Identification of Fossil Wood from the Specimen Creek Area of the Gallatin Petrified Forest, Yellowstone National Park, Montana

Tetsuya Yamamoto

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Abstract

Identification of Fossil Wood from the Specimen Creek area of the Gallatin Petrified Forest, Yellowstone National Park, Montana

by Tetsuya Yamamoto

The petrified fossil forests in the Specimen Creek area of Gallatin Petrified Forest contain spectacular petrified tree stumps, trunks and logs in horizontal and vertical positions. These fossils forests are embedded in early middle Eocene volcaniclastic rocks and piled in sequential layers.

One hundred and nineteen fossil wood samples were collected from three selected layers [unit 1, unit 5 and unit 9, (DeBord 1977)] of the sequentially entombed Fossil Forests in the above area, and identified as follows: 3 families, 9 genera, in Gymnosperms; 13 families, 15 genera in Angiosperms.

PINACEAE: Keteleeria*, Larix*, Pinus, Tsuga*
PODOCARPACEAE: Podocarpus
TAXODIACEAE: Glyptostrobus*, Sequoia, Taxodium*
*ACERACEAE: Acer*
BETULACEAE: Alunus, Betula*
*CORNACEAE: Cornus*
*EBENACEAE: Diospyros*
FAGACEAE: Fagus
HAMAMELIDACEAE: Liquidambar*
*HIPPOCASTANACEAE: Aesculus*
LAURACEAE: Umbellularia*
MAGNOLIACEAE: Lirondendron*, Magnolia*
NYSSACEAE: Nyssa
*OLEACEAE: Fraxinus*
PLATANACEAE: Platanus
*SALICEAE: Salix*

The identified wood stumps were compared with previous pollen analysis of the same layers. In a few cases correlation was observed between fossil stumps and fossil pollen of associated organic levels whereas in most cases no fossil pollen correlated with the adjacent stumps. Overall, correlation was lacking.

The identified woods were plotted on modern climatic ranges and each unit exhibits the following climatic range.

Unit 1. Subtropical to boreal, mostly warm temperate to cool temperate.

Unit 5. Tropical to boreal, mostly subtropical to cool temperate.

Unit 9. Warm temperate to boreal, mostly cool temperate and boreal.

As a result of this study 6 new families (*) and 16 new genera (*) based upon wood are added to the Eocene "Fossil Forest" flora. In addition several features have emerged which suggest the "fossil forest" represents a unique assemblage of plant types. These are:

1) The presence of an uncommon admixture of tree types
2) The lack of correlation in many cases between the vertical fossil trees and the associated microfossils
3) The indications of a strange admixture of climatic ranges within each tree level.
IDENTIFICATION OF FOSSIL WOOD
FROM THE SPECIMEN CREEK AREA OF THE GALLATIN PETRIFIED FOREST,
YELLOWSTONE NATIONAL PARK, MONTANA

by

Tetsuya Yamamoto

A Thesis in Partial Fulfillment of the Requirement
for the Degree Master of Arts in Biology

August 1980
Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Arts.

Arthur V. Chadwick, Associate Professor of Biology

Raymond E. Ryckman, Professor of Microbiology

Earl W. Lathrop, Professor of Biology
ACKNOWLEDGEMENTS

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INTRODUCTION

GENERAL STATEMENT

The Fossil Forests of Yellowstone National Park stand alone in the world for a number of reasons - the extent of the deposits, abundance of different kinds of plant fossils, the upright petrified trees and the geological strata which entomb a succession of upright fossil trees (fig. 1).

For many years, the uniqueness of this phenomenon has attracted attention not only from park visitors, but also from scientists. Since the first description of fossil forest was made a century ago, a number of investigators have attempted to clarify its ecological and geologic history without much success.

The purpose of our present study is to explore the history of the Yellowstone Fossil Forests in an attempt to further our understanding of this portion of the fossil record.

GEOLOGICAL SETTING

Upper Cretaceous and Lower Tertiary sediments were markedly altered by contemporaneous orogenic events that occurred worldwide and caused a large shift in the earth's crust. Huge amounts of volcanic sediments - ash, breccia and lava, were deposited in the Circumpacific Belt extending from the Antarctic through Palmer Peninsula, - the South American Andes, - Mexico, - the North American Rockies, - the Canadian Rockies, - Alaska, - the Aleutian Islands, - Kamchatka Peninsula, - Japan, - Philippines, - Southeast Asia, and New Guinea to New Zealand.
Figure 1

Outcrops of studied site illustrating general locality and nature of horizons containing upright trees. Figure 4 illustrates detailed position of wood on this slope.
In the above mentioned areas, a rich fossil flora has been discovered in these volcanic deposits. The fossil forests of Yellowstone National Park are also found in such a deposit. The Geology of Yellowstone National Park has been recently described by Parsons (1958), Brown (1961), and Smedes and Prostka (1972). The deposits that contain the Fossil Forests are placed in the Absaroka Volcanic Supergroup of early Middle Eocene (early Bridgerian). Those deposits containing the fossil forests in northeastern Yellowstone National Park are called the Lamar River Formation, and those in northwestern Yellowstone National Park are referred to the Sepulcher Formation. Petrologically, these formations consist of lava flows, autoclastic flow breccias, avalanche debris flows, mudflows, tuffs, and well bedded volcanic sediments.

The Sepulcher Formation is divided into two members; the Fortress Mountain member and the underlying Daly Creek member. The Fortress Mountain member outcrops as bluish-grey cliff-forming ash beds with abundant clasts or breccias, and the Daly Creek member as dark reddish brown to grey moderately resistant volcanic andesitic conglomerates and breccias in a pumice and ash of alluvial origin. (Smedes & Prostka, 1970)

PREVIOUS STUDIES

During the past century, there have been several studies done on the fossil flora of Yellowstone National Park. However, as usual for such studies, the fossils which are commonly utilized are largely leaves, stems, cones, seeds, etc. and the fossil wood is generally overlooked. Up until 1976, 31 families and 57 genera of megafossils
(including all leaves, needles, cones, seeds and flowers, etc.) were described from these deposits by Lesquereux (1878), Felix (1896), Knowlton (1899), Read (1930), Andrews (1939), Beyer (1954), and Dorf (1960), while 37 families and 60 genera of microfossils (pollen and spores) were reported by the studies of Fisk (1976) and DeBord (1977). However, only 7 families and 14 genera of wood fossils were included in the above studies up to 1976. Recently, Wheeler and Barghoorn (1976), Wheeler, Scott and Barghoorn (1977), Fritz (1977) and Suss and Müller-Stoll (1977) have added many families and genera so that as of 1977, 20 families and 33 genera were recorded on the basis of fossil wood. Numbers were still poor when compared with the richness of the flora based upon megafossils and microfossils.

PURPOSE OF THE STUDY

More than one model has been considered to give the best explanation for the presence of multiple forest levels containing upright trees. Holmes (1878), Dorf (1959, 1964) and others have advocated that actual forests were sequentially buried by volcanic eruptions, the so-called "burial model". Coffin (1976) and Fisk (1976) have advocated some form of transport model. There is a need for more accurate paleoecological and geological investigation of the fossil forests and their surroundings, and for identification and research on the fossil wood in order to better elucidate the history of this region. The purpose of this study is to enrich our understanding of the diversity of this unique flora while making a contribution
to a correct interpretation of the history of this area by identifying wood from trees which are in situ. A location was chosen on which extensive research has already been done in order to maximize the ability of this study to integrate with the work being done by others.
The study area is located along the north fork of Specimen Creek in the northwest corner of Yellowstone National Park (fig. 2, 3, 4). This location has been designated the Gallatin Fossil Forest and is so labeled on the USGS Crown Butte, Mont. Quadrangle.

In an earlier study Ritland (1968) assigned numbers to levels in three areas of Gallatin Fossil Forest. This study dealt only with Ritland's site 1-b. The levels designated by Ritland for this site were subsequently modified by DeBord (1977) such that the units were numbered downward beginning with top of the Daly Creek member of the Sepulcher formation (Smedes and Prostka 1972). Thus level 1 of DeBord (and of this paper) corresponds with level 25 of Ritland. Because of the subjective nature of level definition, correspondence cannot be ensured between the two systems over the entire measured section but rough proportionality obtains.

Attention was concentrated on horizontal and vertical trees in three different levels, units 1, 5 and 9 of DeBord (1977) (fig. 5). These were chosen specifically because they were among the levels for which detailed palynological information was available, and also because, based upon initial field identification, they included three unique assemblages - namely,

Unit 1 - mixed coniferous - deciduous
Unit 5 - deciduous
Unit 9 - coniferous.
Figure 2

Map: Fossils Forest of Yellowstone National Park and vicinity
Figure 3

Map: Specimen Creek area Gallatin Range
Figure 4

Illustrated outcrop of studied site showing fossil woods on each unit
The Fortress Mountain member

The Daly Creek member

UNIT 1

UNIT 5

UNIT 9
SAMPLE COLLECTION

In the summer of 1977 samples were collected from 123 trees in these levels. Each sample was numbered and a description of the location and morphology of the source tree was recorded. Because the study area is within the boundaries of a national park and is an irreplaceable resource, great care was exercised in collecting samples. In accord with a permit issued by the National Park Service, small portions of wood were taken from the outer portions of intact trees, where possible without disfiguring the remaining stump. This was usually possible since many trees are fragmented already and only about one cubic centimeter was needed for these studies.

LABORATORY WORK

Thin sectioning - Samples were cut along radial, tangential and transverse surfaces and ground to planarity using a series of silicon carbide grits from 220 to 800 mesh. Planar surfaces were mounted to previously ground petrographic slides using "Section-loc" epoxy cement. Specimens were then cut and ground to approximately 50µ on a Microtec II Microsectioneer thin sectioning machine. Cover glasses were glued in place with epoxy.

Modern wood sections were compared with fossil woods as an aid in final assignment of genera. No attempts were made in this present study to assign wood to specific categories. Future publications will take up this work.

**PALEOECOLOGY**

Results of this study were compared with modern climatic ranges for identified genera. Assignments of such ranges to identified genera were based upon the work of others and are subject to the shortcomings of attempting to apply present conditions to the past. Using the generic level rather than the specific should make this assignment somewhat more meaningful.

Palynological data for specific sites in units 1, 5 and 9 were derived from DeBord (1977). Additional information was acquired by reference to slides prepared by DeBord but not used in his thesis. These data are noted only in the discussion section.
RESULTS AND DISCUSSION

A systematic list of the fossil woods indentified in this study and their modern climatic ranges is given in table 1.

Fossil woods were identified into 3 families (9 genera) in Gymnospermae and 13 families (15 genera) in Angiospermae, a total of 16 families (24 genera).

Of the 16 families and 24 genera, the following have already been described from the Eocene Fossil Forests of Yellowstone National Park.

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<td>TAXODIACEAE</td>
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<td>Wheeler et al. 1977.</td>
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### TABLE I

Summary of woods identified from Specimen Creek area of the Gallatin Petrified Forest, Yellowstone National Park, Montana

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<td>2(1)</td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>21(9)</td>
<td>69(37)</td>
<td>29(20)</td>
<td>119(66)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

( ) : Upright Trunks  
T: Tropical  
S: Subtropical  
W: Warm Temperate  
M: Temperate  
C: Cool Temperate  
B: Boreal
Fagus

Beyer 1954.

Nyssa

Wheeler et al. 1978.

Platanus

Beyer 1954.

Among those families previously described on the basis of fossil wood, the following were not identified in this study:

CUPRESSACEAE
Read 1933, Beyer 1954.

ANACARDIACEAE
Wheeler et al. 1977.

ARALIACEAE
Fritz 1977.

JUGLANDACEAE
Wheeler et al. 1976.

LEGUMINOSAE
Wheeler et al. 1976.

MORACEAE
Fritz 1977.

MYRICACEAE
Wheeler et al. 1976.

RHAMNACEAE
Knowlton 1899.

ROSACEAE
Wheeler et al. 1976.

ULMACEAE
Wheeler et al. 1976.

Of the commonest fossil woods from Yellowstone National Park, Abies, Thuja, Platanus, Quercus, Rhus, and Ulmus were not identified in this study. These data suggest that there is yet a rich flora to be uncovered from these deposits using wood taxonomy.

Of the 119 stumps and logs exposed on studied units, 44.5% were in a horizontal position (table 2). A similar percentage has been observed by other authors (Fritz 1979). Of the 21 stumps and logs exposed on Unit 1, 57.1% were in a horizontal position; of the 69 stumps and logs on Unit 5, 46.4% were horizontal and of 29 stumps and logs on Unit 9, 31.0% were horizontal. There is an unusually high percentage of upright stumps on Unit 9, a unit which is unique in several respects.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Wood</th>
<th>Gymnosperms</th>
<th>Angiosperms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
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<td>Horizontal</td>
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<td>4(33.3)</td>
<td>12(100.0)</td>
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<tr>
<td>Unit 1</td>
<td>Upright</td>
<td>6(66.7)</td>
<td>3(33.3)</td>
<td>9(100.0)</td>
</tr>
<tr>
<td></td>
<td>Upright &amp; Horizontal</td>
<td>14(66.7)</td>
<td>7(33.3)</td>
<td>21(100.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Horizontal</td>
<td>19(59.4)</td>
<td>13(40.6)</td>
<td>32(100.0)</td>
</tr>
<tr>
<td>Unit 5</td>
<td>Upright</td>
<td>9(24.3)</td>
<td>28(75.7)</td>
<td>37(100.0)</td>
</tr>
<tr>
<td></td>
<td>Upright &amp; Horizontal</td>
<td>28(40.6)</td>
<td>41(59.4)</td>
<td>69(100.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Horizontal</td>
<td>9(100.0)</td>
<td>0( 0.0)</td>
<td>9(100.0)</td>
</tr>
<tr>
<td>Unit 9</td>
<td>Upright</td>
<td>19(95.0)</td>
<td>1( 5.0)</td>
<td>20(100.0)</td>
</tr>
<tr>
<td></td>
<td>Upright &amp; Horizontal</td>
<td>28(96.6)</td>
<td>1( 3.4)</td>
<td>29(100.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Horizontal</td>
<td>36(67.9)</td>
<td>17(32.1)</td>
<td>53(100.0) (44.5)</td>
</tr>
<tr>
<td>Total</td>
<td>Upright</td>
<td>34(51.5)</td>
<td>32(48.5)</td>
<td>66(100.0) (55.5)</td>
</tr>
<tr>
<td></td>
<td>Upright &amp; Horizontal</td>
<td>70(58.8)</td>
<td>49(41.2)</td>
<td>119(100.0) (100.0)</td>
</tr>
</tbody>
</table>
Of the Gymnospermous woods, Pinus and Picea (PINACEAE) were dominant. Nine of 19 specimens in Pinus and 10 of 17 Picea were upright, those genera being concentrated in Unit 9. The third most common wood was Sequoia (TAXODIACEAE), 13 specimens, in good agreement with previous studies on the coniferous woods of Yellowstone (Knowlton 1899, Read 1933, Beyer 1954, Fritz 1977), but only 4 of these were upright, two specimens on each of Units 1 and 5. The discovery of the wood of Keteleeria (PINACEAE) permits the first report of this fossil wood from North America. The distribution of extant Keteleeria is in central China to Southern Asia. Fossil wood of this genus has been reported from Tertiary strata in China, Formosa, Japan and Germany (Hayata 1933, Watari 1956). Only one specimen of Podocarpus (PODOCARPACEAE) was found. This is only the second record of this genus from North America, the previous report (Fritz, 1977) also being from Yellowstone. Larix and Tsuga (PINACEAE) Glyptostrobus and Taxodium (TAXODIACEAE) were the first records of these fossil woods from Yellowstone although their fossil pollen has been reported by Fisk (1976) and DeBord (1977).

The most significant feature of the angiospermous woods is their concentration in Unit 5 (83.7%) and their absence from Unit 9 which had only one angiosperm in 29 specimens. Betula, Cornus, Diospyros, Fagus, Liquidambar, Liriodendron, Nyssa, Fraxinus and Platanus were collected only from Unit 5. Liquidambar was the most abundant, but no megafossils or microfossils have been reported for this genus. The diversity of this unit is truly unique. Most genera are represented by only 1 or 2 upright trunks, and usually a single genus represents an entire family.
Unit 5 contains 37 upright trees of 19 genera, a diversity only approached in modern tropical rain forests. However, an examination of the genera present is perplexing (table 1). Only two genera represented have fully tropical modern representatives. Most are warm temperate and temperate genera and at least one genus, present as a horizontal trunk, is cool temperate.

In contrast with this picture is the starkness of Unit 9 in which 20 upright stumps represent only 4 genera, all of which are considered temperate and cool temperate genera.

Unit 1, which contains a greater variety of gymnospermous tree types than either Units 5 or 9, does not fit with single climatic range, having a number of both subtropical and cool temperate genera. Further perplexity is entertained by the presence of the tropical angiospermous genus Magnolia (a horizontal 7.5 cm diameter trunk), and the cool temperate angiospermous genus Aesculus.

Table 3 and figure 5 consider the climatic range of each unit based upon both upright and horizontal wood. Considering first the date for upright trees, it is clear that Unit 1 has a diversity of climatic types with peaks in warm temperate and cool temperate regions. Unit 5 contains genera with ranges mostly subtropical to temperate, very much in accord with the climatic condition Dorf has proposed for middle Eocene. However, the diversity of the flora exceeds that one would expect even in a subtropical area. Unit 9 peaks in the cool temperate climatic range, in sharp contrast with the results from Unit 5.

All angiospermous genera identified in this report have been recorded from the Tertiary of North America but almost half of those reported have
TABLE 3

CLIMATIC RANGES 1
Number of Specimens and Percentages in each Unit for Upright and Horizontal Trunks.

<table>
<thead>
<tr>
<th></th>
<th>Tropical</th>
<th>Sub Tropical</th>
<th>Warm Temperate</th>
<th>Temperate</th>
<th>Cool Temperate</th>
<th>Boreal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>1(2.0)</td>
<td>5(9.8)</td>
<td>15(29.4)</td>
<td>9(17.6)</td>
<td>14(27.5)</td>
<td>7(13.7)</td>
</tr>
<tr>
<td>Unit 5</td>
<td>2(1.0)</td>
<td>43(20.5)</td>
<td>67(31.9)</td>
<td>49(23.3)</td>
<td>35(16.7)</td>
<td>14(6.7)</td>
</tr>
<tr>
<td>Unit 9</td>
<td>0(0.0)</td>
<td>0(0.0)</td>
<td>12(15.2)</td>
<td>11(13.9)</td>
<td>28(35.4)</td>
<td>28(35.4)</td>
</tr>
<tr>
<td>Total</td>
<td>3(0.9)</td>
<td>49(14.5)</td>
<td>94(27.7)</td>
<td>68(20.1)</td>
<td>76(22.4)</td>
<td>49(14.5)</td>
</tr>
</tbody>
</table>

CLIMATIC RANGES 2
Number of Specimens and Percentages in each Unit for Upright Trunks only.

<table>
<thead>
<tr>
<th></th>
<th>Tropical</th>
<th>Sub Tropical</th>
<th>Warm Temperate</th>
<th>Temperate</th>
<th>Cool Temperate</th>
<th>Boreal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>0(0.0)</td>
<td>1(5.6)</td>
<td>6(33.3)</td>
<td>3(16.7)</td>
<td>6(33.3)</td>
<td>2(11.1)</td>
</tr>
<tr>
<td>Unit 5</td>
<td>2(1.8)</td>
<td>28(24.8)</td>
<td>35(31.0)</td>
<td>28(24.8)</td>
<td>15(13.5)</td>
<td>5(4.4)</td>
</tr>
<tr>
<td>Unit 9</td>
<td>0(0.0)</td>
<td>0(0.0)</td>
<td>9(15.5)</td>
<td>9(15.5)</td>
<td>20(34.5)</td>
<td>20(34.5)</td>
</tr>
<tr>
<td>Total</td>
<td>2(1.1)</td>
<td>30(16.0)</td>
<td>50(26.6)</td>
<td>39(20.7)</td>
<td>40(21.3)</td>
<td>27(14.4)</td>
</tr>
</tbody>
</table>
Figure 5

Graphs of Climatic Ranges (cf. Table 3). Ordinate registers percentage of trees from respective units which occur presently predominately in tropical (T), subtropical (S), warm temperate (W) temperate (M) cool temperate (C) or Boreal (B) climatic zones.
Figure 5

CLIMATIC RANGES 1 (Upright and Horizontal Trunks)

%  

<table>
<thead>
<tr>
<th></th>
<th>Unit 1</th>
<th>Unit 5</th>
<th>Unit 9</th>
<th>Total</th>
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<tr>
<td>T</td>
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<td></td>
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</tr>
<tr>
<td>S</td>
<td></td>
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<tr>
<td>M</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

CLIMATIC RANGES 2 (Upright Trunks only)

%  

<table>
<thead>
<tr>
<th></th>
<th>Unit 1</th>
<th>Unit 5</th>
<th>Unit 9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
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<tr>
<td>B</td>
<td></td>
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</tr>
</tbody>
</table>
not previously been identified on the basis of any fossils from the Yellowstone flora.

Pollen - Tree Comparisons

Webb (1974) details at length the relationship which exists between the pollen spectrum of soil from a given position in a forest and the surrounding trees. With few exceptions the pollen at the base of a tree should be predominantly pollen from that tree. DeBord (1977) has discussed the discordant pollen percentage values relative to tree importance values for units 5 and 9 on a gross level. With identification of these trees to the genus level now complete, we can make use of his data in an attempt to further evaluate the discrepancies he cites.

Unit 1 (fig. 6, 7) contains two angiospermous trees - one Acer and one Aesculus. Yet no Aesculus pollen was found in any samples from unit 1. Acer was represented by only six grains. Taxodiaceous pollen is exceptionally high in most samples from this unit, not surprisingly since three large taxodiaceous trees are present. But the absence of pollen from a 1.3 m diameter Larix and a .7 m Tsuga in the same unit is difficult to understand. Also a .5 m Picea was represented by less than .5% of the total pollen present.

Unit 5 (fig. 8, 9, 10) contained 28 upright stumps of angiospermous trees. Seven of these were Liquidambar. No pollen of Liquidambar has yet been described from the Yellowstone Fossil Forests and a careful examination of numerous slides from samples taken at the bases of these trees reveals none to be present. Sample 5Z was one of the best preserved from the entire suite of slides processed by DeBord. Taken at the base of a 15 cm Liriodendron, it revealed no pollen from this tree, nor from nearby Liquid-
Figure 6  Detailed representation of Unit 1 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
<table>
<thead>
<tr>
<th>Spore Type</th>
<th>Taxodiaceous</th>
<th>Pinus</th>
<th>Abies</th>
<th>Picea</th>
<th>Cedrus</th>
<th>Thuja</th>
<th>Juniperus</th>
<th>Salix</th>
<th>Alnus</th>
<th>Acer</th>
<th>Ulmus</th>
<th>Tsuga</th>
<th>Carvus</th>
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<td>4</td>
<td>7</td>
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</table>

[Diagram of a map with coordinates and species labels]
Figure 7  Detailed representation of Unit 1 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
<table>
<thead>
<tr>
<th></th>
<th>1D</th>
<th>1R</th>
<th>1Q</th>
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<td>Taxodiaceous</td>
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<td>Abies</td>
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<td>1</td>
<td></td>
</tr>
<tr>
<td>Podocarpus</td>
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</tr>
<tr>
<td>Taxus</td>
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<td>Thuja:Juniperus</td>
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<td>Cedrus</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>Alnus</td>
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<td>4</td>
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<tr>
<td>Caryya</td>
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<tr>
<td>Acer</td>
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<tr>
<td>Rhus</td>
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</tbody>
</table>
ambar. Instead, the predominant angiospermous pollen type was *Alnus*, represented by no upright stumps on this level.

Sample 5R was taken at the base of a 15 cm *Diospyros* surrounded by a *Fraxinus*, *Glyptostrobus*, *Sequoia*, *Umbellularia* and a 1.3 m diameter *Taxodium*. It would not be surprising to find taxodiaceous pollen (*Sequoia* and *Taxodium*) prevalent. However, considering the size and proximity of the *Taxodium*, taxodiaceous pollen is relatively low (37%) and none of the other trees present are represented by a single grain.

Sample 5H is 3 meters closer to the large *Taxodium* than is sample 5R. This sample clearly reflects the proximity to that tree, having nearly two grains in three of taxodiaceous pollen.

Sample 5K is surrounded by the following genera: *Betula*, *Liquidambar*, *Acer*, *Salix* and 1.5 m diameter *Podocarpus*. This sample would be expected to have abundant *Podocarpus* pollen. None were found. The expected increase in *Salix* pollen was observed, but the *Salix* stump was only 4 cm in diameter, hardly large enough to have been responsible for the observed pollen! No *Betula* and no *Acer* pollen was observed. Sample 5M taken 1.6 m closer to the large *Podocarpus* still revealed no *Podocarpus* pollen. Sample 5E, taken 1.6 m east of the same stump contained a larger proportion of bisaccate grains, a few of which were *Podocarpus*-like but *Podocarpus* was represented by less than 1% of the total sample.

Samples 5G and 5I occur between two small *Liquidambar* stumps. 5G is 6.5 m east of the *Podocarpus* and 5I is 10 m west of a large 1.7 m *Taxodium*. Sample 5I had the lowest level of taxodiaceous pollen in the entire unit. Sample 5G, like 5M and 5E severely underrepresents
Figure 8  Detailed representation of Unit 5 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
Figure 9  Detailed representation of Unit 5 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
Figure 10  Detailed representation of Unit 5 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
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the bisaccate component required by its close proximity to Podocarpus.

In summary, Unit 5 demonstrates serious and chronic lack of the correlation which would be expected between pollen type and tree type were the forest and soil level preserved in situ.

Unit 9 (fig. 11, 12, 13) contains entirely Pinus and Picea in the region from which sample data are available. The largest tree exposed on this level has a diameter of 1 meter, but most of the trees exceed 15 cm and were probably reproductively mature. However, in no sample is bisaccate pollen adequately represented. In fact, the average bisaccate component is lower in this level than either the average for five levels studied by DeBord, or Unit 5, which contained only two upright Pinaceae. A single Alnus 47 m from the nearest sample can hardly be responsible for flooding out the pollen of twenty coniferous trees to the extent observed. In addition, Picea pollen, while not tallied independently by DeBord, is severely underrepresented among the bisaccate coniferous pollen.

The overall lack of correlation between tree types and pollen spectra of adjacent organic zones does not lend weight to the burial model. It is difficult to understand the lack of correlation for individual trees but even more of a problem formulating an explanation when an entire unit fails to exhibit even a semblance of homology between mega- and microfossils.

A similar lack of correlation is seen when climatic ranges of the upright trees are analyzed. As already noted, the serious discrepancies between climatic ranges exist within a given level (Unit 1) as well as between different levels (Units 5 and 9).
Figure 11  Detailed representation of Unit 9 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
Figure 12  Detailed representation of Unit 9 showing the position of wood in relation to samples for pollen analysis. Inset table gives data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
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Figure 13  Detailed representation of Unit 9 showing the position of wood in relation to samples for pollen analysis. Inset table give data from pollen analysis by DeBord (1977) for each sample. Numbers are absolute counts.
Such discrepancies encourage the investigation of alternative models to explain the presence of these unique fossil assemblages.

Fisk (1976b) has suggested the following:

"Rapid sedimentation on a freshwater deltaic plain, many or most of the mud flows being deposited subaqueously, can possibly explain both of the perplexing features... (i.e. heterogenous mixture of plants from different climates and absence of animal fossils)."

Fritz (1976) has allowed for several alternatives none of which appears to be entirely satisfactory, but he suggests "the idea of allochthonous logs and stumps should be further tested."

Arct (1979) has established in levels lower in the section than those studied here, a dendrochronological signature which appears to be present on several different levels. Such a finding, if substantiated over a greater vertical distance, would seemingly require a model in which wood and stumps, perhaps from a variety of habitats, were transported and deposited in their present positions. Such a thesis has wide-reaching consequences for paleoclimatology as well as for interpretations of the geological history of this area.
The data obtained from analysis of the wood from selected levels of the fossil tree locality at specimen creek has enabled us to add significantly to the taxonomic information available from these deposits. In addition to this extension of information on the diversity of the flora, we have reached the following conclusions:

1) The individual levels represent an uncommon admixture of tree types, including trees from diverse climatic zones as they grow presently.

2) There is a general lack of correlation between the tree types and the associated pollen types throughout the assemblage. Such correlation would most certainly be expected were the tree - organic zone association a true growth environment.

3) There is an unexpected change in abundances and in species compositions from one layer to the next which can hardly be explained by the present scenario for formation of these deposits.

This data and other data available at present encourage a rethinking of the traditional model for origin of these fossil trees, with serious consideration being given to a model which encompasses the broader base provided by this data. Such a model would have to allow for the transporting and burial of upright as well as horizontal logs and stumps from widely differing but not necessarily distant climate zones.
SYSTEMATIC DESCRIPTION

GYMNOSPERMAE

PINACEAE

Keteleeria Carriere

Keteleeria Sp.

Specimens: SC1B-01016, 05013, 05023, 05029, 05031

TRANSVERSE: Growth ring fairly distinct; ring boundary delineated by a band of darkened late wood; false rings present in part. Ring breadth extremely variable, ranging from 0.28 to 8.4mm; transition from early to late wood abrupt; bands of early wood average 50 cells, 4 times wider than the bands of late wood (average 12 cells), although in some specimens the early and late bands may be subequal. Longitudinal parenchyma diffuse, occurring in tangential lines in some parts; average tangential diameter, 12 x 9µ. Horizontal wall nodules present. Early wood tracheids tangential, radial diameter 40 x 70µ; 3µ wall thickness. Late wood tracheids 40 x 40µ. Longitudinal resin canals abundant, surrounded by 12-15 thick walled epithelial cells.

RADIAL: Longitudinal parenchyma averaging 200µ in length. Early wood tracheids .85mm to 7.2mm in length; radial wall pits present in 1-2 rows, bordered, circular, opposite when in 2 rows; pit diameter 23µ. Late wood tracheids average 4.4mm in length; radial wall pits uniseriate, bordered, circular, 13µ in average diameter. Crossfield pits circular, bordered, mostly taxodioid type, 1-2 pits per crossfield, average diameter 15-16µ.

TANGENTIAL: Rays homogeneous, without ray tracheids, uniseriate, occasionally biseriate in part. Average cell 25 x 26µ in tangential and vertical diameter, height averages 10 cells (200µ) up to 28 cells; horizontal resin canals absent; horizontal wall well pitted; horizontal wall nodules present; gum inclusions present in some cells.
DISCUSSION: The combination of features present in this fossil wood, that is, presence of vertical resin canals alone in the normal wood (no horizontal resin canals) and absence of ray tracheids, is characteristic of *Keteleeria* (Phillips 1940 p. 292, Jane 1970 p. 331, Watari 1956 p. 431). In general the mesozoic fossil woods which have the above characteristics were named *Pinoxyylon* or *Protopiceoxylon* (Knowlton 1900, Read 1932, Bailey 1933, Shimakura 1937, Gothan 1908, 1910), but Watari (1956 p. 434, 435) transferred *Pinoxyylon mabetiense* from the Miocene of Iwate Prefecture, Japan to *Keteleeria* since all important features of *Pinoxyylon* seem to fall into the range of structural variability represented by *Keteleeria*. Greguss (1954 in Watari 1956 p. 435) reported a doubtful example *Keteleeria (?)* SP from the Miocene of Hungary. This is the first fossil wood of *Keteleeria* from the Eocene of the Yellowstone National Park.

*Larix* Miller.

SPECIMENS: SC1B-01007, 01010, 09019, 09021

TRANSVERSE: Growth rings distinct, delineated by a band of darkened late wood, breadth variable, 3.4-7.2mm. Transition from early to late wood gradual or abrupt. Longitudinal parenchyma diffuse, tangential and radial diameters average 40 x 40µ surrounding longitudinal resin canals in part. Resin canals occluded with dark substances. Tracheids average 40 x 20µ in tangential and radial diameter with 5µ wall thickness in late wood. Longitudinal resin canals abundant, in pairs or larger groups with thick walled epithelial cells, occasionally with tylosoids.

RADIAL: Bordered pits on radial walls of the tracheids in uniseriate or partially biseriate rows, circular, average 15µ in diameter, opposite when in biseriate. Average length of early wood tracheids 780µ, of
longitudinal parenchyma 200µ. Crossfield pits circular, bordered, piciform or taxodioid, 2 - 4 pits per crossfield.

TANGENTIAL: Rays uniseriate or fusiform, ray tracheids with dentated walls. Uniseriate rays up to 20 cells and 260µ in height, average 11 cells, 100µ high. Fusiform rays abundant; horizontal resin canals present, average 60µ in diameter, surrounded by 8 - 12 thick epithelial cells. Total fusiform rays height averages 420µ; width, 80µ; horizontal walls nodular, well pitted.

DISCUSSION: The combination of features present in this fossil wood, that is the presence of longitudinal parenchyma, abundant horizontal and vertical resin canals with thick walled epithelial cells, piciform pittings in the crossfield, ray tracheids with dentated wall and nodules, is characteristic of Larix. Another significant feature which indicates Larix is the number of epithelial cells surrounding a horizontal resin canal: up to 12 or more cells (Watari 1956). Fisk (1976) reported the fossil pollen of Larix from the Fossil Forest flora. No fossil wood of this genus has been reported up to this time.

Pinus L.

Pinus sp.

SPECIMENS: SC1B-01008, 01019, 05043, 09002 09007, 09008, 09009, 09010, 09011, 09013, 09016, 09017

TRANSVERSE: Growth ring fairly distinct to distinct; ring boundary delineated by dark, flattened, thick walled late wood cells; transition from early to late wood abrupt to somewhat gradual; ring breadth variable 0.12 to 7.2mm, average 2.5mm; bands of early wood average 1.5 times wider than the bands of late wood. Longitudinal parenchyma
generally absent, but when present, averages 170µ in length, 40 x 40µ in tangential and radial diameters. Tracheids average 45 x 45µ in tangential and radial diameters in early wood, 44 x 23µ in late wood; wall thickness averaging 5µ in early wood, 9µ in late wood. Longitudinal resin canals abundant, normal, with 6-9 thin-walled epithelial cells.

RADIAL: Tracheids averaging 1.25mm to 1.9mm in length; pits on radial walls bordered, circular in outline, average diameter 20µ; in uniseriate or biseriate array; opposite or lateral in part when biseriate; average diameter 10µ in late wood. Pits on tangential wall bordered, average diameter 20µ in early wood; crossfield pits circular, bordered, mostly taxodioid or cupressoid or pinoid type in part, 1-4 pits per crossfield, average diameter 20µ.

TANGENTIAL: Rays uniseriate or fusiform, both with ray tracheids, heterogeneous; height up to (27 cells) 720µ, average (12 cells) 240µ; ray tracheids 35 x 35µ in tangential and vertical diameter. Horizontal wall nodules present; dentition present; horizontal wall thin, smooth, nodular in part. Horizontal resin canals abundant within fusiform rays, mostly large, hollow with 7-8 thin walled epithelial cells, average 50µ in diameter, maximum width 82µ; fusiform ray height average 450µ; wall thickness of epithelial cells average 5µ; dark gum inclusions present.

DISCUSSION: The combination of features present in this fossil wood, that is longitudinal parenchyma absent, horizontal and vertical resin canals abundant, fusiform rays with large resin ducts surrounded by several thin walled epithelial cells, ray tracheids with end wall nodular or dentated, bordered taxodioid or pinoid type pits in the
crossfield, is characteristic of Pinus (PINACEAE).

Pinus or a similar genus has been recorded in many reports from the Fossil Forest flora: Pityoxylon aldersoni and P. amethystinum (Knowlton 1899), Pinus sp. (Conard 1930), Pinus baumai and P. fallax (Read 1933), Pinus pseudotsugoides and P. fallax (Beyer 1954), and Pinus sp. (Fritz 1977). The fossil pollen of Pinus has also been reported from this area (Fisk 1976, DeBord 1977).

**Picea Dietrich.**

*Picea* sp.

**SPECIMENS:** SC1B-01009, 01014, 09001, 09003, 09004, 09005, 09006, 09012, 09015, 09018, 09020, 09022, 09024, 09025, 09026, 09028, 09029

**TRANSVERSE:** Growth rings distinct; ring boundary delineated by flattened thick walled late wood cells; ring breadth 2.0 - 3.4mm; transition from early to late wood generally gradual; abrupt in some rings. Longitudinal parenchyma mostly absent, diffuse when present. Early wood tracheids average 40 x 62µ in tangential and radial diameters; late wood tracheids averaging 35 x 25µ; average wall thickness 4µ in early wood, 6µ in late wood. Longitudinal resin canals abundant; 8-9 thick walled epithelial cells present; average diameter 200µ incluse gum and tylose present, rectangular or rhombic crystals.

**RADIAL:** Tracheids average 1.4mm to 4.2mm in length; pits on radial wall bordered, circular in outline, 30µ in diameter, uniseriate or biseriate in part, opposite or lateral when biseriate; crossfield pits occur mostly as narrow, elliptically bordered piciform type, oval bordered cupressoid type in part, 1-5 mostly 2,3 pits per crossfield, averaging 11µ in diameter.
TANGENTIAL: Rays uniseriate or fusiform, both with ray tracheids; heterogeneous, average height (11 cells) 220µ to (40 cells) 750µ; average diameter 20 x 18µ, tangential and vertical; horizontal wall well pitted, dentition present, gummy inclusions present. Horizontal resin canals abundant within fusiform rays, surrounded by 5-9 thick walled epithelial cells, average diameter 60µ. Total fusiform ray height (average 8-9 cells) 500µ.

DISCUSSION: The combination of features present in this fossil wood, that is, the presence of horizontal and vertical resin canals, thick walled epithelial cells, piciform type bordered pits in crossfield, is characteristic of Larix, Picea and Pseudotsuga. However, Pseudotsuga differs from this fossil wood in having consistent spiral thickening of vertical as well as ray tracheids, at least in the early wood. In further differentiating the woods of Larix and Picea, there are some difficulties. It is generally recognized that the transition from the early to the late wood is abrupt in Larix and gradual in Picea. Watari (1956) reported the number of epithelial cells surrounding a horizontal resin canal is useful for distinguishing the woods of Larix, Picea and Pseudotsuga that is, 5-7 cells in Pseudotsuga, 7-9 in Picea and up to 12 or more in Larix. An assortment of these features indicate this fossil wood to be more similar to Picea. Beyer (1954) and Dorf (1960) reported Picea-like fossil woods from the Eocene of Yellowstone National Park, specifically Piceoxylon larinoides. Recently Fritz (1977) reported fossil woods of Picea sp. from Amethyst mountain. Fossil pollen of Picea from the same locality was reported by Fisk (1976).
Tsuga sp.

SPECIMENS: SC18-01002, 01015, 05033, 05060

TRANSVERSE: Growth ring distinct, ring boundary delineated by the presence of a narrow zone of flattened elements on the outer margin of the ring; ring breadth constant, average 3.2mm; transition from early to late wood abrupt; bands of early wood averaging 12 cells, 3 times wider than the bands of late wood (average 4 cells). Longitudinal parenchyma abundant; diffuse, average diameter 50 x 60µ tangential and radial; horizontal wall pitted. Early wood tracheids average 200µ x 280µ tangential and radial; 8µ average wall thickness. Late wood tracheids diameters averaging 130 x 80µ tangential and radial; 10µ average wall thickness. Longitudinal resin canals absent.

RADIAL: Longitudinal parenchyma strands present. Tracheid pits on radial wall bordered, circular in outline, 30µ diameter; uniseriate or biseriate in part, opposite and contiguous when in biseriate; crassulae present in part; crossfield pits circular or ovoid, bordered, mostly taxodioid, cupressoid in part, 3-4 pits per crossfield, averaging 12µ in diameter; tangential wall pits present.

TANGENTIAL: Rays uniseriate, with ray parenchyma and ray tracheids, heterogeneous, height up to 15 cells, averaging 10 cells 300µ; horizontal wall well pitted; end wall nodules present; indentures present in part; ray parenchyma average diameter 25 x 20µ tangential and vertical. Horizontal resin canals absent.

DISCUSSION: The combination of features present in this fossil wood, that is, absence of vertical and horizontal resin canals, presence of
ray tracheids, taxodioid to cupressoid crossfield pitting, is characteristic of Cedrus and Tsuga. [Neither of these genera have been reported yet, but fossil pollen has been reported by Fisk (1976) and DeBord (1977) from Eocene of Yellowstone National Park.]

According to Phillips (1941), however, Cedrus frequently has both normal and traumatic vertical resin canals. Watari (1956) noted that cupressoid type pitting in the crossfield is characteristic of Tsuga rather than Cedrus. From an assortment of these features, this fossil wood is identified with Tsuga. This is the first report of Tsuga based upon wood from the fossil tree localities in Yellowstone National Park.

PODOCARPACEAE

Podocarpus sp.

SPECIMEN: SC1B-05004

TRANSVERSE: Growth ring distinct, ring boundary delineated by the presence of flattened, thick walled tracheids; ring breadth variable, maximum 60mm, minimum 20mm, average 40mm wide; transition from early wood to late wood gradual. Longitudinal parenchyma abundant, 40 x 50µ diameter tangential and radial, filled with a dark substance; horizontal walls frequently pitted. Tracheids average 60 x 70µ tangential and radial in early wood, 40 x 50µ in late wood, wall thickness in late wood averaging 10µ, twice thicker than early wood. Longitudinal resin canals absent.

RADIAL: Parenchyma cells averaging 300µ in length. Strands present unpitted to tracheids; horizontal walls thin and smooth, nodules frequently present.
Tracheids averaging 1.3mm length in early and late wood; pits on radial walls bordered, circular in outline, 30µ in diameter with circular aperture, uniseriate or biseriate in part, opposite and crowded when biseriate; crassulae present in part; spiral thickenings absent; tangential wall pits rare, bordered, average 13µ in diameter; crossfield pits oval, bordered, mostly taxodioid or podocarpoid type, average 18µ in diameter, 3-4 pits per crossfield.

TANGENTIAL: Rays uniseriate, not fusiform; occasionally biseriate in part, average 33 cells (850µ) in height; gummed in part; horizontal wall smooth, thin, without pits; endwall nodules absent.

DISCUSSION: The combination of features present in this fossil wood, including: longitudinal parenchyma abundant, rays with thin and smooth horizontal wall, no ray tracheids, bordered oval taxodioid or podocarpoid type pits in the crossfield and no horizontal and vertical resin canals, is characteristic of *Podocarpus* (PODOCARPACEAE). *Podocarpus* has previously been reported from the fossil forest flora by Fisk (1976) and by DeBord (1977) on the basis of a few grains of fossil pollen and by Fritz (1977) on the basis of a single specimen of fossil wood.

**TAXODIACEAE**

Glyptostrobus sp.

SPECIMENS: SC1B-01018, 05019, 05062

TRANSVERSE: Growth ring distinct; ring boundary delineated by the flattened thick walled late wood cells, ring breadth average 1.0mm; transition from early to late wood gradual. Longitudinal parenchyma
abundant in tangential lines, average 25 x 18µ in tangential and radial diameter. Early wood tracheids average 60 x 100µ average 60 x 30µ tangential and radial, average 8µ wall thickness. Longitudinal resin canals absent.

RADIAL: Parenchyma cells averaging 185µ in length; horizontal wall smooth and thick. Pits on radial wall of tracheids circular in outline, with circular aperture 25µ in diameter; in uniseriate or partially biseriate arrays, opposite when biseriate; crossfield pits circular, bordered, mostly taxodioid type, 2-4 pits per crossfield, average 8µ in diameter.

TANGENTIAL: Rays uniseriate, homogeneous, without ray tracheids; average 16 cells (400µ), up to 25 cells (600µ) each 25 x 25µ. Indentures present, horizontal resin canals absent.

DISCUSSION: The combination of features present in this fossil wood, including abundant parenchyma, ray tracheids absent, resin ducts absent, mostly taxodioid pits in the crossfield and thick walled parenchyma in horizontal rays, is characteristic of Glyptostrobus, Sequoia and Taxodium, (TAXODIACEAE). These genera are difficult to separate, but Glyptostrobus can be differed by the presence of gradual early—late wood transition and the uncommon presence of opposite biseriate pits on radial walls in Sequoia and Taxodium. Fisk (1976) reported the doubtful fossil pollen of Glyptostrobus from the Yellowstone National Park but no fossil wood has yet been reported. This is the first fossil wood of Glyptostrobus from the Yellowstone National Park.

Sequoia Endlicher

Sequoia sp.
SPECIMENS: SCIB-01003, 01020, 01021, 05015, 05034, 05056, 05057, 05058, 05061, 05069, 09023

TRANSVERSE: Growth ring fairly distinct; ring boundary delineated by the flattened thick walled late wood; ring breadth variable 0.08 to 3.4mm average 0.4mm, false rings present in part; transition from early to late wood abrupt; bands of early wood 2 to 28 cells, 2-3 times wider than the band of late wood, 17 cells in early wood 24 cells in late wood in the same ring. Longitudinal parenchyma abundant, diffuse, 50 x 40µ in average tangential and radial diameter. Early wood tracheids average diameter 60 x 70µ, tangential and radial, average wall thickness 10µ. Late wood tracheids average diameter 40 x 30µ, tangential and radial, average wall thickness 10µ. Longitudinal resin canals absent.

RADIAL: Parenchyma, longitudinal dimension averaging 170µ, smooth walled, gum inclusions present. Tracheids, average length 1.75mm in early wood, 0.62mm in late wood; pits on early wood radial wall bordered, circular in outline, uniseriate or biseriate, opposite or lateral in part when biseriate, 30µ in average diameter; pits on late wood radial wall bordered, uniseriate, circular, 20µ in average diameter; crossfield pits circular, bordered, mostly taxodioid type, 2-3 pits per crossfield, average 15µ in diameter.

TANGENTIAL: Rays uniseriate, occasionally biseriate in part, homogeneous, without ray tracheids, averaging 11 cells (280µ) in height, up to 22 cells (550µ), cells averaging 20 x 20µ, tangential and vertical diameter; horizontal wall smooth.
DISCUSSION: The combination of significant features present in this fossil wood, that is, abundant parenchyma and tracheids, abrupt early-late wood transition, no horizontal or vertical resin ducts, opposite biseriate bordered pits on the radial walls, taxodioid pitting in the crossfield, no ray tracheids, horizontal ray walls thick but smooth with no indenture, is characteristic of Sequoia (TAXODIACEAE). The differences from Taxodium are described in the discussion of Taxodium. Sequoia is one of the most common fossil woods from the Fossil Forests (Knowlton 1899, Read 1933, Beyer 1954, Fritz 1977) and its fossil pollen is also reported in abundance (Fisk 1976, DeBord 1977).

Taxodium Richard.

SPECIMENS: SC18-01017, 05001, 05016

TRANSVERSE: Growth ring fairly distinct; ring boundary delineated by a band of darkened thick walled late wood cells; ring breadth variable, 0.9 to 4.4mm, average 2.5mm; transition from early to late wood abrupt; bands of early wood 11-48 cells, 1.5-3 times wider than the bands of late wood (4-35 cells). Longitudinal parenchyma abundant, diffuse or forming tangential lines in part; horizontal end walls nodular, averaging 45 x 25µ in tangential and radial diameter. Early wood tracheids average diameter 60 x 70µ tangential and radial; 8µ average wall thickness. Late wood tracheids average diameter 40 x 30µ, tangential and radial; 10µ average wall thickness. Longitudinal resin canal absent.

RADIAL: Parenchyma cells 100-350µ in length, average 200µ; horizontal wall smooth. Tracheid length up to 4.2mm, average 3.0mm in early wood, up to 2.0mm, average 1.5mm in late wood; pits on radial wall bordered in early and late wood, circular in outline, 30µ in diameter in early
wood 25µ in late wood. Pits uniseriate or biseriate, opposite or lateral in part when biseriate; uniseriate and circular in late wood; crossfield pits circular, bordered, mostly taxodioid type, cupressoid type in part, average 25µ in diameter, 1-4 pits per crossfield.

TANGENTIAL: Rays homogeneous, uniseriate, occasionally biseriate in part, averaging 13 cells (1.2mm) maximum 39 cells (3.2mm); average 120 x 120µ in tangential and vertical diameter. Horizontal resin canals absent. Indentures present in part.

DISCUSSION: The combination of features present in this fossil wood, that is, abundant parenchyma, abrupt early-late wood transition, no horizontal or vertical resin ducts, mostly opposite biseriate pits on radial wall, taxodioid pitting in the crossfield, no ray tracheids or thick walled horizontal ray cells, is characteristic of Sequoia and Taxodium (TAXODIACEAE). Abies (PINACEAE) and Glyptostrobus (TAXODIACEAE) are similar to Sequoia and Taxodium in many of the above characteristics, but they can be distinguished by the absence of abrupt early-late wood transition. On the other hand, it is very difficult to distinguish Sequoia from Taxodium. The fact that there are reports of fossil pollen of both genera (Fisk 1976) but fossil wood only of Sequoia (Knowlton 1899, Read 1933, Beyer 1954, Fritz 1977), emphasizes the difficulty attendant in distinguishing these fossil woods. The only significant feature which distinguishes the wood of Taxodium from Sequoia is the presence of nodules or indentures on the horizontal ray walls. Most Sequoia lack these nodules or indentures and have very smooth walls. (Phillips 1941, Greguss 1947, Panshin and de Zeeuw 1970). Fossil wood described here are separated by the features mentioned above and belong to Taxodium, the first report of this genus based upon wood from the Fossil Forest flora.
ANGIOSPERMAE
ACERACEAE
Acer L.

_Acer_ sp

SPECIMENS: SC1B - 01012, 05008, 05012, 05036, 05037, 05055

TRANSVERSE: Wood diffuse porous. Growth rings distinct, delineated by marginal parenchyma; ring breadth 5.6 to 6.8mm. Vessels solitary and in multiples of 2-6, solitary pores circular to oval in outline, 80 X 100 µ in tangential and radial diameter, wall thickness 10µ. Fiber tracheids 13µ in diameter, forming radial lines, 3µ wall thickness; spiral thickenings present in part. Parenchyma abundant, paratracheal (vasicentric) or marginal in part; spiral thickenings present; gum ducts present.

RADIAL: Vessel segments 400µ in length; perforation plates exclusively simple; intervessel pits mostly alternate, scalariform and linear in the ends of vessels; spiral thickenings present in the ends of vessels; thin walled tyloses abundant.

TANGENTIAL: Rays homogeneous; two types of rays-uniseriate, mostly 5 cells high (.2mm); multiseriate, fusiform, 35 cells high (1.8mm), up to 4 but average 3 cells wide (.1mm); procumbent cells 30 X 50µ in tangential and vertical diameter; pits into vessels same as intervessel pits; horizontal wall well pitted, end wall well pitted also; tyloses abundant.
DISCUSSION: The combination of features present in this fossil wood, that is, diffuse porous, multiple pore arrangement, spiral thickening on the walls of vessels, simple perforation, alternate intervessel pits with medium diameter (mostly between 5 and 12 µ), uniseriate and multiseriate rays with homogeneous cells, is characteristic of *Acer* (ACERACEAE) and *Tilia* (TILIACEAE). *Tilia* differs from the described fossil wood, however, in having fewer solitary pores, heterogeneous cells, narrow linear multiseriate rays 2 or 3 cells wide. On the other hand, these specimens have the following characteristics in common with *Acer*: Predominantly homogeneous cells, fusiform multiseriate rays 3-4 cells wide. Knowlton (1899) recorded *Acer vivarium* from the Eocene of Yellowstone National Park based upon fossil leaves. Eocene fossil pollen of *Acer* were reported by Fisk (1976) from the Amethyst Mtn. and DeBord (1977) from the Specimen Creek area of Yellowstone National Park. These specimens represent the first record of *Acer* sp. reported on the basis of wood from the Fossil Forests.

**BETULACEAE**

*Alnus* Ehrhart

*Alnus* sp

**SPECIMENS:** SC1B - 05064, 09027

**TRANSVERSE:** Wood diffuse porous. Growth ring distinct, delineated by a band of flattened thick-walled fibers; ring breadth variable, 2.2 mm to 4.0 mm, average 3.0 mm. Vessels mostly solitary, in multiples of 2-3
and nested in part; solitary pores circular 40-100µ in diameter; 3µ wall thickness. Fiber tracheids with bordered pits, 15µ in diameter, 5µ wall thickness forming radial lines. Parenchyma abundant, paratracheal (scanty) and apotracheal (diffuse); strands present.

RADIAL: Vessels with exclusively scalariform perforation plates, number of bars more than 20 (maximum), average 17; intervessel pits mostly opposite, with horizontally elongated pits, diameter 5µ in longer axis; gum ducts present.

TANGENTIAL: Rays homogeneous with procumbent cells only; two types of ray, uniseriate rays mostly 20 cells (400µ) in height dominate; occasional biseriate rays linear to narrow fusiform, average 16 cells (range 7 to 75) in height, average 4 cells (range 2 to 6) 60µ in width; aggregate rays consist of uniseriate and biseriate rays; procumbent cells 15 X 25µ in tangential and vertical diameter; pits into vessels chiefly round to oval, half-bordered; end walls well pitted.

DISCUSSION: An assortment of the following characteristics indicates that this fossil is a member of *Alnus*: diffuse porous wood, vessels solitary and multiples of 2-3, exclusively scalariform perforation plates with more than 20 bars, intervessel pits opposite; uniseriate, biseriate and aggregate rays with homogeneous cells. Fossil pollen of *Alnus* is reported from the Eocene of Yellowstone National Park (Fisk & DeBord, 1974). Recently fossil pollen (DeBord 1977) and fossil wood (W,S & B 1977) of *Alnus* have been reported from the same area where this fossil wood was collected.
Betula L.

Betula sp.

SPECIMENS: SC1B - 05011, 05047

TRANSVERSE: Wood diffuse porous. Growth rings distinct, delineated by a band of flattened thick walled fibers, ring breadth 3.4 to 4.8mm. Vessels solitary and in multiples of 2-3, solitary pores circular to oval 80 X 80µ to 60 X 100µ in tangential and radial diameter, wall thickness 1µ; bordered pits. Parenchyma abundant, paratracheal (scanty) and apotracheal (diffuse), marginal in part.

RADIAL: Vessels with exclusively scalariform perforation plate, number of bars more than 20, up to 26; intervessel pits mostly alternate, occasionally opposite, 5µ in diameter; gum ducts present.

TANGENTIAL: Rays, homogeneous; consisting entirely of erect cells; two types of ray-uniseriate and multiseriate; uniseriate rays rare, mostly 5-7 cells high; multiseriate (.3-.4mm) rays narrow, fusiform, up to 30 cells high (1.9mm) up to 4 cells wide (.1mm); erect cells average 25 X 63µ in tangential and vertical diameter; pits into vessels simple to bordered; end wall well pitted; gum ducts present.

DISCUSSION: The combination of features present in this fossil wood, that is, diffuse porous, wood pores solitary and in multiples of 2-3, perforation plate scalariform with more than 20 bars, intervessel pits
alternate, uniseriate and multiseriate rays with homogeneous cells, is characteristic of Alnus and Betula (Betulaceae). The most significant features differentiating Alnus and Betula are the paucity of uniseriate rays in Betula and abundance of aggregate rays in Alnus. The examined fossil wood has few uniseriate rays and no aggregate rays. Thus this specimen is assigned to Betula. The foliage of Betula was reported by Knowlton (1899) from the Fossil Forests of Yellowstone National Park. This is the first occurrence of Betula reported on the basis of wood from the Eocene Fossil Forests of Yellowstone National Park.

CORNACEAE

Cornus L.

SPECIMENS: SC1B-05021, 05024, 05028, 05039

TRANSVERSE: Wood diffuse porous. Growth rings distinct, delineated by a band of flattened thick walled fibers; ring breadth variable .2 to 2.2mm, average 1.0mm. Vessels mostly solitary, occasionally in multiples of 2; solitary pores circular to oval, 50 X 50µ to 40 X 70µ in tangential and radial diameter, wall thickness 1 to 8µ. Fiber tracheids forming radial rows; tracheids 15µ in wall thickness, with bordered pits on radial walls; parenchyma abundant, paratracheal, vasicentric in part.

RADIAL: Vessel segments average 500µ in length; perforation plate exclusively scalariform, with more than 20, up to 30 bars; intervessel pits mostly
scalariform, opposite and linear in part, small; pit diameter 3μ when opposite; tyloses present.

TANGENTIAL: Rays heterogeneous; two types - uniseriate consisting entirely of erect cells; multiseriate, long to moderately fusiform; height - 46 to 170 cells, 1.4 to 4.4mm, avg. 3.0mm; width - 4 to 10 cells avg. 6 cells, .06 to .5mm, avg. .09mm; procumbent cells 5 X 5μ in tangential and vertical diameter, 13 X 25μ in erect cells; pits into vessels simple to bordered; end walls well pitted.

DISCUSSION: The combination of features present in this fossil wood, that is, diffuse porous wood, vessels solitary, scalariform perforation with more than 20 bars, intervessel pits scalariform or opposite, with small pits, heterogeneous, two types of ray, 4-10 cells wide in multiseriate rays, is characteristic of Cornus (CORNACEAE). Holmes (1880) records fossil leaves of Cornus sp. Lesquereux from Amethyst Mt. Recently fossil pollen of Cornus was reported by Fisk (1976) also from Amethyst Mt. This is the first report of the wood of Cornus from the Fossil Forests of Yellowstone National Park.

EBENACEAE

Diospyros L.

Diospyros sp.

SPECIMENS: SC1B - 05063, 05068
TRANSVERSE: Wood mostly diffuse, semi-ring porous in part. Growth rings distinct, delineated by a narrow band of flattened, thick walled late wood; ring breadth 1.6 to 2.4mm. Vessels solitary or in multiples of 2-3 radially; solitary pores circular to oval in outline, 60µ X 100µ in tangential and radial diameter, 10µ wall thickness. Libriform fibers 8µ in diameter, 3µ wall thickness, form radial rows. Parenchyma abundant, mostly paratracheal vasicentric, aliform in part.

RADIAL: Vessels with exclusively simple perforation plate, intervessel pits alternate, mostly 5µ diameter, pit aperature circular, spiral thickenings absent.

TANGENTIAL: Rays heterogeneous with procumbent and erect cells; multisierate rays linear to narrow fusiform, average 27 cells, 500µ high; 3 cells, 40µ wide; procumbent cells round or polygonal in tangential section, 13 X 15µ in tangential and vertical diameter; erect cells 10 X 38µ; horizontal gum ducts present in part.

DISCUSSION: The combination of features exhibited by this fossil wood, that is, diffuse porous wood, vessels solitary or in multiples of 2-3, perforation plates simple, intervessel pits alternate, heterogeneous rays is characteristic of Acer (ACERACEAE), Diospyros (EBENACEAE), Pterocarya (JUGLANDACEAE) and Umbellularia (LAURACEAE). This fossil wood lacks the spiral thickenings of vessel walls, rather large intervessel pits, both libriform and tracheid fibers and wider fusiform rays that characterize Acer. Pterocarya is very similar to this fossil wood
but differs from it in having larger intervessel pits, and lacking libriform fibers and paratracheal vasicentric parenchyma. **Umbellularia** which like *Acer* exhibits spiral thickenings of vessels and larger intervessel pits further differs from this specimen by the presence of oil cells. Although this specimen lacks storied rays, the assortment of features seem to dictate that this fossil wood is a member of *Diospyros*. Both Knowlton (1899) and Dorf (1960) reported fossil leaves of *Diospyros*, *D. brachysepala* and *D. lamarensis* from the Fossil Forests. This is the first report of fossil wood for this genus from Eocene of Yellowstone National Park. Fossil pollen has not yet been reported. Only two specimens were noted.

**FAGACEAE**

*Fagus* L.

**Fagus** sp.

**SPECIMENS:** SCIB - 05032, 05066

**TRANSVERSE:** Wood diffuse porous. Growth rings distinct, delineated by narrow band of flattened elements; ring breadth 1.0 to 3.6 mm, average 2.0 mm. Vessels solitary, occasionally in multiples of 2-3, solitary pores oval in outline 55 X 70 µ in tangential and radial diameter, 5-8 µ in wall thickness. Fiber tracheids oval in outline 15 X 20 µ diameter, with 5-8 µ wall thickness, forming radial lines. Parenchyma abundant, marginal (paratracheal confluent) or apotracheal diffuse.

**RADIAL:** Vessels 400 - 620 µ in length; perforation plate almost exclusively
simple, occasionally scalariform, intervessel pits mostly alternate with bordered pits 5µ in diameter, linear on the end of vessels; spiral thickenings absent; thick walled tyloses present.

TANGENTIAL: Rays homogeneous with procumbent cells only; multiseriate with very variable height and width, height from 20 to 400 cells, avg. 120 cells, 3.2mm; width 2 to 30 cells avg. 14 cells, .2mm; procumbent cells circular or oval in part, 25 X 25µ or 20 X 30µ in tangential and vertical diameter; pits into vessels simple to bordered; gum ducts and tyloses present; horizontal wall well pitted.

DISCUSSION: The combination of features present in this fossil wood, that is, diffuse porous wood, simple vessel perforation plate, alternate intervessel pits, homogeneous multiseriate ray more than 10 cells in width, is characteristic of *Fagus* (FAGACEAE). Knowlton lists 2 species in *Fagus* from leaf compressions, *Fagus antipofii* Abick, and *Fagus undulata* Knowlton from the Yellowstone River area (in Bayer 1954). Bayer reports *Fagus grandiporosa* sp. nov. based on fossil wood from the slope of Specimen Ridge, in the Yellowstone National Park. Fisk (1976) reports pollen of Nothofagus, but no Fagus pollen has yet been observed.

**HAMAMELIDACEAE**

**Liquidambar L.**

**Liquidambar sp.**

**SPECIMEN:** SC1B - 05002, 05003, 05005, 05026, 05027, 05038, 05040
TRANSVERSE: Wood diffuse porous. Growth rings distinct, delineated by a narrow band of parenchyma and flattened thick walled fibers; ring breadth variable 0.8 to 8.0mm average 2.7mm. Vessels solitary, in multiples of 2 or 3 and in radial chains in part; solitary pores circular to oval in outline 70 X 93μ in tangential and radial diameter; 7μ in wall thickness. Fiber tracheids forming radial rows, 17μ in diameter, 6μ in wall thickness, with bordered pits. Parenchyma abundant, mostly paratracheal scanty, vasicentric and marginal, occasionally apotracheal diffuse parenchyma forms radial lines.

RADIAL: Vessel, perforation plate exclusively scalariform, with up to 38 bars, average 15; intervessel pits mostly opposite with pits 5μ in diameter, circular or rectangular when crowded, linear in the end part of vessels. Thick walled tyloses present.

TANGENTIAL: Rays heterogeneous with procumbent cells and erect cells; two types of ray-uniseriate rays consist of erect cells, average 12 cells high; multiseriate rays fusiform, up to 90 cells high (3.2mm), average 36 cells high (1.3mm); mostly width averages 4 cells (50μ) but occasionally up to 12 cells (100μ); procumbent cells 13 X 16μ in tangential and vertical diameter, 13 X 36μ in erect cells, occasionally 70μ in vertical diameter, pits into vessels bordered, 15μ in diameter; tangential wall well pitted; gum ducts abundant.

DISCUSSION: The combination of features present in this fossil wood, i.e. diffuse porous wood, multiple vessels, scalariform perforation plates, opposite intervessel pits and heterogeneous multiseriate rays,
is characteristic of Liquidambar (HAMAMELIDACEAE) and Liriodendron (MAGNOLIACEAE). The significant differences between Liquidambar and Liriodendron are seen in the arrangement of vessels in the transverse section, and in the type of rays and ray cells present. Liquidambar has multiple vessels and vessels in chain arrays. There are two types of ray, uniseriate and multiseriate, with erect ray cells only for uniseriate. In Liriodendron vessels do not occur as chains, and no uniseriate rays are present. From the described characteristics of the listed wood samples it can be readily demonstrated that these specimens belong to the genus Liquidambar. This is the first record of the wood of Liquidambar from the fossil forest of Yellowstone National Park.

HIPPOCASTANACEAE

Aesculus L.

Aesculus sp.

SPECIMEN: SC1B - 01004, 01006

TRANSVERSE: Wood diffuse porous. Growth rings distinct, delineated by a narrow band of flattened thick-walled late wood; ring breadth averages 2.8 mm. Vessels solitary and in multiples of 2-4 up to 7; solitary pores mostly oval in outline, 50 x 70µ in tangential and radial diameter; wall thickness 5µ average. Fiber tracheids form radial lines, average diameter 18µ, wall thickness 10µ. Parenchyma abundant, paratracheal scanty or vasicentric in part.
RADIAL: Perforation plate of vessels exclusively simple; intervessel pits alternate, 10µ in diameter; spiral thickenings present; dark gummy inclusions present. Parenchyma stranded, tyloses abundant.

TANGENTIAL: Rays heterogenous; uniseriate rays only, average 16 cells high (500µ), margins well-developed, consisting entirely of several upright cells 20 X 100µ in tangential and vertical diameter, procumbent cells round 18µ in diameter; pits into vessels round, half-bordered. Tangential wall pits present in fiber tracheids and parenchyma.

DISCUSSION: The presence of exclusively uniseriate rays is the most significant characteristic of this specimen. This is an important characteristic of Aesculus, Castanea, Populus and Salix. But Castanea features ring porous wood, and Populus and Salix lack spiral thickenings in vessel walls. Thus the combination of features present, i.e. diffuse porous wood, multiple vessels, paratracheal scanty parenchyma, simple perforation plates, spiral thickenings on vessels and heterogeneous uniseriate rays characterizes these specimens as Aesculus. This is the first report of the wood of Aesculus from the fossil forests of Yellowstone National Park.

LAURACEAE

Umbellularia Nuttall

Umbellularia sp.

SPECIMEN: SC1B - 01013, 05014, 05017, 05018, 05030, 05035, 05044
TRANSVERSE: Wood diffuse porous. Growth rings fairly distinct; delineated by a band of flattened elements; ring breadth variable 0.6 mm to 7.4 mm, average 2.5 mm. Vessels mostly solitary, occasionally in multiples of 2-3; solitary pores mostly oval, circular in part, average 160 X 200µ in tangential and radial diameter 50 X 50µ when circular; wall thickness thin (1µ) to thick (8µ), thick walled tyloses present. Libriform fibers form radial lines, 20µ in diameter, 3-8µ (average 5µ) in wall thickness, no spiral thickening. Parenchyma abundant, paratracheal scanty and vasicentric, forming 1-3 seriate chains in tangential lines; gum ducts present.

RADIAL: Vessel segments 400 to 750µ, average 500µ in length; perforation plate exclusively simple; intervessel pits alternate, elongated horizontally 18 X 10µ in diameter, reticulate pits on the end wall of vessels; spiral thickening present occasionally; thick walled tyloses present.

TANGENTIAL: Rays heterogeneous, multiseriate only, linear to narrow fusiform, average height 27 cells (600µ) up to 45 cells (820µ), average width 3 cells (33µ) up to 5 cells (60µ); procumbent cells 14 X 16µ in tangential and vertical diameter, 26 X 62µ in erect cells, pits into vessels bordered, horizontal wall well pitted; tyloses, gum ducts present; oil cells present occasionally on marginal rays.
DISCUSSION: The significant characteristics of this specimen are presence of exclusively heterogeneous multiseriate rays (up to 5) and oil cells on the marginal rays. The presence of heterogeneous up to 5-seriate rays occurs in Nyssa and Umbellularia. Those specimens differ from Nyssa in having exclusively simple perforation plates. Another feature, the presence of oil cells on the marginal rays occurs in Sassafras and Umbellularia. These specimens differ from Sassafras because Sassafras has ring-porous wood whereas wood is diffuse porous in Umbellularia. The combination of features present in this specimen, i.e. diffuse porous wood, solitary and multiple vessels, simple perforation plates, occasional spiral thickening of vessels, heterogeneous up to 5-seriate rays, and oil cells on the marginal rays, is characteristic of Umbellularia. This is the first report of the wood Umbellularia from the Fossil Forest of Yellowstone National Park.

MAGNOLIACEAE

Liriodendron L.

Liriodendron sp.

SPECIMEN: SC1B - 05025, 05042

TRANSVERSE: Wood diffuse porous. Growth rings distinct; delineated by a narrow band of dark small thick walled fibers; ring breadth variable 4.0mm to 0.3mm. Vessels occasionally solitary and in multiples of 2; solitary pores mostly oval, 35 X 85µ, circular in part,
100 X 140µ in tangential and radial diameter; with thin to thick
wall 2-10µ in thickness. Libriform fibers forming radial rows,
25µ in diameter, 8µ in wall thickness, with simple pits. Parenchyma
abundant, dominantly paratracheal vasicentric, marginal in part.

RADIAL: Vessel perforation plates scalariform with 15-26 thin bars;
intervessel pits mostly scalariform, in part opposite with 10µ
diameter pits. Parenchyma strands present; fibers septate.

TANGENTIAL: Rays homogeneous to heterogeneous; exclusively multi­
seriate, up to 5.0mm in height average 75 cells 2.6mm in height,
9 cells 150mm in width; fusiform with 1-3 layers of marginal erect
cells; sheath cells present occasionally; procumbent cells 20 X 20µ
in tangential and vertical diameter, 20 X 70µ in erect cells; pits
into vessels simple to half-bordered; horizontal wall pits present;
 thick walled tyloses present; gum ducts present.

DISCUSSION: The combination features present in this specimen, that
is, diffuse porous woods, solitary and multiple vessels, scalariform
perforation plates with 15-26 thin bars, scalariform and opposite
intervessel pits, homogeneous and heterogeneous exclusive multi­
seriate rays, fusiform rays with marginal erect cells and sheath
cells, is characteristic of Liriodendron. Liriodendron is very
similar to Liquidambar, but lacks chained vessels and uniseriate rays.
This is the first report of the wood of Liriodendron from the Fossil
Forests of Yellowstone National Park.
Magnolia sp.

SPECIMEN: SC1B - 01005, 05065

TRANSVERSE: Wood semi-ring porous, occasionally also nearly diffuse. Growth rings distinct, delineated by a narrow band of flattened thick walled latewood; ring breadth 0.3mm to 2.4mm average 1.2mm. Vessels solitary, occasionally in multiples of 2-3, also in radial chains of several pores; solitary pores mostly oval in outline average 100 X 150µ in tangential and radial diameter, average wall thickness 5µ. Fiber tracheids forming radial rows, average diameter 15 X 25µ in tangential and radial, wall thickness 4µ, with bordered to simple pits. Parenchyma abundant, paratracheal scanty to vasicentric, marginal in part.

RADIAL: Vessel, perforation plates simple and scalariform with 3-6 thick bars; intervessel pits mostly scalariform or linear on the vessel terminations, occasionally alternate 8-10µ in diameter; thick walled tyloses present in part, spiral thickening present in part.

TANGENTIAL: Rays heterogeneous, two types, uniseriate rays mostly 10-12 cells high; multiseriate rays linear to narrow fusiform up to 3 cells wide, height averages 45 cells (1.8mm), ranges up to 60 cells (2.4mm); procumbent cells 40 X 40µ in tangential and vertical diameter, erect cells 40 X 80µ; pits into vessels oval to elongated,
half-bordered, arranged alternately or linearly in 2-4 horizontal rows; wall thickness of ray cells 10µ average; end wall pitting present; horizontal wall pitting present, gum ducts present.

DISCUSSION: The most significant feature of these specimens is the presence of scalariform intervessel pits. This characteristic belongs to only Cornus and Magnolia, occasionally Liquidambar and Liriodendron. Cornus is divided from the specimens by the presence of more than 10 bars on scalariform perforation plates and lack of spiral thickening on vessels. Liquidambar and Liriodendron are divided from the specimens by the presence of opposite intervessels pitting, more than 10 bars on scalariform perforation plates and lack of simple perforation plates. The combination of features present in these specimens, that is, semi-ring and diffuse porous woods, simple and scalariform perforation plates with few thick bars, scalariform intervessel pits, spiral thickening on vessels, uniseriate rays and multiseriate fusiform rays, is characteristic of Magnolia. This is the first occurrence of Magnolia reported on the basis of wood from the Eocene fossil forests of Yellowstone National Park.

NYSSACEAE

Nyssa L.

Nyssa sp.
Specimen: SC1B-05046

TRANSVERSE. Wood diffuse porous. Growth rings distinct, ring breadth 1.2mm to 1.8mm. Vessels multiple or solitary, circular to oval in
outline, 50 x 75 µ in tangential and radial diameter, 3-5 µ wall thickness. Fiber tracheids forming radial rows, 5-8 µ wall thickness, with bordered pits averaging 17 µ in diameter. Parenchyma abundant, marginal or apotracheal diffuse.

RADIAL: Vessel segments average 600 µ in length; perforation plates scalariform with up to 80 thin bars; intervessel pits mostly opposite 5-12 µ in diameter, occasionally linear near the ends of vessels.

TANGENTIAL: Rays, heterogeneous; multiseriate rays average 38 cells, 1.0 mm high; averaging 4 cells wide (100 µ), with thick walls; procumbent cells 20 x 25 µ in tangential and vertical diameter, erect cells 30 x 55 µ.

DISCUSSION: The combination of features present in this fossil wood, that is, diffuse porous, multiple or solitary pore arrangement, marginal or apotracheal diffuse parenchyma, scalariform perforation plates with up to 80 thin bars, opposite intervessel pits and multiseriate heterocellular rays, is characteristic of Liquidambar, Liriodendron and Nyssa. However, Liquidambar differs from the described fossil wood in having uniseriate rays and homogeneous rays, and Liriodendron in having homogeneous rays and in lacking apotracheal diffuse parenchyma. Fisk (1976) reported fossil pollen of Nyssa from Yellowstone National Park and Wheeler, Scott and Barahoon (1978) have reported fossil wood.

OLEACEAE

Fraxinus

Fraxinus sp.

Specimen: SCIB-05020
TRANSVERSE: Wood semi-ring porous to ring porous, number of ring porous layers variable, maximum 8 to minimum 2, average 6; width of ring porous area 1.0mm. Growth ring distinct, delineated by a band of flattened thick walled late wood. Average ring breadth 2.6mm. Vessels solitary, pores circular to oval 100 x 150µ in tangential and radial diameter, 10µ wall thickness. Libriform fiber with single pits 13µ in diameter, 3µ in wall thickness. Parenchyma rare, paratracheal scanty or vasicentric in part.

RADIAL: Vessel segments 250µ in length, perforation plates exclusively simple, intervessel pits alternate, 8µ in diameter, crowded, linear in part.

TANGENTIAL: Rays homogeneous; multiseriate rays linear, average 12 cells (300µ) high; up to 3 but average 2 cells (40µ) wide; procumbent cells round in tangential section, 15µ in diameter. Gum ducts and rhombic crystals frequently present in horizontal rays.

DISCUSSION: The combination of features present in this specimen, that is, ring porous, solitary vessels, simple perforation plates, alternate pitting between vessels, rare parenchyma and multiseriate rays, is characteristic for the genera Fraxinus, Quercus and Sassafras. Quercus is readily distinguished from the described fossil wood in having big multiseriate rays (more than 10 cells thick). However it is very difficult to divide Fraxinus from Sassafras. In addition to above common characteristics, both can exhibit solitary or multiple porous arrangements, small intervessel pits (less than 5µ) and multiseriate rays up to 4 cells. The significant difference between Fraxinus and Sassafras seen in this fossil
wood is the presence of homogeneous rays in *Fraxinus* but both homogeneous and heterogeneous rays in *Sassafras*, and the presence of oil cells in *Sassafras*. Fisk (1976) reported fossil pollen of *Fraxinus* but no fossil wood has been reported at this time.

**PLATANACEAE**

**Platanus Linne**

*Platanus* sp.

Specimens: SC1B-05041, 05045, 05067

**TRANSVERSE:** Wood mostly diffuse porous. Growth rings distinct, delineated by a band of flattened thick walled fibers, ring breadth variable 0.8mm to 1.8mm average 1.5mm wide. Vessels solitary, pores circular to oval in outline 120 x 170µ in tangential and radial diameter, with thin walls (1µ thickness). Fiber tracheids forming radial lines, bordered pits 8µ in diameter with narrow apertures. Parenchyma abundant, apotracheal diffuse, tangential, linear in part, also paratracheal scanty in part.

**RADIAL:** Vessel perforation plates exclusively simple; intervessel pits alternate to opposite in part, 3-10µ mostly 5µ in diameter, spiral thickenings present, thick walled tyloses present. Stranded parenchyma abundant.

**TANGENTIAL:** Rays homogeneous with procumbent cells; multiseriate rays; fusiform, up to 320 cells (8.2mm) in height, up to 23 cells (320µ), average 15 cells (200µ) in width; pits into vessels chiefly round ranging from simple to bordered, horizontal wall well pitted, tangential wall well pitted also; procumbent cells 13-18 x 15-25µ in tangential and vertical diameter; gum ducts and thick walled tyloses present; chambered crystals abundant.
DISCUSSION: The combination of features present in these specimens, that is, diffuse and solitary pore arrangement, apotracheal parenchyma abundant, simple vessel perforation, intervessel pits alternate, homogeneous multiseriate fusiform rays is characteristic of *Fagus* (FAGACEAE) and *Platanus* (PLATANACEAE). *Fagus* differs from the described fossil wood having banded parenchyma and large intervessel pits more than 12µ in diameter. On the other hand these specimens have paratracheal scanty parenchyma and small intervessel pits (mostly less than 10µ). Beyer (1954) reported *Platanus* from Yellowstone National Park and the similar genus *Plataninium* was reported by Felix. Platen also reported this wood (in Wheeler et.al. 1977) from the same area. Recently, Wheeler, Scott and Barghoorn (1977) reported *Plataninium* from Gallatin Fossil Forest of the Yellowstone National Park. Fossil pollen of *Platanus* has been reported from the Yellowstone National Park by Fisk (1976).

**SALICACEAE**

Salix sp.

Specimens: SC1B-01011, 05006

TRANSVERSE: Wood diffuse porous. Growth rings distinct; delineated by a narrow band of thick walled flattened fibers; ring breadth 0.2 to 3.2mm. Vessels solitary, occasionally in multiples of 2-4, solitary pores round, 38µ in diameter, 5-8µ in wall thickness. Libriform fibers forming wavy radial rows; elongated tangentially twice the radial diameter, 8 x 15µ; 3µ in wall thickness; with simple pits. Parenchyma abundant, paratracheal vasicentric and marginal; strands frequently present; gum ducts present.
RADIAL: Vessel perforation plate exclusively simple; intervessel pits alternate, 3µ in diameter, no spiral thickening, thick walled tyloses present.

TANGENTIAL: Rays heterogeneous with procumbent and erect cells; exclusively uniseriate rays, up to 30 cells (900µ) average 18 cells (500µ) in height; uniseriate margins more or less well-developed with 1-2 layers of marginal erect cells; procumbent cells 8 x 25µ in tangential and vertical diameter and erect cells 8 x 38µ; horizontal wall and end wall both well pitted; thin walled tyloses present; frequent polygonal crystals 18µ in diameter.

DISCUSSION: The combination of features present in this fossil wood that is, diffuse porous, multiple or solitary pore arrangement, wavy libriform fiber, vasicentric and marginal parenchyma abundant, simple vessel perforation, alternate intervessel pits, heterogeneous and uniseriate rays, is characteristic of Aesculus (HIPPOCASTANEECEAE) and Salix (SALICACEAE). The significant differences between Aesculus and Salix are the presence of spiral thickening of vessels and homogeneous rays in Aesculus but not Salix. Fossil wood and fossil pollen of this genus from Yellowstone National Park were reported by Knowlton (1899), and Fisk (1976).
REFERENCES


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PLATE I

Figure

1. Keteleeria sp. Transverse section
2. K. sp. Radial section
3. K. sp Tangential section
4. Larix sp. Transverse section
5. L. sp. Radial section
6. L. sp. Tangential section
7. Picea sp. Transverse section
8. P. sp. Radial section
9. P. sp. Tangential section
Figure

1. *Pinus* sp. Transverse section
2. *P.* sp. Radial section
3. *P.* sp. Tangential section
4. *Tsuga* sp. Transverse section
5. *T.* sp. Radial section
6. *T.* sp. Tangential section
7. *Podocarpus* sp. Transverse section
8. *P.* sp. Radial section
9. *P.* sp. Tangential section
PLATE III

Figure

1. *Glyptostrobus* sp. Transverse section
2. G. sp. Radial section
3. G. sp. Tangential section
4. *Sequoia* sp. Transverse section
5. S. sp. Radial section
6. S. sp. Tangential section
7. *Taxodium* sp. Transverse section
8. T. sp. Radial section
9. T. sp. Tangential section
Figure

1. Acer sp. Transverse section
2. A. sp. Radial section
3. A. sp. Tangential section
4. Alnus sp. Transverse section
5. A. sp. Radial section
6. A. sp. Tangential section
7. Betula sp. Transverse section
8. B. sp. Radial section
9. B. sp. Tangential section
PLATE V

Figure

1. *Cornus* sp. Transverse
2. *C.* sp. Radial section
3. *C.* sp. Tangential section
4. *Diospyros* sp. Transverse section
5. *D.* sp. Radial section
6. *D.* sp. Tangential section
7. *Fagus* sp. Transverse section
8. *F.* sp. Radial section
9. *F.* sp. Tangential section
PLATE VI

Figure

1. Liquidambar sp. Transverse section
2. L. sp. Radial section
3. L. sp. Tangential section
4. Aesculus sp. Transverse section
5. A. sp. Radial section
6. A. sp. Tangential section
7. Umbellularia sp. Transverse section
8. U. sp. Radial section
9. U. sp. Tangential section
Figure

1. *Liriodendron* sp. Transverse section
2. *L.* sp. Radial section
3. *L.* sp. Tangential section
4. *Magnolia* sp. Transverse section
5. *M.* sp. Radial section
6. *M.* sp. Tangential section
7. *Nyssa* sp. Transverse section
8. *N.* sp. Radial section
9. *N.* sp. Tangential section
PLATE VIII

Figure

1. Fraxinus sp. Transverse section
2. F. sp. Radial section
3. F. sp. Tangential section
4. Platanus sp. Transverse section
5. P. sp. Radial section
6. P. sp. Tangential section
7. Salix sp. Transverse section
8. S. sp. Radial section
9. S. sp. Tangential section