STRATIGRAPHY AND PALYNOLOGY OF THE FRONTIER FORMATION (UPPER CRETACEOUS), BIG HORN BASIN, WYOMING

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

PETER H. GRIGGS

1970

This is to certify that the

thesis entitled

STRATIGRAPHY AND PALYNOLOGY OF THE
FRONTIER FORMATION (UPPER CRETACEOUS),
BIG HORN BASIN, WYOMING

presented by

Peter H. Griggs

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Geology

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Date Nov. 20, 1970

ABSTRACT

STRATIGRAPHY AND PALYNOLOGY
OF THE FRONTIER FORMATION,
BIG HORN BASIN, WYOMING

By
Peter H. Humphreys Griggs

The Frontier Formation, in the Big Horn Basin, consists of alternating sandstone and shale interbedded with coal, lignite, and bentonite. The sediment source was the Mesocordilleran geanticline, and in the Big Horn Basin, the Frontier sediments were transported from the southwest and deposited to deltaic to marine environments.

Eight sections were measured and collected, in order to correlate and zone the formation. Fifteen stratigraphic horizons have been correlated in various parts of the basin. The formation is divided into four sandstone sequences; post First Wall Creek Sandstone, First Wall Creek Sandstone (Torchlight Sandstone), Second Wall Creek Sandstone, and Third Wall Creek Sandstone (Peay Sandstone). In addition, various bentonites have been correlated throughout the basin.

The pollen, spore, and phytoplankton assemblage consists of 92 genera containing 136 species. Three genera and 19 species are described as new. In addition, seven gymnospermous pollen types, six acritarch types, and one dinoflagellate type were set up but not given specific epithets. Twenty-two taxa were found to be restricted to the Frontier and as such represent an assemblage that

characterized the particular environments of deposition and source of the Frontier sediments.

The Frontier is divided into three zones and two subzones based on the stratigraphic range of several species of phytoplankton and spores. Zone A (Ascodinium verrucosum zone) is the lowest zone and has eight phytoplankton and one spore species restricted to it. The age of this zone is Cenomanian. Zone B is Turonian to Coniacian in age and has ten spore and one phytoplankton species restricted to it. Zone B is divided into two subzones (B_1 and B_2) based on the occurrence of Palaeohystrichophora infusorioides which is present in subzone B_2 but not in B_1. Zone C (Deflandrea victoriensis zone) is the uppermost zone. Its base is marked by the first occurrence of Deflandrea victoriensis which is one of three taxa restricted to this zone. Zone C is Coniacian-Santonian (?) in age.

Postulated floral elements represented by Frontier palynomorphs indicate that the climate was humid, warm temperate to subtropical, and a lush vegetation was spread over the source area coastal plain and delta. Ferns were the most abundant plants, but conifers, angiosperms, and others were present. Marine phytoplankton were found throughout all sections.

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A THESIS

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

DOCTOR OF PHILOSOPHY

Department of Geology

1970

ACKNOWLEDGMENTS

The writer expresses his sincere thanks and appreciation to Dr. Aureal T. Cross of the Department of Geology and the Department of Botany and Plant Pathology, Michigan State University, under whose guidance this study was made, for his assistance and constructive criticism and for his valuable suggestions. The writer is also deeply indebted to Dr. Robert Ehrlich, Dr. James H. Fisher and Dr. Jane E. Smith of the Department of Geology, Michigan State University and to Dr. S. N. Stephenson, Department of Botany and Plant Pathology, Michigan State University, for their suggestions during the study, and critical reading of the manuscript.

Pan American Petroleum Corporation generously supported the field work and provided partial laboratory preparation of the rock samples. Shell Oil Company, through its representative, Mr. T. D. Cook, provided for the printing of the plates.

This study, which is a part of a larger program of study of the "Palynologic Analysis in the Determination of Environments of Deposition in the Rocky Mountain Cretaceous", by Aureal T. Cross and several graduate students at Michigan State University under N.S.F. Grant GA 429, was partially supported by this N.S.F. Grant. The Geological Society of America and the Society of the Sigma Xi also provided funds used specifically for laboratory equipment and supplies and photographic supplies.

Finally to my wife, Linda, my thanks for her patience and understanding.

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INTRODUCTION

Purpose

The purpose of this study is to determine if the rocks of the Frontier Formation (Upper Cretaceous) of the Big Horn Basin can be correlated by the use of acid insoluble palynomorphs, and to interpret the age of these correlated zones and their environments of deposition.

The Frontier Formation of the Big Horn Basin is very well suited for this investigation. Because of the distribution of outcrops around the margin of the basin, it is possible to build a stratigraphic framework that extends both parallel to and at right angles to the ancient shoreline, thus enabling the sampling of both near shore and more offshore marine environments.

Pollen, spores, phytoplankton and other acid insoluble palynomorphs are particularly suited for a study of this type. Higher plant microfossils (pollen, spores, cuticles, etc.) are nearly ubiquitous in their occurrence in most sedimentary environments, whereas phytoplankton are indicative of most marine environments. Palynomorphs are resistant to most degradational processes; their morphology makes possible differentation and recognition; and they

reflect both time and environment related changes in their qualitative and quantitative distribution in the stratigraphic column.

Factors which control the supply of palynomorphs in sediments have been summarized by Cross (1964). His list includes: (1) production rates of plants and dissemination; (2) seasonal production; (3) transportation - wind, water, insects; (4) sedimentation - deposition, settling, burial; (5) preservation - optimum conditions; and (6) weathering.

Scope

At the beginning of Upper Cretaceous (Cenomanian), time uplift of the Mesocordilleran geanticline provided vast quantities of coarse detritus which were deposited under predominantly non-marine conditions in the fore-deep margins of the Cordillera. This primarily coarse clastic lithosome interfingering with marine shales concurrently under deposition in the shelf areas to the east composes the Frontier Formation of Wyoming.

The Frontier Formation, which in the Big Horn Basin consists predominantly of sandstones and shales deposited under non-marine to brackish conditions, is noted for its scarcity of invertebrate fossils (Cobban and Reeside, 1952a; Hunter, 1952). The detailed invertebrate zonation and correlation of the marine shales to the east is difficult to apply to the non-marine portions to the west.

Because of the rather widespread nature of the distribution of palynomorphs in both marine and non-marine rocks, it was felt that a detailed palynological investigation combined with stratigraphic work would yield significant results in the study of the Frontier Formation.

The field work connected with this study was part of a general stratigraphic reconnaissance of the Frontier Formation carried out by Pan American Petroleum Corporation during the summer of 1966. The eight sections collected were selected from some 26 sections measured in the Big Horn Basin (Figure 1, Table 1). Each of the eight sections were selected on the basis of exposure, for ease of measuring and collecting, continuity, and representative distribution around the basin. Samples were collected from each lithologic unit in these sections.

The data assembled from the examination of the acid insoluble organic residues of the samples is of two types: (1) a composite list of the microfossil flora and phytoplankton which comprises a partial record of the fossil flora; (2) qualitative and quantitative data which provides time-stratigraphic information. From these data, compositional, distributional and ecological information can be obtained. Species lists can be compared with lists of known age in order to more closely determine the age of the rocks being studied.

As in many studies of this type, the principal objectives are three fold. These are (1) the zonation and

correlation of the Frontier outcrops collected in the Big Horn Basin, (2) the interpretation of the environments of deposition and (3) a taxonomic treatment of the microfossils.

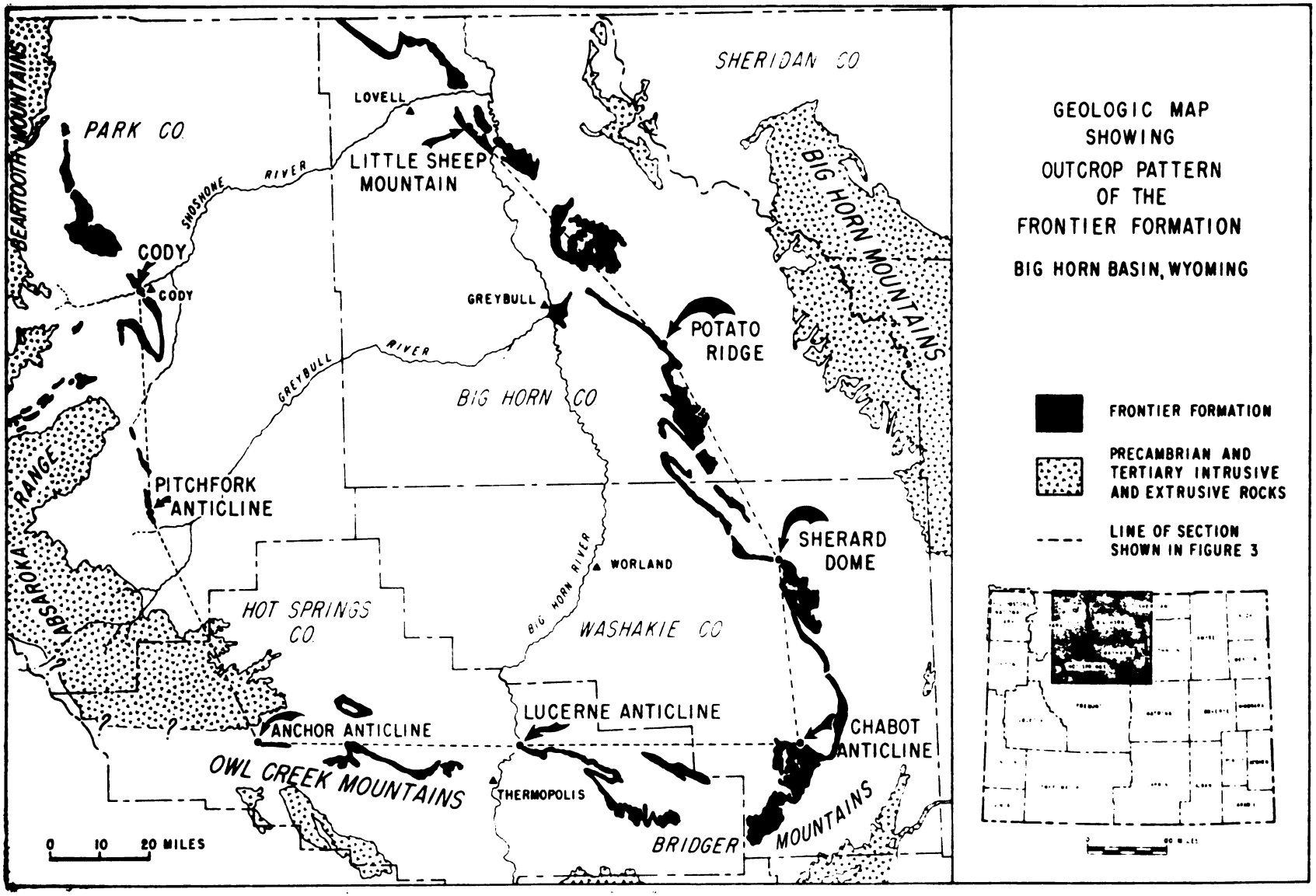

Figure 1. Geologic map showing outcrop pattern of the Frontier Formation, Big Horn Basin, Wyoming.

TABLE I

FRONTIER FORMATION SECTIONS COLLECTED, BIG HORN BASIN, WYOMING

NAME	LOCATION	COLLECTED	SAMPLES MACERATED	EXAMINED
Little Sheep Mt.	SE 25, T56N, R95W	61	43	20
Potato Ridge	10, T51N, R91W	50	33	13
Sherard Dome	22, T47N, R89W	67	44	25
Chabot Anticline	NE 18, T43N, R88W	47	30	21
Lucerne Anticline	SE & NE 9, T43N, R94W	79	52	30
Anchor Anticline	SE 1, T43N, R100W	61	44	28
Pitchfork Anticline	SE 14, T48N, R102W	72	49	31
Cody	NW 31, T53N, R101W	60	47	35

I. METHODS

Field Methods

The sections measured in this study presented dips ranging from nearly horizontal to vertical or slightly overturned. Measurements were made with a Jacob staff and Brunton compass. In some cases, broad horizontal surfaces were measured with a steel tape and the true thickness calculated from the dip. As the section was measured, it was divided into units, each unit being described both graphically and verbally.

Samples were collected by digging a trench or hole that was deep enough to recover relatively fresh rock samples. Although true trench samples (one sample representing about five vertical feet of section) were attempted in the earlier stages of the field work, it was found that this method was impractical considering the time required to trench. Each sample is considered here to be a spot sample and to represent no more than one foot of vertical section. Each unit was sampled at approximately five-foot intervals depending on the lithology. The lithologies were graded in the field as to the expected recovery of palynomorphs with every attempt being made to collect from gray shales and lignitic layers. Very few

samples were taken from sandstones.

Sample Preparation

Of the 477 samples collected, 342 were macerated. These samples were selected on the basis of expected recovery, representation of each lithologic unit in the section and for those units greater than ten feet thick, at ten-foot intervals. Each sample was prepared following the procedure outlined below.

1. Using a mortar and pestal, crush the entire sample to one-fourth inch maximum size.
2. After thoroughly mixing the crushed sample, select a representative fraction. Weigh 5 to 20 grams depending on the expected recovery from the sample.
3. Place the sample in a 250 ml. beaker and digest the sample in 25% hydrofluoric acid (16 hours).
4. Decant, wash and centrifuge three times to remove the hydrofluoric acid.
5. Transfer the residue to 50 ml. centrifuge tubes.
6. Add approximately 25 ml. zinc chloride solution (sp. gr. 1.80), mix thoroughly.
7. Centrifuge at about 1600 rpm for 45 to 60 minutes.
8. Pour off the float into a clean centrifuge tube, wash and centrifuge several times to remove the zinc chloride.
9. Add 25 ml. Schulze's solution (one part concentrated nitric acid to one part saturated aqueous solution

of potassium chlorate), treat for a few seconds to several minutes depending on the sample.

10. Decant, wash and centrifuge three times to remove the Schulze's solution.
11. Transfer the residue to a 15 ml. tapered glass centrifuge tube.
12. To stain add five drops of 2% alcohol solution of Safranin "O" to the residue, let stand for a few minutes.
13. Wash residue several times to remove the Safranin "O".
14. Transfer the residue to 2 dram vials for storage.

The residues were mounted in Cellosize (Hydroxyethyl Cellulose WP09-W-5065AA High, Union Carbide Corporation) on coverslips. Several drops of Cellosize and a drop of residue were mixed with a toothpick on the coverslip, every effort being made to distribute the mixture evenly across the coverslip. The mixture is then allowed to air dry. The Cellosize was prepared in the following manner:

1. Two grams of Cellosize; wet with methyl alcohol and make paste.
2. Place on a hot plate, add 98 ml. of water and heat but do not boil.
3. Heat and stir until liquid becomes clear.
4. Filter while hot and add a few crystals of phenol as a preservative.

This makes about two and half ounces. The coverslips

were then inverted and mounted on the slide with Elvacite 2044 Acrylic Resin (E. I. duPont deNemours Co., Inc.). The Elvacite is prepared by dissolving 40 grams of Elvacite in 75 grams of xylene, stirring occasionally. Six slides were made from each residue.

After the slides were mounted, each one was arbitrarily graded as to the quality of preservation and relative numbers of specimens per slide. The system was rather simple - A was a good sample, B a workable sample and C a poor or barren sample. Of the 342 samples macerated, 57% are either A or B, 19% and 38% respectively, 37% were ranked as C and 5% were either lost in maceration or had no organic residue so that the maceration was not continued. Based on the grading system and the relative stratigraphic position of the samples within the sections, 123 samples were selected for study.

Analysis

Stratigraphic analysis in palynology can develop from two types of data; qualitative, where the stratigraphic range of each taxon within the sections studied, is determined and quantitative, where the abundance of each taxon is determined by counting in some prescribed manner. In this study, three sections, Cody, Lucerne Anticline and Sherard Dome, were studied by a combination of these two methods in order to determine if one or both would be needed to adequately zone and correlate the

Frontier. The Cody and Lucerne Anticline sections are interpreted as being parallel to the shoreline with the more marine Sherard Dome section further to the east. It was found that the qualitative method, the results of which are presented in part V, would adequately zone the Frontier. This method was then used in the analysis of the other five sections.

All taxa counted or tabulated were set up by a thorough examination of four slides from each sample. Each new species found was photographed and its identification established by reference to the published literature.

Counting techniques were developed as part of the Cretaceous palynology program at Michigan State University. Thompson (1969) plotted curves of the number of species encountered against the number of specimens identified in counting a sample. His work demonstrates that with a count of 500 specimens, calculation of percentages would result in a probable error of $\pm$ 0.7% for a calculated 5.0%, $\pm$ 1.5% for a calculated 50.0% and $\pm$ 0.9% for a calculated 90.0%.

The counting procedure consisted of traversing the coverslip in a prescribed pattern. The order and pattern was set and was used by all persons working on the Cretaceous palynology program. At least five traverses were made and no more than 100 specimens were counted in any one traverse. If 500 specimens could not be counted

on one slide, a second or third slide was used. Records were kept of the traverses counted on each slide. No attempt was made to calculate the number of palynomorphs per gram of rock.

Photography

Photographs were taken with a Leitz Orthomat Camera on a Zeiss Standard GFL microscope using a Neofluar 100/1.30 oil and a 25/0.60 dry objective. The latter was used with a 2.0x OPTOVAR setting. Adox KB-14 film was used and the prints were made on Kodabromide F-2, F-3, and F-4 and Adox bromide F-5 papers.

II. GEOLOGY OF THE FRONTIER FORMATION, BIG HORN BASIN

Nomenclature

The name Frontier Formation was originally proposed by Knight (1902) for exposures in southwestern Wyoming near the town of Frontier, about two miles north of Kemmerer in Lincoln County. Since that time, geologists have extended the distribution of this formation by correlation with equivalent strata throughout Wyoming and into parts of Idaho, Utah, Colorado and Montana. Knight's original work was later formalized by Cobban and Reeside (1952a). They also described, in detail, the Frontier at Cumberland Gap, 15 miles south of Frontier, Wyoming. Here the lower half of the formation consists of non-marine sandstones, siltstones, mudstones, and water-laid volcanic rocks with some coal, carbonaceous shales and limestone. The non-marine unit is believed to be Cenomanian in age. The upper beds are marine, consisting of sandstone, siltstone and shale. The marine beds are dated as late Greenhorn (Turonian), early Carlile (Turonian) and early Niobrara (Coniacian).

Frontier correlations were extended into the Big Horn Basin in the early 1900's as oil and gas discoveries focused attention on this area. Washburne (1908)

differentiated two prominent sandstones (A and B) in the lower part of the Colorado Formation near Greybull, Wyoming. Later, Hintze (1915) proposed Peay Sandstone for the lower sandstone (A) and Torchlight Sandstone for the upper sandstone (B). Lupton (1916) was the first to carry the name Frontier into the Big Horn Basin. He applied the name, near Basin, Wyoming, to sandstones and shales that occupy a stratigraphic position somewhat similar to that of the type Frontier.

The Frontier formation as used in this study is defined as those strata which lie above the Mowry shale and which have as an upper limit the top of the first massive sandstone beneath several thousand feet of Upper Cretaceous marine shale known as the Cody shale. It is common practice to pick the Mowry - Frontier contact as the first prominent bentonite below the lowest sandstone of the Frontier. A correlation chart showing the time relationships of the rocks in the study area with those of the European type section and the Western Interior standard section is shown in Figure 2.

Structural Development of the Big Horn Basin

The Big Horn Basin is one of several structural basins in the central Rockies. It was formed during several phases of crustal compression (generally referred to as the Laramide Revolution) that were operative in the Rocky Mountain region from late Cretaceous to the Eocene.

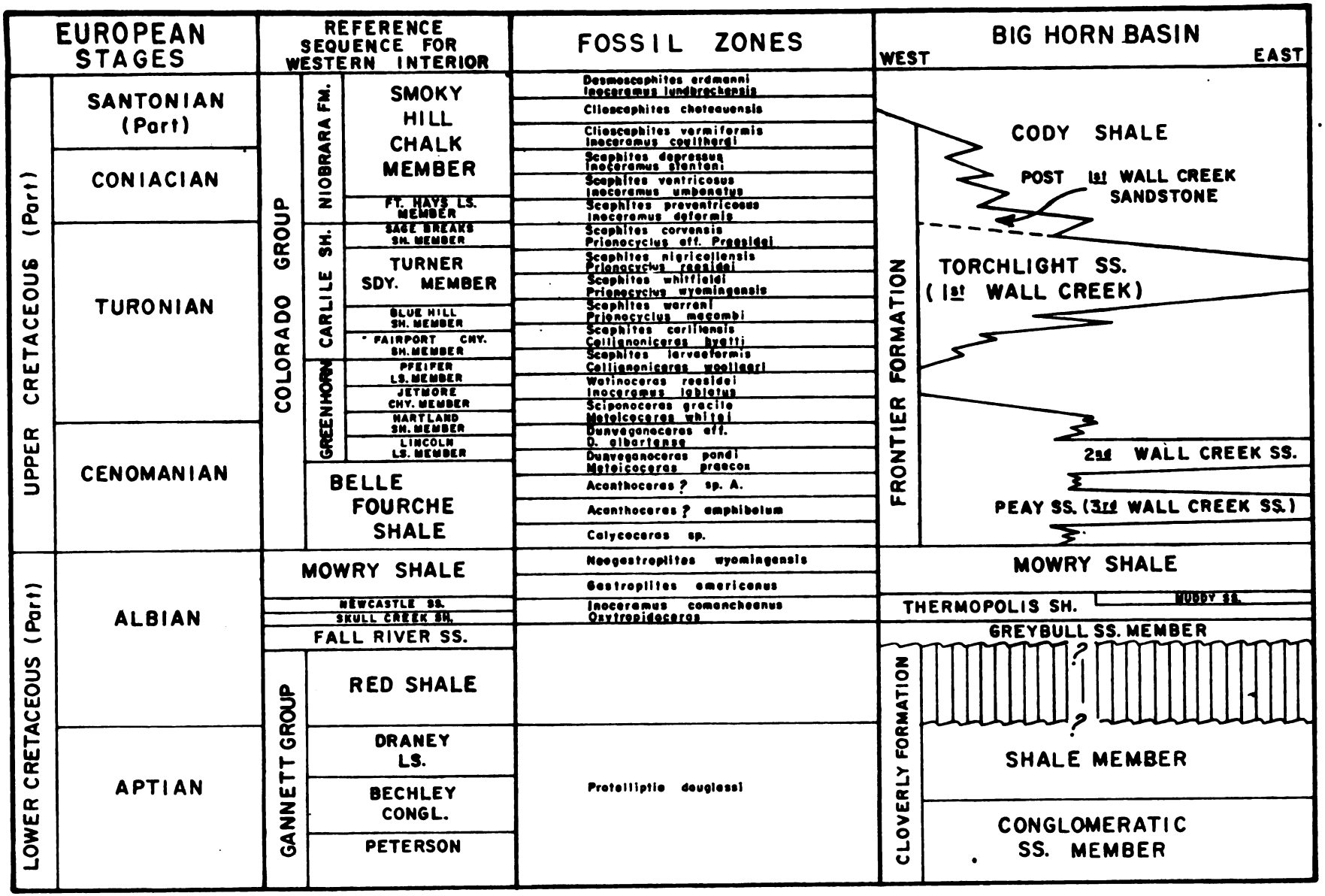

Figure 2. Correlation chart of European type section, reference sequence for Western Interior (Cobban and Reeside, 1952b), fossil zones (Cobban and Reeside, 1952b), and Big Horn Basin section (modified after Goodell, 1962 and this report).

In the study area, the Big Horn Basin rim consists of the Big Horn Mountains on the east, the Owl Creek and Bridger Mountains on the south and the Absaroka Range and Beartooth Mountains on the west. The tectonic genesis of these mountain masses is beyond the scope of this study. However, it can be noted that the principal structures developed in these basement complexes are; low-angle overthrusts, high-angle thrusts, abrupt flexures and tear faults. Within the basin proper, the tabulation of structural features that deform the Paleozoic and Mesozoic rocks include anticlinal flexures, minor low-angle thrusts and normal faults. Each of these are exhibited in Frontier outcrops.

Lithology and Stratigraphy

The Frontier Formation consists of a series of lenticular sandstones interbedded with softer units of shale and mudstones containing minor beds of sandstone, bentonite, porcellanite and coal. The sandstones are yellowish gray, generally fine grained, "salt and pepper" textured, and rich in lithic (chert) fragments. Glauconite is widely disseminated. Large (to three feet) brown calcareous concretations are common in the thicker sandstones.

Goodell (1962) has published on the petrography of the Frontier sandstones. He notes that the source areas were predominantly sedimentary rocks with lesser amounts of volcanic and low rank metamorphic rocks. Rounding and sphericity of detrital particles is immature showing little

effect of prolonged transport. He also notes that the mineralogy becomes differentiated away from the principal distributary systems.

Chert and andesite porphyry conglomerates are rather persistant near the top of the formation, especially along the east side of the basin. Both Hunter (1952) and Van Houten (1962) have suggested a "Big Horn high" in the northern Big Horn Mountains as the source for these pebbles. However, there is no definitive evidence that would suggest that the source of the Frontier sediments was from any other direction than the west (more specifically the southwest). Neither is there any evidence for tectonically positive or negative areas that might have influenced the distribution of sediments.

The shales are massive to fissile, dark gray to brown and generally quite bentonitic. The more bentonitic shales weather deeply and form a deep "popcorn" textured layer on exposed surfaces. Because of this type of weathering, it is extremely difficult to describe these shales and collect samples unless they are exposed in near vertical outcrops.

After the publication of Cobban and Reeside's (1952a) work several papers appeared which treated the stratigraphy and stratigraphic correlation of the Frontier. Masters (1952), Towse (1952), Haun (1953) and Goodell (1962) have all dealt with the Frontier either on a regional basis or in areas other than the Big Horn Basin. Their correlations are based on a regional stratigraphy using both bentonites

and sandstone units as correlative horizons. Goodell's work, which is the most comprehensive on a regional scale, uses a terminology which is more generally applied in the Powder River Basin and east of the Laramie Mountains. There, the Frontier is divided into three units; from top to bottom, First Wall Creek Sandstone, Second Wall Creek Sandstone and Third Wall Creek Sandstone. In the Big Horn Basin the First Wall Creek Sandstone is equivalent to the Torchlight Sandstone and the Third Wall Creek Sandstone equivalent to the Peay Sandstone. These works have shown that correlation by rock units is extremely tenuous and that faunal zones cross lithologically continuous units. Three papers, Hunter (1952), Burk (1953) and Van Houten (1962), deal specifically with the Big Horn Basin. Again the correlations are based on sandstones and bentonites. A complete review of both the physical and paleontological correlations within the basin, together with the palynological zonation and correlation, is presented in Part V.

General Description of the Measured Sections

These sections are described in greater detail in Appendix A. A graphic stratigraphic column for each section is shown in Figure 3.

Little Sheep Mountain, South - 534 feet of Frontier was measured at this section along the eastern side of Little Sheep Mountain Anticline. The section is located about four miles south of U.S. 14, by Jeep road, in the southeast quarter of section 25, T56N, R95W. The beds

dip steeply to the northeast at 74° and strike N55°W. The section follows a drainage cut at right angles to the strike. The base of the section was picked at a four foot bentonite about 100 feet below the first of three sandstone sequences that characterize the section.

The lowest sandstone is the Peay Sandstone of Hintze (1915). It is a marine sand with crossbedding and local large scale ripple marks and worm trails. Abundant black chert pebbles form a lag deposit at the top of the sandstone. The upper sands were deposited under non-marine to brackish conditions. The middle sand is poorly developed, whereas, the upper sand is massive, inconspicuously stratified and contains occasional plant fragments. A chert and andesite pebble conglomerate is found at the top of the upper sandstone. This sandstone correlates with the Torchlight Sandstone described by Hintze (1915) from Torchlight Dome some 23 miles to the south.

Potato Ridge - This section, previously described by Pierce (1948), is located approximately 14 miles northeast of Manderson and seven miles south of Shell in section 10, T51N, R91W. The lower half of the section is well exposed along the north-south trending ridge, whereas, the exposures of the upper half grade into the flat topography of the Cody shale are poorly exposed. The measured section is 532 feet thick and has three sandstone sequences, the upper most being the Torchlight Sandstone.

The lower sandstone, Peay, is marine with cross-

bedding and cut and fill structures. Pelecypod molds are common, gastropod molds and bone fragments are rare. Chert pebble bands are common throughout. South and west of this section the Peay Sandstone splits into a number of sandy units, as the interval thickens, and it can no longer be correlated as a single genetic unit. The upper sands are more massive and indicate brackish to non-marie deposition. The base of the section is marked by a four foot bentonite.

Sherard Dome - This section had previously been measured by Hunter (1952) and Van Houten (1962), both using it in their regional correlations of the Frontier in the Big Horn Basin. The top of the section is located 300 feet north of U.S. 16 in section 22, T47N, R89W. The line of section extends north through deeply incised, east-west trending flatirons. Four sandstone sequences are found in this 545 foot section, the base of which is a 4.6 foot bentonite.

The two lower sandstones are equivalent to the Peay Sandstone at Potato Ridge and Little Sheep Mountain. The sands are marine with benerally parallel bedding. Worm tubes and trails are abundant. At the top of the third sand sequence, which is poorly developed or absent to the north, there is a three foot series of thin beds consisting of black, peaty, fissile shale with abundant plant fragments, sandstone and a thin conglomerate at the top. This

is the only "coal" bed found on the east side of the basin and not believed to be in situ, but rather depositional in nature. Goodell (1962) correlates this sand with the Second Wall Creek Sandstone in the Powder River Basin. There is a 5.6 foot conglomerate at the top of the upper sandstone (Torchlight). Lack of marine indicators may indicate that the two upper sandstones were deposited in non-marine to brackish conditions.

Chabot Anticline - The location of this section was picked over that of Burk's (1953) at Mahogany Butte Anticline because of better exposures for collecting. Burk's section is three miles west of Chabot Anticline and correlation of major units between the two sections was found to be relatively straight forward. The Frontier is well exposed along the tightly folded nose of the anticline. The beds dip 58°-65° northeast and strike N65°W. The section is located in the northeast quarter of section 18, T34N, R88W.

The section measured at Chabot anticline is 749 feet thick. There are five sandstone sequences, four in the lower 450 feet, the fifth sandstone being separated from the fourth by 267 feet of sandy shales and argillaceous sandstones. The first three sandstones can be correlated back to the Peay Sandstone in the northeast part of the basin. The fourth sandstone correlates with the Second Wall Creek Sandstone at Sherard Dome. The upper sandstone is the Torchlight (First Wall Creek Sandstone). Immediately

above the first sandstone there is a four foot bentonite that may be correlated across the southern part of the basin.

Although no invertebrate fossils were found here, Burk (1953) reports a fauna of early Niobraran (Fort Hays) age and another of Niobraran (early Smoky Hills) age, 107 and 252 feet respectively, above the Cody Frontier contact at Mahogany Butte Anticline.

Lucerne Anticline - This section had previously been measured by Hunter (1950) and Burk (1953). It is located approximately six miles northeast of Thermopolis, on the east side of the Big Horn River, and can be reached by a dirt road, 5.6 miles north of Hot Springs State Park. The line of section runs from the southeast to the northeast quarter of section 9, T43N, R94W.

The beds are well exposed along the north flank of Lucerne Anticline where they strike N54°W and dip 18° west. The base of the section is marked by a very conspicuous six foot bentonite. The entire Frontier section (650 feet) is well exposed. The overlying lower Cody shales are capped by terrace gravels.

The number of sandstone units and the percentage of sand in the total thickness of the section increases significantly along the southern and western margins of the basin. It becomes, therefore, increasingly difficult to correlate individual sandstone units as was done on the east side of the basin (i.e., Peay and Torchlight).

At Lucerne Anticline the section can be divided into about six sandstone units. The lower three are in the Peay package of sands. There is a middle sandstone that correlates with the Second Wall Creek Sandstone and the upper sand is the Torchlight Sandstone. Ripple marks, worm trails and rare pelecypods indicate that most of the sands were deposited in brackish to marine conditions.

Burk (1953) reports a fauna of late Carlile age (Sage Breaks Shale Member) from the top of the upper sandstone sequence. The horizon from which Burk collected was reestablished in this study and although not rigorously examined numerous well preserved Inoceramus fossils were collected. Burk also reports a fauna of lower Niobrara (Fort Hays Limestone Member) from concretions 86 to 116 feet above the Frontier and a fauna of Niobrara (lower Smoky Hills Chalk Member) 201 feet above the Frontier.

Anchor Anticline - This section was originally described by Burk (1953). No attempt was made to redescribe the section, instead each unit was reestablished and a few comments were added to Burk's description where necessary (see Appendix A). The section is located in the southeast quarter of section 1, T43N, R100W. The outcrop is reached on State Highways 120 and 116, 34.4 miles west of Thermopolis, then one mile north of the Hart Ranch house. The beds crop out along the north flank of Anchor Anticline and strike N78°E and dip 27° north. The entire section (758

feet) is unconformably overlain by lower Eocene rocks immediately to the west.

There are at least eight prominent sandstones in this section. The lower three are Peay sands, the fourth is the Second Wall Creek Sandstone and the fifth correlates with the Torchlight Sandstone (First Wall Creek Sandstone). Three distinctive sandstones occur higher than the First Wall Creek Sandstone. These sands, of Niobrara age, are restricted to the southwestern corner of the basin, although they can be traced into the Wind River Basin (Goodell, p. 182, 1962).

In general the sands in this section are coarser grained than in those sections to the east. This is especially apparent in the upper part of the section. The section represents an alternating sequence of marine to brackish or non-marine deposition.

There is some question as to whether the basal bentonite is missing. Burk (1953) claims that it is absent and he picks a lower bentonite as the Mowry-Frontier contact. However, he does not correlate it with the basal bentonite at Lucerne Anticline. In this study it is assumed that both bentonites are the same and that Burk's confusion resulted from the expansion of the section to the west (Figure 3).

A fauna of Niobrara age (early Smoky Hills Chalk Member) was collected by Burk (1953) approximately 90 feet above the Frontier. A single Camptonectes platessa White

was collected by Burk (1953) from the top of the upper sandstone. This fossil is characteristic of the Fort Hays Limestone Member of the Niobrara Shale.

Pitchfork Anticline - Pierce and Andrews (1941) originally described the Frontier from the east side of Pitchfork Anticline. However, since the time of their work, numerous excavations for oil field roads and well sites have exposed a more complete section along the western side.

Pitchfork Anticline is located about 15 miles west of Meeteetse and about three miles north of the Greybull River. The section is in the southwest quarter of section 14, T48N, R102W. The beds dip 35^{o} to 45^{o} east and strike N10^{o}W.

The 659 foot section is quite sandy and can be divided into nine sandstone units. The lower five are Peay sands, the seventh correlates with the Second Wall Creek Sandstone, the lower half of the eight correlates with the Torchlight (First Wall Creek Sandstone). The upper half of the eighth sandstone and the ninth sandstone are younger than the Torchlight and are equivalent to the younger sands at Anchor Anticline and Cody. The sands were deposited in a transgressive-regressive sequence with environments ranging from marine or brackish to non-marine.

Cody - This section, located in the northwest quarter of section 31, T53N, R101W, is very well exposed along the north bank of the Shoshone River at Cody, Wyoming. The

Shoshone River flows east out of the Absaroka Range and cuts a deep gorge at nearly right angles to the strike of the upturned Paleozoic and Mesozoic rocks. The strike of the Frontier is N35°W and the beds dip 16° to the northeast. The base of the section is about three-fourths of a mile west of the Shoshone River bridge and the Cody-Frontier contact is about one-fourth of a mile above the bridge.

The section is 649 feet thick and consists of eight sandstone units. The lower four are Peay (Third Wall Creek) sands. As in the Pitchfork Anticline section, it is very difficult to pick a Second Wall Creek sand. However, there is a sand sequence with an associated one foot coal bed that is stratigraphically in the right position and is correlated with the Second Wall Creek to the east (there is a "coaly" unit associated with the Second Wall Creek at Sherard Dome). The upper sandstone is divided into two units; the lower half is the Torchlight (First Wall Creek), the upper half is a younger sand that correlates with sands at Pitchfork and Anchor Anticlines.

Deposition of these sandstones, which are coarses grained than those to the east, was strongly influenced by their proximity to the source of the sediments. Large channels (10 feet deep, 20 feet across), conglomerates and large scale ripple marks indicate depositional environments of much higher energy than to the east.

III. PREVIOUS PALEOBOTANICAL STUDIES

Paleobotany

Paleobotanical interest in the Frontier began in 1843 when Captain John C. Fremont collected fossil plants from a "white indurated clay" on Little Muddy Creek at Cumberland Gap, in Lincoln County, about 15 miles south of the town of Kemmerer, Wyoming. Fremont's collections were later described by James Hall in 1845, who tentatively assigned to them a Jurassic age. Veatch (1906) rediscovered Fremont's plant locality and found it to be 1200 feet stratigraphically below the base of the Oyster Ridge Sandstone (First Wall Creek). Knowlton (1917) described a flora based on the collections of Fremont, Veatch and others. He lists 25 species, representing seven ferns, one Equisetum, one monocotyledon, and 16 dicotyledons. Based on collections from the Wind River Basin, Berry (1929) expanded the flora to include 34 species, representing 24 genera in 16 families and 15 orders. The megaflora of the Frontier formation, based on the above works, is listed in Table 2.

Palynology

Palynological studies of the Frontier began with a

TABLE 2

Frontier Megaflora

(AFTER BERRY, 1929)

Tracheophyta

- Sphenopsida
  - Equisetales
    - Equisetaceae
      - *Equisetum* sp. Knowlton
- Pteropsida
  - Filicales
    - Polypodiaceae
      - *Tapeinidium*? *undulatum* (Hall) Knowlton
      - *Microtaenia variabilis* Knowlton
      - *Microtaenia paucifolia* (Hall) Knowlton
      - *Dennstaedtia*? *fremonti* (Hall) Knowlton
      - *Dryopteris coloradensis* Knowlton
      - *Asplenium occidentale* Knowlton
      - *Anemia fremonti* Knowlton
  - Gymnospermae
    - Cycadales
      - *Nilsonia mehli* Berry
    - Coniferales
      - *Sequoia reichenbachi* (Geinitz) Heer
      - *Protophyllocladus subintegrifolius* (Lesquereux) Berry
  - Angiospermae
    - Monocolyledonaea
      - Araceae
        - *Sabalites* sp.
      - Liliaceae
        - *Smilax*? *coloradensis* Knowlton
    - Dicotyledonaea
      - Myricaceae
        - *Myrica nervosa* Knowlton
      - Salicaceae
        - *Salix cumberlandensis* Knowlton
        - *Salix frontierensis* Knowlton
      - Fagaceae
        - *Quercus stantoni* Knowlton
        - *Dryophyllum lanceolatum* (Knowlton) Berry
      - Moraceae
        - *Ficus fremonti* Knowlton
        - *Ficus inaequalis* Lesquereux
        - *Ficus*? sp. Knowlton
        - *Ficus*? sp. Knowlton

TABLE 2

Staphyleaceae
Staphylea? *fremonti* Knowlton
Sterculiaceae
Sterculia towneri (Lesquereux) Berry
Lauraceae
Cinnamomum hesperium Knowlton
Cinnamomum? sp. Knowlton
Araliaceae
Aralia veatchii Knowlton

Position uncertain
Dewalquea pulchella Knowlton
Phyllites ficifolius Knowlton
Phyllites grandifolius-cretaceus (Lesquereux) Berry
Phyllites cretaceus (Ettinghausen) Berry
Phyllites crassipes (Heer) Berry
Phyllites dentata Knowlton
Phyllites sp. Knowlton

paper by Andrews and Pearsall (1941) in which they describe and illustrate spores from three ferns from the Frontier Formation of southwestern Wyoming. Spores of Anemia fremonti Knowlton are like Cicatricosisporites dorogensis Potonie. Those of Microtaenia paucifolia (Hall) Knowlton resemble species of Deltoidospora (Miner) Pontonie. The spores of Microtaenia variabilis Knowlton appear to be small, thin, inaperturate forms.

Upshaw (1959) provides the only comprehensive palynological investigation of the Frontier prior to this study. His study (Ph.D., University of Missouri, 1959) is on the palynology of the Frontier Formation at Little Horse Creek, seven miles north of Dubois, in the northwestern part of the Wind River Basin. He limited his study to one section (752 feet) and no attempt was made to correlate with other sections in the area. Spores referrable to 99 species in 53 genera plus an additional 95 palynomorphs of uncertain taxanomic position are described. The taxonomy pertains mainly to spores with little or no treatment of pollen and phytoplankton.

Upshaw has published two papers based on his dissertation. The first paper (Upshaw, 1953) describes two new species of Aequitriradites Delcourt and Sprumont, emend. Cookson and Dettmann (A. ornatus and A. fimbriatus) from the Frontier at Little Horse Creek. In his second paper, Upshaw (1964) presents a zonation for his section at Little Horse Creek. By considering the recognition of cyclic lithologic units, delineation of marine and non-marine

zones based on the ratio of spores and pollen to phytoplankton and a time zonation based on the range and occurrence of species of spores, he was able to divide the Little Horse Creek Section into seven zones.

IV. SYSTEMATICS

General Statement

The pollen, spore and phytoplankton assemblage of the Frontier Formation, Big Horn Basin, Wyoming consist of 92 genera containing 136 species. Three new genera and 19 new species are described. In addition, seven gymnospermous pollen types, six acritarch types and one dinoflagellate type were set up but not assigned specific epithets. Certain species in nine different genera were lumped under the designation "spp.", indicating that they were not identified beyond the genus level. Table 3 lists the palynomorph assemblage described from the Frontier of the Big Horn Basin.

The taxanomic treatment is brief and simple. Question marks and the "cf." designation are used frequently. Spores and pollen are arranged alphabetically within the broad categories of monolete and trilete spores and angiospermous and gymnospermous pollen. The classification of the acritarchs used in this study is that suggested by Downie, Evitt and Sarjeant (1963). Fossil dinoflagellates are considered to be algae and a botanical classification is followed here. Downie, Williams and Sarjeant (1961) and Evitt (1963) discuss the affinity of fossil dinoflagellates

TABLE 3

FRONTIER PALYNOMORPHS
BIG HORN BASIN, WYOMING

MONOLETE SPORES

Laevigatosporites Ibrahim
Laevigatosporites granaperturus Hedlund
Laevigatosporites harrdti (Potonie and Venitz) Thomson and Pflug
Laevigatosporites cf. L. irroratus Hedlund
Laevigatosporites ovatus Wilson and Webster
Peromonoletes Couper
Peromonoletes sp. 1
Petalosporites Agasie
Petalosporites quadrangulus Agasie
Schizaea Smith
Schizaea cf. S. triangula Stanley
Schizaeoisporites Potonie
Schizaeoisporites eocaenicus (Selling) Potonie
Verrucatosporites Pflug in Thomson and Pflug
Verrucatosporites favus (Potonie) Thomson and Pflug
Verrucatosporites cf. V. pseudoreticulatus Hedlund

TRILETE SPORES

Acanthotriletes Naumova ex. Potonie and Kremp
Acanthotriletes varispinosus Pocock
Aequitriadites Delcourt and Sprumont emend. Cookson and Dettman
Aequitriadites ornatus Upshaw
Appendicisporites Weyland and Krieger
Appendicisporites cf. A. jansonii Pocock
Appendicisporites matesovai (Bolkhovitina) Norris
Appendicisporites tricornitatus Weyland and Greifeld
Balmeisporites Cookson and Dettman
Balmeisporites glenelgensis Cookson and Dettman
Camarozonosporites (Potonie) Klaus
Camarozonosporites insignis Norris
Camarozonosporites rudis (Leschik) Klaus
Camarozonosporites sp. 1
Cicatricosisporites Potonie and Gelletich
Cicatricosisporites cf. C. carlylensis Pocock
Cicatricosisporites cf. C. cooksonii Balme
Cicatricosisporites crassiterminatus Hedlund
Cicatricosisporites dorogensis Potonie and Gelletich
Cicatricosisporites cf. C. mesozoicus Agasie
Cicatricosisporites cf. C. mohirioides Delcourt and Sprumont

Cingulatisporites (Thomson) Potonie
"Cingulatisporites" pseudoaleolatus Couper
Cingulatisporites radiatus Stanley
Cingutriletes Pierce
Cingutriletes clavus (Balme) Dettmann
Concavisporites (Pflug) Delcourt and Sprumont
Concavisporites butorosus (Manuscript name)
Concavisporites cavatus (Manuscript name)
Concavisporites sp. 1
Concavisporites sp. 2
Concavissimisporites Delcourt and Sprumont emend. Delcourt, Dettmann and Hughes
Concavissimisporites puctatus (Delcourt and Sprumont) Singh
Cyathidites Couper
Cyathidites australis Couper
Cyathidites minor Couper
Deltoidospora (Miner) Potonie
Deltoidospora hallii Miner
Deltoidospora junctum (Kara-Murza) Singh
Deltoidospora psilostoma Rouse
Deltoidospora sp. 1
Densoisporites Weyland and Krieger emend. Dettmann
Densoisporites microrugulatus Brenner
Densoisporites perinatus Couper
Dictyophyllidites Couper
Dictyophyllidites harrissii Couper
Dictyotriletes (Naumova) Potonie and Kremp
Dictyotriletes densomuralis (Manuscript name)
Foveotriletes Van der Hammen ex. Potonie
Foveotriletes cf. F. subtriangularis Brenner
Gleicheniidites (Ross) Delcourt and Sprumont
Gleicheniidites cf. G. circinidites (Cookson) Singh
Gleicheniidites confossus Hedlund
Gleicheniidites senonicus (Ross) Delcourt and Sprumont
Granulatisporites (Ibrahim) Potonie and Kremp
Granulatisporites spp.
Hymenophyllumsporites Rouse
Hymenophyllumsporites cf. H. deltoida Rouse
Klukisporites Couper
Klukisporites pseudoreticulatus Couper
Lycopodiacidites Couper emend. Potonie
Lycopodiacidites intraverrucatus Brenner
Lycopodiacidites cf. L. kuepperi Klaus
Lycopodiumsporites Thiergart ex. Delcourt and Sprumont
Lycopodiumsporites cf. L. marginatus Singh
Matonisporites Couper
Matonisporites impensus Hedlund
Miodeltospora (Manuscript name)
Miodeltospora parva (Manuscript name)
Osmundacidites Couper
Osmundacidites wellmanii Couper

Perotriletes Erdtman ex. Couper
- Perotriletes bursatus Hall
- Perotriletes sp. 1
- Perotriletes sp. 2
- Perotriletes sp. 3

Psilatriletes Van der Hammen ex. Potonie
- Psilatriletes radiatus Brenner

Reticulatisporites (Ibrahim) Potonie and Kremp
- Reticulatisporites exilis (Manuscript name)

Retitriletes Pierce
- Retitriletes cenomanianus Agasie

Staplinisporites Pocock
- Staplinisporites caminus (Palme) Pocock

Stereisporites Pflug
- Stereisporites antiquasporites (Wilson and Webster) Dettmann

Taurocusporites Stover
- Taurocusporites reduncus (Bolkhovitina) Stover
- Taurocusporites cf. T. sigmentatus Stover
- Taurocusporites sp. 1

Tentaculispora (Manuscript name)
- Tentaculispora conspicua (Manuscript name)

Tetrahedrospora (Manuscript name)
- Tetrahedrospora dyscrita (Manuscript name)

Todisporites Couper
- Todisporites minor Couper

Trilobosporites Pant ex. Potonie
- Trilobosporites crassus Brenner

Undulatisporites Pflug
- Undulatisporites scabratus (Manuscript name)
- Undulatisporites sp. 1

Verrucosisporites Ibrahim emend. Potonie and Kremp
- Verrucosisporites pustulatus (Manuscript name)
- Verrucosisporites cf. V. rotundus Singh

Unclassified Trilete Spores
- Trilete scabrate sp. 1
- Trilete spiny sp. 1
- Trilete spiny sp. 2

ANGIOSPERMOUS POLLEN

Clavatipollenites Couper
- Clavatipollenites hughesii Couper

Liliacidites Couper
- Liliacidites cf. L. variegatus Couper

Retitricolpites Van der Hammen ex. Pierce
- Retitricolpites cf. R. georgensis Brenner
- Retitricolpites paraneus Norris
- Retitricolpites vulgaris Pierce

Tricolpites Cookson ex. Couper
- Tricolpites cf. T. bathyreticulatus Stanley
- Tricolpites parvus Stanley
- Tricolpites cf. T. reticulatus Cookson
- Tricolpites sagax Norris

Tricolpopollenites Pflug and Thomson
Tricolpopollenites henrici (Potonie) Pflug and Thomson
Tricolpopollenites cf. T. retiformis Pflug and Thomson
Tricolpopollenites sp. 3

GYMNOSPERMOUS POLLEN

Alisporites Daugherty
Alisporites-type pollen
Caytonipollenites Couper
Caytonipollenites pallidus (Reissinger) Couper
Circulina Maljawkina ex. Klaus
Circulina parva Brenner
Classopollis Wodehouse ex. Wilson and Webster
Classopollis classoides Pflug emend. Pocock and Jansonius
Cycadopites Wodehouse ex. Wilson and Webster
Cycadopites fragilis Singh
Cycadopites scabratus Stanley
Equisetosporites Daugherty emend. Singh
Equisetosporites multicostatus (Brenner) Norris
Eucommiidites Erdtman emend. Hughes
Eucommiidites minor Groot and Penny
Eucommiidites troedssonii Erdtman
Inaperturopollenites Pflug and Thomson
Inaperturopollenites dubius Potonie and Venitz
Inaperturopollenites hiatus (Potonie) Pflug and Thomson
Inaperturopollenites pseudoreticulatus Brenner
Laricoidites Potonie
Laricoidites cf. L. magnus (Potonie) Potonie, Thomson Thiergart
Phyllocladidites Cookson ex. Couper
Phyllocladidites-type pollen
Pityosporites Steward emend. Manum
Pityosporites-type pollen
Podocarpidites Cookson ex. Couper
Podocarpidites-type pollen
Rugubivesiculites Pierce
Rugubivesiculites reductus Pierce
Tsugapollenites Potonie and Venitz
Tsugapollenites-type pollen
Schizosporis Cookson and Dettmann
Schizosporis cf. S. parvus Cookson and Dettmann
Schizosporis scabratus Stanley
Unclassified Gymnospermous Pollen
Monosulcate type 1
Monosulcate type 2

ACRITARCHA

Subgroup Acanthomorphita Downie, Evitt and Sarjeant
Baltisphaeridium Eisenack emend. Downie and Sarjeant
Baltisphaeridium multispinosum Singh

Michrystridium Deflandre emend. Downie and Sarjeant
Michrystridium spp.
Incertae Sedis
Form X sp. 1
Subgroup Polygonomorphitae Downie, Evitt and Sarjeant
Veryhachium (Deunff) Downie and Sarjeant
Veryhachium cf. V. europenum Stockman and Williere
Veryhachium cf. V. stellatum Deflandre
Veryhachium cf. V. trisulcum Deunff
Veryhachium sp. 1
Subgroup Netromorphitae Downie, Evitt and Sarjeant
Leiofusa Eisenack
Leiofusa spp.
Metaleiofusa Wall
Metaleiofusa spp.
Subgroup Herkomorphitae Downie, Evitt and Sarjeant
Cymatiosphaera (O. Wetzel) Deflandre
Cymatiosphaera sp. 1
Cymatiosphaera sp. 2
Subgroup Pteromorphitae Downie, Evitt and Sarjeant
Pterospermopsis W. Wetzel
Pterospermopsis spp.
Subgroup Sphaeromorphitae Downie, Evitt and Sarjeant
Incertae Sedis
Form B sp. 2
Form B sp. 4
Form C sp. 1
Form C sp. 2
Form C sp. 3

ALGAE

DINOFLAGELLATES

Cyst-Family Gonyaulacystaceae Sarjeant and Downie
Gonyaulacysta (Deflandre) Sarjeant
Gonyaulacysta cf. G. edwardsi (Cookson and Eisenack) Clark and Verdier
Gonyaulacysta spp.
Cyst-Family Formeaceae Sarjeant and Downie
Formea Cookson and Eisenack
Formea amphora Cookson and Eisenack
Cyst-Family Peridiniaceae Sarjeant and Downie
Apteodinium Eisenack
Apteodinium granulatum Eisenack
Spinidinium Cookson and Eisenack
Spinidinium microceratum Stanley
Cyst-Family Broomeaceae Sarjeant and Downie
Broomea Cookson and Eisenack
Broomea cf. B. jaegeri Alberti

Canningia Cookson and Eisenack
Canningia cf. C. reticulata Cookson and Eisenack
Canningia cf. C. rotundata Cookson and Eisenack
Canningia cf. C. senonica Clark and Verdier
Cyst-Family Hystrichosphaeridiaceae (Evitt) Sarjeant and Downie
Hystrichokolpoma Klumpp
Hystrichokolpoma ferox (Deflandre) Davey et al
Hystrichosphaeridium Deflandre
Hystrichosphaeridium spp.
Oligosphaeridium Davey and Williams
Oligosphaeridium spp.
Tanyosphaeridium Davey and Williams
Tanyosphaeridium cf. T. variecalamum Davey and Williams
Cyst-Family Microdiniaceae (Eisenack) Sarjeant in Davey et al
Microdinium Cookson and Eisenack emend. Sarjeant in Davey et al
Microdinium cf. M. irregulare Clark and Verdier
Cyst-Family Exochosphaeridiaceae Sarjeant and Downie
Exochosphaeridiaceae Sarjeant and Downie
?Exochosphaeridium phragmites Davey et al
Cyst-Family Hystrichosphaeraceae (O. Wetzel) Sarjeant and Downie
Hystrichosphaera (O. Wetzel) Deflandre
Hystrichosphaera ramosa (Ehrenberg) O. Wetzel
Cyst-Family Deflandreaceae (Eisenack) Sarjeant and Downie
Ascodinium Cookson and Eisenack
Ascodinium scabrosum Cookson and Hughes
Ascodinium verrucosum Cookson and Hughes
Deflandrea Eisenack emend. Williams and Downie in Davey et al
Deflandrea cf. D. acuminata Cookson and Eisenack
Deflandrea cf. D. cooksonii Alberti
Deflandrea echinoidea Cookson and Eisenack
Deflandrea victoriensis Cookson and Manum
Cyst-Family Endoscriniaceae Sarjeant and Downie
Palaeohystrichophora (Deflandre) Deflandre and Cookson
Palaeohystrichophora infusorioides Deflandre
Cyst-Family Pseudoceratiaceae Sarjeant and Downie
Odontochitina Deflandre
Odontochitina costata (Albert) Clark and Verdier
Odontochitina operculata (Wetzel) Deflandre and Cookson
Incertae Sedis
Form F sp. 1
Cyst-Family Membranilarnacaceae Sarjeant and Downie
Chalydophorella Cookson and Eisenack
Chalydophorella discreta Clark and Verdier
Cyst-Family Incertae Sedis
Botrycoccus
Botrycoccus sp.

Cyclopsiella Drugg and Loeblich
?Cyclopsiella sp. 1
Horologinella Cookson and Eisenack
Horologinella apiculata Cookson and Eisenack
Palaeoperidinium (Deflandre) Sarjeant
Palaeoperidinium cretaceum Pocock
Palaeoperidinium spp.

and all agree that it is preferable to treat them under the botanical code.

Upshaw (1959) describes 14 genera and 97 species as new, however, the names of most of the genera and species have never been validly published. Many of the taxa described by Upshaw have been identified in this study and in order to indicate that the names he applied, which have been used here, are not valid, the words "manuscript name" have been placed after the invalid name.

Each specimen described carries a reference to a slide and position on a slide. All samples processed were given a "Pb" number (Paleobotanical). These numbers refer to a master file at Michigan State University in which all data pertaining to collection site, age, lithology and maceration procedure can be obtained. The letter after the "Pb" number refers to a specific slide. The coordinates are from the stage of a Zeiss Standard GFL microscope.

The abundance notations in the descriptions have the following values: rare, less than 1%; occasional, 1 to 5%; common, 6 to 10%; abundant, greater than 10%.

Systematic Descriptions

MONOLETE SPORES

Genus Laevigatosporites Ibrahim 1933

Type species Laevigatosporites vulgaris (Ibrahim) Ibrahim 1933

Laevigatosporites granaperturus Hedlund 1966

Plate 1, Figure 1

1966 Okla. Geol. Survey Bull. 112, p. 20, pl. 5, figs. 2a,b.

Occurrence: rare in all sections.

Reference specimen: slide Pb 7518-B, 28.4 x 103.9.

Remarks: Upshaw's (1959) L. breviscissus is probably the same as this species.

Laevigatosporites haardti (Potonie and Venitz) Thomson and Pflug 1953

Plate 1, Figure 2

1953 Palaeontographica, v. 94, Abt. B, p. 59, pl. 3, figs. 27-38.

Occurrence: rare in all sections.

Reference specimen: slide Pb 7474-B, 27.7 x 105.7.

Laevigatosporites cf. L. irroratus Hedlund 1966

Plate 1, Figure 3

1966 Okla. Geol. Survey Bull. 112, p. 20, pl. 5, figs. 4a,b.

Occurrence: rare in all sections.

Reference specimen: slide Pb 7594-A, 38.2 x 105.6.

Remarks: This spore appears to be the same as Upshaw's (1959) Monolete spm. 3.

Laevigatosporites ovatus Wilson and Webster 1946

Plate 1, Figure 4

1946 Amer. Jour. Bot., 33, p. 273, fig. 5.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7518-B, 28.1 x 101.8.

Remarks: Upshaw (1959) describes this species as L. prolatus.

Genus Peromonoletes Couper 1953

Type species Peromonoletes bowenii Couper 1953

Peromonoletes sp. 1

Plate 1, Figures 5,6

Diagnosis: Bilateral, monolete spore surrounded by a perispore. Elongate, oval in outline. Total length 30-35 microns; width 25-30 microns. Body length 20-25 microns; width 15-20 microns. Exine thin, smooth; perine transparent, irregular. Monolete mark obscure.

Occurrence: rare to abundant in all sections. Represents 10% of sample in Pb 7470 at Sherard Dome.

Reference specimens: slide Pb 7470-A, 42.1 x 104.8; 30.0 x 100.2.

Remarks: Although smaller, this spore is similar to Peromonoletes spm. 1 described by Upshaw (1959).

Genus Petalosporites Agasie 1969

Type species Petalosporites quadrangulus Agasie 1969

Petalosporites quadrangulus Agasie 1969

Plate 1, Figure 7

1969 Micropaleontology, 15, p. 24, pl. 3, figs. 5-7.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7477-B, 38.0 x 102.9.

Genus Schizaea Smith 1798

Schizaea cf. S. triangula Stanley 1965

Plate 1, Figure 8

1965 Bull. Amer. Paleont., 49, no. 222, p. 262, pl. 34, figs. 4-9.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7468-A, 40.4 x 92.6.

Remarks: Frontier specimens do not have as triangular a cross-section to the tectum supporting elements as those described by Stanley (1965). Upshaw (1959) describes this species as Reticuloidosporites retifoveatus.

Genus Schizaeoisporites Potonie 1956

Type species Schizaeoisporites eocaenicus (Selling) Potonie 1956

Schizaeoisporites eocaenicus (Sellings) Potonie 1956

Plate 1, Figure 11

1956 Beih. Geol. Jb., 23, p. 81, pl 11, fig. 108.

Occurrence: rare in all sections.

Reference specimen: slide Pb 7626-A, 43.7 x 98.6.

Genus *Verrucatosporites* Pflug 1952

in Thomson and Pflug 1953

Type species *Verrucatosporites alienus* (Potonie) Thomson and Pflug 1953

Verrucatosporites favus (Potonie) Thomson and Pflug 1953

Plate 1, Figures 9, 10

1953 Palaeontographica, 94, Abt. B, p. 59, pl. 3, figs. 52-55.

Occurrence: rare, restricted to zone B

Reference specimen: pl. 1, fig. 9, slide Pb 7468-B, 50.3 x 90.4; ol. 1, fig. 10, slide Pb 7623-B, 40.8 x 101.5.

Remarks: Upshaw (1959) describes three species of *Polypodiisporites*; *P. paeminosus*, *P. inaequalis* and *P. verrucosus* which are here considered conspecific with *V. favus*.

Verrucatosporites cf. *V. pseudoreticulatus* Hedlund 1966

Plate 1, Figure 12

1966 Okla. Geol. Survey Bull. 112, p. 21, pl. 5, figs. 7a,b.

Occurrence: rare, found only in zone B at Cody station.

Reference specimen: slide Pb 7745-A, 39.4 x 102.2.

Remarks: Although this spore fits the species description given by Hedlund (1966), not enough specimens were found to be certain of the identification.

TRILETE SPORES

Genus Acanthotriletes (Naumova) Potonie and Kremp 1954

Type species Acanthotriletes ciliatus Potonie and Kremp 1954

Acanthotriletes varispinosus Pocock 1962

Plate 1, Figure 13

1962 Palaeontographica, 111, Abt. B, p. 36, pl. 1, figs. 18-20.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7587-D, 44.5 x 100.1.

Genus Aequitriadites (Delcourt and Sprumont) Cookson and Dettman 1961

Type species Aequitriadites dubius Delcourt and Sprumont 1955

Aequitriadites ornatus Upshaw 1963

Plate 2, Figure 5

1963 Micropaleontology, 9, no. 4, p. 428, pl. 1, figs. 1-6, 9-14.

Occurrence: rare, found in zone A at Cody section only.

Reference specimen: slide Pb 7753-B, 40.6 x 95.5.

Remarks: In his dissertation Upshaw (1959) describes this species as Coronaspora ornata. Later, Upshaw (1963) published a description as Aequitriadites ornatus.

Genus Appendicisporites Weyland and Krieger 1953

Type species Appendicisporites tricuspidatus Weyland and Krieger 1953

Appendicisporites cf. A. jansonii Pocock 1962

Plate 2, Figure 2

1962 Palaeontographica, 111, Abt. B, p. 37, pl. 2, fig. 23.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7437-A, 36.7 x 93.5.

Remarks: Frontier species are not as strongly triangular as those described by Pocock (1962). Upshaw (1959) describes this species as Appendicisporites Spm. 3.

Appendicisporites matesovai (Bolkhovitina) Norris 1967

Plate 2, Figures 1, 3

1967 Palaeontographica, 120, Abt. B, p. 94, pl. 12, figs. 11, 13-14.

Occurrence: rare, found in all sections.

Reference specimen: fig. 1, slide Pb 7592-A, 50.2 x 97.0; fig. 3, slide Pb 7589-A, 40.3 x 101.9.

Remarks: This spore is considered here to be the same as Upshaw's (1959) Appendicisporites varius.

Appendicisporites tricornitatus Weyland and Greifeld 1953

Plate 2, Figure 6

1953 Palaeontographica, 95, Abt. B, p. 43, pl. 11, fig. 52.

Occurrence: rare, found in all section.

Reference specimen: slide Pb 7622-A, 33.4 x 98.8

Remarks: This spore is considered here to be the same as Upshaw's (1959) Appendicisporites auritus.

Genus Balmeisporites Cookson and Dettman 1958

Type species Balmeisporites holodictyus Cookson and Dettmann 1958

Balmeisporites glenelgensis Cookson and Dettman 1958

Plate 2, Figure 8

1958 Micropaleontology, 4, no. 1, p. 43, pl. 2, figs. 9-10.

Occurrence: rare, found only in zone B at Lucerne Anticline.

Reference specimen: slide Pb 7735-A, 45.2 x 98.3.

Remarks: Upshaw (1959) illustrates two plates of Balmeisporites spp. He does not identify them as to species.

Genus Camarozonosporites (Potonie) Klaus 1960

Type species Camarozonosporites (Rotaspora) cretaceus (Weyland and Krieger) Potonie 1956

Camarozonosporites insignis Norris 1967

Plate 3, Figures 1, 3

1967 Palaeontographica, 120, Abt. B, p. 96, pl. 13, figs. 12-16.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7588-A, 40.9 x 88.8.

Camarozonosporites rudis (Leschik) Klaus 1960

Plate 3, Figure 2

1960 Geolgischen Bundesanstalt, Jahrbuch, Sonderband 5, p. 136, pl. 29, figs. 12, 14.

Occurrence: rare to occasional, common to all sections.

Reference specimen: slide Pb 7437-A, 32.0 x 102.8.

Remarks: Upshaw (1959) describes this spore as Goniospora minor.

Camarozonosporites sp. 1

Plate 2, Figure 7

Diagnosis: This spore is the same as Goniospora major described by Upshaw. His description follows (Upshaw 1959, p. 180): "The greatest diameter ranges from 39 to 53 microns. The sculpture consists of prominent, sharp, zigzag ridges of relatively large size. A profile of the proximal or distal face crosses 5 to 8 ridges on each face. The trilete mark is simple; the rays extend almost to the equator. The spore coat is relatively thick; folds are infrequent. The color is light yellowish-green."

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7470-A, 36.1 x 92.2.

Remarks: Specimens examined show the trilete mark reaching 1/2 to 3/4 of the radius.

Genus Cicatricosisporites Potonie and Gelletich 1933

Type species Cicatricosisporites dorogensis Potonie and Gelletich 1933

Cicatricosisporites cf. C. carlylensis Pocock 1962

Plate 2, Figure 4

1962 Palaeontographica, 111, Abt. B, p. 40, pl. 2, figs. 33-34.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7477-B, 34.1 x 88.3.

Cicatricosisporites cf. C. cooksonii Balme 1957

Plate 3, Figures 8, 9

1957 C.S.I.R.O. Ref. T.C. 25; p. 19, pl. 1, figs. 23-24, pl. 2, figs. 25-26.

Occurrence: rare, found only in zone B at Sherard Dome.

Reference specimen: slide Pb 7468-B, 41.1 x 92.9.

Remarks: Balme (1957, p. 19) reports a stratigraphic range of Kimmeridgian to Albian for this species in Australia. Its identification is therefore questioned.

Cicatricosisporites crassiterminatus Hedlund 1966

Plate 3, Figure 6

1966 Okla. Geol. Survey Bull. 112, p. 19, pl. 4, figs. 1a-c.

Occurrence: rare, found only in Lucerne Anticline section.

Reference specimen: slide Pb 7588-A, 39.0 x 101.1.

Remarks: Upshaw (1959) describes this spore as Corrugatisporites densus.

Cicatricosisporites dorogensis Potonie and Gelletich 1933

Plate 3, Figure 10

1933 Gessellschaft Naturforschender Freunde zu Berlin, 33, p. 522, pl. 1, figs. 1-5.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7591-A, 46.8 x 98.2.

Remarks: Upshaw (1959) recorded this species from the Frontier Formation of the Wind River Basin.

Cicatricosisporites cf. C. mesozoicus Agasie 1969

Plate 3, Figure 7

1969 Micropaleontology, 15, no. 1, p. 18, pl. 1, fig. 12.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7473-A, 46.4 x 103.0.

Remarks: Too few specimens were found to be certain of the species identification.

Cicatricosisporites cf. C. mohirioides
Delcourt and Sprumont 1955

Plate 3, Figures 4, 5

1955 Mem. Soc. Belg. Geol., n.s., 4, p. 20, pl. 1, fig. 2.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7541-A, 50.3 x 104.0.

Genus Cingulatisporites Thomson in Thomson and Pflug 1953

Type species Cingulatisporites levispeciosus Pflug in Thomson and Pflug 1953

"Cingulatisporites" pseudoaleolatus Couper 1958

Plate 6, Figure 6

1958 Palaeontographica, v. 103, Abt. B, p. 147, pl. 25, figs. 5-6.

Occurrence: rare, found only in zone A at the Cody section.

Reference specimen: slide Pb 7753-B, 45.3 x 101.4.

Remarks: The writer believes that Couper (1958) made a misinterpretation in his original description. It is believed that the "cingulum" is simply a thin outer layer that has split away. Thus the species is incorrectly assigned to the genus Cingulatisporites.

Cingulatisporites radiatus Stanley 1965

Plate 5, Figures 1, 4

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 244, pl. 30, figs. 9-16.

Occurrence: rare, found only in Lucerne Anticline section.

Reference specimen: slide Pb 7621-A, 46.0 x 105.6.

Remarks: Frontier specimens have a thicker "Y" shaped thickening than those described by Stanley (1965).

Genus Cingutriletes Pierce emend. Dettmann 1963

Type species Cingutriletes congruens Pierce 1961

Cingutriletes clavus (Balme) Dettmann 1963

Plate 4, Figure 2

1963 Proc. Roy. Soc. Victoria, v. 77, p. 69, pl. 14, figs. 5-8.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7633-B-2, 48.2 x 102.7.

Remarks: C. clavus is the same as Hyalospora limbata (Manuscript name) described by Upshaw (1959)

Genus Concavisporites (Pflug) Delcourt and Sprumont 1955

Type species Concavisporites rugulatus Pflug 1953

Concavisporites butorosus (Manuscript name)

Plate 5, Figure 2

Diagnosis: Upshaw (1959) described this spore as follows. "The corners are rounded and the sides are concave. The greatest diameter ranges from 30 to 39 microns. The surface is laevigate. The torus is prominent, thick, lies very close to the trilete mark, and in many cases forms prominent disks at the corners. The trilete mark is simple; the rays extend about 3/4 the spore radius, or to the inner edge of the torus. Folds are common. The color is yellowish-brown."

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7448-A, 47.5 x 97.8.

Concavisporites cavatus (Manuscript name)

Plate 5, Figure 8

Diagnosis: Upshaw (1959) described this spore as follows. "The corners are rounded and the sides are straight to slightly concave. The greatest diameter is about 25 microns. The surface is laevigate. The torus is trilobate in appearance, peripheral at the apices, forming disks, and deeply concave in the interlaesurae. The trilete mark is simple; the rays extend to the equator. The spore coat is thin; folds may be prominent."

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7470-A, 34.4 x 101.4.

Concavisporites sp. 1

Plate 5, Figure 9

Diagnosis: Spores are radial, trilete, triangular, concave sides. Corners are rounded, sides concave with a prominent interlaesurae torus immediately adjacent to the trilete mark. The greatest diameter is about 22 microns. Trilete mark distinct, simple; the rays extend more than 3/4 of the spore radius. The surface is smooth.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7475-A, 50.7 x 101.6.

Remarks: This spore is similar to Concavisporites butorosus described by Upshaw (1959).

Concavisporites sp. 2

Plate 5, Figures 3, 6

Diagnosis: Spores are radial, trilete, triangular, concave sides. Torus massive, lies close to the laesura. Corners simple, without disks. The greatest diameter 30 to 35 microns. The trilete mark is simple, the rays extend to the corners.

Occurrence: rare to occasional, common to all sections.

Reference specimen: slide Pb 7588-A, 44.8 x 101.0

Genus Concavissimisporites Delcourt and Sprumont emend. Delcourt, Dettmann and Hughes 1963

Type species Concavissimisporites verrucosus Delcourt and Sprumont emend. Delcourt, Dettmann and Hughes 1963

Concavissimisporites punctatus (Delcourt and Sprumont) Singh 1964

Plate 5, Figure 14

1964 Res. Coun. Alberta Bull. 15, p. 77, pl. 9, figs. 6, 7.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7438-A, 46.8 x 99.2.

Remarks: This spore is the same as Upshaw's (1959) Punctatisporites globosus.

Genus Cyathidites Couper 1953

Type species Cyathidites australis Couper 1953

Cyathidites australis Couper 1953

Plate 5, Figure 10

1953 New Zealand Geol. Survey, Paleont. Bull. 22, p. 27, pl. 2, figs. 11, 12.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7518-A, 42.6 x 101.0.

Remarks: This spore is the same as Upshaw's (1959) Leiotriletes magnus.

Cyathidites minor Couper 1953

Plate 5, Figure 11

1953 New Zealand Geol. Survey, Paleont. Bull. 22, p. 28, pl. 2, fig. 13.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7470-A, 38.2 x 104.8.

Remarks: This spore is the same as Upshaw's (1959) Leiotriletes recavus.

Genus Deltoidospora (Miner) Potonie 1956

Type species Deltoidospora hallii Miner 1935

Deltoidospora hallii Miner 1935

Plate 5, Figure 12

1935 Amer. Midl. Nat., v. 16, p. 618, pl. 24, fig. 7.

Occurrence: rare to common in nearly all samples, ubiquitous species found.

Reference specimen: slide Pb 7470-A, 42.3 x 94.7.

Remarks: This spore is the same as Upshaw's (1959) Leiotriletes gibbus.

Deltoidospora junctum (Kara-Murza) Singh 1964

Plate 5, Figure 5

1964 Res. Coun. Alberta Bull. 15, p. 81, pl. 9, fig. 16.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7518-B, 42.9 x 94.1.

Deltoidospora psilostoma Rouse 1959

Plate 5, Figure 13

1959 Micropaleontology, v. 5, p. 311, pl. 2, figs. 7, 8.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7518-B, 39.5 x 100.4.

Remarks: This spore appears to be the same as Upshaw's (1959) Psilatriletes spm. 2.

Deltoidospora sp. 1

Plate 5, Figure 7

Diagnosis: This type was set up as a catchall for small, 20 microns or less, spores of the genus Deltoidospora.

Occurrence: rare to occasional, common to all sections.

Reference specimen: slide Pb 7470-A, 42.3 x 106.0.

Remarks: Upshaw (1969) illustrates several spores under the genus Leiotriletes that would fall in this group.

Genus Densoisporites Weyland and Krieger emend. Dettmann 1963

Type species Densoisporites velatus Weyland and Krieger 1953

Densoisporites microrugulatus Brenner 1963

Plate 4, Figure 5

1963 Maryland Dept. Geol., Mines and Water Res., Bull. 27, p. 61, pl. 15, fig. 6; pl. 16, fig. 1.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7753-B, 43.9 x 106.8.

Remarks: This spore is the same as Upshaw's (1959) Pterotriletes diversiformia.

Densoisporites perinatus Couper 1958

Plate 4, Figures 1, 4

1958 Palaeontographica, v. 103, Abt. B, p. 145, pl. 23, figs. 6-9.

Occurrence: rare, found only in zone B at Cody section.

Reference specimen: slide Pb 7754-A, 50.9 x 101.5.

Genus Dictyophyllidites Couper 1958

Type species Dictyophyllidites harrissii Couper 1958

Dictyophyllidites harrissii Couper 1958

Plate 4, Figure 7

1958 Palaeontographica, v. 103, Abt. B, p. 140, pl. 21, figs. 5, 6.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7473-A, 44.0 x 90.6.

Remarks: This spore may be the same as Upshaw's (1959) Psilatriletes spm. 4.

Genus Dictyotriletes (Naumova) Potonie and Kremp 1954

Type species Dictyotriletes bireticulatus (Ibrahim) Potonie and Kremp 1954

Dictyotriletes densomuralis (Manuscript name)

Plate 6, Figures 2, 5

Diagnosis: Upshaw (1959) describes this spore as follows: "The greatest diameter ranges from 58 to 65 microns. The surface bears a coarse reticulum which is not noticeably reduced in the proximal polar region. The muri are thick, low ridges; the lumina are polygonal depressions. The thickness of the muri may be 1/2 the diameter of the lumina. The trilete rays are simple, extending almost to the equator. The spore coat is thick; folds are rare."

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7591-A, 46.7 x 90.1.

Genus Foveotriletes Van der Hammen ex. Potonie 1956

Type species Foveotriletes acrobiculatus (Ross) Potonie 1956

Foveotriletes cf. F. subtriangularis Brenner 1963

Plate 6, Figure 3

1963 Maryland Dept. Geol., Mines and Water Res. Bull. 27, p. 62, pl. 16, fig. 2.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7436-A, 35.1 x 95.6.

Remarks: Too few specimens were found to be positive of the species identification of this spore. Upshaw's (1959) Foveotriletes muratus is the same as this spore.

Genus Gleicheniidites (Ross) Delcourt and Sprumont 1955

Type species Gleicheniidites denonicus (Ross) Delcourt and Sprumont 1955

Gleicheniidites cf. G. circinidites (Cookson) Singh 1964

Plate 4, Figure 8

1964 Res. Coun. Alberta, Bull. 15, p. 69, pl. 8, figs. 8, 9.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7474-B, 37.8 x 99.7.

Remarks: Too few specimens were found to be positive of the identification at the species level.

Gleicheniidites confossus Hedlund 1966

Plate 4, Figure 9

1966 Okla. Geol. Survey, Bull. 112, p. 17, pl. 1, figs. 8a-c.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7587-D, 44.5 x 96.2.

Gleicheniidites senonicus (Ross) Delcourt and Sprumont 1955

Plate 4, Figure 6

1955 Mem. Soc. Belge. Geol. n.s. no. 5, p. 26.

Occurrence: rare to occasional, ubiquitous species found in nearly all samples.

Reference specimen: slide Pb 7474-B, 37.5 x 105.8.

Remarks: This spore is the same as Upshaw's (1959) Leiotriletes paryphus.

Genus Granulatisporites (Ibrahim) Potonie and Kremp 1954

Type species Granulatisporites granulatus Ibrahim 1933

Granulatisporites spp.

Plate 4, Figure 4

Diagnosis: Many forms of Granulatisporites are found in the Frontier. However, due to the lack of consistent morphological characters, only one type was set up, Granulatisporites spp., to serve as a catchall for spores of this genus.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7594-A, 48.8 x 91.0.

Remarks: Upshaw (1959) describes three species of Granulatisporites; G. cursus, G. irroratus, and G. amplius, from the Frontier. All of these are included in G. spp.

Genus Hymenophyllumsporites Rouse 1957

Type species Hymenophyllumsporites deltoida Rouse 1957

Hymenophyllumsporites cf. H. deltoida Rouse 1957

Plate 4, Figure 11

1957 Can. Jour. Bot., v. 35, p. 363, pl. 3, figs. 54-56.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7587-D, 33.8 x 95.9.

Remarks: Too few specimens and poor preservation makes positive identification at the species level questionable. This spore is the same as Upshaw's (1959) Lygodiumsporites inornatus.

Genus Klukisporites Couper 1958

Type species Klukisporites variegatus Couper 1958

Klukisporites pseudoreticulatus Couper 1958

Plate 4, Figure 10

1958 Palaeontographica, v. 103, Abt. B, p. 138, pl. 19, figs. 8-10.

Occurrence: rare, found only in zone A at Lucerne Anticline.

Reference specimen: slide Pb 7599-A, 48.9 x 95.3.

Genus Lycopodiacidities Couper emend. Potonie 1956

Type species Lycopodiacidites bullerinsis Couper 1953

Lycopodiacidites intraverrucatus Brenner 1963

Plate 8, Figures 1, 3

1963 Maryland Dept. Geol. Mines and Water Res. Bull. 27, p. 63, pl. 17, fig. 3.

Occurrence: rare, found only in zone B at Sherard Dome.

Reference specimen: slide Pb 7473-A, 36.8 x 94.2.

Remarks: This spore is the same as Upshaw's (1959) Stereozonosporites plectolabiatus.

Lycopodiacidites cf. L. kuepperi Klaus 1960

Plate 7, Figures 3, 6

1960 Geologischen Bundesanstalt, Jahrbuch, Sonderband 5, p. 135, pl. 31, fig. 27.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7477-B, 30.0 x 106.0.

Remarks: Upshaw (1959) described this species as Goniospora labiata. The few specimens found left some doubt as to the identification at the species level.

Genus Lycopodiumsporites Thiergart ex. Delcourt and Sprumont 1955

Type species Lycopodiumsporites agathoecus (Potonie) Thiergart 1938

Lycopodiumsporites cf. L. marginatus Singh 1964

Plate 6, Figure 7

1964 Res. Coun. Alberta Bull. 15, p. 41, pl. 1, figs. 7-10.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7599-A, 46.4 x 89.9.

Remarks: Many specimens in the Frontier lacked the strongly raised network described by Singh (1964). This spore is the same as Upshaw's (1959) Reticulatisporites exilis.

Genus Matonisporites Couper 1958

Type species Matonisporites phlebopteroides Couper 1958

Matonisporites impensus Hedlund 1966

Plate 6, Figure 4

1966 Okla. Geol. Survey, Bull. 112, p. 13, pl. 2, figs. 1a, b.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7438-A, 36.8 x 102.1.

Remarks: Upshaw's (1959) Psilatriletes spm. 4 may be the same as Matonisporites impensus.

Genus Miodeltospora (Manuscript name)

Diagnosis: Upshaw (1959) describes this genus as follows: "Spores are radial, trilete, triangular in equatorial outline with acute-angle apices and, in most cases with straight sides. The spore coat is smooth. A prominent thickening is present at the equatorial margin which may be confined to the interlaesural portions or may include the apices. In the later case, the thickness is greater in the interlaesural areas. The trilete mark is prominent; in most specimens the rays appear as narrow ridges which extend to the equatorial margin. The greatest diameter of the spore seldom exceeds 30 microns."

Miodeltospora parva (Manuscript name)

Plate 6, Figure 8

Diagnosis: Upshaw (1959) describes this species as follows: "The greatest diameter ranges from 21 to 26 microns. The spore coat is smooth. A prominent thickened zone is present at the equatorial margin which may be confined to the interlaesural portions or may include the apices. In the later case, the thickness is greater in the interlaesural areas. The trilete mark is prominent; the rays may appear as narrow ridges which extend to the equator. The spore coat is relatively thin except for the marginal thickenings. The color is light yellowish-brown."

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7592-A, 40.7 x 94.5.

Genus Osmundacidites Couper 1953

Type species Osmundacidites wellmanii Couper 1953

Osmundacidites wellmanii Couper 1953

Plate 6, Figure 9

1953 New Zealand Geol. Survey, Paleont. Bull. 22, p. 20, pl. 1, fig. 5.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7437-A, 44.1 x 103.1.

Genus Perotriletes Erdtman ex. Couper 1953

Type species Perotriletes granulatus Couper 1953

Perotriletes bursatus Hall 1963

Plate 6, Figure 10

1963 Pollen et Spores, v. 5, no. 2, p. 434, 436, pl. 88, figs. 16, 17.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7470-A, 48.0 x 106.1.

Remarks: This spore is the same as Upshaw's (1959) Perotriletes perisaccus.

Perotriletes sp. 1

Plate 7, Figure 10

Diagnosis: Spores are triangular to subtriangular, enclosed within a distinct perispore. The greatest diameter ranges from 22 to 31 microns. The perine is punctate, the central spore body psilate to scabrate. The trilete mark is not distinct on the central spore body, but is clearly visible on the perispore. The rays extend to the equator of the central spore body.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7470-A, 35.5 x 104.7.

Remarks: Perotriletes sp. 1 differs from Perotriletes sp. 2 in that the perine is puncate. Both of these species are the same as Upshaw's (1959) Perotriletes diversiformis.

Perotriletes sp. 2

Plate 7, Figure 9

Diagnosis: Spores are triangular to subtriangular, enclosed within a distinct perispore. The greatest diameter ranges from 20 to 35 microns. The perine is scabrate, the central spore body is psilate to scabrate. The trilete mark is not distinct on the central spore body, but is clearly visible on the perispore. The rays extend to the equator of the central spore body.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7470-A, 38.1 x 89.1.

Remarks: Perotriletes sp. 2 differs from Perotriletes sp. 1 in that the perine is scabrate. Both of these species are the same as Upshaw's (1959) Perotriletes diversiformis.

Perotriletes sp. 3

Plate 6, Figure 12

Diagnosis: Spore completely enclosed by a perine. Greatest diameter 35 to 40 microns; central body 25 to 27 microns. The central spore body and the perine are smooth. The trilete mark is distinct; rays extend 3/4 of the diameter of the central spore body.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7438-A, 33.7 x 98.4.

Remarks: This spore appears to be the same as Upshaw's (1959) Perotriletes argutus, although he notes that P. argutus does not usually show a trilete mark.

Genus Psilatriletes Van der Hammen ex. Potonie 1956

Type species Psilatriletes detortus (Weyland and Krieger) Potonie 1956

Psilatriletes radiatus Brenner 1963

Plate 6, Figure 11

1963 Maryland Dept. Geol., Mines and Water Res. Bull. 27, p. 68, pl. 20, figs. 6, 7.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7473-A, 38.6 x 92.5.

Remarks: This spore is the same as Upshaw's (1959) Psilatriletes lucidus.

Genus Reticulatisporites (Ibrahim) Potonie and Kremp 1954

Type species Reticulatisporites reticulatus Ibrahim 1933

Reticulatisporites exilis (Manuscript name)

Plate 7, Figures 1, 4

Diagnosis: Upshaw (1959, p. 159) describes this spore as follows: "Spores are circular to broadly rounded-triangular in equatoral outline. The greatest diameter ranges from 34 to 51 microns. The surface bears a prominent reticulus. The lumina are bounded by high, membranous muri which appear as projections standing vertically on the spore margin when viewed at right angles, the muri appear as membranes which join the projections together. The trilete mark is simple; the rays extend to the equator of the spore body. The spore coat is relatively thin. The color is pale greenish-yellow.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7529-A, 42.9 x 99.5.

Genus Retitriletes Pierce 1961

Type species Retitriletes ornatus Van der Hammen

Retitriletes conomanianus Agasie 1969

Plate 6, Figure 13

1969 Micropaleontology, v. 15, no. 1, p. 24, pl. 3, figs. 9, 10.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7470-A, 42.7 x 103.6.

Remarks: This spore is the same as Upshaw's (1959) Perotriletes retiplicatus.

Genus Staplinisporites Pocock 1962

Type species Staplinisporites caminus (Palme) Pocock 1962

Staplinisporites caminus (Palme) Pocock 1962

Plate 7, Figures 7, 8

1962 Palaeontographica, v. 111, Abt. B, p. 49-50, pl. 5, fig. 87; pl. 6, figs. 88-90.

Occurrence: rare, found only in Cody and Lucerne Anticline sections.

Reference specimen: slide Pb 7595-A, 40.4 x 99.1.

Genus Stereisporites Pflug 1953

Type species Stereisporites stereoides (Potonie and Venitz) Pflug 1953

Stereisporites antiquasporites (Wilson and Webster) Dettman 1963

Plate 7, Figure 11

1963 Proc. Roy. Soc. Victoria, v. 77, p. 25, pl. 1, figs. 20, 21.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7518-A, 38.6 x 91.1.

Remarks: This spore is the same as Upshaw's (1959) Sphagnumsporites crassatus.

Genus Taurocusporites Stover 1962

Type species Taurocusporites sigmentatus Stover 1962

Taurocusporites reduncus (Bolkovitina) Stover 1962

Plate 7, Figure 16

1962 Micropaleontology, v. 8, no. 1, p. 57, pl. 1, figs. 15-21.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7756-A, 49.0 x 105.4.

Remarks: This spore is the same as Upshaw's (1959) Stereozonosporites verrucosus.

Taurocusporites cf. T. sigmentatus Stover 1962

Plate 7, Figures 2, 5

1962 Micropaleontology, v. 8, no. 1, pp. 56-57, pl. 1, figs. 1-14.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7599-A, 41.4 x 101.8.

Genus Tentaculispora (Manuscript name)

Diagnosis: Upshaw (1959) describes this genus as follows: "Spores are radial, trilete, circular to broadly triangular in equatorial outline. The spore coat is smooth to variously ornamented. A prominent equatorial flange is

1963 Proc. Roy. Soc. Victoria, v. 77, p. 25, pl. 1, figs. 20, 21.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7518-A, 38.6 x 91.1.

Remarks: This spore is the same as Upshaw's (1959) Sphagnumsporites crassatus.

Genus Taurocusporites Stover 1962

Type species Taurocusporites sigmentatus Stover 1962

Taurocusporites reduncus (Bolkovitina) Stover 1962

Plate 7, Figure 16

1962 Micropaleontology, v. 8, no. 1, p. 57, pl. 1, figs. 15-21.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7756-A, 49.0 x 105.4.

Remarks: This spore is the same as Upshaw's (1959) Stereozonosporites verrucosus.

Taurocusporites cf. T. sigmentatus Stover 1962

Plate 7, Figures 2, 5

1962 Micropaleontology, v. 8, no. 1, pp. 56-57, pl. 1, figs. 1-14.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7599-A, 41.4 x 101.8.

Genus Tentaculispora (Manuscript name)

Diagnosis: Upshaw (1959) describes this genus as follows: "Spores are radial, trilete, circular to broadly triangular in equatorial outline. The spore coat is smooth to variously ornamented. A prominent equatorial flange is

usually broadest in the interlaesural areas giving the spore a rounded outline. The flange may be noticeably thinner at the apices. A prominent tentacular thickening is present on the distal surface. Characteristically, this consists of a circular ridge about 15 microns in diameter, enclosing a lumen about 6 microns in diameter. The circular ridge gives rise to several radiating, sinuous ridges which may or may not extend to and across the flange. These ridges become progressively less prominent toward their distal ends. The trilete mark is distinct; the rays are bordered by a prominent, raised lip which is continuous around the ends of the rays and which reaches the inner edge of the flange."

Tentaculispora conspicua (Manuscript name)

Plate 7, Figures 15, 17

Diagnosis: Upshaw (1959) describes this species as follows: "The greatest diameter ranges from 57 to 69 microns. The spore coat is smooth. The central spore body is distinctly triangular in outline, whereas the flange is broadest in the interlaesural areas giving the spore a rounded outline. The flange may be noticeably thinner at the apices. A prominent tentacular thickening is present on the distal surface. This consists of a circular ridge about 15 microns in diameter, enclosing a lumen about 6 microns in diameter. The circular ridge gives rise to several radiating, sinuous ridges which may or may not extend to and across the flange. These ridges become progressively less prominent toward their distal ends. The trilete markiis distinct; the rays are bordered by a prominent, raised lip which is continuous around the ends of the rays and which reaches the inner edge of the flange. The spore coat is relatively thin. The color is light yellowish brown."

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7477-B, 42.9 x 96.0.

Genus Tetrahedrospora (Manuscript name)

Diagnosis: Upshaw (1959) describes this genus as follows: "Spores are radial, trilete, broadly triangular with convex sides in equatorial contour. The spore coat consists of a thin, translucent to transparent exine supported by thick, rigid areas arranged like the edges of a tetrahedron. Three of these thickenings are

peripheral to the distal surface. The other three form prominent lips bordering the trilete rays, and join the distal thickenings at their extremities. The trilete mark is distinct; the rays extend to the equator. Folding of the thin spore coat is common on the tetrahedral faces."

Tetrahedrospora dyscrita (Manuscript name)

Plate 8, Figures 4, 6

Diagnosis: Upshaw (1959) describes this species as follows: "The greatest diameter ranges from 70 to 74 microns. The spore coat is thin, laevigate, wrinkled, but supported by heavy ridges forming a peripheral triangular area on the distal side and running along the rays on the proximal side. The trilete mark is a thin line of commissure; the rays extend to the periphery and are bordered by low, heavy ridges. The color is pale yellow, translucent; the ridges are dark brown."

Occurrence: rare, restricted to zone C.

Reference specimen: slide Pb 7448-A, 42.8 x 92.9.

Genus Todisporites Couper 1958

Type species Todisporites major Couper 1958

Todisporites minor Couper 1958

Plate 9, Figure 2

1958 Palaeontographica, v. 103, Abt. B, pl 135, pl. 16, figs. 9, 10.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7437-A, 43.9 x 94.8.

Remarks: Upshaw (1959) illustrates several spores that may be the same as Todisporites minor.

Genus Trilobosporites Pant ex. Potonie 1956

Type species Trilobosporites hannonicus (Delcourt and Sprumont) Potonie 1956

Trilobosporites crassus Brenner 1963

Plate 9, Figure 1

1963 Maryland Dept. Geol., Mines and Water Res., Bull. 27, p. 70, pl. 23, fig. 2.

Occurrence: rare, found only in zone A.

Reference specimen: slide Pb 7595-A, 42.1 x 98.0.

Remarks: This spore may be identical to Upshaw's (1959) Trilobosporites ampligibbosus.

Genus Undulatisporites Pflug 1953

Type species Undulatisporites microcutis Pflug 1953

Undulatisporites scabratus (Manuscript name)

Plate 7, Figure 13

Diagnosis: Upshaw (1959) describes this species as follows: "The corners are rounded and the sides are more or less straight. The greatest diameter ranges from 43 to 53 microns. The surface is scabrate, infrapunctate. The trilete mark is distinct; the rays extend to the equator, undulate, are not raised, and may or may not have a faint margo. The spore coat is moderately thick; folds are rare. The color is light greenish-yellow.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7594-B, 42.9 x 98.3.

Undulatisporites sp. 1

Plate 7, Figure 12

Diagnosis: Spore triangular to slightly convex. Diameter 23 microns. Surface smooth. Trilete mark distinct; rays extend to equator, strongly undulating and raised.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7475-A, 43.0 x 101.8.

Genus Verrucosisporites Ibrahim emend. Potonie and Kremp 1954

Type species Verrucosisporites verrucosus Ibrahim emend. Potonie and Kremp 1954

Verrucosisporites pustulatus (Manuscript name)

Plate 7, Figure 14

Diagnosis: Upshaw (1959) describes this species as follows: "The greatest diameter ranges from 36 to 44 microns. The surface is covered with low verrucae which vary from 1.0 to 4.5 microns in diameter and are rounded to polygonal in shape. The narrow spaces between the verrucae appear as a negative reticulum. The trilete mark is simple; the rays extend about 3/4 the spore radius. The wall is moderately thick. The color is light greenish-yellow."

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7595-A, 40.6 x 93.3.

Verrucosisporites cf. V. rotundus Singh 1964

Plate 8, Figures 7, 8

1964 Res. Coun. Alberta Bull. 15, p. 96, pl. 13, fig. 3.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7437-A, 50.0 x 103.4.

Remarks: To few specimens were found to be positive of the identification.

Unclassified Trilete Spores

Trilete scrabrate sp. 1

Plate 6, Figure 1

Diagnosis: Trilete spore, rounded to subrounded in outline. Greatest diameter 45 microns. Surface scabrate to finely granulose. Trilete mark indistinct.

Occurrence: rare, found only at Lucerne Anticline section.

Reference specimen: slide Pb 7595-A, 38.0 x 99.1.

Remarks: This species was used as a catchall for scrabrate spores which generally fit the diagnosis.

Trilete spiny sp. 1

Plate 8, Figure 5

Diagnosis: Spores whose surface bares numerous small, blunt spines. Diameter 20 microns.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7446-A, 39.8 x 104.4.

Remarks: This species was used as a catchall for spiny spores which generally fit the diagnosis. Upshaw's (1959) Raistrickia mesozoica would fall in this group.

Trilete spiny sp. 2

Plate 8, Figure 2

Diagnosis: Spores whose surface bears numerous pointed spines. Diameter 30 to 40 microns.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7477-B, 39.0 x 94.7.

Remarks: This species was used as a catchall for spiny spores that generally fit the diagnosis. Upshaw (1959) illustrates several spores that would fit in this group.

ANGIOSPERMOUS POLLEN

Genus Clavatipollenites Couper 1958

Type species Clavatipollenites hughesii Couper 1958

Clavatipollenites hughesii Couper 1958

Plate 9, Figure 5

1958 Palaeontographica, v. 103, Abt. B, p. 159, pl. 31. figs. 19-22.

Occurrence: rare, found only at Sherard Dome section.

Reference specimen: slide Pb 7437-A, 37.0 x 97.8.

Genus Liliacidites Couper 1953

Type species Liliacidites kaitangensis Couper 1953

Liliacidites cf. L. variegatus Couper 1953

Plate 9, Figure 6

1953 New Zealand Geol. Survey, Paleont. Bull. 32, p. 56, pl. 7, figs. 98,99.

Occurrence: rare, found only in zones A and B.

Reference specimen: slide Pb 7468-A, 43.0 x 98.8.

Genus Retitricolpites Van der Hammen ex. Pierce 1961

Type species Retitricolpites ornatus Van der Hammen 1956

Retitricolpites cf. R. georgensis Brenner 1963

Plate 9, Figure 7

1963 Maryland Dept. Geol., Mines and Water Res., Bull. 27, p. 91, pl. 38, figs. 6, 7.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7476-A, 47.3 x 102.3.

Retitricolpites paraneus Norris 1967

Plate 9, Figures 3, 4

1967 Palaeontographica, v. 120, Abt. B, p. 109, pl. 18, figs. 15-20.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7477-B, 32.8 x 93.1.

Retitricolpites vulgaris Pierce 1961

Plate 9, Figure 8

1961 Univ. Minn., Minn. Geol. Surv., Bull. 42, p. 50, figs. 101-102.

Occurrence: rare, common in all sections.

Reference specimen: slide Pb 7437-A, 42.6 x 96.4.

Remarks: Upshaw's (1959) Tricolpate Type 6 appears to be the same as R. vulgaris.

Genus Tricolpites Cookson ex. Couper 1953

Type species Tricolpites reticulatus Cookson 1947

Tricolpites cf. T. bathyreticulatus Stanley 1965

Plate 9, Figure 9

1965 Bull. Amer. Palaeont., v. 49, no. 222, p. 320, pl. 47, figs. 18-23.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7474-B, 37.8 x 92.8.

Tricolpites parvus Stanley 1965

Plate 9, Figure 10

1965 Bull. Amer. Palaeont., v. 49, no. 222, p. 322, pl. 47, figs. 28-31.

Occurrence: rare to occasional, ubiquitous form, common to all sections.

Reference specimen: slide Pb 7470-A, 30.3 x 100.2.

Remarks: Upshaw's (1959) Tricolpate Type 2 may be the same as T. parvus.

Tricolpites cf. T. reticulatus Cookson 1947

Plate 9, Figure 11

1947 Science Repts., Ser. A, v. 2, pt. 8, p. 134, pl. 15, fig. 45.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7470-A, 31.3 x 104.6.

Tricolpites sagax Norris 1967

Plate 9, Figure 12

1967 Palaeontographica, v. 120, Abt. B, p. 107, pl. 17, figs. 12-19.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7436-A, 32.9 x 107.6.

Genus Tricolpopollenites Pflug and Thomson in Thomson and Pflug 1953

Type species Tricolpopollenites parmularius Pflug and Thomson in Thomson and Pflug 1953

Tricolpopollenites henrici (Potonie)
Pflug and Thomson 1953

Plate 9, Figure 13

1953 Palaeontographica, v. 94, Abt. B, p. 95, pl. 11, figs. 59-61.

Occurrence: rare to common, ubiquitous form found in all samples.

Reference specimens: slide Pb 7470-A, 41.5 x 104.2; Pb 7474-B, 34.4 x 93.9.

Remarks: Upshaw's (1959) Tricolpate Type 1, 7, and 8 may be the same as this pollen grain.

Tricolpopollenites sp. 3

Plate 9, Figure 16

Diagnosis: Thompson (1969) describes this type as follows: "preserved in polar view; polar view open circular to intersubangular; psilate (corroded?); exine about one micron thick; colpi with smooth margins, endexine extending across colpi as a thin granular membrane; polar area index 1:3.5; diameter 15 to 20 microns."

Occurrence: rare to occasional, ubiquitous form found in nearly all samples.

Reference specimen: slide Pb 7518-A, 34.4 x 105.3.

Remarks: Upshaw's (1959) Tricolpate Type 4 is the same as T. sp. 3.

GYMNOSPERMOUS POLLEN

Because of poor preservation it was necessary to lump some taxa into the genus-type categories listed below.

Genus Alisporites Daugherty 1941

Type species Alisporites oppii Daugherty 1941

Alisporites-type pollen

Plate 10, Figure 1

Occurrence: rare to common, found in all sections.

Reference specimen: slide Pb 7473-A, 29.6 x 98.8.

Genus Caytonipollenites Couper 1958

Type species Caytonipollenites pallidus (Reissinger) Couper 1958

Caytonipollenites pallidus (Reissinger) Couper 1958

Plate 11, Figure 4

1958 Palaeontographica, v. 103, Abt. B, p. 150, pl. 26, figs. 7-8.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7518-A, 31.5 x 102.5.

Genus Circulina Maljawkina ex. Klaus 1960

Type species Circulina meyeriana Klaus 1960

Circulina parva Brenner 1963

Plate 12, Figure 3

1963 Maryland Dept. Geol., Mines and Water Res., Bull. 27, p. 84, pl. 34, figs. 2, 3.

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7617-A, 46.6 x 98.5.

Genus Classopollis Pflug emend. Pocock and Jansonius 1961

Type species Classopollis classoides Pflug emend. Pocock and Jansonius 1961

Classopollis classoides Pflug emend. Pocock and Jansonius 1961

Plate 10, Figure 2

1961 Micropaleontology, v. 7, p. 439-449, pl. 1

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7518-A, 30.5 x 99.5.

Genus Cycadopites Wodehouse ex. Wilson and Webster 1946

Type species Cycadopites follicularis Wilson and Webster 1946

Cycadopites fragilis Singh 1964

Plate 10, Figure 4

1964 Res. Coun. Alberta, Bull. 15, p. 103, pl. 14, fig. 2.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7518-A, 33.3 x 96.6.

Cycadopites scabratus Stanley 1965

Plate 10, Figure 7

1967 Bull. Amer. Paleont., v. 49, no. 222, p. 271, pl. 37, figs. 10-15.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7474-B, 35.5 x 96.9.

Genus Equisetosporites Daugherty emend. Singh 1964

Type species Equisetosporites chinleana Daugherty 1941

Equisetosporites multicostatus (Brenner) Norris 1967

Plate 10, Figure 6

1967 Palaeontographica, v. 120, Abt. B, pl 14, pl. 16, fig. 15.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7436-A, 44.4 x 100.3.

Genus Eucommiidites Erdtman emend. Hughes 1961

Type species Eucommiidites troedssonii Erdtman 1948

Eucommiidites minor Groot and Penny 1960

Plate 10, Figure 5

1960 Micropaleontology, v. 6, p. 234, pl. 2, fig. 14.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7436-A, 30.9 x 105.2.

Eucommiidites troedssonii Erdtman 1948

Plate 10, Figure 8

1948 Geol. Foren. Forh., v. 70, p. 267, text-figs. 5-10, 12-13.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7518-A, 42.3 x 102.1.

Genus Inaperturopollenites Pflug ex. Thomson and Pflug emend. Potonie 1958

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

Inaperturopollenites dubius (Potonie and Venitz) Thomson and Pflug 1953

Plate 10, Figure 9

1953 **Palaeontographica**, v. 94, Abt. B, p. 65, pl. 4, fig. 89; pl. 5, figs. 1-13.

Occurrence: **rare** to common, ubiquitous form found in **all sections.**

Reference specimen: slide Pb 7436-A, 49.6 x 99.4.

Inaperturopollenites hiatus (Potonie) Pflug and Thomson in Thomson and Pflug 1953

Plate 10, Figure 3

1953 **Palaeontographica**, v. 94, Abt. B, p. 65, pl. 5, figs. 14-20.

Occurrence: rare to common, ubiquitous form found in **all sections.**

Reference specimen: slide 7470-A, 32.1 x 96.3.

Inaperturopollenites pseudoreticulatus Brenner 1963

Plate 12, Figure 2

1963 **Maryland Dept. Geol., Mines and Water Res. Bull. 27,** p. 72, pl. 24, fig. 2.

Occurrence: **rare**, found only in zone A **at Sherard Dome.**

Reference specimen: slide Pb 7438-A, 33.2 x 100.7.

Genus Laricoidites Potonie 1958

Type species Laricoidites magnus (Potonie) Potonie, Thomson, Thiergart (1950)

Laricoidites cf. L. magnus (Potonie) Potonie, Thomson Thiergart 1950

Plate 11, Figure 8

1950 Geol. Jahrb., v. 65, p. 48, pl. C, figs. 9-10.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7436-A, 43.2 x 98.7.

Remarks: This taxa was used as a catchall for large (60-80 microns) inaperturate grains.

Genus Phyllocladidites Cookson ex. Couper 1953

Type species Phyllocladidites mawsonii Cookson 1947

Phyllocladidites-type pollen

Plate 10, Figure 10

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7468-A, 40.8 x 105.5.

Genus Pityosporites Steward emend. Manum 1960

Type species Pityosporites antarcticus Steward 1914

Pityosporites-type pollen

Plate 10, Figure 11

Occurrence: rare, common to all sections.

Reference specimen: slide Pb 7472-A, 40.1 x 93.9.

Genus Podocarpidites Cookson ex. Couper 1953

Type species Podocarpidites ellipticus Cookson 1947

Podocarpidites-type pollen

Plate 10, Figure 12

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7469-A, 39.6 x 93.8.

Genus Rugubivesiculites Pierce 1961

Type species Rugubivesiculites convolutus Pierce 1961

Rugubivesiculites reductus Pierce 1961

Plate 10, Figure 13
Plate 11, Figure 1

1961 Univ. Minn., Minn. Geol. Surv., Bull. 42, p. 41, pl. 2, figs. 64-65.

Occurrence: rare, found in all sections.

Reference specimens: slide Pb 7471-C, 42.8 x 106.4; Pb 7518-B, 43.7 x 92.6.

Genus Tsugapollenites Potonie and Venitz 1934

Type species Tsugapollenites igniculus (Potonie) Potonie and Venitz 1934

Tsugapollenites-type pollen

Plate 11, Figure 2

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7437-A, 41.2 x 91.6.

Genus Schizosporis Cookson and Dettmann 1959

Type species Schizosporis reticulatus Cookson and Dettmann 1959

Schizosporis cf. S. parvus Cookson and Dettmann 1959

Plate 11, Figure 6

1959 Micropaleontology, v. 5, p. 216, pl. 1, fig. 15-20.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7438-A, 47.8 x 96.1.

Remarks: The affinity of Schizosporis is not known. Therefore, some authors place it in the categroy Incertae Sedis.

Schizosporis scabratus Stanley 1965

Plate 11, Figure 3

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 269, pl. 35, figs. 10-.7.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7438-A, 33.0 x 96.6.

Unclassified Gymnospermous Pollen

Monosulcate type 1

Plate 11, Figure 5

Diagnosis: These are smooth to scabrate. Each is broadly oval to round and bears a prominent sulcus. Diameters range from 50 to 70 microns. Exine is very thick (4-5 microns).

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7468-A, 40.1 x 106.1.

Remarks: This taxa is the same as Upshaw's (1959) Monosulcate type 1. He refers it to the genus Androstrobus.

Monosulcate type 2

Plate 11, Figure 7

Diagnosis: These forms are elongate-oval with somewhat pointed ends. Length 70 microns, width 35 microns. A prominent sulcus runs the length of the body.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7477-B, 43.1 x 89.6.

Remarks: This taxa is the same as Upshaw's (1959) Monosulcate type 2.

Group ACRITARCHA Evitt 1963

Subgroup ACANTHOMORPHITA Downie, Evitt and Sarjeant 1963

Genus Baltisphaeridium Eisenack emend. Downie and Sarjeant 1963

Type species Baltisphaeridium longispinosum (Eisenack) Eisenack 1958

Baltisphaeridium multispinosum Singh 1964

Plate 12, Figure 4

1964 Res. Coun. Alberta, Bull. 15, p. 141, pl. 20, figs. 1-2.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7471-C, 38-6 x 90.5.

Remarks: This taxa is probably the same as Upshaw's (1959) Hystrichosphaerida Type 8.

Genus Michrystridium Deflandre emend. Downie and Sarjeant 1963

Type species Michrystridium inconspicum Deflandre 1935

Michrystridium spp.

Plate 12, Figures 5-9

Occurrence: rare to abundant, ubiquitous species found in nearly all samples.

Reference specimens: slides Pb 7471-C, 49.9 x 101.9; Pb 7474-B, 43.9 x 95.5; Pb 7475-A, 29.1 x 91.1; Pb 7518-A, 28.4 x 106.2; Pb 7477-B, 44.0 x 90.1.

Remarks: Because of the various degrees of preservation of these small acritarchs consistent identification was only made at the genus level.

Form X sp. 1

Plate 12, Figure 10

Diagnosis: oval in outline; "periphragm" held up by numerous crowded very short (1-2 microns) processes; overall diameter 15-20 microns.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7588-A, 40.6 x 99.7.

Remarks: This form, described by Thompson (1969), was set up for use in the Cretaceous palynology studies at Michigan State University.

Subgroup POLYGONOMORPHITAE Downie, Evitt, and Sarjeant 1963

Genus Veryhachium (Deunff) Downie and Sarjeant 1963

Type species Veryhachium trisulcum Deunff 1951

Veryhachium cf. V. europenum Stockmans and Williere 1960

Plate 12, Figures 11, 12

1960 Senck. leth., v. 41, no. 1/6, p. 3, pl. 2, fig. 25.

Occurrence: rare, found in all sections.

Reference specimens: slide Pb 7587-D, 50.7 x 105.6; 37.8 x 99.4.

Veryhachium cf. V. stellatum Deflandre 1946

Plate 12, Figures 17, 18

1946 Ann. Paleon., v. 30.

Occurrence: rare, found in all sections.

Reference specimens: slide Pb 7587-D, 33.0 x 93.7; Pb 7592-A, 47.2 x 99.5.

Veryhachium cf. V. trisuleum Deunff 1951

Plate 12, Figure 1

1951 C.R. Acad. Sci., Paris, v. 233, pp. 321-323, figs. 1-6.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7587-D, 45.9 x 97.2.

Veryhachium sp. 1

Plate 12, Figure 15

Diagnosis: Central body slightly polygonal spheroid; psilate; processes 5 to 7, tapering, with acuminate tips, some curved, solid, with indentation of body cavity into bases a few microns; central body about 15 to 22 microns in diameter, processes about 12 to 15 microns long.

Occurrence: rare, found only in Lucerne Anticline section.

Reference specimen: slide Pb 7588-A, 35.6 x 90.9.

Remarks: This form, described by Thompson (1969), was set up for use in the Cretaceous palynology studies at Michigan State University.

Subgroup NETROMORPHITAE Downie, Evitt, and Sarjeant 1963

Genus Leiofusa Eisenack 1938

Type species Leiofusa fusiformis (Eisenack) Eisenack 1938

Leiofusa spp.

Plate 12, Figure 20

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7587-D, 35.8 x 101.4.

Remarks: No attempt was made to separate the species of Leiofusa.

Genus Metaleiofusa Wall 1965

Type species Metaleiofusa arcuata Wall 1965

Metaleiofusa spp.

Plate 12, Figure 19

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7588-A, 48.6 x 90.6.

Remarks: No attempt was made to separate the species of Metaleiofusa.

Subgroup HERKOMORPHITAE Downie, Evitt and Sarjeant 1963

Genus Cymatiosphaera (O. Wetzel) Deflandre 1954

Type species Cymatiosphaera radiata O. Wetzel 1933

Cymatiosphaera sp. 1

Plate 12, Figure 13

Diagnosis: Diameter 10-15 microns.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7474-B, 35.0 x 97.3.

Cymatiosphaera sp. 2

Plate 12, Figure 14

Diagnosis: Diameter 20+ microns.

Occurrence: rare, found in all sections.

Reference specimen: slide 7475-A, 44.0 x 91.8.

Subgroup PTEROMORPHITAE Downie, Evitt, and Sarjeant 1963

Genus Pterospermopsis W. Wetzel 1952

Type species Pterospermopsis danica W. Wetzel 1952

Pterospermopsis spp.

Plate 12, Figure 16

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7472-A, 27.8 x 103.7.

Remarks: No attempt was made to separate the several apparent species of Pterospermopsis found in the Frontier.

Subgroup SPHAEROMORPHITAE Downie, Evitt and Sarjeant 1963

The several forms placed in this group were set up by Thompson (1969) for use in the Cretaceous palynology studies at Michigan State University. They are referred to by informal code name only.

Form B sp. 2

Plate 13, Figure 3

Diagnosis: Granular to coarsely granular, 30 to 55 microns spheres; often broken and/or folded, thin walled.

Occurrence: rare to occasional, ubiquitous form common to all sections.

Reference specimen: slide Pb 7472-A, 44.3 x 89.3.

Form B sp. 4

Plate 13, Figure 2

Diagnosis: Smooth, 60 to 70 microns, ellipsoidal, wrinkled, thin-walled.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7592-A, 47.3 x 99.1.

Form C sp. 1

Plate 13, Figure 5

Diagnosis: Smooth, 15 to 20 microns, discoid to spherical, with medium to thick wall.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7477-B, 32.7 x 101.6.

Form C sp. 2

Plate 13, Figure 6

Diagnosis: Smooth, less than 15 microns, spherical, with medium wall thickness.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7475-A, 44.9 x 101.4.

Form C sp. 3

Plate 13, Figure 4

Diagnosis: Smooth, 25 to 35 microns, spherical, thick-walled, characteristically a fold in surface.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7589-A, 49.1 x 106.4.

ALGAE

DINOFLAGELLATES

Cyst-Family GONYAULACYSTACEAE Sarjeant and Downie 1966

Genus Gonyaulacysta (Deflandre) Sarjeant in Davey, et al 1966

Type species Gonyaulacysta jurassica (Deflandre) Gorka 1965

Gonyaulacysta cf. G. edwardsi (Cookson and Eisenack) Clark and Verdier 1967

Plate 13, Figure 7

1967 Verh. Kon. Ned. Akad. Wet., first series, part 24, no. 3, p. 31, pl. 5, fig. 1.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7732-C, 43.4 x 100.8.

Gonyaulacysta spp.

Plate 13, Figure 8

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7436-A, 35.3 x 96.9.

Remarks: Due to poor preservation of many of the dinoflagellates it was necessary to lump those of the genus Gonyaulacysta together, with the exception of G. edwardsi. Upshaw's (1959) Dinoflagellate type 1 appears to be in the genus Gonyaulacysta.

Cyst-Family FORMEACEAE Sarjeant and Downie 1966

Genus Formea Cookson and Eisenack 1958

Type species Formea amphora Cookson and Eisenack 1958

Formea amphora Cookson and Eisenack 1958

Plate 13, Figure 1

1958 Proc. Royal Soc. Victoria, v. 70, part 1, p. 56, pl. 5, figs. 10-11.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7588-A, 46.9 x 105.4.

Cyst-Family PERIDINIACEAE Sarjeant and Downie 1966

Genus Apteodinium Eisenack 1958

Type species Apteodinium granulatum Eisenack 1958

Apteodinium granulatum Eisenack 1958

Plate 14, Figure 1

1958 Neues Jb. Geol. Palaeont., Abh. 106, p. 386, pl. 23, figs. 8-14, ill. 1.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7446-A, 40.9 x 104.3.

Genus Spinidinium Cookson and Eisenack 1962

Type species Spinidinium styloniferum Cookson and Eisenack 1965

Spinidinium microceratum Stanley 1965

Plate 14, Figure 2

1965 Bull. Amer. Paleont., v. 49, no. 222, pp. 227-228, pl. 22, figs. 5-6.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7446-A, 39.9 x 101.0.

Cyst-Family BROOMEACEAE Sarjeant and Downie 1966

Genus Broomea Cookson and Eisenack 1958

Type species Broomea ramosa Cookson and Eisenack 1958

Broomea cf. B. jaegeri Alberti 1961

Plate 14, Figure 3

1961 Palaeontographica, v. 116, Abt. A, p. 26, pl. 5, figs. 1-7.

Occurrence: rare, found only in zone A at the Cody section.

Reference specimen: slide Pb 7743-A, 47.0 x 103.0.

Remarks: Too few specimens were found to be certain of the identification at the species level.

Genus Canningia Cookson and Eisenack 1960

Type species Canningia reticulata Cookson and Eisenack 1960

Canningia cf. C. reticulata Cookson and Eisenack 1960

Plate 14, Figure 4

1960 Palaeontology, no. 2, p. 251, pl. 38, figs. 1-2.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7438-A, 42.5 x 99.4.

Canningia cf. C. rotundata Cookson and Eisenack 1961

Plate 14, Figure 5

1961 Proc. Roy. Soc. Victoria, v. 74, p. 72, pl. 12, figs. 1-5.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7756-A, 36.4 x 101.3.

Remarks: Due to poor preservation there is some doubt as to whether the specimens placed in this group are truly C. rotundata.

Canningia cf. C. senonica Clark and Verdier 1967

Plate 14, Figure 6

1967 Verh. Kon. Ned. Akad. Wet., first series, part 24, no. 3, p. 20, pl. 1, figs. 12-14, text-fig. 7.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7595-A, 39.7 x 94.8.

Cyst-Family HYSTRICHOSPHAERIDIACEAE (Evitt) Sarjeant and Downie 1966

Genus Hystrichokolpoma Klumpp 1953

Type species Hystrichokolpoma cinctum Klumpp 1953

Hystrichokolpoma ferox (Deflandre) Davey et al 1966

Plate 15, Figure 1

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 181.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7629-A, 49.9 x 108.3.

Genus Hystrichosphaeridium Deflandre 1937

Type species Hystrichosphaeridium tubiferum (Ehrenberg) Davey and Williams in Davey et al 1966

Hystrichosphaeridium spp.

Due to poor preservation it was necessary to refer some specimens to this taxon if they possessed a central body with processes of the type and number most like Hystrichosphaeridium species.

Genus Oligosphaeridium Davey and Williams in Davey et al 1966

Type species Oligosphaeridium complex (White) Davey and Williams in Davey et al 1966

Oligosphaeridium spp.

Plate 14, Figure 7

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7437-A, 28.8 x 105.4.

Remarks: Upshaw's (1959) Hystrichosphaerida Type 1 appears to be in the genus Oligosphaeridium.

Genus Tanyosphaeridium Davey and Williams in Davey et al 1966

Type species Tanyosphaeridium variecalamum Davey and Williams in Davey et al 1966

Tanyosphaeridium cf. T. variecalamum Davey and Williams in Davey et al 1966

Plate 15, Figures 3, 4

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 98, pl. 6, fig. 7, text-fig. 20.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7741-A, 36.8 x 96.0.

Cyst-Family MICRODINIACEAE (Eisenack) Sarjeant and Downie 1966

Genus Microdinium Cookson and Eisenack emend. Sarjeant in Davey et al 1966

Type species Microdinium ornatum Cookson and Eisenack 1960

Microdinium cf. M. irregulare Clark and Verdier 1967

Plate 15, Figure 5

1967 Verh. Kon. Ned. Akad. Wet., first series, part 24, no. 3, p. 65, pl. 7, figs. 5-8, text-fig. 27.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7588-A, 43.3 x 93.5.

Remarks: Upshaw's (1959) Hystrichosphaerida Type 10 is probably a species of Microdinium.

Cyst-Family EXOCHOSPHAERIDIACEAE Sarjeant and Downie 1966

Genus Exochosphaeridium Davey and Williams in Davey et al 1966

Type species Exochosphaeridium phragmites Davey et al 1966

?Exochosphaeridium phragmites Davey et al 1966

Plate 15, Figure 2

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 165, pl. 2, figs. 8-10.

Occurrence: rare to occasional, found in all sections.

Reference specimen: slide Pb 7436-A, 35.5 x 100.1.

Remarks: This species is easily confused with Cleistosphaeridium. Therefore the genus is questioned.

Cyst-Family HYSTRICHOSPHAERACEAE (O. Wetzel) Evitt emend. Sarjeant and Downie 1966

Genus Hystrichosphaera (O. Wetzel) Deflandre 1937

Type species Hystrichosphaera ramosa (Ehrenberg) O. Wetzel 1933

Hystrichosphaera ramosa (Ehrenberg) O. Wetzel 1933

Plate 15, Figures 6, 7

1933 Palaeontographica, v. 78, pp. 35-36, pl. 5, figs. 7, 8, 10-12, 18, 19.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7638-A, 50.9 x 105.5.

Remarks: No attempt was made to separate the various sub-species of H. ramosa set up by Davey and Williams (Davey et al, 1966). Due to the difficulty in separating H. ramosa from H. furcata, some of the latter may be included here.

Cyst-Family DEFLANDREACEAE (Eisenack) Sarjeant and Downie 1966

Genus Ascodinium Cookson and Eisenack 1960

Type species Ascodinium acrophorium Cookson and Eisenack 1960

Ascodinium scabrosum Cookson and Hughes 1964

Plate 16, Figure 1

1964 Paleontology, v. 7, p. 40, pl. 5, figs. 1-3.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7591-A, 42.9 x 90.9.

Ascodinium verrucosum Cookson and Hughes 1964

Plate 16, Figure 2

1964 Paleontology, v. 7, p. 41, pl. 5, figs. 4-7.

Occurrence: occasional to abundant, restricted to zone A.

Reference specimen: slide Pb 7518-A, 38.8 x 97.5.

Remarks: Upshaw's (1959) Dinoflagellata Type 6 is the same as A. verrucosum.

Genus Deflandrea Eisenack emend. Williams and Downie in Davey et al 1966

Type species Deflandrea phosphoritica Eisenack 1938

Deflandrea cf. D. acuminata Cookson and Eisenack 1958

Plate 16, Figure 5

1958 Proc. Roy. Soc. Victoria, v. 70, p. 27, pl. 4, figs. 5-8.

Occurrence: occasional to abundant, ubicquitous form found in all sections.

Reference specimen: slide Pb 7518-A, 34.2 x 89.5.

Remarks: Upshaw's (1959) Dinoflagellata Type 8 appears to be the same as D. acuminata.

Deflandrea cf. D. cooksonii Alberti 1959

Plate 16, Figures 3,6

1959 Geol. Staatsinst. Hamburg, Mitt., v. 28, p. 97, pl. 9, figs. 1-6.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7636-C, 31.6 x 95.0.

Remarks: Upshaw's (1959) Dinoflagellata Type 10 appears to be the same as D. cooksonii.

Deflandrea echinoidea Cookson and Eisenack 1960

Plate 16, Figure 4

1960 Micropaleontology, v. 6, no. 1, p. 2, pl. 1, figs. 5-6.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7744-D, 45.9 x 104.2.

Remarks: Upshaw's (1959) Dinoflagellata Type 9 appears to be the same as D. echinoidea.

Deflandrea victoriensis Cookson and Manum 1964

Plate 16, Figure 7

1964 Proc. Roy. Soc. Victoria, v. 77, p. 522, pl. 76, figs. 3-8.

Occurrence: rare to common, restricted to zone C.

Reference specimen: slide Pb 7636-C, 38.1 x 108.0.

Remarks: Upshaw's (1959) Dinoflagellata Type 2 is the same as D. victorensis.

Cyst-Family ENDOSCRINIACEAE Sarjeant and Downie 1966

Genus Palaeohystrichophora (Deflandre) Deflandre and Cookson 1955

Type species Palaeohystrichophora infusorioides Deflandre 1934

Palaeohystrichophora infusorioides Deflandre 1934

Plate 17, Figures 1, 2

1934 Compte. Rende Acad. Sci. France, v. 199, p. 967, pl. fig. 8.

Occurrence: rare to occasional, restricted to subzone B_2 and zone C.

Reference specimen: slide Pb 7625-A, 47.9 x 103.8.

Cyst-Family PSEUDOCERATIACEAE Sarjeant and Downie 1966

Genus Odontochitina Deflandre 1935

Type species Odontochitina striatoperforata Cookson and Eisenack 1962

Odontochitina costata (Albert) Clark and Verdier 1967

Plate 17, Figure 5

1967 Verh. Kon. Ned. Akad. Wet., first series, part 24, no. 3, p. 58, pl. 13, figs. 4-6.

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7732-C, 42.9 x 102.0.

Remarks: Clark and Verdier (1967) believe O. striatoperforata is synonymous with O. costata.

Odontochitina operculata (Wetzel) Deflandre and Cookson 1955

Plate 17, Figures 3, 4

1955 Austr. Jour. Marine and Freshwater Res., v. 6, pp. 291-292, pl. 3, figs. 5-6.

Occurrence: rare, found only in zone C at Lucerne Anticline.

Reference specimens: slide Pb 7629-A, 40.3 x 95.5; 43.8 x 107.6.

Form F sp. 1

Plate 18, Figure 6

Diagnosis: A distinct form; three large processes, one antapical and one "dog-leg" postcingular; in addition smaller Hystrichosphaeridium-like processes; tabulation not determined; apical (tetratabular) archeopyle.

Occurrence: rare, found only in zone C at Lucerne Anticline.

Reference specimen: slide Pb 7636-C, 31.6 x 95.0.

Remarks: This form was described by Thompson (1969) for use in the Cretaceous palynology studies at Michigan State University. This form is very much like Forma H (Evitt, 1961) from the Senonian of West Pakistan. It is believed that further study will show that Form F sp. 1 is the same as Pseudoceratum ceratioides (Deflandre) Deflandre which has a stratigraphic range in England of Middle Cenomanian to Campanian (Clark and Verdier 1967).

Cyst-Family MEMBRANILARNACACEAE Sarjeant and Downie 1966

Genus Chalydophorella Cookson and Eisenack 1958

Type species Chalydophorella nyei Cookson and Eisenack 1958

Chalydophorella discreta Clark and Verdier 1967

Plate 18, Figure 5

1967 Verh. Kon. Ned. Akad. Wet., first series, part 24, no. 3, p. 24, pl. 2, figs. 9-10, text-fig. 9.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7436-A, 42.0 x 95.8.

INCERTAE SEDIS

Genus Botrycoccus Kutzing

Botrycoccus sp.

Plate 18, Figure 7

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7468-A, 38.6 x 96.6.

Remarks: No attempt was made to break down this genus at the species level.

Genus Cyclopsiella Drugg and Loeblich 1967

Type species Cyclopsiella elliptica Drugg and Loeblich 1967

?Cyclopsiella sp. 1

Plate 18, Figure 4

Diagnosis: Cyst, ellipsoidal in outline; length 40 to 50 microns; circular aperture, 10 microns in diameter present below apex. A distinct constriction occurs slightly below the equator.

Occurrence: rare, found only in zone A at Lucerne Anticline.

Reference specimen: slide Pb 7599-A, 43.1 x 106.0.

Remarks: Drugg and Loeblich (1967) describe two species of Cyclopsiella from the Oligiocene of Mississippi.

Genus Horologinella Cookson and Eisenack 1962

Type species Horologinella apiculata Cookson and Eisenack 1962

Hologinella apiculata Cookson and Eisenack 1962

Plate 18, Figure 2

1962 Proc. Roy. Soc. Victoria, v. 75, p. 272, pl. 37, fig. 4.

Occurrence: rare, restricted to zone B.

Reference specimen: slide Pb 7474-B, 32.6 x 96.0.

Genus Palaeoperidinium Deflandre emend. Sarjeant 1967

Type species Palaeoperidinium pyrophorum Deflandre emend. Sarjeant 1967

Palaeoperidinium cretaceum Pocock 1962

Plate 16, Figure 8

1962 Palaeontographica, v. 111, Abt. B, p. , pl. 14, figs. 219-221.

Occurrence: rare, restricted to zone A.

Reference specimen: slide Pb 7436-A, 37.6 x 93.4.

Palaeoperidinium spp.

Plate 18, Figures 1, 3

Occurrence: rare, found in all sections.

Reference specimen: slide Pb 7620-A, 43.8 x 104.1.

Remarks: No attempt was made to separate the species of Palaeoperidinium with the exception of P. cretaceum.

V. ZONATION AND CORRELATION

Physical Methods

The correlations presented in Figure 3 are based upon previously described sections as well as new sections measured during this study. All of the previously described sections (except Anchor Anticline) were remeasured and described in order to maintain a high level of consistency for stratigraphic interpretation. In addition to the eight sections used here, some 18 other localities were visited and many miles of outcrop traced in order to establish the continuity of various sand units within the Frontier. Bentonites, sandstones, lignitic zones, beds of siliceous or bentonitic shale and concretion zones have been used as marker beds.

The base of the Frontier is established at a distinctive bentonite which is traceable in the subsurface into the Clay Spur Bentonite of the Black Hills (Goodell, 1962, p. 177). This is horizon #1 on the cross section. The thickness of this bentonite was found to range from 3.8 feet, at Cody, to 6.8 feet, at Anchor Anticline. Outside of the Big Horn Basin, it reaches a maximum thickness in the southwestern part of the state where it is

20 to 40 feet thick, thus indicating a source to the southwest. In the subsurface the distinctive resistivity pattern of bentonites on electric logs makes them excellent markers. Indeed, it is possible to correlate several distinctive resistivity patterns in the Mowry and Frontier for great distances in the subsurface.

Horizons #2 through #4 comprise the basal sandstone complex known in northwestern Wyoming as the Peay Sanstone (equivalent to the Third Wall Creek Sandstone of the Powder River Basin). Only at Little Sheep Mountain is this sand a single lithologic unit. South and west of this section, the Peay Sandstone splits into a number of sandy units, reaching a maximum of five at Pitchfork Anticline. A maximum thickness of 400 feet is reached at the Anchor Anticline section in the southwest corner of the basin. The uppermost sandstone of the Peay complex, marked by horizon #4, is characterized by a black chert and andesite porphyry pebble conglomerate at its top.

The thickness of this unit at Cody, Lucerne Anticline, and Chabot Anticline is about the same (230, 220, and 280 feet, respectively). These thicknesses indicate that depositional strike was northwest-southeast and the source of the sediments was to the southwest.

Horizon #3 is a bentonite that Burk (1953) traced across the southern margin of the basin. The correlation of this bentonite into the Pitchfork Anticline section from Anchor Anticline (Burk's westernmost section) is

somewhat questionable.

Horizons #5 and #6 are two bentonites that correlate along the eastern side of the basin. It is possible that bentonites on the western side of the basin (horizons #7 and #10) may extend across and tie into those on the east. However, there is no direct evidence, at this time, to make such a correlation. Goodell (1962, p. 182) mentions that in both the Big Horn Basin and the Powder River Basin the interval between the Third (#4) and Second (#8) Wall Creek Sandstones is a distinct lithosome. The unit consists of bentonitic silt and claystone that forms badland topography in outcrop and weathers into ironstone capped "organ-pipe" bluffs and irregular "popcorn" surfaces. It is in this interval that these bentonites occur.

The interval of the Second Wall Creek Sandstone, horizons #8 and #9, is best developed at Sherard Dome. Although there are sandy intervals in this position to the north of Sherard Dome, because they are poorly developed, they are not correlated with the Second Wall Creek Sandstone. The unit has been traced, however, across the southern and western parts of the basin. Several lines of evidence suggest that the top of this unit was subject to erosion or non-deposition and that a hiatus may be present, especially in the northern part of the basin. At Pitchfork Anticline, convergence of horizons #7 through #10 suggest the presence of several unconformities. The only "coal" beds, indicating continental deposition or

source (if not *in situ*), found in the basin are at the top of this unit, at Cody and Sherard Dome.

Along the eastern and southern margins of the basin, horizons #11 and #12 mark the Torchlight Sandstone (First Wall Creek Sandstone of the Powder River Basin). In this area, this is the uppermost sandstone of the Frontier and it is overlain by the Cody Shale. In the southwestern corner of the basin there are younger Frontier sands above the Torchlight (First Wall Creek) Sandstone. To the west, at Cody, Pitchfork Anticline and Anchor Anticline, the transgressive-regressive nature of this unit is very well developed. The lower regressive interval (#11-#12) varies from a massive unit to several thinner sandstones with interbedded shales which in most cases are non-marine. These shales, which typically weather lavender are usually associated with lignitic layers. The transgressive phase (#12-#13) is typically a quartzose, crossbedded sandstone, with some marine fossils.

At both Pitchfork and Anchor Anticlines there are sandstones of Niobrara age that occur higher in the section than the Torchlight (First Wall Creek) Sandstone. Horizons #14 and #15 correlate the uppermost sandstone at Pitchfork Anticline with an intermediate sandstone at Anchor Anticline. The uppermost sandstone at Anchor Anticline is the youngest Frontier Sandstone in the basin and is not correlative with sandstones in the other sections. Goodell (1962, Figure 13) shows that the post First Wall Creek Sandstone

interval is more or less restricted to the Wind River Basin (Fremont County), where it reaches a thickness to 350 feet. His map shows that the pinchout of this interval passes west of the Cody section, then swings southeast to include Pitchfork and Anchor Anticlines.

Paleontological Methods

Invertebrate Zonation

Correlation of individual units of the Frontier Formation on the basis of invertebrates, is difficult due to the sparse faunas. Of the mollusks that are present, most are long ranging pelecypods and gastropods that are known to occur in certain lithologies only.

The published fossil zones of Cobban and Reeside (1952b) for the Upper Cretaceous are shown in Figure 2. It is beyond the scope of this study to examine in detail the invertebrate fossil zones of the Upper Cretaceous. However, these data does show that the Frontier Formation is principally of Cenomanian and Turonian age and has equivalence in the Great Plains section from the base of the Upper Cretaceous through the Carlile Shale. The basal 400 to 600 feet of the Frontier is Belle Fourche (early Cenomanian) age, as indicated by Calycoceras sp., Acanthoceras? amphibolum Morrow and Acanthoceras? sp. A. The base is nearly everywhere conformable with the Mowry Shale (Albian). The middle 200 to 350 feet of the Frontier is of Greenhorn (late Cenomanian, early Turonian) age.

It is characterized by Dunveganoceras pondi Haas, Metoiceras praecox Haas and Inoceramus labiatus Schlotheim. The upper portion of the Frontier consists of 50 to 200 feet of sandy beds, including the First Wall Creek Sandstone, and is primarily of Carlile (upper Turonian) age as shown by Collignoniceras woollgari (Mantell), Collignoniceras hyatti (Stanton), Prionocyclus wyomingensis Meek, Scaphites whitfieldi Cobban and Prionocyclus reesidei Sidwell.

In the southwestern part of the Big Horn Basin and in the Wind River Basin, the series of sandstones that overlie the First Wall Creek sandstone are of early Niobrara (Coniacian) age. These sandstones are characterized by Inoceramus deformis Meek, Scaphites preventricosus Cobban and Scaphites ventricosis Meek and Hayden.

Palynological Zonation

As was described earlier in this report, the palynological zonation developed during this study is based on a qualitative analysis of the samples. Three sections, Cody, Lucerne Anticline and Sherard Dome, were examined in detail. The stratigraphic range of all palynomorphs described were plotted and a zonation established based on the stratigraphic range of selected taxa. This zonation was then applied to the other five sections.

Distribution of Individual Taxa

The stratigraphic ranges within the three reference

sections of all the palynomorphs comprise the data. These stratigraphic ranges may be either long ranging or of limited range; only the second being of stratigraphic value qualitatively. There are several factors that may contribute to the limiting of the range of an organism. These factors may operate singly or through interactions.

The overall distribution of living plants is controlled by climate. Whereas the local variations are controlled by local environmental factors. Thus, changes in climate or environment may bring about the evolutionary development of new plants. This would be expressed in the stratigraphic column by the introduction of new forms and the disappearance of old groups and species. Local environmental or climatic changes may result in the migration of plants out of the study area. These plants may appear later in the stratigraphic column as the plants migrate back into the area they once occupied. Also the development of new plant communities or associations may result from environmental changes. In the discussion that follows, a few comments are made concerning the overall stratigraphic distribution of taxa within each of the three reference sections.

Sherard Dome - The local ranges in the Sherard Dome section are shown in Figure 4. The distribution of palynomorphs in this section is based on samples from the upper 70 feet of the Mowry Shale and all but the upper 60 feet of the Frontier. Samples were collected from the lower Cody Shale but proved to be unproductive. In this

TABLE 4

Local palynomorph ranges in Sherard Dome section with numbers referring to Figure 4

1. Acanthotriletes varispinosus
2. Gonyaulacysta cf. G. edwardsi
3. Odontochitina costata
4. Foveotriletes cf. F. subtriangularis
5. Gonyaulacysta spp.
6. Inaperturopollenites pseudoreticulatus
7. Chlamydophorella discreta
8. Ascodinium verrucosum
9. Laricoidites cf. L. magnus
10. Deltoidospora sp. 1
11. Form C sp. 3
12. Canningia cf. C. reticulata
13. Cicatricosisporites cf. C. mesozoicus
14. Equisetosporites multicostatus
15. Form X sp. 1
16. Retitricolpites vulgaris
17. Eucommiidites minor
18. Caytonipollenites pallidus
19. Palaeoperidinium cretaceum
20. Tricolpites sagax
21. Undulatisporites sp. 1
22. Phyllocladidites-type pollen
23. ?Exochosphaeridium phragmites
24. Laevigatosporites ovatus
25. Camarozonosporites rudis
26. Cicatricosisporites dorogensis
27. Cyathidites minor
28. Deltoidospora hallii
29. Gleicheniidites senonicus
30. Concavisporites cavatus
31. Stereisporites antiquasporites
32. Tricolpopollenites sp. 3
33. Tricolpites parvus
34. Tricolpopollenites cf. T. retiformis
35. Cycadopites scabratus
36. Monosulcate type 1
37. Inaperturopollenites hiatus
38. Inaperturopollenites dubius
39. Alisporites-type pollen
40. Classopollis classoides
41. Pityosporites-type pollen
42. Deflandrea cf. D. acuminata
43. Form B sp. 2
44. Form C sp. 1
45. Micrhystridium spp.
46. Leiofusa spp.
47. Veryhachium cf. V. trisulcum

TABLE 4

48. Appendicisporites cf. A. jansonii
49. Perotriletes sp. 3
50. Clavatipollenites hughesii
51. Hystrichosphaera ramosa
52. Verrucosisporites cf. V. rotundus
53. Camarozonosporites insignis
54. Todisporites minor
55. Metaleiofusa spp.
56. Reticulatisporites exilis
57. Oligosphaeridium spp.
58. Dictyotriletes densomuralis
59. Concavissimisporites puctatus
60. Matonisporites impensus
61. Pterospermopsis spp.
62. Spinidinium microceratum
63. Laevigatosporites haardti
64. Cicatricosisporites cf. C. carlylensis
65. Deltoidospora psilostoma
66. Osmunacidites wellmanii
67. Lycopodiacidites cf. L. kuepperi
68. Tsugapollenites-type pollen
69. Form C. sp. 2
70. Schizosporis scabratus
71. Lycopodiumsporites cf. L. marginatus
72. Camarozonosporites sp. 1
73. Rugubivesiculites-type pollen
74. Densosporites microrugulatus
75. Schizosporis cf. S. parvus
76. Cycadopites fragilis
77. Appendicisporites matesovai
78. Hystrichosphaeridium spp.
79. Hystrichokolpoma ferox
80. Eucommiidites troedssonii
82. Veryhachium cf. V. stellatum
83. Laevigatosporites cf. L. irroratus
84. Schizaeoisporites eocaenicus
85. Retitriletes cenomanianus
86. Cicatricosisporites cf. C. mohirioides
87. Apteodinium granulatum
88. Granulatisporites spp.
89. Verrucosisporites pustulatus
90. Concavisporites butorosus
91. Form B sp. 4
92. Tricolpites cf. T. reticulatus
93. Circulina parva
94. Botrycoccus sp.
95. Cyathidites australis
96. Tricolpopollenites henrici
97. Concavisporites sp. 2

TABLE 4

98. Retitricolpites cf. R. georgensis
99. Cymatiosphera sp. 1
100. Podocarpidites-type pollen
101. Schizaea cf. S. triangula
102. Verrucatosporites favus
103. Liliacidites cf. L. variegatus
104. Deltoidospora junctum
105. Cicatricosisporites cooksonii
106. Monosulcate type 2
107. Peromonoletes sp. 1
108. Perotriletes sp. 2
109. Perotriletes bursatus
110. Cingutriletes clavus
111. Baltisphaeridium multispinosum
112. Concavisporites sp. 1
113. Perotriletes sp. 1
114. Lycopodiacidites intraverruncatus
115. Taurocusporites pseudoreticulata
116. Dictyophyllidites harrisii
117. Psilatriletes radiatus
118. Veryhachium cf. V. europenum
119. Tricolpites cf. T. bathyreticulatus
120. Horologinella apiculata
121. Gleicheniidites circinidites
122. Palaeohystrichophora infusorioides
123. Trilete spiny sp. 2
124. Cymatiosphera sp. 2
125. Retitricolpites cf. R. georgensis
126. Deflandrea cf. D. cooksonii
127. Petalosporites quadrangulus
128. Tentaculispora conspicua
129. Microdinium cf. M. irregulare

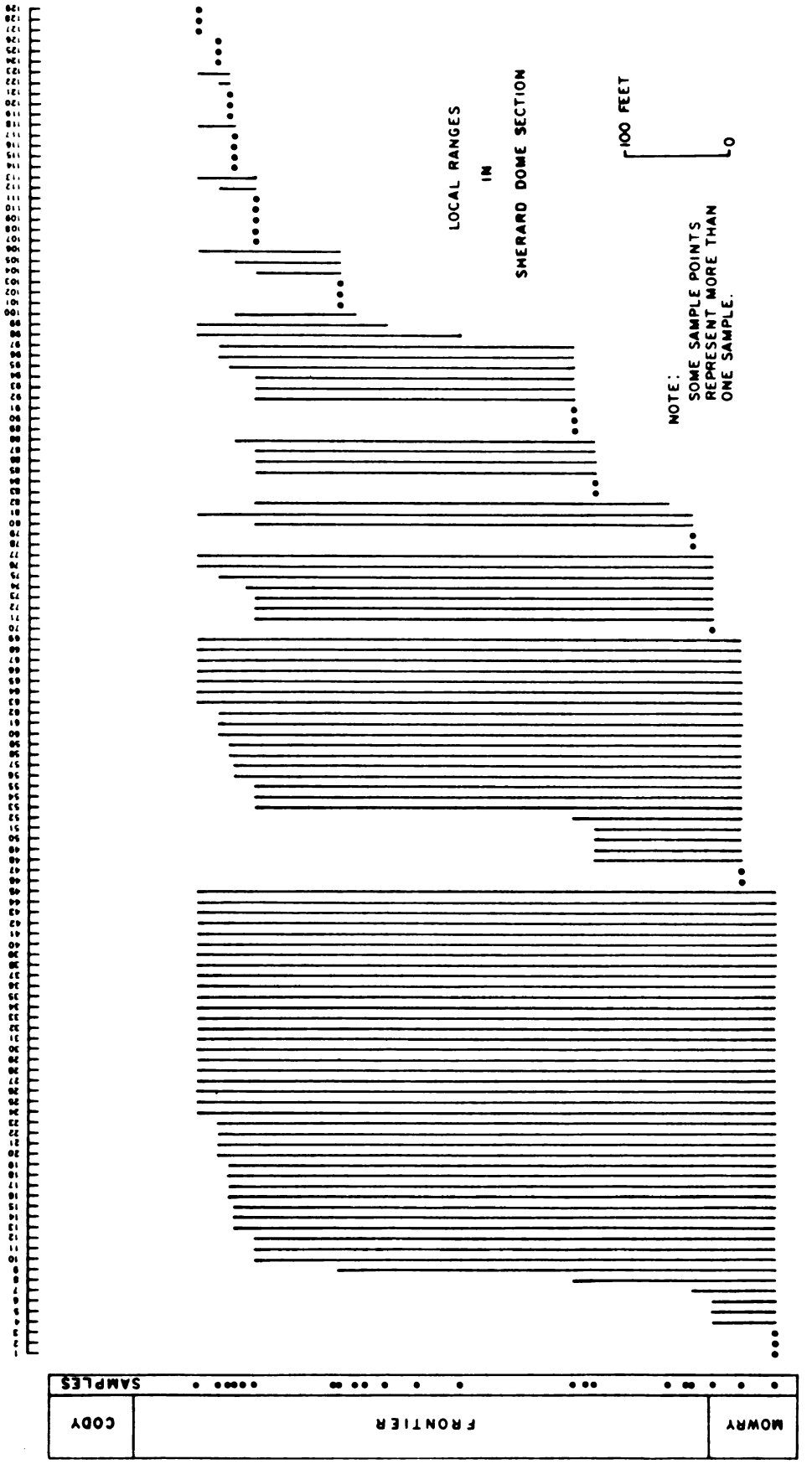

Figure 4. Local range chart for palynomorphs in the Sherard Dome section.

section 129 taxa were identified; of these, nine were found only in the Mowry Shale, 52 were found only in the Frontier and 22 were unrestricted and ranged from the lowest sample in the section to the highest.

Lucerne Anticline - The total ranges in the Lucerne Anticline section are shown in Figure 5. Samples examined in this section range from the upper 30 feet of the Mowry Shale through the Frontier and including the lower 60 feet of the Cody Shale. Of the 147 taxa identified from this section, four were restricted to the Mowry Shale, 49 were found only in the Frontier and only one was restricted to the Cody Shale. Eighteen taxa are unrestricted and range from the lowest sample in the section to the highest.

Cody - The local ranges in the Cody section are shown in Figure 6. Sample distribution in this section ranged from the upper ten feet of the Mowry Shale to the lower 15 feet of the Cody Shale. In this section, 126 taxa were identified; of these, three were found only in the Mowry Shale, 55 were restricted to the Frontier and none were restricted to the Cody Shale. Twenty-four taxa were unrestricted and ranged from the lowest sample in the section to the highest.

In total, 161 palynomorphs were identified in the three reference sections. Of these, 18 are long ranging species that continue from the Mowry Shale through the Frontier and into the lower Cody Shale. None of the taxa are restricted in their stratigraphic range to either the Mowry

TABLE 5

Local palynomorph ranges in Lucerne Anticline section with numbers referring to Figure 5

1. Laricoidites cf. L. magnus
2. Form C sp. 3
3. Form X sp. 1
4. Chlamydophorella discreta
5. Ascodinium verrucosum
6. Verrucosisporites cf. V. rotundus
7. Camarozonosporites sp. 1
8. Cyathidites australis
9. Cingulatisporites radiatus
10. Rugubivesiculites-type pollen
11. Spinidinium microceratum
12. Appendicisporites tricornitatus
13. Gleicheniidites confossus
14. Osmunacidites wellmanii
15. Hymenophylliumsporites cf. H. deltoida
16. Form B sp. 2
17. Eucommiidites minor
18. Schizosporis scabratus
19. Alisporites-type pollen
20. Form C sp. 2
21. Camarozonosporites rudis
22. Deltoidospora psilostoma
23. Tricolpopollenites sp. 3
24. Tricolpites sagax
25. Formea amphora
26. Leiofusa spp.
27. Veryhachium cf. V. stellatum
28. Laevigatosporites ovatus
29. Appendicisporites matesovai
30. Classopollis classoides
31. Canningia cf. C. reticulata
32. Cicatricosisporites dorogensis
33. Cyathidites minor
34. Deltoidospora hallii
35. Dictyotriletes densomuralis
36. Gleicheniidites senonicus
37. Stereisporites antiquasporites
38. Matonisporites impenses
39. Acanthotriletes varispinosus
40. Tricolpites parvus
41. Cycadopites scabratus
42. Inaperturopollenites hiatus
43. Pityosporites-type pollen
44. Caytonipollenites pallidus
45. Deflandrea cf. D. acuminata
46. Micrhystridium spp.

TABLE 5

47. Veryhachium cf. V. europenum
48. Veryhachium cf. V. trisulcum
49. Metaleiofusa spp.
50. Microdinium cf. M. irregulare
51. Deflandrea echinoidea
52. Gonyaulacysta cf. G. edwardsi
53. Form C sp. 1
54. Tricolpites cf. T. bathyreticulatus
55. Palaeoperdinium spp.
56. Camarozonosporites insignis
57. Concavisporites sp. 2
58. Lycopodiacidites cf. L. Kuepperi
59. Retitricolpites cf. R. georgensis
60. Concavisporites sp. 1
61. (Void)
62. Cicatricosisporites crassiterminatus
63. Todisporites minor
64. Retitricolpites cf. R. georgensis
65. Cycadopites fragilis
66. Schizosporis cf. S. parvus
67. Veryhachium sp. 1
68. Circulina parva
69. Cicatricosisporites cf. C. mesozoicus
70. Cingutriletes clavus
71. Laevigatosporites haardti
72. Lycopodiumsporites cf. L. marginatus
73. Trilete spiny sp. 1
74. Tricolpopollenites cf. T. retiformis
75. Inaperturopollenites dubius
76. Tsugapollenites-type pollen
77. Hystrichospheaera ramosa
78. Odontochitina costata
79. Baltisphaeridium multispinosus
80. Psilatriletes radiatus
81. Tanyosphaeridium cf. T. variecalamun
82. Liliacidites cf. L. variegatus
83. Tricolpopollenites henrici
84. Podocarpidites-type pollen
85. Trilete spiny sp. 2
86. Deflandrea cf. D. cooksonii
87. Appendicisporites cf. A. jansonii
88. Deltoidospora sp. 1
89. Foveotriletes cf. F. subtriangularis
90. Botrycoccus sp.
91. ?Exochosphaeridum phragmites
92. Densosporites microrugulatus
93. Cicatricosisporites cf. C. mohirioides
94. Oligosphaeridium spp.
95. Hystrichokolpoma ferox
96. Hystrichosphaeridium spp.

TABLE 5

97. Pterospermopsis spp.
98. Form B sp. 4
99. Undulatisporites sp. 1
100. Miodeltospora parva
101. Granulatisporites spp.
102. Reticulatisporites exilis
103. Palaeoperidinium cretaceum
104. Equisetosporites multicostatus
105. Gleicheniidites cirinidites
106. Concavissimisporites punctatus
107. Peromonoletes sp. 1
108. Cicatricosisporites cf. C. carlylensis
109. Gonyaulacysta spp.
110. Verrucosisporites pustulatus
111. Monosulcate type 1
112. Undulatisporites scabratus
113. Eucommiidites troedssonii
114. Laevigatosporites cf. L. irroratus
115. Taurocusporites sp. 1
116. Trilete scabrate sp. 1
117. Canningia cf. C. senonica
118. Dictyophyllidites harrisii
119. Deltoidospora junctum
120. Phyllocladidites-type pollen
121. Cymatiosphera sp. 2
122. Tricolpites cf. T. reticulatus
123. Klukisporites pseudoreticulata
124. Trilobosporites crassus
125. ?Cyclopsiella sp. 1
126. Taurocusporites cf. T. sigmentatus
127. Laevigatosporites granaperturus
128. Canningia cf. C. rotundata
129. Retitricolpites vulgaris
130. Cymatiosphera sp. 1
131. Retitriletes cenomanianus
132. Concavisporites butorosus
133. Monosulcate type 2
134. Palaeohystrichophora infusorioides
135. Balmeisporites glenelgensis
136. Horologinella apiculata
137. Concavisporites cavatus
138. Taurocusporites reduncus
139. Verrucatosporites pseudoreticulatus
140. Schizaeoisporites eocaenicus
141. Perotriletes sp. 3
142. Tetrahedrospora dyscrita
143. Odontochitina operculata
144. Deflandrea victoriensis

TABLE 5

145. Perotriletes sp. 1
146. Tanyosphaeridium cf. T. variecalamun
147. Form F sp. 1

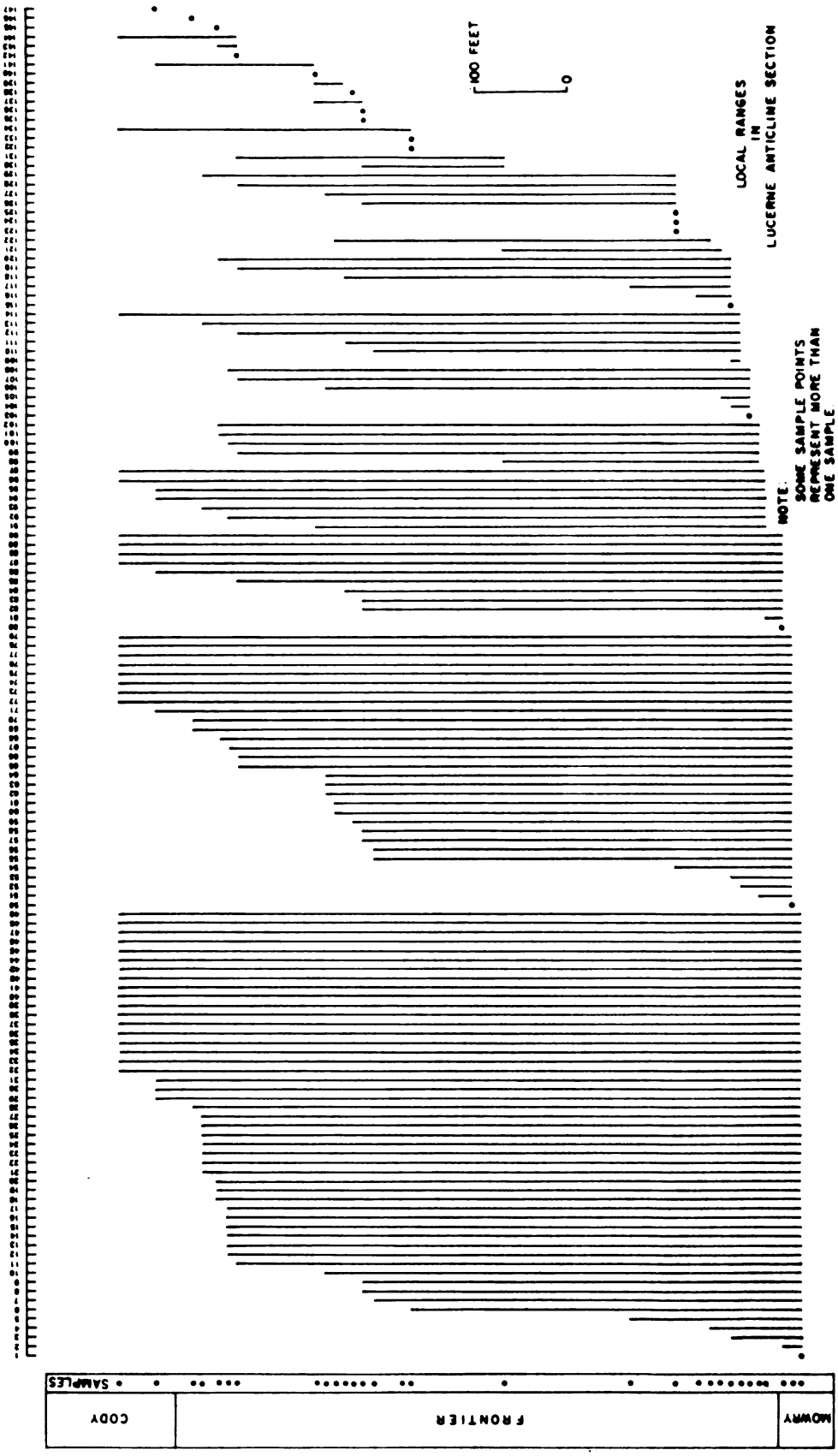

Figure 5. Local range chart for palynomorphs in the Lucerne Anticline section.

TABLE 6

Local palynomorph ranges in Cody section with numbers referring to Figure 6

1. (Void)
2. Odontochitina costata
3. Leiofusa spp.
4. Miodeltospora parva
5. Canningia cf. C. reticulata
6. Gonyaulacysta cf. G. edwardsi
7. Pterospermopsis spp.
8. Tricolpites cf. T. bathyreticulatus
9. Palaeoperidinium cretaceum
10. Metaleiofusa spp.
11. Peromonoletes sp. 1
12. Camarozonosporites sp. 1
13. Eucommiidites troedssonii
14. Rugubivesiculites-type pollen
15. Ascodinium verrucosum
16. Hystrichokolpoma ferox
17. Perotriletes sp. 1
18. Veryhachium cf. V. stellatum
19. Retitricolpites cf. R. georgensis
20. Cicatricosisporites dorogensis
21. Todisporites minor
22. Schizosporis scabratus
23. Dictyotriletes densomuralis
24. Laevigatosporites ovatus
25. Appendicisporites tricornitatus
26. Camarozonosporites rudis
27. Camarozonosporites insignis
28. Cyathidites minor
29. Deltoidospora hallii
30. Deltoidospora sp. 1
31. Gleicheniidites senonicus
32. Stereisporites antiquasporites
33. Matonisporites impensus
34. Tricolpopollenites sp. 3
35. Tricolpopollenites cf. T. retiformis
36. Cycadopites scabratus
37. Cycadopites fragilis
38. Inaperturopollenites dubius
39. Classopollis classoides
40. Pityosporites-type pollen
41. Caytonipollenites pallidus
42. Deflandrea cf. D. acuminata
43. Form C sp. 2
44. Micrhystridium spp.
45. Oligosphaeridium spp.
46. Veryhachium cf. V. europenum

TABLE 6

47. Veryhachium cf. V. trisulcum
48. Form B sp. 2
49. Reticulatisporites exilis
50. Podocarpidites-type pollen
51. ?Exochosphaeridium phragmites
52. Concavisporites sp. 1
53. Cicatricosisporites cf. C. mesozoicus
54. Cicatricosisporites sp. 1
55. Deltoidospora junctum
56. Acanthotriletes varispinosus
57. Tricolpites sagax
58. Schizosporis cf. S. parvus
59. Inaperturopollenites hiatus
60. Alisporites-type pollen
61. Form B sp. 2
62. Hystrichosphaeridium spp.
63. Undulatisporites scrabratus
64. Balmeisporites glenelgensis
65. Spinidinium microceratum
66. Ascodinium scabrosum
67. Taurocusporites cf. T. sigmentatus
68. Form X sp. 1
69. (Void)
70. Retitricolpites cf. R. georgensis
71. Cyathidites australis
72. Laevigatosporites haardti
73. Deltoidospora junctum
74. Concavisporites cavatus
75. Tricolpopollenites henrici
76. Hymenophylliumsporites cf. H. deltoida
77. Perotriletes sp. 2
78. Densosporites microrugulatus
79. Lycopodiumsporites cf. L. marginatus
80. Dictyotriletes densomuralis
81. Tricolpites parvus
82. Tanyosphaeridium cf. T. variecalamun
83. Gonyaulacysta spp.
84. Chlamydophorella discreta
85. Verrucosisporites cf. V. rotundus
86. Verrucosisporites pustulatus
87. Appendicisporites tricornitatus
88. Circulina parva
89. Trilete spiny sp. 1
90. Apteodinium granulatum
91. Concavisporites sp. 2
92. Osmunacidites wellmanii
93. Broomea cf. B. jaegeri
94. Baltisphaeridium multispinosum
95. Granulatisporites spp.

TABLE 6

96. Retitricolpites vulgaris
97. Canningia cf. C. senonica
98. Cingutriletes clavus
99. Deflandrea echinoidea
100. Concavissimisporites punctatus
101. Aequitriadites ornatus
102. Laevigatosporites granaperturus
103. Verrucatosporites pseudoreticulatus
104. Reticulatisporites exilis
105. Laevigatosporites cf. L. irroratus
106. Form B sp. 4
107. Foveotriletes cf. F. subtriangularis
108. Tentaculispora conspicua
109. Phyllocladidites-type pollen
110. Microdinium cf. M. irregulare
111. Lycopodiacidites cf. L. kuepperi
112. Leptozonosporites foveolatus
113. Monosulcate type 1
114. Perotriletes bursatus
115. Taurocusporites sp. 1
116. Densoisporites perinatus
117. Dictyophyllidites harrisii
118. Equisetosporites multicostatus
119. Botrycoccus sp.
120. Verrucatosporites pseudoreticulatus
121. Cymatiosphera sp. 1
122. Palaeohystrichophora infusorioides
123. Taurocusporites reduncus
124. Canningia cf. C. rotundata
125. Horologinella apiculata
126. Deflandrea victoriensis

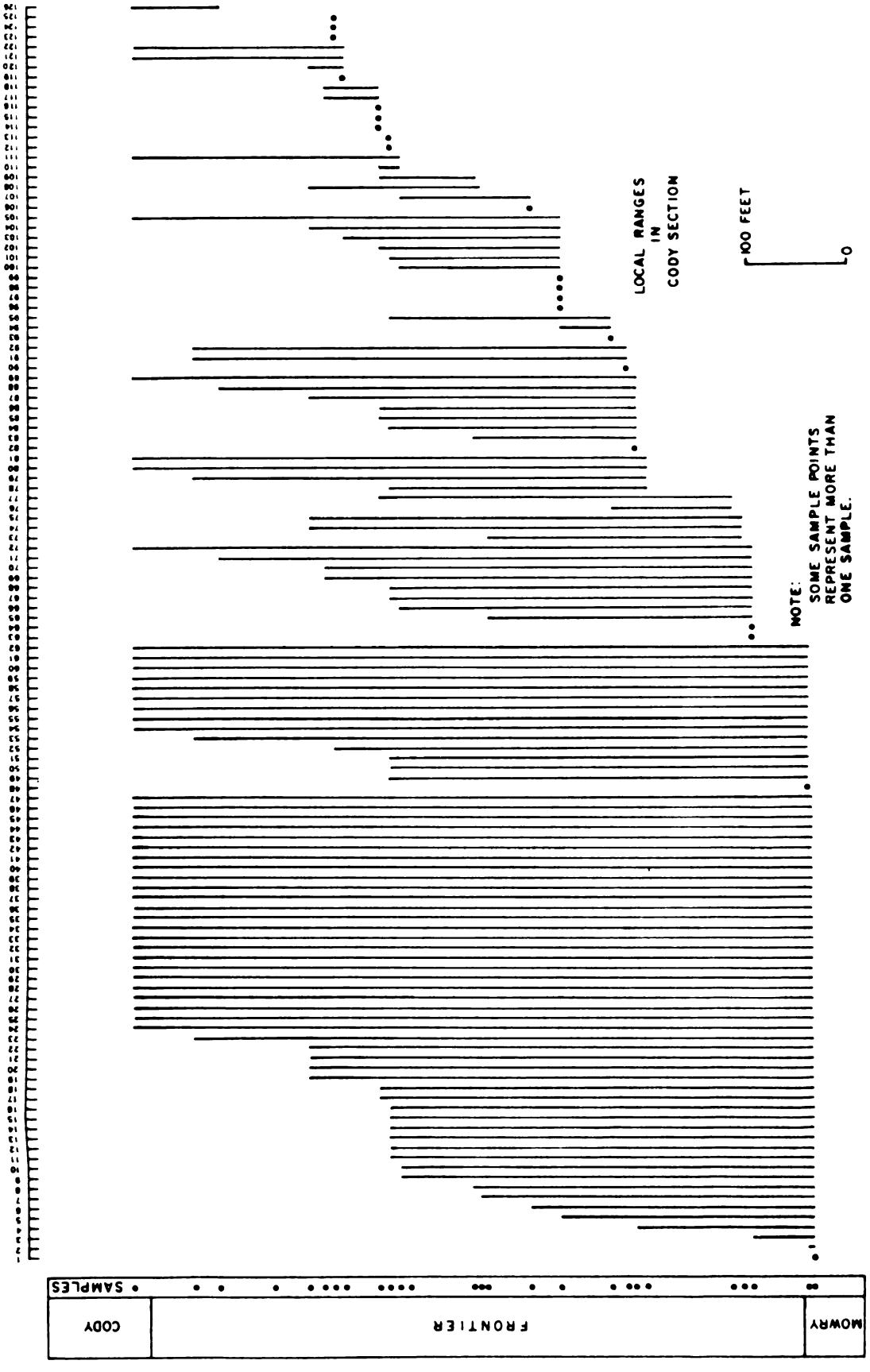

Figure 6. Local range chart for palynomorphs in the Cody section.

or Cody Shales. Twenty-two species were found to be restricted to the Frontier Formation. As a group they represent an assemblage that characterizes the Frontier, representing a reflection of the particular environments of deposition of the Frontier and not particularly implying a time-stratigraphic relationship. Many of these species are rare or spasmodic in their occurrence and their stratigraphic value is limited. All of the 22 species are listed below but those species marked by asterisks (*) are deemed most useful for distinguishing the Frontier because of their relatively abundant representation and restricted range:

Laevigatosporites granaperturus Hedlund*

Verrucatosporites favus (Potonie) Thomson and Pflug*

Balmeisporites glenelgensis Cookson and Dettmann

Cicatricosisporites cf. C. mohirioides Delcourt and Sprumont*

Concavisporites butorosus (Manuscript name)*

Deltoidospora junctum (Kara-Murza) Singh*

Dictyophyllidites harrisii Couper*

Gleicheniidites cf. G. circinidites (Cookson) Singh*

Granulatisporites sp. 1

Reticulatisporites exilis (Manuscript name)*

Staplinisporites caminus (Palme) Pocock

Taurocusporites reduncus (Bolkhovitina) Stover*

Taurocusporites cf. T. sigmentatus Stover*

Tentaculispora conspicua (Manuscript name)*

Undulatisporites scabratus (Manuscript name)

Verrucosisporites pustulatus (Manuscript name)*

Monosulcate type 2

Form B sp. 4

Apteodinium granulatum Eisenack

Canningia cf. C. rotundata Cookson and Eisenack

Canningia cf. C. senonica Clark and Verdier

Horologinella apiculata Cookson and Eisenack

Selected Palynological Zones

The Frontier Formation of the Big Horn Basin has been divided into three zones and two subzones based on the stratigraphic range of three key species of phytoplankton. Two of the zones, A and C, are based on the last and first occurrence, respectively, of two species of phytoplankton. These two species are morphologically diagnostic and occur in abundance. Zone B and its two subzones lie between zones A and C. There are no key species that define this zone and its position is usually determined by its stratigraphic relationship to zones A and C. Due to the time-transgressive nature of the Cody-Frontier contact, there are two palynological zones on the eastern and three on the western side of the basin. The palynological zones together with their correlation between the sections studied is shown in Figure 3.

Zone A (Ascodinium verrucosum zone) - This is the lowest zone in the Frontier and its top is marked by the disappearance of Ascodinium verrucosum, which is the most

diagnostic species present. This zone includes the upper Mowry as it was found to be impossible to separate the Mowry from the Frontier on strictly palynological evidence alone. Unlike zones B and C, there are a number of taxa that are restricted to this zone and occur regularly throughout the zone in all sections. Some of these are known to occur stratigraphically higher elsewhere in the column. However, it is believed that the restriction of these species, all but one of which are phytoplankton, is related to environmental changes higher in the section (zone B), which restrict the presence of these species to the more marine environments of zone A. The eight species of phytophytoplankton and one spore species which are restricted to zone A are listed below:

Staplinisporites caminus (Palme) Pocock

Gonyaulacysta cf. G. edwardsi (Cookson and Eisenack) Clark and Verdier

Gonyaulacysta spp.

Ascodinium scabrosum Cookson and Hughes

Ascodinium verrucosum Cookson and Hughes

Canningia cf. C. senonica Clark and Verdier

Deflandrea echinoidea Cookson and Eisenack

Chlamydophorella discreta Clark and Verdier

Palaeoperidinium cretaceum Pocock

Zone B - In this zone there are no species that occur with the regularity or abundance that would allow them to

lend their name to the zone. There are, however, eleven taxa that occur only in this zone. Most of these are spores and they occur irregularly throughout the zone. Some were found in only one section. The eleven taxa restricted to zone B are listed below:

Schizaea cf. S. triangula Stanley

Verrucatosporites favus (Potonie) Thomson and Pflug

Petalosporites quadrangulus Agasie

Cicatricosisporites cooksonii Balme

Perotriletes bursatus Hall

Lycopodiacidites intraverrucatus Brenner

Densoisporites perinatus Couper

Taurocusporites reduncus (Bolkhovitina) Stover

Tricolpites cf. T. reticulatus Cookson

Monosulcate type 2

Horologinella apiculata Cookson and Eisenack

Zone B has been divided into two subzones (B_1 and B_2) based on the first occurrence (or base) of Palaeohystrichophora infusorioides, which is present in B_2 but not in B_1. Palaeohystrichophora infusorioides is known from Albian through the Campanian, thus it is felt that its first occurrence in this zone indicates a changing environment rather than a first or last occurrence based on evolutionary development as is the case with Ascodinium verrucosum (zone A) and Deflandera victoriensis (zone C). Palaeohystrichophora infusorioides was not found in the Potato

Ridge or Little Sheep Mountain sections. This may suggest that this species is restricted to near shore areas and thus its distribution is environmentally controlled.

Zone C (Deflandrea victoriensis zone) - This is the uppermost zone of the Frontier, its base is marked by the first occurrence of Deflandrea victoriensis, which is the diagnostic species present in the zone. The zone is present only on the western and southwestern sides of the basin where it includes the lower Cody Shale. Besides Deflandrea victoriensis only two other taxa were found to be restricted to this zone. They are Tetrahedrospora dyscrita and Form F. sp. 1.

Age and Correlation

After the basic zonation was established in the three reference sections, it was found to be easily applied to the other five sections by a qualitative examination of all the samples in each section. This demonstrated the validity of the zones.

Zone A, which on the basis of invertebrates and palynomorphs is considered to be of Cenomanian age in its Frontier portion, is characterized by Ascodinum verrucosum. Ascodinum verrucosum was described by Cookson and Hughes (1964) from the Cambridge Greensand and the base of the Chalk Marl (Cenomanian) of England. Clark and Verdier (1967) suggest that it is possible that the Cambridge Greensand represents either part or all of the Varconian (uppermost

Albian) and that the equivalent of the lowermost Chalk Marl is missing in the lower Cenomanian sampling of the Isle of Wight and France. This would restrict Ascodinium verrucosum to the Albian and in particular to the Varconian. Zone A includes part of the upper Mowry Shale. The Mowry Shale is shown by Cobban and Reeside (1952b) to be of Albian age; however, it should be noted that the Mowry-Frontier contact is picked on purely lithologic evidence alone, the first bentonite below the First Wall Creek Sandstone, and is not tightly controlled by fossils. It is believed that this is the first reported occurrence of Ascodinium verrucosum in the United States. The possibility of an Albian age for the lower part of this zone should not be discounted until its occurrence in sections with better invertebrate control are reported in North America.

Five of the nine taxa that are restricted to zone A have a known stratigraphic range that is not younger than Cenomanian. The stratigraphic ranges of the nine taxa are listed below:

Pliensbachian-Barremian (Albian?)

Staplinisporites caminus (Palme) Pocock

Barremian-lower Cenomanian

Palaeoperidinium cretaceum Pocock

Albian (Varconian)-Cenomanian

Ascodinium scabrosum Cookson and Hughes

Ascodinium verrucosum Cookson and Hughes

Cenomanian

Gonyaulacysta cf. *G. edwardsi* (Cookson and Eisenack) Clark and Verdier

Upper Turonian-Senonian

Deflandrea echinoidea Cookson and Eisenack

Upper Santonian

Canningia cf. *C. senonica* Clark and Verdier

Lower and upper Cretaceous

Chlamydophorella discreta Clark and Verdier

Gonyaulacysta spp.

The correlation of zone A through the eight sections shows that in the northern part of the Big Horn Basin the Peay Sandstone complex (Third Wall Creek) is of Cenomanian age; whereas, in the southern half of the basin, this unit is Cenomanian in its lower half and Turonian and possibly Coniacian in its upper half (zone B).

The assignment of an age to zone B is particularly difficult due to the lack of any diagnostic phytoplankton. However, because of the assignment of a Cenomanian age to zone A and a Coniacian-Santonian? age to zone C, it should follow by inference that zone B is Turonian and Coniacian in age. None of the eleven taxa that are restricted to zone B are considered to be index species for the Turonian and and Coniacian.

Zone C is considered to be Coniacian with the possibility of a Santonian age due to the presence of *Deflandrea victoriensis*. This species is reported from the Santonian

of England by Clark and Verdier (1967) and is considered to be an index fossil for the Santonian. The possibility of a Santonian age for the post First Wall Creek Sandstones has not been suggested before. However, it is more likely that the presence of Deflandrea victoriensis in these rock represents an extension of its previously reported range rather than a Santonian age for the rocks. Goodell (1962, p. 177) gives these sands an early Niobrara (Coniacian) age based on invertebrate faunas. Again, as in zone A, more work will be needed to resolve the differences between the age relationship of the phytoplankton and invertebrate faunas.

On the eastern side of the basin, the upper Frontier is in zone B and is probably Turonian to Coniacian in age. The Second Wall Creek Sandstone appears to be time transgressive as it climbs section within zone B toward the west. Subzone B_2 was identified only in the western part of the basin and is not judged to have much value on a regional scale.

VI. ENVIRONMENTAL SIGNIFICANCE OF THE PALYNOMORPHS

The palynological assemblage described and illustrated in this report can be divided into six distinct floral elements:

1. The fern flora consisting of ordinary ferns, tree ferns and water ferns. The diversity of this element is evident from the large number and variety of monolete and trilete spores identified.
2. The cycad flora which probably represents both the Cycadales and Bennettitales. These groups are represented by Cycadopites and possibly Schizosporis pollen and the unclassified monosulcate types.
3. The conifer flora belonging predominantly to the families Pinaceae and Podocarpaceae.
4. The ephedralean flora, represented by Equisetosporites multicostatus.
5. The angiosperm flora, characterized by tricolpate pollen.
6. The marine phytoplankton.

Local and regional topographic and environmental variations probably gave rise to various plant associations, with ferns predominating in the low broad coastal flood

plain areas and cycads and conifers in the better drained coastal plains and uplands. The struggling angiosperm flora was probably represented in both areas. The rare ephedra-lean pollen may have been derived outside the general deposition basin as they indicate a drier more desert or mountain climate.

The relative abundance of spores, pollen and phyto-plankton correlate well with the generally accepted depositional history of the Frontier. The environments of deposition vary from non-marine to marine and migrate laterally in response to marine regression and transgression. Upshaw (1964) has demonstrated that the cyclic nature of deposition is reflected in the ratio of pollen and spores (land derived) to phytoplankton (marine). However, it was found that on a regional scale, it was impossible to make sense out of these ratios when correlating from section to section. Instead, the broader changes in environments from marine (zone A) to brackish or non-marine (zone B) back to marine (zone C) are reflected in the high relative abundance of phytoplankton in zones A and C and spores in zone B.

In his description of the Frontier flora, Berry (1929, p. 131) considers that the plant fossils "... do not indicate an aridity of climate ..." but

> ... seem to me in part to indicate less humid conditions, which I would interpret as due not to a lessened rainfall but to their having grown on beaches or between dunes along a coast where isolation was high, winds were rather

> constant and the sandy surface was apt to afford a less constant water table or one insufficient to keep pace with the increased evaporation due to insolation and wind.

Berry questions the interpretation of climate given by Knowlton. He states (Berry, 1929, p. 131):

> ... The plants most commonly thought of as tropical - these Frontier davallioid ferns, for example, or tree ferns in general - find their optimum modern conditions in temperature rain forests, not in tropical lowlands.

Berry concludes: "... my inference would be that they indicate a warm temperature ... climate."

Upshaw (1959, p. 17) sums up the paleoecological, depositional and environmental considerations when he states:

> ... conditions in Frontier time, as derived by several investigators, appear to have been deltaic in western Wyoming. The area was near sea level and occasional incursions of the sea from the east left brackish-water and marine sediments. The sediment source was the Mesocordilleran geanticline to the west. The climate was humid, warm temperature to subtropical, and supported a lush vegetation. Ferns were the most abundant plants, but conifers, angiosperms, and others were present.

VII. CONCLUSIONS

The zonation and correlation of the Frontier Formation of the Big Horn Basin has been effected by the use of acid insoluble palynomorphs. The age of these zones has been determined by comparison with phytoplankton assemblages from the European type section and the environments of deposition of these zones are discussed from both lithological and paleontological standpoints.

The pollen, spore and phytoplankton assemblage of the Frontier Formation consists of 92 genera containing 136 species. In addition, seven gymnospermous pollen types, six acritarch types and one dinoflagellate type were set up but not given specific epithets. Twenty-two taxa were found to be restricted to the Frontier and as such represent an assemblage that characterizes the particular environments of deposition of the Frontier. The continental influence on Frontier sedimentation is demonstrated by the fact that 16 of the 22 taxa are spores.

The Frontier is divided into three zones and two subzones based on the stratigraphic range of three key species of phytoplankton. These zones have been correlated between the eight sections studied; however, because of the

time-transgressive nature of the Cody-Frontier contact, there are two zones on the eastern side of the basin and three on the western side. Stratigraphic correlations utilizing major sandstone units and bentonites show that lithologic units within the Frontier are time-transgressive.

Age determinations of the palynological zones are in general agreement with those shown by invertebrates, with the exception of the possibility of Albian age rocks in the lower Frontier and a Santonian age for the post First Wall Creek Sandstones in the southwestern part of the basin.

The Frontier Formation consists of alternating sandstone and shale interbedded with coal, lignite and bentonite. The sediments are sequentially and laterally variable. They were deposited in a regressive-transgressive environment, where the Frontier, as a whole, appears to be a regressive unit compared with the transgressive marine shales above and below.

The palynological assemblage has been divided into six floral elements; fern, cycad, conifer, ephedralean and angiosperm floras and the marine phytoplankton. The climate during Frontier time was humid and warm temperate to subtropical. It supported a lush vegetation.

It is felt that a truly effective zonation of the western interior Cretaceous section can be established, based on the stratigraphic range of selected phytoplankton. However, the Frontier or any other formation that is strongly influenced by continental sedimentation is not the best

place to start. This became evident when no index phytoplankton were found for the Coniacian or Turonian. It is recommended that the basic zonation be established in the more marine sections to the east where they can be tied into the established invertebrate zonation. Here the basic disagreements between the stratigraphic ranges of phytoplankton in the European and American standard sections can be resolved. The phytoplankton zonation should then be extended westward into the interfingering clastic wedges that extend eastward from the Mesocordilleran geanticline.

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APPENDICES

Little Sheep Mt. - South
SE, 25, T56N, R95W
Big Horn Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Shale. SM-61* Pb 7556* about 60' above Frontier SM-60 Pb 7555 about 30' above Frontier		
	FRONTIER		
18	Sandstone, fine grained, well sorted, porous, slightly calcareous, massive outcrop, vague ferruginous bands represent stratification; large, ferruginous, thin bedded, platy concretions; several thin discontinuous pebble beds near top, mainly chert with a few andesite pebbles; slightly shaly at top.	73.6'	534.9'
17	Interbedded soft, poorly consolidated sand and black, fissile, carbonaceous shale; sand more abundant; bentontic, "popcorn" weathered surface. SM-59 Pb 7554 461.3' SM-58 Pb 7553 461.3' SM-57 Pb 7552 450.4' SM-56 Pb 7551 431.2' SM-55 Pb 7550 416.2'	45.1'	461.3'
16	Sandstone, soft, very deeply weathered, buff, very fine grained, thin carbonaceous streaks, ferruginous stained, bentontic, "popcorn" surface.	14.1'	416.2'
15	Sandstone, very argillaceous and bentonitic; soft, deeply weathered; lower part of "vast popcorn surface;" sandstone is shaly, moderately hard, but can be soft and weathered; stringers of black fissile shale.	33.8'	402.1'

*SM-66 collection number, Pb 7556 maceration number

SM-54 Pb 7549 402.1'

14	Sandstone, fine to medium grained, porous, friable, soft, deeply weathered, argillaceous, with dark shale stringers; sandier than unit below; ferruginous concretions at base.	16.4'	368.3'
13	Sandstone, very argillaceous and shaly, dark brown to dark gray; breaks into hacky fragments; grades into unit below; very fine grained, dirty, occasional plant fragments.	19.3'	351.9'

SM-53 Pb 7548 347.6'
SM-52 Pb 7547 337.6'
SM-51 Pb 7546 332.6'

12	Mostly shale, dark gray to black, fissile; numerous thin argillaceous, brown, ferruginous sandstone stringers; sand increases toward top; outcrop weathers brownish gray.	33.8'	332.6'

SM-50 Pb 7545 328.8'
SM-49 Pb 7544 323.8'
SM-48 318.8'
SM-47 Pb 7543 313.8'
SM-46 308.8'
SM-45 Pb 7542 303.8'
SM-44 298.8'

11	Shale, dark gray, blocky; a few small carbonaceous fragments, occasional thin sandstone partings; weathers dark gray.	11.8'	298.8'

SM-43 Pb 7541 297.0'
SM-42 292.0'
SM-41 Pb 7540 287.0'

10	Bentonite, very pure, chartreuse color, distinctive, grades into unit at base.	1.9'	287.0'
9	Shale, dark gray to black, fissile to blocky at top, becomes sandier at top, many thin sandstone partings and a few sandstone beds in upper part, slightly bentontic in lower part, sandy lenses often ferruginous; fish scales in black shale 5' above base.	66.3'	285.1'

SM-40 Pb 7539 283.8'
SM-39 278.8'

	SM-38 Pb 7538	273.8'		
	SM-37	268.8'		
	SM-36 Pb 7537	263.8'		
	SM-35	258.8'		
	SM-34 Pb 7536	253.8'		
	SM-33	248.8'		
	SM-32 Pb 7535	243.8'		
	SM-31 Pb 7534	228.8'		
	SM-30 Pb 7533	223.8'		
	SM-29	218.8'		
8	Bentonite, shaly at top, pure at base.		0.7'	218.8'
7	Shale, dark gray to black, bentonitic, "popcorn surface," scattered tiny pebbles.		42.2'	218.1'
	SM-28	218.1'		
	SM-27 Pb 7532	215.9'		
	SM-26 Pb 7531	205.9'		
	SM-25	200.9'		
	SM-24 Pb 7530	195.9'		
	SM-23 Pb 7529	180.9'		
	SM-22 Pb 7528	175.9'		
6	Interbedded brown, ferruginous, sandy shale and resistive beds of light brown weathering, ferruginous sandstone; largely covered.		13.0'	175.9'
5	Sandstone, fine to medium grained, calcareous, well sorted, well rounded, salt and pepper, clean, porous; large scale ripple marks on some surfaces; mostly medium to thick bedding; forms prominent ridge; occasional widely scattered pebbles, abundant black chert pebbles at top; a few ferruginous lenses and concretions (not obviously cross-bedded).		40.9'	162.9'
4	Interbedded sandstone and shale sequence, outcrops as series of ledges; shale, black to dark gray, fissile to blocky, arenaceous; sandstone, fine to coarse grained, slightly calcareous, argillaceous, porous, salt and pepper.		26.9'	122.0'
	SM-21 Pb 7527	105.1'		
	SM-20 Pb 7526	95.1'		
3	Shale, dark gray to black, fissile to blocky, scattered thin sand lenses in upper part, locally with ferruginous bands.		32.0'	95.1'

	SM-19	93.1'	
	SM-18 Pb 7525	88.1'	
	SM-17 Pb 7524	83.1'	
	SM-16	78.1'	
	SM-15 Pb 7523	73.1'	
	SM-14	68.1'	
	SM-13 Pb 7522	63.1'	
2	Shale, silicious, medium gray; weathers light gray, with ferruginous stains (like Mowry); platy and blocky; grades into black shale above; sandy lenses and partings; fish scales.	59.0'	63.1'
	SM-12 Pb 7521	54.1'	
	SM-11	49.1'	
	SM-10 Pb 7520	44.1'	
	SM-9	34.1'	
	SM-8 Pb 7519	29.1'	
	SM-7	24.1'	
	SM-6 Pb 7518	19.1'	
	SM-5	14.1'	
	SM-4 Pb 7517	9.1'	
1	Bentonite, pure with shale interbeds in center, shaly at top.	4.1'	4.1'

MOWRY

Shale, siliceous.

SM-3 Pb 7516	8'	below Unit #1
SM-2 Pb 7515	14'	below Unit #1
SM-1	21'	below Unit #1

Potato Ridge
10, T51N, R91W
Big Horn Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Dark bentonitic shale, poorly exposed.		
	FRONTIER		
22	Mostly medium gray sandy, blocky shale; shalier at top; contains at least two poorly consolidated pebble beds containing pebbles of black chert, quartz, jasper, andesite and granitic rocks to 3"; bands of calcareous concretions to 18". PR-50 522.8' PR-49* Pb 7512* 512.8' PR-48 Pb 7511 504.8'	29.9'	532.7'
21	Sandstone, medium to coarse grained, very ferruginous and calcareous, good porosity; large scale crossbeds; outcrops as brown ledge; bands of scattered chert pebbles to 1/2".	3.2'	502.8'
20	Sandstone, fine to very fine grained, clean, soft, light gray, few black minerals; deeply weathered and unconsolidated; forms sandy, "popcorn" surface.	41.4'	499.6'
19	Mostly very fine grained, tan to light gray, very soft, unconsolidated, deeply weathered sandstone; numerous thin lenses of black shale which decreases in abundance upwards; deeply weathered "vast popcorn surface"; slightly bentontic throughout; grades into sandstone above; due to decrease in shale, color lightens upward.	101.2'	458.2'

*PR-49 collection number, Pb 7512 maceration number

18	Shale, black, mostly blocky, somewhat fissile at base, slightly arenaceous; scattered thin yellowish gray sandy stringers throughout.	26.2'	357.0'
	PR-47 Pb 5710 350.8' PR-46 Pb 7509 345.8' PR-45 Pb 7508 340.8' PR-44 333.8' PR-43 Pb 7507 330.8'		
17	Sandstone, brown, ferruginous, very coarse grained, good porosity; small black chert pebbles throughout; forms ledge.	4.9'	330.8'
16	Sandstone, soft, poorly consolidated, poorly resistant, very fine to fine grained, sorting poor to fair; local black shale stringers.	18.1'	325.9'
15	Interbedded sequence of soft, fine to very fine grained, argillerous sandstone and black, more or less sandy, fissile shale; somewhat more sand than shale, more sand than shale, more sand at top.	31.2'	307.8'
	PR-42 Pb 7506 306.6' PR-41 Pb 7505 301.6' PR-40 296.6' PR-39 Pb 7504 291.6' PR-38 286.6' PR-37 Pb 7503 281.6'		
14	Bentonite, dark greenish yellow, sandy at top.	3.2'	276.6'
	PR-36 273.4'-276.6'		
13	Sandy sequence, shaly at top and bottom, nearly clean sand at center, rounded soil covered slope; interbedded medium gray shaly sandstone and shale at top and base; discontinuous beds of small pebbles in lower part; several thin ferruginous sandy lenses and scattered beds of clean black shale near top and bottom.	50.6'	237.4'
	PR-35 272.8' PR-34 Pb 7502 267.8 PR-33 262.8' PR-32 Pb 7501 257.8' PR-31 Pb 7500 237.8' PR-30 Pb 7499 227.8'		

12	Shale, medium to dark gray, chunky and blocky, very sandy; includes many thin sandstone beds, sand becomes progressively more abundant higher in section.	32.0'	222.8'

PR-29 Pb 7498 220.8'
PR-28 215.8'
PR-27 Pb 7497 210.8'
PR-26 205.8'
PR-25 Pb 7496 200.8'
PR-24 195.8'
PR-23 Pb 7495 190.8'

11	Shale, dark brownish black or black, fissile; nonresistant bare slope; slightly blocky toward top; sandy, calcareous, concretionary bed near base; numerous small carbonaceous fragments.	58.5'	190.8'

PR-22 187.3'
PR-21 182.3'
PR-20 Pb 7494 177.3'
PR-19 172.3'
PR-18 Pb 7493 167.3'
PR-17 162.3'
PR-16 Pb 7492 157.3'
PR-15 152.3'
PR-14 Pb 7491 147.3'
PR-13 Pb 7490 137.3'

10	Shale, black to dark gray, blocky with good fissility, many sandy blebs and partings, bentontic "popcorn" surface; no vegetation on surface.	22.0'	132.3'

PR-12 130.3'
PR-11 Pb 7489 125.3'
PR-10 120.3'
PR-9 Pb 7488 115.3'
PR-8 110.3'

9	Sandstone, dark gray, argillaceous; poorly bedded; shale interbeds; band of pebbles to one-fourth inch at top.	6.6'	110.3'

PR-7 Pb 7487 center of unit

8	Shale, dark gray, finely laminated, bentonitic "popcorn" surface; many thin blebs and partings of fine grained sandstone give spotted appearance to shale.	17.8'	103.7'

PR-6 Pb 7486 103.7'

PR-5 Pb 7485 98.7'

7	Sandstone, thick resistive beds, mostly medium grained, occasionally fine grained; scattered black chert pebbles throughout; occasional lenses and cut and fill structures with abundant large rounded chert and quartz pebbles and large pieces of bone; coarse discontinuous pebble bands at top and bottom; porosity good; large scale crossbedding throughout, higher angle in coarser sand.	18.4'	85.9'
6	Sandstone sequence of irregular sandstone lenses, bentontic in upper half; many scattered pebble lenses with pebbles of black chert to 1"; sand poorly sorted, medium to coarse grained, porous, salt and pepper; large scale cut and fill; crossbedded.	10.2'	67.5'

PR-4 Pb 7484 62.3'

5	Sandstone, resistant series of jagged ledges, medium to coarse grained; many scattered pebbles to 2", irregular pebble lenses; large scale low angle crossbedding throughout; common pelecypod molds, rare gastropod molds; wavy upper surface; good porosity.	8.2'	57.3'
4	Sandstone, medium gray, quite variable throughout, mostly fine grained, occasional medium to coarse grained, sorting fair, porosity fair to poor; common large low angle crossbeds; occasional vertical worm tubes; then beds of black shale and bentonitic shale.	20.7'	49.1'
3	Sandstone, very fine grained, medium to dark blue gray, very well cemented.	13.8'	28.4'
2	Bentonitic unit, very poorly exposed, shaly.	10.6'	14.6'

PR-3 Pb 7483 14.6'
PR-2 Pb 7482 9.0'

1	Bentonite, grayish yellow, pure, grades into unit above.	4.0'	4.0'

MOWRY

Shale, silicious.

PR-1 Pb 7481 10' below Unit #1

Sherard Dome
22, T47N, R89W
Washakie Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
32	Sandstone, medium grained, poorly sorted, very calcareous.	15'+	291'+
31	Shale, dark gray, nonresistant, mostly covered. SD-67 Pb 7480*@ 200' above Frontier SD-66 Pb 7479 @ 200' above Frontier	276'	276'
	FRONTIER		
30	Conglomerate, yellow brown, mostly quartz pebbles, black chert pebbles common but much less abundant; thick planar beds; ferruginous, resistant; scattered ironstone lenses.	5.6'	545.0'
29	Mostly sandstone with numerous thin, dark gray or black shale partings; scattered fine conglomerate lenses with numerous small andesite pebbles; sandstone is fine grained, salt and pepper but dark minerals are rarer, sorting fair to good; locally crossbedded; mostly poorly exposed. SD-65 Pb 7478 528.4'	29.6'	538.4'
28	Conglomerate, very coarse sand matrix, well rounded pebbles to 1" of andesite, chert and white quartz; weathers to yellow band; ferruginous, siliceous, calcareous.	1.9'	508.8'
27	Mostly gray to buff, bentonitic sandstone with some interbedded black, bentonitic shale; mostly covered but forms resistant low ridge; particularly bentonitic at base.	44.4'	507.9'
26	Shale, black, fissile to crumbly, bentonitic at top and grades into bentonitic	27.6'	463.5'

*SD-67 collection number, Pb 7480 maceration number

sand above; rare silty lenses; scattered selenite crystals on weathered surface near top.

SD-62 Pb 7475 460.9'
SD-61 Pb 7474 455.9'
SD-60 Pb 7473 450.9'
SD-59 445.9'
SD-58 Pb 7472 440.9'

25 Six layer unit; from the bottom, black "coaly" fissile shale, scattered round chert pebbles, abundant plant fragments, silty, small sand lenses; black fissile shale, not "coaly"; coarse to medium grained sandstone, iron stained, cross-bedded (?); fissile black shale; sandstone, fine grained, nonresistant; conglomerate with sandy or shaly matrix, well rounded chert pebbles with cusp shaped percussion marks. 2.3' 435.9'

SD-57 Pb 7471 Black shale
SD-56 Pb 7470 Black peaty, fissile shale ("coal")

24 Sandstone, similar to sandstone below and grades into it, fine to medium grained, sorting fair to good, massive, salt and pepper; weathers to bare massive slope; more ferruginous than unit #23 and weathers light yellow brown except beneath "coaly" shale (#25) where it is leached (?) white; thin bedded argillaceous sandstone near base; local large scale crossbeds. 28.6' 433.6'

23 Sandstone, very light gray, salt and pepper; weathers to barren badlands; poorly sorted; weathered portion composed of unconsolidated sand; hard on fresh surface; apparently bentonitic and argillaceous throughout; local bands of crossbedded, hard, concretionary sandstone, which is commonly ferruginous; massive, no evident bedding, gradational contact with sandstone above; lenticular pods of very ferruginous, medium grained sandstone with large low angle crossbeds, which appear to be channels. 41.4' 405.0'

22 Mostly bentonitic shale, black, fissile, carbonaceous with ferruginous stringers; 24.4' 363.6'

several resistant beds of poorly sorted, very fine grained, platy sandstone with abundant small, white, calcareous worm casts; very sandy throughout.

SD-55 Pb 7469 354.2'
SD-54 Pb 7468 349.2'

21 Interbedded light gray, poorly sorted, dirty, very fine grained sandstone and arenaceous gray shale, some black organic shale interbeds; faint ripple marks on sandstone; fairly resistant; calcareous worm casts common in upper sandstone unit; ripples trend on upper surface N40°W. 9.2' 339.2'

SD-53 Pb 7467 339.2'

20 Bentonitic shale, dark gray, weathers medium to light gray; bare slope; bentonite decreases upward, becomes progressively more silty toward top, many thin argillaceous sandstone and siltstone units in upper half, small ironstone concretions; fine, persistent laminae in lower half. 23.0' 330.0'

SD-52 Pb 7466 327.8'
SD-51 322.8'
SD-50 Pb 7465 317.8'
SD-49 312.8'
SD-48 Pb 7464 307.8'

19 Bentonite, grayish yellow, very pure; grades upward into very bentonitic shale; good marker; many bands of white fiberous gypsum. 2.8' 307.8'

SD-47 Channel

18 Shale and sandstone; dark brown to black, silty and sandy shale with numerous thin beds of ferruginous, brown sandstone; sandstone most abundant in upper part; thin bedded, platy sandstone at top with vague large scale ripple marks; tiny fragments of coal and plant material (?); numerous worm trails. 29.0' 305.0'

SD-46 Pb 7463 305.0'
SD-45 301.0'
SD-44 Pb 7462 296.0'
SD-43 291.0'
SD-42 Pb 7461 286.0'

SD-41 281.0'
SD-40 Pb 7460 276.0'

17 Shale, black to brownish black, fissile; weathers to bare slope; scattered bentonitic partings; very similar to units #14 and #15. 14.2' 276.0'

SD-39 Pb 7459 271.8'
SD-38 266.8'
SD-37 Pb 7458 261.8'

16 Bentonite and dark gray bentonitic shale; pure, grayish yellow bentonite grading upward to bentonitic shale. 4.6' 261.8'

SD-36 Chanel

15 Shale, dark brown to brownish black, carbonaceous; weathers to bare, dark brown slope; siliceous, silty; abundant tiny selenite crystals, probably secondary; rare fish scales (Hunter (1952) reports fish scales here); slightly ferruginous. 27.6' 257.2'

SD-35 Pb 7457 254.6'
SD-34 Pb 7456 249.6'
SD-33 244.6'
SD-32 239.6'
SD-31 Pb 7455 234.6'

14 Shale, black, fissile, carbonaceous, slightly silty; nonresistant; no siltstone or sandstone lenses, scattered tiny ferruginous specks; slope weathers black. 17.0' 229.6'

SD-30 Pb 7454 227.6'
SD-29 222.6'
SD-28 217.6'
SD-27 Pb 7453 212.6'

13 Bentonitic shale, light to dark gray, soft silty, nonresistant; thin silty unit at top, also several very thin siltstone lenses throughout. 9.6' 212.6'

12 Sandstone, fine grained, poorly sorted, good porosity, resistant, salt and pepper to light brown; conglomerate bed with large bone fragments and chert pebbles at top, in places this bed is an 18" channel cut into the upper surface, elsewhere it is a thin veneer.

11	Sandstone, sequence of argillaceous and shaly sandstone beds to 6" thick; weathers light brown or brownish gray; shaly parts fissile; iron stain on a few beds. SD-26 Pb 7452 189.2'	11.5'	189.2'
10	Sandstone and shale, sequence of resistive sandstone units to 4' thick, thickness of sandstones varies rapidly east to west (no systematic changes); sandstone units are fine grained, salt and pepper, rare large chips of Mowry and red chert pebbles; poorly exposed benches are unconsolidated sand, sandy shale and thin beds of black, carbonaceous shale; sandstone is locally crossbedded and calcareous; rare worm borrows. SD-25 Pb 7451 164'±	25.3'	177.7'
9	Shale, medium gray to black; weathers to bare, medium grained "popcorn" surface; bentonitic and darker colored in lower half, sandy and silty in upper half, upper half lighter colored; scattered concretionary sandstone and siltstone lenses in upper part; arenaceous material and beds become progressively more abundant in upper half. SD-24 Pb 7450 150.4' SD-23 147.6' SD-22 Pb 7449 143.6' SD-21 138.6' SD-20 Pb 7448 132.6' SD-19 127.6' SD-18 123.6' SD-17 Pb 7447 118.6'	36.8'	152.4'
8	Sandstone, salt and pepper, medium to coarse grained, crossbedded, poor sorting; numerous large flattened Mowry pebbles.	1.4'	115.6'
7	Poorly exposed sequence of shale, sandstone and conglomerate; numerous thin sandstone ledges, very fine to fine grained, poor to moderate sorting, salt and pepper, good porosity, several thin beds of coarse grained sand with large chert pebbles; most of unit is dark gray to black; carbonaceous.		

SD-16 Pb 7446 108.3'
SD-15 Pb 7445 99.3'

6	Shale, black, very fissile, carbonaceous; very distinctive; possibly only a lens; very sharp upper contact.	0.7'	94.3'

SD-14 Pb 7444 Channel

5	Sandstone, first major resistive sandstone in traverse; fine to very fine grained, good porosity, well sorted subangular grains, very abundant worm trails parallel and perpendicular to bedding with calcite tube coatings, salt and pepper; persistant planar or tabular bedding, beds 1" to 1', average 3" to 6" thick, discontinuous shale lenses to 3' thick and occasional shale partings, thin bentonite lenses near top.	32.2'	93.6'

SD-13 Pb 7443 84.6'

4	Poorly exposed slope with 2 or 3 thin resistant sandstone units; sandstone units 1' to 2' thick, small scale crossbeds, worm tubes in crossbedded units, good porosity, clean, fine grained, good sorting, thin bedded, variable in thickness and argillaceous content laterally between sandstone ledges.	16.1'	61.4'

SD-12 Pb 7442 55.4'

3	Shale, sandy, salt and pepper, weathers light tan to buff, becomes progressively more arenaceous toward top, fissile in lower half, thin bedded and very sandy in upper half, many thin sandstone lenses in upper half, bentonitic at top.	23.5'	45.3'

SD-11 42.8'
SD-10 Pb 7441 37.8'
SD-9 32.8'
SD-8 27.8'
SD-7 Pb 7440 22.8'

2	Shale, medium to dark gray, weathers to light gray, fissile, platy, not limey, fish scales, siliceous, grity and slightly silty; looks like Mowry.	17.2'	21.8'

SD-6 Pb 7439 14.6'
SD-5 8.6'

1	Bentonite, pure, distinctive, weathers to thick band of "popcorn," irregular thickness.	4.6'	4.6'

SD-4 Channel

MOWRY

Shale, light to dark gray, siliceous, sandy lenses, fish scales, platy and rather resistant at top, local relief (?) on top.

SD-3 Pb 7438 5' below unit #1
SD-2 Pb 7437 35' below unit #1
SD-1 Pb 7436 65' below unit #1

Chabot Anticline
NE, 18, T43N, R88W
Washakie, Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Shale.		
	FRONTIER		
28	Sandstone, very fine grained, very calcareous, very tight, ferruginous, medium bedded at base, thick bedded and very resistant at top; large scale low angle crossbeds in upper part.	16.7'	749.3'
27	Covered, a few ferruginous concretionary sandstone ledges outcrop locally; interval appears to be largely sandy shale. CA-47* Pb 7586* 727.6' CA-46 Pb 7585 717.6'	267.0'	732.6'
26	Shale, black, blocky, bentonitic, very poorly exposed. CA-45 Pb 7584 467.8' CA-44 457.8' CA-43 Pb 7583 452.8'	12.8'	465.6'
25	Conglomerate, coarse grained, porous, sandstone matrix, very abundant black chert and gray quartz pebbles to 3" long.	0.4'	452.8'
24	Sandstone and shale, interbedded pure layers of black, very fissile shale and clean, fine grained, well sorted, porous, salt and pepper, sandstone to 3" thick. CA-42 Pb 7582 452.4'	5.3'	452.8'
23	Sandstone, light gray, thin bedded, large scale low angle crossbeds, salt and pepper,	14.0'	447.1'

*CA-47 collection number, Pb 7586 maceration number

	very fine grained, argillaceous; poor porosity; clean sandstone at base, some black shale with scattered pebbles at top.	14.0'	447.1'
	CA-41 Pb 7581 447.1'		
22	Mostly black, fissile, carbonaceous shale and a little interbedded light gray, laminated, very fine grained, argillaceous, sandstone in beds 1" thick; sandstone more abundant than in unit #21, weathers to brown band.	6.4'	433.1'
	CA-40 Pb 7580 431.7' CA-39 Pb 7579 426.7'		
21	Mostly black, fissile, slightly carbonaceous shale and interbedded gray or brown, argillaceous sandstone in beds to 1/2 inch thick; weathers to light gray band.	8.9'	426.7'
20	Sandstone, mostly very fine grained, poorly consolidated, deeply weathered, ferruginous, slightly bentonitic, very light gray; weathers to "badland" slope; medium gray, argillaceous and shaly in upper part; slightly resistant rounded ridge with very large dark brown, ferruginous, crossbedded concretions.	17.3'	417.8'
19	Interbedded dark gray to black, fissile, carbonaceous shale and light to medium gray very shaly sandstone; whole sequence is bentonitic and weathers to gray sandy "popcorn" surface; ledge, 3' thick, near top of unit, tan, laminated, fine grained, slightly calcareous, clean sandstone with abundant ripples on upper surface.	37.4'	400.5'
	CA-38 Pb 7578 393.1' CA-37 388.1' CA-36 Pb 7577 378.1' CA-35 370.1' CA-34 Pb 7576 365.1'		
18	Bentonite, light greenish gray, "popcorn" surface, grades into shale above.	3.4'	363.1'
17	Shale, medium brown, carbonaceous, steel gray siliceous at top.	4.0'	359.7'

CA-33 359.7'

16	Bentonite, waxy, gray-green, pure with scattered large selenite crystals.	0.7'	355.7'
15	Grades from black or dark brown, fissile, carbonaceous shale at base to brown, ferruginous, very argillaceous, very argillaceous, shaly, siltstone at top.	19.5'	355.0'

CA-32 Pb 7575 355.0'
CA-31 350.5'
CA-30 Pb 7574 345.5'
CA-29 340.5'
CA-28 Pb 7573 337.5'

14	Sandstone, medium gray, shaly and argillaceous, fine to coarse grained, poorly sorted, poor porosity, thin bedded; poorly exposed; numerous black shale partings.	4.6'	355.5'
13	Sandstone, forms massive resistant ledge, thick bedded, large scale low angle crossbeds throughout; fine grained, well rounded, fair sorting, good porosity, slightly ferruginous; coarse grained, calcareous sand at top (2') with abundant light gray, brown and black chert pebbles scattered throughout; large ferruginous, dark brown, crossbedded, concretions in mid-part; abundant ripple marks near top.	28.4'	330.9'
12	Sandstone, fine grained, argillaceous, gradational contact with shale below, very shaly in lower part; light gray, brown to buff; poor porosity; poorly exposed; more massive and cleaner at top; ripple marks on upper surface.	19.6'	302.5'
11	Shale, dark gray to black, blocky, organic, a few argillaceous sandy lenses in lower part, grades into very shaly sandstone above; poorly exposed, mostly covered.	34.0'	282.9'

CA-27 278.9'
CA-26 Pb 7572 273.9'
CA-25 268.9'
CA-24 Pb 7571 263.9'
CA-23 285.9'
CA-22 Pb 7570 253.9'

10	Sandstone, coarse grained, well rounded, well sorted, good porosity; outcrops as a series of thick or medium bedded ledges; less resistant than unit #9; a few lenses of black shale.	12.3'	248.9'
9	Sandstone, fine to medium grained, very thick bedded and massive, forms very resistant cliff, good porosity, numerous thick ironstone lenses and concretions, some local small scale crossbeds; numerous worm trails on bedding plains in lower part; mostly laminated and massive, salt and pepper to buff, weathers grayish yellow, slightly calcareous, very friable.	54.1'	236.6'
8	Mostly fine grained, light gray, argillaceous and bentonitic sandstone which tends to weather to badlands; abundant black, carbonaceous, blocky shale at base; thick resistive interbeds of very ferruginous, red brown, very fine grained sandstone; a few black shale partings at top. CA-21 181.4' CA-20 Pb 7569 176.4' CA-19 171.4' CA-18 Pb 7568 166.4'	16.1'	182.5'
7	Sandstone, fine to medium grained, calcareous, sorting fair to good, good porosity, buff, weathers light grayish brown, crossbedded throughout; scattered pebbles at top, medium to thick bedded; resistant ledge below main cliff.	8.2'	166.4'
6	Interbedded black, fissile, carbonaceous shale and light gray, argillaceous sandstone; sandstone predominates, shale becomes less abundant in upper part and consists mainly of thin partings; sandstone is locally calcareous, usually with poor porosity; bed with abundant rounded, black chert pebbles near top; bentonitic throughout. CA-17 158.2' CA-16 Pb 7567 148.4' CA-15 138.4' CA-14 Pb 7566 128.4'	89.8'	158.2'

	CA-13	118.4'		
	CA-12 Pb 7565	108.4'		
	CA-11	98.4'		
	CA-10 Pb 7564	88.4'		
5	Bentonite, grayish yellow, pure, deeply weathered "popcorn" surface.		4.3'	68.4'
4	Sandstone, fine to very fine grained, slightly calcareous in lower part, calcareous in upper 2/3, well sorted, clean, porous, siliceous, weathers to light gray; resistant ledge; worm trails and borrows.		11.5'	64.1'
3	Shale, black, soft, fissile, organic in lower part, becomes sandier toward top and at top is very argillaceous, blocky, dark brown sandstone; sandy throughout upper 2/3.		28.6'	52.6'
	CA-9 Pb 7563	49.0'		
	CA-8 Pb 7562	29.0'		
	CA-7	24.0'		
2	Shale, siliceous, like Mowry, medium gray, weathers light gray with brown ferruginous stain; hard, brittle, blocky; weathers to resistant ledgy outcrop.		18.4'	24.0'
	CA-6 Pb 7561	20.6'		
	CA-5	15.6'		
	CA-4 Pb 7560	10.6'		
1	Bentonite, olive colored, very deeply weathered "popcorn" surface.		5.6'	5.6'

MOWRY

Siliceous shale.

CA-3 Pb 7559 top Mowry
CA-2 Pb 7558 5' below top Mowry
CA-1 Pb 7557 10' below top Mowry

Lucerne Anticline
NE, SE, 9, T43N, R94W
Hot Springs Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Shale. LA-79* Pb 7638* 710.5' LA-78 Pb 7637 690.5' LA-77 Pb 7636 670.5'		
	FRONTIER		
33	Sandstone, argillaceous, thin bedded and shaly, fine grained, poor porosity; numerous bands of cream colored, carbonaceous, fossiliferous concretions; tan to buff; abundant wood fragments; numerous unusual tube shaped concretions throughout; well preserved Inoceramus fossils. LA-76 Pb 7635 636.9' LA-75 Pb 7634 626.9'	28.6'	650.5'
32	Shale, black, fissile, organic; sandy at top, grades into unit above, dark gray surface, sharp and gradational change with unit above. LA-74 Pb 7633 621.9' LA-73 617.6' LA-72 Pb 7632 612.6' LA-71 Pb 7631 602.6' LA-70 597.6' LA-69 Pb 7630 592.6' LA-68 587.6' LA-67 Pb 7629 582.6'	39.1'	621.9'
31	Interbedded argillaceous and shaly, medium gray, fine grained sandstone with poor porosity and black to medium gray,	68.0'	582.6'

*LA-79 collection number, Pb 7638 maceration number

	sandy shale; numerous stringers of black, fissile shale; becomes an argillaceous, shaly, buff sandstone at top; black chert pebble beds 43' above base and at top in concretionary ferruginous bed; large (3') ferruginous concretions widely scattered in upper part; Hunter (1950) measured this interval as 38', it is 46' one quarter mile north of this transect.	68.0'	582.6'
	LA-66 Pb 7628 529.8' LA-65 521.8' LA-64 Pb 7627 514.8'		
30	Sandstone, fine to medium grained, good porosity, slightly argillaceous, a few shaly bands, thick bedded; thin beds of black shale near top and bottom; forms resistive ridge; siliceous, calcareous.	18.9'	514.8'
29	Mostly shale, black, fissile, organic, scattered sandy lenses to 2" thick, sandstone partings in lower; gradational upper contact.	23.0'	495.9'
	LA-63 Pb 7626 495.9' LA-62 492.9' LA-61 Pb 7625 487.9' LA-60 482.9' LA-59 Pb 7624 477.9'		
28	Sandstone, very fine grained, poor porosity, light yellowish gray, weathers same, discontinuous ridge; shale interbeds.	2.0'	472.9'
27	Shale, mostly black and fissile, weathers to medium dark brown surface; more or less sandy locally; numerous sandstone partings in lower part.	31.7'	470.9'
	LA-58 Pb 7623 469.2' LA-57 464.2' LA-56 Pb 7622 459.2' LA-55 454.2' LA-54 Pb 7621 449.2' LA-53 444.2'		
26	Interbedded dark gray to black, fissile to blocky shale and light to medium gray, fine grained, argillaceous and shaly sandstone.	9.2'	439.2'

LA-52 Pb 7620 439.2'
LA-51 435.0'
LA-50 Pb 7619 430.0'

25 Sandstone, very fine grained, argillaceous and bentonitic, light to medium gray, banded, "popcorn" surface; a few resistant ledges; medium to thin bedded; very poor porosity; common black shale stringers; very sharp upper surface. 31.7' 430.0'

LA-49 Pb 7618 403.3'

24 Shale, medium gray to black, fissile, bentonitic, weathers to dark gray "popcorn" surface; a few resistive ledges; medium to thin bedded; very sharp lower contact; becomes more sandy and lighter gray toward top. 14.8' 398.3'

LA-48 Pb 7617 398.3'
LA-47 393.5'
LA-46 Pb 7616 388.5'
LA-45 383.5'

23 Sandstone, medium to coarse grained, slightly calcareous, good porosity, subangular to subrounded grains, sorting fair; prominent ridge with long dip slope; thick massive beds, large scale crossbeds, widely scattered pebbles on upper surface, abundant worm trails; offset 1/4 mile south on this unit. 10.0' 383.5'

22 Sandstone, fine grained, argillaceous, bentonitic, numerous black shale stringers; hard "popcorn" surface; very abundant carbonized wood fragments and numerous linguloid brachiopods or small clams; poor porosity; mostly poorly resistant but forms vertical cliff at top; light to medium gray outcrop; discontinuous coaly black shale unit at top. 34.0' 373.5'

LA-44 Pb 7615 373.5'
LA-43 Pb 7614 359.5'
LA-42 349.5'
LA-41 Pb 7613 345.5'

21 Shale, dark gray, fissile to blocky, carbonaceous, numerous sandstone stringers especially in lower part, sandstone thin bedded, platy, fine grained 15.2' 339.5'

LA-40 Pb 7612 339.5'
LA-39 Pb 7611 332.3'

20	Sandstone with numerous thin black lenses of organic shale; sandstone soft, poorly consolidated and very deeply weathered; bentonitic; very poorly exposed; sandstone fine grained.	17.0'	307.3'
19	Shale, dark gray to black, sandy and siliceous, blocky to fissile; numerous thin sandstone partings; sandy throughout; sharp contact with unit #18.	17.8'	307.3'

LA-38 Pb 7610 297.5'
LA-37 Pb 7609 291.5'

18	Sandstone, vertical cliff; thin, tabular, persistant bedding with large low angle crossbeds in lower half, thick bedded and massive in upper half; medium grained, well sorted, good porosity; very rare pebbles in upper half; ferruginous brown outcrop; offset 1/3 mile north on this unit.	20.0'	289.5'
17	Sandstone, argillaceous and shaly; mostly covered by sandstone debris from cliff above; buff to medium gray; thin bedded to shaly, rather soft, a little interbedded shale, slightly bentonitic near top.	25.3'	269.5'
16	Interbedded shale and sandstone, sandstone like above, shale black, fissile, organic, carbonaceous; thick sand bed in center.	6.0'	244.2'

LA-36 Pb 7608 238.2'

15	Sandstone, fine grained, calcareous, mostly thick bedded with common medium scale, planar, crossbeds; well sorted, good porosity; shale lenses in lower part; ledgy outcrop; light gray brown, weathers same; large ironstone concretations.	28.6'	238.2'
14	Interbedded argillaceous siltstone and sandy, silty shale; mostly medium to dark gray; thin bedded siliceous shale unit near base; shale usually silty and blocky, locally black, organic and fissile; siltstone argillaceous, hard,	35.4'	209.6'

	brittle, thin bedded and blocky to almost fissile; sharp contact with unit #13, gradational with unit #15.	35.4'	209.6'
	LA-35 Pb 7607 209.6' LA-34 204.2' LA-33 Pb 7606 199.2' LA-32 192.2'		
13	Sandstone, medium gray, weathers buff with dark brown stain, very fine grained, siliceous, very poor porosity; persistant low ridge.	1.5'	174.2'
12	Shale, black and carbonaceous to medium gray, blocky and very sandy, more or less siliceous, slightly bentonitic, weathers light gray; lenses of medium grained, pink sandstone.	15.5'	172.7'
	LA-31 Pb 7605 167.2' LA-30 162.2' LA-29 Pb 7604 157.2'		
11	Sandstone, very thin bedded to fissile, platy, very fine grained, light gray with brown stain, siliceous; forms resistant ledge; hard, shaly, crossbedded.	2.4'	157.2'
10	Shale, medium to dark gray, fissile to blocky, hard, somewhat silty, slightly siliceous; very poorly exposed.	7.1'	154.8'
	LA-28 Pb 7603 152.7' LA-27 Pb 7602 147.7'		
9	Sandstone, very fine grained, argillaceous and bentonitic; weathers to badlands, numerous resistant ridges of hard, dense, crossbedded, very tight, ferruginous sandstone; rare chert pebbles; light gray, massive; thin, palty, ferruginous, crossbedded sandstone at top; numerous ferruginous, concretionary beds.	57.5'	147.7'
	LA-26 140.2' LA-25 Pb 7601 135.2' LA-24 Pb 7600 121.2' LA-23 Pb 7599 110.2'		
8	Shale, black to medium gray, black and carbonaceous at base, progressively more	18.1'	90.2'

	sandy toward top; medium gray, very sandy at top, grades into unit above; more or less siliceous.	18.1'	90.2'
	LA-22 87.7' LA-21 Pb 7598 82.7' LA-20 77.7' LA-19 Pb 7597 72.7'		
7	Shale, siliceous, medium gray, weathers light gray with brown stain; ledgy, blocky; more or less silty, numerous carbonaceous stringers.	5.3'	72.7'
	LA-18 68.8'		
6	Bentonite, light yellowish gray, pure, "popcorn" surface, well exposed, sharp upper and lower contact.	4.6'	66.8'
5	Shale, siliceous, blocky, hard silty, weathers blue gray; scattered pebbles in lower part.	1.5'	62.2'
	LA-17 Pb 7596 62.2'		
4	Sandstone, fine grained, medium gray, salt and pepper, dark brown to black stain, more or less calcareous, porosity fair to good; abundant medium scale, planar cross-beds; abundant large worm tubes; thin bedded and platy to thick bedded and massive; abundant dark black chert pebbles in upper part.	12.0'	60.7'
3	Sandstone, very fine to fine grained, hard, dense, abundant calcite and silica cement, poor porosity, salt and pepper, bedding 4" to 1' thick; interbedded shale, thin beds and lenses of blocky black shale near top.	12.7'	48.7'
	LA-16 Pb 7595 48.7' LA-15 44.0' LA-14 Pb 7594 39.0'		
2	Mudstone, bedded, slightly silty, medium gray, weathers light gray with brown ferruginous stain; sharp lower contact, quite uniform; thin shale lenses; some very fine grained, argillaceous sandstone near top; rare black shale partings in upper part.	30.0'	36.0'

LA-13		36.0'
LA-12	Pb 7593	31.0'
LA-11		26.0'
LA-10	Pb 7592	21.0'
LA-9		16.0'
LA-8	Pb 7591	11.0'

1 Bentonite, gray yellow color; very pure at base, light and shaly at top. 6.0' 6.0'

LA-7		6.0'
LA-6	Pb 7590	4.0'

MOWRY

Shale, siliceous.

LA-5	Pb 7589	5' below unit #1
LA-4		10' below unit #1
LA-3	Pb 7588	15' below unit #1
LA-2		20' below unit #1
LA-1	Pb 7587	25' below unit #1

Pitchfork Anticline
SE, 14, T48N, R102W
Park Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Shale. PA-72 668.8' PA-71 663.8' PA-70*Pb 7730* 658.8'		
	FRONTIER		
42	Sandstone, single massive bed, medium to coarse grained, scattered small pebbles and several pebble bands in upper half; bone fragments in pebble band near center; well sorted, good prorsity; salt and pepper; light gray on outcrop; very sharp upper and lower contacts.	22.0'	658.8'
41	Shale, medium to dark gray to grayish brown; massive, blocky; numerous very thin sandstone partings; ferruginous; uniform; outcrops weather brown; a few black shale stringers and lenses of medium grained sand near top. PA-69 634.7' PA-68 Pb 7729 629.7' PA-67 624.7' PA-66 Pb 7728 619.7' PA-65 614.7' PA-64 Pb 7727 609.7'	32.1'	636.8'
40	Shale, black, very carbonaceous, hard, massive, abundant plant fragments; weathers platy. PA-63 Pb 7726 601.7'	3.7'	604.7'
39	Sandstone, medium to coarse grained, well sorted, rounded, good porosity; more or less calcareous throughout; irregular crossbeds; contains black shale near top	16.0'	601.0'

*PA-70 collection number, Pb 7730 maceration number

	in lenses to 2" thick, forms resistant ridge; locally abundant carbonaceous wood fragments.		
	PA-62 Pb 7725 595.0'		
38	Sandstone, argillaceous, thin bedded, finely laminated, very fine grained, shaly, soft, light brown; scattered black shale lenses in lower part; pebble bed with numerous shark teeth 8' above base.	21.5'	585.0'
37	Mostly argillaceous sanstone with abundant black shale beds to one foot thick; sandstone very fine to fine grained; shale soft, laminated, black, pure; grades into units above and below.	34.5'	563.5'
	PA-61 Pb 7724 539.0' PA-60 Pb 7723 534.0'		
36	Shale, black to grayish brown, scattered sandy bands, becomes sandier in upper part, numerous yellow brown streaks; concretions of very fine grained, very ferruginous and calcareous sand.	30.8'	529.0'
	PA-59 529.0' PA-58 Pb 7722 523.2' PA-57 518.2' PA-56 Pb 7721 513.2' PA-55 508.2' PA-54 Pb 7720 503.2' PA-53 498.2'		
35	Bentonite, cream color with orange stain, pure; very poorly exposed.	2.3'	498.2'
34	Shale, black, fissile, organic, carbonaceous.	2.6'	495.9'
	PA-52 Pb 7719 495.9'		
33	Sandstone, salt and pepper, well sorted and rounded, porous, friable, siliceous; resistant at top; rare black shale lenses in lower part.	11.5'	493.3'
32	Bentonite, bright yellow green, poorly exposed, grades into unit below.	3.6'	481.8'
31	Shale, black, organic, some yellow stain; blocky, very slightly bentonitic; earthy.	14.1'	478.2'

PA-51 Pb 7718 478.2'
PA-50 474.1'
PA-49 Pb 7717 469.1'
PA-48 494.1'

30	Sandstone, very fine grained, argillaceous, laminated, poor porosity, abundant carbonaceous material give unit rich brown color; abundant plant material.	3.2'	464.1'

PA-47 Pb 7716 461.9'

29	Shale, dark gray, blocky, numerous thin, argillaceous sandstone interbeds; grades upward into very black organic shale with carbonaceous fragments.	9.2'	460.9'

PA-46 460.9'
PA-45 Pb 7715 456.7'
PA-44 Pb 7714 451.7'

28	Sandstone, light grayish brown to light gray, fine grained, very argillaceous and shaly, poor porosity, slightly bentonitic.	4.6'	451.7'
27	Shale, black, organic, sandy at top, bentonitic in upper 1/3' olive colored where bentonitic.	26.2'	447.1'

PA-43 Pb 7713 445.9'
PA-42 440.9'
PA-41 Pb 7712 435.9'
PA-40 Pb 7711 425.9'

26	Sandstone, argillaceous and shaly in lower 2/3; resistant ledge at top; fine to medium grained, poorly sorted, poor porosity, light to medium gray with red-brown stain, siliceous; numerous large worm tubes at top.	7.6'	420.9'
25	Sandstone, light gray, occasionally stained light brown, massive, laminated, fine to medium grained, very argillaceous, slightly bentonitic; tends to weather to badlands; thin bentonite at top; several thin black shale interbeds at base; like unit #19 and #15, but is more argillaceous and shaly; poor porosity.	24.0'	413.3'
24	Sandstone, like unit #22, small wood fragments.	1.0'	389.3'

23	Shale, medium gray, laminated, blocky, slightly bentonitic and silty; carbonaceous wood fragments common. PA-39 Pb 7710 388.3' PA-38 Pb 7709 384.1'	9.2'	388.3'
22	Sandstone, siliceous, very fine grained, medium grained, medium gray, weathers light silvery gray with brown stain on exposed surfaces; very poor porosity.	1.0'	379.1'
21	Interbedded light brown to black, bentonitic shale and sticky, medium to dark brown, shaly bentonite; fairly pure black shale at base. PA-37 Pb 7708 378.1' PA-36 Pb 7707 368.3'	9.8'	378.1'
20	Sandstone, grades laterally from a resistant, fine grained, siliceous sandstone with abundant plant material, shale chips at base and occasional chert pebble bands at top to an interbedded shaly sandstone and black to dark brown sandy shale. PA-35 Pb 7706 354.9'	18.4'	349.9'
19	Sandstone, fine grained, argillaceous and bentonitic, light gray; weathers to rounded light gray ridge with bentonitic "popcorn" bands; slightly calcareous; resembles unit #15.	16.6'	349.3'
18	Interbedded black, fissile, organic shale with common, very small plant fragments and very fine grained, gray, laminated, hard, very argillaceous sandstone; poorly exposed. PA-34 332.6' PA-33 Pb 7705 327.6' PA-32 Pb 7704 312.6'	20.7'	333.3'
17	Sandstone, transitional from clean sand below to black shale above; thin bedded, argillaceous, poor porosity; ledgy outcrop.	5.1'	312.6'
16	Sandstone, gray brown, salt and pepper, slightly calcareous, fine grained, well sorted, well rounded, good porosity,	10.5'	307.5'

	medium to thick bedded; forms a resistant ledge across ridge; weathers light gray brown.		
15	Sandstone, light to medium gray, weathers light gray, bentonitic; weathers to a bare, rounded ledge or badlands, argillaceous, fair porosity, fine grained, scattered dark red-brown, ferruginous lenses.	14.3'	297.0'
14	Shale, dark brown to black, more or less locally sandy; in places forms argillaceous, sandstone. PA-31 Pb 7703 280.3' PA-30 Pb 7702 275.3' PA-29 Pb 7701 270.3'	-12.4'	282.7'
13	Sandstone, very fine grained, numerous very thin shale partings, light gray, stained red brown; siliceous, argillaceous.	1.6'	270.3'
12	Argillaceous sandstone, thin bedded, shaly, poorly resistant, light to medium gray; bentonitic in lower 1/2; a few ferruginous lenses, thin bentonite near base.	7.8'	268.7'
11	Sandstone, medium grained well rounded, bentonitic, porosity poor to fair, weathers light gray; forms badlands; resistive ledge; large scale, low angle crossbeds; numerous resistant, ferruginous, lenticular concretions; numerous very thin bentonites; some dark gray shale in upper 15'. PA-28 Pb 7700 250.9'	47.0'	260.9'
10	Mostly shale and mudstone, blocky to massive, laminated; numerous thin sandstone partings, a few argillaceous sandstone lenses to 3" thick; shale medium to dark gray. PA-27 Pb 7699 209.7' PA-26 Pb 7698 204.7' PA-25 Pb 7697 199.7'	19.2'	213.9'
9	Bentonite, yellowish cream color, pure, rounded ledge.	4.4'	194.7'

8	Sandstone and shale, finely interbedded, very poorly exposed, numerous siliceous sandstone ledges. PA-24 Pb 7696 167.7'	27.6'	190.3'
7	Shale, black, fissile in lower part, becomes blocker and sandier at top, siliceous, grades into unit above; abundant small "phosphatic" pelecypods, fish scales. PA-23 Pb 7695 156.2	11.5'	162.7'
6	Bentonite, bright yellowish green, very pure, massive.	3.0'	151.2'
5	Shale, dark gray to black, blocky, slightly bentonitic, a few bentonitic stringers to 3", carbonaceous, locally quite silty, more siliceous close to bentonite. PA-22 144.8' PA-21 Pb 7694 139.8' PA-20 134.8' PA-19 Pb 7693 129.8' PA-18 124.8' PA-17 Pb 7692 119.8' PA-16 114.8' PA-15 Pb 7691 109.8' PA-14 Pb 7690 99.8' PA-13 94.8'	53.4'	148.2'
4	Bentonite, bright olive green, pure; offset 1000' south.	2.3'	94.8'
3	Sandstone, massive and thick bedded in lower 2/3, tabular with large scale cross-beds in upper 1/3; calcareous, fine to medium grained, porosity fair to good, hard, forms resistant cliff; salt and pepper, slightly ferruginous throughout; very ferruginous, lenticular concretions, very abundant large calcareous worm tubes throughout; strike N10°W, dip 45°SW.	25.0'	92.5'
2	Interbedded hard, fine grained, argillaceous, salt and pepper sandstone with poor porosity and dark brown to black, blocky to fissile, carbonaceous shale; all beds appear to be very lenticular, beds to 3' thick; most of the sands	61.5'	67.5'

have paper thin shale partings; plane bedded; approximately equal amounts of shale and sandstone; very poorly exposed; offset 600 feet along persistent ledge within unit.

PA-12 Pb 7689 46.0'
PA-11 Pb 7688 41.0'
PA-10 Pb 7687 31.0'
PA-9 29.0'
PA-8 Pb 7686 21.0'
PA-7 11-16'
PA-6 11-16'
PA-5 Pb 7685 6.0'

1	Bentonite, bright chartereuse to grayish yellow, pure, massive, thin siliceous shale in center; strike N10°W, dip 35°SW.	6.0'	6.0'

MOWRY

Shale, black, fissile to blocky and massive, siliceous.

PA-4 Pb 7684 5' below unit #1
PA-3 10' below unit #1
PA-2 Pb 7683 15' below unit #1
PA-1 20' below unit #1

Anchor Anticline
SE, 1, T43N, R100W
Hot Springs, Co.

The description of this section is taken from Burk (1953). Additional comments have been added, in parentheses, following Burk's description.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Shale.		
	FRONTIER		
29	Shale at base, becomes sandier upward and grading into argillaceous sandstone, sandstone, and very coarse-grained conglomerate at top of unit. Shale is black, soft, organic, and contains scattered argillaceous sandstone and sandy shale stringers which become more abundant upward until unit is predominantly argillaceous sandstone, about twenty-five feet above base. Sand is generally fine grained quartzose, gray to tan, poorly resistant; becoming more abundant and coarser-grained upward until upper three feet of unit are a very coarse-grained "salt and pepper", gray to buff sandstone, predominantly quartzose, but with some of the larger grains made of black to green minerals; chert granules and pebbles are very abundant and are firmly cemented in the coarse sand; upper surface of unit contains typical calcareous concretions enclosing scattered megafossils and chert pebbles $\frac{1}{4}$" to 3" in diameter. These pebbles commonly form thin lenses. The coarse-grained sand at the top of the unit contains 1" to $1\frac{1}{2}$" spheres of coarse sand cemented by calcareous material; these spheres commonly weather out free. The unit is generally non-resistant forming a low swale, but the upper few feet irregularly form a small ridge. The contact between Units 29 and 30 is very sharp.	61'	758.3'

*AA-61 Collection number, Pb 7682 maceration number

Faunal collection 433100/1B -- Lower Niobrara (Fort Hays) equivalent, collected from top of Unit 29:
Camptonectes platessa White, 1874
(single specimen)

(Conglomerate very calcareous, porous; chert pebbles of many colors, white, green, brown; pebbles are mostly flattened and disk shaped.)

AA-61*Pb 7682*742.3'
AA-60 Pb 7681 737.3'
AA-59 Pb 7680 732.3'
AA-58 Pb 7679 727.3'

28 Sandstone, gray to tan, generally medium-grained, irregularly fine- or coarse-grained; slightly argillaceous, with only a few scattered shale stringers. Uppermost few feet are dark brown sand with small ¼"-1", dark brown, hematitic concretions. Unit weathers tan to brown is slightly resistant, and of relatively uniform lithology throughout. — 35' — 697.3'

(Medium to thick bedded, strongly crossbedded at top; fair to good porosity throughout; forms long dip slope adjoining flat valley; upper most few feet very calcareous.)

27 Shale, black to dark gray, organic, soft, irregularly sandy; easily weathered, forming slight swale in long dip slope. Contacts with Unit 26 and 28 relatively sharp. — 7' — 662.3'

AA-57 Pb 7678 662.3'
AA-56 Pb 7677 657.3'

26 Sandstone, varying irregularly in color from rust to brown, gray, or white; generally coarse- to medium-grained with very few scattered, thin shale and sandy shale stringers, and irregularly argellaceous; scattered worm trails and ripple marks on bedding surfaces; upper few feet of unit contain nearly spherical, hematitic, dark brown sandstone concretions, 2" to 8" in diameter; irregularly crossbedded. Unit as a whole is very resistant, forming prominent — 54' — 655.3'

ridge and long dip slope; various layers irregularly resistant, forming steps in dip slope.

(Argillaceous with abundant interbeds of dark brown or black shale in lower 8'; 10' above base is friable sandstone bed with very abundant chunks of charcoal (30%); massive, tabular (pancake); cross-bedded through middle half; worm trails locally abundant in lower part; good porosity except at base, first good reservoir sand in this section; most resistant sandstone in sequence; slightly siliceous.)

25	Shale, black, soft, platy, organic; poorly indurated with scattered, iron-stained, argillaceous sandstone stringers; weathers easily, becomes dark gray; non-resistant. Contacts with Units 24 and 26 generally sharp.	10'	601.3'
	AA-55 Pb 7676 596.3'		
	AA-54 Pb 7675 591.3'		
24	Argillaceous sandstone, buff to rust and gray in color, medium- to fine-grained; highly cross-bedded; poorly resistant, forming small ledge, weathering tan to light gray.	20'	591.3'
	(Thin bedded and platy, rather poorly exposed.)		
23	Shale, black, organic, platy, soft; poorly indurated; irregularly sandy with few scattered tan argillaceous sandstone stringers in upper few feet of unit; non-resistant, weathering a dark gray, contact with Unit 24 relatively sharp.	38'	571.3'
	(Becomes sandier toward top.)		
	AA-53 Pb 7674 568.3'		
	AA-52 Pb 7673 563.3'		
	AA-51 558.3'		
	AA-50 Pb 7672 553.3'		
	AA-49 548.3'		
	AA-48 Pb 7671 543.3'		
	AA-47 538.3'		
	AA-46 Pb 7670 533.3'		

22	Bentonite, cream to gray, pure, weathering gray to light gray. Contacts with Units 21 and 23 very sharp.	3'	533.3'
21	Shale, black, platy, organic, soft; contains very few scattered argillaceous sandstone stringers; non-resistant weathering dark gray. Contact with Unit 20 very sharp. (Bentonitic at base.) AA-45 530.3' AA-44 Pb 7669 528.3' AA-43 523.3' AA-42 Pb 7668 518.3' AA-41 513.3' AA-40 Pb 7667 508.3' AA-39 Pb 7666 503.3'	32'	530.3'
20	Argillaceous sandstone becoming sandstone in upper third of unit; sand is tan to gray to white, medium- to fine-grained; highly argillaceous and poorly resistant in lower 40', becoming predominantly tan to brown sandstone in upper third of unit with scattered ¼" to 1" stringers of black sandy shale. Upper few feet of unit forms slight ledge below shale of Unit 21. Contact with Unit 19 gradational. (Bentonitic throughout, forms bare, light gray, sandy, "popcorn" surface.)	58'	498.3'
19	Shale, black, very finely bedded, soft, poorly indurated; non-resistant, weathering dark gray; contains scattered bentonite stringers; becomes gradually sandier in upper fourth of unit; sand is very argillaceous. Some selenite crystals in weathered zones of shale. (Bentonitic in upper part, very carbonaceous and organic; "popcorn" surface in flat areas; dip 31°; Burk measured this unit as 27'.) AA-38 Pb 7665 440.3' AA-37 435.3' AA-36 Pb 7664 430.3' AA-35 Pb 7663 425.3' AA-34 420.3' AA-33 Pb 7662 415.3' AA-32 410.3' AA-31 Pb 7661 405.3'	40'	440.3'

18	Bentonite, yellow to cream or gray; slightly sandy. Contacts with Units 17 and 19 very sharp.	1.5'	400.3'
17	Sandstone, white to gray or tan to buff and rust, fine- to medium-grained; with irregular, ¼"-1" stringers of shale, sandy shale, and argillaceous sandstone; generally poorly cemented. Lower few feet of unit contains worm trails, ripple marks, and scattered egg-shaped galls, ¼" to 3" in diameter, made up of hard, well-indurated, slightly siliceous clay. Upper few inches of unit contain scattered black to brown chert pebbles in thin lenses. Unit is resistant forming a very prominent ridge with individual sands forming short steps down the long dip slope. Westward, from the line of section, these various sands have been gradually eroded back, and the sand of Unit 15 caps the ridge, giving the appearance of a strike fault along the ridge. Contact with Unit 16 sharp. (Black and dark gray shale partings in lower part; thick beds in upper part; resistive sandstone ledges to 3' thick; ferruginous.) AA-30 Pb 7660 362.8' AA-29 Pb 7659 352.8' AA-28 342.8' AA-27 Pb 7658 337.8'	66'	398.8'
16	Shale, with argillaceous sandstone and sandy shale in basal part. Shale is black platy, fissile, siliceous, somewhat resistant; slivery on bedding surfaces; becoming soft, highly organic in upper half of unit. Basal 3' of unit a siliceous silty and sandy shale and argillaceous sandstone, grading upward into shale and argillaceous sandstone, grading upward into shale which makes up most of unit. Basal part somewhat resistant, forming slight ledge. Contact with Unit 15 gradational. In the line of traverse, the upper 3.5' of Unit 16 is made up of a pure, yellow to green bentonite, which is directly	22'	332.8'

overlain by the resistant sand of Unit 17; 1000' west of the line of traverse, this bentonite is absent and the sandstone of Unit 17 rests directly on the shale typical of Unit 16.

AA-26 Pb 7657 330.8'
AA-25 Pb 325.8'
AA-24 Pb 7656 317.8'

15	Argillaceous sandstone, gray to buff, weathering light gray, medium- to fine-grained; very argillaceous with scattered shale and sand stringers; non-resistant; containing a 1'-2' resistant sand at top of unit, becoming prominant and thicking to the west of the line of traverse. Contact with Unit 16 gradational. (Sandstone locally laminated, poorly exposed.)	19'	310.8'
14	Sandstone, buff to tan or brown, weathering tan to gray; medium- to fine-grained; blocky, generally plane-bedded; resistant, forming slight ledge in bluff. Contact with Unit 15 sharp, and with Unit 13 very sharp. (Ferruginous and crossbedded, poorly exposed.)	5'	291.8'
13	Shale and argillaceous sandstone, basal few feet a sandy shale and medium- to fine-grained, gray to tan argillaceous sandstone with abundant stringers of black, organic shale which makes up all of the upper three-fourths of the unit. Generally non-resistant, basal sandy part somewhat resistant. AA-23 Pb 7655 286.8' AA-22 Pb 7654 281.8'	10'	286.8'
12	Sandstone, buff to tan, iron-stained, medium- to fine-grained; blocky and somewhat resistant, forming small ledge. Contact with Unit 11 very sharp and gradational with Unit 13. (Siliceous, poor porosity, common irregular crossbeds, rare black shale lenses.)	8'	276.8'

11	Argillaceous sandstone and sandy shale, gray to buff or brown, weathering gray to tan or rust; medium- to fine-grained; very argillaceous, with irregular sand and black, organic shale stringers and lenses; generally non-resistant, but tending to form badlands with pinnacles capped by more resistant sandstone lenses, varying in thickness from 1" to 1'. Scattered resistant, elongate, hematitic concretions, which are dark brown to rust in color and which may have plane- or cross-bedding. Basal and uppermost 3' of unit a black, sandy, organic shale. Contact with Units 10 and 12 very sharp. (Thin bentonite about 15' above base; bentonitic and very sandy through middle 1/3 of unit; about 5' of blocky, sandy, shale at top.) AA-21 268.8' AA-20 Pb 7653 263.8' AA-19 239.8' AA-18 Pb 7652 229.8' AA-17 219.8' AA-16 Pb 7651 209.8'	64'	268.8'
10	Shale, sandy shale, argillaceous sandstone and sandstone. Lower half of unit a black to dark gray, siliceous, fissile, hard shale, weathering into "silver-chips"; with scattered, black, organic shale and sandy shale stringers. Unit becomes sandier and dirtier upward, with thinner, irregular, siliceous siltstone stringers, until a dirty and argillaceous sandstone predominates; with an upper medium- to fine-grained tan to brown sandstone. Unit is generally poorly resistant, with the uppermost part forming a slight ridge. Contact with Unit 9 is sharp. (Contact with unit #9 is gradational, bentonitic in lower part, sandstone at top looks siliceous.) AA-15 Pb 7650 190.8' AA-14 Pb 7649 180.8'	29'	204.8'

9	Bentonite, cream to gray or buff, weathering puffy and gray; fairly pure. Contact with Unit 8 is very sharp, with Unit 10 sharp. (Very distinctive, good marker.)	9'	175.8'
8	Shale, black to gray, platy; irregularly slightly siliceous and fissile; somewhat sandy; weathering light gray and forming "silver-chips". Contacts with Unit 7 and 9 very sharp. (Blocky, waxy, slightly bentonitic.) AA-13 Pb 7648 166.8' AA-12 Pb 7647 161.8'	5'	166.8'
7	Sandstone, predominantly light gray to white; irregularly tan to brown; "salt-and-pepper" sandstone; uppermost 6" of unit contain small, black, well-rounded chert pebbles and granules, varying in size to 1" in diameter; some scattered worm trails. Unit generally poorly resistant and poorly exposed, weathering powdery and white with a few brown shales forming dip slope. Contact with Unit 6 gradational. (Friable, white, powdery, with massive rounded outcrop in upper 25' (very unusual); poor porosity throughout; upper 3' ferruginous and very calcareous; fine to very fine grained.)	49'	161.8'
6	Shale, black to dark gray, weathering gray with some "silver-chips" in lower part; becoming less fissile and more organic, softer, in middle third of unit; then becoming increasingly sandier near top of the unit with abundant black, organic shale stringers; sandy shale predominant in upper 5' of unit. Top of unit selected at base of resistant sand ledge. Basal siliceous shale contains scattered fish scales. Unit is non-resistant, forming prominant swale. Contact with Unit 5 very sharp.	53'	112.8'

AA-11 Pb 7646 104.8'
AA-10 99.8'
AA-9 Pb 7645 94.8'
AA-8 89.8'
AA-7 Pb 7644 84.8'
AA-6 79.8'
AA-5 Pb 7643 74.8'

5	Sandstone, light gray to brown; generally medium- to fine-grained, coarser grained in upper part; "salt-and-pepper" sand, weathering buff to gray; poorly bedded; massive, blocky, resistant, forming prominant ridge. Contact with Unit 4 very sharp. (Very calcareous, abundant ferruginous matrix, rounded grains, poor porosity.)	15'	59.8'
4	Shale, siliceous, fissile, gray to black; weathering into "silver-chips"; irregularly very slightly sandy; basal foot of unit a sandstone, somewhat siliceous; gray to tan; medium- to fine-grained; and with an uppermost foot of bentonite, cream to yellow, fairly pure. Contacts of sand, shale, and bentonite within unit very gradational. Contact with Unit 3 sharp.	9'	44.8'
3	Shale, siliceous, fissile; black to dark gray; hard, platy, resistant, weathering into "silver-chips"; irregularly sandy. Basal 6" a sandstone, hard, non-porous, siliceous, brown to tan; lower 2'-3' somewhat bentonitic with 1"-2" stringers of fairly pure bentonite. Shale is increasingly sandier near top of unit. Shale is slightly massive where sandy. Contact with Units 2 and 4 very sharp. (Forms massive ridge.) AA-4 Pb 7642 31.8 AA-3 Pb 7641 21.8'	29'	35.8'
2	Bentonite, gray with orange streaks; fairly pure; slightly sandy near top of unit. Exposure generally poor as slope is covered with fragments of wash from overlying siliceous shale. Contact with thin sand at top of Unit 1 and thin sand at base of Unit 3 very sharp.	6.8'	6.8'

1	Shale, fissile, siliceous, black to gray, hard, dense; weathering into "silver-chips"; irregularly sandy; abundant fish scales on bedding planes. Unit contains scattered stringers of black, organic shale. Unit somewhat sandy near top; sand is hard, dense, highly siliceous.	30+'

AA-2 Pb 7640 10' below unit #2
AA-1 Pb 7639 40' below unit #2

Cody
NW, 31, T53N, R101W
Park, Co.

Unit	Lithologic Description	Thickness Unit	Thickness Total
	CODY		
	Shale. C-60*Pb 7778*663.8' C-59 Pb 7777 658.8' C-58 653.8'		
	FRONTIER		
41	Sandstone, very massive and thich bedded, rare irregular shale beds to 1' thick, abundant wood fragments usually concentrated in bands throughout; medium to coarse grained; numerous shale blebs; high energy environment; scattered pebbles in upper 5'; percentage of shale increases to 30-40% in the width of outcrop (1/4 mile); large load structures mark contact with unit #40. C-57 Pb 7776 620.8'	28.0'	648.8'
40	Sandstone and shale, interbedded, light to dark gray, finely banded outcrop, rare clean sandstone or black shale beds to 1' thick; coarse grained; clean, ferruginous, calcareous sandstone bed in center; cross-beds and cut and fill structures in upper 1/4. C-56 Pb 7775 615.7' C-55 Pb 7774 610.7' C-54 Pb 7773 605.7'	20.1'	620.8'
39	Sandstone, fine grained, porous, abundant high angle cross-beds, very friable, massive and thick bedded, well sorted, numerous black shale stringers at base; slightly ferruginous; possible root zone in highest black shale. C-53 596.7' C-52 Pb 7772 595.7'	9.0'	600.7'

*C-60 collection number, Pb 7778 maceration number

38	Mostly sandy shale, gray to brown, fairly common black shale in lower part, becomes more sandy toward top and is mostly thin bedded, argillaceous sandstone in upper 10', much like unit #37, but shalier. C-51 Pb 7771 582.6'	29.1'	591.7'
37	Argillaceous sandstone, fine grained, soft, poor porosity, dark gray, locally more or less sandy shale; locally forms resistant ledges; approximately equal amounts of sand and shale; scattered pebbles at top. C-50 Pb 7770 553.3' C-49 Pb 7069 529.6'	29.3'	562.6'
36	Shale, very dark brown, sticky, bentonitic, blocky, organic. C-48 Pb 7768 533.3' C-47 Pb 7767 529.6	3.7'	533.3'
35	Bentonite, pure, cream colored, massive.	6.3'	529.6'
34	Shale, black, organic, massive and blocky; sharp contacts with units #35 and #33. C-46 Pb 7766 523.3' C-45 Pb 7765 517.7'	5.6'	523.3'
33	Sandstone, light gray, fine grained, medium bedded, fairly hard, argillaceous and slightly bentonitic, poor porosity.	5.0'	517.7'
32	Bentonite, dark grayish yellow, very pure, a few plant fragments, massive, blocky.	9.7'	512.7'
31	Shale, brown to black; lignitic, very hard, abundant plant fragments; even bedded. C-44 Pb 7764 502.5' - 503.0'	0.5'	503.0'
30	Sandstone, very fine grained, slightly argillaceous, poor porosity; extremely abundant, large plant fragments; lignitic root zone followed by 4' of "coal" at top.	11.0'	502.5'

C-43 Pb 7763 502.5'
C-42 Pb 7762 501.5'
C-41 493.5'

29	Shale, black, very organic, fissile to blocky, coarse grained sandstone at base with very abundant plant material.	1.2'	491.5'
	C-40 Pb 7761 490.3' - 491.5'		
28	Coal, bitumenious, very porous, locally shaly, yellow stain.	1.0'	491.5'
	C-39 Pb 7760 489.3' - 490.3'		
27	Sandstone, fine grained, very argillaceous with stringers of black shale to 1" thick; poor porosity, bentonitic, abundant plant fragments and numerous paper thin, brown laminations possibly of plant origin; slightly ferruginous, light gray to light brown.	15.2'	489.3'
	C-38 Pb 7759 489.3' C-37 Pb 7758 479.1' C-36 474.1'		
26	Shale, black, very fissile to blocky, very organic and carbonaceous; very sharp upper and lower contact.	10.2'	474.1'
	C-35 Pb 7757 474.1' C-34 468.9' C-33 Pb 7756 463.9'		
25	Bentonite, light tan, very pure.	0.5'	463.9'
24	Shale, very silty, siliceous, medium gray, weathers same with orange-brown stain on weathered surface; weathers to hacky fragments and nodules.	3.6'	463.4'
23	Bentonite, light greenish gray, pure.	2.5'	459.8'
22	Shale, black, very fissile, organic and carbonaceous, yellow stain on some fractured surfaces; blocky at top.	8.2'	457.3'
	C-32 457.3' C-31 Pb 7755 454.1'		
21	Sandstone, medium grained, very porous, friable, beds 3" to 1' thick; very even bedded, calcareous, slightly crossbedded	15.2'	449.1'

	widely scattered pebbles to 1"; slightly ferruginous; stained light brown to orange; forms persistant ledge.		
20	Sandstone, fine grained, bentonitic, argillaceous, light gray, massive, weathers to rounded cliff or badlands; fairly hard and resistive.	16.1'	433.9'
19	Mostly sandstone, light to medium gray, slightly bentonitic, very argillaceous; medium bedded at base, thick bedded and massive at top; abundant thin, dark shale interbeds in lower part, two thicker shale bands in upper part. C-30 Pb 7754 417.8' C-29 Pb 7753 411.0' C-28 Pb 7752 401.0'	16.8'	417.8'
18	Shale, black to dark gray, blocky, massive, silty, yellow stain on fractured surfaces; more massive and bentonitic and medium to light gray at top; grades into unit #19. C-27 401.0' C-26 Pb 7751 396.8' C-25 Pb 7750 391.8'	9.2'	401.0'
17	Siltstone, very shaly, light to medium gray, abundant bright yellow stain on fracture and bedding surfaces; siliceous; forms resistant ridge.	6.9'	391.8'
16	Sandstone, very thick bedding and massive, forms vertical cliff above river; fine to medium grained, very clean, well rounded, porous and friable, salt and pepper; black minerals abundant, rare argillaceous sandstone lenses; abundant medium scale, high angle cross-beds and widely scattered chert pebbles in upper 1/3; numerous ferruginous bands; becomes shalier in upper few feet.	46.3'	384.9'
15	Argillaceous sandstone and sandy shale, most of sequence is dark gray to dark brown and very shaly, poorly resistant, gradational contact with unit below, some coarse grained sand and scattered pebbles at base, abundant bright yellow bands in black shale near base.	28.6'	338.6'

C-24 Pb 7749 325.0'
C-23 Pb 7748 320.0'
C-22 Pb 7747 315.0'

14	Sandstone, fine to medium grained, well rounded, well sorted, good porosity, friable, massive outcrop, thick bedded, common high angle cross-beds; beds of coarse grained sandstone with abundant subangular quartz and chert pebbles about 4' from top; ferruginous concretions in upper part.	24.4'	310.0'
13	Interbedded, very argillaceous, thin bedded, brown to gray sandstone and dark brown, carbonaceous shale; very poorly exposed; mostly covered by debris from ledge above; bentonitic.	11.5'	285.6'
12	Sandstone, fine grained, argillaceous, laminated, poor porosity, scattered black shale interbeds; forms resistant ledge; ferruginous beds, numerous black shale beds at top, salt and pepper; massive outcrop.	21.0'	274.1'
	C-21 Pb 7746 271.1'		
11	Covered.	9.9'	253.1'
10	Shale, nodular at base becoming fissile upwards; scattered yellow stained sandstone stringers.	8.0'	243.2'
	C-20 Pb 7745 240.2' C-19 Pb 7744 235.2'		
9	Sandstone, mostly thick bedded and massive, scattered black shale stringers; like unit below but more argillaceous and porosity is poorer; slightly bentonitic in center; scattered cross-bedding; massive and resistive at top; salt and pepper; weathers light to medium gray with brown stain; sharp upper surface, lower surface is distinct, had local relief and may be an unconformity.	22.6'	235.2'
8	Sandstone, fine to medium grained; thick to very thick bedding and massive; scattered black shale lenses to 1" thick in lower part, very massive and resistive in upper part, clean, sorting fair	37.4'	212.6'

	to good, good porosity; abundant cross-bedding (planar, 1" to 3" long) especially in upper part; some large scale (30' long), very low angle cross-bedding directly overlain by much steeper angle cross-bedding dipping in the opposite direction; scattered pebbles and yellow stain at top.		
	C-18 Pb 7743 190.2'		
7	Mostly sandstone, massive thick beds with numerous black shale beds to 4" thick; locally abundant charcoal; bedding very irregular and lenticular; abundant high and low angle cross-beds; sandstone fine grained, fair porosity, numerous paper thin shale partings.	10.1'	175.2'
	C-17 Pb 7742 170.1' C-16 165.1'		
6	Mostly black, dark gray and a little olive-gray shale and light to medium gray, hard, silty, massive mudstone, finely and profusely interbedded; a few argillaceous sandstone lenses, especially at base; scattered pebbles in lower 1'; weathers to dark gray band; grades into unit above.	14.0'	165.1'
	C-15 Pb 7741 165.1' C-14 161.1' C-13 Pb 7740 156.1' C-12 151.1'		
5	Sandstone, forms massive cliff above river, very sharp lower contact with coarse grained sand and small rare pebbles, very abundant wood fragments and shale chips at base; local relief 1' on lower surface; lower 3' coarse grained, calcareous sandstone with good porosity and bands of abundant mud chips; extremely thick bedded and massive, mostly medium grained, irregularly fine to coarse grained; porosity good to fair; numerous scattered bands of black chert pebbles, some at high angle to bedding; conglomerate 3" thick at top, very sharp upper contact, commonly coarse grained, ferruginous lenses and concretions, sand generally clean;	71.0'	151.1'

sandstone at base and conglomerate at top both stain bright yellow (subareal?); coaly lenses and partings associated (beneath) with some of the conglomerates; large and small scale cross-beds common, particularly in lower half; frequently calcareous.

C-11 Pb 7739 141.1'

4	Shale, medium gray to black, fissile to blocky, sandy at base; grades into sandy unit below; organic; phosphatic fish scales.	29.0'	80.1'

C-10 Pb 7738 80.1'
C-9 76.1'
C-8 Pb 7737 71.1'
C-7 66.1'
C-6 Pb 7736 61.1'
C-5 56.1'
C-4 Pb 7735 51.1'

3	Mostly very fine grained, argillaceous, light gray, medium to thin bedded, laminated sandstone with abundant medium gray to black, fissile shale lenses to 1" thick; siliceous and stained red-brown in upper part; gradational upper contact; porosity in sandstone is poor.	20.7'	51.1'
2	Shale and mudstone, light to dark gray, weathers light gray with brown stain; very silty, fissile to massive and resistant, hard and brittle; siliceous throughout; a few scattered thin bentonites.	26.6'	30.4'

C-3 Pb 7734 24.8'

1	Bentonite, cream colored, pure, grades into unit above; excellent marker.	3.8'	3.8'

MOWRY

Shale, dark gray, fissile to blocky and massive, very sharp upper contact.

C-2 Pb 7733 1' below unit #1
C-1 Pb 7732 6' below unit #1

PLATES

PLATE 1

1 Laevigatosporites granaperturus, x 1000

2 Laevigatosporites haardti, x 1000

3 Laevigatosporites cf. L. irroratus, x 1000

4 Laevigatosporites ovatus, x 1000

5,6 Peromonoletes sp. 1, x 1000

7 Petalosporites quadrangulus, x 1000

8 Schizaea cf. S. triangula, x 1000

9,10 Verrucatosporites favus, 1000

11 Schizaeoisporites eocaenicus, x 1000

12 Verrucatosporites cf. V. pseudoreticulatus, x 1000

13 Acanthotriletes varispinosus, x 1000

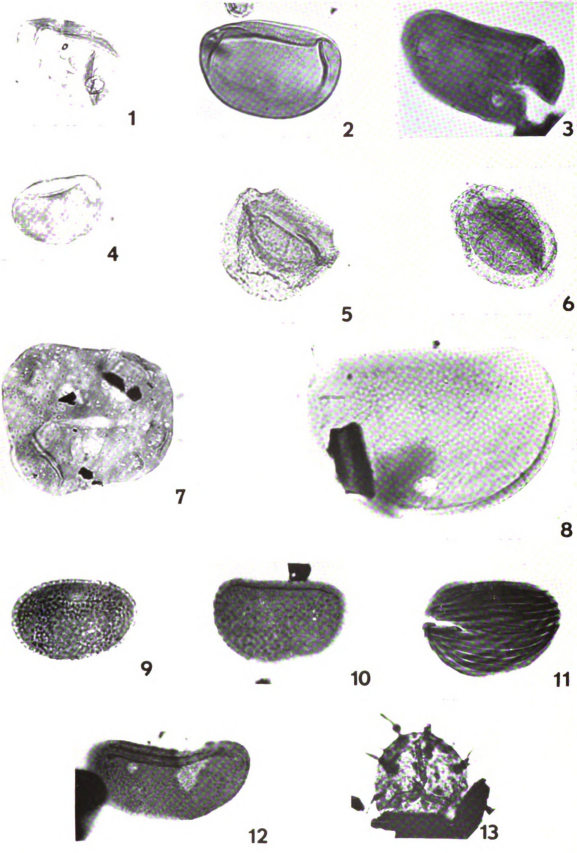


PLATE 1

PLATE 2

1,3 Appendicisporites matesovai, x 1000

2 Appendicisporites cf. A. jansonii, x 1000

4 Cicatricosisporites cf. C. carlylensis, x 1000

5 Aequitriadites ornatus, x 1000

6 Appendicisporites tricornitatus, x 1000

7 Camarozonosporites sp. 1, x 1000

9 Balmeisporites glenelgensis, x 500

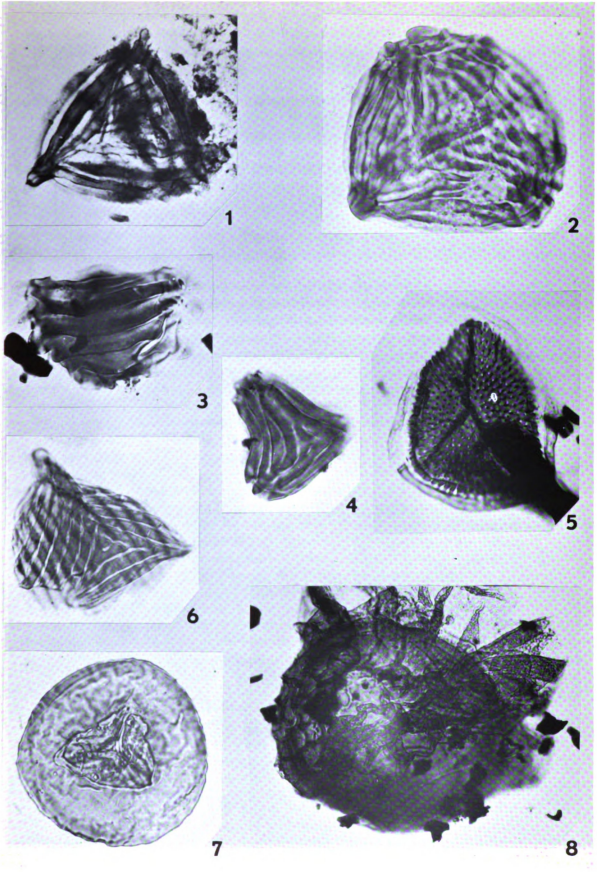


PLATE 2

PLATE 3

1,3 Camarozonosporites insignis, x 1000

2 Camarozonosporites rudis, x 1000

4,5 Cicatricosisporites cf. C. mohirioides, x 1000

6 Cicatricosisporites crassiterminatus, x 1000

7 Cicatricosisporites cf. C. mesozoicus, x 1000

8,9 Cicatricosisporites cf. C. cooksonii, x 1000

10 Cicatricosisporites dorogensis, x 1000

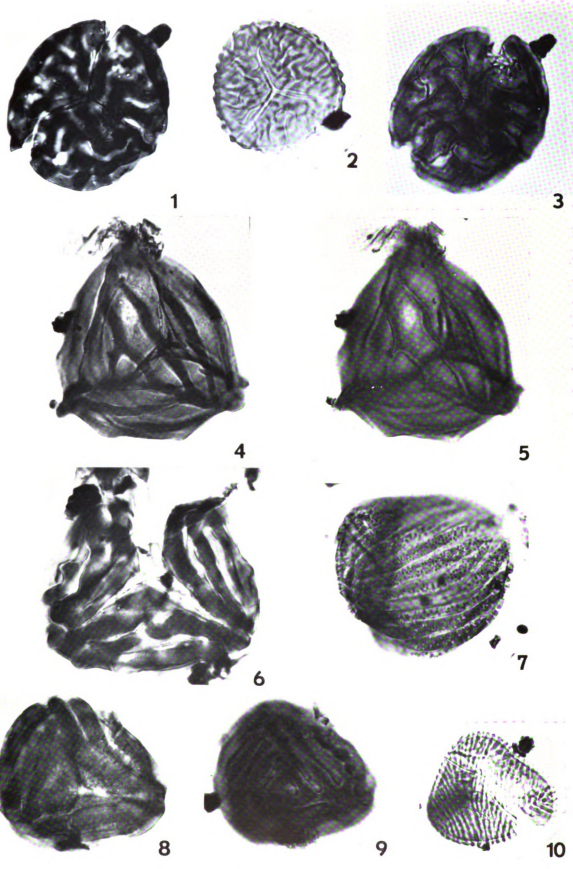


PLATE 3

PLATE 4

1,3 Densoisporites perinatus, x 1000

2 Cingutriletes clavus, x 1000

4 Granulatisporites spp., x 1000

5 Densoisporites microrugulatus, x 1000

6 Gleicheniidites senonicus, x 1000

7 Dictyophyllidites harrisii, x 1000

8 Gleicheniidites cf. G. circinidites, x 1000

9 Gleicheniidites confossus, x 1000

10 Klukisporites pseudoreticulatus, x 1000

11 Hymenophyllumsporites cf. H. deltoida, x 1000

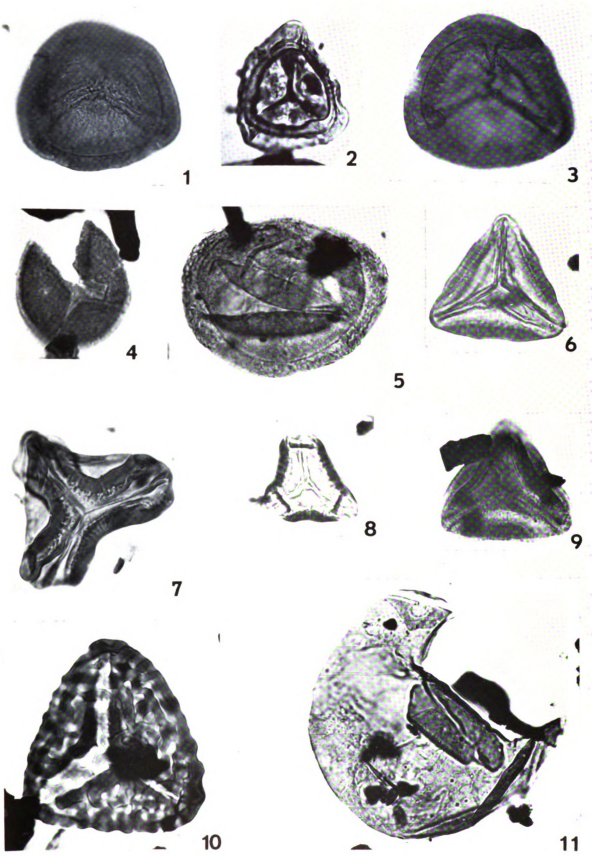


PLATE 4

PLATE 5

1,4 Cingulatisporites radiatus, x 1000

2 Concavisporites butorosus, x 1000

3,6 Concavisporites sp. 2, x 1000

5 Deltoidospora junctum, x 1000

7 Deltoidospora sp. 1, x 1000

8 Concavisporites cavatus, x 1000

9 Concavisporites sp. 1, x 1000

10 Cyathidites australis, x 1000

11 Cyathidites minor, x 1000

12 Deltoidospora hallii, x 1000

13 Deltoidospora psilostoma, x 1000

14 Concavissimisporites punctatus, x 1000

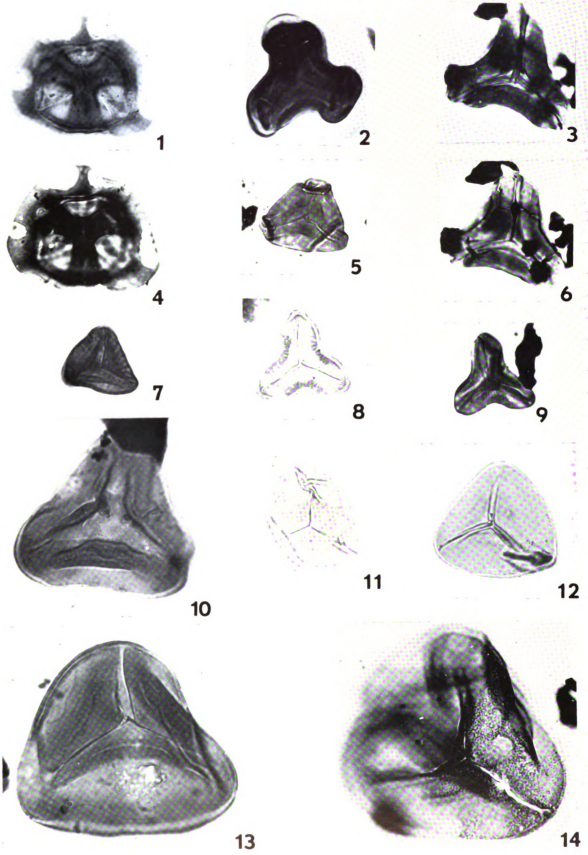


PLATE 5

PLATE 6

1 Trilete scabrate sp. 1, x 1000

2,5 Dictyotriletes densomuralis, x 1000

3 Foveotriletes cf. F. subtriangularis, x 1000

4 Matonisporites impensus, x 1000

6 "Cingulatisporites" pseudoaleolatus, x 1000

7 Lycopodiumsporites cf. L. marginatus, 1000

8 Miodeltospora parva, x 1000

9 Osmundacidites wellmanii, x 1000

10 Perotriletes bursatus, x 1000

11 Psilatriletes radiatus, x 1000

12 Perotriletes sp. 3, x 1000

13 Retitriletes cenomanianus, x 1000

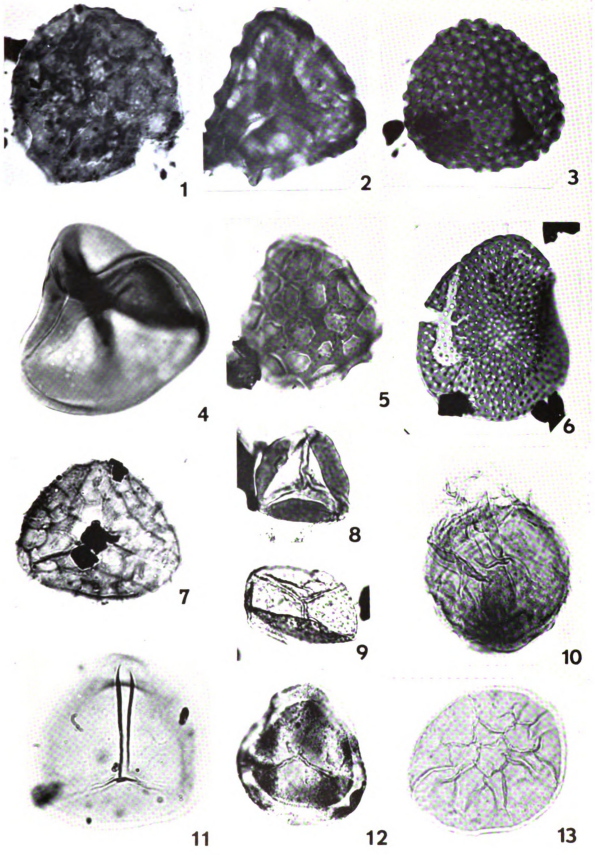


PLATE 6

PLATE 7

1,4 Reticulatisporites exilis, x 1000

2,5 Taurocusporites cf. T. sigmentatus, x 1000

3,6 Lycopodiacidites cf. L. kuepperi

7,8 Staplinisporites caminus, x 1000

9 Perotriletes sp. 2, x 1000

10 Perotriletes sp. 1, x 1000

11 Stereisporites antiquasporites, x 1000

12 Undulatisporites sp. 1, x 1000

13 Undulatisporites scabratus, x 1000

14 Verrucosisporites pustulatus, x 1000

15,17 Tentaculispora conspicus, x 1000

16 Taurocusporites reduncus, x 1000

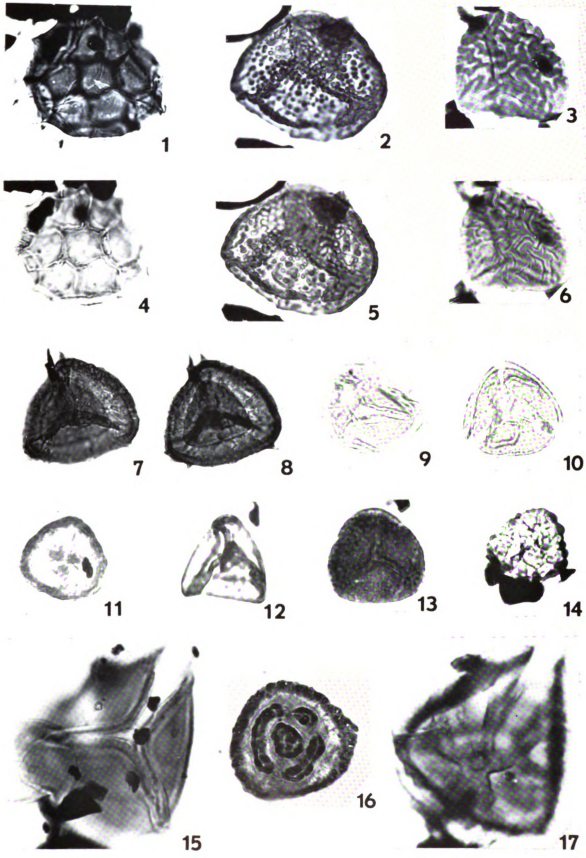


PLATE 7

PLATE 8

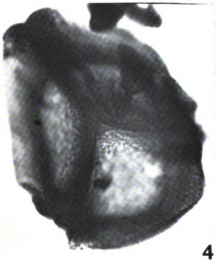
1,3 *Lycopodiacidites intraverrucatus*, x 1000

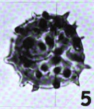
2 Trilete spiny sp. 1, x 1000

4,6 *Tetrahedrospora dyscrita*, x 1000

5 Trilete spiny sp. 2, x 1000

7,8 *Verrucosisporites* cf. *V. rotundus*, x 1000





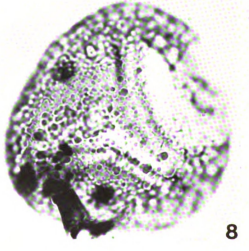


PLATE 8

PLATE 9

1 Trilobosporites crassus, x 1000

2 Todisporites minor, x 1000

3,4 Retitricolpites paraneus, x 1000

5 Clavatipollenites hughesii, x 1000

6 Liliacidites cf. L. variegatus, x 1000

7 Retitricolpites cf. R. georgensis, x 1000

8 Retitricolpites vulgaris, x 1000

9 Tricolpites cf. T. bathyreticulatus, x 1000

10 Tricolpites parvus, x 1000

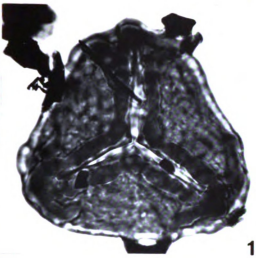
11 Tricolpites cf. T. reticulatus, x 1000

12 Tricolpites sagax, x 1000

13 Tricolpopollenites henrici, x 1000

14,15 Tricolpopollenites cf. T. retiformis, x 1000

16 Tricolpopollenites sp. 3, x 1000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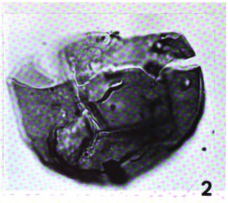
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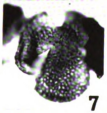
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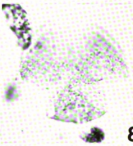
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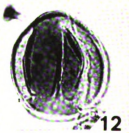
12


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15


16

PLATE 9

PLATE 10

1 Alisporites-type pollen, x 1000

2 Classopollis classoides, x 1000

3 Inaperturopollenites hiatus, x 1000

4 Cycadopites fragilis, x 1000

5 Eucommiidites minor, x 1000

6 Equisetosporites multicostatus, x 1000

7 Cycadopites scabratus, x 1000

8 Eucommiidites troedssonii, x 1000

9 Inaperturopollenites dubuis, x 1000

10 Phyllocladidites-type pollen, x 1000

11 Pityosporites-type pollen, x 1000

12 Podocarpidites-type pollen, x 1000

13 Rugubivesiculites reductus, x 1000

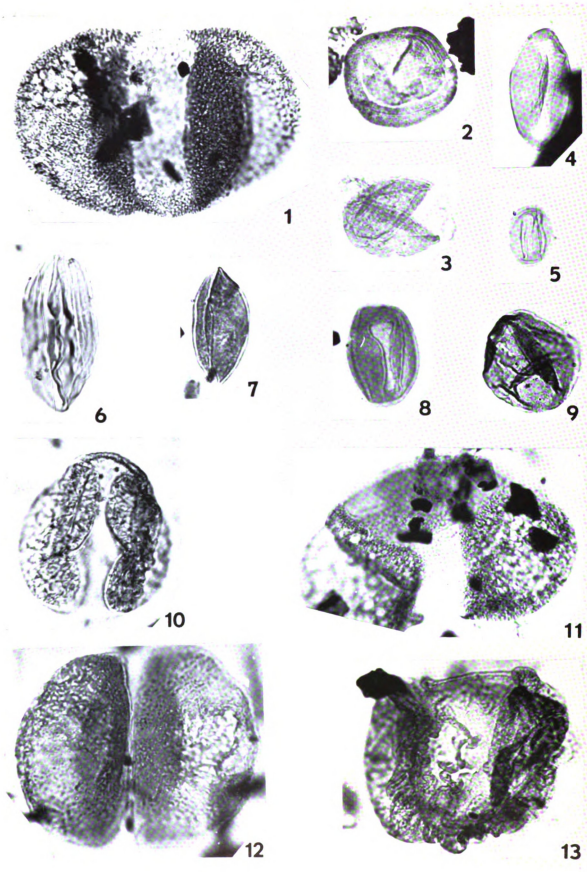


PLATE 10

PLATE 11

1 Rugubivesiculites reductus, x 1000

2 Tsugapollenites-type pollen, x 1000

3 Schizosporis scabratus, x 1000

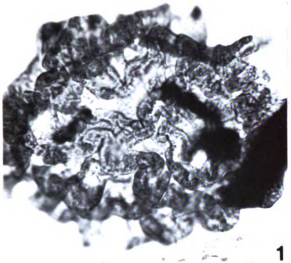
4 Caytonipollenites pallidus, x 1000

5 Monosulcate Type 1, x 1000

6 Schizosporis cf. S. parvus, x 1000

7 Monosulcate Type 2, x 1000

8 Laricoidites cf. L. magnus, x 1000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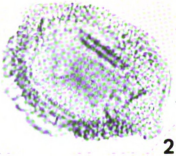
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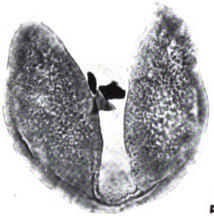
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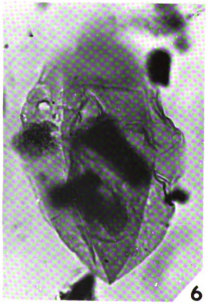
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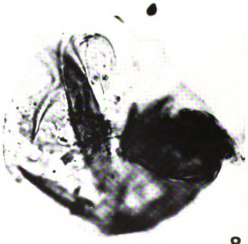
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PLATE 11

PLATE 12

1 Veryhachium cf. V. trisulcum, x 1000

2 Inaperturopollenites pseudoreticulatus, x 1000

3 Circulina parva, x 1000

4 Baltisphaeridium multispinosum, x 1000

5-9 Michrystridium spp., x 1000

10 Form X sp. 1, x 1000

11,12 Veryhachium cf. V. europenum, x 1000

13 Cymatiosphaera sp. 1, x 1000

14 Cymatiosphaera sp. 2, x 1000

15 Veryhachium sp. 1, x 1000

16 Pterospermopsis spp., x 1000

17,18 Veryhachium cf. V. stellatum, x 1000

19 Metaleiofusa spp., x 1000

20 Leiofusa spp., x 1000

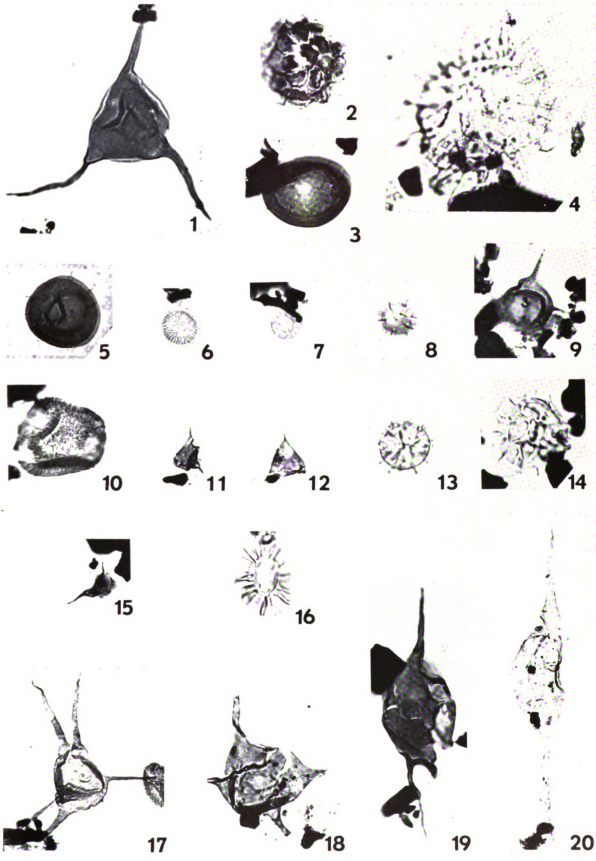


PLATE 12

PLATE 13

1 Formea amphora, x 1000

2 Form B sp. 4, x 1000

3 Form B sp. 2, x 1000

4 Form C sp. 3, x 1000

5 Form C sp. 1, x 1000

6 Form C sp. 2, x 1000

7 Gonyaulacysta cf. G. edwardsi, x 500

8 Gonyaulacysta spp., x 500

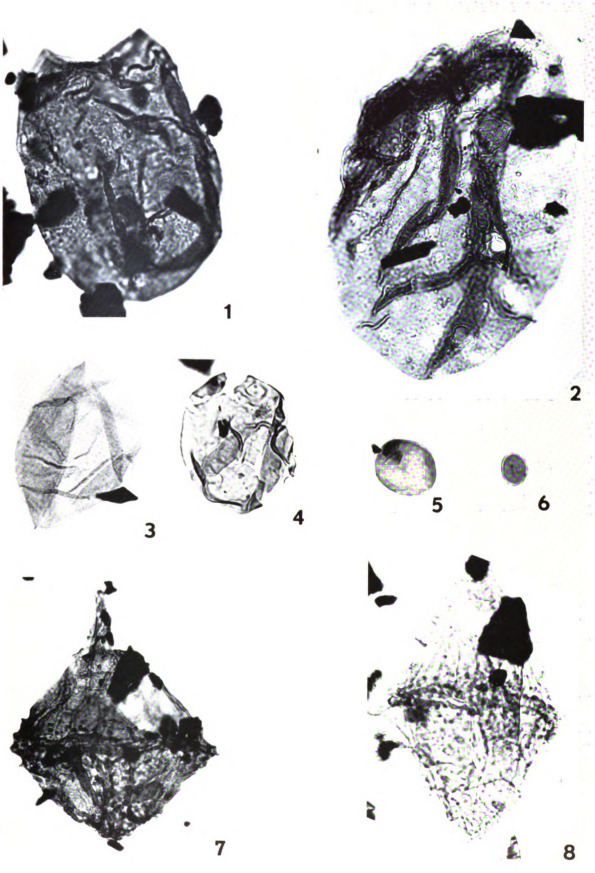


PLATE 13

PLATE 14

1 Apteodinium granulatum, x 1000

2 Spinidinium microceratum, x 1000

3 Broomea cf. B. jaegeri, x 1000

4 Canningia cf. C. reticulata, x 1000

5 Canningia cf. C. rotundata, x 1000

6 Canningia cf. C. senonica, x 1000

7 Cligosphaeridium spp., x 500

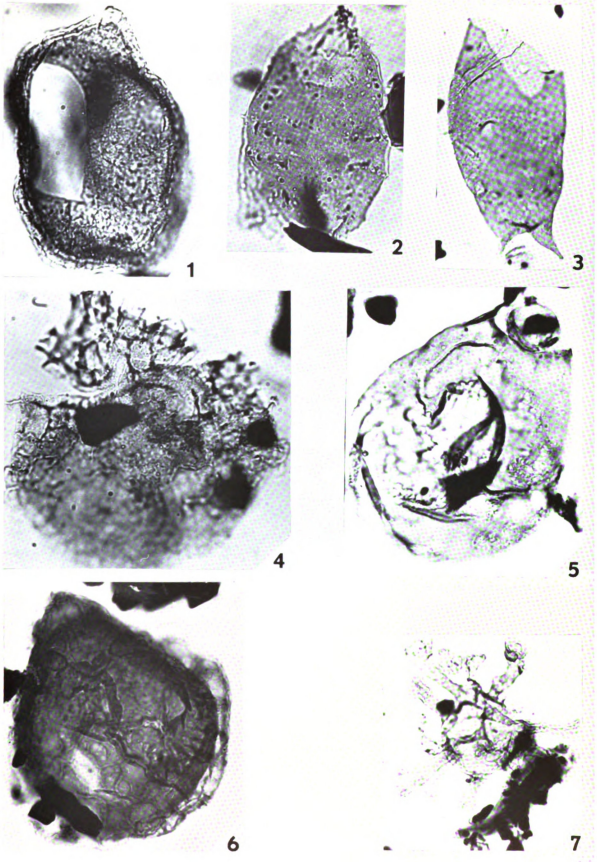


PLATE 14

PLATE 15

1 *Hystrichokolpoma ferox*, x 1000

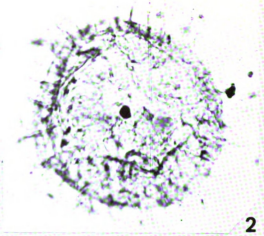
2 ?*Exochosphaeridium phragmites*, x 1000

3,4 *Tanyosphaeridium* cf. *T. variecalamum*, x 1000; 4 photographed by phase contrast.

5 *Microdinium* cf. *M. irregulare*, x 1000

6,7 *Hystrichosphaera ramosa*, x 1000; 7 photographed by phase contrast.

1



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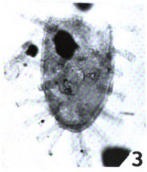

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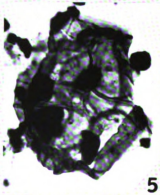

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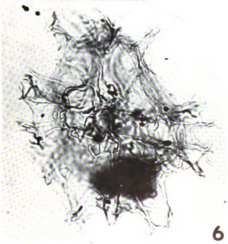

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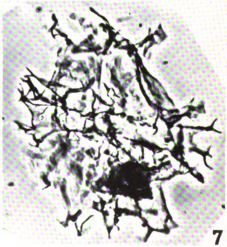

7

PLATE 15

PLATE 16

1 *Ascodinium scabrosum*, x 1000

2 *Ascodinium verrucosum*, x 1000

3,6 *Deflandrea* cf. *D. cooksonii*, x 1000; 6 photographed by phase contrast.

4 *Deflandrea echinoidea*, x 1000

5 *Deflandrea* cf. *D. acuminata*, x 1000

7 *Deflandrea victoriensis*, x 1000

8 *Palaeoperidinium cretaceum*, x 1000

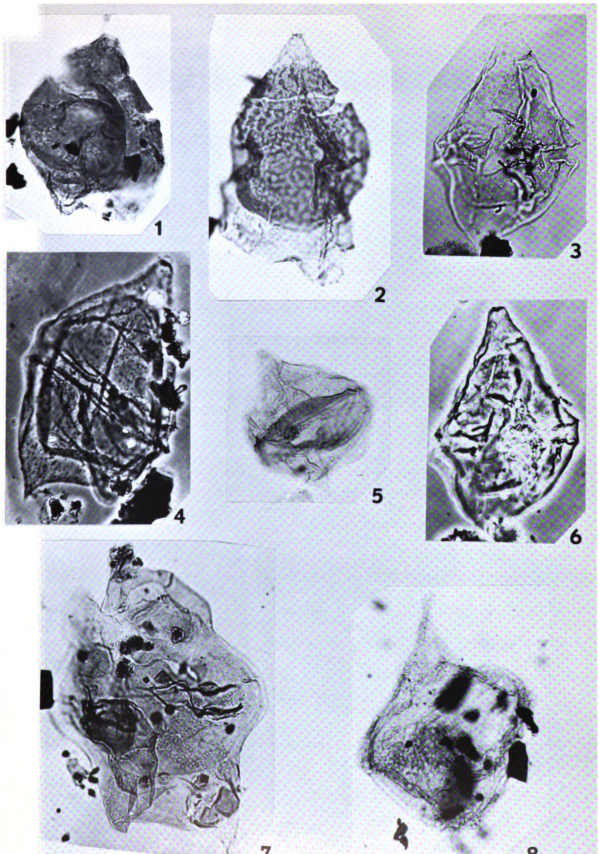

PLATE 16

PLATE 17

1,2 Palaeohystrichophora infusorioides, x 1000; 2 photographed by phase contrast.

3,4 Odontochitina operculata, x 1000; photographed from the same slide but not implied to be two parts of the same specimen.

5 Odontochitina costata, x 500

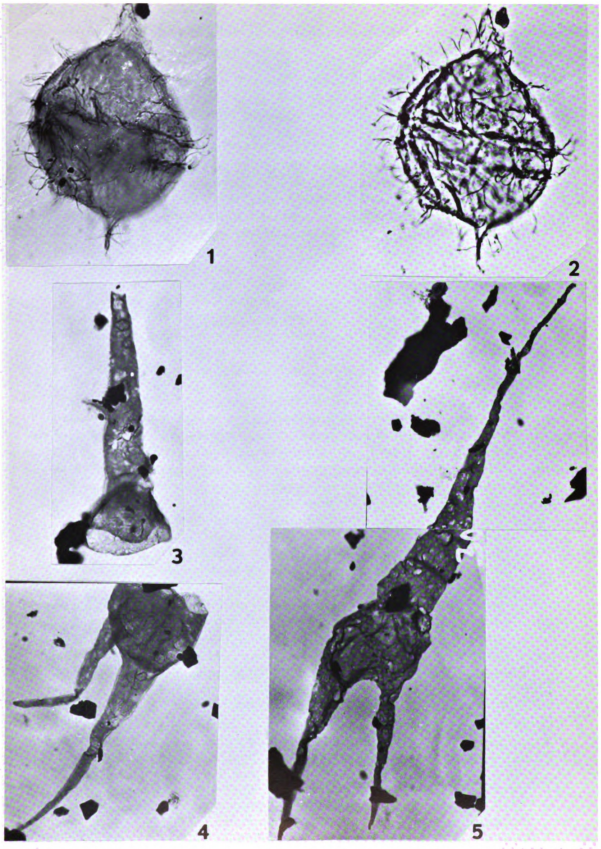

PLATE 17

PLATE 1[8]

1,3 *Palaeoperidinium* spp., x 1000; 3 photographed by phase contrast.

2 *Horologinella apiculata*, x 1000

4 ?*Cyclopsiella* sp. 1, x 1000

5 *Chalydophorella discreta*, x 1000

6 Form F sp. 1, x 1000

7 *Botrycoccus* sp., x 1000

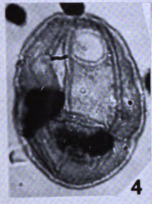

PLATE 18