Anatomical Studies on the Wood of Species of *Picea*, with some Considerations on their Geographical Distribution and Taxonomy

By

Syoji SUDO[1]

Contents

(1) Wood technology division, Dr.

I. Introduction

Picea is one of the most important commercial timber producing genera in Japan as well as in the northern hemisphere of the world. Therfore, it is natural that research works on this genus have been conducted in numerous research fields including taxonomy, morphology, genetics, wood chemistry, forestry, wood anatomy, wood technology, etc.

So far, many reports concerning the wood anatomical characters of this genus have been published since long years ago. Nevertheless, wide gaps still exist in the description of the wood anatomical characters of *Picea* because of the absence of comprehensive studies on this subject in the past. Some correction appears to be also necessary on the previous descriptions for the same reason.

In his previous paper, the present author made minute wood anatomical descriptions on eighteen species and one variety of this genus, and discussed the relations between the sections adopted by REHDER and the wood anatomically separated groups proposed by the author. The author also suggested in the same paper the probable existence of the relation between the geographical distribution and the wood anatomically separated groups.

In referring to the previous reports such as by FUJIOKA[17], KANEHIRA[27][28][29], YAMABAYASHI[58], and SUDO[54] of Japan, and BAILEY[2], BROWN, PANSHIN and FORSAITH[7], BUDCEVICZ[9], GREGUSS[18], KUKACHKA[34], PEARSON and BROWN[42], PENHALLOW[43], PHILLIPS[45], CHENG[52], and TANG[55] of other countries, the author conducted wood anatomical studies with some considerations on the geographical distribution and the taxonomy on thirty-one species and one variety of the genus *Picea*. In carrying out the present study, the author intended to (a) make more detailed descriptions of the wood anatomical characters and grouping of species based on them, and arrange an identification key for species based on the descriptions, (b) discuss the relation between the taxonomical and wood anatomical grouping on more numerous species than those described in his previous paper, (c) ascertain the relation between the geographical distribution and the wood anatomical grouping based on more detailed description of more numerous species than those described in his previous paper[54], and discuss in detail the relations of *Picea* to *Larix* from the view point of wood anatomy, and *Pseudotsuga* of Pinaceae, (d) find the pattern of the main wood anatomical characters in relation to distance from pith and to growth rate, and the difference between the root and the stem by the observation on root wood of several native species in comparison with the stem wood.

These results will be of much help in gaining an understanding not only of the wood anatomical characters which so far have been generally believed to be uniform, but also of the phylogeny of *Picea*.

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II. Species and sections of genus *Picea*

According to Rehder[50], there are about forty species found in the nothern hemisphere. Dallimore and Jackson[12] have described thirty-eight species. Attention should be paid to the fact that, of these described species, Chinese species have not yet been fully established taxonomically, and also the fact that certain name changes and reduction in the number of species are expected in future with the progress in research, as mentioned by Wright[57]. Rehder[50], and Dallimore and Jackson[12] have described twenty-three and eighteen Chinese species of *Picea* respectively. Moreover, Hu[22] has described thirteen Chinese species including species which are also found in Japan and Russia. Cheng[52] mentioned in his recent work about sixteen species distributed in China.

In general, the existence of two or three sections in this genus is taxonomically accepted. Rehder[50] divided this genus into three sections, Eupicea, Casicta, and Omorica, and the others such as Dallimore and Jackson[12], Iwata and Kusaka[23], and Tsin[10] divided it into two sections, namely Eupicea and Omorica. Moreover, Wright[57], based on the distributional and genetic data together with morphological characters, stated that there is no natural break in the genus sufficient to warrant the erection of section lines, and that there are sufficient data to sketch probable phylogenies for several groups of species if not for the genus as a whole, namely *P. rubens-mariana* group of eastern America, northwest American group, Japanese species, southwestern Chinese and Formosan species, Himalayan species, north Eurasian and north Chinese species, and *P. orientalis*.

Table 1. List of species examined

Species examined	No. of specimens	Distribution	Remarks
Picea abies (L.) Karst.	8	Wide distribution in Europe, Yugoslavia to Scandinavia.	
P. asperata Mast.	3	Hopei, Shansi, Shensi, Kanshu, northwestern Szechuan, China.	
P. balfourniana Rehd. et Wils.	1	Western China.	Branch wood
P. bicolor (Maxim.) Mayr.	3	Central Honshû, Japan.	
P. brachytyla (Franch.) Pritz.	2	Northwestern Hupei, eastern Schechuan, China.	
P. breweriana S. Wats.	5	Southwestern Oregon, northern California, U. S. A.	
P. chihuahuana Martinez.	1	Northern Mexico.	
P. engelmanni (Parry) Engelm.	5	British Columbia, Alberta to Oregon, Arizona, New Mexico, North America.	
P. glauca (Moench) Voss	6	Labrador to Alaska, southward to Montana, Minnesota, New York, North America.	
P. glehnii (Fr. Schmidt) Mast.	6	Southern Sakhalin, Hokkaido of Japan.	
P. jezoensis (Sieb. et Zucc.) Carr.	7	Hokkaido, Japan.	
P. j. var. *hondoensis* (Mayr) Rehd.	7	Central Honshû, Japan.	
P. koraiensis Nakai	3	Korea, northeasteran China, Siberia of U. S. S. R.	
P. koyamae Shirasawa	3	Central Honshû of Japan.	
P. likiangensis (Franch.) Pritz.	3	West of Tachienlu of Szechuan, Likiang, Tali of Yunnan, China.	
P. mariana (Mill.) B. S. P.	6	Alaska to Newfoundland, central Minnesota to northern New Jersey, North America.	
P. maximowiczii Regel	3	Central Honshû, Japan.	
P. meyeri Rehd. et Wils.	1	Western China.	Branch wood
P. montigena Mast.	2	Tachienlu in western Szechuan, western Yunnan, China.	
P. morrisonicola Hayata	4	Taiwan.	
P. obovata Ledeb.	1	Northern Europe, Siberia to Asian U. S. S. R.	Branch wood
P. omorica (Pancic) Purkyne	3	Southwestern Yugoslavia.	
P. orientalis (L.) Carr.	2	Caucasus mountains to Turkey.	
P. polita (Sieb. et Zucc.) Carr.	5	Shikoku, Kyushu, Honshû, Japan.	
P. pungens Engelm.	6	Colorado to New Mexico, Utah, Wyoming, U. S. A.	
P. purpurea Mast.	2	Kuan Hsien, Tachienlu in western Szechuan, China.	Branch wood
P. rubens Sarg.	7	Southern Appalachians to Maritime Provinces of Canada.	
P. shirasawae Hayashi	1	Central Honshû, Japan.	Branch wood
P. sitchensis (Bong.) Carr.	8	Pacific coast region, Alaska to northern California, North America.	
P. smithiana Boiss.	4	Western Himalaya.	
P. spinulosa (Griff.) Henry	2	Eastern Himalaya.	
P. wilsonii Mast.	2	Hopei, Shansi, Kansu, Szechuan, Hupei, Shensi, China.	

III. Materials

Of the specimens examined in this work, some are from foreign research institutes and universities as mentioned in the previous chapter, and the others are from the wood collection of the Institute of Forest Botany, Faculty of Agriculture, the University of Tokyo and the Wood Technology Division, Government Forest Experiment Station. Number and localities of the specimens examined for each species are listed in Table 1.

At the present stage, thirty to forty species of this genus are recognized in the northern hemisphere. Therefore, thirty-one species and one variety examined here represent the majority of species of this genus. But *P. schrenkiana*, one of the representative Chinese species, regrettably has not been examined because of the lack of the specimen. Concerning this species, there are fortunately some descriptions given in the previous reports[9)18)52)], and CHENG[52)] shows a photograph of radial section of *P. schrenkiana* which has been very helpful in comparing it with the others.

For some species, only branch or young stem wood specimens have been examined. The author has been careful not to make mistakes of confusing descriptions of the characters of branch or juvenile wood with those of adult wood. For adjustment of descriptions on such specimens, the author made some observations on the variation pattern of the main wood anatomical characters according to the difference of parts, branch and stem, and of ring number for species of which fully matured stem specimens together with branch specimens were available, and discusses it in a later chapter. And he wishes to stress the necessity of such adjustment of the results on the specimens taken from younger wood such as branch wood not only for this genus but also for other genera. It was by making such adjustment as mentioned above that he was able to make descriptions of the important characters of all species examined and discussed. In practice, for this reason the author made particular statement on the ring number or distinction of branch, juvenile and adult, in the description of the main wood anatomical characters if necessary.

IV. Description on the wood anatomical characters of the species*

1. *Picea abies* (L.) KARST.: Norway spruce, Common spruce, European spruce. (Photos. 1, 27, and 56)

* Note Explanation of Abbreviations, and Figures 1 and 2.
S.: Length of the shorter axis of epithelial cells.
R.: Radial diameter of tracheids.
: Radial diameter of axial resin canals.
T.: Tangential length of ray parenchyma cells on the tangential surface.
: Tangential diameter of tracheids.
: Tangential diameter of axial and radial resin canals on the transverse and tangential surface respectively.
Th.: Thickness of cell wall.
V.: Axial length of ray parenchyma cells on the tangential surface.
Fig. 1: Type of ray cells.
A.: Ray cells generally rectangular, oval and elliptical on the tangential surface.
B.: Ray cells generally almost square, or round on the tangential surface.
Fig. 2: Type of fusiform rays.
A.: Epithelial cell of radial resin canals directly contact with axial tracheids.
B.: Epithelial cells of radial resin canals, at least on one side of the fusiform rays, indirectly contact with axial tracheids, and between them there are other ray cells.

A. **Macroscopical features**

Sapwood white to light yellowish brown, demarcation between sapwood and heartwood not distinct. Summer wood somewhat darker in color and narrower than spring wood. Spring wood wider, and gradually grades into summer wood. Soft and light. Growth ring distinct, delineated by the contrast between spring wood and summer wood. With lustre.

Parenchyma not visible.

Rays: very fine, indistinct to the naked eye, but those with radial resin canals easily visible with a hand lens as whitish lines on the transverse surface.

Resin canals: Radial and axial; the former smaller than the latter, visible with or sometimes barely without a hand lens as whitish lines on the transverse surface and not visible or indistinct with a hand lens on the tangential surface: the latter visible with a hand lens as white flecks, solitary or 2-several tangentially contigeous, rarely for some distance along the ring (probably of traumatic origin) on the transverse surface, sometimes visible as light brown streaks on the longitudinal surface.

B. **Microscopical features**

(1) Arrangement of elements

Tracheids: Regular in radial series: radial diameter gradually decreases from spring wood to summer wood, with end walls when adjacent to epithelial cells encircling axial resin canals and on the wall with bordered pits.

Axial parencyma: Generally wanting.

Rays: Uniseriate, rarely biseriate, and fusiform, (a) uniseriate rays; tangential section rectangular or long oval, classified as A type of Fig. 1, numerous, up to 22 cells in height, frequency distribution of ray height of one of the

Fig. 1 Type of ray cells.

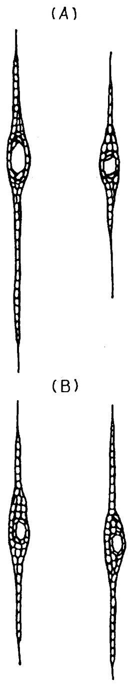


Fig. 2 Type of fusiform rays.

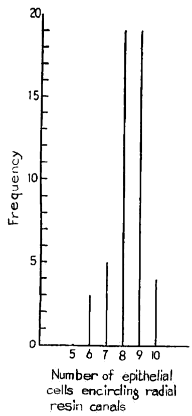


Fig. 3 *P. abies* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.32).

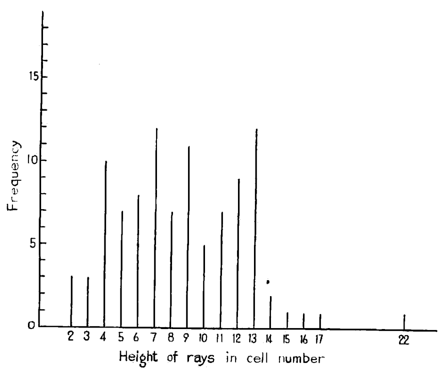


Fig. 4 *P. abies* (adult)
Frequency distribution of height of rays in cell number (Av. 8.86).

specimens shown in Fig. 4, fusiform rays; scattered, not numerous, with one or rarely two radial resin canals in central part, with uniseriate wings on the upper and lower margins of which height up to 11 cells. 4～8 rays found in 1 mm tangential line on the transverse surface. Consist of ray parenchyma cells and ray tracheids, in very low rays, 1～2 cells in height, only ray tracheids found. Ray tracheids generally on the upper and lower margins, occasionally inserted between ray parenchyma cells, generally 1～2 rows.

Resin canals: (a) axial resin canals; mostly found in summer wood and transitional area between summer and spring wood, occasionally wanting from the area of some rings, encircled by epithelium generally in 1 row, partly 2～3 rows, tangential diameter 60～125 μ, of 67 canals, 24 solitary, (b) radial resin canals found in fusiform rays, encircled by epithelial cells, number of the epithelial cells ranges 6～10 (Fig. 3), in the widest central part of the fusiform rays in the tangential section they directly contact with axial elements, not being with any other ray cells between them (Fig. 2-A), tangential diameter up to 30～50 μ. Tylosoids project into radial and axial resin canals, thick-walled and sometimes thin-walled, rarely with pittings.

(2) Description of elements

Tracheids: In spring wood R. up to 50 μ, Th. up to 2 μ, in summer wood R. 6～23 μ. Th. up to 5 μ. T. 7～50 μ. Bordered pits numerous, larger and round on the radial wall in spring wood, less numerous, smaller and with narrow apertures on the radial walls in summer wood, mostly one or rarely paired in part, tangential pitting found in the last few rows of summer wood, radial diameter 7～23 μ. With crassulae. Spiral thickenings found only on the wall of summer wood tracheids in the first few rings, generally not distinct. Tracheid length of one of the specimens 3,400 μ in average.

Ray tracheids: With irregular contour on the margins, often wavy. Walls generally not smooth, with fine dentations. Not frequently indistinct spiral thickenings found on the corner. With bordered pits.

Ray parenchyma cells: Thick-walled, with indentures and end walls nodular. Cross field pitting piceoid, 2～6 per cross field. Often with brownish or yellowish brown contents. V. 14 ～24 μ, T. 8～11 μ.

Epithelial cells: (a) of axial resin canals; generally thick-walled, not infrequently with 1～2 (rarely more) thin-walled cells among them, number of cells increases as the diameter of canals increases, L. 18～50 μ, S. 9～20 μ, end walls nodular, (b) of radial resin canals; generally thick-walled, often with 1～2 thin-walled cells among them per canal, number of the cells nearly constant except juvenile wood, size of the cells increases somewhat as the diameter of the canals increases, L. 12～23 μ, end walls nodular.

Tylosoids: Thick-walled and thin-walled.

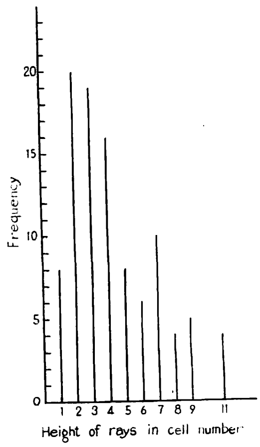


Fig. 5 *P. asperata* (branch wood) Frequency distribution of height of rays in cell number (Av. 4.36).

2. *Picea asperata* Mast. (Photo. 87)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

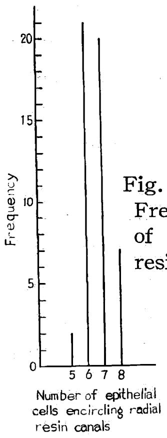


Fig. 6 *P. asperata* (juvenile)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.64).

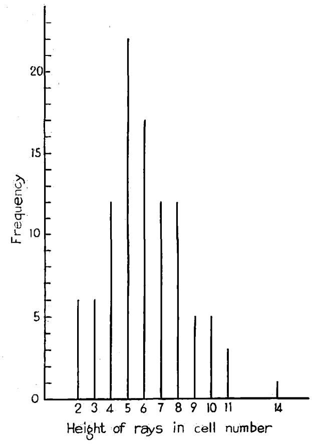


Fig. 7 *P. asperata* (juvenile)
Frequency distribution of height of rays in cell number (Av. 6.12).

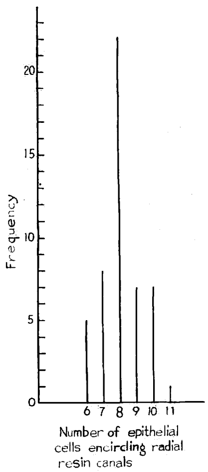


Fig. 8 *P. asperata* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.12).

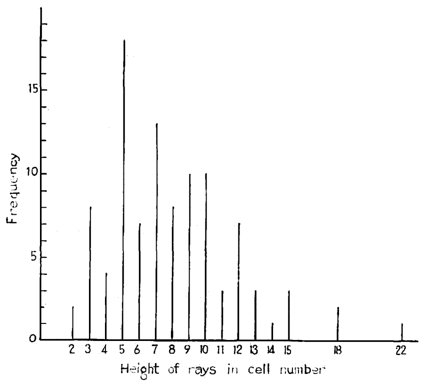


Fig. 9 *P. asperata* (adult)
Frequency distribution of height of rays in cell number (Av. 7.94).

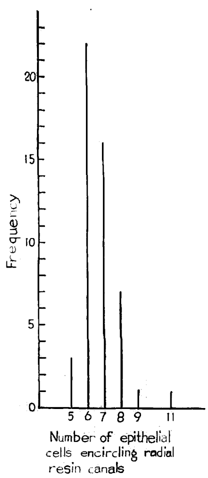


Fig. 10 *P. asperata* (juvenile)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.70).

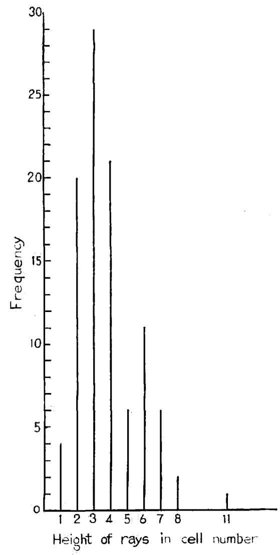


Fig. 11 *P. asperata* (juvenile)
Frequency distribution of height of rays in cell number (Av. 3.80).

Rays: Up to 22 cells in height, examples of frequency of distribution of ray height shown in Figs. 5, 7, 9 and 11. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; tangential diameter 50～137 μ, of 63 canals counted, 27 solitary, (b) radial resin canals; number of epithelial cells encircling the canal 6～11, frequency distribution of the number of cells as shown in Figs. 6, 8 and 10, tangential diameter 25～50 μ.

(2) Description of elements.

Tracheids: In spring wood R. up to 38 μ, Th. up to 3 μ, in summer wood R. 5～25 μ, Th. up to 5 μ, T. 7～48 μ, bordered pits radial diameter 7～25 μ. As a Chinese author[52] mentioned the presence of spiral thickenings on the wall of tracheids of summer wood, were found in summer wood of juvenile part, but very faint. Length 1,700～2,600 μ.

Ray parenchyma cells: 2～6 (2～4) pits per cross field. V. 7～25 μ, T. 5～13 μ.

Epithelial cells: (a) of axial resin canals; L. 12～43 μ, S. 5～15 μ, (b) of radial resin canals; L. 10～25 μ, S. 5～10 μ.

3. *Picea balfourniana* Rehder et Wilson

For this species, only branch wood specimens were available. Therefore, qualitative rather than quantitative description is much more appropriate and description is limited to the more important features. For this reason, features described here reveal more or less the characteristics generally observed in branch wood of this genus.

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Tracheids: Much more irregular in radial series than those of adult wood in stem.

Rays: 1～14 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 12.

Resin canals: (a) axial resin canals; tend to distribute without particular pattern and more or less uniformly diffused, mainly solitary. They are characteristics of juvenile wood.

(2) Description of elements

Tracheids: With spiral thickenings on the wall of tracheids in both spring and summer wood, fairly distinct.

Ray tracheids: With distinct dentations on the wall of ray tracheids and often with spiral thickenings.

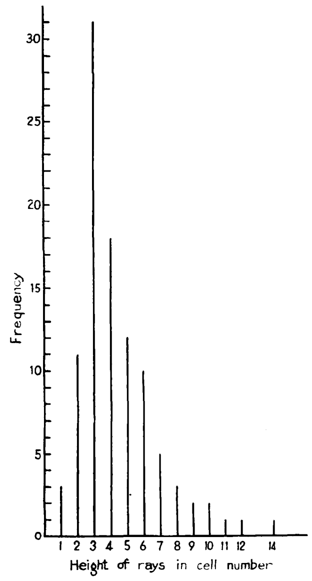


Fig. 12 *P. balfouriana* (branch wood) Frequency distribution of height of rays in cell number (Av. 4.44).

4. *Picea bicolor* (Maxim.) Mayr: Iramomi. (Photos. 28 and 57)

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

Sapwood whitish or very light yellowish brown and heartwood almost the same as that of sapwood, slightly pinkish. And demarcation between them not distinct, but after long exposure, heartwood darkens. Summer wood rather distinct and fine, generally wider than that of

P. jezoensis.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays ; A and B types (Fig. 1), up to 16 cells in height (mostly 2～8), frequency distribution of ray height in one specimen shown in Fig. 14, (b) fusiform rays; with uniseriate wings 2～10 cells in height. Number of rays in 1 mm tangential line on the transverse surface 4～12 (6～8).

Resin canals: (a) axial resin canals; T. 50～110 μ, of 150 canals in one of the specimens, 94 solitary, (b) radial resin canals ; number of epithelial cells per canal 6～10, frequency distribution of the number of cells shown in Fig. 13. T. 32～50 μ.

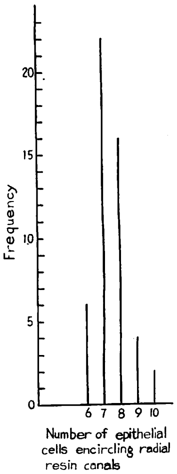


Fig. 13 *P. bicolor* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.47).

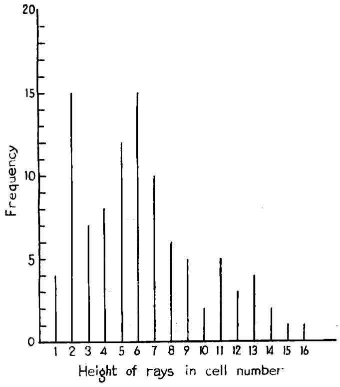


Fig. 14 *P. bicolor* (adult) Frequency distribution of height of rays in cell number (Av. 6.22).

(2) Description of elements

Tracheids: T. 10～43 (15～30) μ. In spring wood R. 12～50 μ, Th. up to 2 μ, in summer wood R. 6～23 μ, Th. up to 5 μ. Bordered pits R. 7～20 μ. Indistinct spiral thickenings found on the wall of tracheids of summer wood, from juvenile part to at most the 30 th ring. L. 5,100 μ.

Ray tracheids: Mostly with fine dentations on the wall, occasionally with rather fairly conspicuous spiral thickenings, particularly on the corner of cells.

Ray parenchyma cells: Pits 2～5 per cross field, sometimes with brownish contents. Sometimes with crystals of calcium oxalate. V. 9～14 μ, T. 13～19 μ.

Epithelial cells: (a) of axial resin canals; L. 16～35 μ, S. 6～13 μ, (b) of radial resin canals; L. 16～35 μ, S. 6～13 μ.

5. *Picea brachytyla* (Franch.) Pritz. (Photos. 29 and 58)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 23 cells in height, frequency distribution of ray height of one of the specimens shown in Fig. 16, (b) fusiform rays; with uniseriate wings up to 9 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 40～125 μ, of 56 canals, 30 solitary, (b) radial resin canals; number of epithelial cells per canal 7～9, frequency distribution of the number of cells in one of the specimens shown in Fig. 15, T. 35～50 μ.

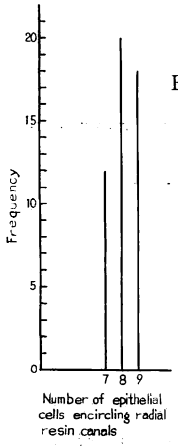


Fig. 15 *P. brachytyla* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.12).

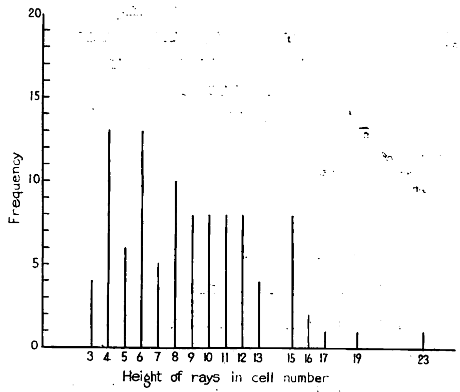


Fig. 16 *P. brachytyla* (adult) Frequency distribution of height of rays in cell number (Av. 8.87).

(2) Description of elements

Tracheids: T. 17～40 μ, in spring wood R. up to 75 μ, Th. up to 2 μ, in summer wood R. 7～30 μ. Bordered pits R. 7～23 μ. With spiral thickenings on the wall of tracheids in both summer and spring wood, as Chinese authors[52,55] mentioned, even in adult wood, but particular care is needed to find them in older part. L. 3,400 μ.

Ray tracheids: With rather distinct spiral thickenings on the wall.

Ray parenchyma cells: Pits per cross field 2～4 (6), sometimes with brown contents, with numerous crystals of calcium oxalate. V. 10～25 μ, T. 10～15 μ.

Epithelial cells: (a) of axial resin canals: L. 20～50 μ, S. 7～20 μ, (b) of radial resin canals: L. 10～20 μ, S. 7～10 μ.

6. *Picea breweriana* S. Wats.: Weepings spruce. (Photos. 3, 30, 31, 59 and 60)

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

In comparison with specimens of other species generally growth rings much narrower and wood harder.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 27 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 18, (b) fusiform rays; with uniseriate wings up to 16 cells in height. 6～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 30～110 μ, of 106 canals in one of the specimens, 41 solitary, (b) radial resin canals; number of epithelial cells per canal 5～9, frequency distribution of cell number per canal of one of the specimens shown in Fig. 17; generally A type,

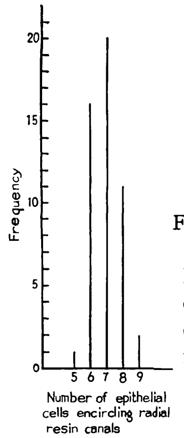


Fig. 17 *P. breweriana* (60 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6. 94).

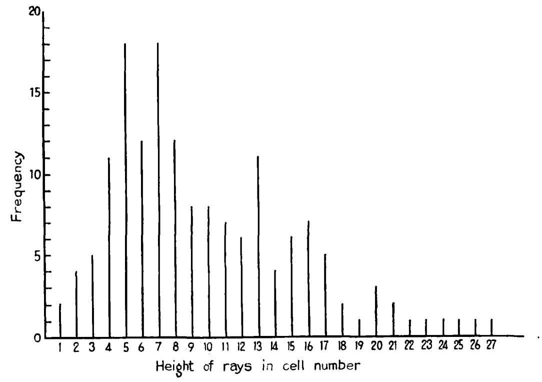


Fig. 18 *P. breweriana* (60 th ring) Frequency distribution of height of rays in cell number (Av. 9. 77).

rarely B type of Fig. 2.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 7～45 μ, in spring wood R. up to 35 μ, Th. up to 3 μ, in summer wood R. 6～24 μ, Th. up to 5 μ. Bordered pits R. 10～20 μ. With spiral thickenings on the wall of tracheids in summer wood (Photos. 30 and 59), even in the 100 th ring although somewhat vague there, and rarely found on the wall of spring wood tracheids, although not clear. L. 3,100～3,300 μ.

Ray tracheids: Occasionally partial occurrence of spiral thickenings observed.

Ray parenchyma cells: Pits 2～4 per cross field, sometimes with brownish contents. V. 16～20 μ, T. 10～17 μ.

Epithelial cells: (a) of axial resin canals; L. 10～30 μ, S. 5～12 μ, (b) of radial resin canals; L. 12～25 μ, S. 7～12 μ.

7. *Picea chihuahuana* Martinez: Chihuahua spruce. (Photos. 4, 32 and 61)

Only young stem wood specimen without heartwood available.

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Rays: (a) uniseriate rays; up to 20 cells in height, frequency distribution of ray height

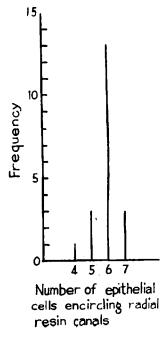


Fig. 19 *P. chihuahuana* (4 & 5 th rings) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 5. 90).

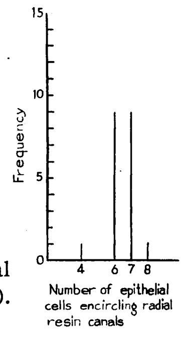


Fig. 20 *P. chihuahuana* (11 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6. 45).

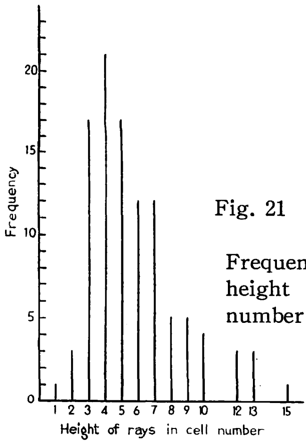


Fig. 21 *P. chihuahuana* (4 & 5th ring) Frequency distribution of height of rays in cell number (Av. 5.75).

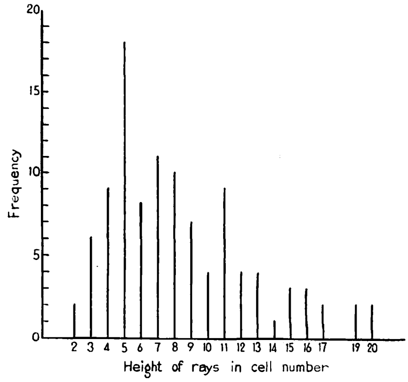


Fig. 22 *P. chihuahuana* (11th ring) Frequency distribution of height of rays in cell number (Av. 8.32).

shown in Figs. 21 and 22, (b) fusiform rays; with uniseriate wings up to 10 cells in height. 6～12 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 20～85 μ, of 50 canals in one of the specimens, solitary 26. (b) radial resin canals; number of the epithelial cells per canals 4～8 in the 11th ring, T. 25～48 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 7～38 μ, in spring wood R. up to 38 μ, Th. up to 2 μ, in summer wood R. 7～20 μ, Th. up to 5 μ. Bordered pits R. 7～18 μ. With spiral thickenings on the wall in summer wood, even in the 18 th ring, although somewhat vague there. L. 2,200 μ.

Ray parenchyma cells: Pits 2～6 per cross field. Sometimes with calcium oxalate crystals, small (Fig. 61), and occasionally with yellow or yellowish brown contents. V. 17～20 μ, T. 7～10 μ.

8. *Picea engelmanni* (Parry) Engelm.: Engelman spruce. (Photos. 5 and 6)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements.

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 29 cells in height, frequency distribution of ray height shown in Figs. 23 and 25, (b) fusiform rays; with uniseriate wings up to 15 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 40～100 μ, of 46 canals, solitary 12 in one specimen, (b) radial resin canals; number of epithelial cells per canal 6～13, frequency distribution of the number of cells in one of the specimens shown in Fig. 24. T. 10～60 μ.

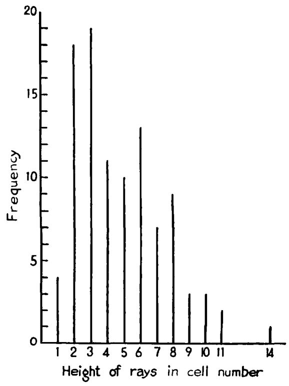


Fig. 23 *P. engelmanni* (2nd ring) Frequency distribution of height of rays in cell number (Av. 4.83).

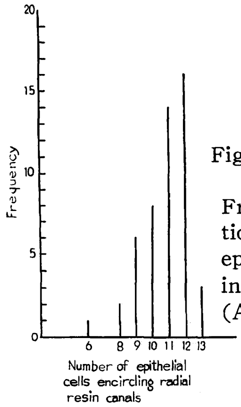


Fig. 24 *P. engelmanni* (200 th ring). Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 10.82).

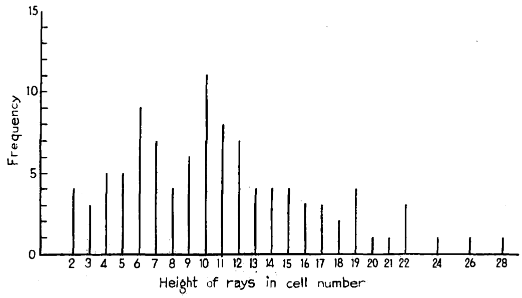


Fig. 25 *P. engelmanni* (200 th ring) Frequency distribution of height of rays in cell number (Av. 10.52).

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 7～50 μ, in spring wood R. up to 50 μ, Th. up to 2 μ, in summer wood R. 5～20 μ, Th. up to 4 μ. Bordered pits R. 15～27 μ. With spiral thickenings on the wall of tracheids of the first few rings, mostly vague and rarely distinct. L. 2,000～3,900 μ.

Ray parenchyma cells: Pits 2～5 per cross field. Occasionally with brown or yellowish brown contents, and in one specimen rare occurrence of crystals of calcium oxalate found. V. 16～23 μ, T. 7～13 μ.

Epithelial cells: (a) of axial resin canals; L. 12～25 μ, S. 6～12 μ, (b) of radial resin canals; L. 12～25 μ, S. 5～11 μ.

9. *Picea glauca* (Moench) Voss: White spruce. (Photo. 63)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

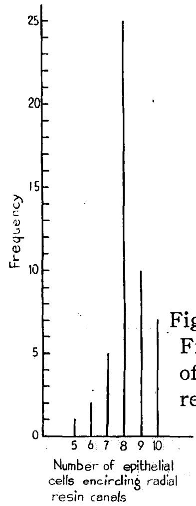


Fig. 26 *P. glauca* (2nd ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.24).

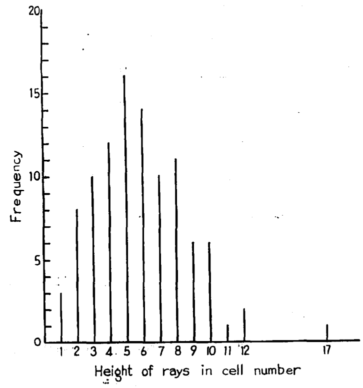


Fig. 27 *P. glauca* (2nd ring) Frequency distribution of height of rays in cell number (Av. 5.85).

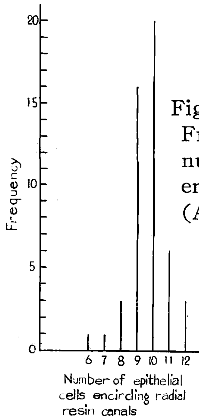
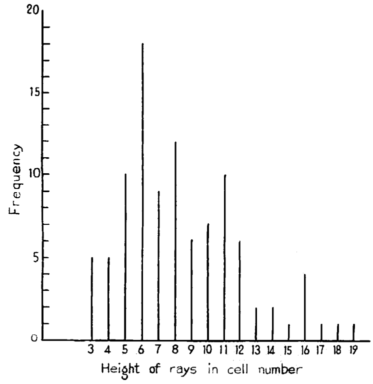


Fig. 28 *P. glauca* (50th ring). Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.66).

Fig. 29 *P. glauca* (50th ring) Frequency distribution of height of rays in cell number (Av. 8.45).



Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 19 cells in height, frequency distribution of ray height shown in Figs. 27 and 29, (b) fusiform rays; with uniseriate wings up to 15 cells in height. 4～10 rays in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals: T. 40～137 μ, of 52 canals in one specimen, 32 solitary, (b) radial resin canals: number of epithelial cells per canal 5～12, frequency distribution of the number of cells shown in Figs. 26 and 28. T. 27～50 μ.

(2) Description of elements

Tracheids: T. 10～43 μ, in spring wood R. up to 50 μ, Th. up to 2 μ, in summer wood R. 6 ～18 μ, Th. up to 4 μ. Bordered pits R. 7～23 μ. With vague spiral thickenings on the wall of summer wood tracheids, and sometimes distinct partially. L. 2,700～3,200 μ.

Ray parenchyma cells: Pits 2～4 per cross field. Sometimes with brown or yellowish brown contents. V. 16～23 μ, T. 7～13 μ.

Epithelial cells: (a) of axial resin canals; L. 12～25 μ, S. 6～12 μ, (b)of radial resin canals; L. 12～25 μ, S. 5～11 μ.

10. *Picea glehnii* (Fr. Schmidt) Mast.: Aka-ezomatsu. (Photos. 7, 20, 33 and 62)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 25 (3～18) cells in height, frequency distribution of ray height and its variation shown in Figs. 118～126, (b) fusiform rays; with uniseriate wings up to 12 cells in height. 6～12 (6～8) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 50～120 μ, of 64 canals in one specimen, 34 solitary, (b) radial resin canals; number of epithelial cells per canal 7～9, frequency distribution of the number of cells shown in Figs. 153～158, T. 25～50 μ.

(2) Description of elements

Almost the same as *P. abies*, except the followings:

Tracheids: T. 7～38 (generally 20～35) μ, in spring wood R. up to 47 μ, Th. up to 2 μ, in summer wood R. up to 20 μ, Th. up to 5 μ. Bordered pits R. 7～20 μ, L. 4,500 μ.

Ray parenchyma cells: Pits 2～5 per cross field, with yellowish brown contents. Size of cells almost the same as that of *P. jezoensis*.

Epithelial cells: (a) of axial resin canals; L. 12～25 μ, S. 6～12 μ, (b) of radial resin canals; L. 10～25 μ, S. 5～10 μ.

11. *Picea jezoensis* (Sieb. et Zucc.) Carr. (Photos. 21, 34, 64 and 65)

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

Sapwood white to light yellow brownish and somewhat pinkish, and after long exposure demarcation between them fairly distinct.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 23 cells in height (mostly 3～15 cells and 5～40 μ in height), frequency distribution of ray height in one of the specimens shown in Fig. 31, (b) fusiform rays; with uniseriate wings 1～16 cells in height. 4～12 (mostly 6～10) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 50～125 μ, R. 35～140 μ, of 40 canals in one specimen, 27 solitary, (b) radial resin canals; number of epithelial cells 6～12 (mostly 7～9), frequency distribution of the number of the cells in one specimen shown in Fig. 30. T. 25～50 μ.

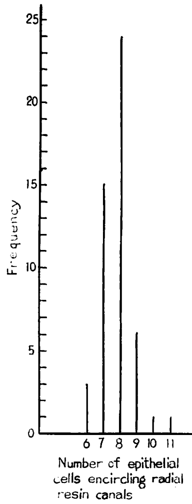


Fig. 30 *P. jezoensis* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.40).

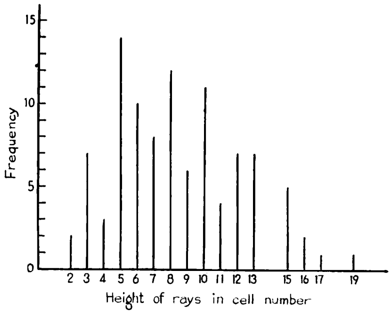


Fig. 31 *P. jezoensis* (adult) Frequency distribution of height of rays in cell number (Av. 8.45).

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 10～45 (15～35) μ, in spring wood R. up to 50 μ, Th. up to 2 μ, in summer wood R. up to 23 μ, Th. 4 μ, variation pattern of radial diameter in one specimen shown in Fig. 97. Bordered pits R. 7～20 μ. With spiral thickenings on the wall of tracheids of summer wood in the first few rings as Miyoshi and Shimakura[39] mentioned, mostly vague, but rarely fairly distinct in part. L. 2,900～4,200 μ.

Ray parenchyma cells: Pits 2～5 per cross field. Often with brown contents. V. 16～21 μ, T. 7～13 μ.

Epithelial cells: (a) of axial resin canals; L. 12～25 μ, S. 6～12 μ, Th. up to 3 μ, (b) of radial resin canals; L. 10～25 μ, S. 5～10 μ.

12. *Picea jezoensis* (Sieb. et Zucc.) Carr. var. *hondoensis* Rehd.: Tôhi. (Photos. 8, 35 and 66)

A. **Macroscopical features**

Almost the same as *P. jezoensis*.

B. **Microscopical features**

Almost the same as *P. jezoensis*, except the following:

(1) Arrangement of elements

Resin canals: (a) axial resin canals: T. 50～140 μ, R. 60～140 μ, (b) radial resin canals: T. 30～50 μ.

(2) Description of elements

Tracheids: T. 20～46 μ, in spring wood R. up to 45 μ, Th. up to 2 μ, in summer wood R. 6～24 μ, Th. up to 4 μ.

Epithelial cells: (a) of axial resin canals; L. 19～30 μ, S. 8～23 μ, Th. up to 3 μ, (b) of radial resin canals; L. 11～17 μ, S. 7～10 μ, Th. up to 3 μ.

13. *Picea koraiensis* Nakai: Chosen-harimomi. (Photos. 9, 36 and 67)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Rays: (a) uniseriate rays; up to 19 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 33, (b) fusiform rays; with uniseriate wings up to 13 cells in height. 4～12 (generally 6～10) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 40～110 μ, of 30 canals in one specimen, 18 solitary, (b) radial resin canals; number of epithelial cells per canal 7～10, frequency distribution of the number of cells of one specimen shown in Fig. 32, T. 25～50 μ.

(2) Description of elements

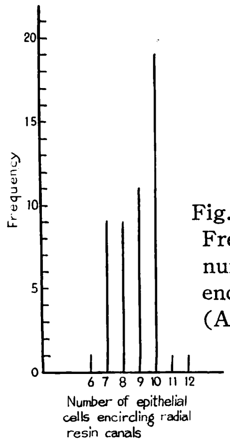


Fig. 32 *P. koraiensis* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.88).

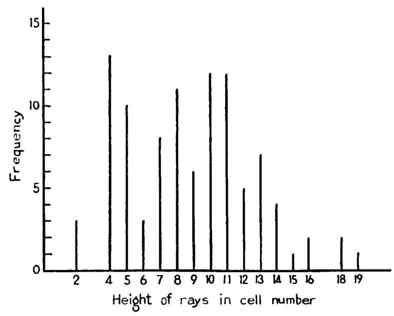


Fig. 33 *P. koraiensis* (adult) Frequency distribution of height of rays in cell number (Av. 8.85).

Almost the same as *P. abies*, except the following:

Tracheids: T. $12\sim47\,\mu$, in spring wood R. $25\sim55\,\mu$, Th. up to $2\,\mu$, in summer wood R. $6\sim44\,\mu$, Th. up to $6\,\mu$. Bordered pits R. $10\sim22\,\mu$, L. $2{,}000\,\mu$.

Ray tracheids: With fine dentations on the wall, although YAMABAYASHI[58] mentioned nothing about this feature.

Ray parencyma cells: Pits $2\sim5$ per cross field. Often with brown contents. V. $12\sim19\,\mu$, T. $6\sim11\,\mu$.

Epithelial cells: (a) of axial resin canals; L. $20\sim45\,\mu$, S. $6\sim14\,\mu$.

14. *Picea koyamae* SHIRAS.: Yatsugatake-tôhi. (Photos. 10 and 11)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays: A and B types of Fig. 1, up to 13 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 35, (b) fusiform rays: with uniseriate wings up to 9 cells in height. $2\sim10$ (mostly $6\sim8$) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals: T. $40\sim125\,\mu$, of 62 canals in one specimen, 34 solitary, (b) radial resin canals: T. $25\sim50\,\mu$.

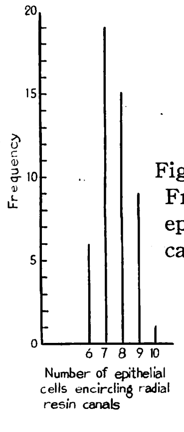


Fig. 34 *P. koyamae* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.00).

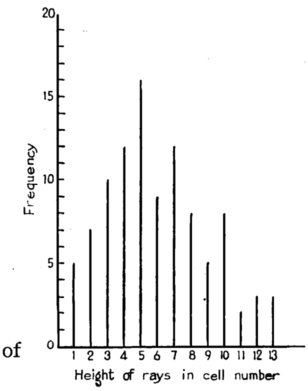


Fig. 35 *P. koyamae* (adult)
Frequency distribution of height of rays in cell number (Av. 6.01).

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. $10\sim43\,\mu$, in spring wood R. $15\sim52\,\mu$, Th. up to $3\,\mu$, in summer wood R. $5\sim25\,\mu$, Th. up to $5\,\mu$. Bordered pits R. $10\sim23\,\mu$. With spiral thickenings on the wall of summer wood tracheids of the first few rings, occasionally of much older part; MIYOSHI and SHIMAKURA[39] mentioned their presence in the wood of up to the $20\sim30$ th rings, vague. L. $3{,}300\,\mu$.

Ray parenchyma cells: Pits $2\sim5$ per cross field, occasionally with brown contents. V. $17\sim32\,\mu$, T. $9\sim16\,\mu$.

Epithelial cells: (a) of axial resin canals; L. $13\sim30\,\mu$, S. $6\sim12\,\mu$, (b) of radial resin canals; L. $8\sim20\,\mu$, S. $5\sim10\,\mu$.

15. *Picea likiangensis* (FRANCH.) PRITZ. (Photos. 37 and 68)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 17 cells in height, frequency distribution of ray height in one of the specimens shown in Figs. 37 and 38, (b) fusiform rays; with uniseriate wings up to 7 cells in height; 6~10 cells found in 1 mm tangential line on the transverse surface.

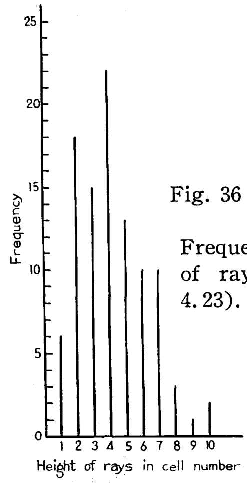


Fig. 36 *P. likiangensis* (13 th ring). Frequency distribution of height of rays in cell number (Av. 4.23).

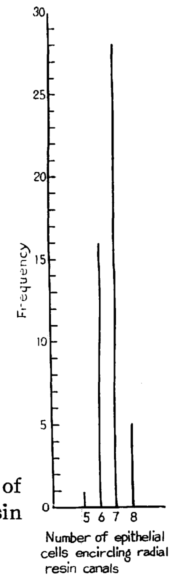


Fig. 37 *P. likiangensis* (13 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.74).

Resin canals: (a) axial resin canals; T. 25~75 μ, of 24 canals in one specimen, 16 solitary, (b) radial resin canals; number of epithelial cells per canal 5~10, frequency distribution of the number of epithelial cells in one specimen shown in Fig. 36. Generally A type, and rarely B type of Fig. 2. T. 35~50 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 7~25 μ, in spring wood R. 5~17 μ, Th. up to 3 μ, in summer wood R. 5~17 μ, Th. up to 4 μ. Bordered pits R. 7~15 μ. With spiral thickenings on the wall of both spring and summer wood tracheids (Photos. 37 and 68), mostly distinct, found everywhere. L. 1,700~1,900 μ.

Ray tracheids: Very often with spiral thickenings on the wall.

Ray parenchyma cells: Pits 2~5 per cross field. Often

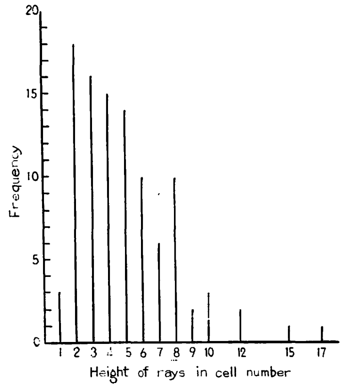


Fig. 38 *P. likiangensis* (branch wood) Frequency distribution of height of rays in cell number (Av. 4.95).

with brown contents, and with crystals of calcium oxalate. V. 17～23 μ, T. 10～23 μ.

Epithelial cells: (a) of axial resin canals; L. 17～35 μ, S. 7～13 μ, (b) of radial resin canals: L. 10～23 μ, S. 7～13 μ.

16. *Picea mariana* (MILL.) B. S. P.: Black spruce. (Photos. 12, 23, 38 and 39)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 16 cells in height, frequency distribution of ray height in two specimens shown in Figs. 40 and 42, (b) fusiform rays; with uniseriate wings up to 7 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 27～117 μ, of 153 canals in one specimen, 80 solitary,

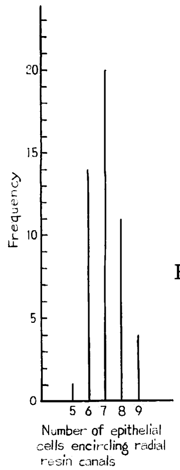


Fig. 39 *P. mariana* (6 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.06).

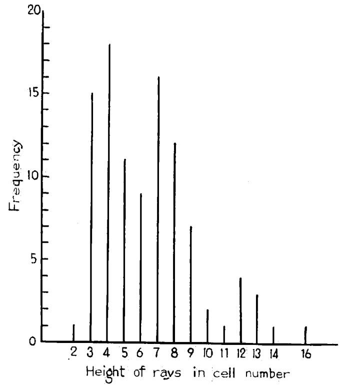


Fig. 40 *P. mariana* (6 th ring) Frequency distribution of height of rays in cell number (Av. 6.41).

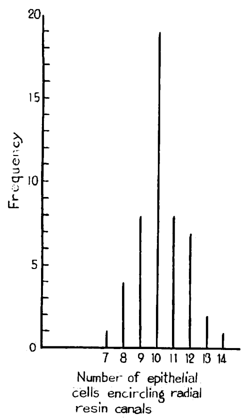


Fig. 41 *P. mariana* (60 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 10.26).

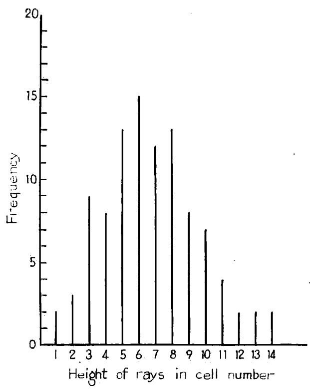


Fig. 42 *P. mariana* (60 th ring) Frequency distribution of height of rays in cell number (Av. 6.74).

(b) radial resin canals; number of epithelial cells per canal 8～14, frequency distribution of the number of cells in two specimens shown in Figs. 39 and 41. T. 22～50 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 10～35 μ, in spring wood R. up to 45 μ, Th. up to 2 μ, in summer wood R. 5 ～5 μ, Th. up to 6 μ. L. 2,800～3,600 μ.

Ray parenchyma cells: Pits 2～5 per cross field. Often with brown or yellowish brown contents. V. 16～23 μ, T. 7～13 μ.

Epithelial cells: (a) of axial resin canals: L. 12～25 μ, S. 6～12 μ, (b) of radial resin canals; L. 12～25 μ, S. 5～11 μ.

17. *Picea maximowiczii* Regel: Himebaramomi. (Photos. 2, 19, 40, 69 and 70)

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

Heartwood with slightly pinkish tinge, and demarcation between sap- and heartwood fairly visible, particularly after long exposure.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 27 (mostly 3～15) cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 44, (b) fusiform rays; with uniseriate wings up to 15 cells in height. 6～12 (generally 8～10) rays in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 25～150 μ, R. 80～130 μ, of 95 canals in one of the specimens, 19 solitary, (b) radial resin canals; number of epithelial cells per canal 5～10, frequency distribution of the number of cells in one of the specimens shown in Fig. 43. T. 25～50 μ. A and B types of Fig. 2.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 10～40 μ, in spring wood R. 30～50 μ, Th. up to 2 μ, in summer wood R. 6～

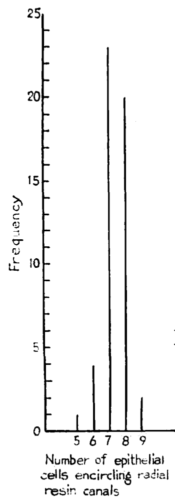


Fig. 43 *P. maximowiczii* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.36).

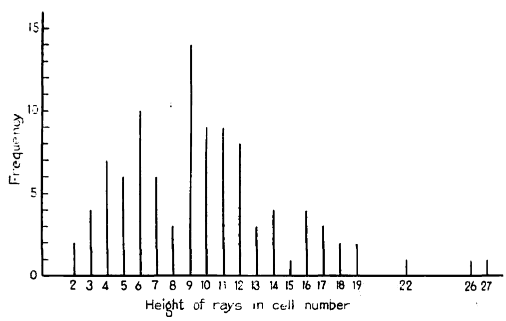


Fig. 44 *P. maximowiczii* (adult)
Frequency distribution of height of rays in cell number (Av. 9.85).

20 μ, Th. up to 6 μ. Bordered pits R. 10～20 μ. With spiral thickenings on the wall of both spring and summer wood tracheids, as BAILEY[2], and MIYOSHI and SHIMAKURA[39] mentioned, generally distinct, found everywhere (Photos. 40, 69 and 70). L. 4,000 μ.

Ray tracheids: Wall generally not smooth, but with fairly distinct spiral thickenings or distinct dentations.

Ray parenchyma cells: Pits 2～5 per cross field, often with brown contents, and crystals of calcium oxalate. V. 14～20 μ, T. 10～18 μ.

Epithelial cells: (a) of axial resin canals; L. 17～32 μ, S. 8～15 μ, occasionally with crystals of calcium oxalate, particularly in the cells adjacent to ray parenchyma cells, (b) of radial resin canals; L. 17～21 μ, S. 6～13 μ, occasionally with crystals of calcium oxalate.

18. *Picea meyeri* REHD. et WILS.

For this species, only branch wood specimens were available. Therefore, qualitative rather than quantitative description is much more suited, and description is limited to the more important features. The features described here reveal more or less the characteristics generally observed in branch wood of this genus.

A. **Macroscopical features**

According to TANG[55], no distinct demarcation between heart- and sapwood, and wood light yellowish.

Other features almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: As TANG[55] mentioned, spiral thickenings found on the wall of both spring and summer wood tracheids, but in the former vague.

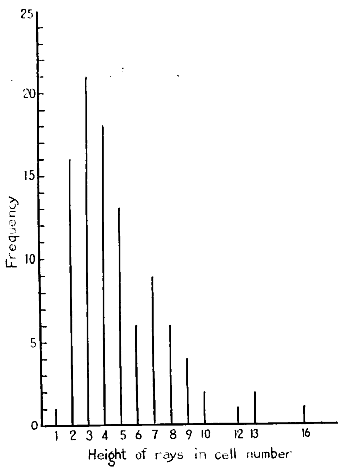


Fig. 45 *P. montigena* (branch wood)
Frequency distribution of height of rays in cell number (Av. 4.88).

19. *Picea montigena* MAST.

(Photos. 41, 42, 71 and 72)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 16 cells in height, frequency distribution of ray height in two specimens shown in Figs. 45 and 47, (b) fusiform rays; with uniseriate rays up to 7 cells in height. 4～10rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canal; T. 30～110 μ, of 61 canals in one of the specimens, 24 solitaly, (b) resin canals; number of epithelial cells per canal 5～10, frequency distribution of the number of cells in one of the specimens shown in Fig. 46, A and B types of Fig. 2, T. 37～60 μ.

(2) Description of elements

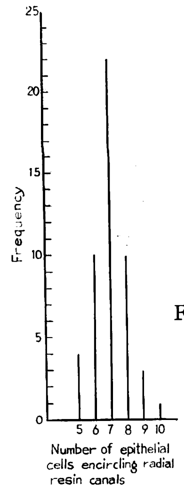


Fig. 46 *P. montigena* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.02).

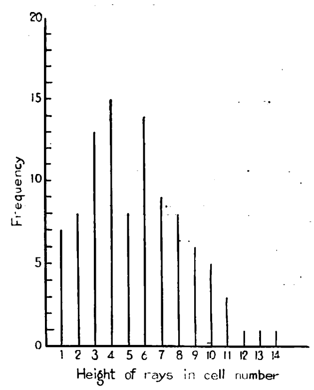


Fig. 47 *P. montigena* (adult)
Frequency distribution of height of rays in cell number (Av. 5.55).

Almost the same as *P. abies*, except the following:

Tracheids: T. 7～35 μ, in spring wood R. up to 30 μ, Th. up to 2 μ, in summer wood R. 7～20 μ, Th. up to 5 μ. Bordered pits R. 7～15 μ. As TANG[55] mentioned, with spiral thickenings on the wall of both spring and summer wood tracheids (Photos. 41 and 71), but another author[52] did not make any mention about them. L. 1,200～1,900 μ.

Ray tracheids: Often with spiral thickenings and with dentations.

Ray parenchyma cells: Pits 2～4 per cross field, no crystals found, although Chinese author[52] mentioned their occurrence. Often with brown contents. V. 15～20 μ, T. 7～18 μ.

Epithelial cells: (a) of axial resin canals; L. 7～27 μ, S. 7～15 μ, (b) of radial resin canals; L. 15～25 μ, S. 7～13 μ.

20. *Picea morrisonicola* HAYATA: Niitaka-tôhi. (Photos. 13, 73 and 74)

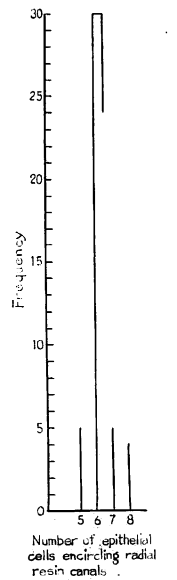


Fig. 48 *P. morrisonicola* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.16).

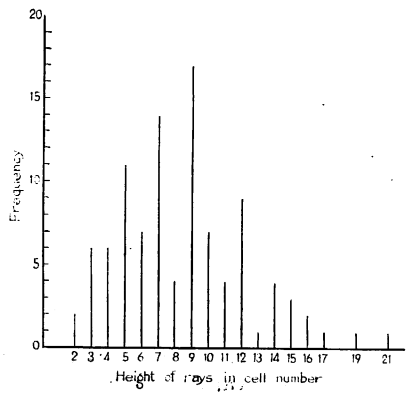


Fig. 49 *P. morrisonicola* (adult)
Frequency distribution of height of rays in cell number (Av. 8.51).

A. **Macroscopical features**

Almost the same as *P. maximowiczii.*

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. maximowiczii,* except the following:

Rays: (a) uniseriate rays; B type of Fig. 1, up to 24 cells in height, frequency distribution of ray height in three specimens shown in Figs. 49, 51 and 53, (b) fusiform rays; with uniseriate wings up to 12 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

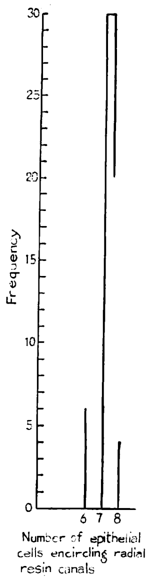


Fig. 50 *P. morrisonicola* (100 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.96).

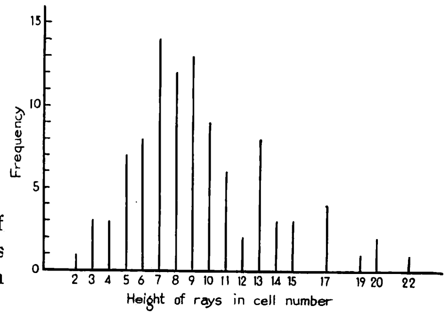


Fig. 51 *P. morrisonicola* (100 th ring) Frequency distribution of height of rays in cell number (Av. 9.32).

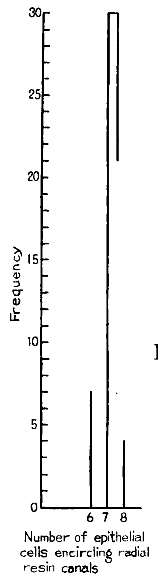


Fig. 52 *P. morrisonicola* (200 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.94).

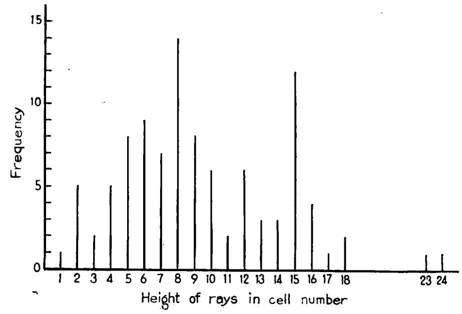


Fig. 53 *P. morrisonicola* (200 th ring) Frequency distribution of height of rays in cell number (Av. 9.43).

Resin canals: (a) axial resin canals; T. 55～135 μ, R. 70～140 μ, of 23 canals in one of the specimens, 3 solitary, (b) radial resin canals; number of epithelial cells per canal 5～8, frequency distribution of the number of cells in three specimens shown in Figs. 48, 50 and 52. A and B types of Fig. 2, T. 18～35 μ.

(2) Description of elements

Almost the same as *P. maximowiczii*, except the following:

Tracheids: T. 7～55 μ, in spring wood R. 30～60 μ, in summer wood R. 7～36 μ, Th. up to 7 μ. Bordered pits R. 10～25 μ. KANEHIRA[29] did not mention the presence of spiral thickenings on the wall, but MIYOSHI and SHIMAKURA[39] did. L. 3,600～6,100 μ.

Ray parenchyma cells: Pits 2～4 per cross field, often with brown or reddish brown contents. Wtih crystals of calcium oxalate as KANEHIRA[29] mentioned. V. 15～22 μ, T. 13～22 μ.

Epithelial cells: (a) of axial resin canals; sometimes with crystals of calcium oxalate, L. 25～45 μ, S. 11～21 μ, (b) of radial resin canals; L. 12～20 μ, S. 8～11 μ.

21. *Picea obovata* LEDEB.: Siberian spruce. (Photo. 43)

For this species, only branch wood specimens were available. Therefore, qualitative rather than quantitative description is much more suited, and description is limited to the more important features. Such features as are described here reveal more or less the characteristics generally observed in branch wood of this genus.

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

Almost the same as *P. abies*, except the following:

Rays: Uniseriate rays up to 8 cells in height, frequency distribution of ray height of one specimen shown in Fig. 54.

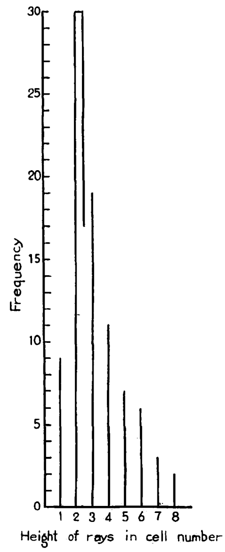


Fig. 54 *P. obovata* (branch wood) Frequency distribution of height of rays in cell number (Av. 3.04).

22. *Picea omorica* (PANCIC) PURKYNE: Serbian spruce. (Photos. 24, 25, 26 and 44)

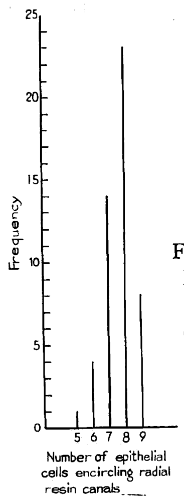


Fig. 55 *P. omorica* (10th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.74).

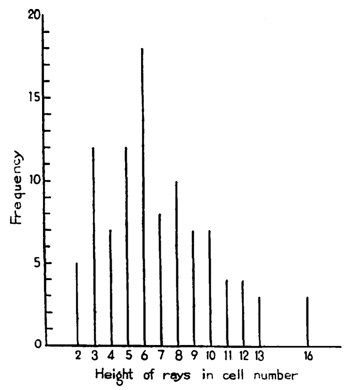


Fig. 56 *P. omorica* (10th ring) Frequency distribution of height of rays in cell number (Av. 6.88).

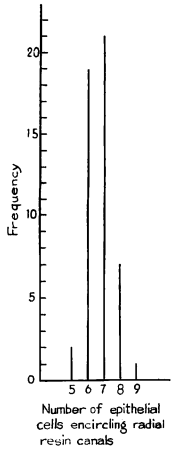


Fig. 57 *P. omorica* (30th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.70).

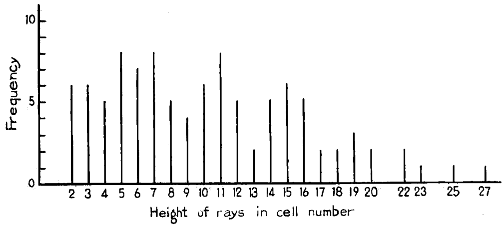


Fig. 58 *P. omorica* (30th ring) Frequency distribution of height of rays in cell number (Av. 10.24).

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*.

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 27 cells in height, frequency distribution of ray height of the specimens shown in Figs. 56 and 58, (b) fusiform rays; with uniseriate wings up to 10 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 37～85 μ, of 31 canals in one of the specimens, 15 solitary, (b) radial resin canals; number of epithelial cells per canal 5～9, frequency distribution of the number of the cells in the specimens shown in Figs. 55 and 57. A and rarely B type of Fig. 2, T. 15～25 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 10～35 μ, in spring wood R. up to 50 μ, in summer wood R. 5～20 μ, Th. up to 4 μ. Bordered pits R. 5～20 μ, L. 2,000～2,900 μ.

Ray parenchyma cells: Pits 2～4 per cross field, often with brown contents and occasionally with crystals of calcium oxalate. V. 17～20 μ, T. 7～20 μ.

Epithelial cells: (a) of axial resin canals; L. 7～35 μ, S. 7～17 μ, (b) of radial resin canals; L. 7～17 μ, S. 5～7 μ.

23. *Picea orientalis* (L.) Carr.: Oriental spruce. (Photo. 45)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 29 cells in height, frequency distribution of ray height in two specimens shown in Figs. 60 and 62, (b) fusiform rays; with uniseriate wings up to 20

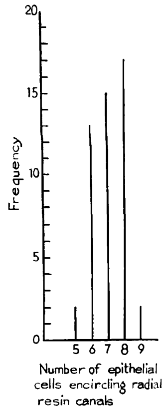


Fig. 59 *P. orientalis* (12 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7. 32).

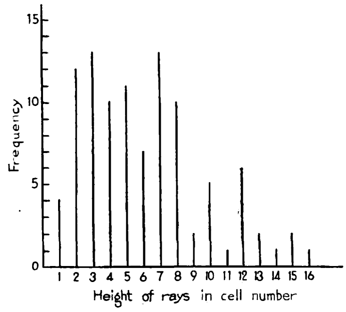


Fig. 60 *P. orientalis* (12 th ring) Frequency distribution of height of rays in cell number (Av. 6. 12).

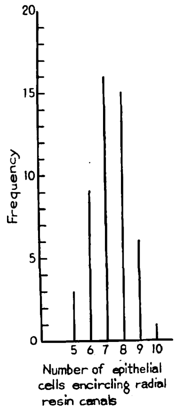


Fig. 61 *P. orientalis* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7. 34).

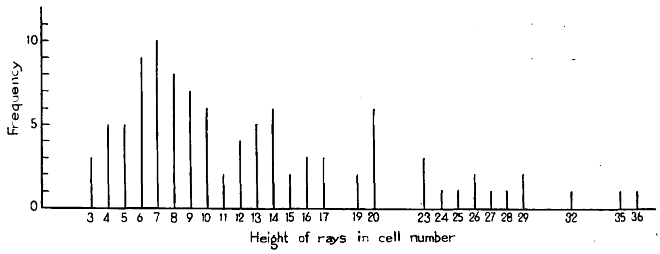


Fig. 62 *P. orientalis* (adult) Frequency distribution of height of rays in cell number (Av. 12. 57).

cells in height. 4～12 (generally 6～10) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 37～125 μ, of 63 canals in one of the specimens, 25 solitary, (b) radial resin canals; number of epithelial cells per canal 5～10, frequency distribution of the number of the cells in two specimens shown in Figs. 59 and 61. A and B types of Fig. 2, T. 20～50 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 15～50 μ, in spring wood R. up to 55 μ, Th. up to 1.5 μ, in summer wood R. 5～35 μ, Th. up to 4 μ. Bordered pits R. 7～23 μ, L. 2,800～3,000 μ.

Ray parenchyma cells: Pits 2～5 per cross field, with brown or yellowish brown contents. V. 15～25 μ, T. 7～17 μ.

Epithelial cells: (a) of axial resin canals; L. 12～32 μ, S. 7～13 μ, (b) of radial resin canals; L. 20～27 μ, S. 7～13 μ.

24. *Picea polita* (Sieb. et Zucc.) Carr.: Harimomi.

(Photos. 14, 46, 47, 75 and 86)

A. **Macroscopical features**

Almost the same as *P. bicolor*.

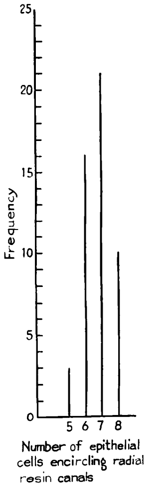


Fig. 63 *P. polita* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.77).

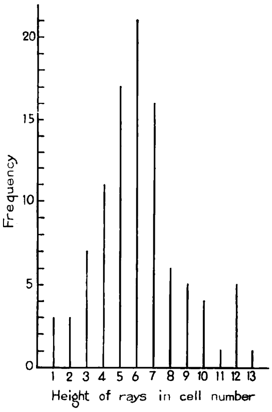


Fig. 64 *P. polita* (adult)
Frequency distribution of height of rays in cell number (Av. 6.14).

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; mostly B type of Fig. 1, up to 13 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 64, (b) fusiform rays; with uniseriate wings up to 8 cells in height. 4～8 (mostly 6) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 50～100 μ, of 24 canals in one of the specimens, solitary 12, (b) radial resin canals; number of epithelial cells per canal 6～8, frequency distribution of the number of cells of one of the specimens shown in Fig. 63. A and B types of Fig. 2, T. 27～43 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 5～50 μ, in spring wood R. 17～46 μ, in summer wood R. 10～28 μ, Th. up to 6 μ. Bordered pits R. 7～20 μ. With spiral thickenings on the wall of only summer wood tracheids, from juvenile to the 30～40 th rings, occasionally even in the wood of around the 100 th ring, although MIYOSHI and SHIMAKURA[39] mentioned the presence only in juvenile wood; occasionally conspicuous in part (Photos. 46 and 47). Spiral thickenings rarely found on the wall of spring wood tracheids, but vague. L. 4,400 μ.

Ray tracheids: Occasionally with spiral thickenings on the wall, fairly distinct on the corner of the cells.

Ray parenchyma cells: Pits 2～5 per cross field, often with brown contents, and often with crystals of calcium oxalate (Photo. 86). V. 12～21 μ, T. 12～29 μ.

Epithelial cells: (a) of axial resin canals; some with crystals of calcium oxalate (Photo. 86). L. 15～35 μ, S. 8～16 μ, Th. up to 3 μ, (b) of radial resin canals; L. 12～19 μ, S. 7～14 μ. (Photos. 46 and 47).

25. *Picea pungens* ENGELM.: Blue spruce, Colorado spruce.
(Photos. 48, 76 and 77)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 24 cells in height, frequency distribution of ray height in two specimens shown in Figs. 66 and 68, (b) fusiform rays; with uniseriate wings up to 16 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 40～100 μ, of 113 canals in one of the specimens, 35 solitary, (b) radial resin canals; number of epithelial cells per canal 6～13, frequency distribution of the number of cells in the specimens shown in Figs. 65 and 67. T. 22～50 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 10～45 μ, in spring wood R. up to 60 μ, in summer wood R. 5～23 μ, Th. up to 4 μ. Bordered pits R. 5～23 μ. With spiral thickenings on the wall of summer wood tracheids, generally in the first few rings, sometimes in the wood of up to the 20～30 th rings, and rarely even in the 120 th ring. L. 1,800～3,500 μ.

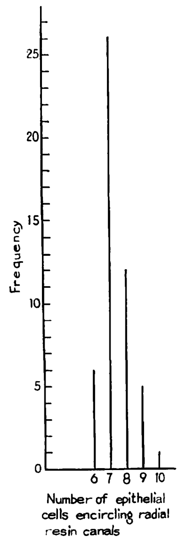


Fig. 65 *P. pungens* (15 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7. 38).

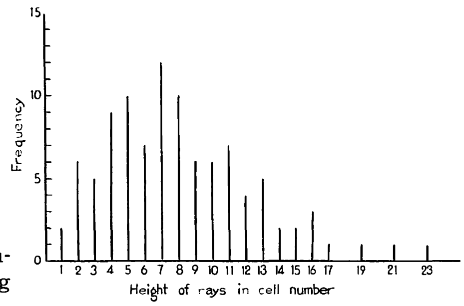


Fig. 66 *P. pungens* (15 th ring) Frequency distribution of height of rays in cell number (Av. 8. 04).

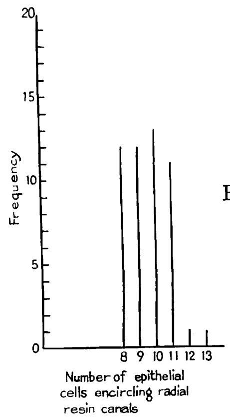


Fig. 67 *P. pungens* (56 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9. 60).

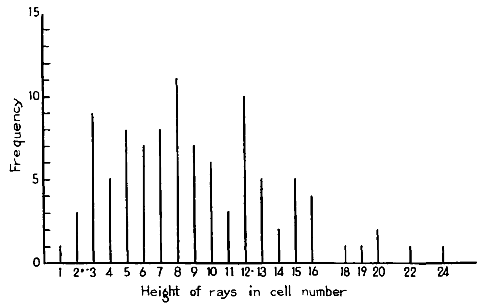


Fig. 68 *P. pungens* (56 th ring) Frequency distribution of height of rays in cell number (Av. 9. 11).

Ray parenchyma cells: Pits 2～4 (6) per cross field, often with brown or yellowish brown contents. V. 16～23 μ, T. 7～13 μ.

Epithelial cells: (a) of axial resin canals; L. 12～25 μ, S. 6～12 μ, (b) of radial resin canals; L. 12～25 μ, S. 5～11 μ.

26. *Picea purpurea* MAST.

For this species, only branch wood specimens were available. Therefore, qualitative rather than quantitative description is much more appropriate and description is limited to the more important features. The features described here reveal more or less the characteristics generally observed in branch wood of this genus.

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

According to TANG[55], no demarcation found between heart- and sapwood, and wood light reddish brown or reddish brown.

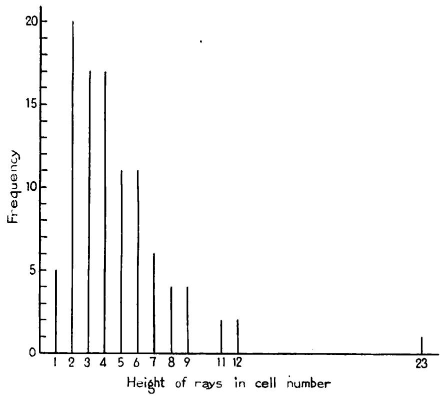


Fig. 69 *P. purpurea* (branch wood) Frequency distribution of height of rays in cell number (Av. 4.64).

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 9 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 69, (b) fusiform rays; with uniseriate wings up to 4 cells in height.

Resin canals: (a) axial resin canals; mostly solitary because of branch wood, T. 50 μ, smaller than those of adult wood of other species, (b) radial resin canals; number of epithelial cells per canal 6～8, T. up to 38 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: With spiral thickenings on the wall of both spring and summer wood tracheids, more conspicuous in summer wood. CHENG[52] mentioned the presence of spiral thickenings in a few tracheids, although BUDCEVICZ[9] and TANG[55] gave no description on them.

Ray parenchyma cells: Pits 2～6 per cross field, often with yellowish contents.

27. *Picea rubens* SARG.: Red spruce. (Photo. 15)

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; up to 17 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 71, (b) fusiform rays; with uniseriate wings up to 11 cells in height. 2～12 (mostly 6～8) rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 37～105 μ, of 74 canals in one of the specimens, 43

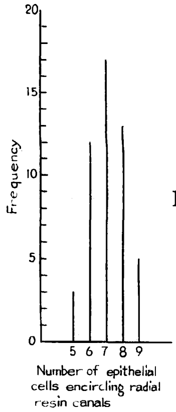
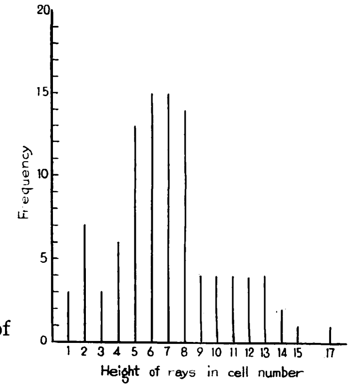


Fig. 70 *P. rubens* (65th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.03).

Fig. 71 *P. rubens* (65th ring)
Frequency distribution of height of rays in cell number (Av. 7.02).



solitary, (b) radial resin canals; number of epithelial cells per canal 5~9, frequency distribution of the number of cells in one of the specimens shown in Fig. 70. T. 27~52 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 7~35 μ, in spring wood R. 7~35 μ, in summer wood R. 6~18 μ, Th. up to 4 μ. Bordered pits R. 7~18 μ. L. 1,900~2,700 μ.

Ray parenchyma cells: Pits 2~5 per cross field, often with brown or yellowish brown contents. V. 16~23 μ, T. 7~13 μ.

Epithelial cells: (a) of axial resin canals; L. 12~25 μ, S. 6~12 μ, (b) of radial resin canals; L. 12~25 μ, S. 5~11 μ.

28. *Picea shirasawae* Hayashi: Himematsuhada.

For this species, only branch wood specimens were available. Therefore, qualitative rather than quantitative description is more appropriate and description is limited to the more important features. It so happens that features described here reveal more or less the characteristics observed in branch wood of this genus.

A. **Macroscopical features**

Almost the same as *P. abies*.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Resin canals: (a) axial resin canals; T. 38~70 μ, all solitary in the first ring, and of 28 canals in the 5th ring of one of the specimens, 12 solitary, (b) radial resin canals; number of epithelial cells per canal 6~9. T. up to 38 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

Ray parenchyma cells: Pits 4~6 per cross field, often with yellowish contents.

29. *Picea sitchensis* (Bong.) Carr.: Sitka spruce. (Photos. 49, 50 and 78)

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

Heartwood with pinkish tinge, and demarcation between heart- and sapwood fairly visible, particularly after long exposure more conspicuous.

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 28 cells in height, frequency distribution of ray height in juvenile and older wood shown in Figs. 73 and 75, (b) fusiform rays; with uniseriate wings up to 20 cells in height, 6～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 35～150 μ, of 172 canals in one of the specimens, 64 solitary, (b) radial resin canals; number of epithelial cells per canal 5～7 in juvenile wood and 9～11 (12) in older wood shown in Figs. 72 and 74 respectively. A and rarely B types of Fig. 2. T. 20～50 μ.

(2) Description of elements

Almost the same as *P. abies*, except the following:

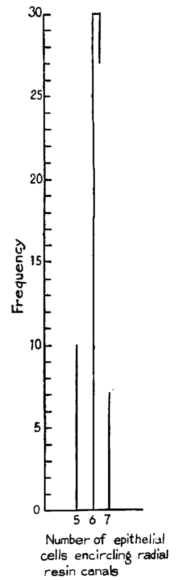


Fig. 72 *P. sitchensis* (10 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 5.94).

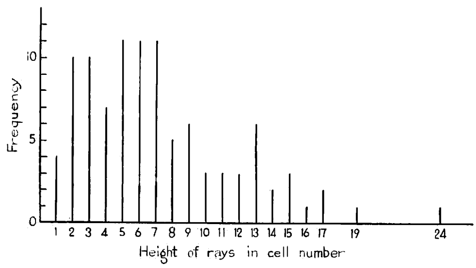


Fig. 73 *P. sitchensis* (10 th ring) Frequency distribution of height of rays in cell number (Av. 7.25).

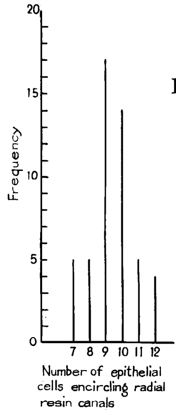


Fig. 74 *P. sitchensis* (190 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.42).

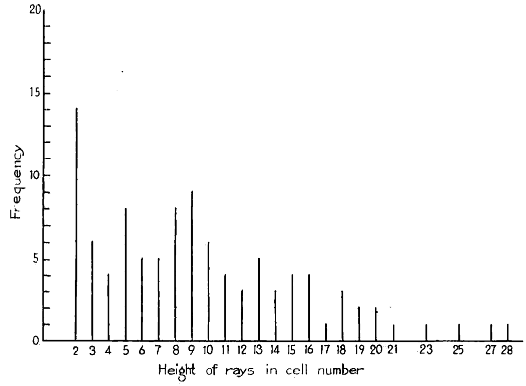


Fig. 75 *P. sitchensis* (190 th ring) Frequency distribution of height of rays in cell number (Av. 9.58).

Tracheids: T. 17～50 μ, in spring wood R. up to 50 μ, in summer wood R. 9～23 μ, Th. up to 5 μ. Bordered pits R. 8～25 μ. L. 3,300～4,300 μ.

Ray parenchyma cells: Pits 2～4 per cross field, often with brown or reddish brown contents. Rarely with crystals of calcium oxalate as KUKACHKA[34] mentioned. V. 15～20 μ, T. 9～18 μ.

Epithelial cells: (a) of axial resin canals; L. 24～45 μ, S. 11～17 μ, (b) of radial resin canals; L. 9～15 μ, S. 6～11 μ.

30. *Picea smithiana* BOISS.: Himalayan spruce. (Photos. 16, 51, 52, 79, 80, 81, and 82)

A. **Macroscopical features**

Almost the same as *P. abies*, except the following:

Heartwood with somewhat pinkish cast, and demarcation between heart- and sapwood barely visible, particularly after long exposure.

B. **Microscopical features**

Almost the same as *P. abies*, except the following:

Rays: (a) uniseriate rays; B type of Fig. 1, up to 16 (rarely 28) cells and 15～40 μ, in height, frequency distribution of ray height in one of the specimens shown in Fig. 77, (b) fusiform rays; with uniseriate wings up to 10 cells in height. 4～10 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 37～100 μ, R. 60～105 μ, of 109 canals in one of the specimens, 59 solitary, (b) radial resin canals; number of epithelial cells per canal 5～11, frequency distribution of the number of cells in one of the specimens shown in Fig. 76. A and B types of Fig. 2. T. 25～40 μ.

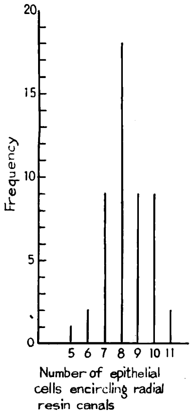


Fig. 76 *P. smithiana* (adult)
Frequency distribution of number of epithelial cells encircling radial resin canals(Av. 8.34).

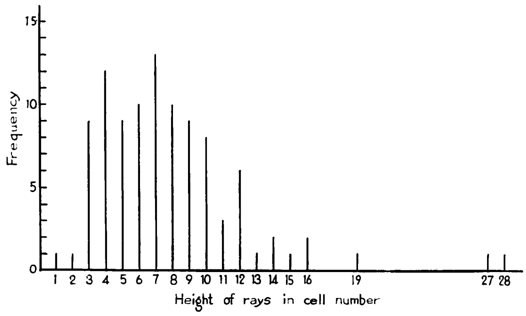


Fig. 77 *P. smithiana* (adult)
Frequency distribution of height of rays in cell number (Av. 7.82).

(2) Description of elements

Almost the same as *P. abies*, except the following:

Tracheids: T. 13～50 μ, in spring wood R. 17～50 μ, in summer wood R. 6～30 μ, Th. up to 7 μ. Bordered pits R. 10～25 μ. With spiral thickenings on the wall of spring and summer wood tracheids, fairly distinct, found everywhere as mentioned by KANEHIRA[27], PEARSON and BROWN[42], and PHILLIPS[45]. L. 5,300 μ.

Ray tracheids: Often with spiral thickenings, or with dentation on the wall.

Ray parenchyma cells: Pits 2～5 per cross field, often with brown contents. With crystals of calcium oxalate. V. 15～26 μ, T. 13～35 μ.

Epithelial cells: (a) of axial resin canals; L. 20～45 μ, S. 6～15 μ. Sometimes with crystals of calcium oxalate, (b) of radial resin canals; L. 13～25 μ, S. 8～11 μ. Sometimes with crystals of calcium oxatate.

31. *Picea spinulosa* (Griff.) Henry (Photos. 17, 18, 53, 84 and 85)

A. **Macroscopical features**

Almost the same as *P. smithiana.*

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. smithiana,* except the following:

Rays: (a) uniseriate rays; B or A and B types of Fig. 1, up to 22 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 79, (b) fusiform rays; with uniseriate wings up to 20 cells in height. 6～12 rays found in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 50～113 μ, of 40 canals in one of the specimens, 10 solitary, (b) radial resin canals; number of epithelial cells per canal 6～10, frequency distribution of the number of cells in one of the specimens shown in Fig. 78. A and B types of Fig. 2. T. 15～25 μ.

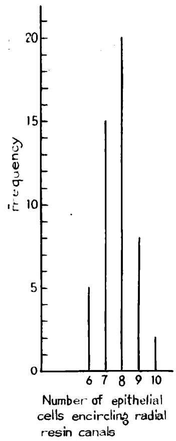


Fig. 78 *P. spinulosa* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.74).

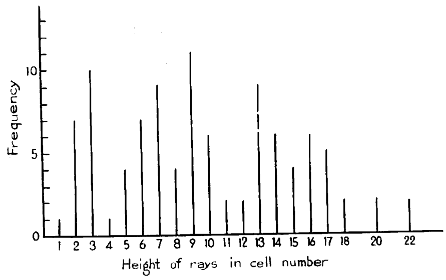


Fig. 79 *P. spinulosa* (adult) Frequency distribution of height of rays in cell number (Av. 9.73).

(2) Description of elements

Almost the same as *P. smithiana,* except the following:

Tracheids: T. 10～48 μ, in spring wood R. up to 65 μ, in summer wood R. 7～25 μ, Th. up to 6 μ. Bordered pits R. 7～20 μ, L. 2,100 μ.

Ray parenchyma cells: V. 2～25 μ, T. 7～20 μ.

Epithelial cells: (a) of axial resin canals; L. 25～35 μ, S. 7～17 μ, (b) of radial resin canals; L. 10～25 μ, S. 10～13 μ. No crystals found.

32. *Picea wilsonii* Mast. (Photo. 83)

A. **Macroscopical features**

Almost the same as *P. abies.*

B. **Microscopical features**

(1) Arrangement of elements

Almost the same as *P. smithiana,* except the following:

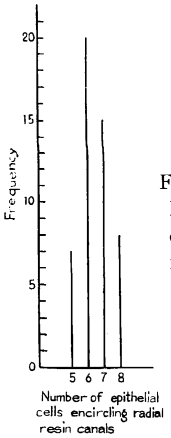
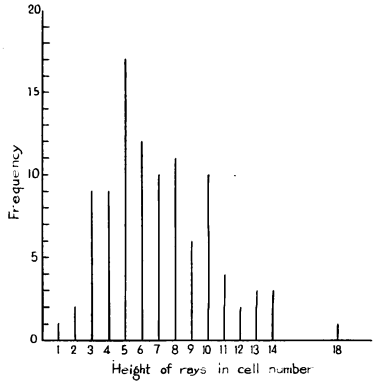


Fig. 80 *P. wilsonii* (adult) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.48).

Fig. 81 *P. wilsonii* (adult) Frequency distribution of height of rays in cell number (Av. 7.04).



Rays: (a) uniseriate rays; A and B types of Fig. 1, up to 14 cells in height, frequency distribution of ray height in one of the specimens shown in Fig. 81, (b) fusiform rays; with uniseriate wings up to 9 cells in height. 6~10 rays in 1 mm tangential line on the transverse surface.

Resin canals: (a) axial resin canals; T. 30~125 μ, R. 60~105 μ, of 50 canals in one of the specimens, 17 solitary, (b) radial resin canals; number of epithelial cells in one of the specimens shown in Fig. 80. A and B types of Fig. 2.

(2) Description of elements

Almost the same as *P. smithiana*, except the following:

Tracheids: T. 7~50 μ, in spring wood R. 17~50 μ, in summer wood R. 8~24 μ, Th. up to 7 μ, L. 3,200 μ.

Ray parenchyma cells: V. 10~20 μ, T. 9~15 μ.

Epithelial cells: (a) of axial resin canals; L. 12~25 μ, S. 6~12 μ, (b) of radial resin canals; L. 12~25 μ, S. 5~11 μ. No crystals found.

V. Outline of wood anatomical characters of *Picea*

A. Macroscopical features

Sapwood white or with light brownish or yellowish tinge, heartwood of some species with pinkish or reddish brown tinge and others with light brownish yellow tinge, being slightly darker than that of sapwood. Demarcation between them in some species fairly visible and in other species not distinct. After long exposure heartwood darkens.

Spring wood wider and lighter in color, summer wood narrower and darker in color, and growth rings fairly clear. Transition from spring wood to summer wood gradual when rings are wide and abrupt when narrow.

With characteristic resinous odor when fresh, and with silky lustre.

Ray: Very fine and not visible to the n. e. on the transverse surface, fairly visible with lens or to the n. e. when with radial resin canals.

Axial parenchyma: Not found.

Resin canals: axial and radial, the former visible with lens as white dots, 2-several tangentially cantiguous or solitary, sometimes grouped in tangential lines along the ring, on the longitudinal surface scarcely visible to the n. e. as darker lines, the latter not visible even

Table 2. The main wood anatomical

Species	Tracheids			Rays		
	Spirals	Length μ	Tang. diameter μ	Height in cell number	Spirals or dentations of ray tracheids	Crystals
Picea abies	Juvenile wood, summer wood	3400	7—50	～22	Dentations	Absent
P. asperata	〃	1700—2600	7—48	～22	〃	〃
*P. balfouriana**	Spring and summer wood			～14	〃	〃
P. bicolor	Juvenile, occas. adult wood, summer wood	5100	12—50	～16	Dentations occas. spirals	Present
P. brachytyla	Spring and summer wood	3400	17—40	～23	Spirals distinct	〃
P. breweriana	Juvenile to adult wood, summer wood	3100—3300	7—45	～27	Dentations and spirals	Absent
P. chihuahuana	Juvenile wood, summer wood	2200	7—38	～20	Dentations	Present
P. engelmanni	〃	2000—3900	7—50	～29	〃	Very rare
P. glauca	〃	2700—3200	10—43	～19	〃	Absent
P. glehnii	〃	4500	7—38	～25	〃	〃
P. jezoensis	〃	2900～4200	10—45	～23	〃	〃
P. j. var. *hondoensis*	〃		20—46	～19	〃	〃
P. koraiensis	〃	2000	12—47	～19	〃	〃
P. koyamae	Juvenile occas. to adult wood, summer wood	3300	10—43	～13	〃	〃
P. likiangensis	Spring and summer wood	1700—1900	7—25	～17	Spirals distinct	Present
P. mariana	Jevenile wood, summer wood	2800—3600	10—35	～16	Dentations	Absent

characters of species of *Picea*

				Radial resin canals			Axial resin canals	
Contents of ray cells	Height of uniseriate wing of fusiform ray	Type of ray cells**	Number of rays per mm	Type of fusiform rays***	Number of epithelial cells	Tang. diameter μ	Tang. diameter μ	Crystals in epithelial cells
Y. brown-brown	~11	A	4— 8	A	6—10	30—50	60—125	Absent
〃	~10	〃	4—10	A	6—11	25—50	50—137	〃
〃		〃		A				〃
Brown	~10	A・B	4—12	A	6—10	32—50	50—110	〃
〃	~ 9	A・B	4—10	A	7— 9	35—50	40—125	〃
〃	~16	A・B	6—10	A B: rare	6— 9	27—45	30—110	〃
Y. brown-brown	~10	A	6—12	A	6— 8	25—48	20— 85	〃
〃	~15	〃	4—10	A	6—13	27—60	40—100	〃
〃	~15	〃	4—10	A	6—12	27—50	40—137	〃
〃	~12	〃	4—10	A	6—12	25—50	50—120	〃
Brown	~16	〃	4—12	A	6—12	25—50	50—125	〃
〃		〃	4—12	A	6—12	30—50	50—140	〃
〃	~13	〃	4—12	A	7—10	27—57	40—110	〃
〃	~ 9	A・B	2—10	A	6—10	25—50	40—125	〃
〃	~ 7	A・B	6—10	A B: rare	6—10	35—50	25— 75	〃
Y. brown-brown	~ 7	A	4—10	A	8—14	22—50	27—117	〃

Table. 2 (つづき)

Species	Tracheids			Rays		
	Spirals	Length μ	Tang. diameter μ	Height in cell number	Spirals or dentations of ray tracheids	Crystals
P. maximowiczii	Spring and summer wood	4000	10—45	～27	Spirals distinct	Present
*P. meyeri**	Spring and summer wood former indistinct				Dentations	Absent
P. montigena	Spring and summer wood	1200—1900	7—35	～16	Spirals distinct	
P. morrisonicola	〃	3600—5400	7—55	～24	〃	Present
*P. obovata**	Juvenile wood, summer wood			～ 8	Dentations	Absent
P. omorica	〃	2000—2900	10—35	～27	〃	Present
P. orientalis	〃	2800—3000	15—50	～29	〃	Absent
P. polita	Juvenile, occas. adult wood, summer wood	4400	5—50	～13	Dentations occas. spirals	Present
*P. pungens**	〃	1800—3500	10—45	～24	Dentations	Absent
P. purpurea	Spring and summer wood former indistinct			～12	Spirals distinct	〃
P. rubens	〃	1900—2700	7—35	～17	Dentations	〃
*P. shirasawae**	〃			～11	〃	
P. sitchensis	〃	3300—4300	17—50	～28	〃	Rarely present
P. smithiana	Spring and summer wood	5300	13—50	～28	Spirals distinct	Present
P. spinulosa	〃	2100	10—48	～22	〃	〃
P. wilsonii	〃	3200	7～50	～14	〃	〃

* : Only branch wood examined ** : See Fig. 1 *** : See Fig. 2

(Continued)

				Radial resin canals			Axial resin canals	
Contents of ray cells	Height of uniseriate wing of fusiform ray	Type of ray cells**	Number of rays per mm	Type of fusiform rays***	Number of epithelial cells	Tang. diameter μ	Tang. diameter μ	Crystals in epithelial cells
Brown	～15	A・B	6—12	A・B	5—10	25—50	25—150	Present
		A		A				Absent
Brown	～ 7	A・B	4—10	A・B	5—10	37—60	30—110	〃
〃	～12	B	4—10	A・B	5— 8	18—35	55—135	Present
		A		A				Absent
Brown	～10	〃	4—10	A B: rare	5— 9	15—25	37— 85	〃
Y. brown-brown	～20	〃	4—12	A B: rare	5—10	20—50	37—125	〃
Brown	～ 8	B	4— 8	A・B	6— 8	27—43	50—100	〃
Y. brown-brown	～16	A	4—10	A	6—13	22—50	40—100	〃
	～ 4	〃		A	6— 8	—38	— 50	〃
Y. brown-brown	～11	〃	2—12	A	5— 9	27—52	37—105	〃
		〃		A	6— 9	—38	38— 70	〃
Brown	～20	A・B	6—10	A B : rare	5—12	20—50	35— 50	〃
〃	～10	B	4—10	A・B	5—11	25—40	37—100	Present
〃	～20	A・B	6—12	A・B	6—10	15—25	50—113	Absent
〃	～ 9	〃	6—10	A・B	5— 8	25—50	30—125	〃

with lens on the longitudinal surface, visible with or occasionally without lens as white lines in rays on the transverse surface.

B. **Microscopical features**

I. **Arrangement of elements**

Tracheids: Regular in radial series; radial diameter gradually decreases from spring wood to summer wood, with end walls when adjacant to epithelial cells encircling axial resin canals.

Axial parenchyma: Generally wanting.

Rays: Uniseriate or rarely biseriate in part and fusiform; (a) uniseriate rays; cells in the tangential section with nearly round or square contour (B type of Fig. 1), or long elliptical, oval or rectangular (A type of Fig. 1), up to 30 cells in height, mostly depending on number of the rings from pith, and also appears to be influenced by the growth rate (Figs. 142~146), (b) fusiform rays; generally with one, or rarely two radial resin canals in the middle, generally with uniseriate wings on the margins, below and above, infrequently two fusiform rays axially connected with uniseriate wings, uniseriate wings lower than uniseriate rays (Figs. 147 and 148), height of uniseriate wings increases in proportion to that of uniseriate rays, number of the rays found in 1 mm tangential line on the transverse surface 4~12. Consist of ray parenchyma cells and ray tracheids. Ray trachids generally on the upper and lower margins, occasionally inserted between ray parenchyma cells, usually one row.

Resin canals: Axial and radial, (a) axial resin canals; mostly found in transitional area between spring wood and summer wood and summer wood, occasionally wanting from the portion of rings, encircled by epithelium generally in one cell layer or partially more than two layers. Tangential diameter normally 20~140 μ, (b) radial resin canals; found in fusiform rays, encircled by epithelial cells in somewhat constant number 5~13, variation of the number originated in number of growth rings from pith and possibly growth rate, rays with the canal classified into two types as shown in Fig. 2 A and B. Tangential diameter 15~60 μ. Besides these normal resin canals traumatic resin canals occasionally found, sometimes with dark resinous contents. Tylosoids originated in epithelial cells project into these resin canals.

II. **Description of elements**

Tracheids: Tangential diameter 7~50 μ, smaller in juvenile part and increases as growth ring number increases, attaining somewhat constant value at a certain ring number (Figs. 93 ~95). Radial diameter gradually decreases from spring wood to the last formed summer wood (Figs. 96~98). Bordered pits larger, round in spring wood and numerous, and small and less numerous in summer wood, in one row or rarely paired on the radial walls, small tangential pitting found in the outer part of summer wood, pits leading to ray parenchyma 2~6 in a cross field and piceoid, small. With crassulae on the walls, spiral thickenings found only on the wall of tracheids in summer wood of juvenile wood of the majority of the members and everywhere in the rest. Tracheids length increases as the growth ring number increases, attaining somewhat constant length at a certain ring number, longest over 6,000 μ, mostly 3,000~6,000 μ.

Ray tracheids: In comparison with the axial tracheids, shorter in length, much more irregular in shape, showing wavy contour, walls not smooth, with fine dentations in the majority of the members and with somewhat distinct spiral thickenings in other species, in the former vague spiral thickenings occasionally found, with bordered pits.

Ray parenchyma cells: Thick-walled, indentured (Photos. 74 and other radial sections), with nodular thickenings on the end walls (Photos. of radial sections), sometimes with brownish or reddish brown or yellowish contents. Some species with crystals of calcium oxalate (Photos. 82 and 84).

Epithelial cells: Generally thick-walled and occasionally thin-walled (Photos. 25, 57, 58, 60 and 77). Crystals of calcium oxalate found in some species (Photos. 79 and 86).

VI. Discussions on the wood anatomical characters

In general, the previous descriptions on the wood anatomical characters of species and the genus appear to have depended mostly on small specimens, and thus sufficient considerations on the variation of features originating from the difference of position within tree, the difference in growing conditions, and other factors have not been given. In this report the author tries to describe the features with consideration of the variations as mentioned above for making better descriptions of them.

1. Tracheids

A. **Tracheid length:** Since SANIO's work[51] on the variation of tracheid length, many researchers have been interested in this problem and numerous reports on this subject are found. Of them, DINWOODIE's recent work[14] on the variation of tracheid length of *P. sitchensis* is quite detailed and gives us a significant suggestion for the discussion of this matter. And there are many reports and books which describe or cite tracheid length of *Picea* species and its variation[7,29,51,52,54,55,58]. Samples used in this study were not taken from the part of the same ages, nor the same height from tha ground in the stem. In the strict sense, it is not reasonable to make direct comparison of the length of each species obtained in this work and also with that found in other reports. At all events, the longest is 6,100 μ in average which was measured in *P. morrisonicola* with over 300 growth rings. For the mean value of tracheid length of this genus, this is one of the longest. According to his descriptions, difference in length found in this genus appear to depend on the age of the part from which the samples are taken rather than the difference of species. Several examples for the variation of tracheid length due to the ages and the distance from pith are shown in Figs. 82, 83 and 84. It is not the matter here to discuss further the factors influencing the length of tracheids, although they are important for the discussion of this subject.

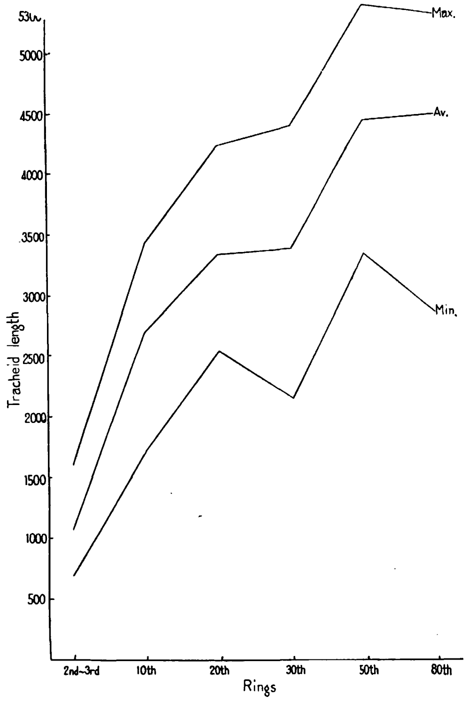


Fig. 82 *P. glehnii*
Relation between the distance from pith and tracheid length.

B. **Diameter:** Tangential diameter increases as the distance from pith increases

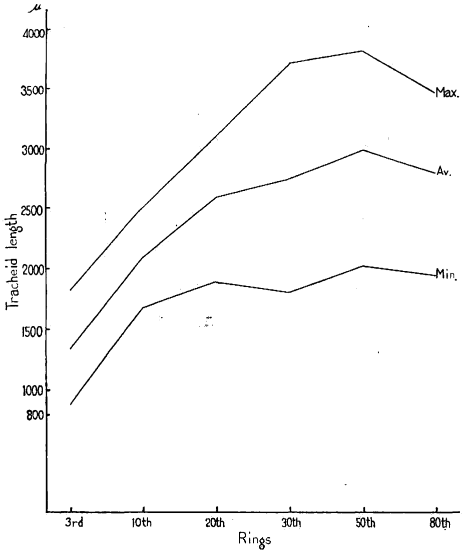


Fig. 83 *P. jezoensis*
Relation between the distance from pith and tracheid length.

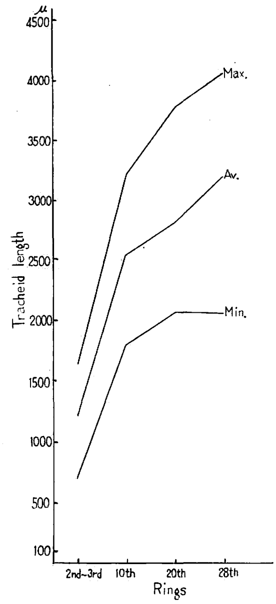


Fig. 84 *P. spinulosa*
Relation between the distance from pith and tracheid length.

up to a certain point from where it remains nearly constant (Figs. 85~95). And this point can be a mark to show the maturity of the sample, although it is a little closer to the pith than the point shown by the tracheid length. Nevertheless, it is not allowable to ignore the distance from pith in growth ring number when we describe the tangential diameter in the strict sense. As shown in Figs., the highest frequency of tangential diameter in the mature part where it is constant or a little fluctuant is found around 25~35 μ or above. Variation of radial diameter is much dependent on the growth ring width. Examples of transition of radial diameter from spring wood to summer wood are shown in Figs. 96~98.

C. **Spiral thickenings on the wall of tracheids:** Presence of spiral thickenings on the wall of tracheids was already pointed out by some researchers such as PFURSCHELLER[44], KANEHIRA[28], PEARSON & BROWN[42], BAILEY[2], KANESHI[31], MIYOSHI & SHIMAKURA[39]. GREGUSS[17] described the rare occurrence of the spiral thickenings in *P. likiangensis* and mentioned it as exceptional for this genus. In general, the spiral thickenings are not found in the commercially well-known species, as *P. abies*, *P. sitchensis* etc., on the world market, and this is also true in Japanese commercial species as *P. jezoensis* and *P. glehnii.* The types of spiral thickenings found on the wall of tracheids are classified into two groups as follows:

1. Spiral thickenings are found on the wall of both summer and spring wood tracheids (Type a).

2. Spiral thickenings are found only on the wall of summer wood tracheids. Generally found only in the juvenile prat, in some species they are detected even in much older part (Type b).

Descriptions on some species were given only on the branch wood, because of the difficulty of obtaining stem wood sample. But the results of the examinations on the other spe-

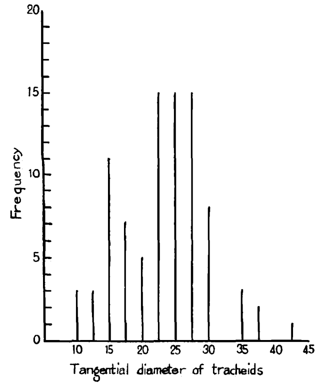


Fig. 85 *P. bicolor*
Frequency distribution of tangential diameter of tracheids.

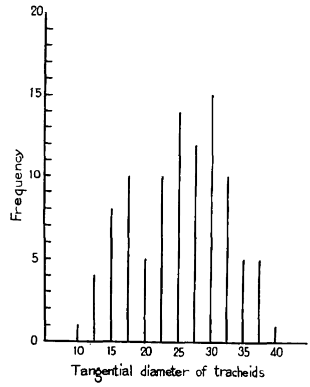


Fig. 86 *P. jezoensis*
Frequency distribution of tangential diameter of tracheids.

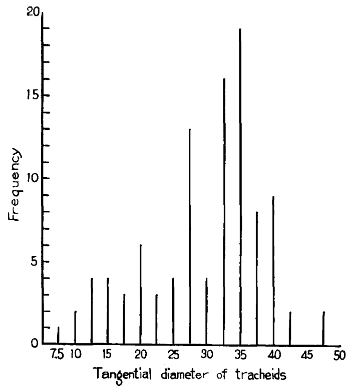


Fig. 87 *P. koraiensis*
Frequency distribution of tangential diameter of tracheids.

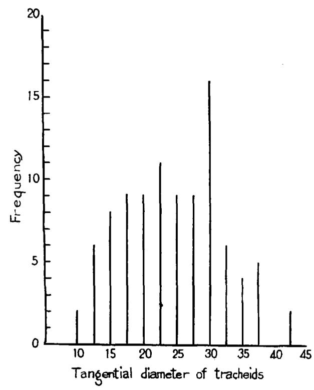


Fig. 88 *P. koyamae*
Frequency distribution of tangential diameter of tracheids.

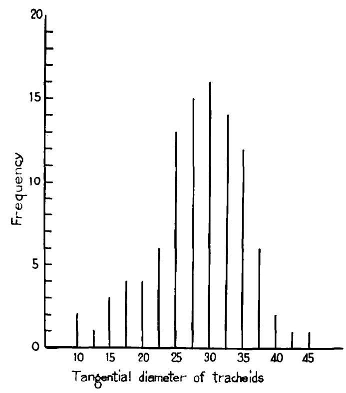


Fig. 89 *P. maximowiczii*
Frequency distribution of tangential diameter of tracheids.

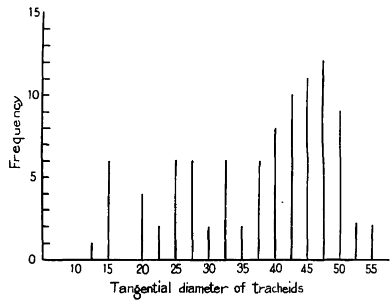


Fig. 90 *P. morrisonicola*
Frequency distribution of tangential diameter of tracheids.

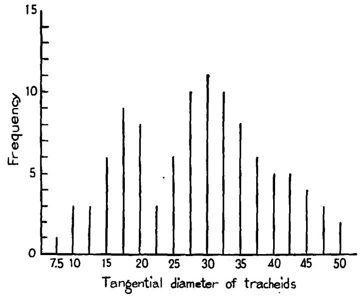


Fig. 91 *P. polita*
Frequency distribution of tangential diameter of tracheids.

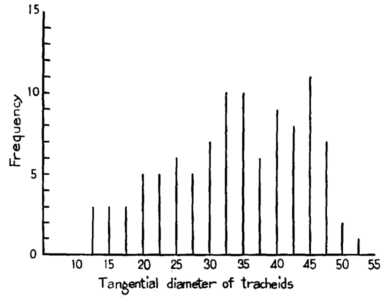


Fig. 92 *P. smithiana*
Frequency distribution of tangential diameter of tracheids.

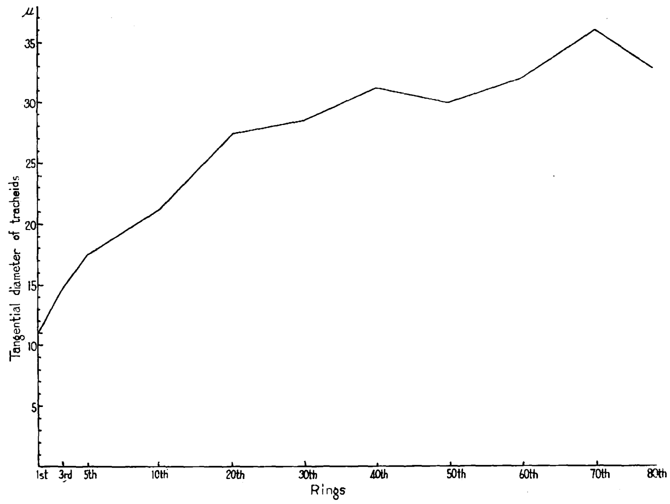


Fig. 93 *P. glehnii*
Relation between the distance from pith and tangential diameter of tracheids.

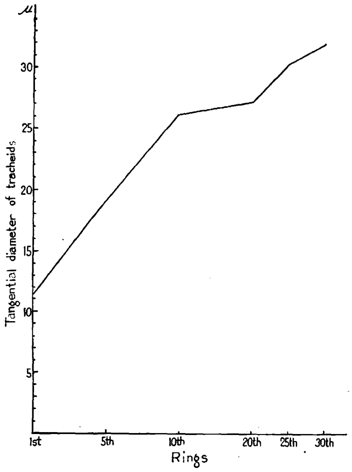


Fig. 94 *P. koyamae*
Relation between the distance from pith and tangential diameter of tracheids.

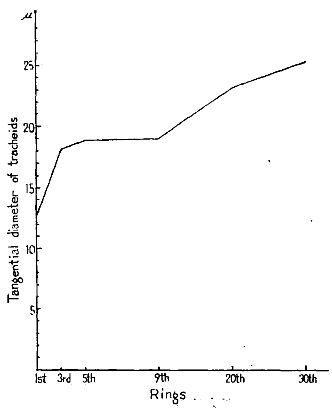


Fig. 95 *P. spinulosa*
Relation between the distance from pith and tangential diameter of tracheids.

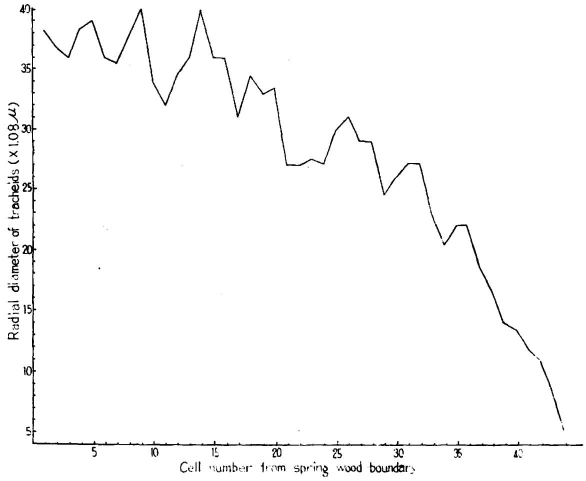


Fig. 96 *P. glehnii*
Variation of radial diameter of tracheids in a ring.

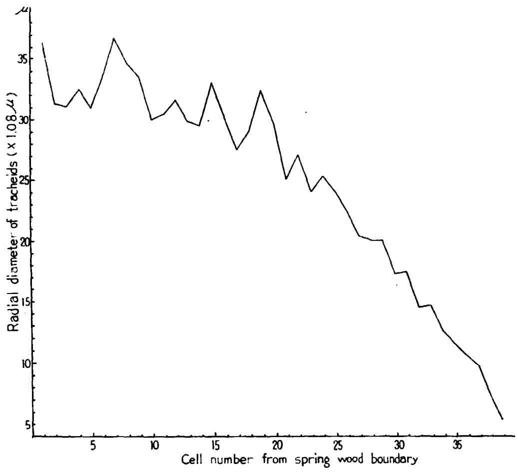


Fig. 97 *P. jezoensis*
Variation of radial diameter of tracheids in a ring.

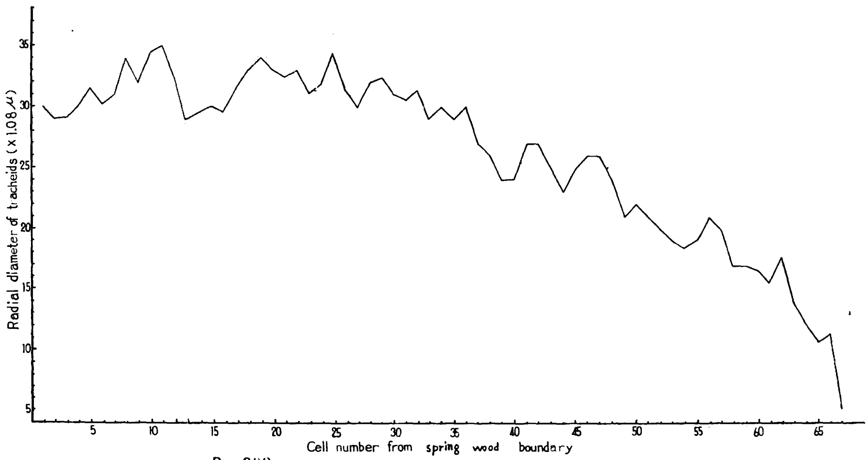


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Fig. 98 *P. j.* var. *hondoensis*
Variation of radial diameter of tracheids in a ring.

Table 3. Presence of spiral thickenings on the wall of tracheids of *Picea*

Species	Part		Distance from pith
	Spring wood	Summer wood	
P. abies		+	First several rings
P. asperata		+	First several rings and branch
P. balfouriana	+	+	Branch
P. bicolor		+	First several rings to 30 th ring
P. brachytyla	+	+	Everywhere and branch
P. breweriana	±	+	First several rings: Spring wood Up to 160 th ring: Summer wood
〃		(+)	Compression wood of 40 th and 50 th rings
P. chihuahuana		+	First several rings and 18 th ring
P. engelmanni		+	Up to 10 th ring
P. glauca		+	First several rings
P. glehnii		+	〃
P. jezoensis		+	〃
P. j. var. *hondoensis*		+	〃
P. koraiensis		+	〃
P. koyamae		+	First several rings, occas. up to 30 th ring
P. likiangensis	+	+	Everywhere
P. mariana		(+)	Up to 20 th ring
〃		(+)	Compression wood of 8 th ring
P. maximowiczii	+	+	Everywhere
P. meyeri	(+)	+	Branch
P. montigena	+	+	Everywhere
P. morrisonicola	+	+	〃
P. obovata		+	First several rings
P. omorica		+	〃
P. orientalis		+	Up to 10 th ring
P. polita	±	+	First several ring: Spring wood Over 30 th ring: Summer wood
P. pungens		+	Over 30 th ring
P. purpurea	(+)	+	Branch
P. rubens		+	First several rings
*P. schrenkiana**	+	+	
P. shirasawae		+	Branch
P. sitchensis		+	First several rings
P. smithiana	+	+	Everywhere
P. spinulosa	+	+	〃
P. wilsonii	+	+	〃

* After Cheng[52]
+ : Present
(+): Present, but not distinct
± : Rarely present

cies of which both branch and stem wood were available showed that the type of the spiral thickenings in stem wood can be judged by that in branch wood. For example, species with the spiral thickenings of b type in stem wood are with the spiral thickenings only on the wall of summer wood tracheids in branch wood. Attention must be paid on the fact that infrequently types of the spiral thickenings are changed in small area by some undeterminable factors, although they are generally very constant within species. Existence of spiral thickenings on the S_3 layer of tracheid wall was recently shown by Côté, according to Panshin *et al.*[41], on *Pseudotsuga menziesii* electron-microscopically. There are several evidences found to support the view that compression wood is one of the causes detected by the author of the disappearance of the spiral thickenengs from the tracheid wall of species with them. As generally accepted, S_1, S_2, and S_3 layers of the secondary wall of the tracheids are transformed into S_1 and the deformed S_2 in the compression wood. Therefore, it is quite reasonable to believe that the spiral thickenings on the S_3 layer are involved in this deformation, vanishing from cell wall.

Based on the types of spiral thickenings, this genus is to be divided into two groups as follows;

a. With the spiral thickenings of Type a

P. balfouriana	*P. maximowiczii*	*P. morrisonicola*	*P. spinulosa*
P. brachytyla	*P. meyeri*	*P. purpurea*	*P. wilsonii*
P. likiangensis	*P. montigena*	*P. smithiana*	

b. With the spiral thickenings of Type b

P. abies	*P. omorica*	*P. koraiensis*
P. asperata	*P. chihuahuana*	*P. orientalis*
P. bicolor	*P. engelmanni*	*P. polita*
P. breweriana	*P. glauca*	*P. pungens*
P. koyamae	*P. glehnii*	*P. rubens*
P. mariana	*P. jezoensis*	*P. shirasawae*
P. obovata	*P. j.* var. *hondoensis*	*P. sitchensis*

2. **Rays**

Rays of *Picea* consist of tracheids and parenchyma cells. Low rays, generally up to three cells in height, not only in juvenile part but also in older part, consist of either only tracheids or of only parenchyma cells. In general, rays consisting of only tracheids show very irregular form.

A. **Height of rays:** Height of rays here is expressed in the number of cells. Phillips[45] showed that in some species of Coniferae height of rays is of some diagnostic value. And also he stressed the necessity of more materials to be examined before using this feature for more than merely auxiliary diagnostic value. The fact that Greguss[18] used this feature for separating species of this genus seems to show his reliance on invariability of this feature, while the author cannot agree with him on this point, because of the fact shown later in this article. Examples of the frequency distribution of ray height are shown in Figs. odd No. of 4～81. In Table 4 frequency distribution and average of ray height in relation to the distance from pith are shown. For the specimens without description of age, only distinction of juvenile and adult wood is made, based on the curvature and width of the rings. The results reveal that the point showing the peak of frequency distribution of ray height gradually shifts to the right side in the

Table 4. Relations between ring number from pith and number of epithelial cells of radial resin canals and ray height in cell number.

Species	Number of epithelial cells of R. R. C. (Ave.)	Ray height in cell number (Ave.)	Age number of rings from pith
Picea abies	6～10 (8.3)	2～22 (8.9)	Adult*
P. asperata	5～11 (6.7)	1～11 (3.8)	Juvenile*
〃	6～11 (8.1)	2～22 (7.9)	Adult
〃	5～ 8 (6.6)	2～14 (6.1)	Juvenile
〃		1～11 (4.4)	Branch
P. balfouriana		1～14 (4.4)	Branch
P. bicolor	6～10 (7.5)	1～16 (6.2)	Adult
P. brachytyla	7～ 9 (8.1)	3～23 (8.9)	Adult
〃		1～12 (3.5)	Branch
P. breweriana	5～ 9 (6.9)	1～27 (9.8)	Adult
P. chihuahuana	4～ 7 (5.9)	1～15 (5.8)	4～5 th
〃	4～ 8 (6.5)	2～20 (8.3)	11 th
P. engelmanni	6～13 (10.8)	2～28 (10.5)	200 th
P. glauca	6～12 (9.7)	3～19 (8.5)	55 th
〃	5～10 (8.2)	1～17 (5.9)	7 th
P. jezoensis	6～11 (8.4)	2～19 (8.5)	Adult
P. koraiensis	6～12 (8.9)	2～19 (8.9)	Adult
P. koyamae	6～10 (8.0)	1～13 (6.0)	Adult
P. likiangensis	5～ 8 (6.7)	1～10 (4.2)	13 th
〃		1～17 (5.0)	Branch
P. mariana	7～14 (10.3)	1～14 (6.7)	60 th
〃	5～ 9 (7.0)	2～16 (6.4)	6 th
P. maximowiczii	5～ 9 (7.3)	2～27 (9.9)	Adult
P. montigena	5～10 (7.0)	1～14 (5.6)	Adult
P. montigena		1～16 (4.9)	Branch
P. morrisonicola	5～ 8 (6.2)	2～21 (8.5)	Adult
〃	6～ 8 (6.9)	1～24 (9.4)	200 th
〃	6～ 8 (6.9)	1～22 (9.3)	100 th
P. obovata		1～ 8 (3.0)	Branch
P. omorica	5～ 9 (6.7)	2～16 (6.9)	10 th
〃	5～ 9 (6.7)	2～27 (10.2)	30 th
P. orientalis	5～10 (7.3)	3～36 (12.6)	Adult
〃	5～ 9 (7,3)	1～16 (6.1)	12 th
P. polita	5～ 8 (6.8)	1～13 (6.1)	Adult
P. pungens	8～11 (9.6)	1～24 (9.1)	Adult
〃	6～10 (7.3)	1～23 (8.0)	15 th
P. purpurea		1～23 (4.6)	Branch
P. rubens	5～ 9 (7.0)	1～27 (7.0)	65 th
P. shirasawae		1～11 (4.2)	Branch
P. sitchensis	5～ 7 (5.9)	1～24 (7.3)	10 th
〃	7～12 (9.4)	2～28 (9.6)	190 th
P. smithiana	5～11 (8.3)	1～28 (7.8)	Adult
P. spinulosa	6～10 (7.7)	1～22 (9.7)	Adult
P. wilsonii	5～ 8 (6.5)	1～18 (7.0)	Adult

* Adult: more than about ten years old.
Juvenile: less than about ten years old.

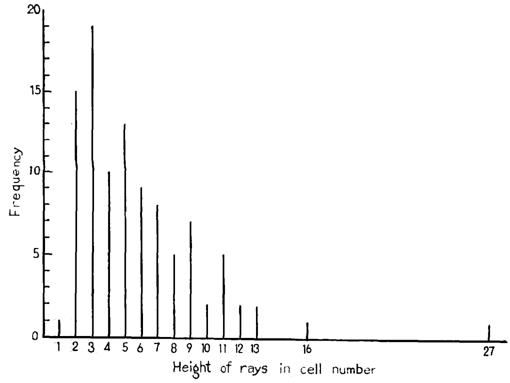


Fig. 99 *P. engelmanni* (A), (2nd ring)
Frequency distribution of height of rays in cell number (Av. 5.94).

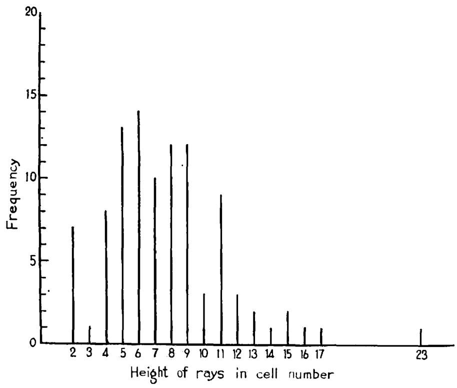


Fig. 101 *P. engelmanni* (A), (10th ring)
Frequency distribution of height of rays in cell number (Av. 7.63).

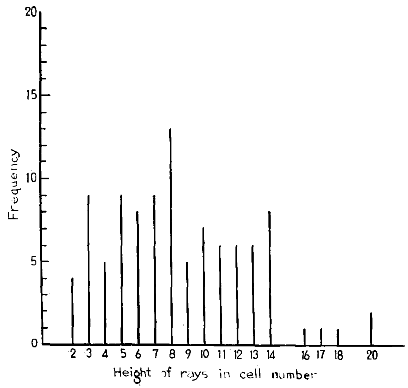
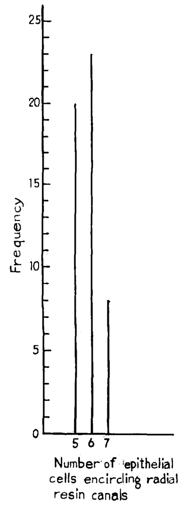


Fig. 103 *P. engelmanni* (A), (20th ring)
Frequency distribution of height of rays in cell number (Av. 8.49).

Fig. 100 *P. engelmanni* (A), (10th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 5.76).



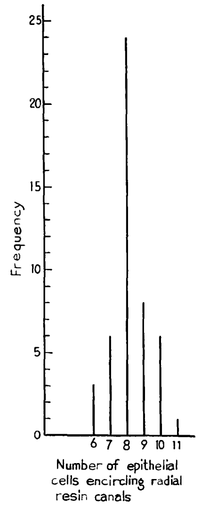


Fig. 102 *P. engelmanni* (A), (20th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.23).

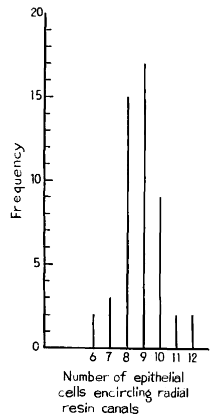


Fig. 104 *P. engelmanni* (A), (30th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 8.84).

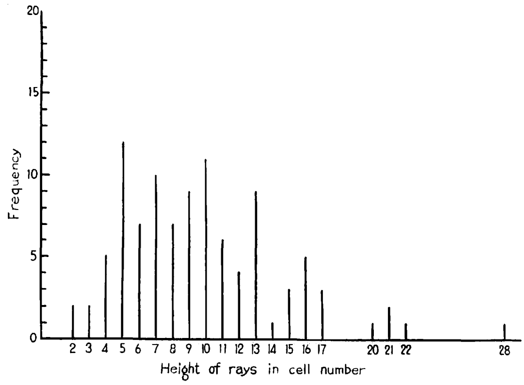


Fig. 105 *P. engelmanni* (A), (30th ring)
Frequency distribution of height of rays in cell number (Av. 9.72).

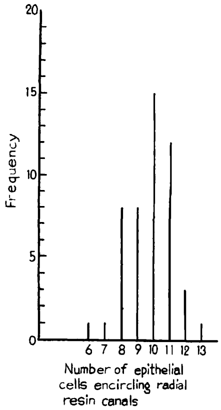


Fig. 106
P. engelmanni
(A), (40th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.80).

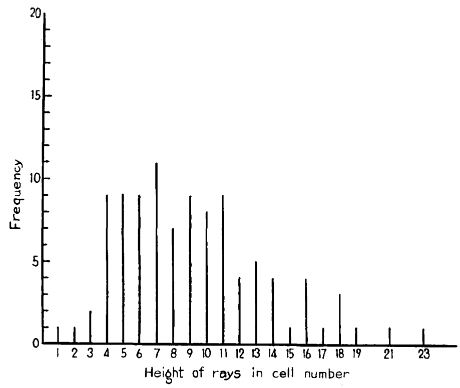


Fig. 107 *P. engelmanni* (A),
(40th ring)
Frequency distribution of height of rays in cell number (Av. 9.19).

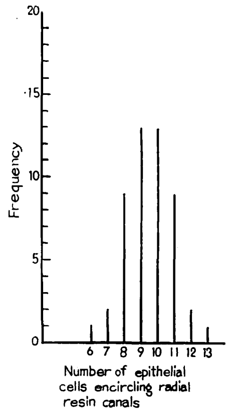


Fig. 108 *P. engelmanni*
(A), (50th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.50).

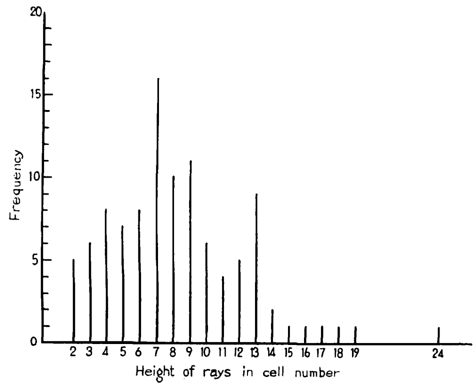


Fig. 109 *P. engelmanni* (A),
(50th ring)
Frequency distribution of height of rays in cell number (Av. 8.27).

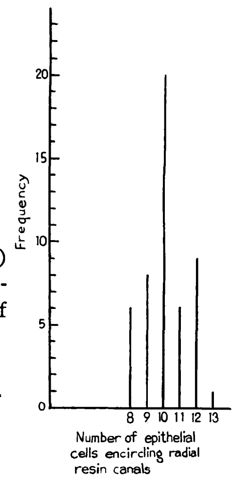


Fig. 110
P. engelmanni
(A), (80th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 10.14).

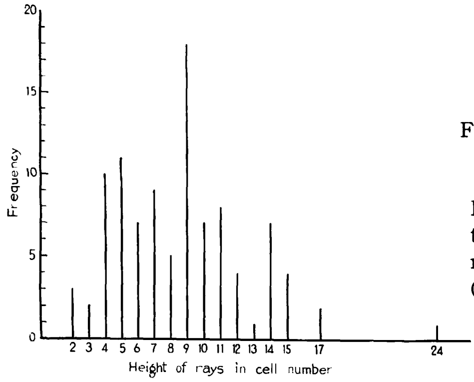


Fig. 111
P. engelmanni
(A), (80 th ring)
Frequency distribution of height of rays in cell number (Av. 8.49).

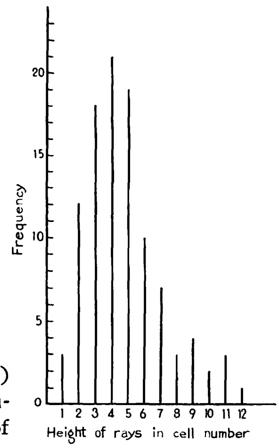


Fig. 112
P. engelmanni
(B), (10 th ring)
Frequency distribution of height of rays in cell number (Av. 4.80).

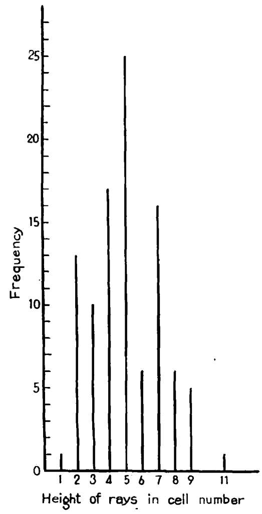


Fig. 113 *P. engelmanni* (B), (40 th ring) Frequency distribution of height of rays in cell number (Av. 5.02).

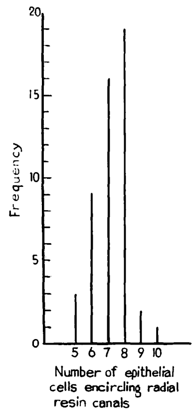


Fig. 114 *P. engelmanni* (B), (80 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.26).

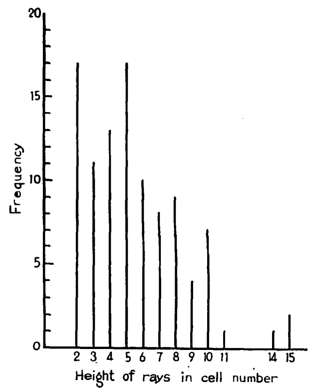


Fig. 115 *P. engelmanni* (B), (80 th ring) Frequency distribution of height of rays in cell number (Av. 5.53).

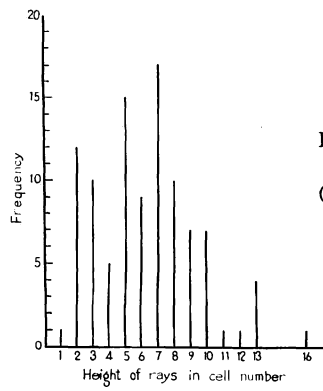


Fig. 116 *P. engelmanni* (B),(100th ring) Frequency distribution of height of rays in cell number (Av. 6.27).

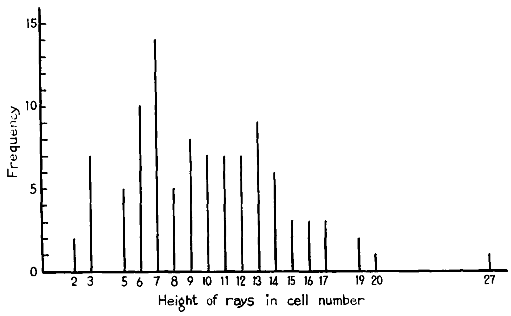


Fig. 117 *P. engelmanni* (B), (150 th ring) Frequency distribution of height of rays in cell number (Av. 9.54).

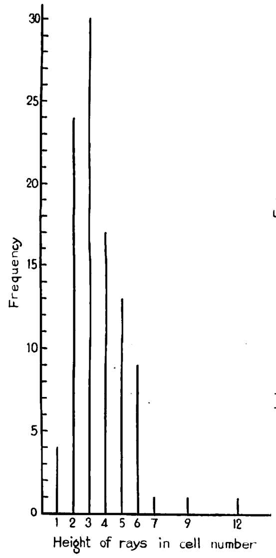


Fig. 118 *P. glehnii* (1 st ring) Frequency distribution of height of rays in cell number (Av. 3.57).

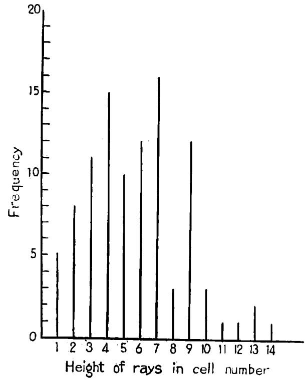


Fig. 119 *P. glehnii* (5 th ring) Frequency distribution of height of rays in cell number (Av. 5.73).

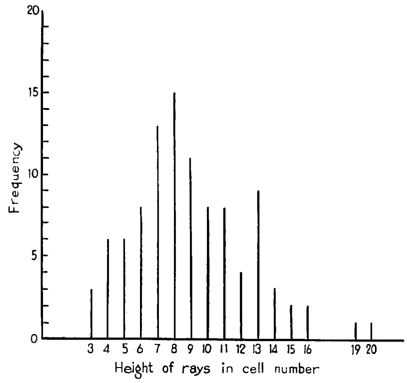


Fig. 120 *P. glehnii* (10 th ring) Frequency distribution of height of rays in cell number (Av. 8.88).

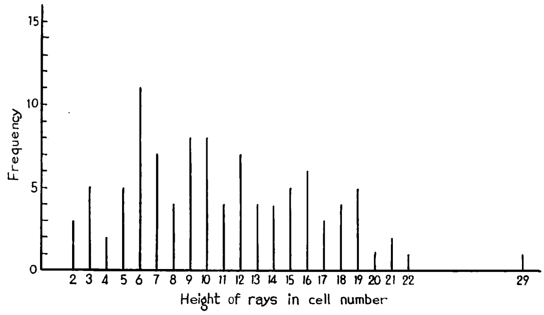


Fig. 122 *P. glehnii* (30 th ring) Frequency distribution of height of rays in cell number (Av. 10.91).

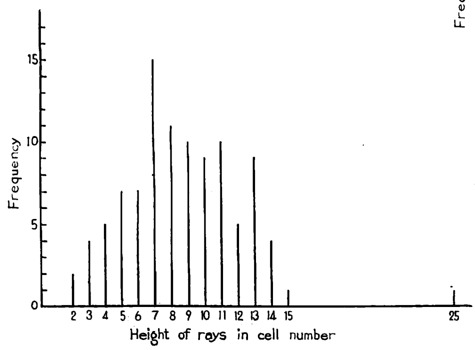


Fig. 121 *P. glehnii* (20 th ring) Frequency distribution of height of rays in cell number (Av. 8.69).

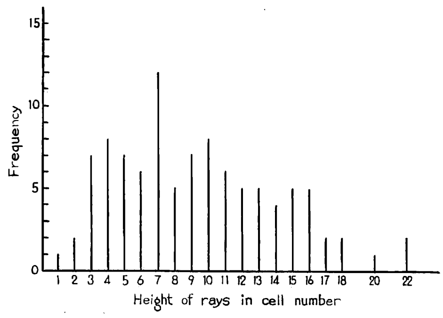


Fig. 124 *P. glehnii* (50 th ring) Frequency distribution of height of rays in cell number (Av. 9.51).

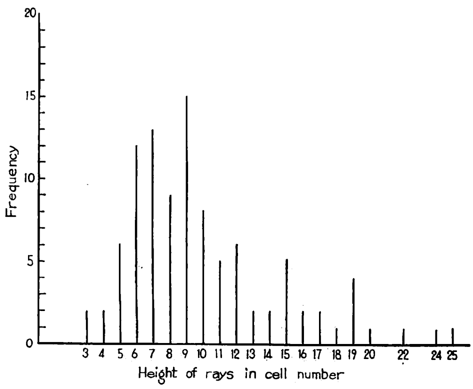


Fig. 123 *P. glehnii* (40 th ring) Frequency distribution of height of rays in cell number (Av. 10.01).

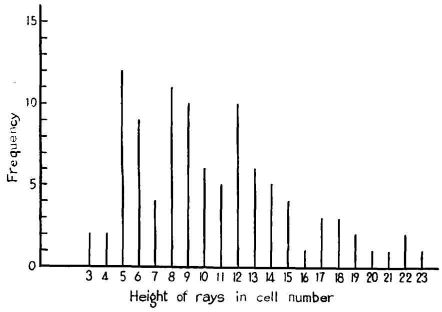


Fig. 125 *P. glehnii* (70 th ring)
Frequency distribution of height of rays in cell number (Av. 10.44).

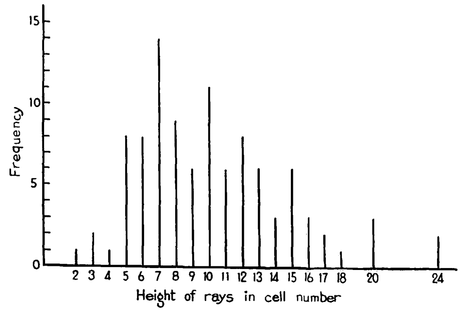


Fig. 126 *P. glehnii* (80 th ring)
Frequency distribution of height of rays in cell number (Av. 10.14).

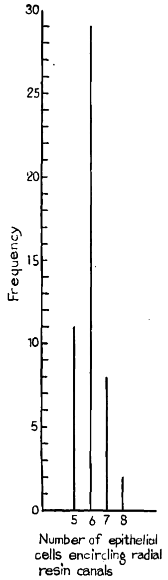


Fig. 127 *P. maximowiczii* (5 th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 60).

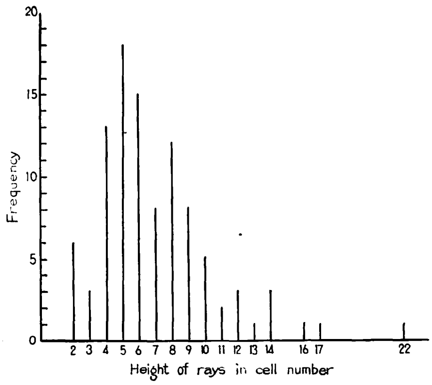


Fig. 128 *P. maximowiczii* (5 th ring)
Frequency distribution of height of rays in cell number (Av. 6.95).

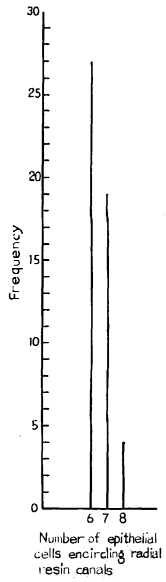


Fig. 129 *P. maximowiczii* (10 th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.54).

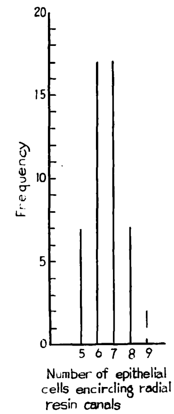


Fig. 131 *P. maximowiczii* (20 th ring)
Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.60).

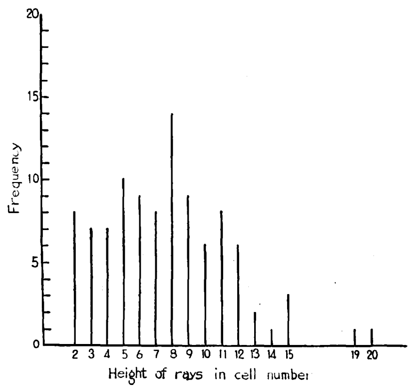


Fig. 130 *P. maximowiczii* (10 th ring)
Frequency distribution of height of rays in cell number (Av. 7.62).

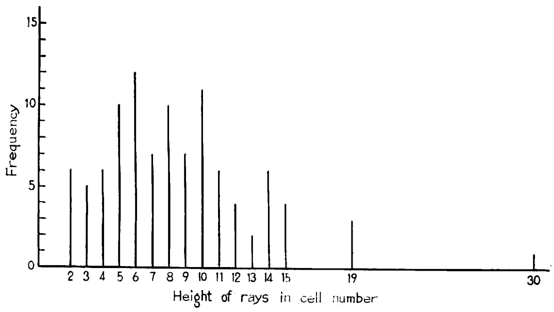


Fig. 132 *P. maximowiczii* (20th ring) Frequency distribution of height of rays in cell number (Av. 8.46).

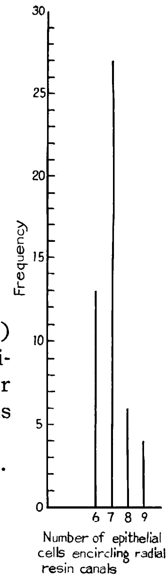


Fig. 133 *P. maximowiczii* (30th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.02).

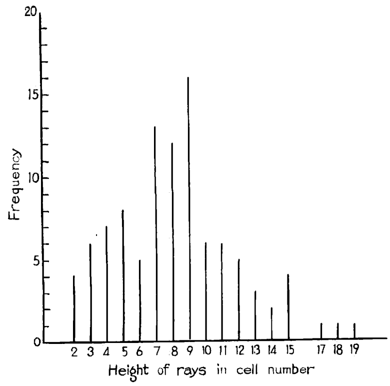


Fig. 134 *P. maximowiczii* (30th ring) Frequency distribution of height of rays in cell number (Av. 8.22).

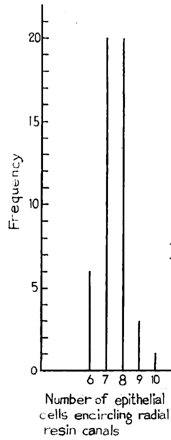


Fig. 135 *P. maximowiczii* (40th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.46).

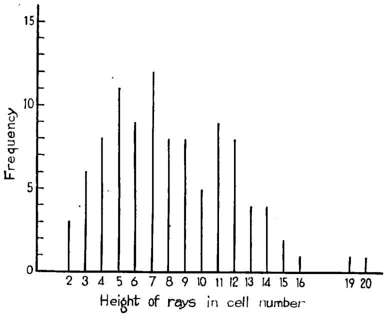


Fig. 136 *P. maximowiczii* (40th ring) Frequency distribution of height of rays in cell number (Av. 8.23).

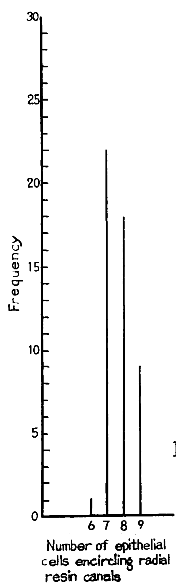


Fig. 137 *P. maximowiczii* (50th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.70).

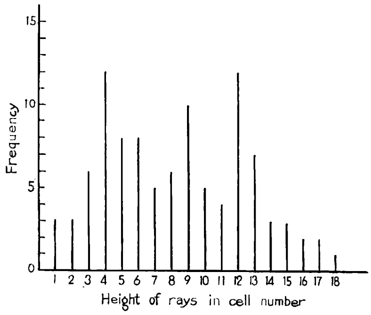


Fig. 138 *P. maximowiczii* (50th ring) Frequency distribution of height of rays in cell number (Av. 8.30).

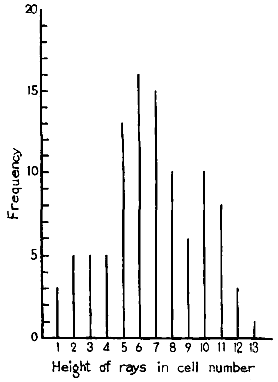


Fig. 139 *P. wilsonii* (30th ring) Frequency distribution of height of rays in cell number (Av. 6.85).

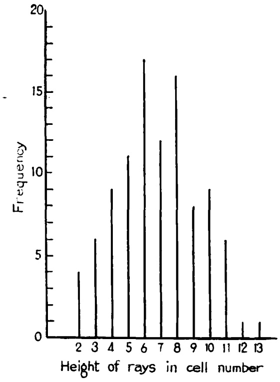


Fig. 140 *P. wilsonii* (80th ring) Frequency distribution of height of rays in cell number (Av. 6.84).

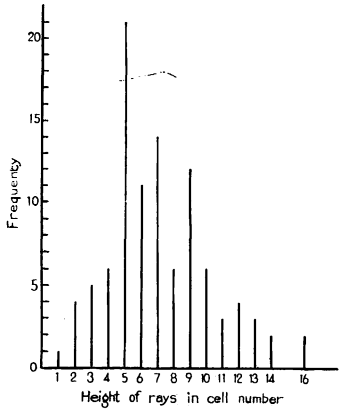


Fig. 141 *P. wilsonii* (150th ring) Frequency distribution of height of rays in cell number (Av. 7.13).

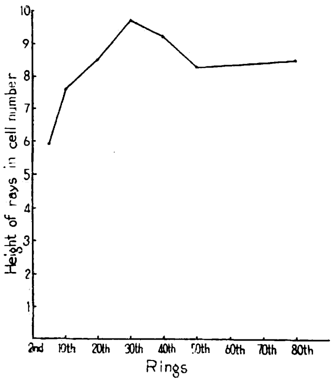


Fig. 142 *P. engelmanni* (A) Relation between the distance from pith and height of rays in cell number.

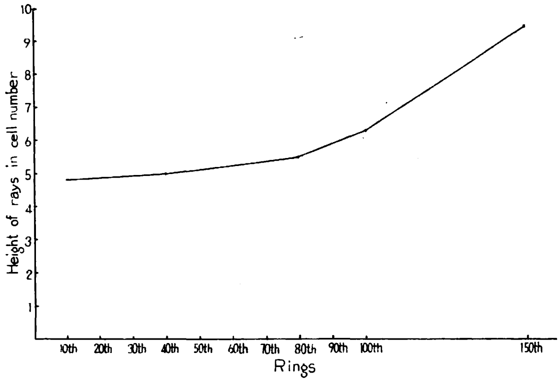


Fig. 143 *P. engelmanni* (B) Relation between the distance from pith and height of rays in cell number.

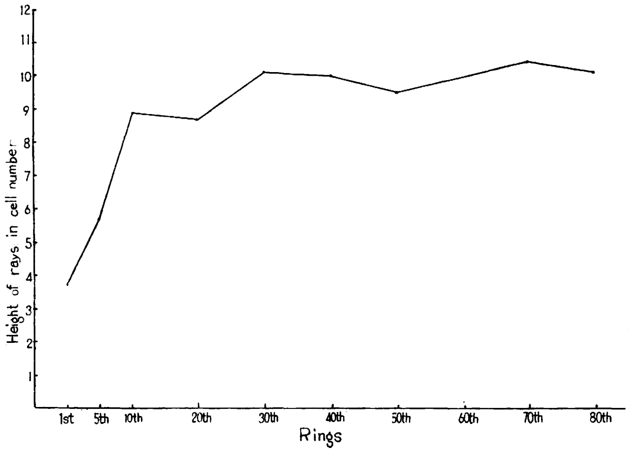


Fig. 144 *P. glehnii* Relation between the distance from pith and height of rays in cell number.

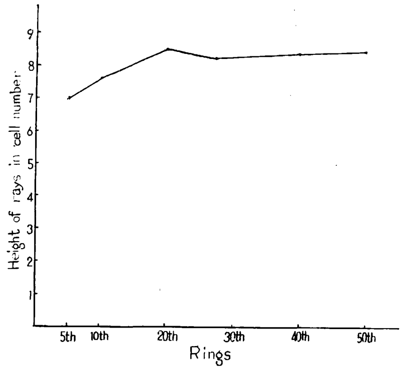


Fig. 145 *P. maximowiczii*
Relation between the distance from pith and height of rays in cell number.

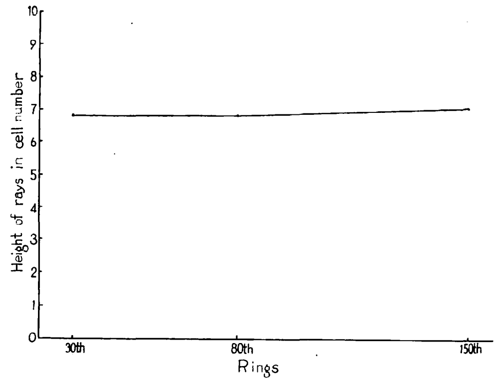


Fig. 146 *P. wilsonii*
Relation between the distance from pith and height of rays in cell number.

figures according to the increasing age of specimens, and that in younger part the distribution of ray height tends to be much more concentrated around the peak than in older part. The peak of frequency distribution is not always only one in older part; it is exclusively one in younger part. Patterns of the variation are shown in Figs. odd No. of 99～111 and 112～117 (ex. 114) etc. The height of ray in average is much higher in the older part than in the younger. To clarify the relation between the distance from pith and the ray height, the author made particular observations on *P. engelmanni*, *P. glehnii*, *P. maximowiczii* and *P. wilsonii*. They are shown in Figs. odd No. of 99～111, 112～117 (ex. 114), 118～126, even No. of 128～138 and 139～141. Relations between the average height of ray and the distance from pith in these four species are shown in Figs. 142～146. Although there are some minor differences in the course of the variation between specimens, it is quite certain that the height of rays increases as the distance from pith in ring number increases, and that there is a certain point from where the height stays constant. And this point probably is the characteristics for species or genus. Consequently, before this point which exists between the 20th and 30th rings the height of rays is lower and variable. As a result, without any consideration on the distance from pith, comparison of ray height between and within species is not to be made particularly for the purpose of the identification. Also there is an interesting fact which is found in a sample of *P. engelmanni* showing very narrow ring up to the 100th ring followed by much wider rings. In this specimen the ring width is as follows; 40 rings/cm around the 40th ring, 28 rings/cm around the 100th ring, 7 rings/cm around the 150th ring and thereafter becomes abruptly much wider. The course of increase of ray height is shown in Fig. 143. In another specimen with 80 rings, growth rate is much higher than the former throughout the disc (4 rings/cm around the 30th ring, 10 rings/cm around the 70th ring). As shown in Fig. 142, in this specimen the average ray height already exceeds 7 cells at the 10th ring and in the former specimen it is still less than 7 cells at the 100th ring. They may be extreme examples to show the influence of growth rate on the height of rays, but this influence is not negligible in describing this feature. On the basis of the above-mentioned observations, the author wishes to stress the necessity of recording the ages and growth rate of specimens examined in describing ray height. So far as the author's observation is concerned, rays lower than 10 cells in average height are mostly of juvenile part or of the specimen of slow-grown trees. In practice, when the adjustment to the effects mentioned above on the ray height is made, ray height of each species will be almost similar and consequently should not be used as a diagnostic feature for their identification, particularly for separating species of this genus.

B. **Fusiform rays:** (1) Shape of fusiform rays in tangential section. It is known that *Picea* has fusiform rays with one or rarely two radial resin canals. These canals are surrounded by thick-walled epithelial cells often being accompanied by a small number of the thin-walled ones. The author proposes to classify the type of fusiform rays based on the shape into two as follows:

a. in the central part of the fusiform rays epithelial cells directly contact with tracheids adjacent to rays and there are no other ray cells between them (Fig. 2-A).

b. in the central part of the fusiform rays epithelial cells contact indirectly with tracheids adjacent to the rays and between them ray cells are found.

Generally this is found on the one side of rays and rarely on the both sides (Fig. 2-B).

In general, B type fusiform rays are accompanied by A type rays. B type rays were observed in 12 species as follows:

P. breweriana (rare)	*P. morrisonicola**	*P. sitchensis* (rare)
*P. likiangensis**	*P. omorica* (rare)	*P. smithiana**
*P. maximowiczii**	*P. orientalis* (rare)	*P. spinulosa**
*P. montigena**	*P. polita*	*P. wilsonii**

It is to be noted that, of the species examined, 7 species marked with asterisk are with the spiral thickenings on the wall of tracheids even in their spring wood. In other species, A type rays are exclusively found.

(2) Uniseriate wings of fusiform rays. Almost all the fusiform rays are with uniseriate wings on their margin. The height of wings increases in proportion to the height of uniseriate rays in the specimens examined, as shown in the following table.

Species	Average height of uniseriate wings of fusiform rays in cell number	Average height of uniseriate rays in cell number
P. abies	5.4	8.9
P. breweriana	6.0	9.8
P. glauca	5.8	8.5
P. jezoensis	4.0	8.5
P. likiangensis	1.1	4.2
P. mariana	5.2	6.7
	3.8	6.5
P. montigena	1.6	5.6
P. orientalis	7.7	12.6
	3.5	6.1

In general, fusiform rays showing typical form for this genus as shown in Photos. 34 and 50 can not be expected until the height of the uniseriate wings reaches 5 cells or more. Frequency distribution of height of uniseriate wings of fusiform rays both in adult and juvenile wood of *P. sitchensis* is shown in Figs. 147 and 148 respectively.

C. **Distribution of biseriate and fusiform rays:** As in other coniferous species, rays in this genus are mostly uniseriate and rarely biseriate in part, apart from fusiform rays. Their per-

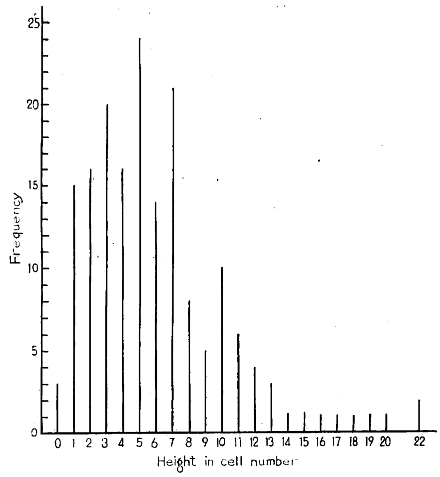


Fig. 147 *P. sitchensis* (190 th ring) Frequency distribution of height of uniseriate wings of fusiform rays.

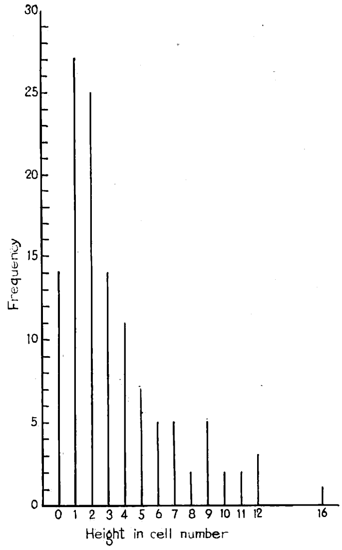


Fig. 148 *P. sitchensis* (10 th ring) Frequency distribution of height of uniseriate wings of fusiform rays.

centage for all the rays was calculated in several species.

In the calculation, the number of the biseriate rays found on the lines at a right angle to the long axis of tracheids on the tangential surface was used. They are as follows:

P. bicolor	1/100	*P. montigena*	2/100
P. engelmanni	4/100	*P. morrisonicola*	2/100
P. glauca	2/100	*P. pungens*	3/100
P. koraiensis	1/100	*P. wilsonii*	2/100
P. maximowiczii	1/100		

When biseriate rays are incidentally closely located, their percentage is larger than usual. Their presence, however, is not frequent in comparison with uniseriate rays.

On the other hand, fusiform rays are very distinct among other rays, because of the large size, although the number of fusiform rays found in the unit area is not large and is almost the same as that of biseriate rays. Presence of fusiform rays in juvenile wood, particularly in the 1st or the 2nd rings from the pith, is very scanty and thereafter increases until it attains a certain number, and then stays constant although still very scanty. Since the increase rate of the number is not high, this change is not easy to find, but it is definite, nevertheless.

D. **Shape of ray cells:** There are two kinds of shape of ray cells found in the tangential section, A and B as shown in Fig. 1. Some species are with only one type of cells, either A or B, while others have two types of ray cells, A and B. Species cited below are with two types of ray cells, and the others are with exclusively A type of ray cells. According to Phillips[45], *P. sitchensis* can be separated from other species by the fact that it has round or square cells in rays. They correspond to the cells of B type here.

P. bicolor (A, B)	*P. morrisonicola* (B)*
P. brachytyla (A, B)*	*P. polita* (B)
P. breweriana (A, B)	*P. sitchensis* (A, B)

P. koyamae (A, B)
P. likiangensis (A, B)*
P. maximowiczii (A, B)*
P. motigena (A, B)*
P. smithiana (B)*
P. spinulosa (A, B)*
P. wilsonii (A, B)*

It is interesting to note that, of these thirteen species, eight species with asterisk mark are with spiral thickenings both on their spring and summer wood tracheid wall.

In general, the tangential section of ray cells in juvenile wood is oval or oblong and they contact axially with adjacent ray cells on their pointed edges. By this fact juvenile wood is easily separated from more matured wood which has flat ends which contact with each other axially (Photos. 43 and 48).

E. **Ray parenchyma cells:** As many reports such as those by Phillips[45], Kukachka[34], Brown *et al.*[7], state, the cell wall of *Picea* is thick, and the features attributed to this are nodular end walls and more or less distinct indentures which are found in the corners of the cell walls in the radial section. In a cross field between tracheids and ray parenchyma cells there are found 2～6 pits and they are half-bordered pits mostly belonging to the piceoid type. Greguss[18] described the existence of differences in the number of pits between species and used this fact as a diagnostic feature in separating species. According to the descriptions on this feature by Budcevicz[9], Cheng[52] and others, it appears to be difficult to use this feature for the same purpose that Greguss aimed, because of the contradictions found in those descriptions. Strictly speaking, all the pits are not piceoid and, particularly in juvenile wood, pit aperture is wider and consequently rims of pits are narrower than those found in adult wood. While pits are in a single or double file in adult wood, they are very often in a triple file in juvenile wood. Moreover, the height of ray cells in juvenile wood is much higher than that of adult wood and they are upright. It is very interesting to note that Harada[20] recently proposed a different conception from the opinions of previous researchers on the structure of half-bordered pits on the basis of the fact found electron-microscopically.

F. **Crystals in ray cells:** Presence of calcium oxalate crystals has been reported by the authors, among them Cheng[52], Kanehira[27] and Kukachka[34]. Presence of the crystals in *P. montigena* by Cheng, in *P. bicolor* and *P. morrisonicola* by Kanehira and rarely in *P. sitchensis* by Kukachka was respectively reported. The author could not ascertain the presence of crystals in *P. montigena*, though Cheng[52] described their presence. The author described their presence in *P. brachytyla* and *P. wilsonii*, whereas Cheng made no reference to their presence in these species. From these facts, the presence of crystals in some species could be said partial or sporadic. There is an interesting tendency found on the presence of crystals in regard to species. Of the fourteen species with crystals listed below so far described by the author and Cheng[52], seven species marked with asterisk are with spiral thickenings on their tracheid wall of both spring and summer wood.

P. bicolor
*P. brachytyla**
P. chihuahuana
P. engelmanni (rare occurrence in one specimen)
*P. likiangensis**
*P. maximowiczii**
*P. morrisonicola**
P. omorica
P. polita
P. sitchensis
*P. smithiana** (rare)
*P. spinulosa**
*P. wilsonii**

G. **Color of ray cell contents:** In ray cells there are often found resinous contents with reddish or yellowish brown tinge. They are cited as follows:

Species with brown or reddish brown resinous contents.

P. bicolor	*P. montigena*
P. brachytyla	*P. morrisonicola*
P. breweriana	*P. omorica*
P. jezoensis	*P. polita*
P. j. var. *hondoensis*	*P. sitchensis*
P. koraiensis	*P. smithiana*
P. koyamae	*P. spinulosa*
P. likiangensis	*P. wilsonii*
P. maximowiczii	

Species with yellowish or brown resinous contents.

P. abies	*P. glehnii*
P. asperata	*P. mariana*
P. chihuahuana	*P. orientalis*
P. engelmanni	*P. pungens*
P. glauca	*P. rubens*

KUKACHKA[34] stated that *P. sitchensis* was readily separated from other native species by the presence of reddish contents.

H. **Spiral thickenings on the wall of ray tracheids:** Presence of tracheids in rays is one of the characteristics of this genus. And also it should be noted that they have spiral thickenings on the wall, and that, if not, they are at least with fine dentations as KANEHIRA[29], KUKACHKA[34], and PHILLIPS[45] described, although YAMABAYASHI[58] did not mention their presence in *P. koraiensis* and *P. jezoensis*. In the previous chapters of the present paper the author described their presence in each species and classified them into two types as follows:

a. Spiral thickenings are distinct or at least recognized.

b. Generally spiral thickenings are not found, though scarcely they are in the ray tracheids near the growth ring boundary. Instead, fine dentations are found.

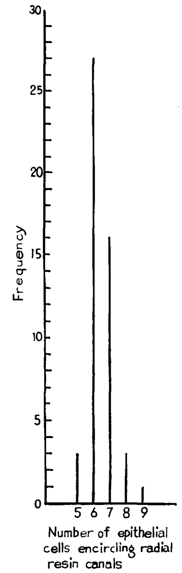
The occurrence of these spiral thickenings and fine dentations on the wall of ray tracheids nearly corresponds to that of the spiral thickenings on the wall of tracheids. When spiral thickenings are distinct on the wall of ray tracheids in certain species, spiral thickenings on the wall of tracheids are also distinct (a type). When only the fine dentations are found on the wall of ray tracheids in certain species, generally no spiral thickenings are found on the wall of tracheids (b type), except on the wall of tracheids of juvenile wood. But there are two exceptional species in which spiral thickenings are more or less recognizable. They are *P. breweriana* and *P. polita*. When ray tracheids show upright and irregular contour in the radial section, spiral thickenings are more or less distinct even in species generally with only fine dentations.

3. Radial resin canals

Presence of radial resin canals is one of the characteristic features of this genus. They are hardly found in the first ring, and in the second and the third rings thick-walled epithelial cells in a small number encircling very small canal or without any visible canal are found in small fusiform rays. Thereafter, small canals increase their diameter and number of the epithelial cells around them in accordance with increasing ring number from pith. And finally the diameter and the number of the epithelial cells encircling the canals becomes constant at a certain ring number.

A. **Epithelial cells:** The previous repɔrts on this genus pubulished in this country[29)33)58)] do not mention the presence of thin-walled epithelial cells, whereas JEFFREY[26)] and BROWN *et al.*[7)] described their presence. Of course, epithelium constists mainly of thick-walled cells and often 1~2 thin-walled cells or more are found among epithelial cells encircling resin canals (Photos. 47, 49, 58 and 60). These thin-walled cells are easily found in the juvenile part; in adult part they are transformed into tylosoids and projected into the canal.

B. **Number of epithelial cells per canal:** Number of the epithelial cells encircling radial resin canals for each coniferous genus is nearly constant. Consequently, this is one of the important identification features for the coniferous species with radial resin canals, as has been shown by many researchers as BROWN *et al.*[7)], JANE[24)], PHILLIPS[45)] etc. Generally seven to nine cells per canal for this genus are accepted as its characteristics, and five to six for *Pseudotsuga* by many workers. In this report, the range of the number of epithelial cells per canal, the frequency distribution of the number and the average number are given and listed in Table 4. The author also noted the existence of a possible relation between these numbers and distance from pith in ring number. For ascertaining this relation, particular observations were made on five species including *P. engelmanni*, *P. glehnii*, *P. maximowiczii P. wilsonii*. The results are shown by histograms in Fig. 100~110 (even number), 114, 149~152, 153~158, 127~137 (odd number), 159~161. And the relation between them in these species are shown in Fig. 162~166. Although there are some fluctuations found, average number of the epithelial cells encircling radial canals increases as the distance from pith expressed in ring number increases. According to Table 4 and Figs. above mentioned, average number increases rapidly from pith for the first 30 or 40 rings and, then, the increasing rate lowers. Around the 30~40 th rings, the average number is 6.5~8 in all species. DIANNELIDIS[13)] pointed out the increase of average number with the age of ring from pith. The average number of the epithelial cells appears to be related with the maturity of wood. Another interesting fact is that the average number of the epithelial cells appears to be influenced by growth rate, slow-grown or fast-grown. Good examples showing this ralation are found in two samples of *P. engelmanni.* They are shown in Figs. 162~163. In one specimen, ring width is 9/cm in the slow-grown part and 5/cm in the fast-grown part. And in another specimen, ring width is 7/cm in the fast-grown part and 40/cm in slow-grown part. In the former specimen the average number increases rapidly from pith as the growth ring number increases, and it is already 10 at the 80 th ring. In the latter it increases slowly from pith and it is still very small even at the older part. In the former, together with the higher average number of epithelial cells, fusiform rays show the typical shape of the genus because of their higher uniseriate wings. In one specimen of *P. wilsonii* the average number is fairly lower than expected from its growth ring number as shown in figure, and in the author's opinion this is also due to the narrow rings of the specimen, 2~3/mm. CHENG[52)] described the average number of the epithelial cells per radial resin canal and BROWN *et al.*[7)] gave 7~9 as average number for the eastern spruces and Sitca spruce. BUDCEVICZ[9)] also listed the average number for many species and he separated the genus into three groups, namely, those with fewer than 8 cells, those with fewer than 10 cells and those with more than 10 cells. According to CHENG[52)] the average number of epithelial cells are;



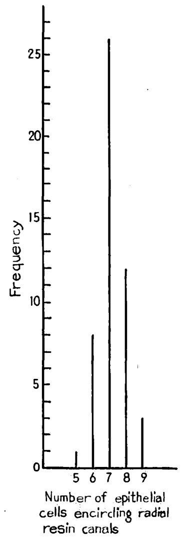
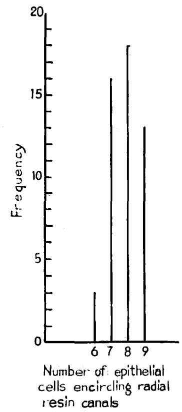


Fig. 149 (10th ring) Fig. 150 (40th ring)
(Av. 6.44) (Av. 7.16)
P. engelmanni (B)
Frequency distribution of number of epithelial cells encircling radial resin canals.



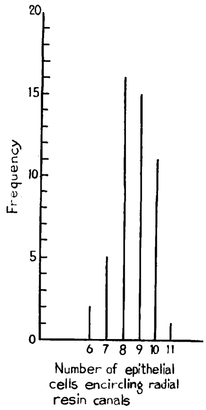


Fig. 151 (100th ring) Fig. 152 (150th ring)
(Av. 7.82) (Av. 8.62)
P. engelmanni (B)
Frequency distribution of number of epithelial cells encircling radial resin canals.

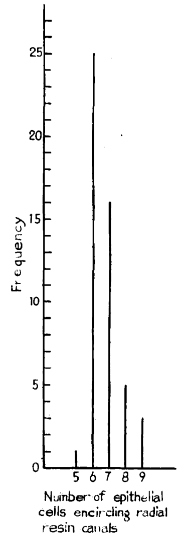


Fig. 153 *P. glehnii*
(5th ring)
(Av. 6.68)
Frequency distribution of number of epithelial cells encircling radial resin canals.

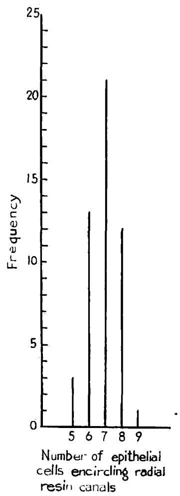


Fig. 154 *P. glehnii*
(10th ring)
(Av. 6.90)
Frequency distribution of number of epithelial cells encircling radial resin canals.

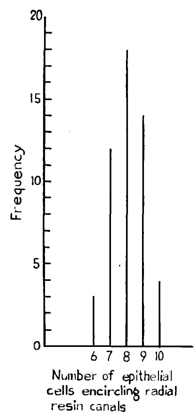


Fig. 155 *P. glehnii*
(20th ring)
(Av. 8.08)
Frequency distribution of number of epithelial cells encircling radial resin canals.

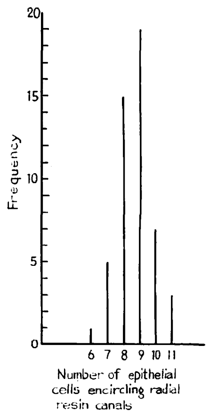


Fig. 156 *P. glehnii*
(30th ring)
(Av. 8.70)
Frequency distribution of number of epithelial cells encircling radial resin canals.

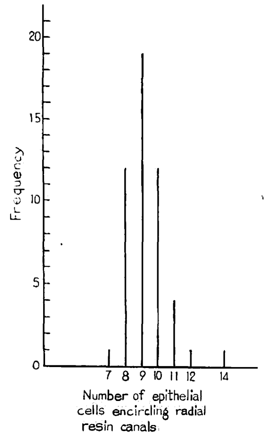


Fig. 157 *P. glehnii* (40 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.28).

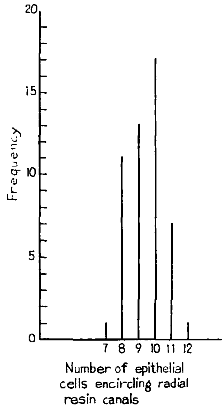


Fig. 158 *P. glehnii* (70 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 9.42).

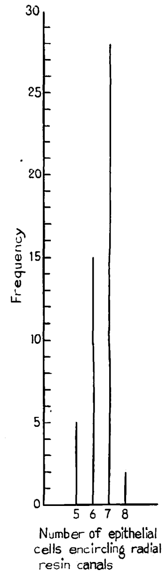


Fig. 159 *P. wilsonii* (30 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.54).

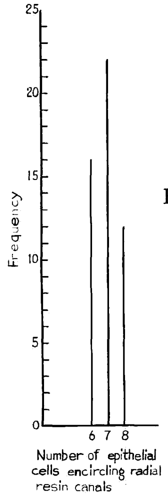


Fig. 160 *P. wilsonii* (80 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 6.92).

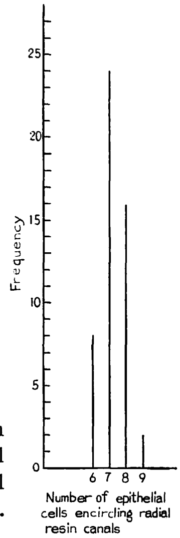


Fig. 161 *P. wilsonii* (100 th ring) Frequency distribution of number of epithelial cells encircling radial resin canals (Av. 7.24).

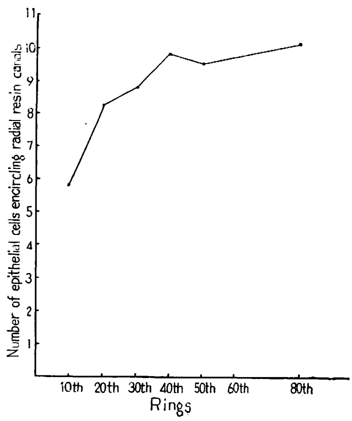


Fig. 162 *P. engelmanni* (A) Relation between the distance from pith and number of epithelial cells encircling radial resin canals.

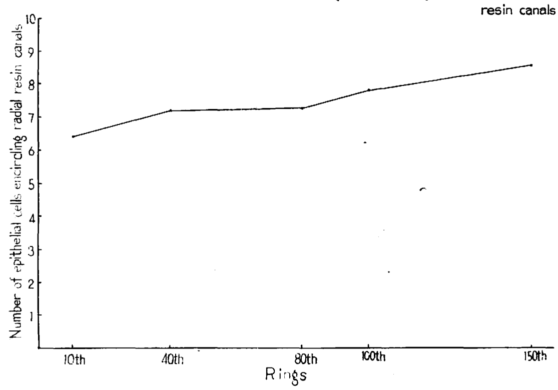


Fig. 163 *P. engelmanni* (B) Relation between the distance from pith and number of epithelial cells encircling radial resin canals.

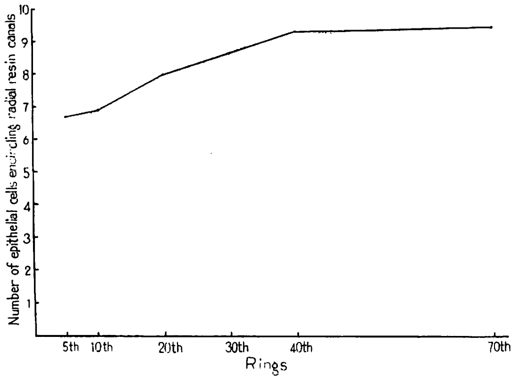


Fig. 164 *P. glehnii*
Relation between the distance from pith and number of epithelial cells encircling radial resin canals.

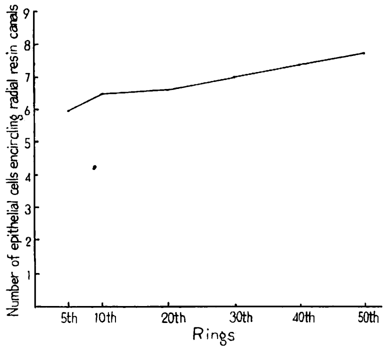


Fig. 165 *P. maximowiczii*
Relation between the distance from pith and number of epithelial cells encircling radial resin canals.

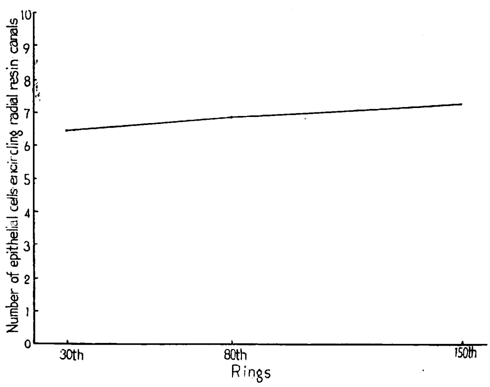


Fig. 166 *P. wilsonii*
Relation between the distance from pith and number of epithelial cells encircling radial resin canals.

P. brachytyla	5～9 (6～7)	*P. neoveithii*	6～8 (7)
P. jezoensis	7～16 (10～12)	*P. purpurea*	8～9
P. montigena	6～9 (6～8)	*P. schrenkiana*	7～12 (8～11)

And Budcevicz[9] described as follows;

P. alcockiana	6～8	*P. asperata*	6～10
P. hondoensis	6～8	*P. breweriana*	8～10
P. obovata	6～8	*P. engelmanni*	7～10
P. omorica	6～8	*P. excelsa*	6～10
P. polita	5～8	*P. glehnii*	8～10
P. pungens	6～8	*P. jezoensis*	6～10
P. wilsonii	6～8	*P. koyamae*	8～10
		P. likiangensis	8～10
		P. mariana	5～10
		P. neoveitchii	7～10

P. brachytyla	10〜12
P. canadensis	7〜10
P. koraiensis	10〜15
P. meyeri	9〜12
P. morinda	8〜13
P. orientalis	12〜15
P. purpurea	10〜14
P. sitchensis	7〜12
P. rubens	7〜10
P. schrenkiana	7〜10

And the author's descriptions are outlined in Table 2. It is easily recognized that there are species which are given unequal average number by different authors; for *P. bicolor*, *P. brachytyla*, *P. engelmanni*, *P. mariana*, *P. omorica*, and *P. pungens*, for example. In comparison with descriptions by others[7)9)52)], the author concluded that it is very hard to find any definite variation in the average number between species in spite of the above-mentioned assertion by BUDCEVICZ, and that the differences found in specimens are firstly due to the ring number from pith and secondly to the growth rate.

4. **Axial resin canals**

In this genus, axial resin canals are generally found in summer wood and transitional area between spring and summer wood. Two to three or more of them are tangentially connected and sometimes solitary. This characteristic feature is used for separating this genus from *Pinus* which has only solitary resin canals.

A. **Presence of the solitary resin canals:** In the wood adjacent to pith, mostly 1st to 3rd rings, in general there are only solitary canals found (Photos. 7, 10 and 18), although it has been believed that resin canals in this genus are mostly non-solitary as mentioned above. JEFFREY[26)] showed this fact in an illustration in his book. In juvenile wood they tend to distribute even in spring wood, too, and consequently they are distributed fairly evenly throughout the ring just as those in the wood of *Pinus*. The author counted the number of axial resin canals and calculated the percentage of the solitary ones to the total number of canals in the ring. And they are listed in taking the ring number consideration as follows:

P. bicolor	68%	adult wood
P. chihuahuana	84%	2nd and 3rd rings
	52%	6th, 7th and 8th rings, 51% 10th and 11th rings
P. engelmanni	68%	5th ring
	34%	150th ring
P. glauca	100%	1st ring, 75% 2nd and 3rd rings, 66% 4th and 5th rings
P. glehnii	55%	adult wood
P. jezoensis	68%	〃
P. koraiensis	60%	〃
P. koyamae	55%	〃
P. maximowiczii	20%	〃
P. morrisonicola	13%	〃
P. polita	50%	〃

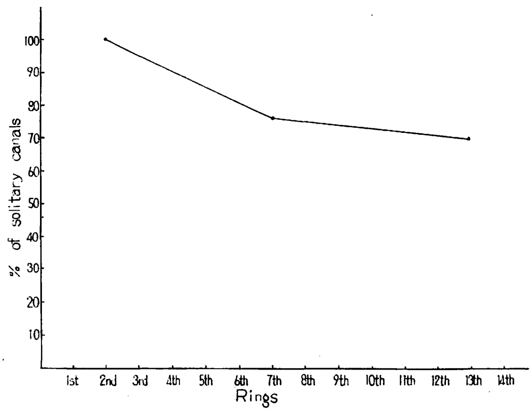


Fig. 167 *P. koyamae*
Percentage of solitary axial resin canals.

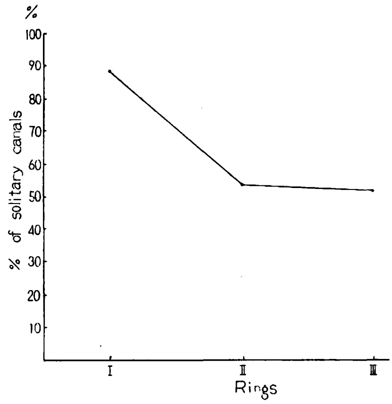


Fig. 168 *P. chihuahuana*
Percentage of solitary axial resin canals.
I : 2nd & 3rd rings
II : 6th, 7th & 8th rings
III : 10th & 11th rings

P. smithiana	45%	adult wood
P. wilsonii	34%	〃

Those results are mostly taken from the limited specimens and it is not easy to draw inference from these results that higher percentages of solitary canals are closely related with the juvenile wood. For ascertaining this relation, the author carried out observations on this feature and calculated the percentage on the discs of *P. chihuahuana* and *P. koyamae*. And they are plotted in relation to the ring number from pith (Figs. 167 and 168). As those figures show, in the first two or, sometimes three rings, solitary canals are 100% of the total number of canals and then their percentage abruptly decrease with irregular fluctuation. Therefore, it is very hard to detect a linear relation between their percentage and ring number from pith beyond the above-mentiond ring number. Be that as it may, it is quite certain that there is a definite relation between the percentage of solitaly canals and juvenile wood.

B. **Number of the epithelial cells around axial resin canals:** It is quite natural that the number of epithelial cells around axial canals increases as the diameter of the canals increases. BUDCEVICZ[9] chose this number as a diagnostic feature for separating species. But the author thinks that the diameter of axial resin canals is generally not constant like that of radial canals, particularly when more than two canals fuse into one, which is often found. Also resin canals originated from more or less traumatic causes, which are much more likely found than in radial ones, hinder our accurate counting of epithelial cells. In Fig. 169 an example of the relation between the diameter of

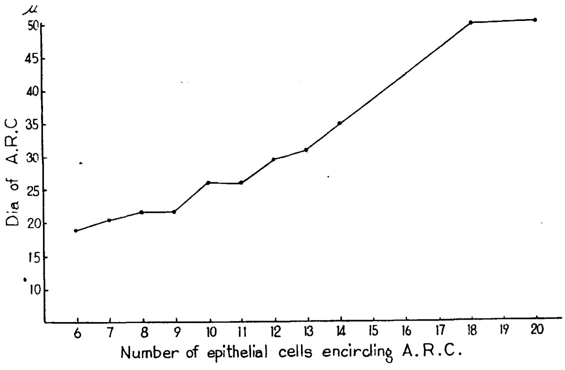


Fig. 169 *P. wilsonii*
Relation between size of axial resin canals and number of epithelial cells encircling A. R. C.

the canals and the number of the epithelial cells is shown.

C. **Epithelial cells:** As JEFFEREY[26] showed in his figure, there are thin-walled and thick-walled epithelial cells found around axial canals as in radial canals. In general, thick-walled cells are numerous, and sometimes almost half of the number of cells around canals are occupied by thin-walled cells. Photos. 20, 23, 24, 25, 31, 49 and 56 show the presence of thin-walled epithelial cells.

D. **Crystals found in epithelial cells:** Crystals of calcium oxalate are found in epithelial cells of some species. They are *P. maximowiczii*, *P. morrisonicola*, *P. polita*, and *P. smithiana* which are with crystals in their ray parenchyma cells (Photos. 29 and 86). Possibility of presence of crystals in species other than the species described here is also expected. Presence of crystals in epithelial cells is found at present in the limited few species and is very scanty.

5. Miscellaneous features

A. **Presence of axial parenchyma:** In reports such as those by BAILEY[2)4] and JEFFEREY[26], the presence of axial parenchyma was discussed. The former described the presence of axial parenchyma in this genus and pointed out the close relation to *Pinus* in this regard. Nevertheless, the presence of axial parenchyma cells is not generally accepted as a reliable feature for this genus, because of the difficulty to ascertain whether they are really axial parenchyma or epithelial cells and parenchyma cells adjacent to epithelial cells encircling resin canals which ceased at a short distance above or below. Noteworthy is the fact that the presence of axial parenchyma was seldom observed in summer wood at ring boundary, as shown in Photos. 19 and 70.

B. **Resinous tracheids:** They are not frequently observed, but at a glance they look like resin cells which are characteristics of some other families, but not of this genus even if they exist. They may be caused by some fungal or traumatic stimulus.

C. **Heartwood:** Generally speaking, wood of this genus is without distinct heartwood but in some species pinkish heartwood is observed which is darkened by long exposure. The species with pinkish tinge in the heartwood are generally with reddish brown contents in ray parenchyma cells.

D. **Tylosoids:** They are observed both in radial and axial resin canals of all species, showing the shape of a small bubble or large balloon. As RECORD[46] described on *P. engelmanni* and *P. rubens*, there are thick-walled and thin-walled tylosoids found in this genus. The latter are mostly crushed when sections are cut. It can be said that the presence of two kinds of tylosoids is one of the characteristic features of the genus. Most of the tylosoids are without pitting on their wall, but in some specimens distinct pitting was observed, as shown in Photo. 22. The occurrence of tylosoids is shown in Photos. 21～26, 57 and 65.

6. Variation of important characters with increasing growth ring number from pith

When observation and, thereafter, comparisons are made on the characteristics of species, it is most important to examine whether the features picked up as characteristics of certain species are variable or not. And, if they are variable, we should note what factor causes the variations and in what degree. In previous reports, differences originated in such variation as that of within species or that of within individuals mentioned hitherto were often described openly as the differences between species. In extreme cases, those unstable features have been used as the diagnostic features in separating species. In this chapter, along with the general discussion, the author summarizes the features which are variable due to the affecting factors.

I. Tracheid length.
II. Tangential diameter of tracheids.
III. Number of the epithelial cells encircling radial resin canals.
IV. Height of rays in cell number.
V. Percentage of solitary axial resin canals.
VI. Presence of radial resin canals.
VII. Spiral thickenings on the wall of tracheids.

Most of these features are influenced by the growth ring number from pith. And, of them, III and IV are possibility also affected by growth rate. Their variation with the increasing number of growth ring from pith is shown in Table 5. Most of these features become more or less stable at the growth rings of the 30～40 th from pith from where the juvenile part is believed to be already terminated, although some of them still continue to show variation which is no longer so wide as in the younger part. Therefore, any descriptions of those features made on the branch or juvenile wood should not be applied as representative for a species or genus, unless some adjustment for the effects of growth ring number in the descriptions is made. Practically, unknown factors other than the growth rate may have also some influences on these features. Therefore, it is unreliable to use, as some have, such features as mentioned above without any adjustment for the purpose of identification of species. The author wishes to stress emphatically that these variable features should be described together with the ring number from pith of the samples examined, and if that is impossible, it should be at least mentioned whether the samples are from juvenile or adult wood, which can be roughly decided by the curvature of the rings. On the other hand, these variations of the main features mentioned in relation to the ring number from pith will have an important role when we discuss the phylogeny of this genus.

Table 5. Pattern of variation of the main wood anatomical characters in relation to increase of ring number from pith

Number of rings from pith / Characters	3 rd	5～6 th	10 th	20 th	30 th	40 th→
Length of tracheids				Over ca. 3000 μ		
Tang. diameter of tracheids					Over ca. 25 μ	
Ray height in cell number				Increasing⟶		Slow increase
Spirals of summer wood tracheid (Species of B group)		Generally absent or indistinct				In some sp. present
% of solitary axial resin canals	Less than 100%					
Radial resin canals	present					
Number of epithelial cells encircling radial resin canals					Av. >6.5～8⟶	

VII. Wood anatomical characteristics of root of Japanese species

The root is generally believed to be a more conservative organ than the stem. And it is expected that there are some differences in wood anatomical features between root and stem of native species of this country as BANNAN[6] showed in his descriptions on the root of *Picea* species from Ontario. Japanese species are not uniform in the point of wood considered anatomically, as mentioned in the previous chapter and in this regard, they are different from Canadian species which are quite uniform. To describe anatomical features of root wood in comparison with those of stem wood is the purpose of this work. By this comparison, common features throughout the genus will be found. And also variable features between species and within species will be described.

For this, lateral roots of *Picea bicolor*, *P. glehnii*, *P. jezoensis*, *P. j.* var. *hondoensis*, *P. maximowiczii* and *P. polita* were examined and compared with their stem woods. As they represent all the groups wood anatomically proposed by the author, descriptions and discussions on these species will be applied to the other species belonging to each group.

A. Macroscopical features

Demarcation between heart- and sapwood generally indistinct except *P. jezoensis* and var. *hondoensis*, which have light colored intermediate wood between them. For separating them from other species this is a reliable diagnosis. It is reasonable to assume that there may be some foreign species with the same feature as this. In comparison with that of stem wood, summer wood narrower and transition from spring wood to summer wood more gradual, softer and lighter in weight.

B. Microscopical features

Tracheids: Transition of radial diameter from spring wood to summer wood more gradual than in stem wood. And wall thickness thinner and difference in wall thickness between spring and summer wood much smaller than in stem wood. Spiral thickenings found on the wall, the appearance of which varies by species and the same concepts as in the stem wood applied to classify their appearance. In *P. maximowiczii* spiral thickenings found in both summer and spring wood, and in other species spiral thickenings found only in summer wood, mostly in juvenile part. Of the latter, *P. bicolor* and *P. polita* with spiral thickenings on the wall of summer wood tracheids in much older part than in other species. Therefore, presence of spiral thickenings on the tracheid wall in root wood corresponds to that in stem wood. This means that the type of the spiral thickenings found in certain species are constant throughout the tree.

Rays: Rays in stem wood consist of ray tracheids and ray parenchyma, but in root rays consisting of only parenchyma are much more frequently found, particularly in the case of lower rays. BANNAN's descriptions[6] on the Canadian spruces were reconfirmed in this regard. As ray cells show irregular contour in the tangential section of root wood, it is not so easy as in stem wood to make classification of cell types. However, the type of the ray cells in root wood of certain species tends to be much alike that of stem wood. Ray tracheids less frequently found, and the spiral thickenings are distinct in *P. maximowiczii*, but in other species only more or less fine dentations are found on the wall.

Resin canals: Axial and radial. The distribution of the former tends to be irregular and

Table 6. The main wood anatomical characters of roots of Japanese species

Species \ Characters	Demarcation between heart- and sapwood	White zone between heart- and sapwood	Ray tracheids	Spirals or dentations of ray tracheids	Crystals in ray parenchyma	Shape of ray cells (Fig. 1)	Spirals of tracheids
Picea bicolor	Indistinct	Indistinct	Less developed	Dentations	Absent	A・B	Juvenile wood, summer wood
P. glehnii	〃	〃	〃	〃	〃	A	〃
P. jezoensis	Distinct	Distinct	〃	〃	〃	〃	〃
P. j. var. *hondoensis*	〃	〃	〃	〃	〃	〃	〃
P. maximowiczii	Indistinct	Indistinct	〃	Spirals distinct	〃	A・B	Spring and summer wood, less distinct
P. polita	〃	〃	〃	Dentations	〃	〃	Juvenile wood, summer wood

less numerous than in stem wood.

The above mentioned features are summerized in Table 6.

C. **Discussions**

Differences in wood anatomical characteristics between root and stem are as follows:

In root 1. Frequency of parenchyma cells found in ray is higher, and on the contrary that of ray tracheids is lower.

2. No crystals of calcium oxalate are found in ray parenchyma cells, even in species with the crystals in those of stem wood.

3. Wall thickness of summer wood tracheids is thinner than that of stem wood and as a result transition from spring wood to summer wood is much more gradual.

They are the general differences between root wood and stem wood in this genus.

As mentioned above, the type of the spiral thickenings on the tracheid wall is almost constant within species, throughout the tree. Since this feature is invariable throughout the tree, it is reasonable to accord it an important role whereby to separate wood anatomically of this genus into the certain groups which the author proposes in this report.

VIII. Grouping of species of *Picea* based on the wood anatomical characters

So far as the past reports the author referred to are concerned, there have been no attempts made to separate this genus into groups or sections on the basis of the wood anatomical characters. Now the first attempt on this point has been made by the author. As he already described and discussed, this genus appears not to consist of wood anatomically uniform species. The evidence is easily recognized by the main wood anatomical characters listed in Table 2. It is conceivable that the reason why up to the present time this fact has not been noted is probably due to the lack of comprehensive studies on adequate material of a sufficiently large number of species of this genus. Also the previous studies have been mostly concentrated on the commercial species which are somewhat uniform in their wood anatomical characteristics as shown in the Table.

In some of the reports, namely those by CHENG[52], BAILEY[2], PHILLIPS[45], PFURSCHELLER[44], KANESHI[31], KANEHIRA[28], MIYOSHI & SHIMAKURA[39], PEARSON & BROWN[42], and GREGUSS[18], existence of wood anatomically heterogeneous species was described, but they have not been discussed systematically in relation to the grouping of the genus on the basis of wood anatomy.

The author proposes that this genus should be divided into two groups from the wood anatomical stand point. For separating them, two types of spiral thickenings on the wall of tracheids are given the most important role. They are as follows:

1) Spiral thickenings almost always found throughout the tree, both in spring and summer wood.

2) Spiral thickenings found only in summer wood, and in general their presence is restricted in juvenile wood, and in some cases also in adult wood.

Spiral thickening are always mentioned as one of the most important features of coniferous genera and species. Moreover, species with spiral thickenings on the wall of both summer and spring wood, except some species of *Picea*, are restricted to those of *Cephalotaxus*, *Pseudotsuga*, *Torreya*, and *Taxus* in which spiral thickenings are one of the most important generic characteristics. Among the coniferous genera, this genus is unique in the point that some species are with spiral thickenings on the wall of tracheids and others are without them. As spiral thickenings are so significant that they are generally used for diagnosis to separate genera, it should be quite reasonable, in the author's consideration, to use them as the most important diagnostic feature for separating this genus into groups.

Species with spiral thickenings on the wall of tracheids both in summer and spring wood are listed in the table in the discussions. Moreover, there are several main wood anatomical features accompanied with the spiral thickenings. Their occurrence is not restricted only to species with the spiral thickening on the wall of tracheids, but also found in other species without this feature. As shown in Table 2, these features are more frequently found in species with spiral thickenings on the spring wood tracheid wall. They are as follows:

a. Much more prominent spiral thickenings on the wall of ray tracheids.
b. Presence of crystals of calcium oxalate in ray parenchyma cells.
c. With fusiform rays of B type shown in Fig. 2.
d. With ray parenchyma cells of B type shown in Fig. 1.

Species with those features mentioned above, together with spiral thickenings on the wall of spring wood tracheids, are as follows:

P. balfouriana	*P. morrisonicola*
P. brachytyla	*P. purpurea*
P. likiangensis	*P. schrenkiana**
P. maximowiczii	*P. smithiana*
P. meyeri	*P. spinulosa*
P. montigena	*P. wilsonii*

* No observations made on this species in this work, and this is after CHENG[52].

In this report, they belong to A group. Species other than species belonging to A group are classified into B group of which the main diagnostic feature is the absence of spiral thickenings in spring wood tracheids. They are as follows:

P. abies	*P. jezoensis*	*P. orientalis*
P. asperata	*P. j.* var. *hondoensis*	*P. polita*
P. bicolor	*P. koraiensis*	*P. pungens*
P. breweriana	*P. koyamae*	*P. rubens*
P. chihuahuana	*P. mariana*	*P. shirasawae*
P. engelmanni	*P. obovata*	*P. sitchensis*
P. glauca	*P. omorica*	

Among the species of this group, there are some species with the same main wood anatomical features as are found in the species of A group. And also there are several species with the spiral thickenings on the wall of summer wood tracheids in both juvenile and adult wood. They are as follows:

a. Spiral thickenings on the wall of summer wood tracheids are found not only in juvenile wood but also in much older wood.

b. Crystals of calcium oxalate are found in ray parenchyma cells.

c. Fusiform rays are occasionally or rarely of B type of Fig. 2.

d. Ray cells are of B type of Fig. 1.

Adopting those features mentioned above, B group is further divided into five small groups, namely B-I, B-II, B-III, B-IV and B-V. For separating small groups, combinations of features, a, b, c, and d are used as follows:

B-I	with a, b, c, and d	*P. polita*
B-II	with a, b, and d	*P. bicolor*
	a, c, and d	*P. breweriana*
	b, c, and d	*P. sitchensis*
B-III	with b and c	*P. omorica*
B-IV	with a	*P. pungens*
	b	*P. chihuahuana*
	c	*P. orientalis*
	d	*P. koyamae*
B-V	with none of these features	*P. abies*
		P. asperata
		P. engelmanni
		P. glauca
		P. glehnii
		P. jezoensis
		P. j. var. *hondoensis*
		P. koraiensis
		P. mariana
		P. rubens
		P. obovata
		(*P. shirasawae*)*

* No detailed observation made because the specimens were of branch material.

Of these five small groups, species of B-V group are the most typical of B group because of the lack of all the features above mentioned which show the closeness to species of A group.

Table 7. Relations between the groups proposed by the author and the sections by REHDER[50], and those by DALLIMORE and JACKSON[12]

Species \ Sections or groups	Groups by the author*	Sections by REHDER**	Sections by DALLIMORE**
Picea abies	B	E	E
P. asperata	B	E	E
P. balfouriana	A	C	E
P. bicolor	B	E	E
P. brachytyla	A	O	O
P. breweriana	B	O	O
P. chihuahuana	B		
P. engelmanni	B	C	E
P. glauca	B	E	E
P. glehnii	B	E	E
P. jezoensis	B	C	O
P. koraiensis	B	E	
P. koyamae	B	E	E
P. likiangensis	A	C	E
P. mariana	B	E	E
P. maximowiczii	A	E	E
P. meyeri	A	E	E
P. montigena	A	C	E
P. morrisonicola	A		E
P. obovata	B	E	E
P. omorica	B	O	O
P. orientalis	B	E	E
P. polita	B	E	E
P. pungens	B	C	E
P. purpurea	A	C	E
P. rubens	B	E	E
P. schrenkiana	A	E	E
P. shirasawae	B	E	E
P. sitchensis	B	C	O
P. smithiana	A	E	E
P. spinulosa	A	O	O
P. wilsonii	A	E	E

* A and B: shown in p. 109～110
** E : *Eupicea* by REHDER, *Eupicea* by DALLIMORE and JACKSON
C : *Casicta* by REHDER
O : *Omorica* by REHDER, *Omorica* by DALLIMORE and JACKSON

On the contrary, B-I group is much more closely related to A group than other groups.

This genus is divided into two or three sections from the taxonomical points of view[10)12)23)50)], and WRIGHT[56] also proposed division of this genus into more numerous sections. To compare the sections based on the wood anatomical features with the sections proposed by these taxonomists, namely three sections, *Eupicea*, *Casicta* and *Omorico* by REHDER[50], two sections, *Omorica* and *Eupicea*, by DALLIMORE and JACKSON[12], IWATA and KUSAKA[23] and CHENG[10] are listed in Table 7, and no particular relations appear to exist between these and author's. But, of the several groups in WRIGHT's grouping, all species or nearly all species belonging to Himalayan and Formosa-China southwest groups and one of the Japanese group belong to A group proposed by the author, and all other species belong to B group. Consequently, grouping by WRIGHT has much more similarity to the grouping proposed wood anatomically by the author. For the much more reasonable grouping of *Picea* and phylogeny of each group, further studies on the relation should be conducted.

IX. A key for the identification of species of *Picea* based on the wood anatomical characters

1. Spiral thickenings on the wall of spring wood tracheids generally found.
   ......*Picea balfouriana*
   P. brachytyla
   P. likiangensis
   P. maximowiczii
   P. meyeri
   P. montigena
   P. morrisonicola
   P. purpurea
   *P. schrenkiana**
   P. smithiana
   P. spinulosa
   P. wilsonii
1. Spiral thickenings generally found only on the wall of summer wood tracheids, mostly in juvenile wood, with occasional or rare presence in adult wood of some species
   2
   2. Crystals of calcium oxalate found in ray parenchyma cells 3
   2. Crystals of calcium oxalate not found in ray parenchyma cells 6
3. Crystals almost always found, spiral thickenings generally found, not only in juvenile wood but also in adult wood. 4
3. Crystals occasionally or rarely found, spiral thickenings generally found only in juvenile wood, although rarely found in adult wood. 5
3. Crystals rarely found, contents of ray parenchyma cells brown or reddish brown, ray calls A and B type of Fig. 1, and fusiform rays A and B type of Fig. 2, presence of spiral thickenings limited juvenile wood. ......*Picea sitchensis*
   4. Fusiform rays and ray cells A type of Figs. 1 and 2. ......*Picea bicolor*
   4. Fusiform rays and ray cells A type of Figs. 1 and 2 with rare or occasional occurrece of B type. ......*P. polita*
5. Fusiform rays A type and rarely B type, ray cells A type. ......*Picea omorica*
5. Fusiform rays A type, ray cells A type. ......*P. chihuahuana*
   6. Presence of spiral thickenings of tracheids in summer wood found even in older part (sometimes beyond the 100 th ring), fusiform ray A and B types, and ray cells A type with rare presence of B type. ......*Picea breweriana*

Note : * According to 51) of Literature.

6. Presence of spiral thickenings in summer wood tracheids found from the juvenile wood to adult wood, but not beyond about the 30th ring ; fusiform rays and ray cells A type. ·········· *P. pungens*
6. Presence of spiral thickenings in summer wood tracheids generally limited to the juvenile wood. ·········· 7
7. Fusiform rays A and rarely B type, ray cells A type. ·········· *Picea orientalis*
7. Fusiform rays A type, ray cells A and B type. ·········· *P. koyamae*
7. Fusiform rays A type, ray cells A type. ·········· *P. abies*

P. asperata
P. engelmanni
P. glauca
P. jezoensis
P. koraiensis
P. mariana
P. rubens
*P. obovata**
(*P. shirasawae***)

X. Distribution of *Picea* species in relation to the grouping on the basis of wood anatomical characteristics

In his previous report[54], the author mentioned the possible existence of some relations between the wood anatomical features and the geographical distribution in this genus, although he could not confirm this fact, because of the lack of sufficient number of species. In this report, he discusses this subject on the majority of *Picea* species found in the northern hemisphere. Of the works on the distribution of *Picea* species, interesting is the work of WRIGHT[57] in which crossibility of species is discussed in detail in relation to their distribution and taxonomy.

In this report, reference of distributions of species is mainly made to the works of HAYASHI[21] and WRIGHT[57]. Distribution of *Picea* is mapped following the figure by HAYASHI[21]. And outline of the distribution of species is shown in Table 1 and Fig. 170. Referring to them, discussions on the relation between distribution and grouping based on the wood anatomical characters which are mentioned in previous chapter is made in the following :

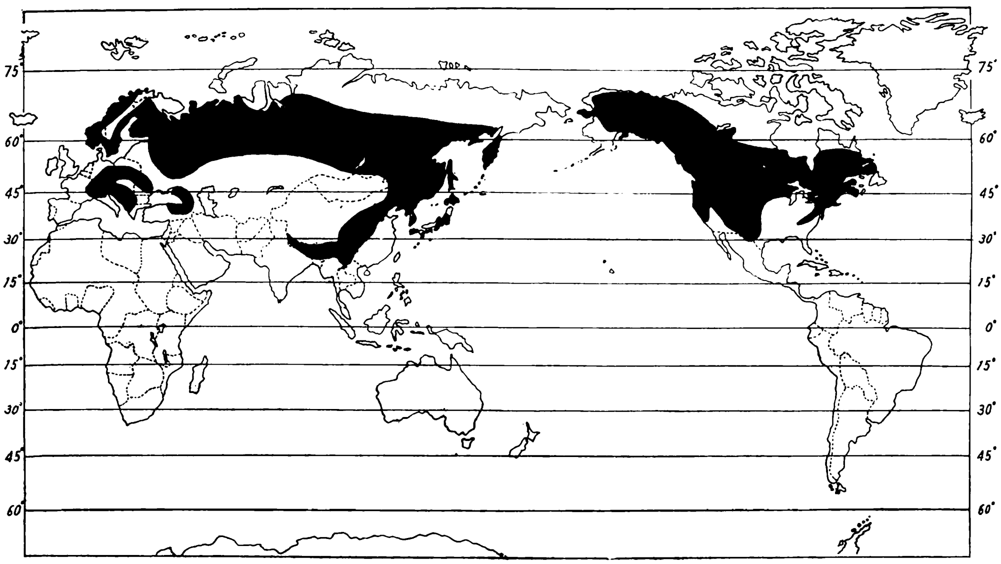
All species belonging to A group are exclusively found in Asia, and most of them are found particularlly in the southern part of Asia. In comparison with other areas, Asia is peculiar in its having a larger number of species and groups. In Japan, there are *P. maximowiczii* of A group and *P. bicolor*, *P. glehnii*, *P. jezoensis*, *P. j.* var. *hondoensis*, *P. koyamae*, *P. polita* and *P. shirasawae* of B group. Of them, *P. biclolor*, *P. j.* var. *hondoensis*, *P. koyamae*, *P. polita* and *P. shirasawae* are found in Honsyû which is the main island in the middle of the archipelago and *P. jezoensis* and *P. glehnii* in Hokkaidô which is the northern island. Therefore, it is certain that in this archipelago species belonging to different groups are found. *P. maximowiczii* of A group has very limited distribution in the central part of Honshû. On the contrary,

Note : * Only branch wood examined. Therefore detailed description as that of other species was impossible.
** Consulting other reports, placed here.

species of B group, except *P. koyamae* and *P. shirasawae* which are found only in the central part of Honshû, have much wider distribution area in the archipelago. And it is interesting to note that in Hokkaidô only species of B group are found.

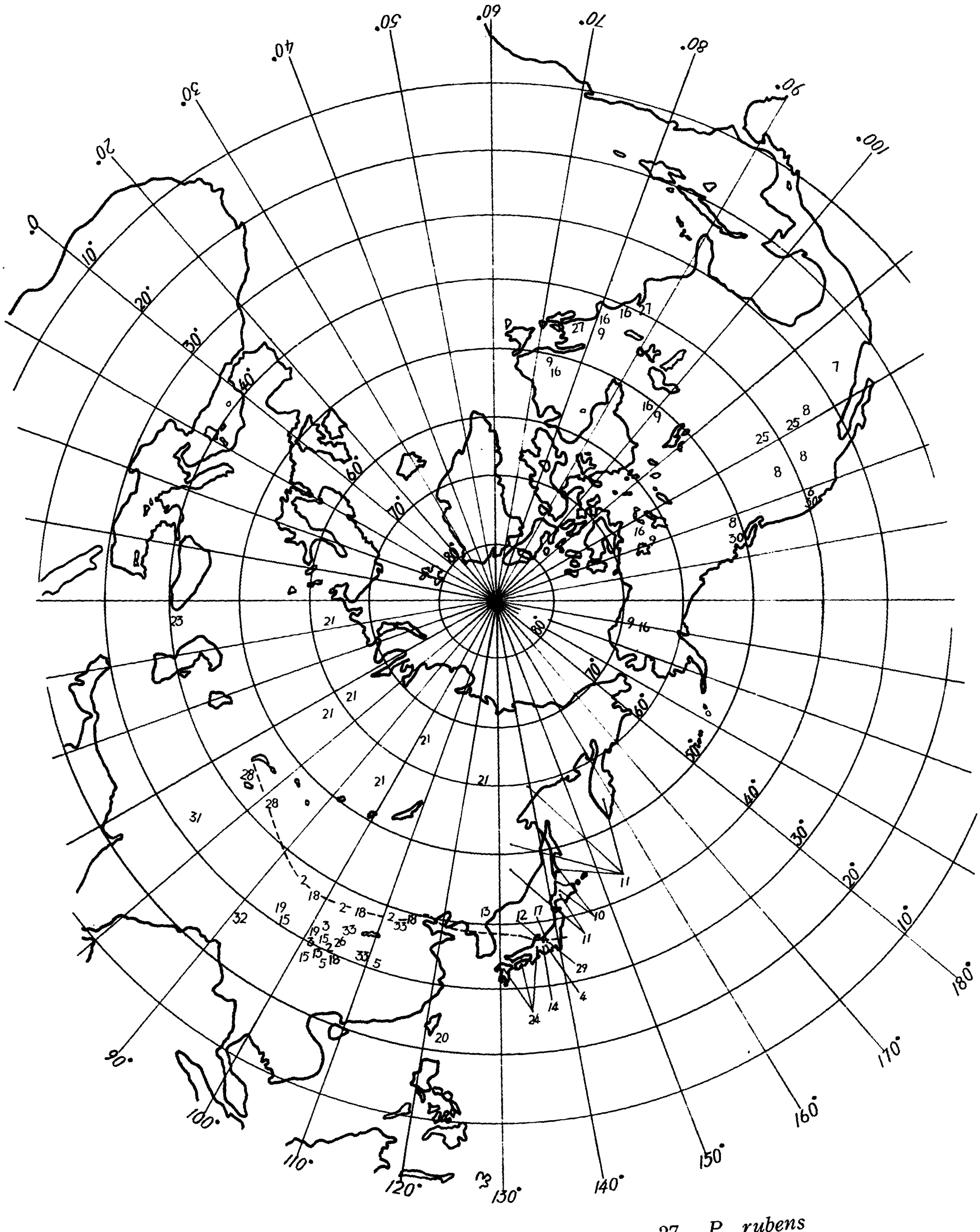
Of species distributing in China and Korea, *P. balfouriana, P. brachytyla, P. likiangensis, P. meyeri, P. montigena, P. purpurea, P. schrenkiana* and *P wilsonii* are of A group, and *P. asperata, P. jezonsis, P. obovata,* and *P. koraiensis* are of B group. Most of the species of A group in this area are found in the southern part. Even *P. schrenkiana* which ranges up to the highest latitude for this group is not found in the area farther north than species of B group with adjacent distribution area to it. Of the species belonging to B group in this area, *P. asperata* distributes in the southernmost part and grows widely together with other species of B group. In northern Asia, there are only species of B group found and none of species of A group.

In southern Asia, there are *P. morrisonicola* in Formosa, *P. smithiana* in western Himalaya and *P. spinulosa* in eastern Himalaya respectively. All of them belong to A group and, consequently, there are no B group species found in this area. In Asia, only A group species are found in the southern part as in Himalaya, Formosa and southwest China, and only B group species are found in the northern part, including northern Japan, U. S. S. R., Korea and Northern China. Between them there are transitional areas such as Japan and China, where species of both groups are found together. In figure 170, the northern limit of distribution of species of A group is shown in an arc. In other parts of Eurasia, *P. abies, P. obovata,* and *P. omorica* in



Distribution of *Picea*(After Hayashi[21])

1. *Picea abies*
2. *P. asperata*
3. *P. balfouriana*
4. *P. bicolor*
5. *P. brachytyla*
6. *P. breweriana*
7. *P. chihuahuana*
8. *P. engelmanni*
9. *P. glauca*
10. *P. glehnii*
11. *P. jezoensis*
12. *P. j.* var. *hondoensis*
13. *P. koraiensis*
14. *P. koyamae*
15. *P. likiangensis*
16. *P. mariana*
17. *P. maximowiczii*
18. *P. meyeri*



Legend

19. *P. montigena*
20. *P. morrisonicola*
21. *P. obovata*
22. *P. omorica*
23. *P. orientalis*
24. *P. polita*
25. *P. pungens*
26. *P. purpurea*
27. *P. rubens*
28. *P. schrenkiana*
29. *P. shirasawae*
30. *P. sitchensis*
31. *P. smithiana*
32. *P. spinulosa*
33. *P. wilsonii*

Species of A group: 3, 5, 15, 17, 18, 19, 20, 26, 28, 31, 32, 33.
Species of B group: rest.

Fig. 170 Distribution of *Picea* species.

Europe, and *P. orientalis* in Caucasus and Asia Minor are found respectively. In this area the southernmost species is *P. orientalis.* And in the northern part there is *P. abies* widely growing. From eastern Europe to Siberia there is *P. obovata* widely distributing and contacting with *P. jezoensis* in northeastern Asia.

In the American continent, *P. sitchensis* is found along the west coast of the northern part. *P. glauca* and *P. mariana* distribute widely from Alaska to Newfoundland and New England through the Great Lakes district, and the latter ranges farther down to the northern Appalachians. *P. pungens* in the southern Rocky mountains, *P. engelmanni* in the western interior mountain district of Canada and U. S. A., and *P. breweriana* in southern Oregon and northern California are found, respectively. Southernmost species of this continent is *P. chihuahuana* which grows in the northern mountains of Mexico. This is one of the southernmost species of this genus.

From these facts it is certain that A group species are found only in Asia. Therefore, there is certainly a relation between the main wood anatomical characteristics of groups and their distribution.

Moreover, there is a more or less positive relation between the main wood anatomical characteristics of the small groups of B group, B-I, B-II, B-III, B-IV and B-V proposed by the author and their distribution. Species belonging to B-V, except *P. asparata,* are growing in the northernmost part of distribution of this genus. In general, other small groups are found in the southern area. As shown in the previous chapter, small groups are classified on the basis of the main wood anatomical characteristics which are found in the species of A group. Therefore, the smaller the suffix number of small groups from B-I to B-V, the more species have similarity to group A. In this sense, of the species of *Picea,* A group species and B-V

Table 8. Locality and number of species of each group distributing each region

Locality \ Number of species			Number of species of A group	Number of species of B group				
				B-I group	B-II group	B-III group	B-IV group	B-V group
Asia	Northern Asia		0	0	0	0	0	4
	Japan		1	1	1	0	1	2+(1)*
	China Korea	Northern region	1	0	0	0	0	3
		Southern region	8	0	0	0	0	1
	Formosa		1	0	0	0	0	0
	Himalaya		2	0	0	0	0	0
North America	Canada, Alaska		0	0	1	0	0	4
	U. S. A.		0	0	2	0	1	4
	Mexico		0	0	0	0	1	0
Europe	Northern and Eastern E.		0	0	0	0	0	2
	Southern E.		0	0	0	1	0	1
	Caucasus		0	0	0	0	1	0

Note: Some species distribute in more than two regions.
* *P. shirasawae*

small group species are the extremes, and between them species belonging to the small-groups from B-I to B-IV are placed. The species of B-I, B-II, B-III, and B-IV small groups are found more in the southern area than those of B-V group. Of the American species, *P. breweriana* is the most closely related to A group, and consequently, the most south asiatic from the wood anatomical stand point. And, it could be said in the same sense that *P. sitchensis*, *P. pungens* and *P. chihuahuana* in this order have similarity to B-I small group and consequently to A group. The relations between them for all the species examined are tabulated in Table 8.

In conclusion, the geographical distribution of these groups wood anatomically separated by the author shows a particular tendency. Namely, the species of A group generally have rather limited distribution, mostly in the southern, southwestern and southeastern parts of Asia. And the species of B group occupy other parts of the northern hemisphere. Of B group, the species of B-V small group are found mostly in the northern part of the distribution of *Picea*. Species of B-I, B-II, B-III and B-IV small groups are generally found more in the southern area than that of species of B-V small group. Therefore, it could be said that species of these four small groups are intermediate between A group and B-V small group not only in the main wood anatomical characteristics, but also in the distribution. Generally speaking, species of B-V small group have wider distribution than species of A groups ; on the other hand, have narrower distribution.

XI. Relations between *Picea* and closely related genera of Pinaceae in wood anatomical charactristics

It is generally accepted that *Picea* is wood anatomically closely relateted to *Larix* and *Pseudotsuga* of Pinaceae, and in this regard discussions mainly for the purpose of the identification of their wood have been made by the previous authors[8)9)17)18)29)43)44)]. According to HARADA[19)] these three genera are separated from the other genera of Pinaceae, *Abies, Cedrus, Keteleeria, Tsuga* and some of *Pinus*, on the basis of the non-existence of wart structure on the wall of bordered pits. In this report, the author makes detailed discussions on the relations of wood anatomical characteristics of these three genera.

Picea* and *Larix

According to BUDCEVICZ[8)9)], in *Larix* (1) walls of ray tracheids are smooth, (2) bordered pits on the wall of tracheids are almost always in 2 rows, (3) with reddish brown heartwood, (4) transition from spring wood to summer wood sharp, and the difference in wall thickness between spring and summer wood is distinct ; in *Picea* (1) with dentations on the wall of ray tracheids, (2) bordered pits on the wall of tracheids are generally in one, and rarely in two rows, (3) without heartwood, (4) wood is almost always whitish except some species, (5) transition between spring and summer wood is sharp and difference in wall thickness between spring and summer wood indistinct. KUKACHKA[34)] showed the differences between them as follows : (1) Transition from spring wood to summer wood is sharp in *Larix* and gradual in *Picea*, (2) walls of ray tracheids are smooth in *Larix* and with dentations in *Picea*. Difference of coloration caused by ferric chloride solution was used by GREGUSS[18)] to separate these two genera.

According to JANE[23)] and PHILLIPS[44)], the number of epithelial cells encircling radial resin canals is 9～12 in *Larix* and 7～9 in *Picea*. But GREGUSS reported that this feature could not be used for separating these genera. DIANNELIDIS[18] showed that there was no fundamental difference in the number of epithelial cells between these genera based on the results obtained from *Larix decidua* and *Picea abies.* As the author stated in the previous chapters, there are sometimes wide variations found in these numbers in *Picea* and probably in *Larix.* And then the observed number can not directly be used for the separation of genera. For this reason, more detailed observations are necessary on the variation of the number of eptithelial cells in relation to growth ring number from pith and probably to other factors in *Larix.* BUDCEVICZ[9] separated *Larix* into two groups on the basis of the number of epithelial cells around radial resin canals as follows:

Group I—with epithelial cells 8～12 per radial resin canal.

Larix dahurica	*L. leptolepis*	*L. sukaczewi*
L. decidua	*L. occidentalis*	
L. griffithii	*L. sibirica*	

Group II—with epithelial cells more then 12 per radial resin canal.

Larix kurilensis	*L. laricina*	*L. lyalii*

Referring to this description, it is recognized that not all the members of *Larix* are inseparable, but only species of Group I are inseparable from *Picea.* For comparison, the main wood anatomical features of B group of *Picea* are cited as follows: (1) Without spiral thickenings on the wall of spring wood tracheids, (2) ray tracheids are generally without spiral thicknenings, but the wall is not smooth and with fine dentations on the wall. In the features such as spiral thickenings on the wall of summer wood tracheids and ray tracheids, B-V group much more closely related than other groups of *Picea* to *Larix,* particularly to group I.

***Picea* and *Pseudotsuga*;** There are generally 5～7 species of *Pseudotsuga* found in the world. Of them, 2～3 commercially known species are well described on their wood anatomical features, but others are not well described. From the previous reports, the number of epithelal cells encircling radial resin canals are quoted as below. *Pseudotsuga macrocarpa;* 5～7 and *P. taxifolia;* 5～6[9], *P. sinensis;* 6～8[52], *Pseudotsuga* spp.;5～6[33], *Pseudotsuga* spp.; 5～6[45]. Besides them, 6 cells for a radial canal were counted in the photopraph of *P. wilsoniana* in TANG's work[55]. These data show that, if they are counted on sufficient materials, there may be two groups of species, namely species with 5～7 cells and others with 6～8 cells per canal. At any rate, in comparison with *Picea, Pseudotsuga* has a smaller number of epithelial cells per radial resin canal. For comparison with *Pseudotsuga,* the main wood anatomical features of A group of *Picea* are summarized as: (1) Spiral thickenings are found on the wall of spring and summer wood tracheids, (2) Spiral thickenings often are found on the wall of ray tracheids. Moreover, their epithelial cell number appears to be slightly smaller than that of B group so far as the author's observation is concerned (Table 2 and 4). But another report[52] shows different numbers. So this must not be used as a reliable distinguishing feature. The main wood anatomical characteristics of *Pseudotsuga* are (1) with spiral thickenings on the wall of spring and summer wood tracheids, and (2) with spiral thickenings on the wall of ray tracheids. These main wood anatomical characteristics of two genera show that there is a positive similarity between *Pseudotsuga* and A group of *Picea,* rather than that between *Larix* and A group of *Picea.* Therefore, the similarity of *Picea* to other two genera is shown as follows: Group I of *Larix*[8] …… B group of *Picea* …… A group of *Picea* …… *Pseudotsuga,* in this order.

JANE[25] and PHILLIPS[45] showed interesting means for comparison of *Larix, Picea* and *Pseudotsuga.*

According to them, in the tangential section the position of the radial resin canal in the fusiform rays is somewhat different from each other in these three genera Ratio of length of upper and lower uniseriate wings of fusiform rays is almost 1 in *Pseudotsuga* and in other two genera it is considerably larger. Consequently, position of resin canals is shifted slightly from the middle of fusiform rays. For expressing the divergence of canals from the middle of fusiform rays, PHILLIPS[45] calculated the ratio of shorter wings to that of longer ones. And this ratio is 2～3 in *Larix*, and 1.5～2 in *Picea*. According to DIANNELIDIS[13], the divergence of the resin canal from the middle of the ray is a little larger in *Larix* than in *Picea*, but the difference is not so large as to be used as a diagnostic feature in separating these genera. Following the PHILLIPS's method, the author calculated the ratio based on his descriptions for *Larix*, *Picea* and *Pseudotsuga*, and examined differences between genus, and within genus. As JANE[25] stated, rough impression of their position in rays gained by the observation is more important than quantative value.

Results are as follows:

Pseudotsuga japonica	1.48	*Picea engelmanni*	2.32
P. menziesii	1.46	*P. glauca*	2.34
Picea brachytyla	1.75	*P. glehnii*	2.51
P. maximowiczii	1.58	*P. jezoensis*	2.09
P. montigena	1.74	*P. mariana*	2.21
P. smithiana	1.59	*P. polita*	1.77
		P. pungens	2.21
		P. rubens	2.17
		P. sitchensis	2.19

In two species of *Pseudotsuga* the ratio is not over 1.5 and it is natural that the position of canals in fusiform rays in this genus appears to be nearer to the center of fusiform rays than in other genera. In *Picea*, even the lowest ratio which is found in *P. maximowiczii* is over 1.5 and the highest is about 2.5 which is higher than the ratio for *Picea* given by PHILLIPS[45]. In A group, the ratio ranges 1.58～1.75, which is fairly lower than that of B group of which the ratio is over 2.0 with one exception of *P. polita*. It is interesting to note that *P. polita* belonging to the closest small group to A group in the main anatomical features is also closely related to A group in this regard.

On the basis of this ratio, A group of *Picea* which is with lower ratio is close to *Pseudotsuga* of which the ratio is slightly lower; on the contrary, B group which is with higher ratio is close to *Larix* which is with much higher ratio.

In conclusion, these three genera are placed in the following gradient line showing the similarity of wood anatomical characters among them. *Pseudotsuga* …… A group of *Picea* …… B group of *Picea* (B-I group …… B-II group …… B-III group …… B-IV group) …… Group I* of *Larix* …… Group II* of *Larix*. *; After BUDCEVICZ[8]

This has no particular relation to the taxonomy of these three genera.

Summary

The author perfomed wood anatomical studies with consideration on the geographical distribution and the taxonomy on thirty species and one variety of genus *Picea* as listed in Table 1.

1) Detailed description of wood anatomical characters of each species, outline of which is shown in Table 6 is made. Based on the description, an identification key for each species is presented.

On adopting these characters as diagnostic features for identification, the author stressed the necessity of the use of specimens taken at least from the thirtieth to the fortieth ring from pith outwards, and the necessity of adjustment of the results on the specimen taken from younger part in following the pattern shown in Table 5. Also the effects of the width of the ring on these characters should be considered. Otherwise, the difference of the results caused by the variations as those mentioned above would be confused with the essential difference of characters between species.

2) Division of this genus into two groups, A and B, was proposed by the author on the basis of the description, and the latter group was divided further into five small-group.

A group includes the following

Picea balfouriana	*Picea morrisonicola*
P. brachytyla	*P. purpurea*
P. likiangensis	*P. schrenkiana*
P. maximowiczii	*P. smithiana*
P. meyeri	*P. spinulosa*
P. montigena	*P. wilsonii*

B group includes the following

B-I	*Picea polita*	B-V	*Picea abies*
B-II	*P. bicolor*		*P. asperata*
	P. breweriana		*P. engelmanni*
	P. sitchensis		*P. glauca*
B-III	*Picea omorica*		*P. glehnii*
B-IV	*P. chihuahuana*		*P. jezoensis*
	P. koyamae		*P. koraiensis*
	P. orientalis		*P. mariana*
	P. pungens		*P. obovata*
			P. rubens
			(*P. shirasawae*)

For dividing this genus into these groups, several wood anatomical features were chosen as the characteristics of each group.

These groupings have no particular relations to the sections generally applied in taxonomy of this genus.

3) Geographical distribution of these groups has a particular tendency as follows:

1. Species of A group have limited distribution, mostly in south, south-west, and south-east region of Asia.
2. Species of B group occupying other parts of the northern hemisphere. And, of them,

species of B-V group are mostly in the northern part of the distributional area of this genus. The species of B-I, B-II, B-III, and B-IV have more southern distribution than that of the species of B-V group. Therefore, it can be said that these species have distributional areas between the species of A and B-V groups. Generally speaking, the species of B-V group have the widest distribution and the species of A group, on the contrary, have the narrowest distribution.

These relations are shown in Fig. 170 and Table 9. A broken line in Fig. 170 shows the northern limit of distribution of the species of A group.

4) From the wood anatomical point of view, it is generally accepted that the genus *Picea* has more similarity to the genera *Larix* and *Pseudotsuga* in Pinaceae. Comparing them with *Picea* on the main wood anatomical characters, the author ascertained the similarity among them. Moreover, he found the following gradient line showing the similarity in wood anatomical characters among these three genera. *Pseudotsuga* —— Species of A group of *Picea* —— Species of B group of *Picea* (B-I group —— B-II group —— B-III group —— B-IV group —— B-V group)—— Group I of *Larix** —— Group II of *Larix**. *; After Budceviz

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EXPLANATION OF PLATES

Photos. 1～26: Cross section

Photo. 1. *Picea abies*, ca. × 35.

2. *P. maximowiczii*, with axial resin canals, ca. × 110.
3. *P. breweriana*, tangentially contiguous axial resin canals, ca. × 40.
4. *P. chihuahuana*, ca. × 65.
5. *P. engelmanni*, with very narrow rings, ca. × 35.
6. *P. engelmanni*, with a small resin canal and tangentially contiguous resin canals, ca. × 110.
7. *P. glehnii*, juvenile wood, with solitary canals diffused throughout the ring, ca. × 45.
8. *P. jezoensis* var. *hondoensis*, with coupled axial resin canals, ca. × 110.
9. *P. koraiensis*, ca. × 110.
10. *P. koyamae*, juvenile wood, with solitary resin canals, ca. × 40.
11. *P. koyamae*, the 15th ring from pith, ca. × 45.
12. *P. mariana*, ca. × 40.

Photo. 13. *P. morrisonicola*, ca. × 110.
14. *P. polita*, ca. × 110.
15. *P. rubens*, ca. × 110.
16. *P. smithiana*, ca. × 45.
17. *P. spinulosa*, ca. × 110.
18. *P. spinulosa*, juvenile wood, with solitary resin canals. ca. × 45.
19. *P. maximowiczii*, an axial parenchyma cell (?) in the outermost part of the ring, ca. × 640.
20. *P. glehnii*, an axial resin canal, surrounded by thin-walled and thick-walled epithelial cells, ca. × 440.
21. *P. jezoensis*, an axial resin canal with tyloids, ca. × 440.
22. *P. smithiana*, an axial resin canal with thick-walled tylosoid with pits, ca. × 440.
23. *P. mariana*, axial resin canals with thin- and thick-walled epithelial cells, ca. × 440.
24. *P. omorica*, an axial resin canal with thick-walled tylosoids, ca. × 440.
25. *P. omorica*, axial resin canals with thin-walled epithelial cells, ca. × 440.
26. *P. omorica*, thin-walled tylosoids, ca. × 440.

Photos. 27～55: Tangential section, ca. × 110.
27. *P. abies*.
28. *P. bicolor*.
29. *P. brachytyla*, a fusiform ray with two radial resin canals and faint spiral thickenings of spring wood tracheids.
30. *P. breweriana*, juvenile wood, spiral thickenings of summer wood tracheids, and lower rays.
31. *P. breweriana*, adult wood, an axial resin canal surrounded by epithelial cells together with tracheids with end wall.
32. *P. chihuahuana*, uniseriate rays and a fusiform ray.
33. *P. glehnii*, uniseriate rays and a fusiform ray.
34. *P. jezoensis*, uniseriate rays and a fusiform ray.
35. *P. j.* var. *hondoensis*, uniseriate rays and a fusiform ray.
36. *P. koraiensis*, uniseriate rays and two fusiform rays.
37. *P. likiangensis*, uniseriate rays and a fusiform ray, and faint spiral thickenings of spring wood tracheids.
38. *P. mariana*, juvenile wood. lower uniseriate rays and fusiform rays.
39. *P. mariana*, adult wood, uniseriate rays and a fusiform ray.
40. *P. maximowiczii*, a fusiform ray, uniseriate rays, an axial resin canal, tracheids with end walls and spiral thickenings of spring wood tracheids.
41. *P. montigena*, uniseriate rays and a fusiform ray and spiral thickenings of spring wood tracheids.
42. *P. montigena*, compression wood, spiral thickenings of tracheids, indistinct even in summer wood, and many spiral cracks.
43. *P. obovata*, branch wood, lower rays, no fusiform rays, and spiral thickenings of summer wood tracheids.
44. *P. omorica*, two fusiform rays and uniseriate rays.
45. *P. orientalis*, a fusiform ray and uniseriate rays.

Photo. 46. *P. polita*, uniseriate rays and a fusiform ray with thin-walled epithelial cells broken off, a biseriate ray and spiral thickenings of summer wood tracheids.

47. *P. polita*, a fusiform ray with a radial resin canal encircled by mainly thin-walled epithelial cells.

48. *P. pungens*, juvenile wood, lower uniseriate rays, and an axial resin canal with small thin-walled tylosoids.

49. *P. sitchensis*, axial and radial resin canals with thin- and thick-walled epithelial cells, and tracheids with end walls.

50. *P. sitchensis*, uniseriate rays and a fusiform ray.

51. *P. smithiana*, uniseriate rays and a fusiform ray with two radial resin canals, and spiral thickenings of spring wood tracheids.

52. *P. smithiana*, uniseriate rays and two fusiform rays, and spiral thickenings of spring wood tracheids.

53. *P. spinulosa*, uniseriate rays and a fusiform ray, and spiral thickenings of spring wood tracheids.

54. *Larix dahurica*, for comparison of the shape of the fusiform ray.

55. *Pseudotsuga japonica*, for comparison of the shape of the fusiform ray.

Photos. 56～87: Radial section

56. *Picea abies*, an axial resin canal and rays, ca. × 110.

57. *P. bicolor*, radial resin canal with thick-walled epithelial cells and tylosoids, ca. × 110.

58. *P. brachytyla*, a thin-walled epithelial cell between thick-walled epithelial cells of a radial resin canal, spring wood tracheids with spiral thickenings, ca. × 440.

59. *P. breweriana*, summer wood tracheids with spiral thickenings, ca. × 110.

60. *P. breweriana*, thin-walled epithelial cells found between thick-walled epithelial cells of a radial resin canal, ca. × 440.

61. *P. chihuahuana*, crystals of calcium oxalate in ray parenchyma cell (in the middle of the ray) and summer wood tracheids with spiral thickenings, ca. × 110.

62. *P. glehnii*, ca. × 110.

63. *P. glauca*, ca. × 110.

64. *P. jezoensis*, ca. × 110.

65. *P. jezoensis*, an axial resin canal, ca. × 440.

66. *P. j.* var. *hondoensis*, ca. × 110.

67. *P. koraiensis*, ca. × 110.

68. *P. likiangensis*, spiral thickenings of spring wood tracheids and lower rays, ca. × 110.

69. *P. maximowiczii*, an axial resin canal, an irregularly shaped ray consisting of only ray tracheids, and spiral thickenings of spring wood tracheids, ca. × 110.

70. *P. maximowiczii*, axial parenchyma (?), and spiral thickenings of spring wood tracheids, ca. × 110.

71. *P. motigena*, spiral thickenings of tracheids, ca. × 110.

72. *P. motigena*, compression wood, no spiral thickenings of summer wood tracheids found, and resinous tracheids in the outermost part of the ring, ca. × 110.

73. *P. morrisonicola*, crystals in ray parenchyma cells and spring wood tracheids with spiral thickenings, ca. × 110.

Photo. 74. *P. morrisonicola*, spiral thickenings of ray tracheids, ca. × 440.

75. *P. polita*, rays and faint spiral thickenings of summer wood tracheids, ca. × 110.

76. *P. pungens*, juvenile wood, ca. × 110.

77. *P. pungens*, a thin-walled cell between thick-walled epithelial cells of axial resin canal, ca. × 440.

78. *P. sitchensis*, juvenile wood, ca. × 110.

79. *P. smithiana*, crystals of calcium oxalate in epithelial cells of axial, resin canal, ca. × 440.

80. *P. smithiana*, tracheids with spiral thickenings and a ray, ca. × 110.

81. *P. smithiana*, juvenile wood, crystals of calcium oxalate in ray parenchyma cells and spiral thickenings of tracheids, ca. × 110.

82. *P. smithiana*, crystals of calcium oxalate in ray parenchyma cells, and spiral thickenings of ray tracheids, ca. × 440.

83. *P. wilsonii*, spiral thickenings of tracheids and ray tracheids, and crystals of calcium oxalate in ray parenchyma cells, ca. × 110.

84. *P. spinulosa*, crystals of calcium oxalate, and spiral thickenings of ray tracheids and tracheids, ca. × 440.

85. *P. spinulosa*, spiral thickenings of tracheids, ca. × 110.

86. *P. polita*, rays, crystals of calcium oxalate in epithelial cells encircling the traumatic axial resin canal, and spiral thickenings of summer wood tracheids, ca. × 110.

87. *P. asperata*, ca. × 110.

トウヒ属の木材解剖学的性質および その種類の地理的分布ならびに分類 との関連について

（要　　旨）

須　藤　彰　司[1]

北半球には，現在30～40種のトウヒ属の種が生育するとされている。その種の数は，研究がすすめば，さらに減少することが期待できる。筆者は，その大部分を占める31種および1変種の木材について解剖学的性質の比較研究を行なった。これらの種類は，北半球の中国，ヒマラヤ，台湾，朝鮮，日本，シベリア，ヨーロッパ，コーカサス，小アジア，北米大陸などに分布している。

現在に至るまで，トウヒ属木材の解剖学的性質については，多くの報告が出されているが，その記載に不十分な点が多く，また，この属の解剖学的性質を総合的にまとめたものはないといってよい。この報告において，筆者は次のような点に重点をおいている。

1. 可能なかぎりの多数の種類を記載し，それに基づいて種の検索表を作成した。
2. 記載項目の取り上げ方にも十分注意し，とくに，樹齢などにともなって変化すると考えられる性質については，十分その変化の経過をとらえて解析した。また，成長の良否と関連があると考えられる性質についても解析を行なった。
3. 幹材とならんで，根材の性質のうち，主要なものを選んで記載し，幹材との比較をした。このことによって，主要な木材解剖学的性質の樹体内における変化の経過を，さらによく理解することができるはずであると考えた。
4. 主要な性質を用いて，この属の中の種のグループ分けの仕方を検討した。そのグループと，Rehderなどによる節との関係を検討した。
5. 上述の各グループに属する種類と地理的分布との関係を検討した。
6. 木材解剖学的に性質の似た属，すなわち，*Larix* および *Pseudotsuga* との木材解剖学的性質における類似性を検討した。

これらの研究の重点は，筆者が前報において得た知識に基づいておかれたものである。

個々の種類の解剖学的性質の記載のうち主要なものについては表に示した。これらの中には，新しく記載された性質が少なくない。また，さらに，これらの性質を用いて，種類の検索表を作成した。

この記載を行なうにあたって，樹齢と関連づけてとらえなければならない性質については，樹齢を併記した。とくにこの点について考慮の払われた性質は，次のようなものである。このうち，とくに4と7については種類の記載の項で，ヒストグラムを用いて示した。

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(1) 木材部材料科材質研究室・農学博士

1. 仮道管の長さ
2. 仮道管の接線方向の直径
3. 仮道管のらせん肥厚の現われ方
4. 水平樹脂道のエピセリウム細胞の数
5. 単独軸方向樹脂道の存在数の全軸方向樹脂道の存在数に対する比率
6. 水平樹脂道の出現
7. 放射組織の細胞高

さらにこれらに加えて，とくに樹齢とのつながりはないと考えられるが，

8. 放射組織細胞の形（接線断面における細胞の形 A type：長方形，長卵形，B type：方形，円形に近い形）
9. 紡錘形放射組織の形（接線断面における紡錘形放射組織の形 A type：放射組織の最も幅の広い部分で，直接水平樹脂道のエピセリウム細胞が仮道管と接している。B type：エピセリウム細胞が，直接仮道管に接しないで，両者の間にさらに放射組織の細胞が認められる（一般には，水平樹脂道の片側に限られている)。
10. シュウ酸石灰の結晶の出現
11. 薄膜のエピセリウム細胞の出現
12. 放射仮道管のらせん肥厚，または鋸歯状肥厚

などにもとくに注意を払った。

これらの木材解剖学的性質のうち，樹齢，あるいは成長と関係があると考えられるもの，すなわち，前者については 1，2，4，5，7 などに，また後者については 4，7 などに，それぞれ関連づけて考察を行なった。それぞれの結果は図に示した。また，写真は，この属の木材解剖学的性質の理解に役立つと考えられる。

これらの性質の変化の経過をまとめて表に示した。この結果からも，少なくとも髄から 30〜40 年輪より若い部分については，十分その記載の取扱いを注意すべきであることを示した。また，多くの性質は樹齢，成長の良否などによって，このように性質が変化することからも，どの性質を識別拠点として選ぶかが問題であることを強調した。

また，日本産数種類の根材について，概括的にではあるが木材解剖学的性質の記載を行なった。この結果から，上述の主要な木材解剖学的性質の樹体内における変化の経過を検討した。この結果，仮道管の膜壁のらせん肥厚の現われ方は，樹体内においてはほとんど同じ経過を示すことがわかった。このほかに，シュウ酸石灰の結晶が根材には認められなかったこと，放射仮道管の出現がより少ないことなどが，幹材との顕著な差であった。

これらの解剖学的性質を中心として，種類の記載を行なった結果から，この属の種は，木材解剖学的に考えた場合には，均一とはいえず，大きく，A，B の 2 グループに分けるのが妥当であると考えた。

その内 A グループに属するものとして

Picea balfouriana	*P. morrisonicola*	*P. brachytyla*
P. purpurea	*P. likiangensis*	*P. schrenkiana*
P. maximowiczii	*P. smithiana*	*P. meyeri*

P. spinulosa　*P. montigena*　*P. wilsonii*

などがあり，他は全てＢグループに属する。

両者の区別点となった性質の最も重要なものは，仮道管の膜壁のらせん肥厚である。

すなわち，

1. らせん肥厚が春材部仮道管にも認められる（Ａグループ)。
2. らせん肥厚が夏材部仮道管にのみ認められ，しかも，一般にはその出現は幼齢部に限られる。種によっては，さらに高齢部にまで認められるものがある（Ｂグループ)。

このＡグループの種には，さらに次のような性質が多く認められる。

1. 放射柔細胞中の結晶
2. 放射仮道管の膜壁のらせん肥厚
3. 紡錘形放射組織に B type が認められることがある。
4. 放射組織細胞の形に B type が認められることがある。

またＢグループの種は，夏材部仮道管のらせん肥厚が，幼齢部にのみか，さらに高齢部にまでつづくかの差，および上述したＡグループに多く認められる性質の組合せ数の多少によりＢ-ⅠよりＢ-Ⅴまでの５つの小グループに分けた。この内 B-Ⅴ グループに属するものは，その性質の組合せの数が最も少ないので，最も単純なものといえる。このＢグループに含まれる種類の細別は次のとおりである。

Ｂ-Ⅰ：*Picea polita*

Ｂ-Ⅱ：*P. bicolor*
P. breweriana
P. sitchensis

Ｂ-Ⅲ：*P. omorica*

Ｂ-Ⅳ：*P. chihuahuana*
P. koyamae
P. orientalis
P. pungens

Ｂ-Ⅴ：*P. abies*
P. asperata
P. engelmanni
P. glauca
P. glehnii
P. jezoensis
P. j. var. *hondoensis*
P. koraiensis
P. mariana
P. obovata
P. rubens
(*P. shirasawae**)

（注＊：枝材のみで十分検討できなかったもの）

以上のグループ分けは，Rehder あるいは Dallimore らによる節の区分とは一致していない。むしろ，Wright が交配性などを考慮して提示したグループ分けと部分的に近い点があるが，一致するとはいえない。

これらの種類のグループは，地理的な分布と，次のような関連を示している。

1. Ａグループの種は，アジアの南，東南部に限られている。しかも，おのおの狭い分布地域をもつものが多い。
2. Ｂグループの種のうち，とくに B-Ⅴ グループの種は，最も北の地域に生育するものが多く，また，おのおのが広い分布地域をもつものが多い。また，Ａグループのもつ性質をより多くもつものは，アジア，またはそれに近く分布するか，その他の地域ではより低緯度の地域に分布している。

これらについては図および表に示した。

この *Picea* は Pinaceae の中では木材解剖学的性質において *Larix, Pseudotsuga* などに類似しているとされている。そこで，上述したような主要な性質と，さらに水平樹脂道の紡錘形放射組織の中における位置，水平樹脂道のエピセリウム細胞数などを考慮しして，木材解剖学的性質の関連について検討を行なった。この結果， *Picea* は木材解剖学的性質からは *Larix, Pseudotsuga* などとは次のような関係のあることを示した。なお，*Larix* のグループ分けは Budceviz が樹脂道のエピセリウムの数から行なったものである。

Pseudotsuga — *Picea* の A グループ — *Picea* の B グループ（B-Ⅰ，B-Ⅱ，B-Ⅲ，B-Ⅳ，B-Ⅴ）— *Larix* グループⅠ — *Larix* グループⅡ

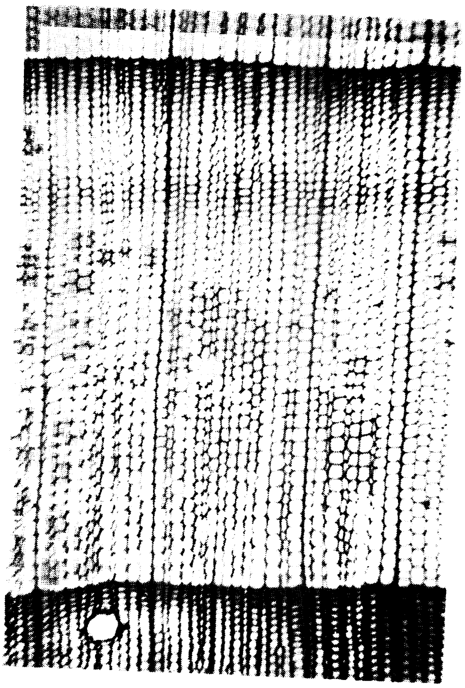
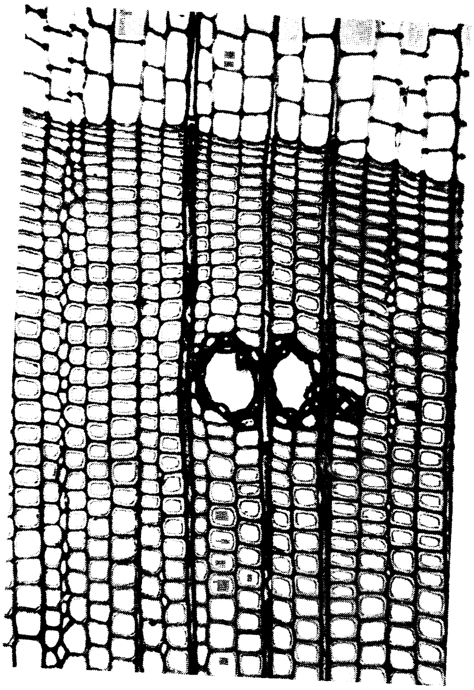


Photo. 1



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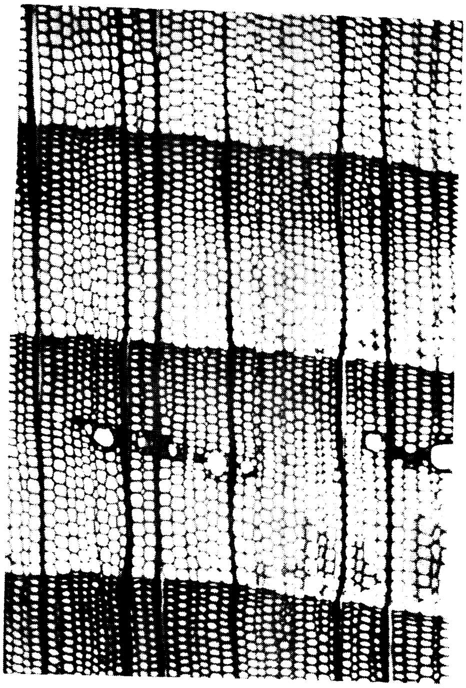

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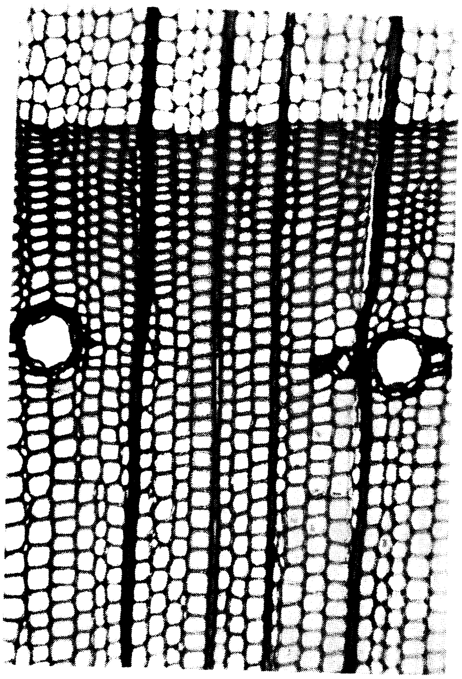

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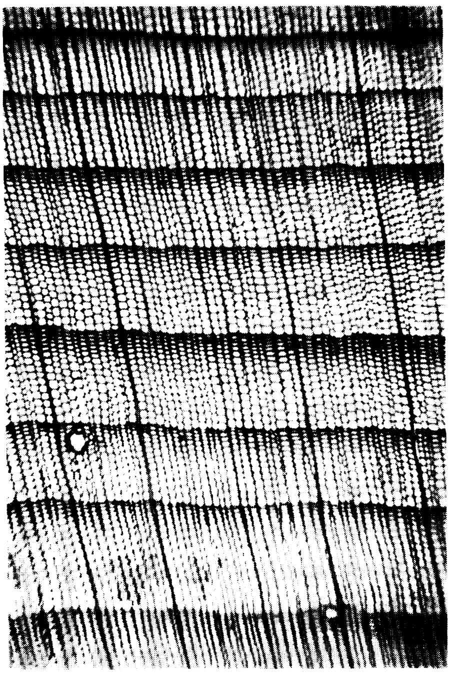

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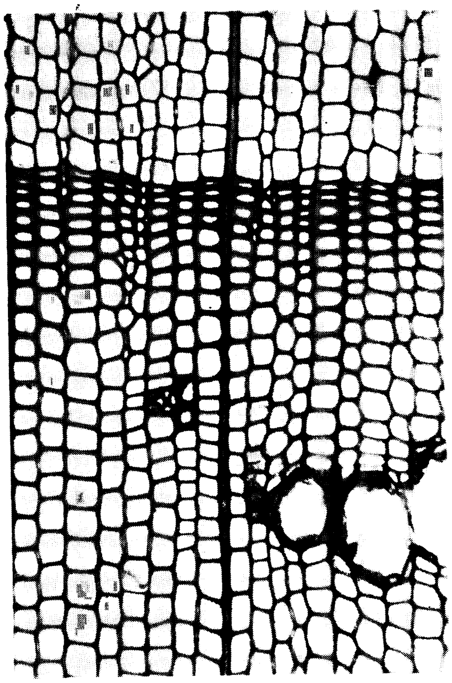

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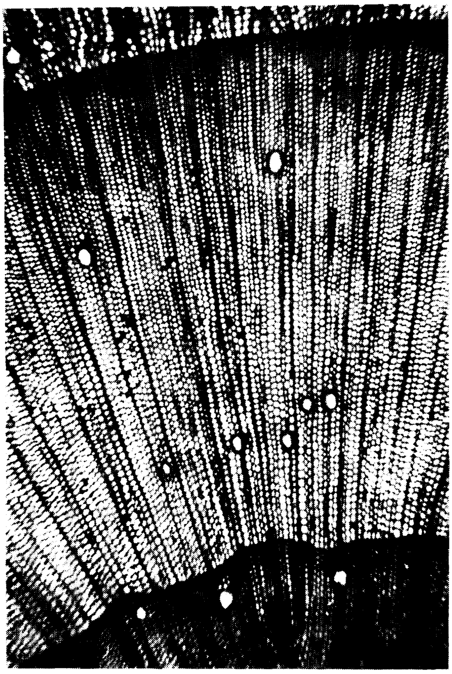

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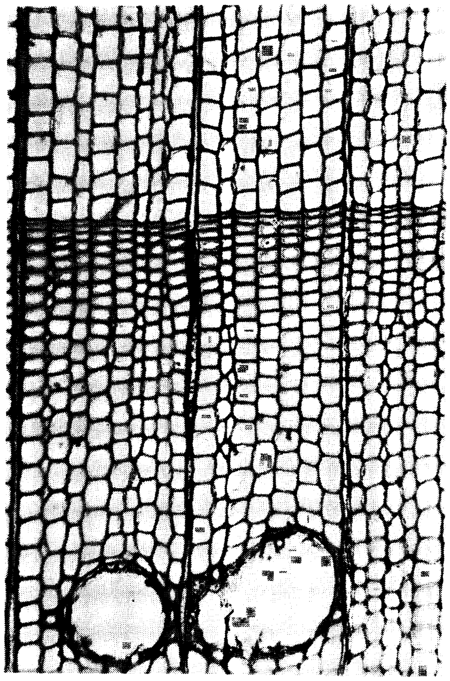

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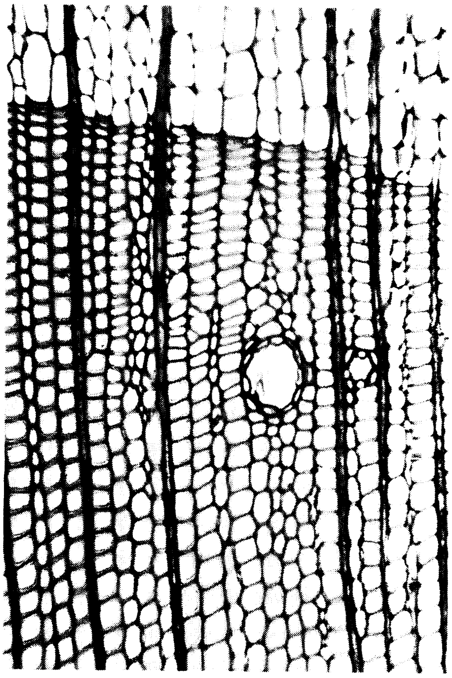
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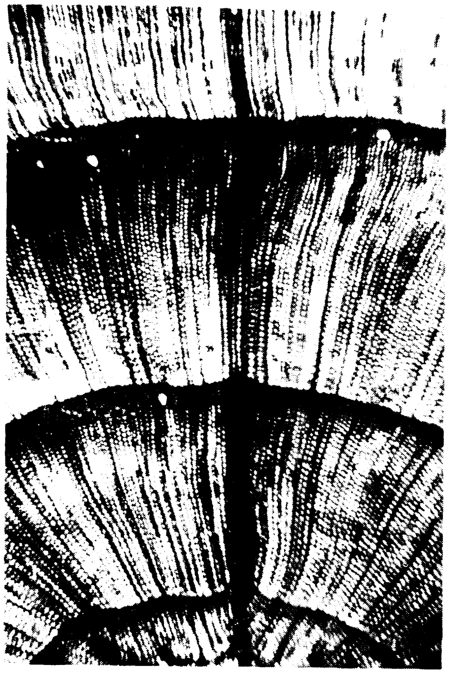
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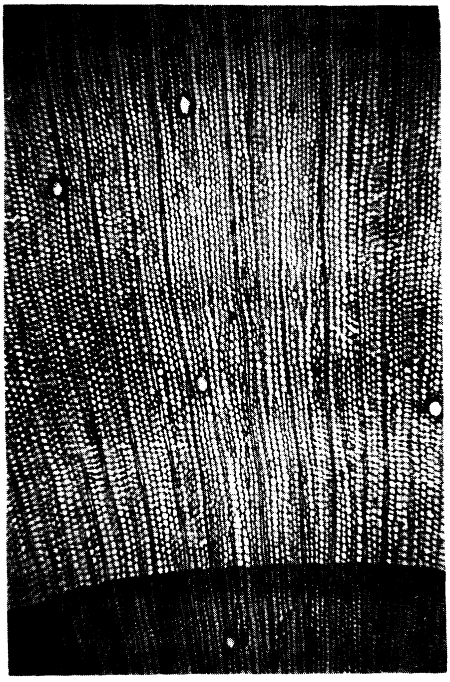
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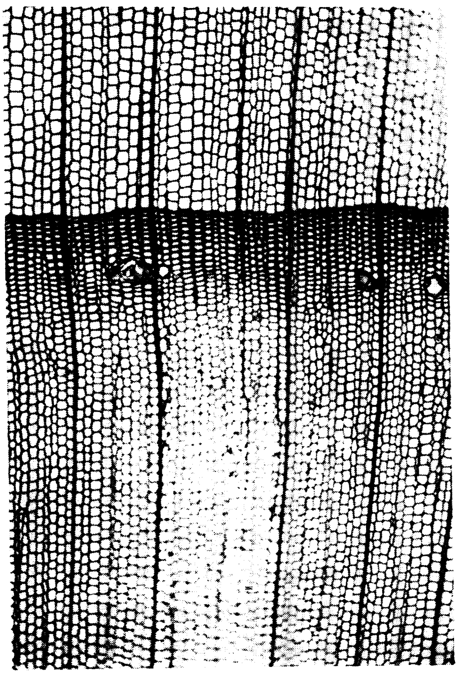
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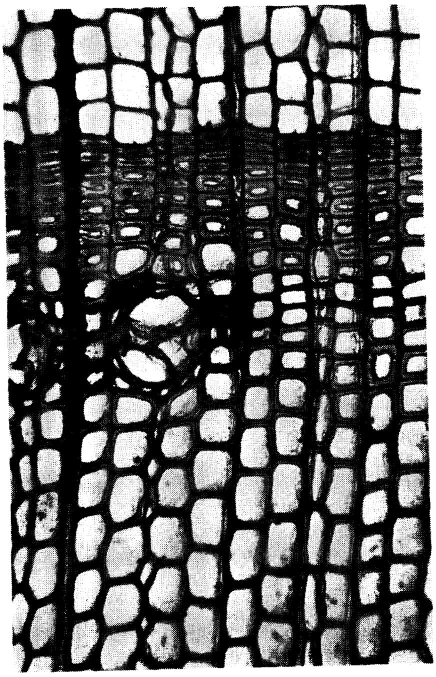

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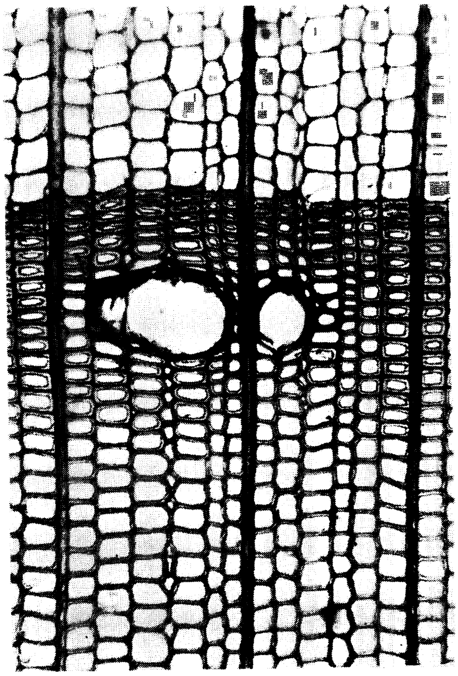

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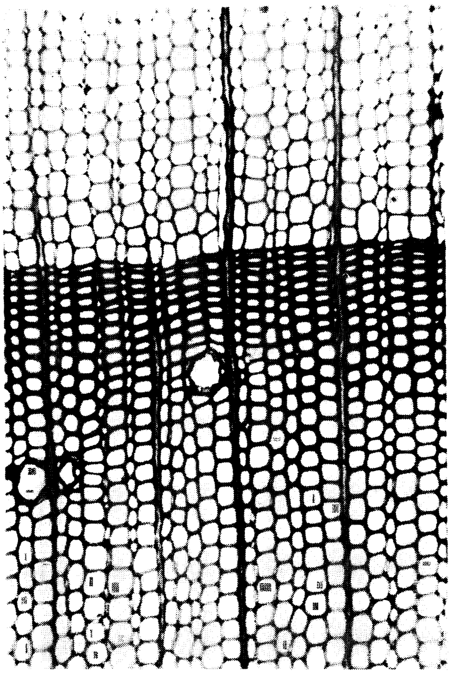

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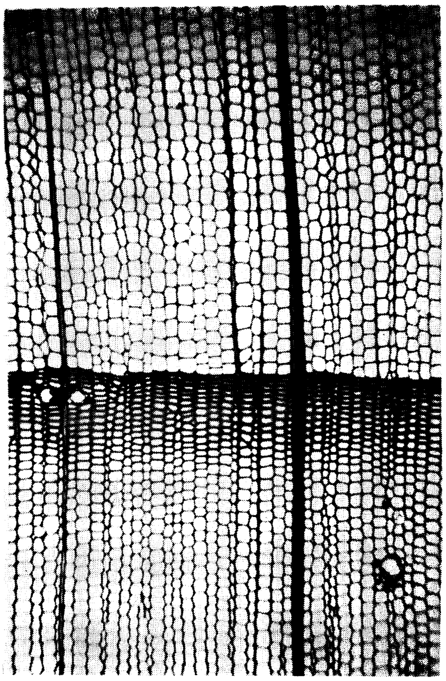

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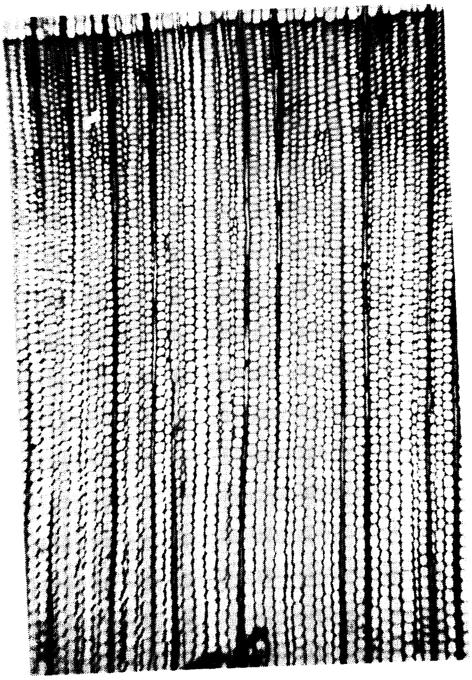

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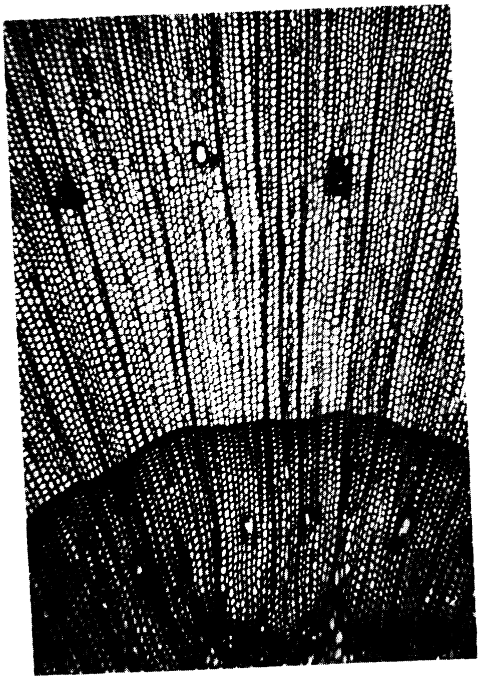
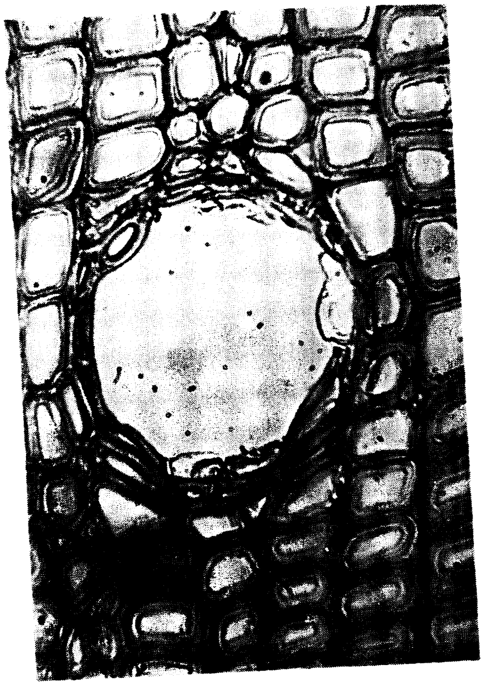


Photo. 18

Photo. 19



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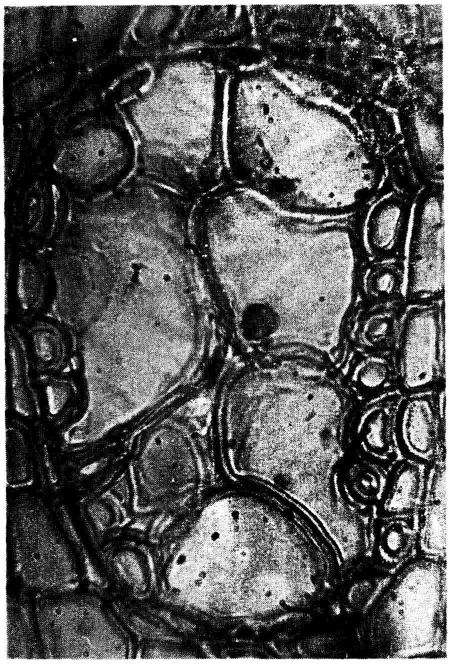

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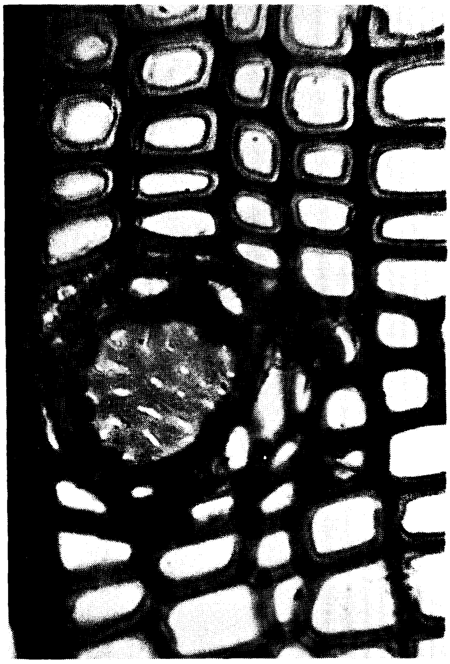

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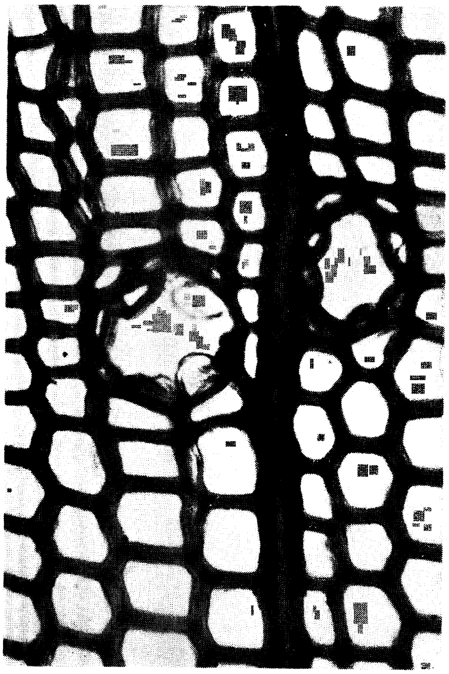

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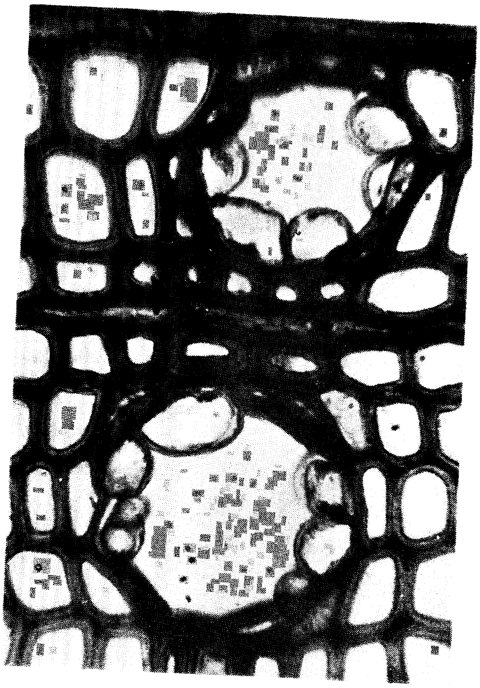
Photo. 24



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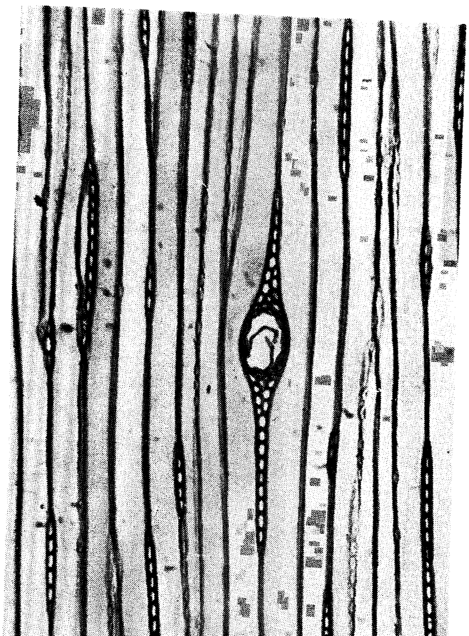

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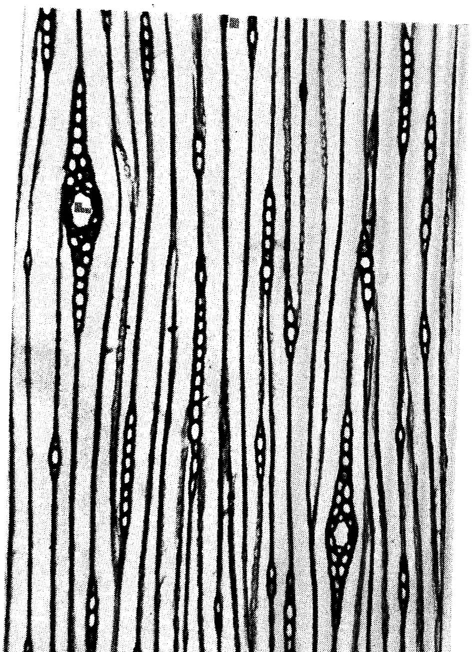

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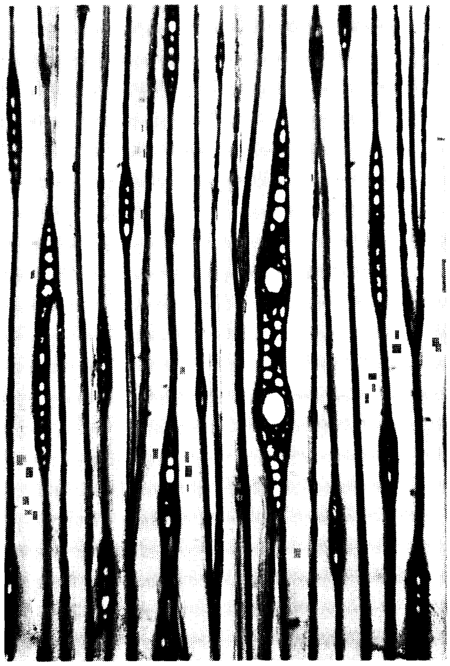

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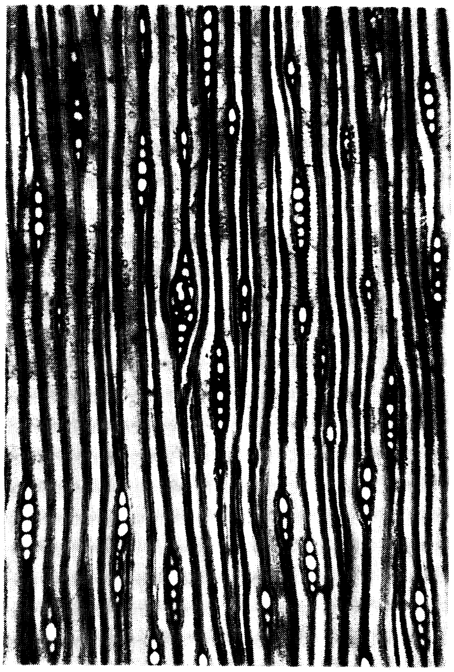
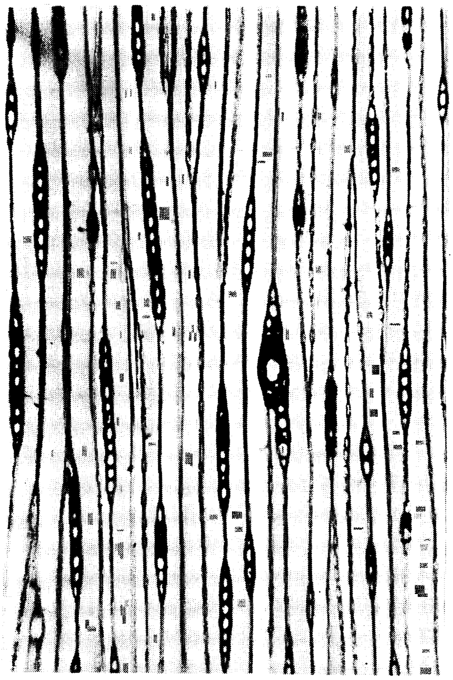


Photo. 30

Photo. 31



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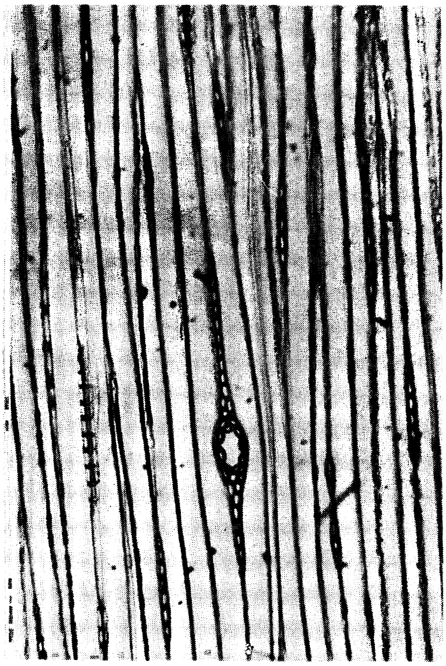

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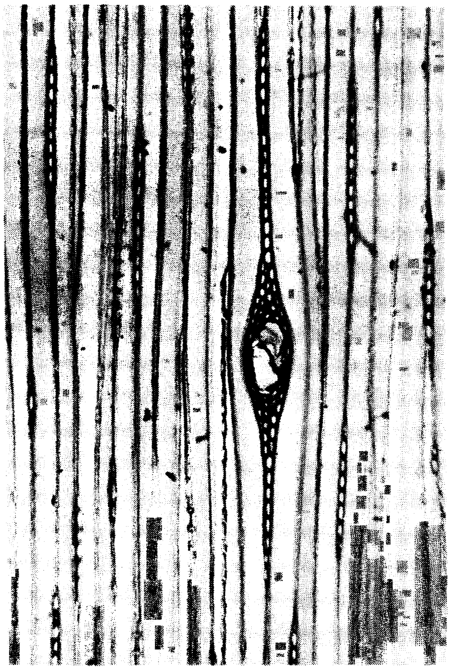

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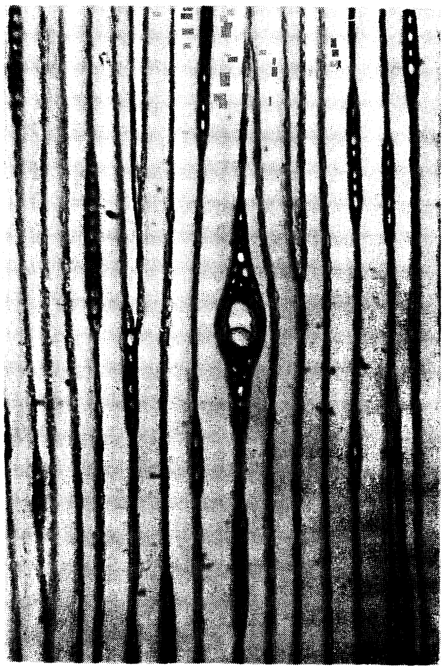

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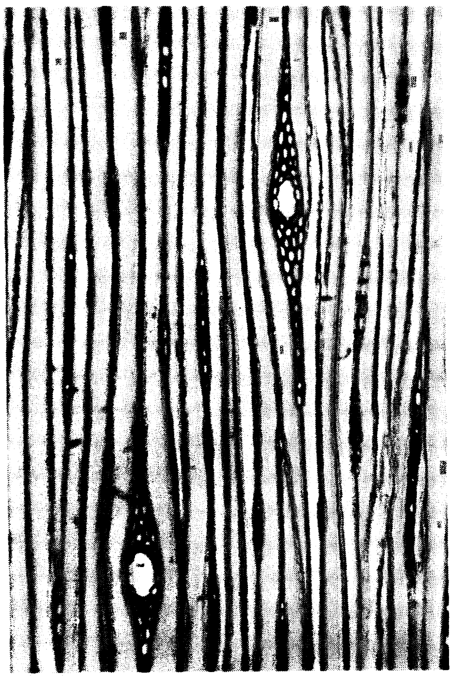

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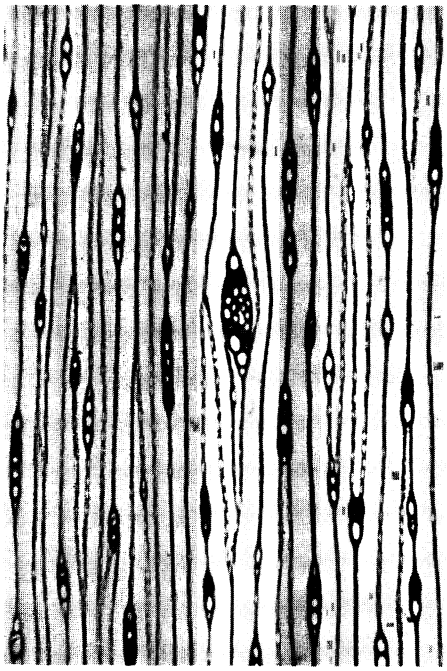
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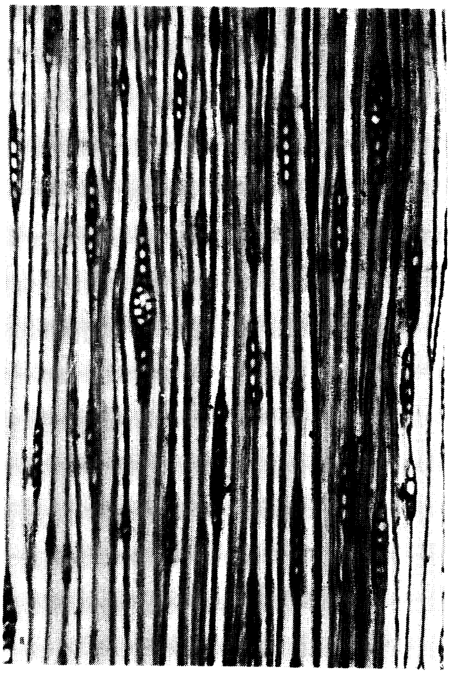
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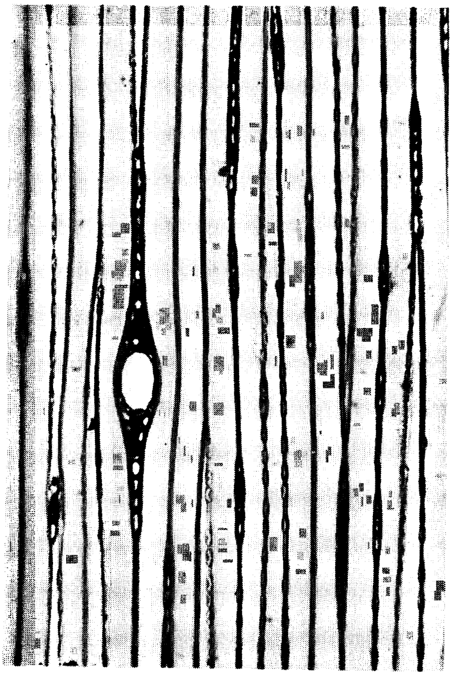
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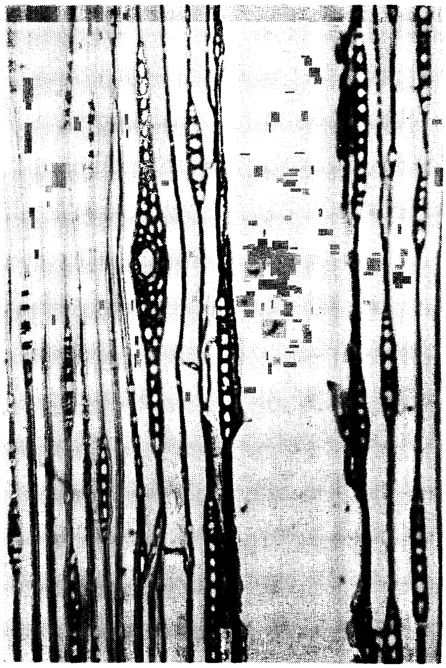
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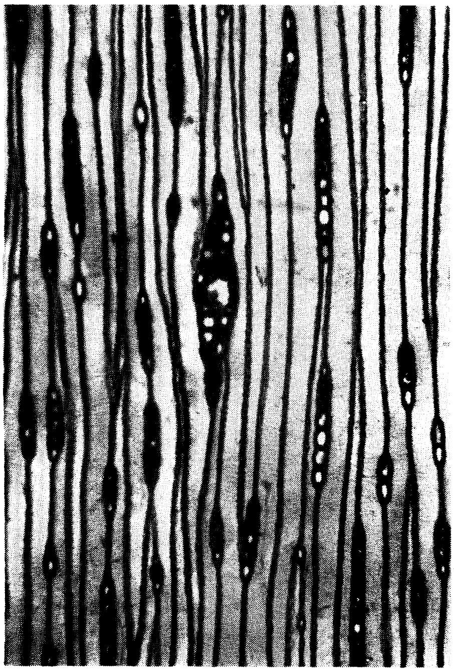

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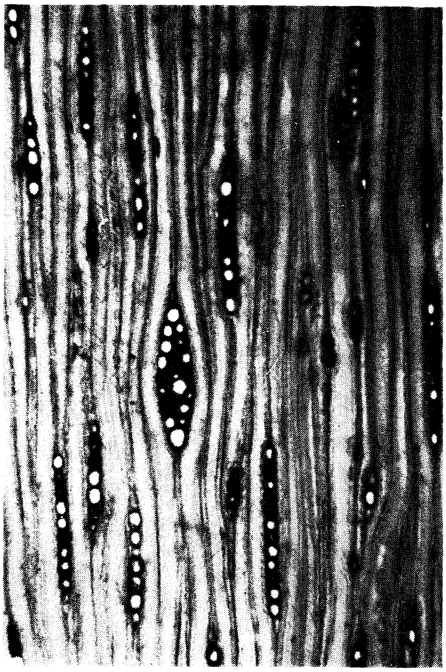
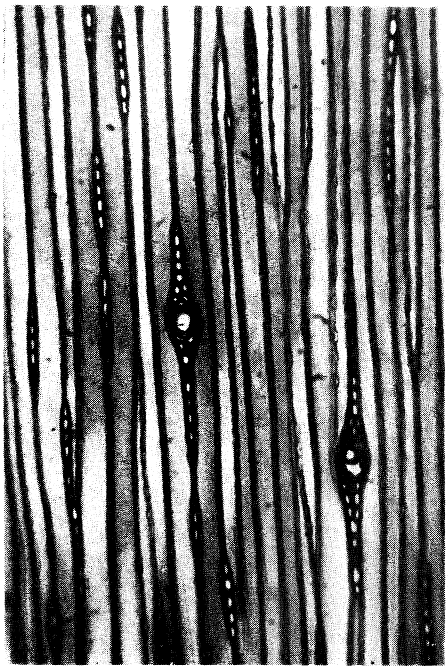


Photo. 42

Photo. 43



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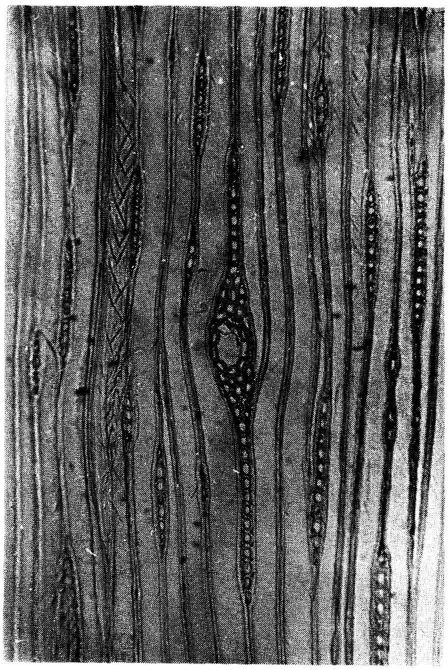

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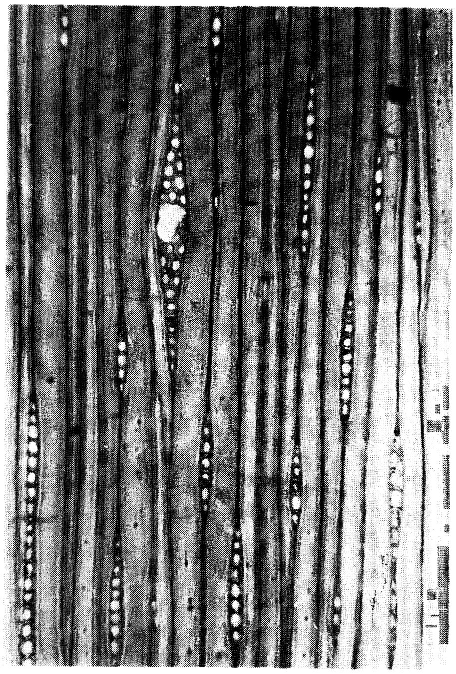
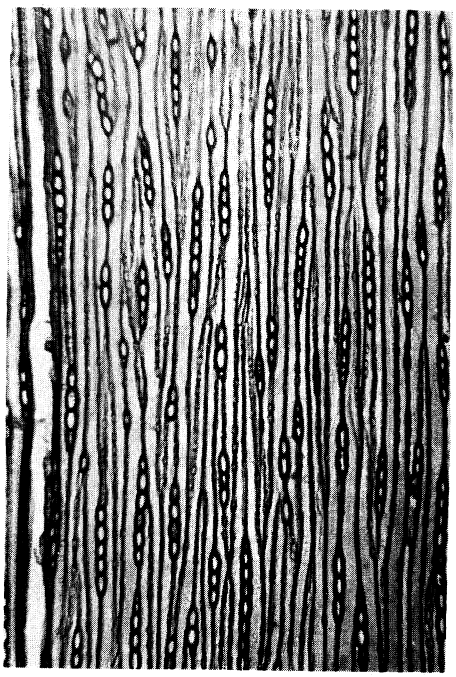


Photo. 46

Photo. 47



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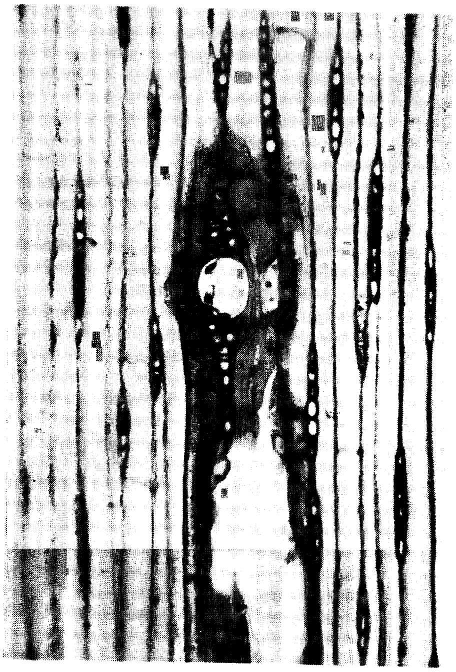

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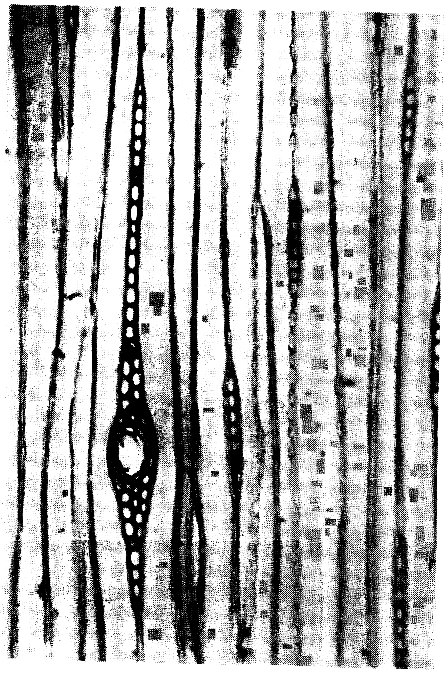

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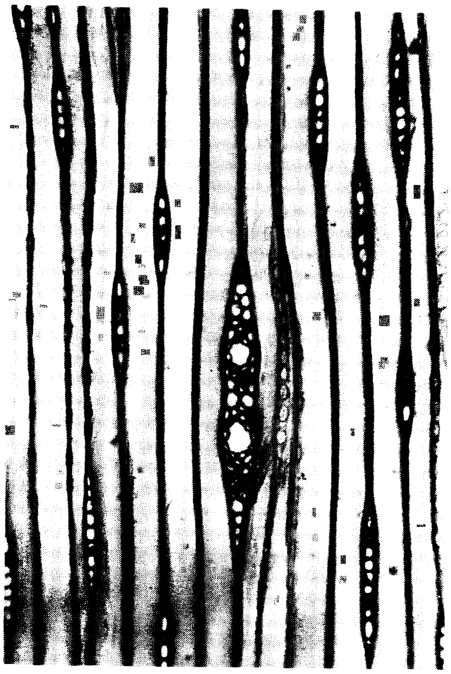

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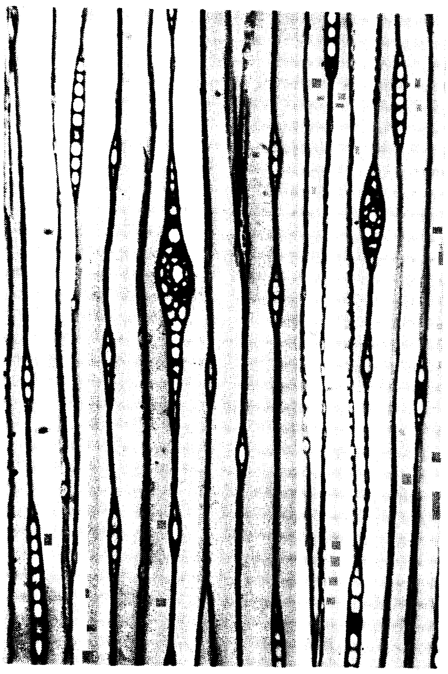

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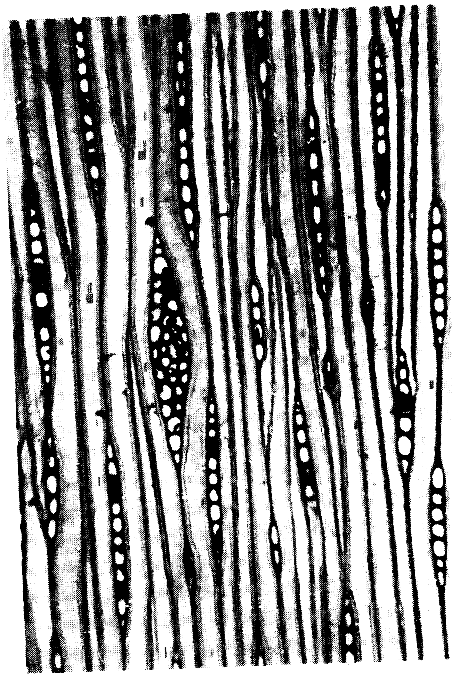

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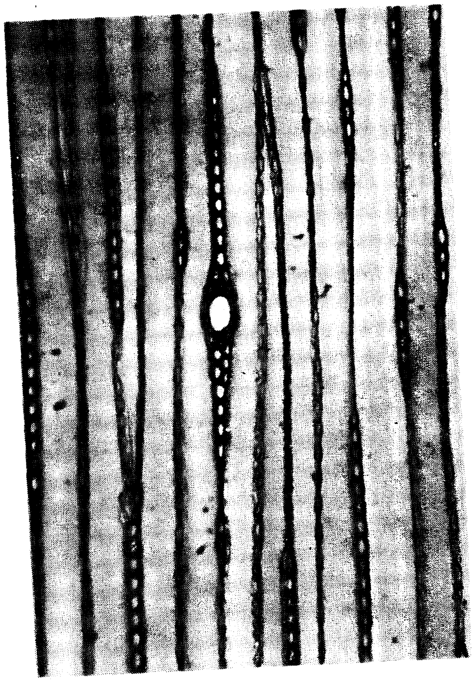
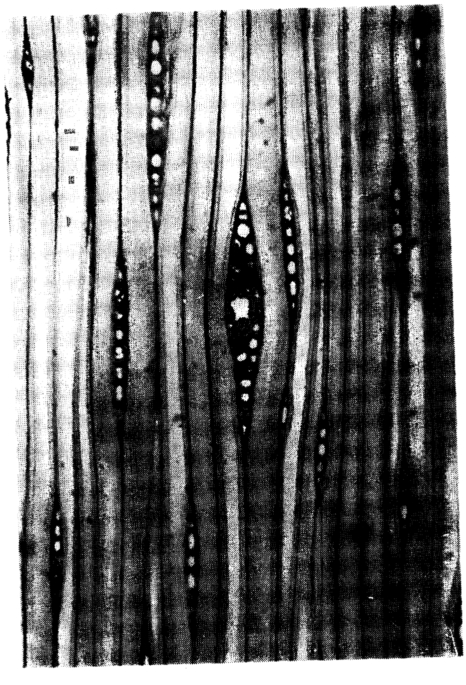


Photo. 54



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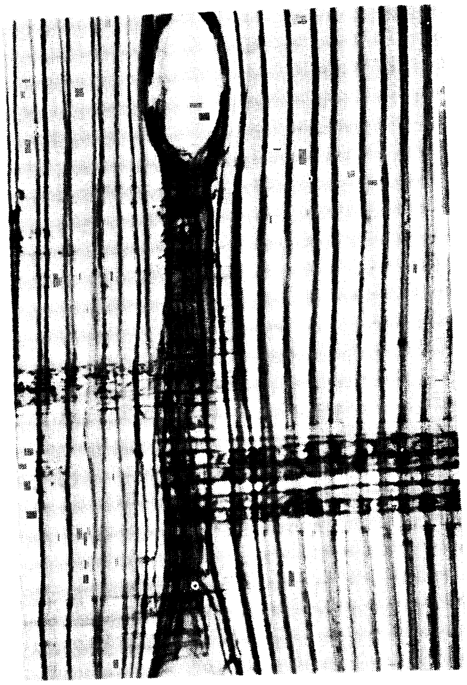


Photo 56

Photo. 57

Photo. 58

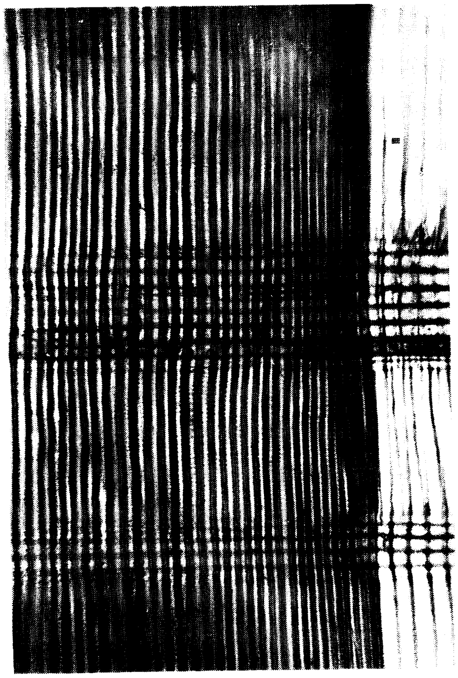
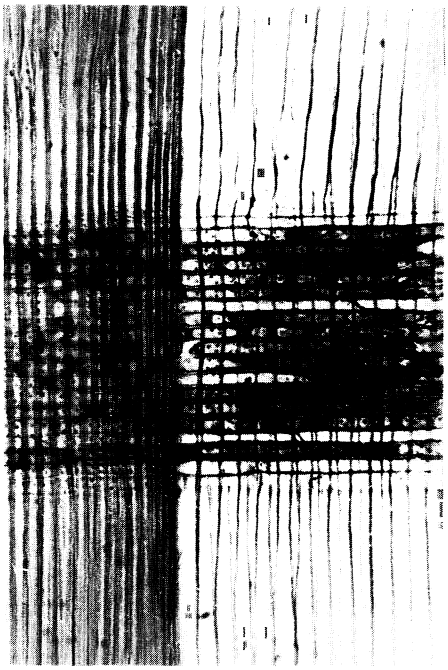


Photo. 59

Photo. 60



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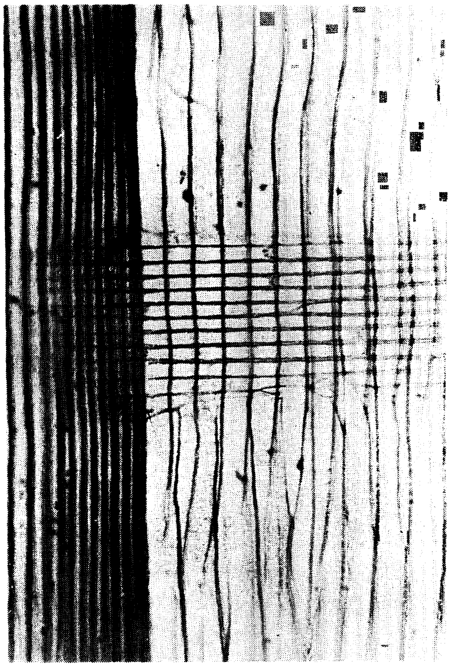

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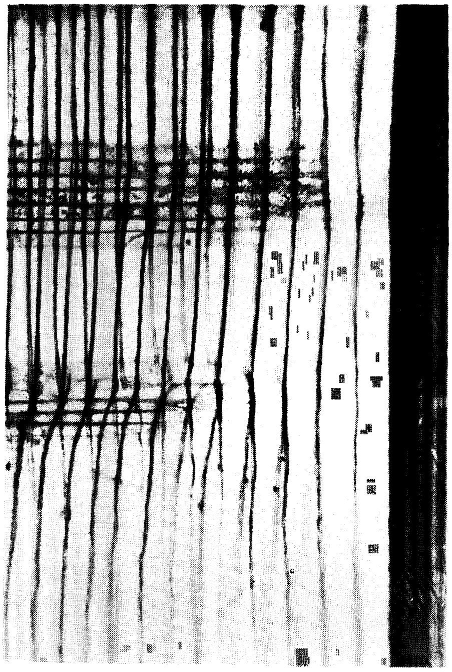

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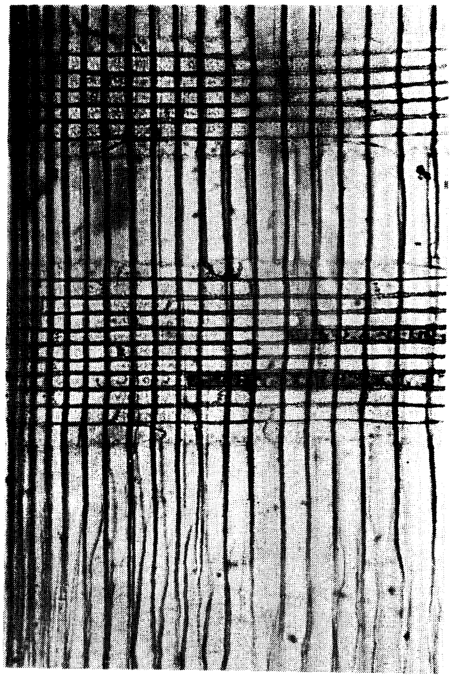

Photo. 64

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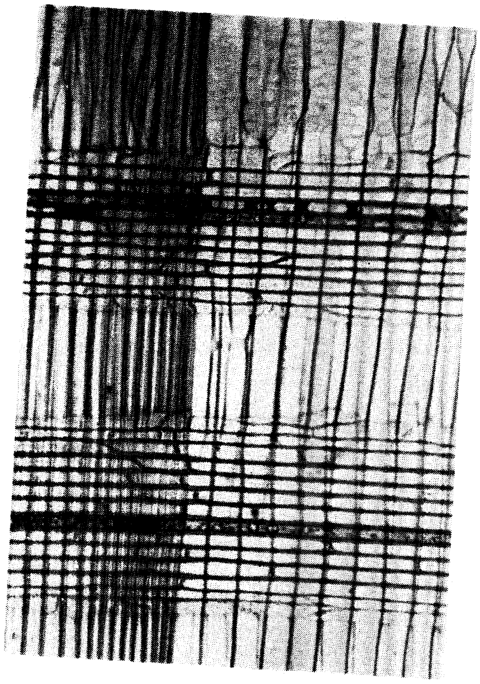

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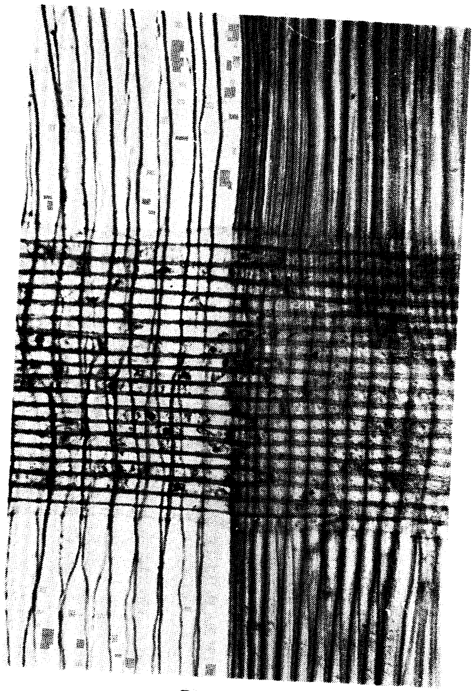

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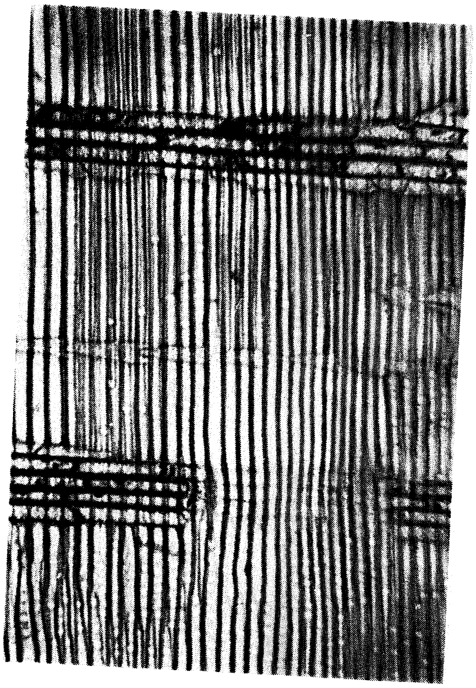

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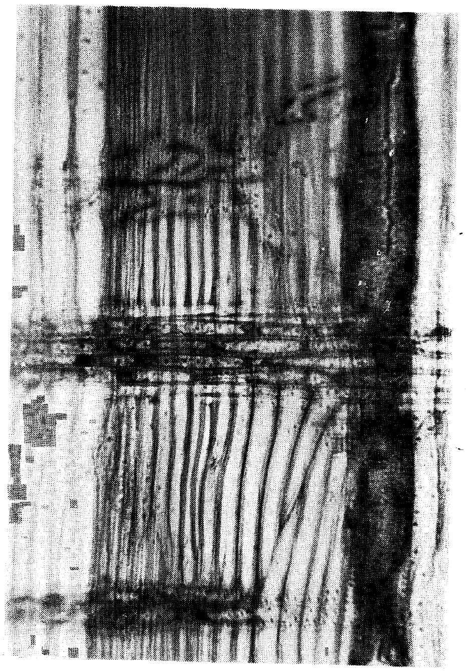

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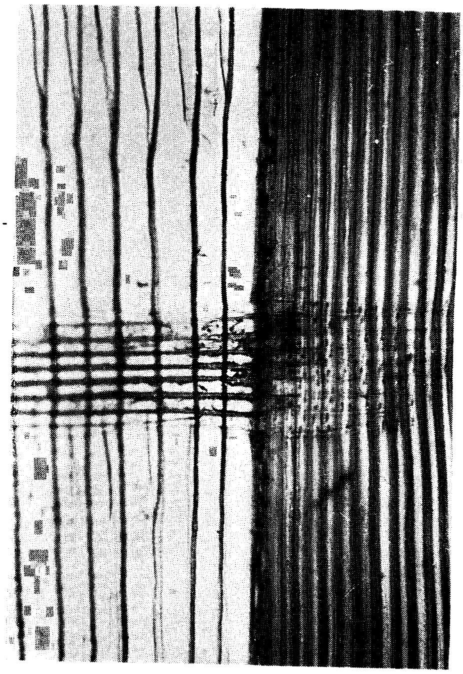

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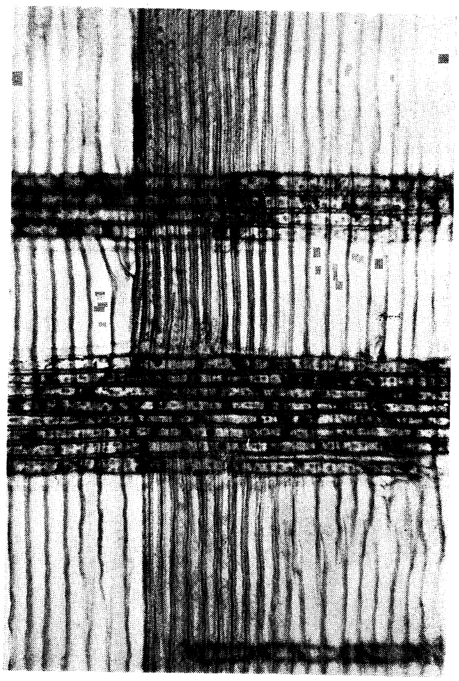

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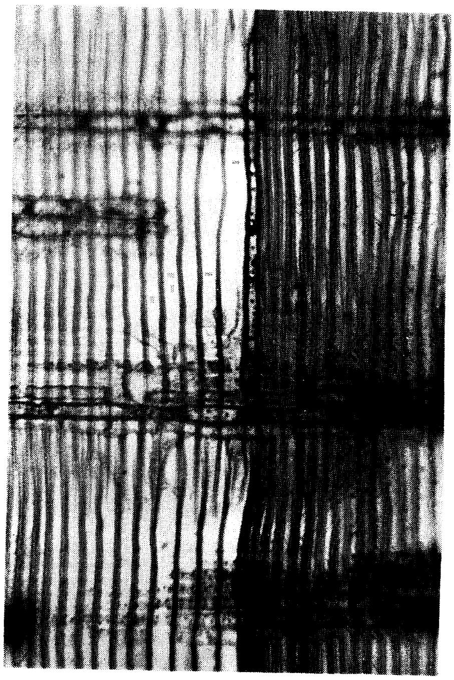

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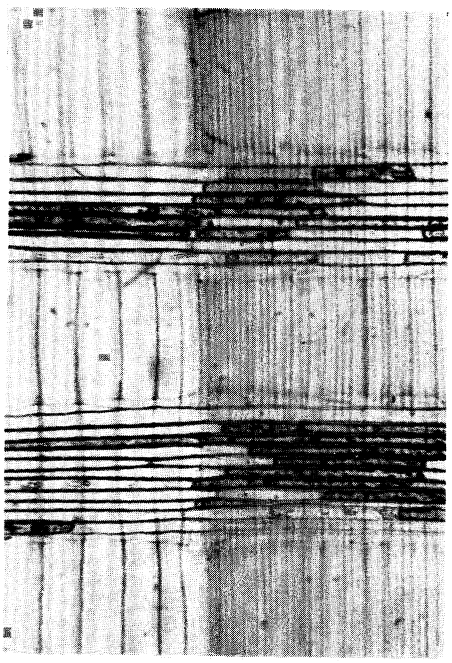

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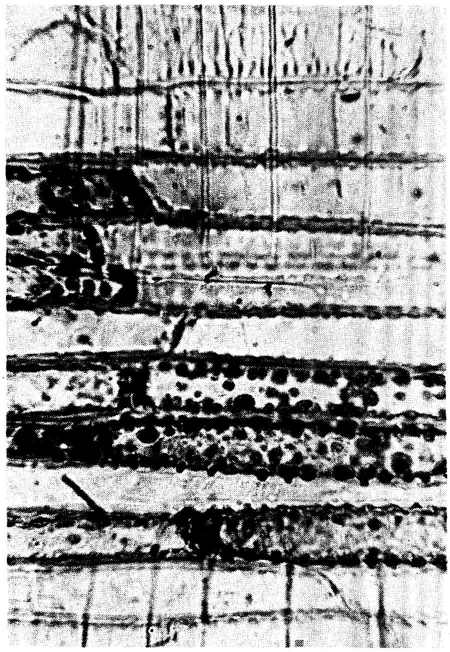

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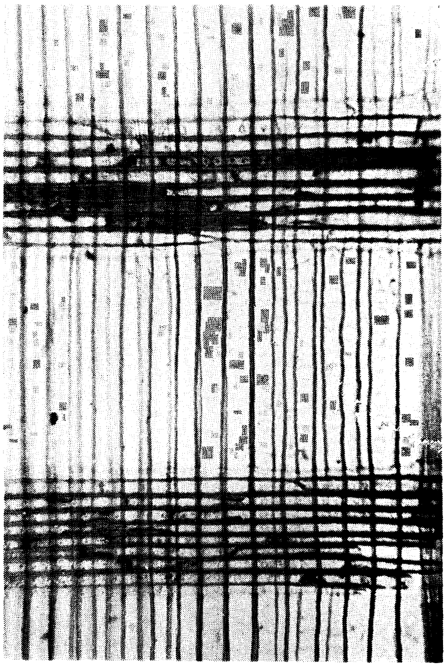

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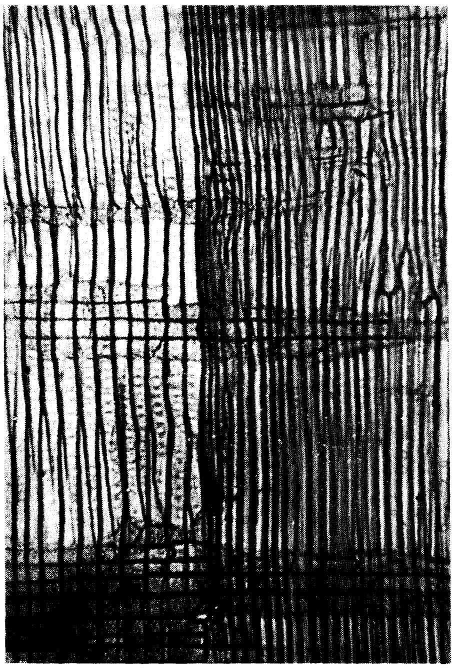

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Photo. 77

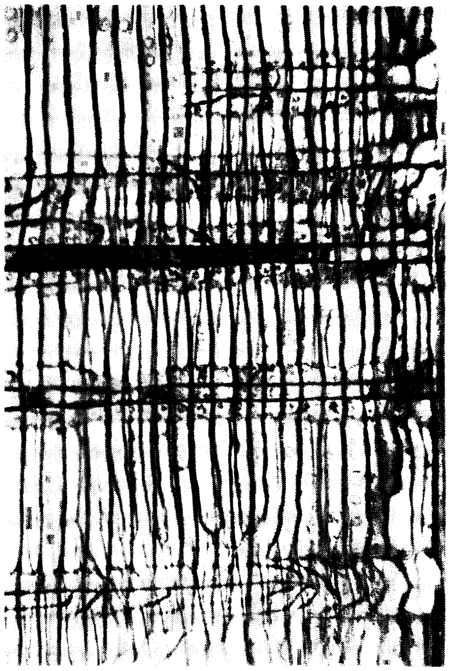
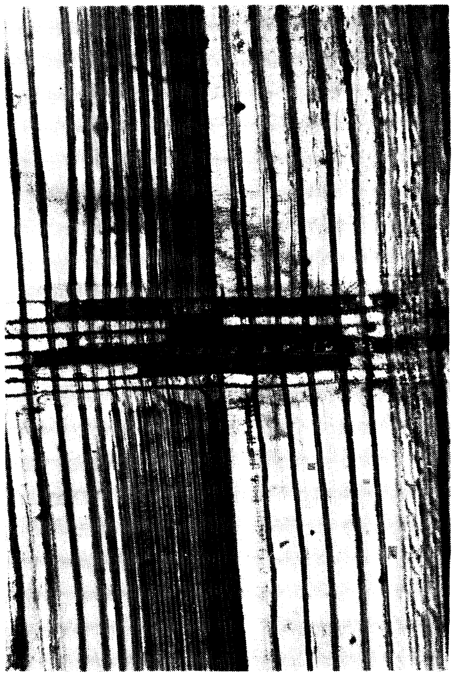


Photo. 78

Photo. 79



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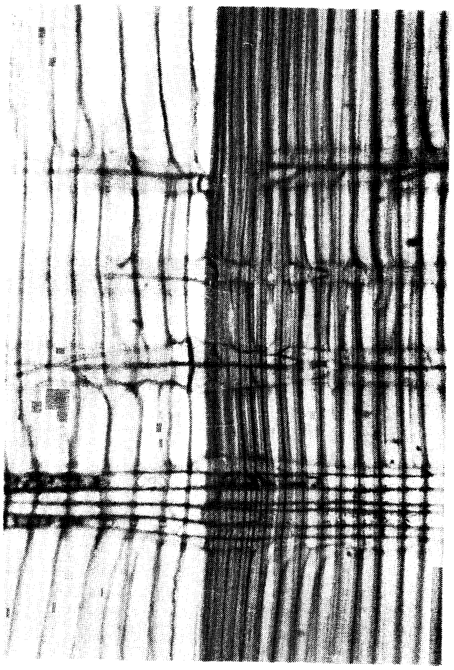
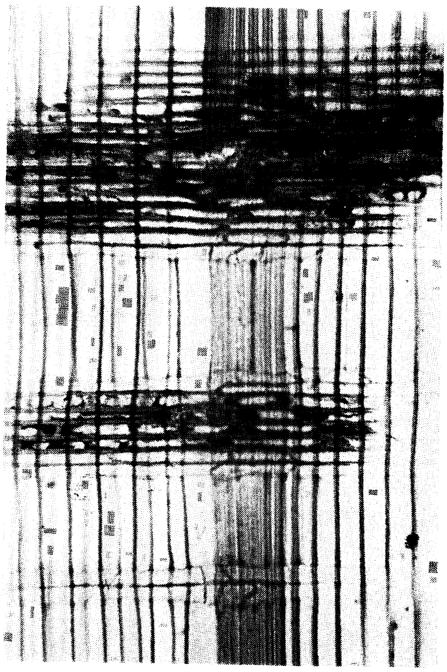


Photo. 81

Photo. 82



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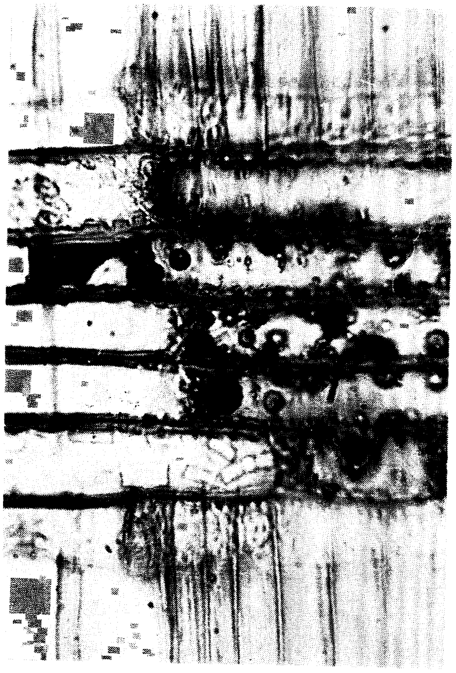

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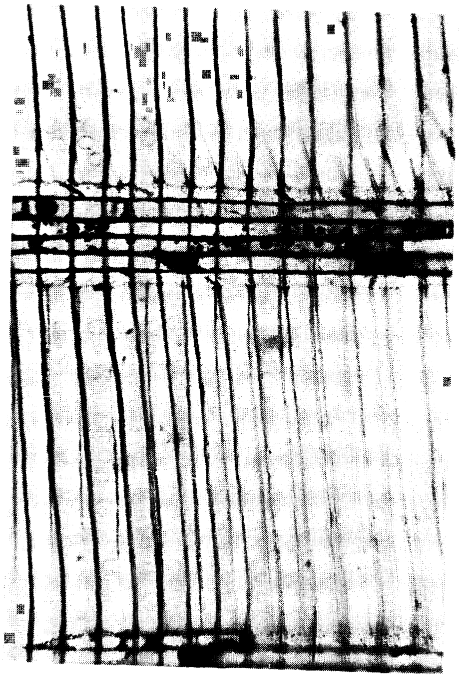
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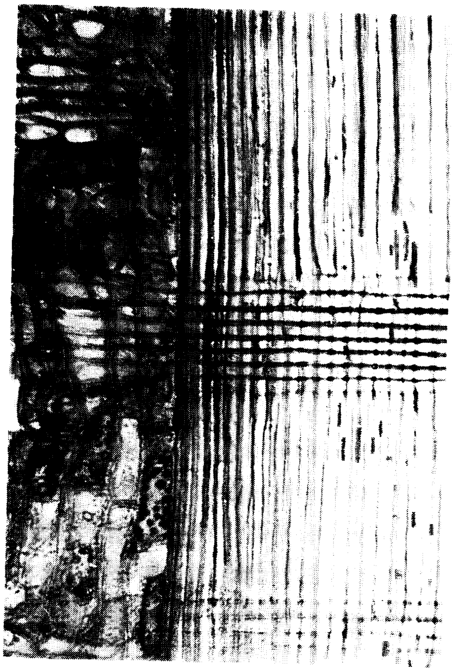
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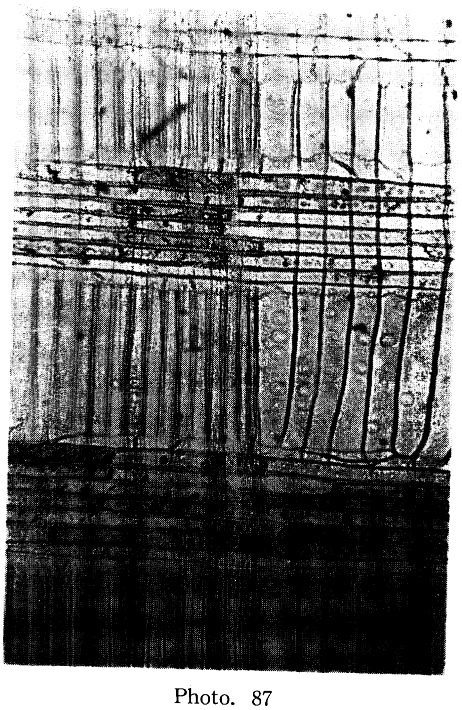
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