: *Retitriletes globosus* Pierce, 1961

Retitriletes cenomanianus Agasie, 1969

Plate 2, Figure 7

1969 *Retitriletes cenomanianus* Agasie, p. 24-26, pl. 3, figs. 9-10.

Size range: 33-40 microns; four specimens measured. This is below the lower size limit of 42 microns given by Agasie, but many of the spores and pollen in this study are smaller than normal. (Kidson, 1971, p. 28, also notes this small size phenomenon, but has no explanation for it.)

Occurrence: Upper Cretaceous. Agasie's report is from the Dakota formation of northeastern Arizona. Griggs (1970) reports this species from the Frontier formation of northwestern Wyoming. In the present study, this form occurs in abundances of 0.4% or less in samples sparsely scattered throughout the sections studied; no trends observed.

Suggested affinity: Unknown.

Discussion: This species may be the same as Lycopodiumsporites novomexicanum Anderson, 1960. The description of R. cenomanianus does not diagnose the difference or even mention the similarity. The size ranges given by the two authors matches almost exactly. The reticula are very similar, but L. novomexicanum is supposed to be bordered by a thin non-staining equatorial flange which is not in evidence on the specimens considered here or on Agasie's.

Agasie does not say whether his specimens are ornamented on both sides or not. My specimens are reticulate on one side only, as are Anderson's. Agasie's appear to be ornamented on only one side also. The type material of the two species should probably be compared in order to ascertain if they are indeed different, and if so, the description of R. cenomanianus should be expanded to reflect these differences.

R. pluricellulus Pierce is very similar also, but much larger.

Genus Sestrosporites Dettmann, 1963

Type species: Sestrosporites irregulatus (Couper) Dettmann, 1963

Sestrosporites pseudoalveolatus (Couper) Dettmann, 1963

Plate 2, Figure 8

1958 Cingulatisporites pseudoalveolatus Couper, p. 147, pl. 25, figs. 5-6.

1963 Sestrosporites pseudoalveolatus (Couper) Dettmann, p. 66-67, pl. 13, figs. 11-16.

1964 Hymenozonotriletes pseudoalveolatus (Couper) Singh, p. 83, pl. 10, figs. 1-3.

1965 Foveosporites cyclicus Stanley, p. 241, pl. 28, figs. 6-10.

1966 Foveotriletes subtriangularis auct. non Brenner: BURGER, D., pp. 246-247, pl. 14, fig. 1.

1970 Aequitriradites ornatus auct. non Upshaw: GRIGGS, P., p. 45, pl. 2, fig. 5.

Size range: 37-40 microns; two specimens. Published range.

Occurrence: Total known range is Wealden (Burger, 1966) to Paleocene (Stanley, 1965). This species was found only in the Palisade Coal sample in this study; three specimens were observed, only one of which was included in the 500 sum. Other Upper Cretaceous occurrences of this form are reported in Kidson (1971, pl. 2, fig. 1, reported as Cingulatisporites cf. C. pseudoalveolatus Couper) and Griggs (1970, pl. 2, fig. 5, reported as Aequitriradites ornatus Upshaw, 1963, which is an incorrect application of Upshaw's species name).

Suggested affinity: Lycopodium.

Discussion: See Dettmann (1963) for description. Singh (1971) recognized that his Hymenozonotriletes pseudoalveolatus (Couper) published in 1964 is a junior synonym of S. pseudoalveolatus (Couper) Dettmann, 1963. Examination of Stanley's illustrations of his Foveotriletes cyclicus confirm that it also is a junior synonym of S. pseudoalveolus.

Foveotriletes subtriangularis Brenner, 1963, has larger foramina, and has no interradial crassitudes. Burger's specimens as well as his description of them do not fit the description of Brenner's species, but the illustration and, in general, the description fit S. pseudoalveolatus.

Aequitriradites ornatus Upshaw, 1963, is ornamented by projecting elements, not by foveolae, and the laesurae extend to the outer margins of the zona. Neither of these features are indicated by Grigg's illustration, which does, however, match the illustrations of *S. pseudoalveolatus* in Dettmann (1963) and in Singh (1964).

The spore reported by Burger (1966, pl. 21, fig. 1) as *Vallizonosporites vallifoveatus* Doring, 1965, also appears to be a *S. pseudoalveolatus*, but its large size of 70-85 microns is above the size range of the latter species as reported in the other publications already cited. Doring's publication was not available for comparison.

Microreticulatisporites diatretus Norris, 1969, is similar, but lacks interradial crassitudes.

S. pseudoalveolatus may have been produced by a coastal coal swamp plant whose spores did not travel far, since they are found only in one coal sample. However, any environmental conclusions made on the basis of a form which occurs so rarely (0.2% of one sample) could not be made with much confidence.

Genus *Stereisporites* Pflug, 1953

Type species: *Stereisporites stereoides* (Potonie and Venitz) Pflug, 1953

Stereisporites antiquasporites (Wilson and Webster) Dettmann, 1963

Plate 2, Figures 9-10

1946 *Sphagnum antiquasporites* Wilson and Webster, p. 273, fig. 2.

1953 cf. *Sphagnites australis* (Cookson) f. *parva* Cookson (pars), p. 464, pl. 2, fig. 26.

1956 *Sphagnumsporites antiquasporites* (Wilson and Webster) Potonie, p. 17.

1957 *Sphagnites australis* Cookson: Balme (pars), p. 15, pl. 1, figs. 1, 2.

1962 *Sphagnumsporites antiquasporites* (Wilson and Webster) Pocock (pars), p. 32, pl. 1, figs. 1-3.

1963 *Stereisporites antiquasporites* (Wilson and Webster) Dettmann, p. 25, pl. 1, figs. 20, 21.

Size range: 18-30 microns, several specimens measured.

Occurrence: Widespread in Jurassic, Cretaceous and Tertiary rocks in many parts of the world. Scattered throughout the sections of the present study in low numbers.

Suggested affinity: *Sphagnum*.

Discussion: The synonomy above is as given by Dettmann (1963), with one minor exception. Dettmann cites figures 25 and 26 of cf. *Sphagnites australis* (Cookson) f. *parva* Cookson, 1953, as synonomous with *S. antiquasporites*. Since Cookson's figure 25 appears to have a quite ornamented, non-psilate exine, it should be excluded.

The presence of *Sphagnum*-type spores indicates that wet, poorly-drained, low-lying terrain was a part of the thesis area in Late Cretaceous time. This terrain need not have been extensive, however, in view of the low percentages of this taxon encountered. (The low numbers may also be an indication that moss plants produce spores at lower rates than higher plants, and/or that the spores are not dispersed far from their parent plants.)

Genus *Styx* Norton in Norton and Hall, 1967

Type species: *Styx minor* Norton in Norton and Hall, 1967

Styx minor Norton

Plate 2, Figure 11

1967 *Styx minor* Norton in Norton and Hall, p. 104, pl. IC.

Size range: 43-58 microns diameter, exclusive of perispore; eight specimens measured.

Occurrence: Oltz (1969) and Norton and Hall (1967, 1969) report S. minor from Upper Cretaceous and lowest Paleocene strata of Montana. Stone (1971) reports this species from the Almond Formation (Upper Cretaceous) of southwestern Wyoming. In this study, two specimens were found in each of two samples, 20 feet and 100 feet, respectively, below the Palisade Coal in the Mount Garfield section, and once (not in the 500 sum) in a sample (Pb5720) near the top of the Rifle Gap section.

Suggested affinity: Filicinae.

Discussion: This form resembles some spores of the genus Balmeisporites, but is much smaller.

The genus Thecaspora Elsik, 1966, would probably accommodate these spores and, perhaps, they should be transferred there after further study. The species T. spinosa Elsik, 1966, somewhat resembles Styx minor, but the spines seem to be longer and finer.

Ghoshispora scollardiana Srivastava, 1967, is very similar to Styx minor, and type materials should be compared to determine if the two species are synonymous.

Genus Todisporites Couper, 1958

Type species: Todisporites major Couper, 1958

Todisporites minor Couper, 1958

Plate 2, Figure 12

1958 Todisporites minor Couper, p. 135, pl. 16, figs. 9-10.

Size range: 30-36 microns; two specimens measured.

Occurrence: Rare occurrences throughout sections studied with no discernible pattern. Sample percentage never over 0.4%. Couper's specimens were Middle Jurassic, but this species is widely reported in Jurassic and Cretaceous sediments from various areas. Other Upper Cretaceous occurrences reported by Griggs (1970) and Kidson (1971).

Discussion: The specimens found in this study were all poorly preserved, and this fact, coupled with their scarcity and sporadic distribution, may mean that these spores were reworked from older strata.

These smooth, round spores with long laesurae are fairly straightforward, as has been the treatment of them in the literature.

Suggested affinity: Osmundaceae. Couper mentions its similarity to the spores of the Jurassic Osmundaceous fern *Todites princeps*.

Todisporites sp.

Plate 2, Figure 13

Description: Trilete spores; laesurae simple, often indistinct, 2/3 spore radius or longer, sometimes approaching equator; equatorial outline circular to subcircular; exine very thin, ca. 1/4 to 1/2 micron (note: Illustration appears to have thicker wall because of phase contrast; note true thickness where corners are bent upwards. These upward bends at the apices were not present on other specimens, and unfortunately, simulate pores, which they are not. Exine smooth, very fragile-appearing, transparent, stains only faintly with Safranin-O.

Size range: 27-32 microns diameter; four specimens measured.

Occurrence: This spore makes up 2.0% of the Palisade Coal composite sample, and is found in percentages of 0.2% or less in a few samples above or near this horizon in the Grand Junction, Rifle Gap, and Wilson Ranch sections. It is interpreted to indicate swampy conditions since it is strongly represented in the Palisade Coal (Two percent can be interpreted as strong representation for a trilete spore, since most of them never attain that figure in this study).

Suggested affinity: Unknown. Couper intended the genus *Todisporites* to be used "for the reception of fossil spores of the type met with in *Todites williamsonii* and *T. princeps*," but the spores considered here are assigned to the genus on purely morphological grounds, and it is not known for certain that they are fern spores. In view of the indistinct laesurae on many specimens, they could even possibly be bryophyte spores.

Discussion: This species was separated from *T. minor* because of its very thin, transparent, very faintly-staining wall.

Genus *Toroisporis* Krutzsch, 1958

Type species: *Toroisporis torus* (Pflug) Krutzsch, 1958

Toroisporis (*Toroisporis*) *longitorus*? Krutzsch, 1959

Plate 2, Figure 14

1959 *Toroisporis* (*Toroisporis*) *longitorus* Krutzsch, in Catalog of Fossil Spores and Pollen, vol. 19, p. 133.

1969 "Undifferentiated large, smooth trilete spores" (pars) in Thompson, pl. 14, fig. 10 only.

1970 *Deltoidospora psilastoma* auct. non Rouse: GRIGGS, P., p. 54, pl. 5, fig. 13.

Description: Trilete spores; laesurae distinct, 2/3-3/4 spore radius, but sometimes almost reaching equator; laesurae bounded by tori 3-5 microns wide; equatorial outline rounded triangular in majority of specimens, with about 20% showing ± straight or slightly concave sides; exine psilate, dense-appearing, ca. 1.5 microns thick; wall structure not clearly visible, but indications of layering are visible in a few specimens.

Size range: 40-52 microns, eight specimens measured.

Occurrence: Found in several samples scattered through the sections studied with no apparent pattern; sample percentage less than 1%. Other Upper Cretaceous occurrences noted in Thompson (1969) and Griggs (1970) (see synonymy). Couper (1958) reports the similar and probably related Dictyophyllidites harrisii from the Jurassic of England.

Suggested affinity: Filicinae? Couper (1958) provisionally relates the similar Dictyophyllidites harrisii to the Cheiropleuriaceae.

Discussion: T. longitorus Krutzsch matches most of the spores found here, but the name is here used preceded by a question mark because some of these spores have straight to concave sides, but are, in every other way, the same as the rest of the population. Also, Krutzsch's species is supposed to show three-layered walls (although his own illustrations do not reveal the layering well). Some of the spores considered here show a tendency to have layered walls, but most structure has been obliterated (by fossilization or maceration?) or, at any rate, is not visible.

Dictyophyllidites harrisii Couper, 1958, is very similar to these spores. What Couper describes as a margo in the description of D. harrisii is probably tori, as found on the spores considered here, and on Krutzsch's specimens (see Couper, 1958, pl. 2, fig. 5, 6). Thus, the only real differences between Couper's species and mine are:

Couper's specimens have slightly longer laesurae, and are 80% concave-sided, with 20% straight to convex, while the reverse situation is true of the spores considered here.

I feel that spores of Toroisporis longitorus Krutzsch and Dictyophyllidites harrisii and my own specimens were produced by closely related plants. The morphology described for my specimens is intermediate between the Jurassic forms of Couper and the Eocene forms of Krutzsch. Thus, these Upper Cretaceous spores may well represent a stage in evolution ± midway between Couper's and Krutzsch's species, which might better be accommodated in the same genus. (Note: I realize these are only form taxa, but I feel that probable close biological relationships merit close taxonomic proximity wherever this is feasible.)

Griggs (1970) mistakenly assigned spores of this type to Deltoidospera psilastoma Rouse, 1959. Rouse's species, however, does not possess tori, which are clearly shown by Griggs' pl. 5, fig. 13.

Toroisporis sp.

Plate 2, Figure 15

Description: Trilete spores; laesurae 1/2-2/3 spore radius, bounded by short, often faint, tori; laesurae usually gaping, equatorial outline rounded triangular to almost circular; exine ca. 1 micron thick, dense-appearing, dark-staining, psilate.

Size range: 42-48 microns; two specimens measured.

Occurrence: Occurs in Palisade Coal sample only, 0.4% of sample.

Suggested affinity: Filicinae?

Discussion: This species somewhat resembles Toroisporis arealis Krutzsch, 1959, and Toroisporis major (Pflug) Stanley, 1965. The latter two species strongly resemble each other and are probably conspecific. The specimens considered here, however, have slightly shorter laesurae, which usually gape, as well as a thinner wall; the tori are often fainter than on Krutzsch's or Stanley's specimens.

The laesurae and tori on Toroisporis longitorus Krutzsch and Dictyophyllidites harrisii Couper are distinctly longer than on this species.

Unknown Trilete Spore-3 includes similar forms, but they lack tori and generally possess longer laesurae.

Genus Triletes Cookson ex Couper, 1958

Type species: Triletes tuberculiformis Cookson, 1947

Triletes verrucatus Couper, 1953

Plate 3, Figure 1

1953 Triletes verrucatus Couper, p. 31, pl. 3, figs. 26-27.

Size range: 38 microns diameter, one specimen.

Occurrence: Jurassic and Cretaceous. Occurs in two samples of the present study from the Mancos Shale in the lower part of the Mount Garfield section in amounts of less than 0.2% of each sample (i.e., not noted within the 500 quantitative sum).

Suggested affinity: Filicales?

Discussion: This species fits Couper's description, but many other described spores are very similar and may be synonymous. In view of the plethora of similar species and the scarcity with which these spores occur in this study, no attempt was made to trace the synonomy of this species.

Genus Triplanisporites Pflug, 1953

Type species: Triplanisporites sinuosus (Pflug) Pflug, 1953

Triplanisporites sp.

Plate 3, Figure 2

Description: Trilete spores, equatorial view; outline ovaloid; maximum equatorial diameter greater than polar axis, or approximately the same length; distal side bulges prominently, often pointed; proximal side bulges somewhat, but is flattened relative to the distal side; exine fairly thick, ca. 1-1/2-2 microns, dense-appearing, usually dark-staining, psilate.

Size range: Maximum equatorial diameter 27-37 microns; several specimens measured.

Occurrence: Occurs in low percentages (up to 1.2%) in a majority of the samples studied (44 samples). Kidson (1971) reported it as Triplanisporites sinuosus Pflug, as did Thompson (1969).

Kidson (1971, p. 76) noted that these spores were more common in the coarser sediments (and, thus, nearer shore), but that this trend was "not readily discernible." In the present study, such an effect was not noted. However, there was a slight tendency for the species to be more common in samples of high $CaCO_3$ content; i.e., in calcareous shales, limestones and shales with calcareous concretions. Coupled with Kidson's findings, this may indicate that these calcareous zones represent nearer shore or lagoonal conditions in this shallow epeiric sea, rather than being an indication of far offshore conditions as in the classical relationship of deeper water sediments in which limestone is supposed to be found further from shore than shale. Indeed, a sample with a higher percentage of this spore than any in this study was collected a few miles from the Rifle Gap section, at Newcastle (Pb8873). This is from a limestone which lies directly atop a sandstone (with no evidence of disconformity), thus indicating fairly nearshore conditions. These observations are based on too few samples and specimens to be regarded as a definite correlation of high sample percentage of this spore with nearshore conditions, however.

Suggested affinity: Stanley (1965) questionably assigns *Triplanisporites* to the Schizeaceae. However, the spores considered here might possibly represent equatorial views of spores which, if seen in polar view, would have been assigned to *Cyathidites*, *Toroisporis*, *Dictyophyllidites*, etc. and, thus, several different fern families.

Discussion: Kidson's (1971) and Thompson's (1969) reports of *Triplanisporites sinuosus* do not fit that species as described in Stanley (1965) because their polar axes are not longer than the equatorial diameter. Kidson's spores are the same as reported here, but Thompson's pl. 14, fig. 7, shows a spore which seems to be different than any included in *Triplanisporites* sp. of the present study in that it has quite acute apices in equatorial view and, thus, does not have an "ovaloid outline."

Unknown Trilete Spore-1

Plate 3, Figure 3

Description: Trilete spore; laesurae indistinct, always over 1/2 spore radius, often extending approximately to edge of spore body; exine ca. 1/2 micron thick, psilate, fragile-appearing, transparent, stains only faintly with Safranin-O, equatorial outline rounded triangular; thin, membraneous zona 1 to 5 microns wide surrounds spore at equator.

Size range: 28-36 microns, including zona; three specimens measured.

Occurrence: Occurs in most coal samples in amounts of 0.2% or less. One anomolous occurrence is in the lower part of Mount Garfield section in sample Pb6741, a shale sample.

Suggested affinity: Unknown. The genus Aequitriradites, which these spores somewhat resemble, has suggested affinities as diverse as Hepaticae and Selaginella (see Dettmann, 1963, p. 92).

Discussion: This spore shows a definite correlation with coals. The one shale occurrence may indicate that a coal swamp was nearby.

The species considered here somewhat resembles Aequitriradites in its indistinct laesurae and zonate condition. Lack of a distal hilum, as well as other differences, exclude it from assignment to Aequitriradites, however.

Unknown Trilete Spore-2

Plate 3, Figure 4

Description: Trilete spore; laesurae slightly raised, extending two-thirds of spore radius (one ray appears to reach equator and form a slight curvatura, but preservation of specimen is too poor to verify this); equatorial contour rounded triangular; exine psilate; distal(?) side bears a thickened rim parallel to the equator, about 1/3 spore radius in from the equator; rim is 2.5-3 microns wide.

Size range: One specimen 47 microns in diameter.

Occurrence: Occurs in five samples randomly scattered throughout the sections of this study; sample percentage never over 0.4%.

A spore from the Upper Cretaceous Pierre Shale of northwestern Kansas, which is very similar to and perhaps conspecific with this type, is figured in Lammons (1969, pl. 4, fig. 10), as Cingulatisporites levispeciosus Pflug, 1953. This name is incorrectly applied, as Lammon's specimen has laesurae which reach the equator and appear to form slight curvature, whereas Pflug (1953, p. 58) specifically states that the Y-mark does not reach the equator.

Suggested affinity: Unknown.

Discussion: This spore most nearly fits the description of the genus Distalanulisporites Klaus, 1960. The type species of the genus is from the Triassic of the Alps.

Lammons' species is almost certainly a representative of this genus. The species figured in the present work is more doubtful, since the nature of the ends of the laesurae was not clearly determinable because of the poor preservation of the specimens observed.

These spores may have been reworked from Triassic or older deposits.

Unknown Trilete Spore-3

Plate 3, Figures 5-6

Description: Undifferentiated trilete spores, rounded triangular to almost circular in equatorial outline; laesurae always at least 2/3 spore radius, sometimes reaching equator; exine usually fairly thick, range 1-2 microns, dense-appearing, dark-staining, psilate.

Size range: 37-64 microns; 10 specimens measured.

Occurrence: Found in 34 samples, representing all sections of this study; up to 0.6% per sample. Thompson (1969, pl. 14, fig. 5, 13) lists "Undifferentiated large smooth trilete spores," some of which are probably the same as those considered here (Thompson's pl. 14, fig. 10 is discussed with ?Toroisporis (Toroisporis) longitorus Krutzsch, see p. of the present study). Various species of wide occurrence and long range are probably included here (see Discussion).

Suggested affinity: Filicinae?

Discussion: Several genera of Mesozoic and Tertiary spores include members which fit the general description given above, or are at least similar. These include Leiotriletes, Matonisporites, Cyathidites, Todisporites. Deltoidospora psilostoma Rouse, 1959, almost certainly has some representatives included in this group, also.

Unknown Trilete Spore-4

Plate 3, Figures 7-8

Description: Trilete spore; laesurae undulose, extending approximately to apices; equatorial outline triangular with strongly concave sides, rounded apices; an arcuate fold or thickening is developed perpendicularly across each apex midway between the center of the spore and the extremity of the apex; exine psilate to chagrenate, dense, dark-staining, fairly thick but exact thickness not determinable.

Size range: 18-23 microns; four specimens measured.

Occurrence: Found in nine samples; no discernible pattern; sample percentage never over 0.4%.

Suggested affinity: Filicinae?

Discussion: I was unable to find any descriptions in the literature which would fit these small spores. Gleicheniidites apilobatus Brenner, 1963, is similar, but the sides are not as concave, and the laesurae less undulose in that species; its wall also appears to be thinner. A spore similar to Brenner's and perhaps conspecific with it is Deltoidospora juncta (Kora-Murza) Singh, 1964, but it does not fit the spores encountered here for the same reasons Brenner's do not fit. Concavisporites juriensis Balme (1957) and C. rugulatus Pflug (1953) are also different from the species considered here.

In view of their small size, unusual apices, and undulose laesurae, these spores may be immature specimens of a described species, possibly of Gleicheniidites senonicus, which always occurs in the same samples in which the spores in question are found. (This "correlation" between this species and G. senonicus was also noted in a study done by Gerald Waanders and me at Amoco Production Company Research Center, Tulsa, Oklahoma, during the summer of 1971. Couper (1958, p. 111, pl. 16, fig. 11-13) describes and illustrates wide morphological differences among spores from the same modern fern sorus due to stage of maturity. These spores had undulose laesurae in early stages, but straight laesurae at maturity.

Unknown Trilete Spore-5

Plate 3, Figure 9

Description: Trilete spore; laesurae distinct, simple, 2/3 spore radius in length; equatorial outline subcircular or subtriangular; exine dense, dark-staining, ca. 2 microns thick; proximal hemisphere unornamented; distal hemisphere covered with low, flattened ridges 2-3 microns wide, which branch but do not form a true reticulum.

Size range: 39 microns (one specimen only).

Occurrence: One specimen found outside the 500 sum in sample Pb6746, from the Mancos Shale from the lower half of the Mount Garfield section.

Suggested affinity: Unknown.

Discussion: This spore fits the generic diagnosis from Dictyotriletes (Naumova) Potonie and Kremp, as given in Pocock (1962, p. 41) except for the fact that its muri (ridges) don't anastomose to form a true reticulum as they do in Dictyotriletes.

MONOLETE SPORES

Genus Laevigatosporites (Ibraham) Schopf, Wilson and Bentall, 1944

Type species: Laevigatosporites vulgaris (Ibraham) Ibraham, 1933

Laevigatosporites haardtii (Potonie and Venitz) Thomson and Pflug, 1953

Plate 3, Figure 10

1934 Sporites haardti Potonie and Venitz, p. 13-14, pl. 1, fig. 13.

1946 Laevigatosporites gracilis Wilson and Webster, p. 273, fig. 4.

1947 Monolites minor Cookson, p. 135-136, pl. 15, fig. 57.

1953 Laevigatosporites haardti (Potonie and Venitz) Thomson and Pflug, p. 59, pl. 3, fig. 57.

Size range: 28-36 microns long, 12 specimens measured.

Occurrence: Found in 52 samples, representing all sections studied; abundance up to 4.4% per sample. Widespread in Upper Cretaceous and Lower Tertiary rocks. Potonie and Venitz (1934) report this species from the Oligocene/Miocene of Germany. Other U. S. Upper Cretaceous reports include Kidson (1971) and Griggs (1970).

Suggested affinity: Polypodiaceae.

Discussion: This species is less globose and has a shorter laesura than Laevigatosporites-sp. 1 and 2. The synonomy given here follows Stanley (1965, p. 252).

Laevigatosporites sp.-1

Plate 3, Figure 11

Description: Monolete spores; laesura simple, often gaping, 1/4-1/3 of spore length; exine smooth, thin, ca. 1/2 micron thick; outline in lateral equatorial view ovaloid; proximal polar margin straight to slightly convex.

Size range: 30-35 x 42-50 microns, five specimens measured.

Occurrence: Found in 49 samples; no pattern discernible in the distribution; sample percentage up to 1.4%.

Suggested affinity: Polypodiaceae.

Discussion: These spores could possibly have been assigned to *Laevigatosporites ovatus* Wilson and Webster, but they had shorter laesurae and thinner walls than are described for that species.

Laevigatosporites sp.-2

Plate 3, Figure 12

Description: Monolete spores; laesurae about half spore length, simple or with very slight lips, non-gaping; exine smooth, thin, ca. 1/2 micron thick, commonly folded, usually stains only faintly; outline in lateral equatorial view ovaloid; proximal polar margin slightly to markedly convex, occasionally with a faint punctation surrounding the laesura.

Size range: 16-26 x 24-34 microns; five specimens measured.

Occurrence: Occurs in 25 samples; percentage up to 1.2% per sample.

Suggested affinity: Polypodiaceae.

Discussion: This species differs from sp.-1 (above) in its smaller size, commonly folded wall and longer laesura.

Genus Polypodiisporites (Potonie) Potonie, 1934

Type species: Polypodiisporites favus (Potonie) Potonie, 1934

Polypodiisporites favus (Potonie) Potonie, 1934

Plate 3, Figures 13-14

1931 Polypodii(?)-sporonites favus Potonie, p. 556, fig. 3.

1934 Polypodiisporites favus (Potonie) Potonie, p. 38, pl. 1, figs. 19-20.

1938 Polypodiumsporites favus (Potonie) Thiergart, p. 295, pl. 22, fig. 14.

1953 Verrucatosporites favus (Potonie) Thomson and Pflug, p. 60, pl. 3, figs. 52-55, pl. 4, figs. 1-4.

1957 Polypodiaceae-sporites favus (Potonie) Thiergart: ROUSE, p. 364, pl. III, fig. 70-72.

1968 Reticuloidosporites pseudomurii Elsik, p. 290, pl. 7, fig. 2.

1969 Reticuloidosporites dentatus Pflug, 1953: LAMMONS, p. 124, pl. 5, fig. 10-12.

1971 Polypodiites senonicus auct. non Ross: KIDSON, p. 81, pl. 4, fig. 23.

Size range: 32-50 microns long; 20 specimens measured.

Occurrence: Occurs in 36 samples; abundance up to 1.2%. Highest percentages are found in coal samples, but in one coal, Pb8957-60, in the Wilson Ranch section, only one specimen was found, outside the 500 quantitative sum.

This species has been widely reported from rocks and coals of Late Cretaceous and Tertiary age.

Suggested affinity: Polypodiaceae.

Discussion: In addition to the synonymy above, Reticuloidosporites dentatus Pflug in Thomson and Pflug, 1953, appears to be very similar to the spores considered here (see Catalog of Fossil Spores and Pollen, vol. 3, p. 34). However, that species is described as echinate, with the individual sculptural elements described as "little teeth;" thus, the ornamentation appears to be "sharper" than in P. favus. Unfortunately, comparisons of type specimens are not possible, as they have been destroyed by war.

Different authors seem to have interpreted the same species as having the sculptural elements arranged in a reticulum, or not so. None of the illustrations in the literature demonstrate a clear, definite reticulum, and the specimens which I have seen do not appear to be reticulate, although there are holes (foveolae) between the sculptural elements. It is my opinion that all the forms mentioned in the synonymy have basically the same morphology, incuding arrangement of sculptural elements, and the differences between them are "paper" differences due to the different languages, writing styles and interpretations used by various authors, and a failure to search the literature and adequately compare "new" species with previously described forms.

There are minor, variable differences in size range and height of sculptural elements among different reports of this species, but these factors are so variable, minor, inconsistent and subject to misinterpretation that they do not allow consistent separation of the different subtypes by later authors and, thus, are not a valid basis for the erection of new taxa. The forms here considered may have been produced by several different "natural" species, but such is often the case with form species, and the main aim of paleopalynological taxonomy should be the consistent recognition of taxa by most workers in the field, not the recording by means of a formal taxonomic designation of every minor deviation or variation from an established taxon. Creation of myriads of slightly different taxa, or taxa which vary on paper only, for a group such as considered here can only lead to confusion among the taxa, with many "misassignments," and an end result worse than if they had all been left as one taxon.

Rouse (1957) was incorrect in using the genus name Polypodiaceaesporites Thiergart for these spores, as that genus is for laevigate spores.

Lammons (1969) reports P. favus under the name of Reticuloidosporites dentatus Pflug, which may possibly be a truly different species (see above).

Although Kidson (1971, p. 81) says the spores he calls Polypodiites senonicus Ross are the same "in every detail" as Ross', comparison of Kidson's and Ross' photographs do not bear this out (see Kidson, 1971, pl. 4, fig. 23, and Catalog of Fossil Spores and Pollen, vol. 1, p. 126). Ross' species has a much longer laesura than Kidson's, and the sculptural elements on Ross' species are much larger than on Kidson's and are non-uniform in size, whereas Kidson's photograph shows verrucae all nearly the same size. I examined five of Kidson's samples, including three of which Kidson reported to contain P. senonicus, but the only verrucate monolete spores noted were of the type here reported as P. favus.

Genus Umbosporites Newman, 1965

Type species: Umbosporites callosus Newman, 1965

Umbosporites callosus Newman, 1965

Plate 3, Figures 15-16

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

Size range: 37-47 microns in length; five specimens measured.

Occurrence: Occurs in eight samples from the Mancos Shale of Mount Garfield, and one sample from the Buck Tongue of the Mancos at West Salt Creek; sample percentage 0.4% or less.

Other occurrences of this species in Upper Cretaceous rocks of the U. S. western interior besides the present study (and Newman's) are reported in Lammons (1969) and Kidson (1971). This species seems to be restricted to lower and middle Campanian strata.

Suggested affinity: Polypodiaceae?

Discussion: This species is one of the most restricted in time range of any occurring in this study.

SPORES INCERTAE SEDIS

Genus *Schizosporis* Cookson and Dettmann, 1959

Type species: *Schizosporis reticulatus* Cookson and Dettmann, 1959

Schizosporis cooksoni Pocock, 1962

Plate 4, Figure 1

1962 *Schizosporis cooksoni* Pocock, p. 76, pl. 13, figs. 197-198.

Size range: Longest dimension 25-45 microns; shortest dimension 20-28 microns; 10 specimens measured.

Occurrence: Occurs in a majority of the samples (42 samples), less than 0.2% to 11.8%, usually 0.4% to 1.0%. No definite trends were noted. The sample with 11.8%, which far exceeded the percentage found in any other sample, was a coal in the middle of the Rifle Gap section, number Pb8898. However, other coals did not show higher percentages than the surrounding shales and often lower percentages were found in coals than in bracketing shales. Pb8898 also included high percentages of other Schizosporis species, but the others are not so anomalous as this species. Perhaps a sporangium(?) was macerated, or this sample represents a particularly favorable local habitat within the coal swamp for the plant responsible for these spores.

Known range Upper Jurassic to Campanian (see Stone, 1971, p. 75).

Suggested affinity: Unknown.

Discussion: This species is similar to S. parvus Cookson and Dettmann, but is smaller and has a thinner wall. Pocock (1962, pl. 13, fig. 197) gives as the holotype of this species a specimen which is probably a member of the Inaperturopollenites hiatus-I. dubius complex (see Inaperturopollenites spp., p. , Plate 6, Figures 2-4, this thesis). Pocock's figure 198 (op.cit.) should be designated as the new type specimen, or an even better specimen could perhaps be designated.

Schizosporis scabratus Stanley, 1965

Plate 4, Figures 2-3

1965 Schizosporis scabratus Stanley, p. 269-270, pl. 35, figs. 10-17.

Size range: 23-32 microns; 10 specimens measured.

Occurrence: Companian-Maestrichtian, western North America. Found in 49 samples in percentages up to 10%, with the highest percentages occurring in coal samples. Thus, these spores (pollen?) must have been produced by plants with high moisture requirements (or tolerance), well-adapted to coal swamp conditions.

Suggested affinity: Unknown.

Discussion: This species was included in the counts and computations of this study as a spore. Stanley (1965, p. 269) tentatively considered the specimens to be pollen grains.

Stone (1971, p. 91, pl. 15, figs. 80, 81) gives a recombination of S. scabratus Stanley as Monosulcites scabratus (Stanley). If Stone has correctly interpreted his specimens as being "monosulcate with occasional flaring at the ends" of the sulcus, they must not be the same as the specimens considered here and in Stanley (1965), which do indeed have a zone of splitting, of variable length, which divides the grain into two hemispheres when it extends all the way around. In most cases the split extends about 3/4 of the way around the specimen, creating the appearance of a split open tennis ball. Many specimens were observed in the course of this study, and the writer is certain that this grain is not monosulcate. No flaring was observed at the ends of the split, as Stone mentions as being present at the ends of the sulci of his specimens. It is not possible to tell for sure from Stone's photographs if his species is truly the same, but certainly his placing of Stanley's species in the genus Monosulcites is unjustified.

Schizosporis cf. S. spriggi Cookson and Dettman, 1959

Plate 4, Figure 4

1959 Schizosporis spriggi Cookson and Dettmann, p. 216, pl. 1, figs. 10-14.

Description: Alete sporomorph; spheroidal to ellipsoidal; a zone of splitting separates the spore around the middle, usually almost completely separating the two halves; exine psilate, 1/2 micron to slightly over 1 micron thick.

Size range: 45-67 microns maximum diameter; five specimens measured.

Occurrence: Occurs in 14 samples sparsely scattered throughout the sections studied; in sample percentages up to 1%; no pattern discernible.

Suggested affinity: Unknown.

Discussion: This species is cited with the cf. designation because it is smaller than the usual size range of 67-111 microns (see Dettmann, 1963, p. 108).

Schizosporis sp.-2

Plate 4, Figures 5-6

Description: Alete sporomorph; spheroidal shape; a split extends at least half way around the spore, isolated hemispheres are sometimes found; exine smooth, thin, ca. 1/2 micron or less in thickness.

Size range: 14-19 microns; six specimens measured.

Occurrence: Found in 25 samples in percentages up to 5.2%. The highest percentages occur in coals, but coal sample Pb8929-31, the top coal in the Rifle Gap section, has only 0.6% of this species.

Suggested affinity: Unknown.

Discussion: This species may represent a plant especially adapted to coal swamps but tolerant of drier areas as well, or its presence in offshore samples may be related to high transportability and high resistance of its spores and, thus, not correlated with growth environment factors.

Schizosporis-2 is smaller and smoother than other species reported here. It is different from Spheripollenites psilatus Couper in its thinner wall and smaller size.

The designation Schizosporis sp.-2 is adapted from the original code used in counting: Schizo-2.

Schizosporis sp.-6

Plate 4, Figures 7-8

Description: Alete spores(?), shape circular to elliptical in polar view; seem to be flattened ellipsoids which often separate at the equator into two saucer-shaped sections; exine ± regulate or imperfectly reticulate, layering not discernible.

Size range: 45-50 microns maximum diameter; six specimens measured.

Occurrence: Found in seven samples--four were coals, one a shale associated with a coal, the other two were marine shales. Abundance 6.0% in coal sample Pb8898 from the Rifle Gap section, 0.2% in all other occurrences.

Suggested affinity: Unknown. Possibly Chlorophyceae; possibly Tracheophyta.

Discussion: Pocock (1962, p. 76-77, pl. 13, figs. 203-204) reported a fossil which he called Schizosporis rugulatus Cookson and Dettmann, but which Dettmann (1963, p. 108) says is not assignable to that species. Pocock's species is virtually identical to Schizosporis sp.-6 except for its larger size (60-87 microns vs. 45-50 microns). They may be conspecific.

Singh (1971, p. 426-427, pl. 79, figs. 5-10, pl. 80, fig. 1) reports a similar form under the name Lecaniella foveata Singh. His species has slightly more delicate-appearing ornamentation than Pocock's and S. sp.-6, but is otherwise the same and may also be conspecific with the latter two forms. The size range of Singh's species is 41-78 microns.

Singh's species is classified as an Acritarch, thus as a microplanktonic form. Pocock lists his species under pollen grains, incertae sedis. S. sp.-6 is classified as a spore and counted as such.

The similar morphology of these forms makes it seem to this writer that they must all be related, and type materials should be compared in order to determine how many species are actually present. These fossils should probably all be included in the same higher category, not scattered from pollen to acritarchs as is now the case.

My species occurred in greatest abundance in coal samples, so it seems likely to have been indigenous to the coal swamp environment. It need not represent a land plant, however, and may possibly represent a fresh water or coal-swamp alga or other aquatic form. It was counted with spores since it seems to be referrable to Schizosporis which was called a spore genus by Cookson and Dettmann (1959), and also since its high abundance in coals may mean it is a land plant entity, or at least a non-marine entity. Its inclusion under Acritarcha would have carried a possible connotation of its being marine microplankton, as most acritarchs appear to be.

Schizosporis sp.-8

Plate 4, Figures 9-10

Description: Alete sporomorph; a short, almost spherical ellipsoid; equatorial split separates spore into two equal halves which sometimes remain joined but often are found as isolated hemispheres; exine ca. 1/2 micron thick, ornamented with radially directed striae or thickenings 1/2 - 1-1/2 microns wide emanating from the poles and reaching the vicinity of the equator; exine smooth between striae.

Size range: 14-20 microns maximum diameter; five specimens measured.

Occurrence: Rare, seven samples. Occurs in some coals and shales near coals. The highest percentage, 1%, is in coal sample

Pb8957-60 in the Wilson Ranch section. A few minor occurrences are from shales not associated with coals. No occurrences were noted below the Palisade Coal, so this may be a useful "guide fossil" except for its low percentage occurrence.

Suggested affinity: Unknown; possibly a coal swamp plant.

Discussion: This species differs from other species of *Schizosporis* by its unique sculpture and small size.

The designation *Schizosporis* sp.-8 is adapted from the original code used in counting: Schizo-8.

GYMNOSPERMOUS POLLEN

(with the exception of monosulcate forms)

Bisaccate Pollen

Bisaccate-1

Plate 4, Figure 11

Description: Bisaccate pollen as found in the genera *Picea* and *Abies* (and possibly a few as in *Pinus*); bladders large, about same length as central body, which they usually cover distally except for a narrow zone in the center; bladders reticulate; body scabrate.

Size range: 45-100 microns long; eight specimens measured.

Occurrence: Occurs in 36 samples, in amounts up to 1.4% per sample; most frequent occurrence and highest percentages are found in the Mancos Shale in the lower part of the Mount Garfield section.

Suggested affinity: *Picea*, *Abies* and (?) some species of *Pinus*, or their fossil equivalents.

Discussion: Most of the pollen included here probably was produced by plants of the genus *Picea* (or an ancestral relative), although *Abies*-like plants probably also contributed some of them.

Bisaccate-5

Plate 4, Figure 12

Description: Bisaccate pollen; very broad in relation to height (ratio on figured specimen 3:1); bladders widely separated, low and flattened.

Size range: Figured specimen 72 microns broad, body 22 microns deep, bladders 18-20 microns deep by 31 microns broad.

Occurrence: Very sparse. Found in three samples from the Mancos Shale of Mount Garfield; up to 0.6% per sample.

Suggested affinity: Coniferales.

Discussion: This is probably a heterogenous taxon. All specimens were rather poorly preserved. Designation Bisaccate-5 reflects the original designation used in counting: V_2-5.

Bisaccate-6

Plate 5, Figure 1

Description: Bisaccate pollen; bladders distally pendant, not constricted at base, or only slightly so, divergent, quite small in relation to body size, reticulate; central body elliptical, broader than long, finely reticulate.

Size range: Length of body 40-45 microns, length of bladders 27-30 microns; three specimens measured.

Occurrence: One specimen was found in each of two samples in the Mancos Shale of the Mount Garfield section; and one outside the 500 sum in sample Pb8916 in the Rifle Gap section.

Suggested affinity: Pinaceae.

Discussion: This species is very similar to Pityosporites alatipollenites (Rouse) Singh, 1964, and probably could have been assigned there. However, the specimens considered here differ from P. alatipollenites in having possibly less constriction at the bases of the bladders, and a wider separation between them. Some specimens of Pinus rugosina Stanley, 1965 (see Stanley, 1965, pl. 39, fig. 3, 4) also resemble this species, but usually the bladders are larger on Stanley's species.

Genus Pinus (Tourn.) Linnaeus, 1753

Pinus semicircularis Stanley, 1965

Plate 5, Figures 2-3

1965 Pinus semicircularis Stanley, p. 277-278, pl. 39, figs. 8-10, pl. 40, figs. 1-7.

Size range: 38-45 microns long; four specimens measured.

Occurrence: Stanley reports this species from the lowest Paleocene of northwestern South Dakota. It occurs in the present study five samples of the Mancos Shale in the upper part of the Mount Garfield section, and in one sample in the lower part of the Rifle Gap section. Sample percentages up to 0.4%.

Suggested affinity: Pinus?

Discussion: While I have reservations about assigning this form to an extant genus, it appears to be the same as that so assigned by Stanley (1965, p. 277).

This species differs from Alisporites thomasii (Couper) Pocock, 1962 (a synonym of which is A. bilateralis Rouse, 1959) only in the definite presence of a central body. (Alisporites is characterized by not having a clearly identifiable central body to which the bladders are attached). Some of Stanley's specimens (see Stanley, 1965, pl. 39, figs. 8-10 and pl. 40, figs. 1-7) show variability in the visibility of the central body, at least in the photographs. Some of my specimens could have been assigned to *A. thomasii*, but were regarded as the same species as those which had a more clearly defined central body; thus, all were called *Pinus semicircularis*. I feel these two species are probably synonymous. Pocock (1962, p. 62) in his description of *A. thomasii* mentions a central body, but calls it "ill-defined." (Singh, 1971, p. 169, establishes the synonomy of Pocock's species with *A. bilateralis* Rouse, 1959.) As mentioned above, Stanley's specimens, as well as mine, also have bodies which could be described as "ill defined." All other features of the two species are essentially the same. Before establishing synonymy as proven, however, further study should be done and type materials compared.

If there is truly a more well-defined central body in Stanley's specimens, it may reflect evolutionary development of the modern genus *Pinus* from an ancestor which produced more typical *Alisporites*-type pollen. My specimens may have slightly less well defined bodies than Stanley's, but seem to fit his description. Thus, if there are indeed two different taxa in this complex, it may be that the middle to upper Campanian time represented by my specimens was a critical time in the evolution of the modern genus *Pinus*.

Genus *Podocarpidites* Cookson, 1947, ex. Couper, 1953

Type species: *Podocarpidites ellipticus* Cookson, 1947

Podocarpidites spp.

Plate 5, Figure 4

Description: Bisaccate; central body ± circular; bladders variable, but fitting generic description (see Singh, 1964, p. 115), reticulate, with some indication of radial ornamentation. Includes at least two species of the genus *Podocarpidites*.

Size range: Length of central body 24-30; three specimens measured.

Occurrence: Reported from rocks of Jurassic through Tertiary age world-wide. Occurs rarely (six samples) in the present study in amounts of 0.4% or less; no pattern discernible.

Suggested affinity: Podocarpaceae.

Discussion: This pollen was all poorly preserved, indicating either long distance water transportation, low preservability, or reworking, none of which can be ruled out as a possiblity without knowledge of how modern *Podocarpus* pollen behaves.

Genus *Rugubivesiculites* Pierce, 1961

Type species: *Rugubivesiculites convolutus* Pierce, 1961

Rugubivesiculites spp.

Plate 5, Figures 5-6

Description: This group is comprised of about equal representation of *R. reductus Pierce*, 1961, and *R. rugosus* Pierce, 1961. See Pierce (1961, p. 40, 41) for descriptions of those species.

Size range: Maximum breadth of central body 40-50 microns; four specimens measured.

Occurrence: Literature range Albian to Paleocene (see Singh, 1971, p. 167). Occurs in this study rarely (eight samples), amounts of 0.4% or less per sample; most frequent occurrence in Mancos Shale in lower part of Mount Garfield section, but also occurs in shales and coals in other sections.

Suggested affinity: Pierce relates these species to the Podocarpaceae.

Discussion: Singh (1971, p. 167) lists a range of Late Albian and Cenomanian for *R. rugosus*, so the presence of that species in the Campanian rocks of the present study would seem to extend the range of the species. However, it is possible that these specimens were recycled from older deposits in view of their sparse, random occurrence. Such occurrence could also be the result of long-range wind transportation, however.

Genus *Vitreisporites* Leschik, 1955, emend. Jansonius, 1962

Type species: *Vitreisporites signatus* Leschik, 1955

Vitreisporites pallidus (Reissinger) Nilsson, 1958

Plate 5, Figure 7

1938 *Pityosporites pallidus* Reissinger, p. 14.

1955 Pollen of *Masculostrobus* E'Carp. in Delcourt and Sprumont, pl. 1, fig. 6.

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

1958 *Vitreisporites pallidus* (Reissinger) Nilsson, p. 77, pl. 7, figs. 12-14.

Size range: 14-16 x 19-23 microns, three specimens measured.

Occurrence: Occurs rarely (17 samples) in amounts of 0.4% or less; no pattern discernible. Widespread in Jurassic and Cretaceous rocks.

Suggested affinity: Caytoniaceae.

Discussion: The sparse occurrence in rocks from varying distance offshore may indicate long distance wind transportation.

Monosaccate Pollen

Genus Tsugaepollenites Potonie and Venitz emend. Potonie, 1958

Type species: Tsugaepollenties igniculus (Potonie) Potonie and Venitz, 1934

Tsugaepollenites?-sp.

Plate 5, Figure 8

Description: Difficult to interpret morphology, but appears to be a monosaccate pollen grain with a delicate, frilly saccus which covers the entire grain but is best developed equatorially; central body is obscured and of indeterminate nature because of enveloping saccus; saccus is delicately rugulate to ± reticulate.

Size range: Maximum diameter, including saccus, is 28-31 microns; two specimens measured.

Occurrence: Occurs once in each of four samples of Mancos Shale in lower portion of Mount Garfield section; two lowest occurrences are not within the 500 quantitative sum.

Suggested affinity: Tsuga??

Discussion: These specimens are of very uncertain origin, and may not even be pollen grains. They were included as gymnosperms in the counting, however.

Perinate Pollen

Genus Concentrisporites Wall, 1965, emend. Pocock, 1970

Type species: Concentrisporites hallei (Nilsson) Wall, 1965

Concentrisporites pseudosulcatus (Briche, Danze-Corzin and Laveine) Pocock, 1970

Plate 5, Figure 9

1958 Equisetosporites hallei Nilsson, pl. 5, fig. 20, non fig. 21.

1962 Monosulcites minimum Cookson in Pocock, pl. 13, figs. 207-208, non fig. 206.

1963 Perinopollenites pseudosulcatus Briche, Danze-Corzin and Laveine, p. 90, pl. 8, fig. 8.

1970 Concentrisporites pseudosulcatus (Briche, Danze-Corzin and Laveine) Pocock, p. 106-107, pl. 26, figs. 5-9.

Size range: 32 microns maximum diameter; one specimen measured.

Occurrence: Occurs in 11 samples from the Grand Junction area; abundance of 0.6% or less. Most common in the Mancos Shale of the lower part of the Mount Garfield section.

Suggested affinity: Cycadophytean? See Pocock, 1970, p. 107. Nilsson mentioned similarity to spores of Equisetites (see Wall, 1965, p. 166).

Discussion: Isolated central bodies of this species would be indistinguishable from "taxodiaceous pollen" as described herein, and may have inflated the percentages of that category slightly.

Pocock's species is similar to C. hallei (Nilsson) Wall. Pocock describes the central body of his species as splitting in such a manner that the edges fold back and simulate the appearance of a monosulcate grain. C. hallei as illustrated in Wall (1965, pl. 9, fig. 13) shows a slight tendency to do this, although such a characteristic is not mentioned in the description. Type materials should be compared to determine whether or not the two species are indeed different. The species reported here has the folded-back edges mentioned by Pocock, so his species name was used. The synonymy given above is from Pocock (1970).

Genus Perinopollenites Couper, 1958

Type species: Perinopollenites elatoides Couper, 1958

Perinopollenites?-sp.

Plate 5, Figure 10

Description: Perinate pollen grains; no pore or other aperture visible; central body circular to subtriangular, psilate, stains darker than perinium; thin, transparent perinium loosely surrounds central body, has "splotchy" appearance (± infrascabrate).

Size range: 16-21 microns diameter, central body; overall diameter 21-26 microns, six specimens measured.

Occurrence: Very rare; occurs in six samples scattered through the sections studied in amounts of 0.2% or less. There may be a slight correlation with coal and lagoonal samples, but too few specimens were found to make any firm statements.

Suggested affinity: Coniferales?

Discussion: This species resembles Perinopollenites elatoides Couper, but is smaller, and no pore was observed. Simplicesporites virgatus Leschik, 1955, is similar also, but is also larger.

Gymnospermous Inaperturate Pollen

Genus Araucariacites Cookson ex. Couper, 1953

Type species: Araucariacites australis Cookson, 1947

Araucariacites spp.

Plate 5, Figure 11, Plate 6, Figure 1

Description: This category contains araucarion pollen of two species, Araucariacites australis Cookson and A. limbatus Balme, in about equal amounts. See Balme, 1957, p. 31, and Couper, 1958, p. 151, for descriptions of these two species.

Size range: 60-70 microns maximum diameter; six specimens measured.

Occurrence: Found in 44 samples, in amounts up to 1.0%, no discernible pattern.

Suggested affinity: Araucariaceae.

Discussion: There seems to be a gradation between A. australis and A. limbatus. There did not seem to be any advantage as far as this study goes in having two slightly different species with many intermediates to resolve, so it was decided to combine the two species.

Genus Inaperturopollenites Thomson and Pflug, 1953

Type species: Inaperturopollenites dubius (Potonie and Venitz) Thomson and Pflug, 1953

Inaperturopollenites spp.

Plate 6, Figures 2-4

Description: This category includes small, scabrate to almost smooth, inaperturate pollen grains with no ligula; grains split open or unbroken. At least two species, Inaperturopollenites dubius (Potonie and Venitz) Thomson and Pflug, 1953, and Thuja? hiatus (Potonie) Stanley, 1965, are represented.

Size range: 21-40 microns, usually 24-32 microns; many specimens measured.

Occurrence: Jurassic, Cretaceous and Tertiary, world wide. Pollen of this type is present in all samples studied, being the dominant palynomorph in many. Sample percentage ranges from 0.2% to 27%. Coal samples generally have lower percentages than adjacent shales. Marine shales have the highest percentages, but samples with very high

microplankton percentages have low percentages of all land derived palynomorphs, including Inaperturopollenites spp.

Suggested affinity: Cupressaceae, probably some Taxodiaceae; see discussion below.

Discussion: The two species mentioned in the description above were combined because many transitional forms were found and there did not appear to be any way to separate them consistently, even though the end members are somewhat different. No ligula was identified with certainty on any of the specimens. A very few had a structure or fold which could questionably have been a ligula; these latter forms were extremely rare, however.

The pollen considered here is usually referred to the Taxodiaceae, usually to Taxodium. Stanley (1965, p. 272-274) considers most pollen of the Taxodiaceae and Cupressaceae to possess a ligula (see Stanley, 1965, p. 272-274). The ligula of this pollen is quite variable, however. Dr. Ralph Taggart, Assistant Professor of Botany at Michigan State University, related to me the results of an unpublished study which he completed in 1966, in southern Illinois, in which sediment samples from modern Taxodium swamps were macerated for palynomorphs. The Taxodium pollen so obtained consisted of 10-20% with ligula, while in the remainder no ligula was observed. Thus, the lack of a ligula in the specimens found in this study need not rule them out as being possibly members of the Taxodiaceae.

In a study currently in progress, of the megafossils of the Blackhawk Formation in Utah, a deposit which is just slightly older than the rocks of the present study, Lee R. Parker of the Botany Department of Michigan State University, reports the presence of Sequoia (Taxodiaceae) in abundance in the Blackhawk, as well as Brachyphyllum in abundance in the middle Blackhawk (oral communication, February, 1972). Brachyphyllum is a form genus of fossil plants with foliage more or less like that found in the Cupressaceae, one member of which is Thuja. No Taxodium megafossils were noted.

Dr. Gary Thompson (1969, p. 57) reports the pollen described here as abundant from the Mancos Shale of southwestern Colorado, a marine deposit which includes the time equivalents of the Blackhawk to the west. He uses the designation Inaperturopollenites sp. 1.

The abundant presence of non-ligulate, supposedly Taxodiaceous pollen in marine sediments adjacent to land areas where the only Taxodiaceous plants found are from types whose modern counterparts (Sequoia) produce pollen with a fairly high percentage of ligulate grains indicates that either fossil Sequoia did not produce ligulate pollen or that this pollen is not the pollen of Sequoia. This pollen could have been produced by some Cupressaceous plant type or types, possibly certain members of the form genus Brachyphyllum. (Brachyphyllum is also listed as producing Classopollis pollen, but Brachyphyllum is a genus for leaves of the type produced by several types of plants, probably largely of the Cupressaceae.) The fact that Brachyphyllum was found in abundance only in the middle Blackhawk by Parker (see above) does not mean that Brachyphyllum did not live in places other than those sampled in the rest of the formation. Plant megafossils, such as these conifer shoots, were not distributed far from their life environment, but pollen is often much more widely dispersed.

The absence of true ligulate Sequoia-type pollen in this study and in Thompson's (1971) is hard to explain. Perhaps Sequoia is not a good name for the megafossils. Perhaps the pollen of Sequoia, Metasequoia, etc., does not travel far from its place of production. It creates a considerably different paleo-environmental picture to interpret this pollen as being from upland conifers such as Sequoia or Thuja, etc., rather than from swamp-dwelling Taxodium, as it has often been interpreted (see Stone, 1971, p. 89, Thompson, 1969, p. 101, Hedlund, 1966, p. 25, 36-38).

In view of the very different ecological requirements of the plants reputed to produce this type of pollen, no firm statement of onshore environmental conditions in Upper Cretaceous time in the study area can be made at this time based on this pollen, even though it is often dominant. It probably does not represent Taxodium swamp vegetation in this study, though, based on the reasoning in the above paragraphs and coupled with the fact of its low representation in coal samples relative to marine shale samples.

Norton (in Norton and Hall, 1969, p. 26, pl. 3, fig. 5) erroneously describes Inaperturopollenites hiatus as a "new species", Monosulcites crescentus. The holotype is unquestionably an inaperturate pollen grain of the type just discussed.

Genus Psilainaperturites Pierce, 1961

Type species: Psilainaperturites psilatus Pierce, 1961

Psilainaperturites psilatus Pierce, 1961

Plate 6, Figure 5

1961 Psilainaperturites psilatus Pierce, p. 44, pl. 3, fig. 76.

1966 Inaperturopollenites cf. I. magnus (Potonie) Thomson and Pflug, 1953, in Hedlund, p. 24, pl. 7, fig. 4.

Size range: 40-70 microns, but usually ca. 50 microns; 12 specimens measured.

Occurrence: Found in 39 samples; abundance up to 1.4%. Occurrences and highest abundances are not correlated with lithology, suggesting that this pollen is wind-distributed and was produced by upland plants.

The range of this species in the literature is Cenomanian, but similar forms have been reported from rocks of various ages (see references in synonymy above).

Suggested affinity: Hedlund mentioned Araucariaceae as a possible affinity; Pierce mentions Pinaceae(?), cf. *Pseudotsuga*; Equisetaceae(?); also similar to *Larix* (but smaller); similar to some marine leiospheres.

Discussion: This species could possibly represent aquatic leiospheres, but is allied with gymnospermous pollen because of its apparent conspecificity with the forms listed above. It is possible that these entities represent aquatic organisms, but if so, they are not restricted to the marine environment.

These forms are distinguished from *Leiosphaeridia* sp.-1 by their thicker walls and larger size, and from *L.* sp.-6 by their thinner walls and larger size.

Genus *Quadripollis* Drugg, 1967

Type species: *Quadripollis krempii* Drugg, 1967

Quadripollis krempii Drugg, 1967

Plate 6, Figure 6

1967 *Quadripollis krempii* Drugg, p. 62, pl. 8, figs. 55-56.

Size range: 38-50 microns, total diameter of tetrad; three specimens measured.

Occurrence: Sparsely scattered throughout the sections studied; in 10 samples; in abundances up to 0.4%; no pattern discernible. Range Santonian to Maestrichtian (see Griggs, 1970, p. 68, *Tetrahedraspora dyscrita* (Manuscript name) Upshaw; see also Drugg, 1967, p. 62). So far reported only from western U.S.

Suggested affinity: Gymnospermous?

Discussion: Upshaw (1959, unpublished Ph.D. thesis, University of Missouri) reports this species as *Tetrahedraspora dyscrita* (Manuscript name), which he regarded as a trilete spore tetrad. This form is included with gymnospermous pollen here because of the resemblance to *Inaperturopollenites limbatus* Balme, as noted also by Drugg (1967). It does not appear to be a trilete spore.

Monoporate Pollen

Genus *Circulina* Malyavkina, 1949, ex Klaus, 1960

Type species: *Circulina meyeriana* Klaus, 1960

Circulina parva Brenner, 1963

Plate 6, Figure 7

1963 *Circulina parva* Brenner, p. 84, pl. 34, figs. 2-3.

Size range: 17-24 microns diameter; four specimens measured.

Occurrence: Found in 10 samples of Mancos Shale from the lower part of the Mount Garfield section; abundance up to 0.8%.

Suggested affinity: Coniferales Incertae sedis.

Discussion: The major difference between this species and Classopollis classoides (see below) is the lack of the concentric annular equatorial thickenings of that species.

Genus Classopollis Pflug, 1953, emend. Pocock and Jansonius, 1961

Type species: Classopollis classoides Pflug, emend. Pocock and Jansonius, 1961

Classopollis classoides Pflug, emend. Pocock and Jansonius, 1961

Plate 6, Figure 8

1950 "Conifer pollen," Reissinger, p. 114, pl. 14, figs. 15-16.

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

1961 Classopollis classoides Pflug, emend. Pocock and Jansonius, p. 443-444, pl. 1, figs. 1-9.

Size range: 19-23 microns in diameter; four specimens measured.

Occurrence: Found in 37 samples; most frequent occurrence is in the Mancos Shale of the lower part of the Mount Garfield section. Sample abundance up to 3.0%. Reported in the literature from Jurassic and Cretaceous rocks worldwide.

Suggested affinity: The genus Classopollis consists of pollen of the type produced by the Mesozoic conifers Cheirolepis, Pagiophyllum and Brachyphyllum.

Discussion: Couper (1958, p. 156-157) emended the genus Classopollis Pflug, and put C. classoides Pflug in synonymy with Pollenites torosus Reissinger, which he redesignated Classopollis torosus and set up as the type species of Classopollis. Pocock and Jansonius (1961, p. 441-442) have shown these actions of Couper's to have been unjustified; C. classoides is not synonymous with C. torosus.

Pocock and Jansonius (1961, p. 445-446) say that Classopollis grains are most abundant in nearshore marine sediments, indicating a coa

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coastal environment since, in their opinion, the pollen is not suited to long distance transport.

Polyplicate Pollen

Genus Equisetosporites Daugherty, 1941, emend. Singh, 1964

Type species: Equisetosporites chinleana Daugherty, 1941

Equisetosporites multicostatus (Brenner) Norris, 1967

Plate 6, Figure 9

1963 Ephedripites multicostatus Brenner, p. 90, pl. 38, figs. 1-2.

1967 Equisetosporites multicostatus (Brenner) Norris, p. 105, pl. 16, fig. 15.

Size range: 31-36 microns; four specimens measured.

Occurrence: Barremian to Campanian, including present study; see Norris (1967, p. 105) and Griggs (1970, p. 77-78). Occurs in 11 samples scattered throughout the present study, in percentages of 0.2% or less.

Suggested affinity: Ephedra.

Discussion: This species must be included in the genus Equisetosporites even though it is now recognized to be ephedran pollen because Equisetosporites has priority.

Equisetosporites sp.-1

Plate 6, Figure 10

Description: Ephedran pollen, polyplicate; outline elliptical, with slight knobs at ends; sculpture of five or six straight longitudinal ribs ca. 1 micron wide and ca. 3 microns high, with wide grooves between; ribs fuse at ends of grains, where the thickened knobs appear.

Size range: 10-12 microns wide, 15-20 microns long; six specimens measured.

Occurrence: Found in 23 samples scattered through the study; sample percentage up to 1.0%. Most common in the Mancos Shale of the lower part of the Mount Garfield section.

Suggested affinity: Ephedra.

Discussion: This species resembles E. patapscoensis Brenner, but is much smaller, and the ends are more pointed.

Equisetosporites sp.-2

Plate 6, Figures 11-12

Description: Ephedralean pollen, polyplicate; outline elliptical, ends more blunt than in E. sp.-1; sculpture of about five straight longitudinal ribs 5-8 microns wide with grooves 2-5 microns wide between them; very subdued knobs at ends of some grains.

Size range: 13-20 microns wide, 24-30 microns long; six specimens measured.

Occurrence: Occurs in Pb4927 (0.2%), Pb6745 (0.4%), Pb6746 (0.6%), and Pb6747 (0.2%); these samples are near the bottom of the Mount Garfield section, in the Mancos Shale.

Suggested affinity: Ephedralean, Ephedra?

Discussion: The distribution of these grains, with its sudden termination, may indicate that they are at the end of their time range, because similar lithology and palynomorph assemblages are found above sample Pb6747, but no more specimens of this species. Samples Pb6745-47 may represent a last "burst of activity" of this form before it became extinct in this area.

These grains somewhat resemble E. patapscoensis Brenner, but none of them reaches the minimum length (31 microns) of Brenner's specimens. It is possible that they are E. patapscoensis, however, as many species in this study are smaller than usual, as noted elsewhere in this work. They differ from E. sp.-1 in their larger size and blunted ends.

Eucommiiditean Pollen

Genus Eucommiidites Erdtman, 1948, emend. Hughes, 1961

Type species: Eucommiidites troedssonii Erdtman, 1948

Eucommiidites couperi Anderson, 1960

Plate 6, Figure 13

1960 Eucommiidites couperi Anderson, p. 21, pl. 11, figs. 7-8.

Size range: 23-28 microns long, 14-19 microns wide; four specimens measured.

Occurrence: Found in 27 samples, in amounts up to 0.4%. Most common in Mancos Shale of lower part of Mount Garfield section. Also reported by Stone (1971) and Thompson (1969).

Suggested affinity: Unknown gymnosperm.

Discussion: These grains are slightly larger than normal for Anderson's, but are morphologically the same. E. debilis Groot and Groot, 1962, is very similar to E. couperi, and further study should be done to determine if they are indeed different.

Eucommiidites troedssonii Erdtman, 1948

Plate 6, Figure 14

1948 Tricolpites (Eucommiidites) troedssonii Erdtman, in Catalog of Fossil Spores and Pollen, vol. 9, p. 151.

1958 Eucommiidites troedssonii Erdtman in Couper, p. 60, pl. 31, figs. 23-27.

1961 Eucommiidites troedssonii Erdtman in Hughes, p. 292, pl. 37, figs. 1-6.

Size range: 20-28 microns long, 15-23 microns wide; eight specimens measured.

Occurrence: Widely reported from Jurassic and Cretaceous rocks. Occurs in 41 samples in this study, in abundance up to 2.6%.

Suggested affinity: Unknown gymnosperm.

Discussion: This species is quite similar to E. minor Groot and Penny, 1960. The latter species, however, is more nearly isodiametric.

Eucommiidites? sp.-1

Plate 6, Figure 15

Description: Pollen with three grooves as Eucommiidites, but which may be all on one face as in Trifossapollenites Rouse; ellipsoidal outline; median groove straight, about same length as lateral grooves (or ring furrow?); lateral grooves slightly geniculate medianally; exine psilate to slightly scabrate, ca. 1 micron thick.

Size range: 18-20 microns long, 15-16 microns wide; two specimens measured.

Occurrence: Only once in 500 sum of sample Pb6778; one specimen each outside of 500 sum found in two samples in the lower part of the Mount Garfield section; 0.4% of sample Pb8932, uppermost sample of Rifle Gap section.

Suggested affinity: Unknown gymnosperm.

Discussion: These specimens may be referrable to the genus Trifossapollenites Rouse, since the grooves appear to be all on the same side on some specimens. Not enough well preserved specimens were found to resolve this question, so they were questionably assigned to the more common genus Eucommiidites.

Eucommiidites sp.-2

Plate 6, Figure 16

Description: Small eucommiiditean pollen; round to rounded elliptical outline, main furrow and open parts of ring furrow about equal length; exine smooth, of indeterminable thickness.

Size range: 9-13 microns long, 7-1/2 to 12-1/2 microns wide; two specimens measured.

Occurrence: Scattered throughout study (18 samples); sample percentage 0.2-0.4%; no discernible pattern.

Suggested affinity: Unknown gymnosperm.

Discussion: This species is distinguished by its nearly isodiametric shape and very small size.

Eucommiidites? sp.-3

Plate 6, Figures 17-18

Description: Eucommiiditean pollen; elongate ellipsoidal shape, ends rounded or bluntly pointed; main furrow straight or sometimes with a fold or geniculus in the center; ring furrows about same length as main furrow; it is often not clear whether the furrows are on the same side or not (see discussion); exine psilate to sometimes faintly scabrate, ca. 1/2 micron thick.

Size range: 12-16 microns long, 8-10 microns wide; many specimens measured.

Occurrence: Found in most samples examined; abundance up to 3.8%.

Suggested affinity: Unknown gymnosperm?

Discussion: This species is assigned questionably to *Eucommiidites* because on some grains the furrows appear to be all on one side. This may be due to crushing of their thin exines, however, since the grains showing such condition are the same in other ways as grains which have furrows on both sides.

These grains do not fit into *Trifossapollenites* Rouse because the main furrow is not longer than the lateral furrows, and because they are much smaller than the lower size limit for the genus (35 microns) as given by Rouse (1957, p. 372).

Eucommiidites? sp.-4

Plate 6, Figures 19-20

Description: Eucommiiditean? pollen; outline elliptical; main furrow and lateral furrows approximately same length or main furrow is slightly shorter; furrows often ragged, or wavy, especially main furrow; lateral furrows often have raised edges which sometimes give the grains the simulated appearance of monosulcate grains with pronounced wide margos; exine smooth, ca. 1/2 micron thick.

Size range: Total range 16-24 microns long, 9-15 microns wide; typically 19-20 microns long by 12-13 microns wide. Many specimens measured.

Occurrence: Occurs in 51 samples; highest abundances in coals. Sample percentages up to 6.0%.

Suggested affinity: Unknown. Gymnospermous?

Discussion: This species was counted with the Non-reticulate Monosulcate category, but was later transferred questionably to the gymnospermous category Eucommiiditean pollen because there do indeed appear to be three furrows on the grains, even though the raised edges on the lateral furrows often closely resemble the margo of a monosulcate grain. Thus, those grains were not included in the gymnosperm counts, and a certain amount of doubt still remains about their true position, but they seem to fit Eucommiidites more closely than any other genus.

The plants producing these grains were tolerant of, or required, high moisture conditions, as can be seen by the high percentages of this grain in most of the coal samples.

NON-RETICULATE MONOSULCATE POLLEN

Genus Clavatipollenites Couper, 1958

Type species: Clavatipollenites hughesii Couper, 1958

Clavatipollenites cf. C. minutus Brenner, 1963

Plate 6, Figures 21-22

1963 Clavatipollenites minutus Brenner, p. 95, pl. 41, figs. 8-9.

Description: See Brenner (1963, p. 95) for description of C. minutus.

The specimens considered here differ from Brenner's in that some grains show a margo bordering the sulcus, which is not mentioned or illustrated by Brenner. Also, the reticulate pattern often is not apparent in surface views of these specimens, although the pilae show very well in optical section. For these reasons, the cf. designation was used rather than a definite assignment to C. minutus.

Size range: 9-18 microns long, 6-13 microns wide; 11 specimens measured.

Occurrence: Occurs in most samples (60 samples) in amounts up to 3.0%.

No pronounced trends were noted in its distribution, which show wide fluctuations not related to the land-derived/microplankton curve or to the lithology. This in itself may indicate that the plants producing this pollen lived far from the influence of the fluctuating sea and were not affected by it or by factors in the basin of deposition.

Suggested affinity: Unknown.

Discussion: Couper (1958) felt that *Clavatipollenites* pollen could have been produced by angiospermous plants, but Brenner (1963) indicated it could have been produced by an extinct type of gymnosperm.

Genus *Confertisulcites* Anderson, 1960

Type species: *Confertisulcites knowltoni* Anderson, 1960

Confertisulcites sp.-1

Plate 6, Figure 23

Description: Monosulcate pollen; elongate elliptical outline; furrow extends to ends of grain, or nearly so, and is bordered by thin lips which overlap and obscure sulcus for most of its length; lips ca. 2-3 microns high; wall thin, 1/2 micron or less, psilate to scabrate.

Size range: 27 microns long, 13 microns wide; one specimen measured.

Occurrence: Found in three samples, 0.2% in two shale samples, one in the Mancos Shale of Mount Garfield, one in the Rifle Gap section. A coal near the middle of the Rifle Gap section, Pb8898, had 0.6%, the highest percentage observed for this species. Thus, the plant producing this pollen may have required or been tolerant of high moisture conditions in view of its pollen having its maximum abundance in a coal sample.

Suggested affinity: Unknown, possibly gymnospermous.

Discussion: The genus Confertisulcites is described as having a "closed furrow in contact throughout length or broadly overlapping" (see Anderson, 1960, p. 27), so the grains considered here are referred to it, although they appear to have the sulcus margins extended into definite membraneous lips, a feature not specifically mentioned in the generic description.

Confertisulcites sp.-2

Plate 6, Figure 24

Description: Monosulcate pollen; outline elongate elliptical with pointed ends; furrow reaches ends of grain, which extend to an often rather sharp point; furrow tightly closed, or overlapping; wall psilate, very thin, less than 1/2 micron, folds easily.

Size range: 23-28 microns long, 11-16 microns wide; six specimens measured.

Occurrence: Found in 44 samples, a majority of the samples studied, representing all sections; abundance up to 2.0%. No pattern was discernible in the distribution.

Suggested affinity: Unknown, possibly gymnospermous or palmaceous.

Discussion: This species fits the generic description of Confertisulcites, and is thus so assigned; however, it also fits the more broadly defined genus Monosulcites, being very similar to M. epakros Brenner, which is reported below. It differs from M. epakros in being less elongate and less pointed at the ends.

This species is similar to C. knowltoni Anderson, which Anderson (1960, p. 27) suggests might have palmaceous affinity. C. knowltoni is significantly larger, however, and has more rounded ends.

Genus Cycadopites Wodehouse, 1933, ex Wilson and Webster, 1946

Type species: Cycadopites follicularis Wilson and Webster, 1946, designated by Potonie, 1958

Cycadopites sp.

Plate 6, Figures 25-26

Description: Monosulcate pollen; ellipsoidal outline, often with somewhat pointed ends; sulcus extends to ends of grains and widens slightly at the ends, often closed in middle by overlapping or nearly overlapping edges; exine fairly firm, ca. 1/2 micron thick, psilate.

Size range: 13-21 microns long, 9-12 microns wide; 12 grains measured.

Occurrence: Found in 58 samples representing all sections; up to 2.6% per sample. Highest percentages in nearshore and ?fresh water shales and siltstones.

Suggested affinity: Possibly Cycadales or Bennettitales.

Discussion: This form resembles Monosulcites minimus Cookson, but is usually smaller, and has a thinner exine. It is smaller than other species of Cycadopites. I believe that it is insufficiently different from similar smooth monosulcate pollen to justify erection of a new species for it.

Genus Monosulcites Cookson, 1947 ex Couper, 1953

Type species: Monosulcites minimus Cookson, 1947

Monosulcites epakros Brenner, 1963

Plate 6, Figure 27

1963 Monosulcites epakros Brenner, p. 75, pl. 25, figs. 5-6.

Size range: 24-30 microns long, 10-13 microns wide; eight specimens measured.

Occurrence: Found in 19 samples of the Mancos Shale of Mount Garfield in Colorado, and in one sample of Buck Tongue Mancos in Utah, as well as the Trout Creek Coal (lower bench) at the top of the Rifle Gap section (coal occurrence 0.2% of sample Pb8929-31). Abundance ranged from 0.2% to 1.4% per sample.

Suggested affinity: Brenner (1963, p. 74, 75) assigns this species to his "Cycadales-Bennettitales-Ginkgoales Complex."

Discussion: The specimens assigned here fit Brenner's description, but all were rather poorly preserved, and may possibly be altered specimens of some other species. To my knowledge this species has been reported previously only from the Lower Cretaceous; thus the poor specimens reported here may represent reworked grains.

This species is distinguished by its sharply pointed ends.

Monosulcites sp.-1

Plate 7, Figure 1

Description: Monosulcate pollen, ellipsoidal outline, rounded ends; sulcus extends almost to ends of grain, is narrow and usually closed, sometimes overlapping; exine firm, thickness not determineable because of ornamentation; ornamentation granulate, with a few blunt short coni, sculpture elements sometimes united at bases.

Size range: 30-33 microns long, 19-22 microns wide; six specimens measured.

Occurrence: Found in 11 samples, including marine very nearshore shales and siltstones, ?fresh water shales and siltstones, and coals; highest percentages in coals. Abundance up to 8.6% per sample. Earliest stratigraphic occurrence is Pb6775, a brackish or possibly fresh water sample from just below the Palisade Coal at the top of the Mount Garfield section.

Suggested affinity: Unknown. See discussion below.

Discussion: This species is similar in general appearance to photographs of Calamuspollenites pertusus Elsik, in Stover, Elsik and Fairchild (1966, pl. I, figs. 1-2) and in Elsik (1968, pl. 14, figs. 12-13). That species is described as being punctate, however, which the forms considered here are not. Elsik's species is reported from the Rockdale Lignite, of Lower Eocene age, of Texas, and is cited as being possibly allied with the Palmae or Magnoliaceae. Since the specimens in this study are more abundant in some coals than in other lithologies, and appear to have morphology somewhat similar to Elsik's species, it is possible that they may also be allied with the Palmae or Magnoliaceae; however, this is only a possibility and no real proof exists for such an alliance.

Monosulcites sp.-2

Plate 7, Figure 2

Description: Monosulcate pollen; small; boat-shaped outline; sulcus narrow, reaches ends of grains, which are extended into points; exine ca. 1/2 micron thick, densely and evenly scabrate (microgranulate).

Size range: 17 microns long, 9 microns wide (type specimen).

Occurrence: Sparsely distributed (five samples) in the Rifle Gap section; also found in sample Pb8953 from the Wilson Ranch section. Sample abundance up to 0.8%.

Suggested affinity: Unknown.

Discussion: The restriction of this form to the sandier sections indicates that it is not transported far out to sea;

except for its sparse occurrence and rather nondescript nature, it might be a useful near-shore indicator.

Monosulcites? sp.-3

Plate 7, Figure 3

Description: Monosulcate? pollen; elongate ellipsoidal shape, rounded ends; narrow sulcus almost reaches ends of grain, is bounded by a wide margo? or possibly by two lateral grooves as in Trifossapollenites Rouse; exine dense, firm, psilate. Occurs singly or in masses.

Size range: 21-23 microns long, 9-12 microns wide; eight specimens measured.

Occurrence: Found in seven shale and siltstone samples scattered through the sections studied; abundance 0.2% to 0.6% per sample.

Suggested affinity: Unknown, possibly gymnospermous.

Discussion: These specimens are difficult to interpret. They perhaps should have been questionably assigned to Trifossapollenites Rouse, but it was not possible to tell for sure if the features bounding the sulcus represented lateral grooves or simply the edges of a wide margo. In view of this uncertainty it seemed most prudent to assign them questionably to the broadly defined form genus Monosulcites Cookson ex Couper, rather than to the more narrowly defined genus Trifossapollenites Rouse.

Monosulcites spp.

Plate 7, Figure 4

Description: This category includes all non-reticulate monosulcate pollen not assignable to the above categories. Much of this pollen is nondescript and poorly preserved, but it fits the broadly defined genus Monosulcites Cookson ex Couper. See Couper(1953, p. 65) for generic description. Ornamentation of the grains reported here is psilate or scabrate.

Size range: ca. 14-24 microns long, variable width.

Occurrence: Found in 45 samples, a majority of the samples of all sections; abundance up to 2.6%, but usually less than 1.0%.

Suggested affinity: Unknown.

Discussion: This mixed category is useless in itself, but was recorded for the purpose of determining total non-reticulate monosulcate pollen representation in the palynoflora, found by adding those in this category to the total of those above.

ANGIOSPERMOUS POLLEN
(with the exception of any non-reticulate monosulcate forms)

Angiospermous Inaperturate Pollen

Unknown Inaperturate Angiosperm-1

Plate 7, Figure 5

Description: Inaperturate pollen; spherical; exine two-layered, inner smooth layer bears a tectate reticulum which makes up the outer layer; reticulum often damaged or incomplete, revealing the inner layer in irregular patches; occasionally, holes penetrate both layers, but are presumably the result of corrosion ratherthan being ulci.

Size range: 20-24 microns diameter; four specimens measured.

Occurrence: Eighteen scattered occurrences in the Mount Garfield and Rifle Gap sections; no pattern discernible in its distribution. Abundance 0.2% to 0.8%.

Suggested affinity: Angiospermous. See discussion below.

Discussion: Taggart (1971, pl. 10, figs. 5 and 10) illustrates two pollen grains which are similar to these. His pl. 10, fig. 5 is *Potamogeton* sp., an inaperturate form somewhat larger than those considered here. His pl. 10, fig. 10 is *Typha* sp., which is monoulcerate, but nearer the size of these grains, which sometimes have holes which are interpreted as due to corrosion, but might possibly be ulci.

Both *Potamogeton* and *Typha* are water plants, but it is not possible to say whether or not Unknown Inaperturate Angiosperm-1 also represents a water plant.

Reticulate Monosulcate Pollen

Genus *Arecipites* Wodehouse, 1933, ex. Anderson, 1960

Type species: *Arecipites punctatus* Wodehouse, 1933, ex. Anderson, 1960.

Arecipites reticulatus (van der Hammen) Anderson, 1960

Plate 7, Figure 6

1954 *Monocolpites reticulatus* Van der Hammen, p. 89.

1954 *Pollenites reticulatus* Van der Hammen, p. 96.

1960 *Arecipites reticulatus* (Van der Hammen) Anderson, p. 18, pl. 1, fig. 19, pl. 7, fig. 6, pl. 8, fig. 3, pl. 10, fig. 7.

Size range: 19-23 microns long, 12-15 microns wide; six specimens measured.

Occurrence: Found in 33 samples erratically scattered through all sections studied; abundance 0.2% to 1.6% per sample. No pattern observed.

Also reported from this general region and time by Stone (1971). Range Campanian--Paleocene.

Suggested affinity: Monocotyledenae? Palmae?

Discussion: Stone (1971, p. 97) lists *Pseudotricolpites reticulatus* Stanley, 1965, as a synonym of *Arecipites reticulatus*. I do not agree, since the description and photographs of Stanley's species differ markedly from those in Anderson (1960) and from the specimens considered here. Stone's specimens may actually represent another species of *Arecipites*.

Arecipites tenuiexinus Leffingwell, 1971

Plate 7, Figures 7-8

1971 *Arecipites tenuiexinus* Leffingwell, p. 41, pl. 5, figs. 8-9.

Size range: 26-32 microns long, 16-24 microns wide; six specimens measured.

Occurrence: Found in 28 samples, representing all sections studied. Abundance 0.2% to 0.8% per sample; no pattern discernible in its distribution.

Leffingwell's specimens were from the Cretaceous-Tertiary boundary in eastern Wyoming.

Suggested affinity: Angiospermous. Monocotyledonous? Palmae?

Discussion: The only clear distinction between this species and *A. reticulatus* is size; *A. tenuiexinus* is the larger of the two.

Genus *Liliacidites* Couper, 1953

Type species: *Liliacidites kaitangataensis* Couper, 1953

Liliacidites complexus (Stanley) Leffingwell, 1971

Plate 7, Figures 9-10

1965 Schizosporis complexus Stanley, p. 267-268, pl. 36, figs. 7-17.

1971 Liliacidites complexus (Stanley) Leffingwell, p. 41, pl. 6, fig. 3.

Size range: 30-40 microns long, 19-40 microns wide; 10 specimens measured.

Occurrence: Found in 49 samples, representing all sections; abundance up to 2.4%. Highest abundances are in coals, but not all coals have high abundance of this form. Literature range Campanian to lowest Paleocene (see Stanley, 1965, Stone, 1971).

Suggested affinity: Angiospermous.

Discussion: This form is regarded as conspecific with Stanley's specimens, even though most of my apecimens do not show the structural details of Stanley's better preserved specimens. Some of the difference may be due to variation between this population and Stanley's simply due to geographical separation--i.e., even if there was no barrier separating the two populations, regional varieties, etc., could develop. The differences are too subtle and subjective to be expressed as a formally described variety, however, and as noted above, may simply be due to preservational differences.

Some of the specimens reported here (i.e., Plate 7, Figure 10) are very similar to those illustrated by Stanley, and by Leffingwell (see synonomy for references), but some (i.e., Plate 7, Figure 9) although non-separable from the others and obviously of the same species, were closer in appearance to Liliacidites leei (see Anderson, 1960, p. 18-19, pl. 1, figs. 9-10, pl. 5, fig. 10, pl. 7, fig. 7, pl. 8, fig. 4-5). Every gradation existed between these two "end members." (One of

Stanley's specimens, pl. 36, figs. 15-17 also resembles L. leei somewhat.) Anderson's specimens are all obviously poorly preserved, and it appears as if they may be conspecific with L. complexus, but that this fact has been overlooked by workers using better preserved material. In the present study, preservation is poorer, and the poorest specimens resemble L. leei; enough well-preserved specimens (definitely of the same species) were found, however, to definitely ally all of the specimens considered here with L. complexus. The type material of L. leei should be compared with that of L. complexus in order to determine for certain if the two species are indeed different.

Liliacidites reticulatus (Brenner) Singh, 1971

Plate 7, Figure 11

1963 Peromonolites reticulatus Brenner, p. 94, pl. 41, figs. 3-4.

1971 Liliacidites reticulatus (Brenner) Singh, p. 189-190, pl. 28, figs. 12-14.

Size range: Central body 22 microns long, 13 microns wide (illustrated specimen).

Occurrence: Found in nine samples scattered through the Mount Garfield and Rifle Gap sections; no pattern noted. Abundance 0.4% or less. The literature range of this species is Barremian through Albian (see Singh, 1971, p. 189). The specimens considered here may be reworked, although it is difficult to visualize the delicate reticulum surviving the reworking process.

Suggested affinity: Angiospermae? Monocotyledonae?

Discussion: This species is distinguished from the very similar L. peroreticulatus (Brenner) Singh by its slightly larger size and slightly more fragile muri, as well as a usually more elongate shape. The luminae on L. reticulatus are larger than those of L. dividuus (Pierce) Brenner, 1963, thus distinguishing it from that species.

Liliacidites cf. L. variegatus Couper, 1953

Plate 7, Figure 12

1953 Liliacidites variegatus Couper, p. 56, pl. 7, figs. 98-99.

Description: Monosulcate pollen; outline elliptical with rounded ends; furrow reaches ends of grain, or almost, is rounded at ends, often overlaps or is closed, except at rounded ends, due to shrinkage; exine reticulate; muri narrow, ca. 1/2 micron or less; luminae up to 2 microns across, usually ca. 1 micron across.

Size range: 23-24 microns long, 16-17 microns wide; three specimens measured.

Occurrence: Found in eight samples, mostly ?fresh water or near-shore shales and associated coals; abundance up to 1.4%.

Suggested affinity: Monocotyledonae? This pollen seems definitely to have been produced by a coal-swamp plant.

Discussion: These forms are referred to Couper's species with the cf. designation because they fall below the minimum size range of L. variegatus and because the sulcus is rarely seen in the open position, so it is not possible to tell if it is "broad," as Couper (1953, p. 56) describes the sulcus of L. variegatus.

Liliacidites sp.-1

Plate 7, Figure 13

Description: Monosulcate pollen; outline roughly circular to rounded ellipsoidal; furrow straight, simple, sometimes slightly overlapping, reaches ends of grain; exine ca. 1 micron thick, coarsely reticulate with low, broad muri (1 micron wide, less high); luminae up to 2 microns across, some open into sulcus.

Size range: 20-24 microns long, 15-22 microns wide; six specimens measured.

Occurrence: Similar distribution to that of *L.* cf. *L. variegatus*, described above, but even more restricted to the vicinity of coals. Occasionally not as abundant in coals as in associated shales. Abundance 0.2% to 1.0%.

Suggested affinity: Angiospermae. Monocotyledonae?

Discussion: This species is distinguished from others by its very robust-appearing, often almost foveolate reticulum and its often circular or subcircular shape.

Liliacidites spp.

Plate 7, Figures 14-15

Description: This category includes all reticulate pollen of the genus *Liliacidites* which is not assignable to any of the above species due to poor preservation, etc. Details of morphology and size widely variable. See Couper (1953, p. 56) for description of the genus *Liliacidites*.

Size range: Variable.

Occurrence: Found in 10 samples, including lagoonal shales and siltstones usually associated with coals, as well as in the coals themselves. Seems to have been from coal-swamp plants. Abundance up to 1.0%.

Suggested affinity: Angiospermae.

Discussion: This category is useful even though broadly defined and "polyphyletic" for the same reasons as discussed under Monosulcites spp., above.

Tricolpate Pollen

Genus Ericaceoipollenites Potonie, 1960

Type species: Ericaceoipollenites roboreus (Potonie) Potonie, 1960

Ericaceoipollenites rallus Stanley, 1965

Plate 7, Figure 16

1965 Ericaceoipollenites rallus Stanley, p. 296-297, pl. 44, figs. 15-18.

Size range: 30-40 microns diameter of tetrad, 21-29 microns diameter of individual grains; six tetrads measured.

Occurrence: Found in 11 samples scattered through the study; abundance 0.2% or less (very rare); no pattern discernible. Literature range Campanian-Paleocene (Stone, 1971, p. 105, Stanley, 1965, p. 297).

Suggested affinity: Ericaceae? Kalmia?

Discussion: Stanley mentions the similarity of this form to the pollen of the extant Kalmia latifolia, the mountain-laurel. A mountain habitat (plus possibly insect pollination?) could explain this pollen's rare, erratic distribution in this study.

This pollen is included with tricolpate pollen because Stanley described it as basically tricolpate, with weak colpi, even though it is usually inaperturate. No definite colpi were observed on the specimens noted in this study.

Genus Fraxinoipollenites Potonie, 1960

Type species: Fraxinoipollenites pudicus (Potonie) Potonie, 1960

Fraxinoipollenites cf. F. variabilis Stanley, 1965

Plate 7, Figures 17-18

1965 Fraxinoipollenites variabilis Stanley, p. 306, p. 45, figs. 29-35.

Description: Tricolpate pollen; prolate to subspheroidal; colpi fairly long, often with an incipient pore or a geniculus in the center, or ± sinuous; clavate-microreticulate with luminae ca. 1/2 micron across; clavae up to 1 micron long, usually slightly less; total thickness of exine ca. 1 micron.

Size range: 15-24 microns long, 14-21 microns diameter; 28 specimens measured.

Occurrence: Stanley's specimens were from the Paleocene of South Dakota. Stone (1971, pl. 18, figs. 116-117) reports forms, which appear to be conspecific with those considered here, from the Upper Campanian of Wyoming, using the name F. variabilis Stanley.

In the present study, this species is found in 56 samples; highest abundance 5.2%. Not found in certain very nearshore or fresh-water shales and siltstones and some coals, and not found in the sample with the lowest Land Derived/Microplankton ratio, number Pb4983. Most abundant in normal marine shales of the Mancos Shale in the Mount Garfield and West Salt Creek sections.

Suggested affinity: Stanley gives the affinity of F. variabilis as Fraxinus? I see no good reason why this generalized tricolpate form should be allied with Fraxinus or any other genus in the absence of much more comparative work, and suggest the affinities are dicotyledonous, no more. The name Fraxinoipollenites is here regarded as purely a form genus.

Discussion: This form is referred to F. variabilis Stanley using the cf. citation because the mean size of these grains is slightly smaller than Stanley's and because Stanley makes no mention of the bend or incipient pore in the colpi of most specimens. (His illustrations do show a tendency toward this feature, however.)

There does not appear to be a great deal of difference between this form and Tricolpites parvus Stanley (1965, p. 322, pl. 47, figs. 28-31), but Stanley calls the latter oblate since it is a polar view species.

Tricolpopollenites micromunus Groot and Penny apparently has larger lumina, as it is described as "relatively coarsely reticulate" (Groot and Penny, 1960, p. 232, pl. 2, figs. 6-7). The rather poor illustration of this species does not indicate a very coarse reticulum, however, and the two forms may be conspecific, although T. micromunus is possibly more spheroidal than Stanley's Tricolpites parvus or my specimens here tentatively assigned to F. variabilis. Type materials should be compared.

Retitricolpites foveoloides Pierce, 1961, is very similar to the grains described here, but on my grains there does not seem to be a tendency for the reticulum to grade into foveolae near the colpi, as it does in Pierce's species. Perhaps the type materials of that species should be compared with my specimens before a connection is ruled out.

Stone (1971, p. 47, pl. 18, figs. 102-103) cites a form similar to specimens studied in this thesis, which may be conspecific, using the name Tricolpopollenites microreticulatus Norton, 1969; Stone's photographs are too poor for true comparison of appearance, but the description given in Norton and Hall (1969, p. 47) does not preclude assigning a conspecific status to *T. microreticulatus* and my species. Stone also puts *Tricolpopollenites tersus* Oltz into synonymy with *T. microreticulatus*, with which I concur.

Tricolpopollenites retiformis Pflug and Thomson has larger luminae than do these specimens.

Genus *Ilexpollenites* (Potonie, 1931) Thiergart, 1937

Type species: *Ilexpollenites iliacus* (Potonie, 1931) Thiergart, 1937

Ilexpollenites sp.

Plate 7, Figures 21-22

1967 Pollen Forma B, Drugg, p. 63, pl. 8, fig. 59.

1969 *Ilexpollenites* sp., Lammons, pl. 7, figs. 8 and 10.

1971 *Pistillipollenites* sp. A, Stone, p. 104-105, pl. 18, figs. 120-121.

Description: Tricolpate pollen; prolate to sub-spheroidal; colpi fairly long, exact length indeterminable because of dense ornamentation, colpi often completely obscured; ornamentation of quite densely packed pilae and gemmae covering entire surface and often obscuring colpi; exine thickness indeterminable.

Size range: 18-25 microns polar axis, 14-17 microns equatorial diameter; six specimens measured.

Occurrence: Found in 21 samples scattered through the sections studied; abundance 0.4% or less. Occurrences are more frequent in the younger, nearer shore sediments of the Price River, Iles and Mesaverde formations, but this form was also found in the oldest samples studied, the marine Mancos Shale of the lower part of the Mount Garfield section. Drugg's specimens were of Maestrichtian age, Stone's were Upper-Campanian-Maestrichtian; Lammons does not discuss his specimens, but the age range of his thesis material is Campanian-Maestrichtian (for references see synonymy above).

Suggested affinity: Gentianaceae?, Aquifoliaceae? (see discussion).

Discussion: This pollen resembles Ilex pollen, but pollen of Rusbyanthus cinchonifolius in the Gentianaceae also has pollen of this general type (see Erdtman, 1952, p. 85, fig. 109B). R. cinchonifolius is tricolporate whereas the species considered here appears to be tricolpate. However, Erdtman (1952, p. 55, fig. 18C) describes pollen of Ilex canariensis as "tricolporoidate," and he describes Sphenostamon, in the same family, as tricolporate. Thus, there does not seem to be much difference in the apertures of the Aquifoliaceae and of Rusbyaenthus (Gentianaceae). Therefore, the pollen described here may have affinities with either the Aquifoliaceae or the Gentianaceae, and the connotation of relationship to Ilex indicated by the genus name Ilexpollenites may be misleading. The latter name is validly applied to this pollen, however, regardless of such possibly misleading connotations; therefore, Stone's (1971) species, assigned by him to Pistillipollenites Rouse, is transferred to Ilexpollenites since it seems to be conspecific with my specimens. Because of the wording of the description of Pistillipollenites Rouse (Rouse, 1962, p. 206), the grains reported here could also be accommodated in that genus. However, since the name Ilexpollenites also applies, and has priority, it is improper to assign these grains to Pistillipollenites.

Genus Myocolpopollenites Elsik, 1966

Type species: Myocolpopollenites reticulatus Elsik, 1966

Myocolpopollenites cf. M. reticulatus Elsik, 1966

Plate 7, Figures 19-20

1966 Myocolpopollenites reticulatus Elsik, in Stover, Elsik and Fairchild, p. 4-5, pl. II, figs. 1-2 (equatorial views).

1968 Myocolpopollenites reticulatus Elsik in Elsik, p. 622, pl. 23, fig. 1 (polar view).

Description: Tricolpate pollen; spheroidal; exine two-layered; inner layer consisting of a reticulum which may be supported by baculae only on the colpi margins and "triradiate crests," (see Elsik, 1966, p. 10-11, for description of triradiate crests); loose-appearing on remainder of grain; colpi margins extend to poles, simulating syncolpi; margins can be seen, on the part of the illustrated grain which has lost its reticulum, to bear rows of projections which are apparently the broken baculae which once supported the reticulum. These do not appear on the remainder of the inner layer exposed by the loss of the reticulum; inner layer ca. 1/2 to 1 micron thick, reticulum extends up to 3 microns above inner layer where it is normally attached, higher where partially detached; muri ca. 1/2 to 1 micron wide; lumina from less than 1 micron up to 3 microns in maximum dimension.

Size range: 31-38 microns maximum diameter; four specimens measured.

Occurrence: Elsik's species was found rarely in a Paleocene lignite from Texas. The specimens considered here were found in seven samples, with abundance up to 0.6%. The highest abundance was in coal sample Pb8957-60 from the Wilson Ranch section, next highest abundance in sample Pb8932 associated with the Trout Creek coal at the top of the Rifle Gap section. Also found in other lithologies, including traces in the marine Mancos Shale.

Suggested affinity: Dicotyledonae.

Discussion: These specimens may be conspecific with Elsik's but are usually smaller, and the lumina do not attain the size of those on Elsik's specimens; therefore, the cf. designation was used. They are certainly closely related to Elsik's species, if not conspecific with it.

The loose nature of the reticulum and the possibility of its detachment are not mentioned by Elsik, but his 1968 publication, pl. 23, fig. 1, shows rows of what could be either granulae or broken baculae(?) the same as seen on the specimen illustrated herein.

Genus *Quercus* Linnaeus

Quercus? cf. Q. *explanata* Anderson, 1960

Plate 7, Figures 23-24

1960 *Quercus explanata* Anderson, p. 19, pl. 5, figs. 15-20.

Description: Tricolpate? pollen; prolate; long colpi extend to poles, have incipient pore or poorly developed pore in many specimens, or colpi bulge and gape in the center; scrobiculate sculpture (densely packed small round holes less than 1 micron across).

Size range: 31-32 microns long, 22-23 microns across; three specimens measured.

Occurrence: Found in four samples from the Rifle Gap section, including one coal sample (Pb8920, 0.4%). Abundance 0.2% to 0.8%; also one occurrence outside the 500 sum in sample Pb4958 from the Mancos Shale from the lower part of the Mount Garfield section.

Suggested affinity: Dicotyledonae; Fagaceae? Quercus?

Discussion: Anderson (1960, pl. 5, figs. 15-19) illustrated several specimens, of similar appearance, as Q. explanata. However, on the same plate, fig. 20, also supposed to represent Q. explanata, is quite strikingly different in appearance from figs. 15-19. The exine is thicker and apparently firmer, with a much stronger tendency to be thinner adjacent to the colpi than are the exines of the other figures. Anderson's figure 20 does not match his description (ibid, p. 19), being reticulate rather than having "the appearance of scabrate sculpture;" i.e., the scale of the ornamentation is larger on fig. 20. I thus assume that Anderson's pl. 5, fig. 20, does not qualify for inclusion in the species Quercus explanata Anderson in view of its deviation from the description of Q. explanata Anderson and since it differs quite obviously from the five other illustrations of Q. explanata given by Anderson on the same plate.

Drugg (1967, p. 49, pl. 7, fig. 29) illustrates a specimen resembling Anderson's (1960) pl. 5, fig. 20, but which is even more pronouncedly reticulate; he calls this form Tricolpites explanata (Anderson) n. comb. Drugg's description of this species is significantly different from that given in Anderson for Q. explanata. Drugg describes his species as reticulate, with a much wider size range than Anderson's, and he makes no mention of the occasional gaping of the middle of the furrows mentioned by Anderson and does not illustrate an equatorial view of his species (all three of the equatorial views shown by Anderson, pl. 5, figs. 15-17, show this gaping). Thus, it may be that Drugg was unduly influenced by fig. 20 of Anderson when he assigned his specimens to Anderson's Quercus explanata, and re-combined it as Tricolpites explanata.

I am not certain that Anderson was correct in assigning his Paleocene species to the extant genus Quercus, although it does appear to be similar to modern oak pollen. No changes in the name will be undertaken here, however.

The specimens considered here are referred to Anderson's species using the cf. designation because they are somewhat smaller than Anderson's, and are scrobiculate rather than having "the appearance of scabrate sculpture" as do Anderson's. However, Anderson's specimens appear to have sculpture similar to those considered here; Anderson simply didn't use the same terminology to describe it.

Elsik (1968, p. 628, pl. 33, figs. 4-7) recombines Q. explanata Anderson as Tricolporopollenites explanata (Anderson) n. comb., basing the name on Anderson's pl. 5, figs. 15 and 16 only. Thus, in my mind, the status of T. explanata (Anderson) Elsik, 1968, is unclear, and the origial name, Q. explanata Anderson seems to be the best alternative until this species is studied and revised in detail and the various type materials compared.

Genus Retitricolpites Van der Hammen, 1956

Type species: Retitricolpites ornatus Van der Hammen, 1956

Retitricolpites minutus Pierce, 1961

Plate 7, Figures 25-27

1961 Retitricolpites minutus Pierce, p. 52, pl. III, figs. 109-110.

Size range: 12-16 microns long, 9-16 microns wide; nine specimens measured.

Occurrence: Pierce's specimens are from the Cenomanian of Minnesota.

In the present study this species is found in all samples except for the two samples, Pb4974 and Pb4983, with the lowest Land Derived/Microplankton ratio (thus farthest from shore); these two samples are from the Mancos Shale of the middle of the Mount Garfield section.

Suggested affinity: Dicotyledonae.

Discussion: Very similar to *Tricolpopollenites micromunus* Groot and Penny, but that species appears to have larger luminae than do these specimens. *T. micromunus*, as reported in Kidson (1971, pl. 8, fig. 29), appears to be the same species as reported here, and is thus not *T. micromunus* in my opinion.

Tricolpopollenites minutus Brenner, 1963, may be similar to *R. minutus*, but is smaller; also, its photographs do not show a trace of the baculae or reticulum mentioned in the description (see Brenner, 1963, p. 93, pl. 40, figs. 5-6), so the species seems to be invalid since it does not comply with Article 38 of the International Code of Botanical Nomenclature (ICBN), 1966, requiring all new fossil plant taxa to be illustrated with a figure or illustration "showing the essential characters" of the taxon in order for it to be validly published.

This species is somewhat similar to *Fraxinoipollenites* cf. *F. variabilis* above but is usually smaller; also, the latter species usually has smaller luminae.

Retitricolpites sp.-1

Plate 7, Figures 28-29

Description: Tricolpate pollen; spheroidal; circular in polar view; colpi long, gaping open; ornamentation distinctly reticulate, with the reticulum rising markedly above the general surface of the mesocolpia in optical section, height of reticulum decreases toward colpi; colpi margins sometimes smooth; polar area is reticulate, but lumina are slightly smaller than in mesocolpia; lumina less than 1 micron up to 1-1/2 microns across; muri ca. 1 micron high in mesocolpia.

Size range: 17-20 microns polar diameter; four specimens measured.

Occurrence: Occurs rarely (eight samples) in the upper half of the Mount Garfield section and in the Rifle Gap section; one grain not in the 500 sum was noted in the coal in the Wilson Ranch section, sample Pb8957-60. Abundance 0.4% or less.

Suggested affinity: Dicotyledonae.

Discussion: This species is similar to *Tricolpopollenites* cf. *T. variofoveatus* described below, but is more often circular, and the reticulum is distinctly higher in the mesocolpia than in the former species. Also, this species has larger lumina and a more distinct reticulum, and the polar area is more highly ornamented.

Kidson (1971, p. 106-107, pl. 8, fig. 11) reports a form as *Retitricolpites* sp. which is probably conspecific with the species described here.

Retitricolpites sp.-2

Plate 7, Figure 30

Description: Tricolpate pollen; prolate; colpi long, reaching poles, often geniculate at equator; ornamentation microreticulate in equatorial mesocolpia, psilate on colpi margins and polar areas; reticulum irregular, lumina small, less than 1 micron across; equatorial views only.

Size range: 16-21 microns long, 11-14 microns wide; five specimens measured.

Occurrence: Found in half of the samples studied, in abundance up to 0.8%; no clear pattern of distribution, but not found in those samples with the highest microplankton percentages.

Suggested affinity: Dicotyledonae.

Discussion: This species is not regarded as the equatorial view of Tricolpopollenites cf. T. variofoveatus or Retitricolpites sp.-1 above, since it is too small in diameter, and the other species mentioned do not seem to be nearly so prolate as does this species. Also, the reticulum is different from R. sp.-1.

Retitricolpites sp.-3

Plate 8, Figures 1-2

Description: Tricolpate pollen; prolate to sub-spheroidal; colpi long, reaching poles, narrow; ornamentation reticulate, lumina sinuous, vermiform, closed; exine ca. 1 to 1-1/2 microns thick.

Size range: 15-22 microns long, 11-16 microns diameter; seven specimens measured.

Occurrence: Found in 35 samples representing all types of sediments in all sections, but highest percentages occur in the Palisade coal and a coal in the Rifle Gap section (sample number Pb8920). Abundance up to 1.4%.

Suggested affinity: Dicotyledonae.

Discussion: Brenner's species Retitricolpites vermimurus (1963, p. 92, pl. 39, figs. 2-3) is somewhat similar to this form, but it is difficult to tell the exact nature of the lumina from Brenner's photographs; also, the muri are higher.

Snead shows the form he calls Salixipollenites sp. A (Snead, 1969, p. 34, pl. 6, figs. 10-11) which has a tendency toward vermiform lumina, but not to the degree found on the species reported here. Also, Snead's form is larger, with wider, deeper colpi.

Retitricolpites sp.-4

Plate 8, Figure 3

1968 Tricolpopollenites hians auct. non (Stanley, 1965): Elsik, p. 622 and 624, pl. 23, figs. 16-19 only, pl. 24, figs. 1-14.

Description: Tricolpate pollen; spheroidal to slightly prolate; colpi long, gaping, notch like in polar view; ornamentation reticulate, lumina 1/2-1 micron across, muri fine, 1/2 micron wide or less; exine ca. 1 micron total thickness.

Size range: 20-22 microns diameter; six specimens measured.

Occurrence: Found in 10 samples of various lithologies from the Mount Garfield and Rifle Gap sections. All samples but one had abundances of 0.4% or less. Coal sample Pb8898 from the middle of the Rifle Gap section had 1.8%. Elsik's (1968) specimens are from a Paleocene lignite from Texas.

Suggested affinity: Dicotyledonae.

Discussion: Elsik's species (see synonymy above) is broadly defined, including small, very prolate forms (Elsik, 1968, pl. 23, figs. 13-15) as well as larger, less prolate forms such as found in this study. The small, very prolate forms are not considered to be conspecific with the forms considered here, and are omitted from the synonymy and from further discussion.

The name Tricolpopollenites hians, used by Elsik (a re-combination of Tricolpites hians Stanley, 1965), is not correctly used according to Stanley's original description and illustrations of T. hians (see Stanley, 1965, p. 321-322, pl. 47, figs. 24-27). Stanley's species has much smaller lumina (0.2-0.3 microns) and should be described as scrobiculate or tectate-perforate rather than reticulate in view of the small size of the lumina. Elsik's illustrated specimens are all clearly reticulate, much coarser than Stanley's.

Retitricolpites vulgaris Pierce (1961, p. 50, pl. III, figs. 101-102) is smaller, but the colpi do not gape as much as they do on R. sp.-4. Also, Pierce's species is spherical, while R. sp.-4 is often somewhat prolate. Pierce's description is rather incomplete and does not describe the nature of the reticulum, but the lumina appear to be smaller in relation to the muri than is normal for R. sp.-4.

Retitricolpites sp.-11

Plate 8, Figure 4

Description: Tricolpate pollen; spheroidal, polar and oblique views common; colpi long, gaping, notch-like in polar view; ornamentation reticulate; lumina largest in polar areas, grades into scrobiculate pattern near colpi; mesocolpia sometimes reticulate, sometimes scrobiculate; lumina up to 1-1/2 microns across in polar regions, muri 1/2-1 micron wide; exine ca. 1 micron thick.

Size range: 15-21 microns diameter; seven specimens measured.

Occurrence: Found in four samples in the upper part of the Grand Junction area sections (including one near the top of the Mancos Shale on Mount Garfield); in three samples from the Rifle Gap section, and from one sample from the upper part of the Buck Tongue of the Mancos Shale at West Salt Creek. Abundance up to 0.4% per sample.

Suggested affinity: Dicotyledonae.

Discussion: Some of the forms included here are difficult to interpret oblique views which may possibly belong to *Tricolpites* cf. *T. variofoveatus* McIntyre, described below.

The designation *Retitricolpites* sp.-11 is derived from the designation, C3r-11, used in the original counts.

Retitricolpites sp.-14

Plate 8, Figures 5-6

1971 *Tricolpites angululuminosus* auct. non Anderson: KIDSON, p. 107, pl. 8, fig. 37.

Description: Tricolpate pollen; prolate; colpi fairly long, reaching vicinity of poles, sometimes show geniculae or incipient poroid structures in the equatorial region, have narrow margo; exine dense, dark-staining, coarsely reticulate to foveolate, 1 to 1-1/2 microns thick; muri 1-2 microns wide, lumina 1/2 to 1-1/2 microns across, sometimes vermiculate near equator.

Size range: 24-28 microns long, 19-21 microns diameter; six specimens measured.

Occurrence: Scattered through the sections studied (25 samples) in low abundance, up to 0.6%, no pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: Kidson's species (see synonymy above) is as described above (at least his illustrated specimen is) and is not *T. anguloluminosus* Anderson (see description of the latter species below). *T. anguloluminosus* is not prolate, has larger lumina and finer muri.

Fraxinoipollenites pachyexinous Leffingwell, 1971, is similar to this species, but is somewhat smaller, and apparently does not have vermiculate lumina (the latter feature is only occasionally present on the forms considered here, however). The two species may be conspecific but type materials need to be compared before making such a determination.

The designation Retitricolpites sp.-14 is derived from the code designation C3r-14, used for this form in the counting process.

Retitricolpites sp.-17

Plate 8, Figure 7

Description: Tricolpate pollen; prolate; colpi short, ca. 1/3 length of polar axis, tightly closed; ornamentation reticulate; lumina very small, ca. 1/2 micron across, over most of grain, grading to slightly over 1 micron in the polar areas; exine structure baculate, baculae ca. 1.75 microns high at equator, grading to ca. 1.25 microns high at poles.

Size range: 36 microns long, 25 microns diameter; one specimen measured.

Occurrence: Found in eight near-shore to on-shore shales, siltstones and coals from the Grand Junction area and Rifle Gap sections; abundance up to 0.6%. This pollen is not transported far from its point of origin, apparently. It does not appear to be restricted to a coal swamp environment because its highest abundance was in sediments associated with coals rather than in the coals themselves.

Suggested affinity: Dicotyledonae.

Discussion: This pollen type is very distinctive. It is distinguished from other forms by its very short colpi and by its reticulum which is largest at the poles. No pollen of this type has been described in the literature, to my knowledge. However, there were insufficient numbers of well-preserved, well-oriented specimens found on which to base a new formal species, in my opinion.

The designation Retitricolpites sp.-17 is taken from the code designation C3r-17, used in the counting process.

Retitricolpites spp.

Plate 8, Figures 8-9

Description: Tricolpate pollen; prolate; reticulate; all specimens of such pollen which could not be assigned to any of the above species due to poor preservation or orientation, etc., are assigned here.

Size range: Variable.

Occurrence: Present in 41 samples, up to 2.0% per sample; most common in marine Mancos Shale.

Suggested affinity: Dicotyledonae.

Discussion: This category was recorded mainly for the purpose of determining total tricolpate pollen and has little usefulness apart from this.

Genus Striatopollis Krutzsch, 1959

Type species: Striatopollis sarstedtensis Krutzsch, 1959

Striatopollis sp.-1

Plate 8, Figures 10-11

Description: Tricolpate pollen; prolate to rhomboidal; colpi long, reach poles; ornamented with striae which run at an angle to the polar axis, not parallel to it; exine ca. 1/2 micron thick.

Size range: 16-18 microns long, 12-17 microns diameter; four specimens measured.

Occurrence: Scattered through the study in 19 samples of various lithologies from coal to marine shale. Abundance up to 0.6%, highest in fresh water or lagoonal samples (samples with very high Land Derived/Microplankton ratios).

Suggested affinity: Dicotyledonae.

Discussion: Striatopollis paraneus (Norris) Singh, 1971, is similar but is striatoreticulate.

Striatopollis sp.-2

Plate 8, Figures 12-13

Description: As in S. sp.-1, but the striae are more nearly parallel to the polar axis than in that species, and are somewhat fainter.

Size range: 30 microns long, 18 microns diameter; one specimen measured.

Occurrence: Found in seven samples, all from the Mancos Shale except for one grain in sample Pb8886X, a siltstone in a sandy zone near the base of the Rifle Gap section. Abundance 0.2% or less.

Suggested affinity: Dicotyledonae.

Discussion: This species is distinguished from S. sp.-1 mainly by its larger size and more parallel striations.

Genus Tricolpites Cookson, 1947, ex Couper, 1953

Type species: Tricolpites reticulatus Cookson, 1947

Comments: Cookson (1947, p. 134) uses the name Tricolpites for two new species, Tricolpites (Tubifloridites) antipodica and T.

reticulata, but did not give a generic description or designate a type species.

Couper (1953, p. 61) described the genus as "Free, isopolar, tricolpate. Exine variable in thickness and sculpture. Size variable." He also designated T. reticulus Cookson, 1947, as the type species. (Tricolpites (Tubifloridites) antipodica is apparently pollen of a Composite and, thus, is probably tricolporate and should, thus, not be included in Tricolpites.)

Couper did not have any specimens of T. reticulatus and did not illustrate it, but merely designated it as the genotype of Tricolpites Cookson ex Couper. The original illustration of T. reticulata in Cookson (1947, pl. 15, fig. 45), as reproduced in the Catalog of Fossil Spores and Pollen, vol. 15, p. 15, does not show the finely reticulate condition she describes as a characteristic of the species. Also, the description does not describe the nature or size of the muri and lumina, etc. The species is probably invalid, as it does not satisfy Article 38 of the ICBN requiring that an illustration be provided which shows the essential characters of the species. However, since I did not have access to an original copy of Cookson's publication in order to check the original photographic illustration, no "formal" invalidation of the type species is undertaken here. However, as additional proof of the difficulty in interpretation of T. reticulatus, probably resulting from the poor original illustration of that species, the following reports of this species should be mentioned. These widely varying forms all bear the name of T. reticulatus Cookson: T. reticulatus Cookson as reported in Srivastava, 1967, pl. IIIP; T. reticulatus Cookson as reported in Norton and Hall, 1969, pl. 7, fig. 1, and T. cf. T.

reticulatus Cookson as reported in Hedlund, 1966, pl. 9, fig. 3. The overall outline and the size and nature of the reticulum varies so widely among those forms that it seems plain that this species is insufficiently described and illustrated in the original publication to allow different workers to use the name consistently. T. reticulatus Cookson, 1947 should either be re-illustrated and re-described by the original author or should be invalidated and a new type species designated for the genus Tricolpites Cookson ex Couper, 1953; the new type species might be one of those described by Couper, although it would be better, in my opinion, if the new type species were illustrated with a photograph in addition to the original drawings in Couper, 1953.

Another weakness of the original publication of T. reticulatus Cookson, 1947, was that the publication was apparently never very widely distributed, in view of the trouble I had in unsuccessfully trying to obtain a copy in time to incorporate ideas derived from observation of the original photograph into this thesis.

Tricolpites anguloluminosus Anderson, 1960

Plate 8, Figures 14-15

1960 Tricolpites anguloluminosus Anderson, p. 26, pl. 6, figs. 15-17, pl. 8, figs. 17-18.

1965 Tricolpites bathyreticulatus Stanley, p. 320-321, pl. 47, figs. 18-23.

1969 Salixipollenites sp. cf. Tricolpites bathyreticulatus Stanley, in Snead, p. 34, pl. 1, fig. 8.

Size range: 19-26 microns diameter (polar view, eight specimens measured); polar axis measured 21 and 22 microns on two specimens in equatorial view.

Occurrence: Campanian to lower Paleocene. Found in this study in 50 samples; most common and most abundant in the marine

Mancos Shale of the lower part of the Mount Garfield section, but not found in those samples with very high percentages of microplankton. Abundance up to 2.0%.

Suggested affinity: Dicotyledonae. Has been said to resemble *Fraxinus* and *Bucklandia* (see Stanley, 1965, p. 321) and *Salix* (see Snead, 1969, p. 34).

Discussion: Anderson's and Stanley's descriptions and photographs match so closely that there is no justification for the retention of two species names; therefore, Stanley's *T. bathyreticulatus* is rejected as a junior synonym of *T. anguloluminosus* Anderson, 1960.

The species illustrated by Stone (1971, pl. 18, figs. 114-115) as *Tricolpites* cf. *T. anguloluminosus* Anderson is a more robust, larger, more prolate form than Anderson's, and should not be allied with it.

Thompson (1969, pl. 18, fig. 16) illustrates a large, robust grain with a partially detached reticulum as *Tricolpites* cf. *T. bathyreticulatus*; this specimen is difficult to interpret, but is probably of a different species. Thompson's pl. 18, fig. 18, *Tricolpites* cf. *T. anguloluminosus* is conspecific with the forms considered here; it very much resembles the illustrations by Stanley, 1965.

Elsik (1968, p. 624, pl. 24, figs. 15-16, pl. 25, fig. 1) combines *T. anguloluminosus* Anderson, *Tricolpopollenites platyreticulatus* Groot, Penny and Groot, and *Tricolpites bathyreticulatus* Stanley under the name *Tricolpopollenites anguloluminosus* (Anderson) comb. nov., without giving any reasons or justification for so doing. I do not agree that *T. platyreticulatus* Groot, Penny and Groot, 1961, is synonymous with *T. anguloluminosus*. The former species has a wider size range of lumina than does *T. anguloluminosus* (and *T. bathyreticulatus*). *T. platyreticulatus* is slightly prolate, while the other species is spherical to oblate. *T. platyreticulatus* is also smaller than the other species considered, and is widely separated from them stratigraphically. I thus feel that to use the synonymy of *T. anguloluminosus* as given by Elsik would result in too broad a concept of the species, would negate its stratigraphic usefulness, and would reduce it to the status of a "waste basket" taxon; such usage is in this case unjustified, unnecessary, and to be avoided. However, the specimens illustrated by Elsik do appear to belong to *T. anguloluminosus*, but are slightly smaller (ca. 19 microns diameter).

Tricolpites interangulus Newman, 1965

Plate 8, Figures 16-18

1965 *Tricolpites interangulus* Newman, p. 10-11, pl. 1, fig. 3.

1965 *Tricolpites microreticulatus* Belsky, Boltenhagen and Potonie, p. 75, pl. 12, figs. 8-9.

1967 *Tricolpites reticulatus* Cookson in Norton and Hall, p. 105-106, pl. 1, fig. E.

1969 *Tricolpites* sp. B, Snead, p. 51, pl. 5, fig. 13.

1969 *Tricolpites reticulatus* Cookson in Oltz, p. 141-142, pl. 41, fig. 103.

1971 *Gunnera microreticulata* (Bel., Boltenh. and Pot.) Leffingwell, p. 37 and 40, pl. 7, figs. 7-8.

1971 *Tricolpites reticulatus* Cookson in Stone, p. 102, pl. 18, fig. 112.

Description: See Newman (1965, p. 10-11) for description.

Size range: 21-28 microns diameter; eight specimens measured.

Occurrence: Senonian to lowest Paleocene. Found in 35 samples; abundance up to 7.0%. Occurrences were extremely rare in the marine Mancos Shale of the lower half of the Mount Garfield section. The highest abundance occurred in sample number Pb6775, a shale just below the Palisade Coal at the top of the Mount Garfield section.

Suggested affinity: Gunneraceae. Gunnera petaloidea, illustrated by Selling (1947, p. 167, pl. 12, figs. 231-234), is very similar to T. interangulus, but it is somewhat larger.

Discussion: Gunnera microreticulata (Bel., Boltenh. and Pot.) Leffingwell, 1971, is regarded as a junior synonym of T. interangulus Newman, 1965, in spite of Leffingwell's statement that his specimens have a smaller reticulum than T. interangulus, for these reasons: 1) Leffingwell puts T. microreticulatus in synonymy with his specimens, and the former species has at least as large a reticulum as does T. interangulus Newman, maybe even slightly larger; thus Leffingwell's species could not at the same time be a synonym of T. microreticulatus and have a smaller reticulum than T. interangulus unless all three species are the same, as they are here regarded. 2) My specimens show much variation in size of lumina, with no clear lines to be drawn between large and small end members. There is a continuum, and all of the reticula, even the largest, have lumina 1/2 micron or less in diameter. Therefore, 3) the size differences are so small (minute fractions of a micron) and so variable that they do not constitute a valid basis for distinguishing two species. There may be incompletely differentiated geographical races, but not two species.

The polar thickening mentioned by Leffingwell is also a variable feature.

This species appears to be very similar to, perhaps conspecific with, T. reticulatus Cookson, 1947, but is not placed in synonymy with that species because the illustration given in Cookson, 1947, is inadequate for comparison.

Tricolpites mutabilis Leffingwell, 1971

Plate 8, Figures 19-20

1968 Tricolpopollenites sp. in Elsik, p. 624 and 626, pl. 23, figs. 2 and 4-7 only.

1971 Tricolpites erugatus auct. non Hedlund: KIDSON, p. 108, pl. 8, figs. 19-20.

1971 Tricolpites mutabilis Leffingwell, p. 44-45, pl. 8, figs. 1-3.

Size range: 10-17 microns diameter; 10 specimens measured.

Occurrence: Campanian to Paleocene. Found in all samples except for two which had very low Land Derived/Microplankton ratios (samples Pb4980 and 4983); abundance up to 5.2% per sample. Highest percentage was found in a coal sample, but not all coal samples had high percentages of this species.

Suggested affinity: Dicotyledonae.

Discussion: Kidson's species (see synonymy above) appears to be conspecific with T. mutabilis. The species T. erugatus Hedlund is more circular in polar view and is also prolate, while the forms considered here are ± spherical to oblate.

Tricolpites cf. T. psilascabratus Norton, 1969

Plate 8, Figure 21

Description: Tricolpate pollen; oblate to spherical, ± circular in polar view; colpi long, reaching poles, gaping, with thin ragged edges; exine psilate to chagrenate or to very slightly scabrate, ca. 3/4 micron thick.

Size range: 18-24 microns; 10 specimens measured.

Occurrence: Found in 34 samples; abundance up to 0.8%; no pattern observed.

Suggested affinity: Dicotyledonae.

Discussion: This species is cited using the cf. designation because my specimens are often chagrenate when viewed using oil immersion and only rarely scabrate. Norton's species is described as being scabrate when viewed under oil immersion.

Tricolpites cf. Tricolporites traversei Anderson

Plate 8, Figures 22-23

1960 Tricolporites traversei Anderson, p. 26, pl. 2, fig. 20.

1969 Tricolporites traversei Anderson in Thompson, p. 64, pl. 18, fig. 5.

1971 Eucommiidites(?) sp. in Kidson, p. 87-88, pl. 6, fig. 11 only.

Description: Tricolpate pollen; prolate to rhomboidal; colpi long, with geniculus or constriction in center; grain often with bulges and folds in the equatorial region; exine psilate, 1/2 to 1 micron thick.

Size range: 10-12 microns long, 8-11 microns diameter, 15 specimens measured.

Occurrence: Found in all samples studied except for sample Pb4983 from the Mancos Shale of Mount Garfield. This sample had the lowest Land Derived/Microplankton ratio of any sample studied and, thus, presumably represents conditions very far from shore. The abundance of this species was up to 10.4%, one of the most abundant palynomorphs of the entire study. The highest percentages were found in coal samples, but not all coals had high percentages of this form, and high percentages were also noted in lagoonal shales and siltstones associated with the coals.

Suggested affinity: Dicotyledonae.

Discussion: This species is very similar to Anderson's and may be conspecific with it. The cf. designation was used because Anderson's illustrated specimen (see synonymy above) is more prolate than the forms encountered here, and because these specimens do not appear to be tricolporate, as Anderson says his are. (However, Anderson says of his species that the pore is "not distinctly visible but manifested in a bow-shaped furrow;" thus, his species probably has colpi as found on the specimens considered here.)

Thompson's species (see synonymy) is conspecific with the species reported here.

Kidson (1971, pl. 6, fig. 11-12) gives two illustrations as Eucommiidites(?) sp. His fig. 11 appears to be conspecific with the species reported here, but his fig. 12 appears to indeed illustrate a representative of the genus Eucommiidites.

Tricolporopollenites minor Takahashi, 1961, is quite similar except for its larger size and clearly defined pores.

Tricolpites sp.-1

Plate 8, Figure 24

Description: Tricolpate pollen; spheroidal to slightly prolate or oblate; colpi of moderate length, not quite reaching poles, edges often ragged-appearing, gaping open; exine tectate-perforate, giving a scrobiculate appearance in surface view, ca. 1 micron thick.

Size range: 13-15 microns long, 11-15 microns diameter; six specimens measured.

Occurrence: Found in 33 samples, about half the samples studied; abundance up to 2.6%. Most common and most abundant in the normal marine Mancos Shale, but not found in samples furthest from shore.

Suggested affinity: Dicotyledonae.

Discussion: This species is very similar to *T. parvus* Stanley, 1965, which is significantly larger, however.

This species differs from *Fraxinoipollenites* cf. *F. variabilis* Stanley in having smaller luminae and in its usually smaller size.

Tricolpites sp.-2

Plate 8, Figure 25

Description: Tricolpate pollen; prolate; colpi long, reaching vicinity of poles; baculate (pilate?) exine, intectate, gives scabrate surface view; exine ca. 1/2 micron thick.

Size range: 13-16 microns long, 9-12 microns diameter; six specimens measured.

Occurrence: Found in 23 samples scattered through the sections of the present study, but it is the most abundant in the marine Mancos Shale of the lower half of the Mount Garfield section. Abundance 0.2% to 0.4%.

Suggested affinity: Dicotyledonae.

Discussion: Structural elements are further apart than on *T.* sp.-1 above; this species is also more prolate than *T.* sp.-1.

Tricolpites sp.-3

Plate 8, Figures 26-27

Description: Tricolpate; prolate; very small; colpi long, usually closed; ornamentation of short baculae, giving a micro-granulate or scabrate appearance in surface view; exine ca. 3/4 micron thick.

Size range: 10-12 microns long, 6-8 microns diameter; six specimens measured.

Occurrence: Found in 54 samples of varied lithologies; rarest in coals, otherwise no pattern noted. Abundance up to 5.6% per sample.

Suggested affinity: Dicotyledonae.

Discussion: Distinguished from similar forms by its very small size.

Tricolpites sp.-4

Plate 8, Figures 28-29

Description: Tricolpate pollen; almost exclusively oblique and distorted views seen, shape uncertain, probably ± equidimensional; colpi have thin, smooth margo; exine tectate-perforate, giving a scrobiculate appearance in surface view; exine apparently quite flexible, as it is always folded and distorted, ca. 1 micron thick.

Size range: 22-30 microns maximum measurement; four specimens measured.

Occurrence: Found in 16 samples; most common in the Mancos Shale of the lower part of the Mount Garfield section. Abundance up to 1.2%.

Suggested affinity: Dicotyledonae.

Discussion: Despite their distorted condition and consequent difficulty of identification, these grains probably represent a single species.

Tricolpites sp.-5

Plate 8, Figure 30

Description: Tricolpate pollen; spherical, with circular outline in polar view; colpi long, gaping, with thin, usually ± ragged edges; exine psilate, very thin (ca. 1/2 micron or less).

Size range: 14-17 microns diameter; four specimens measured.

Occurrence: Found in 39 samples; abundance up to 1.4%. No pattern discernible in the distribution.

Suggested affinity: Dicotyledonae.

Discussion: This species is similar to *Tricolpites psilascabratus* Norton, 1969, but is smaller, thinner-walled, and smoother. It differs from *T. mutabilis* Leffingwell in being more circular in polar view, and thinner-walled. Some confusion is possible with *T. mutabilis*, however, and intermediate forms exist.

T. erugatus Hedlund, 1966, is ± prolate, and has a thicker wall.

Tricolpites sp.-6

Plate 8, Figure 31

Description: Tricolpate pollen; spheroidal, mostly oblique views; colpi long, sometimes gaping, with smooth margins; exine psilate to slightly scabrate, ca. 1 micron thick.

Size range: 17-21 microns diameter; three specimens measured.

Occurrence: Found in 12 samples of varying lithology, but attains greatest abundance in coal samples. Abundance up to 3.2%.

Suggested affinity: Dicotyledonae, probably a coal-swamp plant.

Discussion: This species differs from *T.* sp.-5 in its thicker wall and usually larger size, and from *T.* cf. *T. psilascabratus* by having more well-defined colpi with smoother edges.

The differences between this form and *T. mutabilis* are determined rather subjectively, and some specimens of each of these two species may have been included in counts of the other. The two species may be the same, but the oblique views recorded here could not be related with certainty to T. mutabilis. T. sp.-6 is usually larger than T. mutabilis.

Tricolpites sp.-7

Plate 8, Figure 32

Description: Tricolpate pollen; ± spherical, circular in polar view; colpi long, reaching poles, margins somewhat ragged; exine scabrate, 1 to 1-1/2 microns thick.

Size range: 14-20 microns diameter; six specimens measured.

Occurrence: Found in 23 samples, in amounts up to 1.6% per sample. Most abundant in coals, but not all coals have it in abundance.

Suggested affinity: Dicotyledonae. May represent a coal-swamp plant.

Discussion: This species differs from T. mutabilis in its more circular outline and thicker wall. It differs from T. cf. T. psilascabratus and from T. psilascabratus Norton, 1969, in having a thicker exine. T. erugatus Hedlund, 1966, differs in being prolate. T. sp.-6 has a thinner exine.

This species as well as T. sp.-6 and T. mutabilis have similar distribution, characterized by maxima in coal samples. These species are also morphologically similar and hard to separate, and seem to intergrade. There may be only one species involved, which should then bear the name T. mutabilis Leffingwell.

Tricolpites sp.-8

Plate 8, Figures 33-35

Description: Tricolpate pollen; oblate; rounded triangular in polar view, sides convex, but often folded inward to create a pseudo-concave appearance; colpi short, simple, slightly open, positioned at equatorial apices of grains; exine clavate (almost baculate, i.e., clavae only slightly expanded at their free ends), clavae arranged in a striato-reticulate pattern; exine ca. 1 micron thick.

Size range: 22-26 microns diameter; five specimens measured.

Occurrence: Found in four samples from the upper part of the Mount Garfield section and from the Rifle Gap section, plus one questionable occurrence from the Mancos Shale in the lower part of the Mount Garfield section. Abundance up to 0.8%; highest abundance in sample Pb6775, a probably lagoonal shale just below the Palisade Coal.

Suggested affinity: Dicotyledonae.

Discussion: This distinctive striato-reticulate grain does not appear in the published literature and could have been described as a new formal species. However, in my opinion, not enough well-preserved and well-oriented specimens were available in order to clearly enough illustrate its morphology and establish its size range, etc.

This species apparently is not transported far from shore and may be a useful nearshore indicator.

Tricolpites sp.-9

Plate 8, Figures 36-37

Description: Tricolpate pollen; prolate; colpi long, straight, simple; exine psilate, ca. 1/2 micron thick.

Size range: 9-14 microns long, 4 to 7-1/2 microns diameter; six specimens measured.

Occurrence: Found in 31 samples; abundance up to 2.0%; usually less than 1.0%; no recognizable pattern.

Suggested affinity: Dicotyledonae.

Discussion: This species is distinguished from similar forms by its very small size.

Genus Tricolpopollenites Pflug and Thomson, 1953

Type species: Tricolpopollenites parmularius Pflug and Thomson, 1953

Tricolpopollenites cf. T. extraneus Groot, Penny and Groot, 1961

Plate 8, Figure 38

1961 Tricolpopollenites extraneus Groot, Penny and Groot, p. 134, pl. 26, figs. 19-20.

Description: Tricolpate pollen; oblate; colpi long, bordered by prominent margo; exine 1-1/2 to 2 microns thick, reticulate; muri coarse, ca. 1 micron wide, up to 1-1/2 microns high; lumina small, irregular, ca. 1 micron wide.

Size range: 18.5 microns diameter; one specimen measured.

Occurrence: One specimen each in seven samples from the Mount Garfield and Rifle Gap sections. Most of the samples were in near-shore or shore sediments, but one, Pb6746, was from the marine Mancos Shale on Mount Garfield.

Suggested affinity: Dicotyledonae. Groot, Penny and Groot give the affinity of their species as Salix?

Discussion: This species strongly resembles T. extraneus, but that species is described as being "ornamented with dome-shaped projections" (Groot, Penny and Groot, 1961, p. 134) which give the reticulate pattern, although this is not evident from the illustrations (ibid, pl. 26, figs. 19-20). Also, T. extraneus looks as if it has finer muri than do the specimens considered here.

Tricolpopollenites cf. T. variofoveatus (McIntyre) Elsik, 1968

Plate 9, Figures 1-3

1965 Tricolpites variofoveatus McIntyre, p. 210, figs. 19-22.

1968 Tricolpopollenites variofoveatus (McIntyre) Elsik, p. 624, pl. 31, figs. 5-8, 10.

Description: Tricolpate pollen; free, radiosymmetric, isopolar, probably spheroidal, only polar views noted; amb subtriangular to circular, sides convex; colpi long, narrow to fairly wide open, reaching nearly to poles; a suggestion of the "indefinite poroid area in the colpi at the equator," noted by McIntyre on some of his specimens, is present on some of these specimens; sculpture microreticulate, lumina vary from ca. 1 micron across in the mesocolpia to 1/2 micron or less toward the poles and the colpi, on a majority of specimens the colpi margins and often he polar areas as well are psilate; exine ca. 3/4 micron to 1 micron thick.

Size range: Diameter (polar view) 16-25 microns; 10 specimens measured.

Occurrence: Found in 42 samples, in abundances up to 1.8%. Highest percentages occur in coals, but not all coals have high percentages. McIntyre (1965) and Elsik (1968) report T. variofoveatus from Paleocene strata; Elsik's specimens are from a lignite.

Suggested affinity: Dicotyledonae.

Discussion: This species is cited with the cf. designation because its size median is larger than that of McIntyre's species, and because the forms considered here exhibit a wider range of ornamentation than McIntyre's, and may represent a highly polyphyletic group.

Anderson (1960, pl. 5, fig. 20) illustrates a specimen which he refers to his Quercus explanata, but which deviates sufficiently from the description and the other illustrations of that species to be excluded (see discussion of this under Quercus? cf. Q. explanata Anderson. Anderson's specimen may be the same as those illustrated here, although it is significantly larger.

Drugg (1967, p. 49, pl. 7, fig. 29) describes and illustrates a species which he refers to Anderson's species just discussed, which he recombines as Tricolpites explanata (Anderson) Drugg. However, as discussed above, this is almost certainly based on Anderson's pl. 5, fig. 20 and, thus, is not the same as the species Q. explanata Anderson as that species is described and otherwise illustrated. Drugg's pl. 7, fig. 29, is probably the same as those considered here, but it also is larger.

Agasie (1969, p. 28, pl. 4, fig. 5) illustrates a specimen he calls Tricolpites sp.-2, which is probably the same as some of the grains included here.

Kidson (1971, pl. 8, figs. 4-5) illustrates two grains as "Retitricolpites cf. R. geraniodes Brenner" which appear to be the same as those considered here; his fig. 5 is surely conspecific with Agasie's Tricolpites sp.-2.

Thompson (1969, pl. 18, figs. 12-13) illustrates two specimens as Tricolpites cf. T. explanata (Anderson) Drugg which do not fit Anderson's species for the same reasons Drugg's specimens do not (see above). Thompson's pl. 18, fig. 13, appears to be conspecific with the forms under discussion here. However, his fig. 12 is somewhat more highly ornamented in the polar area and colpi margins, and its relationship to these forms is less certain. No description is given.

Finally, Oltz (1969, p. 147, pl. 41, fig. 125) describes as a new species Tricolpites apivariatus Oltz, a pollen type whose description is more or less the same as McIntyre's (1965) description of T. variofoveatus. Oltz's specimens are larger, however, with an "equatorial diameter 23-28 microns," while McIntyre's were 10-21 microns in equatorial diameter, 15-17 microns in polar diameter. (Oltz's illustration, supposed to be magnified 390X, calculates out to be 41 microns in polar diameter, so it is not known for sure if the magnification or the size range is incorrect). Oltz's illustration is so poor it is difficult to tell if it bears much resemblance to McIntyre's forms or not.

My specimens bridge the size gap between Oltz's and McIntyre's species. Although there are two morphological end members in the taxon considered here, the morphological variations are not correlated with size, and there is a full range of intermediate forms connecting the end members and making it impossible to say where one subtype stops and the next begins. (The two end members are: 1) specimens which are psilate in the polar areas and 2) specimens which are reticulate in the polar areas, but on which the ornamentation is markedly smaller in the polar area than in the mesocolpia. The colpi margins are psilate or nearly so in both subtypes. See illustrations.)

In view of the above discussion, it is possible that McIntyre's species, Oltz's "species" and my specimens are all conspecific, in which case Elsik's (1968) recombination of McIntyre's species, as Tricolpopollenites variofoveatus (McIntyre) Elsik, would be applicable. However, in view of the difficulty in comparing with Oltz's photograph and in view of the size differences and morphological gradations involved, it is not possible to determine conspecificity without comparison of the type materials used by McIntyre, Oltz, and me.

See description of *Retitricolpites* sp.-1 above for differences between that species and *T.* cf. *T. variofoveatus*.

Aquilate Pollen

Genus *Aquilapollenites* Rouse emend. Funkhouser, 1961

Type species: *Aquilapollenites quadrilobus* Rouse, 1957

Comment: This genus as used herein follows the treatment given in Tschudy and Leopold, 1971, which regards several genera described by Mtchedlishvili (*in* Samoilovitch et al., 1961), Srivastava (1968a), Chlonova (1961), and Simpson (1961), as junior synonyms of *Aquilapollenites*. These genera are *Mancicorpus* Mtchedlishvili emend. Srivastava, 1968a, *Triprojectus* Mtchedlishvili, 1961, *Projectoporites* Mtchedlishvili, 1961, *Parviprojectus* Mtchedlishvili, 1961, *Integricorpus* Mtchedlishvili, 1961, *Tricerapollis* Chlonova, 1961, and *Taurocephalus* Simpson, 1961.

These grains are not included with tricolpate pollen because in many cases the apertures deviate from normal colpi.

Aquilapollenites attenuatus Funkhouser, 1961

Plate 9, Figure 4

1961 *Aquilapollenites attenuatus* Funkhouser, p. 194 and 196, pl. 2, fig. 1.

Size range: Length of polar axis 40-45 microns; two specimens measured.

Occurrence: Found in two samples, Pb6775 (0.6%) and Pb6778 (one specimen, not in 500 sum) from the freshwater or nearshore upper portion of the Mount Garfield section.

Literature range Upper Campanian to Upper Maestrichtian (Tschudy and Leopold, 1971, p. 155-156).

Suggested affinity: Dicotyledonae.

Discussion: This species is similar to A. amplus Stanley, 1961, which is usually larger, however, and has colpi at the ends of the equatorial projections. A. attenuatus Funkhouser is tridemicolpate.

Tschudy and Leopold (1971, p. 156) mention the similarity of this species to A. accipiteris, A. ascriptivus, A. aucellatus, A. augustus, A. drumhellerensis, A. hispidus and A. regalis of Srivastava (1969).

Aquilapollenites cf. A. bertillonites Funkhouser, 1961

Plate 9, Figure 5

1961 Aquilapollenites bertillonites Funkhouser, p. 196, pl. 2, fig. 5.

1961 Aquilapollenites murus Stanley, p. 347, pl. 5, figs. 1-9, pl. 6, figs. 1-9.

Description: Aquilate pollen; iso- or heteropolarity usually not determinable, but best preserved specimens seem to be isopolar; ornamentation ± striate with no preferred direction of striae, this may correspond to Funkhouser's bertillon pattern; equatorial projections attenuated.

Size range: See Plate 9, Figure 5; magnified X1000. Specimens were obliquely oriented and difficult to measure. Seems to be within the ca. 25 micron polar axis range given by Funkhouser (1961, p. 196).

Occurrence: Found in six samples scattered through the stratigraphic range of this study; only two were within the 500 sum counted for their respective samples. The literature range of A. bertillonites Funkhouser is lower and middle Maestrichtian (see Tschudy and Leopold, 1971, fig. 2 and p. 160). The present report would extend the range to the Middle Campanian, if these specimens are indeed representatives of A. bertillonites.

Suggested affinity: Dicotyledonae.

Discussion: This species seems to belong to A. bertillonites, based on the ornamentation and attenuated projections; however, all the specimens were poorly preserved and did not show sufficient characteristics to justify their definite assignment to that species. The hitherto reported much younger stratigraphic range of A. bertillonites would also seem to indicate that the species reported here could be a different species.

Aquilapollenites calvus Tschudy and Leopold, 1971

Plate 1, Figures 6-7

1971 Aquilapollenites calvus Tschudy and Leopold, p. 138-140, pl. 1, fig. 4, pl. 3, figs. 1-5.

Size range: Length of polar axis 22-30 microns; nine specimens measured.

Occurrence: Found in 17 samples; abundance up to 1.6%. Occurrences least frequent in marine Mancos Shale.

Literature range Middle (Lower?) Campanian to Upper Maestrichtian (Tschudy and Leopold, 1971, p. 138-139).

Suggested affinity: Dicotyledonae.

Discussion: This species is similar to Mancicorpus anchoriforme Mtchedlishvili, 1961, as given in Srivastava, 1968a (p. 1486, pl. II, figs. 15-16). However, the spines along the colpi and on the ends of the equatorial projections of A. calvus are not mentioned by Srivastava, nor do they show in his photographs. Therefore, M. anchoriforme is regarded, for the time, as a distinct species. Tschudy and Leopold (p. 140) also give reasons for distinguishing their species from M. notabile and M. anchoriforme Mtchedlishvili, M. albertensis Srivastava, and Tricerapollis unicus Chlonova.

Aquilapollenites navicolpites Funkhouser, 1961

Plate 9, Figures 8-9

1961 Aquilapollenites navicolpites Funkhouser, p. 196, pl. 2, figs. 2-3.

Size range: Length of polar axis 25-33 microns; six specimens measured.

Occurrence: Found in 17 samples from the Mancos Shale of the Mount Garfield and West Salt Creek sections; abundance up to 0.6%; only one specimen was noted from West Salt Creek (Buck Tongue of Mancos).

Literature range Campanian (Funkhouser, 1961, p. 196).

Suggested affinity: Dicotyledonae.

Discussion: This species is distinguished from others by the latitudinal grooves occupying the equator.

This species' distribution seems to indicate it was produced by upland plants, possibly being carried to the basin of deposition largely by wind currents, since it is found only in marine samples and in low percentages. In the very nearshore or onshore samples it was presumably masked by the local flora.

Aquilapollenites quadrilobus Rouse, 1957

Plate 9, Figure 10

1957 Aquilapollenites quadrilobus Rouse, p. 371, pl. 1, fig. 14.

1961 Aquilapollenites polaris Funkhouser, p. 198, pl. 1, figs. 1-2.

1961 Aquilapollenites pulcher Funkhouser, p. 198, pl. 1, fig. 7.

1961 Aquilapollenites pulvinus Stanley, p. 347-348, pl. 7, figs. 1-12.

1969 Aquilapollenites hirsutus Srivastava, p. 139, pl. V, fig. 30.

Size range: Length of polar axis 24-30 microns; six specimens measured.

Occurrence: Found in half the samples studied (32 samples); abundance up to 0.6%; most abundant in lagoonal (or possibly fresh-water) samples.

Literature range Middle (Lower?) Campanian to Upper Maestrichtian (Tschudy and Leopold, p. 125-126).

Suggested affinity: Dicotyledonae.

Discussion: The synonymy above follows Tschudy and Leopold (1971, p. 125-131). A. turbidus Tschudy and Leopold, 1971, is similar, but is smaller, and is ± isopolar. See Tschudy and Leopold, p. 159, for description of A. turbidus as well as its past confusion with A. quadrilobus Rouse.

A. quadrilobus is the most commonly encountered species of Aquilapollenites in this study.

Aquilapollenites rigidus Tschudy and Leopold, 1971

Plate 9, Figure 11

1971 Aquilapollenites rigidus Tschudy and Leopold, p. 152-154, pl. 1, fig. 1, pl. 4, figs. 1-3.

Size range: Length of polar axis 34 microns; one specimen measured.

Occurrence: Found in three samples of Mancos Shale; abundance 0.2% or less. Lower and Middle Campanian literature range (Tschudy and Leopold, 1971, p. 153).

Suggested affinity: Dicotyledonae.

Discussion: This species is very similar to A. steckii Srivastava, 1968, but differs in that the equatorial projections are more slender than the polar projections, the reverse being the case in A. steckii. More detailed differences are listed in Tschudy and Leopold, 1971, p. 154.

Aquilapollenites trialatus Rouse var. uniformis
Tschudy and Leopold, 1971

Plate 10, Figure 1

1971 *Aquilapollenites trialatus* Rouse var. *uniformis* Tschudy and Leopold, p. 145 and 148, pl. 1, fig. 7, pl. 4, fig. 8.

Size range: Length of polar axis 35-47 microns; three specimens measured.

Occurrence: Found in 10 samples; abundance up to 0.6%. One specimen outside the 500 sum was found in sample Pb4940 from the marine Mancos Shale near the base of Mount Garfield. All the other occurrences were stratigraphically much higher. Three samples from the Buck Tongue of the Mancos at West Salt Creek had occurrences, including the highest abundance, 0.6% in sample Pb4712. Five occurrences were noted from the top seven samples studied from the Mount Garfield section, and one specimen was counted in sample Pb8919 from near the middle of the Rifle Gap section.

Literature range Lower to Upper Campanian (Tschudy and Leopold, 1971, p. 145).

Suggested affinity: Dicotyledonae.

Discussion: This variety is distinguished from Tschudy and Leopold's *A. trialatus* var. *variabilis* by its more uniform ornamentation of the grain body. The specimens reported here sometimes showed a tendency for reduced size of the reticulum in the equatorial region, but not to the degree found in var. *variabilis*. The two varieties may be incompletely differentiated in this area.

Aquilapollenites spp.

Plate 9, Figure 12

Description: *Aquilapollenites* pollen which could not be assigned to any species because of poor preservation, obscuring debris, etc.

Size range: Variable.

Occurrence: Found in 29 samples; abundance up to 1.0%; no pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: This category was included in order to preserve a record of the total contribution of aquilate pollen to the microflora.

Tricolporate Pollen

Genus *Cupanieidites* Cookson and Pike, 1954

Type species: *Cupanieidites orthoteichus* Cookson and Pike, 1954

Cupanieidites major Cookson and Pike, 1954

Plate 9, Figures 13-14

1954 *Cupanieidites reticularis* Cookson and Pike, p. 213, pl. 2, figs. 83-85.

1971 *Cupanieidites inaequalis* Leffingwell, p. 49, pl. 9, figs. 5, 9-10.

Size range: 19-28 microns; nine specimens measured.

Occurrence: Found in 52 samples; abundance up to 1.8% per sample. Least common in coal samples and far offshore samples.

Suggested affinity: Sapindaceae, Cupanieae.

Discussion: This species is distinguished from *C. reticularis* (see below) by its much finer reticulum. However, there is much variation in the reticula of both species, and many intermediate forms had to be arbitrarily assigned to one or the other.

The genera *Cupanieidites* Cookson and Pike, 1954, and *Duplopollis* Krutzsch, 1959, are very similar and possibly should be combined. The entire complex of species representing these two genera is in dire need of taxonomic revision, in my opinion.

Cupanieidites reticularis Cookson and Pike, 1954

Plate 9, Figure 15

1954 Cupanieidites reticularis Cookson and Pike, p. 214, pl. 2, figs. 87-89.

Size range: 19-29 microns diameter; six specimens measured.

Occurrence: Found in 20 samples scattered through the study; abundance up to 0.8% per sample. Most common and most abundant in the marine Mancos Shale of Mount Garfield.

Suggested affinity: Cookson and Pike (1954, p. 214) mention this form's similarity to the pollen of the extant species, Lepiderema punctulata and Sarcopteryx stipitata (both from southeast Asia and Australia).

Discussion: This form appears to grade into C. major by a decreasing in size of the reticulum (see discussion of C. major).

Genus Tricolporopollenites Pflug and Thomson, 1953

Type species: Tricolporopollenites kruschii Pflug and Thomson, 1953

Tricolporopollenites? cf. T. globularius Groot, Penny and Groot, 1961

Plate 9, Figures 16-17

1961 Tricolporopollenites globularius Groot, Penny and Groot, p. 135, pl. 26, figs. 28-29.

Description: Tricolporate (tricolpate?) pollen; spherical; colpi long, each with a geniculus or poorly developed pore(?) at the equator; exine appears two-layered, outer layer scabrate, total thickness of exine 1 to 1-1/2 microns in mesocolpia, inner layer absent near colpi, and outer layer very thin near colpi.

Size range: 32-39 microns diameter; three specimens measured.

Occurrence: One specimen in each of three coal samples, Pb8898, Pb8920, and Pb8957-60.

Suggested affinity: Groot, Penny and Groot list the affinities of their species as Cornaceae?

Discussion: These specimens are less scabrate than *T. globularius*, and may be slightly larger. It is not at all certain that they are tricolporate; they may simply be tricolpate grains with bulges or geniculae in the colpi at the equator. Groot, Penny and Groot do not mention the two-layered structure of the exine as seen in these specimens.

Tricolporopollenites minor Takahashi, 1961

Plate 9, Figures 18-19

1961 *Tricolporopollenites minor* Takahashi, p. 320, pl. 24, figs. 18-31.

Size range: 14-17 microns long; 10-14 microns diameter, eight specimens measured.

Occurrence: Found in 43 samples; up to 1.4% per sample; no pattern discernible.

Suggested affinity: Takahashi (1961, p. 320) relates this species questionably to the Cyrillaceae.

Discussion: This species is similar to *Psilatricolporites prolatus* Pierce, 1961, but that species does not have pores which protrude and sometimes cause the equator to bulge as on the species reported here. *Tricolpites* cf. *Tricolporites traversei* Anderson is also somewhat similar, but that species is generally smaller and the pores are indistinct or absent.

Tricolporopollenites sp.-1

Plate 9, Figures 20-21

Description: Tricolporate pollen; oblate; outline rounded triangular in polar view; colpi at apices, short, 8-12 microns long, dumbell-shaped (see sketch), bounded by a heavy margo up to three microns wide, bearing a crosswise pore in the center which measures ca. 1 to 1-1/2 microns x 2-4 microns; exine apparently two-layered, with pores developed in inner layer, colpi in outer; exine less than 1 micron thick; inner layer smooth, ornamentation of outer layer is granulate with scattered large, low, round verrucae 4-6 microns across but only ca. 1/2 micron high.

Size range: 28-34 microns diameter; three specimens measured.

Occurrence: Found only in samples Pb6775 and 6778, outside of the 500 quantitative sum. These samples are respectively just below and just above the Palisade Coal near the top of Mount Garfield.

Suggested affinity: Dicotyledonae.

Discussion: These are very distinctive, unique grains. I was unable to find any published description of them. However, no new formal species will be described because only a very few were found and because there might be a possibility that they are modern contaminants, in view of their scarcity, their well-preserved condition, and their presence in only two samples which were part of the same maceration suite. If they are indigenous, these grains may represent an insect-pollinated plant, since its pollen apparently was not shed in abundance into the sedimentary basin. Also, two grains were observed attached together, or at least in contact, which would also support the hypothesis of insect pollination.

Tricolporopollenites sp.-2

Plate 10, Figure 2

Description: Tricolporate pollen; prolate; colpi long, bearing a very small, indistinct pore at the equator; grains often fold in equatorial region; exine psilate to faintly scabrate, ca. 1 micron thick except at poles, where it is up to 2 microns thick.

Size range: 30 microns long, 22 microns wide; one specimen measured.

Occurrence: Found in seven samples; abundance up to 0.6% per sample. Highest abundance in lagoonal or freshwater samples.

Suggested affinity: Dicotyledonae.

Discussion: Characterized by the small, indistinct pore and the polar thickenings.

Tricolporopollenites? sp.-3

Plate 10, Figures 3-4

Description: Tricolporate(?) pollen; spheroidal to slightly prolate; colpi long, with a strong geniculus, sinuous area, or poorly defined pore at the equator in each colpus; ornamentation reticulate to foveolate, grading to psilate toward colpi margins and sometimes toward poles; exine ca. 1 micron thick.

Size range: 16-22 microns in diameter and length of polar axis; eight specimens measured.

Occurrence: Found in 23 samples; abundance up to 1.0%; no pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: This species somewhat resembles *T. microreticulatus* Pflug and Thomson, but the latter species has more clearly defined pores and does not exhibit a decrease in size of the lumina toward the colpi or poles.

Tricolporopollenites sp.-4

Plate 10, Figures 5-7

Description: Tricolporate pollen; prolate to sometimes almost spheroidal; colpi long, each bearing a small pore at the equator, pores sometimes cause a rhomboidal shape of the grains due to a bulging of the equator; exine baculate, with the baculae organized into a scrobiculate (microreticulate with ± round lumina) ornamentation pattern; exine ca. 1-1/2 microns thick.

Size range: 18-29 microns long, 15-20 microns diameter; 10 specimens measured.

Occurrence: Found in 42 samples; abundance up to 3.0%; no pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: This species is distinguished from *T.* sp.-3 above by having more clearly defined pores, smaller lumina and more prolate shape.

Tricolporopollenites sp.-5

Plate 10, Figure 8

Description: Tricolporate pollen; prolate to almost spheroidal; colpi long, each bearing a well-developed pore at the equator; exine baculate, having a scabrate to scrobiculate sculpture in surface view; exine 2 microns thick.

Size range: 29-35 microns long, 27-34 microns in diameter; four specimens measured.

Occurrence: Found in eight samples; abundance 0.4% or less; no pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: This species is distinguished from the preceding one by its larger size and thicker wall.

Vitis? sp. cf. V? affluens Stanley, 1965

Plate 10, Figures 9-10

1965 Vitis? affluens Stanley, p. 311, pl. 46, figs. 18-21.

1969 Vitis sp. cf. V? affluens Stanley in Snead, p. 29, pl. 7, figs. 8-9.

Description: Tricolporate (or tricolpate?) pollen; spheroidal (oblate?), with ± circular outline in polar view; colpi long, usually closed, containing an indistinct pore(?) or other thickened area in the equatorial region; exine dense-appearing, dark-staining, psilate to scabrate (or corroded?), ca. 3/4 to 1-1/2 microns thick, usually thickness not determinable.

Size range: 15-20 microns diameter; six specimens measured.

Occurrence: Found in 29 samples scattered through the sections studied; sample percentage up to 1.4%; no pattern discernible.

Suggested affinity: Dicotyledonae, Vitis? (see discussion).

Discussion: This species differs from Stanley's in being non-reticulate and in having a more circular outline, plus closed colpi. The wall appears to be thicker than in Snead's species, and the size range is larger, but otherwise it appears very similar to Snead's forms. Snead mentions that his are sometimes very finely reticulate, a condition not observed here; however, the specimens noted herein are all rather poorly preserved, and fine reticulation might have been destroyed.

There is no sound reason for allying my specimens with Vitis; they are questionably placed there only because of their strong resemblance to Snead's forms, which he puts in the genus Vitis, and their lesser resemblance to Stanley's forms, which are regarded by Stanley as questionably assignable to _Vitis_.

Triporate Pollen

Genus _Alnipollenites_ Potonie, 1931

Type species: _Alnipollenites verus_ Potonie, 1931

Alnipollenites trina (Stanley) Norton and Hall, 1969

Plate 10, Figure 11

1965 _Alnus trina_ Stanley, p. 289, pl. 43, figs. 4-6.

1969 _Alnipollenites trina_ (Stanley) Norton and Hall, p. 42, pl. 5, fig. 20.

1971 _Sporopollis laqueaeformis_ auct. non Weyland and Greifeld: KIDSON, p. 119, pl. 9, fig. 11.

Size range: 14-23 microns diameter; 12 specimens measured.

Occurrence: Campanian--L. Paleocene, western North America (see Kidson, 1971, p. 119 and Stanley, 1965, p. 389).

Found in about half the samples studied (31 samples); abundance up to 3.0%. Most abundant in coals and freshwater siltstones and shales of the Rifle Gap section.

Suggested affinity: Probably _Alnus_ or a close relative or progenitor.

Discussion: This species differs from most pollen of the modern genus _Alnus_ in being triporate. A few four-pored specimens were also noted, however.

Genus _Conclavipollis_ Pflug, 1953

Type species: _Conclavipollis anulopyramis_ Pflug, 1953

Conclavipollis? cf. _C. wolfcreekensis_ Newman, 1965

Plate 10, Figures 12-13

1965 Conclavipollis wolfcreekensis Newman, 1965, p. 13-14, pl. 1, fig. 10.

Description: Triporate pollen; oblate; shape triangular with slightly concave sides, shape of interior ± triangular; exine psilate, ca. 1-2 microns thick (thickness usually hard to determine); pores equatorial, annulate, with very dense, dark-staining annuli, usually with long pore canal as in C. wolfcreekensis, atrium not visible, it is uncertain if one is present or not; some pores appear to be slitlike (brevicolpi), but grains on which this condition was noted were otherwise the same as the normal, triporate forms.

Size range: 19-23 microns diameter; four specimens measured.

Occurrence: Found in six samples; abundance up to 1.8%. Abundance was 0.4% or less in all occurrences except coal sample Pb8957-60 from the Wilson Rance section. This latter sample had the 1.8%. Three of the occurrences were from the marine Mancos Shale, while the other three were from coals, much higher than the Mancos stratigraphically. This may indicate that two morphologically similar species or "stratigraphic-environmental varieties" have been included in this category.

Suggested affinity: Dicotyledonae.

Discussion: The facts that some members of this category exhibited elongate pores (brevicolpi), and that not all specimens had the long pore canals found in C. wolfcreekensis Newman prompted me to use the cf. designation and question mark in the citation of this category. The above deviations from the morphology of C. wolfcreekensis did not correspond to the two "stratigraphic-environmental varieties" noted above.

Genus <u>Engelhardtioides</u> Potonie, Thomson and Thiergart, 1950

<u>Type species</u>: <u>Engelhardtioides microcoryphaeus</u> (Potonie), Thomson and Thiergart, 1950

<u>Engelhardtioides</u> cf. <u>E. minutus</u> Newman, 1965

Plate 10, Figure 14

1965 <u>Engelhardtioides minutus</u> Newman, p. 13, pl. 1, fig. 8.

<u>Description</u>: See Newman, 1965, p. 13.

<u>Size range</u>: 10-13 microns diameter; five specimens measured.

<u>Occurrence</u>: Found in 20 samples, mostly restricted to the marine Mancos Shale in the lower part of the Mount Garfield section. Abundance up to 0.6%.

<u>Suggested affinity</u>: Dicotyedonae. <u>Engelhardtia</u>?

<u>Discussion</u>: These specimens appear to be conspecific with Newman's <u>E. minutus</u>, but his occurs stratigraphically higher, in the predominantly fresh-water Williams Fork Formation, while the species reported here was found in the marine Mancos Shale, with all occurrences except one being far below the Palisade Coal. The one exception was in Mancos-type, near-shore shale near the top of the Rifle Gap section, presumably of Upper Campanian age. (The other occurrences are presumably Middle Campanian, while Newman's, from basically the same area, are from Upper Campanian and Maestrichtian rocks.) Type material of Newman's species should be compared with these specimens in order to determine whether or not they are conspecific.

My specimens were all rather poorly preserved, another reason the cf. designation was used.

Genus Extratripopollenites Pflug in Thomson and Pflug, 1953

Type species: Extratriporopollenites fractus Pflug in Thomson and Pflug, 1953

Extratriporopollenites sp.

Plate 10, Figure 15

Description: Triporate pollen of the Normapolles complex; oblate; shape triangular with concave sides and protruding corners; shape of interior of grain triangular; exine psilate to chagrenate, two-layered, with interloculum; total thickness of exine ca. 2 microns, thicker toward pores; pores equatorial, annulate, with long pore canal (4-5 microns).

Size range: 20-23 microns diameter; four grains measured.

Occurrence: Found in 20 samples scattered through the study; abundance up to 0.6%; highest abundance in Buck Tongue of Mancos Shale at West Salt Creek.

Suggested affinity: Dicotyledonae.

Discussion: This species is definitely assignable to Extratriporopollenites due to the extended pores and interloculum, even though some specimens were poorly preserved. However, this species was not assignable with certainty to any of the myriad published species of that genus.

This species is distinguished from Conclavipollis wolfcreekensis Newman by its more protruding pores and its interloculum.

Genus Momipites Wodehouse, 1933

Type species: Momipites coryloides Wodehouse, 1933

Momipites sanjuanensis Anderson, 1960

Plate 10, Figures 16-18

1960 Momipites sanjuanensis Anderson, p. 25, pl. 11, figs. 1-3.

Size range: 12-17 microns diameter; 17 specimens measured.

Occurrence: Found in 54 samples; abundance up to 29.0%, usually less than 2.0%. Not found in samples with lowest Land Derived/ Microplankton ratios (far offshore samples). Most abundant in lagoonal shales and siltstones and associated coals of the Price River and Iles formations. Sample Pb8932, a shale associated with the Trout Creek coal of the top of the Rifle Gap section, had the highest abundance, 29.0%, the dominant palynomorph in that sample. The second highest occurrence was the Trout Creek Coal itself, with 5.2%.

Suggested affinity: Dicotyledonae.

Discussion: Anderson (1960, p. 8) says M. sanjuanensis may represent the upland or inland flora in the San Juan Basin of New Mexico. However, in the present study, the high percentages in coals and lagoonal sediments may indicate that this species is a component of coal swamp and shoreline (or nearby) vegetation in the area of this study.

Genus Myrtaceoipollenites Potonie, 1951

Type species: Myrtaceoipollenites thiergarti Potonie, 1951

Myrtaceoipollenites peritus Newman, 1965

Plate 10, Figure 19

1965 Myrtaceoipollenites peritus Newman, p. 14, pl. 1, fig. 11.

Size range: 19-25 microns; six specimens measured.

Occurrence: Found in seven samples; abundance 0.2% or less. All but one of the occurrences are in nearshore or lagoonal samples stratigraphically higher than the Palisade Coal; however, one occurrence was noted from the marine Mancos Shale of the lower part of the Mount Garfield section.

Suggested affinity: Dicotyledonae.

Discussion: According to Newman (1965, p. 3) this species does not occur as low in the section as the Buck Tongue of the Mancos. In the present study, the only occurrence of this species which is stratigraphically lower than the Buck Tongue is an occurrence of one specimen from sample Pb6749 near the middle of the Mount Garfield section. This may be an indication the the range of this taxon is not as restricted as Newman thought.

The specimen illustrated by Kidson (1971, pl. 9, fig. 6) as *M. peritus* is incorrectly assigned to this species and appears to belong to *Extratriporopollenites* or some other Normapolles genus.

Normapolles sp.-1

Plate 10, Figures 20-21

Description: Triporate pollen; oblate; shape subtriangular with slightly convex sides and strongly protruding corners; interior of grain circular; exine ± rugulate with short irregular rugulae and low verrucae; exine at least two-layered, indistinct, overall thickness 1-1/2 to 2 microns, much thicker at pores; pores equatorial, annulate, vestibulate; no definite interloculum apparent.

Size range: 24-28 microns diameter; two specimens measured.

Occurrence: One specimen each in two samples, Pb8929-31 and sample Pb8932, which represent the Trout Creek lower coal bench and its overlying shale respectively, in the Rifle Gap section.

Suggested affinity: Dicotyledonae.

Discussion: This form could not be fit into any of the genera of the Normapolles complex described by Pflug, 1953, or to any other published taxon. Not enough specimens were found for erection of a new taxon. If the specimens found had been better preserved, they would probably fit into one of the already established Normapolles genera, and are, thus, assigned the generalized designation Normapolles sp.-1. This species is distinguished from Myrtaceoipollenites peritus by having vestibulate pores.

The genera and species of the Normapolles complex are separated on the basis of characters which often do not show well, if at all, on specimens of average or poor preservation. This fact has, I feel, resulted in a taxonomically chaotic situation which should be remedied by revision of the entire complex, which would presumably result in many fewer species and possibly fewer, more clearly distinguishable genera.

One example picked at random from the literature will illustrate the need for revision: Elsik, 1968, reported several species of the Normapolles complex, including Trudopollis pertrudens (Pflug) Pflug, 1953, the type species of Trudopollis. This species is listed in Elsik's synonymy (Elsik, 1968, p. 642, 644 and 646) as having been assigned to the following genera: Pollenites, Extratriporopollenites (17 different species), Trudopollis (14 different species), Oculopollis, Eucalyptus (two species), Myrica (two species), and Sporopollis. Other authors might do best in referring Normapolles specimens which are not well preserved simply to Normapolles sp.-1, 2, 3, etc., until such time as an extensive monographic treatment and taxonomic revision of this group has been written.

Normapolles sp.-2

Plate 10, Figure 22

1969 Extratriporopollenites audax auct. non Pflug: LAMMONS, p. 152, pl. 7, fig. 17.

Description: Triporate pollen; oblate; shape triangular with convex sides and protruding corners, shape of interior of grain rounded triangular; exine psilate to scabrate, two-layered, layering usually indistinct, overall thickness ca. 3/4 micron thick, thicker toward pores; pores equatorial, annulate, atriate; no interloculum.

Size range: 15-23 microns diameter; eight specimens measured.

Occurrence: Found in 44 samples, ca. 2/3 of the samples studied; abundance up to 1.6%. No pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: This rather variable, ± generalized Normapolles type could not be fitted with certainty into any published category lower than Stemma Normapolles Pflug.

Fairchild and Elsik (1969, pl. 38, fig. 62) illustrate a specimen, which very much resembles the specimens reported here, using the name Nudopollis terminalis (Pflug and Thomson) Pflug, 1953. The pores of the latter species appear to be more thickened and more protruding, however, and Fairchild and Elsik's species may be incorrectly referred to it. The exact nature of the pores of Fairchild and Elsik's species is not determinable from the photograph, so it is not certain whether it is conspecific with my specimens.

Lammon's species (see reference above) bears virtually no resemblance to E. audax Pflug (see Catalog of Fossil Spores and Pollen, vol. 14, p. 54), and is conspecific with the specimens reported here. The genus name *Extratriporopollenites* is inapplicable to these specimens, as they do not have the interloculum possessed by members of that genus.

Genus *Proteacidites* Cookson, 1950, ex Couper, 1953

Type species: *Proteacidites adenanthoides* Cookson, 1950

Proteacidites thalmanni Anderson, 1960, var. A

Plate 10, Figure 23

1960 *Proteacidites thalmanni* Anderson, p. 21, pl. 2, fig. 2, pl. 10, fig. 12.

1969 *Proteacidites thalmanni* Anderson, var. 1, Thompson, p. 68, pl. 19, fig. 12.

1969 *Proteacidites thalmanni* Anderson, var. 2, Thompson, p. 69, pl. 19, fig. 11.

Size range: 16-24 microns diameter; 12 specimens measured.

Occurrence: Ubiquitous, found in all samples excepting the three with the lowest Land Derived/Microplankton ratios (thus, farthest from shore), and excepting three of the six coal samples. Abundance up to 2.2% per sample.

Suggested affinity: Dicotyledonae; probably Proteaceae or Symplocaceae.

Discussion: This variety is distinguished from the variety below by its convex sides, smaller pores, and smaller mean size.

This variety is a combination of *P. thalmanni* Anderson, var. 1, and *P. thalmanni* Anderson, var. 2, of Thompson (see synonymy above for reference), with possibly an occasional specimen of Thompson's *Proteacidites* cf. *P. thalmanni* var.-4 also included. (The names given for these forms in Thompson's plate descriptions are apparently in error; the names given above were taken from Thompson's plates and are presumed to be the correct names intended to be assigned to these forms by Thompson, although these numbers do not correspond to those in his text.) The specimens of P. thalmanni Anderson, 1960, which have straight to concave sides and often larger size comprise the variety reported below. The latter variety was of more restricted occurrence in this study than variety A.

In Anderson's study (see reference in synonymy), most of the illustrations are of the straight to concave-sided type, which may indicate that that type occurred more frequently than those here called variety A, in the area of Anderson's study. The predominance of the "A" type in northwestern Colorado may be correlated with environmental shifts, or may be due to an earlier evolutionary stage of these forms, since Anderson's samples were slightly younger than those of this study. There is some intergradation of the two varieties, but in general, they seem to comprise two separable populations.

Proteacidites thalmanni Anderson, 1960, var. 3, Thompson, 1969 (Manuscript name)

Plate 10, Figure 24

1960 Proteacidites thalmanni Anderson, p. 21, pl. 2, figs. 1, 3-4, pl. 10, figs. 9-11, 13.

1969 Proteacidites thalmanni Anderson, var. 3, Thompson, p. 69, pl. 19, fig. 10.

Occurrence: Found in 43 samples, i.e., about 2/3 of the samples studied; abundance up to 0.8% per sample. Most common in marine Mancos Shale.

Suggested affinity: Dicotyledonae; probably Proteaceae or Symplocaceae.

Discussion: This species is distinguished from the preceding one by its straight to concave sides and more open pores. For further comments regarding this form, see discussion of variety A, above.

Genus Sporopollis Pflug, 1953

Type species: Sporopollis documentum Pflug, 1953'

Sporopollis sp.

Plate 10, Figures 25-26

1969 Sporopollis sp. in Lammons, pl. 7, fig. 11.

1971 Plicapollis sp. in Stone, p. 110, pl. 20, fig. 138.

Description: Triporate pollen; oblate; shape triangular, sides ± straight; exine psilate to corroded scabrate, ca. 1 micron thick, layering not discernible on these specimens; pores equatorial, circular; thickenings extend from pores to the polar area of each hemisphere, forming the "Y-Doppelmarke" described by Pflug (1953) as a generic character.

Size range: 17-25 microns diameter; eight specimens measured.

Occurrence: Found only in eight samples from the Mount Garfield section; abundance up to 1.0%. Highest abundance in Palisade Coal, but also present in marine Mancos Shale. The Palisade Coal forms tended to be slightly smaller and more strongly plicate than the Mancos Shale representatives, and may possibly represent another species.

Suggested affinity: Dicotyledonae.

Discussion: The similarity between the genera Sporopollis and Plicapollis Pflug has led to much confusion and many misassignments in the literature. Triporate plicate (torate) forms have been assigned to both. However, Pflug (1953, as reproduced in Catalog of Fossil Spores and Pollen, vol. 14, p. 156) describes Plicapollis as being tricolporate, while Sporopollis appears to be triporate. Both of these genera and the species thereof should be carefully re-studied, re-described and re-illustrated (see also comments under discussion of Normapolles sp.-1).

Stone's species (see synonymy above) appears to be conspecific with the species reported here, and does not appear to be tricolporate; thus, Plicapollis sp. is an inappropriate name for his species.

These specimens resemble Sporopollis peneserta Pflug, but are larger. They also resemble Plicapollis silicatus Pflug, the status of which is unclear, since it does not appear to be tricolporate, and is only briefly described. Sporopollis laqueaeformis Weyland and Greifeld, 1953, has much more strongly protruding pores than does the species reported here.

Newman's S. laqueaeformis Weyland and Greifeld has shorter pores than Weyland and Greifeld's, and may be misassigned. Newman's species also appears to be different from those reported here; the plicae are narrower, etc.

Genus Tilia (Tourn.) Linnaeus

Tilia cf. T. wodehousei Anderson, 1960

Plate 10, Figure 27

1960 Tilia wodehousei Anderson, p. 23, pl. 2, fig. 11-13.

Size range: 12-15 microns diameter; three specimens measured.

Occurrence: Rare; found in nine samples; abundance 0.2% or less; no pattern discernible.

Suggested affinity: Tilia.

Discussion: This species is smaller than Anderson's, but the morphology is essentially the same.

Genus Triatriopollenites Pflug, 1953

Type species: Triatriopollenites rurensis Pflug and Thomson in Thomson and Pflug, 1953

Triatriopollenites granulatus (Simpson) Leffingwell, 1971

Plate 10, Figure 28

1961 Engelhardtia granulata Simpson, 1961, p. 445, pl. 14, figs. 3-4.

1969 Labropollis globosus (Pflug) Krutzsch, 1968, in Thompson, p. 67, pl. 19, fig. 6.

1971 Triatriopollenites granulata (Simpson) Leffingwell, p. 51 and 54, pl. 10, figs. 8-9.

1971 Engelhardtioides minutus auct. non Newman: KIDSON, p. 115-116, pl. 9, fig. 7.

1971 Engelhardtioides minutus auct. non Newman: STONE, p. 108, pl. 20, fig. 133.

Size range: 11-19 microns diameter; eight specimens measured.

Occurrence: Found in 19 samples; sample Pb6747, near the middle of the Mount Garfield section (in the Mancos Shale), is the lowest occurrence. Abundance up to 0.6%; highest abundance in nearshore samples. Literature range Campanian-Paleocene (see Leffingwell, 1971, p. 54, and Kidson, 1971, p. 115-116).

Suggested affinity: Dicotyledonae. Myricaceae? Betulaceae? Engelhardtia?

Discussion: Kidson's and Stone's specimens (see synonymy for references) are thought to represent T. granulatus rather than E. minutus due to the presence of the crescentic exinous thinnings described by Leffingwell (1971, p. 51 and 54). Thompson's specimens also represent T. granulatus, but the status of the name Labropollis globosus (Pflug) Krutzsch, 1968, is unclear. Krutzsch's (1968) figs. 32 and 33, pl. 1, appear to be virtually identical to Leffingwell's (1971) fig. 9, pl. 10, except that the crescentic exinous thinnings of Leffingwell's specimen are not clearly shown by Krutzsch's. The other specimens illustrated by Krutzsch (1968, pl. 1, figs. 31 and 34-39) do not appear to be as similar to Leffingwell's specimens, and the similarity of the two figures mentioned may be coincidental. Type materials should be compared in order to determine whether or not the two species are indeed synonymous. If they are, Labrapollis globosus (Pflug, 1953) Krutzsch, 1968, would be the name applicable to the species.

Triporopollenites tectus Newman, 1965, is very similar to this species, and may be another junior synonym. Type materials should be compared in order to clarify this situation also.

Genus Triporopollenites (Pflug, 1952) Thomson and Pflug, 1953

Type species: Triporopollenites coryloides Pflug in Thomson and Pflug, 1953

Triporopollenites sp.-1

Plate 10, Figures 29-30

Description: Triporate pollen; spherical to possibly oblate; shape round to rounded triangular; exine scabrate (may be due to corrosion), ca. 1 micron thick; pores equatorial, with annulus ± as in Corylus, protruding very slightly above surface.

Size range: 17-23 microns diameter; 15 species measured.

Occurrence: Found in 28 samples; abundance up to 11.0%. Most abundant in certain coals, but not all coals have this species in abundance. Coal Pb8920 is anomalous in that it has no representation of this species at all; however, this coal is also anomalous in having a higher percentage of microplankton than the other coals. This may simply indicate a flooding of the lagoon by a minor transgressive episode.

Suggested affinity: Dicotyledonae, possibly Myricaceae?

Discussion: Some of the specimens of the broadly defined *Triporopollenites bituitus* (Potonie) Elsik, illustrated by Elsik (1968, pls. 17-18) from a Paleocene lignite from Texas resemble *T.* sp.-1, but are usually larger.

Triporopollenites sp.-1 is distinguished from the very similar *T.* sp.-2 (below) by a more triangular shape, a more rigid exine, and a rougher surface; distinguished from *T.* sp.-3 and 4 by less protruding pores and rougher surface.

T. sp.-1-4 are designated in preference to assigning these species to established or new species of *Betulaceoipollenites*, *Triporopollenites*, or similar genera because of the already taxonomically chaotic situation surrounding these generalized triporate forms. Due to their generalized morphology and variation in preservation, it would be difficult, if not impossible, to correctly assign these to published species, and for the same reasons, it would be imprudent to erect new formal species for them. These forms are probably not Betulaceous, especially in view of their prominence in coals, even though they have Betulaceae-like pollen. Myricaceae may be a more likely botanical relationship, based on the present distribution of many Myricaceae in low, humid areas.

Triporopollenites sp.-2

Plate 10, Figure 31

Description: Triporate pollen; spherical; shape round; exine psilate to somewhat scabrate (possibly due to corrosion), thickness ca. 1 micron, usually not determinable, wall appears to be two-layered, but this is not apparent on most specimens; pores equatorial, with annulus $\pm$ as in *Corylus*, protrude slightly above surface.

Size range: 18-26 microns diameter; 12 specimens measured.

Occurrence: Found in 20 samples, i.e., about a third of the samples studied; abundance up to 11.0%. Most abundant in coals, but comments made in discussing the occurrence of *B*. sp.-1 regarding coal sample Pb8920 also apply here.

Suggested affinity: Dicotyledonae, possibly Myricaceae?

Discussion: Distinguished from *T*. sp.-1 by the more rounded shape and slightly smoother and less rigid exine. Transitional forms are found, however, and there may only be one variable species involved. *T*. sp.-3 and 4 have more strongly protruding pores, more triangular shape, and more rigid exine.

This species may be conspecific with *Triporopollenites plektosus* Anderson, 1960. It is not assigned there for the reasons given in the discussion of *T*. sp.-1 above.

Triporopollenites sp.-3

Plate 10, Figures 32-33

Description: Triporate pollen; oblate; outline rounded triangular with protruding corners; shape of interior of grain circular; exine psilate to slightly scabrate (corroded?), 1 to 1-1/2 microns thick, thicker toward pores, appears two-layered on well-preserved specimens; pores equatorial, with prominent thickened annulus protruding up to 4 microns above surface of grain, similar to *Betula* pollen.

Size range: 17-27 microns diameter; 10 specimens measured.

Occurrence: Found in 36 samples; abundance up to 1.2%. No pattern discernible.

Suggested affinity: Dicotyledonae, possibly betulaceous or myricaceous.

Discussion: This species has a more random distribution than the preceding one, suggestive of an upland plant. This distribution might be interpreted as corresponding with betulaceous affinity, since this pollen strongly resembles betulaceous pollen. However, this pollen looks almost exactly like the sketch of the myricaceous species *Canacomyrica monticola* given in Erdtman (1966, p. 278, fig. 162B).

This species is distinguished from *T.* sp.-1, 2, and 4 by its more strongly protruding pores.

Triporopollenites sp.-4

Plate 10, Figure 34

Description: As given for *T.* sp.-3 above, but pores protrude less and their edges are more gently rounded. This may be conspecific with *T.* sp.-3; they were counted separately, however, and are so presented here.

Size range: 20-23 microns diameter; five specimens measured.

Occurrence: Found in five samples from the stratigraphically higher (above the Palisade Coal) and nearer shore (or lagoonal) samples of the study. Not found in the Mancos Shale. Abundance up to 4.2%, usually less than 1.0%. Highest abundance in coal sample Pb8957-60.

Suggested affinity: Dicotyledonae.

Discussion: Although the differences between this species and *T.* sp.-3 above are slight and rather subjective, they were counted separately, and their different distribution seems to corroborate the validity of the separation. *T.* sp.-4 seems to be transported less distance from its point of origin than does *T.* sp.-3. The latter seems to represent an inland or upland plant, while T. sp.-4 seems to represent a coal swamp plant.

The pores of this species protrude more than those of T. sp.-1 and 2, and the exine is smoother. Subtle subjective shape differences also separate it from 1 and 2.

Triporopollenites sp.-5

Plate 10, Figures 35-37

1969 Triporopollenites cf. T. scabroporus Newman in Thompson, p. 66, pl. 18, figs. 26 and 28 only.

Description: Triporate pollen; oblate spheroidal, with exine usually infolded between pores, giving a pseudoconcave outline with the pores appearing to be on the ends of short "arms;" shape thus from almost round to triangular with protruding corners and concave sides, shape of interior ± round to ± triangular; exine scabrate, ca. 1 to 1-1/2 microns thick, appears two-layered on well-preserved specimens; pores equatorial, with annuli, scabrate inner surface of pores is rougher than rest of exine.

Size range: 19-26 microns diameter; 10 specimens measured.

Occurrence: Found in 25 samples; abundance up to 2.2%. Most common in marine Mancos Shale in lower part of Mount Garfield section. Highest percentage is in the stratigraphically lowest sample studied.

Suggested affinity: Dicotyledonae.

Discussion: This form and that reported by Thompson (see synonymy above) appear to be conspecific (Thompson's pl. 18, fig. 27, is a different species, considered to be conspecific with T. sp.-6, below). They do not appear to me to be the same as T. scabroporus Newman. The latter species strongly resembles Proteacidites magnus Samoilovitch, 1961, as reported in Drugg (1967, p. 57, pl. 8, figs. 40-41).

Triporopollenites sp.-6

Plate 11, Figures 1-2

1969 Triporopollenites cf. T. scabroporus Newman in Thompson, p. 66, pl. 18, fig. 27 only.

Description: Triporate pollen; oblate; shape triangular with protruding corners; shape of interior of grain round; exine smooth to scabrate (corroded?), two-layered, does not appear to be definitely interloculate; exine 1 to 1-1/2 microns thick overall; pores equatorial, vestibulate, with strongly scabrate inner surface of vestibulum; the ektexine flexes outward ca. 30° to almost 90° from the intexine in forming the vestibula, creating a large vestibular cavity and causing the exopores to protrude strongly above the surrounding surface of the grain.

Size range: 18-25 microns diameter; 10 specimens measured.

Occurrence: Found in 19 samples from the marine Mancos Shale of the Mount Garfield section only; abundance up to 1.6%.

Suggested affinity: Dicotyledonae.

Discussion: The vestibulate nature of the pores clearly separates this form from T. sp.-5 above. The two were both included under the name Triporopollenites cf. T. scabroporus Newman by Thompson (1969, p. 66), although he counted them separately. It is my opinion that neither of these forms are conspecific with Newman's species (see discussion of T. sp.-5 above).

Due to its complex pore structure, this species may be assignable to one of Pflug's (1953) Normapolles genera, possibly Extratriporopollenites, but these forms do not appear to have interlocula, as does that genus.

Triporopollenites sp.-7

Plate 11, Figures 3-4

Description: Triporate pollen; ± spheroidal to oblate; polar view shape ± circular; exine psilate to scabrate; there seems to be a very thin, fragile, transparent outer layer (or tenui-tectum?) similar to a very delicate perinium on a spore; this layer is difficult to see and is usually visible only on well-preserved specimens, using phase contrast with oil immersion, and the layer does not show very well, if at all, in photographs; pores equatorial, with ± ragged margins, weakly developed annulus, non-protruding.

Size range: 22-27 microns diameter; six specimens measured.

Occurrence: Found in three coal samples—Pb8898 and Pb8929-31 from the Rifle Gap section, and Pb8957-60 from the Wilson Ranch section. Abundance was 0.2% (one specimen counted) in Pb8898, 0.6% in Pb8929-31 (Trout Creek Coal), and 5.0% in Pb8957-60. This pollen obviously represents a coal-swamp plant.

Suggested affinity: Dicotyledonae.

Discussion: The very thin outer layer and rather ill-defined, non-protruding pores distinguish this species from others. A new species was not described since the nature of the outer layer is not well understood, and no specimens were found which convincingly showed the feature in photographs.

Genus Trudopollis (Pflug, 1953) Potonie, 1960

Type species: Trudopollis pertrudens (Pflug) Pflug, 1953

Trudopollis meekeri Newman, 1965

Plate 11, Figure 5

1965 Trudopollis meekeri Newman, p. 14 and 16, pl. 1, fig. 12.

Size range: 23-27 microns diameter; six specimens measured.

Occurrence: Found in 10 samples of varying lithology scattered through the study; abundance up to 0.6%. No pattern discernible.

Suggested affinity: Dicotyledonae.

Discussion: This pollen type is a "guide fossil" for rocks of Campanian age in northwestern Colorado, as reported in Newman, 1965.

Kidson (1971, pl. 9, fig. 4) shows a specimen he calls T. meekeri which appears to be a representative of Betulaceoipollenites Potonie or a similar genus, but is not a Normapolles-type grain.

Genus Ulmoideipites Anderson, 1960

Type species: Ulmoideipites krempi Anderson, 1960

Ulmoideipites sp.

Plate 11, Figure 6

1969 Planera sp. in Fairchild and Elsik, p. 85, pl. 38, fig. 40.

Description: Triporate pollen (very rarely tetraporate); spheroidal to slightly oblate, often folded, polar view shape circular; exine with ulmoid sculpture (with small low verrucoid elements), 1 micron thick (or less); pores equatorial, with annulus, non-protruding.

Size range: 20-24 microns diameter; six specimens measured.

Occurrence: Found in a third of the samples studied; abundance up to 1.2%. Not found in lower half of Mount Garfield section, but no other pattern discernible.

Suggested affinity: Ulmaceae; probably *Planera*, based on the triporate condition.

Discussion: This species is similar to *Ulmoideipites krempi* Anderson, but does not show the arci of that species. My species appears to be conspecific with an undescribed form called *Planera* sp. by Elsik (see synonymy above). *Planera* is the "water elm," a stream-side tree of the southern U.S. Such a habitat seems compatible with the distribution of *Ulmoideipites* sp. in this study.

Polyporate Pollen

Genus *Erdtmanipollis* Krutzsch, 1962

Type species: *Erdtmanipollis pachysandroides* Krutzsch, 1962

Erdtmanipollis pachysandroides Krutzsch, 1962

Plate 11, Figure 7

1962 *Erdtmanipollis pachysandroides* Krutzsch, p. 281, pl. 8, figs. 1-8.

1965 *Pachysandra cretacea* Stanley, p. 294, pl. 44, figs. 1-9.

1969 *Erdtmanipollis cretaceus* (Stanley) Norton in Norton and Hall, p. 43, pl. 5, fig. 21.

1969 *Erdtmanipollis cretacea* (Stanley) Oltz, p. 140, pl. 41, fig. 100.

Size range: ca. 30 microns diameter; one specimen found.

Occurrence: One specimen counted in sample Pb8934, a shale associated with the Trout Creek Coal at the top of the Rifle Gap section. Range Upper Campanian to Oligocene (Stone, 1971, p. 114).

Suggested affinity: *Pachysandra* or *Sarcococca*, family Buxaceae.

Discussion: The synonymy above is as given by Stone (1971, p. 113-114). I agree with the conclusion of Norton and Hall (1969, p. 43) that the form genus *Erdtmanipollis* is preferred to the modern genus name Pachysandra for these fossil forms due to the difficulty of distinguishing the pollen of Pachysandra from that of Sarcococca, also of the Buxaceae.

Erdtmanipollis procumbentiformis (Samoilovitch, 1961) Krutzsch, 1966, is the same as E. pachysandroides except that its size range is apparently consistently around 40 microns (39.4-42.6 microns in Samoilovitch et al., 1961, p. 199, and 38-44 microns in Srivastava, 1969, p. 978). Although I usually do not favor differentiating fossil taxa on the basis of size alone, this may be sufficient basis for a separate species in this case. Further investigations should be made in order to determine the importance of this size difference. If the species are not different, E. procumbentiformis would be the proper name for these forms according to the rules of priority.

Genus Liquidambarpollenites Raatz, 1937

Type species: Liquidambarpollenites stigmosus (Potonie) Raatz, 1937

Liquidambarpollenites? sp.

Plate 11, Figure 9

Description: Polyporate pollen; spheroidal, usually folded or collapsed; ca. 10-12 pores; pores have ± ragged edges, no annuli, are 1-1/2 to 2-1/2 microns in diameter; exine smooth, up to 1 micron thick, usually thinner.

Size range: 16-17 microns diameter (three grains).

Occurrence: Found only in sample Pb6775, a shale just below the Palisade Coal on Mount Garfield. Three grains counted.

Suggested affinity: Dicotyledonae.

Discussion: The form genus Liquidambarpollenites Raatz seems to be intended for smooth polyporate pollen; therefore, these grains are so assigned, even though there is no evidence of any affinity between this form and the modern genus Liquidambar.

Genus Polyporina Naumova ex Potonie, 1960

Type species: Polyporina multistigmosa (Potonie) Potonie, 1960

Polyporina cribraria Srivastava, 1969

Plate 11, Figure 8

Size range: ca. 21-25 microns; four specimens measured.

Occurrence: Found in eight samples; abundance up to 0.8% per sample. Highest occurrence stratigraphically is at top of the Palisade section. Most abundant in sample Pb6778, a shale 12 feet above the Palisade Coal on Mount Garfield.

Suggested affinity: Probably Chenopodiaceae; also similar to pollen of Liquidambar.

Discussion: This species superficially resembles Liquidambar brandonensis Traverse and Liquidambar mangelsdorfiana Traverse, 1955, but is smaller and has more pores and is not reticulate.

Lammons (1969, p. 149, pl. 8, fig. 2) describes a species as Liquidambar cf. brandonensis Traverse, 1955, which is very similar to the species reported here in size and appearance, but which is described as having a finely reticulate sculpture. My specimens superficially appear reticulate (microreticulate or scrobiculate), but careful focusing confirms their non-reticulate, ± infragranulate nature. Lammons' grains are much smaller than Traverse's, with much smaller pores, and are probably conspecific with the species reported here, which is allied with the Chenopodiaceae by Srivastava (1969, p. 978).

The specimens reported here frequently exhibit fewer than 50 pores, while Srivastava's description (ibid.) calls for more than 50 pores.

The grains are otherwise the same, and are judged to belong to the same species.

Srivastava (ibid.) says this pollen may indicate changes in shoreline. Its range in this study, terminating above the Palisade Coal where the sediments become ± continental after a marine sequence, may support this idea.

The high abundance in sample Pb4974, a far offshore sample, may reflect the change in shoreline caused by the minor transgression represented by this sample. The other occurrences are from nearshore or moderate distances offshore.

MICROPLANKTON

Class *Dinophyceae*

Comments: This class includes all living and fossil dinoflagellates and those hystrichospheres reflecting dinoflagellate tabulation. Since the relationships of the fossils to extant taxa has not been established in most cases, an artificial system devised by Sarjeant and Downie (1966) is followed herein.

Cyst-Family Aeroligeraceae

Genus *Cyclonephelium* Deflandre and Cookson, 1955
emend. Williams and Downie *in* Davey, et al., 1966

Type species: *Cyclonephelium compactum* Deflandre and Cookson, 1955

Cyclonephelium? spp.

Plate 11, Figure 10

Description: All specimens encountered which appeared to be referrable to the genus *Cyclonephelium* are included here because all were too poorly preserved for certain identification to species. Some may not be properly referrable to Cyclonephelium, so a question mark was used in the citation. See Cookson and Eisenack, 1962, p. 493, for generic description.

Size range: 60-75 microns maximum dimension; five specimens measured.

Occurrence: Found in 14 marine shale samples scattered through the studied sections; abundance up to 1.2%. The genus Cyclonephelium ranges from Jurassic to Oligocene, worldwide, and Upper Campanian-Maestrichtian of thesis area. Found by Thompson (1969) in lower and upper Mancos from southwest Colorado; upper Almond of southwestern Wyoming by Stone (1971), and Maestrichtian (Navarro Group) of Texas by Zaitzeff (1967).

Discussion: These forms are definite indicators of marine environment.

Cyst-Family Deflandreaceae

Genus Deflandrea Eisenack, 1938

Type species: Deflandrea phosphoritica Eisenack, 1938

Deflandrea cf. D. cooksoni Alberti, 1959

Plate 11, Figures 11-12

Description: Cavate dinoflatellate cyst with dorso-ventral outline tripartite to fusiform with expanded mid area; central body slightly oblate, causing equator to bulge; no cingulum or sulcus developed; epitract sometimes rises vertically from mid-region, then begins to narrow toward apical horn, forming shoulders, and sometimes begins to taper directly from the mid-area, not forming shoulders; a prominent bluntly-pointed apical horn is present; hypotract exhibits similar variation in its taper, forming two antapical horns of unequal length, connected by a membrane bearing a few short spines along its lower margin, sometimes the membrane extends to the tips of the antapical horns, with the hypotract in that case presenting the appearance of a single large obliquely tapered horn with a serrate margin; short spines ("coni") and/or prominent granulae are usually sparsely scattered over the outer surface of the test, both walls of the cyst otherwise chagrenate; no tabulation observed; archeopyle large, apparently intercalary, developed at approximately the apex of the central body.

Size range: 70-102 microns long, 40-57 microns wide; eight specimens measured.

Occurrence: Found in eight samples from the Mancos Shale of the Mount Garfield section; abundance up to 0.6%.

Literature range of *D. cooksoni* Upper Senonian to Danian (see Stone, 1971, p. 64).

Discussion: These specimens resemble the species cited as *D. cooksoni* Alberti in the theses of Zaitzeff (1967), Lammons (1969), and Stone (1971). I was not able to obtain a copy of Alberti, 1959, by the time this was written for comparison with the original photos and description, so my specimens are only tentatively referred to *D. cooksoni*. The forms mentioned above do not show the spiny nature of the membrane joining the antapical processes, nor the scattered coni or granulae found on my specimens, nor are these features mentioned. My specimens may represent a more highly ornamented local variety of the forms assigned to *D. cooksoni* in the three theses mentioned above, as they are quite similar in every other characteristic.

Deflandrea sp.-1

Plate 12, Figures 1-2

Description: Deflandreoid dinoflagellate with thin, punctate, hyaline outer wall and thicker-walled, more opaque, spherical central body; epitract has shoulders, is topped by a prominent, blunt apical horn which sometimes has what appears to be a pore at its apex; hypotract bears one prominent pointed antapical horn, with the second horn being expressed as a rounded bump; punctae found on all parts of outer wall, but least developed near the apices, central body apparently smooth, nonpunctate; outer wall bears several horizontally disposed groups of short (ca. 1 micron long) spines or bumps forming the margins of the cingulum, occasionally spines also occur elsewhere (spines and cingulum not always well expressed); horseshoe-shaped archeopyle is present on the epitract at approximately the apex of the central body; all views of the test may be presented by these fragile specimens.

Size range: 55-75 microns overall length, 37-45 microns in width (and also diameter of central body); 12 specimens measured.

Occurrence: Found in 19 samples of marine shale scattered throughout the sections studied; abundance up to 7.8%.

Discussion: This species does not seem to be described in the literature. However, I believe that more specimens should be examined and a more thorough literature search made before formally describing this form as a new species.

Thompson (1969, pl. 10, fig. 2) illustrates a species which he calls *Deflandrea* sp. 3 which includes forms which may be conspecific with my *D.* sp.-1 as well as *D.* sp.-2 (see discussion of *D.* sp.-2).

Deflandrea sp.-2

Plate 12, Figures 3-4

Description: As for D. sp.-1, but outer wall is not punctate, is less transparent, and has scattered granulae. Also, the cingular spines are sharper, and some of the groups of spines are vertically disposed.

Size range: 70-80 microns long, 41-50 microns wide; four specimens measured.

Occurrence: Found in 15 marine shale samples scattered through the study; abundance up to 1.0%.

Discussion: This species is similar to Deflandrea sp. 4 of Thompson (1969, p. 42, pl. 9, fig. 4) in possessing rows of cingular spines, but that species appears to be wider in relation to its length, and shows other shape differences as well; it is also smaller than my species.

Thompson's D. sp. 3 is also very similar to this form, as it is to my D. sp.-1. Thompson's sp. 3 may include both my sp.-1 and sp.-2, which are separated mainly on the basis of ornamentation. D. sp.-1 is punctate, while D. sp.-2 has scattered granulae. Thompson's D. sp. 3 includes smooth, punctate and granular forms. Thompson does not mention the rows of spines along the cingulum as noted on D. sp.-1 and D. sp.-2 of this study, however, and his specimens are larger.

Cyst-Family Gonyaulacystaceae

Genus Gonyaulacysta Deflandre, 1964, emend.
Sarjeant in Davey et al., 1966

Type species: Gonyaulacysta jurassica (Deflandre) Deflandre, 1964

Gonyaulacysta? cf. G. delicata Davey, 1969

Plate 12, Figures 5-6

1969 Gonyaulacysta delicata Davey, p. 123-124, pl. 1, figs. 7-8, figs. 10A and B.

Description: Cavate dinoflagellate cyst; subspherical shape; test wall clearly divided into plates by low crests, but the actual tabulation could not be determined due to the crushed and debris-obscured nature of the specimens; no apical horn present; cingulum laevo(?)-rotary; sulcus not observed; specimens easily distorted due to thin cyst wall.

Size range: 41-62 microns maximum dimension; three specimens measured.

Occurrence: Found in three samples from the Mancos Shale of the lower part of Mount Garfield: Samples Pb4945X and Pb6741 (one specimen counted in each) and sample Pb4954 (one specimen observed outside the 500 sum).

Davey's specimens were from the Cenomanian of Saskatchewan.

Discussion: This species is tentatively referred to Gonyaulacysta due to its overall resemblance to G. delicata Davey, although the tabulation could not be determined.

Cyst-Family Gymnodiniaceae

Genus Dinogymnium Evitt, Clarke and Verdier, 1967

Type species: Dinogymnium acuminatum Evitt et al., 1967

Dinogymnium digitus (Deflandre) Evitt, Clarke and Verdier, 1967

Plate 12, Figure 7

1936 Gymnodinium digitus Deflandre, p. 166, pl. 12, fig. 4-5.

1967 Dinogymnium digitus (Deflandre) Evitt, Clarke and Verdier, p. 18-19.

Size range: 65-75 microns long, 19-23 microns wide; four specimens measured.

Occurrence: Found in eight samples of the Mancos Shale, six in the Mount Garfield section, two from the Buck Tongue at West Salt Creek; abundance up to 0.6%.

Literature range Upper Cretaceous of various widespread areas (see Evitt et al., 1967, p. 18-19, and Zaitzeff, 1967, p. 89-83.

Discussion: This species is larger, with fewer longitudinal folds than D. sp.-1, below.

Dinogymnium sp.-1

Plate 12, Figures 8-10

1967 Gymnodinium nelsonense Cookson in Zaitzeff, p. 80-81, pl. 21, figs. 10-13a, pl. 22, figs. 1-2.

Description: Test biconical with equatorial cingulum of varying prominence dividing the test into two ± equal halves, hypotract often slightly more rounded than epitract, and usually with fewer longitudinal folds; epitract topped by a moderately wide apical archeopyle; sulcus usually marked by a ± prominent longitudinal fold; both tracts bear a few longitudinal folds (two or three to about six); surface smooth to slightly scabrate.

Size range: 50-58 microns long, 18-20 microns wide; six specimens measured.

Occurrence: Found in 22 marine shale samples scattered through the sections studied, but mostly restricted to the Mancos Shale of Mount Garfield; abundance up to 0.8%.

Zaitzeff's species (see synonymy) is reported from the Maestrichtian of Texas.

Discussion: The specimens reported here form a clear morphological gradation (among specimens all nearly the same size) from forms with a poorly defined cingulum and very few longitudinal folds through forms with slightly more numerous folds and somewhat more prominent cingulum to forms with a prominent cingulum and several folds. This gradational series is illustrated by Figures 8-10 on Plate 12.

This form is tentatively regarded as conspecific with the species referred to *Gymnodinium nelsonense* Cookson, 1956, by Zaitzeff, 1967 (see synonymy above). The specimens reported here seem to have a slightly larger archeopyle and often bear fewer folds than Zaitzeff's, so the species will not be formally named until I have had time to examine more specimens from my own material and to make more extensive comparisons with Zaitzeff's material.

Since Zaitzeff's thesis study was completed all species of fossil dinoflagellates formerly assigned to *Gymnodinium* Stein were re-assigned to the new genus *Dinogymnium* by Evitt, et al., 1967, who restrict the application of the name *Gymnodinium* to the motile cells of extant forms. These authors also emended *Dinogymnium* (*Gymnodinium*) *nelsonense* (Cookson) to exclude Cookson's (1956) original figures 8 and 9. Since Zaitzeff's specimens somewhat resemble the specimens illustrated in Cookson's figures 8 and 9, but do not resemble the holotype specimen (figure 10) or the specimen in Cookson's figure 11, they should not be referred to *Dinogymnium nelsonense* (Cookson) Evitt, Clarke and Verdier.

Dinogymnium spp.

Plate 12, Figures 11-14

Description: Several species of small *Dinogymnium* tests not referable to the above categories are included in this category. Most are punctate and have few folds, especially on the hypotheca. These forms are ± fragile and often fairly wide in relation to their length; thus, they are found flattened in many different attitudes, making comparison and consistent identification very difficult. It was mainly for this reason that these species were grouped together. Previously described species probably contributing to this group include *D. westralium* (Cookson and Eisenack) Evitt, Clarke and Verdier, 1967, *Gymnodinium* sp. 1 of Zaitzeff, 1967, and *Dinogymnium* sp. 1 of Thompson, 1969. Possibly a few specimens of *D. acuminatum* Evitt, Clarke and Verdier, 1967 and *D. heterocostatum* (Deflandre) Evitt, Clarke and Verdier, 1967, may also be included.

Size range: 21-42 microns long, 14-29 microns wide; many specimens measured.

Occurrence: Found in 35 samples of marine shale, including three samples from West Salt Creek and one from Rifle Gap; all other occurrences are in the Mount Garfield section. Abundance up to 2.4%.

Discussion: This group is a definite indicator of marine conditions, as are the other species of this genus reported herein.

Cyst-Family Hystrichosphaeraceae

Genus *Hystrichosphaera* O. Wetzel, 1933, ex Deflandre, 1937

Type species: *Hystrichosphaera furcata* (Ehrenberg) Wetzel, 1932

Hystrichosphaera ramosa (Ehrenberg) O. Wetzel, 1932, emend. Davey and Williams in Davey, et al., 1966

Plate 13, Figure 1

1838 *Xanthidium ramosum* Ehrenberg.

1854 *Spiniferites ramosus* Mantell.

1932 *Hystrichosphaera ramosa* (Ehrenberg) O. Wetzel, p. 144.

Size range: 27-34 microns diameter of body, processes 12-15 microns long; six specimens measured.

Occurrence: Found in low numbers in 22 marine shale samples scattered through the sections studied; abundance 0.4% or less.

Literature range Jurassic to Pleistocene, widespread geographically (see Zaitzeff, 1967, p. 62).

Discussion: These specimens fulfilled the criteria for assignment to *H. ramosa*, but did not seem to fit exactly into any of the published varieties of the species.

H. ramosa seems to be composed of many types of morphologically similar organisms not necessarily closely related, as evidenced by the several recognized varieties and the very long stratigraphic range of the species.

Cyst-Family Hystrichosphaeridiaceae

Genus *Cleistosphaeridium* Davey, Downie, Sarjeant and Williams, 1966

Type species: *Cleistosphaeridium diversispinosum* Davey, Downie, Sarjeant and Williams, 1966

Cleistosphaeridium sp.

Plate 13, Figures 2-3

Description: Chorate dinoflagellate cysts with spheroidal central body bearing many distally closed hollow processes not opening into endocoel; more than 50 processes usually with distal ends tapering to a single point or bifurcating to form two sharp points; however, a few processes are multifurcate or end in a small knob; tabulation not determinable; an apical archeopyle with ± angular edges was noted on one specimen; wall faintly granular.

Size range: 30-35 microns diameter of central body, processes 10-15 microns long; four specimens measured.

Occurrence: One specimen counted in sample Pb4972, and one observed outside the 500 sum in samples Pb4960 and Pb6745, all from the Mancos Shale of Mount Garfield. Also, one specimen was counted in sample Pb4741a from the Buck Tongue of the Mancos at West Salt Creek.

Discussion: This species differs from *Polysphaeridium* spp. as reported in Thompson (1969, pl. 4, figs. 3 and 5) by having sharper processes. *Cleistosphaeridium* sp. 1 of Zaitzeff (1967, p. 48-49, pl. 7, figs. 8-9, pl. 8, figs. 1-2) is similar but has fewer processes, which are solid.

C. disjunctum Davey, et al., 1966, differs in having less numerous processes.

Genus *Hystrichosphaeridium* Deflandre, 1937, emend. Eisenack, 1958

Type species: *Hystrichosphaeridium tubiferum* (Ehrenberg) Davey and Williams *in* Davey, et al., 1966

Hystrichosphaeridium sp.

Plate 13, Figure 4

Description: Chorate dinoflagellate cyst with rounded ellipsoidal central body bearing ca. 20 hollow processes forming small, open funnels at their distal ends; processes about same diameter (ca. 1 micron) throughout their length except for their expanded distal ends; tabulation not determinable; archeopyle not observed.

Size range: Central body 16 x 21 microns; processes 8-10 microns long; one specimen measured.

Occurrence: One specimen counted in sample Pb4960 and one observed outside the 500 sum in sample Pb6749; both these samples are from the Mancos Shale of Mount Garfield. One additional specimen was noted outside the 500 sum in sample Pb4750a from West Salt Creek.

Discussion: Several described species are similar to this form (although most are larger). However, due to the rare occurrence and poor preservation of these specimens, they were not assigned to any published species.

Genus Polysphaeridium Davey and Williams in Davey, et al., 1966

Type species: Polysphaeridium subtile Davey and Williams in Davey, et al., 1966

Polysphaeridium cf. P. sp. 4 of Zaitzeff, 1967

Plate 13, Figure 5

1967 Polysphaeridium sp. 4 in Zaitzeff, p. 42-43, pl. 6, figs. 9 and 11.

Description: Fits description given by Zaitzeff, but may have shorter processes (see discussion below).

Size range: 27 x 32 microns diameter, processes 4-6 microns long; one specimen measured.

Occurrence: One specimen counted in sample Pb4974 of the Mancos Shale of Mount Garfield, one specimen outside the 500 sum noted in sample Pb4732 from the Buck Tongue of the Mancos at West Salt Creek.

Discussion: These specimens are probably conspecific with Zaitzeff's. The length of the processes on his holotype specimen is given as 10-12 microns (see reference in synonymy above), while the specimens reported here have processes 4-6 microns long. However, direct measurement and correction for 500X magnification of his holotype illustrated in his pl. 6, fig. 9, yielded process length measurements of 6-8 microns, closer to the lengths of the processes of the specimens reported here. Zaitzeff's 500X stated magnification appears to be approximately correct as determined by comparing the actual measured maximum diameter of the holotype with the stated measurement (31 vs. 35

microns; this magnification discrepancy due to printing is not large enough to account for the discrepancy in measured vs. stated process lengths, which appears to indicate that Zaitzeff misstated the length of the processes).

Genus Surculosphaeridium Davey, Downie, Sarjeant and Williams, 1966

Type species: Surculosphaeridium cribrotubiferum (Sarjeant) Davey, et al., 1966

Surculosphaeridium? cf. S. vestitum (Deflandre) Davey, Downie, Sarjeant and Williams, 1966

Plate 13, Figure 6

1966 Surculosphaeridium vestitum (Deflandre) Davey, et al., p. 162, pl. 9, fig. 8, text-fig. 42.

1969 Surculosphaeridium cf. S. vestitum (Deflandre) Davey, et al., in Thompson, p. 34, pl. 4, fig. 6.

Description: Chorate dinoflagellate cyst with spherical or ellipsoidal central body bearing numerous solid distally closed bi- or multifurcated processes; branches diverge from main part of process at small acute angles, sometimes the branches rebranch in a similar manner; processes widest at base, but bases of neighboring processes do not interconnect; the tabulation was not determinable on these rare, somewhat poorly preserved specimens, and the archeopyle was not observed.

Size range: Central body 30-43 microns x 23-32 microns, processes 12-20 microns long; two specimens measured.

Occurrence: One specimen counted in sample Pb4956 from the Mancos Shale in the lower part of the Mount Garfield section; one counted in each of samples Pb4732 and Pb4750 from the Buck Tongue of the Mancos at West Salt Creek.

Discussion: These specimens appear to be conspecific with those of Thompson (see synonymy above) based on the nature of the processes. They are assigned only questionably to the genus Surculosphaeridium Davey, et al., because that genus is defined on the basis of its reflected tabulation, whereas the tabulation was not determinable on these specimens.

Cyst-Family Pseudoceratiaceae

Genus Odontochitina Deflandre, 1935

Type species: Odontochitina operculata (O. Wetzel, 1933) Deflandre and Cookson, 1955

Odontochitina striatoperforata Cookson and Eisenack, 1962

Plate 13, Figure 7

1962 Odontochitina striatoperforata Cookson and Eisenack, p. 490, pl. 3, figs. 14-19.

Size range: 54-59 microns wide at operculum; antapical horns 80-100 microns long; two specimens measured.

Occurrence: Two specimens counted and one outside the 500 sum; found in three samples from the Mancos Shale of the lower part of the Mount Garfield section.

Literature range Albian to Maestrichtian, worldwide (see Zaitzeff, 1967, p. 90).

Discussion: This species is a definite marine indicator, but is so rare that its usefulness is limited in this study.

Cyst-Family Uncertain

Genus Horologinella Cookson and Eisenack, 1962

Type species: Horologinella lineata Cookson and Eisenack, 1962

Horologinella apiculata Cookson and Eisenack, 1962

Plate 13, Figures 8-9

1962 Horologinella apiculata Cookson and Eisenack, p. 272, pl. 37, fig. 4.

Size range: 15-23 microns x 14-20 microns; many specimens measured.

Occurrence: Found in 43 marine shale samples scattered through all sections of this study; abundance up to 12.0%; in addition, one specimen was counted in sample Pb8916, which may be a brackish or fresh water sample (probably lagoonal) based on its high Land Derived/ Microplankton ratio of 8.86. Literature range Campanian, Australia (see reference in synonymy above).

Discussion: These specimens are very similar to entities of the genus Tetraporina Naumova, 1939, ex Naumova, 1950. They are not assignable to that genus, however, because it is described as having four pores (Playford, 1963, p. 658-659), while the specimens reported here have from 0 to 5 pores. Only the pore beside the "median beak-like projection" was mentioned by Cookson and Eisenack (1962, p. 272) in their description of Horologinella apiculata. However, the present specimens, which are comparable in every other respect, sometimes have a poorly developed pore on each of the four "corners," which is often expressed only as a "dimple" in the wall. The variable presence of these pores makes them easy to overlook; indeed, they seem to be absent more often than not. The pore or "concave opening" (ibid.) beside the apical projection is not always present, either, and neither is the projection. These features should be accounted for in a formally emended species description for H. apiculata.

No median projection is mentioned or illustrated for Tetraporina by Naumova or other authors, and only four pores are present (although according to Playford (1963, p. 658-659), these pores are also variable and often absent). For these reasons, the specimens reported here are not assigned to Tetraporina, although they are almost certainly closely related to the forms assigned to that genus.

The forms assigned by Kidson (1971, p. 135, pl. 10, figs. 5 and 10) to Tetraporina horologia (Staplin) Playford and T. glabra Naumova respectively are probably incorrectly assigned, and should be assigned to Horologinella apiculata, as both show evidence of the median projection of that species. I studied five slides from Kidson's West Salt Creek section, in which several specimens of H. apiculata were observed, but no bona fide examples of the genus Tetraporina were observed. T. horologia is much larger than the forms reported by Kidson. Kidson's illustrated specimen measured 24 microns in diagonal length (no size range given), while Playford (1963, p. 659) gives a diagonal length range of 44-71 microns for his specimens of T. horologia. His specimens of T. glabra Naumova are reported as being 50-54 microns in diagonal length; Kidson's are much smaller.

The type materials of all species of Tetraporina and Horologinella should be restudied and compared in order to definitely determine the status of the two names. One of them may be invalid, but for the present, I regard my specimens as assignable to Horologinella and not to Tetraporina.

Genus Palaeohystrichophora Deflandre, 1935

Type species: Palaeohystrichophora infusorioides Deflandre, 1935

Palaeohystrichophora infusorioides Deflandre, 1935

Plate 14, Figure 1

1935 Palaeohystrichophora infusorioides Deflandre.

1939 Palaeohystrichophora infusorioides Deflandre, 1935, in Deflandre and Courteville, p. 98, pl. 2, fig. 2.

Size range: 42-75 microns long x 32-45 microns wide; eight specimens measured.

Occurrence: Found in 25 samples from the marine Mancos Shale of Mount Garfield; abundance up to 3.2%.

Literature range: Upper Cretaceous, worldwide (see Zaitzeff, 1967, p. 105).

Discussion: This species is also present in the Buck Tongue of the Mancos (see Kidson, 1971, p. 148) although no specimens were encountered in the five samples of the Buck Tongue at West Salt Creek, Colorado, which I counted.

The presence of this species in a sample is an indication that the sample was deposited in a marine environment.

Unknown Dinoflagellate-1

Plate 14, Figures 2-3

Description: Test fusiform, expanded at mid-area, appears to consist of only one thin wall; epitract usually a narrow cone, sometimes with slight shoulders developed, apical horn tapers to a blunt point; hypotract roughly hemispherical in outline, sometimes more pointed, bears apparently only a single sharp to blunt or almost non-existent antapical horn; girdle and sulcus bordered by rows of irregular, short (1-2 microns) variously-shaped spines; these spines also mark plate boundaries, but the specimens were all so distorted that the tabulation could not be determined; the archeopyle appears to be intercalary, but the exact number and type of plates involved could not be determined.

Size range: 42-56 microns long, 27-40 microns wide at girdle; nine specimens measured.

Occurrence: Found in 31 marine shale samples scattered through the sections studied; abundance up to 2.0%. A definite marine indicator. All of these specimens appear to belong to the same species.

Discussion: These specimens were too distorted for certain assignment to any of the several published species which they resemble.

The published species to which these specimens may belong include:

1. Deflandrea echinoidea Cookson and Eisenack, 1960. This form is similar, but usually seems to have a wider, more pentagonal shape and more spines.

2. Palaeohystrichophora sp. in Srivastava, 1970, pl. 1, fig. 13, looks very much like Unknown Dinoflagellate-1 (hereafter called UD-1), but no description is given.

3. Deflandrea limpida Singh, 1971, is very similar to UD-1, and may be conspecific with it; however, it appears to be more pentagonally shaped. The distorted condition of UD-1 leaves the possibility open that they would have had the same shape if better preserved.

D. limpida appears to be the same as reported by W. Brideaux (1971, p. 99-101, pl. 29, figs. 99-103) as Spinidinium vestitum.

4. Spinidinium styloniferum Cookson and Eisenack, 1962, as given in Kidson, 1971, pl. 11, fig. 6, may be conspecific with UD-1, but the single photograph does not show sufficient detail to reasonably establish conspecificity. S. styloniferum, as illustrated in Cookson and Eisenack, 1962, pl. 1, figs. 1-4, appears to differ by its more numerous and slightly more robust spines.

5. Spinidinium densispinatum Stanley, 1965, as given in Stone, 1971, p. 65, pl. 4, fig. 17, is probably conspecific with UD-1, but the distorted condition of UD-1 makes me reluctant to state that they are definitely conspecific.

Stone's identification of this species may be incorrect, as Stanley's S. densispinatum and S. microceratum (which Stone regards as synonymous) are wider in relation to length than Stone's species, with some of Stanley's specimens appearing to be almost round in dorso-ventral view (see Stanley, 1965, pl. 21, figs. 1-5 and pl. 22, figs. 5-6). Stone's species (and UD-1), if referrable to any published species, may belong to Deflandrea limpida Singh, 1971.

Unknown Dinoflagellate-2

Plate 14, Figure 4

Description: Shape roughly circular in dorso-ventral view, appears to consist of one thin wall; epitract a hemisphere topped by a bluntly pointed apical horn; hypotract a hemisphere with one antapical horn ± like the apical horn, and a second horn represented by a low, rounded bump; girdle and sulcus not clearly defined, not indented; plate boundaries incompletely demarcated by rows of very short (1/2 to 1 micron) sawtooth-like spines, tabulation not decipherable; the nature of the archeopyle is unclear, as the fragile tests usually had irregular holes in them at several locations.

Size range: 51-56 microns long, 43-46 microns wide; three specimens measured.

Occurrence: Found in 13 marine Mancos Shale samples, all in the Mount Garfield section except for one specimen outside the 500 sum in sample Pb4712 from West Salt Creek. (This latter sample was the most "marine" sample of the five I counted from West Salt Creek, and is thought to reflect far offshore conditions. Thus, this species may indicate far offshore conditions.) Abundance up to 3.6%.

Discussion: This species resembles Canninginopsis denticulata Cookson and Eisenack, 1962. However, the latter is larger (90-120 microns long) and has more abundant spines, which appear to be flat on top as opposed to the sharply pointed spines of Unknown Dinoflagellate-2.

Unknown Dinoflagellate-3

Plate 14, Figures 5-6

Description: Cavate dinoflagellate cyst; fusiform, expanded at mid-area; outer wall thin, ornamented with scattered short blunt spines, occasionally lined up apparently along plate margins, plates otherwise not apparent; cingulum marked by parallel folds, which are often not well-developed; sulcus not visible; archeopyle usually not clearly visible, but appears to be intercalary; a moderately long, moderately pointed apical horn is present on the epitract, with a similar antapical horn present on the hypotract; central body thin, smooth, fragile, fills much of the internal cavity of the test; entire test often much folded and distorted.

Size range: Overall length 24-48 microns, width 23-35 microns; seven specimens measured.

Occurrence: Found in 34 marine shale samples, all but two are from the Mancos Shale of Mount Garfield; abundance up to 2.6%.

Discussion: This form is similar to Deflandrea diebeli Alberti as reported in Kidson (1971, pl. 14, fig. 8). However, the latter has an oblate central body which does not fill as much of the test as in Unknown Dinoflagellate-3. Also, its apices appear to be more attenuated.

Unknown Dinoflagellate-4

Plate 14, Figures 7-9

Description: Cavate dinoflagellate cysts; roughly fusiform to roughly pentagonal or irregular shape in dorso-ventral view; outer wall thin, hyaline, smooth, with a quite long, usually folded apical horn and a similar, usually shorter antapical horn (sometimes a second folded antapical horn appears to be present); cingulum and sulcus not well defined; central body smooth or slightly scabrate, slightly prolate, fills most of test cavity; archeopyle not definitely observed, but probably intercalary (tabulation not decipherable, however).

Size range: 58-100 microns overall length, 30-48 microns in width; 10 specimens measured.

Occurrence: Found in 45 samples scattered through the sections studied, including three occurrences in lagoonal samples (Pb6778 = one specimen outside the 500 sum, Pb8932 and Pb8934 = one specimen counted in each); abundance up to 2.8%.

Discussion: The distorted nature of these easily folded specimens made it impossible to identify them to a published species; indeed, there are possibly several species represented, perhaps from diverse genera.

Unknown Dinoflagellate-5

Plate 14, Figure 10

Description: Cavate dinoflagellate cyst; shape in dorso-ventral view fusiform with expanded central-area; outer wall reticulate (reticulation usually visible or obvious only with phase contrast microscopy), reticulum appears to be an anastamosing network of threads covering a smooth substrate, lumina 1-3 microns across, threads end at plate boundaries; tabulation not determinable due to poor preservation; epitract and hypotract each bear a similar bluntly pointed horn; cingulum marked by parallel folds, sulcus not observed; archeopyle not observed; central body prolate, smooth, usually extends full width of test.

Size range: 74-90 microns long, 44-52 microns wide; six specimens measured.

Occurrence: Found only in Mount Garfield Mancos Shale sample Pb4945X; abundance 2.2%.

Discussion: The reticulum is definitely a feature of these specimens, and is not merely a pattern of corroded holes. However, corrosion may have enhanced the visibility of a reticulate pattern of construction of the outer wall.

This appears to be a valid species, as this pattern was not observed in other samples of the same lithology and similar preservation, nor in any other samples. Thus, the restriction of this form to one sample means it should be a good stratigraphic or environmental indicator. The principal environmental indicator of this study, the Land Derived/Microplankton ratio, does not give any clue as to whether the restriction is environmentally controlled or not, since ratios near the .133 ratio of sample Pb4945X exist in other samples, and this ratio, while low, is not the lowest of the study. Thus, for the present, this species is regarded as a potential stratigraphic marker in this area, although it is possible that currently unrecognized environmental factors control its distribution.

Group Acritarcha

Subgroup Acanthomorphitae

Genus Baltisphaeridium Eisenack, 1958, emend. Downie and Sarjeant, 1963

Type species: Baltisphaeridium longispinosum (Eisenack) Eisenack, 1958

Baltisphaeridium sp.

Plate 15, Figure 1

Description: Spherical vescicles with closed processes numbering 70-100, possibly more, around the periphery in optical section; processes very thin, hairlike, 1 to 1-1/2 microns long, simple, solid.

Size range: 21-25 microns diameter; six specimens measured.

Occurrence: Found in 18 marine shale or siltstone samples, all but two of which are from the Mount Garfield section. Abundance up to 0.8%. In addition to the above, one specimen was noted outside the 500 sum in sample Pb8919, a lagoonal shale from the Rifle Gap section.

Discussion: This species is distinguished from Micrhystridium deflandrei, below, by its larger size and more numerous, much finer spines.

Genus Micrhystridium Deflandre, 1937, emend. Downie and Sarjeant, 1963

Type species: Micrhystridium inconspicuum (Deflandre) Deflandre, 1937

Comment: The species of this genus (except for M. deflandrei) are listed numerically rather than being assigned to formal species because the taxonomy of the genus is in a chaotic state, with very similar or identical forms named as different species or even in different genera (i.e., Baltisphaeridium), and obviously different species included under a single species name. Obviously, such errors are present in almost every genus of organisms, but I feel that the magnitude of the problem in Micrhystridium is greater than normal, and the group is in such dire need of taxonomic revision (beyond the scope of this study) that it is virtually impossible to be certain of the validity of many of the published new species and assignments to pre-existing species. Therefore, no attempt is made to assign the forms reported here to published species (with the exception of M. deflandrei), although where possible, similarities to published species are noted.

Micrhystridium deflandrei Valensi, 1948

Plate 15, Figures 2-4

1948 Micrhystridium deflandrei Valensi, Bull. Soc. geol. Fr., vol. 5, no. 18, p. 545, text-fig. 5, nos. 3 and 5.

1969 Form S sp. 1, Thompson, p. 26, pl. 1, fig. 12.

1970 Micrhystridium spp. (in part) in Griggs, pl. 12, fig. 6.

1970 Micrhystridium deflandrei Valensi in Davey, p. 362-364, pl. 6, figs. 10-11.

Size range: 8-14 microns diameter, including spines; eight specimens measured.

Occurrence: Found only in marine samples, i.e., Mancos Shale and Mancos tongues in Mesaverde sediments; found in most such samples; abundance up to 6.4%.

Literature range Jurassic to Campanian (see references in synonymy above).

Discussion: This species is one of the most consistently identified species of the genus, and is thus named rather than following the numerical system used for other species of this genus found in this study. It is distinguished from other species by the very numerous, very short spines.

Micrhystridium sp.-1

Plate 15, Figures 5-6

Description: Spherical vescicles with closed processes numbering 10-15 around the periphery in optical section; processes thin, 1/6 to 1/4 body diameter in length, apparently solid, bases expanded very slightly.

Size range: Body diameter 7-15 microns; many specimens measured.

Occurrence: Found in 50 samples; abundance up to 7.8%. Found in most samples from the Mancos Shale, including the Buck Tongue at West Salt Creek. A few occurrences were noted in Mancos tongues in the Iles and Price River formations. One anomalous occurrence was noted in sample Pb8934 (one counted); this sample had a quite high Land Derived/Microplankton ratio, with most of the microplankton consisting of probably euryhaline (thus not exclusively marine) forms. These occurrences probably represent lagoonal, brackish water conditions (see Masters, 1965).

Discussion: This species differs from M. sp.-2 by having shorter spines, with their bases slightly wider than those of M. sp.-2. M. deflandrei has much more numerous, much shorter processes.

Forms referable to this species have been called Micrhystridium rigidum Davey (1970, pl. 7, fig. 11-12), M. wattonensis Wall (1965, pl. 7, fig. 11), M. inconspicuum Deflandre in Kidson, 1971, pl. 9 fig. 19, and M. spp. (in part) in Thompson, 1969, pl. 1, fig. 6. There are also lesser resemblances to many other species, including M. breve Jansonius in Sarjeant, 1970, pl. 2, fig. 9.

Micrhystridium sp.-2

Plate 15, Figure 7

Description: Spherical vesicles with thin, hairlike closed processes numbering 8-12 around the periphery in optical section; processes 1/2 to 1 body diameter in length, solid, bases very small, not expanded.

Size range: 6-10 microns body diameter; eight specimens measured.

Occurrence: Found in a majority (34 samples) of the marine Mancos samples studied, including a few occurrences in Mancos tongues in the Iles and Price River formations.

Discussion: This species is distinguished from M. sp.-1 by having fewer, longer spines with narrower bases.

This species is similar to M. piliferum Deflandre in Davey, 1970, pl. 7, fig. 3-4.

Micrhystridium sp.-3

Plate 15, Figures 8-9

Description: Spherical vesicles with wide closed processes with thin, knoblike tips; processes number 8-18 around the periphery in optical section; processes 1/3 to 1 body diameter in length, hollow, 1-2 microns wide at base, tapering to a point or to a knob less than 1/2 micron across.

Size range: 6-17 microns body diameter; 12 specimens measured.

Occurrence: Found in a majority of the Mancos Shale samples from Mount Garfield, and in one sample from the Buck Tongue of the Mancos at West Salt Creek. Total 27 occurrences; abundance up to 3.8% per occurrence.

Discussion: This species is a reliable indicator of marine conditions; it is found only in samples with Land Derived/Microplankton ratios of 4.54 or less.

This form is distinguished from other Micrhystridium species by its hollow spines, usually with knoblike ends.

Micrhystridium sp.-4

Plate 15, Figure 10

Description: Spherical vesicles with 7-10 thin, hairlike processes with wide, possibly hollow bases; body wall thin, fragile, often folded; processes 1/3 to 1/2 body diameter in length, fragile, often broken off.

Size range: 14-17 microns body diameter; five specimens measured.

Occurrence: Found in 10 samples from the Mancos Shale, lower part of Mount Garfield section; one or two specimens per sample.

Discussion: This species is found only in marine rocks, but its rare occurrence diminishes its usefulness as a marine indicator.

This species is distinguished from M. sp.-2 by its larger size and fewer processes. It is distinguished from M. sp.-6 by its thinner, more delicate processes which are also usually fewer in number.

Micrhystridium sp.-5

Plate 15, Figure 11

Description: Spherical to ellipsoidal vesicles with 9-12 short (1-3 microns long), closed processes with bases about equal in width to the height of the process; body wall thin, smooth, fragile, often folded.

Size range: 12-17 microns maximum body diameter; six specimens measured.

Occurrence: Found in 17 marine shale samples scattered through the sections studied; abundance up to 1.0%.

Discussion: This form is a definite indicator of marine conditions. It is distinguished from other forms by its low number of very short, wide-based processes. This species may be conspecific with M. minutispinum Wall, 1965.

Micrhystridium sp.-6

Plate 15, Figures 12-13

Description: Spherical to subpolygonal vesicles with 10-12 long, closed, ?solid processes with wide folds forming at bases; processes roughly one body diameter in length; body wall thin, smooth, fragile, sometimes folded.

Size range: 13-19 microns body diameter; eight specimens measured.

Occurrence: Found in six samples from marine shales; abundance up to 0.6%. Stratigraphically lowest occurrence is in sample Pb5554 from the upper part of the Mancos Shale in the Mount Garfield section; thus, this may be a form which reached this area or evolved here later than most of the other species in the study.

Discussion: This species seems to be ± intermediate between Veryhachium and more typical species of Micrhystridium, since it sometimes has an almost polygonal test. It has more spines than does Veryhachium, and is not referrable to that genus even though there is often a striking resemblance to certain of its species.

Micrhystridium fragile Deflandre, 1947 (see Zaitzeff, 1967, pl. 1, figs. 1-4) is similar to this species, although the spines are thinner and more fragile appearing than on M. sp.-6. If this species is conspecific with the long-ranging (Jurassic-Tertiary) M. fragile, it could not represent a new evolutionary introduction in the upper Mancos, although such might be surmised from its distribution in this study.

Subgroup Herkomorphitae

Genus *Cymatiosphaera* Wetzel, 1933, emend. Deflandre, 1954

Type species: *Cymatiosphaera radiata* Wetzel, 1933

Cymatiosphaera spp.

Plate 15, Figures 14-17

Description: Includes all specimens of *Cymatiosphaera* found in this study. Most are similar to *C. parva* Sarjeant, 1959, p. 343, and *C. costata* Davey, 1970, p. 379; see published descriptions of those species; a few specimens were larger than the above species and had higher "frills."

Size range: 5-26 microns; 20 specimens measured.

Occurrence: Found in almost all samples of Mancos Shale from Mount Garfield, plus one specimen counted from the Buck Tongue of Mancos from West Salt Creek, one from a marine siltstone in the Wilson Ranch section (Iles Formation), and one outside the sum in a marine shale parting sample from the Cozette sandstone in the Palisade section. Abundance in Mancos up to 12.6%. All occurrences were in samples with Land Derived/Microplankton ratios of 3.70 or less. Thus, this genus is a good indicator of marine conditions, at least in the area of this study.

Discussion: This group was originally split into four species, which were combined after counting because they were not clearly separated from each other, and all had essentially the same stratigraphic distribution.

Subgroup Netromorphitae

Genus *Leiofusa* Eisenack, 1938

Type species: *Leiofusa fusiformis* (Eisenack) Eisenack, 1938

Leiofusa cf. *L. jurassica* Cookson and Eisenack, 1958

Plate 15, Figures 18-19

1958 *Leiofusa jurassica* Cookson and Eisenack, p. 51, pl. 10, figs. 3-4.

Description: Morphologically the same as *L. jurassica*, but upper size limit of this form just approaches lowest size limit of *L. jurassica*.

Size range: 11-27 microns overall length; eight specimens measured.

Occurrence: Found in 21 samples of the Mancos Shale in the lower part of the Mount Garfield section; one specimen counted in a Mancos tongue near the top of the Rifle Gap section (sample Pb5720), and one specimen was noted outside the 500 sum in a sample from the Buck Tongue of the Mancos at West Salt Creek. Abundance in Mount Garfield section up to 1.8% per sample.

Discussion: This species is a definite indicator of marine conditions and was not found in any presumed fresh water or lagoonal samples.

Subgroup Platymorphitae

Genus *Halophoridia* Cookson and Eisenack, 1962

Type species: *Halophoridia xena* Cookson and Eisenack, 1962

Halophoridia xena Cookson and Eisenack, 1962

Plate 15, Figure 20

1962 *Halophoridia xena* Cookson and Eisenack, p. 271, pl. 37, figs. 6-8.

<u>Size range</u>: 39 x 32 microns overall, inner body ca. 28 microns long; one specimen measured.

<u>Occurrence</u>: Found in four samples (Pb4965, one specimen outside 500 sum; Pb6755, one specimen counted; Pb4969, one specimen outside 500 sum; Pb4980, one specimen counted) from the marine Mancos Shale from the middle of the Mount Garfield section.

Literature range ?Upper Albian-Cenomanian (see Cookson and Eisenack, 1962, p. 271).

<u>Discussion</u>: The hourglass-shaped central body of <u>Halophoridia</u> is very similar to certain species of <u>Horologinella</u> Cookson and Eisenack, which is classified as a dinoflagellate genus in Norris and Sarjeant (1965, p. 32). The two genera are probably closely related, although Norris and Sarjeant (1965, p. 31) classified <u>Halophoridia</u> as an acritarch. The four "corners" of some specimens of <u>Horologinella apiculata</u> Cookson and Eisenack reported above have filmy material clinging to them which may represent remnants of an enclosing membrane as is present in <u>Halophoridia xena</u>.

Genus <u>Trigonopyxidia</u> Cookson and Eisenack, 1961

<u>Type species</u>: <u>Trigonopyxidia ginella</u> (Cookson and Eisenack) Cookson and Eisenack, 1961

<u>Trigonopyxidia ginella</u> (Cookson and Eisenack) Cookson and Eisenack, 1961

Plate 15, Figure 21

1960 <u>Trigonopyxis ginella</u> Cookson and Eisenack, p. 11, pl. 3, figs. 18-20.

1961 <u>Trigonopyxidia ginella</u> (Cookson and Eisenack) Cookson and Eisenack.

<u>Size range</u>: 57 microns from angle to opposite side; one specimen measured.

Occurrence: Only two specimens were found, in specimens Pb4960 and Pb6745 respectively; both were outside the 500 sum.

Literature reports: Upper Albian to Cenomanian of western Australia (see synonymy for reference), Uppermost Maestrichtian to Lower Danian of Denmark (Wilson, 1971, p. 1260, pl. 2, fig. 18).

Discussion: Exclusively marine, but its extremely rare distribution limits its usefulness as a marine indicator.

Subgroup Polygonomorphitae

Genus Veryhachium Deunff, 1954, emend. Downie and Sarjeant, 1963

Type species: Veryhachium trisulcum (Deunff) Deunff, 1954

Veryhachium reductum (Deunff) de Jekhowsky, 1961

Plate 15, Figure 22

Size range: ca. 20 microns from apex to opposite wall; three specimens measured.

Occurrence: Found in 12 samples from the Mancos Shale of Mount Garfield; abundance 0.6% or less. In addition, one specimen outside the 500 sum was noted in a lagoonal shale associated with the Trout Creek Coal in the Rifle Gap section (sample Pb8934).

Literature range Ordovician to Permo-Triassic (see Downie and Sarjeant, 1964, p. 152). The occurrence of this form in Upper Cretaceous deposits may indicate reworking. Kidson (1971) also reports this species from Upper Cretaceous sediments of the Rocky Mountain area.

Discussion: This species most closely resembles V. reductum var. breve de Jekhowsky in Wall, 1965, pl. 4, fig. 11, but does not have as rounded ends on the processes as does that variety.

Subgroup Pteromorphitae

Genus *Pterospermopsis* W. Wetzel, 1952

Type species: *Pterospermopsis danica* W. Wetzel, 1952

Pterospermopsis cf. *P. australiensis* Deflandre and Cookson, 1955

Plate 15, Figure 23

1955 *Pterospermopsis australiensis* Deflandre and Cookson, p. 286, pl. 3, fig. 4.

Description: Capsule circular in apical view, collapsed, chagrenate; equatorial wing thin, hyaline, psilate, 1/3 to 1/2 body diameter in width, with circular contour; wing is usually ± flat, or with only a few irregular folds.

Size range: 23-30 microns overall diameter; six specimens measured.

Occurrence: Found in 24 samples of Mancos Shale from Mount Garfield and in one sample from West Salt Creek (Buck Tongue); abundance up to 2.4%. Strictly a marine form. Literature range of *P. australiensis* is Jurassic-Tertiary (see Stone, 1971, p. 74).

Discussion: This specimen is identical with *P. australiensis* in most respects, but differs in that the wing is frequently flat and not folded, or with fewer folds than in Deflandre and Cookson's illustrations (1955, fig. 53 and pl. 3, fig. 4). It is also similar to their *P. ginginensis*, but smaller.

This form may be conspecific with the species cited by Drugg (1967, p. 34, pl. 6, fig. 11) as *Pterospermopsis* cf. *P. ginginensis*.

Pterospermopsis sp.-1

Plate 15, Figure 24

Description: Capsule subcircular to ellipsoidal in apical view, collapsed, smooth; equatorial wing thin, psilate, about

1/3 maximum body diameter, with 15-25 regular, crescentic, radial folds which usually do not extend to the periphery of the wing; wing partially overlaps capsule, apparently on one hemisphere only.

Size range: 31-34 microns maximum overall diameter; three specimens measured.

Occurrence: Found in eight samples from the marine Mancos Shale from the lower part of Mount Garfield; abundance 0.4% or less. A definite marine indicator.

Discussion: This species is similar to *P. harti* Sarjeant, 1960, which is much larger, however, and whose folds lack the crescentic nature of those of *P.* sp.-1.

Singh (1971, p. 422, pl. 78, figs. 4-7) reports a species as *P. harti* which has somewhat crescentic folds, but is larger than *P.* sp.-1 and has a wider range of width of the wing.

Subgroup Sphaeromorphitae

Genus *Leiosphaeridia* Eisenack, 1858, emend. Downie and Sarjeant, 1963

Type species: *Leiosphaeridia baltica* Eisenack, 1958

Leiosphaeridia sp.-1

Plate 15, Figure 25

Description: Spherical to ellipsoidal bodies without processes; collapsed, often folded; no pylome; wall very thin, fragile, smooth.

Size range: 18-36 microns in diameter; 15 specimens measured.

Occurrence: Ubiquitous, found in all samples counted, including coals; lowest abundance was in Palisade Coal, highest in marine Mancos Shale samples; abundance from 0.6% to 13.6% per sample.

Discussion: These specimens somewhat resemble Cupressaceae-Taxodiaceae pollen (see Inaperturopollenites spp. above), but were classified as microplankton because their abundance remained high in highly marine samples in which the percentage of Inaperturopollenites was very low, and because many specimens tended to be ellipsoidal, a feature not common in inaperturate gymnospermous pollen.

The fact that it was found in all samples, including coals, may mean that this form is not an indicator of marine conditions, but is a euryhaline form found in a variety of aquatic environments.

This form is distinguished from L. sp.-2 by its thinner wall and greater size range and from L. sp.-4 by its larger size.

Leiosphaeridia sp.-2

Plate 15, Figure 26

Description: Spherical to ellipsoidal bodies without processes; collapsed, usually folded; no pylome; wall thin, smooth.

Size range: 12-28 microns diameter; many specimens measured.

Occurrence: Found in all samples except for two coal samples and one lagoonal siltstone (Pb8932, Rifle Gap section). Abundance up to 6.6%.

Discussion: This form seems to have had similar environmental requirements to L. sp.-1 and is thus also not regarded as a good indicator of marine conditions.

This form is distinguished from L. sp.-1 by its thicker wall and usually smaller size. L. sp.-4 is thinner-walled and usually smaller, while L. sp.-5 is thicker-walled and usually smaller. L. spp. 4 and 5 are quite distinct end members, but there are some intermediate forms; these are included in L. sp.-2. L. sp.-2 also includes forms which are less spherical and larger than either L. spp.-4 or 5; therefore, it is regarded as a separate taxon, although it was impossible to avoid its including some aberrant members of L. spp.-4 and 5.

Leiosphaeridia sp.-3

Plate 15, Figure 27

Description: Spherical to ellipsoidal bodies without processes; collapsed, often folded; no pylome; wall thin, ornamented with sparsely scattered, irregularly distributed granules up to 1 micron across.

Size range: 18-21 microns; six specimens measured.

Occurrence: Found in 13 samples from the marine Mancos Shale of Mount Garfield, and one sample (Pb8919) from the Iles formation of the Rifle Gap section (a presumably lagoonal sample). Abundance up to 0.8%; only one specimen outside the 500 sum was noted in sample Pb8919.

Discussion: The granulae distinguish this from similar forms. This species appears to be a fairly reliable marine indicator, except for an occasional occurrence in lagoonal (marginal marine) sediments.

Leiosphaeridia sp.-4

Plate 15, Figures 28-30

Description: Spherical bodies without processes; collapsed, often folded; no pylome; wall very thin, smooth.

Size range: 6-16 microns diameter; many specimens measured.

Occurrence: Found in all samples counted; abundance 1.2% to 18.6%. Highest percentages occur in marine samples with very low Land Derived/Microplankton ratios, lowest in presumably fresh water or lagoonal shales and coals.

Discussion: This species is thought to represent a euryhaline aquatic organism especially suited to but not restricted to marine waters. Its presence in moderate abundance in coals rules out its use as a marine indicator.

See discussion of *L.* sp.-2 for distinguishing characters of *L.* spp.-2, -4 and -5.

Leiosphaeridia sp.-5

Plate 15, Figure 31

Description: Spherical bodies without processes; collapsed, sometimes folded; no pylome; wall moderately thin, dense-appearing, dark-staining, chagrenate.

Size range: 10-18 microns diameter; many specimens measured.

Occurrence: Found in most samples counted; abundance up to 10.0%.

Found only rarely in lagoonal samples, and only one specimen was counted from a coal sample.

Discussion: This species is distinguished from *L.* sp.-6 by its smaller size. See discussion of *L.* sp.-2 for distinguishing characters of *L.* spp.-2, -4 and -5.

Although these forms are most abundant in marine sediments, their occasional presence in coals and other apparently continental or marginal marine samples indicates that they are probably aquatic organisms adapted to marine waters but also tolerant of fresh or brackish water. They do not resemble any known land plant spores or pollen.

Thompson (1969, p. 30, pl. 2, fig. 10) reports a form he calls Form C sp. 1 which may be conspecific with this species. Form C sp. 1 of Griggs (1970, p. 88, pl. 13, fig. 5) also appears to be the same.

Leiosphaeridia sp.-6

Plate 15, Figure 32

Description: Spherical bodies without processes; collapsed, often folded; no pylome; wall moderately thin, dense-appearing, dark staining, chagrenate.

Size range: 20-36 microns diameter; 14 specimens measured.

Occurrence: Found in 54 samples. Found in almost all Mancos Shale samples; also scattered in lagoonal deposits; abundance up to 3.0% per sample.

Discussion: Distinguished from L. sp.-5 by its larger size. This species has slightly less frequent occurrence than L. sp.-5 but is otherwise similar in its distribution. The same comments as to habitat, etc., apply as were given for L. sp.-5.

This species has a thicker wall than L. sp.-1, and stains more darkly.

Thompson (1969, p. 30, pl. 2, fig. 11) reports a form he calls Form C sp. 3 which may be conspecific with this species.

Leiosphaeridia sp.-7

Plate 16, Figure 1

Description: Spherical to ellipsoidal bodies without processes; collapsed, sometimes folded; no pylome; wall moderately thin, ornamented with fine microgranulae spaced 1/2 to 1 micron apart, microgranulae 1/2 micron or less in diameter.

Size range: 14-20 microns maximum diameter; 10 specimens measured.

Occurrence: Found in a total of 41 samples, mainly in marine Mancos Shale and its transgressive tongues intercalated between continental deposits; three specimens were found in samples of probable lagoonal origin (one in sample Pb6778 and two in sample Pb8934). Abundance in Mancos up to 3.4%.

Discussion: This species is distinguished from other small leiospheres by its microgranulate wall. It's distribution suggests that it should not be regarded as a definite indicator of marine conditions, although it occurs only rarely in presumed brackish water samples.

Micrhystridium deflandrei differs from this species by its pointed spines as opposed to small, equidimensional microgranulae.

Leiosphaeridia? sp.-8

Plate 16, Figure 2

Description: Spherical bodies without processes; collapsed, often folded; no pylome; wall ca. 1 micron thick, with ± microgranulate appearance which appears in optical section to be caused by upwardly bulging infragranulae or possibly low microverrucae; sculpture elements are regularly arranged and closely packed, less than 1/2 micron across; they form a ± mosaic pattern in surface view.

Size range: 25-35 microns diameter; eight specimens measured.

Occurrence: Found only in nine samples from the marine Mancos Shale from the Mount Garfield section; abundance up to 0.8%. This species seems to be a reliable indicator of marine conditions.

Discussion: This species is cited with a question mark because of the nature of the ornamentation, which does not appear to be of typical granulae and thus may not satisfy the conditions specified in the description of the genus Leiosphaeridia (see Norris and Sarjeant, 1965, p. 36). The wall is thicker than the other species of Leiosphaeridia reported above; however, the description of Leiosphaeridia does not specify wall thickness, but merely states it to be "thin" (ibid.).

Seemingly this means thin in comparison to Tasmanites, which has a wall several microns thick (see Eisenack, 1958, p. 2).

Leiosphaeridia? sp.-9

Plate 16, Figures 3-4

Description: Spherical bodies with granulae or occasionally also a few coni or very short spines; collapsed, sometimes folded; no pylome; some grains appear to be cracked or possibly divided into fields.

Size range: 25-35 microns diameter; seven specimens measured.

Occurrence: Found only from eight samples of Mancos Shale from Mount Garfield; abundance up to 0.6%. This species seems to be a reliable indicator of marine conditions.

Discussion: The problematical nature of these specimens, with their occasional hints of division into fields (?tabulation) and their occasional coni (or short spines?) caused me to use a question mark in assigning them to the genus Leiosphaeridia. The overall aspect of most specimens is leiosphere-like.

Leiosphaeridia sp.-10

Plate 16, Figure 5

Description: Ellipsoidal to subspherical bodies without processes; collapsed, often folded, often with cracks and holes in the wall which do not appear to be archeopyles or pylomes; wall very thin, fragile, hyaline, smooth, but occasionally scattered fine micro-granulae are present.

Size range: 48-70 microns maximum diameter; five specimens measured.

Occurrence: Found in eight samples from the marine Mancos Shale of Mount Garfield and West Salt Creek; abundance up to 1.8%.

Also, one specimen was counted from sample Pb8886X from the Rifle Gap section.

Discussion: This fossil appears to reliably indicate marine conditions. Its usefulness is limited due to its limited occurrence, however.

This species is distinguished from L. sp.-1 by its larger size.

Leiosphaeridia sp.-11

Plate 16, Figure 6

Description: Subspherical to ellipsoidal bodies without elongate processes; collapsed, often folded; no definite pylome, but some specimens show a tendency to tear at one end; wall thin, fragile, ornamented with microgranules less than 1/2 micron across, usually closely packed, but spaced up to 1 micron apart on some specimens; spacing usually constant on any one specimen.

Size range: 31-45 microns maximum diameter; eight specimens measured.

Occurrence: Found in 21 samples from the Mancos Shale and its transgressive tongues; abundance up to 1.0%. Exclusively marine.

Discussion: Distinguished from L. sp.-8 by its thinner wall. Also, the ornamentation of L. sp.-11 is more distinctly granular. The elements of L. sp.-8 are very densely packed and form a ± mosaic appearance not noted in L. sp.-11.

Leiosphaeridia sp.-12

Plate 16, Figures 7-8

1971 Quisquilites(?) ornatus auct. non Hemer and Nygreen, 1967: KIDSON, p. 134, pl. 10, fig. 12.

1971 Quisquilites(?) pluralis auct. non Hemer and Nygreen, 1967: KIDSON, p. 134, pl. 10, fig. 14.

Description: Ellipsoidal bodies without processes; collapsed, often folded, often with cracks or holes which simulate pylomes, but no true pylome present; wall very thin, less than 1/2 micron thick, fragile, psilate or provided with sparsely to quite closely spaced, very small microgranulae, 1/4 micron across or smaller; there is a gradation from smooth to ornamented forms, with the smooth forms occurring mostly in the large end of the size range.

Size range: 12-17 microns x 21-35 microns; nine specimens measured.

Occurrence: Found in 38 samples from the Mancos Shale and its transgressive tongues; abundance up to 4.2%.

Discussion: Both of the forms illustrated by Kidson (see synonymy above) from the Buck Tongue of the Mancos Shale are assignable to the species described here. The names Quisquilites(?) ornatus and Q.(?) pluralis Hemer and Nygreen are not applicable to these small, thin-walled forms. Hemer and Nygreen's specimens are described as having walls 2 microns thick for Q.(?) ornatus and 1-4 microns thick for Q.(?) pluralis (see Hemer and Nygreen, 1967, p. 192). The species reported here and in Kidson, 1971, have very thin walls, less than 1/2 micron thick. Hemer and Nygreen's species are much larger, also: Length 72-84 microns for Q.(?) ornatus and 58-76 microns for Q.(?) pluralis.

None of the species discussed here are referable to the genus Quisquilites Wilson and Urban, which is described as having a three-layered wall (see Norris and Sarjeant, 1965, p. 53). L. sp.-12 has single-layered walls. In the case of the Lower Carboniferous species of Hemer and Nygreen, the wall structure was apparently not determinable.

Subgroup Uncertain

Genus *Palaeostomocystis* Deflandre, 1935

Type species: *Palaeostomocystis reticulata* Deflandre, 1935

Palaeostomocystis cf. *P. apiculata* Cookson and Eisenack, 1960

Plate 16, Figures 9-10

1960 *Palaeostomocystis apiculata* Cookson and Eisenack, p. 12, pl. 3, fig. 15.

Size range: 30-43 microns x 18-26 microns; five specimens measured.

Occurrence: Found in six samples from the marine Mancos Shale from the lower part of the Mount Garfield section; abundance 0.4% or less. A definite marine indicator.

Literature range of *P. apiculata* is Santonian? to Campanian of Australia (Cookson and Eisenack, 1960, p. 12).

Discussion: This form has very small spinules on some specimens, but others have only microgranulae, and some are unornamented. The various types intergrade. Cookson and Eisenack indicate that their species *usually* has spinules.

The usual presence of spinules or microgranulae at each end separates this species from *P. laevigata* Drugg, 1967, although the unornamented forms would be put into that species were it not for their intergradation with ornamented forms.

These specimens are not so significantly different from *P. apiculata* as to justify erection of a new species. They may be identical, or they may represent different geographical varieties. Cookson and Eisenack illustrate only one specimen, so it is difficult to know the range of ornamentation exhibited by their species from their brief description.

Unknown Acritarch-1

Plate 16, Figure 11

Description: Ellipsoidal double-walled bodies; inner wall of indistinct thickness, possibly ca. 1/2 micron thick, outer wall much thinner; both walls fragile, psilate; outer wall is like a thin, wrinkled, membraneous "perinium" closely surrounding the inner wall; no pylome.

Size range: 21-26 microns x 32-40 microns; seven specimens measured.

Occurrence: Found in 13 marine shale samples; lowest sample stratigraphically was Pb4969, from the middle of the Mount Garfield section. Definite marine distribution.

Discussion: This form could not be identified with any published species of acritarch, but was classified as a marine acritarch because of its distribution in exclusively marine rocks.

OTHER MARINE MICRO-ORGANISMS

Genus *Palambages* O. Wetzel, 1961

Type species: *Palambages morulosa* O. Wetzel, 1961

Comments: Certain authors (i.e., Drugg, 1967, p. 12, and Zaitzeff, 1967, p. 34) place this genus in the class Chlorophyceae, but I agree with Singh (1971, p. 429) that "the natural affinity of *Palambages* is as yet uncertain."

Palambages sp.-1

Plate 16, Figures 12-13

Description: Irregularly spheroidal masses of smooth spherical to oval membraneous cells; cell walls very thin, fragile, easily folded; no apertures noted.

Size range: Individual cells 20-24 microns in diameter, masses 55-65 microns in diameter; three specimens measured.

Occurrence: One specimen found in each of six samples from the marine Mancos Shale of Mount Garfield (only four occurrences were included in the fixed sum counts). Exclusively marine.

Suggested affinity: Chlorophyceae?

Discussion: This species is similar to *P. morulosa* O. Wetzel, but that species is larger, and its cells appear to have apertures, which were not noted on these specimens.

P. deflandrei Gorka, 1963, is similar, but seems to have smaller cells in relation to the size of the mass. Also, Gorka's species has a "foamy filling" between the cells which was not noted in these specimens. *P. deflandrei* also has more regularly spherical colonies, with possibly less distortion of each cell by its neighbors.

Palambages sp.-2

Plate 17, Figure 1

Description: Irregularly spheroidal to ellipsoidal masses of spherical to possibly ellipsoidal cells; the cells are covered with granulae and occasional spinules, no apertures were observed.

Size range: Cells 22 microns diameter, colony 48 x 64 microns; one specimen measured.

Occurrence: One specimen counted in sample Pb4969 from the marine Mancos Shale of Mount Garfield; in two other Mount Garfield Mancos samples, Pb4962 and Pb5554, one specimen was observed outside the 500 sum.

Suggested affinity: Chlorophyceae?

Discussion: The species reported by Zaitzeff (1967, p. 34, pl. 3, fig. 1) as *P. deflandrei* Gorka may be conspecific with the form reported here, but no apertures could be distinguished on my specimens. Zaitzeff's species is incorrectly assigned to *P. deflandrei* Gorka, 1963. Gorka's species is smooth; Zaitzeff's is granular. Zaitzeff's species has peripheral apertures, while apertures are neither illustrated nor described for Gorka's species. Gorka describes a "foamy filling" between the cells of the colonies of her specimens; this "foamy filling" is not discussed or illustrated by Zaitzeff. Finally, Gorka's colonies are larger than Zaitzeff's, and the cells are smaller in relation to the size of the colony, with the cell size increasing with increasing colony size (see Gorka, 1963, p. 76-77, pl. 9, fig. 2, and Zaitzeff, 1967, p. 34, pl. 3, fig. 1).

Palambages? sp.-3

Plate 17, Figures 2-3

Description: Spherical, apparently solid masses of 100-200 small spheroidal or ellipsoidal cells closely packed and, thus, assuming polygonal shapes; walls of cells smooth, thin, no apertures; some cells toward the center of the mass are much larger than the cells of the rest of the mass (two such extra large cells are present inside the holotype, one can be seen in pl. 17, fig. 2, which was taken at approximately the middle focal plane of the mass); the largest of these larger cells are roughly 2-1/2 times the diameter of the average cells of the mass; there appear to be several hundred cells in each mass; these masses are not to be confused with *Schizosporis reticulatus* Cookson and Dettmann (see discussion below).

Size range: Average individual cells 4-11 microns in diameter; larger central cells 18-20 microns maximum diameter (shape irregularly polygonal); diameter of mass 33-58 microns in diameter; three masses measured.

Occurrence: Found in four samples randomly scattered through the sections studied; two were marine shales, one a marginal marine shale, and one was a coal. In one marine shale (Pb6746), two specimens were counted, one in the other marine shale (Pb5562), one in the marginal marine sample (Pb6775), and one specimen outside the 500 sum in the coal (Pb8957-60).

Suggested affinity: Chlorophyceae?

Discussion: These masses superficially very much resemble *Schizosporis reticulatus* Cookson and Dettmann, 1959, but closer examination reveals great difference, other than size (*S. reticulatus* is roughly twice as large as *P.*? sp.-3).

It is my opinion, from extensive literature research, that probably none of the reports of *S. reticulatus* outside the vicinity of Australia are actually conspecific with Cookson and Dettmann's species. Their species is definitely a hollow sphere which splits easily and regularly into two ± equal hemispheres. None of the several reports of this species from other areas which I examined illustrated this feature, and very few mentioned it.

Also, *S. reticulatus* has a definite, regular reticulum with high, vertical-sided muri, and apparently no closure over the upper ends of the lumina, presenting the appearance of a honeycomb, with its many parallel polygonal prisms. Even if the prisms have closed tops, their regular nature and vertical, parallel sides are very different than the cells of *P.*? sp.-3 and most non-Australian *S. reticulatus* specimens reported.

S. reticulatus, as reported in Pocock (1962, pl. 13, fig. 202), appears to be very similar to P.? sp.-3, although much larger, and does not appear to be conspecific with S. reticulatus Cookson and Dettmann.

Brenner (1963, p. 96-97, pl. 42, fig. 4, pl. 43, figs. 1-2) reports a form similar to P.? sp.-3 (but twice as large), which he recognizes as being cellular rather than reticulate, but for which he uses the name S. reticulatus. Brenner's species has basically spherical cells which are irregularly distorted by mutual interference due to close packing and which sometimes, thus, assume roughly polygonal shapes. These cells appear to me to be quite different from the regular, vertical-sided prisms of S. reticulatus Cookson and Dettmann. Also, Brenner does not mention or illustrate the split condition of the "exine" characteristic of S. reticulatus, and the individual cells of his specimens each have a pore, a feature not found on Cookson and Dettmann's specimens.

The species reported here is considered to be a smaller relative of the forms reported by Brenner, Pocock, and other authors, from non-Australian materials, as Schizosporis reticulatus Cookson and Dettmann, but none of these forms are, in my opinion, likely to be closely related to the true S. reticulatus of the Australian region.

The specimens reported here seem best accommodated in the genus Palambages O. Wetzel, although there are many more than "8-18?" cells and the cells are usually not oval as described by Wetzel (1961, p. 338, pl. 1, fig. 11). Wetzel's illustration of the type species shows cells which appear to be closely packed spheres or ellipsoids rather than being strictly oval. Other authors (i.e., Gorka, 1963, p. 76-77, Manum and Cookson, 1964, p. 24) have assigned forms to this genus with much larger numbers of cells than the 8-18? mentioned by Wetzel. It is my opinion that the genus Palambages should be formally emended to include spherical cell form and possibly up to 100 or 200 cells per mass, but in the meantime, the specimens reported here are only tentatively assigned to Palambages.

Microforaminifera

Plate 17, Figure 4

Description: Two chitinous inner linings of coiled benthonic foraminifera were found.

Size range: ca. 20 microns maximum dimension.

Occurrence: One specimen counted in marine Mancos Shale sample Pb6755 from Mount Garfield, and one specimen outside the 500 sum in sample Pb8932, a lagoonal shale associated with the Trout Creek Coal in the Rifle Gap section.

Discussion: The occurrence of a foram test in sample Pb8932 confirms its marginal marine nature, which is also supported by the presence of one dinoflagellate cyst and by its stratigraphic association with a coal sample. The remainder of the palynomorphs in this sample indicate a more continental origin.

PALYNOMORPHS INCERTAE SEDIS

Unknown Palynomorph-1

Plate 17, Figures 5-7

Description: Entities with round to elliptical outline, may be disc-shaped(?) bodies or flattened spheres or ellipsoids, possessing a thin central area, usually with a thicker, rounded projection in the immediate center; this thin area is 1/2 to 3/5 of the total diameter; central area surrounded by a thicker, darker-staining marginal area with a slightly crenulated or ± serrate inner margin.

Size range: 19-26 microns maximum diameter; eight specimens measured.

Occurrence: Found in 15 samples representing all sections except West Salt Creek; abundance up to 0.4%.

Discussion: This species was counted as a land-derived palynomorph because of its occurrence in coals and other non-marine or marginal marine rocks. It is not known whether this form was produced by a land-plant, or whether it represents a fresh-water or euryhaline alga.

Some Pterospermopsis cysts which have lost their central body resemble this form; however, details of the marginal area, as well as the common presence of a central raised area, are unlike the features of published species of Pterospermopsis, and it is my opinion that the specimens definitely do not belong to that genus.

To my knowledge, this represents a new taxon of palynomorphs incertae sedis, but until its morphology is better understood and further specimens are studied, no formal name will be proposed.

ANALYSIS AND APPLICATION OF DATA

Ranges of Palynomorphs

The ranges of the palynomorphs encountered in each stratigraphic section of the study are presented in Figures 3 and 4, and in Tables 1 and 2. Each of the 214 palynomorph types identified was given a number for ease of plotting the range charts and other graphic presentations. Table 1 is a list of these numbers opposite the names of the palynomorphs they represent. The list is arranged in the order in which the range of the palynomorphs were plotted on the range chart for the Grand Junction Area Composite Section (Figure 3) with the eight types not appearing in the composite section being placed at the end of the list. The numbers from Table 1 are used for these palynomorphs wherever they appear in graphic materials in this dissertation. This facilitates comparison of information about a given palynomorph from one graphic presentation to another.

Palynomorph types which appear in coals are followed by an asterisk in Table 1. Those appearing only in coals are marked by a double asterisk.

As implied above, all but eight of the 214 kinds of palynomorphs identified in this study occurred in the Grand Junction Area Composite Section; thus that section serves as a good basis of comparison with the other sections.

The ranges of most of these palynomorphs are too long to be useful for time correlation here. The range of some palynomorphs in this

TABLE 1: Master list of palynomorphs identified in this study. The numbers correspond to the numbers used for these palynomorphs in all graphic presentations of this thesis. The arrangement of the first 206 species is based on their appearance in Figure 3, the detailed range chart for the Grand Junction Area Composite section.

1. Tsugaepollenites? sp.
2. Triporopollenites sp.-6
3. Veryhachium reductum
4. Circulina parva
5. Dictyophyllidites? sp.
6. Engelhardtioides cf. E. minutus
7. Leiofusa cf. L. jurassica
8. Palaeostomocystis cf. P. apiculata
9. Micrhystridium sp.-3
10. Leiosphaeridia sp.-3
11. Palaeohystrichophora infusorioides
12. Dinogymnium sp.-1
13. Tricolpites sp.-1
14. Tricolporopollenites sp.-5
15. Foraminisporis wonthaggiensis
16. Vitreisporites pallidus
17. Tricolpites sp.-9*
18. Triporopollenites sp.-5*
19. Bisaccate-1
20. Cupanieidites reticularis
21. Retitricolpites sp.-2*
22. Laevigatosporites sp.-2*
23. Cymatiosphaera spp.
24. Leiosphaeridia sp.-6*
25. Ilexpollenites sp.*
26. Extratriporopollenites sp.-1*
27. Hystrichosphaera ramosa
28. Eucommiidites couperi*
29. Leiosphaeridia? sp.-11
30. Tricolpites sp.-2
31. Arecipites reticulatus*
32. Classopollis classoides*
33. Tricolporopollenites sp.-4*
34. Araucariacites spp.*
35. Micrhystridium sp.-2
36. Proteacidites thalmanni var. 3*
37. Unknown Dinoflagellate-1
38. Psilinaperturites psilatus*
39. Leiosphaeridia sp.-7
40. Unknown Dinoflagellate-3
41. Micrhystridium deflandrei
42. Unknown Dinoflagellate-4
43. Hologinella apiculata
44. Leiosphaeridia sp.-12
45. Retitricolpites spp.*
46. Cupanieidites major*

Table 1 (cont'd.)

47. Micrhystridium sp.-1*
48. Proteacidites thalmanni var. A*
49. Leiosphaeridia sp.-5*
50. Leiosphaeridia sp.-2*
51. Eucommiidites? sp.-3*
52. Todisporites minor*
53. Concentrisporites pseudosulcatus*
54. Tricolporopollenites? sp.-3*
55. Toroisporis (Toroisporis) longitorus?
56. Camarozonosporites hamulatis*
57. Tricolpites interangulus*
58. Unknown Trilete Spore-3*
59. Polypodiisporites favus*
60. Triporopollenites sp.-3*
61. Tricolpites cf. T. psilascabratus*
62. Tricolpites sp.-5*
63. Eucommiidites troedssonii*
64. Cyathidites minor*
65. Triplanosporites sp.*
66. Schizosporis cooksoni*
67. Tricolporopollenites minor**
68. Liliacidites complexus*
69. Confertisulcites sp.-2*
70. Eucommiidites? sp.-4*
71. Schizosporis scabratus*
72. Laevigatosporites sp.-1*
73. Laevigatosporites haardti*
74. Momipites sanjuanensis*
75. Gleicheniidites senonicus*
76. Tricolpites sp.-3*
77. Tricolpites anguloluminosus*
78. Cycadopites sp.*
79. Tricolpites mutabilis*
80. Fraxinoipollenites cf. F. variabilis*
81. Clavatipollenites cf. C. minutus*
82. Retitricolpites minutus*
83. Tricolpites cf. Tricolporites traversei*
84. Leiosphaeridia sp.-1*
85. Leiosphaeridia sp.-4*
86. Inaperturopollenites spp.*
87. Micrhystridium sp.-4
88. Quadripollis krempii
89. Striatopollis sp.-2
90. Schizosporis cf. S. spriggi*
91. Pterospermopsis sp.-1
92. Tilia cf. T. wodehousei*
93. Striatopollis sp.-1*
94. Pterospermopsis cf. P. australiensis
95. Tricolpites sp.-4
96. Deflandrea sp.-1
97. Retitricolpites sp.-3*

Table 1 (cont'd.)

98. *Acanthotriletes* cf. *A. levidensis*
99. Unknown Palynomorph-1*
100. *Tricolpopollenites* cf. *T. variofoveatus**
101. Normapolles sp.-2*
102. *Monosulcites* spp.*
103. *Deflandrea* cf. *D. cooksoni*
104. *Equisetosporites* sp.-1*
105. *Umbosporites callosus**
106. *Retitricolpites* sp.-14*
107. *Schizosporis* sp.-2*
108. Unknown Inaperturate Angiosperm*
109. *Micrhystridium*-5
110. Unknown Dinoflagellate-2
111. *Leiosphaeridia* sp.-10
112. *Aquilapollenites trialatus* var. *uniformis*
113. *Deflandrea* sp.-2
114. *Triporopollenites* sp.-1*
115. *Aquilapollenites navacolpites*
116. *Monosulcites epakros**
117. *Sporopollis* sp.*
118. *Eucommiidites* sp.-2*
119. *Dinogymnium nelsonense*
120. *Aquilapollenites* spp.*
121. Unknown Dinoflagellate-5
122. *Gonyaulacysta*? cf. *G. delicata*
123. *Palambages* sp.-1
124. *Arecipites tenuexinus**
125. *Monosulcites*? sp.-3
126. *Triletes verrucatus*
127. *Kuylisporites scutatus*
128. *Equisetosporites multicostatus*
129. *Cicatricosisporites* spp.
130. *Eucommiidites*? sp.-1
131. *Aquilapollenites quadrilobus**
132. *Vitis*? cf. *V*? *affluens**
133. *Tricolpites* sp.-7*
134. *Leiosphaeridia*? sp.-8
135. *Leiosphaeridia*? sp.-9
136. *Cingulatisporites dakotaensis**
137. *Aquilapollenites rigidus*
138. *Baltisphaeridium* sp.
139. Unknown Trilete Spore-4
140. *Podocarpidites* spp.
141. *Surculosphaeridium*? cf. *S. vestitum*
142. *Ericaceoipollenites rallus**
143. *Cyclonephelium* spp.
144. *Schizosporis* sp.-6*
145. *Stereisporites antiquasporites**
146. *Quercus*? cf. *Q. explanata**
147. *Klukisporites pseudoreticulatus*
148. *Aquilapollenites* cf. *A. bertillonites*

Table 1 (cont'd.)

149. Trigonopyxidia ginella
150. Hystrichosphaeridium sp.
151. Rugubivesiculites spp.*
152. Cleistosphaeridium sp.
153. Osmundacidites wellmanni*
154. Unknown Trilete Spore-2
155. Dinogymnium digitum
156. Appendicisporites sp.
157. Liquidambarpollenites? sp.
158. Bisaccate-5
159. Palambages sp.-2
160. Tricolporopollenites sp.-2*
161. Liliacidites reticulatus*
162. Triporopollenites sp.-2*
163. Chomotriletes fragilis
164. Unknown Trilete Spore-1*
165. Liliacidites spp.*
166. Myocolpopollenites cf. M. reticulatus*
167. Tricolpites sp.-8
168. Retitricolpites sp.-4*
169. Odontochitina striatoperforata
170. Unknown Trilete Spore-5
171. Palambages? sp.-3*
172. Retitriletes cenomanianus
173. Alnipollenites trina*
174. Tricolpopollenites cf. T. extraneus*
175. Confertisulcites sp.-1*
176. Bisaccate-6
177. Aquilapollenites calvus*
178. Tricolpites sp.-6*
179. Triatriopollenites granulatus*
180. Myrtaceoipollenites peritus*
181. Conclavipollis? cf. C. wolfcreekensis*
182. Trudopollis meekeri*
183. Microforaminiferan
184. Halophoridia xena
185. Perinopollenites? sp.*
186. Ulmoidipites sp.*
187. Unknown Acritarch-1
188. Polysphaeridium cf. P. sp. 4 of Zaitzeff
189. Retitricolpites sp.-1*
190. Pinus semicircularis
191. Micrhystridium sp.-6
192. Retitricolpites sp.-11*
193. Styx minor
194. Polyporina cribraria
195. Aquilapollenites attenuatus
196. Tricolporopollenites sp.-1
197. Liliacidites cf. L. variegatus
198. Liliacidites sp.-1*
199. Monosulcites sp.-1*

Table 1 (cont'd.)

200. Retitricolpites sp.-17*
201. Sestrosporites pseudoalveolatus**
202. Toroisporis sp.**
203. Schizosporis sp.-8*
204. Todisporites sp.*
205. Triporopollenites sp.-4*
206. Leiotriletes varius*
207. Appendicisporites potomacensis
208. Monosulcites sp.-2*
209. Tricolporopollenites? cf. T. globularius
210. Triporopollenites sp.-7**
211. Perotriletes sp.*
212. Normapolles sp.-1*
213. Erdtmanipollis pachysandroides
214. Monosulcites sp.-2

* Found in coal samples.
** Found only in coal samples.

study is not coincident with the range given for the same taxa in the literature for nearby areas. Some of these have shorter ranges; others have greater ranges. Thus, some of these taxa are unreliable for correlation purposes here, even though they may have short ranges in the rocks studied here. The distribution of some other short-ranging forms is too sparse or scattered to allow their ranges to be used confidently for correlation. Nine forms were judged to have meaningful ranges for the purposes of time correlations between the various sections. These are listed below, in the Correlations portion of this thesis.

Figure 3 is a plot showing the actual points of occurrence of each palynomorph in the Grand Junction Area Composite section. Many of the palynomorphs have large gaps in their ranges, or occur only sporadically. Some of these gaps correlate with paleoenvironmental factors, and these correlations are discussed under the Paleoenvironmental Indicators and Correlations headings below.

Paleoenvironmental Indicators

Several types of environmental indicators or environment-related phenomena which are evident in the graphic presentations of this report are discussed below.

1. Interrupted Ranges

One such phenomenon is the prominent zone of gaps in the ranges of many palynomorphs which extends from approximately the 900 foot level to approximately the 1,200 foot level of Figure 3 (detailed range chart of palynomorphs occurring in the Grand Junction Area Composite section). This zone of interruptions in ranges was presumed and later determined (see below) to represent the deeper water, far offshore conditions

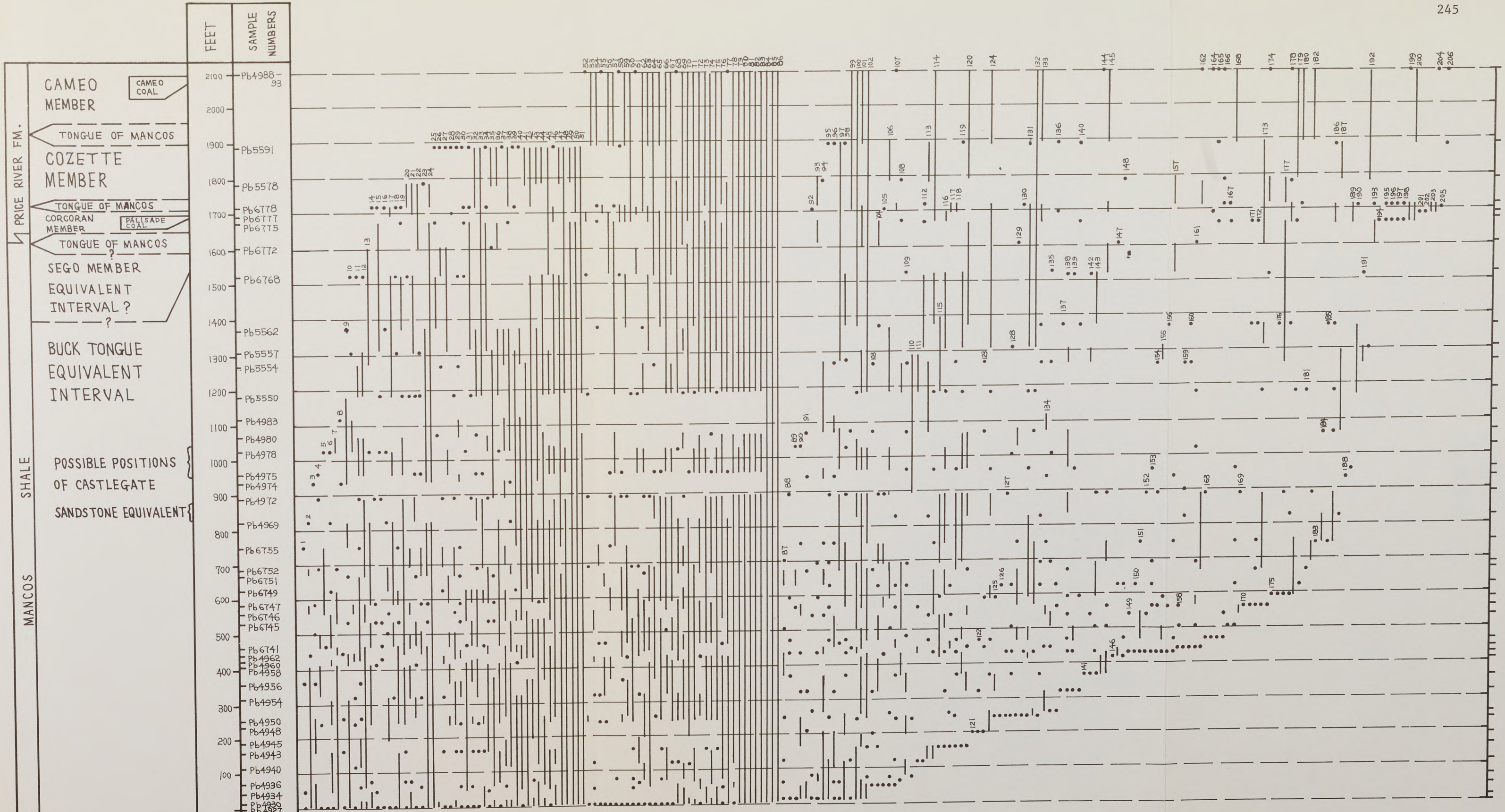


Figure 3: Detailed range chart for palynomorphs occurring in the Grand Junction Area Composite Section. Species numbers at upper ends of range lines are from Table 1.

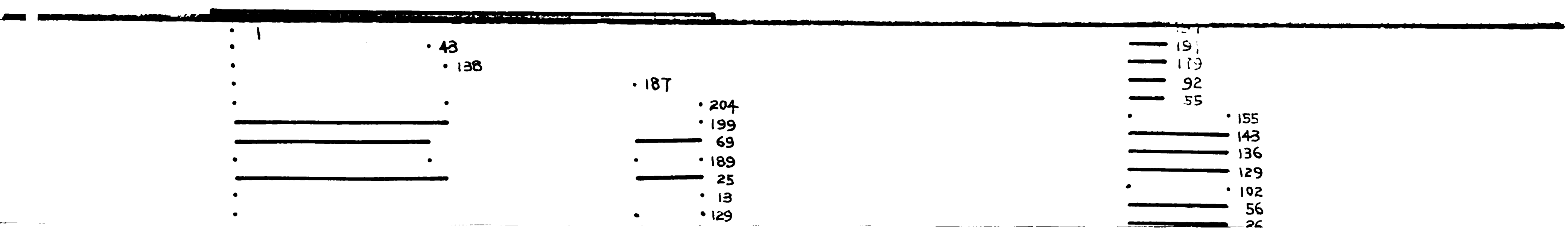
caused by the Buck Tongue transgression. The representation of land-derived palynomorphs is very restricted in this zone, indicating that their source, and thus the shoreline, was farther from the site of deposition than it was in preceding or following samples. Even the ranges of many of the microplankton are interrupted. The total flora is thus less diverse than in most other samples, but preservation is good in the samples involved, indicating that the range gaps and low diversity are not the result of poor preservation.

This zone of gaps has no clearly recognizable counterpart in the detailed range chart of West Salt Creek palynomorphs (Figure 4a), but this is to be expected, since the West Salt Creek section was much closer to the shoreline at the time of maximum Buck Tongue transgression than was the Grand Junction Area Composite Section.

Another zone of interrupted ranges, not as well defined, is associated with the Palisade Coal zone, which occurs at about the 1,700 foot level of Figure 3. Other zones of less striking interruptions also occur, but their significance is not well understood; they are probably the result of varied factors, such as quality of preservation, sampling interval, etc.

2. Introduction of Species

Another feature of Figure 3 thought to be related to environmental factors, is the manner in which species appear upward through the section. Throughout the lower part of the diagram, species are added along the lower right sector in a continuous, rather uniform manner. Then at approximately the same level as the Buck Tongue zone of interrupted ranges mentioned above, the rate of introduction of species drop to near zero, and remains low throughout the Buck Tongue interval, and



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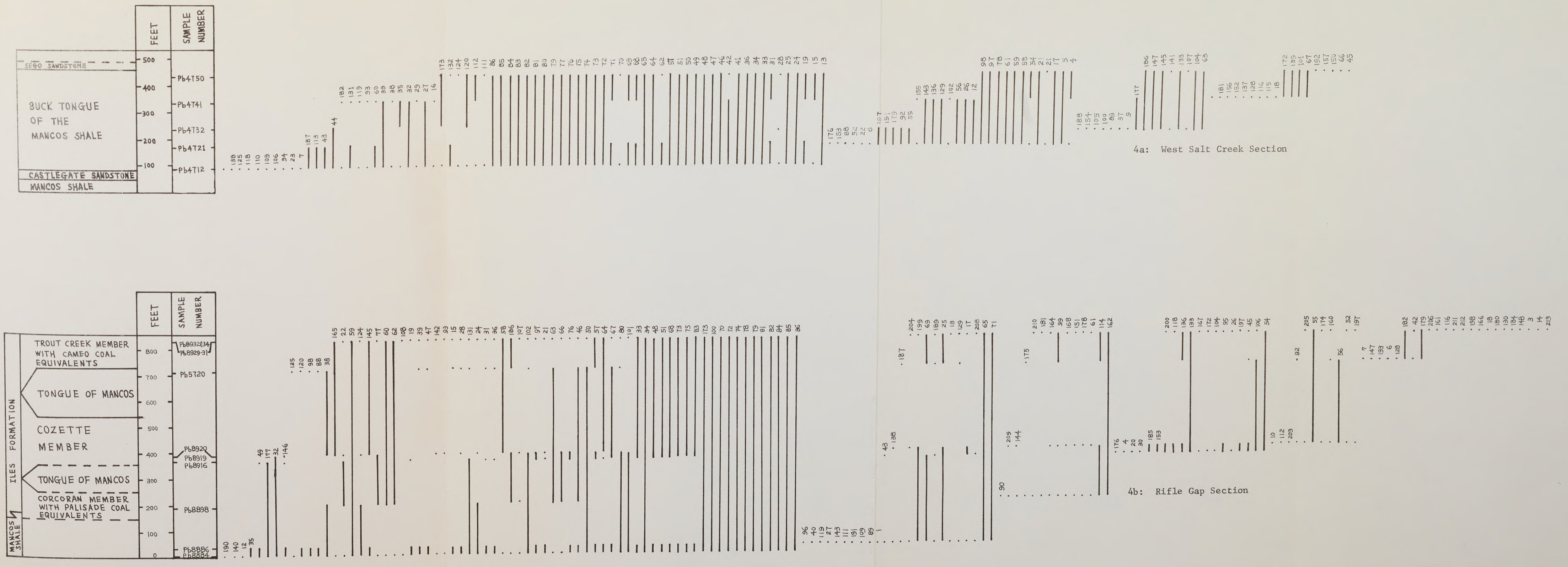

Figure 4: Detailed range charts for palynomorphs occurring in the West Salt Creek and Rifle Gap sections. Species numbers at upper ends of range lines are from Table 1.

up to the sample just below the Palisade Coal. At this point, several more palynomorph types are added to the flora. These new species are quite clearly related to the proximity of the coal swamp environment (or other nearby shoreline environments).

The reduction in number of new species added near the base of the Buck Tongue interval (this interval was determined on the basis of other evidence than that now under discussion) probably reflects the longer distance the palynomorphs were transported in the Buck Tongue sea to the site of deposition.

The large group of terminations of ranges noted for sample Pb5591, the second sample from the top in Figure 3, is due, in part, to the environmental difference between this sample (a lagoonal sample) and the top sample (a coal), and, in part, is due to the large stratigraphic gap between the two. This gap is the result of the paucity of adequately preserved palynomorphs in the intervening samples.

3. Land Derived/Microplankton Ratio

A very useful environmental indicator in this study was the ratio of land-derived palynomorphs to microplanktonic organisms, called the Land Derived/Microplankton ratio, or abbreviated as LD/M ratio. This measure gives a quantitative estimate of the relative "marine-ness" of each sample, with those samples furthest from the ancient shoreline having the lowest LD/M ratios, and those from the least marine-influenced environments (in this study, the latter were coal swamp environments) having the highest ratios. This measure has been previously used for distinguishing marine and non-marine rocks by Upshaw (1964). A similar but inverted ratio of hystrichospheres/pollen and spores was used by Sarmiento (1957).

In this study, the LD/M ratio was calculated by dividing the relative percentage of all pollen and spores in a sample by the relative percentage of all microplankton in the sample. Microplankton included not only dinoflagellates, hystrichospheres, and spiny marine acritarchs, but also leiospheres. These are small, usually smooth, usually spheroidal entities often assumed to be exclusively of marine origin. In this study, although the relative percentages of leiospheres was highest in normal marine samples, a few leiospheres were found in all depositional environments, including coal swamps. Thus, this group includes euryhaline aquatic organisms. Their inclusion in the LD/M ratios of this study lowers these ratios in all environments, and thus has little effect on the shape of the LD/M curves (Figure 7). The fact that the coals in this study contained some euryhaline leiospheres indicates that these coals formed in swamps which contained brackish waters at least part of the time. The alternative to this situation is that some of these leiospheres may possibly represent fresh-water organisms. This possibility should be investigated further in future studies.

The fact that all samples except coals contained some marine microplankton (in addition to the ubiquitous leiospheres) is an indication that no totally continental sediments except coals are found in the sections sampled for this study. Non-coal samples with high LD/M ratios are regarded as belonging to the general category of lagoonal sediments (as characterized by Masters, 1965, Figure 2a), a marginal marine environmental complex behind a barrier bar. Some of these samples with high LD/M ratios may be the products of salt marshes or estuaries or other non-lagoonal marginal marine environments near a mainland beach where no barrier beach was developed. This is suggested by the absence of coals in the sediments associated with some of the high LD/M ratio samples, such as samples Pb4741 and Pb4750 in the West Salt Creek section. Detailed sedimentological work beyond the scope of this study would be required in order to determine if this is the case.

After consideration of sample lithology, stratigraphic position in relation to sandstones and coal zones, and type of microplankton present, an arbitrary figure of 7.95 was selected as the highest LD/M value which would be regarded as indicating normal marine conditions in this study. Samples above 7.95 were regarded as marginal marine, mostly falling within the lagoonal category of Masters (1965). Samples between this value and 5.0 were regarded as very nearshore marine, while those below 5.0 were considered to represent conditions further from shore or otherwise more marine. Samples with a ratio approaching the 7.95 upper limit and containing very few, if any, microplankton besides leiospheres may also represent marginal marine conditions, especially if they are in sandy sediments. Sample Pb8884, the lowest sample in the Rifle Gap section, is such a sample (see Figure 7c).

The use of the LD/M ratio in correlation and its relation to some time lines will be discussed under Correlations below.

4. Relative Abundance Percentages

Another environmental indicator, used in this study mainly to reinforce conclusions based on the LD/M curve, is the use of the relative percentages of the total flora contributed by various types and combinations of palynomorphs. Those relative percentage curves which aided in environmental interpretations or in correlations are presented in Figure 7 (large chart in pocket).

The curves of the angiospermous categories and the total angiosperms generally tend to parallel the LD/M ratio curve, supporting its use as an indicator of relative "marine-ness" of samples. Some angiosperms had their lowest values in coals, however, indicating that they represent plants not living in the coal swamps. The curve for total gymnosperms tended to be a rough mirror image of the LD/M curve except in highly marine zones, where low percentages of all land-derived palynomorphs indicated that these sediments were deposited far from the shoreline. Total triporates and total spores parallel the LD/M curve. A correlation was noted between the curves of the total percentage of gymnosperms and the number of species present per sample. The explanation for this correlation has not yet been determined.

Correlations

Figure 8 illustrates the correlations of the subordinate sections with the Grand Junction Area Composite Section (referred to in the following discussion as the GJAC Section), the major reference section for this study. The justification for these correlations is given below. All information available was used for correlations; this includes the various forms of palynological data already discussed, as well as lithologic information and correlations from various sources. Data on which the correlations are based are illustrated graphically in Figures 3, 6 and 7.

Buck Tongue position in GJAC Section--The position of the equivalent of the Buck Tongue of the Mancos Shale was determined in the GJACS by palynologic evidence alone. Two types of palynologic evidence supported the correlation shown in Figure 8, namely environmental evidence of equivalent position, and time evidence determined from palynomorph range data.

The environmental evidence used has already been mentioned above. First, the prominent zone of interrupted palynomorph ranges extending from the location of sample Pb4980 to sample Pb5550 in the GJAC Section (see Figure 3) appears to have environmental significance, and occurs at the same level at which the Land Derived/Microplankton curve reaches its lowest point. This level represents the most marine conditions in the area, associated with the Buck Tongue transgression. (The zone between the positions of samples Pb4972 and Pb4974 at about the 900 foot level in the GJAC Section, where many palynomorphs found above and below were missing, was possibly also associated with the same transgression, although its meaning is less clear.) Another line of evidence showing that the zones of interrupted ranges correlated with more marine conditions, probably representing far offshore conditions, was the cessation of introduction of new species into the flora beginning at the level of these interruptions and continuing through the interval determined to be equivalent to the Buck Tongue (see page). This cessation is explained by assuming that the shoreline was far to the west during this interval, so that palynomorphs had to be transported farther to reach the site of deposition. The graph of the number of species per sample (see Figure 7a) tends to be lower in the initial part of this most marine interval than in the preceding and following samples. This would be expected if the assumption that the site of deposition of sediments in this interval was farther from shore than that of the preceding and following samples is correct.

The graphs of the LD/M ratio for the West Salt Creek section, and for that portion of the GJAC Section containing the zone of interrupted ranges and continuing upward to the level of sample Pb6768, are very similar in appearance (refer to Figure 7). This fact, coupled with the evidence already mentioned, was the basis for the correlation of these sections shown in Figure 8. The approximate top of the Buck Tongue as shown is regarded as a fairly certain correlation, based on coordinated environmental (high LD/M ratio and similar curve shape) and lithologic grounds. The lithologic evidence is a sandy zone, possibly corresponding to the Sego Sandstone, 25 feet above sample Pb6768.

Time correlations of the West Salt Creek section and the GJAC Section were based on the ranges of species number 9, 110, 12, 143 and 187 (see Table   for the taxa represented by these numbers). These ranges are shown in Figure 7 next to the lithologic sections.

Species 187 is not useful in establishing a time correlation with the GJACS, except as evidence that the base of the West Salt Creek section must be higher than the level of sample Pb4969 in the GJACS.

Species 9, 110, 12 and 143 show a very similar configuration of the ends of their ranges (or points of occurrence) in both sections currently under discussion. This fact is regarded as indicating a time correlation of samples Pb4712 and Pb4741 of the West Salt Creek section with samples Pb5554 and Pb6768, respectively, of the GJAC Section. Accepting the time correlation of samples Pb4712 and Pb5554 means that the main transgressive phase of the Buck Tongue began earlier in the Grand Junction area than it did at West Salt Creek. This is to be expected, since it would have taken some time for the strand line to traverse the approximately 40 miles between the two sections as transgression progressed, even though the transgression is assumed to be rapid (see page 255, below), and this is regarded as a valid correlation. However, the correlation of samples Pb4741 and 6768 is not defensible because this correlation means that a point over 100 feet below the top of the Buck Tongue at West Salt Creek was receiving sediments at the same time as a point very near the base of the presumed Sego Sandstone equivalent in the GJAC Section. That this sandstone is equivalent to the Sego is implied by its stratigraphic position below the Corcoran Member and by the shapes of the upper parts of the LD/M curves in both sections (see Figure 7). Since this time correlation appears to be invalid, it must be because the ends of the ranges of species 12 and 143 in sample Pb4741 at West Salt Creek do not represent the true ends of the ranges of these species in that area, even though no specimens were found in sample Pb4750. This does not invalidate the correlation of samples Pb4712 and Pb5554, however.

Further considerations regarding the Buck Tongue--After the correlation of the West Salt Creek section with the GJAC Section was determined, as described above, it was noticed that the LD/M curves for the Buck Tongue interval in both sections indicated that the LD/M ratios in both sections were lowest near the base of the Buck Tongue interval (see LD/M curves in Figures 7a and 7b). This indicates that the most marine conditions in the Buck Tongue occurred early in its deposition, with the remainder of the Buck Tongue deposits becoming less marine upward through time. "Marine-ness" of samples as determined by LD/M ratios is thought to be related to distance from shore. Cross, Thompson and Zaitzeff (1967) found that the number of dinoflagellates increases offshore for some distance in the Gulf of California. Although my LD/M ratios are based on all microplankton, and although they are ratios based on relative percentages of land derived and planktonic palynomorphs, the most likely environmental factor causing a low LD/M ratio in this study is long distance from shore, perhaps more than 50 miles. The discussion of palynomorph ranges on page 246 also indicated that the zone near the base of the Buck Tongue equivalent interval in the GJAC Section might represent far offshore conditions of similar magnitude.

This zone of presumably far offshore (or highly marine for whatever reason) conditions near the base of the Buck Tongue, with marine-ness decreasing upward through the tongue, indicates that the initial transgression of the Buck Tongue sea was relatively rapid, followed by a slower regressive period which continued throughout the remainder of the time of Buck Tongue deposition.

This situation of relatively rapid transgression and slower regression is reflected in the nature of the contacts of the Buck Tongue with its bracketing sandstones. The sharp contact with the underlying Castlegate Sandstone probably indicates a rapid transgression which smoothed out the surface of the Castlegate (Kidson, 1971, p. 32), but did not result in deposition of a transgressive sandstone. The contact with the overlying Sego is complexly interfingered, indicating a slow withdrawal punctuated by many minor re-invasions or stillstands of the sea.

Although the LD/M ratio curves for the GJAC Section and the West Salt Creek section indicated a situation about as expected on the basis of the contacts just described, these curves appeared to be in conflict

with a model of paleoenvironmental zonules derived by factor analysis which was presented by Kidson (1971) as Figure 7 in the appendix of his thesis. This factor analysis diagram is reproduced in this thesis, with Dr. Kidson's permission, as Figure 5.

Because of the discrepancies between Kidson's factor analysis model and the LD/M curves which I prepared for only two sections, I decided to draw these curves for all of Kidson's sections, using the raw data presented in his Chart 1 in order to calculate the LD/M ratios. These are illustrated in Figure 6.

The dashed line on the LD/M curve for the West Salt Creek section in Figure 6 represents the curve based on LD/M ratios calculated for the five samples from that section which I counted. This curve is noticeably lower than the solid line curve, plotted from Kidson's counts of all productive samples from the section. However, the curve based on my counts seems to bear a definite relationship to the other curve. The dashed line is seen to connect, or approximately connect, the low points of the solid line curve, thus defining a "base line" value of basically the same shape, minus the extreme fluctuations, of the solid line curve. This base line shows a low point at the lowest sample I counted (Pb4712), with the curve rising from the point steadily up through the West Salt Creek section. This reflects a rapid transgression in order for a very low LD/M ratio to be attained at the base of the section, followed by a gradual regression, with the top two samples (which I counted) having LD/M ratios over 7.95. This LD/M ratio is within the arbitrary brackish water value established for this study (see page 250 above). In Figure 5, Kidson's data, shown by a solid line, shows a very high LD/M ratio for the three lowest samples

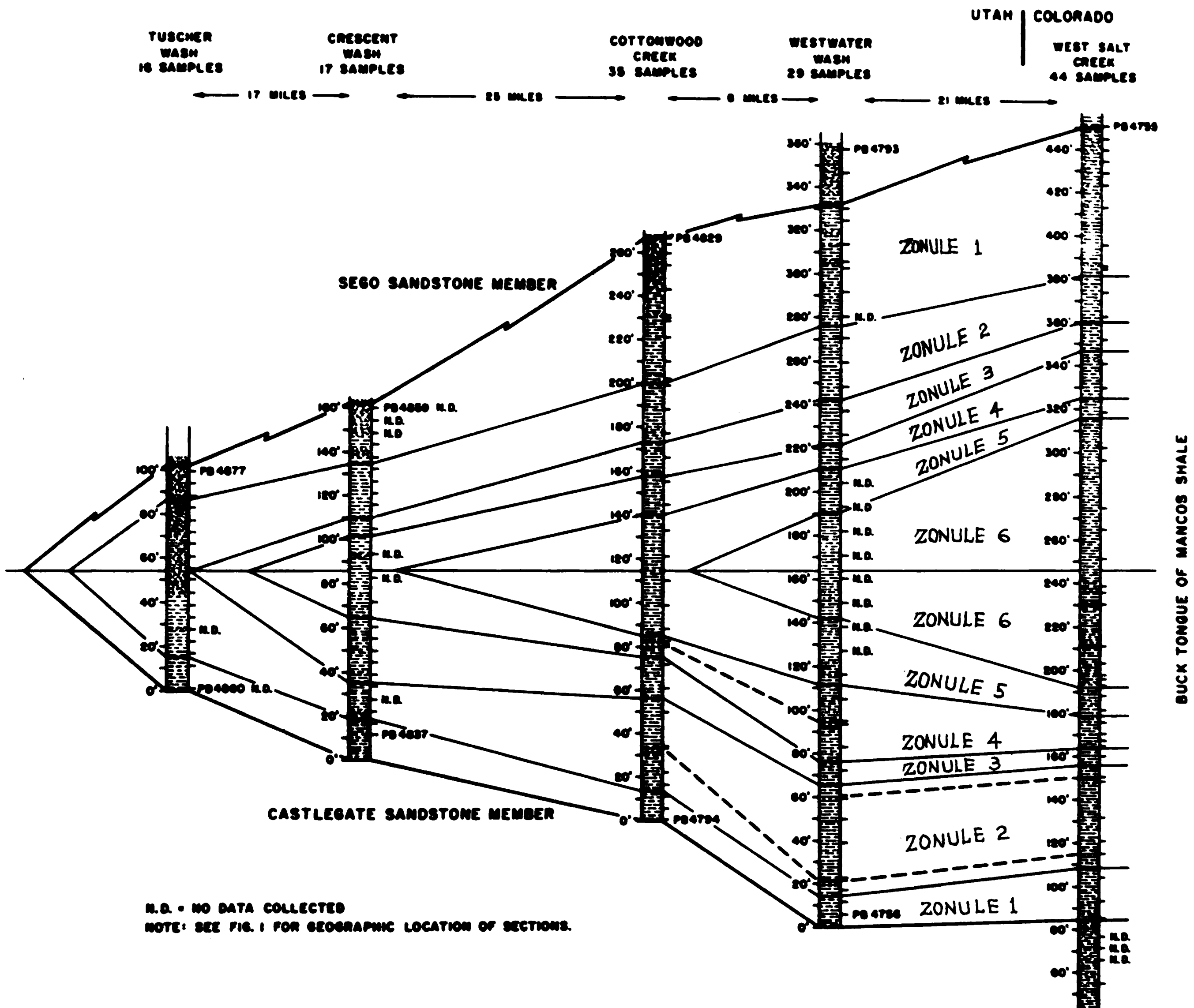

FIG. 5 NATURAL MODEL OF BUCK TONGUE OF MANCOS SHALE WITH ZONULES (INTERPRETED FROM FACTOR ANALYSIS OF DATA) SUPERIMPOSED ON LITHOLOGIC SECTIONS. Reprinted from Kidson, 1971, p. 184, Fig. 7, with zonule numbers added.

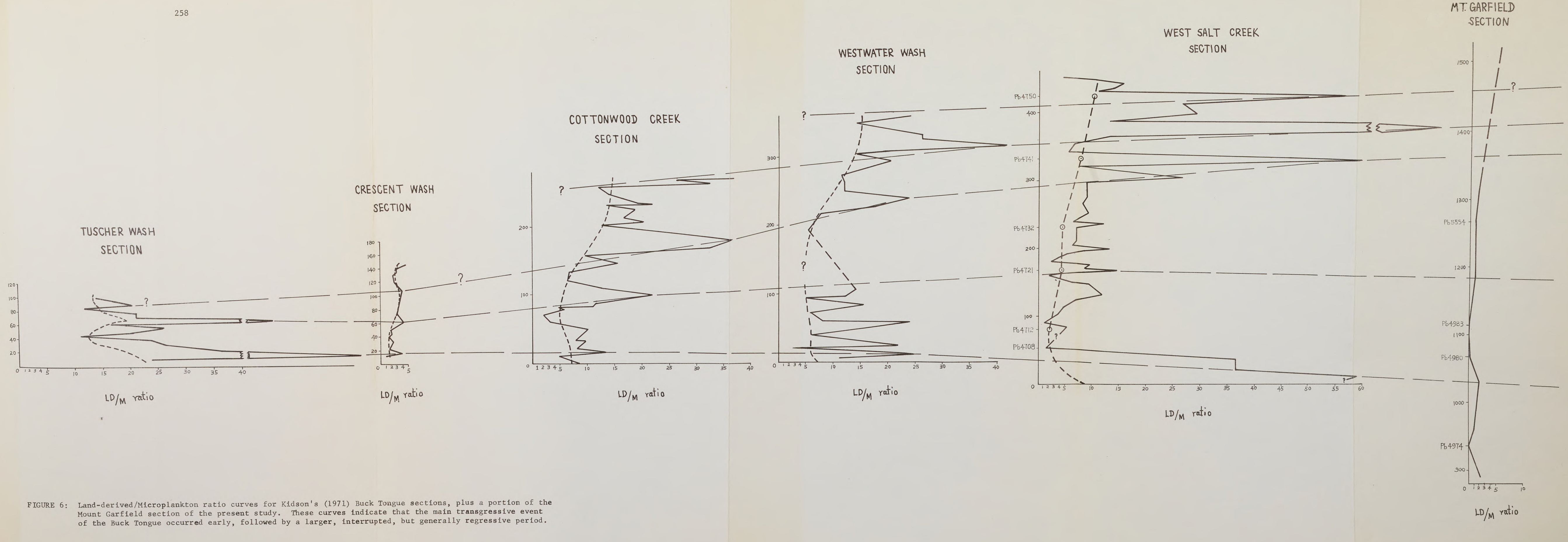

FIGURE 6: Land-derived/Microplankton ratio curves for Kidson's (1971) Buck Tongue sections, plus a portion of the Mount Garfield section of the present study. These curves indicate that the main transgressive event of the Buck Tongue occurred early, followed by a larger, interrupted, but generally regressive period.

in the West Salt Creek section. The "base line" (dashed line in the same figure) was extended to the bottom of the diagram extrapolating from Kidson's data. This shows a significant change from a much higher LD/M ratio below. This zone of high LD/M ratios may reflect nearshore or brackish conditions related to the progradation of the Castlegate Sandstone, although Kidson lists these samples as being from the Mancos Shale below the Castlegate. Just above this is the only productive sample (Pb4708) from the sandy interval presumed to be the actual Castlegate. It is from a shale parting, and has a very low, normal marine LD/M ratio. This may reflect a slight transgression interrupting the main regressive trend of the Castlegate, which appears to terminate in a sandstone sampled about 80 feet above the base of the section (a little below sample Pb4712). This conjecture cannot be verified, although it seems reasonable, because the other samples from the Castlegate interval did not yield sufficient palynomorphs for study.

The dashed "base line" effect noted above as derived from my counts was extrapolated to the other sections of the Buck Tongue in Kidson's study (see Figure 6) although I did not count any more of Kidson's slides. This base line removes the extreme fluctuations of the solid line curves plotted from Kidson's data and puts the values of the LD/M ratios closer to those expected had I counted the same samples. This allows closer comparison to the standard of marine vs. non-marine conditions used elsewhere in my dissertation.

All of these base lines show the most marine conditions to be near the base of the sections, not in the middle as in Kidson's Figure 7 (my Figure 5). Thus, the depositional environments as determined by LD/M ratios closely fit the model of rapid transgression followed by slower regression postulated for the Buck Tongue based on the nature of its upper and lower contacts, but deviate strikingly from the much more symmetrical model derived from factor analysis. Broken lines have been drawn connecting the positive peaks of the solid line curves on Figure 6 in an attempt to make comparison between this diagram and Figure 5 easier. These lines, which connect points with similar paleoenvironmental conditions (as is postulated for the lines making up the horizontal "V" of Figure 5) do not define a wedge, as in Figure 5, but run out into the Sego Sandstone. This is compatible with the intertonguing nature of the contact. Thus, these two methods of paleoenvironmental analysis yield quite different results, with the results from LD/M ratios seeming to be more in line with the true sedimentary situation in the basin of deposition. Possibly the factor analysis zonules may represent a climatic shift or change in some other environmental factor on shore.

The possibility that the environmental shift resulting in the factor analysis-derived wedge of Figure 5 took place on land rather than in the basin of deposition is supported by this list of observations.

1. The wedge does not appear to be related to the conditions of sedimentation indicated by the upper and lower contacts of the Buck Tongue (and supported by the LD/M ratio results).

2. Kidson's samples generally had low percentages of microplankton (see Kidson, 1971, Chart 1), which means that the factor analysis study was based mainly on land-derived palynomorphs.

3. The position of the maximum expression of the environmental factor (the horizontal line in Figure 5) occurs later than the maximum "marine-ness" as expressed by the LD/M curves. This latter condition would be expected if the environmental factor chiefly responsible for the zonules of Figure 5 was a climatic shift, affecting the land flora,

initiated by the Buck Tongue transgression. There would have been a lag between the time of the maximum Buck Tongue transgression and the time any climatic change caused by that transgression (for instance a more marine-influenced climate in the highlands beyond the low coastal plain) could be expressed as a change in the composition of the land flora. This lag could be the reason for the factor analysis maximum (horizontal center line of Figure 5) occurring later than the time of maximum marineness as defined by the LD/M ratios.

As the sea began to regress, the land climate may have been less influenced by marine conditions, allowing the land floras to begin to resume the relationships and floral composition they had prior to the maximum transgression.

4. One more fact which indicates that the factor analysis zonules are not directly related to conditions within the basin of deposition is the fact that a different depositional environment existed in the transgressive (lower) half of zonule 1 of Figure 5 than in the regressive (upper) half. The lower half is characterized by marine shale, the upper by sandstones and shales interbedded, with a few limestones. The LD/M ratios indicate a normal marine environment in the lower portion, and probably marginal marine environments in the upper portion. This would be a reasonable situation if the zonule is related to a land environment and not a basinal one. The upper part of zonule 1 could represent a readjustment of the land flora to conditions as they existed during the initial phase of the Buck Tongue transgression.

Since both these methods (LD/M ratios and factor analysis) cannot represent paleoenvironmental conditions in the basin of sedimentation because they yield such different results, and since LD/M ratios seem to fit basinal conditions better than zonules derived from factor analysis, it seems that the factor analysis model should be tested in an area where well-established environmental zones exist, recognized on other grounds, before it can be regarded as definitely useful in delimiting basinal environments. The LD/M ratio method could be subjected to this test as well for comparison.

It is my opinion that the LD/M ratio will accomplish the same purpose which the above factor analysis study was intended to do, (i.e., interpret the environments of deposition in the Buck Tongue palynologically) and that LD/M ratios will do the job reliably and probably more economically and quickly than the computerized factor analysis.

The LD/M ratios also seem to be more easily explainable in terms of basinal events as reflected by the upper and lower contacts of the Buck Tongue, etc. Thus, I do not see the advantages to be derived from using factor analysis in preference to LD/M ratios here. I believe that there exists such a climate of enthusiasm surrounding computerized techniques that simpler methods may often be ignored. I have observed a subtle pressure in the geological sciences (and in other areas as well) to use these more glamorous and "more scientific" computerized techniques, with anything else being regarded as obsolete. Such obsolescence is not necessarily the case. The method or methods of resolving a particular problem which results in doing so most reliably, quickly and economically is obviously the method to be used. Scientists should resist pressure to use computerized problem-solving techniques where simpler methods will suffice, whose results may be more easily interpretable and more quickly and economically obtained. Computers have certain justified applications for which no simpler method exists, but it is my opinion that use of computers sometimes becomes the end rather than the means, and I believe this tendency should be avoided.

Correlation of Rifle Gap Section With GJAC Section--Correlation of these sections was accomplished as in the case of the preceding correlation, using time and environmental data determined on the basis of palynomorphs. In addition, the positions of the samples taken at Rifle Gap were already known in relation to lithologic units recognizable in both sections, and were thus already correlated on that basis. It was found that the palynologic data supported the lithologic correlations.

The approximate Upper Cretaceous (Campanian) strand line trend (see Figure 1), as derived from the work of Zapp and Cobban (1960) and Hale and Van de Graaf (1964), extends in a northeast-southwest direction at such an angle that it passes directly or almost directly through the positions of the Rifle Gap section and the GJAC section. Thus, every sedimentary unit which formed at Rifle Gap during the time the strand lines had such a trend should have a counterpart in the GJAC section which formed at essentially the same time. Exactly the same type of sediment need not be forming at each section at each instant, because there is a lateral shifting of environments along the shoreline. However, persistent major sedimentary zones recognizable in both sections should be roughly comparable as to their times of origin, even though each individual lens or bed making up the zone may not correspond exactly in time in each section. For example, the Corcoran Member of the Iles (Price River) Formation can be recognized in both sections under discussion. This member is composed of littoral sandstones, shales and siltstones mainly of lagoonal origin, and coals. These subunits replace each other laterally in a complex fashion, and thus are not continuous in time. However, the entire complex of environments formed because of the presence of a shoreline at or near their point of deposition. Since the general trend of shorelines in the area is such that the same shoreline was present in both the Grand Junction area and the Rifle Gap area at about the same time, shoreline-related sediments of the same major lithologic unit (Corcoran Member in this case) must have formed along essentially the same shoreline, and thus at about the same time, in both locations. Palynologic data of this study show a lagoonal shale (sample Pb6775) near the middle of the Corcoran Member in the GJAC section to be the approximate time equivalent of a coal (sample Pb8898) near the middle of the Corcoran Member in the GJAC section to be the approximate time equivalent of a coal (sample Pb8898) near the middle of the Corcoran Member at Rifle Gap (see Figure 8), thus supporting the reasoning of the above discussion. This correlation is based on the fact that species number 200 (Retitricolpites sp.-17) begins at this level in both sections (see Figure 7). This is an easily recognized species which is not restricted to any specific sedimentary environment, thus allowing it to be used as a reliable marker species.

Palynological time correlation of the uppermost coal zone in the two sections (the Cameo Coal in the GJAC section, the Trout Creek Coal in the Rifle Gap section) is not possible because of a flaw in the sampling procedure. A sample should have been obtained from the shale above the coal at both locations, to eliminate the effect on palynomorph ranges imposed by the restricted coal swamp environment, but such a sample was collected only in the Rifle Gap section. These coals both contain specimens of species 200 and 206, and did not contain the other species judged to have time significance in this study (see Figure 7). However, it is not possible to say whether the apparent end of the range of species 187 below the Cameo Coal in the GJAC section is the true end of this range, because this species is not found in coals and the top sample in that section is a coal. Thus, a time correlation of the

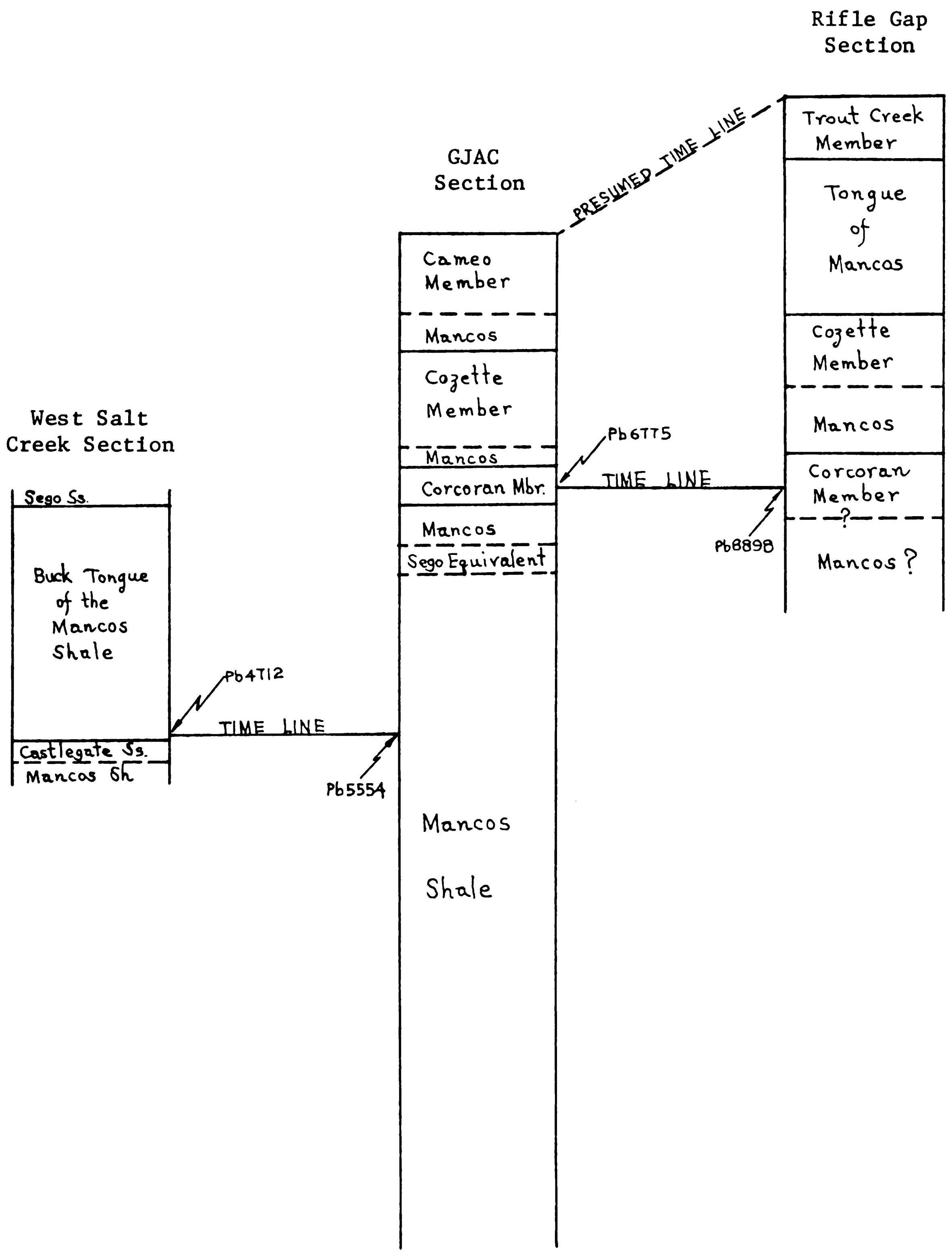

Figure 8: Correlation diagram of Grand Junction Area Composite Section, West Salt Creek section, and Rifle Gap Section.

two coals in question is not ruled out, but neither is it certainly established.

Applying the same reasoning to the Cameo-Trout Creek Member as was applied to the Corcoran Member, the coals of the Cameo-Trout Creek Member should be of the same (or very similar) age since they are shoreline-related sediments lying along the same--or almost the same--shoreline. As noted above, this correlation cannot be supported definitely by palynology due to poor sampling procedure. The Trout Creek Member is separated by a greater thickness of sediment from the Corcoran Member (and its herein established time line, see above) in the Rifle Gap section than the equivalent Cameo Member is separated from the Corcoran Member in the GJAC section. This means there was a greater sedimentation rate at Rifle Gap, which also seems to be indicated by the sandy nature of the sediments of that section. If the two members being discussed are the same age in both sections, there must have been local subsidence in the Rifle Gap area in order to accommodate a thicker sedimentary sequence and still not prograde the strand line far to the east of its postulated location. Various situations could be postulated which would result in this situation, but first, additional palynological sampling or other research leading to the drawing of fairly precise time lines needs to be done in order to determine if the Cameo and Trout Creek Coals are actually comparable in age, as expected by their position in relation to the same (or nearly the same) strand line.

Supporting the correlation of the Corcoran Member by time-related data is a similar high peak in the total spores curve at coal samples in the Corcoran Member in both sections and a peak in the LD/M curve at both coals. The Cozette Member coal, the next coal above the Corcoran Member at Rifle Gap, has lower values for both these curves, thus confirming palynologically the fact that it is a different coal, as can be seen by its stratigraphic position as part of the Cozette Member.

Position of the Wilson Ranch Section in the GJAC Section--Only two samples were studied from the Wilson Ranch section, sample Pb8953, a marine shale, and sample Pb8957-60, a coal. Since no other samples here contained sufficient well-preserved palynomorphs for study, and the two samples counted contained none of the eight species used to correlate the other sections (see Figure 7), it is not possible to correlate these two sections except to set broad limits in the Grand Junction Area Composite section within which these two samples at Wilson Ranch must have equivalent units. The species list of forms present at the Wilson Ranch section is given in Table 2. Comparing this list with the range chart for the GJAC section, it was found that based on the ranges of species 109, 139, 142 and 189, the Wilson Ranch section must fall between the levels of samples Pb4975 and Pb6778 in the GJAC section. This zone is about 750 feet thick, so this correlation is not as precise as desirable but it does show that the coal at Wilson Ranch could be no higher than the Palisade Coal. The coal in question is at the very base of the Castor Member of the Iles Formation, according to Masters (1965). I was not able to find any correlation of the Castor Member with any of the units of the Price River, Iles or Mancos Formations of the Book Cliffs and Grand Hogback, so no refinement of the palynologic correlation can be made on the basis of lithologic correlation. The Wilson Ranch section is also of some value to this study because it contains a coal, which provides one more sample on which to define the coal flora of this study (see below).

TABLE 2: Palynomorphs found in the two samples studied from the Wilson Ranch section. Numbers are from Table 1.

		Sample Pb8953	Sample Pb8957-60
5.	Dictyophyllidites? sp.	x	
13.	Tricolpites sp.-1	x	
17.	Tricolpites sp.-9	x	
18.	Triporopollenites sp.-5		x
21.	Retitricolpites sp.-2	x	x
22.	Laevigatosporites sp.-2	x	
23.	Cymatiosphaera spp.	x	
24.	Leiosphaeridia sp.-6	x	
25.	Ilexpollenites sp.	x	
27.	Hystrichosphaera ramosa	x	
31.	Arecipites reticulatus	x	
32.	Classopollis classoides		x
33.	Tricolporopollenites sp.-4	x	
34.	Araucariacites spp.	x	x
35.	Micrhystridium sp.-2	x	
36.	Proteacidites thalmanni var. 3	x	x
37.	Unknown Dinoflagellate-1	x	
39.	Leiosphaeridia sp.-7	x	
41.	Micrhystridium deflandrei	x	
42.	Unknown Dinoflagellate-4	x	
43.	Horologinella apiculata	x	
45.	Retitricolpites spp.	x	
46.	Cupanieidites major	x	x
47.	Micrhystridium sp.-1	x	
48.	Proteacidites thalmanni var. A	x	
49.	Leiosphaeridia sp.-5	x	x
50.	Leiosphaeridia sp.-2	x	x
51.	Eucommiidites? sp.-3	x	
54.	Tricolporopollenites? sp.-3	x	
57.	Tricolpites interangulus	x	
58.	Unknown Trilete Spore-3		x
59.	Polypodiisporites favus	x	x
60.	Triporopollenites sp.-3		x
61.	Tricolpites cf. T. psilascabratus		x
62.	Tricolpites sp.-5	x	
64.	Cyathidites minor	x	
65.	Triplanosporites sp.	x	
66.	Schizosporis cooksoni	x	x
67.	Tricolporopollenites minor	x	
68.	Liliacidites complexus	x	x
69.	Confertisulcites sp.-2	x	x
70.	Eucommiidites? sp.-4	x	x
71.	Schizosporis scabratus	x	x
72.	Laevigatosporites sp.-1		x
73.	Laevigatosporites haardti	x	
74.	Momipites sanjuanensis	x	x
75.	Gleicheniidites senonicus	x	x

Table 2 (cont'd.)

		Sample Pb8953	Sample Pb8957-60
76.	Tricolpites sp.-3	x	
77.	Tricolpites anguloluminosus	x	x
78.	Cycadopites sp.	x	x
79.	Tricolpites mutabilis	x	x
80.	Fraxinoipollenites cf. F. variabilis	x	x
81.	Clavatipollenites cf. C. minutus	x	x
82.	Retitricolpites minutus	x	x
83.	Tricolpites cf. Tricolporites traversei	x	x
84.	Leiosphaeridia sp.-1		x
85.	Leiosphaeridia sp.-4	x	x
86.	Inaperturopollenites spp.	x	x
90.	Schizosporis cf. S. spriggi		x
93.	Striatopollis sp.-1		x
97.	Retitricolpites sp.-3		x
99.	Unknown Palynomorph-1	x	x
100.	Tricolpopollenites cf. T. variofoveatus		x
101.	Normapolles sp.-2	x	x
102.	Monosulcites spp.	x	x
107.	Schizosporis sp.-2	x	x
109.	Micrhystridium-5	x	
113.	Deflandrea sp.-2	x	
114.	Triporopollenites sp.-1		x
120.	Aquilapollenites spp.	x	
124.	Arecipites tenuexinus		x
128.	Equisetosporites multicostatus	x	
131.	Aquilapollenites quadrilobus	x	x
132.	Vitis? cf. V? affluens		x
133.	Tricolpites sp.-7	x	x
139.	Unknown Trilete Spore-4	x	
142.	Ericaceoipollenites rallus	x	
144.	Schizosporis sp.-6		x
145.	Stereisporites antiquasporites	x	x
160.	Tricolporopollenites sp.-2		x
162.	Triporopollenites sp.-2		x
164.	Unknown Trilete Spore-1		x
165.	Liliacidites spp.		x
166.	Myocolpopollenites cf. M. reticulatus		x
171.	Palambages? sp.-3		x
172.	Retitriletes cenomanianus	x	
173.	Alnipollenites trina	x	x
177.	Aquilapollenites calvus	x	
178.	Tricolpites sp.-6		x
179.	Triatriopollenites granulatus	x	x
180.	Myrtaceoipollenites peritus		x
181.	Conclavipollis? cf. C. wolfcreekensis		x
185.	Perinopollenites? sp.		x
186.	Ulmoidipites sp.		x
189.	Retitricolpites sp.-1		x

Table 2 (cont'd.)

	Sample Pb8953	Sample Pb8957-60
198. Liliacidites sp.-1	x	
199. Monosulcites sp.-1		x
203. Schizosporis sp.-8		x
204. Todisporites sp.	x	x
205. Triporopollenites sp.-4		x
209. Tricolporopollenites? cf. T. globularius		x
210. Triporopollenites sp.-7		x
214. Monosulcites sp.-2	x	

Discussion of the coals in this study

Included in the suite of 60 samples studied were six coal samples. Palynomorphs which occur in coals are indicated in Table 1, the master list of all palynomorphs recognized in the study, by an asterisk following their name or designation. Those species which were found only in coals were marked with a double asterisk (only four such species were found). The forms in Table 1 which are marked with asterisks thus make up the species list of the coal flora of all the coals studied, and no other listing of these species is presented. The total flora includes 119 different types of palynomorphs.

Figure 9 is a plot of the relative abundance percentages of the species in each coal. From this plot it can be seen that no two coals exhibit any strong degree of similarity; not even those coals occurring in sedimentary units correlated by other methods earlier can be correlated by this method of comparing relative abundance plots. This does not mean that each coal is unrelated to the others. Possibly the non-correlation by relative abundance percentages reflects a lateral shifting of local sub-environments in the coal swamps. Also, it was noted earlier, in the discussion of correlation of the Rifle Gap and GJAC sections, that these coals are not continuous, and that each coal bed may not have an exact equivalent in both sections. These factors of shifting lateral sub-environments and non-equivalence of individual coal beds or lenses could possibly have resulted in the non-correlability of the coals by relative abundances. The larger members of the Iles (Price River sediments, of which these coals are components, represent relatively major, widespread events. These members can be correlated palynologically, as demonstrated in the Correlations section above.

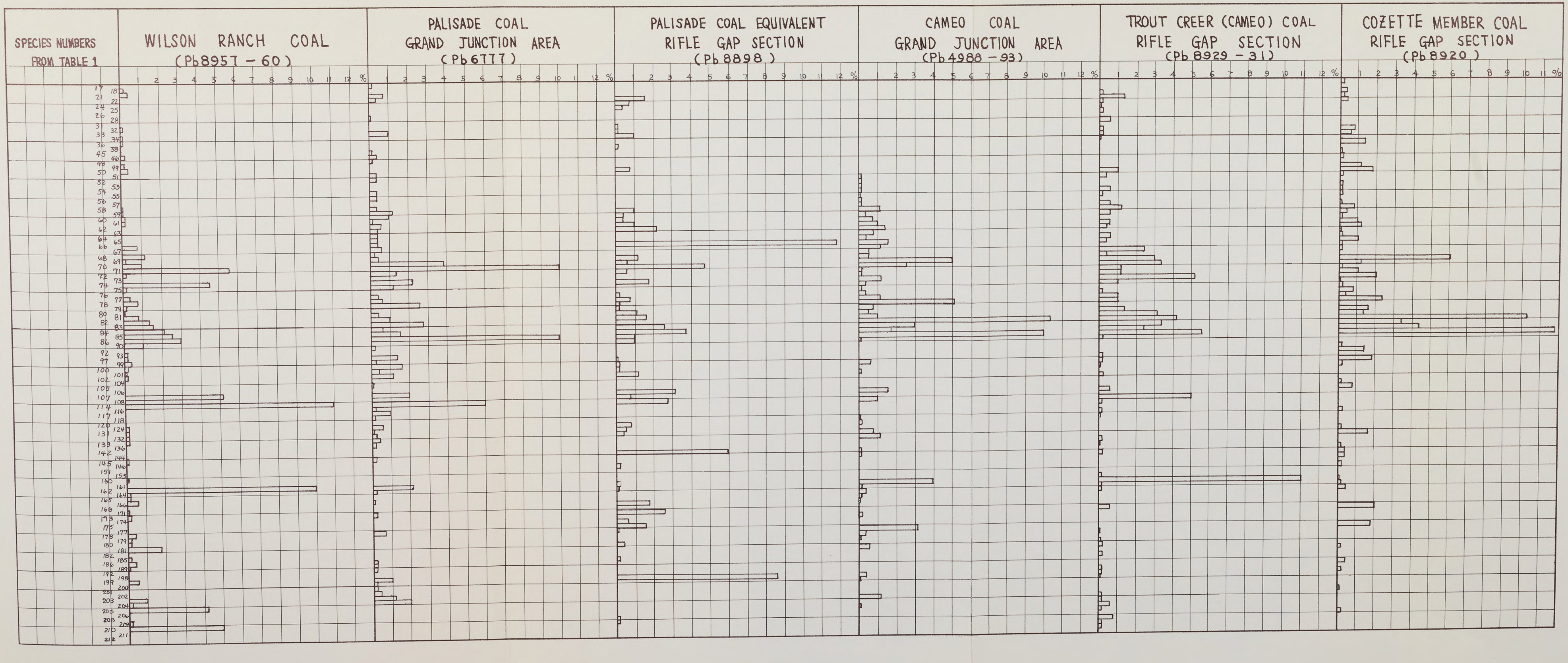

Figure 9: Relative abundance percentage histogram for palynomorphs occurring in coal samples.

RESULTS AND CONCLUSIONS

A major result of this study is the recognition of 214 different types of acid insoluble microfossils of specific or approximately specific taxonomic rank. This suite of palynomorphs included land-derived spores and pollen as well as marine dinoflagellates and acritarchs. Several of the Leiosphere-type acritarchs were found to be present in rocks from both marine and non-marine depositional environments, and are regarded as being euryhaline aquatic organisms.

No new species were formally named, because it is my opinion that more comprehensive literature research than was feasible for the purposes of this study needs to be performed and type specimens or material from the type localities of all similar species needs to be examined before new names are devised. Monographic studies need to be done starting immediately in order to remedy the existing chaotic situation in palynological taxonomy. Authors should refrain from naming new species except possibly for very grossly different new forms, which should only be named after the most thorough study. Studies with principally non-taxonomic objectives should use some type of code designation for presumably new but incompletely compared species as an alternative to describing new formal species.

Another major finding of this study is that a portion of the Mancos Shale in the Grand Junction Area Composite section can be seen on the basis of palynological evidence to be the equivalent of the Buck Tongue of the Mancos Shale. The latter unit is developed to the west of the thesis area and was studied in detail by Kidson (1971). A further comparison of the data of this study with Kidson's data from the West Salt Creek section, and additional analysis of Kidson's data from his other sections indicate that a factor analysis study included as an appendix of Kidson's study reached conclusions regarding paleoenvironmental relationships within the Buck Tongue which are different from those indicated by the environmental indicator used in this study, which is the ratio of land-derived palynomorphs to microplankton. The environmental model derived using this ratio is closer to the situation expected on the basis of the nature of the contacts of the Buck Tongue with its underlying and overlying units.

The Rifle Gap section was correlated with the Grand Junction Area Composite section on the basis of palynology as well as on the basis of lithologic units recognizable in both sections. The time equivalence of at least one of these units in both sections, which lie along approximately the same strand line as postulated by other authors, seems to lend additional credence to these strand line positions.

Several types of data were found to have paleoenvironmental significance in this study. These were the ratio of land-derived palynomorphs to microplankton, the relative abundance percentages of various palynomorphs, zones of interrupted species ranges, and the rate of introduction of species into the flora through time. The land derived/microplankton ratio was the most reliable indicator of marine, non-marine and marginal marine conditions.

Six coal samples were studied, and a designation was made of those species found in coals and those restricted to coals. These coal beds are discontinuous local units and it was not possible to correlate them on the basis of the relative abundance of palynomorphs occurring in each coal. The larger, more persistent members with which the coals are associated were correlated, in some cases, by other types of palynologic data.

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APPENDIX

APPENDIX

Lithologic Descriptions of Intervals Sampled in the Stratigraphic Sections

The first four sections listed here (Mount Garfield through Cameo sections) taken together compose the Grand Junction Area Composite Section, referred to in the text in various places. This section is a composite extending from the Mancos Shale about 1,700 feet below the top of the Corcoran Sandstone up through the Cameo coal zone of the Cameo Member of the Price River Formation (see Young, 1955). The first column of footages for these sections lists the footage above the base of the Mount Garfield section, thus above the base of the Composite Section. The total composite section includes 2,112 stratigraphic feet.

Footages for all sections are measured from the base of one sample to the base of the next higher sample. Footages are given in relation to the base of each section, as well as from a recognizable lithologic datum in each section.

The maceration numbers followed by asterisks represent the samples which were counted quantitatively (500 fixed-sum counts) and which yielded the data for the conclusions arrived at in the thesis. All references to sample numbers in the thesis use these Pb numbers rather than the longer collection numbers. The samples, residues, and slides are all filed at Michigan State University Paleobotany/Palynology Laboratory under these same numbers.

MOUNT GARFIELD SECTION: Lithologic descriptions of units sampled. (Unsampled intervals are not described here.)

Samples taken from section exposed in SW 1/4, Sec. 1, T11S, R99W, and S 1/2, Sec. 2, T11S, R99W, Mesa County, Colorado (West Face of Mount Garfield), and SE 1/4, Sec. 1, T11S, R99W, Mesa County, Colorado (South Face of Mount Garfield, above pediment remnant).

Samples are not given in normal stratigraphic succession. They are given sequentially from base upward.

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Base of section begins in Mancos Shale about 1700' below the top of the Corcoran sandstone.				
Iron carbonate, two units; top 6" unit gray, hard, massive, calcareous, weathers orange; bottom 12" unit gray, hard, brittle, thin-bedded, calcareous; the two zones form a prominent zone of orange-capped hills near the base of Mount Garfield.	0'	1698' 6"	7/15/67I-13	Pb4927*
Siltstone, gray, hard, thin-bedded, very calcareous; 18" thick.	1' 6"	1697'	7/15/67I-14	Pb4928
Limestone, silty, gray, hard, massive to blocky or thin-bedded; forms slight shoulder; 3' sample.	7'	1691' 6"	7/15/67I-15	Pb4929
Siltstone, dark gray to black, few light layers, blocky to platy, calcareous, concretionary, plant fragments; 3' sample.	12' 6"	1686'	7/15/67I-16	Pb4930*
Siltstone, limy, gray with white lenses, interbedded with limy gray shale with few concretionary bodies; 3' sample.	18'	1680' 6"	7/15/67I-17	Pb4931

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Siltstone, limy, gray with white lenses, platy, concretionary; 3' sample.	29'	1669' 6"	7/15/67I-18	Pb4932
Siltstone, same as Pb4932; 3' sample.	40'	1658' 6"	7/15/67I-19	Pb4933
Siltstone, same as Pb4932, but gypsiferous; 3' sample.	51'	1647' 6"	7/15/67I-20	Pb4934*
Siltstone, same as sample Pb4932; 3' sample.	62'	1636' 6"	7/15/67I-21	Pb4935*
Siltstone, same as Pb4932, with 3" hard limy gray siltstone layer in middle of unit sampled which forms slight ledge; weathers orange; 3' sample.	78' 6"	1620'	7/16/67I-1	Pb4936*
Siltstone, same as Pb4932, with 3" orange-weathering ledge 6" below middle (at 1604' level); 3' sample; this is part of a zone of several orange-weathering thin siltstone and limestone ledges, up to the next sample (Pb4938).	94'	1604' 6"	7/16/67I-2	Pb4937
Siltstone, limy, gray with white lenses, hard, blocky to massive, composite sample 1' below and 4" above thin bentonite of next sample (Pb4939).	105'	1593' 6"	7/16/67I-3	Pb4938
Bentonite, with orange limonitic stain, marks orange-weathering zone along shoulder formed by hard siltstone of sample Pb4938; 2" bentonite is at level 1592'6".	106'	1592' 6"	7/16/67I-4	Pb4939

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Siltstone, limy, gray with white lenses, slightly fissile to blocky, small amount of limonite stain; 3' sample.	122' 6"	1576'	7/16/67I-5	Pb4940*
Siltstone, gray to black, with white lenses, slightly calcareous; 3' sample.	139'	1559' 6"	7/16/67I-6	Pb4941
Iron carbonate, gray with white lenses, hard, slightly calcareous, limonitic, forms prominent orange-weathering marker bed; slight petroliferous odor; 18" thick.	144' 6"	1554'	7/16/67I-7	Pb4942
Shale, black, blocky, concretionary, slightly calcareous, some gypsum, some plant material; typical Mancos Shale; 3' sample.	161'	1537' 6"	7/16/67I-8	Pb4943*
Shale, same as Pb4943, but not calcareous; 3' sample.	183'	1515' 6"	7/16/67I-9	Pb4944
Shale, black, blocky, concretionary, and shale, limonitic; orange-weathering marker bed; 3' composite sample.	194'	1504' 6"	7/16/67I-11	Pb4946
Shale, black to brown, platy to blocky, concretionary; with 1'6" orange-weathering, limonitic bentonitic zone at level 1494'6", and a 6" chippy, orange, iron carbonate ledge at level 1494'	205'	1493' 6"	7/16/67I-10	Pb4945X*
Shale, black, blocky to platy, concretionary; typical Mancos; 3' sample.	227'	1471' 6"	7/16/67I-12	Pb4947

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, as in Pb4945, with some gypsum; 3' sample.	249'	1449' 6"	7/16/67I-13	Pb4948*
Iron carbonate, gray, hard, conchoidal fracture; large clear calcite crystals up to 2" diameter; Inoceramus remains, and ostracods were found; layer forms shoulder of varying prominence; layer is 6" to 18" thick.	264'	1434' 6"	7/16/67I-14C	Pb4949
Shale, black, platy, slightly weathered, much gypsum; 18" sample above top of sample Pb4949.	265' 6"	1433'	7/16/67I-15	Pb4950*
Shale, black, platy to blocky, concretionary, much gypsum, with 2" brown limonitic shale marker-bed at level 1418'; 3' sample.	280' 6"	1418'	7/18/67I-1	Pb4951
Shale and siltstone, black, hard, blocky, concretionary, much gypsum; much plant material, a few small angiosperm leaf fossils; brown limonitic band at level 1403'6"; 3' sample above and below this band.	295'	1403' 6"	7/18/67I-2	Pb4952
Shale, black, blocky to platy, concretionary, locally shows red-brown weathered surface; 3' sample.	306'	1392' 6"	7/18/67I-3	Pb4953
Shale, black with few white lenses, platy, brittle, slightly calcareous, much gypsum; 3' sample.	326'	1372' 6"	7/18/67I-4	Pb4954*
Shale, black, platy, concretionary, with one small brown limonitic zone; 3' sample.	348'	1350' 6"	7/18/67I-5	Pb4955
Shale, gray, blocky, concretionary, with tan, hard, limy concretion layer at level 1328'6"; 3' sample.	370'	1328' 6"	7/19/67I-1	Pb4956*

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, dark gray, platy to blocky; typical Mancos; 3' sample.	392'	1306' 6"	7/19/67I-2	Pb4957
Shale, as in Pb4957; 3' sample.	414'	1284' 6"	7/19/67I-3	Pb4958*
Zone in which two discontinuous lithologies alternate in the same bed. 1. Iron carbonate, limy, gray, hard, massive, with conchoidal fracture; a few *Baculites perplexus* (early form); bed 15" thick, locally forms small shoulder; sample Pb4959; this alternates with: 2. Bentonite, white, soft, 2-3" thick, overlain by 1' brown shale which is overlain by 18" black typical Mancos Shale, which is overlain by a 3/4" white bentonite; sample Pb6739. The lower bentonite at some places passes directly under the iron carbonate lenses and at others disappears in the vicinity of the iron carbonate lenses.	420'	1278' 6"	7/19/67I-4 11/18/66I-1	Pb4959 Pb6739
Bentonite, yellow; 1-1/2" thick.	426' 6"	1272'	7/19/67I-5	Pb4960*
Bentonite, yellow to white; 3" thick.	431' 6"	1267'	7/19/67I-6	Pb4961
Shale, black to dark green-gray, conspicuous dark zone; 4' sample.	435'	1263' 6"	11/18/66I-2	Pb6740
Limestone, silty, gray to brown, thin-bedded, with few poorly preserved fossils; layer is 1' thick; forms slight shoulder; beneath this is 10" of black typical Mancos Shale, underlain by a 1" bentonitic layer. Composite sample of entire zone.	439' 6"	1259'	7/19/67I-7	Pb4962*

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Bentonite, white, pure, 4" thick.	446'	1252' 6"	7/19/67I-8	Pb4963
Bentonite, white, 1" thick.	451' 6"	1247'	7/19/67I-9	Pb4964
Shale, gray, platy to blocky, concretionary; typical Mancos; lighter zone above dark zone below; 4' sample.	458'	1240' 6"	11/18/66I-3	Pb6741*
Shale, as in Pb6741, not concretionary; 4' sample.	480'	1218' 6"	11/18/66I-4	Pb6742
Shale, as in Pb6741; 5' sample.	498'	1200' 6"	11/18/66I-5	Pb6743*
Shale, as above, with 6-8" shaly limestone layer, chocolate-brown weathering, at 1185'6" level; 5' sample; just below sample is zone of an occasional large concretion; unsampled.	517'	1181' 6"	11/18/66I-6	Pb6744
Shale, dark gray, platy to blocky; typical Mancos; 4' sample.	536'	1162' 6"	11/18/66I-7	Pb6745*
Shale, as in Pb6745; 5' sample.	558'	1140' 6"	11/18/66I-8	Pb6746*
Shale, as in Pb6745; 5' sample.	578'	1120' 6"	11/18/66I-9	Pb6747*
Shale, as in Pb6745; 5' sample; just above this is a zone of silty limestone beds and large concretions in the shale.	598'	1100' 6"	11/18/66I-10	Pb6748
Limestone, silty; contains fossil razor clams; 1' bed. Sample is of fossil clams; not for maceration.	613'	1085' 6"	11/18/66I-11a	

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, dark gray, platy to blocky, calcareous, concretionary, with 1' silty limestone bed at level 1081'6"; 4' sample; this general lithology continues up to about 4' below the next sample (Pb6750).	616'	1082' 6"	11/18/66I-11	Pb6749*
Shale, dark gray, platy to blocky, slightly calcareous, few concretions; typical Mancos; 5' sample.	638'	1060' 6"	11/18/66I-12	Pb6750
Shale, as in Pb6750; 5' sample.	658'	1040' 6"	11/18/66I-13	Pb6751*
Shale, as in Pb6750; 5' sample.	678'	1020' 6"	11/18/66I-14	Pb6752*
Shale, as in Pb6750; 5' sample.	698'	1000' 6"	11/18/66I-15	Pb6753
Shale, as in Pb6750; 5' sample.	718'	980' 6"	11/18/66I-16	Pb6754
Shale, as in Pb6750; 5' sample.	738'	960' 6"	11/18/66I-17	Pb6755*
Shale, black to brown, platy to blocky; with 4" zone of slightly calcareous ironstone concretions in middle, at 958' level; 3' sample.	740' 6"	958'	7/19/67I-10	Pb4965
Shale, black to brown, blocky, with conchoidal fracture, some gypsum; 3' sample.	760' 6"	938'	7/19/67I-11	Pb4966
Shale, black, blocky to platy, some gypsum; typical Mancos Shale; 3' sample.	782' 6"	916'	7/19/67I-12	Pb4967
Shale, black, blocky, with conchoidal fracture, plus zone of ironstone concretions at 897' level; 3' sample.	801' 6"	897'	7/19/67I-13	Pb4968

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, black, hard, blocky to platy, concretionary, slightly calcareous; typical Mancos; 3' sample.	826' 6"	872'	7/19/67I-14	Pb4969*
Siltstone, black to gray-brown, with a few lighter lenses, platy to blocky, slight orange limonitic stain, slightly calcareous; 3' sample.	848' 6"	850'	7/19/67I-15	Pb4970
Siltstone and fine sandstone, hard, tan to orange, concertionary, limonitic, very calcareous; forms slight shoulder; 3' sample.	870' 6"	828'	7/19/67I-16	Pb4971
Shale, black, platy to blocky, some gypsum; typical Mancos; 3' sample.	892' 6"	806'	7/20/67I-1	Pb4972*
Shale, as in Pb4972; 3' sample.	914' 6"	784'	7/20/67I-2	Pb4973
Shale, as in Pb4972; 3' sample.	936' 6"	762'	7/20/67I-3	Pb4974*
Shale, as in Pb4972; 3' sample.	958' 6"	740'	7/20/67I-4	Pb4975*
Shale, as in Pb4972; 3' sample.	980' 6"	718'	7/20/67I-5	Pb4976
Shale, as in Pb4972; 3' sample.	1002' 6"	696'	7/20/67I-6	Pb4977
Siltstone and shale, gray, blocky, conchoidal fracture, slightly calcareous, with 6" hard, gray limestone bed, bearing occasional ironstone concretions and a few poorly preserved fossils at 671' level; 2'6" composite sample.	1027' 6"	671'	7/20/67I-7	Pb4978*

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, black, blocky, concretionary, with some plant material, some gypsum; 3' sample.	1046' 6"	652'	7/20/67I-8	Pb4979
Shale, black, blocky, concretionary, much gypsum; a 10" hard gray limestone layer which forms a small ledge and contains Baculites perplexus, early form, occurs at 630' level; 3' composite sample for maceration, plus B. perplexus specimen collected as 7/20/67 I-9a.	1068' 6"	630'	7/20/67I-9	Pb4980*
Shale, gray, blocky, with plant material; a zone of brown iron-stained silty limestone concretions, which contain abundant fossil clams and forms a brown line in the shale at the 613'6" level; 3' composite sample of the concretion zone plus the shale above and below, for maceration; also sampled fossil clams as 7/20/67 I-10a.	1085'	613' 6"	7/20/67I-10	Pb4981
Shale, black to brown, blocky to platy, some gypsum; typical Mancos; 3' sample.	1096'	602' 6"	7/20/67I-11	Pb4982
Shale, gray-brown, platy to blocky, slightly weathered; 3' sample.	1118'	580' 6"	7/20/67I-12	Pb4983*
Shale, gray, hard, blocky to platy; slightly calcareous concretionary zone occurs in the middle of the sample at 596'6" level; 3' composite sample.	1129'	596' 6"	7/20/67I-13	Pb4984
Iron carbonate, gray with slight limonitic brown stain, hard, thin-bedded to blocky with conchoidal fracture; forms slight ledge; no fossils; 1' sample.	1140'	558' 6"	7/20/67I-14	Pb4985

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Siltstone, gray to brown, hard, blocky with conchoidal fracture, slightly calcareous, some plant material; forms steep slopes; 2' sample.	1162'	536' 6"	7/22/67I-1	Pb5549
Shale, gray to brown, blocky; some plant material, few poorly preserved clam fossils; 3' sample.	1184'	514' 6"	7/22/67I-2	Pb5550*
Shale, gray, blocky to platy, with some fossil plant fragments; 3' sample.	1206'	492' 6"	7/22/67I-3	Pb5551
Siltstone, limy, gray to brown, hard, blocky, concretionary, some gypsum; few fossil fish scales and plant fragments; weathers yellow, forms steep slopes; 2' sample.	1228'	470' 6"	7/22/67I-4	Pb5552
Shale, black to gray-brown, blocky, much gypsum; some fossil plant material and fish scales; 3' sample.	1250'	448' 6"	7/22/67I-5	Pb5553
Siltstone, gray, very fine, hard, blocky, conchoidal fracture, concretionary, much gypsum; fossil plant fragments; forms steep slope; 2' sample.	1272'	426' 6"	7/22/67I-6	Pb5554*
Siltstone, limy, gray, very fine, hard; conchoidal fracture; sparse limestone concretions, Inoceramus prisms; 2' sample.	1283'	415' 6"	7/22/67I-7	Pb5555
Shale, gray, hard, blocky with conchoidal fracture, concretionary, much gypsum; some fish scales and plant fragments; 3' sample.	1305'	393' 6"	7/22/67I-8	Pb5556

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, as above, with _Inoceramus_ prisms, and with a thin-bedded brown limy siltstone zone at 388' level; 3' composite sample.	1310' 6"	388'	7/22/67I-9	Pb5557*
Limestone, gray, massive, no fossils, weathers orange; 14" thick.	1319' 6"	379'	7/22/67I-10	Pb5558
Siltstone, limy, brown to gray, blocky to massive; few limestone concretions, some of which contain fossil clams, etc.; forms slight brown-weathering zone on slope; 2' sample for maceration, plus fossil clam as 7/22/67I-11a.	1333' 6"	365'	7/22/67I-11	Pb5559
Shale, gray, blocky, concretionary, slightly calcareous; some plant material; 3' sample.	1343' 6"	355'	7/22/67I-12	Pb5560
Shale, dark to medium gray, finely silty; 5' sample.	1347' 6"	351'	11/ 7/66I-1	Pb6759
Shale, gray to brown, hard, slightly silty, conchoidal fracture; contains plant fragments; 2' sample.	1365' 6"	333'	7/22/67I-13	Pb5561
Limestone, silty, brown, two layers; bottom one is 6" thick; it is separated from the top layer by 2' of gray, hard, blocky shale; top layer is 4-8" thick. Sample Pb6760 is 4' sample of this zone and shale above; sample Pb5562 is 3' sample of this zone only. Level 327'6" falls halfway between the two limestones.	1370' 6"	327' 6"	7/22/67I-14 11/ 7/66I-2	Pb5562* Pb6760
Shale, dark to medium gray, finely silty; 4' sample.	1387' 6"	311'	11/ 7/66I-3	Pb6761

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Siltstone, gray-brown, with thin sandstone layers; 5' sample. This general lithology begins just above sample Pb6761 and continues to top of sample Pb6763; forms weak ledge.	1402' 6"	296'	11/ 7/66I-4	Pb6762
Siltstone and shale interbedded, greenish to gray, with thin sandstone layers 1" to several inches thick; 4' sample.	1423' 6"	275'	11/ 7/66I-5	Pb6763
Shale, dark gray, weathers chippy; some brown silty zones; 5' sample.	1444' 6"	254'	11/ 7/66I-6	Pb6764
Shale, as in Pb6764; 5' sample. Just above this is 30' zone of several sandy layers in the shale.	1462' 6"	236'	11/ 7/66I-7	Pb6765
Shale, dark, and sandstone, in thin layers; 5' sample.	1482' 6"	216'	11/ 7/66I-8	Pb6766
Shale, dark, soft; typical Mancos type; 5' sample.	1502' 6"	196'	11/ 7/66I-9	Pb6767
Shale, as in Pb6767; 5' sample.	1522' 6"	176'	11/ 7/66I-10	Pb6768*
Shale, as in Pb6767; 5' sample. 2' above sample is 1' platy, red-weathering sandstone with borings.	1542' 6"	156'	11/ 7/66I-11	Pb6769
Shale and platy sandstone interbedded, gray to brown; 5' sample; capped by 18" platy sandstone which forms a conspicuous ledge.	1562' 6"	136'	11/ 7/66I-12	Pb6770
Shale and sandstone as in Pb6770; 5' sample; capped by 5' massive sandstone.	1582' 6"	116'	11/ 7/66I-13	Pb6771

Lithologic description of sampled interval	Level of base of sample in feet above base of Section	Level of base of sample in feet below top of Corcoran Sandstone	Collection Number	Maceration Number
Shale, dark gray; typical Mancos; 5' sample.	1602' 6"	96'	11/ 7/66I-14	Pb6772*
Shale, dark gray, between two sandstones; basal sand 2' thick, upper sand 1' thick, shale sample 3' thick.	1622' 6"	76'	11/ 7/66I-15	Pb6773
Shale, dark gray; typical Mancos; 5' sample; above it is sandy zone which may be base of Corcoran sandstone.	1639' 6"	59'	11/ 7/66I-16	Pb6774
Shale, dark, soft, clayey; 4' sample; shale is parting between two massive white sandstones; top sand is 18-19' sandstone of Corcoran member; Palisade Coal Zone lies atop it.	1675' 6"	23'	11/ 7/66I-17	Pb6775
Palisade Coal Zone, consists of 6" lignitic shale at base, then 30" of coal with shaly partings, then 30" dark shale parting, then 15" upper coal. Sample composited from run-of-mine coal and shale pieces collected at top of chute at portal.	1698' 6"	0' 0"	11/ 7/66II-1	Pb6777
Shale, dark, Mancos-like; 5' sample.	1717' 6"	-19'	11/ 7/66I-19	Pb6778

PALISADE SECTION

Samples taken from section exposed beside Interstate-70 highway near Palisade, Colorado, near an abandoned coal mine in the Book Cliffs; E 1/2, SE 1/4, Sec. 4, T11S, R98W, Mesa County, Colorado.

Samples are not given in normal stratigraphic succession. They are given sequentially from base upward.

Lithologic description of sampled interval	Level of base of sample in feet above top of Corcoran Sandstone	Level of base of sample in feet above base of Composite Section	Collection Number	Maceration Number
Base of section being at top of Corcoran Sandstone.				
Shale and siltstone, brown to gray, hard, thin-bedded, with white sandy lenses and some plant material; 3'6" thick. Lies atop 50' massive to platy Corcoran Sandstone, white-capped in upper 10-20'.	0'	1698' 6"	7/24/67I-1	Pb5563
Shale and siltstone, lignitic, and lignite, interbedded; 1' thick.	3' 6"	1702'	7/24/67I-2	Pb5564
Clay, gray to orange, bentonitic; 4" thick.	4' 6"	1703'	7/24/67I-3	Pb5565
Coal, soft, slightly weathered, with some fossil resin; Palisade Coal Zone, here composed of one 3' bed of coal overlain and underlain by lignitic material; entire zone about 8' thick. Coal sampled at 1' intervals, later recombined for maceration.	4'10"	1703' 4"	7/24/67I-4-6	Pb5566-68
Lignite and lignitic shale interbedded, black; 1' thick.	7'10"	1706' 4"	7/24/67I-7	Pb5569
Siltstone, brown, lignitic, weathers orange; 6" thick.	8'10"	1707' 4"	7/24/67I-8	Pb5570
Shale, black to brown, lignitic, slightly concretionary; 3'2" thick.	9' 4"	1707'10"	7/24/67I-9	Pb5571

Lithologic description of sampled interval	Level of base of sample in feet above top of Corcoran Sandstone	Level of base of sample in feet above base of Composite Section	Collection Number	Maceration Number
Shale, brown to black, soft, blocky to platy, slightly weathered, some gypsum, some fossil plant material; 3' sample.	18'	1716' 6"	7/24/67I-10	Pb5572
Shale, siltstone, and silty shale, interbedded, bluish-black to brown, blocky, concretionary; 3' sample; approximate base of Mancos Shale tongue which extends upward from here to the base of the Cozette Member 24' higher (48' above top of Corcoran).	23' 6"	1722'	7/24/67I-11	Pb5573
Shale, silty, black, blocky, concretionary, conchoidal fracture, some plant fragments; few gastropods (*Turritella*?); 3' sample.	29'	1727' 6"	7/24/67I-12	Pb5574
Shale, silty, black, blocky, concretionary; some plant material, few ostracods; 3' sample.	34' 6"	1733'	7/24/67I-13	Pb5575
Shale, as in Pb5575, but with no ostracods; 3' sample.	40'	1738' 6"	7/24/67I-14	Pb5576
Sandstone, gray-brown, with gray shale and siltstone partings; 4'6" thick, partings sampled. This is picked as the base of the Cozette Member of the Price River Formation; continues 130' above top of this sampled zone. Above this sample is a 4'6" cross-bedded sandstone with *Ophiomorpha* borings.	48'	1746' 6"	7/24/67I-15	Pb5577
Siltstone, gray, hard, platy to concretionary, calcareous; parting lens in massive Cozette sandstone; 8' interval sampled.	75'	1773' 6"	7/24/67I-16	Pb5578*

COLORADO RIVER SECTION

Samples taken from partings in sandstones of Cozette and Cameo Members of Price River Formation plus intervening Mancos Shale tongue, sampled in S 1/2, SE 1/4, Sec. 3, T11S, R98W, Mesa County, Colorado. Just east of Interstate-70 bridge over Colorado River near Palisade, Colorado, above small abandoned dam.

Samples are not given in normal stratigraphic succession. They are given sequentially from base upward.

Lithologic description of sampled interval	Level of base of sample in feet above top of Cozette Sandstone	Level of base of sample in feet above base of Composite Section	Collection Number	Maceration Number
Base of section begins in the Cozette Member of Price River Formation 82' below the top of the Cozette Sandstone.				
Shale, blue-gray, hard, blocky, with some silt and sand; parting in massive Cozette sandstone which contains Ophiomorpha borings; 48' above base of sandstone, which is 130' thick; 2' sample.	-82'	1799'	7/25/67I-1	Pb5590
Shale, gray-brown, platy, almost lignitic; this is the counterpart of the coal which is usually developed above these sandstones; 3' sample, lying atop Cozette sandstone.	0'	1881'	7/25/67I-2	Pb5591*
Shale, gray-brown, soft, platy, with very abundant plant material, just atop 6" limy red fine sandstone; 3' sample.	14'	1895'	7/25/67I-3	Pb5592
Mancos Shale Tongue overlying Cozette Member				
Shale, gray-brown, blocky, silty, with abundant plant fragments; 3' sample; this is approximately the lower disconformable contact of a Mancos Shale tongue with the underlying Cozette Member.	36'	1917'	7/25/67I-4	Pb5593

Lithologic description of sampled interval	Level of base of sample in feet above top of Cozette Sandstone	Level of base of sample in feet above base of Composite Section	Collection Number	Maceration Number
Shale, lignitic, gray-brown, blocky; orange limestone concretion zone at top; 3' sample; 9'6" above top of sample is 2' massive sandstone.	56'	1937'	7/25/67I-5	Pb5594
Shale, siltstone and sandstone interbedded, platy to blocky, atop 2' sandstone mentioned in sample description for Pb5594; 5' composite sample up to base of a 6" sandstone; this may be the base of the Cameo Member, i.e., the gradational top of the Mancos Shale tongue, and the highest occurrence of the Mancos in this area.	67' 6"	1948' 6"	7/25/67I-6	Pb5595
Siltstone and shale interbedded, gray to brown, hard, platy; 2' parting at 23-25' above 6" sandstone mentioned above; atop this is more sandstone; at 15' above sample, sandstone is massive to cross-bedded sandstone of the Cameo Member of the Price River Formation; sandstone is 105' thick, white-capped in top one-third, and is overlain by the Cameo Coal further east. (Cameo Coal has been removed by erosion of this locality.) This is the sandstone which caps Mount Garfield, near Grand Junction, Colorado.	91'	1972'	7/25/67I-7	Pb5596

CAMEO SECTION

Sampled Cameo Coal zone on right rib of portal and above portal at Reliable Coal and Mining Company's Roadside Mine off Interstate-70, near Cameo, Colorado, middle of Sec. 34, T10S, R98W, Mesa County, Colorado. (Lowest two samples taken 40' east of portal.)

Samples are not given in normal stratigraphic succession. They are given from base upward.

Lithologic description of entire coal zone	Level of base of sample in feet above top of Cameo Sandstone	Level of base of sample in feet above base of Mt. Garfield Section	Collection Number	Maceration Number
Cameo Member of the Price River Formation				
Lignitic shale, brown to black, partly oxidized, with few layers of very fine sand and silt; 3' sample, to base of coal (Pb4987). Lowermost unit in Cameo Coal zone.	0'	2092'	7/21/67I-1	Pb4986
Coal and lignitic shale, interbedded, brown to black, thin-bedded, partly oxidized; 10" sample.	3'	2095'	7/21/67I-2	Pb4987
Coal, with much resin; a few thin, red, shaly bands; 5'8" thick, sampled every 1', later recombined samples; lower bench of Cameo Coal Zone.	3'10"	2095'10"	7/21/67I-3-8	Pb4988-93*
Shale, lignitic at top and bottom, platy to blocky, with few calcareous ironstone concretionary lenses; this is the shale separating the upper and lower benches of the Cameo Coal; 4' thick.	9' 6"	2101' 6"	7/21/67I-9	Pb4994
Coal, with some resin, partly oxidized; 1' thick.	13' 6"	2105' 6"	7/21/67I-10	Pb4995
Coal, pure, dark, with 1" sandy lignite at base; 1' thick.	14' 6"	2106' 6"	7/21/67I-11	Pb4996

Lithologic description of entire coal zone	Level of base of sample in feet above top of Cameo Sandstone	Level of base of sample in feet above base of Mt. Garfield Section	Collection Number	Maceration Number
Coal and lignitic shale, interbedded, gray to black; 10" thick.	15' 6"	2107' 6"	7/21/67I-12	Pb4997
Lignitic shale, gray to brown, hard, blocky to platy, with plant fossils; 2'8" thick.	16' 4"	2108' 4"	7/21/67I-13	Pb4998
Coal and lignitic shale, interbedded, with abundant resin; 1' thick.	19'	2111'	7/21/67I-14	Pb4999
Lignitic shale, gray to brown, with few thin coal layers; few thin limy sandstone lenses; 18" thick. Top of Cameo Coal zone.	20'	2112'	7/21/67I-15	Pb5000

RIFLE GAP SECTION: Lithologic descriptions of units sampled. (Unsampled intervals are not described here.)

Sampled shales from upper Mancos Shale and lower Iles Formation, and the coals associated with the Trout Creek Sandstone. Sampled in W 1/2, T5S, R92W, Garfield County, Colorado, along road on west side of Rifle Gap Dam and Reservoir.

Samples are not given in normal stratigraphic succession. They are given sequentially from base upward.

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Mancos Shale				
Siltstone, gray-brown, blocky, slightly calcareous, some gypsum; 3' sample. (Lowermost unit of Mancos sampled here).	0' 0"	961'	9/ 2/68II-1	Pb8878
Shale, silty, gray to black, blocky, slightly calcareous, slightly gypsiferous; 3' sample.	22'	939'	9/ 2/68II-2	Pb8879
Shale, as above; 3' sample; there is a covered interval between this and previous sample; 10' above top of sample is a sandy zone	60'	901'	9/ 2/68II-3	Pb8880
Iles Formation				
Shale, silty, gray to black, platy, hard, some gypsum; 6" parting 3' above base of sandy zone. This is designated as the base of the Iles Formation, with the sediments above being predominately sandy, those below mainly shale and siltstone; 15' above top of sample is a 2' massive sandstone.	76'	885'	9/ 2/68II-4	Pb8881

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Siltstone, dark-gray to brown, calcareous, some gypsum, few plant fragments; 6' sample between two massive sandstones; above upper massive sandstone is a zone of thin-bedded sandstone for several feet.	93' 6"	867' 6"	9/ 2/68II-5	Pb8882
Shale, silty, gray, very hard, very calcareous, parting in sandy zone; 6" sample.	120' 6"	840' 6"	9/ 2/68II-6	Pb8883
Shale and siltstone interbedded, hard, platy, slightly calcareous, some plant fragments; 6" parting in sandy zone.	135'	826'	9/ 2/68II-7	Pb8884*
Shale and siltstone interbedded, gray to brown, hard, very slightly calcareous, some gypsum; 6" sample topped by more sandstone.	155' 6"	805' 6"	9/ 2/68II-8	Pb8885
Shale and siltstone, as in Sample Pb8885, sandy; 8" parting.	165' 6"	795' 6"	9/ 2/68II-9	Pb8886*
Shale and sandstone interbedded, gray, platy; 4" parting.	184' 6"	776' 6"	9/ 2/68II-10	Pb8887
Siltstone and fine sandstone interbedded, gray to brown, very hard, very calcareous; 6" parting.	207' 4"	753' 8"	9/ 2/68II-11	Pb8888
Siltstone, sandy, brown to gray, hard, very calcareous, some plant material; 18" parting in Corcoran Sandstone. (This is in the lower bench of the Corcoran Sandstone).	218' 4"	742' 8"	9/ 2/68II-12	Pb8889
Siltstone, as in Sample Pb8889 with a few fossil clams; 14" sample.	238' 4"	722' 8"	9/ 2/68II-13	Pb8890

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Siltstone, as in Sample Pb8889, sandier; 1' parting in Corcoran.	259' 6"	701' 6"	9/ 2/68II-14	Pb8891
Shale and siltstone, sandy, gray to brown, slightly calcareous; 3' sample, between two sandstone zones.	280' 6"	680' 6"	9/ 2/68II-15	Pb8892
Coal and lignitic shale interbedded; 2' sample, rests on top of main bench of Corcoran Sandstone	315' 6"	645' 6"	9/ 2/68II-16	Pb8893
Coal, pure, 18" thick, atop last sample (Pb8893).	317' 6"	643' 6"	9/ 2/68II-17	Pb8894
Siltstone, black to brown, carbonaceous, parting between two coals; 4' sample.	319'	642'	9/ 2/68II-18	Pb8895
Coal, pure, 1' thick.	323'	638'	9/ 2/68II-19	Pb8896
Shale, lignitic, brown to black; 4' thick, between two coals	324'	637'	9/ 2/68II-20	Pb8897
Coal, pure; 2' thick.	328'	633'	9/ 2/68II-21	Pb8898*
Shale and siltstone, lignitic; 3' sample.	330'	631'	9/ 2/68II-22	Pb8899
Coal, pure; 1' thick; overlain by 7'6" massive sandstone.	343'	618'	9/ 2/68II-23	Pb8900
Coal, pure; 3' thick.	360'	601'	9/ 2/68II-24	Pb8901
Shale and siltstone, lignitic, gray to brown, between two coals; 18" sample.	363'	598'	9/ 2/68II-25	Pb8902

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Coal, pure, 10" thick.	364' 6"	596' 6"	9/ 2/68II-26	Pb8903
Siltstone, lignitic, brown to gray; 2'8" thick.	365' 4"	595' 8"	9/ 2/68II-27	Pb8904
Coal, pure; 6" thick.	368'	593'	9/ 2/68II-28	Pb8905
Shale and siltstone, lignitic, brown to gray, sandy; 3' sample.	368' 6"	592' 6"	9/ 2/68II-29	Pb8906
Coal and lignitic shale interbedded, black; 1' sample; atop this is 5'6" massive sandstone.	382' 6"	578' 6"	9/ 2/68II-30	Pb8907
Shale, gray, some plant fragments; 5" sample, topped by 3'6" massive sandstone.	397' 1"	563'11"	9/ 2/68II-31	Pb8908
Shale and siltstone interbedded, gray, hard, slightly calcareous, with some plant fragments; 3' sample.	402'	559'	9/ 2/68II-32	Pb8909
Shale, gray to brown, hard, blocky, sandy; 3' sample; above this is a sandier zone, which may be base of Cozette sandstone.	422' 6"	538' 6"	9/ 3/68I-1	Pb8910
Siltstone and sandstone interbedded, gray to brown; 18" parting between two massive sandstones.	439' 6"	521' 6"	9/ 3/68I-2	Pb8911
Shale, gray to brown, hard, blocky, concretionary, slightly calcareous; 1' parting in massive sandstone zone.	460'	501'	9/ 3/68I-3	Pb8912

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Shale and siltstone interbedded, gray to brown, hard, sandy, gypsiferous; 3' sample topped by 7' massive sandstone.	472' 6"	488' 6"	9/ 3/68I-4	Pb8913
Shale and siltstone, as in Sample Pb8913, 3' sample atop 7' sandstone.	482' 6"	478' 6"	9/ 3/68I-5	Pb8914
Shale, lignitic, black to brown, soft, platy; 3' sample; above this is more sandstone.	488' 6"	472' 6"	9/ 3/68I-6	Pb8915
Shale and siltstone interbedded, brown to black, sandy, calcareous, gypsiferous, abundant plant fragments; 3' sample.	499' 6"	461' 6"	9/ 3/68I-7	Pb8916*
Shale, lignitic, dark gray to dark brown, platy; 1' sample, topped by coal of next sample.	515' 6"	445' 6"	9/ 3/68I-8	Pb8917
Coal, pure; 6" thick.	516' 6"	444' 6"	9/ 3/68I-9	Pb8918
Shale, black to gray, hard, platy, carbonaceous; 2' thick.	517'	444'	9/ 3/68I-10	Pb8919*
Coal, shaly, 18" thick.	519'	442'	9/ 3/68I-11	Pb8920*
Shale and lignitic shale interbedded, gray, brown and black, platy to blocky; 2' sample, topped by sandy zone.	520' 6"	440' 6"	9/ 3/68I-12	Pb8921
Shale and siltstone interbedded, gray to brown, hard, slightly calcareous; 2'6" sample, below 15' massive sandstone.	532' 6"	428' 6"	9/ 3/68I-13	Pb8922

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Shale, gray, hard, platy, sandy; 6" sample.	553'	408'	9/ 3/68I-14	Pb8923
Shale and siltstone interbedded, gray, hard, blocky to platy; 18" parting in sandstone zone; 18" above is massive 20' sandstone which is upper massive sandstone of Cozette Member. (Top of this sandstone is at 587'6".)	564' 6"	396' 6"	9/ 3/68I-15	Pb8924
Pelecypod coquina zone, sandy, some shale and limestone, 12-17' thick, extends 23-25' above top of 20' massive sandstone; below coquina zone and above massive sandstone is 8-10' of thin-bedded sandstone. Sample Pb8925 is sample of coquina 15' above top of massive sandstone.	602' 6"	358' 6"	9/ 3/68I-16	Pb8925
Limestone, brown, sandy, coquina; 1' thick.	609' 6"	351' 6"	9/ 3/68I-17	Pb8926
Shale, lignitic, brown to black, platy, very slightly calcareous; 3' thick; lies atop coquina zone; this marks the top of the Cozette Member at this locality.	610' 6"	350' 6"	9/ 3/68I-18	Pb8927
Shale, black, marine, weathered; 2' sample from Mancos Shale tongue between Cozette Member and Rollins-Trout Creek interval (Cameo Member).	841' 6"	119' 6"	6/ 9/71I-1	Pb5720*
Shale and siltstone interbedded, brown to gray, hard, carbonaceous to lignitic; 1' sample below second (lower) Trout Creek Coal; between Pb5720 and Pb8928 is some unsampled shale, topped by 89' Trout	951' 6"	9' 6"	9/ 3/68I-19	Pb8928

Lithologic Descriptions of Sampled Intervals	Level of base of sample in feet above base of Section	Level of base of sample in feet below Trout Creek Coal Zone	Collection Number	Maceration Number
Creek Sandstone, which is, itself, overlain by the Trout Creek Coal Zone, consisting here of two major upper beds and a third minor unsampled coaly zone below these.				
Coal, pure, 2'10" thick. (Lower bench of lower Trout Creek Coal).	952' 6"	8' 6"	9/ 3/68I-20	Pb8929-31*
Shale, gray, hard; 8" thick.	955' 4"	5' 8"	9/ 3/68I-21-23	Pb8932*
Coal, pure; 1' thick. (Upper bench of lower Trout Creek Coal).	956'	5'	9/ 3/68I-24	Pb8933
Shale, black, hard, concretionary, calcareous, gypsiferous, Mancos-like parting 4' thick between the two major Trout Creek Coals.	957'	4'	9/ 3/68I-25	Pb8934*
Coal, pure, 4'6" thick. (Upper Trout Creek Coal).	961'	0' 0"	9/ 3/68I-26-29	Pb8935-38

WILSON RANCH SECTION

Sampled shales from upper Mancos Shale and one coal at the base of the Iles Formation. Sampled in SW 1/4 Sec. 30, T5N, R92W, Moffat County, Colorado.

Only the coal, sample Pb8957-60, and one shale sample, Pb8953 (taken 118'6" below the coal) yielded sufficient palynomorphs for study. Therefore, I judged it unnecessary to include a detailed description of the samples from this section. The reader is referred to Morris (1969) for a description of Morris' Milk Creek section, collected at almost the same locality as my section.

WEST SALT CREEK SECTION

This section, measured and sampled by Evan Kidson and included in his Ph.D. dissertation (Kidson, 1971), was also studied by me for comparison with the Mount Garfield section of this thesis, as described earlier. The reader is referred to Kidson's work for a description of this section. The samples from which I re-counted slides were Pb4712, Pb4721, Pb4732, Pb4741, and Pb4750.

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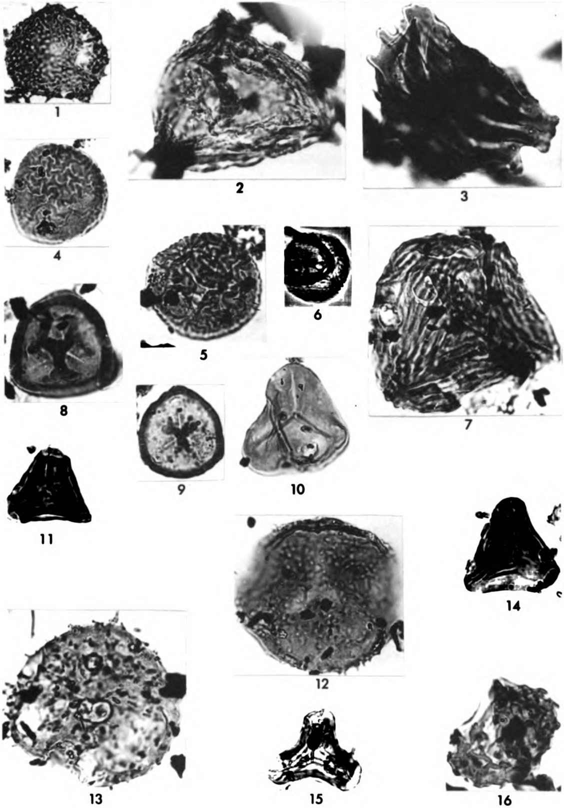

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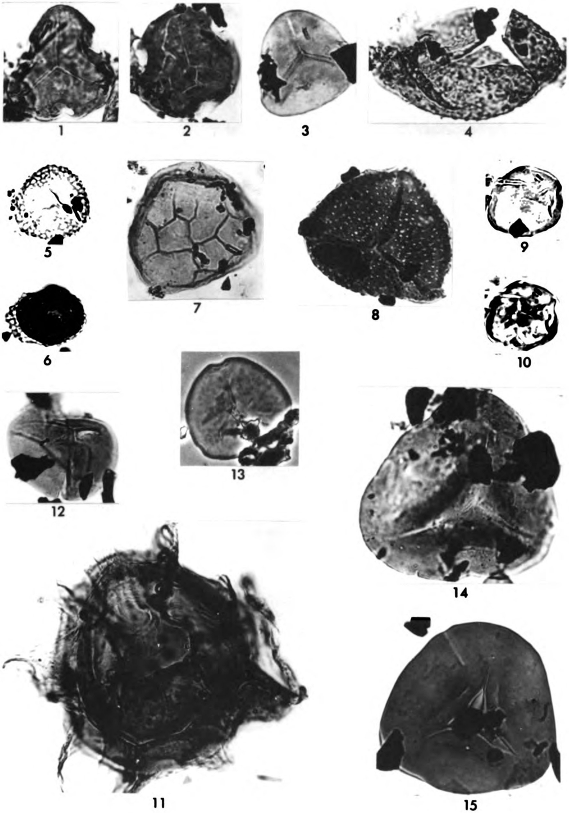

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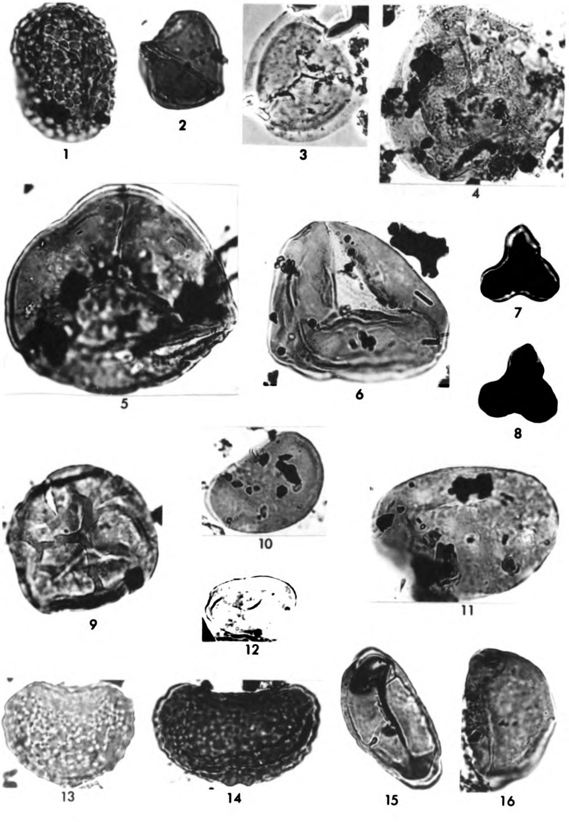

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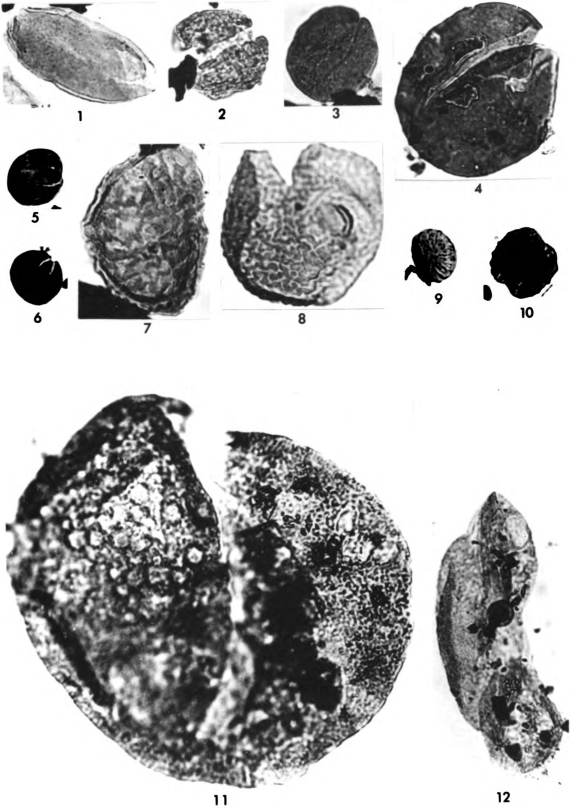

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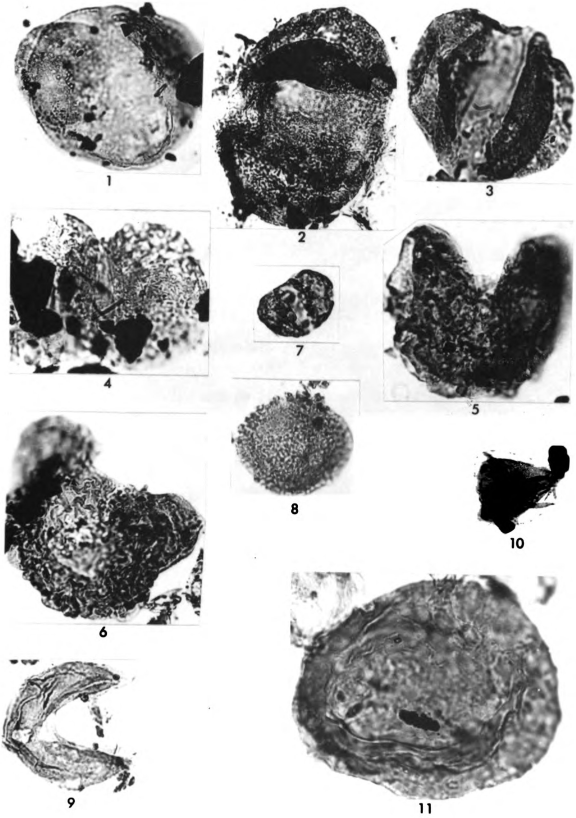

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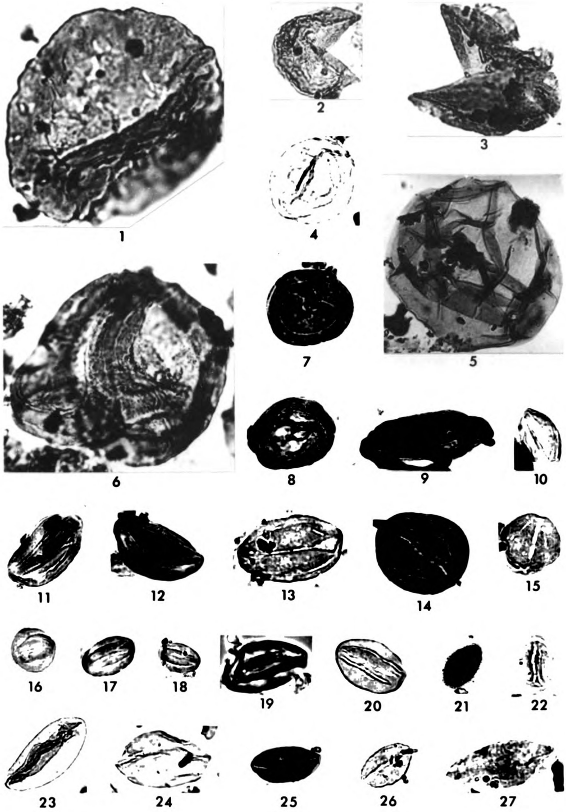
PLATE 6



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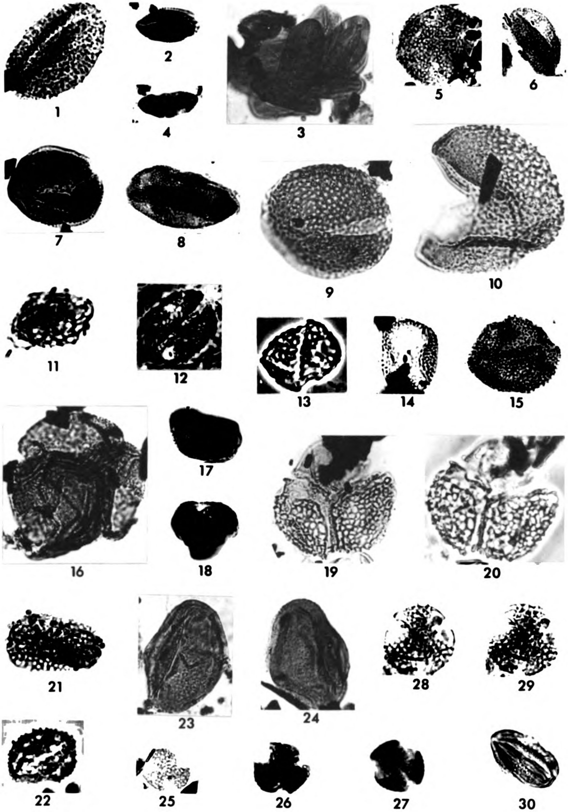
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PLATE 8

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PLATE 8

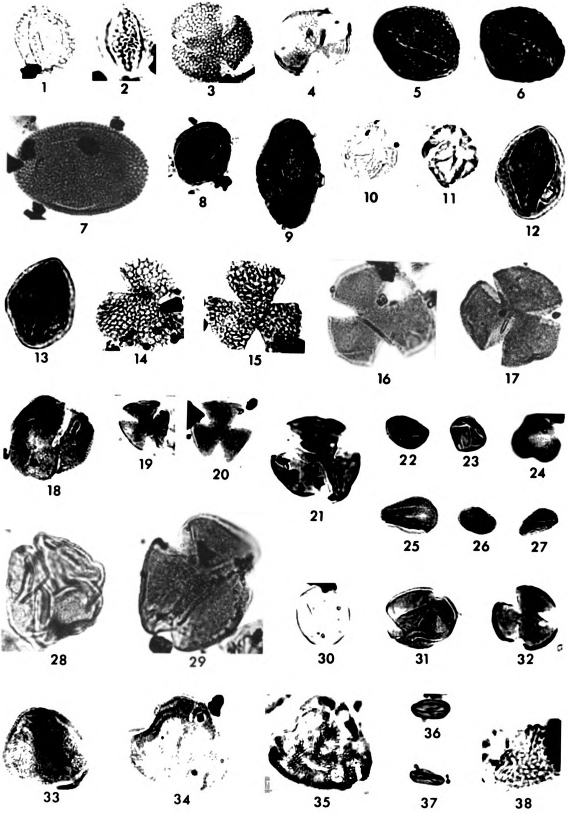
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PLATE 9

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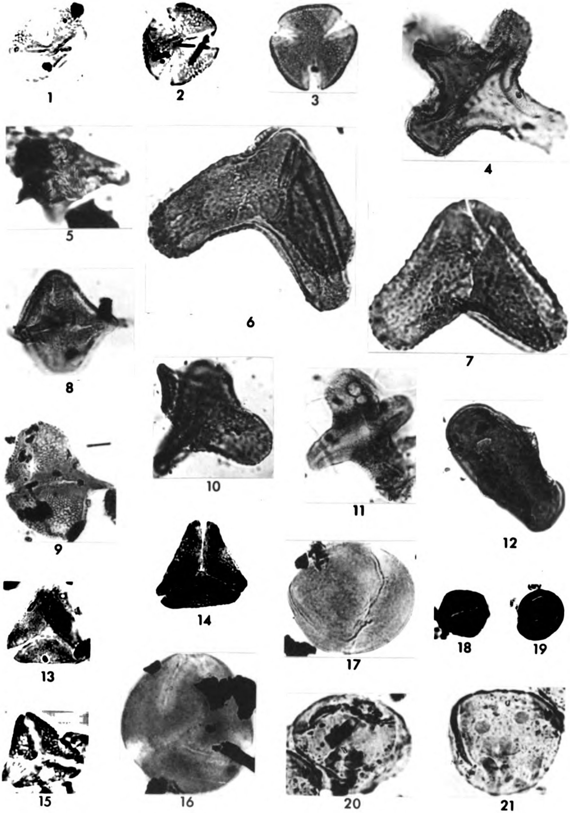

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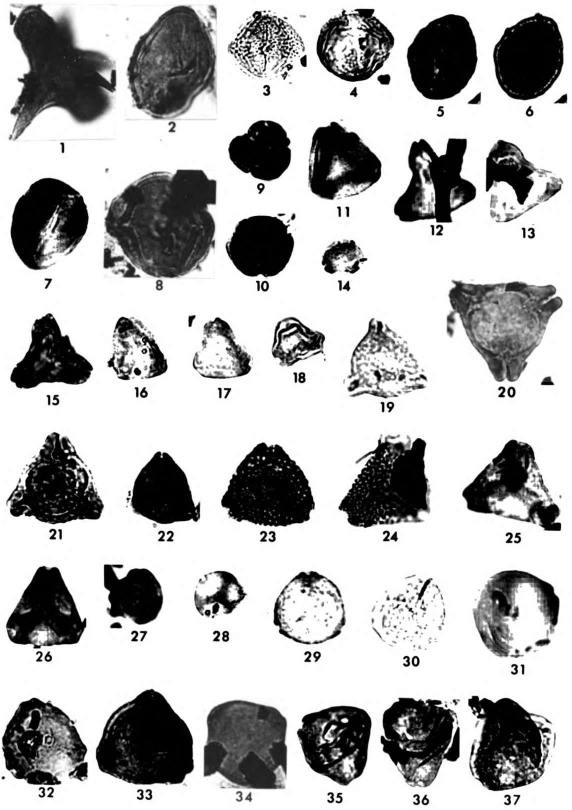
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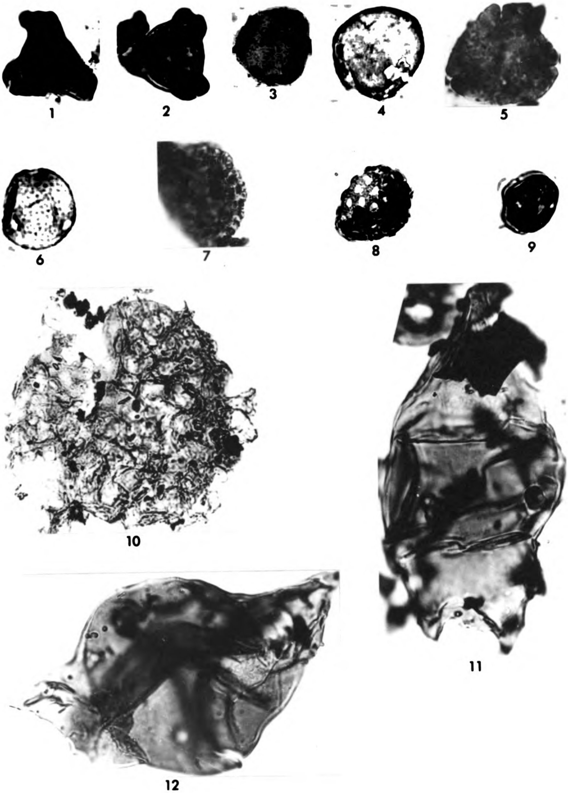

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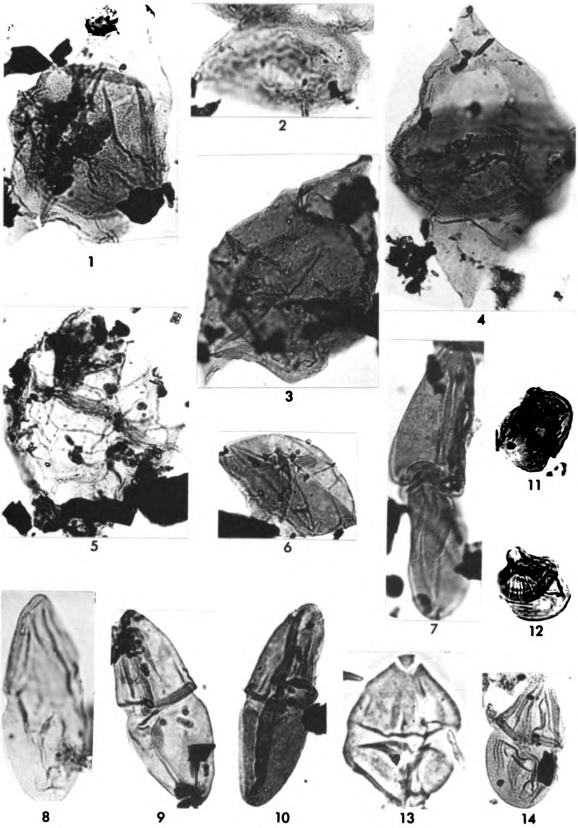

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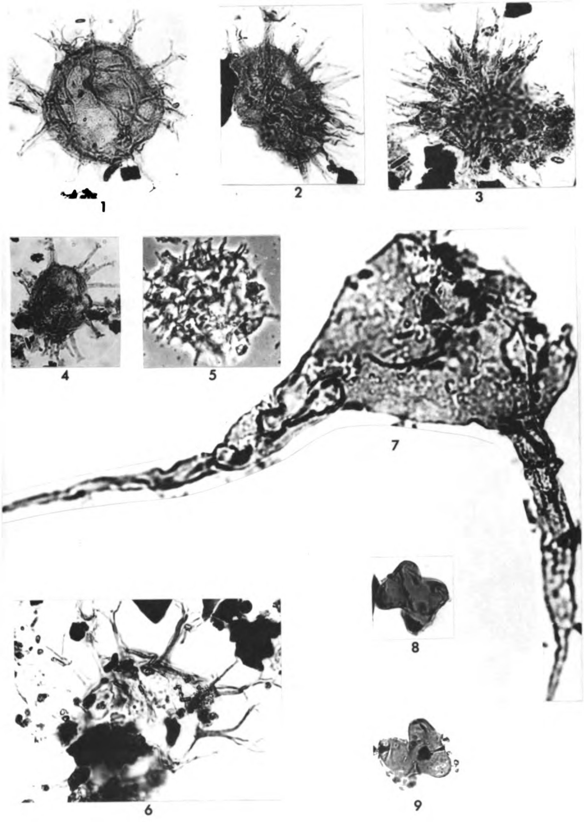

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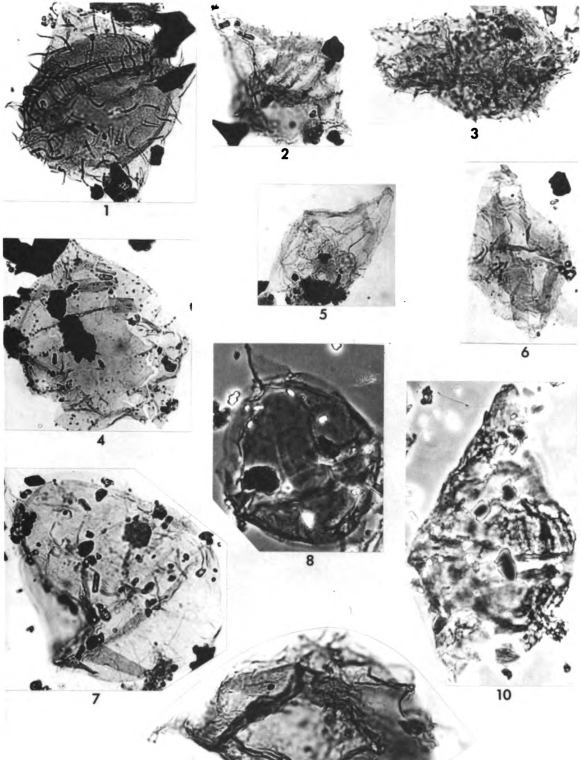

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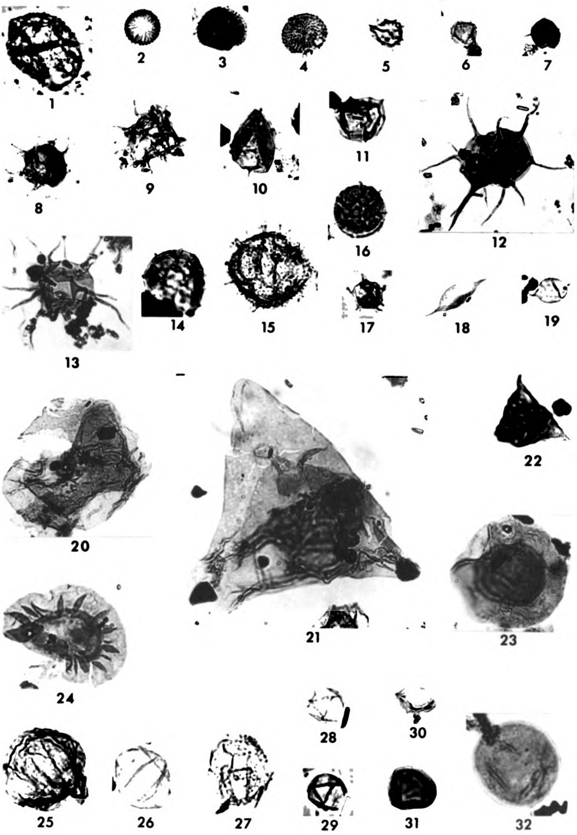
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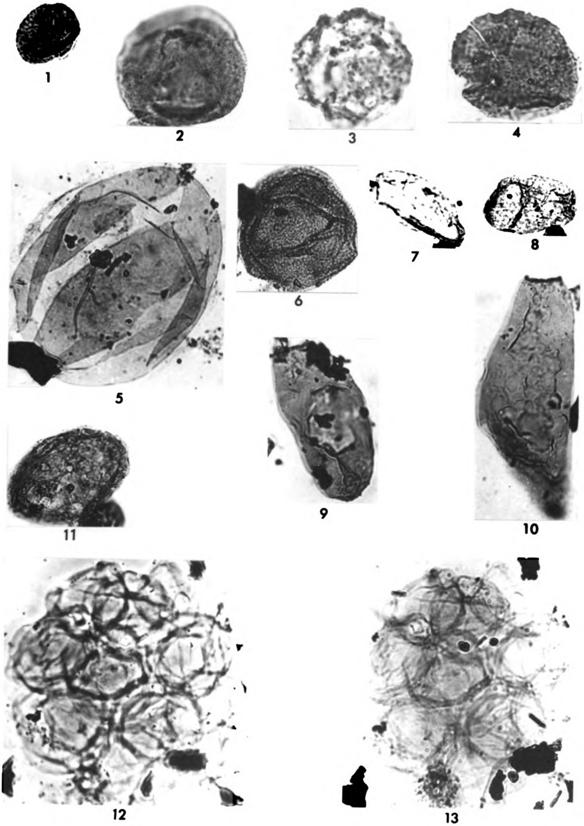

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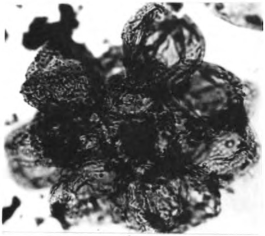

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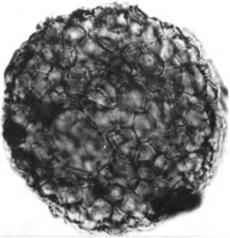

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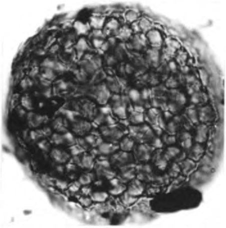

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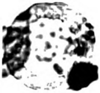

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