A paleobotanical study of Judith River and Lance Formations along the Yellowstone River in Montana
by Jacob Bauer

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the Degree of Master of Science in Botany and Bacteriology
Montana State University

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INTRODUCTION

The increased knowledge of fossil flora, though still far from complete, has caused a considerable number of changes in the classification of fossil plants during the last decade. The contributions that others have offered, have necessitated a complete revision of the whole subject and since no general account of the complete fossil flora of the Judith River and Lance formations, including the recent advances in paleontology exists; the writer therefore proposes to commence by a brief enumeration of the characters found in the important genera.

The primary result of this work shall be the establishment of the paleontological sections which shall constitute the type of sections of these formations, for the comparison and reference in the study and correlation of other formations such as the Denver, Eagle, Claggett, and Bearpau occurring in the upper and lower Cretaceous periods.

The other, largely concomitant, results that are either economical or scientific in their nature have also been reached in the process of elaboration of the fossil plants of the Judith River and Lance in their typical regions. A detailed study of the histology of certain silicified fossil woods are included in this paper. The fossil wood, which was completely encased and hermetically sealed in the violent flow of magma at the time of volcanic eruptions, was collected from deposits in the Bozeman Lake Beds. The questions concerning the general geologic correlation of the Judith River and Lance formations depends upon the data which determins the age of these formations— i.e. (a) the time interval representing the type section, and (b) the relations of the Judith River and Lance formations in other regions of Montana.

HISTORICAL

According to Knowlton (8), the first record of collections of fossil plants obtained from the Judith River formation were made in the summers of 1888 to 1892 by Mr. T. H. Stanton and Mr. J. B. Hatcher. The principle results of their work was the accurate determination of the positions of the Judith River Beds in the upper Cretaceous section, and the removal of all doubts as to the correlation of these beds with the Belly River Beds of Canada. These results are offered as a contribution to the Mesozoic history of the northern interior region of Montana. Both men had previously visited the mouth of the Judith River in the winter of 1902 and 1903 to establish the facts regarding certain observations made in 1888. In 1888 to 1892 Mr. Hatcher spent considerable time collecting vertebrate fossils from the Judith River beds, making only incidental observations on the stratigraphy of the region. A few of the fossil plants were collected at that time from the mouth of the Judith River and near Willow Creek, tributary to the Musselshell River.

MATERIALS AND METHODS

PALEOBOTANICAL MICROTECHNIQUE

There are two general methods used in sawing fossil wood. One is the use of a diamond charged saw running in a lubricant. The writer has never used this device and believes it is less suited to the cutting of such very hard large specimens, furthermore the expense associated with the apparatus used by the writer is materially less than that of the diamond charged saw. The saw used consisted of a sheet iron disk, a rolled copper disk, or electrolytic copper disk, running in a reservoir of abrasive which was mixed to a semi-liquid consistency.

The sawing is done with the above mentioned disks, 20 to 22 guage, 12 inches in diameter, running at an approximate speed of 1800 r.p.m. with its edge in a reservoir of liquid abrasive, about the consistency of cream. The liquid abrasive is made of equal parts of carborundum, Kaolin, Volcanic ash, and water. The mounted section rides against the saw, being held in place by its weight or by the operator.

The cut surface is ground with the following grades of carborundum; 100, 150, FW, and 320. Polishing is done on a revolving brass disk, or on a poplar wood wheel, or on buffers with a semi-liquid mixture of tin oxide and water. On the cut surface, finer grinding is done by hand upon a glass plate with plenty of carborundum. Polishing is followed in the same manner as the method of finer grinding. The latter method, grinding and polishing by hand, has a few advantages over the mechanical method. For example; if the section becomes extremely thin a series of inspections can be made, with the aid of a microscope, enabling one to grind just to the desired thinness to bring out the desired object, while with the mechanical method, the revolving wheel will cut more than desired and as a result the section is lost. (2) At high speeds, often thin sections are cracked or destroyed, while grinding or polishing by hand allows one to note how the process is progressing. (3) Extreme care must be taken when polishing by the mechanical method or else the sections will be torn off by the speed of the disk, while the method by hand allows the operator to regulate his speed and pressure.

The polished surface is now fastened to a micro-slide, after gradually heating the slide until it is rather warm, a small amount of shellac (flake), or raw balsam or sealing wax is placed on the micr-slide. After the fixative is melted, the polished surface is placed in the melted fixative and the section is pressed very firmly to the slide. A steel clamp applied to the section insures perfect sealing. The mounted section is allowed to cool. As soon as the section has become cool the next cut may be made. One precaution must be observed; the section must not be dipped into cold water for the purpose of cleaning, cooling or inspection after cutting or polishing. The section is cleaned for inspection by wiping off all surplus abrasive with a dry cloth.

The cutting process is repeated sawing as close as possible to the micro-slide. The grinding and polishing process as described before is repeated. When changing from one operation to another all of the loose abrasive is cleaned from the cement. When it becomes necessary to soften or remove the fixative, use xylol on balsam or absolute alcohol on shellac, or Sodium thiosulphate on sealing wax.

When sections became extremely thin, the surplus carborundum was washed off, the section was then polished with Stannic oxide until a velvet lustre was obtained. The section was washed again and was allowed to dry thoroughly before mounting. The use of balsam for final mounting is desirable for fossil wood sections. All sections were covered with micro-cover glasses No. 0 for final permanent work so as to enable one to examine them with the higher powered objectives.

Sections were ground thin enough by this method for examination with the aid of a 2 millimeter oil immersion objective. Excellent photomicrographs were also obtained from material prepared by this technique.

TAXONOMY OF FOSSIL WOODS

A survey of the literature on the subject shows a heterogeneity of ideas concerning the diagnostic data which must be assembled to describe fossil wood accurately. Difficulty in comparison has been encountered, due to varying degree of importance placed on features of the fossil wood. According to Read (10), Kraus, Gothan, Penhallow, Jeffery, Bailey, Holden, Torrey, and a host of other men have commented on the relative value of the various tissues of the wood for systematic purposes. Torrey has compiled a table of data which is of particular interest and value. The table of data is as follows:

"Annual rings--- present or absent; regular or irregular wood as compared with late wood; transition from early to late wood; width of rings; compactness of early and late wood."

"Resin canals--- present or absent; normal or traumatic, horizontal or vertical or both; size and shape, secretory cells as to size, shape, thickness, of walls, number of rows, thyloses."

"Wood rays--- Seriation; height and variability; shape of cells in cross section; attitude of terminal walls; pitting of lateral, terminal, and upper and lower walls with reference to number, size, and character; irregular thickening of walls; ray tracheids, with reference to distribution type of pitting and thickenings of walls; resin."

"Wood parenchyma--- terminal or diffuse, abundant, or scarce; distribution; contents, size."

"Tracheids--- variation in size; bars of Sanio; pitting, with reference to distribution of pits in radial and tangential walls in various parts of the ring; nature of pits; spiral thickenings; resinous tracheids; thyloses."

"Medulla--- size, sclerotic cells, resinous structure."

It has been the custom to describe fossil woods and designate them with the ending, oxylon, even when evidence has been available to suggest that these were referable to modern genera. Notable exceptions occur, however, for instance, fossil wood of Sequoian affinities are usually placed in the genus Sequoia rather than Sequoioxylon, even though pines from the same horizon are called Pitoxylon. Such an irregular system is confusing. To the writer it seems only logical to regard associated woods and leaves as the same species.

The fossil wood described in this paper was collected from the Bozeman Lake Beds located in the Madison Valley south of Logan, Montana, except the Sequoia wood which was collected from the Judith River formation 4 miles east of Columbus, Montana.

The wood collected from Logan, Montana, belongs in the Ulmaceae. This fossil wood is mostly silicified and many finer structures such as the details of structure of some of the walls in the tracheal tubes are lost due to petrification. In all cases the annual rings are well developed, and an abrupt transition between the early and late wood is noticeable. The tracheal tubes are very numerous and scattered, occurring most abundantly in the spring and summer wood. The transverse section, (Plate XVIII, figure 2) shows the transition between spring and summer wood. The tracheal tubes are elliptical to circular in form. The xylem rays (Plate XVIII, figure 3) are numerous and form a ray of cells 16 to 20 cells thick. A few of the rays that are one-celled thick extend for a considerable distance adjacent to the tracheal tubes. The individual cells in section are almost square with rounded corners, thin walls, and in most cases are filled with a yellow colored material.

While the writer was preparing fossil wood sections, brown streaks appeared in the tracheal tubes of the radial sections. Microscopic analysis of these brown streaks is described as follows: In some of the tracheal tubes (Plate XVII, figure 4), the material is collected at the ends, but in other tracheal tubes they are only half filled with this colored material. This mass of blackish material has usually shriveled somewhat, thus leaving a space between it and the tracheal wall. In some of the tracheal tubes and in a few ray cells are black and yellow globular bodies (Plate XV; figure 3, Plate XVI, figures 1, 2, 3, and 4) though others contain a foamy substance. Some of the globular bodies seem to be made up of a series of smaller bodies forming clusters. According to Knowlton (9), Penhallow refers to the globular bodies in the cells of Callixylon newberryi as starch and resin, but its chemical nature has never been determined.

In Plate XVI, figure 2 and 3 illustrates a globular body having a stalk-like projection, the base of the stalk resting on the cell wall of a tracheal tube. It is peculiar to find only one of these globular bodies with such a long stalk which measured 60 microns in length. Some of the medium size globular bodies have small projections measuring 8 microns in length. On further observation at a magnification of 960 this stalk-like projection appears to be made up of very fine thread-like structure resembling strands of mycelium. Due to poor preservation the writer is unable to determine whether this strand-like material is a mycelium and whether these strands are septate or non-septate. While observing several slides of thread-like strands were found mostly in tracheal tubes, however, a few occurred in ray cells. These strands are long and narrow, branching freely and irregularly. No thread-like strands were found to be connected to the globular bodies, except the one mentioned above.

The following is a description of the fossil wood of the Judith River formation (Pinus and Sequoia) and Bozeman Lake Beds (Ulmus):

Tribe Abietineae

The fossil representative of the genus Pinus was described by Linneaus. (Plate XVII, figure 1).

Annual rings--- not observed.

Resin canals--- the ray tracheids are reticulate, dentate and some appear smooth walled. The pitting appears to be on some of the walls of the tracheal tubes. Some of the cells show a presence of resin in the rays.

Wood parenchyma--- absent.

Tracheids------- The pitting occurs in single rows and seems to be confined chiefly to the tracheal walls.

Tribe Taxodineae

The fossil representative of the genus Sequoia was described by Knowlton in 1933. (Plate XVII, XVIII, figures 3 & 1).

Annual rings--- not observed.

Resin canals--- the canals are numerous and distinguished by their dark contents. They occur mainly in the spring and summer wood.

Wood rays------ the linear wood rays are uniseriated although some appear biseriate. The lateral cell walls are rarely pitted although a few show some pitting.

Tracheids------- the tracheids are variable in size. Bars of Sanio are present. The radial walls are strongly pitted with border pits in one or two rows (occasionally more). Read (11) states that in some species the tangential walls are pitted in the late wood.

Family Ulmaceae

The fossil representative of the genus Ulmus was described by Felix in 1933. (Plate XVIII, figure 2 & 3).

Annual rings---- the annual rings are present, consisting of 2 or 3 rows of thickened cells. In the succeeding spring wood the ducts are much larger than in the late wood which makes the annual rings easily to be seen by the unaided eye.

Resin canals---- the resin canals are numerous and scattered, occurring most abundant in the spring and summer wood. These resin canals are almost circular, in some cases slightly elongated radially. None of the ducts are arranged in notable radial rows. Some of the resin ducts measure 110 microns wide and 425 microns in length.

Wood rays--- the medullary rays are numerous and easily visible to the unaided eye. Some of the medullary rays that are a single cell in thickness pass for a considerable distance adjacent to the ducts. The individual cells of the large rays are nearly circular in cross-section and are also thin walled.

Tracheids--- The tracheids are not preserved, probably destroyed through silicification.

GEOLOGY

Near mile-post 20 on the Northern Pacific right-of-way (east of Park City) is a cliff about two miles west consisting of three beds of sandstone with intervening shale or softer sandstone as shown in figures 1 and 2. The dip is low as the Eagle sandstone approaches the river beneath the Claggett formation. At mile-post 25 the Eagle sandstone can best be seen in the hills on the south side of the Yellowstone River. The top of the Eagle sandstone passes below water level at a siding called Youngs Point. Beyond Park City, another sandstone and shale about three hundred feet thick immediately overlies the Eagle sandstone and is visible across the river. These beds make up the lower part of the Claggett formation, which dips gently westward and gradually disappears beneath the water level. At mile-post 32 (west of Rapids) all of the white sandstone has passed from view and the hill slopes are composed of the overlying Judith River formation. This formation has no decided

Fig. 1

Fig. 2

characteristics by which it may be recognized and identified with the exception of the volcanic material which it contains, however, the underlying Claggett formation contains no volcanic material. The slopes composing the Judith River formation has a whitish grey tint and is rather monotonous in color and appearance. The sandstone composing the upper part of this formation is well exposed in Countryman's Bluff (fig. 3), between mile-post 37 and 39 where the writer's collection of fossil plants was obtained. The formation yields fresh and brackish water invertebrates, numerous fragments of fossil plants, and some marine flora.

Turning now to the geological application of Paleobotany, we may say that this application of the study of fossil plants makes its strongest appear. The sedimentary rocks, which are practically the only rocks that contain fossils, have been divided by geologists into a number of major divisions and then again into smaller sub-divisions. Technically speaking, a formation is defined as a "mappable lithogic unit"-- i.e., it is a bed or layer or rock, or a series of layers, that is sufficiently distinct lithologically from those below or above, and sufficiently large in extent, to permit its representation in an area (mapped by a separate color or other distinctive conventions).

FORMATIONS

Eagle Sandstone. The name Eagle sandstone, according to Knowlton (7), was given by W. H. Weed to the formation overlying the Colorado shale in north-central Montana. The typical Eagle formation as defined by Weed consists of three distinct units containing respectively, ripple marks, cross bedded layers, and marine shales. Weed further states that the lower member is very persistent and characteristic over a large area in north-central Montana, even where other divisions of the formations are not readily recognized.

According to Knowlton (7), Stanton and Hatcher described the Eagle sandstone as the lowest formation of the Montana Group, consisting of a dull grey to brownish massive ledge making sandstone about one hundred feet thick; the middle division of the Eagle sandstone is a thin-bedded shaly sandstone, while the upper is composed of rusty-brown concretions, which are locally very numerous. The Eagle sandstone is conformable with the overlying Claggett formation, from which it is distinguished by its lithologic character. Figures 1 and 2 show the Eagle sandstone east of Youngs Point, Montana.

<u>Claggett Formation</u>. According to Knowlton (7), the name Claggett was given to this formation by Stanton and Hatcher. This formation which overlies the Eagle sandstone is seperable into two divisions; a lower one of shale and the upper one consisting predominately of sandstone. The lower division of the Claggett consists of a dark marine shale similar both lithologically and paleontologically to the Bearpaw shale. At the top there is a bed of massive rust-brown sandstone ranging from one to twenty feet in thickness. These beds were included in the Claggett

formation by Stanton and Hatcher in their reports due to the fact that the formation contained some marine flora.

Judith River Formation. The Judith River formation is chiefly of brackish water origin and lies between two marine beds. The formation, according to Knowlton (8), was named by Hayden in 1871, but at that time its stratigraphical position was not understood. According to Knowlton (7), in 1903 Stanton and Hatcher determined that the formation was a member of the Montana group and is possibly equivalent of a part of the Pierre shales.

The Judith River formation, according to the above authorities, consists of alternating beds of light-colored sandstome and clay, in which occur thin beds of carbonaceous shale. In the area studied the formation contains some coal but is not known to have coal deposits of commercial value, although plant material is abundant. The formation also contains bones of vertebrates, some sicilified wood, and stems, though well preserved fossil leaves are exceedingly rare. The sandstone beds of the formation are hard and form definite benches, but because they are numerous and not separable by thick beds of shale or clay, most of the beds join in producing a rough, steep escarpment, which has the appearance of range hills from a distance. At many places, near the top of the formation a strata ranging less than a foot to several feet in thickness is made up of almost wholly of shells. The Judith River formation is of upper Montana age and is composed of continental sediments that are intercalated without erosion or apparent interruption

Fig. 3

Fig. 4

Fig. 5

of deposition between the marine Claggett formation and the Bearpaw shale above. Figures 3, 4, and 5 shows the Judith River formation near mile-post 37.

The plants found in the Judith River formation are described as follows:

Family Fucaceae.- This specialized group of brown algae is relatively small. The body of brown algae is a flat thallus which forks repeatedly, a type of branching called dichotomous.

The fossil representative of the genus Fucus was described in 1887 by Lesquereux. This genus is restricted to the nothern hemisphere. Fucus is a tidal form and is not found in deep water. This specimen has two main branches, two secondaries on each branch and two tertiaries as shown in Plate I, figure 1.

Family Schizaeaceae.- These plants have erect, single, pinnate, or dichatomous, or vine-like, elongate leaves, with sheathed, alternate, paired, palmately, lobed or pinnate leafy divisions. These plants, according to White (16), are mostly found in the tropical climates.

The fossil representative of the genus Aneima was described by Knowlton in 1916. This specimen no doubt belongs to the genus Aneima (15), as illustrated in Plate I, figures 3 and 4. This specimen probably represents only a fragment of lateral divisions of a comparatively large frond. These ferns are cut deeply into linear, sharply toothed, rather obtuse segments; apical portion of the frond is well preserved; fronds being alternate above and opposite near the base. The veination