CONTRIBUTIONS TO PALÆONTOLOGY

I

FOSSIL FLORAS OF YELLOWSTONE NATIONAL PARK

Part I. Coniferous Woods of Lamar River Flora

By Charles B. Read

With six plates

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CONTENTS

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INTRODUCTION

The purpose of the series of papers, of which this is the first, is to consider the fossil floras of the Yellowstone National Park. Considerable time has lapsed and many collections have been made since the floras were monographed by Knowlton;[1] therefore it seems desirable to reconsider them. Likewise, the recent advances in ligneous anatomy make a revision even more necessary.

Mention of the fossil forests of the Yellowstone is first met in the reports of the Hayden Survey for the year of 1878, when a geologic reconnaissance of the Park was made under the direction of W. H. Holmes.[2] The record mentions the occurrence of great quantities of fossil wood in the vicinity of Junction Butte and in the cliffs on the sides of the valley of the "East Fork of the Yellowstone" or Lamar River. Concerning the great thickness of volcanic breccia measured in a section on the face of Amethyst Mountain, Holmes [3] writes—

> "These strata rest upon the unevenly eroded strata of the paleozoic and granite rocks, and form a great part of the mountain ranges which enclose the valley. They are horizontal and apparently conformable throughout the entire thickness of 5000 feet. The greater part of this immense group of strata is filled with the silicified remains of ancient forests."

Holmes distinguished between the two widespread series of eruptives, the early acid and the early basic volcanics, recording the silicified woods as occurring in the latter.

The next scientific observations on the fossil plants were made by J. Felix in 1896,[4] the result of a short stay at Yancey's in the park. A number of species of fossil wood was described in a short paper, inadequately illustrated—a common fault of the early papers on the subject. Four dicotyledonous and two coniferous woods were discussed. The greatest contribution of this work is the interesting comparison of stem and root wood. Platen [5] has more recently published a short paper on this material, in which the nature of the fossils is clearly demonstrated.

[1] F. H. Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, 651-882, pls. 77-121, 1899.
[2] W. H. Holmes, U. S. Geol. and Geog. Surv. Territories of Wyoming and Idaho, pt. 2, 47-52, 1878.
[3] W. H. Holmes, U. S. Geol. and Geog. Surv. Territories of Wyoming and Idaho, pt. 2, 48-49, 1878.
[4] J. Felix, Zeitschr. Deutsch. d. Geol. Gesell., 249-260, Jahr. 1896.
[5] P. Platen, *Prometheus*, vol. 20, 241-246, 1909.

The only detailed taxonomic treatment of the Tertiary floras of the Park is Knowlton's monograph.[1] In this paper about one hundred and fifty species are described from three distinct horizons. Several woods are considered, and among them three of coniferous nature. Of these, two are from the Lamar River flora and one from the Intermediate flora[2] of Crescent Hill. Here, as in Felix' paper, the descriptions are inadequate. Great difficulty is encountered in their application.

In connection with this work, the accompanying reports of several members of the United States Geological Survey must be mentioned.[3] Included in the volume with the account of the flora is a series of papers dealing with the geology and paleontology of the Park area. W. H. Weed,[4] in a preliminary paper, discusses the stratigraphy of the southern end of the Snowy Range and mentions the sections exposed at various places in the Lamar Valley; likewise, accounts of the fossil forests are to be found in the Yellowstone National Park[5] and Absaroka Folios.[6]

Only a few statements of contributing value have been made since Knowlton's paper. Platen's[7] revision has been mentioned. Both Penhallow[8] and Seward[9] have commented on the occurrence and woods to the extent of regarding the species of pine similar or identical. Stopes[10] mentions these in her paper on the flora of the Lower Greensand. A popular paper published by the Park Service[11] is likewise available.

ACKNOWLEDGMENTS

The field and laboratory studies which form the bases for this and succeeding papers have been made possible through the financial assistance of the Carnegie Institution of Washington. To Dr. R. W. Chaney of that Institution, the writer is greatly indebted, not only for advice and encouragement, but also for the working facilities which have been so generously provided. Mr. H. L. Mason, of the University of California, has contributed many valuable suggestions during the course of the work, and his untiring interest in the field work has added much to the collections.

[1] Arnold Hague and Associates, U. S. Geol. Survey Mon. 32, pt. 2, 1-893, pls. 1-121, 1899.
[2] F. H. Knowlton, U. S. Geol. Survey, Mon. 32, pt. 2, 347, 1899.
[3] Arnold Hague and Associates, U. S. Geol. Surv., Mon. 32, pt. 2, 1899.
[4] W. H. Weed, U. S. Geol. Survey, Mon. 32, pt. 2, 203-212, 1899.
[5] Arnold Hague, W. H. Weed, J. P. Iddings, U. S. Geol. Survey, Folio 30, 1896.
[6] Arnold Hague, U. S. Geol. Survey, Folio 52, 1899.
[7] P. Platen, *Prometheus*, vol. 20, 241-246, 1909.
[8] D. P. Penhallow, *Manual of North American Gymnosperms*, pages 227, 346-347, 1907.
[9] A. C. Seward, *Fossil Plants*, vol. 4, pages 347-348, 1919.
[10] M. C. Stopes, *Catalogue of Mesozoic Plants: The Cretaceous Flora*, pt. 2, pages 77, 102-103, 1915.
[11] F. H. Knowlton, *Fossil Forests of the Yellowstone National Park*, Gov. Printing Office, 1914.

The type slides of the woods described by Dr. Knowlton have been made available through the courtesy of Dr. Roland W. Brown of the United States Geological Survey.

To the officials of the National Park Service and in particular to Horace M. Albright, R. W. Toll, Dorr G. Yeger and E. N. Jones the writer wishes to express appreciation for the many kindnesses and courtesies extended while in the Park.

John Bauman of the Tower Falls Ranger Station has contributed greatly. His intimate knowledge of the area studied has been of utmost value in the reconnaissance.

GENERAL CONSIDERATIONS

The plant-bearing series of early basic breccias outcrops over a wide area in the northeast corner of the Park. Here the woods and leaves of the Lamar River flora occur in intercalated layers of silts and tuffs throughout most of the section, which measures 5000 feet in certain localities. Silicified woods are often so abundant as to afford a convenient index to the strata.

It is not the purpose of this paper to discuss the age and correlation of this flora in detail; not enough field work has been done to justify an elaborate treatment of that phase of the problem, yet some preliminary statement of the writer's point of view seems both necessary and desirable. Knowlton [1] has pointed out the affinities between the flora of the Older Basic Breccias and that of the Auriferous Gravels of California, this being the basis for the establishment of the age of the Yellowstone flora as Upper Miocene. Recent work has shown that the Auriferous Gravels flora is in need of revision. With regard to this flora, Chaney [2] has stated that—

> "During the past ten years evidence has accumulated which indicates that the Auriferous Gravels contain several distinct floras in horizons ranging from Eocene to Miocene."

Of these, the flora most similar to the Lamar River assemblage is tentatively regarded as Eocene, although more data must be accumulated to conclusively demonstrate this age reference. It is significant, however, that many of the species in question are known from definitely recognized Eocene horizons in other regions, and several of them are found in the large Fort Union flora.

Two hundred and fifty miles northwest of the Park near the town of Missoula, Montana, the occurrence of a typical redwood association of Bridge Creek age in deposits of lacustrine origin has been recorded.[3] This is quite critical in a consideration of the age of the

[1] F. H. Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, 790, 1899.
[2] R. W. Chaney, Written communication, 1930.
[3] O. E. Jennings, Mem. Carnegie Mus., vol. 8, No. 2, 385-450, pls. 22-33, 1920.

Lamar River flora, since it establishes the presence of an association of plants of known age at a point within the Rocky Mountains and not far removed from the area covered by the early basic breccias. Similar, although less complete floras, occur at other stations in the

TABLE 1—*Distribution of Tertiary plants of Lamar River flora of Yellowstone National Park.*[1]

Species	In Park			Outside Park					
	Lamar River	Intermediate	Fort Union	Laramie	Denver and Livingston	Fort Union	Green River	Auriferous Gravels	Undifferentiated Eocene of British Columbia
Asplenium iddingsi	X		X						
Osmunda affinis	X				X				
Lygodium kaulfusii	X		X				X		X
Equisetum canaliculatum	X	X	X						
Equisetum deciduum	X		X						
Taxites olriki	X		X					X	X
Sequoia langsdorfii	X	X	X	X		X	X	X	X
Juglans californica	X							X	
Juglans crescentia	X		X						
Juglans rugosa	X		X	X	X		X	X	X
Hicoria antiqua	X					X			
Populus balsamoides	X							X	X
Salix varians	X						X	X	X
Salix angusta	X				X		X	X	
Salix elongata	X						X		
Corylus macquarryi	X				X	X	X		X
Castanea pulchella	X		X						
Quercus furcinervis	X							X	
Ulmus pseudofulva	X					X			
Ulmus minima		X				X			
Planera longifolia	X				X		X		
Ficus shastensis	X							X	
Ficus sordida	X							X	
Ficus densiflora	X		X						
Ficus asiminæfolia	X		X					X	
Magnolia californica	X							X	
Magnolia pollardi	X		X						
Laurus primigenia	X		X						
Laurus californica	X		X					X	
Laurus grandis	X		X					X	
Persea pseudocarolinensis	X							X	
Malopœnna lamarensis	X		X						
Platanus guillelmæ	X		X	X	X	X	X		
Rhus mixta	X							X	
Elæodendron polymorphum	X	X				X			
Sapindus affinis	?	X	X			X			
Sapindus wardii	X		X						
Rhamnus rectinervis	X			X	X				
Aralia notata	X	X	X		X	X		X	
Aralia whitneyi	X							X	

[1] Revision may show that some of these old references are incorrect generically, but for correlation purposes the present determinations suffice.

Rockies, notably at Florissant, Colorado, where an excellent flora is well known.[1] The Lamar River flora is also a redwood association, but differs from the great Middle Tertiary redwood forests of western America in the presence of a large number of species common in definitely known Eocene horizons not yet reported from younger strata. These are listed with their distribution.

The conclusion to be drawn seems obvious. The Lamar River flora contains certain elements which can be accounted for only by regarding the assemblage as somewhat older than Miocene. Such a setting back of the age of the early basic breccias is not out of accord with the views expressed by others. Cockerell,[2] as early as 1909, questioned the Miocene reference of this flora, and remarked—

> "The conclusion seems legitimate that the Yellowstone Intermediate and Lamar floras are Upper Eocene or at least older than Miocene. Were they really Miocene, with so much resemblance to even the basal Eocene, the Florissant flora, to get as far on the side as its lack of affinity would suggest, would have to be projected somewhere into the future."

Jones and Field [3] have arrived at a similar conclusion as to the age of the breccias, employing an entirely different line of reasoning. Their study of the geologic history of the Grand Canyon of the Yellowstone has suggested that the ages of the Tertiary volcanics must be set back to allow time for the complex series of events which have taken place. They state that—

> "The plants from the later or basic breccias are regarded, however, as belonging to the base of the Neocene period. In view of the erosional history of the Park, it is open to question whether even the latest of the breccias are as young as the Neocene."

Tentatively the view is taken that the Lamar River flora is Upper Eocene or Lower Oligocene in age, but more conclusive discussion of the subject is reserved for detailed treatment in a future paper.

Materials collected during the field season of 1929, as well as those of previous expeditions examined, indicate the presence of four species of coniferous woods in the Lamar River flora. Ample confirmation of this is found in the nature of leaf impressions and occasional cones which occur at many of the localities, associated with the petrifactions.

In Knowlton's monograph [4] are described three coniferous woods: *Sequoia magnifica, Pityoxylon aldersoni* and *P. amethystinum.* A

[1] F. H. Knowlton, Proc. U. S. Nat. Museum, vol. 51, 241-296, 1916.
[2] T. D. A. Cockerell, Amer. Nat., vol. 44, 31-47, 1910.
[3] O. T. Jones and R. M. Field, Amer. Jour. Sci., 5th ser., vol. 17, 260-278.
[4] F. H. Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, 755-765, 1899.

question has been brought up by several students of wood structure concerning the separation of the latter two. It has been found impossible to regard them as other than identical and synonymous with *P. fallax* described by Felix [1] and figured by Platen.[2]

Sequoia magnifica is based on types now in the National Museum. The slides are all cut from stem wood, probably from the main axis. Few lateral branches of this species are observed in the deposits. The matrix in which the petrifactions are embedded commonly contains numerous impressions of leafy twigs referable only to *Sequoia*. These were called *Sequoia langsdorfii* by Knowlton,[3] in accordance with the prevalent custom of applying different specific names to different organs preserved, unless actual connection was demonstrated. Certain cone-like structures were also referred to *Sequoia*. Thus abundant evidence for the presence of the genus *Sequoia* is found in the deposits.

The types of *Pityoxylon aldersoni* and *P. amethystinum* have been likewise secured from the National Museum. Material of these synonymous species is common over the whole of the area studied. Fascicles of needles are occasional and Knowlton [4] has listed several species. Impressions of parts of cones are recorded from several localities.

In this connection, the interesting cone, *Pinus premurrayana,* [5] from a station east of Yellowstone Lake may be mentioned. Knowlton has discussed it and comments on the remarkable preservation. Its close simulation of *Pinus murrayana,* now the most abundant conifer in the Park, suggested to him that this might not be a fossil but a modern cone. Since the region immediately east of the lake contains numerous hot-spring basins, it seems reasonable to suppose that silicification might take place in a comparatively short time, the waters often being highly charged with silica. It suffices to state that the fossil status of this cone must be regarded with question until further field work can make clear the occurrence.

In several localities in which collections were made, a type of coniferous wood quite different from any of those already recorded was observed. This material shows certain characteristics which identify it with the *Cupressinoxylon* type; others which suggest its taxaceous affinity. Leafy twigs referable to the genus *Torreya* occur in deposits closely associated and afford additional evidence of the presence of some member of this family.

[1] J. Felix, Zeitschr. deutsch. d. Geol. Gesell., 118-119, Jahr. 1896.
[2] P. Platen, *Prometheus,* vol. 20, 241-246, 1909.
[3] F. H. Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, 682-683, 1899.
[4] F. H. Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, 679-680, 1899.
[5] F. H. Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, 677-678, 1899.

PRESERVATION OF THE WOODS

Numerous writers have commented on the phenomena attending petrifaction of woods. St. John [1] has reviewed the literature on this subject, and has regarded petrified woods as falling into three categories with the characteristics which are listed below:

"1. Infiltration of mineral matter into the cell cavities, and the intercellular spaces, with the vegetable tissue preserved.

"2. Complete replacement of the plant tissues, but this may be due to the spaces being filled first, and later the tissues being replaced. (Differential replacement.)

"3. Complete replacement of portions of the mass and filling only of cavities in other parts."

While studying the woods of the Lamar River flora, it became apparent that woods falling into all of these classes were present. Additional observations were made on the preservation of the woods. Two fundamental types and their intergradations have been met with, namely those of infiltration and differential replacement. Miss St. John's third type is regarded as a combination of these, and can not be considered as distinct. It is rather common in the woods collected. Another type of preservation, also an intermediate, is recognized in certain small branches of roots and in fragments from larger branches and roots. In these a leaching of the carbonaceous materials has taken place in specimens which were formerly infiltrated only. Such woods are quite friable and are undesirable for sectioning. On large trunks a zone of this wood is found in the outer portions. Obviously this is a condition prior to differential replacement, but is distinct in that it has taken place at a rather late date, probably since the wood has reached the zone of weathering.

Occurring in the tuffs and breccias with the woods are numerous cylindrical masses of chalcedony. Some of these may be ascribed to inorganic origin, but others can only be regarded as products of complete replacement of wood. The shape strongly suggests this, and the presence of infiltrated wood containing irregular areas totally replaced by chalcedony may be advanced as further proof of this process, in such cases in intermediate phases.

With few exceptions the wood studied is silicified. These exceptions refer to material partly or wholly calcareous.

Infiltrated woods are the most valuable for anatomical work. Such woods are jet black and must be ground to extreme thinness before they can be studied, but they usually show much more detail than woods in which replacement has followed infiltration. These latter, while they may show the grosser structures excellently, in most cases lack a fine preservation of pitting.

[1] R. N. St. John, Econ. Geol., vol. 22, 729-739, 1927.

SUMMARY

The Lamar River flora of Yellowstone National Park occurs throughout a series of beccias 5000 feet thick in places. The flora is of a transitional type, showing on the one hand a marked resemblance to certain early Eocene floras of Western America and on the other to well-known Middle Tertiary floras. It must be regarded as much older than the Upper Miocene to which it has been referred —either Lower Oligocene or Upper Eocene. Four species of coniferous woods are recognized in the flora, these generally identical with forms growing in the modern redwood forests.

TAXONOMY OF THE WOODS

A survey of the literature on the subject shows a heterogeneity of ideas concerning the diagnostic data which must be assembled to describe woods accurately. Difficulty in comparisons has been encountered, due to varying degrees of importance placed on features of the wood. Kraus,[1] Gothan,[2] Penhallow,[3] Jeffrey,[4] Bailey,[5] Holden,[6] Torrey,[7] and a host of others have commented on the relative values of the various tissues of the wood for systematic purposes. Torrey [8] has compiled a table of data which is of particular value since it enables the writer to diagnose materials in a concise but accurate manner. With modifications, his method has been adopted in this paper. The table of data is as follows:

Annual Rings—Present or absent; regular or irregular in contour; early 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 thickenings 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.

[1] G. Kraus, Schimper's *Traite de Paleontologie Vegetale*, vol. 2, 363-385, 1870-1872.

[2] W. Gothan, Preuss. Geol. Landesanstalt und Bergakademie, Berlin, new series, pt. 44, 108 pages, 1905; Kungl. Svenska Vet.-Akad. Handl., Stockholm, vol. 42, No. 10, 1-44, pl. 1, 1907; vol. 45, No. 8, 1-56, pl. 1-7, 1910.

[3] D. P. Penhallow, *Manual of North American Gymnosperms*, 1907.

[4] E. C. Jeffrey, *Anatomy of Woody Plants*, 317-356, 1917.

[5] I. W. Bailey, Bot. Gaz., vol. 48, 47-55, pl. 5, 1909.

[6] Ruth Holden, Proc. Amer. Acad. Arts and Sci., vol. 48, 609-623, 1913.

[7] R. E. Torrey, Bot. Gaz., vol. 58, 168-177, 1914; Mem. Boston Soc. Nat. Hist. vol. 6, No. 2, 41-106, pls. 8-15, 1923.

[8] R. E. Torrey, Mem. Boston Soc. Nat. Hist., vol. 6, No. 2, 56-58, 1923.

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

Medulla—Size; sclerotic cells; resinous structures.

NOMENCLATURE

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 woods of sequoian affinities are usually placed in the genus *Sequoia* rather than *Sequoioxylon,* even though pines from the same horizons are called *Pityoxyla.* Such an irregular system is confusing. To the writer it seems only logical to regard associated woods and leaves as the same species when there is morphological evidence to demonstrate the point. It is held that actual continuity is not necessary in the cases of Tertiary plants, which bear close resemblance to living species, to establish this. In this paper the policy adopted is to refer those woods whose affinity to modern forms is clear to their respective genera without the *-oxylon* termination. Materials of uncertain affinity and those which can be identified no further than the family are placed in genera terminated with the customary suffix.

TRIBE ABIETINEÆ

Genus PINUS (Tourn.) Linne

Annual Rings—Present, usually distinct, variable.

Resin Canals—Present, normal in both directions, usually large, the secretory cells thin walled.

Wood Ray—Linear ones uniseriate, in the later types with marginal and interspersed tracheids, ray tracheids reticulate, dentate, or smooth walled; pitting usually on all walls, both of ray tracheids and ray parenchyma, in the latter the pits simple or slightly bordered and modified into large oopores. Resin common in rays.

Wood Parenchyma—Absent.

Tracheids—Bars of Sanio present, pitting uniseriate or multiseriate, when the latter, opposite; pits chiefly confined to the radial walls, but in some species on the tangential walls of the late wood.

Pinus baumani new species

Annual Rings—Well marked, late wood dense, the transition abrupt; diameter of tracheids in early wood averaging 58 μ.

Resin Canals—Present in both directions, the vertical with one or occasionally two rows of thin-walled secretory cells; the horizontal canals in

fusiform rays slightly attenuated; vertical canals not abundant, confined chiefly to the latter half of the ring of growth.

Wood Rays—Few to 20 cells high, chiefly 6 to 10; ray tracheids marginal or interspersed, rays often constricted near these interspersions, sparingly dentate, heavily pitted on all walls; parenchyma pitted on all walls, the lateral medium sized and of the oopore or slightly bordered type, 2 to 4 per tracheid field. The whole ray with a narrow and linear aspect due to the oblong to oval shape of the elements as viewed in tangential section.

Wood Parenchyma—Absent.

Tracheids—Pitting chiefly uniseriate, bars of Sanio present.

Medulla—Not observed.

A number of specimens of this wood are at hand. In all cases the annual rings are well developed, and an abrupt transition between the early and late wood is observable. The resin canals occur sparingly and are confined with few exceptions to the latter half of the ring. One of the most noticeable contrasts between this wood and that of *P. fallax* is found in the number of resin ducts present. The rays are chiefly low, and the constituents show narrow and oblong lumens when viewed in tangential aspect. They are typically pinoid of the section *Scleropitys.*[1] Marginal tracheids are present and show a poorly preserved dentate condition. The parenchyma of the rays likewise is characteristic of the genus, pits being of the oopore or slightly bordered types. The tracheids show pits chiefly in one row and separated by well-marked bars of Sanio. The fusiform rays, which are not abundant, are narrow and slightly attenuate.

This wood is typical of the hard pine group, showing not only the dense late wood indicative of that section, but likewise the characteristic ray tracheids. Attempts to compare it with previously described species have met with little success so far as the fossil forms are concerned. Among the modern pines affinity to a number is suggested, but no indications of specific identity have been observed in the material examined. With the Cretaceous and Eocene woods of the Atlantic seaboard [2] no great affinity is suggested. *Pityoxylon peali* [3] from the nearby Upper Gallitin Basin seems similar to this fossil in many respects. Since these deposits were not visited during the 1929 reconnaissance, no materials of this species are available for comparison. The illustrations accompanying the original description are not sufficient to verify any determination.

Occurrence—Fossil Forest, Specimen Ridge.

Collection—Univ. Calif. Col. Pal. Bot. No. 1278; slides 1278 a-f.

In Plate 3, figures 1 and 6, and plate 6, figure 2, are transverse sections which show the abrupt transition from early to late wood. The resin ducts are not nearly so numerous as in *P. fallax.*

In plate 3, figures 3 and 5 are sections showing the appearance of the wood in radial view. Figure 3 shows some of the details of the tracheid pitting. In figures 2 and 4 the fusiform rays appear less attenuate than is the case in *P. fallax.* The elements composing the rays are oblong to oval.

[1] I. W. Bailey, Amer. Nat., vol. 44, 284-293, 1910; E. C. Jeffrey and M. A. Chrysler, Bot. Gaz., vol. 42, 4, 1906.

[2] E. C. Jeffrey and M. A. Chrysler, Bot. Gaz., vol. 42, 1-14, 1906; Ruth Holden, Proc. Amer. Acad. Arts and Sci., vol. 48, 609-623, 1913; I. W. Bailey, Annals Bot., vol. 25, 315-325, 1911.

[3] F. H. Knowlton, Bull. Torr. Bot. Club, vol. 23, 251, pl. 271, 1896.

Pinus fallax (Felix) new combination

Pityoxylon fallax Felix, Zeitschr. Deutschr. d. Geol. Gesell., 254, Jahr. 1896.
Pityoxylon aldersoni Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, 763, 1898.
Pityoxylon amethystinum Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, 764, 1898.

Annual Rings—Well marked, characteristically wide, the transition from early to late wood gradual, late wood forming an indeterminate zone as a result of transition; average diameter of early wood tracheids about 45 μ.

Resin Canals—Present in both directions; large, numerous, scattered throughout the whole ring; chiefly single but occasionally in pairs or threes, then fused laterally; secretory cells in one or two rows, thin walled; thyloses not observed; horizontal ducts smaller than vertical, in narrow, attenuate fusiform rays.

Wood Rays—Chiefly uniseriate, except those bearing resin canals; few to 18 cells in height, chiefly low; cells broadly oval as viewed in tangential section; tracheids of rays marginal and abundantly pitted; parenchyma with several large oopores per cross field, typically abietinean.

Wood Parenchyma—Absent.

Tracheids—Pitting of the pinean type, pits in 1 or 2 series; when the latter, they are opposite.

Medulla—Large, sclerotic.

Several writers have commented on the similarity of *P. aldersoni* to *P. amethystinum*. Penhallow [1] was inclined to regard them as identical. A study of the material recently collected, as well as the slides of the type material, has convinced the writer that separation is impossible. Further, it becomes necessary to place these species in synonymy with *P. fallax* (Felix), the nature of which is known as result of a restudy of the slides by Platen.[2]

While the material available does not compare in excellency of preservation with the other species of pine described in this paper, the fossil is so interesting as to merit a full discussion. The unusually broad rings of growth and the abundance of resin canals, which are often present throughout the whole of the annual increment, give the wood a very characteristic appearance. The structure is open and the transition gradual. Low, uniseriate rays made up of elements which appear oval or even broadly angular in tangential section distinguish this wood from *P. baumani;* likewise the occasional laterally bulging walls of the parenchyma cells suggest a diagnostic character. The fusiform rays are more attenuate than in the other Yellowstone species. In some respects this fossil bears a resemblance to certain California coastal pines of the closed cone section, possibly superficial, but certainly strengthened by the occurrence with *Sequoia.*

The writer has been fortunate in securing a well-preserved branch of this species. The protoxylem is, of course, endarch; numerous canals abut directly on the primary wood and on the pith in the interfacicular areas. This is regarded as a character of great diagnostic worth in the recognition of members of the group *Scleropitys,* [3] into which this pine is placed.

Among the Tertiary pines, the only one comparable is *Pinus* (*Pityoxylon*) *columbiana* [4] from the Kettle River Oligocene deposits. As described, the general habit of growth suggested by the rings is the same. The

[1] D. P. Penhallow, *North American Gymnosperms,* 346-347, 1907.
[2] P. Platen, *Prometheus,* vol. 20, 241-246, 1909.
[3] E. C. Jeffrey and M. A. Chrysler, Bot. Gaz., vol. 42, 4.
[4] D. P. Penhallow, *North American Gymnosperms,* 348, 1907.

height of the rays and the shape of the individual cells likewise afford features of similarity. A comparison of the pitting of the Yellowstone pine with Penhallow's species can not be made, since these details are not even well enough preserved to allow detailed observation. Both species show characters which place them in the *Insignis* or hard-pine group. They differ in the much lower rays and in the presence of resinous parenchyma in large areas surrounding the resin canals—all characteristics of *Pinus columbiana.*

Occurrence—Specimen Ridge, Fossil Forest, Yancey Forest, Crescent Hill. This wood is common at most outcrops of the breccia.

Collection—U. S. Nat. Mus. Col. Pal. Bot. No. 110-11, 12; 122-24; 131-33; 158-63. Univ. Calif. Col. Pal. Bot. No. 1279; slides 1279, a, b; 1280 a-e.

Plate 2, figures 1 and 2, and plate 5, figures 4 and 6, show the very characteristic appearance of the wood in transverse section, including the abundant resin canals, the gradual transition from early to late wood, and the very wide rings.

Plate 2, figures 3 and 4, show the general appearance of the linear and fusiform rays. Figures 5 and 6 are introduced to show the pitting of the tracheids and the general aspect of the rays. In none of the material examined was there detail of ray pitting.

In plate 6, figure 3, the pith and the primary and adjacent secondary wood are seen. The pith is sclerotic in places and the resin canals are situated almost directly on the metaxylem, suggesting that reference should be made to the section, Scleropitys.

TRIBE TAXODINEÆ

Genus SEQUOIA Endl. Syn. Conif. 197. 1847

Annual Rings—Present, late wood usually distinct as compared with early wood, transition abrupt; rings rather narrow but variable in width.

Resin Canals—Traumatic only, in one or both directions, small vertical canals usually in tangential series, secretory cells with ligneous walls in one or several rows, thyloses commonly present.

Wood Rays—Linear rays uniseriate or partly biseriate; ray tracheids absent except when recalled by traumatism; upper and lower walls of ray parenchyma cells thin and rarely pitted, lateral walls with a few pits, these with the orifices slightly bordered or broadened into oopores. Resin commonly present.

Wood Parenchyma—Diffuse, not distinctly zonate, abundant, chiefly in early wood, resinous, cells large, prominent.

Tracheids—Variable in size in the different parts of the ring; bars of Sanio present; radial walls strongly pitted with bordered pits in one or two rows (occasionally more), opposite in cases of bi- or multi-seriation, tangential walls pitted in the late wood of some species.

Sequoia magnifica Knowlton

Cupressinoxylon eutretron Felix, Zeitschr. deutsch. d. Geol. Gesell., 225, Jahr. 1896.[1]

Sequoia magnifica Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, 761, 1899.

Annual Rings—Well developed, variable but usually narrow, zone of summer wood only a few cells wide, transition abrupt; tracheids of early wood averaging about 64 μ in diameter.

[1] This reference is made provisionally. Platen has stated that *C. eutretron* seems referable to *Sequoia*, but since no figures have been seen by the writer, no attempt is here made to place the species in complete synonymy.

Resin Canals—Not observed.

Wood Rays—Uniseriate or biseriate in part, height few to 20 cells, chiefly 10 to 16, narrow; terminal and upper walls unmarked; lateral walls with 2 or 3 medium-sized oval oopores per cross field.

Wood Parenchyma—Abundant diffuse, or in some cases zonate in the latter half of the ring; filled with drops of resinous secretions; lumens smaller and more flattened than the surrounding tracheids.

Tracheids—Variable in size in different parts of the ring; pitting commonly in one row, but occasionally in two, then opposite; bars of Sanio present.

Medulla—Not observed.

While the most complete records of fossil Sequoias are those of leaves, several woods have been recorded. These are listed below.

TABLE 2—*The occurrence of woods of Sequoia.*

Species	Taramie Cretaceous	Porcupine Creek Eocene	Bear River Eocene	Cochrane Eocene	Lamar Valley	Auriferous Gravel	California Pliocene	California Pleistocene
S. langsdorfii		X	?	?				
S. burgessii	X	X						
S. (?) penhallowii						X		
S. montanense	X							
S. dakotense	X							
S. laramiense	X							
S. magnifica					X			
S. sempervirens							X	X

The oldest authentic record of *Sequoia* wood which has come under the writer's observation is from the Laramie beds of the Rocky Mountain and Great Plains regions.[1] Penhallow[2] has compared *Sequoia burgessii* from these strata with *S. magnifica* and has remarked that—

"*S. burgessii* resembles this fossil in many essential features, but differs from it in the very essential fact that it has conspicuous resin canals in the medullary rays, which Dr. Knowlton . . . states . . . are certainly wanting in *S. magnifica.*"

The writer has had occasion to examine a great many specimens of *S. magnifica* and has in no case observed traumatic passages. Torrey[3] recently described a wood attributed to *S. burgessii* from the Laramie of Colorado in which the details of ray pitting are described. A similarity to *S. magnifica* is observed in the number of pits per cross field and their size.

With *Sequoia langsdorfii*, woody remains of which were described by Penhallow[4] from the Great Valley Group of British Columbia, this fossil likewise finds some points of agreement. The sporadic occurrence of resin

[1] R. E. Torrey, Mem. Boston Soc. Nat. Hist., vol. 6, No. 2, 74-80, 1923.

[2] D. P. Penhallow, Royal Soc. Canada, Trans., 2d ser., vol. 9, sec. 4, 42, f. 5-8, 1903.

[3] R. E. Torrey, Mem. Boston Soc. Nat. Hist., vol. 6, No. 2, 79-80, 1923.

[4] D. P. Penhallow, *Manual North American Gymnosperms*, 226, 1907.

canals can not be taken into consideration as a character which allows separation of the two. These are occasional on the outer face of the late wood in *S. langsdorfii,* there probably traumatic. The general aspect of the rays, including the height, seriation and shape of individual cells as viewed in tangential section suggests a strong similarity if not identity. Since the lateral ray pits in *S. langsdorfii* were not seen, the affinity of this wood and its synonymy with other species must remain in doubt.

Returning to the resin ducts, Jeffrey [1] and his students have pointed out that in these older woods there is a striking tendency toward the development of resin canals as the result of traumatic stimuli—much greater than is the case with the later Tertiary and modern Sequoias. Much emphasis has been placed on this decreasing tendency as a feature of phylogenetic worth. No evidence of traumatism in the Yellowstone species has been noted in the great quantity of materials which has passed through the writer's hands during the course of the field and laboratory studies.

With regard to the anatomical details of *Sequoia magnifica,* the wood has a distinctly modern aspect. The annual rings show a definite demarcation between the early and late wood, and the resin cells are often confined to the latter half of the ring of growth. In tangential aspect the rays are quite variable in height and show the Sequoian feature of partial biseriation. The pitting of the rays is confined to the lateral walls and is of the small oval oopore type. It is the small number of these per tracheid field which definitely sets this species off from *S. sempervirens.* The tracheids show more common uniseriate than biseriate pitting and, when the latter is the case, the pits are opposite. Bars of Sanio have been observed in well-preserved areas.

In one locality a number of standing stumps still ensheathed in the bark were found. An alternation of thin-walled parenchymatous elements with lenticular masses of thick-walled fibrous cells characterizes this tissue system; manifestly identical with the bark cut off by modern Sequoias. Unfortunately the inner portion is entirely replaced by silica and the structure obliterated. In none of the material collected was it possible to observe the cambial cells and their more immediate derivatives—the uncrushed phloem elements.

Occurrence—Specimen Ridge, Fossil Forest, Yancey Forest, Crescent Hill. This wood is common at all outcrops of the plant-bearing breccias.

Collection—U. S. Nat. Mus. Col. Pal. Bot. No. 143-150; 155-157. Univ. Calif. Col. Pal. Bot. No. 1282; slides 1282 a-d; 1041 a, b.

In plate 1, figures 1 and 2, and plate 6, figure 1, the sharp contrast and the abrupt transition between the early and late wood in the rings of growth characteristic of most *Sequoia* woods can be seen. Scattered throughout the rings, but particularly in the latter half, are numerous resin cells.

The general aspect of the wood in radial section is seen in figure 3 of Plate 1. Figure 5 of Plate 1 and figure 6 of plate 4 show details of the rays and present the pitting of the tracheids. Numerous resin cells are seen in the sections.

In Plate 1, figures 4 and 6, the heights of the rays and their partly biseriate condition are shown in tangential sections. Resinous parenchyma cells are present in these views.

Plate 5, figure 5, is a transverse section of bark and shows the nature of the Sequoian bark found associated with the trunks.

[1] E. C. Jeffrey, Proc. Nat. Acad. Sci. vol. 11, No. 1, 101-105, 1925.

TRIBE CUPRESSINEÆ

Genus CUPRESSINOXYLON Goeppert

The genus *Cupressinoxylon* in its present usage includes woods of a number of genera and has been used as a depository for a great many species whose true reference can not be ascertained because of faulty preservation. The general type of *Cupressinoxylon* is conservative and is met with in a number of genera. Consequently it is with extreme difficulty that segregation can be made even in well-preserved material. The diagnosis is as follows:

Annual Rings—Present, variable.

Resin Canals—Absent.

Wood rays—Uniseriate or occasionally biseriate in part, height varying widely, ray cells entirely parenchymatous, pitting mostly on lateral walls, these small and chiefly 1 to 6 per cross field.

Wood Parenchyma—Diffuse, extremely variable in quantity and distribution; resinous.

Tracheids—Bars of Sanio present, bordered pits usually on the radial walls but in some genera also on the tangential walls in 1 or 2 (occasionally more) rows; when the latter, opposite.

Cupressinoxylon lamarense, new species

Annual Rings—Distinct, irregular in contour and in width; late wood forming a narrow and dense zone, transition rather gradual except in wounded regions; average diameter of tracheids in early wood of ring 34 μ.

Resin Canals—Absent.

Wood Rays—Uniseriate, few to 22 cells in height; pitting confined to the upper and lower and lateral walls, there small oculipores (?); in tangential section the rays narrow, cells oval or slightly oblong, resinous in places.

Wood Parenchyma—Occasionally present; then not in any regular arrangement.

Tracheids—Pitting seldom observable; apparently uniseriate.

Medulla—Not observed.

The material upon which this species is based was obtained from two logs, one in the Yancey Forest [1] and the other on Specimen Ridge.[2] Neither log showed preservation worthy of favorable comment.

The occurrence of masses of wounded tissue has caused the writer to make a careful study of this wood in the hope that the traumatism might suggest the systematic position of the material. This can not be satisfactorily determined by a study of the normal tissues since they are without detail of preservation. The yearly increments show a gradual transition from early to late wood. One of the most noticeable features of the wood is brought out clearly in the transverse section. Depressions in the rings of growth are to be seen at certain points where dense masses of tracheary tissue assume the superficial appearance of aggregated rays. Pronounced discordances of annual rings are likewise present in these areas. The only satisfactory explanation of this condition is that these represent wounded areas; the contour suggests a traumatic reaction to pressure of some sort. A careful study has failed to reveal the presence of canals in the abnormal tissue. This fact is of importance since it immediately eliminates members of the abietinean alliance from the discussion.

[1] "Yancey's Forest" refers to the group of fossil stumps below Lost Lake and approximately one and one-half miles by road from Tower Falls Ranger Station.

[2] Collected in the talus at the base of Specimen Ridge.

In the transverse section there appear numerous cells which bear a resemblance to resinous tissue. Longitudinal sections show that in most instances these are not resin parenchyma cells, but tracheids filled with dark masses of partially decayed ligneous materials which have become detached from the cell walls. Strands of true wood parenchyma occur only infrequently. In the transverse section they may be distinguished by the flattened lumens which are of less radial diameter than the surrounding tracheids.

The rays are normally of less than medium height, and in the traumatic areas they appear low. The individual components are elongate oval; the rays consequently narrow. The discordance of the tracheids is very pronounced in traumatic areas sectioned in the tangential plane. Details of pitting are scarcely discernible. Numerous small pits appear to have been located on the upper and lower as well as on the lateral walls. The tracheids likewise fail to show details, but occasionally traces of uniseriate bordered pits are seen. Other markings which may have been present on the tracheal walls are not preserved.

In a number of respects this wood bears a resemblance to genera of the Taxaceæ. The paucity of resin cells even in the traumatic areas agrees well with the observations of Bliss.[1] Seward[2] states that taxaceous genera can only be separated from *Cupressinoxyla* on the basis of the presence of spiral tracheids in the secondary wood. In this respect, the Lamar Valley wood presents a negative characteristic, but the practical value of this criterion must be modified by the obvious fact that spiral markings can not be expected in other than the best-preserved petrifactions.

The reference of this wood to *Cupressinoxylon* must be made on purely anatomical grounds. Its true affinities are open to question, since the wood shows certain characteristics which suggest a taxaceous alliance, an affinity further borne out by the presence in the associated deposits of leafy twigs referable to *Torreya.*

Occurrence—Yancey Forest, Specimen Ridge.

Collection—Univ. Calif. Col. Pal. Bot. No. 1281; slides 1281 a-g.

Plate 4, figures 1, 2 and 3, and plate 5, figures 1 and 3 show the appearance of the wounded areas as contrasted with the normal wood. No evidences of traumatic ducts can be seen. Many of the cells which suggest resin parenchyma are tracheids which have been filled with material detached from the cell walls.

In Plate 4, figure 5, and plate 5, figure 2, the contrast between wounded and unwounded wood as it occurs in tangential section is seen.

Plate 4, figure 4, shows the general aspects of the radial section.

[1] M. C. Bliss, Bot. Gaz., vol. 66, 54-60, 1918.

[2] A. C. Seward, *Fossil Plants,* vol. 4, 202-203, 1919.

CONCLUSIONS

1. The woody remains of the Lamar River flora contain four species of conifers. The presence of these is abundantly confirmed by the associated leaf and cone impressions.

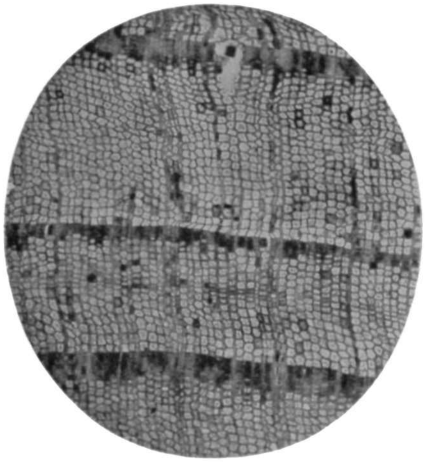
2. *Sequoia magnifica* is characterized by a type of wood which is of a distinctly modern aspect and is closely allied to the present day *Sequoia sempervirens*.

3. Additional proof of the validity of this reference to the genus *Sequoia* is furnished by the presence of bark of the type characteristic of that genus.

4. Two species of the genus *Pinus* are recorded in the flora, *P. baumani* and *P. fallax*. Both are of the section *Scleropitys* as is shown in *P. baumani* by the ray tracheids which bear the characteristic irregularities of the walls, and in *P. fallax* by the presence of resin ducts in several rows in the first ring of growth, the innermost abutting on the primary wood.

5. These pines are of advanced types and suggest that the genus, *in its most restricted definition,* was established by Upper Eocene or Lower Oligocene times.

6. *Cupressinoxylon lamarense* is a wood of the general type of the *Cupressinoxyla,* but the paucity of resin cells even in the wounded areas suggests an affinity to the Taxaceæ. This is further borne out by the presence of leafy twigs in close association which are referable only to *Torreya.*



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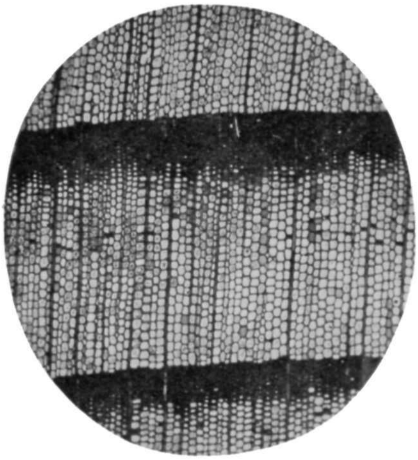

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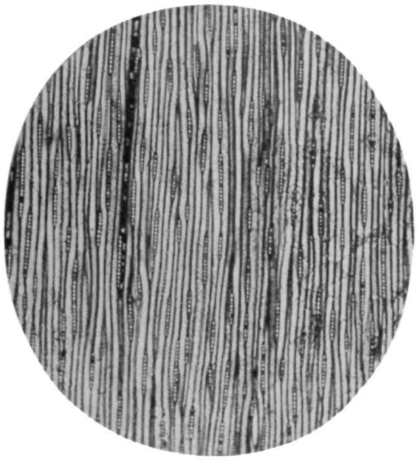

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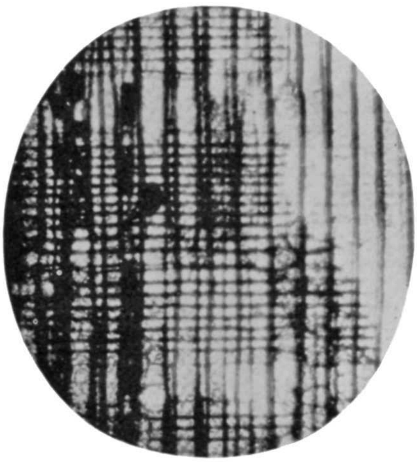

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Sequoia magnifica

FIG. 1—Transverse section. × 40.
FIG. 2—Transverse section. × 40.
FIG. 3—Radial section. × 40.
FIG. 4—Tangential section. × 40.
FIG. 5—Radial section. × 120.
FIG. 6—Tangential section. × 120.

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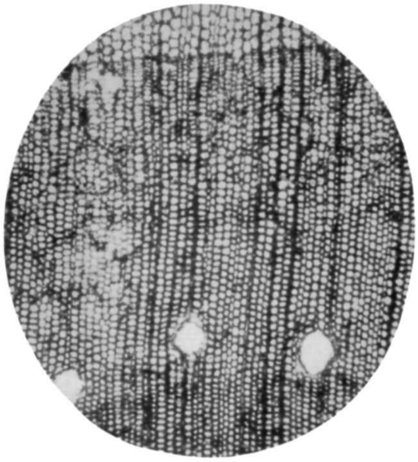

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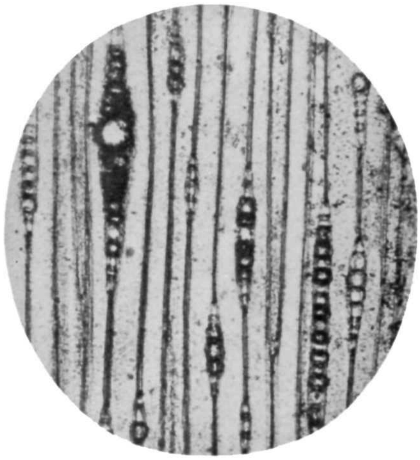

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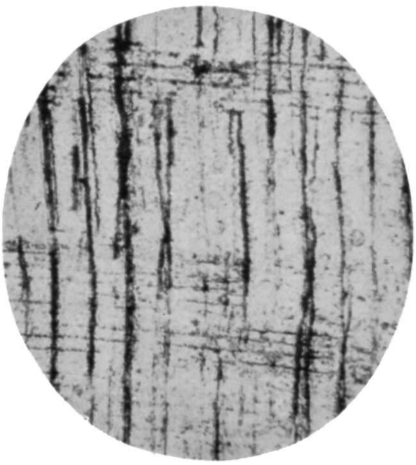

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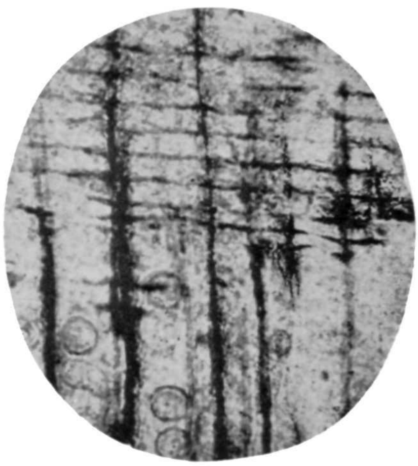

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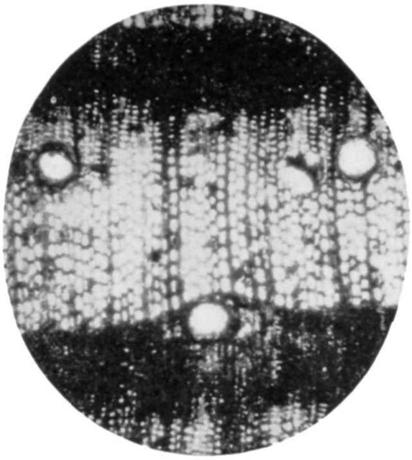
Pinus fallax

FIG. 1—Transverse section. × 8.
FIG. 2—Transverse section. × 40.
FIG. 3—Tangential section. × 120.
FIG. 4—Tangential section. × 120.
FIG. 5—Radial section. × 120.
FIG. 6—Radial section. × 200.



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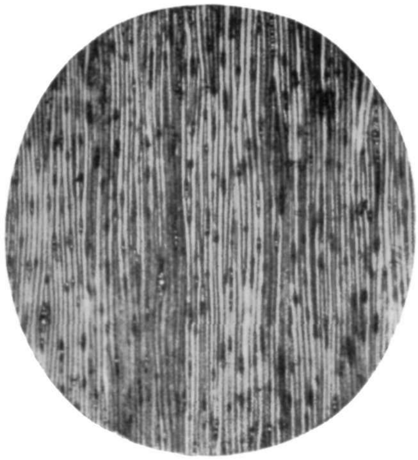

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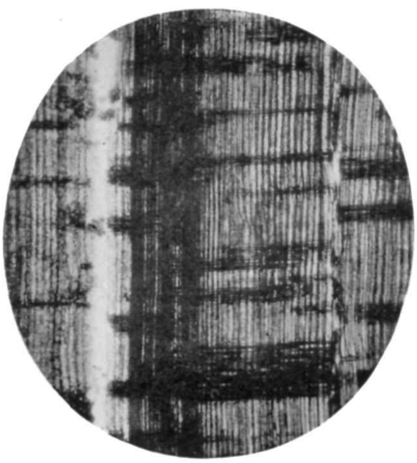

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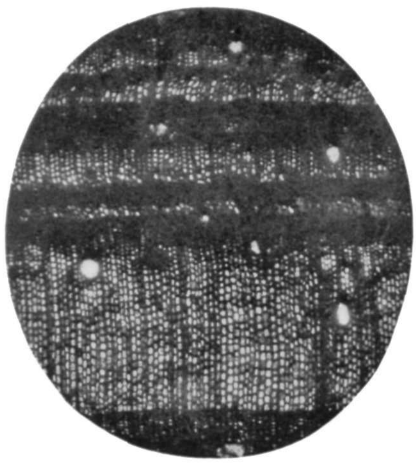

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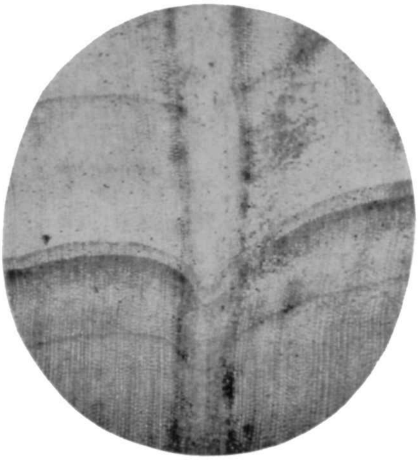
Pinus bowanii

Fig. 1—Transverse section. × 80.
Fig. 2—Tangential section. × 25.
Fig. 3—Radial section. × 200.
Fig. 4—Tangential section. × 120.
Fig. 5—Radial section. × 25.
Fig. 6—Transverse section. × 25.



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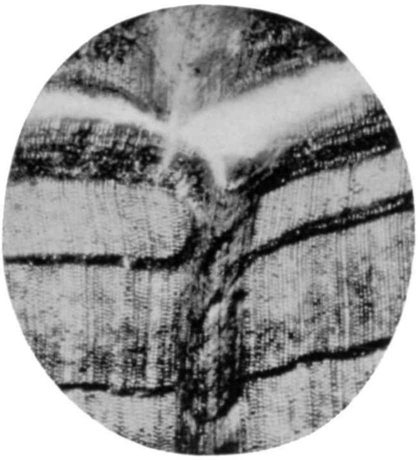

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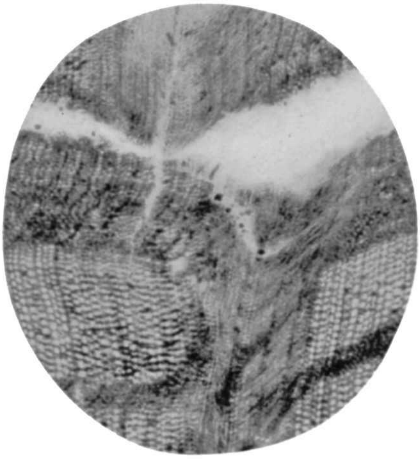

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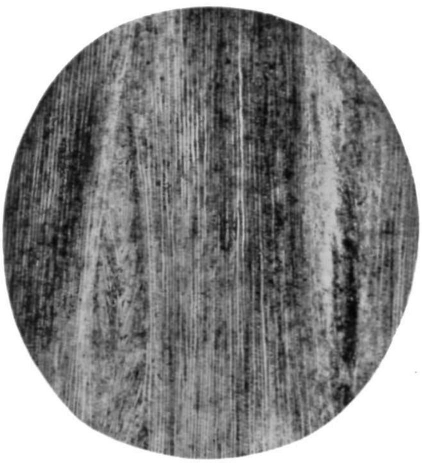

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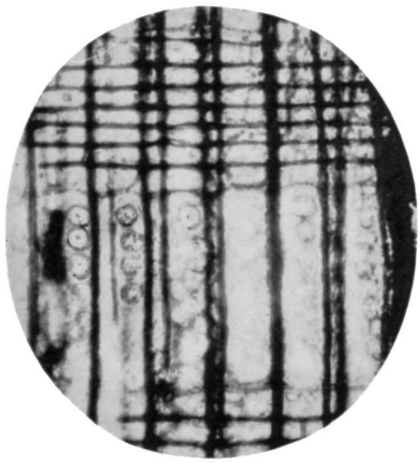

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Cupussinoxylon lamarense

FIG. 1—Transverse section. × 25.
FIG. 3—Transverse section. × 40.
FIG. 5—Tangential section. × 25.

FIG. 2—Transverse section. × 25.
FIG. 4—Radial section. × 25.

Sequoia magnifica. FIG. 6—Radial section. × 180.

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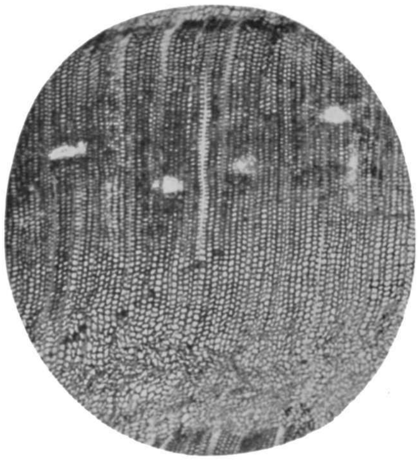

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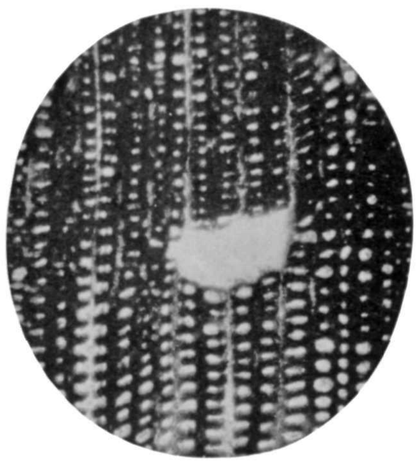

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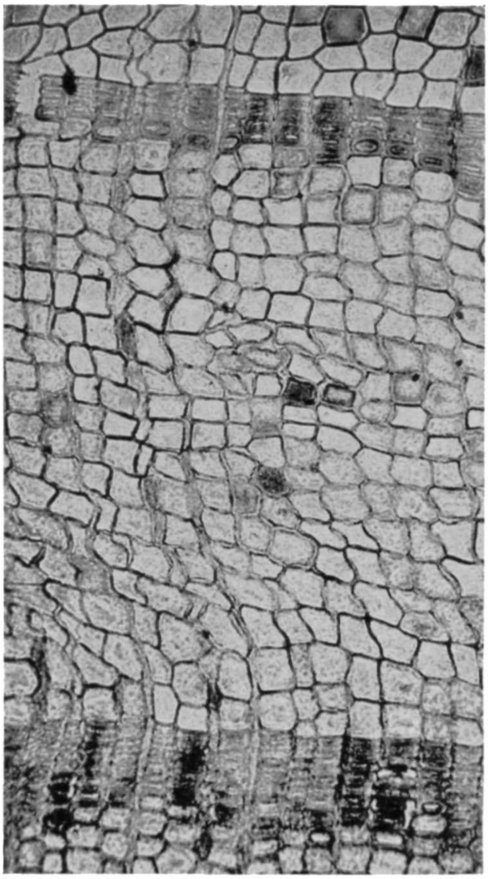
Cupressionoxylon lamarense

FIG. 1—Transverse section. × 60. FIG. 2—Tangential section. × 60.
FIG. 3—Transverse section. × 40.

Pinus fallax

FIG. 4—Transverse section. × 40. FIG. 6—Transverse section. × 120.

Sequoia magnifica. FIG. 5—Transverse section. × 140.



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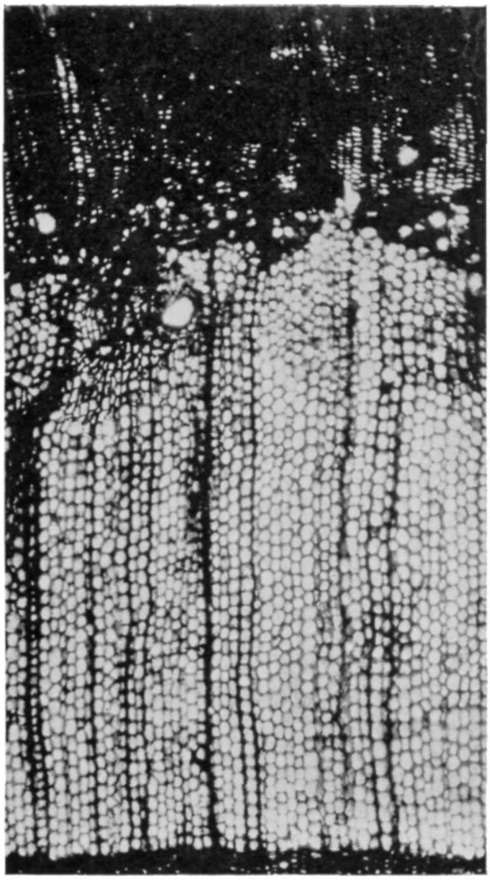

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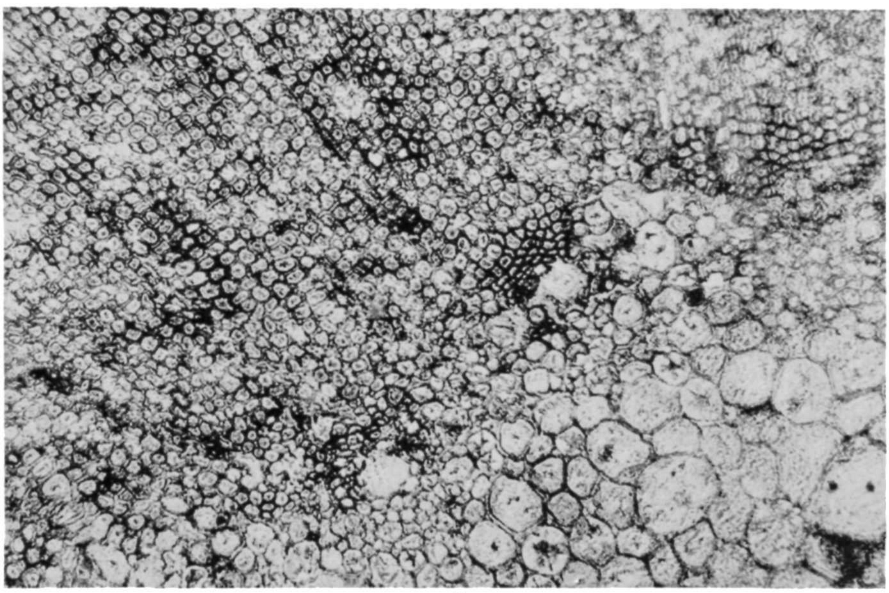

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Fig. 1—*Sequoia magnifica*, transverse section. × 120.
Fig. 2—*Pinus bowanii*, transverse section. × 75.
Fig. 3—*Pinus fallax*, transverse section of primary and secondary wood. × 75.