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Sylvia Frances Spindel
The University of Montana

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MICROFOSSILS OF THE UPPER PART
OF THE FORT UNION FORMATION,
SOUTHEASTERN MONTANA

by

Sylvia Spindel

A. B. Vassar College, 1970

Presented in partial fulfillment of the
requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA
1974

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

Date
Acknowledgements

I am indebted to Dr. James A. Peterson for his guidance, suggestions, and assistance throughout the course of this study. Special thanks are due to Dr. Robert Fields and Dr. Charles Miller for their valuable ideas and constructive criticism.

It is a pleasure to acknowledge assistance received from my husband, Michael Burnside, who aided with the photography, and Jim Ferguson, who prepared some of the drafting.

My parents and brother and sister have provided continued understanding and encouragement. I thank them all.

This work was supported in part by a grant from the Montana Bureau of Mines and Geology. The Bureau also furnished pollen samples for the study.
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CHAPTER I
INTRODUCTION

Purpose

This investigation comprises a study of the micropaleontology of the Tongue River Member of the Fort Union Formation in the Sheridan coal field located in southeastern Montana and northeastern Wyoming. Samples were collected from three outcrop sections located in Rosebud and Bighorn counties, Montana (Fig. 1). Seven subsurface core samples obtained from the Montana Bureau of Mines and Geology were also included in the study.

The Fort Union sedimentary deposits in the vicinity of the Sheridan coal field vary so much in lithology that the sequence of beds shown in one columnar section is scarcely recognizable in another section measured a few feet away. Stratigraphic correlation within this complex section is very difficult, and a major objective of this study is to investigate whether or not microfauna and microflora can be used as a correlation tool. A second objective is to determine whether or not any paleontological changes occur within the upper Paleocene rocks of the Fort Union Formation so that a possible Paleocene-Eocene boundary can be defined.
Previous Work

During the early half of this century U.S. Geological Survey reconnaissance parties were sent to eastern Montana primarily for the purpose of classifying the public land of the area in regard to coal. As a result, much of the area was divided into blocks of land, designated as coal fields, usually 700 square miles in size.

A significant publication resulting from this work was that of Baker (1929), on the northward extension of the Sheridan coal field, in which he described and mapped a major portion of the study area. Since that time there have been no published papers on the geology of the Sheridan coal field. However, beginning in the early 1960's renewed interest in coal as a prime source of fuel resulted in further study, especially by the Montana Bureau of Mines and Geology, including an extensive coring and surface geology program. Publications by Groff (1966) and Matson (1966) and others from the Bureau have added considerably to the published material on coal resources of the area.

Prior to the work on coal, the early government surveys provided much paleontological data in attempting to determine the Cretaceous-Tertiary boundary. Stanton and Knowlton (1897), on the basis of vertebrate remains in the Upper Cretaceous, placed the boundary at the top of the dinosaur-bearing Lance Formation. In 1940 Dorf counted over four hundred species of fossil flora which demonstrated that Lance floras could be readily distinguished from those of the overlying Fort Union. Calvert (1912) formulated a method for locating the boundary in which he placed the contact at the change downward from
coal-bearing rocks without dinosaur remains to rocks with fairly abundant dinosaur remains but no coal. Thus far, the latter method has been most accepted by geologists.

The upper part of the Fort Union thus has largely been ignored, mainly because the upper Fort Union and the lowermost Wasatch are not readily distinguishable lithologically. Swain (1949) studied some collections of ostracodes taken from the Tongue River Member (Upper Paleocene) of the Fort Union but made no attempt at stratigraphic correlation within the member.

Considerable interest has also developed in the use of palynology in defining the Upper Cretaceous-Tertiary contact, and this has become the presently accepted method. Leffingwell (1966) established three palynological assemblage zones within the Upper Lance (Late Cretaceous) and Fort Union in southeastern Wyoming, while Norton and Hall (1969) did the same in northeastern Montana.

Geologic Setting

The Sheridan coal field is part of a large region of northeastern Wyoming, northwestern South Dakota, and eastern Montana which is underlain by coal-bearing rocks. It occupies part of the wide Powder River Basin located between the Black Hills and the Big Horn Mountains. The basin lies near the western margin of the Great Plains Province but exhibits a surface relief greater than is common over most of the Great Plains. The old upland surface that once extended over the region has been trenched by deep valleys bordered in many places by precipitous slopes. Thick beds of yellow-weathered sandstone form bluffs, mesas, and rugged dissected hills. The maximum surface relief
within the study area is approximately 1500 feet and slumping is common throughout. However, surface rocks are nearly horizontal, dips rarely exceeding more than two or three degrees.

The rocks comprise a complex of Tertiary strata which lies near the southwest margin of an extensive area of coal-bearing rocks, terminated on the southwest and west by the Big Horn Mountains. The study area is about forty miles northeast of the mountains, far enough away from them so that the strata have not been sharply folded or faulted. Exposed rocks within the area belong to the coal-bearing members of the Paleocene Fort Union Formation and the overlying Eocene Wasatch Formation.

The Fort Union encircles the entire Powder River Basin and is approximately 2900 feet thick on the west side and 2200 feet thick on the east side. The differences in thickness are apparently a result of distance from the source of supply (Brown, 1958).

Deposition of the Fort Union occurred during the extend of the Laramide orogeny, which took place immediately after the withdrawal of the Late Cretaceous sea (Love, 1960). At that time original uplift of the Big Horns, Black Hills, and the Laramie Mountains occurred. As a result, a large volume of sediment was transported into the swampy floodplain environment of the newly formed Powder River Basin. The Late Cretaceous sea gradually withdrew from west to east across Montana and central Wyoming.

The transition from marine to non-marine conditions was gradual and continuous. The terrain that received the sediments was a vast,
low-lying, and intermittently subsiding floodplain. Across it flowed meandering and braided streams, through poorly drained inland swamps and marshes (Weichman, et. al., 1965).

According to Brown (1958) coal beds probably accumulated during periods of non-deposition of clastics and were later buried by sediment-bearing currents. He has pointed out that many of the coal seams interfinger with the brackish water tongues of the marine Cannonball Member to the east. This indicates that they, and probably all Fort Union coals, were deposited at or near sea level in extensive coal swamps and marshes that may, at times, have been considerably inland from the open coast.

Love, McGrew, and Thomas (1963) postulate that periodically the basin of deposition remained more or less static, during which time the materials that were to become coal seams accumulated. Then came subsidence, and perhaps changes in stream flow and direction, that caused the accumulated organic matter or peat to be buried by sand or silt. Thus, through an interrupted succession of subsidences several thousand feet of lignitic strata were deposited at or near sea level.

Stratigraphy

In southeastern Montana the Fort Union Formation is about 4500 feet thick and is subdivided in ascending order into the Tullock, Lebo, and Tongue River members (Fig. 2, Column 3). Brown's (1958) sequence can be divided into a lower, somewhat darker portion (known as the "somber beds" to early geologists) and an upper, much lighter colored portion. West of Miles City the lower part comprises the Tullock and
Lebo members, but east of Miles City and in the Dakotas these are combined as the Ludlow Member, which to the east interfingers with the marine Cannonball Member (Fig. 2, Columns 4 & 5).

The Tullock Member consists of 150 to 300 feet of interfinger, light yellowish-gray calcareous sandstone and siltstone, brownish-gray claystone, and several lenticular coal beds.

The Lebo Shale consists of 100 to 250 feet of interfinger, light yellowish-gray calcareous sandstone and siltstone, brownish-gray claystone, and several lenticular coal beds.

The Lebo Shale consists of 100 to 250 feet of dark gray claystone, non-persistent, soft grayish-brown sandstone, abundant ferruginous concretions, and a few beds of impure coal.

The Tongue River Member underlies most of the study area and contains seven thick coal beds mapped by Baker (1929). They include, in ascending order, the Canyon, Dietz, Anderson, Smith, and Roland beds. The beds tend to be lenticular, tapering in all directions from their centers, and tend to overlap one another at their edges. The member also consists of massive, light colored sandstone and interbedded siltstone and claystone above and below the persistent coal beds. It thins to approximately 800 feet near Sheridan, Wyoming.

According to Baker (1929), the base of the member corresponds to "the plane of lithologic change from somber colored beds, predominately shale below, to the lighter colored buff sandstone and interbedding gray shale above". This shale is not exposed in the area here described.

The thickest and best known coal bed of the Tongue River is the Roland at the top of the Fort Union. It reaches a thickness as great as ninety feet in eastern Wyoming, but is only about seven feet thick in the study area. There is no marked lithologic difference between the beds below and above the Roland coal. The Roland can usually be
Figure 2. Cross section of Cretaceous and early Tertiary rocks in Wyoming, Montana and North Dakota. After Brown, 1948.
recognized though, by the presence, above the coal, of a highly fossiliferous sandstone or coquina. The latter contains abundant fragments of gastropods and clams that are fresh water in origin.

All the coal beds, particularly in the Tongue River Member, have burned along their outcrops and under shallow cover to form thick masses of brick red clinker or natural slag. This clinker consists of sandstone and shale which is fused and baked from heat of combustion of the coal beds. These clinker rocks resist erosion and often form protective caps on steep-sided buttes and mesas.

The upper limits of the Fort Union have been disputed, but perhaps not so vigorously as the lower limits. One reason for this disagreement arises from the fact that at many localities, the uppermost Fort Union and the Lowermost Wasatch are not readily distinguishable lithologically. The contact is apparently transitional. The Wasatch Formation consists of drab, brown to gray claystone, siltstone, and carbonaceous shale interbedded with buff sandstone lenses and coal beds which form a pink and gray variegated sequence.

At Kingsbury Ridge, about four miles southwest of Buffalo, Wyoming, on the west side of the Powder River Basin, the lignitic Fort Union strata are overlain unconformably by conglomeratic and greenish to variegated sandy beds containing the Eocene guide fossils *Hyracotherium* (eohippus), *Coryphodon*, and turtles (Brown, 1948). For some time these beds were included in the Fort Union sequence, but the overwhelming paleontological evidence of their Eocene age eventually caused their reassignment. The Kingsbury Conglomerate is a convenient marker for the Paleocene-Eocene boundary on the west side of the basin, but it
fingers out eastward into the lignitic Wasatch strata and does not appear on the east side of the basin. Thus, a convenient and striking lithologic marker is missing there when a search for the Paleocene-Eocene contact is made.

The lack of diagnostic fossils suggests that perhaps this portion of the sedimentary basin was so swampy during the coal forming stages of Paleocene-Eocene time that acidic conditions destroyed any vertebrate remains. The only forms with a chance for fossilization were those living in rivers, such as the crocodile-like champosaurs, turtles, and large fish.
CHAPTER II

METHODS

Field Procedures

Field work was carried out during the summer of 1971. Three sections to be measured and sampled were chosen on the basis of maximum exposure and their place in the stratigraphic section according to Baker's 1929 map of the eastern half of the Sheridan coal field. It was hoped that deposits of the Upper Paleocene and possibly Lower Eocene rocks would be represented by the samples.

To achieve minimum contamination and collection of the freshest sediments possible, samples were taken from channels about one foot deep and packed in tightly sealed plastic bags.

Access to the sections can be gained by a well graded dirt road going eastward from Decker (Fig. 1). The strata measured and sampled are shown in Fig. 3. The geographic location of the sections are given below and in Fig. 1.

Section #1 - S 3/4 sec 32, T 9S, R 41E, Big Horn County, Montana

Section #2 - N 3/4 sec 24, T 8S, R 43E, Big Horn County, Montana

Section #3 - N 1/2 sec 21, T 8S, R 44E, Rosebud County, Montana

Sections 1 and 3 are known to be above the Roland coal, and contain a fossiliferous sandstone bed which Baker recognizes as an horizon marker which caps the Roland bed. Section two is located just above
Figure 3. Stratigraphic columns of measured sections.
the Smith coal bed and below the Roland.

Microfaunal Lab Procedure

Standard microfossil techniques were used to recover ostracodes. Treatment was kept as simple as possible in order to ensure minimum damage to fossils. Samples were soaked for a few hours in warm water or a detergent solution containing Quaternary 'O'. Kerosene was used as an aid in distintegration for those samples which would not break down by simpler methods. Samples were then gently flushed with a spray nozzle attached to the sink faucet, through a series of screens. A set of sieves composed of 16-32-64-120 mesh screens was used. All size samples were examined, but the majority of microfossils was found in screens of 32-mesh size.

Palynological Lab Procedure

The object of preparation of a sediment sample is to concentrate any spores or pollen grains present and render them as visible as possible. This is done by disintegration of the rock, removal of extraneous matter, and embedding the pollen in a suitable medium. After each step in the treatment, samples were washed and concentrated by centrifusing three times. Distilled water was used throughout to avoid the contamination of pollen grains and diatoms often found in tap water.

Samples were first broken down to pea size and then treated with a solution of ten percent hydrochloric acid to dissolve carbonates. They were then soaked in concentrated hydroflouric acid for forty eight hours to remove any silicates present. The next step involved
heavy liquid separation using a saturated solution of zinc chloride. The final solution was washed with a mixture of one part glycerine to ten parts water. All residues were mounted in glycerine jelly on coverslips that were in turn cemented with clear nail polish on glass slides.
CHAPTER III

OSTRACODA

A homogeneous group of fossils were found in six samples. They were found only at sections #1 and #3. All individuals were identified as *Ilyocypris arvadensis* Swain. Figure 3 shows the location of fossiliferous samples in the measured sections, along with the lithologies associated with them. In both cases fossils were extracted from samples no more than forty feet above or below the coquina bed. Samples from section #1 were removed from sands and cherty sands, while those from section #3 were found in carbonaceous maroon shales.

Swain (1949) examined collections of ostracodes from the Tongue River Member in southeastern Montana and North Dakota, and from the Eocene Flagstaff Limestone and Green River Formation in Wyoming and Utah. He identified the following species from the upper Tongue River collections: *Erpetocypris ?* sp., *Ilyocypris arvadensis* Swain, and *I. arvadensis tuberculata* Swain var. He found that all three are also abundant in the Eocene collections. According to Swain, *I. arvadensis* is very close to the recent freshwater *I. bradyi* Sars, but differs from it in possessing an anterodorsal groove that is particularly well defined on the right valve.

The presence or absence of ostracodes in the early Tertiary is evidently controlled by facies variations. In a general way, where these ostracodes occur in moderate or great abundance, a lacustrine environment is indicated.
The stratigraphic value of ostracodes is not demonstrated in this paper. Paleocene and Eocene non-marine ostracodes from the region are not well known and should be investigated further. It seems likely that additional work will demonstrate their usefulness. Until the complex facies relationships in the Paleocene and Eocene of the area are understood the ranges of the ostracodes will remain uncertain.

SYSTEMATIC DESCRIPTION
Order OSTRACODA Latreille
Family CYPRIDAE Baird, 1846
Subfamily CYPRINAE Sars, 1928
Genus ILYOCYPRIS Brady and Norman, 1889
ILYOCYPRIS ARVADENSIS Swain, 1949
Plate 1, Figs. 6a, 6b

Shell sub-quadrate in side view; greatest height about one-fifth from anterior end; hinge margin straight, about three fifths of shell length; ventral margin nearly straight, slightly concave towards the middle where edges of valves bend gently inward; anterior margin broadly rounded, truncate above; posterior margin more narrowly rounded, extended below. Left valve larger than right, overlapping and extending beyond the other most strongly along ventrum; as viewed dorsally, valves convex, greatest thickness slightly post-median.

Anterodorsal surface of each valve bears two short, narrow sulci or furrows that define a small lobe; anteriorly is a third shorter sulcus that defines a second small lobe. Anteroventrally on right valve a shallow groove occurs parallel to anterior margin and terminates ventrally in a small pit. Entire surface of each valve finely pitted.

Hinge of left valve consists of a narrow groove for reception of the slightly rabbeted edge of right valve. Muscle scar consists of a
subvertical row of three spots.

Average length: 1.119 mm.
height: 0.69 mm.
thickness: 0.48 mm.

Occurrences: Section #1 (See Fig. 3)
32-42'
52-62'
72-77'
92-102'
115-125'

Section #3
10-20'
40-50'
112-122'
CHAPTER IV
RESULTS

Palynological Control Section

The control section for this study is a composite stratigraphic section covering an area of about 20 square miles in southeastern Montana (Appendix B). This control section embodies six subsurface samples called 79, 63, 61, 45, 73, and 82. These samples were taken from the Canyon, Dietz, Anderson, and Smith coal beds, respectively, of the Tongue River Member. They were obtained from the Montana Bureau of Mines and Geology. Pollen samples had previously been prepared from these cores.

Also included in the composite section are four surface samples overlying the Smith coal and extending 110 feet above the top of the Roland coal bed. A total of 80 surface samples were analyzed for pollen content, but only four were found to contain pollen in significant quantity for detailed study. The surface samples were collected from three measured sections, #1, #2, #3 (Fig. 3). Those used in this study are called A, B, C, and D. Samples A, B, and C were taken from section #3 at 40-50', 50-60', and 92-100' respectively. A yellow to gray clayey shale makes up the sediments of these samples. Sample D was taken from section #2 at 95-100' where sediment is a maroon clayey shale.

It must be kept in mind that the breakdown technique for the subsurface samples may have differed from that of the surface samples.
Therefore, the outcome of the analysis may have been somewhat biased.

A composite stratigraphic section was necessary because the pollen samples used in this study were taken from sites that are widely scattered, where subsurface data is scant, and measured outcrops are not continuous. The geographic localities of each sample site is shown in Fig. 1.

Palynological control from the section was obtained from coals and associated lithologic units whose stratigraphic positions within the Fort Union Formation are well established.

**Analytical Procedures**

Pollen control assemblages were analyzed quantitatively in order to precisely determine the magnitude of any vertical floristic changes. Taxa were selected for quantitative analysis on the basis of abundance, relative frequency, and restricted stratigraphic range. Pollen taxa that offered little stratigraphic or statistical significance because of their small numbers were not used in the analysis. They include:

- Cupanieidites inaequalis
- Cyathidites minor
- Tricolpites parvus
- Inaperturepollenites
- juniperoides
- Zlivisporis nova-
- amexicanum
- Kurtzipites trispissatus
- Triporites shannonoides
- Ephedripites ovatus
- Insulapollenites rugulatus
- A total of twenty five species assignable to twenty-one genera were chosen for analysis. Relative pollen abundances were determined by counting the pollen found within a representative area of the slide.
An average of thirty pollen grains were counted per slide, and two hundred grains were counted per sample. Relative percentages of the twenty-five taxa were calculated (Fig. 4). The pollen of *Taxodium* spp. may also include species of *Metasequoia*, *Glyptostrobus*, and *Sequoia*, none of which can easily be distinguished. This complex was consequently eliminated, and the relative percentages of the remaining twenty-four taxa were recalculated (Fig. 5).

Two pollen and spore assemblages were recognized with a zonal transition between them. The older, Assemblage A, is composed of taxa whose uppermost stratigraphic range is sample 82 of the composite section. This assemblage includes species which occur in the Canyon, Dietz, Anderson, and Smith coal beds. The zonal transition, marked by significant increases and decreases, occurs between the Smith coal and Sample C and includes samples A and B. The younger Assemblage B includes samples C and D. A list of species occurring in each assemblage and in the zonal transition is given in Table 1.

Seven species are found to be restricted entirely to the lowermost assemblage. Three species are found only in the lowermost assemblage and the transition zone. Two species are restricted to the uppermost assemblage while one is restricted to both Assemblage B and the zonal transition.

Of the twenty-five species that were analyzed four are spores of the Filicophyta. There are three species belonging to the Coniferophyta and one Cycadophyta. The remaining species are of the Anthophyta. These include four genera of the family Juglandaceae, three of the family Betulaceae, and one each of the families Ulmaceae, Myricaceae, and
Figure 4: Histogram showing the relative abundance of the taxa listed.
Saliaceae. The remaining genera are form genera, believed to have an affinity to the dicotyledons.

Based on the total number of taxa it can be seen that both the assemblages and the Transition Zone are dominated by angiosperm pollen. Leffingwell (1966) and Norton and Hall (1969) found that this dominance of angiosperms differentiates the early Tertiary Fort Union from Upper Cretaceous assemblages. Apparently the angiosperms found an optimum environment during the Tertiary.

Discussion of Assemblages

**Assemblage A.** The top of Assemblage A coincides with the Smith coal bed and occurs in samples 79, 63, 61, and 45, all of which are coals. The base of the zone has not been precisely determined, but a cursory examination of assemblages near the base indicates that Assemblage A is there. Assemblage A is characterized by an abundance of the fern spores: *Gleicheniidites senonicus*, *Reticuloidosporites pseudomurii*, *Laevigatosporites discordatus*, and *Laevigatosporites ovatus*.

With the exception of *Laevigatosporites ovatus* these spores were recovered only from the coal samples. Coal is less likely to contain a regional assemblage than is a clastic sample because the streams carrying the clastic load to the depositional site will introduce pollen from a much larger area. However, spores will be most likely to occur in the coal samples since the depositional site would have been favorable to the growth of ferns, mosses, and other spore-producing plants.

Of the angiosperm pollen found six are seen to decrease in number towards the top of the assemblage. These include: *Carya vidrifluminipites*. 
Maceopolipollenites amplus, Ulmipollenites sp., Monosulcites sp.,
Tricolporopollenites sp., and Triporopollenites sp.

Five angiosperm species increase to the top: Carya veripites,
Maceopolipollenites rotundus, Myrica annulites, Fraxinoipollenites
pachyexinous, and Tricolpopollenites sp.

The above increases and decreases seem to suggest that nearly
half the community in Assemblage A is in a state of flux. As will be
observed, this change becomes much greater in the transition zone.

Transition Zone. The base of the Transition Zone occurs at the
Smith coal bed, and the top is approximately halfway between the Smith
and Roland beds at sample C. Only one spore species, Laevigatosporites
ovatus, continues across this zone into Assemblage B. The most im­
portant change within this zone occurs at sample A, where there is an
apparent increase in five angiosperm pollen species as follows:
Carya veripites, Maceopolipollenites amplus, Maceopolipollenites
rotundus, Pterocarya stellatus, and Fraxinoipollenites pachyexinous.
Except for Fraxinoipollenites pachyexinous, which is a form genus, all
the species which increase at this level belong to the family
Betulaceae. The gymnosperm pollen, Pinuspollenites sp. and Taxodium sp.
and the fern spore Laevigatosporites ovatus also increase at this level.

Also noted is a marked decrease in other pollen species as follows:
Carya vidrifluminipites, Myrica annulities, Ulmipollenites sp.,
Tricolpopollenites sp., Tricolporopollenites sp., and Triporopollenites
sp. It is interesting to note that tricolpate and tricolporate pollen
noticeably decrease in number at this level. Since all these pollen
are form genera, their family affinities are not known, nor is it known
what the optimum environment would be for the parent plants of these pollen species. It seems probable that a change in the environment occurred at this time which brought about a decrease in tricolpate and tricolporate producing plants in the community.

The qualitative composition of the zonal transition is intermediate between those of Assemblage A and Assemblage B because only one of the twenty five taxa, Alnus sp., is restricted to the Transition Zone. Carya veripites, Myrica annulites, Fraxinoipollenites pachyexinous, and Tricolporopollenites sp. occur in both Assemblage A and the Transition Zone but are not present in Assemblage B. Conversely, Pterocarya stellatus is present in the upper two assemblages but not in the lower one.

Only four taxa, all angiosperms, increase toward the top of the Transition Zone. These include Maceopolipollenites amplus, Myrica annulites, Ulmipollenites sp., and Tricolpopollenites sp.

Seven taxa (six angiosperms and one spore) decrease toward the top of the assemblage. These include Laevigatosporites ovatus, Carya veripites, Maceopolipollenites rotundus, Pterocarya stellatus, Fraxinoipollenites pachyexinous, Monosulvites sp., and Tricolporepollenites sp.

Assemblage B. Assemblage B is most similar to Assemblage A with the exception that Corylus tripollenites and Carya juxtaporites are restricted to Assemblage B and Carya veripites, Myrica annulites, and Fraxinoipollenites pachyexinous not present. Relative frequencies of the remaining pollen are similar to those of Assemblage A.
Discussion and Comparison

The floral changes described in this paper were previously studied by Leffingwell (1966) in formations in and adjacent to the type Lance area in southeastern Wyoming. Leffingwell's study is centered on those floristic changes which occur at or near the Lance-Fort Union contact. He found two significant floristic changes. One occurs at the Lance-Fort Union contact, and the other between the Tullock and Lebo members of the Fort Union Formation. Leffingwell's younger assemblage (Assemblage C) covers the changes followed in this study, that of the Tongue River Member of the Fort Union Formation. My study ranges about 110 feet above Leffingwell's (Fig. 6).

The vertical changes in both studies compare favorably in that both are characterized by a predominance of taxodiaceous pollen along with significant quantities of juglandaceous pollen. The following taxa were found in both studies: Laevigatosporites discordatus, Gleicheniidites senonicus, Pinuspollenites sp., Taxodium spp. Carya veripites, Varya Vidrifluminipites, Pterocarya stellatus, Maceopolipollenites amplus, Maceopolipollenites rotundus, and Fraxinoipollenites pachyexinus.

Leffingwell has not precisely determined the stratigraphic position of the top of his assemblage, but he believes that it may be coincident with the Fort Union-Wasatch contact. He bases this possibility on "the occurrence of a distinctively different flora in the Eocene Felix coal near Gillette, Wyoming. According to Dobbin and Barnett (1927), the Felix coal is at least 500 feet above the Roland bed in that area, and Leffingwell does not have evidence of the precise relationship. Since
Laevigatosporites discordatus
Praxinoipollenites pachyexinous
Maceopolipollenites amplus
Maceopolipollenites rotundus
Carya vidrifuminipites
Carya veripites
Pterocarya stellatus
Gleicheniidites sennicus
Taxodium spp.
Pinuspollenites spp.
no flora that is distinctly Eocene was found in my study I am inclined to agree with Leffingwell.

There is no evidence of a transition zone or change between the Smith and Roland coal beds in Leffingwell's study. Perhaps, if he had had samples at the same stratigraphic position as mine, a marked change would also have been apparent in his study.
### TABLE 1.

**LIST OF SPECIES**

<table>
<thead>
<tr>
<th>Palynomorph</th>
<th>A</th>
<th>TZ</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gleißeniidites senonicus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reticuloidosporites pseudomurii</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laevigatosporites discordatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laevigatosporites ovatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Araucariacites sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycadopites scabratus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinuspollenites sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxodium spp.</td>
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<td></td>
<td></td>
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<tr>
<td>Alnus sp.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Carpinus ancipites</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Corylus tripollenites</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Carya veripites</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Varya vidrifluminipites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carya juxtaporites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maceopolipollenites amplus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Maceopolipollenites rotundus</td>
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<td></td>
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</tr>
<tr>
<td>Pterocarya stellatus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Myrica annulites</td>
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<td></td>
</tr>
<tr>
<td>Salix discolporites</td>
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<td></td>
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<tr>
<td>Ulmipollenites sp.</td>
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<td></td>
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<tr>
<td>Fraxinoipollenites pachyexinous</td>
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<tr>
<td>Monosulcites sp.</td>
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<tr>
<td>Tricolpopollenites sp.</td>
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<td></td>
</tr>
<tr>
<td>Tricolporopollenites sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triporopollenites sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER V
INTERPRETATIONS

Family Relationships

Organ genera are those which have no match with living genera, but can fairly easily be assigned to natural families. At the lower taxonomic levels many of the spores and gymnosperm pollen can be assigned to organ genera. Among the angiosperms, however, many cases of doubt as to family relationships exist. These pollen grains cannot be assigned to natural families even though species within genera may have resemblance to the palynomorphs of living genera. The term form genus is applied to genera for which we have no proof of precise botanical affinity. Names such as Monosulcites Tricolporopollenites, and Tricolpopollenites are form genera in the fullest sense. It seems likely that many Tertiary palynomorphs will never be assigned to natural families.

Since most of the taxa I have dealt with in this paper are either form or organ genera, little, of anything is known about their biological or phylogenetic relationships. Relationships indicated in the following section are merely suggestions based on what is known about the morphology of the palynomorphs and their relationships to modern pollen.
Relationships of Pollen to Climate

There are several possible reasons for the major characteristic changes in the microflora that differentiates Assemblages A and B and the Transition Zone of my study. Serious consideration must be given the possibility that unconformities or diastems of some time significance do exist within the section. Thus, some of the changes may have been evolutionary. It is therefore possible that a Paleocene-Eocene boundary may exist in the Transition Zone. However, there is no indication that any of the taxa dealt with in this paper are distinctly Eocene.

It is postulated that environmental, probably climatic, conditions may have influenced the flora.

The two spores Laevigatosporites discordatus and L. ovatus are, according to Rouse (1962), possibly related to Dryopteris and Asplenites. Dryopteris is possibly the most frequently recognized genus of ferns in the North American Tertiary. The present distribution of the modern genus is temperate, but Pabst (1962) has stated that early Tertiary species find their closest modern relatives in Mexican and Central American species.

Gleicheniidites senonicus, the third spore found, is related to G. emarginata and G. linearis, described by Selling (1946) from the Hawaiian Islands.

Of the four genera of conifers, Taxodium spp. is the most abundant microflora. This is possibly due to the fact that Taxodium spp. has been broadly defined to include the pollen of Metasequoia, Sequoia, and Glyptostrobus. The pollen grains of these four genera are so similar that for practical purposes fossil forms are not separated.
These genera are found in moist areas in temperate and tropical regions. *Taxodium*, however, has been reported in relatively dry areas in New Mexico, while *Metasagquoia* has been found in cool, moist areas of China.

Most specimens of *Pinuspollenites* are broken or torn. This might indicate that these trees grew in the highlands to the southwest and west, and their pollen was carried to the site of deposition, particularly by the streams flowing down from the highlands.

The pollen grains identified as the modern *Araucariacites* are found today only in the southern hemisphere in the Andes (Willis, 1958).

The fourth gymnosperm, possibly related to the cycads, is *Cycadopites scabratus*. Cycads today are found in tropical and subtropical areas where there is adequate soil and moisture.

Of the twenty five species of palynomorphs described from the upper Fort Union fossil flora, eighteen are believed to be from angiosperms. The family Juglandaceae is represented by three genera. According to Griggs (1966) the pollen of *Carya* indicate upland habitats. The pollen of *Maceopolipollenites* are morphologically intermediate between the modern pollen *Engelhardtia* and that of *Carya* (Leffingwell, 1966). Today, *Carya* is found in temperate climate in eastern Asia and eastern North America in various habitats. The same is true for *Pterocarya*.

Only one palynomorph, *Salix discolorites*, is assignable to this genus. Modern *Salix* is almost world-wide in distribution with present centers in the north-temperate and sub-artic regions.
In the family Betulaceae there is one species assigned to each of three genera. Corylus tripollenites is found today in woodland thickets in the temperate regions of the northern hemisphere. Alnus sp. if found mostly in wet habitats in north-temperate regions of North America and in the Andes Mountains of South America. Carpinus also is north-temperate in habitat.

The modern genus of Myrica annulites is found in subtropical and moist areas.

The remaining five genera cannot be assigned to families, and are thus form genera. Only one has possible affinities to a family. Rouse (1962) found that Tricolporopollenites sp. resembles pollen grains of the genus Nyssa. Nyssa is indigenous to eastern North America and Asia. Its habitats range from dry or moist woods to wet coastal swamps. Norton and Hall (1969) postulate that Monosuliites is related to the palms. Of the remaining three genera, the only botanical affinity offered is to the dicotyledons.

The presence of a fern flora with a rich development of angiosperms, plus temperate and subtropical gymnosperms indicates a flora that possibly developed on a large floodplain. The boundary between subtropical and temperate zones was thus much farther north than it is today. Griggs (1966) found that there is more mixing of species from these two zones than there is today. This would account for the presence of temperate species in my study. The climate was thus warm temperate in aspect.
Vertebrate Evidence

Although few vertebrate remains have been found in the Tongue River Member in my area, Fort Union beds have produced Paleocene mammals in various areas, particularly in the mid-Paleocene deposits near the Crazy Mountains in Montana. Insectivores, carnivores, and herbivores that were primitive and relatively small have been found (Romer, 1967).

The herbivores were in great abundance. Their low crowned cheek teeth were adequate for soft vegetation. Further, they were not fleet of foot, and therefore probably lived in forests (Colbert, 1973).

The area was thus populated by mammals who lived off the abundant vegetation of the forested areas.

Environment of Deposition

On the basis of my microfloral study, along with the evidence from the general patterns of distribution, stratigraphy and vertebrate paleontology already mentioned in this paper, it would seem that the sediments were deposited in forested and backwater areas where rates of sedimentation were quite varied. Continuous subsidence in the depositional basin was balanced by deposition. The surface of the area was thus maintained at or near the level of a nearby body of water.

Thick sandstone units are characteristic of Assemblages A and B (Appendix A). In the Transition Zone massive sandstone is not as prominent as clayey shales.

The Transition Zone may represent a time when the backwater areas were at some distance from the large streams that carried coarse sediment into the area during the deposition of Assemblage A and B.
Age and Correlation

The microfossil flora of the sequence studied includes fourteen taxa that are also present in Leffingwell's (1966) sequence and ten taxa that are present in the Lebo Member of Norton and Hall's (1969) sequence. The probable Paleocene age of the upper part of the Fort Union thus generally complements that given by Leffingwell and Norton and Hall. The similarity of my sequence with Leffingwell's heavily favors placing the age of my section at or near equivalence with Leffingwell's.

The taxa I have found have been noted in both Paleocene and Eocene sediments (Rouse, et. al., 1966; Wodehouse, 1933; Hail and Leopold, 1960). Pollen such as Platacarya and Tilia crassipites Wodehouse, not included in my taxa, have not been reported in rocks older than Eocene (Hail and Leopold, 1960).

Although the evidence indicates that the ages of my zones are late Paleocene, it should be noted that the section studies may be several hundred feet below the Paleocene-Eocene contact.
CHAPTER VI

SUMMARY AND CONCLUSIONS

The floral succession from upper Fort Union rocks reveals a transitional change possibly due to climatic influences. The microflora indicates that this area was covered with a temperate to warm temperate vegetation. The climate was more humid and warmer than that existing today.

The interval was deposited on a wide floodplain close to a large body of water. The transition zone may represent a time when backwater areas were at some distance from the large streams that carried coarse sediment into the area.

There is no indication of a significant Eocene element in my study. The Paleocene-Eocene contact probably exists in the 500 foot interval above the sequence studied here.
CHAPTER VII
TAXONOMY

PTERIDOPHYTA

Family: Gleicheniaceae

Organ genus: Gleicheniidites Ross ex Delcourt and Sprumont emend. Dettman, 1963

Gleicheniidites senonicus

Plate 1, Fig. 3

Description: Small triradiate spores, triangular in polar view with sharply rounded corners and concave sides; psilate. Size 21 to 45 μm.

Stratigraphic occurrence: Assemblage A.

SPORES OF UNCERTAIN FAMILIAL AFFINITY

Form genus: Reticuloidosporites Pflug in Thompson and Pflug, 1953

Reticuloidosporites pseudomurii Elsik, 1968

Reticuloidosporites pseudomurii Elsik, Pollen et Spores, v. 10, no. 2, p. 290, pl. 7, fig. 2, 1968

Description: Specimen ornamented with low verrucae that in some areas of the spore are joined by narrow exinous thickenings to form a partial pseudoreticulum. The verrucae are of variable size, characteristically with a few large (approximately 4 to 8 μm) elements scattered among smaller
(approximately 1 to 3 µm) elements. Ornamentation is reduced and is of equal size adjacent to the monosulcate scar. Size 34 to 37 µm X 22 to 36 µm.

Stratigraphic occurrence: Assemblage A.

Form genus: Laevigatosporites Ibrahim, 1933
Laevigatosporites discordatus Pflug, 1953
Plate 1, Fig. 1

Description: Monosulcate spore with equatorial contour ellipsoidal; psilate. Size 59 to 60 µm X 48 to 50 µm.

Stratigraphic occurrence: Assemblage A.

Laevigatosporites ovatus Wilson and Webster, 1946
Plate 1, Fig. 2

Laevigatosporites ovatus Wilson and Webster, Amer. Jour. Bot., V. 33, p. 273, fig. 5.

Description: Monosulcate, subcircular spore, exine mostly smooth, but with granular patches; translucent. Size 40 to 41 X 30 to 31 µm.

Stratigraphic occurrence: Assemblage A and B, Transition Zone.

GYMNOSPERMAE

Family: Cycadaceae

Organ genus: Cycadopites Wodehouse ex Wilson and Webster, 1946
Cycadopites scabratus Stanley
Plate 2, Fig. 13

Description: Monosulcate grain with shape more or less fusiform in polar view. Ornamentation is scabrate. Sulcus margins overlap in the center and the ends of the sulcus are open. Length of the sulcus is equal to that of the grain. Size 28 to 30 µm X 13 to 15 µm.

Stratigraphic occurrence: Assemblage A.

Family: Taxodiaceae
Genus: Taxodium Kremp, 1949
Plate 2, Fig. 7a, 7b

Description: Inaperturate grains; Spheroidal in equatorial view. Ornamentation scabrate with an exine so thin that it often splits. Size of equatorial diameter 21 to 23 µm.

Stratigraphic occurrence: Assemblage A and B, Transition Zone.

Family: Pinaceae
Plate 1, Fig. 5

_Pinuspollenites sp._ Norton, Paleontographica, V. 125 (B) p. 27, Pl. 4, Fig. 1, 1969.

Description: Bivesiculate grain with overall length 60 to 80 µm. Central body is elliptical in polar view with bladders circular in polar view.

Family: Araucariaceae
Genus: _Araucariacites sp._
Plate 1, Fig. 4
Description: Oblate grain with one colpus extending the length of the grain. Size 30 to 40 μm long.

Stratigraphic occurrence: Assemblage A.

ANGIOSPERMAE

Family: Betulaceae
Genus: Alnus Mill.
Alnus sp. Rouse
Description: Oblate in shape with four pores that are equatorial. Pores are small and elongate. Ornamental reticulate-rugulate. Size 29 μm.

Stratigraphic occurrence: Transition Zone.

Genus: Corylus
Corylus tripollenites Rouse, 1966.

Corylus tripollenites Rouse, Symp. on Palyn. of the Late Cret.

Plate 2, Fig. 8

Description: Shape subtriangular with three pores. Pore margins thickened with psilate surface. Size 25 to 35 μm in diameter.

Stratigraphic occurrence: Assemblage B.

Genus: Carpinus
Carpinus ancipites Wodehouse, 1933

Plate 2, Fig. 12

Carpinus ancipites Wodehouse, Torrey Bot. Club Bull., V. 60, p. 510, fig. 42, 1933.
Description: An oblately flattened grain which is angular in outline. Has three pores which are elliptical in shape. Texture smooth. Size 27 to 44 μm.

Stratigraphic occurrence: Assemblage B.

Family: Juglandaceae

Genus: Carya Nutt.

*Carya veripites* Wilson and Webster, 1946

Plate 2, Fig. 11


Description: Circular to slightly triangular in equatorial view, oblately flattened. Triporate, pores round to broadly elliptical, located in one hemisphere. Exine smooth to translucent; polar areas thinner. Size 27 to 33 μm.

Stratigraphic occurrence: Assemblage A and Transition Zone.

*Carya vidrifluminipites* (Wodehouse) Wilson & Webster, 1946

Plate 2, Fig. 14

*Hicoria vidrifluminipites* (Wodehouse) Torrey Bot. Club Bull., V. 60, p. 503, fig. 29, 1933


Description: More angular than *Carya veripites* and is 3 to 9 μm larger in size. Triporate, pores round to broadly elliptical, located in one hemisphere. Size 30 to 36 μm. Exine thickens around pole.
Stratigraphic occurrence: Assemblage A and B, Transition.

*Carya juxtaporites* (Wodehouse) Rouse, 1962

Plate 2, Fig. 9


Description: Triporate grain with pores round to broadly elliptical, located in one hemisphere. Rounder than other two species. Size 30 to 35 μm.

Stratigraphic occurrence: Assemblage B.

Organ genus: *Maceopoli polinotes* Leffingwell, 1966

*Maceopoli polinotes amplus* Leffingwell, 1966

Plate 2, Fig. 10


Description: Triporate grain, pores equatorial. Grain oblate to subtriangular in polar view. Exine on one hemisphere thinned to form a circular to triangular circumpolar area about 12 μm in diameter.

Stratigraphic occurrence: Assemblage A and B, Transition.

*Maceopoli polinotes rotundus* Leffingwell, 1966

Description: Triporate grain with equatorial pores. Oblate shape and rounded triangular in polar view. Ornamentation scabrate. Size 24 to 34 μm.

Stratigraphic occurrence: Assemblage A and B, Transition.

Organ genus: *Pterocara* Raatz

*Pterocarya stellatus* (Pot.) Thiergart, 1937

Description: A stephanoporate grain with pores circular to slightly elliptical, usually five in number. Psilate. Size of diameter 10 to 24 um.

Stratigraphic occurrence: Transition Zone, Assemblage B.

Family: Ulmaceae

Organ genus: Ulmipollenites Wolff, 1934

Ulmipollenites sp. Norton, Paleontographica, V. 125 (B) Plate 3, Fig. 18

Description: Tetraporate grain with outline subcircular in polar view. Pores circular in outline and located on the equator of the grain. Size 30 to 40 um.

Stratigraphic occurrence: Assemblage A and B, Transition.

Family: Saliciaceae

Genus: Salix

Salix discolporites Wodehouse, 1933 Plate 2, Fig. 15

Salix discolporites Wodehouse Torrey Bot. Club Bull., V. 60, p. 506, fig. 34, 1933.

Description: Tricolpate grain generally more or less deeply 3-lobed. Furrows are long and tapering. Exine is thick and coarsely reticulate with the network towards the margins of the furrows. Size 24 to 34 um.

Stratigraphic occurrence: Assemblage A.
Family: Myricaceae
Genus: Myrica
Myrica annulites Rouse & Martin, 1966
Plate 3, Fig. 17
Description: Triporate grain slightly angular in outline. Pores slightly protruding with definite thickening of wall to give an annulus. Size 27 to 34 um.
Stratigraphic occurrence: Assemblage A and B.

ANGIOSPERM POLLEN OF UNCERTAIN FAMILIAL AFFINITY
Form genus: Fraxinoipollenites Potonie, 1951
Fraxinoipollenites pachyexinous Leffingwell
Plate 3, Fig. 22
Description: Tricolpate grain with colpi extending nearly to poles. Shape is prolate. Ornamentation reticulate. Size 17 to 23 um X 13 to 20 um.
Stratigraphic occurrence: Assemblage A, Transition.
Form genus: Monosulcites Norton, 1969
Monosulcites sp. Norton, Paleontographica, V. 125 (B), p. 35, Pl. 3, Fig. 7, 1969.
Plate 3, Fig. 19
Description: Monosulcate grain, spindle to oval shaped in polar view. Exine densely bacculate. Size of grain 25 to 46 um.
Stratigraphic occurrence: Assemblage A and B, Transition.

Form genus: Tricolpopollenites sp. Norton & Hall, 1969

Tricolpopollenites sp. Norton & Hall, Paleontographica, V. 125 (B), p. 49, Pl. 7, fig. 15, 1969.

Plate 3, Fig. 20a, 20b, 20c

Description: Tricolpate grain with smooth margins and ends tapering to a point. Psilate. Size 13 to 10 um X 11 to 8 um.

Stratigraphic occurrence: Assemblage A and B, Transition.

Form genus: Tricolporopollenites sp. Pflug & Thompson, 1953


Description: The grain is tricolporate with generally long colpi and a wide pore in the form of an elliptical slit. Ornamen­
tation reticulate. Size 20 to 25 um X 10 to 12 um.

Plate 3, Fig. 21

Stratigraphic occurrence: Assemblage A, Transition.

Form genus: Triporopollenites sp. Pflug & Thompson, 1953

Triporopollenites sp. Pflug & Thompson in Paleontographica, V. 94 (B), p. 82, 1953.

Description: Triporate grain with circular pores. Smooth sculpture, with equatorial diameter 20 to 30 um.

Stratigraphic occurrence: Assemblage A and B, Transition.
SELECTED REFERENCES


Dorf, E., 1940, Relationship between floras of the type Lance and Fort Union Formations: Geol. Soc. America Bull., V. 51, pp. 213-236.


Kremp, G., 1949, Pollenanalytische Untersuchung des miozanan Braunkohlenlagers von Konin an der Warthe, Paleontographica, V. 90, pp. 53-93.


APPENDIX A

DESCRIPTIONS OF MEASURED SECTIONS

SECTION #1
S1/2 sec. 32, T. 9S, R. 41E

<table>
<thead>
<tr>
<th>Sample</th>
<th>Lithology</th>
<th>Fossils</th>
</tr>
</thead>
<tbody>
<tr>
<td>120-125'</td>
<td>Well indurated green claystone</td>
<td>Wood fragments</td>
</tr>
<tr>
<td>115-120'</td>
<td>Light gray evenly bedded sandstone</td>
<td></td>
</tr>
<tr>
<td>109-115'</td>
<td>Light gray sandy clay</td>
<td></td>
</tr>
<tr>
<td>100-109'</td>
<td>Covered</td>
<td></td>
</tr>
<tr>
<td>90-100'</td>
<td>Sandy claystone</td>
<td>Wood fragments, Few ostracodes</td>
</tr>
<tr>
<td>82-92'</td>
<td>Buff-colored calcareous sandstone</td>
<td></td>
</tr>
<tr>
<td>72-82'</td>
<td>Light gray calcareous sandstone</td>
<td>Some ostracodes</td>
</tr>
<tr>
<td>62-72'</td>
<td>Brown silty claystone</td>
<td></td>
</tr>
<tr>
<td>52-62'</td>
<td>Light tan to gray sandstone</td>
<td>Many ostracodes</td>
</tr>
<tr>
<td>42-52'</td>
<td>Clinker bed</td>
<td>Gastropods, Clams, Many ostracodes</td>
</tr>
<tr>
<td>32-42'</td>
<td>Coquina bed</td>
<td></td>
</tr>
<tr>
<td>26-32'</td>
<td>Light yellow limestone</td>
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</tr>
<tr>
<td>20-26'</td>
<td>Black impure lignite</td>
<td></td>
</tr>
<tr>
<td>10-20'</td>
<td>Covered</td>
<td></td>
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<tr>
<td>Sample</td>
<td>Lithology</td>
<td>Fossils</td>
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<tr>
<td>----------</td>
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</tr>
<tr>
<td>0-10'</td>
<td>Grayish silty shale</td>
<td>Many ostracodes</td>
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<tr>
<td>SECTION #2</td>
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<tr>
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<tr>
<td>230-240'</td>
<td>Brown sandstone</td>
<td>Clam fragments</td>
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<tr>
<td>220-230'</td>
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<td>Clam fragments</td>
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<tr>
<td>210-220'</td>
<td>Brown sandstone</td>
<td>Clam fragments</td>
</tr>
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<td>200-210'</td>
<td>Light gray to brown fine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>grained shale</td>
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</tr>
<tr>
<td>175-200'</td>
<td>Covered</td>
<td></td>
</tr>
<tr>
<td>165-175'</td>
<td>Light gray clayey shale</td>
<td></td>
</tr>
<tr>
<td>160-165'</td>
<td>Light tan calcareous sandstone</td>
<td></td>
</tr>
<tr>
<td>150-160'</td>
<td>Light gray to yellow clayey shale</td>
<td></td>
</tr>
<tr>
<td>140-150'</td>
<td>Light gray to yellow clayey shale</td>
<td></td>
</tr>
<tr>
<td>130-140'</td>
<td>Light gray to yellow clayey shale</td>
<td></td>
</tr>
<tr>
<td>125-130'</td>
<td>Light tan calcareous sandstone</td>
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<td>120-125'</td>
<td>Maroon to black carbonaceous</td>
<td>Sample D Pollen</td>
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<td>shale with sulphur and gypsum</td>
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<td>shale with sulphur and gypsum</td>
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<td>grained shale</td>
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<td>Sample</td>
<td>Lithology</td>
<td>Fossils</td>
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<td>-----------------------------------------------</td>
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<td>40-50'</td>
<td>Black shale</td>
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<td>30-40'</td>
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<tr>
<td>20-30'</td>
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<td>10-20'</td>
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<td>0-10'</td>
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**SECTION #3**

N\(_2\) sec. 21, T. 8S, R. 44E

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<td>92-102'</td>
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Appendix B

COMPOSITE STRATIGRAPHIC SECTION

LEGEND
Plate 1
All 1200 x except where noted

Fig. 1. *Laevigatosporites discordatus*

Fig. 2. *Laevigatosporites ovatus*

Fig. 3. *Gleicheniidites senonicus*

Fig. 4. *Araucariacites sp.*

Fig. 5. *Pinuspollenites spp.*

Fig. 6a., 6b. Ostracoda -- *Ilyocipris arvadensis*
Plate 2

All 1200 x except where noted

Fig. 7a, 7b. *Taxodium* spp.

Fig. 8. *Corylus tripollenites*

Fig. 9. *Carya juxtaporites*

Fig. 10. *Maceopolipollenites amplus* x 480

Fig. 11. *Carya veripites* x 480

Fig. 12. *Carpinus ancipites*

Fig. 13. *Cycadopites scabratus*

Fig. 14. *Carya vidrifluminipites*

Fig. 15. *Salix discoloripites*

Fig. 16. *Maceopolipollenites rotundus*
Plate 3
All 1200 x except where noted

Fig. 17. *Myrica annulites*

Fig. 18. *Ulmipollenites sp.*

Fig. 19. *Monosulcites sp.*

Fig. 20a., 20b., 20c. *Tricolporopollenites sp.*

Fig. 21. *Tricolporopollenites sp.*

Fig. 22. *Fraxinoipollenites pachyexinous*

Fig. 23. *Triporopollenites sp.*