PÁL GREGUSS

XYLOTOMY OF THE LIVING CONIFERS

AKADÉMIAI KIADÓ·BUDAPEST

P. GREGUSS

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Wood anatomy has gained a substantial importance in wood working (match, pulp and paper, cellulose, wood fiber, artificial silk) industries, forestry and wood sculpture, and also among researchers of archeology, paleontology, botanical phylogeny, phytogeography, climatology, geology and petrography, and so on.

A worthy successor to his previous publications in this field, this latest volume by the author provides a condensed exposition of the method of wood identification on a xylotomical basis, discussing the four main wood types, *Cycads*, *Conifers*, *Monocotyledons* and *Dicotyledons*. The xylotomical features of the individual conifer families are then described. The bulk of the book is taken up by a detailed description of the hitherto undiscussed 155 species of conifers.

It is hoped that the present book by Professor Greguss will meet as favourable reception as did his previous publications.

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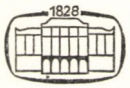
by

PÁL GREGUSS

D. Sc. (Biol.), Em. Professor of Botany, University of Szeged

808 microphotos on 175 plates and 145 plates with drawings



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*For detailed description of the families Cycadinae, Cycadaceae, Stangericeae and Zamiaceae the reader is referred to P. Greguss: Xylotomy of the Living Cycads, Akadémiai Kiadó, Budapest 1968, pp. 47—122.

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PREFACE

This book is a direct continuation of the author's monographs "Identification of Living Gymnosperms on the Basis of Xylotomy" and "Xylotomische Bestimmung der heute lebenden Gymnospermen". The favourable reception of these two monographs has prompted him to procure samples also of wood species not treated so far, and to publish as a supplement, in a separate volume, the result of their examination according to the same norms as before. In his previous works, the author had treated 345 gymnosperm and 5 chlamydosperm species. The actually known conifer species number about 550. Since the publication of his two previous volumes in 1955, the author has received samples of about 160 species of cycads and conifers, in particular of the more rare monotypical ones or of those of an enhanced scientific interest, which today thrive in North and South America, Africa, Australia, New Zealand, Asia, or in the Siberian Far East. Procuring samples of these has proved even more difficult and cumbersome than in the case of the previously described species. Considering also the present book, the author has treated a total of 500 conifer species, roughly 90 percent of the total extant population, in addition to the 38 species of cycads discussed in a separate monograph. Speaking in more detail, this work has raised the numbers of species procured and described by the author to 100 for *Pinus*, 80 for *Podocarpus* and 60 for *Juniperus*.

This volume being an organic continuation of the above-mentioned books in German and English, its general structure is the same, and only a few additional remarks seem indicated.

We shall not repeat a discussion of xylotomical terms: the reader is referred instead to P. Greguss: "Einführung in die Palaeoxylotomie" (1968c). We shall give but a very brief xylotomical characterization first of the four main types of wood, and then of the six families of conifers, in order to permit an easy preliminary orientation as to the systematic position of any material in hand. The present treatment of these fundamentals is a somewhat revised version of the relevant passages in the volume "Identification of Living Gymnosperms on the Basis of Xylotomy". For completeness, we shall describe one representative of each of the ten cycad genera: xylotomy, leaves and leaf epiderms of the remaining 73 cycad species have been treated in a separate monograph (Greguss 1968a).

The xylotomic image of a wood being somewhat – although not fundamentally – different according to the age and/or environment of the tree, we shall invariably state whether the wood examined is a sample from an older tree trunk

or a thinner bough (although this may be irrelevant in so far as e.g. the smallest conifer, *Dacrydium laxifolium* has a stem only 1 to 2 mm thick).

Correct nomenclature has also in the present case caused some difficulties. We have generally followed Dallimore–Jackson (Handbook of Coniferae, 1925) and Krüssman (Die Nadelgehölze, 1955), furthermore Gaussen's nomenclature (1960, 1964, 1967) for *Pinus*, Bailey and Cookson's (1951) for the podocarps and Johnson's (1959) for the cycads. For certain rare species that do not figure in any of the above works we have accepted the identification of the person who was kind enough to provide the sample.

In the technical tasks, and more particularly in preparing the sections, the author was assisted by Research Assistant L. Siprák. Drawings of the sections were prepared by Middle School Master Dr. Margit Szabados and by Miss Lenke Gosztonyi, under direct supervision by the author. In photo laboratory work, Research Assistant Mrs G. Róbert lent a hand; typing and other secretarial work was performed by Mrs Maya Holtz; the author was assisted in proofreading and related activities by his wife, Dr. Teréz Greguss-Forray. The author wishes to express his sincere gratitude to them all for their kind and useful help. Photos were all taken by the author himself, using the simplest of apparatus (indeed, in the last few years, even the technical tasks of section cutting and darkroom work were to an increasing degree performed by the author himself). The Hungarian version of the manuscript was read by Professors Sándor Sárkány and Árpád Haraszty, to whom the author wishes to extend his appreciation. For the careful and expert work of translation due thanks are expressed here to Dr. Bálint Balkay, who assisted by Dr. József Stieber has also extended valuable help to the author in the technical arrangement of the material. Further thanks are due to the Class of Biological Sciences of the Hungarian Academy of Sciences, for having promoted the publication of the present volume; and to Professor Dr. Imre Horváth, Head of the Department of Botany, József Attila University, Szeged, successor and one-time pupil of the author, for having made possible to the author after his retirement to achieve this work at his Institute. And finally, the author wishes to express his gratitude to the Publishing House of the Hungarian Academy of Sciences for having produced a volume as fine and correct as the previous ones.

Szeged, 31 December 1971.

The Author

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AMOR, I. M.: Instituto Forestal de Investigaciones y Experiencias Maderas y Aplicaciones, Laboratoria de Anatomia, Madrid, España (148)
BEDEKLINTER, B.: Division of Botany, Department of Agriculture, Pretoria, Union of South Africa (24)
DE BELDER, R.: Arboretum Kalmthouth, Belgium (29, 32)
BOBROV, E.: Museum of the Institute of Botany, Leningrad, U.S.S.R. (106, 119, 125, 127, 129)
BUCHINGER, M.: Secretaria de Estado de Agricultura y Gañaderia de la Nación, Buenos Aires, Argentina (71)
CHENG, Tsun Ching: Institute of Forest Products, Ministry of Forestry, Wan Shu Shan, Peking, China (91, 107, 116, 121, 134, 136, 151, 157, 158)
DADSWELL, H. L.: Division of Forest Products, Melbourne, Australia (52, 59, 60, 86)
DYER, R. A.: Pretoria, Union of South Africa (28)
GAUSSEN, H.: Laboratoire Forestier de Toulouse, France (89, 92)
GOVERS, A.: Forest Research Institute, Bogor, Indonesia (38)
HARRISON, T.: Sarawak Museum, Kuching, Sarawak (54)
Mrs. A. HEJNOVICZ, A.: Polska Academia Nauk, Arboretum Kórnickie, Kornik-Poznania, Poland (118)
ITO, M.: Gifu University, Nagara, Japan (126)
JEATES, I. S.: Massey Agricultural College, University of New Zealand, Palmerston (48, 67)
JOHNSON, L.: Botanical Gardens, Brisbane, Australia (25)
Mrs. KAISER, M.: Southern Illinois University, Carbondale, U.S.A. (53, 54, 57, 58, 60, 62, 63, 64, 68, 69, 75, 76, 82, 83, 84)
LANDON, F. H.: Forest Research Institute, Lepong, Selangor, Malaya (42)
DE LEON, P.: Jardin Botanico de la Universidad, Havana, Cuba (30)
LIBBERT, E.: Botanical Gardens, Rostock, Germany (33)
LIU, S. C.: Historical Research Commission of Taiwan Province, Taiwan (66, 145, 155)
LOTHIAN, T. R. N.: Botanical Gardens, Adelaide, Australia (34, 87, 88)
MAIR, K.: Royal Botanical Gardens, Sydney, Australia (51, 89)
METCALFE, C. R.: Royal Botanical Gardens, Kew, England (92, 106, 117, 124, 153, 157)

* The numbers in brackets refer to the pages where the respective sample has been specially treated.

MONSALUD, M. R.: Forest Products Research Institute, University of the Philippines, Laguna (56, 72)

PANDEY, K. K.: Department of Scientific and Industrial Research, Palmerston, New Zealand (43, 44, 46, 47)

DE LA PARRA, R. V.: Secretaria de Agricultura y Gañaderia, Mexico (94, 103, 115, 132, 141)

ROTHKUGEL, M.: Instituto de Botanica, Buenos Aires, Argentina (68)

SAITO, J.: Government Forest Experiment Station, Meguro, Japan (65, 113, 154)

SARLIN, P.: Direction du Service Forestier du Gouvernement Français, Nouméa, New Calédonie (55)

SMITH, C. M.: Smithsonian Institution, Washington, U.S.A. (40, 81, 85, 88, 90, 95, 108, 122, 130, 131, 133, 137, 138, 139, 140, 144, 147, 156)

STERN, L.: Yale University, School of Forestry, U.S.A. (73)

SZAFER, W.: Botanical Gardens, Cracow, Poland (23)

TARNAVSCHI, I. T.: Botanical Gardens, Bucharest, Romania (109)

TRANKOVSKY, D.: Botanical Institute of Moscow University, U.S.S.R. (95, 96, 97, 98, 99, 100, 101, 102, 103, 120, 143)

DE VARGAS, A.: Museo Nacional de Historia Natural, Santiago, Chile (45, 77)

WILKES, W.: Forestry Department of Brisbane, Australia (27, 57, 61)

WOMERSLEY, J. S.: Department of Forests, Lae, Territory of Papua and New Guinea (41, 44, 49, 51, 70, 78, 104, 105)

YATSENKO-KHMELEVSKY, A. A.: Komarov Botanical Institute, Leningrad, U.S.S.R. (93, 135, 149)

YU, G. H.: Academia Sinica, Peking, China (63, 110, 111, 112, 113, 114)

Niedersächsische Forstliche Versuchsanstalt, Göttingen, German Federal Republic (142, 146)

Tropical Products Department of the Royal Tropical Institute, Amsterdam, Netherlands (36, 37, 38, 39, 41, 46, 50, 73, 79)

INTRODUCTION

TYPES OF WOOD IN ARBORESCENT PLANTS

The successful identification by xylotomic means of any trunk or bough fragment of a living or fossil plant presupposes a knowledge of fundamentals concerning wood structure, tissue types, and their relative disposition in space, since the most characteristic traits of all wood species are invariably connected with the spatial disposition of tissue types. This gives rise in all woods to a typical and specific pattern that is visible sometimes to the naked eye and is in most of the cases made visible by a magnifying glass. Under the microscope, finally, the wood reveals the most minute details and characters of texture typical of the plant species in hand.

Even with the unaided eye or using just a magnifying glass, the various wood types can be placed in one of at most four basic types or groups. In sufficient knowledge of the characters of these four groups, even the smallest splinter of wood can, merely by its external features, be readily assigned to one or another of these four groups.

The first stage in wood identification is the inspection of a cross section.

1. Cycas type. (Plate I, Photos 1a and 1b.) If the cross section (C) reveals, inside one or several xylem and phloem rings, a well-developed pith with major ducts or separate bundles, and if moreover there are rays traversing the xylem, composed of one, two or more rows of cells side by side, then the wood sample in hand comes from the class *Cycadinae* of the subphylum *Gymnospermae.*

2. Coniferous type. (Plate I, Photos 2a and 2b.) If the cross section (C) exhibits elements of more or less equal cross section, arranged in a regular alternation of annual (growth) rings, then the sample in hand belongs to the class *Coniferae* of the subphylum *Gymnospermae.*

3. Monocotyledonous palm type. (Plate II, Photos 3a and 3b; as to habit, see Plate IV.) If the cross section (C) shows scattered, larger bundles, collateral closed vascular bundles, surrounded by bundles of sclerenchyma, scattered in a ground tissue, then the wood in question belongs to some monocotyledonous angiosperm, most probably to a palm (*Palmae*).

4. Dicotyledonous type. (Plate II, Photos 4a and 4b: for a texture diagram see P. Greguss: "Holzanatomie der Europäischen Laubhölzer und Sträucher", Akadémiai Kiadó, Budapest 1959.) If the cross section (C) reveals in addition to smaller lumina also much larger cavities – the cross sections of vessels – scattered irregularly in the matrix or arranged in annual rings according to some pattern, this indicates that the wood belongs to a dicotyledonous angiosperm species.

GENERAL PART

CLASSIS A.
OUTLINE XYLOTOMY OF THE CYCADINAE

Within the cycad class, L. A. S. Johnson has distinguished three families with a total of ten genera: I. *Cycadaceae* (1. Cycas); II. *Stangeriaceae* (2. Stangeria); III. *Zamiaceae* (3. Lepidozamia, 4. Macrozamia, 5. Encephalartos, 6. Dioon, 7. Microcycas, 8. Zamia, 10. Bowenia). Although differing to some extent in habit, foliage and reproductive apparatus, the 140 or so species of these ten genera exhibit a number of common xylotomical characters which distinguish them sharply from the other three wood types, even from the other gymnospermous class, the conifers. We shall discuss these characters below.

Plate III shows the texture of a Cycas trunk, reduced five times. This texture is clearly distinct from all the other three main types, notably the conifers and the monocotyledonous and dicotyledonous trees.

Cross section (**C**). One of the most striking cross-sectional features of the cycads is the presence in the middle of the section of a well-defined pith composed of parenchyma cells (1), usually with numerous mucilage canals (2) which usually communicate with the similar mucilage canals of the cortex (8) through the primary rays. In most cycads there are among the so-called proper conductive bundles also certain common bundles (14) which, issuing from the pit, pass through the larger primary rays into the cortex and from there, as true leaf base bundles, into the leaves. The collateral conductive bundles (5, 6, 7) tend to meander irregularly both in the pith and in the cortex, some of them parallel to the trunk axis, others perpendicular to it, yet others covering the full angular range in between these two. Some cells of the pith contain oxalate druses (3).

Another typical feature of cycads is that the well-defined and well-developed pith is surrounded by 1 to 8 xylem rings and as many phloem rings in alternation, cf. Pl. III. These are thin as a rule, except for *Dioon spinulosum* in which xylem and phloem are very well-developed single rings. In the xylem, the tracheids are most often radially disposed, of more or less uniform cross section, similarly as in coniferous wood, but the xylem exhibits no annual rings similar to those of the conifers. Rays are very seldom uniseriate, most often bi- and multiseriate (up to 15 rows) (4). These so-called primary rays pass directly from the pith to the cortex. This multiseriate ray structure is typically cycadean, distinct from all coniferous wood tissues. (Let me point out here that, for this reason, it is wrong in my opinion to identify any fossil wood with multiseriate rays as an Araucarioxylon.) All ray cell walls are smooth and very thin, even simple pitting is very rare. The xylem ring (5) is invariably surrounded by a phloem ring (7); between them, there may be a cambium one or two cells wide (6). Often the rather distinct

collateral open bundles are disposed in a ring. The phloem includes both phloem parenchyma and phloem fibres, easy to distinguish, as well as sieve tubes.

Among the phloem elements there are, especially close to the xylem but also in the broader rays and in the pith fairly numerous idioblasts or transfusion cells [Photo (15)] exhibiting a considerable variety of thickening types, including in addition to the reticulate type also the bordered and scalariform types of the tracheids. In some instances these transfusion cells are clearly seen to be essentially protoxylem elements; the bordered or scalariform thickening is apparent even in the highly elongated ones. These protoxylem elements elongate more and more towards the xylem, becoming at first short tracheids, then long tracheids whose evolution out of protoxylem elements can occasionally be traced in full detail.

Among the parenchyma cells of the cortex, numerous wide-lumened mucilage canals (2) are scattered. The cortex terminates in a layer of periderm (9), through which the bundles issuing in the pith (12) and elsewhere lean out (13) into the leaf bases (10) or leaf scars (11).

Tangential longitudinal section (**T**). Ray cells are varied in height and width; this is another marked difference from conifer rays. In addition to a few uni- and biseriate rays there are numerous multiseriate ones [Photo (18)], occasionally up to 15 cells wide and 100 cells tall. This multiseriate ray structure is distinctively cycadean. In tangential sections or on polished surfaces, quite thin-walled parenchyma cells are fairly frequent among the tracheids.

Radial longitudinal section (**R**). The most important features are that the ray cells are almost invariably upright and that in the cross fields the individual pits or pit rows are arranged vertically rather than horizontally, most often in the araucarioid pattern (Plate III. 4). Pit apertures are most often horizontal or slightly leaning. In the genera with exclusively scalariform tracheids (e.g. Zamia) there are no typical cross fields. In this case, no pitting is shining through the ray cells, either; at least, none can be evinced even by the most painstaking observation. In those genera, on the other hand, which possess both kinds of pitting, cross fields are restricted to where e.g. a tracheid with bordered pits contacts a smooth-walled ray cell. Most cross fields are upright; the number of pits in one field may be 3 to 30.

Another feature of the class is the pitting of the tracheids. In some woods, pitting is exclusively araucarioid (16) (e.g. Encephalartos), whereas in others the thickening of the tracheids is quite fern-like, that is, scalariform (17); yet others exhibit bordered pits with a considerable variety of transitions up to reticulate, spiral and annular thickenings. Pitting in tracheids adjacent to the phloem is most often araucarioid; transitions including reticulate and scalariform are observed towards the protoxylem, whereas the protoxylem elements proper are invariably spirally thickened. This feature much resembles the spiral thickening in the vessels of monocotyledons, e.g. of the palms (Plate IV). All in all, if any of the above-described features are observed in a wood section, it is justified to conclude upon some genus of the Cycadinae. Detailed examination can then proceed in the right direction. (Cf. P. Greguss, 1968a.)

CLASSIS B.
XYLOTOMY OF CONIFERAE

Most coniferous woods exhibit textures considerably different from those of the above-discussed cycads. Their most striking feature, apparent most often to the naked eye, is a well-developed xylem composed of elements of more or less uniform cross section, the so-called tracheids. This large-scale structure is much the same in all conifers, whereas the microscopic images exhibit a fairly wide variety of essential characters. H. Pilger (1926) groups all living conifers into seven families, notably *Araucariaceae*, *Podocarpaceae*, *Taxaceae*, *Cephalotaxaceae*, *Cupressaceae*, *Taxodiaceae* and *Pinaceae*. Certain authors contract the Taxaceae and Cephalotaxaceae into one order, *Taxales*.

The main xylotomical features of the conifer families are described in the following.

FAMILY I. ARAUCARIACEAE

Plate V, Photos 1–15.

C. Annual ring boundaries vague (Photo 1–3) or just discernible (Photo 4). Tracheid sections usually rounded (Photo 2). Resin ducts absent. Some species have xylem parenchyma cells filled with resin (Photos 5 and 13).

R. In the radial walls of the tracheids, there are bordered pits in 2 or 3 rows, alternating (Photos 12 to 15). Pit borders honeycomb-like, definitely hexagonal (Photo 13). If there is just one row of contiguous pits, then the lines of contact between them are invariably horizontal (Photo 12). Cross fields exhibit 1 to 16 minute pits, either separate (Photos 10, 12a) or with chambers touching, most often crowded araucarioid fashion into a honeycomb pattern (Photos 11, 14). All walls of ray cells as well as of axial parenchyma cells smooth and thin (Photos 5, 11, 13). Spiral thickening in the tracheids is rare and restricted to a few species (*Agathis rhomboidalis*, Plate XXV). There are thick-walled ray cells (idioblasts) in the rays of some species (Photo 7; also *Agathis macrophylla* and *A. rhomboidalis*, Plate XXV).

T. Rays are 1 to 20, more seldom 25 cells tall. Cells are more or less cask-shaped (Photos 6, 8, 9). There may be some sporadic small bordered pits (Photo 6) in the tangential walls of the tracheids.

FAMILY II. PODOCARPACEAE

Plate VI, Photos 1 – 13.

C. Most annual ring boundaries just discernible (Photo 3): few are sharp (Photos 2 and 4). Tracheid sections usually angular (Photos 1 and 2), sometimes rounded (Photo 3). Resin ducts absent; xylem parenchyma abundant (Photo 4) but not ubiquitous (missing from Photo 1 and from some *Dacrydium* species).

R. In radial walls of tracheids, bordered pits usually in 1, 2 or 3 rows, usually opposite (Photo 8); some of them standing quite apart, others touching or crowded; line of contact oblique in most compressed twins (Photo 7). No spiral thickening in the xylem. Cross fields exhibit one or two, very seldom two to four rather small circular or elliptical podocarpoid pits with broad leaning or almost vertical apertures (Photos 9, 10, 13). Other pits are round or elliptical, broad-pored (Photo 11). The round or procumbent elliptical pit pore may fill out the entire cross field (German "Eiporen", "egg pores", Photo 12). Occasionally the entire cross field will contain just a single pit (Photo 13). Rays lack transverse tracheids (Photo 8). Horizontal walls of most ray cells smooth, thin; thinnings and simple pits very rare. Tangential walls invariably thin and smooth, very seldom with one or two spot thickenings. Corner pits ("indentures") are absent or very rare, almost indiscernible.

T. Rays 1 to 60 cells tall, usually uniseriate; only the tallest ones are biseriate in a height of one or two cells (Photo 6). End walls of axial parenchyma cells usually smooth; thickenings very exceptional (Photo 5).

FAMILY III. TAXALES (TAXACEAE + CEPHALOTAXACEAE)

Plate VII, Photos 1 – 14.

C. Annual ring boundaries distinct to hardly discernible (Photos 1, 2). Tracheid sections rounded or angular. Resin ducts absent. Some genera have resin-filled axial parenchyma cells (Photo 2).

R. The axial tracheids exhibit loose thin spiral thickenings, solitary or pairwise, or four in a row (Photos 4 – 14). The cross fields show 1 to 3 (less often 4 to 6) round or oblique elliptical, podocarpoid, dacrydioid or cupressoid pits (Photos 6, 10, 11, 12, 14). Some genera have xylem parenchyma cells with end walls smooth or slightly thickened in spots (Photos 8, 13). Tangential walls of ray cells invariably smooth (Photo 9); horizontal walls smooth, considerably thickened locally (in the Taxaceae) or sparsely pitted (Photos 6, 9 – 12). By the tangential walls of the ray cells there are some occasional indentures. Transverse tracheids absent.

T. Rays 1 to 28 cells tall, mostly uniseriate (Photos 3, 5, 7), occasionally partly or wholly biseriate. Certain genera (*Taxus*) lack axial parenchyma cells: in the other genera, the end walls of these cells are smooth or slightly thickened, nodular or uneven (*Cephalotaxus*).

FAMILY IV. CUPRESSACEAE

Plate VIII, Photos 1–19.

C. Annual ring boundaries obscure to discernible (Photo 1) to striking (Photos 2, 3, 4). Tracheid sections angular or rounded (Photos 2, 3, 4). Xylem parenchyma widespread, often with resin in the cells. There are no specific resin ducts.

R. In some species all ray cell walls are smooth and thin (Photo 15); in others, the horizontal walls are pitted but the tangential ones are mostly smooth (Photo 16), locally with spot or rosary-like or seldom dentate thickenings (Photos 11, 14, 18, 19). Horizontal walls of axial parenchyma cells smooth (Photo 12) or slightly thickened; the thickening may be nodular in some sections (Photos 6–8, 13). Cross fields exhibit 1 to 3, more seldom 4 to 6 cupressoid pits with elliptical chambers and narrow leaning or vertical apertures (Photos 10, 11, 15, 18, 19). Some other species have broad procumbent, elliptical pit chambers (taxodioid pits, or podocarpoid pits). There is no spiral thickening in the tracheids, at best only a spiral striation in the late wood. In the radial walls of tracheids the bordered pits are almost exclusively uniseriate, rarely biseriate opposite, in which case the Sanio line is rather conspicuous (Photo 17). Certain tracheid walls are covered by fine pores or nodules (Photo 5): the bordered pits of certain *Callitris* species are flanked by so-called awns or callitrisoid thickenings (Photo 9). There are some exceptional transverse tracheids in certain species.

T. Rays 1 to 30 cells tall. Ray cell sections circular (Photo 6) or upright elliptical (Photos 12, 13). Tangential walls of ray cells smooth (Photo 12) or with scalariform or sieve-like thickenings (Photo 13). End walls of longitudinal parenchyma cells smooth (*Widdringtonia*) or with rosary-like and very seldom dentate thickenings (*Juniperus*, *Chamaecyparis*).

FAMILY V. TAXODIACEAE

Plate IX, Photos 1–17.

C. Annual ring boundaries most often striking and sharp (Photos 1–4), seldom obscure or just discernible (Photo 5). Resin-filled xylem parenchyma cells frequent but resin ducts absent. There are some resin bladders, though (*Cedrus*).

R. In the radial walls of tracheids, there are bordered pits in one to three (seldom up to five) rows (Photo 16), most often scattered or opposite. Horizontal

walls of ray cells smooth (Photo 11), sparsely or densely pitted. Tangential walls almost invariably smooth and thin (Photos 10, 12, 18), with very sporadic spot thickenings (one or two per wall). The tracheid walls exhibit no spiral thickening. Resin ducts absent. There is some axial parenchyma (with the exception of *Sciadopitys*). End walls of axial parenchyma cells smooth or with nodular or lenticular (Photos 7, 8), or dentate thickenings (Photo 9). Some species have transverse tracheids, too (*Sequoia sempervirens*, *Metasequoia glyptostroboides*): cross fields exhibit 1 to 5 (at most 8) taxodioid pits (Photo 11), or procumbent elliptical or rounded broad pores (glyptostroboid pits, Photo 15), or cupressoid pits and transitional forms (Photos 13–14). Indentures sporadic in some species but usually absent.

T. Rays 1 to 60 cells tall, uniseriate (Photo 17), occasionally biseriate in a height of 1 to 10 cells. Tangential walls of ray cells usually smooth. End walls of axial parenchyma cells smooth (Photo 6) or thickened in a nodular or dentate fashion (Photo 10).

FAMILY VI. PINACEAE

Plate X, Photos 1–20.

C. Annual ring boundaries invariably marked, conspicuous (Photos 1–4). Tracheid sections invariably angular, except perhaps in some late tracheids. Resin ducts may be present or absent (Photos 1–4). Epithelial cells lining the resin ducts may be thin- or thick-walled (Photo 4, and Photos 2 and 3, respectively). Some genera possess some axial parenchyma (*Abies*, *Larix*).

R. Transverse tracheids absent (Photos 14, 17) or present (Photos 15, 18–20). Some species have rays without transverse tracheids or resin ducts (*Abies*, *Keteleeria*, *Pseudolarix*). Some species have both thick- and thin-walled ray parenchyma cells (*Picea*, *Abies*). Tangential walls of ray parenchyma cells very rarely smooth, most often thickened in the dentate (Photo 14) or more seldom the rosary fashion; Cross fields exhibit 1 to 6 (seldom 8) pits or large oval pinoid pits filling out the entire field (*Eiporen*, Photo 18) or 1 to 4 small round piceoid pits with leaning slit-like apertures (Photos 14–16, 19) or taxodioid pits (17, 20 Photos). Some genera contain some xylem parenchyma (*Abies*, *Larix*), others lack it (*Pinus*). Some genera exhibit spiral thickening in their late tracheids (*Picea*): other genera have it in the axial and transverse tracheids of all their species (Photo 19).

T. Rays 1 to 45 cells tall, most of them uniseriate (Photo 5); those including resin ducts may be tri- to quinqueseriate, however (Photos 6–9). End walls of longitudinal parenchyma cells nowhere smooth, invariably with nodular, dentate (Photos 10, 13) or spiral thickening. Walls of transverse tracheids smooth (*Tsuga*, *Pinus Haploxylon*) or dentate (*Pinus Diploxylon*) or spiral (Photo 12). The tangential walls of the ray cells exhibit sieve-like structures (Photo 11).

SPECIAL PART

CLASSIS A.
XYLOTOMY OF FAMILIES, GENERA AND TYPICAL SPECIES OF CYCADINAE

FAMILY I. CYCADACEAE

1. (351)* *Cycas revoluta* Thunb. (1784)

Plates XI A and B, Photos 1–13.

The spread of this species covers South China, East India, Taiwan and Southern Japan. A tree attaining 1 to 8 m height, it is widely grown in glasshouses.

The sample examined originates from the Botanical Gardens of Cracow, from an old, dried-out specimen. The diameter of the stem together with the leaf stumps is about 20 cm, that of the stem proper is 12 cm.

Macroscopic examination (Photo 1). The cross section shows a typical polyxylic structure; the three characteristic main parts of the Cycads are clearly distinct. The diameter of the pith is 4·5 cm (Photo 1a); the thickness of the phloem and xylem rings, 16 mm each (cd, cd); that of the cortex, 2·5 cm (e). On the polished surface, scattered light dots represent mucilage canals both in the pith and in the cortical portion; the dark dashes and spots represent bundles of the cortex. The vascular bundle ring consists of two definite xylem rings and two phloem rings. Outside the first abnormal ring, a third xylem ring begins to develop in places.

Microscopic examination. Cross section. The pith largely consists of thin-walled isodiametric parenchyma cells (Photo 8e). Among them, there are mucilage canals (g).

Bundle ring (Photos 2cd, 3cd, 4cd, 6cd). Out of the pith issue primary rays which divide the vascular bundle ring into broad segments. Thinner rays divide the broad segments into narrower ones (Photo 6h). Among the broad rays (Photo 7e), at the beginning of the tracheid rows, there are wood primanei or transfusion cells (Photo 7b). In cross section, the tracheids are generally rounded square, pentagonal or crowded polygonal; their lumina are always rounded; among them, sporadic thin-walled parenchyma cells tend to occur (Photo 6c).

Both the primary and the secondary rays continue beyond the xylem bundle ring into the cortex (3h, 5h, 6h). Their size and structure does not change across

* The bold-face numbers refer to species elaborated in the present volume, the bracketed ones are continuations of those in the author's *Identification of Living Gymnosperms on the Basis of Xylotomy* (1955).

the border (Photo 6h). At the ends of the xylem bundles, however, there are several rows of thin-walled cambium cells and the phloem bundle continues from there in the same width as the xylem bundle (Photos 4cd, 5d). The phloem bundle consists of thick-walled sclerenchyma fibres and parenchyma cells (Photo 5d). The phloem fibres are thick-walled; their lumina are narrow slits (Photo 5). The remains of the phloem primanei are arranged on the outside of the phloem layer.

First abnormal ring. The bundle ring referred to above may repeat itself outside the phloem layer twice and even three times (Photos 1, 2, 3cd, cd, cd).

Cortex (Photos 1e, 2e, 3e). Structure and arrangement of the ground tissue cells, of the mucilage canals and cortical bundles in the cortex agree with the corresponding features of the pith. The mucilage canals are readily visible to the naked eye (Photos 2g, 3g).

Periderm. On *C. revoluta* the leaf bases remain on the trunk for a long time and assume the role of a periderm (Photo 1).

T. The rays are 1 to 6 (Photo 9h), in extreme cases 15 to 20 cells wide.

Tracheids. The tangential walls are generally smooth; any pitting observed probably reaches across from the radial side. Besides the tracheids, transfusion cells could also be identified in places.

Radial section. Rays. Most ray cells are procumbent or upright rectangles (Photo 10).

Where the ray cells contact axial tracheids, cross fields tend to develop. These include 10 to 20 and even 25 simple pits, arranged according to the araucarioid pattern or loosely touching. The apertures are oblique, slit-shaped or linear (Photos 10, 11, 13).

Transfusion cells. In places parenchymatic transfusion cells are observed beside the rays, directly adhering to the tracheids. Their pitting agrees by and large with that of the tracheids but the pit apertures are much wider (Photo 7b).

Tracheids. In the tracheids, bordered pits are arranged in 1 to 3 rows, in the araucarioid pattern or somewhat loosely (Photo 12).

FAMILY II. STANGERIACEAE

2. (352) *Stangeria paradoxa* T. Moore (1853)

Plates XII A and B, Photos 1—13.

Its area of distribution is the region of Port Elisabeth in South Africa, where it is found in forests and on prairies. It is extensively grown in glasshouses. The material examined was obtained from the Division of Botany, Department of Agriculture, Pretoria, courtesy of Mr. B. Bedeklinter.

Macroscopic examination. The stem sample examined comes from the upper part of an oldish specimen. Its diameter is 12 to 14 cm; pith diameter is 6 cm,

bundle ring thickness 4 to 5 mm, thickness of the cortex about 3 to 4 cm. The polished section reveals a well-developed pith and cortex. On the other hand, the single ring is poorly developed, owing to the subterranean tuberous nature of the stem (Photos 1, 2). In the interior of the pith, the dark spots represent meandering vascular bundles, the light ones scattered mucilage canals (Photos 1g, 2g). The bundle ring is barely 4 to 5 mm wide (Photos 1cd, 2cd) and divided into several segments by broad rays. The bundle ring is surrounded by the cortex (Photos 1e, 2e) whose structure agrees with that of the pith (Photos 1a, 2a). The exterior of the cortex bears a thin periderm (Photos 1f, 2f) whose surface bears no leaf scars.

Microscopic examination. The pith consists of more or less isodiametric cells of rounded square, rectangular, circular or elliptical section (Photos 3a, 8). The mucilage canals running in the pith are shown in Photos 3g, 6g, 7g. In their vicinity, there are sporadic xylem bundles which pass through the primary rays to the cortex.

Bundle ring. There are relatively narrow vascular bundles (Photo 3cd) between broad rays (Photo 3h). In section, the tracheids are somewhat angular or rounded, square, rectangular, penta- or polygonal (Photo 5c). Among them there are a few sporadic xylem parenchyma cells, usually next to the rays (Photo 5). In the continuation of the xylem bundles, underdeveloped phloem bundles are seen (Photo 3).

The phloem fibres are comparatively thin-walled (Photo 4d), hardly different from the parenchyma cells in the ground tissue and phloem (Photo 4).

In *tangential section* (Photos 9, 10), the rays (Photos 9h, 10h) are 1 to 15 cells wide.

Between the rays there are tracheids whose thickening is scalariform without exception (Photos 9, 10, 12, 13); there is no araucarioid pitting in this wood.

Radial section. The ray cells are more or less isodiametric, square, upright rectangular or hexagonal (Photo 11h). There are no cross fields.

FAMILY III. ZAMIACEAE

LEPIDOZAMIA

3. (353) *Lepidozamia hopei* Regel (1876)

Plates XIII A and B, Photos 1—12.

Schuster in his Cycad monograph calls this species *Macrozamia denisonii* var. *hopei* (Hill) Schuster, while Johnson (1959) places it as an independent species into the genus *Lepidozamia* established by Regel in 1876.

The author obtained from the Botanical Gardens of Brisbane (courtesy of Mr. L. Johnson) a dried-out stem sample of *Macrozamia hopei*, about 30 cm long and 12 cm in diameter.

Macroscopic examination. In cross section, the polyxylic structure of the stem is apparent. The diameter of the broad dark pith is 6·5 cm (Photo 1a). In the ground tissue of the pith, proper and common vascular bundles and mucilage canals (dark spots in Photo 1g) are scattered. Outside the pith there is a first, so-called normal vascular bundle ring (Photos 1cd, 2cd); its xylem portion is 7 mm, its phloem portion 3 mm thick. The first abnormal xylem ring is somewhat thinner (4 mm); the corresponding phloem ring is barely 2·5 mm thick. The double vascular bundle ring is surrounded by a thin cortex (Photos 1e, 2a), and a periderm (Photo 1f) hardly 1 to 2 mm thick (Photos 1, 2).

Microscopic examination. Cross section. The pith largely consists of more or less isodiametric, thin-walled, loose parenchyma cells (Photo 5e). Among the thin-walled ground tissue cells there are locally thicker-walled idioblasts (Photo 6). The vascular bundles of the pith are meandering to and fro and a regular longitudinal or cross-section picture can but seldom be made (Photo 2). Mucilage canals usually occur close to the bundles. Their inner walls are lined with epithelial cells (Photo 5g).

The vascular bundle ring is divided into more or less broad collateral vascular bundles by the primary rays issuing from the pith. The primary rays, 15 to 20 cells wide, include the common bundles of the pith and usually also the mucilage canals (Photo 7/1). Some rays include thick-walled sclerenchyma cells looking like septate fibres (Photo 7/3).

Xylem bundles. In the xylem, the lumina of the tracheids are invariably rounded (Photos 3c, 4c), circular or elliptical. Among the tracheids, a few thin-walled wood parenchyma cells are occasionally observed (Photo 4).

Cambium. The xylem is in places flanked on its outer side by a cambium 3 or 4 cell layers thick (Photo 4c, m). The cambial cells are smooth and thin-walled.

Phloem bundles (Photo 3d). Similarly to the xylem, the phloem is dissected by primary and secondary rays (Photo 4/1, 2, d, h).

On the outer side of the *cortex* there is a rather broad layer of sclerenchyma cells (Photo 6).

Periderm (Photo 1f) cells are rectangular, suberized and close-packed, in radial rows as a rule.

Radial section. Rays. Most ray cells are upright or square (Photo 11). Communication between axial and ray parenchyma cells is sometimes through a simple scalariform pitting (Photo 11h).

Tracheids. The most characteristic property of the wood is the typical araucarioid pitting and scalariform thickening and perforation (Photos 8–12). In the opposite wall of the same tracheid, there are bordered pits arranged in the araucarioid pattern (Photos 8, 12). No modern pitting has been observed. No such scalariform perforation has been established up to now except in *Cycas media.*

Tangential section. The primary rays are multiseriate, 15 to 20 cell layers wide; the secondary rays are generally uni- to triseriate (Photo 7). In the broader rays, mucilage canals and vascular bundles coming from the pith are seen (Photo

7/1, 2). Among the thin-walled ray cells, thick-walled sclerenchyma fibres are rather frequent (Photo 7/3), which in all probability also pass from the pith into the cortex.

MACROZAMIA

4. (354) *Macrozamia miquelii* (F. Muell.) A. DC. (1868)

(*Macrozamia tridentata* (F. Muell.) Schuster)

Plates XIV A and B, Photos 1—11.

Its area of distribution is the narrow coastal strip of Eastern Australia. The stem is in most cases subterranean, rhizome-like, with 80 to 100 leaves of about 2 m length in a tuft on the emerging apex of the stem. The leaflets are 23 to 36 cm long and 5 mm wide.

The material was received from the Forestry Department, Brisbane (courtesy of Mr. W. Wilkes).

Macroscopic examination. The rhizome examined was 4 to 5 cm thick and polystelic (Photo 1).

Microscopic examination. There is no well-defined, separate pith. Although there are some parenchyma cells in the middle of the xylem, these cannot be regarded as a pith as known from other Cycads.

The phloem bundles are in correspondence with the xylem bundles (Photos 2c, 2d, 3c, 3d, 4c, 4d); their width equals the thickness of 2 to 8 phloem fibres (Photo 5d). Their outer ends gradually taper until, similarly to the inner ends of the xylem bundles, they become uniseriate (Photos 2, 3, 4).

The phloem bundles consist of fibres and parenchyma cells; fibre plates alternate with plates or isolated cells of phloem parenchyma.

The thickness ratio of phloem to xylem is variable but the xylem is always thicker (Photo 1c, d).

The cortex. The rhizome includes several steles so that the cortical portion is comparatively thin.

The cortex is surrounded by a periderm whose suberized cells are crowded into a pattern resembling a brick wall (Photo 2e).

Radial section. Ray. In the contact areas between ray cells and tracheids, there are cross fields whose height is the same as that of the ray cells. One cross field includes 10 to 18 pits, but definite pit fields do not develop everywhere (Photo 8h).

In the tracheid walls, bordered pits may be arranged in 2 to 5 rows; their chambers are compressed in the araucarioid pattern; their apertures are linear or slit-shaped, horizontal. Sometimes the apertures of two adjacent tracheids may coalesce, but there is no scalariform thickening; the tri- or quadriseriate

araucarioid pitting of the tracheids is characteristic also of this species (Photos 8–11).

Tangential section. Most rays are uni- to quadriseriate (typically bi- or triseriate). Broad rays are very scarce (Photo 7h).

ENCEPHALARTOS

5. (355) *Encephalartos altensteinii* Lehm. (1834)

Plates XV A and B, Photos 1–12.

Its area of distribution is South Africa where it is found mostly on sunny hillsides in the company of Acacia and succulents. The material was received for examination from Mr. R. A. Dyer, South Africa.

Macroscopic examination. The stem sample examined is a disk of about 22 cm diameter and 3 cm thickness. It includes a massive pith of about 12 cm diameter.

Microscopic examination. The pith largely consists of thin-walled, more or less isodiametric parenchyma cells (Photos 1a, 2a). Among them there are a few scattered mucilage canals lined with flat epithelial cells (Photos 1g, 2g, 5g, 7g). Among the thin-walled parenchyma cells, thicker-walled ones of the same size are rather frequent (Photos 6aa, bb), mainly near the origin of the vascular bundles. These are probably idioblasts. Also in the pith there are some meandering vascular bundles whose xylem consists of barely 10 to 15 tracheids (Photos 1b, 2b, 5cd).

Vascular bundle ring (Photos 1cd, 2cd). The isodiametric parenchyma cells of the pith show almost imperceptible transitions towards the primary ray cells (Photo 2h). In the rays, they gradually grow longer and narrower, and so do the thick-walled parenchyma cells (Photo 6). The xylem bundles have the width of 2 or 3, exceptionally of 6 tracheids (Photo 4c); single xylem bundles wider than that are rare and tend to be split up by uni- and biseriate rays (Photo 4h).

In cross section, most tracheids are square (Photo 4) or polygonal.

Phloem bundle ring (Photo 3). Outside the xylem bundle ring there are a few rows of cambium surrounded in their turn by the phloem bundle ring. The phloem bundles consist of thick-walled phloem parenchyma cells and phloem fibres (Photo 3d). In section, the fibres are square or procumbent rectangular.

Radial section. The ray cells are square or upright rectangular. In the axial tracheids in direct contact with ray cells, cross fields are observed.

Tracheids. In their walls the bordered pits form 2 to 4 rows arranged in the araucarioid pattern (Photo 10). The apertures are short, linear or slit-shaped; in some cases, however, the slits are substantially elongate in the horizontal direction and even span the walls of the tracheids: the bordered pitting gradually passes into a scalariform thickening (right-hand side of Photo 10). In some tracheids, this scalariform thickening shows a peculiar modification, especially at

or near the ends of the tracheids. The pit apertures grow substantially wider; the chambers of the bordered pits elongate horizontally, resulting in veritable ladder steps (Photos 9, 11, 12). As behind these, on the opposite side of the tracheid, bordered pitting is readily visible, these ladder steps can be regarded as a true scalariform perforation (Photos 10, 11) and the conductive element can in turn be regarded as a vessel, a trachea. The number of steps can be as large as 60 (Photo 11). This scalariform, perforation-like penetration locally passes into true reticular thickening; similar structures can be observed exceptionally in some monocotyledons, e.g. in palms.

Some tracheids are joined by horizontal, others by oblique end walls, communication being assured through the bordered pits in said end walls, and, in the author's opinion, also through the scalariform perforations (Photo 11).

In *tangential section*, the rays are uni- to quinqueseriate (Photo 8h); the primary ones may be up to 15 cells wide.

Their height is varied; the cells in the uniseriate rays are typically up to 150 μ high and 25 to 30 μ wide.

The tangential walls of most tracheids are smooth (Photo 8). In places, however, there are clusters of tiny bordered pits of 8 to 10 μ size, with circular chambers. Where several such pits are close-packed, the chambers tend to be hexagonal. The apertures are linear, horizontal or oblique. Some tracheid walls exhibit scalariform perforation, which is, however, much more pronounced in the radial walls (Photo 11).

DIOON

6. (356) *Dioon edule* Lindl. (1843)

Plates XVI A and B, Photos 1—13.

The sample examined was received from Mr. R. de Belder's Arboretum, Kalmthout, Belgium.

Macroscopic examination. The trunk sample examined (Photo 1) is conspicuous for the lack of a pith. The place of the pith cells is occupied by a skein of roots each of 1 to 3 mm diameter. The roots bear the tubercles so typical of the Cycads. Outside a vascular bundle ring (Photo 1a) of 7 to 8 mm thickness there is a cortical layer about 2 cm thick (Photo 1e), surrounded in its turn by a ring of leaf bases.

Microscopic examination. The ground tissue of the pith is for the most part replaced by the skein of pith roots of 1 to 3 mm thickness. The cross-sectional structure of these pith roots proves them to be true roots (Photo 2).

Vascular bundle ring (Photo 3cd). The xylem bundle ring (Photos 3c, 6c, 7c) is divided by primary and secondary rays (Photos 4h, 5h, 6h) in segments or collateral bundles 2 to 4 tracheids wide. In section, the tracheids are irregular

squares or polygons. The tracheid rows are locally interrupted by thin-walled parenchyma cells (Photo 5).

Phloem bundles (Photos 3d, 4d, 6d, 7d). The cambium consisting of 3 or 4 cell layers is surrounded by phloem bundles which correspond with the xylem bundles. The phloem fibres and parenchyma cells are arranged in radial rows (2x); most bundles consist of 1 to 3 such rows (Photo 4).

The ray cells are much broader in the phloem than in the xylem; they are approximately square; their radial dimension is typically 100 to 105 μ; their width ranges from 70 to 100 μ (Photos 4, 6).

The *vascular bundle ring* is surrounded by a cortical layer among whose parenchyma cells mucilage canals and conductive bundles are seen to meander (Photo 3e).

The outermost part of the cortex is the periderm whose outer portion is a thick cork layer. The leaf bases adhere to this latter (Photo 7).

Radial section. Most ray cells are square or upright. Pith ray cells in contact with axial tracheids do not usually develop well-defined cross fields; such fields are restricted to ray cells contacting tracheids with bordered pitting (Photo 9).

In the tracheid walls, the bordered pits are arranged in the araucarioid pattern (Photo 11).

The width of one tracheid includes as a rule 2 or 3 rows of bordered pits (Photo 9); the apertures of these are considerably elongate horizontally, usually slit-like (Photo 10). The slits locally grade into scalariform thickenings. In some tracheids, scalariform thickening is exclusive (Photo 12).

Tangential section (Photo 8). There are two kinds of ray, one 1 to 8 (Photo 8h), the other 15 to 20 cell layers wide. The latter carry the conductive bundles which, having in all probability issued from the pith, emerge into the cortex and continue as leaf scar bundles into the leaves.

MICROCYCAS

Microcycas calocoma (Miq.) A. DC. (1868)

7. (357) Plates XVII A and B, Photos 1—12.

Unique species of a monotypical genus, it occurs in the more elevated regions of Western Cuba. The material was obtained from Ponce de Leon, Havana. It was a disk 2 cm thick (Photo 1).

In the trunk sample of 10 cm diameter, the pith is 2·5 to 3 cm thick (Photos 1a, 2a, 3a). In it, the lighter spots indicate the mucilage canals. The pith is surrounded by a wide vascular bundle ring of 1 cm thickness (Photos 1c, 2cd, 3cd, 5cd). Even to the naked eye the xylem (Photo 3c) appears somewhat thicker than the phloem (Photo 3d). Our piece of stem includes only one vascular ring, but the bases of older trunks include several rings, so that the species is polyxylic. Outside the unique vascular bundle ring, the cortex is 2 to 2·5 cm thick (Photos

1e, 3e). It is similar to the pith; on its outer side, a periderm of somewhat denser substance (Photos 1f, 3f) occurs.

Cross section. The pith consists of thin-walled, isodiametric parenchyma cells. Their thin walls locally bear clusters of tiny pits.

Pith bundles. Scattered among the parenchyma cells of the ground tissue, the vascular bundles of the pith comprise each 8 to 20 loosely arranged tracheids as well as some sporadic, very thin-walled xylem parenchyma cells and a very few thick-walled phloem fibres.

The mucilage canals (Photo 3g) of the pith are lined with thin-walled epithelial cells. Their diameter is 220 to 240 μ.

Transfusion cells (Photos 1b, 3b). They form clusters on the periphery of the pith, near the points of issue of the xylem bundles, or constitute rosary-like rows of protoxylem elements. Some are isodiametric, others more elongate, yet others drawn out into veritable tracheids. Their walls exhibit reticular and scalariform thickening which can in places be traced back to bordered pitting. At some places they almost adhere to the tracheid bundles, as if the tracheids came to exist by elongation from these transfusion cells (Photos 6b, 7b, 8b).

Rays (Photos 2h, 4h). The cells of the primary rays agree in structure and shape with the parenchyma cells of the pith and cannot be morphologically distinguished from them, clearly illustrating how the primary rays of the Cycads originate in the pith (Photos 2h, 2r, 3, 5).

Xylem bundles (Photos 2c, 5c). The tracheid rows are either uniseriate or 2 to 8 tracheids wide; the latter constitute broader, continuous xylem bundles (Photo 2). Among them, some very thin-walled parenchyma cells form chains abutting at the ray cells from which they can hardly be distinguished morphologically and structurally (Photo 5).

Phloem bundles (Photos 2d, 4d). The xylem ring is surrounded by 2 or 3 cell layers of cambium whose cells are slightly smaller than the ray cells and somewhat flattened radially. Both the broader primary and the narrower secondary rays continue through the cambium into the phloem. The phloem bundles are as wide as the corresponding xylem bundles (Photo 4).

The cortex (Photos 1e, 3e). The phloem ring is surrounded by a cortical layer whose thin-walled parenchyma cells are of the same structure as those of the pith (Photos 1, 3).

Radial section. Rays (Photo 9h). The walls of the ray cells situated in the interior of the ray are smooth, whereas the walls contacting the tracheids bear smaller or larger simple pits in an irregular scatter. This pitting of the ray cells definitely differs from the ray pitting of the conifers. These pits have no chambers because they have formed in the primary cell wall. All in all, there are no pitted cross fields in *Microcycas* (Photo 9).

Axial tracheids. The pitting of the tracheids is rather variable. In some tracheid walls there are only bordered pits; in others the thickening is scalariform or reticular. The tracheids bearing the different sorts of pitting are sometimes intermixed whereas in some places there are only scalariform (Photo 10) or only

araucarioid tracheids. The ends of some tracheids join transverse walls which are pitted in the same pattern as the axial walls. The bordered pits in the radial walls, however, invariably form an araucarioid pattern (Photos 11, 12).

Tangential section. Rays (Photo 8h). In sections through the phloem, the rays appear 1 to 12 cell layers wide. Some ray cells contain tiny calcium oxalate crystal druses (Photo 8).

Conductive bundles. The fibres composing the elongate phloem bundles are thick-walled, with narrow, slit-like lumina. The tracheids of the xylem bundles are also elongate, their walls usually exhibit scalariform thickening (Photo 8).

Transfusion cells arranged between the phloem and the xylem bundles are particularly abundant in the tangential view. Their walls show scalariform and reticular thickening (Photo 8b).

CERATOZAMIA

8. (358) *Ceratozamia mexicana* Brongn. (1846)

Plates XVIII A and B, Photos 1—13.

The area of distribution of *Ceratozamia* is South-Eastern Mexico. Two or three *Ceratozamia* species thrive there. The best known species is *Ceratozamia mexicana*. The author has obtained a trunk sample of *C. mexicana* from R. de Belder, proprietor of the Kalmthouth Arboretum in Belgium.

Macroscopic examination (Photo 1). The diameter of the trunk is about 15 cm. Its cross section reveals even to the naked eye the typical structure of the Cycads; it is a monoxylic tree.

Microscopic examination. The pith largely consists of thin-walled isodiametric cells (Photo 2a). It includes proper and common bundles (lower parts of Photos 2c, d); the latter emerge through the primary rays into the cortex and into the leaves. Such a collateral bundle is composed of 3 to 10 rows of tracheids and possibly as many phloem rows (Photo 3c).

Vascular bundle ring (Photos 1cd, 2cd, 3cd). The isodiametric cells of the pith gradually pass into the primary rays where they somewhat lengthen radially (Photos 2h, 4h, 6h).

The primary rays (Photos 2h, 5h) divide the xylem ring (c) into narrower or broader xylem bundles. These latter, 3 to 10 tracheids wide, are divided into even narrower segments by uni- and biseriate rays. At the ends facing the pith of the xylem bundles some xylem primanei or transfusion cells can be observed; considerably lengthened, these subsequently change into tracheids (Photo 8b).

The xylem is followed by a cambium layer of 3 or 4 cell layers thickness (Photo 3d) and then by a phloem ring (d). Composed largely of parenchyma cells (Photos 4d, 6d), the phloem bundles correspond to the xylem bundles (Photo 2c, d). Phloem fibres are fairly scarce (Photos 3, 4, 6). Their walls are comparatively thin,

their lumina linear rather than slit-like (Photos 4, 6). Radially flattened and tangentially elongate, the cells of the uni- and biseriate rays become cylindrical between the external portions of the phloem bundles (Photo 6).

Cortex (Photos 1e, 3e). In shape, structure, size and pitting, the parenchyma cells of the cortex agree with the similar cells of the pith.

In the cortex, the number of mucilage canals (g) (Photos 2g, 7g) and of the tiny collateral conductive bundles (cd) considerably increases toward the periphery.

Radial section. The ray cells are generally square or upright (Photo 12h). Where the ray cells contact the tracheids, some tracheid walls develop cross fields corresponding in size to the ray cells, with 4 to 14 pits in the araucarioid pattern.

In the tracheid walls, bordered pits are generally aligned in 2 or 3 rows in the araucarioid pattern (Photo 10). Linear and horizontal or somewhat oblique (Photo 11), the apertures are considerably elongate locally; in such cases they reach across the tracheids, so that the bordered pitting gradually passes into scalariform (Photos 11, 12, 13). This pitting may be interrupted in places corresponding to the horizontal walls of the ray cells.

The scalariform thickenings may locally split up Y-shape, as a result of the chamber of a bordered pit being inserted between two other bordered pits. In the tracheid walls, where the bordered pits are interlocked alveolarly in the araucarioid pattern, the linear apertures of the pits may be crossed (Photo 13).

Tangential section (Photo 9). Most rays are uni- to triseriate (Photo 9h), but the primary rays may be up to 20 cells thick. Some tracheids adhere to thin-walled parenchyma cells; other tracheids adhere to transfusion cells which may be shorter or longer than these; the longest ones are lengthened into tracheids (Photo 12).

ZAMIA

9. (359) *Zamia floridana* A. DC. (1868)

Plates XIX A and B, Photos 1—13.

Its area of distribution is Florida, the Biscayne Bay region where it lives on coral reefs and in pine-woods. One of the samples was received from the Botanical Gardens, Rostock.

Macroscopic examination (Photo 1). On the cut and cleaned surface of the stem, the inner structure is visible to the naked eye. In the pith of 5 to 18 mm diameter (Photos 1a, 2a), the dark spots arranged in a circle are proper bundles of the pith or common bundles which through the primary rays emerge into the cortex. The light spots visible both in the pith and in the cortex represent mucilage canals. The pith is followed by a vascular bundle layer, 1 to 2 mm wide (Photos 1cd, 2cd) and by the cortex, 10 to 12 mm thick (Photos 1e, 2e). The outermost layer

is the periderm of denser substance (Photo 1f). Leaf bases are rare on the exterior of the cortex because the subterranean stem loses all leaves.

Microscopic examination. The pith (Photos 2a, 3a) is largely composed of very thin-walled, more or less isodiametric parenchyma cells. Among the parenchyma cells there are mucilage canals (Photos 2g, 3g) of relatively small diameter (140 to 150 μ), whose walls are lined with comparatively large epithelial cells.

On the periphery of the pith, mucilage canals form a more or less regular circle next to the protoxylem elements, and next to the places where the primary rays insert themselves into the xylem (Photo 2).

Vascular bundle ring (Photo 4cd). The xylem bundles (c) penetrate conically between the primary rays (Photo 4h). In their vicinity, calcium oxalate crystals are remarkably numerous. So are transfusion cells at the points of issue of some rays, and also among the tracheids, where the phloem bundles begin (Photos 5b, 6b, 7b). Among the transfusion cells there are isodiametric, elongate and quite tracheid-like ones. This shows how transfusion cells will change into tracheids.

In section, the tracheids are angular, their lumina rounded. Among them, there are a few xylem parenchyma cells.

Phloem bundles (Photo 4d) correspond with the xylem bundles but are much less developed.

The cortex (Photos 2e, 8e). The parenchyma cells of the cortex differ from those of the pith only in being somewhat larger. Among the parenchyma cells there are mucilage canals and cortical bundles parallel to the periphery, meandering to and fro in the external part of the cortex (Photo 3). In the parenchyma cells, calcium oxalate crystal druses are remarkably abundant (Photo 8i), almost forming layers locally; such layers may include up to 15 calcium oxalate crystals.

The periderm (Photo 8f) may consist of several layers. The specimen examined bears 3 such layers, each very rich in calcium oxalate crystals (Photo 8).

Radial section (Photos 10–12). The ray cells are about square in section. The walls of the ray parenchyma cells are smooth, thin and unpitted (Photo 11h).

Tracheids (Photo 13). In this species there is only one kind of tracheid, with scalariform thickening.

In *tangential section* (Photo 9), the rays are 1 to 5 (Photo 9h) sometimes 8 cell layers wide; some primary rays are even wider than that.

BOWENIA

10. (360) *Bowenia serrulata* (W. Bull.) Chamberlain (1912)

Plates XX A and B, Photos 1–12.

Two species of the *Bowenia* genus are known: *B. serrulata* (André) Chamberlain and *B. spectabilis* Hook. Of the former, the author has received a small trunk sample from Mr. T. R. N. Lothian, Director of the Botanical Gardens, Adelaide.

Macroscopic examination (Photo 1). The diameter of the pith (a) is about 1 cm; the monoxylic vascular bundle ring is of about the same thickness (c, d). The cortical portion (e) including the periderm (f) is thickest, about 1·5 cm.

Microscopic examination. Cross section. The pith (Photos 2a, 3a) largely consists of thin-walled isodiametric cells, close-packed, with rare intercellular ducts.

Among the thin-walled cells of the *ground tissue*, there are mucilage canals lined with epithelial cells (Photos 2g, 4g).

Rays (Photos 2h, 3h). From the pith, primary rays issue, dividing the xylem and phloem rings into wider or narrower collateral tracheid bundles (Photo 2). The individual collateral bundles are clearly separate (Photos 2cd, 3cd). The parenchyma cells of the primary rays gradually grow thinner and radially longer in their outward passage between the xylem bundles. At the edge of the xylem ring, the primary rays begin to flare out (Photo 2); the shape of the cells changes and their size increases here.

Tracheids. At the points of issue of the xylem bundles, protoxylem elements (transfusion cells) are almost invariably present.

Phloem bundles. The broader rays dissect the phloem bundles similarly to the xylem bundles; hence, the phloem bundles correspond with the xylem bundles (Photos 2, 3d).

Cortex (Photos 4, 5e). The histological structure of the cortex agrees with that of the pith. However, mucilage canals are much more frequent in the cortex than in the pith, and the cortical bundles, which are likewise collateral rather than concentric, are also more numerous. Also, structure and size of the mucilage canals agree with those of the pith (Photo 4g).

Periderm (Photo 5f). The cortex is limited outwards by a periderm (Photo 5). In the external portion of the cortex, near the periderm, the number of mucilage canals increases.

Radial section. Rays. Most ray cells are upright or square, but some are hexagonal and alveolarly packed (Photo 10h). The cross fields of the ray cells contacting the axial tracheids bear no explicit pitting (Photos 9, 10). In the ray cells, calcium oxalate crystal druses are rather frequent.

Tracheids. In the longitudinal walls of the tracheids, the bordered pits are either close-packed in the araucarioid pattern (Photos 8, 11) or, considerably lengthened transversally, they grade into scalariform thickening in which case the ladder steps span the whole width of the tracheid (Photo 7). In other cases, the apertures of the bordered pits become slit-like and pass gradually into a scalariform perforation (Photo 12). In the immediate vicinity of the phloem most tracheids bear a bordered pitting, whereas towards the cortex, scalariform thickening is prevalent.

The tangential section (Photo 6) exhibits the characteristic Cycad structure. Both in the phloem and in the xylem, the rays are uni- to quadriseriate (Photo 6h) or more.

CLASSIS B.
XYLOTOMY OF CONIFERS

FAMILY I. ARAUCARIACEAE

11. (361) *Agathis beckingii* Meyer and Drees

Plate XXI, Photos 1–4 and Fig. 1.

The sample investigated, collected in Indonesia, has been kindly put at my disposal by the Tropical Products Department of the Royal Tropical Institute, Amsterdam.

The sample presumably represents a thickish trunk, as suggested by the almost straight annual ring borders and by the rings themselves, which are 4 to 6 mm thick.

C. (Photos 1, 2.) Annual ring boundaries obscure, hardly discernible, indicated only by the somewhat narrower lumina of the least rows of tracheids in the late band. There is no change at all in tracheid wall thickness across the boundary. Radial dimension of early tracheids 55 to 60 μ; width about the same; size of late tracheids 40 to 45 μ. Sections rounded; lumina follow cell outline; double wall thickness 8 to 10 μ. Parenchyma scarce; just one or two sporadic cells (Photo 2) filled with a russet-brown substance. Rays uniseriate; transverse and tangential walls smooth. Rays spaced 2 to 25 tracheids apart.

R. (Photo 3.) Ray cells usually 28 to 32 μ high. All ray cell walls smooth and thin. Cross fields exhibit 4 to 12 araucarioid pits, each of 8 to 12 μ size, crowded in an alternate pattern. Chamber circular or procumbent elliptical, aperture almost vertical, linear or narrow elliptical, in the minor axis of the elliptical chamber. Radial size of tracheids 55 to 60 μ. Tracheid walls bear bordered pits, uniseriate or biseriate alternate, even triseriate in the broadest cells. No parenchyma cells could be detected in this view; they could definitely be established in cross section, though.

T. (Photo 4.) Rays usually 8 to 10 cells tall (with extremes of 1 and 15), uniseriate; the tallest rays are locally biseriate in a height of 1 or 2 cells. Cell height variable, typically 28 to 32 μ; typical width 13 to 14 μ. The taller rays include among their quite thin-walled parenchyma cells also some thicker-walled ones. Typical tangential size of tracheids 40 to 45 μ. Their walls exhibit a few scattered bordered pits, usually arranged in rows of 6 to 8, uniseriate or biseriate alternate.

12. (362) *Agathis endertii* Meyer and Drees

Plate XXII, Photos 1–4 and Fig. 2.

The sample studied has been put at my disposal by the Tropical Products Department of the Royal Tropical Institute, Amsterdam. This is a tree living in Indonesia. The sample comes from a thickish trunk, as revealed by the almost straight growth rings of 1 to 6 mm thickness.

C. (Photos 1, 2.) Annual ring borders obscure, hardly discernible, indicated merely by one or two rows of late tracheids. Early tracheids 60 to 70 μ in radial dimension; width about the same. Radial dimension of single row of late tracheids 40 to 42 μ (Photo 2). These are somewhat thicker-walled than the rest of the tracheids. Cell sections rounded, square, polygonal, circular or elliptical; lumen invariably following cell outline. Thickness of double wall 6 to 8 μ. Parenchyma not abundant, just one or two cells scattered in the growth rings; walls much thinner than those of the tracheids; interior filled with a dark brown substance. Rays uniseriate, spaced 2 to 10 tracheids apart.

R. (Photo 3.) Ray cells typically 21 to 22, exceptionally 28 μ high. Marginal cells tend to be lower than internal ones. The upper and lower margins of the rays are locally lined by thin-walled parenchyma cells. All ray cell walls smooth and thin, without any pitting.

Cross fields exhibit 2 to 6 araucarioid pits (up to 8 in marginal cells) in one row or opposite in two rows. Pit apertures linear or narrow elliptical, almost vertical in the minor axis of the somewhat elliptical chamber. Apertures of two vertically contiguous pits may coalesce (Photo 3). Typical pit size 10 to 11 μ. Wherever there are larger numbers of pits, they are invariably arranged in a typical araucarioid pattern. Radial size of tracheids may attain 70 μ. Their walls bear bordered pits in 2 rows (or 3, exceptionally even 4 rows in the broadest cells). In some walls, only the apertures of the bordered pits are visible, without the chambers. No parenchyma has been observed in this view.

T. (Photo 4.) Rays 1 to 20, (mainly 5 – 10) cells tall; cell height varied, typically 18 to 21 μ; cell width 16 to 17 μ. Extreme height may attain 35 μ: marginal cells tend to be higher than internal ones; some others are only half this height and also slightly less wide. All cell walls smooth and thin. Tracheids may exceptionally attain 70 μ tangential size. Their walls sometimes exhibit bordered pits, some of which form small clusters. Most walls are smooth and unpitted, however. The cells of the taller rays are usually thin-walled, but one or two cells may be thicker-walled: also, thin- and thick-walled cells may occur together in certain rays.

13. (363) *Agathis labillardieri* Warb.

Plate XXIII, Photos 1–4 and Fig. 3.

This is a tree living in Indonesia. The sample examined was kindly provided by the Tropical Products Department of the Royal Tropical Institute, Amsterdam. It probably derives from a thickish trunk, as revealed by the almost straight annual rings of 3 to 8 mm thickness.

C. (Photos 1, 2.) Growth ring boundaries hardly discernible, indicated locally by one or two rows of last tracheids in the late wood (Photo 2). Early tracheids have radial dimensions of 50 to 55 μ and about the same width; the extreme tracheids of the late wood measure 35 to 40 μ radially; sections are rounded, with lumina following cell outlines. Double-wall thickness 8 to 10 μ. Parenchyma rather scarce, 3 or 4 cells per sq. cm. Much thinner-walled than the tracheids, these cells are filled with a dark brown substance. Rays uniseriate, spaced 2 to 15 tracheids apart. Ray cells have smooth transverse and tangential walls.

R. (Photo 3.) Ray cells 30 to 32 μ high; marginal cells somewhat higher than internal ones. Cross fields exhibit 2 to 8 araucarioid pits in one or two rows, loose or crowded. Pit chambers rounded, procumbent or slightly oblique elliptical; apertures linear, more or less narrow slit-like, or elliptical, most often in the minor axis of the elliptical chamber. Apertures fairly often non-parallel, crossing. Sometimes the chamber has no aperture at all, in which case the cross fields seem to be filled with simple pits. Radial dimension of tracheids 50 to 55 μ; their walls bear bordered pits in single or double rows (occasionally also in triple and quadruple rows in the broadest tracheids) in the araucaroid pattern. The flattened pits have transverse diameters of 17 to 18 μ, and circular apertures. No parenchyma cells were observed in this view.

T. (Photo 4.) Rays 1 to 20 cells tall. Some of the taller rays widen to biseriate in a height of 1 or 2 cells. Cell sections usually upright ellipses of various height, most often 30 to 32 μ; some of the internal ones are much smaller, however. Walls are usually thin, but quite a few cells, although thin-walled in a general comparison, are distinctly thicker-walled than the others. Tangential dimension of tracheids 45 to 50 μ. Their walls exhibit locally clusters of 6 to 8 bordered pits.

14. (364) *Agathis philippensis* Warb.

Plate XXIV, Photos 1—4 and Fig. 4.

A giant tree up to 60 metres tall on the island of Paragua and in the high mountains of Bataan province (Western Luzon in the Philippines). It provides excellent timber and a valuable resin. The sample examined comes from Bogor, Indonesia, by courtesy of Mr. Govers.

C. (Photos 1, 2.) The sample was cut from a thick stem, as revealed by almost straight growth ring borders and by the thickness (up to 100 tracheids) of the individual rings. Annual ring boundary hardly discernible, indicated just by one or two rows of thicker-walled tracheids in the late wood. All tracheids are 50 to 55 μ wide. Early tracheids have radial dimensions of 80 to 90 μ, whereas the immediately adjacent one or two rows of late tracheids have radial dimensions of only 35 to 40 μ. Double walls are 12 to 14 μ thick. Sections rounded, elliptical or polygonal, with lumina following cell outline. Some late tracheids have very narrow, almost pinhole-like lumina. Rays are spaced 3 to 20 tracheids apart. Their transverse walls are entirely smooth, unpitted.

R. Ray cells 24 to 25 μ high. All cell walls smooth and thin, unpitted. Cross fields usually exhibit 2 to 5 araucarioid pits of 8 to 10 μ size with elliptical, very seldom slit-like apertures in various orientations. Where the pits fill out the cross field, they are crowded into the araucarioid pattern. The broader rays tend to have some parenchymal lining (cf. Fig. 4). In the walls of the axial tracheids, the bordered pits constitute 1 to 3 rows and are crowded in the araucarioid pattern. Apertures are circular. Some very rare tracheids exhibit a very fine spiral thickening: there is no similar spiral thickening in any other Agathis species, nor in the podocarps. This thickening is consequently a distinctive feature of this species.

T. (Photo 4.) Rays 1 to 10 cells tall: none are taller than that. Cell wall mostly thin, with a few slightly thicker-walled cells scattered in certain rays. In the tangential walls of some tracheids there are clusters of 5 or 6 bordered pits. No axial parenchyma was detected in this wood.

15. (365) *Agathis rhomboidalis* Warb.

Plate XXV, Photos 1—4 and Fig. 5.

This is a three living in Indonesia. The sample examined was kindly provided by the Tropical Products Department of the Royal Tropical Institute, Amsterdam. The almost straight annual ring boundaries and the thickness (3 to 6 mm) of the annual rings suggest a thickish trunk.

C. (Photo 1.) Annual ring boundaries discernible but not sharp, indicated most often by a late-wood ring 2 or 3 tracheids wide. There is no conspicuous difference in tracheid wall thickness between early and late wood; at best, the outermost row of tracheids in the late wood is smaller and thicker-walled than the first row in the adjacent early wood. Radial dimension of tracheids 35 to 45 μ, width about the same. Sections rounded squares, polygons, ellipses or circles, sizes rather variable even within one growth ring. Parenchyma nonexistent or exceedingly scarce, just 1 or 2 cells per sq. cm. Rays uniseriate, spaced 3 to 15 tracheids apart: tangential and transverse walls entirely smooth.

R. (Photo 3.) Ray cells 22 to 26 μ high. All ray cell walls very thin (1 to 2 μ) and perfectly smooth. Cross fields exhibit 2 or 15 araucarioid pits; apertures linear or short elliptical; orientation varied according to the orientation of the pits. These are fundamentally cupressoid pits with the aperture in the minor axis of the pit chamber. Some cross fields have just one pit, but pits are invariably more numerous in the marginal than in the internal cells.

Rays include in addition to their thin-walled cells also some very thick-walled ones with simple pits in their walls, fully conformable in size and shape to the other, thin-walled ray cells. Such thick-walled parenchyma cells tend to occur also in other Agathis species and in some cycads as well. The lumina of the very thick-walled cells are narrow, almost slit-like, so that they may almost be regarded as idioblasts. The thick walls exhibit a conspicuous layered structure.

Radial dimension of early tracheids 35 to 45 μ; some tracheid walls exhibit one or quite often two rows (even three rows in the broadest tracheids) of alveolarly crowded araucarioid pits. The diameter of the somewhat flattened bordered pits is 14 to 15 μ: their apertures are rounded or short elliptical. No axial parenchyma cells were observed in the radial view, but some rays have a parenchymal lining (Photo 3 and Fig. 5).

T. (Photos 2, 4.) Rays 1 to 14 cells tall, with 8 to 10 cells as the most typical range. Sections upright elliptical or circular, height varied, up to 30 μ. A typical width coupled to this height is 17 to 18 μ. Most ray cells are thin-walled, but some of the median cells are much thicker-walled than the others. This structure is, incidentally, rather characteristic of the genus *Agathis*. Tracheids 35 to 45 μ in the tangential dimension; their walls fairly often exhibit bordered pits, either scattered, or crowded araucarioid fashion in small clusters of one or two rows. Apertures short linear or elliptical. Diameters of elliptical pits 15 to 16 μ. No parenchyma could be detected in this view, either.

16. (366) *Agathis vitiensis* Bentham and Hooker

Plate XXVI, Photos 1–4 and Fig. 6.

A tree up to 20 m tall, living in the Fiji Islands. The sample cut from a thick trunk was kindly provided by the Smithsonian Institution, Washington.

C. (Photo 1.) Annual ring boundaries hardly discernible, indicated just by one or two rows of somewhat smaller tracheids. Sections rounded; width about the same as radial dimension (both ranging from 25 to 42 μ). Rays spaced 3 to 30 tracheids apart: next to them, the tracheid walls are somewhat more strongly lignified, as suggested by their more pronounced dyeing. The wall section in contact with the ray is thinner than the tangential wall section. The horizontal walls of the ray cells contain no pits.

R. (Photo 3.) All ray cell walls very thin (up to 1 μ) and smooth. Cross fields include 5 to 12 pits. Apertures almost vertical slits 5 to 8 μ tall. In the radial

walls of the tracheids there are 1 to 3 rows of bordered pits in a typical araucarioid pattern (Photo 4). No xylem parenchyma is seen in this view, either. There is some marginal parenchyma, though (Photo 3, and Fig. 6).

T. (Photo 2.) Rays are conspicuous for their scarcity. They are 1 to 12 cells tall. The tangential walls of the tracheids locally reveal clusters of alveolarly crowded bordered pits of 12 to 14 μ diameter. Apertures vertical, slit-like. Ray cells typically 28 to 35 μ high, 10 to 12 μ wide. In some rays there is an alternation of higher and lower ray cells. Tangential walls of ray cells also entirely smooth. No xylem parenchyma is visible.

17. (367) *Araucaria dioica* (Vell.) Stellfeld

Plate XXVII, Photos 1—4 and Fig. 7.

Its home is in Brazil. The sample examined, kindly provided by the Tropical Products Department of the Royal Tropical Institute, Amsterdam, derives from a thickish trunk, as revealed by its almost straight and fairly wide annual rings.

C. (Photos 1, 2.) Annual ring boundaries vague, hardly discernible, indicated just by one or two rows of tracheids with narrower lumina. Radial dimension of early tracheids 30 to 35 μ, width about the same. Radial dimension of late tracheids 20 to 22 μ; width much the same as in the early ones. Sections rounded square, polygonal, locally irregular. Rays uniseriate, spaced 2 to 18 tracheids apart; transverse and tangential walls smooth and thin, unpitted. The annual rings exhibit very scarce parenchyma cells filled with a brown substance. Generally speaking, parenchyma cells are exceedingly rare in Araucaria.

R. (Photo 3.) Ray cells typically 23 to 24 μ high. Transverse and tangential walls entirely smooth and very thin, unpitted. In the cross fields, small araucarioid pits number 4 to 12, usually somewhat more in the marginal cells than in the internal ones. Apertures oblique, or almost horizontal linear, included or almost so. The radial walls of the tracheids bear araucarioid bordered pits of 17 to 18 μ size; apertures rounded or short, procumbent or slightly oblique, elliptical. No axial parenchyma cells could be detected in this view.

T. (Fig. 7 and Photo 4.) Rays 1 to 6, typically 3 or 4 cells tall. Rays taller than six cells are very scarce. Cell width 17 to 18 μ. Tangential width of tracheids 30 to 35 μ; their walls locally exhibit clusters of 8 to 10 bordered pits of 12 to 14 μ size. No xylem parenchyma cells have been observed in this view, either.

18. (368) *Araucaria hunsteinii* K. Schum.

Plate XXVIII, Photos 1—4 and Fig. 8.

The sections were prepared of a sample taken from a thick trunk, kindly provided by Mr. J. S. Womersley of the Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photos 1, 2.) The wood exhibits no distinct annual ring boundaries: the presence of such can be divined in places only. Radial dimension and width of rounded tracheids 70 to 80 μ. Some other, much smaller tracheids are 40 to 50 μ in diameter.

Among the rounded tracheids there are visible intercellular ducts locally. Some tracheids exhibit trabeculae, others contain a dark filling. Rays are spaced 2 to 30 tracheids apart, the wider spacings being the more common. Transverse walls entirely smooth.

R. (Photo 3.) All walls of ray cells smooth and very thin. Cell height typically 24 to 28, more seldom up to 35 μ. Cross fields exhibit 2 to 6 pits as a rule; marginal cells may have up to 8. Apertures of pits oblique, reaching clear across the chambers. Some tracheids are lined on both sides by thin-walled marginal parenchyma which lacks any pitting. Bordered pits of 17 to 18 μ size, arranged araucarioid fashion in one to three rows, are observed in the radial walls of tracheids.

T. (Photo 4.) Rays 1 to 23 cells tall, typically araucarioid. Some are uniseriate throughout; some short ones are biseriate; some tall ones are partially biseriate. Cells typically 21 to 28 μ high, 18 to 21 μ wide. All their walls are smooth and thin. Some rays include some quite thick-walled cells: this phenomenon is observed in other Araocaria species, too. Tracheids locally join transverse walls bearing bordered pits. The transverse walls of the axial parenchyma cells, if any, are smooth and thin.

FAMILY II. PODOCARPACEAE

19. (369) *Dacrydium beccarii* Parlatore

Plate XXIX, Photos 1–4 and Fig. 9.

A tree up to 5 m tall, living in Borneo. The sample examined, cut from a thick trunk, was kindly provided by Mr. F. H. Landon, The Forest Research Institute, Kepong, Selangor.

C. (Photo 1.) There are no discernible annual ring boundaries; ring interfaces are vague, just suggested by slight differences in tracheid size. Both early and late tracheids are 35 to 40 μ wide: the radial dimension of the early ones is 50 to 55 μ, that of the late ones, 30 to 35 μ. All have walls of the same thickness; there is no difference at all in this respect between early and late tracheids. Sections usually rounded square or polygonal. In the growth ring fields, abundant parenchyma cells are almost uniformly scattered: they are filled with a dark substance. Rays spaced 1 to 10 tracheids apart, with no pitting at all in their horizontal walls.

R. (Photo 3.) Transverse and tangential ray cell walls smooth and thin, unpitted. There is usually one dacrydioid pit per cross field. In the marginal cells of some internal cross fields, there are cupressoid pits of 14 to 16 μ size. There may be

two smaller pits side by side if the aperture is in the minor axis of the elliptical chamber. In the radial walls of the tracheids, bordered pits are scattered or uniseriate, of 19 to 20 μ size; apertures are rounded or slightly elliptical. The cross fields between axial parenchyma cells and ray cells exhibit no pitting, which proves both cell walls to be very thin. Transverse walls of the axial parenchyma cells are thin and smooth, with sparse chamberless pits of 7 to 8 μ size in the radial walls.

T. (Photos 2, 4.) Rays 1 to 14 (typically 6 to 8) cells tall; short ones of just 1 or 2 cells are also fairly frequent. Ray cells 10 to 14 μ high in the rows; solitary ones may be up to 20 μ high. All their walls are smooth and thin. Their width is 10 to 11 μ. The tracheids are 35 to 40 μ wide. Their tangential walls exhibit sparse pits of 7 to 8 μ size. Horizontal walls of axial parenchyma cells smooth and thin, unpitted.

20. (370) *Dacrydium bidwillii* Hooker fil.

Mountain pine

Plate XXX, Photos 1—4 and Fig. 10.

A New Zealand shrub growing to a height of 2 to 3 m. The sample, a piece of a thickish stem or bough, was kindly provided by Mr. K. K. Pandey of the Department of Scientific and Industrial Research, Palmerston, New Zealand.

C. (Photos 1, 2.) Growth ring boundaries sharp, early and late zones well-defined. Tracheid sections square, upright or procumbent rectangular; width 10 to 11 μ; radial dimensions 28 to 30 μ in early zone, 6 to 7 μ in late zone; walls thick, lumina almost slit-like. Annual rings vary in width from 10 to 50 tracheids. Early tracheids thinner-walled. Not a single xylem parenchyma cell could be detected in a width of 17 growth rings; the presence of any axial parenchyma is most questionable. Rays spaced 2 to 15 tracheids apart; transverse walls smooth; pits can at best be divined only.

R. (Photo 3.) Transverse and tangential ray cell walls smooth and thin. Horizontal walls occasionally split apart. They locally exhibit thinnings, that is, indistinct pits. There are no indentures. Ray cells 14 to 17 μ high. In both the early and late wood, there is just one dacrydioid pit per cross field, filling out the entire field or at least three quarters of it. Pits rounded or elliptical, 13 to 15 μ long, 11 to 12 μ wide. In the corner cells there are most often 3 or 4 smaller round pits of 6 to 7 μ diameter. In the tracheid walls there are either solitary pits or pit rows, each pit being of 13 to 14 μ size. Apertures circular. No axial parenchyma could be detected in this view, either.

T. (Photo 4.) Rays 1 to 20, most often 8 to 12 cells tall. Ray cell sections elliptical, 14 to 17 μ high, but some of the internal cells are much lower and the solitary cells are usually higher. Cell width 7 to 8 μ, all walls smooth and thin. In the walls of the axial tracheids there is a striking abundance of loosely con-

tiguous but most often scattered minute bordered pits, especially in the late wood. Size 6 to 7 μ, apertures oblique, crossing. No xylem parenchyma in this view, either.

21. (371) *Dacrydium biforme* Pilger

(*D. colensoi* Kirk, non Hooker)

Plate XXXI, Photos 1—4 and Fig. 11.

This tree up to 12 m tall is living in New Zealand. The sample, a section of a thickish trunk, was kindly provided by Mr. K. K. Pandey (see foregoing species).

C. (Photos 1, 2.) Annual ring boundary conspicuous, rings 15 to 50 tracheids wide, the late-wood band comprises the last 4 to 6 rows of each ring. Tracheids in the early band thinner-walled, 24 to 26 μ wide, 28 to 30 μ in radial dimension, square in section. Late tracheids 7 to 8 μ in radial dimension, sections flattened rectangular, lumina almost slit-like. In a field of 15 growth rings, not a single axial parenchyma cell was detected. Rays 2 to 10 tracheids apart, uniseriate.

R. (Photo 3.) Transverse walls of ray cells smooth and thin: there are, however, some sparse pit-like thinnings. Locally the two adjacent transverse walls are split apart. Ray cells 17 to 20 μ tall. Cross fields usually bear a single pit filling out the entire field, or occasionally two smaller pits side by side: the latter is the case also in the marginal cells. The solitary elliptical pits are of 10 to 11 μ size with apertures 7 to 8 μ wide. Early tracheids 28 to 30 μ wide. In their walls, bordered pits of 14 to 16 μ size, with circular or short elliptical apertures, are scattered or aligned in rows.

T. (Photo 4.) Rays typically 8 to 10, more seldom 1 to 20 cells tall, with the tallest ones biseriate in a height of one or two cells. Height and shape of ray cells rather varied in the taller rays. The solitary cells may be taller than the typical 17 to 20 μ; their transverse walls are thicker than the radial ones. Tracheids 24 to 26 μ wide. Their tangential walls exhibit very sparse bordered pits of 7 to 8 μ size, with oblique linear apertures.

There is no axial parenchyma in any view.

22. (372) *Dacrydium falciforme* Pilger

Plate XXXII, Photos 1—4 and Fig. 12.

A smallish shrub inhabiting Borneo and the Philippines. The sections examined were prepared out of a trunk sample kindly provided by Mr. J. S. Womersley, Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photos 1, 2.) Growth ring boundaries almost nonexistent, suggested merely by differences in tracheid lumina. Outlines and lumina of tracheids are both

perfectly rounded. Radial dimension 40 to 50 μ early wood, 28 to 30 μ in late wood. There is no difference at all in double wall thickness, which is 7 to 8 μ. The abundant xylem parenchyma cells are thin-walled, in conspicuous contrast to the thick-walled adjacent tracheids; they are filled with dark granules. Transverse walls of rays smooth; rays spaced 2 to 14 tracheids apart.

R. (Photo 3.) All ray cell walls very smooth and thin; double wall almost 3 μ thick. Width of tracheids 40 to 50 μ. Cross fields enclose rather small pits, usually one each, more seldom two arranged side by side. Pit size 3 to 6 μ, aperture oblique linear or slit-like. In the marginal cells there are usually two pits side by side, but some cross fields have no pits at all. In the radial walls of some tracheids there are crowded pits arranged in the araucarioid pattern. In the tracheid walls, bordered pits occur either alone or in pairs. The size of the solitary ones is 12 to 13 μ. Apertures nearly vertical linear or slit-like. The cross fields between axial parenchyma cells and ray cells may exhibit some pitting. Transverse walls of axial parenchyma cells very thin and smooth. Their radial walls exhibit large pits of 12 to 13 μ size.

T. (Photo 4.) Rays 1 to 14, typically 6 to 8 cells tall. Cell sections most often upright elliptical, 17 to 18 μ high, 7 to 8 μ wide. Transverse wall thicker than the very thin radial wall. Tangential walls perfectly smooth. Tracheids of 35 to 40 μ size, with very scarce bordered pits in the tangential walls. Transverse walls of axial parenchyma cells very thin (up to half a micron) and perfectly smooth. So are also the radial walls which bear minute pits of 4 to 5 μ size.

23. (373) *Dacrydium fonkii* Bentham

(*Lepidothamnus fonkii* Philippi)

Plate XXXIII, Photos 1—4 and Fig. 13.

A low shrub living in Chile. The sections examined were prepared of boughs half a centimetre thick and probably 6 years old, kindly provided by Señor A. de Vargas, Museo Nacional de Historia Natural, Santiago, Chile.

C. (Photo 1.) Growth ring boundary conspicuous; early wood just a few tracheids wide and invariably narrower than late wood. Tracheid sections rounded square or circular, lumina following the cell outlines. Walls of uniform thickness. A few scattered axial parenchyma cells are visible in the growth ring fields. Rays most often uniseriate, locally widening to biseriate.

R. (Photo 3.) Transverse and tangential walls of ray cells smooth. Owing to the thinness of the axial tracheids, there are 2 or 3 or even 4 pits of 3 to 4 μ size one above another, even 5 in the taller marginal cells. The bordered pits in the axial tracheid walls are arranged in one or sometimes two vertical rows, fairly close-packed. Pit size 8 to 9 μ, apertures circular. Transverse walls of axial parenchyma cells perfectly smooth; radial walls exhibit simple pits of 5 to 6 μ size.

This structure is indicative of a quite dwarfed *Dacrydium* species living under highly unfavourable conditions.

T. (Photos 2, 4.) Rays 1 to 8, typically 1 to 2 cells tall. Some of the solitary cells are up to 50 μ high, but typical height is only 22 to 24 μ; typical width is 10 to 11 μ. All walls are thin and smooth. Tangential walls of tracheids bear numerous bordered pits of 4 to 5 μ size with oblique linear or circular apertures. Transverse walls of axial parenchyma cells smooth and very thin.

24. (374) *Dacrydium intermedium* T. Kirk

Yellow Silver Pine

Plate XXXIV, Photos 1—4 and Fig. 14.

A tree up to 10 m tall living under the temperate climate of New Zealand. The sections covering 23 growth rings were prepared of a thickish trunk sample kindly provided by Mr. K. K. Pandey, Department of Scientific and Industrial Research, Palmerston, New Zealand.

C. (Photos 1, 2.) Growth ring boundaries conspicuous, but late wood just 2 or 3 tracheids wide. Rings include tracheids of uniform size of rounded square section. Width 20 to 21 μ; radial dimension 28 to 30 μ in early wood and 14 μ in late wood, where outlines are flattened rectangular. Rays uniseriate, or biseriate over short sections, spaced 1 to 8 tracheids apart.

R. (Photo 3.) Ray cells up to 25 μ high. Transverse and tangential walls smooth, with fairly frequent splitting between transverse walls. Cross fields usually exhibit 1 to 3 pits; in the marginal cells, pits number usually 4 but sometimes up to 9 in the tallest ones. Pit size 4 to 5 μ; aperture oblique, in the minor axis of the elliptical chamber. Tracheids 28 to 30 μ wide. Their radial walls bear bordered pits up to 13 μ size in single or double rows. This tracheid structure much resembles the ray structure of some *Araucaria* species. Seen side by side, the sections of, say, *Dacrydium intermedium* and *Araucaria* are hard to distinguish.

T. (Photo 4.) Rays 1 to 20, typically 6 to 8 cells tall. Cell height up to 25 μ; the internal cells are slightly lower and 8 to 9 μ wide. The transverse wall is somewhat thicker than the entirely smooth radial and tangential walls. Tracheids up to 21 μ wide, with sparse bordered pits of 6 to 7 μ size loosely scattered in their walls.

No xylem parenchyma was detected in any view.

25. (375) *Dacrydium junghuhnii* Miq.

Plate XXXV, Photos 1—4 and Fig. 15.

The sample of this tree living in Indonesia was kindly provided by the Tropical Products Department of the Royal Tropical Institute, Amsterdam.

The thickness (2 to 5 mm) of the growth rings and the almost straight ring boundaries suggest a thickish trunk.

C. (Photo 1.) Growth ring boundaries usually hardly discernible, seldom conspicuous. Tracheids 35 to 40 μ wide; radial dimension 45 to 55 μ in early wood, 40 to 50 μ in late wood; the difference is negligible. Sections rounded square or polygonal; the lumina precisely follow the outlines. Wall thickness uniform, 10 to 11 μ for double wall. Rays uniseriate, spaced 2 to 10 tracheids apart; ray cells filled with dark golden granulate matter. Abundant parenchyma cells solitary, paired or in clusters of 3 or 4, filled with a dark substance.

R. (Photo 3.) Ray cells 18 to 35 μ high; all walls smooth and thin; there is no pitting even in the transverse walls. Cross fields usually filled by a large dacrydioid pit of 13 to 15 μ size, circular or elliptical. Some cross fields in the early wood enclose a pair of circular dacrydioid pits whose apertures fill out almost the entire chamber, with only a narrow border visible here and there. Some cross fields are empty. Pit apertures upright linear, that is, the pitting is typically podocarpoid. Transverse walls rather often split apart; walls of marginal cells somewhat undulous. Radial dimension of tracheids 45 to 55 μ; their walls exhibit bordered pits, either solitary, or loosely scattered, or in pairs joined along oblique or vertical lines. Pit size 17 to 18 μ; shape somewhat elliptical, procumbent. Apertures circular or short elliptical. End walls of axial parenchyma cells smooth and thin; radial walls exhibit small circular pits of 8 to 10 μ size, loosely scattered, spaced 3 to 6 simple-pit diameters apart.

T. (Photos 2, 4.) Rays 1 to 30, typically 15 cells tall, the tallest ones locally widening to biseriate in heights of one or two cells. Outlines upright ellipses of more or less eccentricity: the solitary cells are 35 μ high and 14 to 15 μ wide; all their walls are smooth and thin. Tracheids 35 to 40 μ in tangential size: their walls exhibit scarce bordered pits of 13 to 14 μ size, with circular or slightly leaning elliptical apertures. End walls of parenchyma cells smooth and thin, with sparse simple pits of 13 to 14 μ size spaced at least 4 but typically 20 to 25 pit diameters apart. Some tracheid walls are striated.

26. (376) *Dacrydium kirkii* F. Mueller

Manoao

Plate XXXVI, Photos 1–4 and Fig. 16.

A tree growing to a height of 25 m, living in New Zealand. The section examined, about 15 growth rings wide, was prepared of a sample from a thickish trunk, kindly provided by Mr. K. K. Pandey, The Department of Scientific and Industrial Research, Palmerston, New Zealand.

C. (Photos 1, 2.) Growth ring boundaries marked only by 4 or 5 rows of tracheids showing narrower lumina. Radial dimension of early-wood tracheids

35 to 40 μ; width 24 to 30 μ. Sections rounded square or polygonal. Some tracheids, particularly in the late wood, are filled with a dark substance. Rays uniseriate, spaced 1 to 10 tracheids apart. No axial parenchyma could be detected in the cross section examined.

R. (Photo 3.) Transverse and tangential walls of ray cells smooth and thin. Transverse walls often split apart. Most cross fields enclose a single large circular dacrydioid pit almost filling out the field. The pits have round chambers of 14 to 15 μ diameter with broad oblique elliptical apertures 10 to 11 μ tall. In the marginal cells and in some internal ones there are occasionally 2 to 4 pits side by side. Tracheid size 35 to 40 μ. Tracheid walls exhibit single rows, or occasionally two parallel rows just touching, of bordered pits in an alternate arrangement. Pit size is 14 μ.

T. (Photo 4.) Rays 1 to 20, typically 8 to 10 cells tall, and even the tallest ones will not widen to biseriate anywhere. Ray cell height typically 16 to 18 μ; width 12 μ. Transverse walls thicker than the very thin tangential walls. The solitary ray cells are usually higher, though. Tracheids 24 to 30 μ wide: their tangential walls occasionaly exhibit bordered pits of 7 μ size.

No xylem parenchyma was detected in any view.

27. (377) *Dacrydium laxifolium* Hooker fil.

Mountain Rimu

Plate XXXVII, Photos 1—5 and Fig. 17.

The sample has been kindly provided by Mr. I. S. Jeates, Massey Agricultural College, University of New Zealand.

This is the smallest conifer, a ground-hugging shrub not exceeding a stem length of half a metre and a height above ground of 25 cm. It lives in New Zealand at an altitude of 1000 to 1500 metres, near the snow line. In the winter, its boughs and leaves just emerge above the snow. Leaves small, 3 to 4 mm long, scattered on the bough. The "stem", complete with cortex, is no more than 2 mm thick. Of this, the wood takes up about 1 mm (Photo 1).

C. (Photos 2, 3.) In the interior of the stem there is a relatively voluminous pith parenchyma composed of cells of 35 to 40 μ size. In the wood of 0·5 to 0·7 mm thickness there are some 10 to 12 growth rings, each of which is 2 to 15 tracheids wide. The tracheids of angular section form regular radial rows. They are 24 to 25 μ wide: the radial dimension of the early ones is about 24 to 25 μ, that of the late ones only 8 to 10 μ. Walls of uniform thickness (7 to 8 μ for double wall), lumina rounded square or rectangular, considerably flattened near the growth ring boundary. Parenchyma scarce; just one or two cells in the entire section. Tangential walls of ray cells smooth and thin; transverse walls unpitted. Rays uniseriate, spaced 1 to 5 tracheids apart.

In the cortex (Photo 2) there are sclerenchyma bundles of 2 to 8 cells.

R. (Photo 4.) Ray cells typically 17 to 22 μ, exceptionally up to 40 μ high. Horizontal walls smooth, uniformly thick, unpitted. Tangential walls smooth and thin, without indentures. Cross fields enclose 2, 4 or 6 dacrydioid pits of 7 to 8 μ size, mostly in two axial rows; pit chambers hardly discernible. Bordered pits of tracheids arranged either in a single, or in a double row, most often in the araucarioid pattern. Pit size 8 to 10 μ; apertures circular. Parenchyma scarce; transverse walls of parenchyma cells very thin, smooth, without thickenings or pitting. Cell width equals that of tracheids.

T. (Photo 5.) Rays typically less than four cells tall; the entire height range is 1 to 7 cells; one-cell rays are quite frequent. Rays 7 to 8 μ wide; tangential walls smooth and thin. Bordered pits absent or very rare in tangential walls of tracheids.

28. (378) *Dacrydium novo-guineense* Gibbs.

Plate XXXVIII, Photos 1—4 and Fig. 18.

A tree up to 10 m tall living in New Guinea. The sections were cut from a thick trunk, a sample kindly provided by Mr. J. S. Womersley, The Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photo 1, 2.) Growth ring boundaries hardly discernible, indicated just by a difference in tracheid-lumen size. Tracheid width 30 to 35 μ; radial dimension 40 to 45 μ in the early wood, 25 to 30 μ in the late wood, next to the boundary. Sections rounded polygonal; lumina follow outline. Rays spaced 1 to 15 tracheids apart. Xylem parenchyma very rare.

R. (Photo 3.) Transverse and tangential walls of rays smooth and thin; transverse walls often split apart. Most cross fields enclose a single round dacrydioid pit of 7 to 8 μ size with a more or less long linear or elliptical aperture, almost vertical, in the minor axis of the elliptical chamber. Each cross field between axial and ray parenchyma cells contains a solitary simple pit. This shows how thin the walls of both cells are. Tracheids 40 to 45 μ wide; their radial walls bear loose bordered pits in single rows; pit size 14 to 15 μ; apertures slightly leaning elliptical. Transverse walls of axial parenchyma cells smooth and thin; their radial walls exhibit round pits of 9 μ size.

T. (Photo 4.) Rays 1 to 14, typically 6 to 8 cells tall. Most cells 20 to 22 μ high; the internal ones are lower, the solitary ones are higher. Width typically 8 to 9 μ; all walls smooth; radial and transverse walls also thin. Tangential walls exhibit scattered bordered pits of 7 μ diameter with vertical slit-like apertures. Axial parenchyma scarce; transverse walls very thin and smooth; radial walls exhibit several pits of 7 μ size.

29. (379) *Dacrydium westlandicum* T. Kirk

Plate XXXIX, Photos 1—4 and Fig. 19.

The sample was provided by the Tropical Products Department of the Royal Tropical Institute, Amsterdam. This is a tree living in New Zealand. The sample was cut from a thickish stem, as suggested by the almost straight growth ring boundaries and the width of the rings (0·5 to 1 mm).

C. (Photo 1.) Growth ring boundaries conspicuous by a change in tracheid size and wall thickness. Late wood just 3 or 4 tracheid rows wide. Tracheid sections rounded square or polygonal; lumina usually follow cell outline. Tracheid width 25 to 30 μ; radial dimension 35 to 40 μ in the early and 20 to 25 μ in the late wood; double wall thickness 16 to 17 μ in the late tracheids, 8 to 10 in the early ones. Annual rings no more than 10 to 20 tracheids wide. Parenchyma very scarce or absent: none was observed in a section of 1 cm^2. This is rather remarkable in that most of the *Dacrydium* species studied so far have revealed some axial parenchyma. Indeed, M. Kaiser in his monograph (1950, 1954) subdivides podocarps in two large groups according as their wood does or does not include axial parenchyma cells. In the latter case, there is a remarkable similarity to *Phyllocladus*, whose wood contains no axial parenchyma cells, either. Rays uniseriate, spaced 2 to 10 tracheids apart.

R. (Photo 3.) Ray cells typically 18 to 19 μ high; the marginal ones may be higher. Transverse walls smooth and thin, unpitted, possibly thinned locally. Tangential walls also smooth, without pits or thickenings. Transverse walls split apart here and there. Most cross fields enclose a large elliptical single pit almost filling out the field. Pit size 20 to 21 μ; height 14 to 16 μ. Aperture usually oblique; more seldom a procumbent ellipse that reaches clear across the cross field. Double pits are absent even from the broadest early-wood cross fields. Radial dimension of tracheids 35 to 40 μ; their walls exhibit loosely scattered somewhat elliptical pits of 14 to 16 μ size.

T. (Photos 2, 4.) Rays 1 to 15 cells tall. Lone ray cells 32 to 34 μ high and 12 μ wide, others typically 16 to 17 μ high and 12 to 13 μ wide. Tangential dimension of tracheids 25 to 30 μ; their walls are sparsely pitted; only in the latewood tracheids are pits more numerous. Pit size 8 to 10 μ; apertures mostly slit-like, often crossing in opposite walls of the same cell.

No parenchyma was detected in any view.

30. (380) *Microstrobus fitzgeraldi* (F. Mueller) Gard and Johns

(*Pherosphaera fitzgeraldi* F. Mueller)

Plate XL, Photos 1—4 and Fig. 20.

An abundantly branching low shrub of the Blue Mountains, New South Wales, Australia. The sample examined was a piece of a bough no more than 15 mm

thick, although 35 years old. It was kindly provided by Mr. K. Mair, Royal Botanical Gardens, Sydney.

C. (Photo 1.) Growth ring borders discernible but not conspicuous. Width of tracheids 20 to 24 μ; radial dimension about the same in the early wood, but only 10 to 12 μ in the late wood. There is hardly any difference in double wall thickness (7 to 8μ). Sections square, rectangular, penta-, hexagonal in early tracheids; flattened elliptical in late tracheids. Growth rings relatively thin, 4 to 25 tracheids wide. Xylem parenchyma scarce, 1 or 2 cells per ring, but there are some rings with no parenchyma at all. Rays uniseriate, spaced 2 to tracheids apart. Their transverse walls are smooth, unpitted.

R. (Photo 3.) Ray cells typically 14 to 15 μ high. Their transverse walls, especially in the late wood, often exhibit fairly numerous simple pits, although some transverse walls are thin and perfectly smooth. Most cross fields enclose just one or two large podocarpoid pits with broad, oblique apertures, whose chamber almost entirely fills out the field. The cross fields between rays and axial parenchyma cells are unpitted. Radial dimension of axial parenchyma cells 20 to 22 μ; walls smooth and thin, with scattered simple pits of 7 to 8 μ size in the radial walls. Radial dimension of early tracheids 20 to 24 μ; their walls exhibit scattered bordered pits of 14 to 15 μ size. Bordered pits are more abundant in the radial walls of late tracheids.

T. (Photos 2, 4.) Most rays 1 to 4 cells tall; taller rays are scarce. A few rays are biseriate. Solitary ray cells are 20 to 22 μ high and 10 to 12 μ wide; transverse walls thicker than radial walls; tangential walls entirely smooth, unpitted. Tangential dimension of tracheids 20 to 24 μ; walls exhibit solitary and scattered bordered pits 14 to 15 wide, with apertures in opposite walls of cell crossed. Axial parenchyma cells 140 to 200 μ long, 19 to 20 μ wide; transverse walls smooth and thin; tangential walls bear sporadic simple pits; the apertures of the tracheid pits behind them are oblique slits.

31. (381) *Phyllocladus hypophyllos* Hooker fil.

Plate XLI, Photos 1—4 and Fig. 21.

A tree or shrub 2 to 10 m tall in the higher hills of the Philippines, New Guinea and Borneo.

The sections examined were prepared from a sample of a thickish trunk, kindly provided by Mr. J. J. Womersley, The Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photos 1, 2.) Annual ring boundaries discernible; late wood just a few tracheids wide; annual rings 40 to 80 tracheids wide; radial dimension of tracheids 40 to 60 μ in early wood, only 15 to 20 μ in late wood. Sections square, more seldom hexagonal, with rounded corners. Wall thickness uniform in both early and late tracheids. Rays uniseriate, spaced 1 to 15 tracheids apart.

R. (Photo 3.) Ray cells 24 to 28 μ high; internal ones somewhat shorter than marginal ones; all walls smooth and very thin. Cross fields usually enclose one, seldom two phyllocladoid pits that fill out the entire field. Pits circular, oblique or procumbent elliptical or rounded square; size 15 to 20 μ; chambers half-moon-shaped. *P. hypophyllos* differs from the subsequent species, *Ph. major*, in that cross fields with two pits side by side are fairly frequent. Elsewhere, though, there may be 4 or 5 cross fields in a row without a single phyllocladoid pit.

Radial dimension of tracheids 40 to 60 μ; the bordered pits in their walls form loose single rows. The pits are slightly elliptical, procumbent; their transverse axes are 26 to 28 μ long; the pits in a row locally join horizontal or slightly oblique walls. Apertures most often circular or short elliptical, but almost slit-like in late tracheids.

T. (Photo 4.) Rays 1 to 15, typically 7 to 8 cells tall. Late tracheids bear a few bordered pits of 7 to 8 μ size: apertures vertical or oblique, slit-shaped.

Ray cells 24 to 28 μ high, 7 to 10 μ wide; some internal cells are lower, whereas the marginal cells may be higher. All ray cell walls smooth and thin.

This species lacks axial parenchyma, just as the other Phyllocladus species do: at least, none was detected in any view, including a cross section of 1 sq. cm.

32. (382) *Phyllocladus major* Pilger

Plate XLII, Photos 1–4, Fig. 22.

This species lives in New Guinea, Indonesia and the Moluccans. The sample examined was kindly provided by the Division of Forest Products, Melbourne.

C. (Photos 1, 2.) Annual ring boundaries just discernible; late wood no more than one or two tracheids wide. Late tracheids slightly thicker-walled than early ones. Most growth rings 10 to 15 tracheids wide, with 30 tracheids as a maximum.

Tracheids 40 to 50 μ wide; radial dimension 55 to 60 μ in early, 30 to 35 μ in late wood; sections rounded; lumina follow cell outline. Walls somewhat thicker where three tracheids meet. Rays uniseriate.

R. (Photo 3.) Ray cells 18 to 20 μ high; marginal cells slightly higher (20 to 22 μ). Transverse and tangential walls smooth and thin, unpitted. Most cross fields enclose one dacrydioid or phyllocladoid pit; marginal fields may enclose two. Pit size 15 to 20 μ; double pits have a joint width of 16 to 18 μ. Apertures large, chambers half-moon-shaped with distinct borders. This typical phyllocladoid structure is duplicated in some *Podocarpus* and *Dacrydium* species, too. In the late wood, however, apertures are almost linear and vertical. Radial dimension of tracheids 55 to 60 μ; their walls exhibit loosely scattered bordered pits of 17 to 18 μ size, with circular or short procumbent elliptical apertures. Bordered pits may be more crowded, in which case they invariably join oblique faces.

There may be two pits side by side in the widest tracheids.

T. (Photo 4.) Rays uniseriate, 1 to 12, typically 8 cells tall. Cell height 18 to 20, seldom up to 22 μ; internal cells somewhat lower (17 to 18 μ); width 10 to 12 μ; all walls smooth and thin. In the tracheid walls there are locally small bordered pits of 12 to 14 μ size. Tangential dimension of tracheids 40 to 50 μ.

No xylem parenchyma was detected in any view: this *Phyllocladus* species lacks xylem parenchyma, just as the others do.

33. (383) *Podocarpus alpinus* R. Brown

(*Podocarpus lawrencii* Hooker fil.

Nageia alpina F. Müller)

Plate XLIII, Photos 1—4 and Fig. 23.

A shrub 1 to 3 m tall living at altitudes between 1200 and 1500 m in Victoria, Australia and in Tasmania. The sample examined, an oldish bough or stem as indicated by the arching of the growth rings, was kindly provided by Mrs. Margaret Kaiser, Carbondale, U.S.A.

C. (Photo 1.) Growth ring boundaries vague, almost indiscernible. Early and late tracheids hardly differ as to size and width of lumina. Sections rounded, lumina follow outline. Radial dimension of tracheids 20 to 22 in early wood, 16 to 18 μ in late wood; the tracheids along the ring boundary are slightly flattened. Parenchyma abundant; the thin-walled parenchyma cells are filled with a resin-like substance. Rays uniseriate, spaced 2 to 10 tracheids apart. Their transverse walls bear comparatively numerous simple pits, which is rather remarkable in a podocarp.

R. (Photo 3.) Ray cells 17 to 18 μ tall. Transverse walls relatively thick, locally with simple pits. Tangential walls perfectly smooth, with no thickening at all. Most cross fields enclose one small pit; some corner cells enclose two. Pit size is 4 to 5 μ; apertures are oblique, slit-like. Radial dimension of tracheids 20 to 22 μ. Their walls exhibit loose single strings of bordered pits. Pit size 9 to 10 μ; apertures are somewhat oblique gashes. Axial parenchyma cells 400 to 500 μ long, 14 to 15 μ wide; transverse walls smooth; radial walls exhibit rows of minute simple pits 3 to 4 μ in diameter.

T. (Photos 2, 4.) Rays 1 to 10 cells tall; cell height 17 to 18 μ. Rays of one or two cells are very frequent. All axial-parenchyma cell walls smooth and thin, with no variation in thickness in the transverse walls.

34. (384) *Podocarpus amarus* Blume

Black Pine

Plate XLIV, Photos 1–4 and Fig. 24.

This species lives in Queensland, Australia; also in Java and the Philippines. The sections examined were kindly provided by Mrs. M. Kaiser of Carbondale, U.S.A.

C. (Photo 1.) Annual ring boundaries very obscure, divined rather than observed in places. Tracheid sections circular, elliptical or rounded square. Next to tracheid rows of wide lumina there are rows of quite narrow-lumened tracheids. Typical tracheid diameters are 45 to 50 μ. Xylem parenchyma very scarce among the tracheids. Rays uniseriate, cell walls very thin, unpitted.

R. (Photo 3.) Ray cells typically 17 to 18 μ tall. All walls smooth and very thin. Most cross fields enclose a single elliptical pit of 14 to 18 μ size, but the corner cells of some wider tracheids enclose two. Some pits are perfectly round, dacrydioid. A very few rays are lined on one side or both by a very thin, so-called marginal parenchyma (Fig. 24). In the axial tracheid walls, bordered pits are loosely arranged in single or double rows. Pit size is 17 to 18 μ; apertures are circular. Radial size of early tracheids 45 to 50 μ. Axial parenchyma rare; cell walls smooth and thin. Some of the widest tracheids exhibit pairs of bordered pits side by side.

T. (Photo 2, 4.) Rays 1 to 18, typically 8 cells tall; cell height 17 to 18 μ; all walls smooth and thin. Upper and lower margins of some rays distinctly lined with thin marginal parenchyma cells. A single cell of axial parenchyma was observed in the tangential view.

35. (385) *Podocarpus beccarii* Parlatore

(*P. motleyi* Dummer

Agathis motleyi Warb.)

Plate XLV, Photos 1–4 and Fig. 25.

This tree lives in Malaysia, Sarawak and Borneo.

The sections examined were prepared from a sample cut from a thick trunk, kindly provided by Mr. T. Harrison, The Sarawak Museum, Kuching, Sarawak.

C. (Photo 1.) Growth ring boundaries quite obscure, just divined in places. Tracheid sections circular, elliptical or rounded square; typical diameters 50 to 60 μ. Abundant parenchyma cells form contiguous sheets in the annual rings, or are scattered at random, more or less parallel to the ring boundaries. They

are filled with a dark brown resin-like substance. Rays uniseriate; all cell walls smooth and thin.

R. (Photo 3.) Ray cells typically 26 to 28 μ tall. All ray cell walls thin, but the transverse walls may exhibit comparatively large simple pits. There is usually one podocarpoid pit per cross field, with a chamber diameter of 13 to 14 μ, and a slightly oblique, elongate elliptical aperture. Marginal and some internal fields may enclose two and more seldom even three pits. Some cross fields are entirely unpitted, however. In the cross fields interfacing with axial parenchyma cells there are no pits at all. Radial dimension of early tracheids 50 to 60 μ; their walls exhibit bordered pits, most often in single rows, but some twin pits also occur. Single pit size 24 to 25 μ; apertures circular or short elliptical. The bordered pits, if crowded, are separated by Sanio lines. Walls of axial parenchyma cells thin; the radial walls exhibit rows of round pits of 10 to 12 μ diameter.

T. (Photos 2, 4.) Rays 1 to 40, typically 15 to 20 cells tall; the tallest rays may widen to biseriate in a height of 5 to 6 cells near their middle. Cells typically 26 to 28 μ tall, 10 to 14 μ wide. All walls smooth and very thin; there is no thickening even in the transverse walls. Tangential walls of tracheids bear bordered pits of 10 to 12 μ size.

36. (386) *Podocarpus comptonii* Buchholz

Miner.

Plate XLVI, Photos 1—4 and Fig. 26.

This tree lives in New Caledonia. The sections examined were cut from a thickish trunk, as revealed by the width and slight arching of the growth rings. The sample was kindly provided by Mr. P. Sarlin, Direction du Service Forestier du Gouvernement Français, Nouméa, Nouvelle Calédonie.

C. (Photo 1.) Annual ring boundaries vague, indicated at best by differences in tracheid size. Width of tracheids 50 to 60 μ; radial dimension typically 50 to 60 μ in early, 20 to 22 μ in late wood. Late tracheids rectangular or elliptical in section, radially flattened. Xylem parenchyma scarce. Rays uniseriate, spaced 1 to 10 tracheids apart.

R. (Photo 3.) Ray cells 17 to 21 μ tall. Transverse and tangential walls smooth and thin, unpitted. Most cross fields enclose one dacrydioid pit of 10 to 14 μ size, but some enclose two. Pit apertures almost circular, or oblique elliptical. There are locally 2 or 3 unpitted cross fields side by side. The cross fields between axial and ray parenchyma cells are unpitted. In the walls of the axial tracheids, bordered pits form single axial rows or pairs; the pits in a pair often join oblique faces. This is a typical podocarpoid feature. Tangential and transverse walls of axial parenchyma cells smooth and very thin.

T. (Photos 2, 4.) Rays 1 to 20, typically 8 to 10 cells tall. Typical cell height 17 to 21 μ; width 10 to 12 μ. The cells in the rays one or two cells tall are usually

higher. Tangential walls of tracheids bear scarce small bordered pits of 10 to 12 μ size; apertures are oblique linear. All walls of axial parenchyma cells smooth; even the transverse walls exhibit no thickening. The tangential walls bear simple pits of 9 to 10 μ size.

37. (387) *Podocarpus costalis* C. Presl.

Plate XLVII, Photos 1—4 and Fig. 27.

This is a tree living in the Philippines. The sections were prepared of a sample cut from a thick trunk, as revealed by the almost straight growth ring boundaries and by the width of the rings. The sample was kindly provided by, Mr. M. R. Monsalud, Forest Products Research Institute, University of the Philippines, Laguna.

C. (Photo 1.) Growth ring boundaries discernible, but not conspicuous. Wall thickness hardly changes across the boundary: double wall 7 to 8 μ thick in late and 6 to 7 μ thick in early tracheids. Tracheid width 30 to 35 μ, radial dimension typically 40 to 50 μ in early, 25 to 30 μ in late wood. Sections rounded square or polygonal. Lumina closely follow cell outline. Thin-walled parenchyma cells scattered but rather abundant in the growth rings; in places there are 6 to 8 parenchyma cells in a terminal position, so to speak, on the ring boundary. Xylem parenchyma cells filled with a golden substance. Rays uniseriate; tangential and transverse walls unpitted.

R. (Photo 3.) Solitary ray cells 20 to 22 μ tall; the others are slightly shorter (17 to 18 μ). Transverse walls smooth and thin, unpitted. Marginal cells somewhat taller and with slightly undulous outer walls. Tangential walls also smooth and thin, unthickened. Most cross fields enclose a single, typically podocarpoid pit of 12 to 13 μ size. Chambers circular or elliptical; apertures elliptical or linear, in the minor axis of the elliptical chamber. Cross fields in early wood exhibit typical dacrydioid pits, of the same size as other pits, but lacking apertures. This difference is especially conspicuous across the growth ring boundaries. The cross fields between rays and xylem parenchyma cells are unpitted. Radial dimension of axial tracheids 40 to 50 μ; radial walls bear bordered pits of 18 to 20 μ size, scattered or in single rows. Apertures circular; diameter 6 to 7 μ. Axial parenchyma cells thin-walled, transverse walls smooth and thin; radial walls exhibit small simple pits of 8 to 10 μ size. Some of these are circular and without apertures; others have elliptical apertures. These pits are spaced 60 to 70 μ apart.

T. (Photos 2, 4.) Rays 1 to 8 cells tall; cells 17 to 18 μ high, 8 to 10 μ wide. Tangential dimension of tracheids 30 to 35 μ; bordered pits of 9 to 10 μ size are scarce in their walls. Apertures are oblique slits. Parenchyma cells as wide as tracheids, with very thin and smooth, unthickened walls. In the tangential walls there are round simple pits of 8 to 10 μ size.

38. (388) *Podocarpus decipiens* (Back) N. Gray

Plate XLVIII, Photos 1—4 and Fig. 28.

The sections investigated were kindly put at my disposal by Mrs. M. Kaiser, Carbondale, U.S.A. Their cross sectional structure implies a thick trunk.

C. (Photo 1.) Annual ring boundaries very vague, locally even indiscernible. Tracheid sections most often rounded square, penta- or hexagonal; typical radial dimension of large tracheids 70 to 75 μ; the corresponding width is 50 to 55 μ. A few sporadic parenchyma cells among the tracheids are filled with a granulate content. Rays uniseriate, spaced 2 to 10 tracheids apart.

R. (Photo 3.) Ray cells 19 to 20 μ high. Transverse and tangential walls smooth and very thin, unpitted. Most cross fields enclose a single podocarpoid pit, but a few ones enclose two. Pit size is 5 to 7 μ. Aperture almost vertical linear or elliptical. Walls of marginal ray cells slightly undulous. Their cross fields here may enclose even 2 or 3 pits. Radial dimension of tracheids 70 to 75 μ. Their walls exhibit bordered pits, alone or in pairs. Pit size is 18 to 20 μ. Axial parenchyma cells relatively tall and 28 to 30 μ wide. Their radial walls bear small circular pits. Their transverse and tangential walls are smooth and thin.

T. (Photos 2, 4.) Rays uniseriate, 1 to 48, typically 10 to 15 cells tall. The tallest ones widen to biseriate in a height of 3 to 4 cells. Cells 19 to 20 μ high; width about the same or slightly less. Tangential walls of tracheids most often devoid of bordered pits: those few that are visible are of 8 to 10 μ size. Walls of axial parenchyma cells very thin. Even the transverse walls are smooth and thin, unpitted. The tangential walls exhibit scattered minute simple pits.

39. (389) *Podocarpus dispermus* Buchholz

Plate XLIX, Photos 1—4 and Fig. 29.

This tree lives in Eastern Australia. The sections examined were prepared of a sample cut from a thickish trunk, as suggested by the course and width of the growth ring boundaries. The sample was kindly provided by Mr. W. Wilkes, Forestry Department, Brisbane, Australia.

C. (Photo 1.) Annual ring boundaries vague, hardly discernible in places, fairly easy to recognize in others. Ring width is varied, from 15 to 80 tracheids. Tracheid width is 30 to 50 μ; radial dimension is 30 to 50 μ in early tracheids at the ring boundary, 18 to 20 μ in late tracheids next to them. Tracheid sections most often rounded square or polygonal. The latest tracheids are flattened rectangular or elliptical in section. Parenchyma cells are fairly abundant in the annual ring fields; in places there are 8 to 10 almost touching cells, in a terminal position along the annual ring boundary. They are filled with a golden substance. Rays 1 to 10 tracheids apart.

R. (Photo 3.) Rays relatively low. Cells 18 to 20 μ high. Transverse and tangential walls smooth and thin, unpitted. The transverse walls of the ray cells are fairly often split apart. The cross fields exhibit 1 or 2, fairly often even 3 minute podocarpoid pits, even 4 in the marginal cells. Pit chamber size is 6 to 7 μ. Apertures almost vertical, linear. Cross fields between axial and ray parenchyma cells unpitted.

Radial dimension of axial tracheids 30 to 50 μ. Their walls exhibit solitary, more seldom paired bordered pits, loosely scattered; pit size is 17 to 18 μ; apertures are circular.

Tangential and transverse walls of axial parenchyma cells smooth and thin; transverse walls unpitted, at best slightly nodular. Radial walls exhibit several minute pits of 6 to 7 μ size.

T. (Photos 2, 4.) Rays relatively low, 1 to 6 but typically only 1 to 2 cells tall. Solitary ray cells are 17 to 18 μ high.

Tangential size of tracheids 30 to 50 μ. Their tangential walls include a very few bordered pits of 7 μ size. Transverse walls of axial parenchyma cells smooth and thin, very seldom with some uneven thickening.

40. (390) *Podocarpus distichus* Buchholz

Plate L, Photos 1–4 and Fig. 30.

The tree lives in New Caledonia. The sample examined was kindly provided by Mrs. M. Kaiser, Carbondale, U.S.A. The trunk fragment of about 10 mm width included 25 growth rings.

C. (Photo 1.) Annual ring width varied, from 8 to 40 tracheids. Ring boundaries vague, hardly discernible; lumina of late tracheids next to the ring boundary somewhat narrower, but there is no difference in wall thickness between early and late tracheids. Tracheid width 20 to 25 μ, radial dimension 30 to 35 μ in early, 20 to 25 μ in late wood. Sections rounded square or polygonal, lumina follow outline by and large, with some thickening in the corners. Parenchyma very scarce. Some annual rings have no parenchyma at all; others include just a few sporadic cells. The thin-walled parenchyma cells are clearly distinct from the adjacent tracheids. Mrs. Kaiser's finding (1954) that *P. distichus* lacks xylem parenchyma thus requires a correction: the parenchyma is distinctly visible in the photo.

Rays uniseriate, spaced 1 to 10 tracheids apart. Their transverse walls fairly often bear simple pits.

R. (Photo 3.) Ray cells 18 to 20 μ high. Transverse walls comparatively thick, with some simple pits locally; tangential walls smooth and thin, without indentures. Cross fields usually enclose a single podocarpoid pit of 8 to 9 μ size, and an almost vertical linear aperture not reaching beyond the chamber outline. In the corner cells, pairs of pits one above the other are rather frequent. These

pits are of 7 to 8 μ size. Radial dimension of tracheids 30 to 35 μ; their walls bear loose uniseriate strings of bordered pits of 13 to 15 μ size; apertures are circular or almost vertical short elliptical. In the rare event that an axial parenchyma cell meets a ray parenchyma cell, the two form unpitted cross fields.

T. (Photos 2, 4.) Rays 1 to 10 cells tall. Solitary ray cells 24 to 28 μ high, 12 to 14 μ wide. Tangential walls smooth, unpitted, thin; transverse walls slightly thicker.

Tangential size of xylem parenchyma cells 14 to 16 μ; their length is 140 to 180 μ; a row of parenchyma cells usually includes 8 to 10 cells. End walls smooth and thin; radial walls bear simple pits of 6 to 7 μ diameter. Tangential dimension of tracheids 20 to 25 μ. Their walls exhibit sparse bordered pits of 12 to 13 μ size.

41. (391) *Podocarpus droynianus* F. Mueller

Plate LI, Photos 1–4 and Fig. 31.

This species lives in Western Australia: it is a shrub rather than a tree. The sample examined was kindly provided by the Division of Forest Products, Melbourne.

C. (Photo 1.) Annual ring boundaries not conspicuous but locally rather readily discernible. Some rings are 60 to 70, others are 100 tracheids wide. Wall thickness of tracheids the same in the early and late tracheids. Width of tracheids 24 to 28 μ, radial dimension 30 to 35 μ in early and 20 to 22 μ in adjacent late tracheids. Lumina radially elongate rectangles in early and radially compressed ones in late tracheids. Most others are rounded square, rectangular or polygonal. Double walls 14 μ thick. Parenchyma abundant; most cells scattered over the growth ring, others form small clusters; both types filled with a dark substance. Rays uniseriate, spaced 1 to 16 tracheids apart. Some tracheids are also filled with a dark substance resembling the parenchyma filling.

R. (Photo 3.) Ray cells typically 17 to 18 μ high. Transverse and tangential walls very thin and smooth, unpitted. Indentures are absent. Most cross fields enclose a single pit; marginal cells sometimes enclose two in a vertically or transversely disposed pair. Pit size is 8 to 10 μ. Chamber somewhat elliptical, procumbent, aperture almost vertical, linear or slit-shaped. Radial dimension of tracheids 30 to 35 μ. Their walls exhibit bordered pits of 12 to 14 μ size in loose uniseriate strings. Apertures oblique or almost vertical elliptical. Radial dimension of axial parenchyma cells 20 to 22 μ; end walls smooth and thin. Radial walls sometimes exhibit circular simple pits.

T. (Photos 2, 4.) Rays 1 to 4 cells tall, very seldom taller, typically just 1 or 2 cells tall. Solitary cells 22 to 24 μ, internal ones 17 to 18 μ high; all walls smooth and thin. Tangential size of tracheids 24 to 28 μ. Their walls bear loose uniseriate strings of bordered pits of 10 to 12 μ size, with short linear or circular apertures. Tangential size of axial parenchyma cells 18 to 20 μ; end walls smooth and very thin; tangential walls exhibit small circular simple pits.

42. (392) *Podocarpus gnidioides* Carr.

(*Podocarpus alpina* var. *arborescens* Brongn. et Griseb.)

Plate LII, Photos 1—4 and Fig. 32.

This tree up to 12 m tall lives in New Caledonia. The sample examined, the very hard wood of a bough or trunk 30 to 40 years old, was kindly provided by the Division of Forest Products, Melbourne.

C. (Photo 1.) Growth rings relatively narrow; some are only 4 or 5 tracheids wide; even the widest do not exceed 25 tracheids. Annual ring boundaries well discernible, early and late wood conspicuously different. Late wood locally no more than 3 or 4 tracheids wide, whereas elsewhere it occupies almost half of the annual ring. Wall thickness of early and late tracheids hardly different; late tracheids have narrow lumina, almost gash-like next to the ring boundary. Sections slightly rounded square, penta- or hexagonal. Width 20 to 25 μ; radial dimension 25 to 30 μ in early, 20 to 25 μ in late tracheids. Parenchyma scarce; parenchyma cells scattered in the growth ring fields.

R. (Photo 3.) Ray cells 16 to 17 μ high. Marginal ones somewhat higher, with slightly undulous outer walls. Transverse and tangential walls very thin and smooth, unpitted, lacking indentures and showing at best only thinnings in places. Most cross fields enclose a single podocarpoid pit of 8 to 10 μ size, but the marginal fields may enclose up to four slightly smaller ones. Chambers short procumbent ellipses; the almost vertical apertures most often reach the chamber outline. This is typical podocarpoid pitting. Transverse walls locally split apart.

Radial dimension of tracheids 25 to 30 μ. Their walls bear loose single strings of bordered pits of 14 to 15 μ size, with circular or short elliptical, slightly leaning apertures. End walls of axial parenchyma cells smooth and thin, unpitted, unthickened. Their radial walls exhibit small simple rounded pits. The interfaces of axial and ray parenchyma cells are unpitted.

T. (Photos 2, 4.) Rays 1 to 6 cells tall. The solitary ray cells are 20 to 21 μ, the other ones only 16 to 17 μ high. Transverse walls smooth, sparsely pitted. Tangential dimension of tracheids 20 to 25 μ; their walls bear numerous bordered pits of 11 to 12 μ size with circular or very short linear apertures. End walls of axial parenchyma cells very thin, smooth; their tangential walls exhibit loosely disposed small simple pits.

43. (393) *Podocarpus guatemalensis* Standl.

Plate LIII, Photos 1—4 and Fig. 33.

The sections examined, kindly put at my disposal by Mrs. M. Kaiser, Carbondale, U.S.A. were prepared of a thick trunk having growth rings 4 to 7 mm wide.

C. (Photo 1.) Annual ring boundary hardly discernible, just indicated by a slight difference in tracheid size. Wall thickness unchanged across the ring boundary; double wall 7 μ thick. Sections rounded polygonal or circular. Width 35 to 50 μ, radial dimension typically 45 to 60 μ in early, 15 to 20 μ in late tracheids. Parenchyma abundant; parenchyma cells filled with a golden granulate substance scattered uniformly over the annual ring field. Rays uniseriate, spaced 1 to 10 tracheids apart.

R. (Photo 3.) Ray cells 17 to 20 μ high. Transverse walls smooth and thin, with very scarce simple pits. Tangential walls smooth and thin, without corner pits. Most cross fields enclose a single pit of 6 to 8 μ size, which is one third to two thirds of ray cell height. Some pits have a circular chamber and no aperture. Other pits are, on the other hand, almost cupressoid, with the elliptical aperture in the minor axis of the elliptical chamber. Marginal cells sometimes enclose two cupressoid or podocarpoid pits. Radial dimension of early tracheids 45 to 60 μ; their radial walls exhibit loosely scattered bordered pits of 22 to 23 μ size, with round or short oblique elliptical apertures. Axial parenchyma cells 400 to 500 μ long, 14 to 17 μ wide; all walls smooth and thin; transverse walls unpitted, unthickened. In places there are pairs of bordered pits in the early tracheid walls, almost invariably disposed with their lines of contact vertical or slightly leaning.

T. (Photos 2, 4.) Rays 1 to 12, typically 6 to 8 cells tall; solitary cells 23 to 24 μ, internal ones 17 to 20 μ high, 10 to 12 μ wide. Transverse wall somewhat thicker than radial wall. Tangential dimension of early tracheids 35 to 50 μ. No bordered pits have been observed in their tangential walls. Some parenchyma cells in the taller rays are conspicuously thicker-walled than the adjacent thin-walled parenchyma cells. Transverse walls of axial parenchyma cells smooth and thin, unthickened, unpitted. Their width equals that of the tracheids.

44. (394) *Podocarpus ladei* Bailey

Plate LIV, Photos 1—4 and Fig. 34.

A slender tree of 5 to 6 m height, living in Australia. The sample examined was provided by the Forestry Department, Brisbane, courtesy of Mr. W. Wilkes. The sections were prepared of a thickish trunk, as revealed by the almost straight course and the thickness of the annual rings.

C. (Photo 1.) Annual ring boundaries obscure, hardly discernible, indicated just by one or two rows of narrower-lumened tracheids. Early tracheids 30 to 35 μ in both width and radial dimension. Later tracheids have slightly narrower lumina. Most sections rounded square, lumina follow outline. Double wall 12 to 13 μ thick. Rays spaced 1 to 30 tracheids apart. Parenchyma scarce, just one or two cells per growth ring, filled with a golden granular substance.

R. (Photo 3.) Ray cells 14 to 16 μ high; all walls smooth and thin, unpitted. Most cross fields enclose a single pit of 5 to 6 μ size; some enclose two, side by side. Apertures almost vertical gashes. Chambers circular; some chambers lack apertures and some cross fields lack pits. Marginal cells slightly taller than internal ones (17 to 18 μ). Interfaces of axial and ray parenchyma cells unpitted. Radial dimension of tracheids 30 to 35 μ; their walls exhibit scattered bordered pits of 14 to 15 μ size, with oblique elliptical or vertical slit-like apertures.

T. (Photos 2, 4.) Rays 1 to 20, typically 8 to 10 cells tall, mostly uniseriate, but a few lower ones are widened to biseriate in their entire height. Walls uniformly thin; double wall thickness 4 μ; tangential walls smooth and thin. Tracheid walls bear sparse small bordered pits of 7 to 8 μ size with slightly oblique and more often vertical slit-like apertures. Transverse walls of axial parenchyma cells thin and smooth.

45. (395) *Podocarpus lambertii* Klotzsch

Plate LV, Photos 1—4 and Fig. 35.

This is a tree living in Brazil. The sections examined, prepared from an oldish trunk, were kindly put at my disposal by Mrs. M. Kaiser, Carbondale, U.S.A.

C. (Photo 1.) Annual ring boundaries not conspicuous but discernible; some rings have a considerable width (8 to 10 mm or about 150 tracheids). Typical radial dimension and width of tracheids 30 to 40 μ. The outermost late tracheids are slightly flattened, sometimes with gash-like lumina. There is no change in wall thickness across the ring boundary. Double walls are 6 to 7 μ thick. Parenchyma cells filled with a golden content irregularly but rather densely scattered in the rings. Rays uniseriate, spaced 2 to 8 tracheids apart; transverse walls unpitted.

R. (Photo 3.) Ray cells 15 to 17 μ high. Transverse walls thin but locally with further thinnings and even pits. Transverse walls quite often split apart, especially close to where they join the tangential walls, most of which are oblique. There are no indentures. Most cross fields enclose just a single pit whose height (6 to 7 μ) equals one-third or half the height of the ray cell. Apertures oblique slit-like, but chambers circular. Interfaces between ray and axial parenchyma unpitted. Marginal cells sometimes enclose 2 pits disposed one above the other, or in opposite corners. Radial dimension of tracheids 30 to 40 μ. Their walls usually bear uniseriate strings of borderd pits, but there may be locally two pits side by side, disposed in the araucarioid pattern. Apertures oblique circular or vertical linear. All walls of axial parenchyma cells smooth and thin. Cells 300 to 400 μ long, 14 to 16 μ wide. Size of bordered pits in radial walls of tracheids 14 to 15 μ.

T. (Photos 2, 4.) Rays 1 to 22, typically 7 to 8 cells tall. Solitary cells 20 to 22 μ high; others 15 to 17 μ high, 10 to 11 μ wide; all walls smooth and thin.

Tangential size of tracheids 20 to 22 μ; their walls locally bear rows of bordered pits. All walls of axial parenchyma cells, including even the transverse ones, are smooth and thin, unthickened and unpitted.

46. (396) *Podocarpus macrophyllus* var. *maki* Siebold

(*Podocarpus chinensis* Wall, *P. maki* Siebold)

Plate LVI, Photos 1—4 and Fig. 36.

Area of distribution: China and Japan.

Sections prepared of a sample cut from a nine-year-old bough, kindly provided by Mr. G. H. Yu, Academia Sinica, Peking, China.

C. (Photo 1.) Most annual ring boundaries are conspicuous, but some are vague, just indicated by a slightly different tracheid size. Radial dimension 20 to 25 μ in early, 14 to 16 μ in late tracheids. There is no difference in wall thickness. Sections most often rounded square, also flattened rectangular next to the ring boundaries. Abundant parenchyma cells usually scattered, but some form palisades of 8 to 10 parallel to the ring boundary. Rays uniseriate, spaced 1 to 8 tracheids apart. Transverse walls pitted.

R. (Photo 3.) Ray cells relatively low, solitary ones 24, others typically 17 μ high. Transverse walls of ray cells thick, with rather frequent thinnings or simple pits, which is fairly rare in podocarps. Tangential walls quite smooth and thin, however, without any thickening. Most cross fields enclose 2 or 4 small pits (4 to 5 μ), usually in vertical pairs or in two rows. Apertures oblique elliptical or slit-like. This is somewhat different from typical podocarp xylotomy. Radial dimension of axial tracheids 20 to 25 μ. Their walls bear loose bordered pits of 14 to 16 μ size with circular or short oblique elliptical apertures. Axial parenchyma cells usually 250 to 300 μ long, 12 to 14 μ wide; transverse walls smooth and thin, unpitted.

T. (Photos 2, 4.) Rays uniseriate, 1 to 7 cells tall. Ray cells 17 to 18 μ high, 13 to 14 μ wide, all walls thin. Tangential dimension of tracheids 20 to 25 μ; their walls bear a few small bordered pits of 6 to 8 μ size with circular or short linear apertures. All walls of axial parenchyma cells smooth and thin, unthickened and unpitted.

47. (397) *Podocarpus matudai* Lundell

Plate LVII, Photos 1—4 and Fig. 37.

The sections prepared out of a thin bough were thankfully received from Mrs. M. Kaiser, Carbondale, U.S.A. For relevant literature see Buchholz and Grey (1948, 1953).

C. (Photo 1.) Annual ring boundaries quite obscure; there is no discernible difference between early and late tracheids. Sections angular; typical radial dimensions 18 to 22 μ, widths 16 to 18 μ; width of lumina rather varied. Scattered in the growth ring field there are thin-walled parenchyma cells. Rays uniseriate. Tracheids thick-walled, most often with rounded lumina.

R. (Photos 3a, b). Rays low, just 1 to 4 cells tall. Solitary ray cells 20 to 22 μ high, internal ones slightly lower. Transverse and tangential walls of ray cells smooth and thin, unpitted. Most cross fields enclose a single pit, but some exceptional ones enclose two, one above the other. Pit size is 5 μ. Chambers rounded, apertures oblique or almost vertical slits. Tangential walls often include angles of 45 to 60° with transverse walls. Transverse walls fairly often split apart. Radial dimension of axial tracheids 18 to 22 μ. Their walls usually bear single rows of tracheids, some of them almost touching. At the ends of some broader tracheids, there may be pairs of bordered pits of 12 to 13 μ size side by side. Their apertures are circular or slit-like. Axial parenchyma cells 300 to 350 μ long, 8 to 9 μ wide. A single instance of a thick-walled parenchyma cell was observed in one of the rays. Its simple pitting proved it to be a parenchyma cell rather than a thick-walled tracheid (Photo 3b).

T. (Photos 2, 4.) Rays 1 to 5, typically only 1 or 2 cells tall. Solitary cells 20 to 22 μ high, 9 to 10 μ wide; all walls smooth and thin. All walls of axial parenchyma cells smooth and thin; transverse walls very thin, unpitted, unthickened. Tangential size of tracheids 16 to 18 μ.

48. (398) *Podocarpus montanus* var. *densifolius* Buchholz and Gray

Plate LVIII, Photos 1—4 and Fig. 38.

This species lives at altitudes of 2000 to 3000 m in the Cordilleras of Peru and Columbia. I gratefully received the sample examined, a piece of a bough 5 mm thick and 6 years old, from Mrs. M. Kaiser, Carbondale, U.S.A.

C. (Photo 1.) Annual ring boundaries inconspicuous but discernible. Some growth rings fall into rather readily distinguished early and late bands of about equal width. The early band passes gradually into the late one, in connexion probably with the high-altitude habitat of the tree. Radial dimension of early tracheids 24 to 26 μ; sections rounded pentagonal or hexagonal, and so are also the outlines of the lumina. Double walls 7 to 8 μ thick. Radial dimension of late tracheids somewhat less, but wall thickness the same as in the early ones. Parenchyma very scarce in the growth rings. The thin-walled parenchyma cells stand in sharp contrast to the surrounding thicker-walled tracheids. Rays uniseriate, spaced 1 to 18 tracheids apart, transverse walls perfectly smooth.

R. (Photo 3.) Ray cells 19 to 22 μ high. Transverse walls thin and smooth, unpitted. Tangential walls also smooth and thin, without indentures. Most cross fields enclose 1 or 2 podocarpoid pits almost totally filling out the field.

Pit size is 8 to 9 μ; apertures are broad oblique ellipses; chambers of adjacent pit pairs usually touching, occasionally even crowded. Narrow cavities are observed between the transverse walls of ray cells, especially where they join the tangential walls. The cross fields of the single-cell rays most often hold three pits in a vertical row, but some enclose just one dacrydioid pit filling out the entire field. This latter situation is typical of spring cross fields. Radial dimension of axial parenchyma cells 16 to 18 μ. End walls smooth and thin; radial walls bear a few round simple pits of 6 to 7 μ size. Radial dimension of tracheids 24 to 26 μ. Their walls exhibit sparse, loosely arranged bordered pits of 13 to 14 μ size.

T. (Photos 2, 4.) Rays 1 to 6, typically only 1 or 2 cells tall, probably because the sample was cut from a young bough. Solitary ray cells are 28 to 30 μ high, 13 to 14 μ wide. The other ray cells are typically 19 to 22 μ high and of the same width as the solitary ones. Tangential walls smooth. Tangential size of tracheids 23 to 24 μ; the very rare bordered pits in their walls are of 12 to 13 μ size. Xylem parenchyma very scarce; indeed, none was observed in the tangential view.

49. (399) *Podocarpus nagi* Makino

(*Podocarpus nageia* R. Brown)

Plate LIX, Photos 1—4 and Fig. 39.

This tree up to 25 metres tall lives in Japan, in China and on Taiwan.

The sections examined were prepared of a thickish trunk that had annual rings 6 to 7 mm wide. The sample was kindly provided by Mr. Joshio Saito, The Government Forest Experiment Station, Meguro, Tokyo, Japan.

C. (Photo 1.) Annual ring boundaries rather well-defined. Late wood just 5 or 6 tracheids wide, whereas the early wood may grow to a width of 200 tracheids. Radial dimension 35 to 40 μ in early, 10 to 12 μ in late tracheids. There is no discernible difference in wall thickness, however. The late tracheids are just a little compressed radially, into procumbent rectangles. Abundant parenchyma cells scattered, with some preference for the late wood. Rays uniseriate, spaced 2 to 15 tracheids apart. Tracheid section most often angular, square or hexagonal. Size varied.

R. (Photo 3.) Ray cells 16 to 18 μ high. Marginal cells somewhat higher than internal ones. Transverse and tangential walls entirely smooth and thin. There are no indentures. Most cross fields enclose just one podocarpoid or dacrydioid pit. Unpitted cross fields are, however, also quite numerous. Pit size is 12 to 13 μ; apertures are circular or elliptical; the latter are in the minor axis of the elliptical chambers. Some pits fill out one-third of their cross fields, in which case they are typically dacrydioid. Some corner fields enclose two pits.

Radial size of early tracheids 35 to 40 μ. Their walls exhibit loose single strings of bordered pits of 15 to 16 μ size, with circular or short elliptical apertures.

Interfaces of axial and ray parenchyma cells unpitted. Axial parenchyma cells 350 to 400 μ long, 14 to 16 μ wide; transverse walls perfectly smooth in some cells; in some others they exhibit low prominences of fine nodules. Their radial walls bear a few round simple pits of 8 to 9 μ size.

T. (Photos 2, 4.) Rays 1 to 30 cells tall, uniseriate, but quite a few ones widen to biseriate in their middle or at their ends; indeed an exceptional few are biseriate throughout their height. Ray cells are 16 to 18 μ high and 10 to 11 μ wide. All their walls are smooth and thin.

50. (400) *Podocarpus nakaii* Hayata

Plate LX, Photos 1—4 and Fig. 40.

This species lives in China and Taiwan. The sample was kindly put at my disposal by Mr. S. C. Liu, Historical Research Commission of Taiwan Province. The sections were cut from a bough 5 years old.

C. (Photo 1.) Annual ring boundaries fairly well-defined; early and late tracheids rather distinct along the boundary. Early tracheids predominantly angular, square; late ones predominantly rounded with circular or elliptical lumina; only the lumina of those next to the ring boundary are radially compressed, rectangular or gash-like. Tracheid width 24 to 26 μ, radial dimension 24 to 26 μ in the early, 15 to 18 μ in the late tracheids. Parenchyma abundant; most parenchyma cells solitary, scattered, but some are arranged, terminally as it were, parallel to the ring boundary. Wall thickness is 6 to 7 μ in the late, 4 to 5 μ in the early tracheids. Rays uniseriate.

R. (Photo 3.) Rays very low, 1 to 3 cells tall, probably owing to the youth of the sample. Ray cells typically 18 to 20 μ high, seldom higher. Outer walls usually undulous; transverse walls comparatively thick with fairly numerous well-defined simple pits. Transverse walls sometimes split apart. Tangential walls usually smooth, but locally with some minor unevennesses. Most cross fields enclose 2 podocarpoid pits; the marginal cells tend to enclose four, in two rows. Pit size is 7 μ; apertures are elliptical or linear. Pits are cupressoid, that is, their chambers are slightly oblique ellipses with the aperture in the minor axis. The oblique chamber about the aperture is well-defined. In other cases, only a circular or elliptical chamber is visible, without an aperture. Radial dimension of tracheids 24 to 26 μ. Their walls most often bear loose uniseriate strings of bordered pits of 14 to 15 μ size, with circular apertures. Some of the adjacent pits are compressed araucarioid fashion. Parenchyma cells 250 to 300 μ long, 13 to 14 μ wide. Transverse walls smooth and thin; radial walls exhibit small round simple pits.

T. (Photos 2, 4.) Solitary ray cells are 26 to 28 μ high; others have heights of 18 to 20 μ. Quite often there are 2 or 3 rays quite close to each other between the same two tracheids. Transverse walls of some axial parenchyma cells smooth;

others exhibit nodular or lenticular thickenings. Most walls are smooth and thin, however. Tangential dimension of late tracheids 24 to 26 μ. Their walls locally exhibit small bordered pits of 8 to 9 μ size.

51. (401) *Podocarpus nivalis* Hooker fil.

Alpine totara

Plate LXI, Photos 1–4 and Fig. 41.

A shrub 1 to 2 m high in the high mountains of New Zealand. The sample was kindly provided by Mr. I. S. Jeates, Massey Agricultural College, University of New Zealand, Palmerston. The sections examined were cut from a thickish bough of 3 cm diameter, with growth rings 1 to 2 mm wide.

C. (Photo 1.) Annual ring boundaries discernible but not invariably conspicuous, because tracheid wall thickness is much the same in the early as in the late wood. Elsewhere, however, the late wood, 8 to 10 tracheids wide, stands apart rather markedly from the much thicker early wood. Tracheid lumina rather narrow; width 16 to 20 μ, radial dimension 16 to 20 μ in the early, 10 to 12 μ in the late wood. Tracheid sections rounded polygons, circles or ellipses. Sizes rather varied. Abundant solitary parenchyma cells filled with a sulphur-yellow content are scattered all over the growth ring fields.

R. (Photo 3.) Ray cells 18 to 20 μ high. Their transverse walls fairly often bear simple pits, but their tangential walls are invariably smooth and thin. Transverse walls locally split apart. Most cross fields enclose just one podocarpoid pit; corner cells usually enclose 2 to 4. Pit size is one-third or half the ray height (7 to 9 μ). Radial dimension of early tracheids 16 to 20 μ; bordered pits of 15 to 16 μ size are loosely arranged in the radial walls. Locally crowded, they join horizontal faces araucarioid-fashion. All walls of axial parenchyma cells usually smooth and thin, but some end walls exhibit thickenings and even pits. Width the same as that of tracheids.

T. (Photos 2, 4.) Rays 1 to 8, typically 3 to 4 cells tall, but one- and two-cell rays are also fairly frequent. Ray cells 18 to 20 μ high, 12 to 13 μ wide. Tangential walls unpitted. Tangential dimension of axial tracheids 16 to 20 μ; walls of late tracheids exhibit comparatively numerous small bordered pits, loosely arranged side by side. Pit size is 8 to 9 μ; apertures circular or slightly oblique elliptical. Transverse walls of most axial parenchyma cells smooth, but some may exhibit small nodes or lenticular thickenings.

52. (402) *Podocarpus novae-caledoniae* Vieillard

Plate LXII, Photos 1—4 and Fig. 42.

This is a shrub living in New Caledonia. The sections, prepared of a thinnish bough, were kindly put at my disposal by Mrs. M. Kaiser, Carbondale, U.S.A.

C. (Photo 1.) Annual ring boundaries so vague as to be quite indiscernible in places. Radial dimension of tracheids ranges from 30 to 55 μ; their width covers much the same range. There is no difference in wall thickness. Parenchyma scarce. Rays uniseriate, spaced 2 to 8 tracheids apart.

R. (Photo 3.) Ray cells 13 to 23 μ high. All ray cell walls very thin and smooth, unpitted. Transverse walls locally split apart. Tangential walls also smooth and thin; indentures absent. Most cross fields enclose 1 or 2 pits; corner cells quite often enclose 3 or 4. Pit size (8 to 9 μ) one-third or half of ray cell height. Chamber rounded, aperture oblique, slit-shaped or linear. These are typical podocarpoid pits. Radial dimension of early tracheids 30 to 55 μ. Their walls exhibit loose uniseriate strings of bordered pits of 14 to 16 μ size. Apertures are circular or vertical linear. In the broader tracheids, there may be 2 pits side by side.

Axial parenchyma cells are 250 to 300 μ long, 16 to 17 μ wide. Radial walls smooth with scarce small simple pits. End walls also smooth and thin, unthickened, unpitted.

T. (Photos 2, 4.) Rays 1 to 8, typically 1 to 3 cells tall. Single-cell rays 24 to 25 μ high; height of internal cells only 13 to 23 μ in places. Tangential size of early tracheids 30 to 35 μ; bordered pits are very scarce in their walls. All walls of axial parenchyma cells smooth and thin; transverse walls unpitted, unthickened.

53. (403) *Podocarpus nubigenus* Lindley

(*Saxe-Gothaea gracilis* Hort)

Plate LXIII, Photos 1—4 and Fig. 43.

This tree lives in Chile, in the mountains around Valdivia, Patagonia. The sample was presumably cut from a thickish trunk, as implied by the thickness and almost straight course of the growth rings. It was collected by Max Rothkugel of Buenos Aires. Anatomically, especially in the radial view, it differs to some extent from the typical podocarp structure.

C. (Photo 1.) Annual ring boundaries distinct. The broader rings may be up to 80 tracheids wide; of that, the late wood comprises 6 to 10 tracheids. Along the ring boundary, the tracheids are radially flattened rectangles with almost gash-like lumina. Radial dimension of early tracheids 22 to 30 μ; width about the same. Sections rounded rectangular or hexagonal. Tracheid walls of uniform

thickness; there is hardly any difference between early and late tracheids. Double wall 3 to 4 μ thick. The fairly abundant thin-walled solitary parenchyma cells are scattered over the annual ring fields; clusters of 3 or 4 cells are exceedingly rare. These cells are filled with a golden substance; their end walls are entirely smooth. Rays mostly uniseriate, with several small simple pits in their transverse walls.

R. (Photo 3.) Ray cells typically 18 to 20 μ high; transverse walls often split apart. Transverse walls locally thick but smooth; elsewhere they bear numerous simple pits in rows, which is a fundamental difference from most podocarps. Most tangential walls are smooth but some exhibit a dentate thickening, and at the contacts with the transverse walls there are some very well-defined indentures. This is another rare, almost isolated phenomenon among podocarps. Most cross fields enclose one or two small pits, a few ones enclose 3 or 4. Pit size is 3 to 4 μ; apertures are oblique linear. Its ray structure indeed resembles *Saxe-Gothaea* whose horizontal walls also bear close-spaced small simple pits. In cross fields with two pits, the pits are disposed on opposite sides, next to the two bordering transverse walls. In cross fields with three pits, the pits are disposed either in a vertical row or in a triangle. Transverse walls of axial parenchyma cells usually smooth; in their radial walls, irregularly scattered simple pits of various shapes are fairly frequent. Radial dimension of tracheids 22 to 30 μ. Their walls bear bordered pits, usually scattered but sometimes packed in the araucarioid pattern, with the contacting faces horizontal. This, however, is a distinctly podocarpacean feature.

T. (Photos 2, 4.) Rays 1 to 12 cells tall, those of 1 to 3 cells being most frequent. Ray cells typically 18 to 20 μ high, 8 to 9 μ wide. Marginal cells do not differ significantly from internal ones. Transverse walls of axial parenchyma cells usually smooth, but some exhibit 2 or 3 rosary-like thickenings. This also differs from the podocarp type, and so does the presence of distinct indentures. The tangential walls include few minute simple pits of 3 μ size, with oblique linear apertures. Tangential size of tracheids 25 to 30 μ. Their walls include very rare, scattered bordered pits of 5 to 6 μ size, with oblique slit-like apertures. If the sample had not been received directly from Chile, its anatomical properties would cast a serious doubt on its being a podocarp. The earlier name *Saxe-Gothaea gracilis* Hort was based on superficial resemblance to the genus *Saxe-Gothaea*.

54. (404) *Podocarpus palustris* Buchholz

Plate LXIV, Photos 1—4 and Fig. 44.

The single radial section I received from Mrs. M. Kaiser shows little tangential detail. Still, it permits to draw conclusions concerning the entire structure of the wood.

C. The section was probably cut from a fairly old trunk, as the individual growth rings are 10 to 25 tracheids wide. The late wood takes up 3 to 6 tracheids. Annual ring boundary sharp, definite; the narrow-lumened late tracheids differ sharply in size from the wide-lumened early ones: radial dimension of tracheids 25 to 50 μ in the early and 7 to 10 μ in the late wood. The section includes a fair amount of parenchyma uniformly spread over the growth ring.

R. (Photos 1 to 4.) Ray cells typically 20 to 21 μ high. Marginal ray walls undulous; transverse walls within the ray perfectly smooth and very thin, unpitted. Tangential walls also smooth and thin. Cross fields enclose 1 or 2 comparatively large dacrydioid or podocarpoid pits: marginal fields enclose 3 or 4. Pit size is 10 to 12 μ. The pits occupy central positions in the cross fields. Chambers round or short procumbent elliptic; apertures broad or linear. The procumbent elliptical chambers with the apertures in their major axes recall taxodioid pits. Cross fields between axial and ray parenchyma cells unpitted.

The walls of the axial tracheids bear bordered pits of 14 to 15 μ size in one or two rows. Pits lying side by side may or may not touch. In the former case, the touching faces meet in oblique lines. A crowding of bordered pits is particularly conspicuous near the ends of the tracheids. In some broad tracheids (50 μ wide or so) there may be even 3 pits side by side.

Axial parenchyma cells are 250 to 300 μ long and 15 to 16 μ wide. Their walls bear small round simple pits. All walls smooth and thin; the end walls also are of uniform thickness.

T. In the absence of a tangential section one may conclude rather little upon a tangential structure (the tangential portion of Fig. 44 has been constructed on the basis of the cross and radial sections). The radial section shows no ray higher than 12 cells; also the walls of the axial parenchyma cells, as seen from the radial side, look perfectly smooth and thin.

55. (405) *Podocarpus papuanus* Ridley

Plate LXV, Photos 1–4 and Fig. 45.

A tree up to 30 m tall, it lives at altitudes from 2000 to 2500 m in New Guinea. The sections examined were cut from an oldish trunk sample, as revealed by the rather uniform structure of the wood. The sample in question was kindly provided by Mr. J. S. Womersley, Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photo 1.) Annual ring boundaries vague, hardly discernible, just implied by narrower lumina in the late tracheids. There is no change at all in tracheid wall thickness across the ring boundary. Radial dimension of tracheids is 30 to 40 μ in the early, 20 to 25 μ in the late wood. Sections rounded; lumina follow cell outlines. Parenchyma scarce. Rays uniseriate with unpitted transverse walls.

R. (Photo 3.) Ray cells typically 16 to 18 μ high. Solitary ray cells 18 to 20 μ

high. Transverse walls of ray cells smooth and thin, unpitted. Tangential walls also smooth and thin, lacking indentures. Most cross fields enclose one pit; some enclose two. Pit size is 8 to 10 μ; apertures are oblique elliptical or linear; that is, the pits are typically podocarpoid. The transverse walls are locally split apart, especially where they join the tangential walls. Cross fields joining axial and ray parenchyma cells unpitted. Radial dimensions of tracheids 30 to 40 μ. Their walls exhibit bordered pits, usually in loose uniseriate rows, sometimes in pairs. Pit size is 14 to 15 μ; apertures are circular. All walls (also end walls) of axial parenchyma cells smooth; end walls unpitted; radial walls exhibit simple round pits.

T. (Photos 2, 4.) Rays 1 to 22 cells, typically 10 to 12 cells tall. Ray cell height 16 to 18 μ, width 8 to 9 μ, all walls smooth and thin. Tangential size of tracheids 45 to 50 μ; no bordered pits were observed in their tangential walls. End walls of axial parenchyma cells smooth and thin or nodular in a few exceptional cases. Their tangential walls bear small round pits of 8 to 10 μ size.

56. (406) *Podocarpus parlatorei* Pilger

Plate LXVI, Photos 1–4 and Fig. 46.

This tree lives in Northern Argentina and Bolivia. The sample was kindly provided by Mrs. M. Buchinger, Secretaria de Estado de Agricultura y Gañaderia de la Nación, Buenos Aires, Argentina. The sections were prepared of a thickish trunk, as implied by the almost straight growth ring boundaries.

C. (Photo 1.) Annual ring boundaries fairly sharp in places, just discernible in others. The individual rings are 15 to 60 tracheids wide. There is no striking change in tracheid wall thickness across the ring boundary. Double wall thickness is 7 μ. Radial dimension of tracheids 40 to 50 μ in early, 15 to 20 μ in late wood. Sections rounded square or polygonal. Parenchyma cells fairly abundant, uniformly scattered in both the early and the late wood, filled with a dark golden substance. Rays uniseriate.

R. (Photo 3.) Transverse walls of ray cells relatively thick, with fairly frequent thinnings and a few distinct pits. The tangential walls are smooth, however. There are also characteristic indentures which is something of a rarity among podocarps. The transverse walls tend to split apart where they meet the tangential walls. Most cross fields include one cupressoid pit, but some enclose two. Chambers slightly oblique elliptical, apertures in the minor axis. Length of aperture 8 to 9 μ. Marginal fields enclose 2 or occasionally 3 pits. Cross fields between axial and ray parenchyma cells exhibit 2 or 3 small elliptical pits which shows the ray parenchyma to be thick-walled. Radial dimension of early tracheids 40 to 45 μ. The bordered pits in their walls are either solitary and loosely scattered or paired into twins. Pit size 14 to 15 μ; apertures circular or short linear. Axial parenchyma cells 300 to 400 μ long and 14 to 15 μ wide. Their walls bear small

circular or elliptical pits of 8 to 10 μ size. The thickenings and thinnings in the transverse ray cell walls recall some yews (*Taxus*). Mean height of ray cells is 17 μ.

T. (Photos 2, 4.) Rays 1 to 20, typically 8 to 10 cells tall. Medium height of one ray cell 17 μ; width 10 to 12 μ. Walls rather thick (5 to 6 μ for the transverse wall). Tangential dimension of tracheids 36 to 40 μ. Bordered pits in tangential walls few and far between; their size is 10 to 12 μ; their apertures are almost vertical slits. End walls of ray cells either smooth, or thickened rosary fashion or irregular. These features also deviate significantly from the general xylotomy of the podocarps. Axial parenchyma cells about as wide as the tracheids. Their walls bear small round pits of 8 to 10 μ size.

57. (407) *Podocarpus philippensis* Foxw.

Plate LXVII, Photos 1—4 and Fig. 47.

This tree lives in the Philippines. The sample was provided by Mr. M. R. Monsalud, The Forest Products Research Institute, University of the Philippines, Laguna. It was cut from a thick trunk, as revealed by the ray and growth ring pattern.

C. (Photo 1.) Annual ring boundaries vague but discernible. Tracheid sections rounded: lumina follow cell outlines. There is no change in tracheid wall thickness across the ring boundary, which latter is indicated by a few narrower-lumened tracheids. Radial dimension of tracheids 45 to 50 μ in early, somewhat less in late wood. Width 35 to 40 μ, locally up to 50 μ. Parenchyma scarce, scattered over the growth ring fields. Rays uniseriate.

R. (Photo 3.) Ray cells typically 17 μ high. Transverse walls smooth and thin, unpitted. Tangential walls also smooth and thin, without indentures. Most cross fields enclose one pit; a few enclose two. Marginal fields most often exhibit 2 or 3 typical podocarpoid or dacrydioid pits. Chambers of podocarpoid pits elliptical; size 10 to 12 μ; aperture almost vertical, elliptical or linear, in the minor axis of the chamber. The dacrydioid pits are as large as the chambers of the podocarpoid pits, but they lack chambers or have hardly visible ones. Cross fields between axial and ray parenchyma cells unpitted. Radial dimension of early tracheids 45 to 50 μ. Their walls exhibit one or twin bordered pits of 16 to 17 μ size, with rounded apertures of 6 to 7 μ diameter. End walls of axial parenchyma cells smooth and thin, unthickened, unpitted. Radial walls exhibit round simple pits of 8 to 10 μ size.

T. (Photos 2, 4.) Rays mostly 1 to 10 cells tall. Cell height 17 μ, width 10—12 μ. Tangential dimension of parenchyma cells 25 to 30 μ; end walls smooth or somewhat nodularly thickened, with one or two nodes. This thickening is fairly frequent in this species. The tangential walls bear strings of simple pits of 10 μ size.

58. (408) *Podocarpus pilgeri* Foxw.

Plate LXVIII, Photos 1—4 and Fig. 48.

The sample of this tree living in Philippines and Indonesia was kindly provided by the Tropical Products Department of the Royal Tropical Institute, Amsterdam. It was cut from a thickish trunk, as revealed by the growth ring pattern. The rings are 4 to 8 mm wide.

C. (Photo 1.) Annual ring boundaries vague, hardly discernible, indicated just by a slight change in tracheid width across the ring boundary. Sections rounded square or polygonal: lumina exactly follow cell outline. Most tracheids thick-walled; double wall 12 to 14 μ thick; there is no difference in wall thickness between early and late tracheids. Parenchyma cells filled with a dark coffeebrown substance very abundant; most of them solitary; clusters of two or three cells are rare. Rays uniseriate, spaced 1 to 10 tracheids apart. Their transverse and tangential walls are smooth and thin.

R. (Photo 3.) Ray cells 18 to 20 μ high, 14 to 15 μ wide, all walls smooth and thin. Taller ray cells up to 23 μ high. Transverse walls locally split apart. Most cross fields enclose one podocarpoid pit only. Its size (8 to 10 μ) equals one-third to one-half of ray cell height. Unpitted cross fields are fairly frequent. The cross fields between axial and ray parenchyma cells are also unpitted. Radial dimension of tracheids 45 to 50 μ. The bordered pits in their walls are scattered, solitary, of 18 to 22 μ size, with circular or short elliptical apertures. No pit pairs arranged side by side have been observed. End walls of parenchyma cells smooth and thin; their radial walls bear small simple pits of 10 to 12 μ size, most often spaced one pit diameter apart.

T. (Photos 2, 4.) Rays 1 to 15, exceptionally up to 18 cells tall. The most typical range is 8 to 10 cells. Most sections elongate elliptical, of 18 to 20 μ height; marginal cells somewhat higher than internal ones; width 8 to 10 μ. Transverse walls thicker than radial ones. Tangential size of tracheids 35 to 40 μ; walls unpitted or very sparsely pitted, with bordered pits of 12 to 14 μ size. End walls of parenchyma cells smooth and thin, unthickened. In tangential dimension they equal the tracheids. Their walls bear some sporadic simple pits.

59. (409) *Podocarpus polystachus* R. Brown

Plate LXIX, Photos 1—4 and Fig. 49.

Area of distribution: Malaysia. The material examined was kindly provided by Yale University, U.S.A. Its inventory number is 28-962. The sections were cut from a thickish trunk.

C. (Photo 1.) Annual ring boundaries not conspicuous but discernible. Rings 40 to 120 tracheids wide. Tracheid sections rounded square or polygonal. Width

40 to 50 μ; radial dimension about the same in early tracheids, 12 to 20 μ in late ones. Parenchyma cells thin-walled, abundant, scattered all over the annual rings. Rays uniseriate, transverse walls unpitted.

R. (Photo 3.) Ray cells typically 17 to 18 μ high. Transverse walls smooth and comparatively thin, unpitted but locally thinned. There is some very low marginal parenchyma along some rays. Tangential walls smooth and thin, locally with indentures. Most cross fields enclose one podocarpoid pit, but some enclose two. Pit size is 7 to 8 μ; chambers are circular or slightly oblique elliptical; apertures oblique or upright ellipses in the minor axis of the chamber. Transverse walls locally split apart. Radial dimension of tracheids 40 to 50 μ; their walls bear loose uniseriate strings of bordered pits, or biseriate strings in the widest tracheids. Pit size is 20 to 21 μ; apertures circular. In places, especially near the ends of the tracheids, pits are crowded biseriate. Axial parenchyma cells 300 to 350 μ long, 18 to 20 μ wide. End walls thin, exceptionally thickened or pitted.

T. (Photos 2, 4.) Rays 1 to 22, typically 8 to 10 cells tall. Marginal cells 18 to 20 μ high, internal ones somewhat lower; width is 10 to 12 μ. Transverse walls somewhat thicker than radial ones. Tangential dimension of tracheids 40 to 50 μ; in their walls, bordered pits are rather scarce; pit size is 11 to 22 μ; apertures are almost vertical slits. Xylem parenchyma cells about as wide as the tracheids. Their end walls are smooth and thin, unthickened and unpitted, at most somewhat uneven. The other walls exhibit small simple pits of 8 to 10 μ size.

60. (410) *Podocarpus purdieanus* Hooker fil.

(*Podocarpus jamaicensis* Hort.

P. mucronata Hort.)

Plate LXX, Photos 1—4 and Fig. 50.

This is a tree up to 40 m tall living in Jamaica. The sections examined, cut of a thickish bough, derive from L. H. Bailey's collection: their inventory number is 26.289.

C. (Photo 1.) Annual ring width varied, from 8 to 100 or so tracheids. Ring boundaries not conspicuous but rather well discernible. Tracheid width 35 to 45 μ; radial dimension 40 to 50 μ in early, 14 to 16 μ in late tracheids. Sections rather angular, tetragonal or polygonal. The cross section exhibits some tracheids far different in size from the usual range. Parenchyma cells abundant, solitary, scattered all over the annual ring fields.

R. (Photo 3.) Ray cells 17 to 20 μ high. Transverse and tangential walls of ray cells smooth and thin, unthickened, unpitted. Most cross fields enclose one or two podocarpoid pits. Chamber size 10 to 11 μ; apertures oblique or almost

vertical slits. Marginal cross fields tend to include 2 or 3 elliptical pits side by side. Many cross-field pits lack chambers, in which case the apertures are circular or elliptical circopores. These tend to occur in the cross fields of some early tracheids. Radial dimension of tracheids 40 to 50 μ; their walls bear bordered pits of 16 to 17 μ size. In the broader tracheids, twin pits are fairly numerous. Their common faces are vertical or slightly oblique. All walls of axial parenchyma cells smooth and thin. End walls also smooth, unthickened.

T. (Photos 2, 4.) Rays 1 to 10 cells tall. Solitary cells 24 to 26 μ high; internal cells 17 to 20 μ high. Width 13 to 14 μ. Tangential dimension of tracheids 35 to 45 μ. Their walls bear no bordered pits. All walls of axial parenchyma cells smooth and thin; end walls remarkably thin and unpitted.

61. (411) *Podocarpus rumphii* Blume

Plate LXXI, Photos 1–4 and Fig. 51.

This species lives in the mountainous region of Arfak in New Guinea, at altitudes from 2000 to 2500 metres.

The sections examined, kindly put at my disposal by Mrs. M. Kaiser, derive from Florentio Tamesis' collection; they bear the inventory number 17.623.

The growth ring pattern indicates a thickish trunk.

C. (Photo 1.) Annual ring boundaries hardly discernible. There is hardly any change in tracheid size and wall thickness across the ring boundary. Tracheid width 30 to 45 μ; radial dimension 45 to 50 μ in early, 20 to 25 μ in late wood. Double wall thickness is 7 μ. Xylem parenchyma cells fairly abundant, solitary, scattered all over the growth rings. Rays uniseriate.

R. (Photo 3.) Ray cells 16 to 18 μ high. Transverse ray cell walls comparatively thick, smooth, locally somewhat thinned, exceptionally also pitted. Tangential walls perfectly smooth and somewhat thinner than transverse walls. Most cross fields enclose a single podocarpoid pit of 8 to 10 μ size, with circular or elliptical chambers and linear apertures. Apertures lie in the minor axes of the elliptical chambers. The cross fields between axial and ray parenchyma cells are unpitted. There are a few exceptional indentures. Radial dimension of tracheids 45 to 50 μ. Their radial walls bear relatively few bordered pits of 16 to 18 μ size. Most pits are in loose uniseriate strings; they are somewhat compressed at the ends of the broader tracheids. Tangential walls of axial parenchyma cells thin; transverse walls also usually thin, very seldom with slight nodular thickenings. The tangential walls exhibit small round or elliptical pits.

T. (Photos 2, 4.) Rays 1 to 70, typically 10 to 15 cells tall. Even the tallest rays include no biseriate sections. Solitary ray cells 20 to 22 μ high; internal ones 16 to 18 μ high. Width is 10 to 12 μ. Transverse walls thicker than radial ones. Tangential dimension of tracheids 30 to 45 μ; there are small bordered pits of 10 to 12 μ size in the tangential walls of the late tracheids. Apertures

oblique slits, locally crossed. Radial dimension of axial parenchyma cells equals that of tracheids. End walls smooth and thin, unpitted. In the tangential walls there are small round simple pits.

62. (412) *Podocarpus rusbyi* Buchholz

Plate LXXII, Photos 1–4 and Fig. 52.

The material investigated was kindly put at my disposal by Mrs. M. Kaiser, Carbondale, U.S.A. It derives from a thin bough not more than 4 years old.

C. (Photo 1.) Annual ring boundaries fairly conspicuous; there is a significant change in both tracheid size and wall thickness across the ring boundary. Width of rings 20 to 40 tracheids. The early wood passes gradually into the late wood. Most sections angular; lumina not rounded, either. Tracheid with 28 to 30 μ; radial dimension about the same in the early and 15 to 20 μ in the late wood. Wall thickness 7 to 8 μ in late tracheids. Parenchyma cells scarce, scattered. Rays uniseriate, spaced 1 to 11 tracheids apart.

R. (Photo 3.) Ray cells 19 to 21 μ high; transverse walls smooth and thin, unpitted; tangential walls also smooth and thin, without indentures. Most cross fields enclose two pits, one above the other, but some enclose one or three. Pit size 6 to 8 μ, shape circular or procumbent elliptical; the broad apertures are oblique or almost vertical in most of them. Cross fields joining axial and ray parenchyma cells unpitted. End walls of axial parenchyma cells smooth and thin. Radial dimension of axial parenchyma cells 16 to 18 μ; that of tracheids, 28 to 30 μ. In the walls of the latter, bordered pits of 13 to 14 μ size are arranged in loose strings. Their apertures are circular or slightly leaning elliptical.

T. (Photo 2, 4.) Rays 1 to 6, typically only 1 or 2 cells tall, presumably owing to the youth of the bough. Tangential walls of ray cells smooth and thin. Axial parenchyma cells equal tracheids in tangential size; their end walls are smooth and thin; their tangential walls bear a few simple pits of 4 to 5 μ size. Tangential dimensions of tracheids 28 to 30 μ. Their walls exhibit some very scarce bordered pits of 13 to 14 μ size.

63. (413) *Podocarpus salomonensis* Wascher

Plate LXXIII, Photos 1–4 and Fig. 53.

This is a tree living in Australia. The sections examined, prepared of an oldish trunk, marked P.F.P. (Australia) and numbered 8.305, were kindly put at my disposal by Mrs. M. Kaiser.

C. (Photo 1.) Annual rings 10 to 60 tracheids wide. Ring boundaries fairly conspicuous; late wood 6 to 15 tracheids wide. Tracheid width 30 to 35 μ; radial

dimension 35 to 40 μ in early, 15 to 20 μ in late wood. Lumina of latest tracheids locally almost gash-like. Parenchyma cells scarce. Rays uniseriate.

R. (Photo 3.) Ray cells 18 to 20 μ high. Transverse walls smooth and thin, unpitted. Tangential walls also smooth and thin. Most cross fields enclose only one podocarpoid pit of 12 to 14 μ size. Apertures linear or elongate elliptical, slightly leaning, almost vertical. Some pits lack apertures; their chambers are slightly leaning elliptical; these are typical dacrydioid pits. Cross fields between axial and ray parenchyma cells unpitted. Radial dimension of axial tracheids 35 to 40 μ; the bordered pits of 14 to 16 μ size in their walls are arranged in loose uniseriate strings, somewhat compressed at the ends of the tracheids.

T. (Photos 2, 4.) Rays 1 to 25, typically 6 to 12 cells tall. Ray cells 18 to 20 μ high, 12 to 13 μ wide. All walls smooth and thin.

Tangential dimension of tracheids 30 to 35 μ. In their tangential walls, bordered pits of 10 to 12 μ size are fairly frequent. End walls of axial parenchyma cells smooth and very thin. Their tangential walls exhibit small pits of 12 to 13 μ size with almost vertical slits for apertures.

64. (414) *Podocarpus salignus* D. Don.

(*P. chilinus* Richard)

Plate LXXIV, Photos 1–4 and Fig. 54.

This tree up to 20 m tall lives in Chile.

In Dallimore (1925), *Podocarpus salignus* D. Don. is identified with *Podocarpus chilinus* Richard. The sections examined in this work were cut from a sample received directly from Chile, together with a corresponding shoot and leaves. The material can consequently be positively identified as *Podocarpus salignus*. The xylotomical details prove these two trees to be different beyond doubt. This difference may, incidentally, be due to the fact that the material investigated and presented here was cut from a bough of 12 mm diameter of *Podocarpus salignus* D. Don., whereas *Podocarpus chilinus*, described earlier, was cut from a thickish trunk from Fillips' collection. The two woods should by no means be identified, as they differ in essential features.

C. (Photo 1.) Annual ring boundaries discernible. Late wood just 3 or 4 tracheids wide, whereas the entire ring may have a width of 120 tracheids. Tracheid sections radially or tangentially elongate rounded rectangles of 20 to 24 μ width and 28 to 30 μ radial size. The wall thickness does not change across the ring boundary. Radial dimension of late tracheids 12 to 16 μ. Parenchyma cells rather abundant, thin-walled, mostly solitary but quite often also in clusters of 3 or 4; also in rows of 3 or 4, in terminal position, as it were, parallel to the ring boundary. Rays uniseriate, spaced 2 to 15 tracheids apart. Lumina round or elliptical, especially in the late tracheids.

R. (Photo 3.) Ray cells typically 16 to 18 μ high. Transverse walls comparatively thick (7 to 8 μ for double wall), with a few scattered pits in them. They are rather often split apart. Tangential walls smooth and thin; there are a few indentures where they meet the transverse walls. Cross fields enclose 1 or 2, more seldom 3 podocarpoid pits; marginal fields may enclose 4. Pit size 8 to 9 μ; apertures oblique or almost vertical slits. Chambers circular or slightly leaning elliptical. Radial dimension of tracheids 28 to 30 μ; the bordered pits in them are of 14 to 16 μ size. Apertures circular or short elliptical. They form loose uniseriable strings, locally also small clusters joining horizontal faces in an araucarioid pattern. Interfaces of axial and ray parenchyma cells unpitted. End walls of axial parenchyma cells smooth and thin. Their radial walls include several small round simple pits of 7 to 8 μ size.

T. (Photos 2, 4.) Rays 1 to 8 cells tall. Ray cells 16 to 18 μ high, 10 to 12 μ wide; transverse walls comparatively thick (6 to 7 μ for double wall). Axial parenchyma cells 350 to 450 μ long; all walls smooth and thin, unthickened, unpitted, including also the end walls. Radial walls bear some sporadic round simple pits without apertures. Other pits exhibit oblique or almost vertical apertures.

65. (415) *Podocarpus schlechteri* Pilger

Photo LXXV, Photos 1—4 and Fig. 55.

This is a species living in New Guinea. Sections examined were cut from the wood of an oldish tree whose annual rings were 4 to 6 mm wide on an average. The sample was kindly provided by Mr. J. S. Womersley, The Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photo 1.) Annual ring boundaries quite obscure, only divined in places. Tracheid sections rounded. Radial dimensions 35 to 50 μ in early, 25 to 30 μ in late wood; widths equal radial dimensions. Parenchyma cells scarce, thin-walled and mostly solitary. Rays uniseriate, spaced 1 to 14 tracheids apart.

R. (Photo 3.) Ray cells 16 to 20 μ high, marginal ones somewhat higher than internal ones. Al walls of ray cells very thin, unthickened, unpitted. Tangential walls also smooth and thin; at the meeting of transverse and tangential walls there are no indentures, but the transverse walls are fairly often split apart. Most cross fields enclose one podocarpoid pit of 10 to 12 μ size, with a circular or elliptical chamber, and a vertical or oblique aperture that is in the minor axis if the chamber is elliptical. In quite a few cross fields there are no pits at all. There may be 2 to 4 such empty cross fields side by side. Cross fields between axial and ray parenchyma cells unpitted or provided with hardly visible pits. Radial dimension of axial tracheids 35 to 50 μ. Their walls bear scattered bordered pits, forming small clusters near the ends of the tracheids. These pits are of 16 to 18 μ size, and of short procumbent elliptical shape; they locally join

horizontal faces araucaroid fashion. Apertures circular or short elliptical: these latter may be arranged crosswise.

Axial parenchyma cells 300 to 400 μ long, 12 to 13 μ wide. All walls smooth and thin, with scarce simple pits of 8 to 10 μ size.

T. (Photos 2, 4.) Rays 1 to 10, typically 3 or 4 cells tall. Some solitary ray cells may be up to 55 μ high and 20 to 22 μ wide, whereas the internal cell of the multicells rays are only 16 to 20 μ high and 8 to 10 μ wide. All ray cell walls are thin and smooth. Tangential dimension of tracheids 25 to 50 μ. Bordered pits of 11 to 13 μ size very scarce in their walls. All walls of axial parenchyma cells smooth and thin; even the end walls are devoid of thickenings and pitting.

66. (416) *Podocarpus sellowii* Klotzsch

Plate LXXVI, Photos 1–4 and Fig. 56.

This tree living in Brazil may grow to a height of 5 to 7 m. The trunk section examined was kindly provided by the Royal Tropical Institute, Amsterdam.

C. (Photo 1.) Rays of varied width, from 20 to 80 tracheids. Annual ring boundaries not conspicuous, but well enough discernible locally. Tracheid width 28 to 35 μ, radial dimension about the same in early wood, 20 to 25 μ in late wood. There is no change in wall thickness across the ring boundary: double walls 7 to 8 μ thick in both early and late wood. Sections round, elliptical, or rounded tetragonal. In the late wood, radially compressed ellipses tend to predominate. In some growth rings there are scattered solitary thin-walled parenchyma cells filled with a brown resin. Rays uniseriate, spaced 2 to 15 tracheids apart.

R. (Photo 3.) Ray cells 17 to 20 μ high. Transverse walls uniformly thin, fairly often split apart, locally thinned. Tangential walls smooth and thin, lacking indentures. Cross fields exhibit cupressoid pits with oblique linear apertures, reaching clear across the minor axis of the elliptical chamber, or even beyond it. Two pits in a cross field are extremely rare even in marginal positions. In case there are two pits, however, they are arranged one above the other. Cross fields between axial and ray parenchyma cells unpitted. Transverse walls of axial parenchyma cells smooth and thin; radial walls exhibit small round pits with oblique linear apertures. In the walls of the axial tracheids, the bordered pits invariably form loose single strings. They are of 13 to 14 μ size, with short slightly leaning procumbent elliptical chambers and oblique or almost vertical slit-like apertures: the apertures in opposite walls are locally crossed.

T. (Photos 2, 4.) Rays 1 to 10 cells tall, most often uniseriate, but there are also some rather low biseriate ones. Solitary ray cells 17 to 20 μ high; internal ones of much the same size; their width is 10 to 12 μ. End walls of axial parenchyma cells smooth and thin; their radial walls exhibit small simple pits. Tangential dimension of tracheids 28 to 35 μ, their walls bear sporadic small bordered pits of 12 to 14 μ size and oblique slit-like apertures.

67. (417) *Podocarpus spinulosus* R. Brown

Plate LXXVII, Photos 1—4 and Fig. 57.

This is a low shrub living in New South Wales, Australia. I received the sample examined from the Royal Botanical Gardens, Sydney, courtesy of Mr. K. Mair.

C. (Photo 1.) The sections were prepared of a bough about 10 years old and 10 mm thick. Annual ring boundary discernible but not sharp. There is no change in tracheid wall thickness across the ring boundary; double wall thickness is 4 to 5 μ. The earlier tracheids are somewhat larger and wider-lumened. (Width 21 to 24 μ; radial dimension 21 to 24 μ in early wood, 16 to 18 in late wood.) Early tracheid sections rounded tetra-, penta- and hexagonal; late ones radially somewhat flattened elliptical or circular. Parenchyma cells fairly abundant, scattered loosely in the growth rings or forming smaller or larger clusters here and there. Rays uniseriate, all walls smooth. Axial and ray parenchyma cells filled with a golden substance.

R. (Photo 3.) Ray cells typically 17 to 18 μ high. Transverse walls smooth and thin, with a few exceptional simple pits in them. Tangential walls smooth and thin, without indentures. Cross fields enclose one simple pit, or two arranged in a vertical pair. The pits in the pairs are of 6 to 7 μ size; their outlines are circular or procumbent elliptical. The single pits are of 8 to 10 μ diameter, with wide oblique apertures reaching clear across the chambers. Cross fields between axial and ray parenchyma cells unpitted. Radial dimension of axial parenchyma cells 7 to 10 μ; transverse walls smooth and thin. In their radial walls there are scattered simple pits of 7 to 8 μ size. Radial dimension of tracheids 21 to 24 μ in this view. In their walls there are scattered bordered pits of 14 to 15 μ size with circular apertures.

T. (Photos 2, 4.) Rays 1 to 4 cells tall, but single-cell rays are most frequent. Solitary ray cells 20 to 21 μ high, 10 to 12 μ wide; tangential walls smooth, unpitted. Tangential size of tracheids 21 to 24 μ, their walls exhibit frequent small bordered pits of 8 to 10 μ size. Apertures circular, or oblique slits, crossing in opposite walls of the same cell. End walls of axial parenchyma cells smooth and thin; radial walls bear scattered pits of 7 to 8 μ size with oblique slit-like apertures.

68. (418) *Podocarpus sylvestris* Buchholz

Plate LXXVIII, Photos 1—4 and Fig. 58.

This is a tree up to 14 m tall living in New Caledonia. The material examined derives from the Buchholz collection; it bears the inventory number 1351.

C. (Photo 1.) Annual ring boundaries conspicuous; early and late wood distinct enough, as there is a fair difference in tracheid sizes. Tracheid width 35 to 45 μ; radial dimension 50 to 55 μ in early, 20 to 25 μ in late wood. Wall thickness

3 to 4 μ in early, 7 to 8 μ in late tracheids. Sections rounded tetra- or pentagonal; lumina follow outline. Some late tracheids have flattened elliptical or indeed gash-like lumina. Ring width varied, from 10 to 60 tracheids. Transition between early and late wood gradual. Thin-walled axial parenchyma cells rather scarce. Rays spaced 4 to 15 tracheids apart. Transverse walls smooth and unpitted. Tangential walls also smooth.

R. (Photos 3, 4.) In the axial walls of the tracheids, bordered pits are arranged in loose strings or in close-packed rows, almost araucarioid fashion. The size of the solitary pits in the broader tracheids is 18 to 20 μ; their height is 16 to 18 μ. Their apertures are short oblique elliptical. Rays 1 to 10, typically 5 to 6 cells tall. Transverse walls smooth, unpitted. Tangential walls smooth, unpitted, unthickened. Transverse walls fairly often split apart. Most cross fields enclose a single pit of 11 μ size, which sometimes almost fills out the cross field. Apertures slit-like or linear, oblique, in the minor axis of the almost procumbent large elliptical chamber. This makes the aperture almost vertical; that is, the pit is typically podocarpoid. Axial parenchyma cells 200 to 300 μ long, 15 to 18 μ wide. Radial walls locally thick and pitted. Pit size 6 to 8 μ, rounded, without apertures. Some other pits have almost vertical apertures. These are in fact the apertures of the bordered pits behind the parenchyma cells, shining through the thin parenchymal walls. End walls smooth, unpitted. In the radial walls of the tracheids, bordered pits locally occur in pairs; the lines of contact of the pairs are most often vertical or oblique, sometimes horizontal. The pits of some cross fields have no apertures at all, in which case the chambers are the round circopores so typical of the podocarps.

T. (Photo 2.) Rays uniseriate, 1 to 20, typically 2 to 5 cells tall. Cell sections short or slightly elongate ellipses. Cell height 18 to 20 μ, width 13 to 14 μ. Marginal cells somewhat higher. All walls smooth and thin. Tangential walls of tracheids locally exhibit bordered pits of 10 to 11 μ diameter. Apertures short, almost vertical linear, not reaching across the chamber. Axial parenchyma equals tracheids in tangential dimension. Its end walls are smooth and very thin; its radial walls exhibit circular simple pits.

69. (419) *Podocarpus urbanii* Pilger

Jacca

Plate LXXIX, Photos 1—4 and Fig. 59.

A tree up to 15 m tall living in the mountains of Jamaica. The material was kindly put at my disposal by Mr. C. M. Smith, Smithsonian Institution, Washington. The sections examined were cut of a thick trunk whose annual rings were 2 to 6 mm wide.

C. (Photo 1.) Annual ring boundaries fairly conspicuous, well visible. Late wood usually 3 to 4 tracheids wide. There is no change in wall thickness across

the ring boundary. A typical diameter of an early tracheid is 30 to 40 μ, but there are much smaller ones, too. Radial dimension of late tracheids 15 to 18 μ; width the same as in early tracheids. Parenchyma cells very numerous, filled with a dark substance, distributed fairly evenly over the growth rings. Rays uniseriate.

R. (Photo 3.) Ray cells 17 to 18 μ high. Transverse walls smooth and thin, unpitted, tangential walls also smooth and thin, lacking indentures. Most cross fields enclose one relatively large podocarpoid or dacrydioid pit of 12 to 13 μ size. Chambers round or elliptical, apertures elliptical, oblique or almost vertical. Cross fields between axial and ray parenchyma cells unpitted, but unpitted fields are fairly frequent also in the cross fields with the axial tracheids. Radial dimension of tracheids 30 to 40 μ. Their walls exhibit bordered pits in loose uniseriate strings, also a few twin pits in the broader tracheids. Size of solitary pits 14 to 15 μ; apertures circular or slightly oblique elliptical. At the ends of the tracheids, the pits are crowded araucarioid fashion, with horizontal lines of contact. Axial parenchyma cells 350 to 400 μ long, 10 to 15 μ wide. All walls smooth and thin, unthickened. Radial walls exhibit strings of small simple pits of 7 to 8 μ size. The linear apertures are almost vertical in some of them.

T. (Photos 2, 4.) Rays 1 to 18 cells tall, typically uniseriate, but locally widened to biseriate in a height of one or two cells. Solitary ray cells 18 to 20 μ high, 10 to 12 μ wide. Tangential size of axial tracheids 30 to 35 μ; their walls bear numerous large bordered pits of 13 to 14 μ size. Apertures round or slightly oblique linear. Tangential dimension of axial parenchyma cells equals that of tracheids; all walls smooth and very thin; even the end walls are unthickened and unpitted. Tangential walls exhibit loose strings of small pits of 8 to 10 μ size.

70. (420) *Podocarpus ustus* Brongn. and Gris.

Plate LXXX, Photos 1—4 and Fig. 60.

This is a very rare low shrub living in New Caledonia. A few specimens were found by Prof. Compton. The sections examined were prepared of a thickish bough or a thinnish trunk. The slide No. 1729 derives from the collection of J. T. Buchholz; the sections were kindly put at my disposal by Mrs. M. Kaiser.

C. (Photo 1.) Annual ring boundaries discernible but not conspicuous. Tracheid size, wall thickness and shape of section hardly change across the ring boundary. Radial dimension and width of early tracheids 30 to 40 μ; the outermost late tracheids have radial dimensions of 15 to 20 μ. Double wall 6 to 7 μ thick. Sections rounded, tetra-, penta- or hexagonal. Sizes and shapes varied over the annual rings. M. Kaiser (1954) states this species to lack parenchyma. In the section examined, however, fairly numerous axial parenchyma cells were observed, scattered all over the annual rings. Rays uniseriate, with unpitted transverse walls, spaced 1 to 10 tracheids apart.

R. (Photos 3.) Ray cell height 18 to 20 μ. Transverse walls of ray cells smooth, but with slight thickenings in places. Transverse walls locally split apart. Tangential walls perfectly smooth, unthickened, devoid of indentures. Most cross fields enclose one podocarpoid pit of 8 to 10 μ size with a circular or slightly oblique elliptical chamber, with a narrow elliptical aperture in the minor axis of the elliptical chamber. Some pits have no apertures, in which case they assume the form of circopores. The pits of some cross fields are entirely taxodioid in shape. In the marginal cross fields there are 2 or 3, very exceptionally even 4 pits. Radial dimension of axial tracheids 30 to 40 μ; their tangential walls exhibit small bordered pits of 13 to 14 μ size in loose uniseriate strings. Apertures short elliptical or linear. The broadest tracheids locally exhibit transverse pit pairs. At the ends of the tracheids there are pit clusters joining horizontal or oblique walls. Axial parenchyma cells 300 to 400 μ long, 15 to 16 μ wide; end walls smooth and thin; radial walls bear small round pits of 8 to 10 μ size. Cross fields between axial and ray parenchyma cells unpitted.

T. The tangential structure is shown in Photos 2 and 3.

71. (421) *Podocarpus vieillardii* Parlatore

(*Dacrydium elatum compactum* Carrière

D. tenuifolia Parl.)

Plate LXXXI, Photos 1–4 and Fig. 61.

A tree living in Australia, up to 15 m tall. The material examined derives from J. T. Buchholz's collection; it bears the inventory number 1046. The sections were kindly put at my disposal by Mrs. M. Kaiser.

C. (Photo 1.) The sections examined were prepared of a bough or trunk 30 years old. Annual ring boundaries vague, hardly discernible; rings 15 to 50 tracheids wide. There is no change in wall thickness across the ring boundaries. Sections rounded, highly varied in size and shape. Typical radial dimension 45 to 50 μ in early, 25 to 30 μ in late wood. Parenchyma cells scarce, scattered over the growth ring. Rays uniseriate, tangential walls smooth: no pitting is visible in the transverse walls, either. Rays spaced 1 to 10 tracheids apart. Double wall 7 μ thick.

R. (Photo 3.) Ray cells typically 17 to 20 μ high; transverse walls smooth and thin, unpitted. Tangential walls also smooth and thin, unthickened, unpitted. Transverse walls locally split apart. Most cross fields enclose a simple podocarpoid or dacrydioid pit. Pit size 10 to 12 μ; chambers slightly oblique elliptical; apertures short linear or elliptical, oblique, almost vertical in the typical podocarpoids pits. Some marginal fields enclose two pits. Some cross fields lack pits. Radial dimension of tracheids 25 to 50 μ. In their walls, bordered pits form

loose single strings; the pits are crowded araucarioid fashion at the ends of some tracheids. Pit size 15 to 16 μ, apertures oblique or almost vertical ellipses, locally crossing in opposite walls. Axial parenchyma cells 300 to 350 μ long, 10 to 12 μ wide; all walls thin, thickening or pitting rare in end walls. Radial walls exhibit loose circular or elliptical simple pits. Cross fields between axial and ray parenchyma cells unpitted.

T. (Photos 2, 4.) Rays 1 to 15, typically 1 to 10 cells tall; rays 1 to 3 cells tall also quite frequent. Ray cells 17 to 20 μ high, 15 to 20 μ wide. Sections most often short elliptical; all walls smooth and thin. Tangential dimensions of tracheids varied, typically 30 to 35 μ. Their walls exhibit scarce pits of 12 to 13 μ size. All walls of axial parenchyma cells thin, even the end walls are unthickened and unpitted. There are a few exceptional nodes, though.

72. (422) *Podocarpus vitiensis* Seemann

Plate LXXXII, Photos 1–4 and Fig. 62.

This tree living in the Fiji Islands grows to a height of 15 to 20 m. The sections investigated derive from the collection of Yale University; they bear the inventory number 28.378. The material was kindly put at my disposal by Mrs. M. Kaiser.

C. (Photo 1.) Annual ring boundaries obscure, hardly discernible, divined at best. Width of tracheids 20 to 30 μ; radial dimensions range from 20 to 40μ. Wall thickness is uniformly 7 to 8 μ. Xylem parenchyma cells fairly abundant, scattered over the growth rings. Rays uniseriate, spaced 2 to 10 tracheids apart; tangential walls smooth and thin, transverse walls unpitted.

R. (Photo 3.) Ray cells 17 to 18 μ high, or somewhat higher. Transverse and tangential walls of ray cells smooth and thin, unpitted, unthickened. Most cross fields enclose one small pit of 7 to 8 μ size, but marginal fields sometimes enclose two, one above the other. Apertures oblique, elliptical. Some cross fields are unpitted. Some of the taller rays are lined on both sides by very low marginal parenchyma cells. This is a rather rare phenomenon in podocarps.

Radial dimension of tracheids 20 to 40 μ. In their walls, bordered pits form loose uniseriate strings. Pit size is 16 to 18 μ. At the ends of some tracheids, the bordered pits are somewhat crowded. Apertures are circles or short oblique gashes, locally crossing in opposite cell walls.

Cross fields between axial and ray parenchyma cells unpitted. All walls of axial parenchyma cells smooth and thin; end walls also unpitted and unthickened.

T. (Photos 2, 4.) Rays 1 to 10, typically 5 to 6 cells tall, but rays just one or two cells tall are also fairly frequent. Cell height 17 to 18 μ, width 12 to 14 μ; sections rounded or slightly elongate, upright elliptical. Tangential dimension of tracheids 20 to 30 μ; bordered pits in their walls very scarce, scattered, of 12 to 13 μ size, with oblique slit-like apertures. All walls of axial parenchyma cells

smooth and thin; even the end walls are unthickened and unpitted. Marginal parenchyma cells, much lower than internal ones, well visible on either side of taller rays.

FAMILY III. TAXACEAE

73. (423) *Taxus floridana* Chapman

(*Taxus baccata* var. *floridana* (Elves et Henry))

Plate LXXXIII, Photos 1—4 and Fig. 63.

A shrub growing to a height of 5 to 6 m, it lives in Western Florida. The material investigated was kindly provided by Mr. C. M. Smith of the Smithsonian Institution, Washington, U.S.A. The sections were prepared of a thick trunk; a fragment 15 mm wide included 14 annual rings.

C. (Photo 1.) Annual ring boundaries conspicuous, owing to a change in tracheid size and wall thickness across the ring boundary. Tracheids typically 18 to 22 μ wide; radial dimension 35 to 40 μ in early wood, 15 to 20 μ in late wood. Sections and lumina of late tracheids rounded. Double-wall thickness is 7 to 8 μ in the late, 5 to 6 μ in the early tracheids. Ring width is varied; it may attain 50 to 60, exceptionally even 100 tracheids. No parenchyma cells or resin ducts in the growth ring fields. Rays uniseriate.

R. (Photo 3.) Ray cells 18 to 20 μ high. Thickening of transverse walls non-uniform. These walls exhibit a distinct simple pitting. Tangential walls entirely smooth, however. Indentures frequent. Most cross fields enclose one or two small piceoid pits; spring tracheids' cross fields may enclose three. Pit size 6 to 7 μ; apertures linear or short elliptical. Transverse walls 6 to 7 μ thick. Radial dimension of early tracheids 35 to 40 μ. All tracheid walls exhibit loosely coiled spiral thickenings, with the turns of the spiral spaced 8 to 12 μ apart. This is a distinct difference from the thickenings in *Picea* and *Pseudotsuga*. Bordered pits in tracheid walls loosely uniseriate, of 14 to 16 μ size.

T. (Photos 2, 4.) Rays 1 to 18, typically 7 to 8 cells tall. Ray cells 18 to 20 μ high, 10 to 11 μ wide; sections elongate elliptical. Transverse walls thick; radial walls much thinner. Tangential walls totally unpitted. Tangential dimension of tracheids 18 to 26 μ, but some are much narrower. All tracheids exhibit loosely coiled spiral thickenings. Some of these are almost perpendicular to the trunk axis: others are somewhat more markedly sloping.

FAMILY IV. CUPRESSACEAE

74. (424) *Callitris drummondii* Benth. and Hooker fil.

(*Frenela drummondii* Parlatore)

Drummond's Cypress Pine

Plate LXXXIV, Photos 1—4 and Fig. 64.

This Western Australian tree grows to heights of 10 to 15 m. The material investigated was kindly provided by the Division of Forest Products, Melbourne. The sections were cut of a thickish bough or trunk.

C. (Photo 1.) Differs considerably in cross section from the conifers known so far, including also the *Cupressaceae*, in that the wood includes a number of axial ducts, most often near the annual ring boundaries, but fairly often also deeper in the rings; sometimes these ducts are disposed side by side, in which case they may coalesce almost into plates. At a first glance they look like an included pith, which is not contradicted by their cross sections; still, they continue over considerable lengths axially, exactly like the resin ducts of certain pines. These vertical or, so to speak, platy ducts are fairly frequent in the wood; there is one in almost each annual ring. The ducts are filled with thin-walled parenchyma cells; these are by no means metamorphosed tracheids as their walls exhibit simple pits only. The cells lining them are in all probability the typical epithelial cells of axial ducts. Some of them have a golden content. In the vicinity of the ducts, axial parenchyma cells are remarkably abundant; they are likewise filled with a dark resin. Another remarkable feature is that the outer walls of the cells lining the ducts, i.e. those in direct contact with the tracheids, are much thicker than the cell walls within the ducts. Epithelial cell size is 35 to 80 μ, whereas the adjacent tracheids are of 28 to 30 μ size only. Double wall thickness of tracheids 8 to 9 μ, that of the parenchyma only 5 to 6 μ. These parenchyma cells have entirely smooth, unpitted walls. Annual ring boundaries fairly conspicuous; early and late wood also rather distinct. Width of tracheids 20 to 25 μ; radial dimension 20 to 22 μ in early, 18 to 20 μ in late wood. Sections most often rounded polygonal, fairly often regular hexagonal. Axial parenchyma cells abundant in the rings, particularly in the late wood, close to the ring boundaries. These cells are sometimes disposed terminally. They are filled with a dark brown substance. Rays uniseriate, spaced 2 to 15 tracheids apart.

R. (Photos 3, 4.) Ray cell height varied, from 14 to 26 μ. Marginal cells almost invariably higher than internal ones. Transverse walls comparatively thick (6 to 7 μ), with fairly abundant simple pits, which locally pass into an almost rosary-like thickening.

Tangential walls smooth and very thin, unpitted, without indentures. Transverse walls locally split apart. Most cross fields enclose one pit; some enclose two side by side. The taller marginal fields may include up to 4 cupressoid pits.

Cross fields between axial and ray parenchyma cells may enclose 2 or 3 simple pits. Transverse walls of axial parenchyma cells smooth and thin, unthickened, unpitted. Some ray cells are filled with a golden granulate substance.

The axial ducts mentioned above and their structure merit special attention. These ducts are filled with parenchyma cells of varied size in the 30 to 120 μ range. Their walls locally exhibit simple pits. Bordered pits in the axial walls of the tracheids are invariably loosely uniseriate. No side-by-side pit pairs have been observed.

T. (Photo 2.) Rays 1 to 10, typically 5 to 6 cells tall; there are also a few rays taller than 10 cells. Ray cells 14 to 26 μ high, 13 to 14 μ wide; marginal cells slightly higher than internal ones. All walls smooth and thin. Tangential dimension of tracheids 20 to 25 μ. Their walls exhibit uniseriate bordered pits, somewhat alternate; pit size is 10 to 12 μ; apertures are in the minor axes of the elliptical chambers, almost vertical. The walls locally exhibit callitrisoid thickenings. End walls of axial parenchyma cells smooth and thin, unthickened, unpitted. The structure of the axial ducts is the same in this view as in the radial one. Width of these ducts ranges from 100 to 150 μ.

75. (425) *Callitris morrisoni* R. T. Baker

Morrison's Cypress-Pine

Plate LXXXV, Photos 1—4 and Fig. 65.

A tree up to 7 m tall living in Western Australia. The sections were cut of a bough about 1 cm thick, 3 to 4 years old. The material was kindly provided by Mr. T. R. N. Lothian, The Botanical Gardens, Adelaide, Australia.

C. (Photo 1.) Annual ring boundary effaced, indicated only by strings of terminal parenchyma cells. Tracheid sections rounded, more or less isodiametric; typical radii 16 to 20 μ. The frequent parenchyma cells contain a dark filling. Rays uniseriate, seldom biseriate, spaced 2 to 15 rays apart. Growth rings may be up to 60 tracheids wide.

R. (Photo 3.) Transverse walls of ray cells comparatively thin, locally with further distinct pit-like thinnings, locally split apart. Ray cells 14 to 15 μ high. Most cross fields enclose 1 or 2 pits, marginal cells sometimes enclose 3 or 4. In the two-pit fields, the pits may be disposed side by side or one above the other. There are distinct indentures where the transverse and tangential walls meet. In the tracheid walls the bordered pits form loose uniseriate strings. Pit size is 5 to 6 μ, apertures are oblique. Callitrisoid thickening in the wood very rare. Transverse walls of axial parenchyma cells entirely smooth; radial walls bear a few scattered simple pits.

T. (Photos 2, 4.) Rays 1 to 8, typically 2 to 4 cells tall. Ray cells 14 to 15 μ high, internal cells somewhat lower. Tangential walls perfectly smooth. Tracheid with 18 to 20 μ. Transverse walls of axial parenchyma cells smooth and very thin. Their radial walls bear simple pits.

76. (426) *Callitris preissii* Miq.

Plate LXXXVI, Photos 1—4 and Fig. 66.

This is an evergreen tree living in Australia and Tasmania. The sections were prepared from a piece of bough 17 years old, kindly provided by Mr. T. R. N. Lothian, The Botanic Gardens Adelaide, Australia.

C. (Photo 1.) Sections rounded in both the early and late tracheids. Walls evenly thick. Early tracheids have radial dimensions of 24 to 26 μ and about the same width. Rays spaced 2 to 20 tracheids apart. Transverse walls perfectly smooth. Parenchyma cells abundant, filled with a dark resinous substance. They may form almost uninterrupted palisades along the annual ring boundaries. This species differs very little in its cross sectional structure from the other *Callitris* species.

R. (Photos 3, 3a). Transverse walls of ray cells smooth, bearing some simple pits, and locally split apart. Tangential walls invariably smooth. Ray cells 28 to 30 μ high. Cross fields in the early wood tend to include 2 or 3 pits one above another; the marginal fields may enclose up to six in two transverse rows. These pits are of 5 to 6 μ size with oblique apertures. Tracheid walls bear bordered pits of 10 to 12 μ size. Some tracheids exhibit a distinct callitrisoid thickening. Transverse walls of axial parenchyma cells smooth. Cross fields between ray and axial parenchyma cells unpitted.

T. (Photos 2, 4.) Rays 1 to 8 cells tall. Ray cells 28 to 30 μ high and 8 to 9 μ wide. Marginal and solitary ray cells may be somewhat higher than that. Rays one cell tall are remarkably numerous. Tangential walls of tracheids exhibit very few bordered pits or none at all. In some tracheids the callitrisoid thickening embracing the bordered pits is clearly visible, especially close to the rays. Walls of axial parenchyma cells thin and smooth. Tangential dimension of early tracheids 24 to 26 μ.

77. (427) *Cupressus arizonica* var. *bonita* Lemmon

(*C. glabra* Sudworth)

Arizona Cypress

Plate LXXXVII, Photos 1—4 and Fig. 67.

A tree up to 5 m tall, it is probably a variety of lower stature of *Cupressus arizonica*. It lives in Arizona, U.S.A. The sections investigated were prepared of a bough 18 years old, 1 cm thick. The material was kindly put at my disposal by Mr. C. M. Smith of the Smithsonian Institution, Washington, U.S.A.

C. (Photo 1.) Its cross sectional structure hardly differs from that of *Cupressus arizonica* s.s. except perhaps in that it has fewer axial parenchyma cells, scattered over the growth rings. Tracheid sections rounded in the early wood, flattered, with gash-like lumina in the extreme late wood. Radial dimension of early tracheids 28 to 30 μ; width about the same. Wall thickness unchanged across the ring boundary. Rays spaced 3 to 15 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells thick, with numerous pits; tangential walls smooth or slightly nodose. There are indentures where the two types of wall meet. Transverse walls locally split apart. Ray cells 17 to 18 μ high. Most cross fields enclose two pits, one above the other; marginal fields tend to enclose three to six, disposed in the corners. Pit size is 6 to 7 μ; oblique apertures reach clear across the chambers. Tracheid walls bear bordered pits of 14 μ size, invariably in loose uniseriate strings, with no pairs of pits side by side.

Transverse walls of axial parenchyma cells uniformly thick. Their radial walls bear scarce small pits of 5 to 6 μ size.

T. (Photos 2, 4.) Rays 1 to 12 cells tall; this wood includes no rays up to 33 or so cells tall, fairly frequent in *Cupressus arizonica* s.s. Most rays are just 5 to 6 cells tall, probably owing to the sections having been prepared of a bough. Ray cells 17 to 18 μ high and about as wide. Transverse walls slightly thicker than radial ones. Tracheid width 28 to 30 μ. Their tangential walls bear few bordered pits, with short crossing gashes for apertures. Transverse walls of axial parenchyma cells exhibit nodose thickenings, with up to 4 nodes. In their tangential walls there are small cupressoid pits of 6 to 7 μ size with oblique slits for apertures.

78. (428) *Cupressus dupreziana* Camus

Plate LXXXVIII, Photos 1—4 and Fig. 68.

A tree growing to a height of 8 to 10 m, it lives in the Hoggar Mountains, Sahara, in the region of Ghat and Djanet, where it forms closed forests. The sections were prepared of a bough 25 to 30 years old, 5 cm thick. The material was kindly provided by Professor H. Gaussen of the Laboratoire Forestier de Toulouse, France.

C. (Photo 1.) Annual rings relatively narrow, 4 to 20 tracheids wide. Ring boundaries sharp; late wood usually 3 to 4 tracheids wide. There are local rows of terminal parenchyma cells close to the late bands. Most tracheid sections tetra- or hexagonal; radial dimensions 18 to 20 μ, width about the same. Late tracheids flattened with almost gash-like lumina. Rays spaced 2 to 20 tracheids apart, with sporadic pits in their transverse walls.

R. (Photo 3.) Transverse walls of ray cells comparatively thick (4 to 6 μ), with numerous simple pits. Tangential walls perfectly smooth. Transverse walls locally split apart; there are distinct indentures where the walls join. Most cross

fields enclose 1 or 2 cupressoid pits of 8 μ size; marginal fields usually enclose 3 or 4, arranged in the corners. Apertures oblique elliptical, included or almost so. Bordered pits in radial walls of tracheids loosely uniseriate, of 12 to 14 μ size; apertures circular. Ray cells 26 to 28 μ high. Axial parenchyma cells 7 to 8 μ wide; transverse walls smooth or thickened cask shape. The structure resembles that of the other *Cupressus* species.

T. (Photos 2, 4.) Rays 1 to 14, typically 6 or 7 cells tall. Cell height and width equally 26 to 28 μ. Sections circular or elliptical. Transverse walls thicker than radial ones; tangential walls perfectly smooth. Tracheid size 26 to 28 μ; the walls exhibit numerous bordered pits of 7 to 8 μ size with round apertures. Transverse walls of axial parenchyma cells smooth, with slight cask-shaped thickenings at the middle. Nodose thickening very rare. Tangential walls bear numerous simple pits of 5 to 6 μ size with slightly oblique apertures.

79. (429) *Cupressus forbesii* Jepson

Plate LXXXIX, Photos 1—4 and Fig. 69.

A tree growing to a height of 5 to 7 m, living in California. The sections examined were prepared of a thickish trunk. The material was kindly provided by Mr. C. M. Smith of the Smithsonian Institution, Washington, U.S.A.

C. (Photo 1.) Annual ring boundaries distinct; rings 5 to 30 tracheids wide. There is no change in tracheid wall thickness across the ring boundary. Late wood 4 to 5 tracheids wide; width of early tracheids 17 to 20 μ, radial dimension 24 to 26 μ. Sections polygonal, most often tetra- and hexagonal. Parenchyma cells relatively scarce; there are just a few solitary ones in the late wood. Rays spaced 1 to 15 tracheids apart, uniseriate, with frequent pits in their transverse walls.

R. (Photo 3.) Transverse walls of ray cells thick, with numerous simple pits. Tangential walls seldom smooth, most often thickened rosary-like. There are indentures where the walls join, and the transverse walls are often split apart. Cross fields enclose 1 or 4 cupressoid pits of 7 to 8 μ size, with slightly oblique apertures, included or almost so. Ray cells 17 to 26 μ high; internal ones slightly lower. In radial walls of tracheids, bordered pits form loose uniseriate strings. Pit size is 14 μ; apertures are circular. Pairs of pits side by side are nowhere to be seen. Transverse walls of axial parenchyma cells smooth or slightly nodose. Radial walls exhibit scarce pits of 4 μ size.

T. (Photos 2, 4.) Rays 1 to 15, most often 6 to 8 cells tall. Ray cells 17 to 26 μ high, 14 μ wide. Walls uniformly thick, transverse walls most often smooth. Tracheid walls have a few bordered pits of 7 μ size, with oblique apertures reaching clear across the chamber. Transverse walls of axial parenchyma cells smooth or slightly thickened in the nodular manner. Tangential walls bear a few simple pits of 6 to 7 μ size.

80. (430) *Heyderia formacrolepis* L.

Plate XC, Photos 1—4 and Fig. 70.

A native of China. The sections were prepared of a thick trunk slice. The description is based on a field of view 12 annual rings wide. The material was kindly put at my disposal by Professor Tsun Ching Cheng of the Institute of Forest Products, Peking, China.

C. (Photo 1.) Annual ring boundaries fairly distinct. Late rings 10 to 60 tracheids wide; late wood takes up no more than 3 to 6 tracheids. Tracheid sections rounded hexagonal, sometimes tetragonal; tracheid width 28 to 35 μ; radial dimension 30 to 32 μ in early, 14 to 15 μ in late tracheids. Last tracheids slightly flattened rectangular. All lumina rounded, following cell outlines. There are parenchyma cells scattered among the tracheids, fairly often also in rows along the ring boundary. Their dark contents and thin walls make for a ready distinction from the tracheids. Rays spaced 2 to 15 tracheids apart, with scattered simple pits in their transverse walls.

R. (Photo 3.) Transverse walls of ray cells generally pitted, 4 μ thick; tangential walls thickened in the nodose, rosary or dentate fashion. There are well-defined indentures where the walls meet. Cross fields enclose one or at most two cupressoid pits even in the early tracheids; marginal cells enclose 3 or 4. Pit size is 7 to 7 1/2 μ; the linear or slit-like aperture is in the minor axis of the elliptical chamber. Ray cells 21 to 22 μ high; marginal cells may be 24 to 26 μ high. Tracheids 30 to 32 μ wide, with uniseriate rows of bordered pits of 14 to 15 μ size in their walls. There are conspicuous crassula between them; their apertures are circular.

Axial parenchyma cells 20 to 22 μ wide; their transverse walls are but exceptionally smooth; they bear most often one or two pits. In their radial walls there are small pits of 3 to 4 μ size with slit-like apertures. In the cross fields between axial and ray parenchyma cells there are 3 or 4 simple procumbent elliptical pits.

T. (Photos 2, 4.) Rays 1 to 12, typically 6 or 7 cells tall, but rays one to three cells tall are also fairly frequent. The tallest rays widen to biseriate in a height of one or two cells near their middles or at their ends. Ray cells 20 to 26 μ high; the internal ones may be of different height, even if adjacent. Their width is 13 to 14 μ. Tangential walls smooth or somewhat reticulate, indicative of the pitting in the tangential walls. Tracheids 28 to 35 μ wide; their tangential walls bear no bordered pits, at least not in the sections examined. Transverse walls of axial parenchyma cells slightly nodose in places, dentate elsewhere. Some transverse walls bear as many as 4 or 5 teeth, which shows these walls to be pretty thick.

81. (431) *Juniperus brevifolia* Antoine

Plate XCI, Photos 1—4 and Fig. 71.

A shrub hardly a metre and a half high, living in the Azores. The material was kindly provided by Professor H. Gaussen, Laboratoire Forestier de Toulouse, France. The sections examined were prepared of a bough 9 years old and 6 mm thick.

C. (Photo 1.) Annual ring boundaries hardly discernible. There is no change in tracheid wall thickness across the ring boundary. Sections of tracheids angular; radial dimension 24 to 26 μ, width 18 to 22 μ. Late tracheids flatter; their lumina are very seldom gash-like, however. Abundant parenchyma cells are usually disposed parallel to the ring boundary, often enough terminally. They are filled with a yellowish brown substance. Rays uniseriate.

R. (Photo 3.) Ray cells 10 to 22 μ high. Some marginal ones may attain 30 μ. The cross fields of these latter may enclose up to 6 pits.

Transverse walls rather sparsely pitted, locally split apart. Tangential walls exhibit 3 or 4 rosary-like thickenings, also indentures. Most cross fields enclose 1 or 2 cupressoid pits, with the apertures in the minor axes of the elliptical chambers: marginal fields enclose 3 or 4, occasionally up to 6 pits. These pits are of 5 to 6 μ size. Radial dimension of early tracheids 24 to 26 μ.

T. (Photos 2, 4.) Rays 1 to 8, typically 1 to 3 cells tall. Solitary cells 20 to 22, internal ones sometimes only 10 to 12 μ high: the height range is rather considerable. Tangential walls of ray cells pitted or thickened in scalariform, that is, juniperoid fashion. Tangential size of tracheids 18 to 22 μ; the few bordered pits in the walls of the late tracheids are of 7 to 8 μ diameter. Transverse walls of axial parenchyma cells smooth or thickened rosary fashion. Their tangential walls bear a few circular or elliptical simple pits.

82. (432) *Juniperus cedrus* Webb and Berthelot

Canary Island Juniper; Canary Island Cedar; Sabina Tree

Plate XCII, Photos 1—4 and Fig. 72.

A tree 20 to 25, exceptionally 30 m tall, living in the Canaries but cropping up also on New Zealand and in Africa. The sections examined were cut of a piece of a thickish trunk, eight annual rings wide, received from the Royal Botanical Gardens, Kew, England.

C. (Photo 1.) Annual ring boundary fairly sharp. Rings 30 to 70 tracheids wide. Xylem parenchyma cells filled with a dark resin tend to be arranged parallel to the ring boundaries, in the form of palisades. Tracheid width 28 to 30 μ; radial dimension about the same in the early, 8 to 10 μ in the late wood. Lumina

of the late tracheids are narrow gashes. There is no change in tracheid wall thickness across the ring boundaries. Rays spaced 1 to 8 tracheids apart. Their transverse walls bear several pits.

R. (Photo 3.) Transverse walls of ray parenchyma cells smooth, sparsely pitted, locally split apart. Tangential walls smooth or very finely nodose. Most cross fields enclose one cupressoid pit; very few enclose two. Pit size is 7 to 8 μ. Corner cells tend to enclose two pits. There are indentures where the transverse walls join the tangential ones. Tracheids are 28 to 30 μ wide, with bordered pits forming loose uniseriate strings in their walls. Pit size is 17 to 18 μ; apertures are round. Transverse walls of axial parenchyma cells thick with one or two nodes. Radial walls bear elliptical cupressoid pits of 7 to 8 μ size.

T. (Photos 2, 4.) Rays 1 to 7, typically 6 or 7 cells tall, but rays just 2 to 5 cells tall are also fairly frequent. Cell sections usually circular or short elliptical; height 14 to 15 μ, width about the same. Marginal cells locally higher than internal ones; tangential walls smooth. Tracheids 28 to 30 μ wide; their tangential walls exhibit a few bordered pits of 7 μ size. Transverse walls of axial parenchyma cells smooth or cask-shaped, or with nodose or rosary-like thickenings. The simple pits in their walls are of 6 to 7 size.

83. (433) *Juniperus davurica* Pall.

Plate XCIII, Photos 1—4 and Fig. 73.

A low ground-hugging shrub, native of Siberia. The sections examined were prepared of a 13-year-old bough. The material examined was kindly provided by Professor A. A. Yatsenko-Khmelevsky of Leningrad.

C. (Photo 1.) Annual ring boundaries sharp. Early wood much wider than late wood: the latter is most often only 4 or 5 tracheids wide. Tracheid sections angular, tetragonal; width 15 to 20 μ, radial dimension 17 to 28 μ in early wood, and as little as 4 to 5 μ in latest tracheids. Parenchyma cells most often disposed in the late wood, parallel and close to the ring boundary, forming palisades of more or less width. Rays spaced 2 to 15 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells comparatively thick, locally split apart, rather copiously strewn with simple pits. Tangential walls thickened in the dentate or rosary pattern, with up to 6 nodes. Indentures frequent. Cross fields enclose most often 2 or 3, more seldom 4 cupressoid pits of 5 to 6 μ size, with transverse or slightly oblique elliptical or slit-like apertures. Marginal fields fairly often enclose up to 6 pits.

Tracheids 17 to 28 μ wide. Bordered pits of 14 to 16 μ size form loose uniseriate strings in their walls. Axial parenchyma cells 10 to 11 μ wide; transverse walls thick, with one or two pits.

T. (Photos 2, 4.) Ray 1 to 8, typically 3 or 4 cells tall. Ray cells 19 to 20 μ high, 8 to 9 μ wide. Marginal and solitary cells may be somewhat higher than

that. Transverse walls 4 to 5 μ thick; tangential walls thickened in the reticular or scalariform fashion, radial walls somewhat thinner. Tracheids 15 to 20 μ wide; walls of late tracheids exhibit fairly frequent bordered pits of 6 to 7 μ size. Transverse walls of axial parenchyma cells thickened in the nodose or dentate fashion; the two types of thickening locally occur together in the walls of one and the same cell. The transverse walls of some other cells are uniformly thick.

84. (434) *Juniperus flaccida* Schult.

Mexican Juniper

Plate XCIV, Photos 1—4 and Fig. 74.

A tree growing to a height of 10 to 12 m, it lives in Texas and Mexico. The sections examined cover 17 annual rings; they were prepared of an oldish trunk. The material was kindly put at my disposal by Ing. Rigoberto Vasquez de la Parra, Secretaria de Agricultura y Gañaderia, Mexico.

C. (Photo 1.) Growth ring boundary made discernible by the strong flattening of the late and the larger size of the early tracheids. Width of tracheids 28 to 36 μ, radial dimension 28 to 40 μ in early, 10 to 12 μ in late wood. Sections rounded tetragonal or hexagonal, walls as thick in the late as in the early tracheids. Thin-walled parenchyma cells arranged more or less parallel to the ring boundary in late wood of some annual rings. Rays spaced 2 to 15 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells usually smooth, sparsely pitted. Tangential walls either smooth or thickened rosary fashion. Cells 10 to 20 μ high; cross fields enclose 1 or 2 cupressoid pits of 4 to 5 μ size; marginal fields enclose 3, 4, or 5. Apertures oblique linear or slit-like. Radial dimension of tracheids 28 to 40 μ. Bordered pits of 17 to 18 μ size form uniseriate strings in their walls. Apertures short elliptical, crossed in places. Width of axial parenchyma cells 14 to 15 μ; transverse walls bear one or two nodular thickenings; radial walls exhibit small pits of 7 μ size.

T. (Photos 2, 4.) Rays 1 to 18, typically 8 to 10 cells tall, but rays just 2 to 4 cells tall are also frequent. The taller rays tend to widen to biseriate near middle height. Ray cell height ranges from 10 to 20 μ. Width is 10 μ; transverse walls are comparatively thin; radial walls distinctly so. Transverse walls locally exhibit one or two transverse laths (trabeculae? awns?). Tangential dimension of tracheids 28 to 36 μ; late tracheids tend to have numerous bordered pits of 9 to 10 μ size, in their walls. Apertures circular or short slits, locally crossing. Tangential dimension of axial parenchyma cells 34 to 35 μ; transverse walls thickened rosary fashion; tangential walls locally exhibit a few simple pits.

85. (435) *Juniperus isophyllos* C. Koch

Plate XCV, Photos 1—4 and Fig. 75.

A sample of this shrub living in the Caucasus was kindly provided by Professor Daniel Trankovsky of the Botanical Institute of Moscow University.

C. (Photo 1.) The bough about 1 cm thick included 8 annual rings. Ring borders discernible but not conspicuous; early wood passes gradually into late wood. Tracheid width 18 to 20 μ; radial dimension 18 to 20 μ in early, 10 to 12 μ in late wood. Sections somewhat angular in most places, rounded elsewhere. Lumina of latest tracheids almost gash-like. Parenchyma cells scattered over the annual rings, disposed in the vicinity of and largely parallel to the ring boundary. They are filled with a golden granulate substance. Rays uniseriate, comparatively close-spaced.

R. (Photo 3.) Ray cells 17 to 18 μ high. All ray cell walls thick and pitted; tangential walls thickened in the rosary or dentate fashion. Most cross fields enclose two cupressoid pits one above the other; marginal fields or fields in taller ray cells enclose 3 or 4, disposed in the corners. In the radial walls of the tracheids, bordered pits of 10 to 11 μ size form loose uniseriate strings. Cross fields between axial and ray parenchyma cells bear several simple pits.

T. (Photos 2, 4.) Rays to 8 cells tall; rays of 10 cells are very rare indeed. Cell height 17 to 18 μ, width 14 to 16 μ typically. Tangential walls smooth or thickened in the reticulate or scalariform fashion. End walls of axial parenchyma cells slightly nodose or pitted. Tracheid walls locally bear small bordered pits of 8 to 10 μ size.

86. (436) *Juniperus lucayana* Britt.

Red Cedar

Plate XCVI, Photos 1—4 and Fig. 76.

This tree of the Bahamas grows to a height of 10 to 12 m. The sections examined, covering 12 annual rings, were cut from a thick trunk. The material was kindly provided by Mr. C. M. Smith of the Smithsonian Institution, Washington.

C. (Photo 1.) Annual ring boundaries distinct. Late wood, 4 or 5 tracheids wide, occupies one-eighth or one-tenth of each ring. The entire ring may be up to 50 tracheids wide. Radial dimension of tracheids 35 to 40 μ in early, 8 to 10 μ in late wood. The lumina of the latter are narrow gashes. There is no discernible change in tracheid wall thickness across the ring boundary. Sections generally isodiametric, rounded tetragonal or hexagonal. Axial parenchyma cells mostly solitary, most often disposed terminally in late wood. Rays spaced 1 to 15 μ tracheids apart.

R. (Photo 3.) Transverse walls of ray cells usually smooth, sparsely pitted locally. Tangential walls smooth or slightly thickened rosary fashion; there are indentures where they join the transverse walls. The latter are locally split apart. Ray cells 20 to 21 μ high; cross fields most often enclose 2 cupressoid pits in the early and one in the late wood. Pit size 7 μ; apertures short elliptical, in the minor axis of the chamber. Marginal fields sometimes enclose 3 or 4 pits. Tracheids are 35 to 40 μ wide; in their walls there are loosely disposed bordered pits of 19 to 20 μ size with circular apertures of 6 μ diameter. Axial parenchyma cells 5 to 6 μ wide, with small pits of 3·5 μ size in their radial walls. The thick axial walls bear 1 or 2 pits.

T. The tangential structure is shown in Photos 2 and 4.

87. (437) *Juniperus oblonga* M. B.

Plate XCVII, Photos 1—4 and Fig. 77.

This species lives in Kashmir and the Caucasus. The sections examined were cut from a bough 1 cm thick and 8 years old, kindly provided by Professor D. Trankovsky of the Botanical Institute of Moscow University.

C. (Photo 1.) Annual ring boundaries sharp; the late wood comprises one-third or one-half of the rings; it emerges gradually from the early wood. Walls of late tracheids significantly thickened; early tracheids thin-walled with unrounded tetragonal sections. Tracheid width 14 to 20 μ; radial dimension 18 to 20 μ in early, 5 to 6 μ in late wood; the lumina of the late tracheids are gash-like. At the beginning of certain late bands, the axial parenchyma cells are more or less cylindrically disposed. They are filled with a dark resinous substance.

R. (Photo 3.) Ray cell height 20 to 25 μ. In the transverse walls, simple pits are fairly abundant. These walls are split apart locally. The tangential walls exhibit 3 to 5 rosary-like thickenings. This type of thickening occurs also in the transverse walls. Indentures are scarce. Cross fields most often enclose pairs of circular pits, one above the other; marginal fields enclose three, or locally six in two vertical rows. Pit size is 5 to 5·5 μ. Radial dimension of tracheids 18 to 20 μ in early, 11 to 12 μ in late wood. Their walls bear bordered pits of 11 to 12 μ size with circular apertures. Radial dimension of the highly elongate axial cells 14 μ. Their radial walls exhibit small circular pits. Transverse walls slightly nodose.

T. (Photos 2, 4.) Rays 1 to 10 cells tall; rays taller than that are exceptional. Solitary and marginal cells 24 to 25 μ high; internal ones slightly lower (20 μ); all about 10 μ wide. Tangential walls exhibit scalariform or reticulate thickenings. Tracheids 14 to 20 μ wide; bordered pits in their tangential walls are few and far between. Transverse walls of axial parenchyma cells exhibit 2 or 3 nodular or uneven thickenings. The small pits in their tangential walls are of 5 to 6 μ size.

88. (438) *Juniperus polycarpos* C. Koch

Plate XCVIII, Photos 1—4 and Fig. 78.

This tree lives in Kashmir and in the Caucasus. The section examined cover 16 annual rings. The material, a trunk slice, was kindly provided by Professor D. Trankovsky of Moscow.

C. (Photo 1.) Annual rings comparatively narrow, 8 to 20 tracheids wide; ring boundaries sharp. Late wood up to 5 tracheids wide, sharply distinct from early wood. Tracheid sections most often slightly rounded tetra- or hexagonal, forming clearly defined rows. Tracheid width 25 to 32 μ; radial dimension 25 to 35 μ in early wood, only 7 to 8 μ in late wood at the ring boundary. Late tracheids have gash-like lumina. Axial parenchyma cells scattered in some annual rings, with a preference for the late wood, terminally arranged in others. Rays spaced 2 to 15 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells 3 to 4 μ thick, with numerous simple pits. Tangential walls locally smooth but most often with 3 to 5 rosary-like thickenings. There are distinct indentures where they join the transverse walls. Cross fields most often enclose 1 or 2 cupressoid pits; marginal fields enclose 3 or possibly 4. Pit size is 6 to 7 μ; apertures are oblique. Tracheids are 25 to 35 μ wide. Their radial walls bear uniseriate rows of bordered pits of 14 μ diameter with circular apertures. Axial parenchyma cells 8 to 10 μ wide. Transverse walls bear one or two nodes. Radial walls exhibit a few small pits of 6 to 7 μ size.

T. (Photos 2, 4.) Rays 1 to 12, but typically 1 to 3 and 6 to 7 cells tall. Ray cells 23 to 24 μ high, 10 to 14 μ wide; internal cells somewhat lower, with more or less circular outlines. Tracheids 25 to 32 μ wide. In the tangential walls of the late tracheids, small bordered pits of 6 to 7 μ size are fairly frequent. Their apertures are crossed here and there. Transverse walls are 3 to 4 μ thick; tangential walls exhibit reticulate thickenings or 2 or 3 transverse ladders. Transverse walls of axial parenchyma cells nodose, or thickened rosary or cask fashion. Thin and smooth walls are exceptional.

89. (439) *Juniperus pseudosabina* Fisch and Meyer

Plate XCIX, Photos 1—4 and Fig. 79.

This shrub living in the Altai Mountains and in the Turkestan resembles *Juniperus sabina* in habit. The bough fragment 7 to 8 mm thick examined by us derives from the Botanical Institute of Moscow University.

C. (Photo 1.) The bough examined comprises 25 or 26 annual rings. Ring boundaries distinct. Ring width ranges from 4 to 20 tracheids. Tracheid sections rectangles or hexagons, radially somewhat flattened. Width is 16 to 18 μ; radial

dimension is 14 to 16 μ in the early and 6 to 8 μ in the late wood. Lumina of late tracheids almost gash-like. Parenchyma cells scarce, filled with a golden substance, scattered in the late wood, locally in rows parallel to ring boundary. Rays uniseriate; their walls frequently exhibit simple pits.

R. (Photo 3.) Ray cells 16 to 17 μ high; walls 3 1/3 μ thick, with several simple pits. Most cross fields enclose 2 or 2×2 or 3 pits, in vertical pairs or rows. The tangential walls exhibit rosary-like or dentate thickenings. Tracheid walls exhibit loose uniseriate strings of bordered pits of 8 to 9 μ size, most often with circular openings. End walls of axial parenchyma cells nodose or thickened in the middle. The cross fields between axial and ray parenchyma cells exhibit 3 or 4 small simple pits.

T. (Photos 2, 4.) Rays 1 to 10, typically 4 to 6 cells tall. Cells 16 to 17 μ high, tangential walls locally exhibit scalariform or reticulate thickening. Ray cell walls comparatively thick (4 to 5 μ), with several simple pits. End walls of axial parenchyma cells nodularly thickened.

90. (440) *Juniperus sargentii* (Henry) Takeda

Plate C, Photos 1—4 and Fig. 80.

This is a shrub living in the Kurdistan (Middle East). The sample examined, a bough section 6 mm thick comprising 17 annual rings, derives from the Herbarium of the Botanical Institute of Moscow University.

C. (Photo 1.) Annual ring boundaries sharp; ring width ranges from 8 to 30 tracheids. The late wood occupies a width of 6 to 8 tracheids. Tracheid width 20 to 22 μ; radial dimension about the same in the early wood. Sections of late tracheids radially compressed rectangular; lumina thin gashes. Early tracheid walls 3 to 4 μ thick. Parenchyma cells filled with a dark resinous substance fairly abundant in annual rings, frequently forming palisades parallel to the ring boundaries in the vicinity of the late bands. Rays uniseriate, comparatively close-spaced (2 to 16 tracheids apart).

R. (Photo 3.) Ray cells 16 to 17 μ high; all walls thick and pitted; tangential walls exhibit dentate and even more often rosary-like thickenings. Most cross fields enclose 2 or 3 cupressoid pits of 3 to 4 μ size in vertical rows. Marginal fields may enclose 4 and even 6 pits in two rows. Cross fields between axial and ray parenchyma cells enclose several small simple pits. Indentures frequent. In radial walls of tracheids, bordered pits form loose uniseriate strings. Pit size 11 to 12 μ; apertures circular.

T. (Photos 2, 4.) Rays 1 to 7 cells tall. Ray cells 11 to 12 μ wide. Tangential walls locally pitted or reticularly thickened. End walls of axial parenchyma cells smooth or slightly nodose. Tangential walls bear small round simple pits. In the tracheid walls there are a few scattered bordered pits of 6 to 8 μ size.

91. (441) *Juniperus shugnanica* Kom.

Plate CI, Photos 1—4 and Fig. 81.

This species inhabits Kashmir and Eastern Asia.

The sample kindly provided by the Botanical Institute of Moscow University was a bough about 15 years old and 6 mm thick.

C. (Photo 1.) Annual rings comparatively narrow, 10 to 15 tracheids wide. Ring boundaries discernible. Late wood most often 4 to 5 tracheids wide. Some rings lack axial parenchyma cells; others abound in scattered or terminally disposed ones. Tracheid sections most often tetragonal with slightly rounded corners. Both radial dimension and width 18 to 22 μ. Late tracheids strongly compressed radially, lumina almost gash-like. Rays spaced 2 to 25 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells often abundantly pitted. Tangential walls show rosary-like or dentate thickenings. Cross fields enclose one or possible two pits one above the other; marginal fields tend to enclose three in a vertical row. Pit size 5 to 6 μ; apertures oblique. Tracheids are 18 to 22 μ wide; their walls exhibit relatively few bordered pits of 13 to 14 μ size. Width of axial parenchyma cells 7 to 10 μ; their transverse walls, 3 to 4 μ thick, bear one or two nodes.

T. (Photos 2, 4.) Rays 1 to 10 cells tall; the height range of 1 to 3 cells is fairly frequent. Ray cells 18 to 22 μ high, 10 to 11 μ wide; tangential walls exhibit reticulate or scalariform, typically juniperoid thickenings. Tracheid width 18 to 20 μ; tangential walls exhibit loose uniseriate strings of bordered pits of 6 to 7 μ size. Walls of late tracheids exhibit a marked spiral striation. Transverse walls of axial parenchyma cells pitted, with 1 to 4 thickenings. Their tangential walls tend to exhibit small circular or short elliptical pits of 6 to 7 μ size.

92. (442) *Juniperus semiglobosa* Rgl.

Plate CII, Photos 1—4 and Fig. 82.

A sample of this tree living in Kashmir and further to the East was kindly provided by Professor D. Trankovsky of the Botanical Institute of Moscow University. The sections examined cover several annual rings.

C. (Photo 1.) Annual rings of varied width (30 to 120 tracheids). Ring boundary conspicuous, although the tracheid wall thickness does not change across it. Section tetra- or hexagonal; corners slightly rounded, lumina more so, particularly in the late wood. Radial dimension of early tracheids 18 to 20 μ; width about the same. Late tracheids radially flattened, with gash-like apertures. Xylem parenchyma cells filled with a dark substance, most often disposed in the late wood, parallel to the ring boundary. Rays spaced 3 to 30 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells remarkably thick (5 to 6 μ), bearing numerous simple pits. Tangential walls exhibit 1 to 5 dentate or rosary-like

thickenings. There are definite indentures. Most cross fields enclose 2 cupressoid pits, but some enclose only one and the marginal cells tend to enclose 3 to 6. Ray cells 18 to 22 μ high. Outer walls of marginal cells locally undulous. Radial dimension of tracheids 18 to 20 μ. Their walls exhibit uniseriate strings of bordered pits of 12 to 13 μ size. Apertures circular or short elliptical. Transverse walls of axial parenchyma cells exhibit one or two nodular thickenings; radial walls bear simple pits of 5 to 6 μ size and circular or procumbent elliptical shape.

T. (Photos 2, 4.) Rays 1 to 8, typically only 3 or 4 cells tall. Ray cells typically 18 to 22 μ high and 17 to 18 μ wide, that is, almost isodiametric in outline. Tangential walls smooth or thickened reticularly, that is, in the juniperoid fashion. Tangential dimension of tracheids 18 to 20 μ. Late tracheids exhibit a few bordered pits of 7 μ size. Transverse walls of some axial parenchyma cells smooth; others exhibit rosary-like or cask-shaped thickenings. Their tangential walls show a few scarce simple pits of 6 to 7 μ size, with slightly oblique apertures.

93. (443) *Juniperus seranschanica* Kom.

Plate CIII, Photos 1—4 and Fig. 83.

The sections of this species living in Kashmir and further to the East were prepared of a bough 7 years old, a sample provided by the Botanical Institute of Moscow University.

C. (Photo 1.) Annual ring 15 to 25 tracheids wide. Ring boundaries distinct; late wood 6 to 8 tracheids wide. Early tracheids 18 to 22 μ wide and of about the same radial dimension. Latest tracheids flattened, with almost gash-like lumina. Wall thickness does not change from the early to the late wood, however. Xylem parenchyma cells rather frequent in the annual rings, mostly scattered, but some of them are arranged more or less terminally. Rays uniseriate, spaced 3 to 15 tracheids apart.

R. (Photo 3.) Transverse walls of ray cells comparatively thick (5 to 6 μ for the double wall), with numerous simple pits. Tangential walls thickened, most often in the dentate fashion; indentures definite. Cross fields enclose 2 or 3 pits one above another; marginal fields tend to enclose 4 or possibly 6 in two vertical rows. The small cupressoid pits measure 5 to 6 μ. Tracheid size 18 to 22 μ; the walls exhibit bordered pits in loose uniseriate strings. Pit size 14 to 15 μ; apertures circular. Transverse walls of axial parenchyma cells slightly nodose. Radial walls bear small simple pits of 5 to 6 μ size.

T. (Photos 2, 4.) Rays 1 to 6, typically 2 to 3 cells tall. Ray cells 17 to 18 μ high; internal ones somewhat lower; width 8 to 9 μ; transverse walls much thicker than radial ones. Tangential walls exhibit several simple pits or scalariform juniperoid thickening. Tracheids 20 to 22 μ wide. Their walls exhibit scattered small bordered pits of 6 to 7 μ size.

Transverse walls of axial parenchyma cells show 1 to 3 nodose thickenings. Tangential walls bear small pits of 5 to 6 μ size.

94. (444) *Juniperus sibirica* Burgsd.

Plate CIV, Photos 1—4 and Fig. 84.

This plant lives in Kashmir, the Caucasus, East Asia and Sibiria. The sections were prepared of an old trunk slice that included 45 annual rings in a width of 1 cm. The material examined derives from the Botanical Institute of Moscow University.

C. (Photo 1.) Annual ring boundaries sharp; the rings are 6 to 20 tracheids wide. The late wood occupies a width of just 3 or 4 tracheids. Tracheid sections angular; width of early tracheids 18 to 28 μ; radial dimension 22 to 24 μ. Late tracheids flattened with gash-like lumina. Xylem parenchyma cells very scarce, one or two per annual rings. Rays uniseriate, rather wide-spaced.

R. (Photo 3.) Ray cells 16 to 20 μ high, transverse walls thick and copiously pitted, locally split apart. Tangential walls thickened rosary or dentate fashion. There are distinct indentures. Most cross fields enclose one circular pit of 6 to 8 μ size, but some enclose two; marginal fields enclose four and possibly six. Radial dimension of tracheids 22 to 24 μ. Bordered pits of 13 to 14 μ size form loose uniseriate strings in their walls. Apertures circular. Axial parenchyma cells very rare also in this view.

T. (Photos 2, 4.) Rays 1 to 8, exceptionally 10 cells tall; typical height is 3 to 5 cells. Ray cells 16 to 20 μ high, 7 to 8 μ wide; transverse walls relatively thick, tangential walls thickened in the reticulate or scalariform, juniperoid fashion. Tracheids 18 to 28 μ wide; their walls exhibit scarce bordered pits of 8 to 9 μ size, with slit-like apartures locally crossed. The scarce axial parenchyma cells exhibit 1 to 4 rosary-like or dentate thickenings in their transverse walls and scarce simple pits of 6 to 7 μ size in their tangential walls.

95. (445) *Juniperus thalassica* Lipsky

Plate CV, Photos 1—4 and Fig. 85.

This plant lives in Kashmir and East Asia. The sections examined were prepared of a thickish trunk slice that included 7 annual rings in a width of 1 cm. The material was provided by the Botanical Institute of Moscow University.

C. (Photo 1.) Annual rings of varied width, typically 50 to 60 tracheids wide. Ring boundaries sharp; late wood 3 to 5 tracheids wide. Tracheid wall thickness unchanged across the ring boundary. Tracheid sections angular, tetra- or hexagonal. Radial dimensions 25 to 35 μ; width 20 to 24 μ. Axial parenchyma cells prefer the vicinity of the late wood where they occur scattered or in palisades parallel to the ring boundaries. Rays spaced 3 to 15 tracheids apart.

R. (Photo 3.) Ray cells 17 to 18 μ high; transverse walls remarkably thick (7 μ), copiously strewn with simple pits. Tangential walls smooth or provided with

1 to 5 bead-like thickenings. There are definite indentures. Transverse walls locally split apart. Cross fields enclose one or, more seldom, two cupressoid pits of 5 to 6 μ size, with oblique slit-like apertures. Marginal fields tend to enclose 3 or 4 pits. Radial dimension of early tracheids 25 to 35 μ. Their walls show rather few bordered pits of 14 μ size with circular apertures. Some tracheids exhibit trabeculae (see left side of upper left part of Fig. 85). Transverse walls of axial parenchyma cells have one or two nodose thickenings; there are small elliptical simple pits in the radial walls.

T. (Photos 2, 4.) Rays 1 to 15, mostly 3 to 7, exceptionally 18 cells tall. Cell height 17 to 18 μ; width 8 to 9 μ; solitary cells may be somewhat higher. Walls uniformly thick. Tangential walls of ray cells often thickened reticularly, but the scalariform juniperoid thickening is also fairly frequent. Tracheid width is 25 to 30 μ. Tangential walls of late tracheids exhibit loose uniseriate strings of bordered pits of 7 to 8 μ size, with circular apertures. Transverse walls of axial parenchyma cells slightly thickened in the nodose or dentate fashion. The simple pits in their tangential walls measure 7 to 8 μ across.

96. (446) *Juniperus turkestanica* Kom.

Plate CVI, Photos 1—4 and Fig. 86.

A tree or shrub growing to a height of 5 to 6 m, living in the Turkestan; it recalls *Juniperus pseudosabina* in its general habit. The sections were prepared of a 6-year-old bough of 7 mm diameter, kindly provided by the Botanical Institute of Moscow University.

C. (Photo 1.) Annual ring boundaries distinct. Rings 50 to 70 tracheids wide: the late wood takes up a width of 5 to 6 tracheids. Sections angular, tetra- or hexagonal. Early tracheids measure 18 to 20 μ in both width and radial dimension. Late tracheids flat, with gash-like lumina. Parenchyma cells sporadically scattered all over the growth ring, with a preference for forming palisades parallel to the ring boundaries near the middle of the rings. Rays uniseriate, spaced 2 to 15 tracheids apart.

R. (Photo 3.) Ray cells 17 to 18 μ thick, transverse walls copiously pitted, locally split apart. Tangential walls bear 3 to 6 bead-like thickenings. Indentures visible. Cross fields enclose 1 to 3 cupressoid pits, most often arranged vertically. Corner fields tend to enclose 3 to 6 pits. Pit size is 5 to 6 μ. Apertures are oblique or almost horizontal, linear. Radial dimension of tracheids 18 to 20 μ; their walls bear sporadic bordered pits of 14 μ size with circular or somewhat oblique elliptical apertures.

Transverse walls of axial parenchyma cells smooth or with 1 to 3 nodular thickenings.

T. (Photos 2, 4.) Rays 1 to 12, exceptionally up to 18 cells tall. The tallest rays exceptionally widened to biseriate at middle height. Ray cells 17 to 18 μ high,

7 to 8 μ wide. Transverse walls relatively thin (4 μ for double wall), radial walls thin, tangential walls thickened in the scalariform, juniperoid fashion. Tangential dimension of tracheids 18 to 20 μ; late tracheids exhibit loosely arranged bordered pits of 14 μ size with circular apertures.

The tangential walls of the axial parenchyma cells bear simple pits of 7 μ size.

97. (447) *Juniperus turcomanica* B. Fedtch.

Plate CVII, Photos 1—4 and Fig. 87.

The sections of this Kashmiri and East Asian plant were prepared of a 7-year-old bough of 6 mm diameter, provided by the Botanical Institute of Moscow University.

C. (Photo 1.) Annual ring boundaries conspicuous in places, almost indiscernible in others. Tracheid sections most often rounded, lumina also circular or elliptical; some early tracheids may have angular tetragonal or hexagonal outlines, however. Early tracheids measure 14 to 15 μ both in width and radially; the width may be slightly more, that is, some radial flattening is possible. Walls equally thick in early and late tracheids. Xylem parenchyma cells often form palisades parallel to ring boundaries. Rays uniseriate.

R. (Photo 3.) Ray cells 17 to 18 μ high. Transverse walls sprinkled with simple pits; tangential walls exhibit rosary-like or dentate thickenings. There are indentures. Cross fields most often enclose two small cupressoid pits of 5 to 6 μ size in a vertical pair. Marginal cells may enclose up to 6 pits in two vertical rows. Several adjacent tracheids may exhibit contiguous-looking trabeculae. Size of early tracheids 14 to 15 μ; their walls bear sparse bordered pits of 12 to 13 μ size. The transverse or oblique end walls of the axial parenchyma cells show one or two nodes. In their radial walls there are 3 or 4 simple pits.

T. (Photos 2, 4.) Rays 1 to 10 cells tall. Ray cells 17 to 18 μ high and 10 to 11 μ wide. The tangential walls are thickened reticularly, or in the scalariform, juniperoid fashion. Tangential size of tracheids 14 to 15 μ; the scarce bordered pits in their walls are of 5 to 6 μ size. The tangential walls of the axial parenchyma cells bear a few simple pits.

98. (448) *Juniperus utahensis* Lemmon

Desert Juniper, Utah Juniper

Plate CVIII, Photos 1—4 and Fig. 88.

A tree or shrub 5 to 6 m high, living in the Rocky Mountains, California, Arizona, New Mexico and the Sierra Nevada. The material examined, a thickish trunk sample, was kindly provided by Ing. Rigoberto Vasquez de la Parra, Secretaria de Agricultura y Gañaderia, Mexico.

C. (Photo 1.) Annual rings 10 to 50 tracheids wide. Boundaries sharp, late wood usually 6 to 10 tracheids wide. Tracheid sections angular, tetra- or hexagonal. Wall thickness the same in early and late tracheids. Radial dimension and width both 17 to 22 μ in early tracheids. Late tracheids slightly compressed radially; lumina slit-like. Parenchyma cells filled with a dark substance fairly numerous, with a preference for an arrangement parallel to the ring boundary in the middle of the annual ring or in the late wood. Rays uniseriate.

R. (Photo 3.) Ray cells 17 to 18 μ high, transverse walls remarkably thick (5 to 6 μ), rather sparsely strewn with simple pits. Tangential walls exhibit 2 or 3 dentate or rosary-like thickenings, as well as indentures. Most cross fields enclose one cupressoid pit, but some enclose two. Elliptical chambers oblique, with an aperture of 5 to 6 μ size in its minor axis. Other cross fields exhibit one or two circular or elliptical pits. Some marginal fields enclose four pits, one in each corner. Radial dimension of early tracheids 17 to 22 μ, apertures circular. Transversal walls of axial parenchyma cells slightly nodose, their radial walls include a few simple pits of 5 to 6 μ size.

T. (Photos 2, 4.) Rays 1 to 18, typically 2 to 7 cells tall. Ray cells 17 to 18 μ high and about as wide; sections circular or low elliptical. All walls uniformly thick; tangential walls with reticular or scalariform, juniperoid thickenings. Tangential dimension of tracheids 17 to 22 μ. Late tracheids exhibit few bordered pits of 13 to 14 μ size with circular apertures. The transverse walls of axial parenchyma cells bear 3 or 4 bead-like thickenings. In the tangential walls there are several simple pits of 6 to 7 μ size.

99. (449) *Libocedrus arfakensis* Gibbs.

Plate CIX, Photos 1—4 and Fig. 89.

This is a tree growing to a height of 20 to 25 m in the Arfak Mountains of New Guinea. The material in hand was kindly provided by Mr. J. S. Womersley, Department of Forests, Lae, Territory of Papua and New Guinea. The sample from which the sections were cut was a piece of a thick trunk.

C. (Photo 1.) There are no discernible annual ring boundaries. No early and late wood can be distinguished: it is merely the disposition of the axial parenchyma cells that suggests some periodicity. Tracheid sections rounded tetragonal or hexagonal. Sizes varied; radial dimensions range from 30 to 55 μ; there are in places rows of small and large tracheids running side by side. Tracheid widths range from 30 to 50 μ. Thin-walled axial parenchyma cells are scattered in the annual rings, filled with a dark substance. Rays uniseriate, spaced 3 to 20 tracheids apart.

R. (Photo 3.) Ray cells 22 to 26 μ high; some internal cells may be much lower, though. All walls smooth and thin; transverse walls fairly often split apart. Most cross fields enclose one or two cupressoid pits of 8 to 9 μ size; marginal fields

tend to enclose 3 or 4. The pits are circular or elliptical with oblique slits for apertures. Radial dimension of tracheids 30 to 55 μ. Their walls exhibit loose uniseriate, sometimes biseriate strings of bordered pits of 15 to 16 μ size, with circular or short elliptical apertures.

Transverse walls of axial parenchyma cells smooth or slightly nodose. Cross fields between axial and ray parenchyma cells unpitted or provided with pits without apertures, only the chambers of which are visible.

T. (Photos 2, 4.) Rays 1 to 25, typically 8 to 10 cells tall. Tallest ones locally widen to biseriate at middle height. Ray cells 22 to 26 μ high; some internal cells may be lower than that. Width 10 to 12 μ; all walls smooth and thin, unpitted.

Tangential dimension of tracheids 30 to 50 μ; their walls exhibit a few sporadic bordered pits of 10 to 12 μ size. Transverse walls of axial parenchyma cells either smooth or uneven or slightly nodose. Tangential walls bear sparse simple pits of 9 to 10 μ size.

100. (450) *Libocedrus papuana* F. Mueller

Plate CX, Photos 1—4 and Fig. 90.

A little known tree, it lives in the Territory of Papua (and Australia?). The material, a piece of a thickish trunk, was kindly put at my disposal by Mr. J. S. Womersley, Department of Forests, Lae, Territory of Papua and New Guinea.

C. (Photo 1.) Annual ring boundary effaced, hardly discernible. There is no change in wall thickness where the late and the early wood meet. Width of tracheids 30 to 35 μ; radial dimension 50 to 60 μ in early, 20 to 25 μ in late wood. Sections rounded tetragonal or vaguely hexagonal. Axial parenchyma cells scarce, scattered all over the annual rings. Rays uniseriate.

R. (Photo 3.) Ray cells 20 to 32 μ high. All walls smooth and very thin, unpitted. Cross fields in early wood enclose 1 to 2 cupressoid pits; marginal fields enclose 4 to 6. Pit size is 7 to 8 μ; apertures are oblique slits. Cross fields between axial and ray parenchyma cells unpitted. Tracheids exhibit bordered pits of 16 to 17 μ size, with circular or short elliptical apertures. Radial dimensions of early tracheids 50 to 60 μ. Transverse walls locally split apart. Tangential walls almost perpendicular to transverse ones. Transverse walls of axial parenchyma cells smooth and thin. Cells 170 to 180 μ long, bearing pits of 10 to 11 μ size with oblique slit-like apertures. In axial walls of tracheids, bordered pits of 19 to 20 μ size form one or two rows.

T. (Photos 2, 4.) Rays 1 to 15 cells tall; ray cells 20 to 32 μ high, 7 μ wide; all walls very smooth and thin. Tangential dimension of tracheids 24 to 26 μ. Walls sparsely strewn with pits of 6 to 7 μ size having oblique slit-like apertures. All walls of axial parenchyma cells smooth and very thin. The tangential walls exhibit some small pits, though.

FAMILY V. TAXODIACEAE

101. (451) *Athrotaxis cupressoides* Don.

Plate CXI, Photos 1—4 and Fig. 91.

This is a tree 5 to 10 m tall living in Tasmania. The sections were prepared of a bough piece 3 cm thick, kindly provided by the Royal Botanical Gardens, Kew, England.

C. (Photo 1.) Annual rings comparatively thin, 5 to 20 tracheids wide. The late wood, 2 to 6 tracheids wide, has but one-fifth or one-sixth of the early wood's width. Radial dimension of tracheids 25 to 35 μ; width about the same. Late tracheids close to the ring boundary flat, with almost gash-like lumina. Xylem parenchyma cells fairly abundant. Rays 1 to 8 tracheids apart. Transverse walls of ray cells smooth, with very sparse simple pits in them. Tangential walls also smooth in most cases.

R. (Photo 3.) Ray cells 17 to 20 μ high; tangential walls smooth, transverse walls somewhat thicker, locally with indentures. Tangential walls locally thinned or pitted. Cross fields of early tracheids exhibit typical taxodioid pits, either one or two in a vertical pair. The marginal fields enclose 3 or 4 such pits of 5 to 6 μ size with oblique apertures. Transverse walls fairly often split apart. Bordered pits uniseriate in the tracheid walls. Pit size 15 to 16 μ; apertures circular. Axial parenchyma cells thin-walled. The ray structure of this wood reveals it to be a close relative of the Cupressaceae.

T. (Photos 2, 4.) Rays 1 to 10, typically 6 to 7 cells tall. Ray cells 17 to 20 μ high, 7 to 8 μ wide. Some marginal cells are higher than the internal ones. Their tangential walls are in most cases entirely smooth, with at most a few small nodes here and there. Transverse walls somewhat thicker than radial ones. Tracheids 25 to 35 μ wide; their walls bear numerous small bordered pits of 7 to 8 μ size, with circular apertures, scattered rather than disposed in rows. Transverse walls of axial parenchyma cells very thin, smooth and unpitted. In their tangential walls there are small circular pits.

102. (452) *Cryptomeria japonica* var. *elegans* (Henkel and Hochst.) Mast.

(*Cryptomeria elegans* Veith, *C. gracilis* Hort.)

Plate CXII, Photos 1—4 and Fig. 92.

This tree up to 40 metres tall, living in Japan, East Siberia and the Caucasus, resembles Cryptomeria japonica in its appearance. The sections examined were prepared of a thickish trunk. Annual rings 3 to 8 mm wide; pseudo-rings 1 to 2 μ wide. The material investigated was kindly put at my disposal by Professor E. Bobrov of the Museum of the Institute of Botany, Leningrad.

C. (Photo 1.) Annual ring boundaries sharp; early and late wood clearly distinct. Late wood 10 to 30 tracheids wide, which suggests a highly variable climate. Tracheid sections tetra- or hexagonal, with slightly rounded corners in the early tracheids. Width 30 to 35 μ; radial dimension 40 to 50 μ in early, 15 to 20 μ in late wood. Thin-walled axial parenchyma cells, fairly numerous, scattered in the late wood, especially near the ring boundary. Rays uniseriate, spaced 1 to 10 tracheids apart.

R. (Photo 3.) In the transverse walls of the ray cells, simple pits are fairly abundant. Tangential walls thin, usually smooth, but some bear very fine small rosary-like thickenings. Transverse walls locally split apart. Ray cells 18 to 20 μ high; marginal ones somewhat higher. There are some not too pronounced indentures. Cross fields enclose 1 or 2 taxodioid small pits; marginal fields enclose 3 or possibly 4. Major axis 10 to 11 μ long; apertures procumbent elliptical, with a narrow chamber showing on the top and bottom side. In the radial walls of the tracheids there are solitary bordered pits spaced 3 to 10 pit diameters apart, also somewhat closer-spaced near the ends of the tracheids. Pits strictly uniseriate. Their size is 17 to 18 μ; their apertures are circular.

Axial parenchyma cells typically 170 to 200 μ long, 20 to 22 μ wide; the transverse walls may be lenticularly thickened or slightly pitted. The radial walls bear some sparse small round pits of 6 to 7 μ size.

T. (Photos 2, 4.) Rays 1 to 12, typically 3 and 6 cells tall. Ray cell sections most often upright ellipses typically 18 to 20 μ high. Width in the same range. Transverse walls exhibit simple pits; so do, in places, also the radial walls. The tangential walls of the tracheids exhibit very scarce bordered pits or none at all. Transverse walls of axial parenchyma cells usually smooth, sometimes nodose. The entire wood structure much resembles that of *Sequoia gigantea*, the only difference being in the transverse and tangential wall structures of the axial and ray parenchyma cells.

103. (453) *Cryptomeria japonica* var. *sinensis* Sieb. and Zucc.

(*Cryptomeria fortunei* Hooibrenk)

Plate CXIII, Photos 1—4 and Fig. 93.

A giant tree up to 50 m tall living in China, it is fundamentally a variety of *Cryptomeria japonica*. The sections were prepared of a thick trunk. The sample was kindly provided by Professor Tsun Ching Cheng, Institute of Forest Products, Peking, China.

C. (Photo 1.) Annual rings thick, up to 8 mm (150 tracheids) wide. Ring boundaries conspicuous. Radial dimension of tracheids 70 μ in early, 10 to 12 μ in late wood. Width of early tracheids 35 μ, that of late tracheids only 28 to 30 μ. Late tracheids thick-walled with lumina following cell outline. Tracheid sections

tetra- or hexagonal, more angular than rounded. Parenchyma cells arranged more or less parallel to ring boundaries are frequent in the early and especially in the late wood. Rays uniseriate, seldom biseriate, spaced 3 to 15 tracheids apart. Transverse and tangential walls both smooth.

R. (Photo 3.) Transverse walls of ray cells uniformly thick (3 μ), but locally thinned in a way recalling a pitting. Tangential walls invariably smooth. No indentures.

Most ray cells 18 to 20 μ high. Cross fields usually enclose one or two pits of 7 μ size, with oblique apertures, almost cupressoid in disposition. Marginal cross fields may enclose 3 or 4 pits. The bordered pits with round apertures in the tracheid walls are of 17 to 18 μ size.

Tracheid width 10 to 70 μ. This tree almost fully agrees in ray structure with *Cryptomeria japonica* s.s. The transverse walls of its axial parenchyma cells are smooth or nodose, however; in this respect ir rather resembles *Sequoia gigantea*, so that it is fairly difficult to distinguish the two xylotomically. This resemblance is further enhanced by the circumstance that the transverse walls of the axial parenchyma cells tend to exhibit the discus-like thickenings so typical of *Sequoia gigantea*. Also, taxodioid pits are fairly frequent in the early cross fields. It is thus not by far impossible that some of the Tertiary fossils identified as *Sequoia gigantea* should in fact have been specimens of *Cryptomeria japonica*, provided no cones or leaves were found together with the trunks.

T. (Photos 2, 4.) Rays 1 to 32 cells tall: this is a distinct difference from *Cryptomeria japonica* s.s. whose rays are rather low, seldom attaining a height of 10 cells. This might be due to an age difference, however. Rays generally uniseriate, but some are uniseriate in half their height and biseriate in the other half. Indeed, some rays are entirely biseriate. Ray cells are 15 to 35 μ high; some internal ones measure only 15 to 20 μ, though. Typical width is 17 to 20 μ. Tangential walls smooth.

104. (454) *Cunninghamia konishii* Hayata

Plate CXIV, Photos 1—4 and Fig. 94.

A tree up to 40 m tall, it lives on Taiwan in the company of *Cunninghamia lanceolata* and *Taiwania cryptomerioides*. The sections were prepared of an oldish trunk. The sample was kindly provided by Mr. C. M. Smith, of the Smithsonian Institution, Washington, U.S.A.

C. (Photo 1.) Annual ring boundaries distinct; rings comparatively narrow (15 to 40 tracheids). Tracheid width 30 to 50 μ; radial dimension 45 to 50 μ in early, only 10 to 12 μ in late wood. Late tracheids thick-walled with gash-like lumina. Parenchyma cells scattered all over early and late wood, filled with a darkish substance. Rays spaced 3 to 15 tracheids apart.

R. (Photo 3.) Transverse walls of most ray cells smooth, but some bear simple

pits. Tangential walls smooth and thin, however. Ray cells 24 to 26 μ high; internal cells somewhat lower. Cross fields enclose one pit or two, forming a vertical or transverse pair. Pit size 6 to 7 μ; apertures almost vertical. Marginal fields tend to enclose 3 or 4 cupressoid pits. The bordered pits in the tracheid walls are of 14 to 16 μ size. Apertures circular or short upright elliptical. Some bordered pits in the tracheid walls form transverse pairs. Some pairs even exhibit a Sanio line between them. Transverse walls of axial parenchyma cells smooth and thin; there are in their radial walls scattered small pits of 7 μ size. Transverse walls of ray parenchyma cells locally split apart. Cross fields between axial and ray parenchyma cells usually enclose several small pits.

T. (Photos 2, 4.) Rays 1 to 15, typically 8 to 10 cells tall, with biseriate sections spanning 4 to 5 cells in the tallest ones. Ray cells 24 to 26 μ high; internal cells somewhat lower. Transverse walls thicker than radial ones; tangential walls rather thin. Tracheid width 30 to 50 μ; bordered pits of 7 μ diameter are rather scarce in their tangential walls. Transverse walls of radial parenchyma cells slightly thickened in the nodular fashion, with up to 5 nodes. Tangential walls bear small pits of 7 μ size.

FAMILY VI. PINACEAE

105. (455) *Abies borisii-regis* Mattfels

(*Abies alba* Miller v. *acutifolia* Turill.)

Plate CXV, Photos 1—4 and Fig. 95.

This tree up to 45 metres tall living in the Rhodope and Atlas Mountains is according to Dallimore (1925) a variety of *Abies alba*, whereas Gaussen (1964) considers it a separate species. In many respects it resembles *Abies cephalonica* and *Abies alba*. The sections examined were prepared of a bough of about arm thickness cut off one of the specimens in the Botanical Gardens of Bucharest.

C. (Photos 1, 2.) Annual ring width varied. Ring boundaries sharp; late and early wood distinct; most of the ring is made up of late wood. Tracheid width 20 to 30 μ; radial dimension about the same in early wood, but only 5 to 6 μ in late wood. Lumina of the latter almost gash-like; lumina of early tracheids rounded, elliptical or circular. Some rings enclose thick-walled axial parenchyma cells disposed almost terminally, at the ring boundary, whereas some other rings include no axial parenchyma at all. Rays uniseriate, with numerous simple pits in their transverse walls.

R. (Photo 3.) All walls of ray cells remarkably thick and densely pitted. Transverse double wall 9 to 10 μ thick; it bears numerous simple pits. Tangential walls exhibit 3 or 4 dentate thickenings and indentures at their ends. The cross fields enclose one small pit, or two, most often in a vertical pair. The marginal cells

usually enclose 2 or 3 pits in vertical rows. Pit size is 3 to 4 μ. There are narrow crescent-shaped chamber areas on either side of the apertures. Outer walls of marginal cells tend to be undulous. Bordered pits of 13 to 14 μ size form very loose uniseriate strings in the radial walls of the tracheids. Radial walls of axial parenchyma cells bear small round pits.

T. (Photo 4.) Rays 1 to 18, typically 8 to 10 cells tall. All walls of ray cells thick and pitted. Cells 17 to 18 μ high, 10 to 11 μ wide. Their tangential walls tend to exhibit a reticulate pitting. The marginal cells of some rays are much higher than the internal ones. Tangential dimension of tracheids 20 to 30 μ. Bordered pits of 10 to 11 μ size form uniseriate strings in their walls. Small simple pits are numerous in the tangential walls of the axial parenchyma cells; their transverse walls are dentate.

106. (456) *Abies delavayi* Franchet

(*Abies fargesii* Mast. non Franchet)

Delavay Fir

Plate CXVI, Photos 1—4 and Fig. 96.

Living in Southwest Szechwan, China, this is a tree up to 30 m tall. The sections were prepared of an oldish trunk, a sample kindly provided by Mr. G. H. Yu of the Academia Sinica, Peking, China.

C. (Photo 1.) Annual ring boundaries distinct. The early wood gradually passes into the late wood which is just 3 to 6 tracheids wide. Most rings have a width of 30 to 70 tracheids. Early tracheid diameter 30 to 40 μ. Annual ring fields exhibit a few scattered axial parenchyma cells. Rays uniseriate, spaced 2 to 15 tracheids apart. Tangential walls thickened dentate fashion.

R. (Photo 3.) Transverse walls of ray cells strongly pitted; tangential walls thickened rosary or dentate fashion. Most cross fields enclose 1 or 2 simple pits of 6 to 8 μ size; marginal fields locally enclose 3 or 4. Chamber round; the narrow aperture reaches clear across the chamber and is almost vertical. There are no transverse tracheids. $5 \times 10 = 50$ cross fields usually enclose 60 to 65 simple pits.

T. (Photos 2, 4.) Rays 1 to 35 cells tall; the taller ones locally widen to biseriate. Sections of ray cells short elliptical, 14 to 24 μ high. Their tangential walls bear 6 to 12 simple pits. The late wood is rich in axial parenchyma cells whose transverse walls are dentately thickened. The small bordered pits in the tangential walls of the late tracheids are scattered or arranged in axial rows. Their size is 6 to 7 μ; their apertures are circular.

The structure of this wood much resembles that of *Abies fargesii*: there is hardly any difference between them.

107. (457) *Abies fargesii* Franchet

Farges Fir

Plate CXVII, Photos 1—4 and Fig. 97.

This Chinese tree is frequent in Hopeh but occurs also in East Szechwan. The sections were cut of an oldish trunk. The sample was kindly put at my disposal by Mr. G. H. Yu, Academia Sinica, Peking, China.

C. (Photos 1, 2.) The cross-sectional structure resembles that of *Abies delavayi* so much that it is hardly possible to tell them apart xylotomically.

R. (Photo 3.) The radial section resembles that of *Abies delavayi*, although there is a difference in the mean number of pits per cross field. Whereas in Abies delavayi there are 60 to 65 pits in a cross field area of $5 \times 10 = 50$ fields, there are slightly more (70 to 75) in over the same area in *Abies fargesii*. This figure is not constant, however. One cross field encloses 1 to 4, seldom 5 pits of 5 to 8 μ size. Tracheid size is 27 to 40 μ; bordered pits form uniseriate strings in their walls. Pit diameter is 17 to 18 μ; apertures are round. Ray cell walls exhibit indentures. The axial parenchyma cells are 190 to 200 μ long, 10 to 12 μ wide. Their radial walls bear small round pits.

T. (Photo 4.) The tangential view is the only one to exhibit some differences from the other species. There are no biseriate rays at all. Rays are 1 to 25, typically 10 to 12 cells tall. The cells are 12 to 30 μ high, 8 to 10 μ wide. Sections are somewhat elongate elliptical. There are some 6 to 8 simple pits in their tangential walls. The small bordered pits in the tangential walls of the tracheids are of 7 to 8 μ size. Xylem parenchyma very scarce.

All in all, the two species are hard to distinguish on a xylotomical basis; it is only a comparison of ray cell height variances that would presumably solve the problem.

108. (458) *Abies faxoniana* Rehder and Wilson

(*Abies fargesii* Pax non Frau.)

Faxon Fir

Plate CXVIII, Photos 1—4 and Fig. 98.

This is a tree growing to a height of 20 to 25 m, living in Western Szechwan, China. The sample examined was kindly put at my disposal by Mr. G. H. Yu of the Academia Sinica, Peking.

C. (Photos 1, 2.) In cross section, there is no difference from either *A. fargesii* or *A. delavayi*, except perhaps that there is no xylem parenchyma at all, in the

sections examined. The earliest tracheids are 45 to 60 μ wide. The late wood comprises a width of only 4 to 6 tracheids.

R. (Photo 3.) Ray structure hardly differs from those of the two foregoing species, except perhaps in that most cross fields exhibit two or three pits in a row, single pits being rather rare. Pit size is 6 to 8 μ. Ray cells are 16 to 29 μ high. The outer walls of the slightly higher marginal cells are undulous. The tangential walls are dentately thickened. Most marginal fields include 4 to 6 simple pits, and occasionally also some small calcium oxalate crystals. Pits round, of 5 to 6 μ size. The bordered pits in the tracheid walls are loosely uniseriate, exceptionally biseriate. Pit size is 20 to 22 μ.

T. (Photo 4.) In tangential structure, too, differences from the foregoing two species are slight. Rays are 1 to 22, typically 8 to 10 cells tall, nowhere widened to biseriate. Ray cell sections circular or short elliptical, 16 to 29 μ high, 12 to 16 μ wide. Their tangential walls bear several simple pits. There is no xylem parenchyma in this section, either.

109. (459) *Abies forrestii* Craib.

Forest Fir

Plate CXIX, Photos 1—4 and Fig. 99.

This is a tree growing to a height of 20 to 40 m, living in Yunnan Province, China. The sections were prepared of a bough 2 cm thick, kindly provided by Mr. G. H. Yu of the Academia Sinica, Peking, China.

C. (Photo 1.) In cross sectional structure it resembles the rest of the *Abies*. The late band occupies a width of 6 to 8 tracheids in the wide growth ring. There is little xylem parenchyma in the annual ring fields.

R. (Photo 3.) Most cross fields enclose one to three small pits, the pit pairs or triplets being usually arranged in vertical rows. The marginal fields may enclose even 6 or 8 pits in two rows. This trait is in some contrast to the species described above. There are locally some xylem parenchyma cells on the annual ring boundary; some of these have small calcium oxalate crystals in their interior. Their radial walls bear pits somewhat smaller than those in the cross fields. They are of 2·5 to 3 μ size. The bordered pits of 14 to 15 μ size in the tracheid walls form loose uniseriate strings.

T. (Photos 2, 4.) It is in the tangential view that this species can be distinguished from the foregoing ones. Rays 1 to 8 cells tall; those of 3 to 6 cells height locally widen to biseriate. Ray cell sections are upright elliptical, 22 to 24 μ high, 14 to 16 μ wide. The small simple pits in their tangential walls are disposed next to the radial walls.

110. (460) *Abies georgei* Orr.

Plate CXX, Photos 1—4 and Fig. 100.

This is a tree up to 30 metres tall living in Western China. The sections were prepared of a bough piece of 3 cm diameter, about 10 to 12 years old, kindly provided by Mr. G. H. Yu of the Academia Sinica, Peking, China.

C. (Photo 1.) Annual rings distinct; the late band, most often 6 to 8 tracheids wide, emerges gradually from the early wood, which latter takes up nine-tenths of the annual ring in most of the cases. Ring width typically ranges from 25 to 80 tracheids. The early tracheids have tetragonal, often square sections: their radial dimension is typically 20 to 25 μ; their width is about the same. Tracheid walls are uniformly thick; wall thickness is virtually unchanged across the ring boundaries. The lumina of the latest tracheids next to the annual ring boundary are often slit-like: the radial dimension is just 10 to 15 μ here. In the late wood there usually are a few scattered xylem parenchyma cells filled with a golden substance. There are no resin ducts in this wood. Rays are uniseriate, with numerous small simple pits in their horizontal walls.

R. (Photo 3.) Ray cells thick-walled; the transverse walls bear numerous simple pits; the tangential walls tend to exhibit 5 or 6 simple dentate thickenings. Cross fields enclose 1 to 3 small borderless pits; marginal fields may enclose up to six. Pit size is 5 to 6 μ; shapes are circular or slightly oblique elliptical. The wood is likely to exhibit indentures and locally also some trabeculae.

The bordered pits of 14 to 15 μ size in the walls of the axial tracheids are very loosely uniseriate, with circular or short elliptical apertures.

T. (Photos 2, 4.) Rays 1 to 8, typically 5 or 6 cells tall. All ray cell walls thick. Cells 17 to 18 μ high. Their tangential walls exhibit several simple pits rendering the walls more or less sieve-like. The tangential sections examined exhibited just a few scarce xylen parenchyma cells. All walls of these, including also their transverse walls, are simply pitted. Bordered pits are absent from or scarce in the tangential walls of the early tracheids. They are of 5 to 6 μ size, with oblique slit-like lumina. In the tracheids of the late wood, the bordered pits are more numerous and closer-spaced, of 4 to 5 μ size, with oblique slits for apertures.

111. (461) *Abies mariesii* Mast.

Abo-momi, Aomori todomatsu, Maries Fir, Aomori Fir

Plate CXXI, Photos 1—4 and Fig. 101.

This is a tree growing to 24 m height in the mountains of Central Japan. The sections were prepared of a thickish trunk with annual rings 6 to 7 mm wide, kindly provided by Mr. Yoshio Saito, The Government Forest Experimental Station, Meguro, Tokyo, Japan.

C. (Photos 1, 2.) The cross sectional structure shows nothing extraordinary. Annual ring boundaries sharp; rings wide; the 20 or so late tracheids emerge by a gradual thickening of walls from the early ones. Radial dimension of early tracheids 27 to 40 μ. Rays spaced 2 to 10 tracheids apart. Xylem parenchyma absent or very scarce.

R. (Photo 3.) In the cross fields there are one or two simple pits; the latter are disposed side by side, even in the early tracheids. Triplets of pits are exceedingly rare. Apertures of the small pits oblique or almost vertical, nowhere horizontal. Ray cells 13 to 18 μ high. Transverse walls sparsely pitted; tangential walls thickened in dentate fashion and provided with indentures. The tracheids have bordered pits of 14 to 16 μ size with circular apertures in their radial walls. No axial parenchyma was detected in this view, either.

T. (Photo 4.) Rays 1 to 25, typically 8 to 12 cells tall, uniseriate. There are some biseriate sections in the tallest rays, though. Sections of ray cells short elliptical, 13 to 18 μ high, 6 to 10 μ wide. Their tangential walls bear several simple pits.

112. (462) *Abies recurvata* Mast.

Min Fir

Plate CXXII, Photos 1—4 and Fig. 102.

This tree up to 40 m tall occurs in Western Szechwan, China. The sections examined were cut from a bough 1 cm thick, kindly provided by Mr. G. H. Yu of the Academia Sinica, Peking, China.

C. (Photo 1.) Tracheid sections rounded rather than angular. The clearly distinct late wood has the width of 4 or 5 tracheids. There are a few exceptional xylem parenchyma cells close to the annual ring boundary.

R. (Photo 3.) Internal cross fields enclose 2 or 3 simple pits in vertical or horizontal rows. Marginal fields most often enclose 4 to 6 simple pits of 4 to 4·5 μ size. Ray cells 18 to 25 μ high; marginal cells somewhat higher than internal ones. Their transverse walls bear numerous simple pits. The scarce axial parenchyma cells along the ring boundaries locally contain small calcium oxalate crystals. Bordered pits of 13 to 14 μ size usually form loose uniseriate strings in the radial walls of the tracheids.

T. (Photos 2, 4.) Rays 1 to 20 cells tall, but most are lower than ten cells. The tangential walls of the ray cells bear several simple pits of 10 to 11 μ size.

113. (463) *Abies religiosa* Schlecht. and Cham.

(*A. hirtella* Lindely)

Ojamel, Pina bete, Axoyatl, Sacred Fir. 103.

Plate CXXIII, Photos 1—4 and Fig. 103.

A giant tree up to 50 m tall, it lives in Central Mexico and Guatemala, at altitudes of 2000 to 3000 m. The sections examined were prepared of a slice of a thick trunk, a sample kindly provided by Ing. R. V. de la Parra, Secretaria de Agricultura y Gañaderia, Mexico.

C. (Photos 1, 2.) It differs in cross-sectional structure from the rest of the Abies only inasmuch as close to the annual ring boundary there are thin-walled parenchyma cells with several simple pits in their walls. Tracheid width is 30 to 35 μ, radial dimension is 40 to 75 μ in the early and 10 to 12 μ in the late wood, next to the ring boundary. The thin-walled parenchyma cells adjacent to these latter are of about the same size.

R. (Photo 3.) The broad cross fields enclose few pits even in the early wood (most often one, more seldom two). These pits of 6 to 8 μ size have almost vertical apertures. The transverse walls of the ray cells are rather densely pitted; the tangential walls exhibit nodular and locally dentate thickenings. Ray cell height varies from 20 to 28 μ. The marginal cells are usually somewhat higher than the internal ones and their external walls are somewhat undulous. The bordered pits in the early tracheids are locally crowded, with transversely arranged pairs of pits of 20 to 22 μ size in the broader tracheids. There are indentures where the tangential walls meet the transverse ones.

T. (Photo 4.) Rays 1 to 45, typically 12 to 15 cells tall. Some of the taller rays are biseriate in a height of 10 to 12 cells. Ray cells 20 to 28 μ high and 10 to 16 μ wide. Their tangential walls bear several simple pits. The bordered pits in the tangential walls of the tracheids are of 14 μ size, with oblique slit-like apertures, most of them crossed in opposite cell walls. Transverse walls of axial parenchyma cells exhibit 2 or 3 nodular thickenings. The pits in their tangential walls are of 7 to 8 μ size.

114. (464) *Larix gmelinii* var. *olgensis* Ostenfeld and Syrah

(*L. olgensis* Henry)

Plate CXXIV, Photos 1—4 and Fig. 104.

A tree attaining a height of 30 m, it lives in East Asia about Vladivostok. The sections examined were prepared of a thickish trunk slice, 7 annual rings of which had an aggregate thickness of one centimetre. The sample was kindly

supplied by Professor Tsun Ching Cheng, The Institute of Forest Products, Ministry of Forestry, Wan Shu Shan, Peking, China.

C. (Photo 1.) Annual ring boundary well-defined, sharp. Rings about 40 tracheids wide, made up almost exactly half-and-half by early and late wood. Early tracheids thin-walled, late ones thick-walled (6 to 7 μ). The lumina of the latter are circular, elliptical or rounded hexagonal. Tracheids are 24 to 25 μ wide; their radial dimension is 30 to 35 μ in the early, as little as 8 to 9 μ in the late wood. Lumina of the latest tracheids almost gash-like. The late wood tends to include fairly frequent resin ducts of 70 to 80 μ diameter or less; twin ducts are also rather frequent. The epithelial cells lining these ducts are thick-walled. Axial parenchyma cells tend to crop up close to these ducts.

R. (Photo 3.) There are heterogeneous rays. The transverse tracheids are in marginal positions; their walls, including the tangential, are smooth and thin. They exhibit the typical *Larix* feature of overlapping rooftile fashion. Ray parenchyma cells 20 to 23 μ high; all walls pitted; tangential walls dentately thickened. The cross fields in the early wood exhibit 4 or 6, or even 8 small piceoid pits of 4 to 5 μ size, with oblique gashes for apertures, most often in an alternate arrangement. In the walls of the early tracheids, bordered pits form biseriate rows. The chambers are almost horizontal, elliptical. Pit size is 20 to 24 μ. No xylem parenchyma could be detected in this view.

T. (Photos 2, 4.) Rays 1 to 30 cells tall, remarkably thin. Ray cells 20 to 23 μ high, 8 to 9 μ wide, that is, elongate elliptical in section. All walls thick; the tangential walls exhibit several simple pits. The rays with resin ducts in them are slender fusiform, uniseriate in a height up to 12 cells above the ducts. The ducts themselves are more or less elliptical in section, lined with thick-walled epithelial cells. Such thin rays occur only in Larix and in some exceptional species of Picea. In the tangential walls of the tracheids there are a very few scattered small bordered pits of 14 μ size. Resin ducts occupy central positions in the broader rays. Their apertures are rather narrow. No xylem parenchyma was detected in this view, either.

115. (465) *Larix gmelinii* var. *principis-rupprechtii* Pilger

(*L. principis-rupprechtii* Mayer)

Plate CXXV, Photos 1—4 and Fig. 105.

The geographical spread of this tree covers Manchuria and Korea. The sections examined were cut from a thickish trunk sample, whose individual annual rings were 6 to 7 mm wide. The sample was kindly provided by Professor Tsun Ching Cheng, The Institute of Forest Products, Ministry of Forestry, Wan Shu Shan, Peking, China.

C. (Photo 1.) Annual ring boundaries sharp. Early and late wood distinct. Rings 60 to 70 tracheids wide, about one-third of each ring is taken up by the

late wood. Tracheid width 40 to 45 μ. Radial dimension 65 to 70 μ in early wood. Sections rectangular or hexagonal in early wood, walls thin (2 to 2·5 μ). Tracheid sections in late wood hexagonal; walls thick (7 μ); lumina rounded, which is somewhat of a difference from Larix olgensis. Resin ducts tend to occur in both the early and the late wood. They are radially somewhat elongate elliptical, of 50 to 55 by 40 to 45 μ size. This is a typical *Larix* feature. The epithelial cells lining them are not as thick-walled as in *Larix olgensis*. Rays most often uniseriate, but those adjacent to the resin ducts may widen to quinqueseriate.

R. (Photo 3.) Rays heterogeneous. Ray parenchyma cells 17 to 24 μ high; their transverse walls bear numerous simple pits; their tangential walls are dentately thickened. The transverse tracheids occupy marginal positions. They are somewhat lower than the parenchyma cells. Their transverse walls are smooth and thin; the radial walls bear a few bordered pits of 6 to 7 μ size. The transverse tracheids overlap rooftile fashion. The cross fields in the early wood most often enclose 2 or 3 piceoid pits in single rows: double rows are rare, being largely restricted to marginal parenchyma cells unflanked by transverse tracheids. Pit size is 5 to 6 μ. Apertures are vertical or slightly oblique gashes.

T. (Photos 2, 4.) Rays are of two kinds. Some are uniseriate, 1 to 25 cells tall and strikingly narrow. The cells in them are typically 17 to 24 μ high and 8 to 9 μ wide, almost invariably elongate elliptical. The tangential walls bear several small simple pits. The rays are flanked by transverse tracheids. The rays including resin ducts are the tallest. The ducts are more or less at the middle of these rays. Their width is 28 to 30 μ, their height 45 to 50 μ. Their sections are thus upright elliptical. The epithelial cells lining them are thick-walled. Tangential dimensions of tracheids 40 to 45 μ; the walls of the late ones bear small bordered pits of 7 to 8 μ size, with vertical gash-like apertures. Axial parenchyma cells are restricted to the neighbourhood of the rays bearing resin ducts. Their transverse walls are thickened dentately. The epithelial cells bear numerous simple pits.

116. (466) *Larix griffithii* Hooker fil.[1]

Sikkim Larch

Plate CXXVI, Photos 1—4 and Fig. 106.

A tree growing to a height of 20 m living in Nepal, Sikkim and Bhutan, and occurring also in Tibet. The sample examined, a piece of a thick trunk, with 12 annual rings per centimetre, was received from the Royal Botanical Gardens, Kew, England.

C. (Photo 1.) Annual ring boundary distinct; the late wood, having a width of 5 to 12 tracheids, is sharply distinct from the early wood which is some 10 to 12 tracheids wide. Tracheid sections angular, tetra- or hexagonal; width 25 to 60 μ; radial dimension 35 to 75 μ in early wood, 10 to 12 μ in late wood. Wall thickness 7 μ (for double wall) in late tracheids, only 1 to 2 μ in early ones. There

are scattered resin ducts lined by thick-walled epithelial cells in the growth ring fields. Most rays are uniseriate but next to the resin ducts they may widen to bi- or triseriate. In the late wood there usually are a few axial parenchyma cells next to the resin ducts, with several simple pits in their transverse walls.

R. (Photo 3.) In the heterogeneous rays, the transverse tracheids tend to occupy marginal positions. Their outer walls are undulous, smooth and thin, bearing small bordered pits of 8 to 10 μ size with circular apertures. The ends of the tracheids usually overlap rooftile fashion. The tangential walls are also perfectly smooth. The interval ray parenchyma cells are 22 to 24 μ high; their transverse walls bear numerous small pits. The dentately thickened tangential walls exhibit indentures. The cross fields in the early wood enclose 5 or 6, more seldom 8 small piceoid pits in two rows, sometimes in an alternate arrangement. Pit size is 5 μ. The early tracheids are 35 to 75 μ wide; their bordered pits are most often arranged in transverse or slightly oblique pairs. These pits are of 28 to 30 μ size with circular apertures of 6 to 7 μ diameter. Crassulae are fairly frequent between pits. The solitary bordered pits are procumbent elliptical as a rule. Axial parenchyma cells very rare, most often disposed close to the axial resin ducts.

T. (Photos 2, 4.) Rays are of two kinds. The uniseriate ones are 1 to 35, typically 8 to 10 cells tall. Ray cell height varies from 20 to 35 μ; width is 14 to 15 μ. The sections are short or elongate elliptical. The common transverse walls are thick; the tangential ones are somewhat thinner and more abundantly sprinkled with simple pits. These narrow uniseriate rays are typical of *Larix*. The rays including resin ducts are fusiform in section, 15 to 30 cells tall, tri- to quinqueseriate. The ducts most often occupy the middle of the rays. They are lined with thick-walled epithelial cells. The rays enclosing resin ducts may be up to 45 μ wide. Axial parenchyma cells, some of which play the role of epithelial cells in connexion with some of the resin ducts, are most often found in the neighbourhood of the latter. They differ from the epithelial cells proper in that they are 300 to 400 μ long, with dentate transverse walls, whereas the length of the epithelial cells is just 70 to 80 μ. Solitary xylem parenchyma cells are very rare. Tracheids are 25 to 60 μ wide. Their tangential walls bear relatively loose uni- or biseriate strings of small bordered pits of 6 to 7 μ size, with vertical gash-like apertures.

The typical diameter of the resin ducts is 35 to 40 μ. Their sections are typically upright elliptical.

117. (467) *Larix polonica* Racib.

Plate CXXVII, Photos 1—4 and Fig. 107.

This tree inhabits Poland. I received the sections examined, cut from a trunk 60 years old, from Dr. Alina Heynowicz who had discussed them in her doctoral thesis.

C. (Photos 1, 2.) Annual ring boundaries sharp; early and late wood distinct. Rings 10 to 30 tracheids wide. In some rings, the late wood is almost as wide as the early wood. Tracheid width 35 to 40 μ; radial dimension 70 to 80 μ in early, 18 to 20 μ in late wood. Walls very thick (16 μ for double wall). Sections of early tracheids radially elongate rectangular or hexagonal. Between some broad tracheid rows there are some rows of significantly thinner tracheids with gash-like or pinhole-like lumina. There are resin ducts, often twinned, in both the early and the late wood. They are of 90 to 100 μ diameter, sometimes slightly elongate radially. The epithelial cells lining them number 10 to 14. Rays uni- or multiseriate; the latter include resin ducts.

R. (Photo 3.) Ray cells 17 to 18 μ high. Rays heterogeneous, with transverse tracheids in marginal positions, sometimes also in the interior of the ray. These are as high as or lower than the internal parenchyma cells. In the transverse walls of the parenchyma cells simple pits are fairly abundant. The tangential walls, dentately thickened, exhibit indentures. The cross fields enclose 4 to 6 small piceoid pits of 5 to 6 μ size, almost invariably with vertical slit-like apertures. Transverse tracheids most often overlap rooftile fashion, sometimes with beak-like prominences. Their walls are smooth and unthickened; the radial ones bear small bordered pits of 8 to 10 μ size. Their apertures are short linear. The transverse tracheids locally occur in vertical pairs or triplets. Radial dimension of axial tracheids 70 to 80 μ. Their walls bear bordered pits in uniseriate strings or in transverse pairs separated by crassulae. These pits are of 22 to 24 μ size with circular apertures of 10 μ diameter. Axial parenchyma cells very scarce, most often disposed next to the resin ducts. Their walls bear small simple pits; the end walls are dentately thickened.

T. (Photo 4.) Rays 1 to 40 cells tall; some rays enclosing resin ducts may be even taller. Resin ducts elliptical rather than circular in sections, sometimes disposed at one-third of ray height. Epithelial cells thick-walled, numbering 10 to 12. Ray cell height 17 to 18, seldom up to 20 μ; width 10 to 12, seldom up to 14 μ. Sections upright elliptical; all walls thick; tangential walls sometimes thickened reticulately. Tangential dimension of tracheids 35 to 40 μ. The bordered pits of 12 to 14 μ size in the walls of the late tracheids have vertical linear or slit-like apertures.

118. (468) *Larix sukaczewii* Dyer

Plate CXXVIII, Photos 1—4 and Fig. 108.

This is a tree living in Siberia. The sections examined were cut from a trunk sample at least 70 years old, including 13 to 15 annual rings in a width of 1·5 cm. The sample was kindly provided by Professor E. Bobrov of the Museum of the Institute of Botany, Leningrad.

C. (Photos 1, 2.) Annual ring boundaries very sharp; rings relatively narrow, typically 20 to 25 tracheids wide. The late wood usually takes up a width of 5 to 8 tracheids. Tracheid sections most often tetragonal or hexagonal, or radially elongate rectangles of 38 to 40 μ width. Radial dimension of tracheids 50 to 72 μ in early, 16 to 18 μ in late wood. The sections of the latter tend to be radially compressed rectangles. Their lumina are almost slit-like. Resin ducts of 80 to 120 μ diameter tend to run in the late wood. Their sections are circular or radially somewhat elongate elliptical. The epithelial cells lining them are thick-walled. The sections examined exhibit no xylem parenchyma cells. Rays spaced 2 to 15 tracheids apart; the broader ones enclose resin ducts.

R. (Photo 3.) All walls of ray parenchyma cells bear simple pits. Tangential walls distinctly thickened in the dentate fashion. In the cross fields of the early tracheids there are 6 to 8, exceptionally even 10 simple pits, most often in two rows and displaced in an alternate pattern. The small piceoid pits are of 6 to 7 μ diameter; their apertures are oblique or vertical slits.

The transverse tracheids overlap in the typical rooftile *Larix* fashion. They locally flank the ray parenchyma cells 2 or 3 deep. Their external walls are smooth and thin. Their radial walls bear bordered pits of 9 to 10 μ size with circular or short slit-like apertures. The radial dimension of the axial tracheids is 50 to 72 μ; the walls of the early tracheids most often bear loosely scattered solitary pits of 23 to 24 μ size. Some of these are close-packed, with well visible crassulae between them. Apertures are circular, of 5 μ diameter. Xylem parenchyma cells very rare in the radial view. Their end walls are dentately or nodosely thickened; their radial walls bear small simple pits.

T. (Photo 4.) The uniseriate rays are 1 to 22, typically 8 to 10 cells tall. Cell sections are elongate ellipses 20 to 22 μ high and 12 to 13 μ wide. The broader rays, 18 to 22 cells tall, enclose resin ducts of elliptical section disposed at or near the middle of the rays. The top or bottom portions or both of the rays with resin ducts are uniseriate in a height of 6 to 18 cells. Epithelial cells lining the resin ducts are thick-walled. Tangential walls of ray cells pitted more or less reticulately. The tangential walls of the tracheids locally exhibit strings of small bordered pits with oblique gashes or round holes for apertures. No typical xylem parenchyma was detected in this view.

119. (469) *Picea fennica* Rgl.

Plate CXXIX, Photos 1–4 and Fig. 109.

A native of Kashmir and the European part of the Soviet Union. The sections were prepared of a bough 8 mm thick and 8 years old, kindly supplied by Professor D. Trankovsky of Moscow.

C. (Photo 1.) Annual ring boundaries distinct. The late wood emerges gradually from the early wood and gets gradually denser towards the annual ring

boundary. It is most often 6 to 8 tracheids wide. The entire rings are no wider than 15 to 20 tracheids, which may be due to the tender age of the bough. In the annual rings, solitary and twin resin ducts of 50 to 60 μ diameter, with circular or radially somewhat elongate openings, are fairly numerous. The epithelial cells lining them are thick-walled. There are no solitary xylem parenchyma cells. Tracheid sections tetra- or hexagonal, rather angular. Tracheid walls much thinner in the early than in the late wood. Most rays uniseriate. Resin ducts prefer to run next to rays.

R. (Photo 3.) Ray cells 18 to 22 μ high. The transverse tracheids flanking the rays may be up to 26 μ high. External walls most often undulous; transverse walls smooth; radial walls bear small bordered pits of 3 to 4 μ size. Transverse walls of ray parenchyma cells thick (3 to 4 μ) with numerous simple pits. Tangential walls thickened dentate fashion. Cross fields enclose 2, 3 or 4, marginal fields even 6 small piceoid pits, most of whose apertures are mere slits. Radial dimension of tracheids 20 to 25 μ. Bordered pits of 14 μ size with circular apertures form loose uniseriate strings in their walls. Wood structure hardly differs from those of the other *Picea* species.

T. (Photos 2, 4.) The uniseriate rays are 1 to 20 cells tall, widening to biseriate over short sections in the middle or at the ends. Ray cell height 18 to 22 μ; width 10 to 11 μ; some internal cells may be somewhat lower. All walls thick and reticularly thickened. Tracheid width 22 to 24 μ. The tangential walls bear just a few sparse bordered pits of 8 to 9 μ size, with oblique slits for apertures. No xylem parenchyma is seen. Rays enclosing resin ducts scarce, most often disposed almost symmetrically in the middle of some wider, fusiform rays. Some of the rays are no taller than 8 cells. Some of the widest rays may even enclose two resin ducts.

120. (470) *Picea montigena* Mast.

Plate CXXX, Photos 1—4 and Fig. 110.

This is a tree up to 30 m tall living in Western China. The sections examined were prepared of a thickish trunk; a portion 15 mm wide of the sample included 11 annual rings. The sample was kindly provided by Mr. Tsun Ching Cheng of the Institute of Forest Products, Peking, China.

C. (Photo 1.) Annual ring boundaries distinct. Early and late wood of about the same width, but the early wood is rather wider in the broader rings. Tracheid sections most often tetragonal, angular; width 30 to 35 μ; radial dimension about the same in early and 7 to 10 μ in late wood. Early tracheids much thinner-walled than late ones. There are some rare thin-walled xylem parenchyma cells in the late wood, which is somewhat of a rarity in a *Picea*. Resin ducts relatively numerous; most of them solitary, although some form palisades, as it were, composed of 2 to 6 ducts, parallel to the annual rings. Diameter of duct typically

50 to 60 μ, but some are much narrower. They are lined by thick-walled epithelial cells.

R. (Photo 3.) Rays heterogeneous. The outer walls of the radial tracheids flanking the rays are slightly undulous. They exhibit dense spiral thickenings similar to those in the axial tracheids: this is a feature recalling *Pseudotsuga*. Their walls bear small bordered pits of 3 to 4 μ size, with circular apertures. The internal cells are 18 to 20 μ high; their transverse walls are 3 to 4 μ thick, and pitted with numerous simple pits. Tangential walls dentately thickened. Cross fields enclose 2, 3 or 4 small piceoid pits, with oblique gashes for apertures. All tracheid walls exhibit close-spaced spiral thickenings almost perpendicular to the long axis of the tracheid. In addition the tracheid walls exhibit strings of bordered pits of 15 to 16 μ size, with circular or oblique slit-like apertures. The fact that all tracheids, axial and radial, of this species exhibit spiral thickenings tends to separate it from the rest of the *Picea* species and to relate it to *Pseudotsuga*. It would be interesting to check up on this similarity to, or better kinship with, *Pseudotsuga* also on the basis of external morphology. Of the *Picea* species, it only resembles *P. likiangensis* (which is considered a synonym by some: cf. Dallimore, p. 418) and somewhat less *P. spinulosa*.

T. (Photos 2, 4.) The tangential view exhibits typial *Picea* features. Rays uni- to quinqueseriate; those rays that are not uniseriate enclose resin ducts. Uniseriate rays 1 to 20 cells tall. The tallest widen to biseriate in a height of 1 or 2 cells near the middle or the ends. All walls thick; tangential walls reticularly pitted. The broader rays contain the resin ducts either at the center, or displaced from it vertically or horizontally. The rays with resin ducts are fusiform at one end, and uniseriate at the other, in a height of 5 to 10 cells. Epithelial cells thick-walled. The most striking feature of the tracheids is a pronounced thickening consisting of very thin and very close-spaced spiral ribs, which is a feature recalling *Pseudotsuga*. This thickening is observed in all tracheids, not just the late ones, which makes it a generic feature. Another remarkable trait is the presence of axial parenchyma just as in *Pseudotsuga* or the recently discovered *Cathaya*. The axial parenchyma cells tend to occur close to the axial resin ducts.

121. (471) *Picea rubens* Sargent

Red Spruce

Plate CXXXI, Photos 1—4 and Fig. 111.

This is a tree up to 30 m tall living in Nova Scotia, on Prince Edward Island, in the mountains of the Northeastern United States and in the Alleghenies. The sections were prepared of a thick trunk with annual rings 3 to 5 mm wide. The sample was kindly provided by Mr. C. M. Smith of the Smithsonian Institution, Washington, U.S.A.

C. (Photo 1.) Annual ring boundaries distinct; late wood emerges gradually from early wood. Late wood 15 to 20, early wood 30 to 40 tracheids wide. Early tracheids thin-walled; late tracheids thicker-walled (6 to 7 μ). Next to the annual ring boundaries there are strongly flattened tracheids of 8 to 10 μ radial size, with almost gash-like lumina. Resin ducts are largely restricted to the early wood. Their diameter is 70 μ or less. The epithelial cells lining them are thick-walled (6 to 8 μ for the double wall). There are no isolated xylem parenchyma cells either close to the resin ducts or next to the annual ring boundaries. In places, 4 or 5 resin ducts are arranged palisade fashion, parallel to the growth ring boundary. Most rays uniseriate; the broader ones enclose resin ducts.

R. (Photo 3.) Ray cells 14 to 18 μ high; some of the internal ones may be lower, though. External walls of transverse tracheids slightly undulous; the inner faces of the walls bear a fine spinulous ornament, presumably the projection of a fine spiral thickening. This structure, however, is visible under considerable magnification only. The tracheids exhibit small bordered pits of 6 to 7 μ size, with circular or short slit-like apertures. Transverse walls of ray parenchyma cells densely pitted; tangential walls dentately thickened. There are locally some transverse tracheids or tracheid pairs also in the interior of the rays. Most cross fields enclose 3 to 6 small piceoid pits of 6 to 7 μ size with oblique slits for apertures. In some fields, the pits are disposed in two rows, but the single-row arrangement is dominant in the fields of lesser height. Radial dimension of axial tracheids 65 to 70 μ. Their walls exhibit loose uniseriate strings of bordered pits of 20 to 21 μ size. The apertures of these latter are circles of 4 to 5 μ diameter.

T. (Photos 2, 4.) There are two types of ray. The uniseriate ones are 1 to 25, exceptionally up to 40 cells tall, but the typical height is 8 to 10 cells. Ray cells are 14 to 18 μ high and 7 to 8 μ wide. Their sections are somewhat elongate, upright elliptical. The broader rays enclose resin ducts, most often disposed near middle height but fairly often also in the lower or higher parts of the rays. In a typical case, the uniseriate portions may be 4 cells tall below and 24 cells tall above the duct. The ducts are typically 50 to 52 μ high and 30 to 35 μ wide. The epithelial cells lining them are thick-walled. The tangential walls of the ray parenchyma cells are reticularly pitted. The tangential dimension of the axial tracheids is 30 to 35 μ; bordered pits (of 7 μ size) are restricted to the walls of the late tracheids. They have vertical gashes for apertures. Axial parenchyma very rare or nonexistent.

122. (472) *Picea spinulosa* (Griffith) Henry

Sikkim Spruce

Plate CXXXII, Photos 1—4 and Fig. 112.

This is the tallest species of *Picea*, living in Sikkim territory, Eastern Himalayas, at altitudes of 2500 to 3000 m, and growing to a height of 60 to 65 m.

The sections examined were cut from a thick trunk whose annual rings were 3 to 5 mm wide. The sample derives from the Royal Botanical Gardens, Kew, England.

C. (Photo 1.) Annual ring boundaries sharp. Early wood passes gradually into late wood. The former is 35 to 40, the latter 10 to 12 tracheids wide. Tracheid width 20 to 30 μ; radial dimension 20 to 40 μ in early, 8 to 10 μ in late wood. The late tracheids next to the annual ring boundary are flattened radially, with almost gash-like lumina. In some rings, xylem parenchyma cells are fairly abundant among the latest tracheids. Their thin walls are conspicuously different from the thick walls of the adjacent tracheids. They are filled with a dark substance. Their structure reminds of *Pseudotsuga*.

The annual ring fields contain numerous resin ducts of 80 to 100 μ diameter. Epithelial cells thick- or thin-walled. Some of these ducts exhibit wing-like formations composed of axial parenchyma cells. Rays uniseriate or broader: the latter enclose resin ducts.

R. (Photo 3.) Ray cells 24 to 26 μ high. The internal ones tend to be somewhat lower. Their transverse walls exhibit numerous simple pits. Tangential walls dentately thickened. Most cross fields enclose 2 to 4 small piceoid pits of 6 to 7 μ size, with oblique gashes for apertures. Where there are four of these pits, these are disposed in the four corners of the field. Most transverse tracheids are lower than the outermost ray parenchyma cells. Their inside wall surfaces are finely spiculate in places. Some of the spiculae continue in a fine spiral thickening. Their walls exhibit small bordered pits of 5 to 6 μ size. This is another feature recalling *Pseudotsuga*. The axial tracheids are 20 to 40 μ wide. All tracheids of the late wood are conspicuous for a fine spiral thickening. In the early tracheids this thickening is not so pronounced. This is also a feature typical of *Pseudotsuga*. In addition to the spirals, there are also bordered pits of 17 to 18 μ size in the tracheids. Their apertures are circular or slightly oblique slit-like.

Axial parenchyma cells are visible only in sections passing through an annual ring boundary. Their presence is not in doubt, however.

T. (Photos 2, 4.) Rays remarkably low, typically 1 to 10 cells tall. Rays 18 to 20 cells tall are quite exceptional. The uniseriate rays locally widen to biseriate in a height of 4 to 5 cells. Even the rays enclosing resin ducts are relatively low, not exceeding 15 cells, except where two rays meet end on. Some rays enclosing resin ducts are only 100 μ tall and 22 to 25 μ wide. The cells in the uniseriate rays are typically 24 to 26 μ high and 17 to 18 μ wide. Their tangential walls exhibit small circular simple pits. Tangential dimensions of tracheids 20 to 30 μ. Their walls bear a fine spiral ornament. The spiral threads are slightly oblique or almost horizontal. In the walls there are very loosely scattered bordered pits of 7 to 8 μ size with oblique gashes for apertures. This is another pseudotsugan trait. Among the tracheids there are some scarce axial parenchyma cells as wide as the tracheids. Their transverse walls exhibit 2 or 3 dentate thickenings. In the axial walls there are scattered small pits of 4 to 5 μ size, with oblique slit-like

apertures. These parenchyma cells do not cluster next to resin ducts, but scatter among the tracheids. This, too, recalls *Pseudotsuga*. Axial parenchyma cells 300 to 350 μ long, with small pits in their radial walls.

123. (473) *Picea tianschanica* Rupr.

Plate CXXXIII, Photo 1—4 and Fig. 113.

This is a tree living in Kashmir and East Asia. The sections examined were cut from a bough 7 mm thick and 7 years old. The sample in question was received from the Museum of the Institute of Botany, Leningrad.

C. (Photo 1.) Annual ring boundaries sharp. Early wood only 4 or 5 tracheids wide, whereas the thick-walled tracheids of the late wood may stand 15 to 30 deep. Tracheid sections angular in early wood, more rounded in late wood. Lumina follow cell outline more or less. Tracheid width 18 to 22; radial dimension about the same in early, 8 to 10 μ in late wood. The lumina of the latest tracheids are flattened elliptical, or slit-like. Resin ducts prefer the late wood. They are of 40 to 45 μ diameter; their epithelial cells are thick-walled. Some ducts form palisades in the late wood, more or less parallel to the ring boundary. Rays comparatively close-spaced, 1 to 10 tracheids apart. There are some rare axial parenchyma cells next to the annual ring boundaries.

R. (Photo 3.) Ray cells 18 to 30 μ high. Marginal cells may be higher than that. Transverse tracheids are comparatively scarce; of a hundred rays, only one will contain a transverse tracheid on an average. The inside wall surfaces of these tracheids are finely spiculate; some of the spicules continue in spiral thickenings. The transverse tracheids exhibit bordered pits of 7 to 8 μ size with circular apertures. The transverse walls of the ray parenchyma cells are strewn with close-spaced simple pits. Tangential walls dentately thickened. Cross fields enclose 3 to 6 small piceoid pits of 5 to 6 μ size, with oblique slit-like apertures. In some fields, 6 and exceptionally even 8 pits form two vertical rows. Radial dimension of early axial tracheids 18 to 22 μ. Their walls exhibit more or less loose uniseriate strings of bordered pits of 13 to 14 μ size.

T. (Photos 2, 4.) Rays 1 to 22 cells tall; those enclosing resin ducts are rather lower. The ducts tend to run in the middle or in the upper or lower third of the rays. Some rays are fusiform, with uniseriate sections 1 or 2 cells tall at both ends, but in some of these rays one of the uniseriate sections may be 6 to 8 cells tall. Tangential walls finely, reticulately pitted. Cell height variable, 18 to 30 μ; width 14 to 15 μ. The walls of the late tracheids exhibit a fine spiral thickening recalling the genus *Pseudotsuga*. These spirally thickened walls also exhibit small bordered pits of 6 to 7 μ size with circular or short gash-like apertures. The spiral thickening is fairly widespread also in the early wood. Although the presence of axial parenchyma cells could be established beyond doubt in the cross section, none were observed in the tangential view.

124. (474) *Pinus amaniana* Koidz.

(*Pinus armandii* Wilson non Franchet)

Amani-goyoumatsu, Takane-goyou

Plate CXXXIV, Photos 1—4 and Fig. 114.

A tree 10 to 15 m tall in Japan, on the islands Tanega and Yaku of the Osumi group. In habit and xylotomy it resembles *Pinus armandi*. The sections examined were cut from a thick trunk which included 7 annual rings 1 to 3 mm wide in a width of 1 cm. The sample was kindly provided by Mr. Mitsugu Ito, Gifu University, Nagara, Gifu, Japan.

C. (Photos 1, 2.) Annual ring boundary sharp; early and late wood distinct. Late wood 8 to 10 tracheids wide. Tracheid width 50 to 55 μ; radial dimension 80 to 85 μ in early wood, 10 to 13 μ in late wood next to ring boundary. Some of the tracheids are much smaller, though. Latest tracheids radially compressed with almost slit-like lumina. Axial resin ducts tend to occur singly in the late wood. They are most often of circular outline, typically of 120 to 130 μ diameter. The epithelial cells lining them are thin-walled. Rays mostly uniseriate, except for the ones enclosing resin ducts which are tri- to quinqueseriate.

R. (Photo 3.) Rays heterogeneous. The ray parenchyma cells are 20 to 27 μ high. The transverse tracheids are somewhat lower. All their walls are smooth and thin (typical Haploxylon feature); their radial walls exhibit small bordered pits of 9 to 10 μ size with circular or slit-like apertures. The transverse walls of the ray parenchyma cells bear numerous pits of 10 to 15 μ size. All tangential walls are smooth. Most cross fields enclose one or two oculipores filling out the entire field, 20 to 24 μ long and 17 to 19 μ high, with broad oblique elliptical apertures. *Pinus armandi* differs from *P. amaniana* in that the two oculipores tend to be disposed in a vertical pair in the former and side by side in the latter. This trait of *P. amaniana* resembles *P. lambertoides*. In the walls of the tracheids, slightly elliptical (procumbent) bordered pits of 14 to 16 μ size with circular apertures form loose uniseriate strings. In the broadest tracheids, however, there are also twin pits side by side. In some taller rays there are one or two transverse tracheids among the ray parenchyma cells. Thin-walled ray cells have not been observed, however. The broader rays enclose transverse resin ducts lined by perfectly smooth-walled epithelial cells.

T. (Photo 4.) The uniseriate rays are 1 to 15 cells tall, some of the taller ones being biseriate in middle height. Ray cells 20 to 27 μ high, 9 to 10 μ wide; transverse tracheids somewhat lower. The bi- and triseriate rays are fusiform, with resin ducts most often symmetrically disposed. The tangential walls of the ray parenchyma cells are smooth; the transverse tracheids have bordered pits in their walls. Tangential dimensions of axial tracheids 50 to 55 μ; they exhibit

small bordered pits of 5 to 6 μ size with circular apertures in loose uniseriate strings. Axial parenchyma cells tend to occur close to the resin ducts: they are 200 to 220 μ long and bear small simple pits in their walls.

125. (475) *Pinus brutia* var. *eldarica* Medvedjev

(*Pinus halepensis* Miller var. *brutia*)

Plate CXXXV, Photos 1—4 and Fig. 115.

A tree living in Afghanistan and the Caucasus, it is according to Gaussen a variety of *Pinus brutia.* The sample derives from the Museum of the Institute of Botany, Leningrad, U.S.S.R.

C. (Photos 1, 2.) Annual ring boundaries highly conspicuous owing to a considerable change in tracheid size and wall thickness across them. Early tracheids thin-walled; late ones remarkably thick-walled. Tracheid width 50 to 55 μ; radial dimension 70 to 75 μ in early, 18 to 20 μ in late wood. The lumina of the late tracheids are narrow, radially compressed elliptical or slit-like. Early and late wood rather distinct also within one and the same ring. Ring width varies from 15 to 50 tracheids. In the narrower rings, the late wood takes up almost half of the ring. The thick-walled tracheids have almost regular procumbent rectangular sections. Resin ducts fairly numerous; they tend to occur at the beginning or in the middle of the late wood. Locally there are fairly close-spaced pairs or triplets of such ducts. A typical duct diameter is 210 to 220 μ. The epithelial cells lining them are thin-walled. Rays uniseriate, but the ones enclosing resin ducts may be multiseriate. Transverse walls of ray parenchyma cells smooth, those of transverse tracheids reticularly thickened.

R. (Photo 3.) Height of both ray parenchyma cells and transverse tracheids varied (20 to 30 μ). Transverse walls of ray parenchyma cells comparatively thick, with several simple pits. Tangential walls dentately or lenticularly thickened. Some exhibit indentures. Cross fields enclose 2 to 4 comparatively small pinoid pits of different sizes (7 to 14 μ). In the fields with four pits, these tend to be disposed at the four corners. Among the thick-walled ray parenchyma cells there are also some thin-walled ones, pitted exactly like the thick-walled cells. The ray parenchyma cels are locally flanked by transverse tracheids standing 2 or 3 deep. The walls of these are usually smooth, with a few small, hardly discernible acicular prominences that tend to emerge from the walls of the bordered pits. The radial walls of the transverse tracheids exhibit bordered pits of 7 to 8 μ size. Radial dimension of axial tracheids 70 to 75 μ. In their walls there are loose strings of bordered pits of 18 to 20 μ size with circular apertures. There is no xylem parenchyma in this wood.

T. (Photo 4.) Uniseriate rays 1 to 40 cells tall; the tallest ones widen to biseriate in one or two places along the ray. The resin ducts are located in the middle

or in the lower or upper third of the ray. The uniseriate rays exhibit a fairly frequent alternation of thick- and thin-walled ray parenchyma cells. The thick-walled ones are 22 to 24 μ high, 10 to 12 μ wide. In the tangential walls of the thick-walled cells there are 4 or 5 small simple pits. The transverse tracheids are invariably thinner than the thick-walled ray parenchyma cells. Tangential dimension of axial tracheids 50 to 55 μ. Their walls bear some very scarce bordered pits.

126. (476) *Pinus brutia* var. *pithyusa* Stev.

Plate CXXXVI, Photos 1–4 and Fig. 116.

Its geographical spread covers the Mediterranean region, including Thracia and Greece, and the Caucasus. The sections were cut of a thickish trunk sample, kindly provided by Professor (Mme) H. Czeczott, Warsaw, Poland.

C. (Photos 1, 2.) The cross sectional structure somewhat resembles the foregoing form, *Pinus brutia* var. *eldarica*, but there are also some significant differences, notably that the late wood is almost always considerably narrower than the early wood in the same ring. There is no conspicuous difference in tracheid wall thickness across the ring boundary. Tracheid width 50 to 60 μ, radial dimension about the same in early wood, 15 to 20 μ in late wood. Lumina of latest tracheids almost slit-like. Resin ducts are scarcer, with a preference for the late wood. Measuring 170 to 180 μ across, they are lined with thin-walled epithelial cells. Rays uniseriate with numerous simple pits in their transverse walls. The broader rays enclose resin ducts.

R. (Photo 3.) Ray cells 14 to 22 μ high, marginal cells somewhat higher. The thick-walled ray parenchyma cells are densely sprinkled with simple pits. Their tangential walls are dentately thickened. The insides of the transverse tracheid walls bear small spicules which do not, however, coalesce into a set of spiral lines, except in some very rare cases. This is a distinct difference from the preceding variety. Cross fields most often enclose pairs of small pinoid pits, almost invariably side by side. Pit diameter usually equals one third of cell height (8 to 9 μ). There are also entirely smooth-walled transverse tracheids without spicules. This phenomenon can usually be observed where several transverse tracheids flank the same ray. Radial dimension of axial tracheids 50 to 60 μ; bordered pits of 18 to 20 μ size with circular apertures form loose uniseriate strings in most of them; pairs of pits side by side are rather exceptional. Among the thick-walled ray cells there are also some quite thin-walled ones.

T. (Photo 4.) Uniseriate rays 1 to 20 cells tall, invariably heterogeneous, with transverse tracheids and thin-walled ray parenchyma cells in internal as well as marginal positions. The widths and heights of both types of cell are rather varied (14 to 22 and 7 to 14 μ, respectively). Tangential walls of thick-walled ray parenchyma cells almost sieve-like owing to numerous simple pits. Tangential

dimension of axial tracheids 45 to 50 μ; bordered pits are rather scarce in their walls. All in all, this variety is rather markedly different from *Pinus brutia* var. *eldarica*.

127. (477) *Pinus brutia* var. *stankewiczi* Sukac.

(*Pinus stankewiczi* (Suk) Kom.)

Plate CXXXVII, Photos 1—4 and Fig. 117.

This variety lives in the Crimea, near Sondok. The sections examined were cut from a branch 10 cm thick, received from the Museum of the Institute of Botany, Moscow.

C. (Photos 1, 2.) Annual ring boundaries not very conspicuous but discernible. There is no significant change across the ring boundary either in tracheid size or wall thickness. Tracheid sections dominantly tetragonal or hexagonal. Width 30—40 μ; radial dimension about the same in early wood, 20 to 22 μ in late wood. The late tracheids are radially compressed rectangular; their walls are of uniform thickness. Resin ducts, typically of 180 to 190 μ diameter, are rather frequent. There are in places palisades of 2 to 8 ducts side by side, more or less parallel to the annual ring boundary. Some rings are very wide, measuring 100 to 120 tracheids. Most rays uniseriate; the broader ones enclose resin ducts.

R. (Photo 3.) Rays heterogeneous; besides the thin-walled ray parenchyma cells there are also fairly numerous thick-walled ones with walls 3·5 to 4 μ thick. Cross fields usually enclose 3 or 4 comparatively small pinoid pits of 10 to 13 μ size, disposed in the four corners of the field. Other fields enclose 6 or 8 pits disposed in two vertical rows. The transverse tracheids are 28 to 30 μ high; their outer walls are almost smooth or ornamented with minute blunt teeth reaching into the lumen. No reticulate thickening is observed. The bordered pits of the tracheids are of the same size as the small pits in the ray parenchyma cells (8 to 13 μ). In the walls of the axial tracheids, bordered pits usually constitute uniseriate strings. They are somewhat flattened, elliptical, of 15 to 16 μ size; their apertures are short procumbent elliptical. Axial parenchyma cells very rare. Their transverse walls exhibit nodular thickenings; their long walls bear loosely scattered simple elliptical pits.

T. (Photo 4.) Uniseriate rays 1 to 10 cells tall. Most of them are not heterogeneous; there are just one or two transverse tracheids on the flanks or in the interior of some rays. Thin-walled parenchyma cells 20 to 24 μ high; thick-walled ones 14 to 16 μ high and 10 to 11 μ wide; transverse tracheids 28 to 30 μ high. Rays enclosing resin ducts comparatively low, 40 to 42 μ wide, 140 to 150 μ tall. The portion where the duct is running looks inflated. Tangential dimension of axial tracheids 30 to 40 μ. Their tangential walls exhibit a very few scarce small bordered pits of 6 to 7 μ size. Some tracheids join transverse walls penetrated by bordered pits.

128. (478) *Pinus cooperi* Blanco

(*Pinus lutea* Blanco)

Pino amarillo, P. chino

Plate CXXXVIII, Photos 1—4 and Fig. 118.

A tree 20 to 30 m tall, it lives in the high mountains of Durango county, Mexico, and also in Virginia and Florida, U.S.A. The sections were prepared of a thickish trunk whose annual rings were 3 to 5 mm wide. The sample derives from the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries sharp, conspicuous. Late tracheids much thicker-walled than early ones (14 and 8 μ respectively for the double wall). Tracheid width 30 to 40 μ; radial dimension about the same in early, 20 to 25 μ in late wood. Lumina of late tracheids procumbent elliptical or slit-like. Sections of early tracheids tetra- or polygonal; lumina follow cell outline. Resin ducts of 170 to 180 μ diameter fairly numerous; they prefer the late wood. The epithelial cells lining them are thin-walled. There are no axial parenchyma cells, not even next to the resin ducts. Transverse walls of ray parenchyma cells smooth, those of transverse tracheids strongly reticulate.

R. (Photo 3.) Rays heterogeneous, composed of thin- and thick-walled parenchyma cells and transverse tracheids. Thin-walled parenchyma cells typically 22 to 24 μ high; transverse tracheids and thick-walled parenchyma cells somewhat lower. Cross fields of parenchyma cells usually enclose 1 or 2, but fairly often also 3 or 4 pinoid pits of circular or other shape. Tangential walls of thin-walled parenchyma cells smooth; those of the thick-walled ones are nodose or pitted, and so are the transverse walls. Pit size is 14 to 15 μ typically, but some are much smaller. The pointed or blunt teeth in the radial walls of the transverse tracheids hardly reach to the middle of the lumen, and only a few ones reach across it, forming a sort of ladder. This is a typical Diploxylon feature. In the radial walls of the axial tracheids, bordered pits of 18 to 20 μ size with circular apertures most often constitute loose uniseriate strings; two pits side by side do not occur except in the broadest spring tracheids, in which case the pairs are separated by crassulae.

T. (Photo 4.) Rays uniseriate; those enclosing resin ducts are inflated, fusiform. The wood is characterized by the abundance of transverse tracheids. Uniseriate rays including no thick-walled ray parenchyma cells, or transverse tracheids, except those flanking the ray, are few and far between. Ray cell height varies from 21 to 24 μ. The rays enclosing resin ducts are typically 25 to 30 cells tall; the transverse tracheids flanking them stand 3 to 5 deep. Tangential dimension of axial tracheids 30 to 40 μ; their walls bear very few bordered pits if any.

129. (479) *Pinus elliottii* Engel.

Slash Pine

Plate CXXXIX, Photos 1—4 and Fig. 119.

This tree, 8 to 30 m tall, lives in California and Louisiana, U.S.A. The sections examined were cut from a thickish trunk, as revealed by the thickness and course of the annual rings. The individual rings are 8 to 12 mm wide. The sample derives from the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries hardly discernible; there is very little difference in tracheid size and wall thickness across the ring boundary. Double walls 8 to 10 μ thick; tracheid width 45 to 50 μ, radial dimension about the same in early wood, 30 to 35 μ in late wood. Fairly numerous resin ducts of 240 to 300 μ diameter lined with thin-walled epithelial cells are scattered all over the growth ring fields. Transverse walls of ray parenchyma cells smooth; those of transverse tracheids strongly reticulate. No axial parenchyma could be detected even close to the resin ducts.

R. (Photo 3.) Rays heterogeneous. Thin-walled ray parenchyma cells 24 to 26, transverse tracheids 18 to 21 μ high. Walls of transverse tracheids exhibit dentate and reticulate thickenings; most teeth reach to the middle of the lumen; others reach across the lumen, giving rise to ladder-like configurations. Marginal tracheids somewhat higher, with slightly undulous outside walls. Most of the cross fields of the ray parenchyma cells enclose a single large typically pinoid pit of 12 to 14 μ size, having a slightly oblique broad elliptical aperture. Some other cross fields enclose 2 or 3 or even 4 elliptical pits, filling them out entirely. The xylotomical structure of this wood much resembles that of *Pinus caribea*; indeed, the two are indentified by some authors. Radial walls of axial tracheids bear loosely scattered bordered pits. Closely crowded pits are rare, being largely restricted to the slightly wider early tracheids. They are separated by crassulae. The taller rays enclose transverse resin ducts lined with very thin-walled epithelial cells.

T. (Photo 4.) There are two kinds of ray. The uniseriate ones are 1 to 25 μ cells tall; all walls of their parenchyma cells are smooth and thin. All rays are flanked by transverse tracheids. In some of the taller rays there are, however, a few scarce transverse tracheids and/or thick-walled ray parenchyma cells also among the thin-walled parenchyma cells. The broader rays invariably enclose resin ducts at middle height. All walls of the epithelial cells lining them are thin; the resin ducts are almost invariably flanked by transverse tracheids. The maximum height of the ducted and unducted rays is about the same. Tangential dimension of axial tracheids 45 to 50 μ, somewhat less in the late wood. Ray parenchyma cells 24 to 26 μ high; transverse tracheids (both external and internal ones) 18 to 21 μ high. Tangential walls of axial tracheids bear a very few small scattered bordered pits of 14 to 18 μ size, with oblique gash-like apertures, which tend to be crossed in opposite cell walls.

130. (480) *Pinus greggii* Engel.

(*Pinus patula* var. *macrocarpa* Masters: *P. patula* var. *stricta* Bentnam.)

Gregg's Pine

Plate CXL, Photos 1—4 and Fig. 120.

A tree 10 to 15 m tall, it is a native of Mexico. The sections examined were cut from a thickish trunk sample kindly put at my disposal by Ing. R. V. de la Parra, Secretaria de Agricultura y Gañaderia, Mexico.

C. (Photos 1, 2.) Annual rings 4 mm wide. Ring boundaries sharp; late and early wood distinct. Tracheid width typically 30 to 35 μ; typical radial dimensions 40 to 50 μ in early, 8 to 10 μ in late wood. Lumina of late tracheids almost gash-like; their walls are much thicker than those of the early tracheids. Resin ducts of 120 to 150 μ diameter prefer the late wood, the vicinity of the ring borders. The epithelial cells lining them are thin-walled. Rays uniseriate, except for the ones enclosing resin ducts, which are tri- to quadriseriate. Tracheid sections in late wood procumbent rectangular or sharply angular polygonal. Lumina follow cell outline.

R. (Photo 3.) Rays heterogeneous, flanked by transverse tracheids. There are a few transverse tracheids also inside some rays. Ray parenchyma cells 23 to 24 μ high. Their transverse walls are smooth and thin; their tangential walls are also thin. Cross fields enclose 3 to 6 pits which most often fill them out entirely. Pit size varies from 6 to 15 μ; shapes range from elliptical to slit-like. Walls of transverse tracheids spiculate; some of the spiculae coalesce to form a ladder, but most of them attain only one-third or one-fourth of cell height. In this respect they resemble *Pinus sylvestris*. The apertures of the pits are flanked on both sides by sickle-shaped borders. Radial dimension of axial tracheids 40 to 50 μ. Their walls exhibit uniseriate strings of bordered pits of 24 to 25 μ. Most of these are solitary, but some join transverse walls. Apertures are circular. There occur a few trabeculae in adjacent tracheids.

T. (Photo 4.) Rays uniseriate or tri-, quadriseriate: the latter enclose resin ducts.

Uniseriate rays 1 to 22 cells tall; ducted rays attain a height of 30 cells. Transverse tracheids are frequent in both types of ray, most often in flanking positions, but quite often also among the ray parenchyma cells. The latter may number up to 5 in the tallest rays. Ray parenchyma cells 23 to 24 μ high, 17 to 18 μ wide. Most parenchyma cells thin-walled; transverse tracheids thick-walled. Resin ducts, if any, do not invariably run in the middle of the ray: they sometimes occupy positions farther up or down. Tangential dimension of axial tracheids 30 to 35 μ; the late ones bear small bordered pits of 7 to 8 μ size. There is no xylem parenchyma in this wood.

131. (481) *Pinus hartwegii* Lindl.

(*Pinus montezumae* var. *hartwegii* Engel.)

Pino de Mejico, Rough branched Mexican pine

Plate CXLI, Photos 1—4 and Fig. 121.

A tree 10 to 15 m tall, it lives in the Sierra Nevada of California. The sections examined were cut from a thick trunk whose annual rings were 1 to 2·5 mm wide. The sample was provided by the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries sharp. Late wood much narrower than early wood. Tracheid wall thickness 1·5 to 2 μ in early, 6 to 7 μ in late wood. Tracheid width 35 to 40 μ; typical radial dimension 40 to 50 μ in early, 8 to 10 μ in late wood. Sections tetragonal or hexagonal with slightly rounded corners. Lumina of late tracheids circular, elliptical or rounded hexagonal. Resin ducts, typically of 140 to 150 μ diameter, prefer the late wood; they are lined with thin- and smooth-walled epithelial cells. There are no xylem parenchyma cells in this wood, except in the immediate vicinity of the resin ducts. Rays uniseriate, with abundant transverse tracheids; the broader ones enclose resin ducts.

R. (Photo 3.) Ray cells 19 to 30 μ high. Walls of thin-walled ray parenchyma cells smooth and thin; the thick-walled ones exhibit pits of 6 to 7 μ size. The tangential walls bear one or two nodular thickenings. The walls of the transverse tracheids are reticularly thickened, although in some of these cells the spicules do not attain more than one-third of lumen width. The pits in their walls are of 9 to 10 μ size and have circular or oblique slit-like apertures. Some cross fields enclose a single large pit; others enclose 2 to 6 smaller ones. The solitary pits are of 20 to 25 μ size; the others measure 10 to 15 μ. Radial dimension o axial tracheids 40 to 50 μ. Their walls bear loose strings of predominantly single pits of 24 to 25 μ size, having circular apertures of 7 to 8 μ diameter. There are, however, also a few pairs of pits side by side.

T. (Photo 4.) Uniseriate rays 1 to 30 cells tall. Transverse tracheids numerous in both flanking and internal positions. Ray parenchyma cells typically 19 to 20, seldom up to 28 μ high, 10 to 12 μ wide. Tangential walls of ray parenchyma cells smooth and thin; those of transverse tracheids reticulate. The broader rays enclose resin ducts of 22 to 24 μ diameter and of elongate fusiform shape. The ducts are flanked by transverse tracheids. There are also some thick-walled ray parenchyma cells. The tangential walls of the axial tracheids bear fairly scarce bordered pits of 7 μ size with oblique slit-like apertures.

132. (482) *Pinus hwangshanensis* Hsia

(*P. argyi* Lemée et Lev.)

Plate CXLII, Photos 1—4 and Fig. 122.

This is a native of Anhwei Province, China. The samples examined were cut from a thickish trunk showing 3 annual rings in a width of 10 mm. The sample was kindly supplied by Professor Tsun Ching Cheng, The Institute of Forest Products, Peking.

C. (Photos 1, 2.) Annual ring boundary sharp; early and late tracheids differ significantly in shape, size and wall thickness. Tracheid width 25 to 40 μ; radial dimension 50 to 60 μ in early, 10 to 12 μ in late wood. The late tracheids have slit-like lumina and walls 4 to 5 μ thick. The sections of the early tracheids are elongate tetra- or hexagonal; the late tracheids are dominantly tetragonal with rounded lumina. Early and late wood are of about equal width (30 to 40 tracheids). Resin ducts typically of 80 to 90 μ diameter are not too numerous. They are lined with thin-walled epithelial cells. There is no xylem parenchyma.

R. (Photo 3.) Ray parenchyma cells 20 to 24 μ high. Some of the taller rays are flanked by transverse tracheids standing 3 to 5 deep. Transverse walls of transverse tracheids spiculate; the spicules attain one-third of lumen height; reticulate thickening is rare. The walls of the transverse tracheids exhibit bordered pits of 6 to 7 μ size with circular or short elliptical apertures. The transverse walls of the ray parenchyma cells are thick (6 to 7 μ for the double wall) and locally split apart. These walls are sparsely strewn with pits of 7 to 8 μ size. Tangential walls smooth and thin. Most cross fields enclose one or two oculipores that fill them out entirely. These pores are 12 to 14 μ high for a maximum diameter of 20 to 23 μ. Their shapes are rounded rectangular or elliptical. In the broader fields there may be even two such pores side by side; their size is about half of that of the solitary pits. Radial dimension of early axial tracheids 50 to 60 μ. Their walls bear loose uniseriate strings of bordered pits of 20 to 23 μ size with circular apertures.

T. (Photo 4.) Most rays uniseriate; tri- to quinqueseriate rays enclosing resin ducts are fairly rare. Uniseriate rays typically 1 to 10 cells tall; ducted ones may attain a heigth of 20 to 25 cells. The uniseriate rays are markedly heterogeneous, with transverse tracheids fairly abundant in the interiors of the rays as well as in the marginal positions. There are both thick- and thin-walled ray parenchyma cells. Ray cells 20 to 24 μ high, 12 to 13 μ wide, somewhat narrower near the ends of the rays. Axial tracheids 25 to 40 μ wide. Their tangential walls exhibit a few scattered small bordered pits of 7 to 8 μ size with circular apertures. The ducted rays are more or less elongate fusiform. The epithelial cells lining the resin ducts are thin-walled.

133. (483) *Pinus krempfii* Lecompte

(*Ducampopinus krempfii* (Lec.) Chev.)

Plate CXLIII, Photos 1—4 and Fig. 123.

This is an endemic species living in Indochina, a tree growing to a height of 15 to 20 m. The sections were prepared of a thick trunk sample kindly provided by Professor A. A. Yatsenko-Khmelevsky of Leningrad, U.S.S.R.

The xylotomy of *Ducampopinus* has been rather widely discussed. It was precisely on a xylotomical basis that Chevalier established a new genus, *Ducampopinus*, for this plant. J. T. Buchholz in 1951 examined a bough 6 or 7 years old and found that

1) It differs from the genus *Pinus* in possessing some xylem parenchyma.

2) It lacks ray tracheids and transverse resin ducts.

The same was stated by H. Gaussen (1960, 1964).

On this basis, Buchholz considers *Ducampopinus* a separate genus related to *Keteleeria* and *Pseudolarix*. Rollet (1955) gives a somewhat cursory description of the xylotomy of *Ducampopinus*, with no mention at all of its xylem parenchyma or of the pitting of its cross fields. E. V. Butkevitch (1968) discusses the xylotomy of *Ducampopinus* in some detail. In the present author's opinion, however, Butkevitch is in error when calling the pits of the cross fields taxiodioid: the photo shown here (Photo 3) proves these to be pinoid. Moreover, *Ducampopinus* has no separate xylem parenchyma cells, because the parenchyma cells shown in Fig. 8 of Butkevitch' paper are essentially thick-walled epithelial cells invariably connected with the resin ducts.

The present author has discussed the above-outlined problems in some detail, having taken some of the fundamental data from the Soviet authors' publications. He considers it beyond doubt that *Ducampopinus* possesses both vertical and horizontal resin ducts, which is indisputably a *Pinus* feature especially if the ducts in question are lined with thin-walled epithelial cells. (Photos 1, 2, 4.) Photos 1 and 2 show sections of transverse resin ducts at two different magnifications. In both photos, three types of epithelial parenchyma cells can be distinguished in and around the ducts. The first is quite thick-walled with narrow lumina. Its walls are layered. The second has much thinner walls and consequently much wider lumina. Many of these cells are filled with a dark resinous substance. The third type of epithelial cell occurs in the ducts proper; it is quite thin-walled. These three types are quite distinct in cross section, and can be distinguished also in the axial sections. On the top left hand side of Fig. 1, one cell is very thick-walled, unevenly thickened (type 1), irregularly pitted, although some of the pits are regular, circular. The same figure shows the second type of epithelial cell whose wall is uniformly, moderately thick and bears round simple pits, irregularly scattered or in regular strings. The first and second types of epithelial cells communicate through simple pits. The third type is unpitted; its walls are smooth and thin.

All the three above-mentioned types of epithelial cells occur, then, in the vicinity of the resin ducts. The axial sections, however, may so pass through the periphery of a duct that the epithelial cells intersected give the impression of independent parenchyma cells or cell groups. The parenchyma cells figured by Butkevitch in his Fig. 8 are such epithelial cells of resin ducts rather than independent parenchyma cells. The present author has examined at least 50 sections looking for thick-walled parenchyma cells independent of the resin ducts and has not found a single one. He has found no such parenchyma cells in the radial and tangential sections, either, and concludes that *Ducampopinus*, just like all other *Pinus* species, possesses no independent axial parenchyma cells outside the immediate vicinity of the resin ducts, so that, xylotomically at least, the new name *Ducampopinus* is unjustified.

Gaussen's statement that *Ducampopinus* has no transverse tracheids should also be modified: Photo 3 clearly shows the smooth-walled transverse tracheids that relegate this species to the subgroup Haploxylon. To establish its relations of kinship would, of course, require more detailed investigations. The pitting of the cross fields is decidedly pinoid, not taxodioid, cf. Photo 3.

All in all, in view of the presence of smooth-walled transverse tracheids and the absence of scattered axial parenchyma cells, the distinction of this species by the generic name *Ducampopinus* is unjustified and, in the present author's opinion, the older and more expressive name *Pinus krempfii* Lecomte should be retained (See: Greguss, 1962).

134. (484) *Pinus kwangtungensis* Chun.

Plate CXLIV, Photos 1—4 and Fig. 124.

It lives in the mountains of Hainan island of China, where it attains a height of 30 m. The sections were prepared of a thick trunk sample having annual rings 2 to 5 mm wide, kindly put at my disposal by Professor Tsun Ching Cheng, The Institute of Forest Products, Peking.

C. (Photos 1, 2.) Annual ring boundaries sharp, early tracheids thin-walled, late ones much thicker-walled and also much flatter. Late wood 6 to 8 tracheids wide. Tracheid width 30 to 48 μ; radial dimension 50 to 60 μ in early, 12 to 14 μ in late wood. Resin ducts, typically of 90 to 100 μ diameter, lined with thin-walled epithelial cells prefer the late wood. Most rays uniseriate, but those enclosing resin ducts are tri- to quinqueseriate. There is no xylem parenchyma.

R. (Photo 3.) Ray cells 18 to 23 μ high, as a rule, but some are lower than that. Transverse walls of ray parenchyma cells 5 to 6 μ thick, locally split apart. Most tangential walls smooth; the others exhibit no more than one or two nodular thickenings, either. In the transverse walls there are relatively large pits of 8 to 10 μ size. There are no thin-walled ray parenchyma cells. Outer walls of transverse tracheids smooth and thin; their radial walls exhibit bordered pits of 6

to 8 μ size with short slit-like lumina. Cross fields in the early wood enclose one oculipore, or more often 2 or 3 side by side. Pit size is 30 to 35 μ for the solitary ones and 20 to 24 μ for the rest. Radial dimension of early axial tracheids 50 to 60 μ; their walls bear solitary or twin pits of slightly flattened elliptical shape. The solitary ones are of 26 to 28 μ size. Their apertures are circular or short elliptical, of 9 to 10 μ diameter. Crassulae are frequent between the twin pits.

T. (Photo 4.) Uniseriate rays 1 to 8 cells tall, with transverse tracheids in flanking and sometimes also in internal positions. Ray parenchyma cells 18 to 23 μ high, transverse tracheids somewhat lower, both 8 to 9 μ wide. Tangential dimension of axial tracheids 30 to 48 μ; the late ones exhibit a few scattered bordered pits of 7 to 8 μ size with circular or short linear apertures. The latter may be crossed in opposite cell walls.

135. (485) *Pinus lawsoni* Roezl.

(*Pinus altamirana* Shaw)

Lawson's Pine

Plate CXLV, Photos 1—4 and Fig. 125.

This is a tree up to 30 m tall living in Central and Western Mexico. The sections examined were cut from a thick trunk sample composed of annual rings 15 to 16 mm wide, received from the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Some annual rings are 180 to 200 tracheids wide. Ring boundaries conspicuous, although there is practically no change in tracheid wall thickness across them. The boundary is outlined mainly by changes in tracheid size and shape. Tracheid width 50 to 60 μ; radial dimension about the same in early wood, 15 to 20 μ in late wood. Sections of early tracheids rounded tetra- or hexagonal; lumina follow cell outline; lumina of late tracheids circular, elliptical or rounded polygonal. Resin ducts of 120 to 150 μ diameter lined with thin-walled epithelial cells prefer the early wood, but there are some in the late wood as well. Rays uniseriate, but those enclosing resin ducts are tri- or quadriseriate.

R. (Photo 3.) Ray parenchyma cells 24 to 28 μ high; transverse tracheids somewhat lower (22 to 24 μ). Transverse and tangential walls of thin-walled ray parenchyma cells smooth and thin; those of the thick-walled ones exhibit small simple pits and, in the tangential walls, also one or two nodular thickenings. The horizontal walls of the transverse tracheids show minute spiculate thickenings, but the spiculae, of 3 to 5 μ size, do not reach beyond one-third or one-fourth of the lumen. Horizontal walls of tracheids running in the interior of the rays similarly spiculate. Cross fields of early tracheids enclose one to four oculipores of different size; single pores filling out an entire field are not infrequent.

In the fields with several pores, these latter are invariably arranged side by side, filling out the field evenly. Pit size ranges from 10 to 30 μ. Some of the taller rays are flanked by transverse tracheids standing 4 or 5 deep. Radial dimension of early axial tracheids 50 to 60 μ; their walls exhibit loosely scattered or touching bordered pits of 26 to 28 μ size and slightly flattened, ellipticall shape, with apertures of 7 to 10 μ diameter. At the ends of certain tracheids the bordered pits are somewhat crowded, joining transverse or oblique faces. A single axial parenchyma cell was detected. Its wall bore a string of simple pits. It presumably ran next to a resin duct.

T. (Photo 4.) Uniseriate rays 1 to 20 cells tall; transverse tracheids form 3 or 4 rows on both flanks and also sometimes in the middle. Ducted rays are of elongate fusiform section; the resin ducts tend to run at middle height within the ray. The epithelial cells lining them are thin-walled. Ray parenchyma cells 22 to 28 μ high, 8 to 9 μ wide. Transverse tracheids somewhat narrower. Tangential dimension of axial tracheids 50 to 60 μ; the late ones exhibit some small bordered pits of 7 to 8 μ size with circular apertures. No axial parenchyma in this view.

136. (486) *Pinus luchuensis* Mayr.

Luchu Pine

Plate CXLVI, Photos 1—4 and Fig. 126.

This tree growing to a height of 30 to 35 m lives on Luchu island south of Japan. Externally it resembles *Pinus thunbergi.* The sample, a thick trunk with annual rings 5 to 10 mm wide, was provided by the Smithsonian Institution, Washington, U.S.A.

C. (Photo 1.) The late wood, occupying about one-third or one-half of each ring, is sharply distinct from the early wood, although the walls of the early tracheids are hardly thinner than those of the late ones. Tracheid width 24 to 45 μ; radial dimension 50 to 60 μ in early, 15 to 16 μ in late wood. Early tracheids have tetra-, hexa- or otherwise polygonal sections with rounded corners. Late tracheid sections procumbent rectangles or polygons, strongly flattened, with procumbent elliptical or slit-like lumina. Wall thickness is 7 to 8 μ in late, 6 to 7 μ in early wood. Resin ducts of 150 to 170 μ maximum diameter, lined with thin-walled epithelial cells, prefer the late wood, the vicinity of the ring boundary. There is no xylem parenchyma. Transverse walls of uniseriate rays pitted; ducted rays are tri- to quinqueseriate.

R. (Photo 3.) Ray parenchyma cells 24 to 25, transverse tracheids 16 to 20 μ high. There are thin- and thick-walled ray parenchyma cells. Both transverse and tangential walls of thin-walled ones smooth and thin. The thick-walled ones are rather profusely pitted with simple pits of 10 to 15 μ diameter. Transverse tracheids locally stand 4 or 5 deep. Their horizontal walls are smooth locally,

whereas elsewhere they bear spiculae of 5 to 6 μ size protruding into the lumen, and attaining one-quarter to one-third of its height. There is no distinct reticulate thickening in the tracheids. Some of the outermost transverse tracheids, significantly higher than the rest, exhibit a variety of shapes. Their walls bear bordered pits of 9 to 10 μ size with circular apertures. Early cross fields most often enclose pits filling out the entire field, of rounded rhomb or ovoid shape. The solitary pits have a radial dimension of 30 to 35 μ and a height of 15 to 16 μ. The smallest pits are of 8 to 10 μ diameter. Radial dimension of early axial tracheids 50 to 60 μ; their walls exhibit loose uniseriate strings of bordered pits; only in the broadest tracheids are there two pits side by side. Pit size 21 to 22 μ; apertures circular, of 5 to 6 μ diameter. There is no axial parenchyma.

T. (Photos 2, 4.) Uniseriate rays 1 to 20 cells high. They include strikingly numerous transverse tracheids and thick-walled ray parenchyma cells. Ray parenchyma cells 24 to 25, transverse tracheids 16 to 20 μ high: the former are 10 to 12, the latter 9 to 10 μ wide. In the ducted rays, the resin ducts may run at the middle or at one end. In this latter case there may be a uniseriate section up to 10 cells tall, with transverse tracheids among the thin- and thick-walled ray parenchyma cells. Tangential dimension of axial tracheids 24 to 45 μ; late tracheids bear a few scattered bordered pits of 7 to 8 μ size.

137. (487) *Pinus lumholtzii* Robin and Fern

Pino borba caida, Pino triste, Weeping Pine

Plate CXLVII, Photos 1—4 and Fig. 127.

This is a tree 10 to 20 m tall living in the Western Sierras of Mexico. The sections examined were prepared of a thickish trunk sample having annual rings 1 to 3 mm wide, received from the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries sharp; late wood 5 to 10 tracheids wide. Ring width varies from 7 to 25 tracheids. Tracheid width 25 to 30 μ; radial dimension 45 to 50 μ in early, 8 to 10 μ in late wood. Sections of early tracheids slightly rounded tetra- or hexagonal; lumina of some latest tracheids just gashes. Resin ducts typically of 150 to 170 μ diameter, prefer the beginning of the late wood. The walls of the epithelial cells lining them are smooth and thin. Most rays uniseriate; those enclosing resin ducts are tri-, quadriseriate. All rays include numerous reticulately thickened, transverse tracheids, most often in flanking positions. Wall thickness of late axial tracheids considerable (10 μ); that of the early ones only 2·5 to 3 μ.

R. (Photo 3.) Rays intersect axial tracheids at a somewhat obtuse angle. Ray parenchyma cells 19 to 20 μ high, whereas the highest transverse tracheids attain 25 to 40 μ. Ray parenchyma cells thin-walled. Cross fields enclose 1 to 6 simple

pits, most often of procumbent elliptical shape, filling out the entire field. Walls of transverse tracheids reticulately thickened. Radial dimension of axial tracheids 45 to 50 μ; their walls exhibit loose uniseriate strings of bordered pits of 21 to 22 μ size with circular apertures of 6 to 7 μ diameter.

T. (Photo 4.) Uniseriate rays 1 to 20 cells tall, comprising remarkably numerous transverse tracheids. In one instance, a ray 8 cells tall included just one parenchyma cell; the rest were tracheids. Typically, one-third to one-fourth of all cells making up a ray are tracheids. Tangential walls of transverse tracheids likewise reticulately thickened. Ducted rays are 20 to 25 cells, or 380 to 400 μ, tall, and 50 to 60 μ wide. Axial tracheids bear bordered pits of 10 to 11 μ size in loose uniseriate strings. Their apertures are short gashes, locally crossed in opposite cell walls. In some other tracheids there are bordered pits of 21 to 22 μ size. These pits were presumably displaced from the radial to the tangential plane by a process of torsion. There are a very few axial parenchyma cells, 650 to 660 μ long and 30 to 40 μ wide. Their walls bear simple pits of 7 to 8 μ size, with oblique slits for apertures. Their end walls also bear simple pits. These axial parenchyma cells may pertain to some resin duct. However, their walls are rather thickish (3 μ), whereas the epithelial cells have walls 0·5 to 1 μ thick. There are also some very exceptional short axial tracheids.

138. (488) *Pinus oocarpa* Schiede

Ocote macho

Plate CXLVIII, Photos 1—4 and Fig. 128.

A Central American tree 10 to 18 m tall, it is most abundant in Southern and Western Mexico. The sections examined were cut from a thick trunk sample having annual rings 5 to 7 mm wide, supplied by the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries conspicuous but not sharp. There is little change in tracheid size or wall thickness across the ring boundary. Tracheid width 24 to 35 μ; radial dimension 35 to 40 μ in early, 20 to 22 μ in late wood. Wall thickness 7 μ in late, 5 μ in early tracheids. Most early tracheid sections are rounded tetra- or hexagonal; late ones are often procumbent rectangular. Lumina of latter elliptical or slit-like. Early wood passes gradually into late wood; both may be about 30 to 35 tracheids wide. Resin ducts typically of 190 to 200 μ diameter, are lined with thin-walled epithelial cells. Uniseriate rays spaced 3 to 20 tracheids apart. The broader rays enclose resin ducts. There is no axial parenchyma.

R. (Photo 3.) Rays heterogeneous. The taller rays are composed of thick- and thin-walled parenchyma cells, as well as transverse tracheids in flanking, but fairly often also in internal positions. All walls of thin-walled ray parenchyma

cells smooth and thin; all walls of the thick-walled ones strewn with simple pits. The walls of the former are 1·5, those of the latter 3·5 to 4 μ thick. Cross fields enclose 1 to 5 simple pits of a variety of shapes; some of the fields are entirely filled out by these pits. Outer walls of transverse tracheids slightly undulous. Their inside walls are smooth here and spiculate there; even reticulate thickenings are fairly frequent. Their radial walls exhibit bordered pits of 7 to 8 μ size with slit-like apertures. Radial dimension of axial tracheids 35 to 40 μ. Their radial walls exhibit loose uniseriate strings of bordered pits of 19 to 20 μ size, with circular or short elliptical apertures of 7 μ diameter.

T. (Photo 4.) Uniseriate rays 1 to 35 cells tall. They may exhibit two or three alternations of transverse tracheids and thin-walled ray parenchyma cells. Thin-walled cells 8 to 10, transverse tracheids 6 to 7 μ wide. Thin-walled cells typically 17 to 18 μ high. Tangential walls of thin-walled cells smooth, those of transverse tracheids reticulately thickened. Ducted, broader rays 26 to 28 μ wide, of elongate fusiform shape. Ducts tend to run at middle height. The upper and lower ends are uniseriate in a height of 5 to 6 cells. These uniseriate ends largely consist of transverse tracheids. Tangential dimension of axial tracheids 24 to 35 μ; their walls bear a few scattered bordered pits of 6 to 7 μ size with oblique linear apertures.

139. (489) *Pinus pringlei* Shaw

Plate CXLIX, Photos 1—4 and Fig. 129.

A tree 10 to 20 m tall, living in Western Mexico. The sections examined were cut from a thickish trunk sample having annual rings 2 to 5 mm wide, kindly provided by Ing. R. Vasquez de la Parra, Secretatia de Agricultura y Gañaderia, Mexico.

C. (Photos 1, 2.) Annual ring boundaries sharp. Width of late wood ranges from 8 to 25 tracheids. Tracheid width 30 to 50 μ; radial dimension 40 to 45 μ in early, 14 to 15 μ in late wood. Sections of early tracheids roundish, often circular; thick-walled late tracheids are more often procumbent rectangular or hexagonal in section, with walls 7 to 8 μ thick. Their lumina are rounded, circular, elliptical or rounded polygonal. There is no xylem parenchyma. Resin ducts of 210 to 220 μ diameter, lined with thin-walled epithelial cells, prefer the late wood. Rays spaced 3 to 15 tracheids apart, uniseriate, except for the ducted ones which are tri- to quadriseriate.

R. (Photo 3.) Rays heterogeneous. All walls of ray parenchyma cells smooth, thin, unpitted. Cell height 22 to 24 μ. Transverse tracheids may be lower or higher than that. There are also thick-walled parenchyma cells; their transverse walls bear simple pits in a variety of sizes. The larger ones measure 8 to 10 μ. The walls of these cells are 3 to 4 μ thick. Cross fields enclose 1 to 4 simple oculipores of a variety of shapes and sizes. These most often fill out the entire field.

Their sizes range from 8 to 20 μ; oblique or procumbent elliptical shapes are most common. Horizontal walls of some transverse tracheids bear spicules of 5 to 6 μ size that do not reach the median line of the lumen, whereas others exhibit a reticulate thickening. Their radial walls bear bordered pits of 7 to 8 μ size with circular apertures. On the flanks of some rays, transverse tracheids stand 3 or 4 deep. Radial dimension of axial tracheids 40 to 45 μ; their walls exhibit uni- or biseriate strings of pits; the solitary pits are of 22 to 24 μ size and circular or elliptical shape. They have circular apertures of 6 to 7 μ size. The pits are separated by crassulae.

T. (Photo 4.) Uniseriate rays 1 to 15 cells tall, heterogeneous. Transverse tracheids most often occupy flanking positions but there are quite a few internal ones, too. Ray parenchyma cells 22 to 24, transverse tracheids 15 to 18 μ high, thin-walled parenchyma cells 15 to 17, transverse tracheids 8 to 10 μ wide. Tangential walls of transverse tracheids reticulately thickened. Tangential dimension of axial tracheids 30 to 50 μ. Their walls exhibit sparse small bordered pits of 7 μ size with short linear apertures.

140. (490) *Pinus rudis* Endl.

(*P. montezumae* var. *rudis* Shaw)

Plate CL, Photos 1—4 and Fig. 130.

This is a tree 8 to 25 m tall living in Central America, especially in Oaxaca County, Mexico. The sections examined were cut from a thickish trunk sample having annual rings 2 to 4 mm wide, kindly provided by the Niedersächsische Forstliche Versuchsanstalt, Göttingen, German Federal Republic.

C. (Photos 1, 2.) Annual ring boundaries conspicuous but not quite sharp. Early wood passes gradually into late wood, which latter is 10 to 15 tracheids wide. Late tracheids not much thicker-walled than early ones. Tracheid width 25 to 30 μ, radial dimension 35 to 45 μ in early, 15 to 18 μ in late wood. Sections of early tracheids usually isodiametric, tetra- or hexagonal. Latest tracheids flattened rectangular in section; some lumina just thin gashes. Resin ducts of 80 to 90 μ diameter, lined with thin-walled epithelial cells, prefer the late wood. Ducts are fairly scarce, there are no more than 5 or 6 per square centimetre. Uniseriate rays spaced 3 to 15 tracheids apart.

R. (Photo 3.) Rays heterogeneous. There are thick- and thin-walled ray parenchyma cells. Walls of the former smooth, thin, unpitted; walls of the latter 3 to 4 μ thick, pitted with simple pits; their tangential walls are smooth or bear 2 or 3 nodose thickenings. Cross fields enclose 1 to 4 oculipores. Even the solitary ones of 24 to 26 μ size, fill out almost the entire field. Shapes are round or upright or procumbent elliptical. Horizontal walls of transverse tracheids slightly spic-

ulate in early wood; in the late wood, the spicules attain the median line of the lumen, but reticulate thickenings are very rare. Their radial walls bear bordered pits of 8 to 9 μ size. Radial dimension of early axial tracheids 35 to 45 μ; most of these bear loose single uniseriate strings of bordered pits of 21 to 22 μ size, with circular apertures.

T. (Photo 4.) Uniseriate rays 1 to 30 cells tall, heterogeneous. Margins are almost invariably occupied by transverse tracheids. In the interior, an alternation of thin-walled parenchyma cells with transverse tracheids is fairly frequent; some thick-walled parenchyma cells also occur among them. Thin-walled ray parenchyma cells 25 to 35 μ high, 20 to 21 μ wide; transverse tracheids 12 to 13 μ wide. Their tangential walls are reticulately thickened. Broad rays enclose resin ducts of 25 to 30 μ diameter. These rays are also flanked by transverse tracheids. Tangential dimension of axial tracheids 25 to 30 μ. Their walls exhibit a few sparse bordered pits of 7 to 8 μ size, with circular or short elliptical apertures.

141. (491) *Pinus sibirica* (Rupr.) Mayr.

Plate CLI, Photos 1—4 and Fig. 131.

This is a tree living in Siberia, about Tobolsk. The material examined derives from the Botanical Institute of Moscow University. The sections were prepared of a thick trunk, as suggested by the almost straight annual ring boundaries and the width of the rings.

C. (Photos 1, 2.) Annual ring boundaries conspicuous, sharp. Late wood typically 6 to 8, early wood 30 to 40 tracheids wide. Width of tracheids 30 to 35 μ; radial dimension 35 to 40 μ in early, 14 to 16 μ in late wood. Sections almost square to radially elongate rectangular in early wood; radially flattened rectangular with slit-like lumina in late wood. Wall thickness 1·5 to 3 μ in early, 3 to 6 μ in late tracheids. Resin ducts of 140 to 180 μ diameter are scattered all over the growth rings, with some preference for the late wood. Rays spaced 2 to 20 tracheids apart. There is no xylem parenchyma.

R. (Photo 3.) Rays heterogeneous. Thick-walled ray parenchyma cells 24 to 25, transverse tracheids 22 to 24 μ high. There are thick-walled ray parenchyma cells with pitted and smooth or nodosely thickened tangential walls and thin-walled ones with smooth and thin tangential walls. Cross fields usually enclose a single large pinoid pit of 17 to 18, occasionally up to 24 μ size. Other fields exhibit 2 or 3 smaller pits side by side or one above another. These pits are of 10 to 14 by 7 to 8 μ size. Horizontal walls of transverse tracheids smooth and thin, which is a Haploxylon feature. Their radial walls bear small bordered pits of 4 to 5 μ size. In the walls of the axial tracheids, bordered pits of 17 to 20 μ size with circular apertures tend to form loose uniseriate strings. Two pits side by side are rather rare. All ray parenchyma cells thick-walled.

T. (Photo 4.) Rays uniseriate, but for the ducted ones which are multiseriate. Uniseriate rays 1 to 20, ducted ones 15 to 20 cells high. Ducts run at middle height or at one end of the respective ray. Transverse tracheids in internal positions are rare and more or less restricted to the tall rays.

142. (492) *Pinus sondereggeri* H. H. Chapman

(*Pinus palustris* P. Taeda)

Plate CLII, Photos 1—4 and Fig. 132.

This species lives in North America, especially in California. The sections examined were prepared of a thickish trunk sample whose annual rings were up to 12 mm wide received from the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries sharp; early and late wood distinct; the latter may be up to 70 tracheids wide; the early wood may be four to five times as wide as the late wood. Tracheid width 35 to 40 μ; radial dimension 50 to 60 μ in early, 15 to 20 μ in late wood. Sections rounded tetra- or hexagonal in early, radially compressed rectangular with narrow elliptical lumina in late wood. Wall thickness 2 to 3 μ in early, 5 to 6 μ in late wood. Resin ducts of 170 to 180 μ diameter lined by thin-walled epithelial cells prefer the late wood, but there are some also in the early wood. The ducts usually touch the broader rays.

R. (Photo 3.) Rays heterogeneous. There are thin- and thick-walled ray parenchyma cells. All walls of the former are smooth and thin, unpitted. Those of the latter are 8 to 10 μ thick and provided with simple pits. Horizontal walls of transverse tracheids bear small spiculae. Some of these do not reach the median line of the lumen, whereas in the cross fields of the late wood they tend to give rise to a reticulate thickening. Cross fields enclose 1 to 4 simple pits filling them out almost entirely. Pit sizes range from 6 to 15 μ. Tangential walls of thick-walled parenchyma cells also thick, with one or two pits in them. Radial dimension of axial tracheids 50 to 60 μ; their walls bear loose uniseriate strings of bordered pits of 10 to 14 size. Apertures are oblique gashes, locally crossed in opposite cell walls.

T. (Photo 4.) Uniseriate rays 1 to 20 cells tall, heterogeneous, usually flanked by transverse tracheids standing up to 5 deep; there are, however, groups of 2 to 3 such tracheids within the tallest rays. Height of thin-walled ray parenchyma cells 24 to 26 μ; width, 11 to 14 μ. Transverse tracheids are narrower (7 to 10 μ). Resin ducts run in inflated central sections of rays. These sections are 50 to 60 μ wide. Tangential dimension of axial tracheids typically 35 to 40 μ. Their walls bear small bordered pits with circular apertures.

143. (493) *Pinus taiwanensis* Hayata

Plate CLIII, Photos 1—4 and Fig. 133.

A tree 20 to 35 m tall, resembling *Pinus densiflora*, living on Taiwan island. The sections examined were prepared from a thick trunk sample with annual rings 1·6 mm wide on an average; the sample was kindly provided by Mr. S. C. Liu of the Historical Research Commission of Taiwan Province.

C. (Photos 1, 2.) Annual ring boundaries sharp: the essential changes across them involve tracheid sections, size, shape and wall thickness. Tracheid width 40 to 50 μ; radial dimension typically 70 to 80 μ in early, 20 to 22 μ in late wood. Some late tracheids may have walls up to 10 μ thick; the lumina of these are very narrow or quite slit-like. Sections of early tracheids typically tetragonal; hexagonal shapes are much rarer. Resin ducts of 210 to 230 μ diameter lined by thin-walled epithelial cells prefer the late wood. There are in their vicinity thin-walled xylem parenchyma cells which do not, however, belong to the ducts proper. Rays uniseriate, spaced 1 to 15 tracheids apart. The broadest rays enclose resin ducts.

R. (Photo 3.) Rays heterogeneous. There are thin- and thick-walled ray parenchyma cells; walls of the former smooth and thin, those of the latter 3 to 5 μ thick and pitted. Most cross fields enclose one or two oculipores resembling those of *Pinus silvestris*. These pores are 30 to 35 μ long and 20 to 21 μ wide, of elliptical or obtuse rhomb shape. In the thick-walled parenchyma cells, two pores side by side are more frequent. Transverse walls of transverse tracheids exhibit small sharp spiculae not reaching the median line of the lumen. In the late tracheids, reticulate thickenings are quite frequent, though. This wood structure much resembles that of *Pinus silvestris*. Bordered pits in radial walls of transverse tracheids are of 8 to 9 μ size and have circular apertures. Radial dimension of axial tracheids 70 to 80 μ; their walls exhibit uni- or biseriate strings of bordered pits, the biseriate ones being essentially strings of pit pairs. Single pits measure 28 to 29, twin pits 23 to 24 μ; apertures are circular or procumbent elliptical. Some rays are composed entirely of transverse tracheids. The tallest rays enclose resin ducts at middle heigth. These are lined with smooth- and thin-walled epithelial cells.

T. (Photo 4.) Uniseriate rays 1 to 25, seldom up to 30 cells tall, heterogeneous, including thin-walled parenchyma cells and transverse tracheids. Most transverse tracheids occupy flanking positions, but some occur in the interior of the ray. Ray parenchyma cells 20 to 24 μ high and 17 to 20 μ wide; transverse tracheids somewhat lower and narrower. Walls of transverse tracheids reticulately thickened. Ducted rays 50 to 55 μ wide, fusiform, 20 to 25 cells tall. Ducts run at middle height. The epithelial cells lining them are smooth- and thin-walled. On the flanks of the ducted rays, transverse tracheids may stand up to 5 deep. Tangential dimension of axial tracheids up to 50 μ. Their walls bear a few bordered pits of 9 to 10 μ size with short slit-like apertures. Some short tracheids join end walls bearing bordered pits.

144. (494) *Pinus tenuifolia* Bentham

(*Pinus pseudo-strobus* var. *tenuifolia* Shaw)

False Weymouth Pine

Plate CLIV, Photos 1—4 and Fig. 134.

A tree 20 to 25 m tall, it lives in Central America, mainly in subtropical Mexico. It resembles *Pinus montezumae*. The sections examined were prepared of a bough about 5 cm thick and about 20 years old, kindly supplied by the Niedersächsische Forstliche Versuchsanstalt, Göttingen, German Federal Republic.

C. (Photos 1, 2.) Annual ring boundaries distinct. There is no change in wall thickness across the boundary, but tracheid sizes do change significantly. The early wood tends to pass gradually into the late wood, but in some instances the late wood, not more than 4 to 5 tracheids wide, stands rather well apart. Ring width ranges from 8 to 50 tracheids. Radial dimension of tracheids 30 to 35 μ in early wood (this presumably holds only for branches), and 8 to 10 μ in late wood. Sections almost perfect squares, rectangles and seldom hexagons in early wood, radially flattened rectangles in late wood. Resin ducts of 70 to 75 μ diameter lined by thin-walled epithelial cells prefer the late wood. Rays uni- to quadriseriate, with resin ducts in the broadest ones. There is no xylem parenchyma.

R. (Photo 3.) Rays heterogeneous, composed of thin- and thick-walled parenchyma cells and transverse tracheids. The latter are exceptional in internal positions. Ray parenchyma cells 20 to 22 μ high. Most transverse tracheids are lower, but the outermost ones may be much higher than that. Walls of thick-walled ray parenchyma cells 3 μ thick. Cross fields enclose 1 to 4 oculipores of circular or elliptical shape which most often fill out the entire field. The big solitary pores measure 14 to 16 μ, the smaller ones 8 to 10 μ. Horizontal walls of transverse tracheids bear spiculae. Some of these do not attain the median line of the lumen, whereas others coalesce into a reticulate thickening. Radial dimension of early axial tracheids 30 to 35 μ. The late ones are much narrower. Their walls bear loose uniseriate strings of bordered pits of 15 to 17 μ size.

T. (Photo 4.) There are two types of ray. The uniseriate ones are 1 to 10 cells tall and heterogeneous, with transverse tracheids one or two deep occupying flanking positions. There are fairly numerous transverse tracheids also within the rays. Height of thin-walled parenchyma cells 20 to 22 μ; that of transverse tracheids 14 to 16 μ; parenchyma cells are 13 to 14, tracheids are 10 to 11 μ wide. The tangential walls of the latter are reticulately thickened. Ducted rays are rather squat fusiform in section, 14 to 15 μ wide. Tangential dimension of axial tracheids 24 to 26 μ. Their walls bear small bordered pits of 6 to 7 μ size with circular or short linear apertures.

145. (495) *Pinus tropicalis* Morelet

(*Pinus terthrocarpa* Shaw)

Plate CLV, Photos 1—4 and Fig. 135.

This tree of Western Cuba and Florida grows to a height of 12 to 20 m. The sections examined were prepared of a thickish trunk, as revealed by the width of the annual rings (1·5 mm on an average). The material examined derives from the Smithsonian Institution, Washington, U.S.A.

C. (Photos 1, 2.) Annual ring boundaries very sharp, conspicuous; early and late tracheids differ significantly in shape, size and wall thickness. Tracheid width typically 55 to 60 μ; radial dimension 70 to 80 μ in early, 16 to 18 μ in late wood. Double-wall thickness of late tracheids may attain 14 to 16 μ. The lumina of these tracheids are almost gash-like. Sections procumbent rectangular, penta- and hexagonal, with corners more rounded in late than in early wood. Resin ducts of 180 to 210 μ diameter lined by thin-walled epithelial cells frequent, preferring places close to ring boundary in late wood or near end of early wood. Remarkably enough, there are some scarce thick-walled axial parenchyma cells with pitted transverse walls among the tracheids. These do not run next to any resin duct, but rather far apart, solitary or in groups, the latter giving the impression of a resin duct in the process of formation. Also, even though rather thick, their walls are distinctly thinner than those of the tracheids, that is, they are decidedly parenchyma cells. This proves that even *Pinus* may exceptionally possess axial parenchyma cells. Some of these cells are filled with a golden or darker resinous substance. They do not differ in size from the adjacent tracheids. Rays uni- or multiseriate; the latter enclose resin ducts.

R. (Photo 3.) Rays heterogeneous, including both thin and thick-walled parenchyma cells. Most transverse tracheids occupy flanking positions, but there are also a few internal ones. Their transverse walls are thick, studded with small blunt prominences, which do not, however, attain more than one-fifth or one-sixth of lumen width. No reticulate thickening has been observed anywhere in the sections. The internal tracheids do not even exhibit the above-mentioned prominences; their horizontal walls are almost entirely smooth in most cases. The tangential walls of the thick-walled tracheids bear one or two nodular thickenings. Most early cross fields enclose a single large pit, but some enclose two or three side by side. Radial dimension of pits 50 to 60 μ, height 18 to 20 μ, almost equal to ray cell height. Ray parenchyma cells 25 to 27 μ high; height of transverse tracheids about the same. The radial walls of the latter exhibit small bordered pits of 10 to 12 μ size with circular apertures. The taller rays enclose resin ducts lined by thin-walled epithelial cells. Radial dimension of early axial tracheids 70 to 80 μ. Their walls bear solitary or twinned bordered pits; there are conspicuous crassulae between the latter. Pit size is 23 to 24 μ; the width of a pit twin is 46 μ. In some tracheids, however, there are uniseriate strings of pits. No end walls of axial parenchyma cells could be observed in the radial view

T. (Photo 4.) Uniseriate rays 1 to 35, typically 10 to 15 cells tall. Structure heterogeneous, involving thick- and thin-walled ray parenchyma cells as well as transverse tracheids. Some rays are up to 500 μ tall, with individual ray parenchyma cells up to 30 μ high and 16 to 17 μ wide. Ducted rays are inflated at middle height to a width of 35 to 40 μ. The upper and lower parts of the ducted rays are uniseriate in heights of 8 to 10 cells. Several sections have revealed not a single bordered pit in the tangential walls of the axial tracheids. Nor could any axial parenchyma cell be detected in this view. We have presumably failed to make sections that intersect any one of these cells. In any case, the anatomy of *Pinus tropicalis* is so typical as to be hard to confuse with any other species.

146. (496) *Pinus uncinata* Ramond

Pin à crochets, Pino negro, Pino moro

Plate CLVI, Photos 1—4 and Fig. 136.

This form is treated in a variety of ways by different authors. Some regard it as a variety of *Pinus montana;* others, including Gaussen (1960, 1964) consider it to be an independent species, and so does also the present author on the basis of the xylotomical features.

A tree up to 25 m tall, it lives mainly in the East Alps and the High Pyrenees, also locally in Central Spain. The material examined was cut from a thickish trunk provided by the Instituto Forestal de Investigaciones y Experiencias Maderas y Aplicaciones, Laboratorio de Anatomia, Madrid.

C. (Photos 1, 2.) Annual ring boundaries distinct. Tracheid width 35 to 40 μ; radial dimension 60 to 65 μ in early, 10 to 12 μ in late wood. Latest tracheids are radially flattened rectangles, often with slit-like lumina. Sections of other tracheids rounded tetra-, penta- or hexagonal. Wall thickness 3 to 4 μ. Most rings are 70 to 100 tracheids wide. Resin ducts of 120 to 130 μ diameter fairly numerous; these prefer the late wood. Rays uniseriate, except for the ducted ones. Horizontal walls of transverse tracheids exhibit spiculate and reticulate thickenings.

R. (Photo 3.) Rays heterogeneous; ray parenchyma cells 18 to 20 μ high and most often thick-walled, with large simple pits in the transverse walls. Dentate thickening very rare in transverse walls. Most tangential walls smooth and thin; thickenings rare. Cross fields enclose single pits filling them out entirely; two pits side by side are a rarity. Pits are procumbent elliptical, 30 to 32 μ across and 14 to 15 μ high, somewhat smaller than that in the late wood. There are no thin-walled parenchyma cells. The transverse tracheids are about as high as the ray parenchyma cells; only the outermost ones are somewhat higher and undulous on the outside. Also, they exhibit small spicules similar to those of *Pinus silvestris*. These seldom attain the median line of the lumen, but some locally coalesce

to form a reticulate thickening. Some of the tallest rays are flanked by 3 or 4 rows of tracheids, which is a difference from *Pinus silvestris*. In the radial walls of the axial tracheids, there are scattered bordered pits of 17 to 18 μ size with circular apertures. Two pits side by side in the same tracheid are exceptional.

T. (Photo 4.) Rays 1 to 15 cells tall, uniseriate except for the ducted ones. In the tangential view, the heterogeneous structure is conspicuous, because the transverse tracheids are considerably narrower (6 to 7 μ) than the ray parenchyma cells (12 μ). Fusiform ducted rays are up to 30 cells tall and 30 to 32 μ wide, bi- or triseriate above and below the ducts.

147. (497) *Cathaya argyrophylla* Chun and Kuang

(*Pseudotsuga argyrophylla* (Chun et Kuang) emend. Greguss)

Plate CLVII, Photos 1—4 and Fig. 137.

The material investigated was kindly provided by Professor A. A. Yatsenko-Khmelevsky of Leningrad.

Chun et Kuang in Vol. 43 (1958), No. 4 of the Botanicheskiy Zhurnal gave a description of the external morphology of recently discovered *Cathaya argyrophylla* and *C. nangshuanensis*, and stated these to constitute a new genus, a fossil form of which had turned up in Germany. The paper includes six plates of drawings and two of photographs. The same number of Botanicheskiy Zhurnal contains a paper by A. A. Yatsenko-Khmelevsky and E. V. Butkevitch (1958), dealing in some detail with the xylotomy of *Cathaya argyrophylla* and containing six drawings.

In Vol. 43 of Botanicheskiy Zhurnal, E. V. Butkevitch discusses also the xylotomy of *Ducampopinus krempfii*, recently elevated to the rank of an independent genus, and concludes that since this form differs from the rest of the *Pinus* species in possessing some xylem parenchyma and in having taxodioid pits in the cross fields, it is justified to declare it a new genus.

Although not directly connected with the problems to be discussed here, it is nevertheless worth mentioning that Gaussen in his "Les gymnospermes actuelles et fossiles" (1964) took the data relating to *Cathaya* and *Ducampopinus* from the above-mentioned authors: in his systematic key, he employs the very important characters in question as follows:

(1) Tracheides des rayons à parois lisses ..... *Pseudotsuga*
or

(2) Tracheides des rayons à parois finement dentées ..... *Cathaya*
or

(3) Pas de tracheides des rayons ..... *Ducampopinus*

As we shall see next, these statements are not quite correct because (1) all transverse tracheids in all species of *Pseudotsuga* are spirally thickened rather

than smooth, (2) those of *Cathaya* are also finely spiralled rather than spiculate, and (3) *Ducampopinus* does possess transverse tracheids having smooth and thin walls.

Of the samples put at our disposal, we have prepared numerous sections and have subjected them to a thorough scrutiny. Our examinations have convinced us that the form called *Cathaya argyrophylla* does not merit the new generic term *Cathaya* because, even in the most minute xylotomical detail, it fully agrees with all the living *Pseudotsuga* species. It is highly probable, on the other hand, that the specific name argyrophylla will turn out to be justified.

Xylotomical features. These have been discussed among others by Yatsenko-Khmelevsky and Butkevitch. The present author does not wish to comment here on their findings and measurement results, which are entirely conformable to fact, but desires to point out only the following of their statements.

(1) "*Cathaya* is closely related to *Picea*, and the genera *Pseudotsuga* and *Larix*."

(2) "Internal walls of transverse tracheids minutely spiculate, locally forming more or less discernible spirals."

(3) "Relating *Cathaya* to *Pseudotsuga* presents some obstacles as *Pseudotsuga* is characterized by smooth walls in its transverse tracheids, more or less." (cf. Fig. 6 of their paper.) "In *Picea*, however, these walls are commonly spiculate (cf. Fig. 5, ibid.). The same spiculation has been observed also in *Cathaya*. *Cathaya*, then, stands closer to *Picea* than to *Pseudotsuga*."

(4) "The xylotomical features, taken together, consequently exclude the possibility of identifying *Cathaya* with *Picea* or *Pseudotsuga*, and hence there is overwhelming evidence that this plant constitutes an independent genus."

We shall attempt in the following to reconcile these characterizations with our own findings.

(1) Our xylotomical examination has revealed *Cathaya* to be of a decidedly pseudotsugan xylotomical structure, as proved by the fact that all its axial and transverse tracheids are spirally thickened (cf. our Photos 2a, b, 3a, b and 4) *Pseudotsuga* is the only genus of the family *Pinaceae* invariably to possess spirally thickened transverse tracheids, notably in both the early and late wood. This is proved by all relevant photos of *Pseudotsuga species* (cf. *Pseudotsuga japonica*, Plate CLX herein; *P. macrocarpa; P. taxifolia;* also, *P. gausseni*, Plate CLVIII herein). Gaussen is consequently in error when stating the transverse tracheids of *Pseudotsuga* to be smooth-walled. Fig. 6 of the cited paper, showing smooth transverse tracheids in *Pseudotsuga menziesii* (erroneously cited as *mangiesii)* Mirb. Fraco is also wrong. Gaussen probably derived his erroneous information from the Soviet authors.

There doubtless are spiral thickenings in the axial tracheids also of *Picea* and *Larix*, but these are restricted to the late wood. Also, the transverse tracheids of *Picea* exhibit minute spicules and may, very exceptionally, be spirally thickened, too (cf. e.g. *Picea linkiangensis* and *P. montigena*), but there certainly are no such spirally thickened transverse tracheids in *Larix*. The xylotomical structure of Cathaya is entirely pseudotsugan in all its traits, so that it is well-

nigh impossible to distinguish the two on a xylotomical basis. Hence, Butkevitch' statement that *Cathaya* stands closer to *Picea* than to *Pseudotsuga* is erroneous in my opinion.

This, then, is our brief xylotomical reflexion on the points (1) to (4) raised above. *Cathaya* is, consequently, no independent genus in our opinion, but a typical *Pseudotsuga* species, so that, at least on a xylotomical basis, the new generic name *Cathaya* is unjustified. (Incidentally, in the present author's opinion, its external morphology is also distinctly pseudotsugan.) Its correct name might be *Pseudotsuga argyrophylla* Chun et Kuang (Greg. nov. comb.). This close relationship could possibly be confirmed by chemical means.

The pollen of *Cathaya* presents an altogether different problem. The pollen grains of *Pseudotsuga* are round, whereas those of *Cathaya* possess two air bladders, which fact relates them to *Abies*, *Picea*, *Pinus* and the rest of the bladdered coniferous pollens. This is indeed a stumbling block on the way of placing this species into *Pseudotsuga*. Still, a not quite reliable source has asserted to me that some of the living *Pseudotsuga* have more or less bladdered rather than purely spherical pollen grains. This data, if proved correct, would remove the last obstacle from placing *Cathaya* into the genus *Pseudotsuga*. The relevant research is still in course, however.

Let us emphasize as a supplement a few traits common to *Cathaya* and *Pseudotsuga*. Most of the resin ducts run in the late wood (Photo 1). The solitary parenchyma cells are also disposed next to the annual ring boundary. The transverse walls of the longitudinal parenchyma cells are thickened dentately. The pitting of the axial parenchyma cells and the tangential structure of the rays is also the same, and so are the pitting of the thick tangential walls of the ray parenchyma cells and the small piceoid pits of the cross fields. Cross fields include typically 4 or 6 simple pits, with narrow, slightly oblique apertures that reach up to and even beyond the chamber outline.

This comparison leads to the definitive conclusion that the cross field structure of *Cathaya* agrees with those of all the *Pseudotsuga* species. Let us repeat that, xylotomically, it is well-nigh impossible to distinguish *Cathaya* from *Pseudotsuga* and that, consequently, on a purely xylotomical basis, the distinction of the genus *Cathaya* is unjustified.

148. (498) *Pseudotsuga gausseni* Flous

Plate CLVIII, Photos 1—4 and Fig. 138.

The sections examined were prepared of a thickish trunk sample having annual rings 1·5 mm wide on an average, kindly put at my disposal by Professor Tsun Ching Cheng, Institute of Forest Products, Peking, China.

C. (Photo 1.) Annual ring boundaries conspicuous, sharp; early and late tracheids differ markedly in size, shape and wall thickness. Tracheid width typical-

ly 35 to 40 μ; radial dimension 35 to 60 μ in early, 14 to 18 μ in late wood. Sections square or radially elongate hexa- or polygonal. Late tracheids thick-walled, sections rounded, lumina circular or procumbent elliptical. Resin ducts of 80 to 90 μ diameter comparatively rare; the epithelial cells lining them are thick-walled. Some of these ducts are flanked on both sides by wings of slightly thinner-walled parenchyma cells. This is a more or less general pseudotsugan feature. Ducts prefer the late wood and the vicinity of the rays. Some ducts form more or less coalesced pairs. There are xylem parenchyma cells in the ring fields and also next to the ring boundary. Most rays are uniseriate but the ducted ones are broader.

R. (Photo 3.) Ray cells 17 to 22 μ high. Transverse walls 3 to 4 μ thick, bearing rather close-spaced simple pits; tangential walls dentately thickened. Most cross fields enclose 2 to 4 circular small pits of 5 to 6 μ size with oblique slit-like apertures. Rays are flanked by transverse tracheids whose walls exhibit a fine spiral thickening. Radial dimension of axial tracheids 35 to 60 μ; all tracheids exhibit fine spiral laths, spaced 3 to 6 μ apart. The radial walls exhibit in addition bordered pits of 20 to 22 μ size with circular apertures. All walls of the axial parenchyma cells next to the ring boundary finely pitted. Pit size 5 to 6 μ; the cells are 300 to 350 μ long and 12 to 13 μ wide. Their end walls are dentately thickened. An important feature of this species is that the thickenings in the axial and transverse tracheid walls are invariably identical. The transverse tracheids have bordered pits of 7 to 8 μ size in their walls.

T. (Photos 2, 4.) Most rays uniseriate, but some are biseriate though unducted; the ducted ones are bi- to triseriate. Rays 1 to 20, typically 1 to 10 cells tall, but rays 2 to or 3 cells tall are the most frequent. Typical ray parenchyma cell height is 17 to 22 μ. The marginal tracheids are lower as a rule and only 15 to 17 μ wide. Their sections are circular or procumbent elliptical. Tangential walls of parenchyma cells perforated sieve fashion. All walls of ray parenchyma cells thick and pitted. Also in this view, the walls of the axial tracheids are seen to be densely, spirally thickened, but bordered pits of 13 to 14 μ size are less numerous in their tangential walls. The resin ducts in the rays are surrounded by 8 to 10 epithelial cells. The height of a duct is 35 to 40 μ. Tangential size of axial parenchyma cells about the same as that of tracheids; their walls exhibit numerous simple pits of 5 to 6 μ size in a loose bi- or triseriate arrangement. End walls dentately thickened; some number up to 5 teeth.

149. (499) *Pseudotsuga glauca* Mayr.

(*Pseudotsuga douglasi* var. *glauca* Mayr.)

Fraser River Douglas Fir, Rocky Mountains Douglas Fir

Plate CLIX, Photos 1—4 and Fig. 139.

A giant tree up to 40 m tall, it lives in the Rocky Mountains, in Colorado, Utah, Arizona, New Mexico and Western Mexico. The sections examined were prepared of a thick trunk whose annual rings were 1·5 to 3 mm wide. The sample in question was received from the Royal Botanical Gardens, Kew, England.

C. (Photos 1, 2.) Annual ring boundaries sharply marked. There is a significant change in tracheid shape, size and wall thickness across the ring boundary. Tracheid width 25 to 40 μ: radial dimension 50 to 60 μ in early, 12 to 16 μ in late wood. Sections of early tracheids angular, square, radially elongate rectangular or polygonal. Sections of late tracheids angular, lumina circular, procumbent elliptical or slit-like; their double walls are 9 to 10 μ thick. Resin ducts of 80 to 130 μ diameter are fairly frequent in late wood. The epithelial cells surrounding them (13 or 14 in number) are thick-walled. There are in places coalesced pairs of ducts, and even 8 to 10 ducts arranged palisade fashion parallel to the ring boundary. These latter might be resin cysts rather than true resin ducts. Axial parenchyma very scarce; there are rings containing not a single such cell.

R. (Photo 3.) Ray cells 16 to 20 μ high. Transverse tracheids slightly lower than ray parenchyma cells. Transverse walls of these latter comparatively thick (5 to 6 μ), strewn with simple pits. Tangential walls dentate. Cross fields enclose 3 or 4 pits; marginal fields enclose up to 6. The walls of the transverse tracheids exhibit very fine spiral laths, and also small bordered pits of 6 to 7 μ size. Radial dimension of axial tracheids 50 to 60 μ; all tracheids have fine close-spaced spiral laths in their walls, and also bordered pits of 14 to 16 μ size. Only one axial parenchyma cell could be ascertained; the thickening in its end wall is uneven rather than dentate. The epithelial cells connected with the axial resin ducts have thick and densely pitted walls.

T. (Photo 4.) Uniseriate rays 1 to 22, ducted rays up to 30 cells tall. The cells in the uniseriate rays are 18 to 20 μ high and 12 to 13 μ wide; sections are upright, slightly elongate ellipses. Tangential walls reticulately thickened. All walls thick, 7 to 8 μ for the double wall. Ducted rays 35 to 40 μ wide; the thick-walled epithelial cells connected with a duct number 10 to 12 but this number varies somewhat as a function of duct size. Ducts most often run at middle height in tall rays but this is not a general rule. Tangential dimension of axial tracheids 25 to 40 μ; all tracheids bear very fine spiral laths spaced 3 to 6 μ apart and including an angle of 140 to 160° with the trunk axis. Bordered pits are a rarity in the tangential walls. Only one parenchyma cell could be observed.

150. (500) *Pseudotsuga japonica* (Shirasawa) Beissner

(*Abies japonica* Rovelli, *Tangai japonica* Shirasawa)

Plate CLX, Photos 1—4 and Fig. 140.

This is a tree 20 to 30 m tall, living in Southeast Japan. The sections examined were prepared of a thick trunk sample having annual rings 1 to 2 mm wide, kindly put at my disposal by Mr. Yoshio Saito, The Government Forest Experiment Station, Meguro, Tokyo, Japan.

C. (Photo 1.) Annual ring boundaries conspicuous, sharp; some rings may be up to 120 tracheids wide. Tracheid width 25 to 35 μ, radial dimension 40 to 45 μ in early, 12 to 16 μ in late wood. Sections of early tracheids square, radially elongate rectangular, or hexagonal. Sections of late tracheids radially flattened and rounded rectangles; lumina procumbent ellipses or slits. Width of late wood one-third to one-half of total ring width. Early wood passes gradually into late wood. There are fairly often strings of axial parenchyma cells along the annual ring boundaries. This is a typical pseudotsugan feature. Rather scarce resin ducts of 100 to 110 μ diameter, surrounded by thick-walled parenchyma cells which presumably belong to the ducts, prefer the beginning of the late wood. Rays uniseriate; the broader ones enclose resin ducts.

R. (Photo 3.) Ray cells 18 to 25 μ high. Transverse tracheids somewhat lower. Transverse walls of ray parenchyma cells thick (4 to 5 μ), bearing numerous simple pits. Tangential walls dentately thickened. Most cross fields enclose 4 or 5 small piceoid pits but some enclose 6 to 7. Pits prefer position in the corners of the fields. Pit size is 5 to 6 μ; apertures are oblique gashes. Walls of transverse tracheids exhibit fine spiral thickenings, also a few bordered pits of 7 to 8 μ size, with circular or short slit-like apertures. Radial dimension of early axial tracheids 40 to 45 μ; all their walls exhibit very fine spiral laths spaced 3 to 6 μ apart, also loose uniseriate strings of bordered pits of 16 to 18 μ size, with circular apertures. End walls of xylem parenchyma cells nodosely or dentately thickened. The taller rays have transverse tracheids also in internal positions: these are easily recognized by their spiral thickening.

T. (Photos 2, 4.) Rays 1 to 20, typically 8 to 10 cells tall, but those 2 or 3 cells tall are also fairly frequent. Ray cells 18 to 25 μ high, 14 to 15 μ wide typically. Their tangential walls are pitted sieve-like. Tangential dimension of axial tracheids 25 to 35 μ; all tracheid walls bear almost indiscernibly fine spirals spaced 3 to 6 μ apart. Walls of late tracheids sometimes bear bordered pits of 13 to 14 μ size. Axial parenchyma cells of same tangential dimension as tracheids. Their end walls are unevenly thickened. Ducted rays are 18 to 20 cells tall. The duct is not invariably at middle height, that is, the tallest rays are often asymmetrical about a transverse axis. The epithelial cells belonging to one duct number 8 to 10. Ducted rays are 30 to 35 μ wide.

151. (501) *Pseudotsuga wilsoniana* Hayata

(*Pseudotsuga forrestii* Craib.)

Plate CLXI, Photos 1—4 and Fig. 141.

This tree, 15 to 20 m tall, lives in Southwest China, Yunnan province, and in the high mountains of Taiwan. The sections examined were prepared of a bough fragment 6 years old. The sample was kindly provided by Mr. S. C. Liu, Historical Research Commission of Taiwan Province, Taiwan.

C. (Photo 1.) Annual rings 20 to 40 tracheids wide; ring boundaries distinct; late wood takes up one-fifth or one-sixth of ring. Radial dimension and width of early tracheids both 20 to 35 μ; sections usually square or slightly elongate rectangular at the beginning of the early wood. Walls of early tracheids 2 to 3, those of late tracheids 6 to 7 μ thick. Sections of late tracheids radially flattened rectangular: their radial dimension is 9 to 10 μ. There are fairly numerous xylem parenchyma cells next to the ring boundary, and none or very few in the ring fields. Lumina of most late tracheids rounded. Resin ducts of 40 to 45 μ diameter lined with thick-walled epithelial cells are fairly numerous. On either side of a duct, axial parenchyma cells tend to form wing-like configurations. This is one of the typical features of *Pseudotsuga*. Most rays uniseriate; the broader ones enclose resin ducts.

R. (Photo 3.) Ray cells 20 to 22 μ high. Their transverse walls are comparatively thick (4 μ) and bear numerous simple pits. Their tangential walls are nodosely or dentately thickened. Most cross fields enclose 2 to 4 small piceoid pits of 4 to 5 μ size with slightly oblique linear or slit-like apertures. Transverse tracheids scarce. Their walls exhibit a fine, almost indiscernible spiral thickening. Radial dimension of early axial tracheids 20 to 35 μ; their walls exhibit the same type of almost indiscernible spiral thickening. In some late tracheids, this thickening seems to be missing, but it is present beyond doubt in the early tracheids. The bordered pits of 14 to 15 μ size with circular apertures occurring in the axial tracheid walls form loose uniseriate strings. Axial parenchyma cells 200 to 250 μ long; end walls uneven, thickened bead-like or dentately; other walls bear small simple pits of 4 to 5 μ size.

T. (Photos 2, 4.) Rays 1 to 10, typically 2 to 6 cells tall. In the uniseriate rays, the ray parenchyma cells are 10 to 12 μ wide, with close-spaced simple pits in their walls. The cells are 20 to 22 μ high. Tangential dimension of transverse tracheids 20 to 22, exceptionally up to 26 μ; their walls exhibit dense fine spirals. End walls of axial parenchyma cells uneven, thickened bead-like; other walls bear numerous round simple pits of 5 to 6 μ size. The epithelial cells connected with the resin ducts agree in structure with the axial parenchyma cells. In the taller rays there are resin ducts of comparatively small diameter.

152. (502) *Tsuga caroliniana* Engel.

(*Abies caroliniana* Champau)

Crag Hemlock, Hemlock, Southern Hemlock

Plate CLXII, Photos 1—4 and Fig. 142.

A tree 20 to 25 m tall in the Alleghenies of North America. The sections investigated were prepared of a thickish trunk sample having annual rings about 1 mm thick on an average, received from the Smithsonian Institution, Washington, U.S.A.

C. (Photo 1.) Annual ring boundaries conspicuous, owing to differences in tracheid size, shape and wall thickness across them. Walls of early tracheids 2, those of late tracheids 7 μ thick. Tracheid width typically 30 to 35 μ; radial dimension 50 to 60 μ in early, 14 to 16 μ in late wood. Lumina of late tracheids narrow slit-like or elliptical. There are solitary xylem parenchyma cells filled with a dark substance next to the ring boundary. Such cells are scarce in the ring fields proper. The late wood, usually 8 to 10 tracheids wide, takes up one-third to one-fourth of ring width. Resin ducts of 50 to 60 μ diameter are restricted to the late wood, to the immediate vicinity of the ring boundary, where they may form palisades; in some rings, however, there is no resin duct at all. Owing to the impossibility of detecting resin ducts, properly speaking, in the radial or tangential sections, these formations should more precisely be called resin cysts rather than ducts. Such cysts occur also in *Cedrus*. Rays uniseriate.

R. (Photo 3.) Ray cells 18 to 20 μ high. Transverse walls comparatively thick (6 to 7 μ), generally smooth, but some scarce simple pits may occur. Tangential walls dentately thickened, provided with indentures. Cross fields enclose 2 or 3, locally even 4 or 6 small piceoid pits of 6 to 7 μ size having oblique slit-like apertures. Rays are flanked by entirely smooth-walled transverse tracheids whose radial walls bear bordered pits of 7 to 8 μ size, with circular or oblique elliptical apertures. Radial dimension of early axial tracheids 50 to 60 μ; their walls exhibit solitary or paired bordered pits of 18 to 20 μ size, in loose or close-packed arrangements. Axial parenchyma cells 100 to 150 μ long, 12 to 14 μ wide. Their walls are densely pitted with very small simple pits of 4 to 5 μ size.

T. (Photos 2, 4.) Rays 1 to 20 cells tall, uniseriate. None are biseriate or ducted. Ray cells 18 to 20 μ high, 10 to 11 μ wide; sections elongate elliptical. Tangential walls bear numerous simple pits giving rise to a sieve-like perforation. Axial parenchyma cells as wide as the tracheids; all walls bear simple pits; end walls dentately thickened. Tangential walls of axial tracheids bear small bordered pits of 7 to 8 μ size.

153. (503) *Tsuga formosana* Hayata

Formosan Hemlock

Plate CLXIII, Photos 1—4 and Fig. 143.

This tree lives in the mountains of Taiwan island. The sections examined were cut from a thickish trunk sample having annual rings 0·5 mm wide on an average, received from the Royal Botanical Gardens of Kew, England.

C. (Photo 1.) Ring boundaries remarkably sharp, owing to differences in tracheid size, shape and wall thickness across them. Early and late wood of about equal width, but the early wood is wider locally. Rings 10 to 25 tracheids wide. Tracheid width 40 to 50 μ, radial dimensions 60 to 65 in early, 12 to 15 μ in late wood. Sections of most early tracheids square or radially elongate rectangular, those of late tracheids radially flattened rectangles. No resin ducts or resin cysts. Xylem parenchyma very scarce or absent. Rays uniseriate.

R. (Photo 3.) Ray parenchyma cells 18 to 19 μ high. Transverse walls comparatively thick (4 to 5 μ), uniform, rather densely pitted with simple pits. Tangential walls dentately thickened and provided with indentures. Most cross fields enclose 2 or 3 small piceoid pits, marginal fields enclose 4 or 5. Apertures are short linear; pit size is 4 to 5 μ. Rays flanked by smooth-walled transverse tracheids with undulous outer walls. Radial dimension of early axial tracheids 60 to 65 μ; their walls exhibit loose single or paired bordered pits of 22 to 23 μ size, with circular apertures of 6 to 7 μ diameter. Crassulae are conspicuous between the paired pits.

T. (Photos 2, 4.) Rays 1 to 20, typically 8 to 10 cells tall. Height of ray parenchyma cells 18 to 19 μ, width 14 to 15 μ, sections circular, square or low upright elliptical. Marginal cells tend to be higher than internal ones. Tangential walls exhibit a sieve-like perforation. Tangential dimensions of axial tracheids 40 to 50 μ; no bordered pits could be detected in their tangential walls. No xylem parenchyma was observed, either. The question whether this wood possesses a very few parenchyma cells or none at all could be decided only by preparing series sections.

154. (504) *Tsuga sieboldii* Carr.

(*Tsuga tsuja* A. Mserray, *Abies tsuga* Sieb. et Zucc.)

Southern Japanese Hemlock

Plate CLXIV, Photos 1—4 and Fig. 144.

A huge tree up to 30 m tall living in Southern Japan. The sections examined were prepared of a trunk slice 2 cm thick having annual rings 1·5 mm wide on an average, received from the Institute of Forest Products, Ministry of Forestry, Wan Shu Shan, Peking, China.

C. (Photo 1.) Annual ring boundaries conspicuous, owing to considerable contrast between early and late tracheids. Sections of early tracheids angular, almost perfect square or radially somewhat elongate rectangular; radial dimension and width both 35 to 60 μ typically. Radial dimension of late tracheids 12 to 14 μ, sections procumbent rectangular, walls thick, lumina gash-like or procumbent elliptical. Late wood takes up one-third or one-quarter of ring width. Early wood passes gradually into late wood. Xylem parenchyma cells restricted to annual ring boundary, to the beginning of the early wood. They do not show up in the radial or tangential sections except if these cut the annual ring boundary. There are no resin ducts.

R. (Photo 3.) Typical ray parenchyma cell height 17 to 20 μ; transverse tracheids flanking the rays are somewhat lower (15 to 16 μ). Transverse walls of parenchyma cells comparatively thick (5 to 6 μ), rather densely pitted with simple pits. The tangential walls, some of which are long and strongly leaning, are densely pitted and often provided with indentures. Cross fields enclose 2 to 6 small piceoid pits of 5 to 6 μ size, with oblique linear apertures. Walls of transverse tracheids smooth, thin, unthickened, unpitted. Radial walls exhibit small bordered pits of 6 to 7 μ size. Radial dimension of early axial tracheids 35 to 60 μ; late ones are much narrower. The bordered pits in their walls are of 18 to 20 μ size; their circular apertures are of 7 μ diameter. Axial parenchyma cells are 250 to 300 μ long and 12 to 13 μ wide. Their radial walls bear several simple pits of 6 to 7 μ size.

T. (Photos 2, 4.) Rays 1 to 24 cells tall, individual cells 17 to 20 μ high, 13 to 14 μ wide. Tangential walls of axial tracheids 35 to 60 μ wide; they bear a few bordered pits of 12 to 13 μ size. The tangential section did not cut the annual ring boundary and consequently showed only one xylem parenchyma cell whose end wall was dentately thickened.

155. (505) *Tsuga yunnanensis* Mast.

Yunnan Hemlock, Tich cha

Plate CLXV, Photos 1—4 and Fig. 145.

A tall tree up to 35 m, living in the provinces Yunnan and Szechwan of China. The sections examined were prepared out of a thick trunk sample having annual rings of 1 mm width on an average, kindly provided by Professor Tsun Ching Cheng of the Institute of Forest Products, Peking, China.

C. (Photo 1.) Annual ring boundaries sharp, owing to differences in tracheid size, shape and wall thickness across them. Late wood takes up about one-third or one-quarter of ring. Typical rings 10 to 15 tracheids wide. Sections of early tracheids almost perfect square or radially somewhat elongate rectangular; radial dimensions 45 to 50 μ, width 30 to 40 μ typically. Radial dimension of

late tracheids 14 to 15 μ, sections radially flattened rectangular, lumina almost slit-like. There are at the ring boundary a few xylem parenchyma cells whose end walls are finely pitted. There are no resin cysts.

R. (Photo 3.) Ray cells 18 to 24 μ high, transverse walls 3 to 4 μ thick, pitted with numerous simple pits. Tangential walls dentately thickened; some are provided with indentures. Cross fields enclose 2 to 4 small piceoid pits of 6 to 7 μ size with oblique slit-like or linear apertures. Outer walls of transverse tracheids thin, undulous, unpitted, unthickened. Radial walls exhibit small bordered pits of 6 to 7 μ size. There are some scattered axial parenchyma cells at the ring boundary: their end walls are nodosely thickened, their radial walls exhibit small pits of 6 to 7 μ size. In the walls of the axial tracheids there are loosely scattered solitary bordered pits of 17 to 18 μ size, with circular apertures of 7 μ diameter. Some of these pits are crowded and separated by crassulae. In some early tracheids, twin pits could be observed.

T. (Photos 2, 4.) Rays 1 to 25 cells tall; ray cells 18 to 24 μ high, 12 to 14 μ wide; sections slightly elongate elliptical; tangential walls thickened sieve-like. Tangential dimension of axial tracheids 30 to 40 μ; walls of late tracheids bear small bordered pits of 8 to 10 μ size with oblique slit-like apertures. The axial parenchyma cells occurring in the late wood are 150 to 180 μ long, 20 to 25 μ wide; their end walls are dentately thickened. Their tangential walls bear small simple pits of 7 to 8 μ size.

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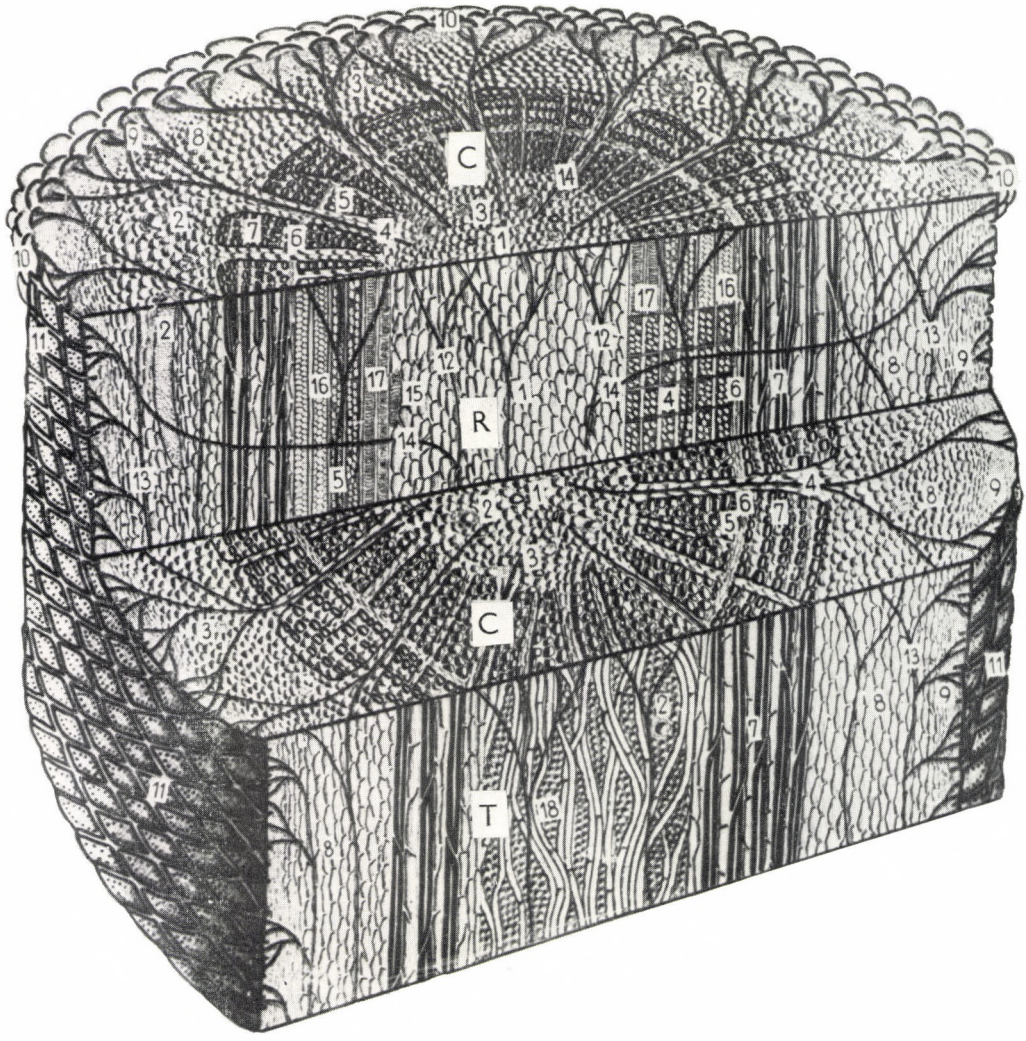
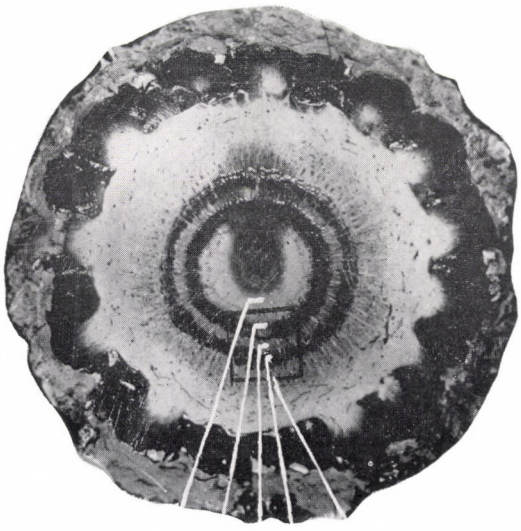
PLATES to the General Part (I—X)



I. Internal structure of a *Cycas* trunk

1. Pith; 2. Mucilage canals; 3. Calcium oxalate crystal druses; 4. Primary rays; 5. Xylem; 6. Cambium; 7. Phloem; 8. Cortex; 9. Periderm; 10. Leaf bases; 11. Leaf scars; 12. Ray bundles; 13. Bundles leaning out into the cortex and thence into the leaf bases; 14. Common bundles leaning out from the pith into the leaves through the primary rays; 15. Transfusion cells; 16. Tracheids showing araucarioid pitting; 17. Tracheids showing scalariform thickening; 18. Multiseriate rays. (Original)

II. Fig. 1a: Cross section of trunk of *Cycas revoluta* (× 1/2). a = pith, b = xylem ring, c = phloem ring. Fig. 1b: internal structure of conductive bundles (× 15). Fig. 2a: section of a fir (*Picea*) bough 12 years old (× 10). Fig. 2b: cross sectional structure of a fir bough (× 30). (Original)



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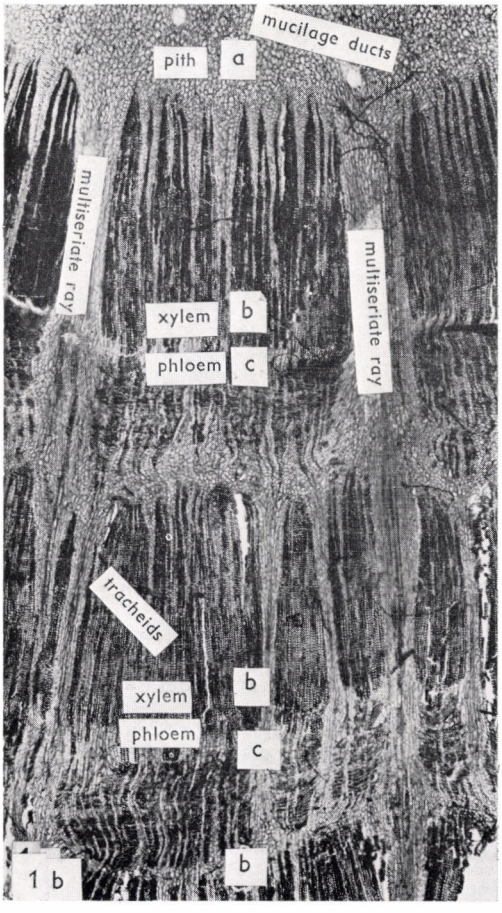
2 a



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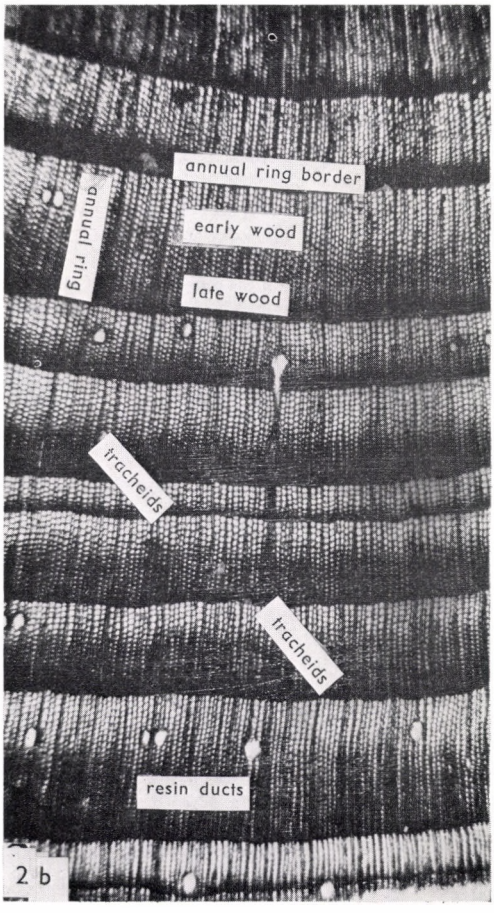

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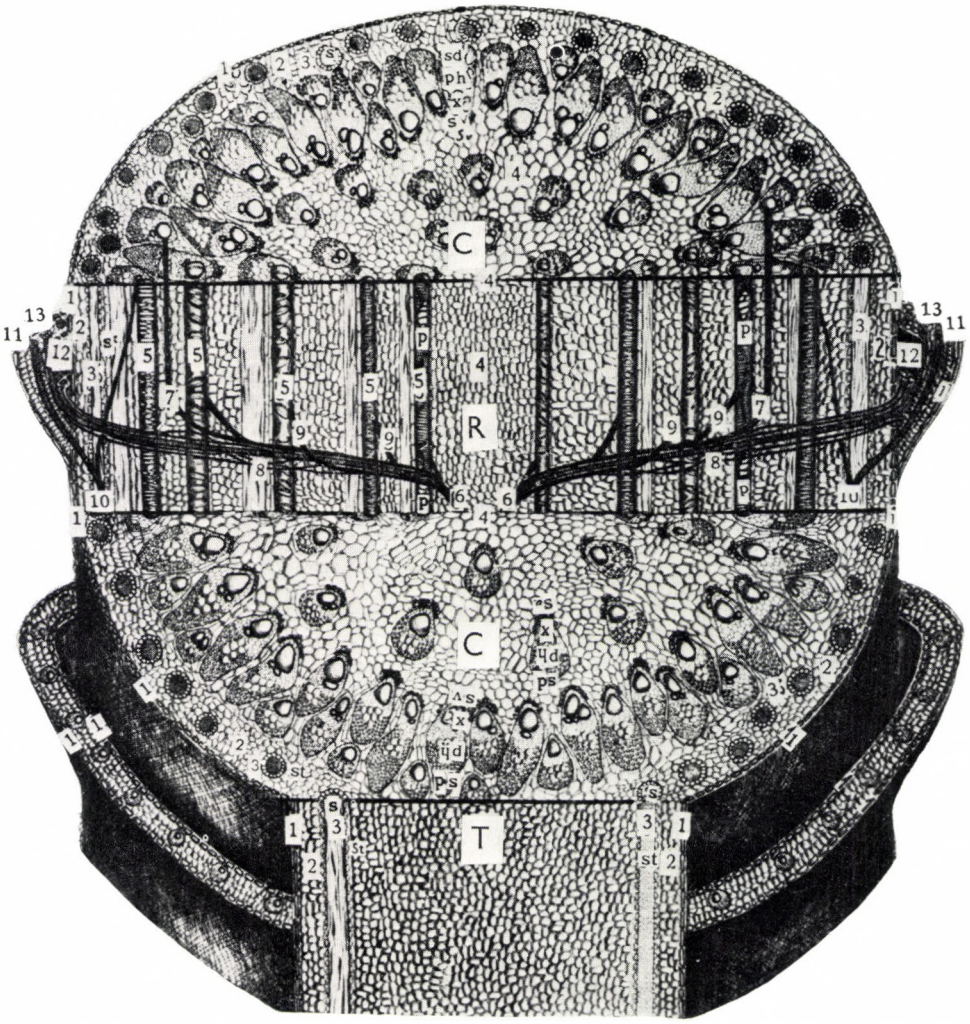
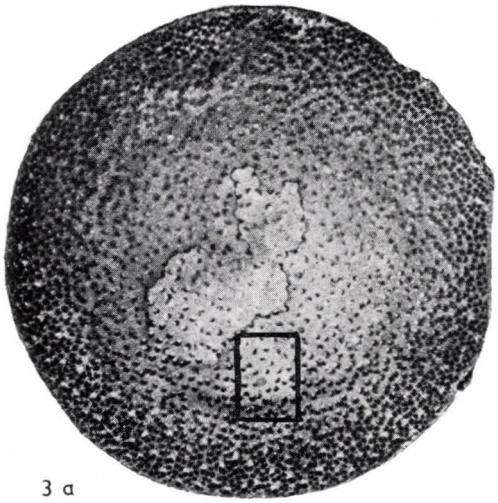


III. Internal structure of a palm trunk (*Raphis*)

Cross section: 1. Epidermis on the trunk and leaves; 2. Cortical parenchyma cells; 3. Sclerenchyma fibres (Sc) bearing stigmata (St); 4. Pith with collateral bundles scattered in the ground tissue. The individual bundles are composed of X = xylem, Ph = phloem, Sd = Sclerenchyma dorsale, Sv = Sclerenchyma ventrale. *Radial section:* Leaf bases (11, 13) on both sides of the trunk. The conductive bundles exhibit vessels with annular, scalariform and spiral thickening (5). Perforation at P. Heavy lines show path of vascular bundle from the pith outward (7, 8, 9, 10). *Tangential section:* 1. Epidermis; 2. Cortical parenchyma; 3. Sclerenchyma fibres with stigmata. (Original)

IV. Fig. 3a: cross sectional structure of a palm trunk (*Raphis*, ×2). Fig. 3b: Anatomical structure of a palm trunk (*Raphis*, ×30). Fig. 4a: cross sectional structure of a dicotyledonous tree (linden, *Tilia*, ×5). Fig. 4b: anatomical structure of a dicotyledonous tree (linden, *Tilia*, ×50). (Original)



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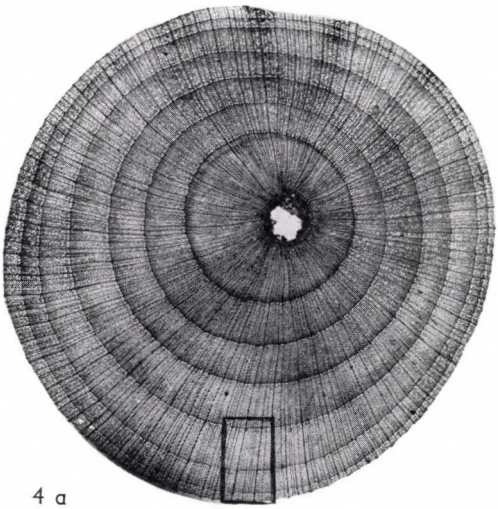

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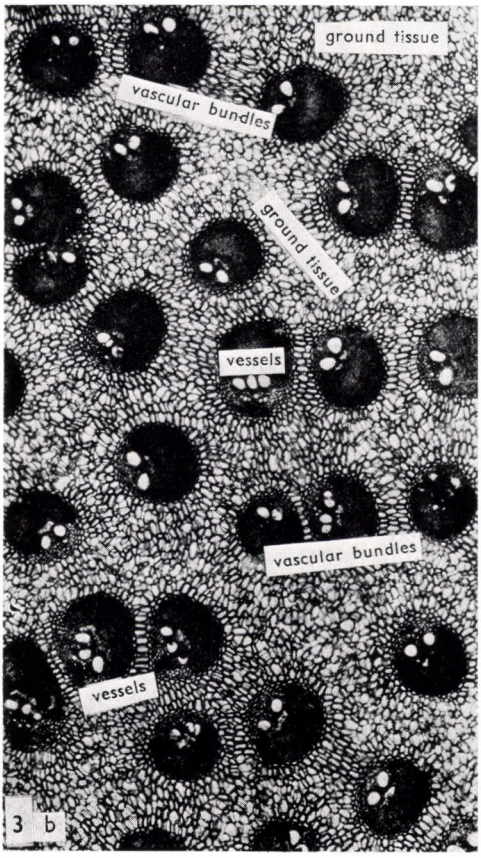
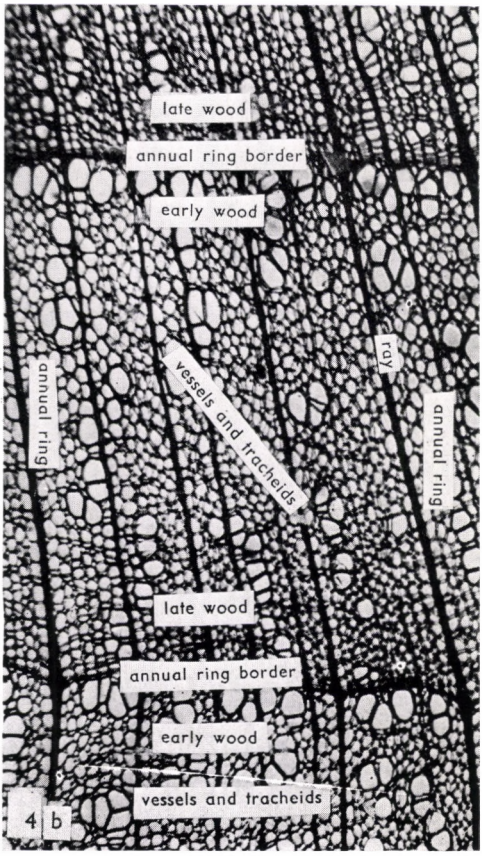

ground tissue
vascular bundles
ground tissue
vessels
vascular bundles
vessels
3 b


late wood
annual ring border
early wood
ray
vessels and tracheids
annual ring
annual ring
late wood
annual ring border
early wood
vessels and tracheids
4 b

V. Main xylotomical features of the *Araucariaceae*

Photos 1—3. Vague annual ring boundaries: 1. *Araucaria balansae* Brongn. and Grieseb.; 2. *Agathis robusta* Mast.; 3. *Araucaria angustifolia* (Bertol.) Ktze.-C. (× 100)

Photo 4. Slightly marked annual ring boundaries. *Agathis lanceolata* (Pancher) Warb. R. (× 100)

Photo 5. Cross field between ray parenchyma and axial parenchyma cells, unpitted. *Agathis lanceolata* (Pancher) Warb.-R. (× 300)

Photo 6. Cask-shaped ray cells. Some tracheids have bordered pits in alternate arrangement in their tangential walls. *Araucaria muelleri* Brongn. and Griseb. T. (× 100)

Photo 7. Thick-walled parenchyma cells in some rays. *Agathis macrophylla* (Lindl.) Mast.-T. (× 100)

Photo 8. Low rays. *Araucaria angustifolia* (Bertol.) Ktze.-T. (× 100)

Photo 9. Tall rays. *Agathis lanceolata* (Pancher) Warb.-T. (× 100)

Photo 10. Araucarioid pitting in the cross fields. *Agathis beccarii* Warb.-R. (× 300)

Photo 11. All walls of ray parenchyma cells smooth and thin. Typical araucarioid pitting in the cross fields. *Agathis australis* Salisb.-R. (× 300)

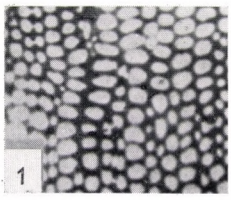
Photo 12. Single and alternate double and triple rows of pits in tracheid walls. *Agathis palmerstonii* F. Mueller-R. (× 300)

Photo 12a. Pitting in a cross field of *Araucaria bidwillii* Hooker fil.-C.

Photo 13. Honeycomb pattern of bordered pits in the tracheids. Resin-filled axial parenchyma cell with smooth end wall. *Agathis palmerstonii* F. Mueller-R. (× 300)

Photo 14. Araucarioid pitting of cross fields in axial tracheids. Alternate honeycomb-pattern pitting. *Araucaria columnaris* (Forst.) Hooker fil.-R. (× 300)

Photo 15. Idem, in *Araucaria klinkii* Lauterb.-R. (× 300)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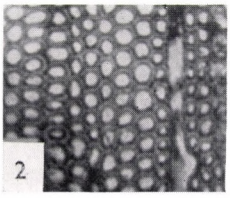
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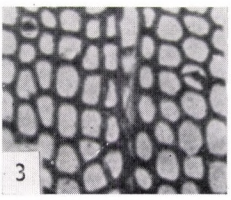
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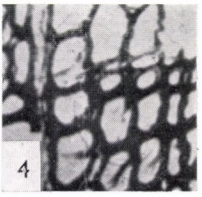
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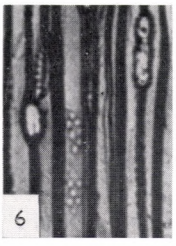
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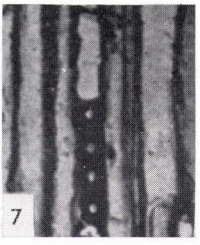
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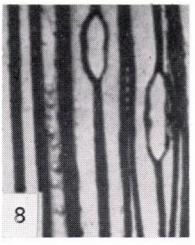
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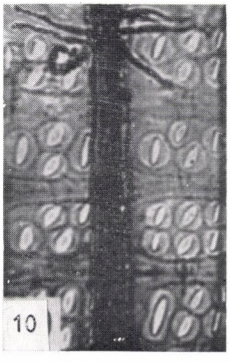
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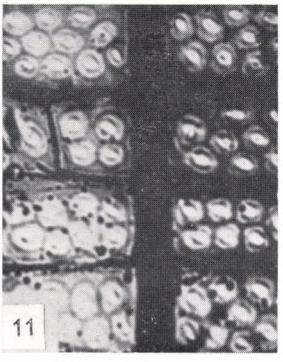
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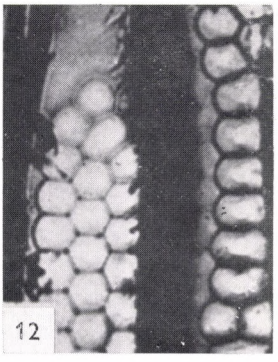
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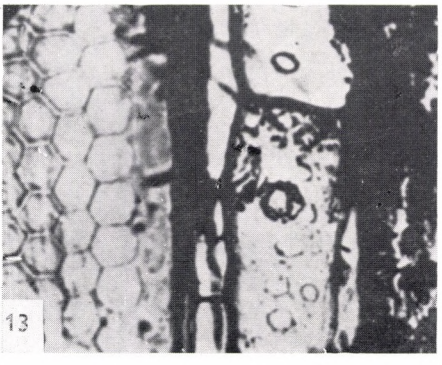
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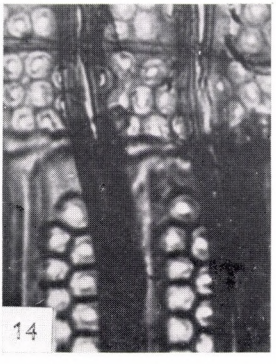
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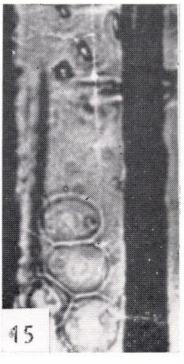
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VI. Main xylotomical features of the *Podocarpaceae*

Photo 1. Conspicuous annual ring boundaries with angular tracheid sections. *Phyllocladus glaucus* Carr.-C. (× 100)

Photo 2. Vague annual ring boundary, with angular tracheid sections. *Podocarpus macrostachyus* Parlatore-C. (× 100)

Photo 3. Vague annual ring boundaries with rounded tracheid sections. *Podocarpus montanus* Lodd.-C. (× 100)

Photo 4. Vague annual ring boundaries. Some rings include axial parenchyma cells. Tracheid sections rounded. *Podocarpus oleifolius* D. Don.-C. (× 100)

Photo 5. Axial parenchyma cells with smooth and thin end walls. Taiwania cryptomerioides. T. (× 200)

Photo 6. Low and tall rays. *Podocarpus gracilior* Pilger-T. (× 100)

Photo 7. Solitary and opposed bordered pits in tracheids. Twin pits joining oblique or transverse faces. *Podocarpus longifoliatus*

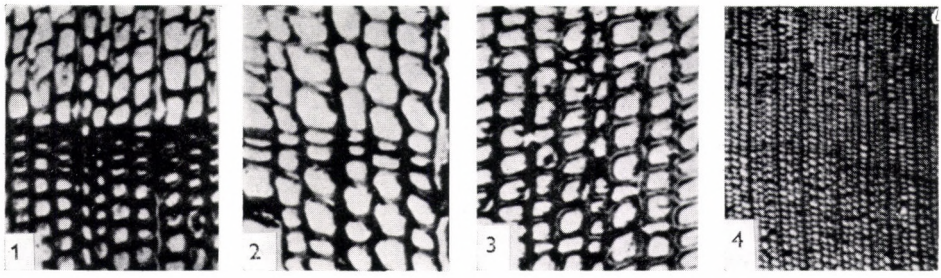
Photo 8. Opposed bordered pits in tracheid walls join vertical faces. Cross fields exhibit podocarpoid pits. *Podocarpus oleifolius*

Photos 9—10. Podocarpoid pits in cross fields. All walls of ray cells smooth and thin. Cross fields between axial and ray parenchyma cells unpitted. *Podocarpus coriaceus*, *P. dacrydioides*

Photo 11. Typical dacrydioid pits in the cross fields. *Dacrydium araucarioides* Brongn. and Griseb.-R. (× 300)

Photo 12. Podocarpoid pits in the cross fields. *Dacrydium franklinii* Hooker fil.-R. (× 300)

Photo 13. Podocarpoid pits in the cross fields. *Podocarpus spicatus* R. Br.-R. (× 300)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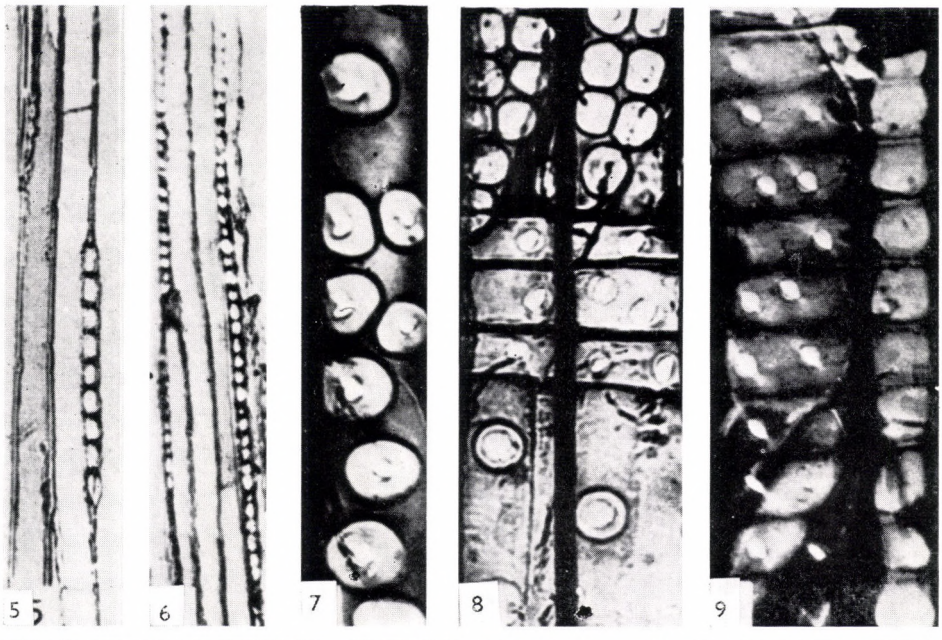
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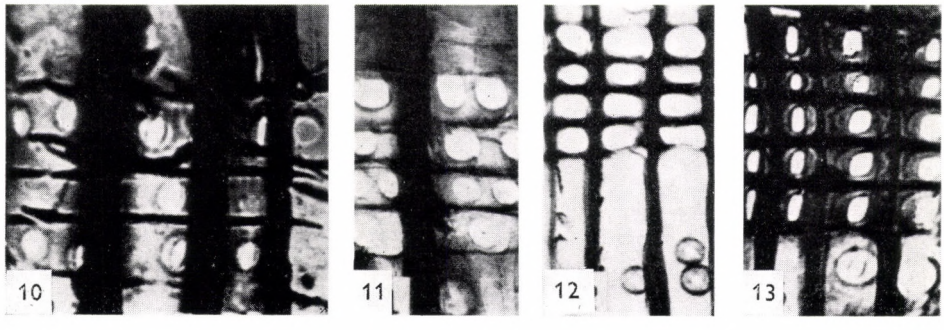
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VII. Main xylotomical features of *Taxales* (Taxaceae + Cephalotaxaceae)

Photo 1. Conspicuous annual ring boundary. *Taxus cuspidata* Sieb. and Zucc.-C. (× 10)

Photo 2. Distinct annual ring boundary. Resin-filled axial parenchyma cells scattered in the ring. *Cephalotaxus drupacea* Sieb. and Zucc.-T. (× 100)

Photo 3. Low rays and axial parenchyma cells. *Cephalotaxus drupacea* Sieb. and Zucc.-T. (× 100)

Photo 4. Solitary or paired spiral thickenings in the tracheids. *Torreya taxifolia* Arn.-R. (× 300)

Photo 5. Circular ray cells. *Torreya grandis* Fort.-T. (× 100)

Photo 6. Transverse walls of ray cells unevenly thickened. Cross fields enclose cupressoid pits; tracheid walls show loosely coiled spiral thickening. *Taxus chinensis* Rehder-R. (× 300)

Photo 7. Tall ray. *Torreya taxifolia.* Arn.-T. (× 100)

Photo 8. Rosary-like thickening in end wall of axial parenchyma cells. *Cephalotaxus fortunei* Hooker fil.-R. (× 300)

Photo 9. Parallel spiral thickenings in tracheids. Tangential walls of ray cells smooth. Cross fields show small cupressoid pits. *Torreya nucifera* Sieb. and Zucc.-R. (× 300)

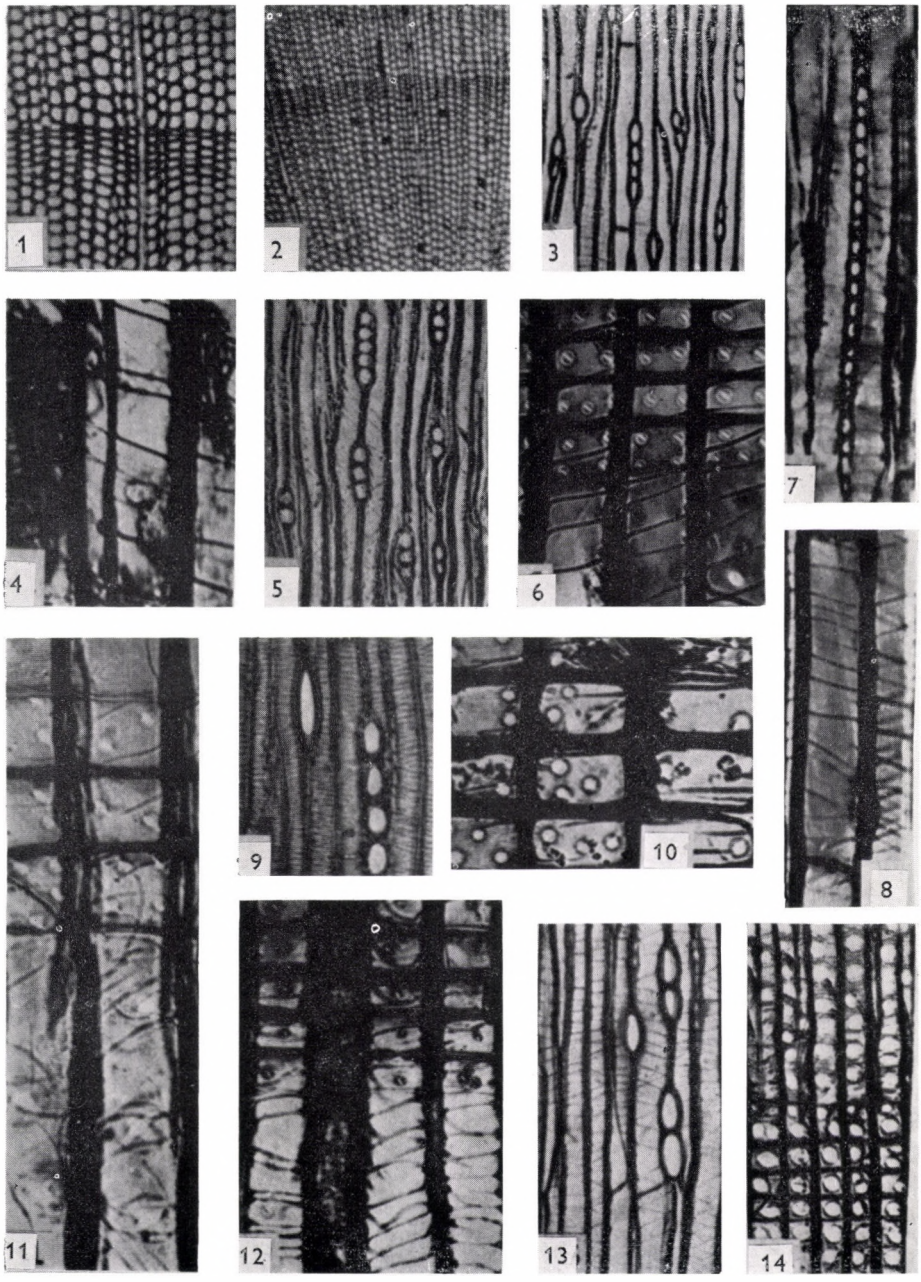
Photo 10. Cupressoid pits in cross field. *Cephalotaxus fortunei* Hooker fil.-R. (× 300)

Photo 11. Uneven thickening in transverse walls of ray parenchyma cells. Circular pores in cross fields (a phenomenon frequent in *Taxus*). *Cephalotaxus drupacea* Sieb. and Zucc.-R. (× 300)

Photo 12. Cross fields with cupressoid pits, transverse walls of ray cells thick; axial parenchyma cells resin-filled; loosely coiled spiral thickening. *Cephalotaxus drupacea* Sieb. and Zucc.-R. (× 300)

Photo 13. End wall of axial parenchyma cells smooth, tangential wall exhibits a simple thickening. *Torreya nucifera* Sieb. and Zucc.-T. (× 300)

Photo 14. Dacrydioid cross fields. *Taxus canadensis* Marsch.-R. (× 300)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VIII. Main xylotomical features of the *Cupressaceae*

Photo 1. Vague annual ring boundary, some resin-filled parenchyma cells in the ring field. *Callitris glauca* R. BR.-C. (× 100)

Photo 2. Distinct annual ring boundary. *Juniperus glaucescens* Florin.—C. (× 100)

Photo 3. Distinct annual ring boundary. Tracheid sections angular. *Chamaecyparis thyoides* Britton-C. (× 100)

Photo 4. Distinct annual ring boundary. Tracheid sections angular. There are some axial parenchyma cells in the ring field. *Callitris verrucosa* R. BR.-C. (× 100)

Photo 5. Nodular thickening in tracheid walls. *Actinostrobus pyramidalis* Miq.-Z. (× 300)

Photo 6. Ray cell sections circular. Axial parenchyma cells resin-filled, with nodularly thickened end walls. *Juniperus occidentalis* Hooker fil.-T. (× 100)

Photo 7. Rosary-like thickenings in the end walls of axial parenchyma cells. *Juniperus bermudiana* L.-T. (× 300)

Photo 8. Idem, in *Chamaecyparis lawsoniana* Parlatore-T. (× 300)

Photo 9. Callitroid thickenings in the tracheid walls. *Callitris glauca* R. BR.-T. (× 300)

Photo 10. Typical cupressoid pits in cross fields. *Libocedrus austro-caledonica* Brongn. and Grise-R. (× 300)

Photo 11. Tangential walls of ray cells exhibit rosary-like thickenings. Cupressoid pits in the cross fields. *Cupressus arizonica* Greene.-R. (× 300)

Photo 12. End wall of axial parenchyma cells smooth. *Callitris intratropica* Bentham and Hooker-T. (× 300)

Photo 13. Scalariform thickening in the tangential wall of a ray cell. Rosary-like thickening in the end walls of axial parenchyma cells. *Juniperus recurva* Buchholz Ham.-T. (× 300)

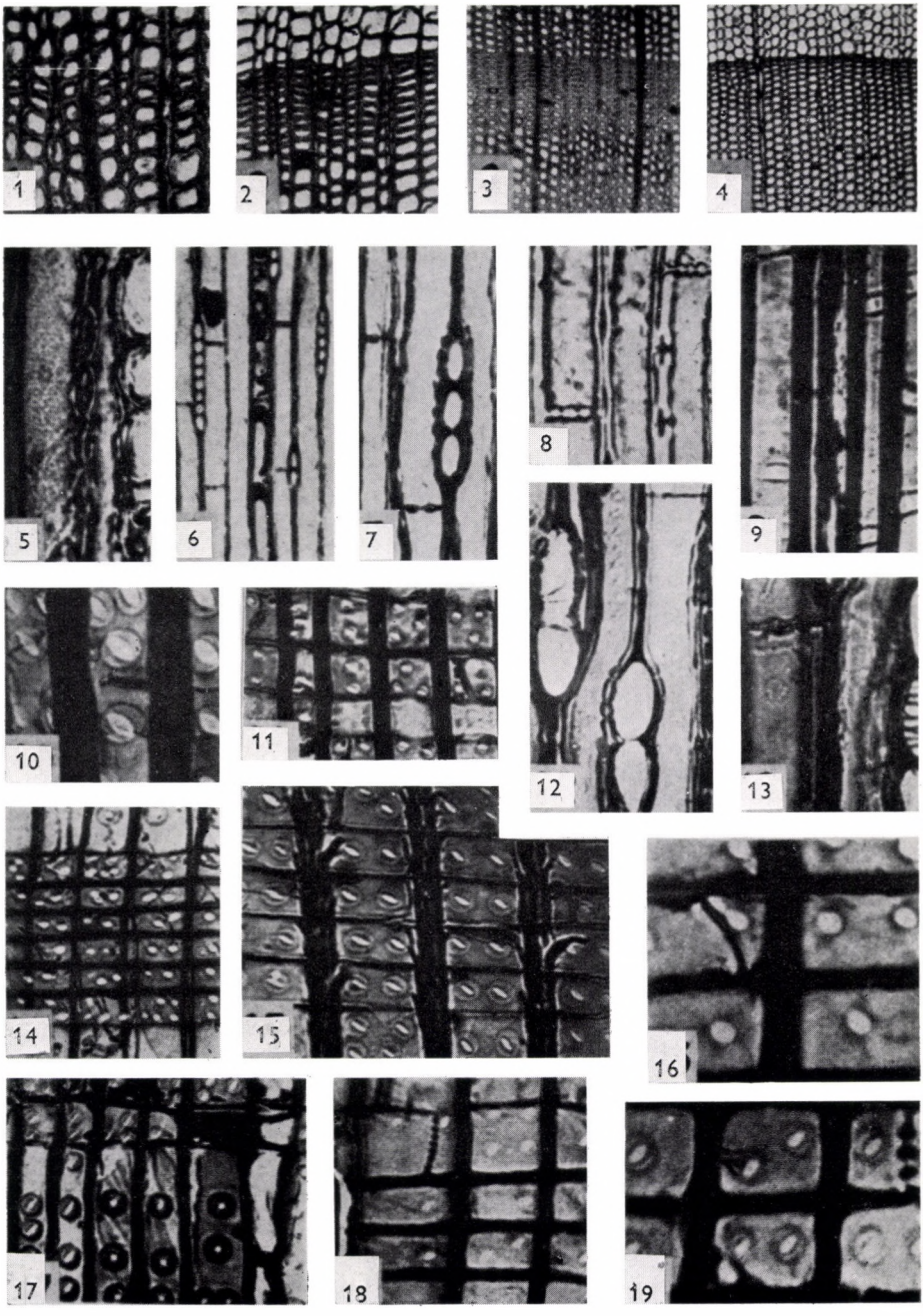
Photo 14. Rosary-like thickening in the tangential walls of ray cells. Typical cupressoid pits in cross fields. *Juniperus ashei* Buchholz-R. (× 300)

Photo 15. All walls of ray cells smooth and thin; cross fields enclose cupressoid pits. *Tetraclinis articulata* Mast.-R. (× 300)

Photo 16. Indenture at the transverse wall of a ray parenchyma cell. Taxodioid pits in the cross fields. *Thuja standishii*

Photo 17. Crassulae separating chambered pits of axial tracheids. *Libocedrus plumosa* (D. Don.) Sargent-R. (× 300)

Photos 18—19. Tangential walls of ray cells thickened rosary-fashion. Cross fields exhibit typical cupressoid pits. 18: *Libocedrus formosana* Florin. 19: *Juniperus foetidissima* Vieillard-R. (× 300)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IX. Main xylotomical features of the Taxodiaceae

Photos 1—3. Vague and conspicuous annual ring boundaries. Resin-filled axial parenchyma cells concentrated in the early or late zone. 1. *Taxodium mucronatum* Ten.; 2. *Cryptomeria japonica* (L.) Don; 3. *Cunninghamia lanceolata* (Lamb.) Hooker fil.-C. (× 100)

Photo 4. A sharp annual ring boundary. *Sequoia sempervirens*-C. (× 100)

Photo 5. Vague annual ring boundary. *Sequoia gigantea* Decne.-C. (× 100)

Photo 6. End walls of axial parenchyma cells smooth; rounded cell lumina filled with resin. *Sequoia gigantea* Decne.-T. (× 300)

Photo 7. Rosary-like thickening in end walls of axial parenchyma cells. *Taxodium mucronatum* Ten.-T. (× 300)

Photos 8—9. Conspicuous rosary-like thickening in the end walls of some axial parenchyma cells. *Cryptomeria japonica* D. Don.-T. (× 300)

Photo 10. End wall of axial parenchyma cell exhibits the dentate type of thickening. *Taxodium ascendens* Brongn.-T. (× 300)

Photo 11. Taxodioid pitting. *Taxodium distichum* (× 400)

Photo 12. Glyptostroboid pits in the cross fields. *Cunninghamia lanceolata* (Lamb.) Hooker fil.-R. (× 300)

Photo 13. Cupressoid and taxodioid pits in the cross fields. Tangential walls of ray cells smooth. *Taxodium ascendens* Brongn.-R. (× 300)

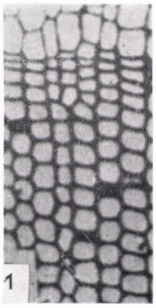
Photo 14. Glyptostroboid and taxodioid pits in the cross fields. Transverse walls of ray cells smooth. *Cryptomeria japonica* D. Don.-R. (× 300)

Photo 15. Typical taxodioid pitting in the cross fields. *Sequoia gigantea* Decne-R. (× 300)

Photo 16. Taxodioid pitting in the cross fields. Tangential walls of ray cells smooth. Radial wall of tracheid exhibits triseriate opposed chambered pits. *Sequoia sempervirens* (Lamb.) Endl.-R. (× 300)

Photo 17. Low and tall rays. *Taxodium distichum* Rich.-T. (× 100)

Photo 18. Smooth and thin tangential walls in ray cells. *Taiwania cryptomerioides*. (× 700)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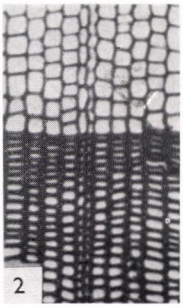
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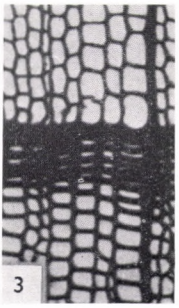
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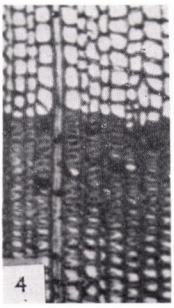
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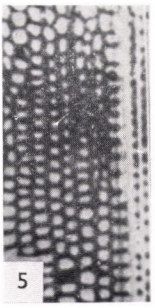
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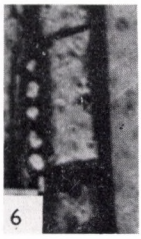
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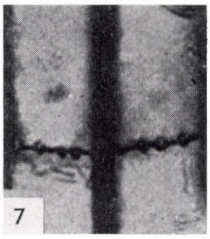
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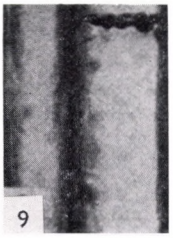
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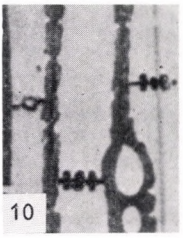
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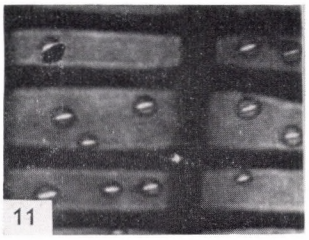
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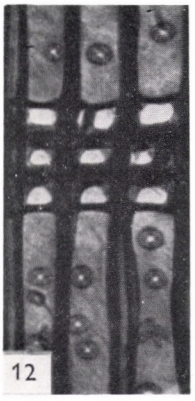
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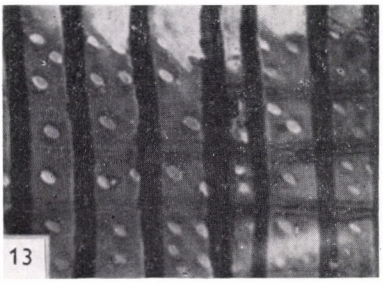
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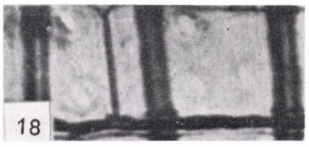
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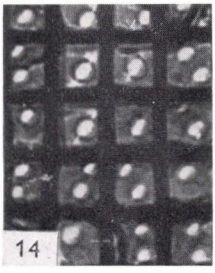
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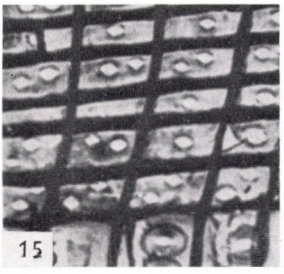
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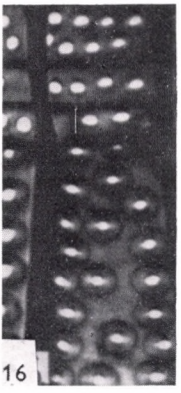
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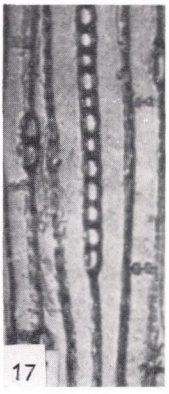
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X. Main xylotomical features of the *Pinaceae*

Photo 1. Conspicuous annual ring boundary. Tracheid sections angular; resin ducts absent. *Abies alba* Miller-C. (× 100)

Photo 2. Circular resin duct in late wood. Epithelial cells thick-walled. *Picea jezoensis* (Sieb. and Zucc.) Carr.-C. (× 100)

Photo 3. Conspicuous annual ring boundary; epithelial cells lining duct thick-walled. *Larix potaninii* Batal.-C. (× 100)

Photo 4. Conspicuous annual ring boundary. Epithelial cells lining resin ducts thin-walled. *Pinus sabineana* Dougl.-C. (× 100)

Photo 5. Uniseriate rays, unducted. *Abies alba* Miller-T. (× 100)

Photo 6. Biseriate ray, unducted. *Keteleeria davidiana* Beisser-T. (× 100)

Photo 7. Multiseriate ray with a resin duct of circular section lined with thick-walled epithelial cells. Duct in central position. *Picea likiangensis* Pritz.-T. (× 100)

Photo 8. Multiseriate tall ray with an oval resin duct at the middle of the section, lined with thick-walled epithelial cells. *Larix laricina* K. Koch-T. (× 100)

Photo 9. Multiseriate heterogeneous ray structure, duct, lined with thin-walled epithelial cells. *Pinus silvestris* L.-T. (× 100)

Photo 10. End walls of axial parenchyma cells nodular or dentate. *Tsuga heterophylla* Sarg.-T. (× 300)

Photo 11. Tangential walls of ray cells exhibit sieve-like thickenings. *Cedrus deodara* Lond.-T. (× 300)

Photo 12. A spirally thickened transverse tracheid. *Picea smithiana* Boiss.-R. (× 300)

Photo 13. Dentate thickening in the end wall of an axial parenchyma cell. *Tsuga mertensiana* Carr.-T. (× 300)

Photo 14. A homogeneous ray structure. Tangential walls of ray cells dentately thickened. Cross fields piceoid. *Abies coreana* Wilson-R. (× 300)

Photo 15. Piceoid cross fields. *Picea mariana* B.S.P.-R. (× 300)

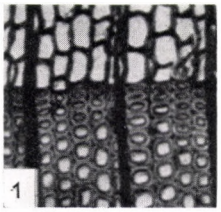
Photo 16. Heterogeneous ray structure, with a smooth-walled transverse tracheid, and piceoid cross fields. *Tsuga canadensis* Carr.-R. (× 300)

Photo 17. A homogeneous ray structure. Taxodioid cross fields. *Abies alba* Miller-R. (× 300)

Photo 18. A heterogeneous ray structure. Pinoid cross fields, oopores, dentately thickened transverse tracheids. *Pinus thunbergii* Parlatore-R. (× 300)

Photo 19. All walls of transverse and axial tracheids spirally thickened. A piceoid cross field. *Pseudotsuga macrocarpa* Mayr.-R. (× 300)

Photo 20. Taxodioid cross field, heterogeneous ray structure, smooth-walled transverse tracheids. *Larix occidentalis* Nutt.-R. (× 300)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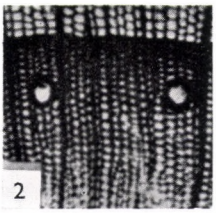
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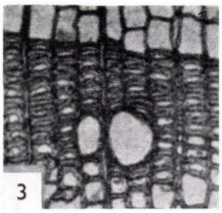
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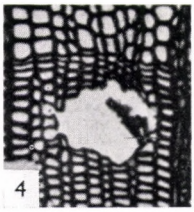
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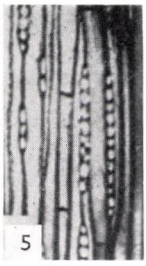
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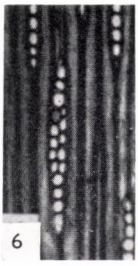
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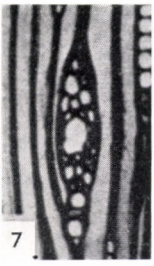
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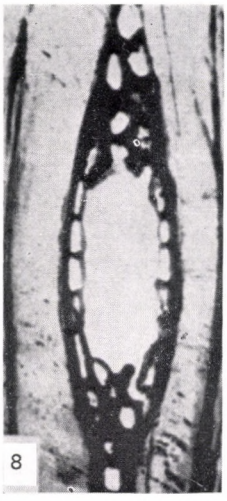
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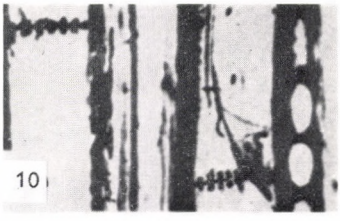
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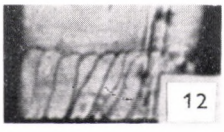
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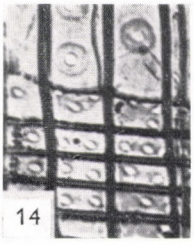
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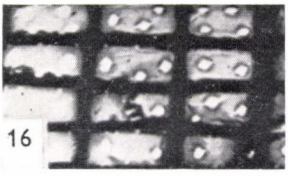
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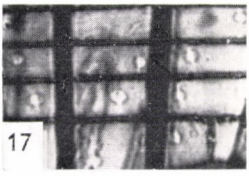
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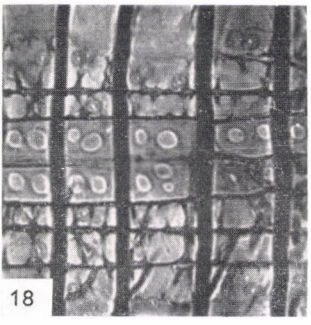
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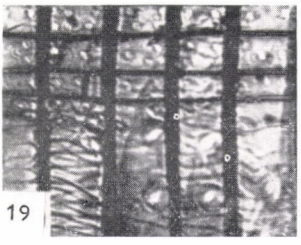
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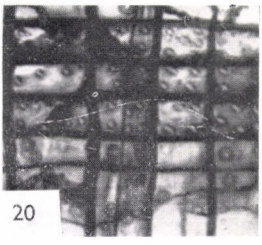
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PLATES to the Special Part (Photos XI-CLXV, and Figs 1–145.)

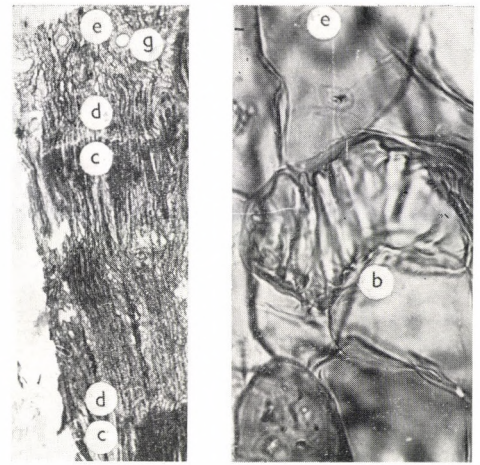
Letter symbols used in photos and in figures

I. CYCADS (Plates XI–XX)

a = pith; b = transfusion cell; c = xylem ring; d = phloem ring; e = bark; f = periderm; g = mucilage canal; h = ray; i = crystals

II. CONIFERS (Plates XXI–CLXV)

a = tracheid (radial view); b = thick-walled ray parenchyma cell; c = tracheid, tangential view; d = axial xylem parenchyma cell; e = marginal parenchyma cell; f = thin-walled ray parenchyma cell; g = transverse tracheid; i = resin duct



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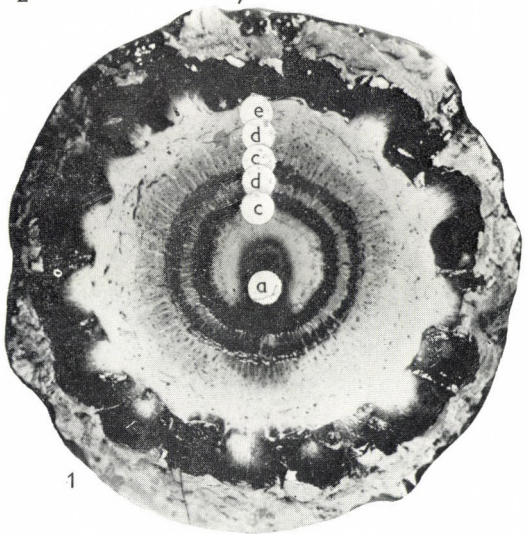

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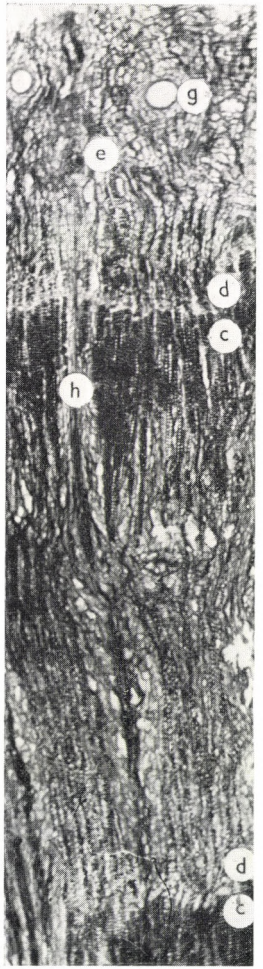

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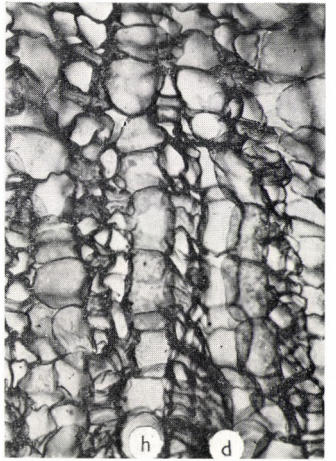

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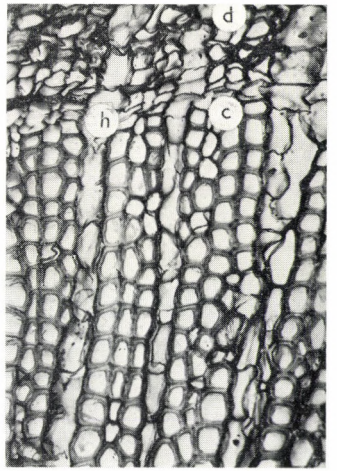

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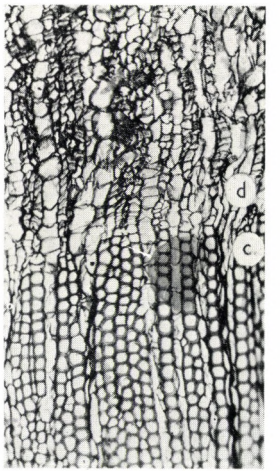

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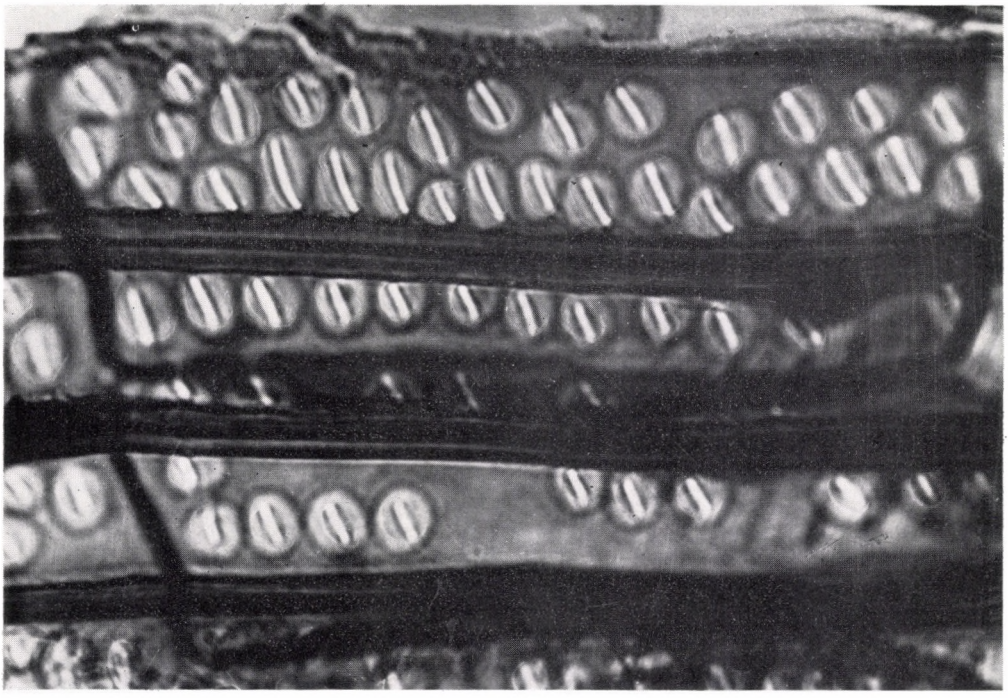
XI A and B: *Cycas revoluta* Thunb.



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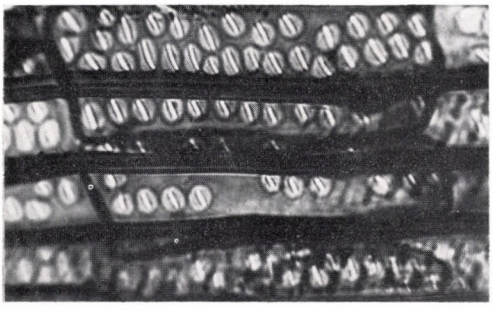

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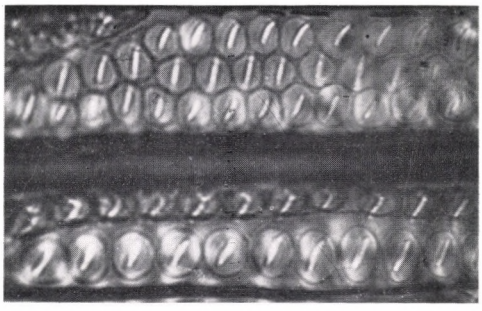

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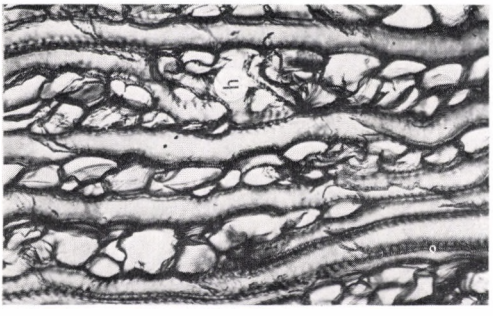

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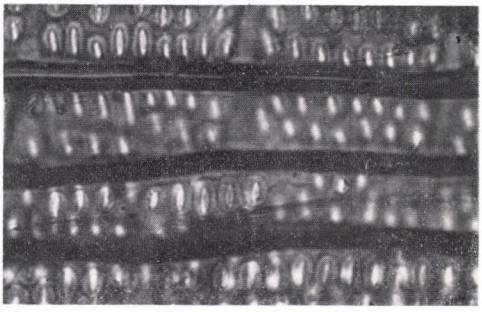

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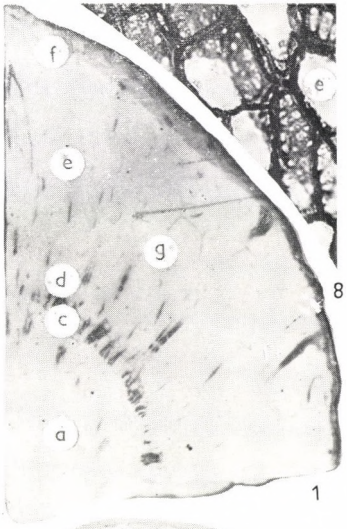

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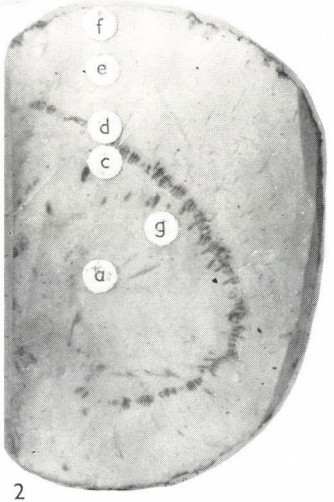

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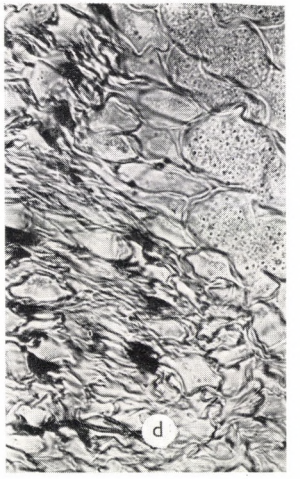

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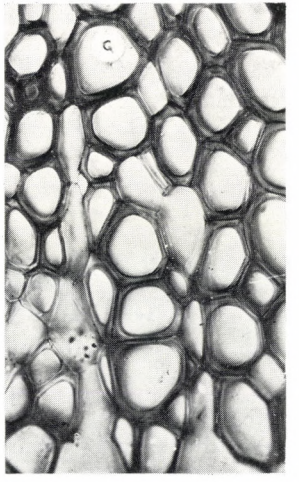

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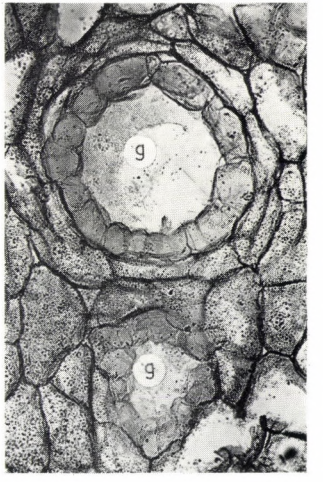

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XII A and B: *Stangeria paradoxa* T. Moore

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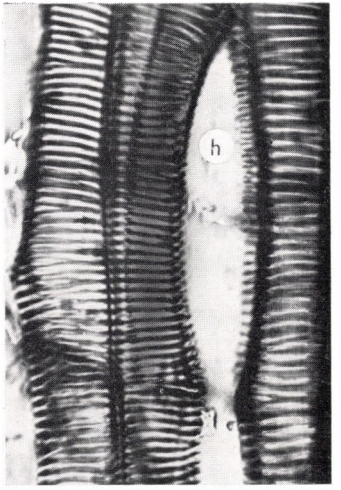

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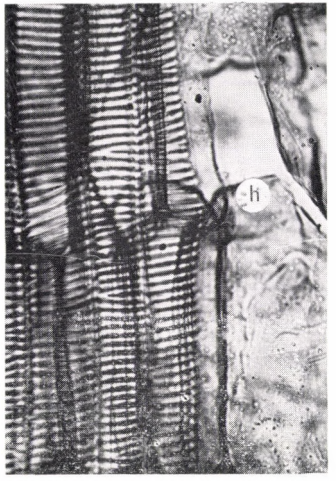

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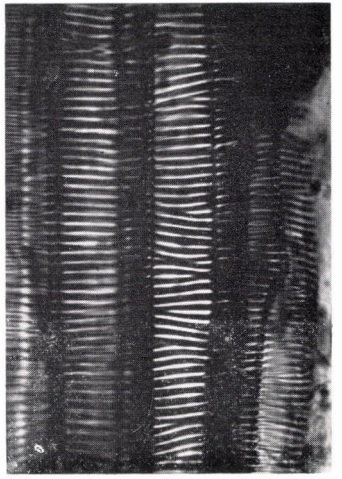

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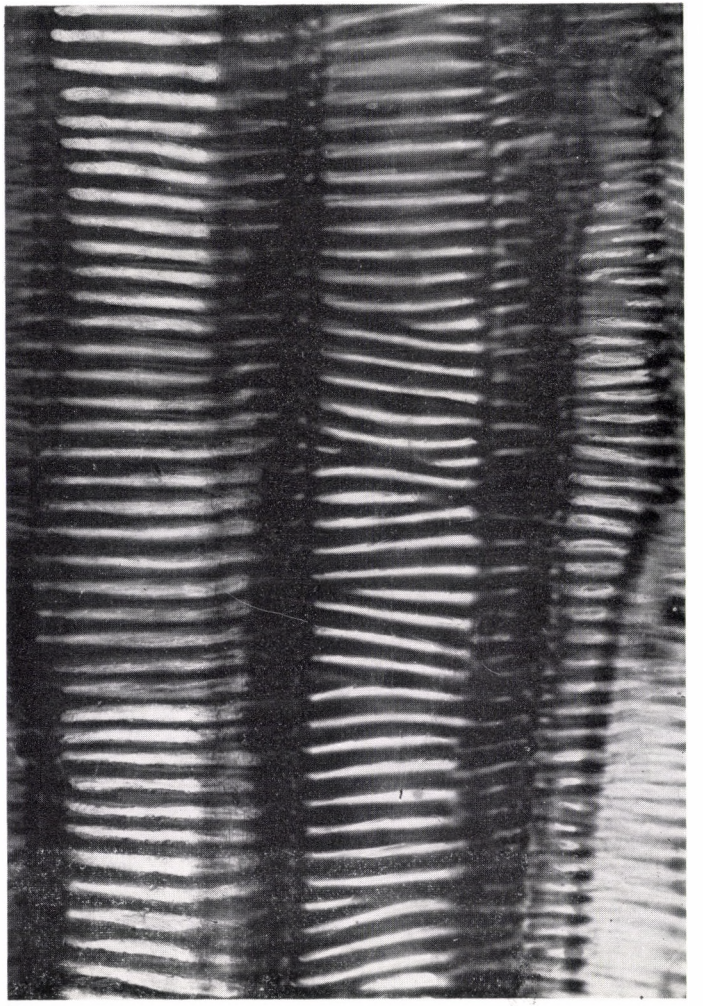

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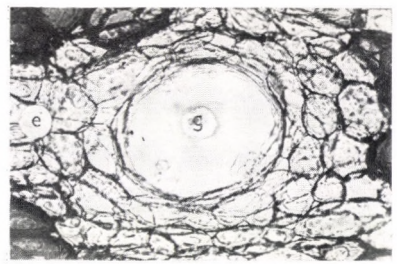

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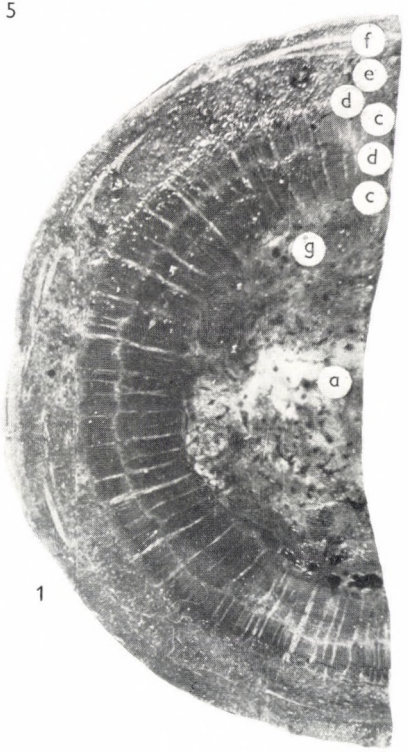

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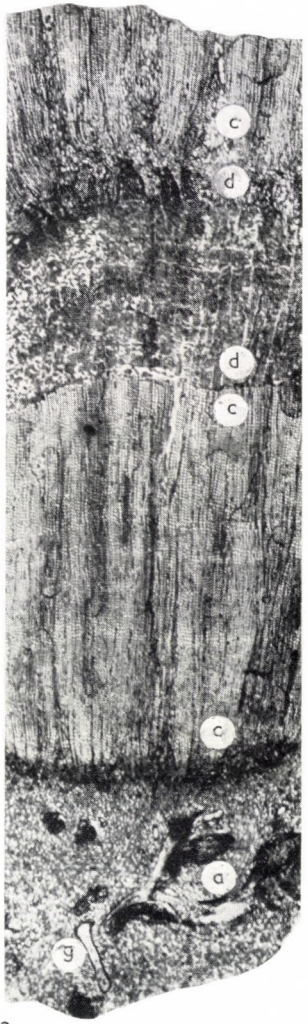

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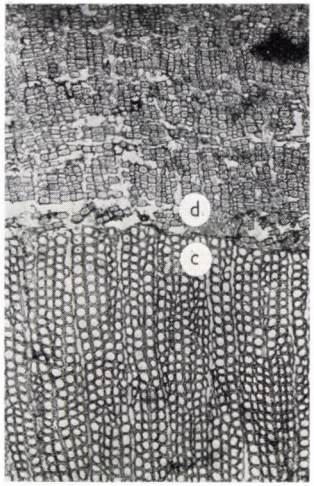

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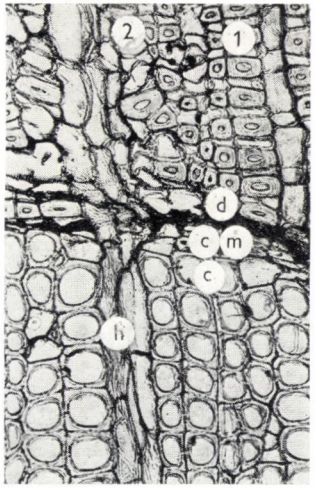

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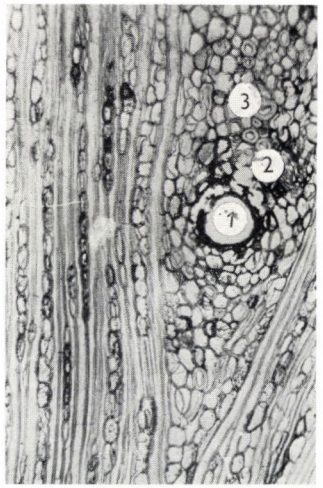

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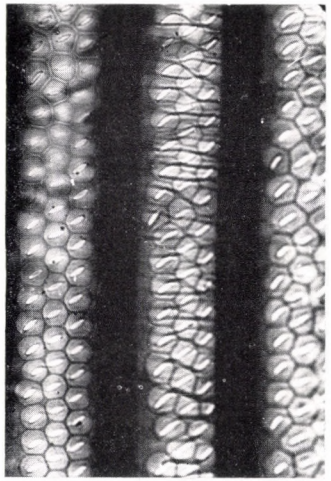
XIII A and B: *Lepidozamia hopei* Regel



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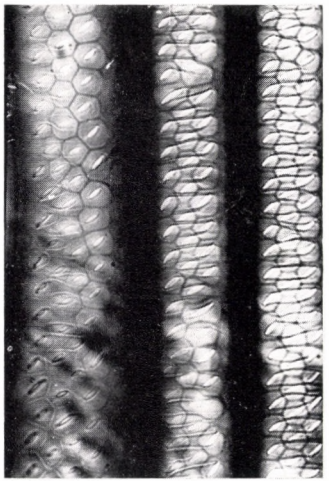

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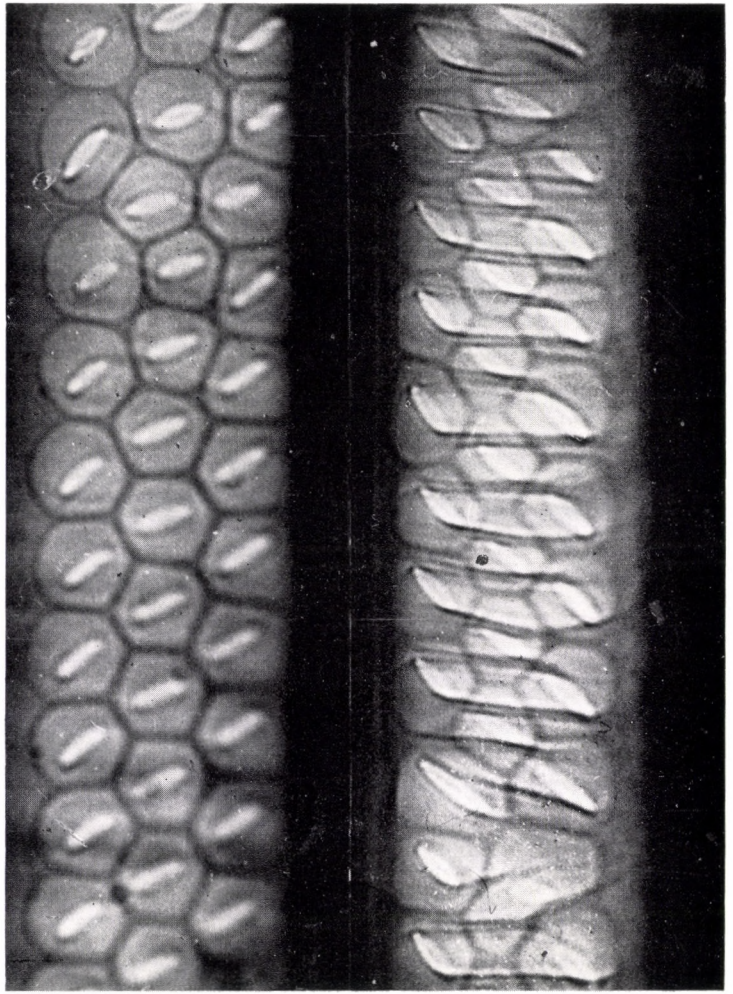

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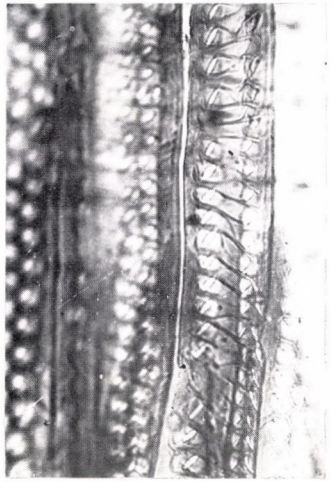

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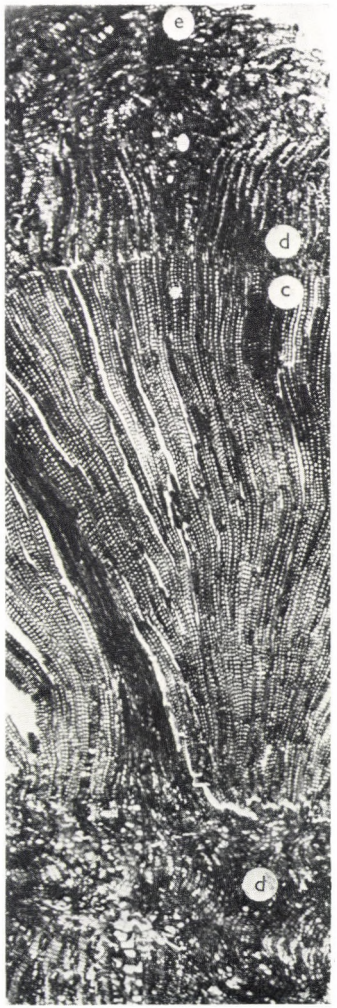

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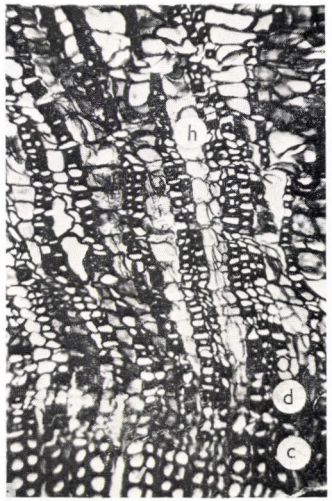

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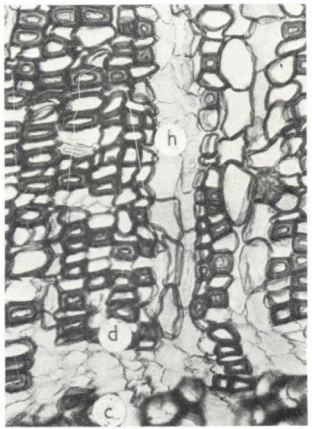

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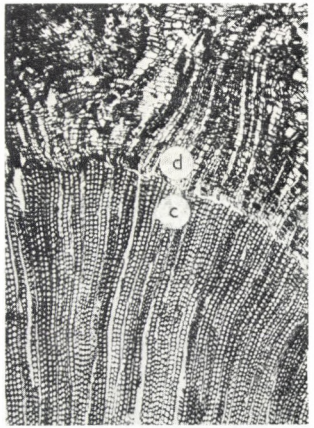

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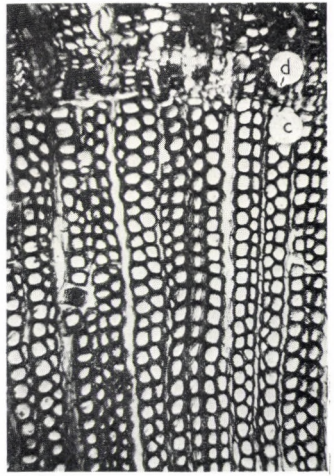

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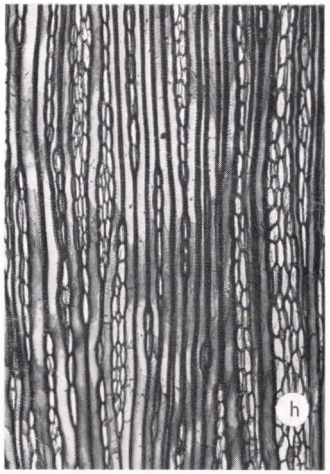
XIV A and B: *Macrozamia miquelii* (F. Muell.) A.DC.



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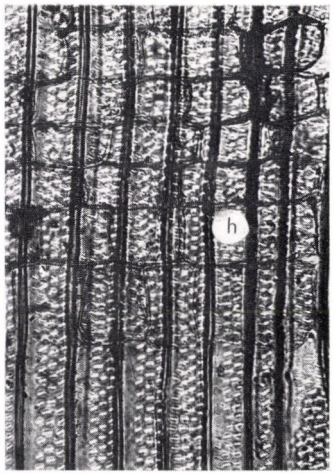

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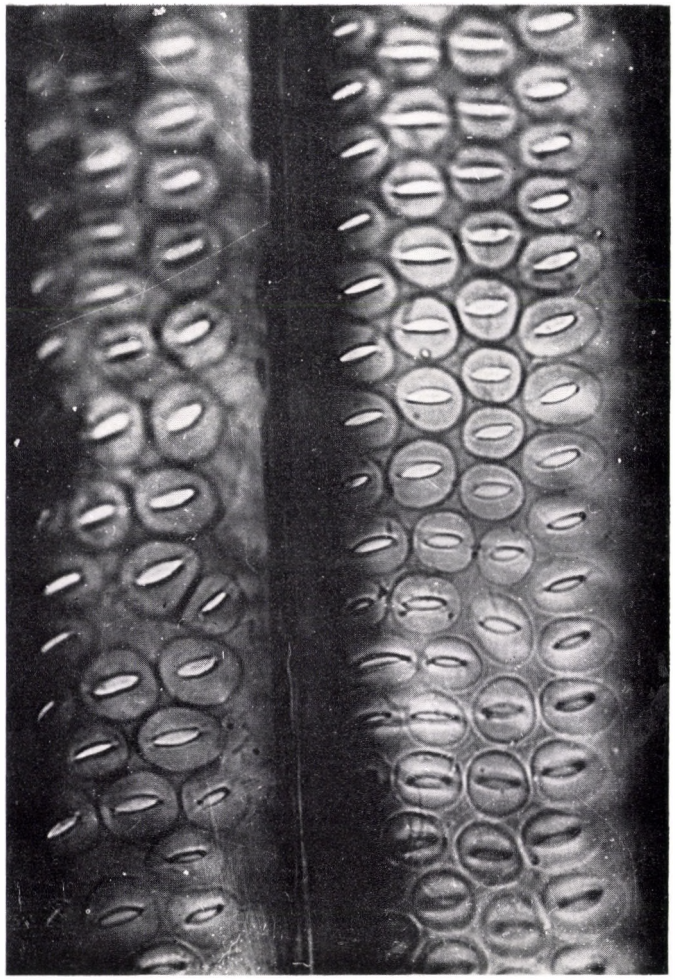

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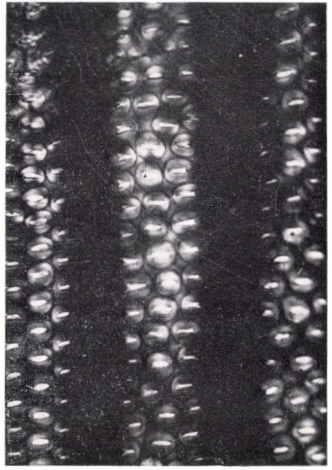

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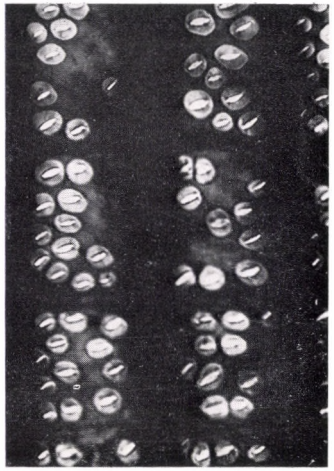

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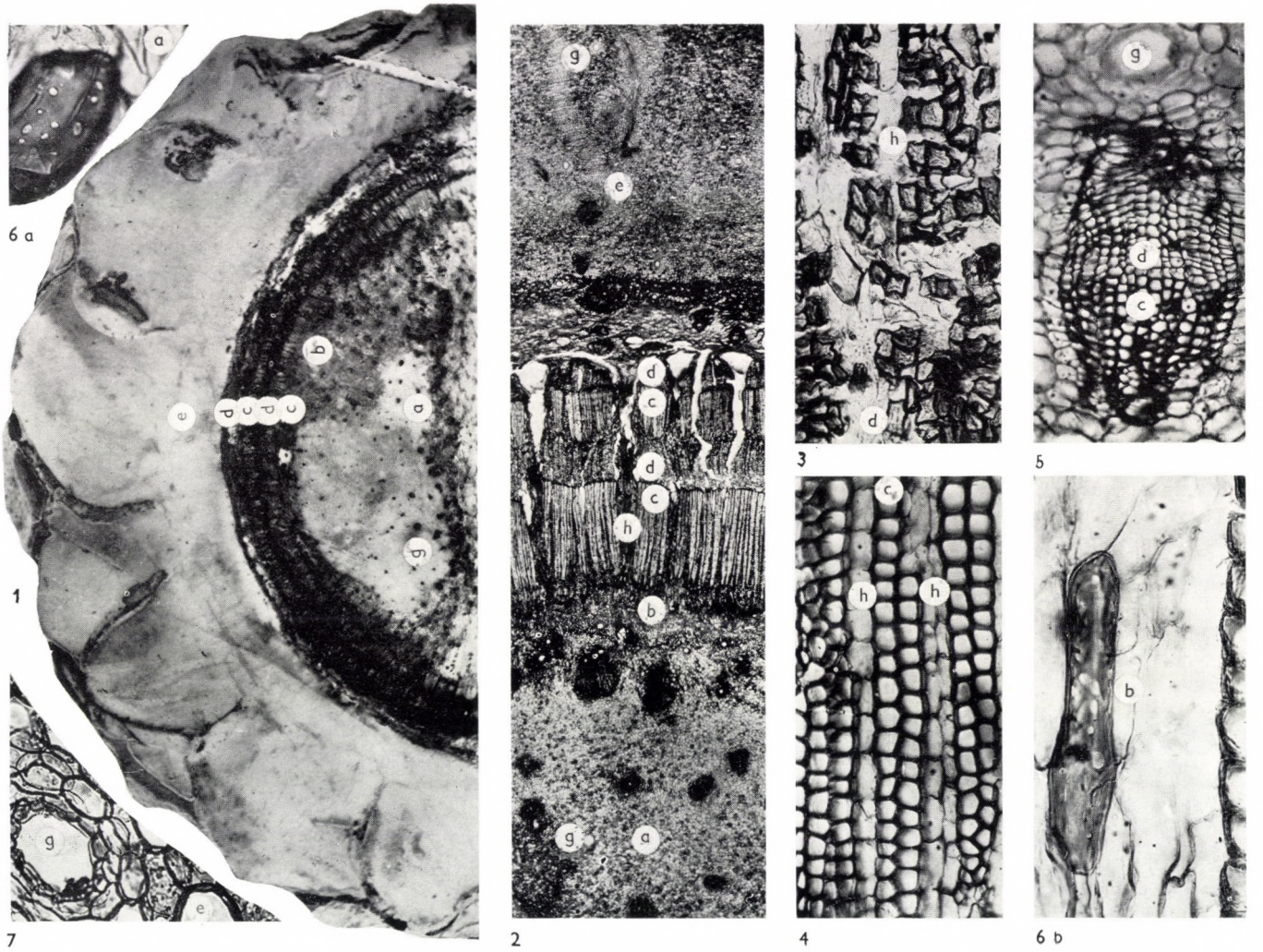

XV A and B: *Encephalartos altensteinii* Lehm.

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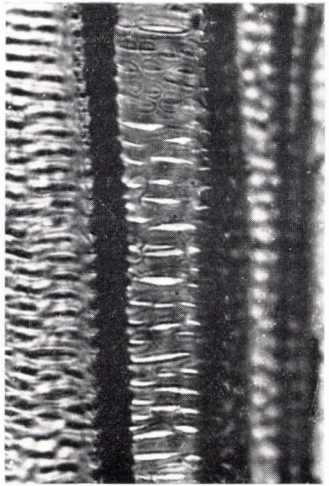

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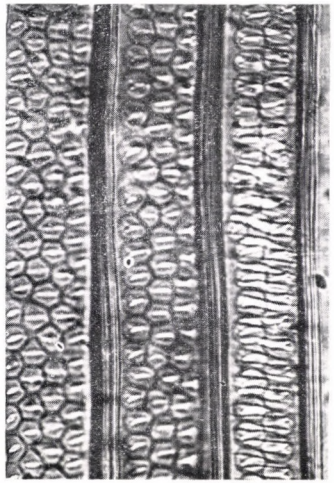

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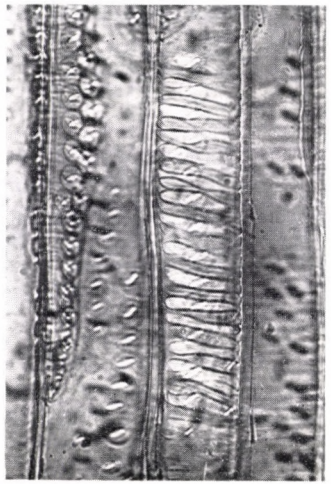

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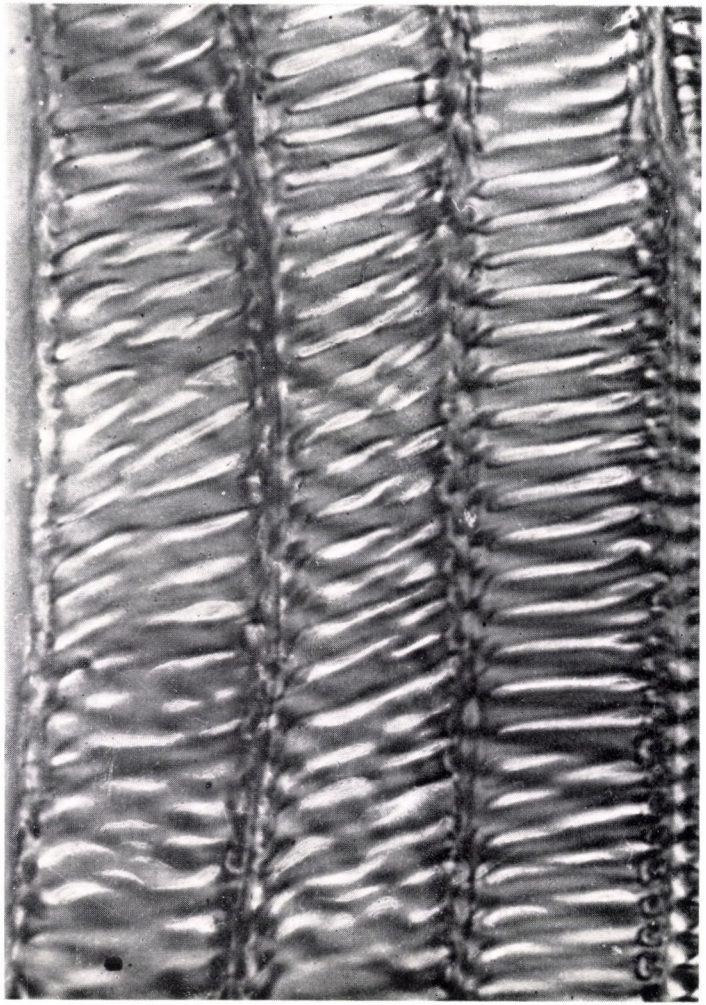

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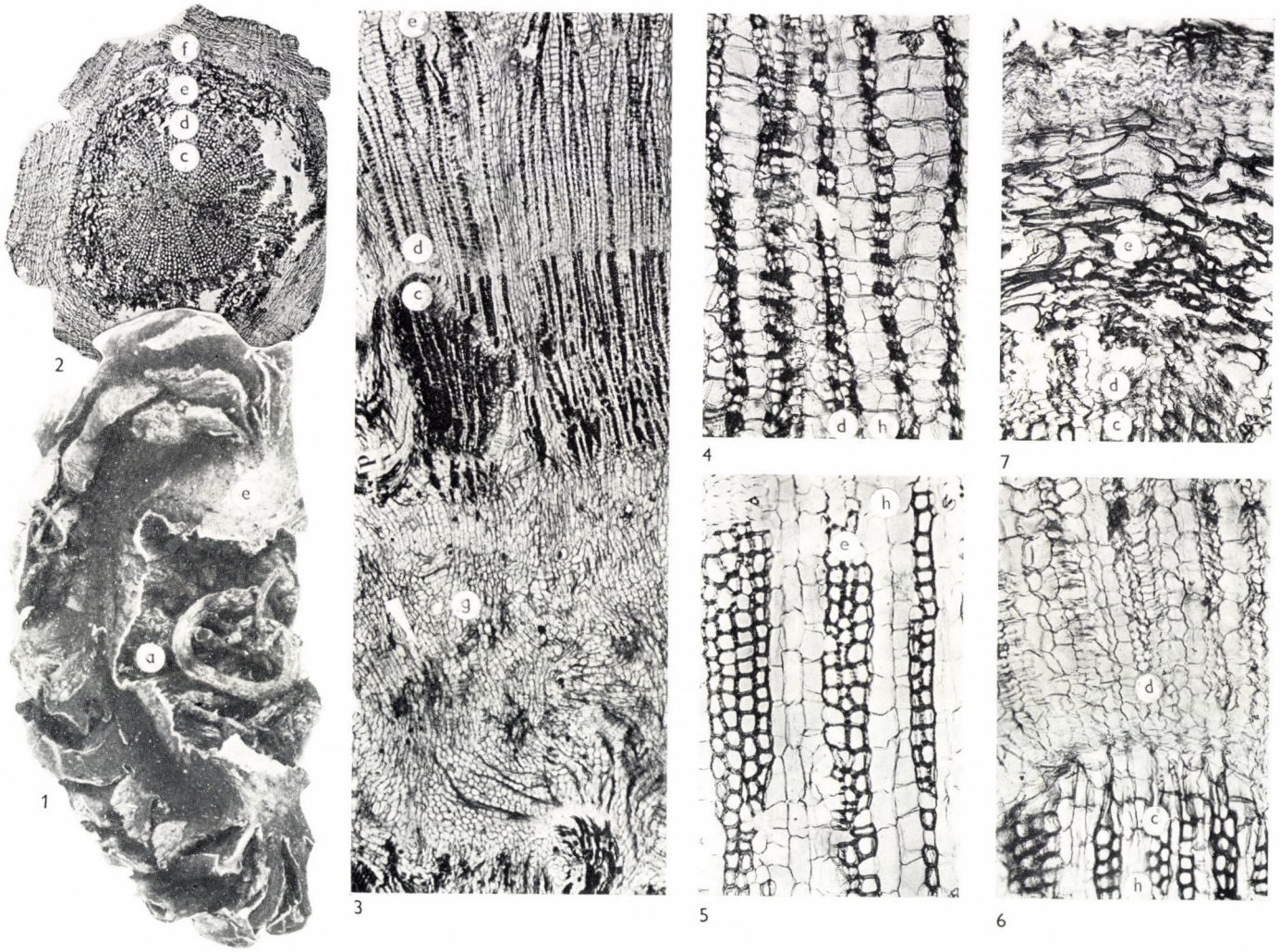
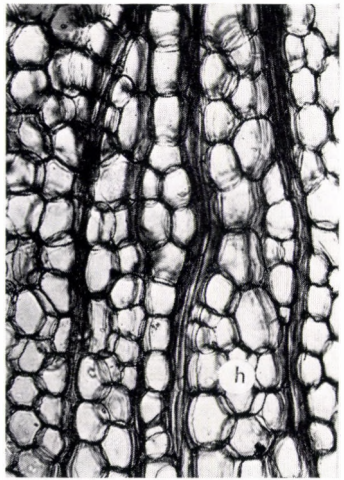


X VI A and B: *Dioon edule* Lindl.



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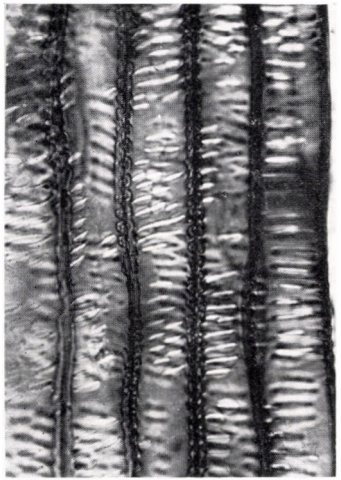

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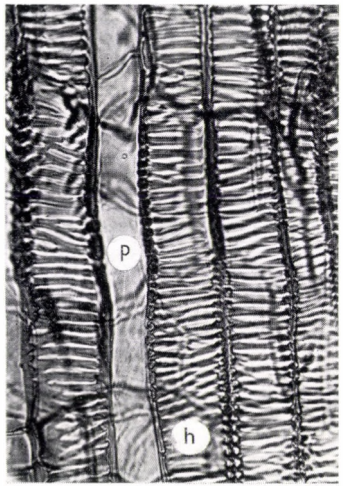

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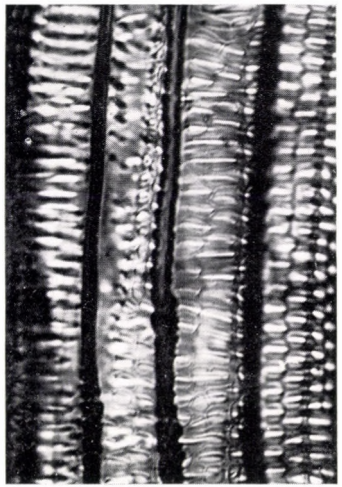

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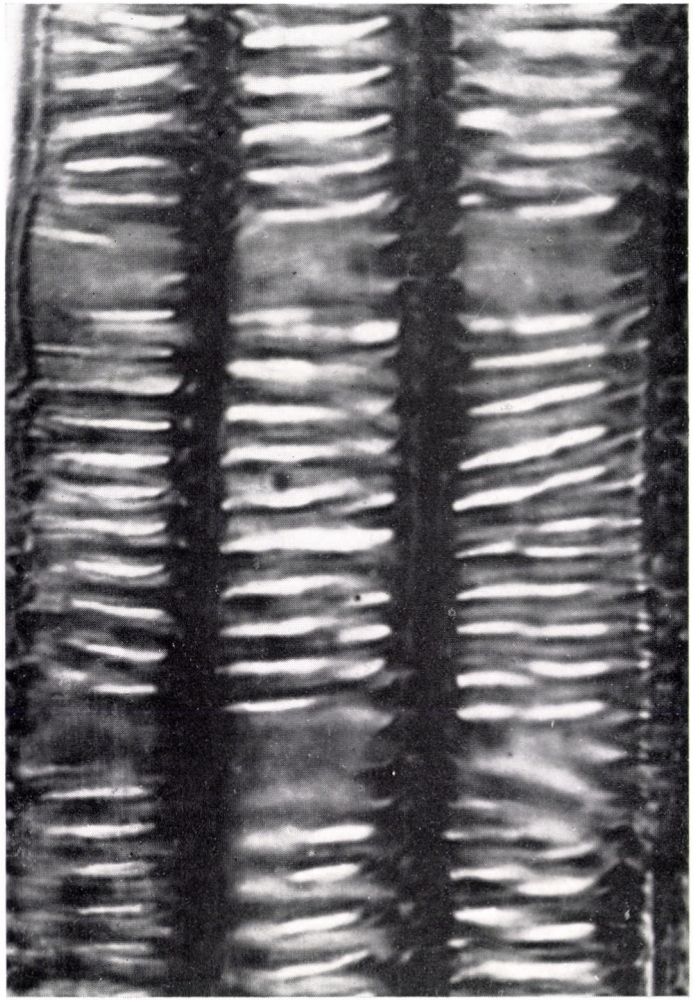

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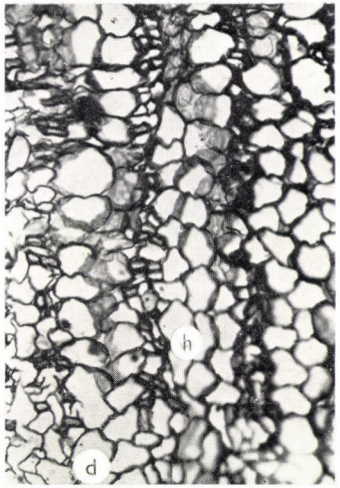

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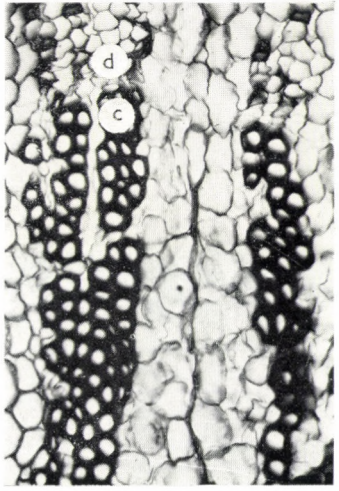

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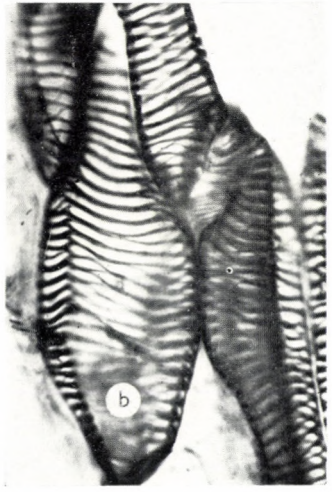

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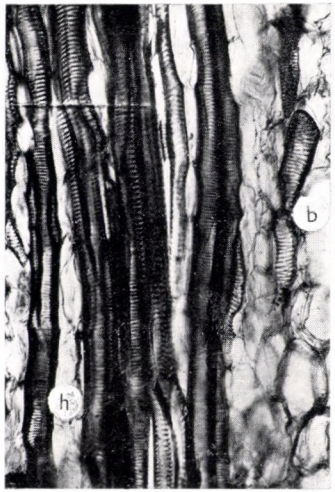
XVII A and B: *Microcycas calocoma* (Miq.) A.DC.



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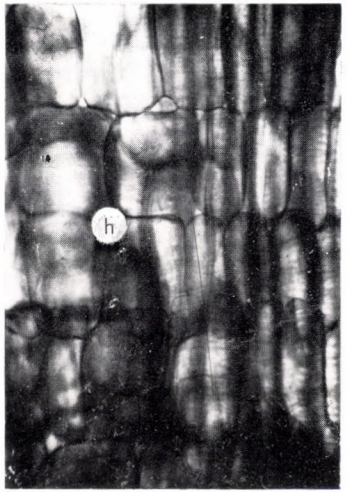

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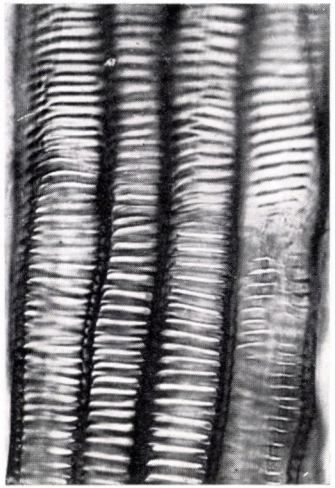

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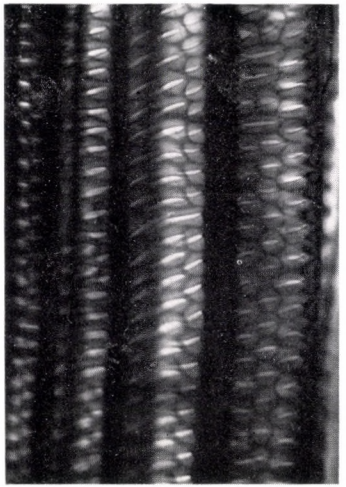

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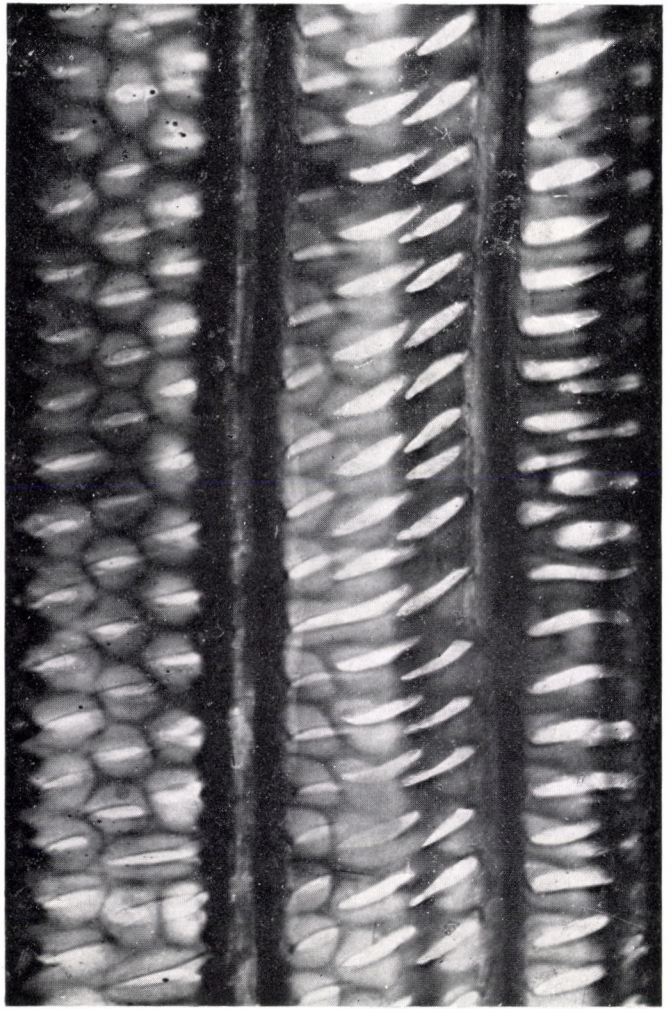

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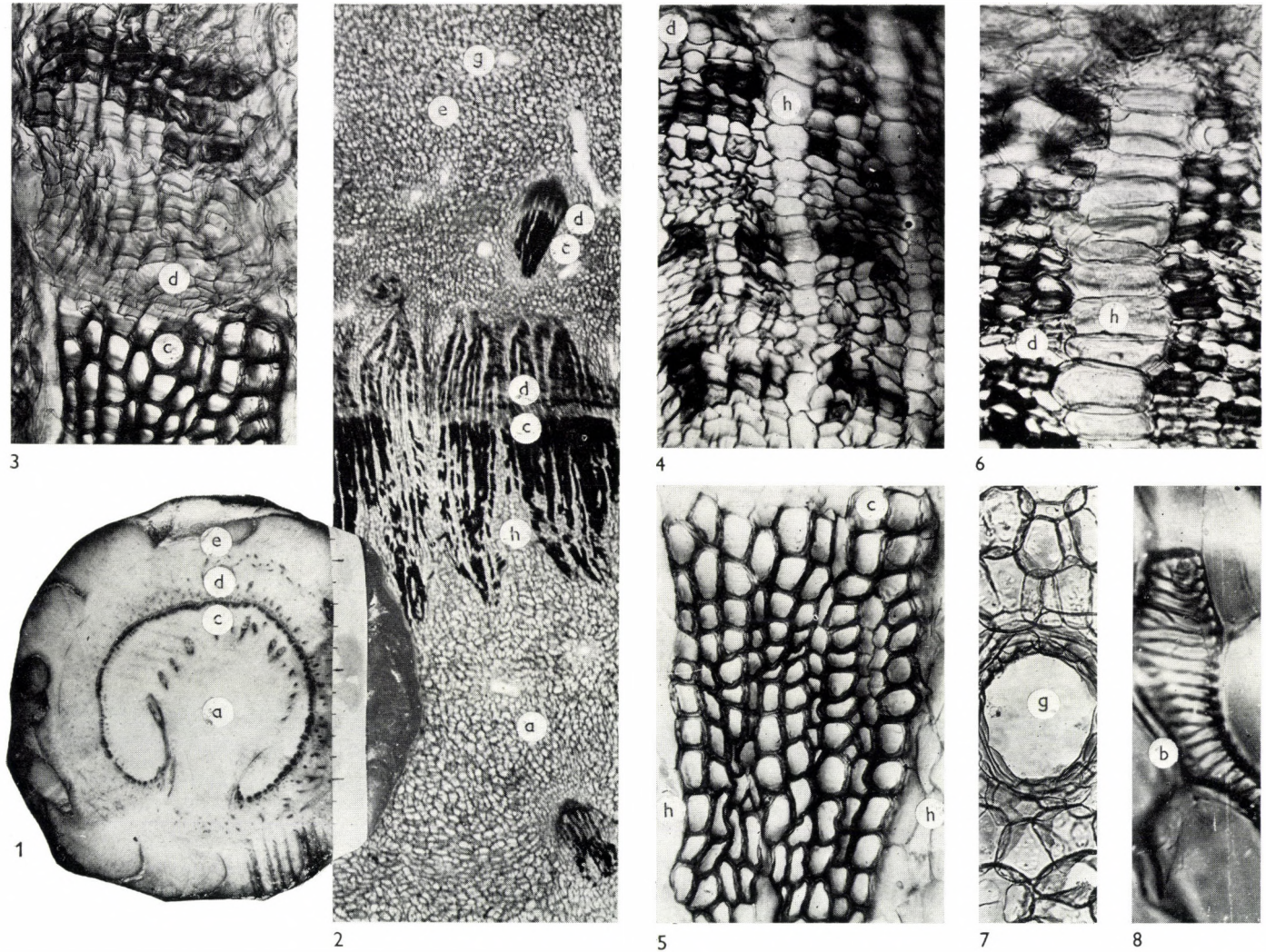
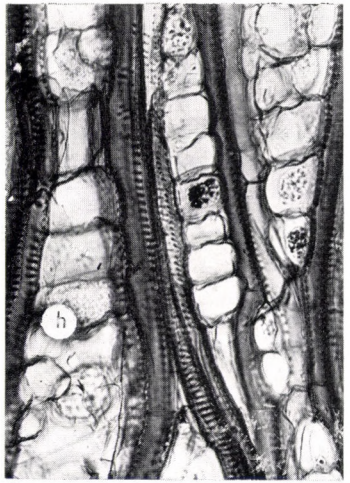


XVIII A and B: *Ceratozamia mexicana* Brongn.



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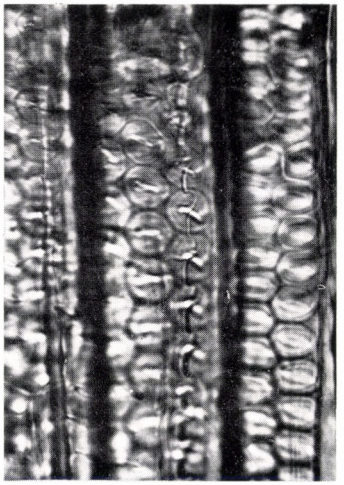

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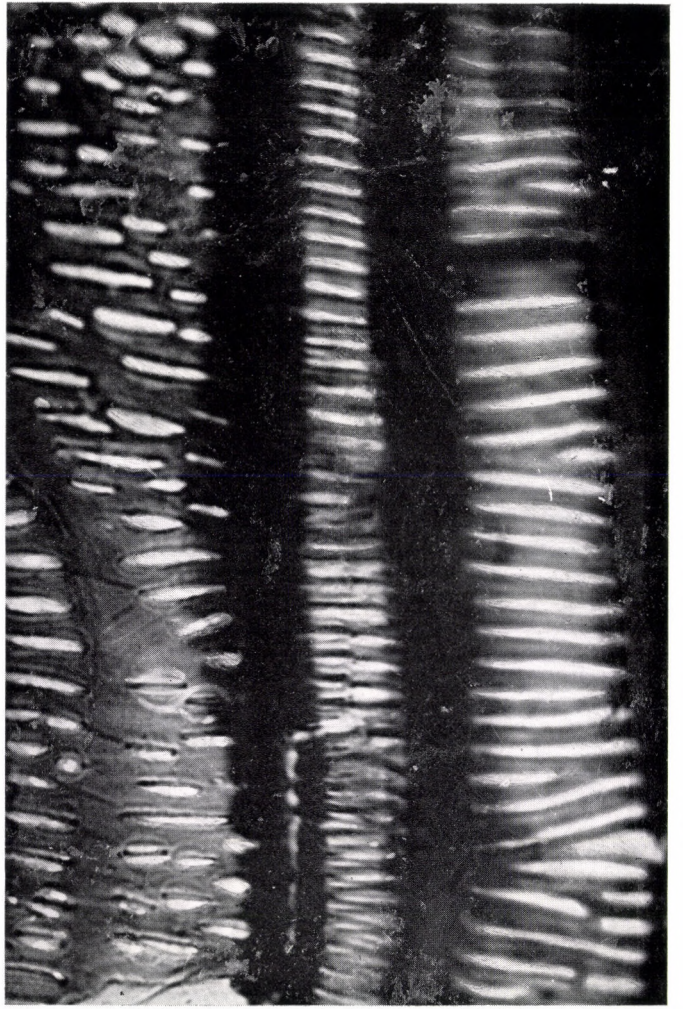

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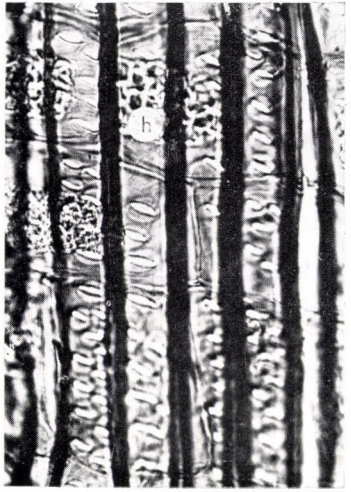

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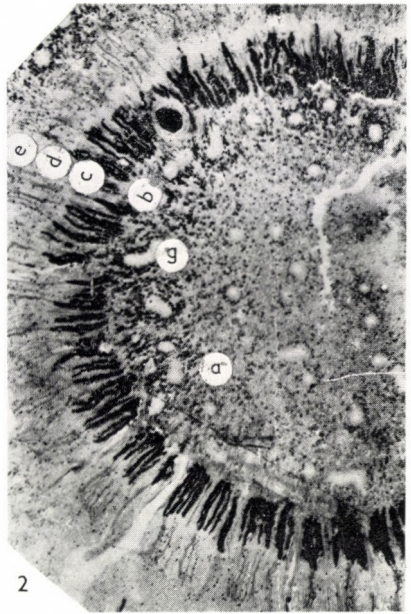

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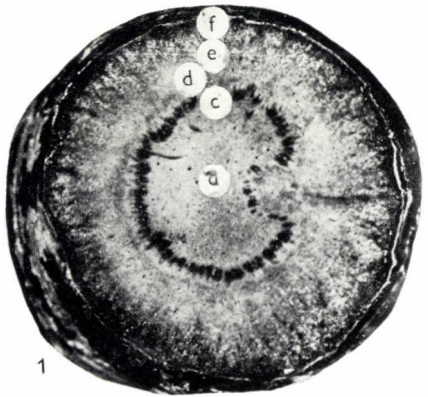

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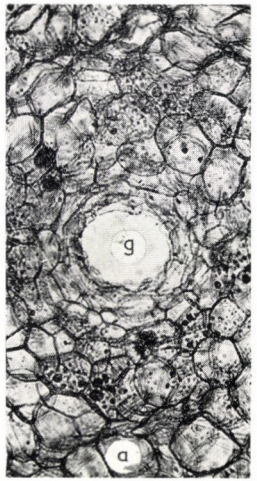

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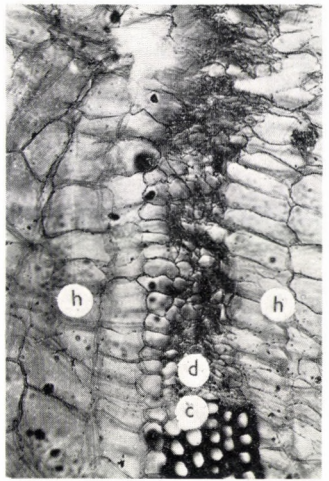

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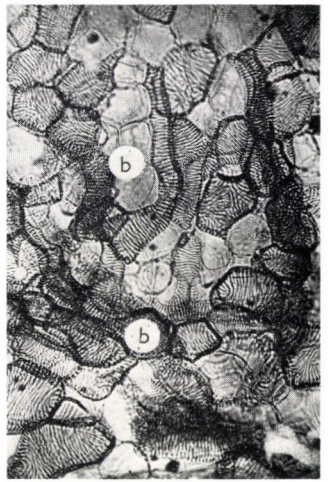

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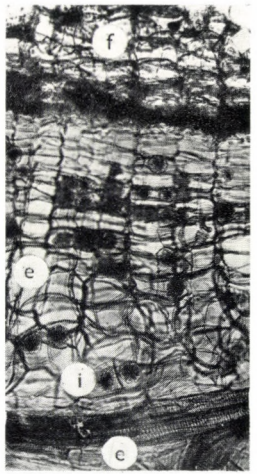

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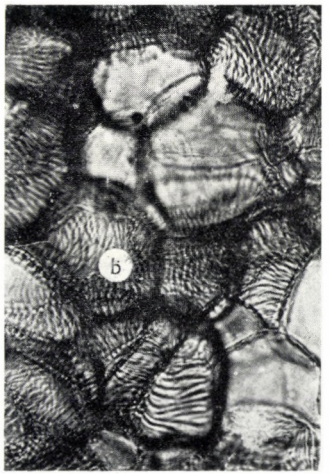

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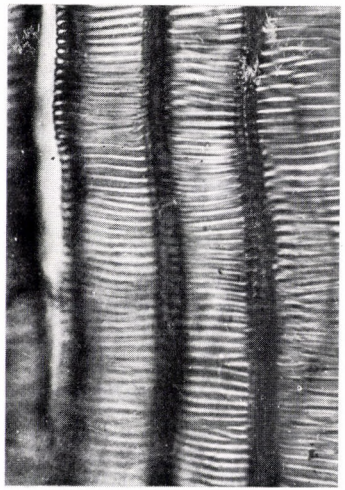
XIX A and B: *Zamia floridana* A.DC.



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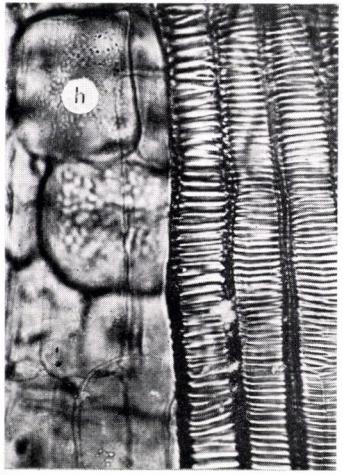

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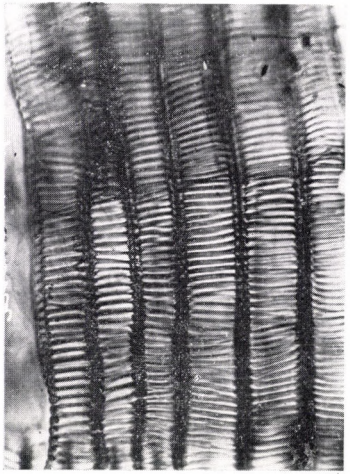

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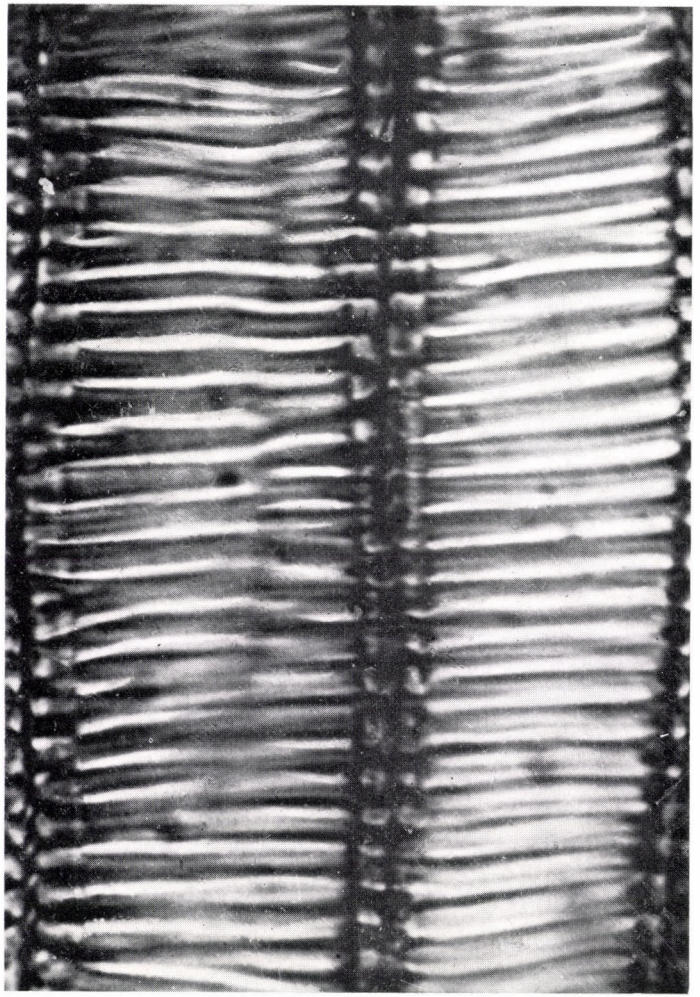

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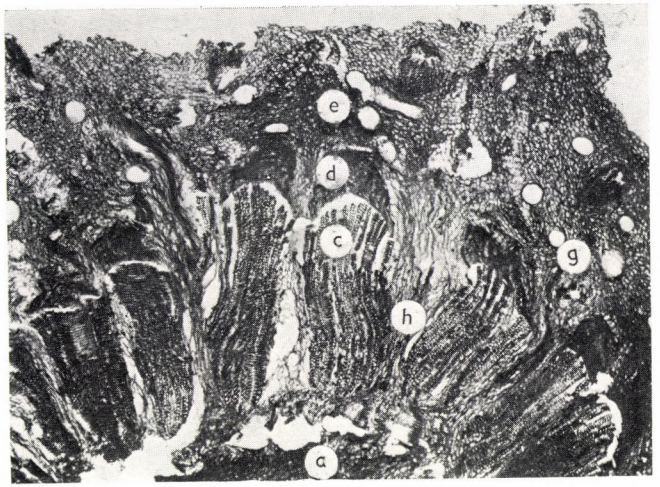

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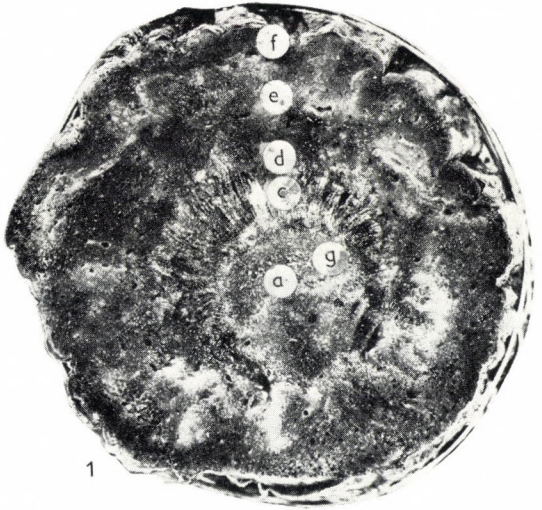

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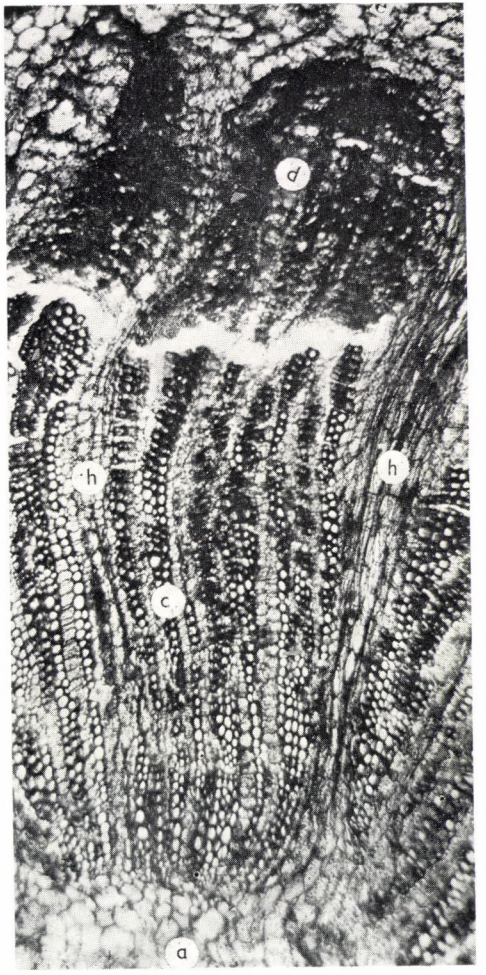

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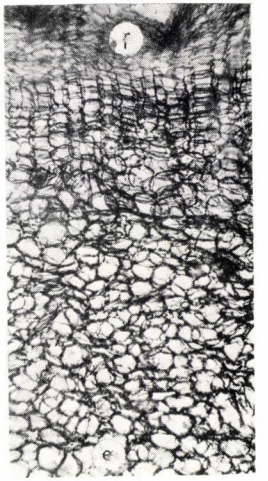

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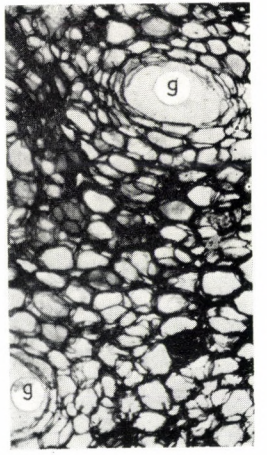

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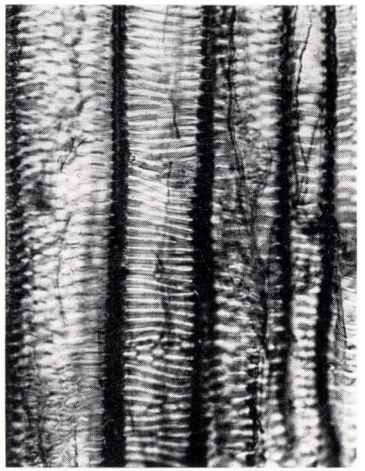
XX A and B: *Bowenia serrulata* (W. Bull.) Chamberlain

6



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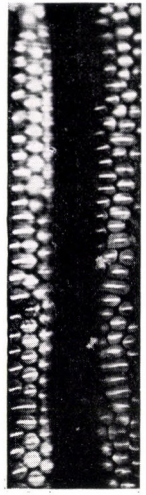

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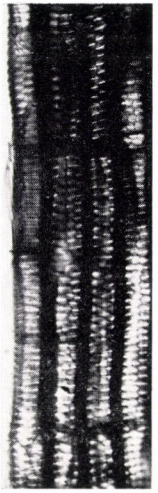

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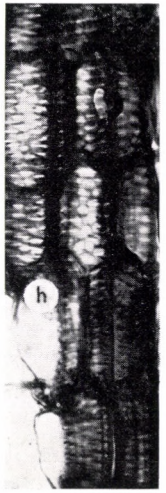

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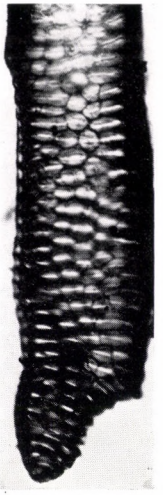

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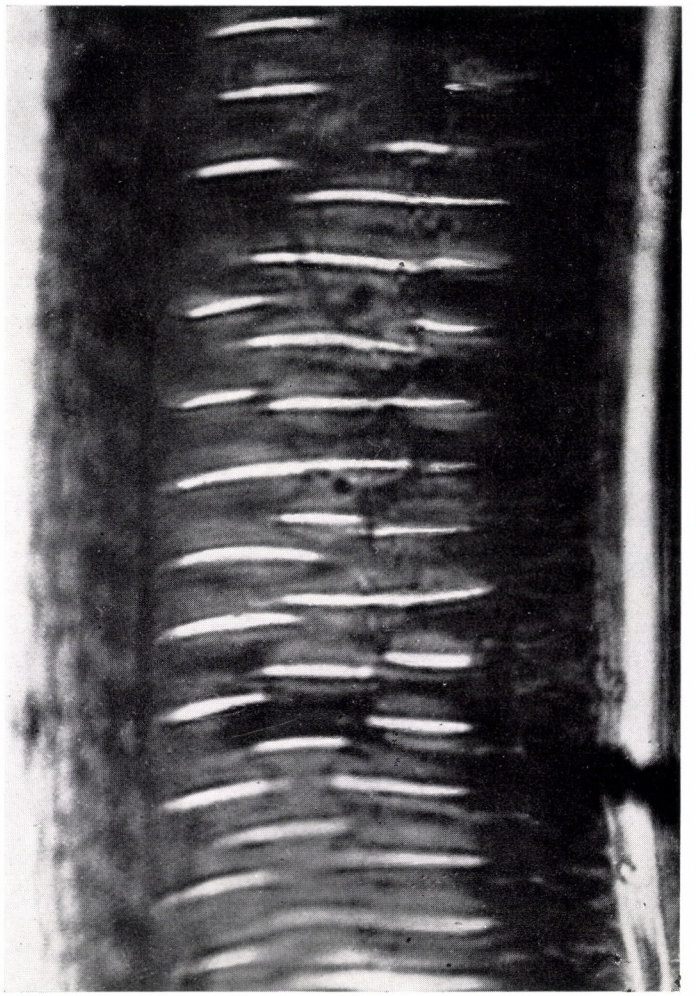

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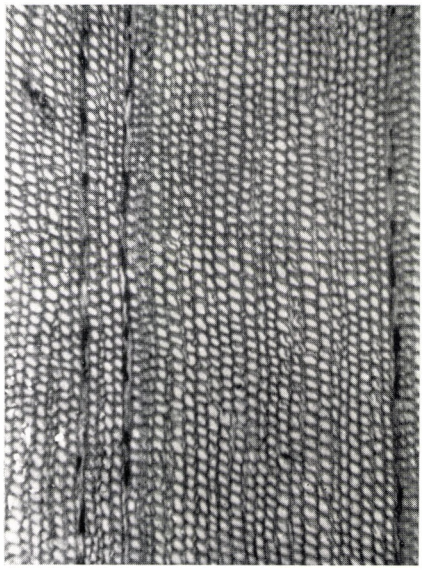

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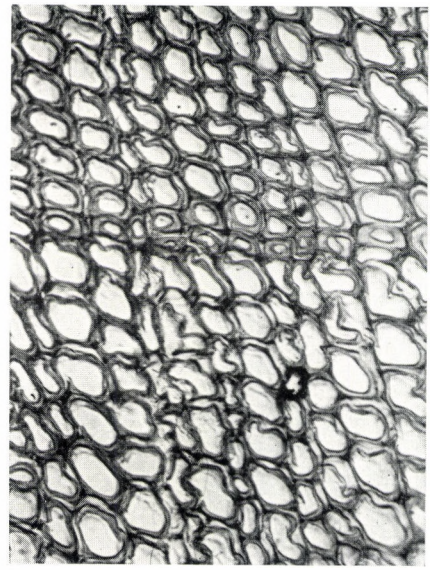
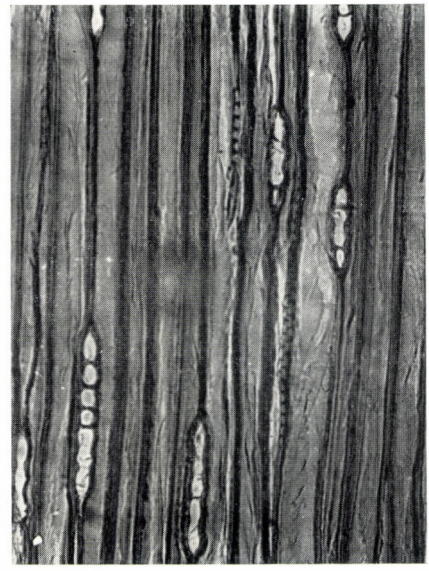


2.(× 100)

3.(× 400)



4.(× 100)

XXI. *Agathis beckingii* Meyer and Drees

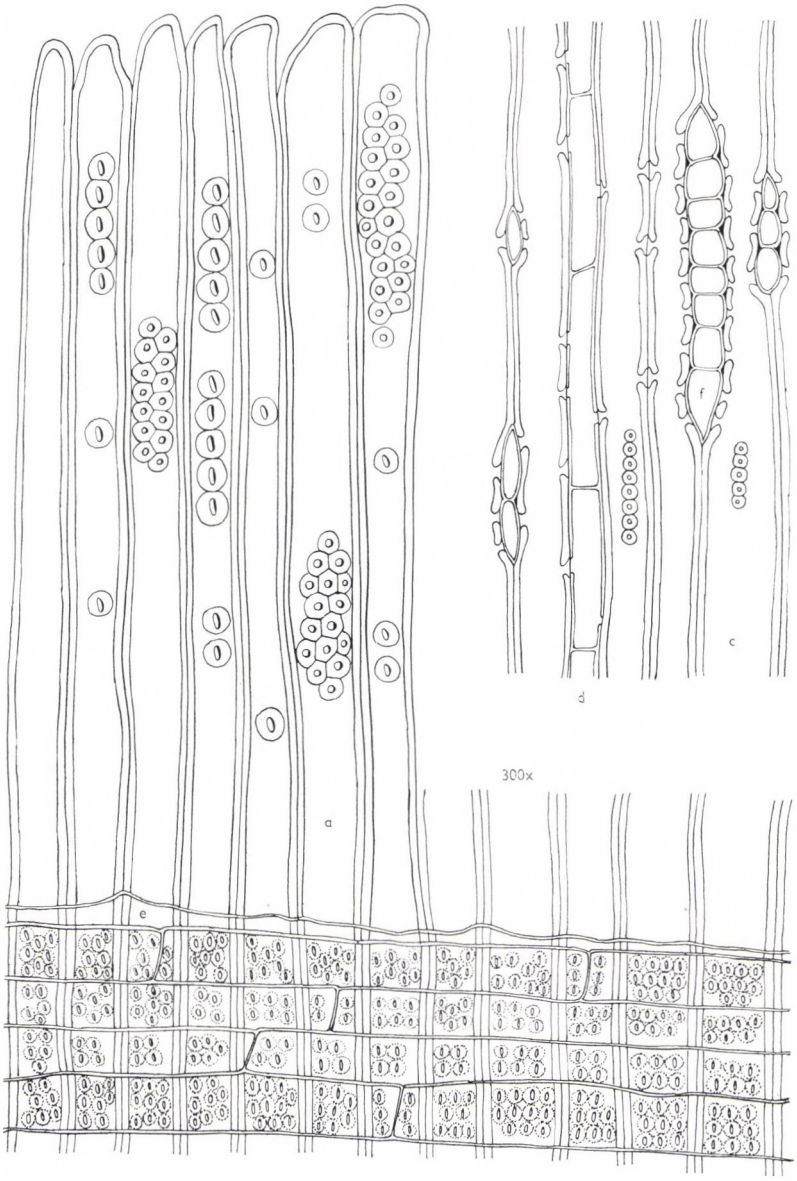
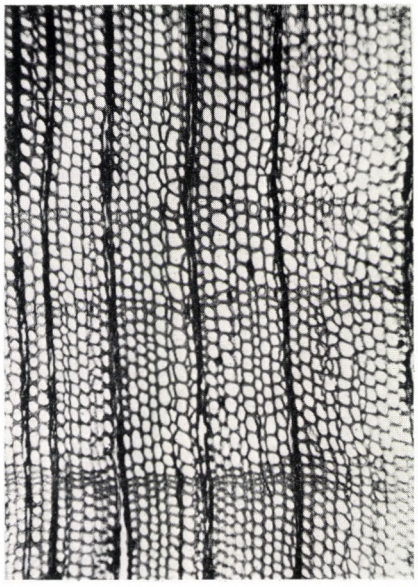


Fig. 1. *Agathis beckingii* Meyer and Drees



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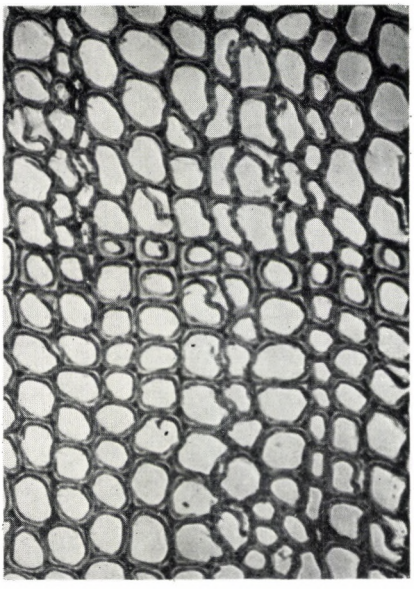

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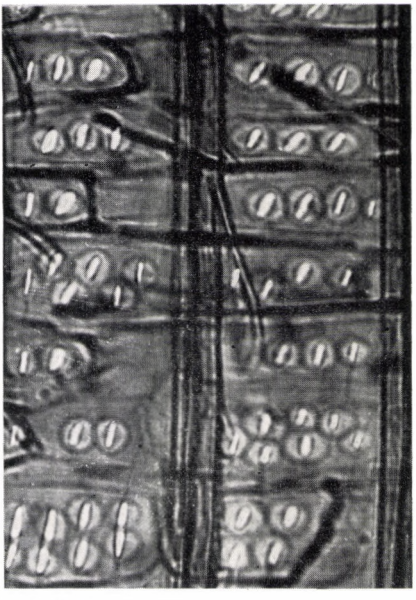


3. (x 300)

4.(x 100)

XXII. *Agathis endertii* Meyer and Drees

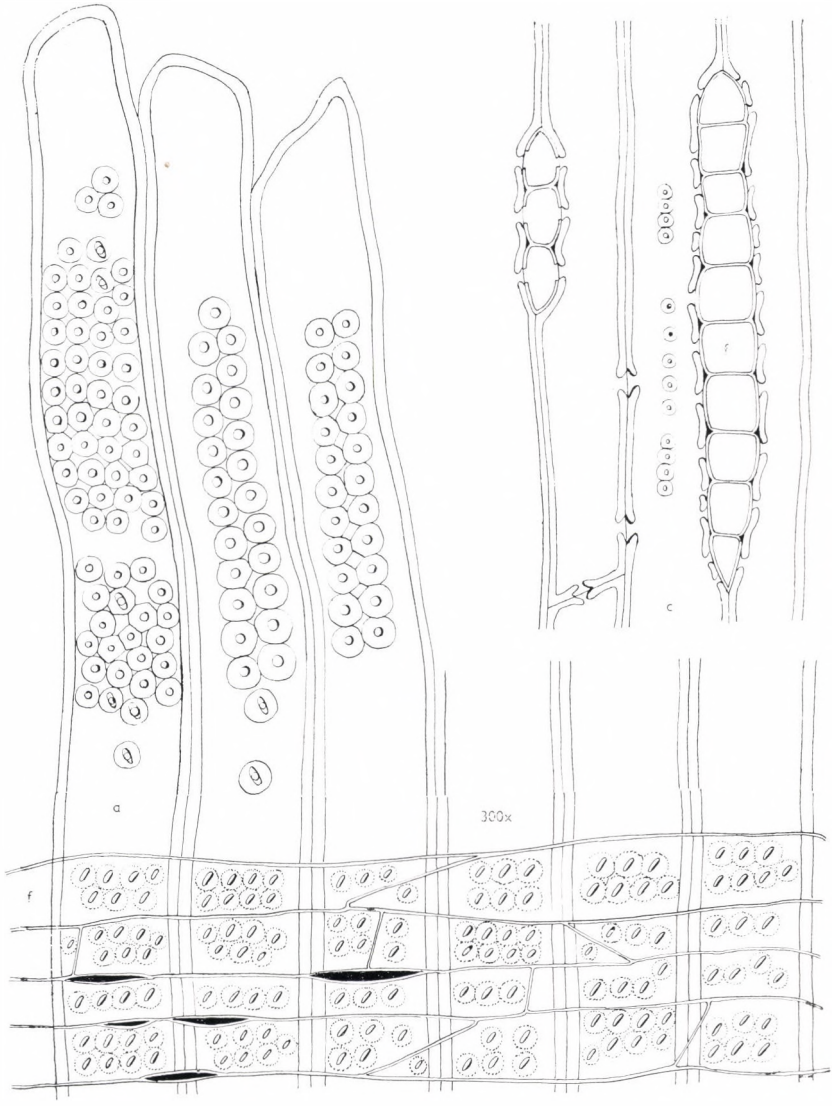
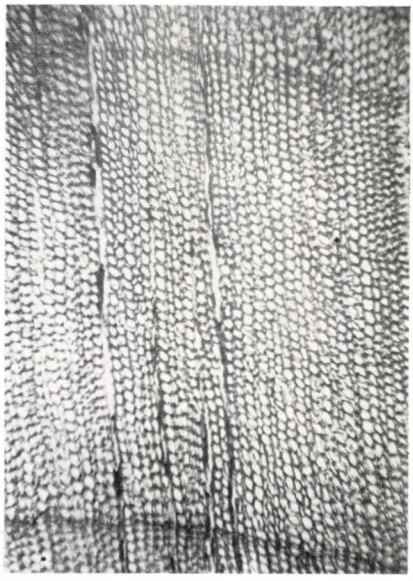


Fig. 2. *Agathis endertii* Meyer and Drees



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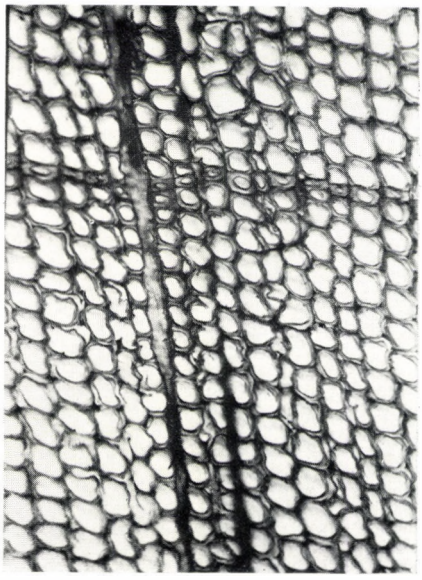

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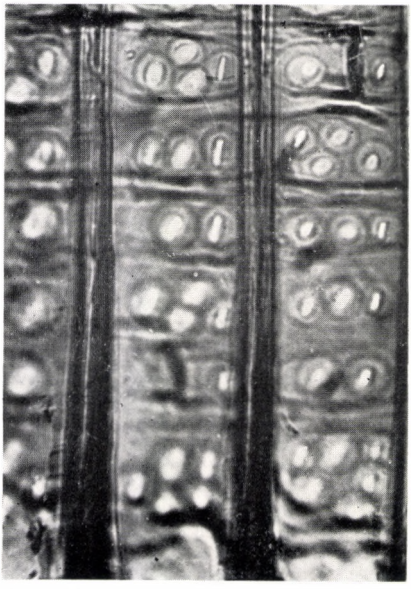

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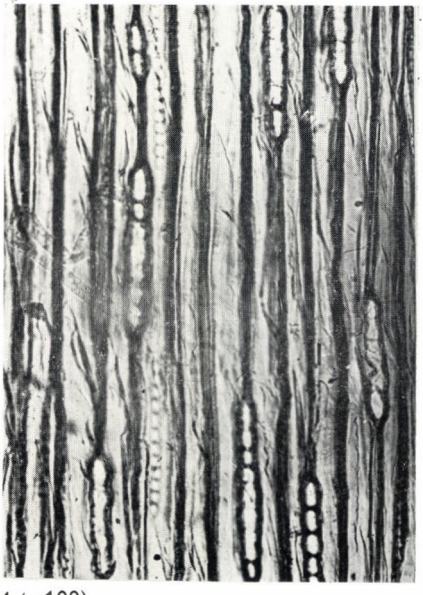


4. (× 100)

XXIII. *Agathis labillardieri* Warb.

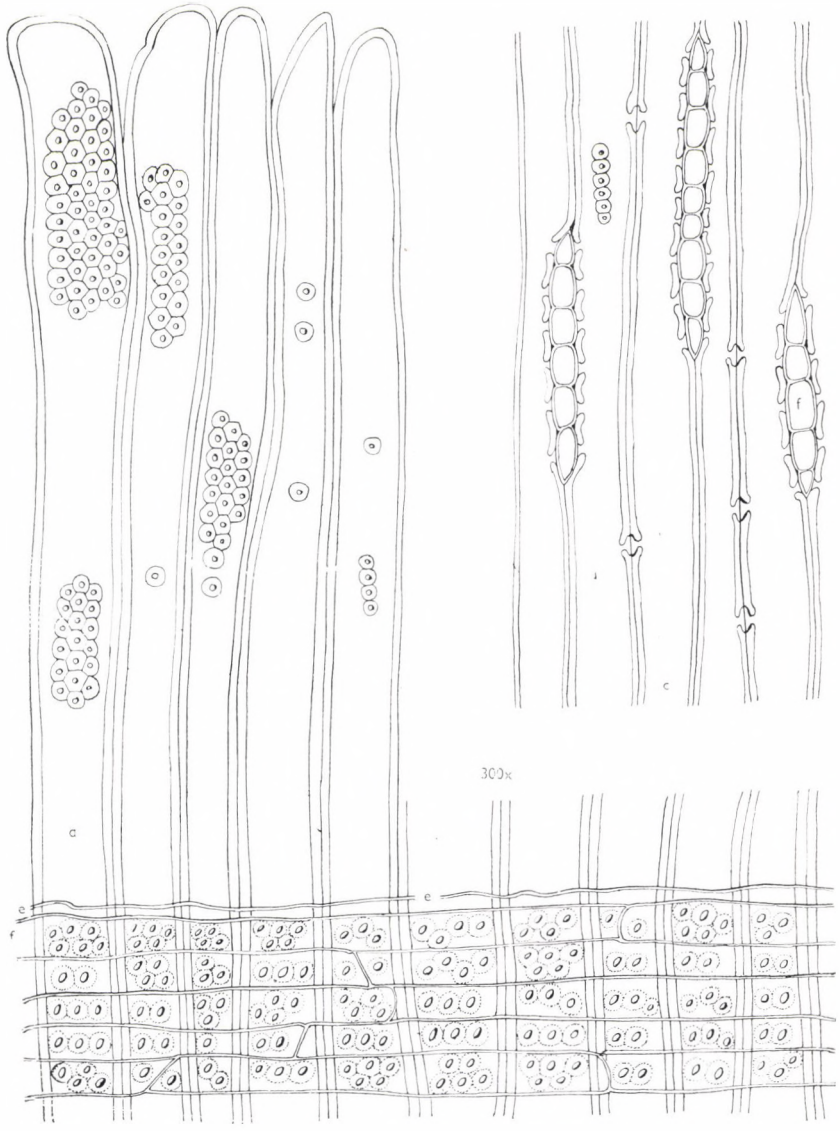
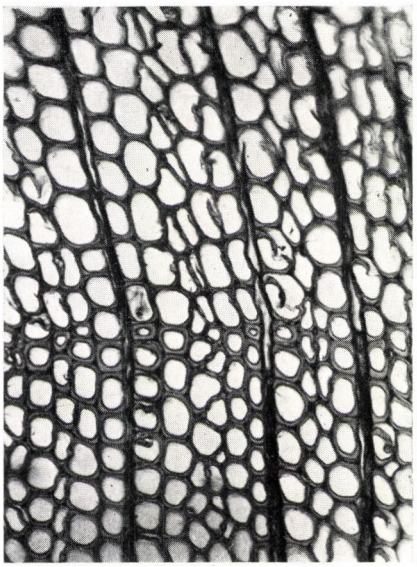


Fig. 3. *Agathis labillardieri* Warb.



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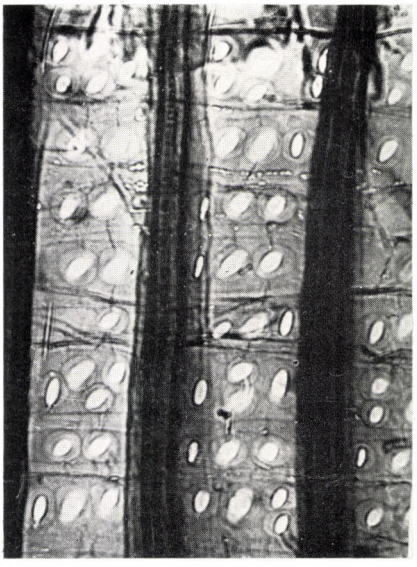
2.(x 100)



3.(x 300)

4. (x300)

XXIV. *Agathis philippensis* Warb.

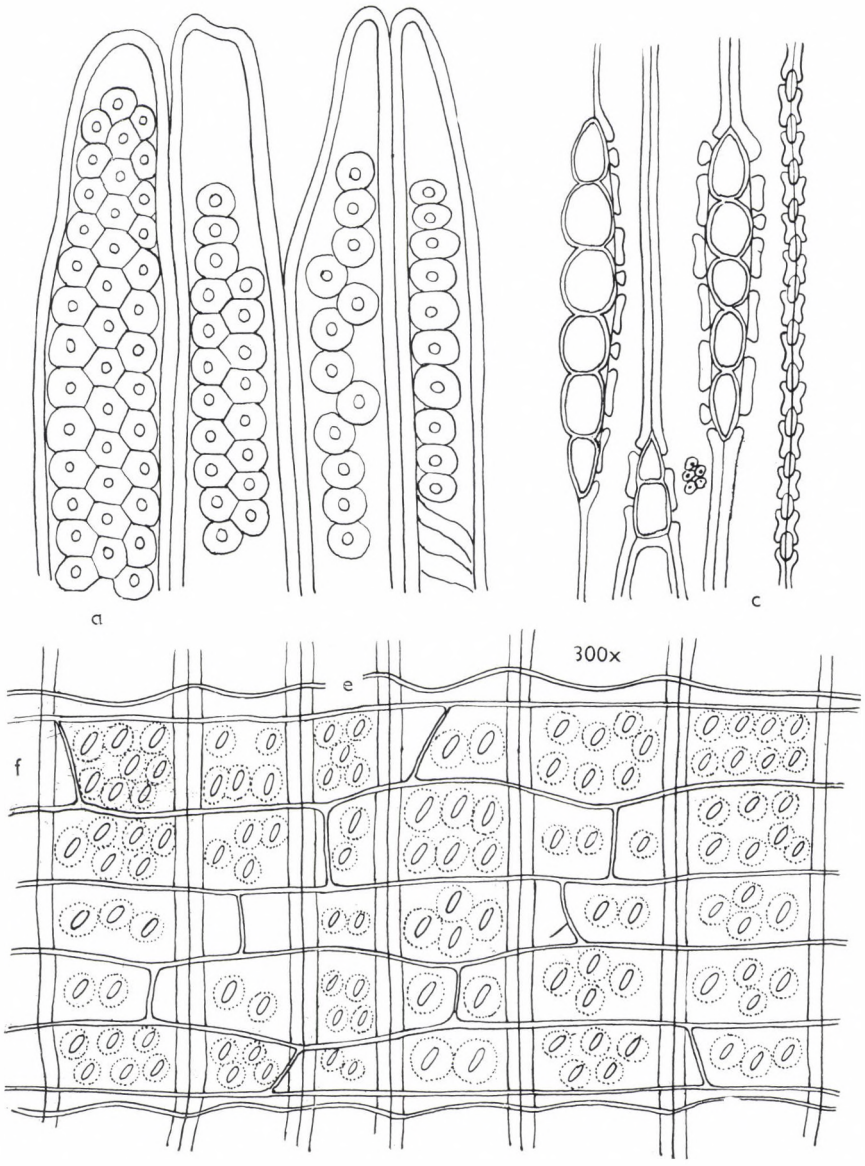
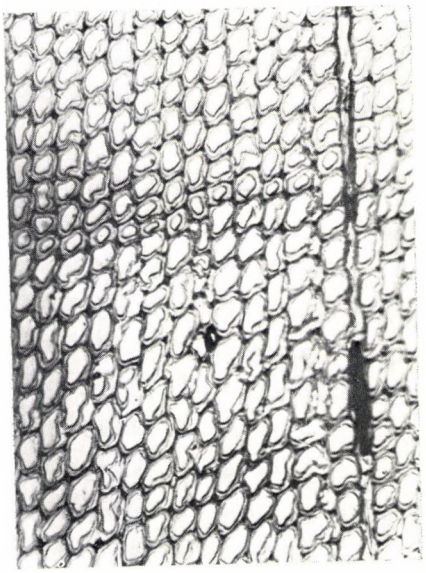


Fig. 4. *Agathis philippensis* Warb.



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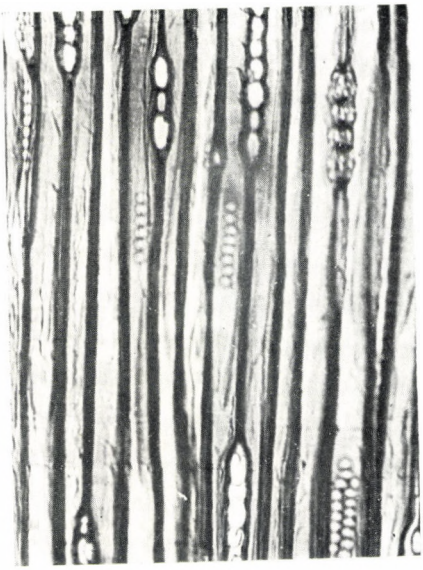

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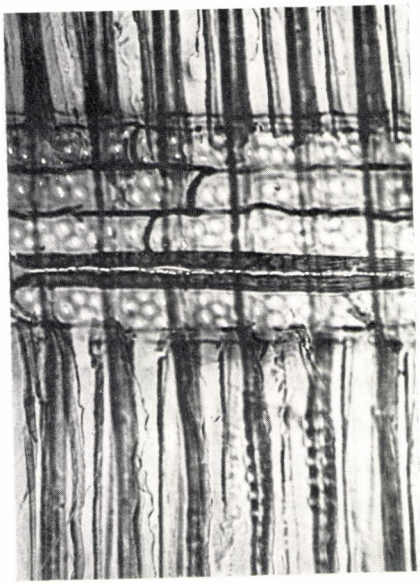


3.(x 300)

4.(x 500)

XXV. *Agathis rhomboidalis* Warb.

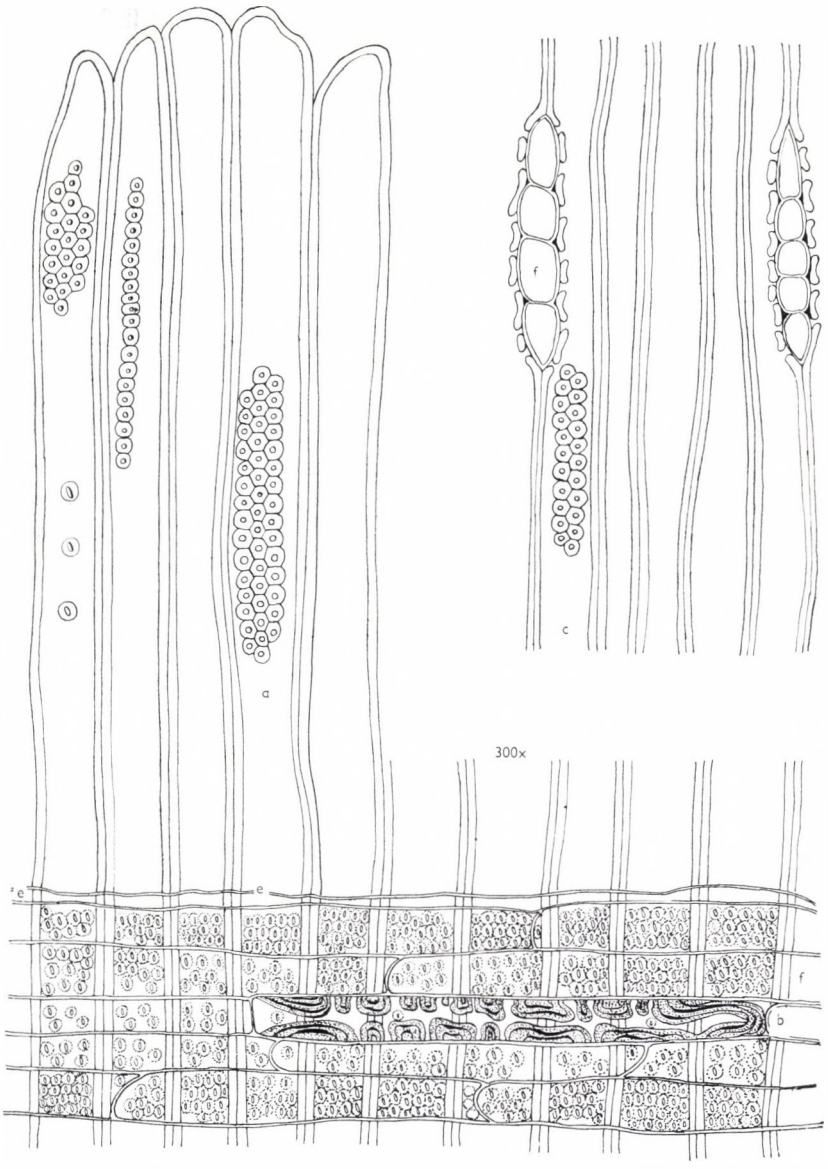
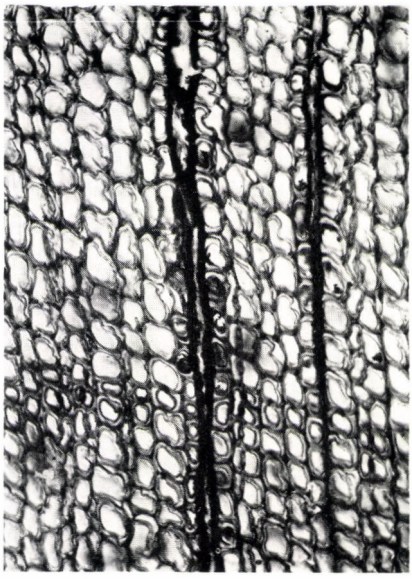


Fig. 5. *Agathis rhomboidalis* Warb.



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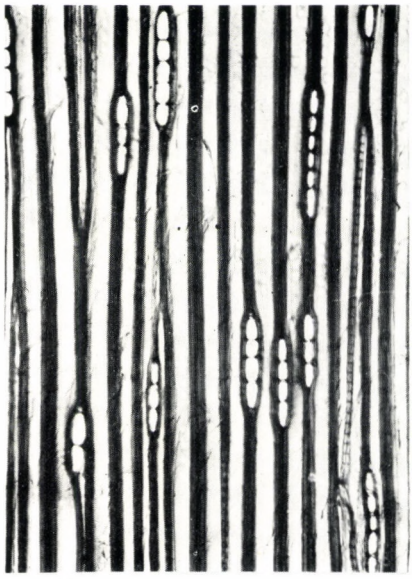
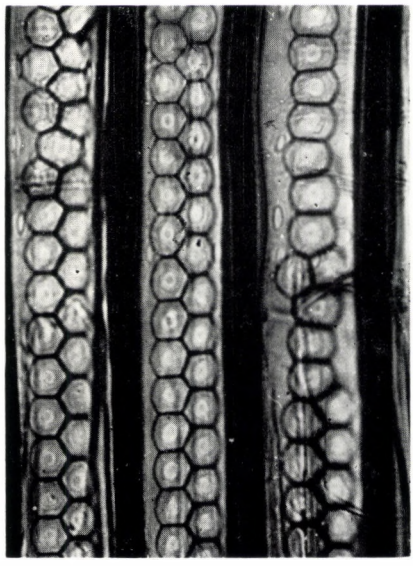


2.(x 100)

3.(x 300)



4.(x 300)

XXVI. *Agathis vitiensis* Bentham and Hooker

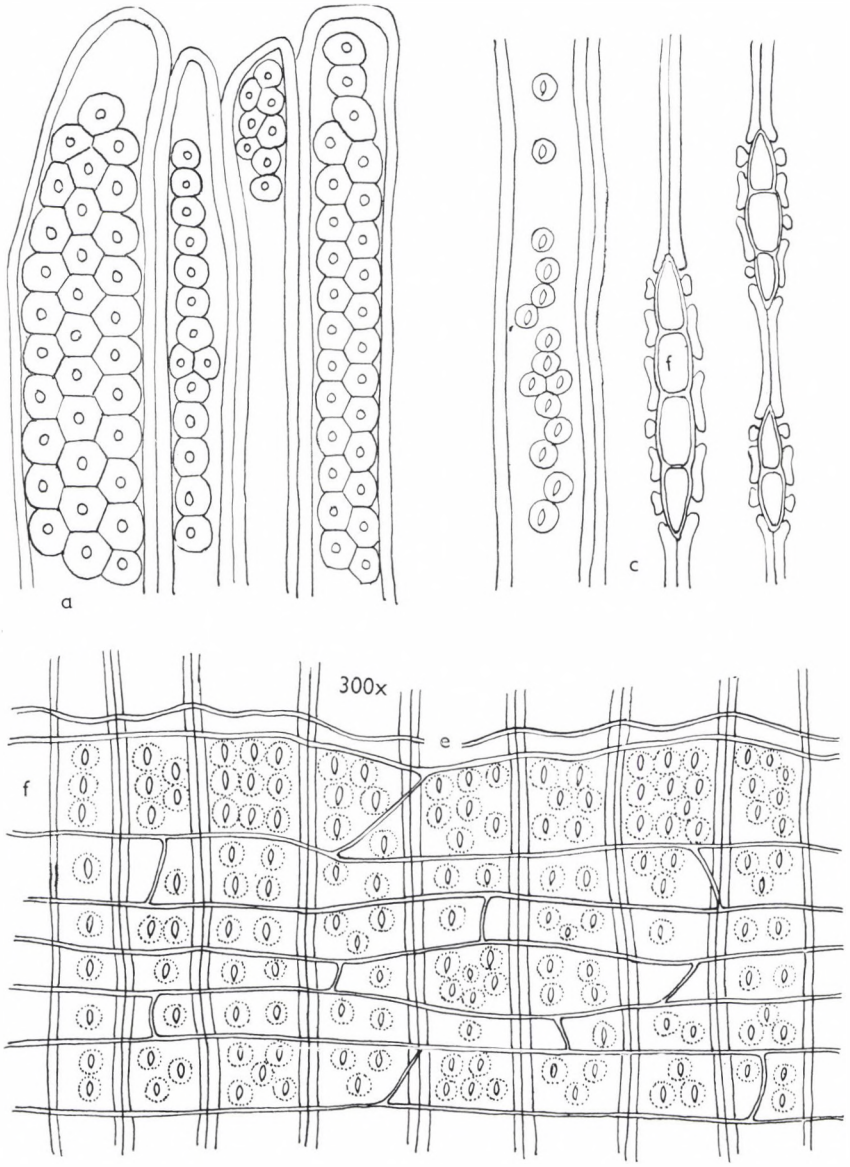
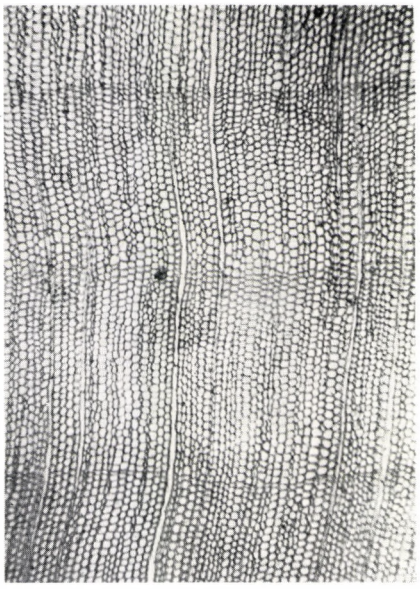
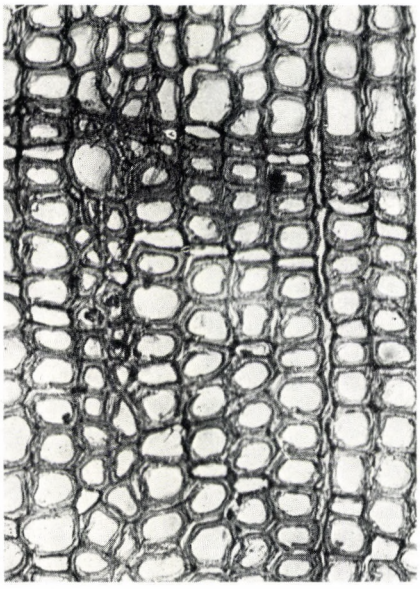


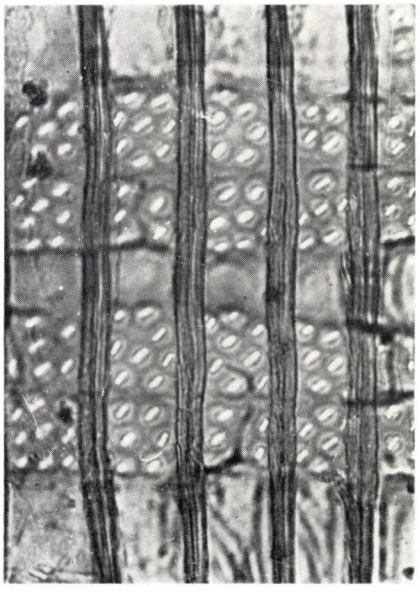
Fig. 6. *Agathis vitiensis* Bentham and Hooker



1. (x 30)



2. (x 100)



3. (x 400)

4. (x 100)

XXVII. *Araucaria dioica* (Vell.) Stellfeld

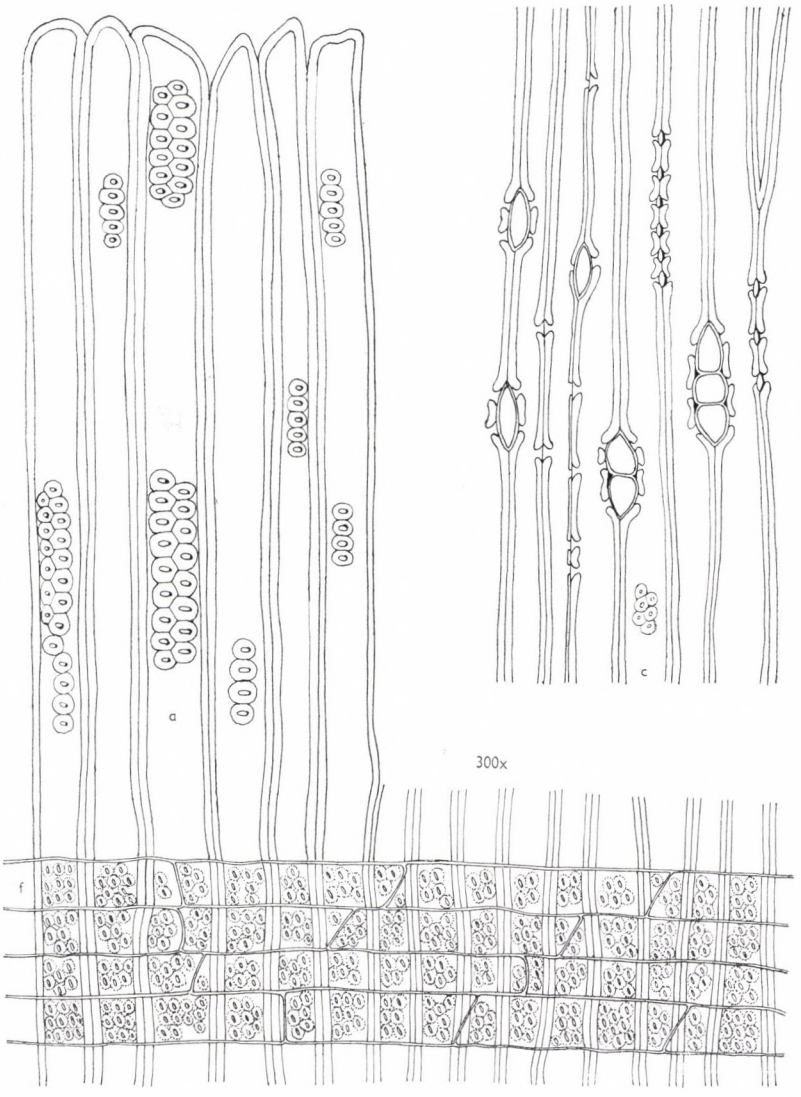
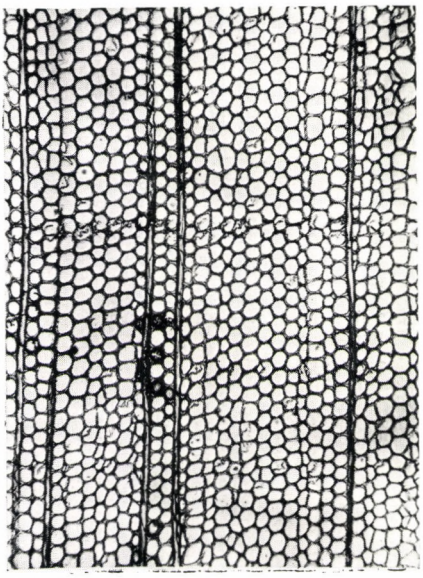


Fig. 7. *Araucaria dioica* (Vell.) Stellfeld



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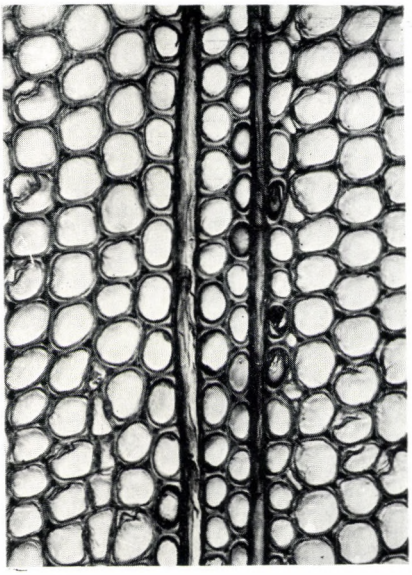

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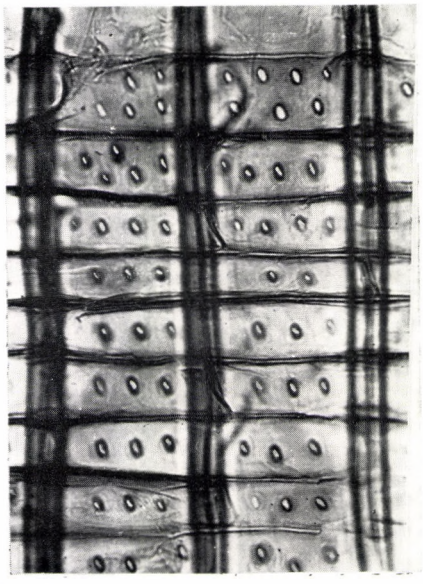
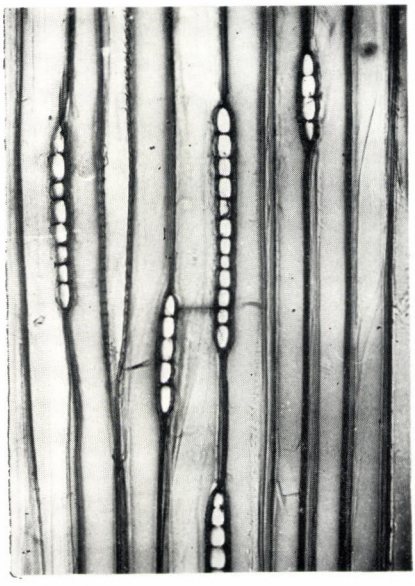


3. (x 300)



4.(x 100)

XXVIII. *Auracaria hunsteinii* K. Schum,

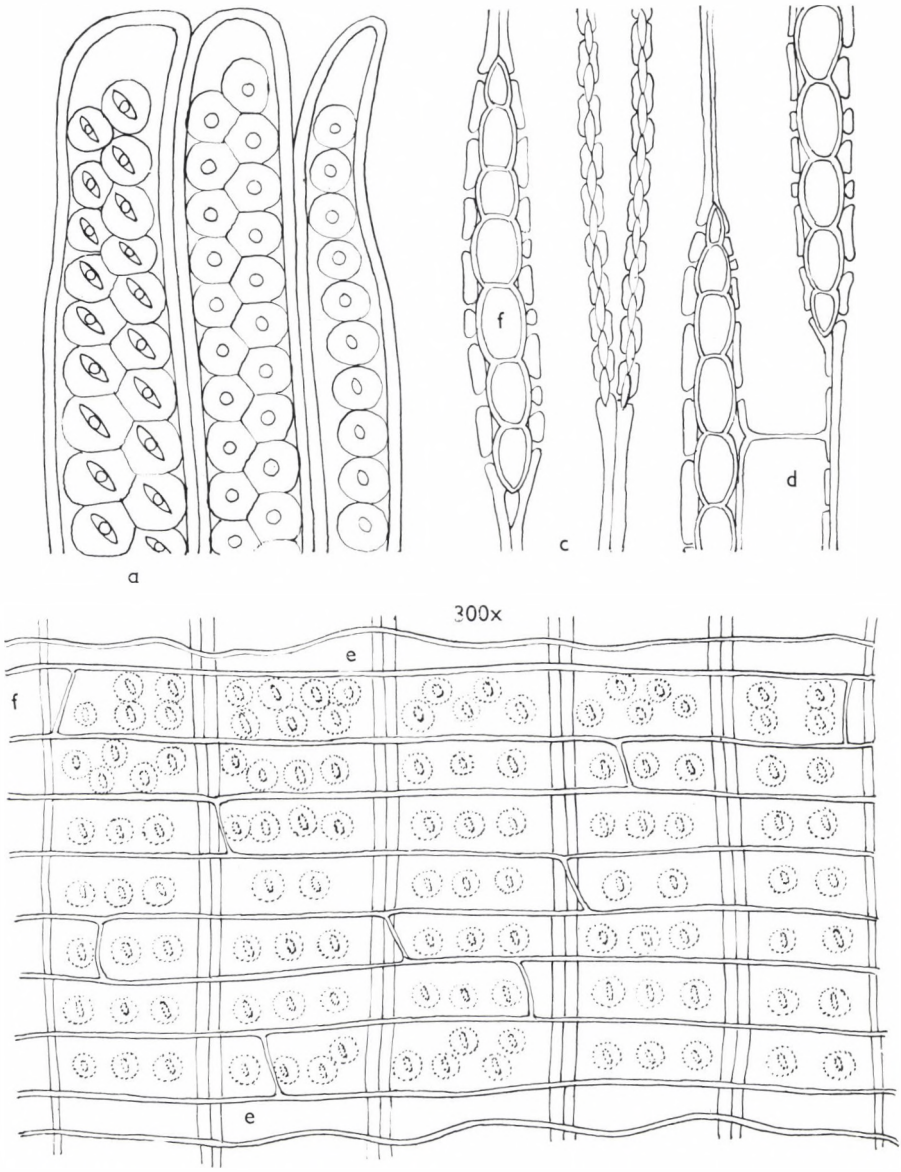
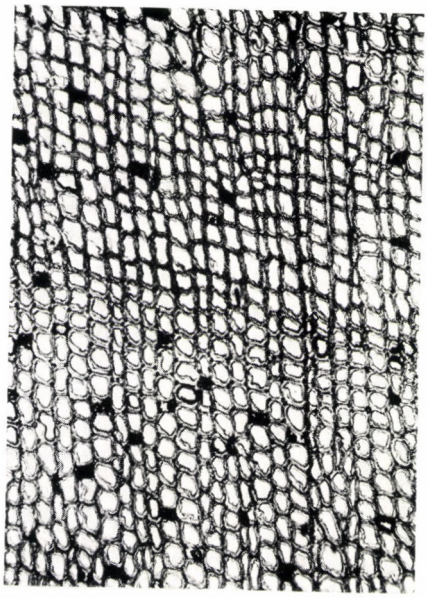
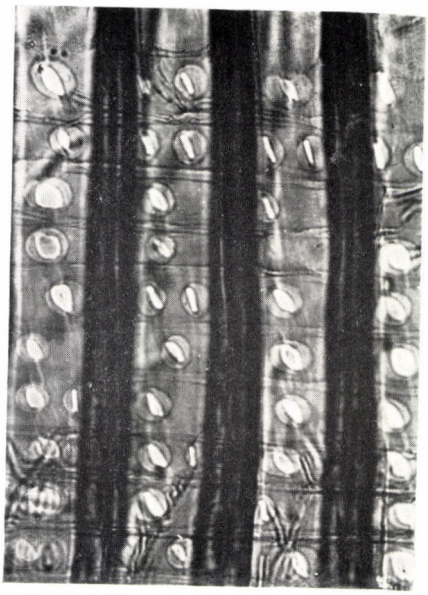


Fig. 8. *Auracaria hunsteinii* K. Schum.

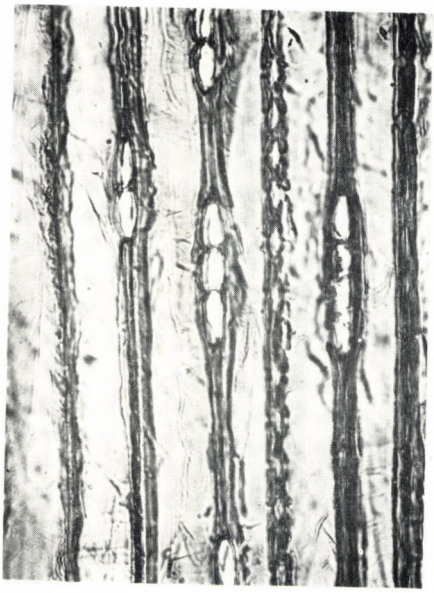


1. (× 100)

2. (× 100)



3. (× 300)



4. (× 300)

XXIX. *Dacrydium beccarii* Parlatore

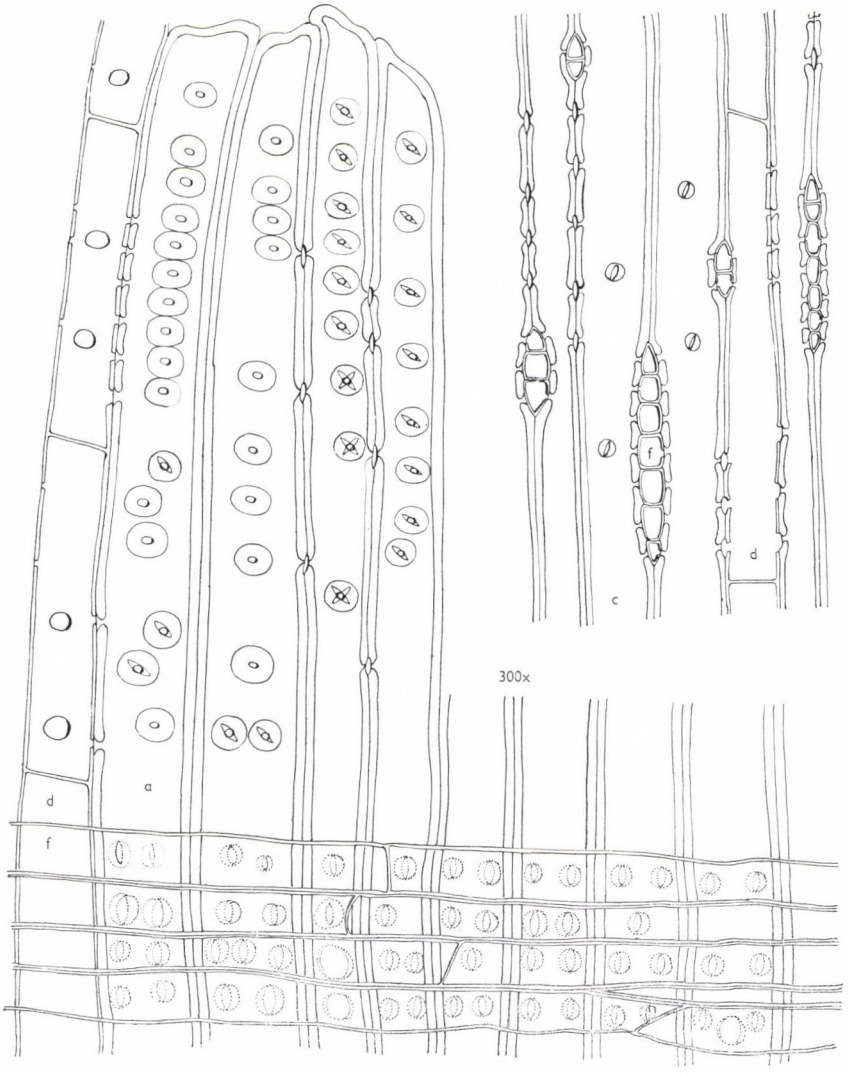
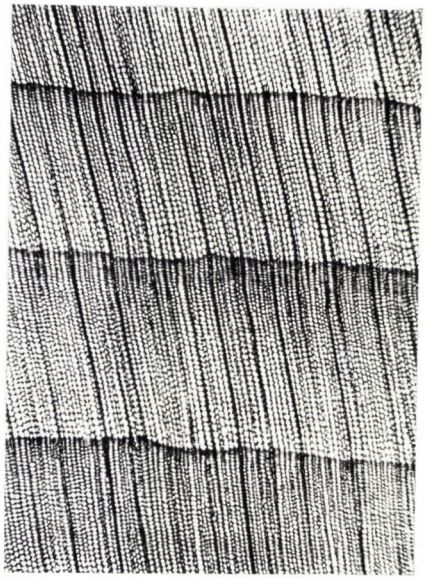


Fig. 9. *Dacrydium beccarii* Parlatore



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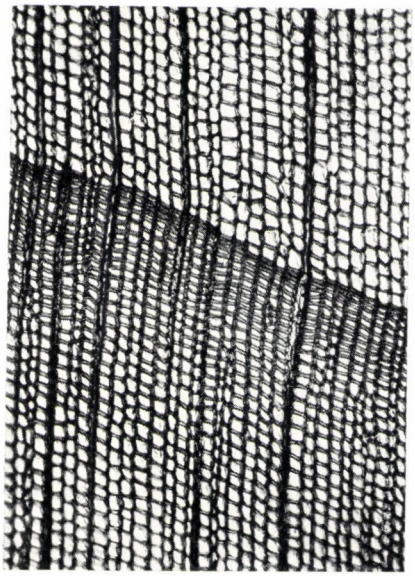

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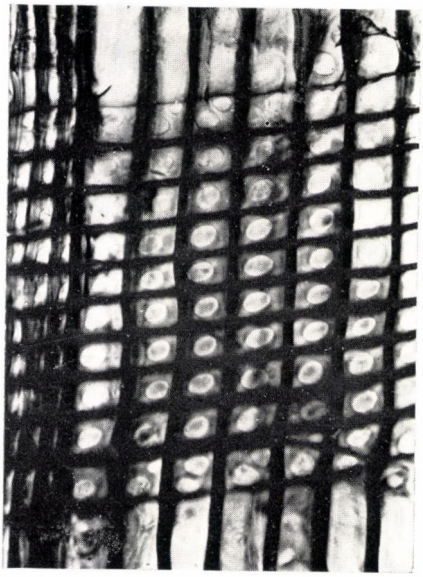
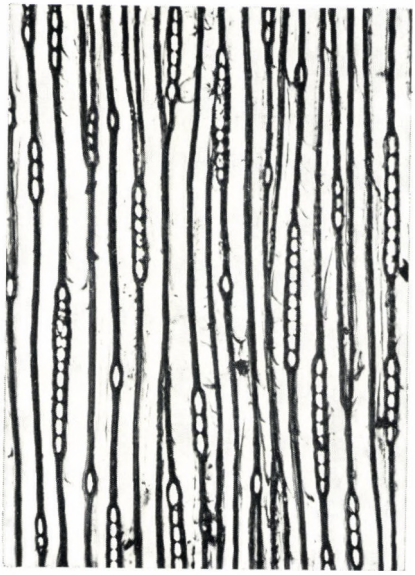


3.(x 300)



4.(x 100)

XXX. *Dacrydium bidwillii* Hooker fil.

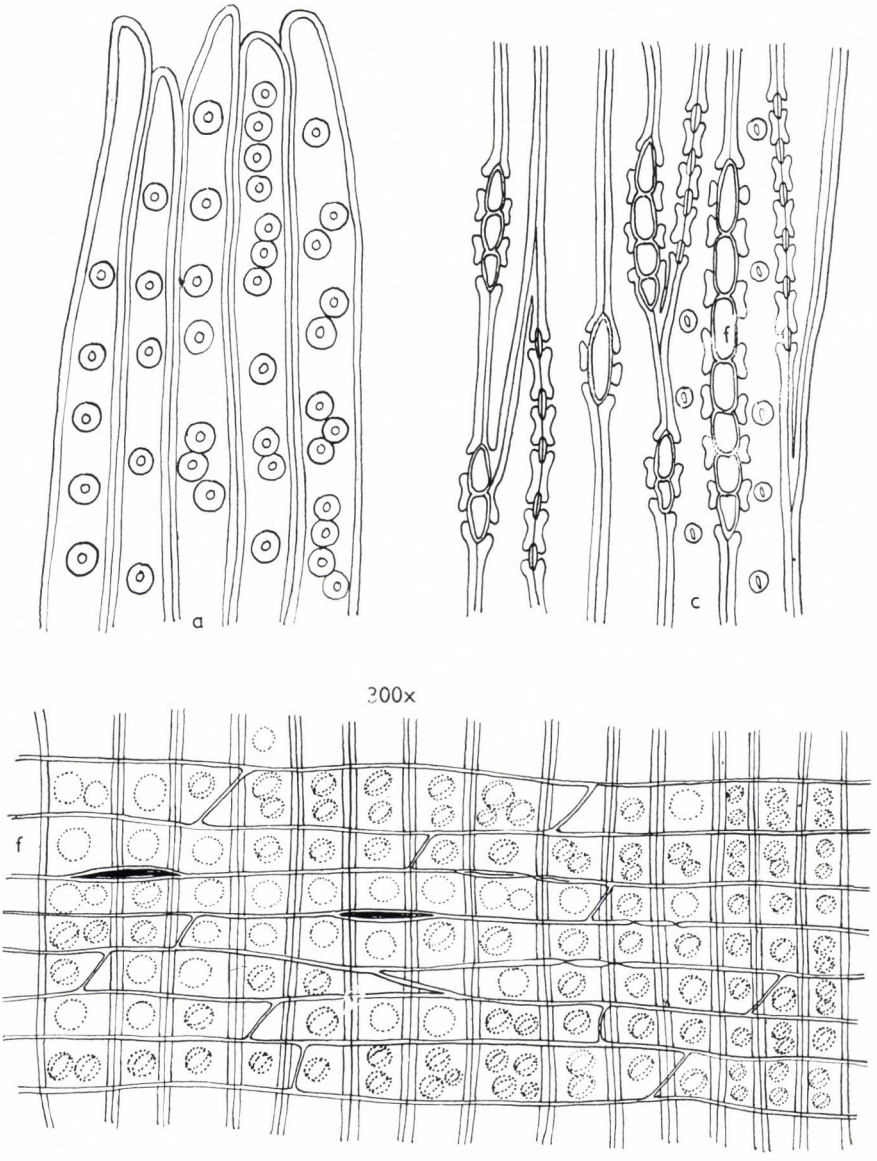
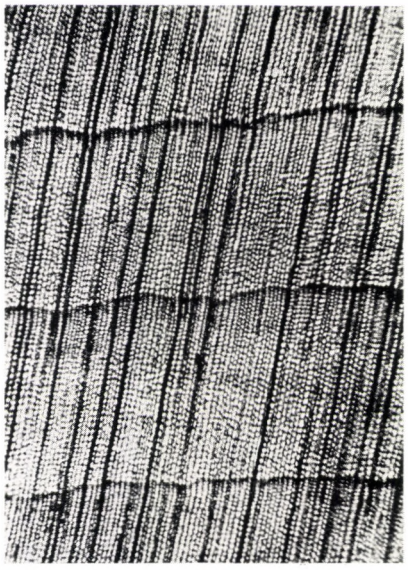
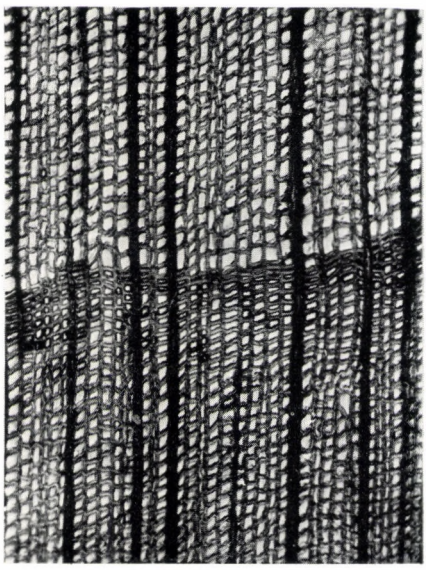


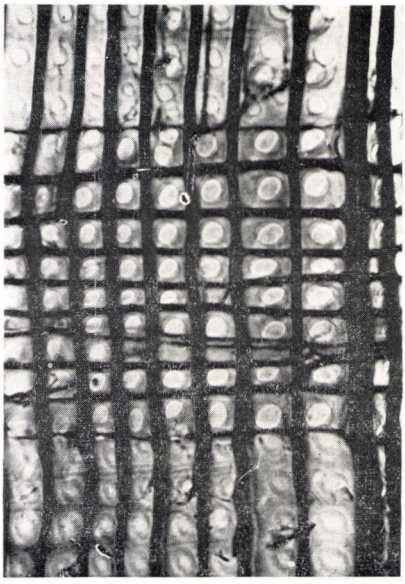
Fig. 10. *Dacrydium bidwillii* Hooker fil.



1.(× 30)



2.(×100)



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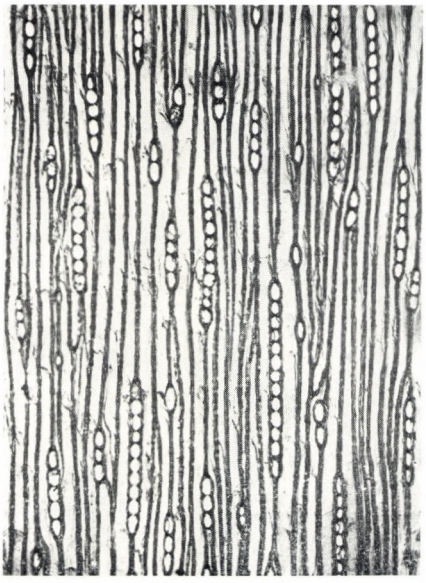


4.(×100)

XXXI. *Dacrydium biforme* Pilger

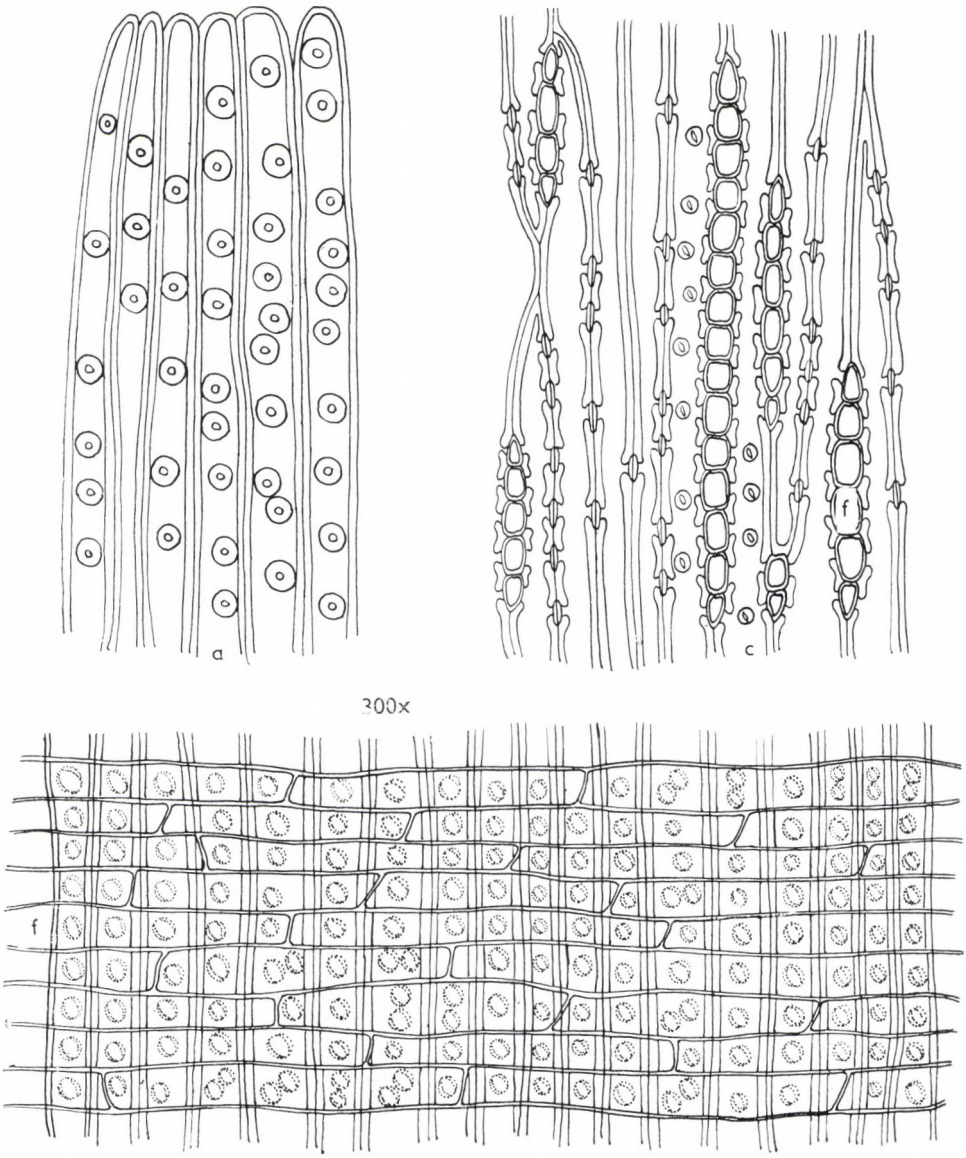
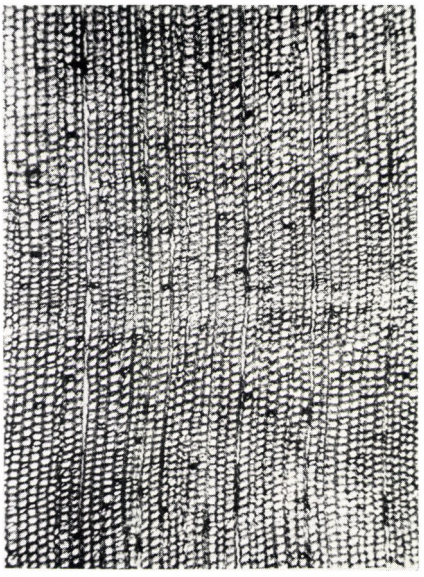


Fig. 11. *Dacrydium biforme* Pilger



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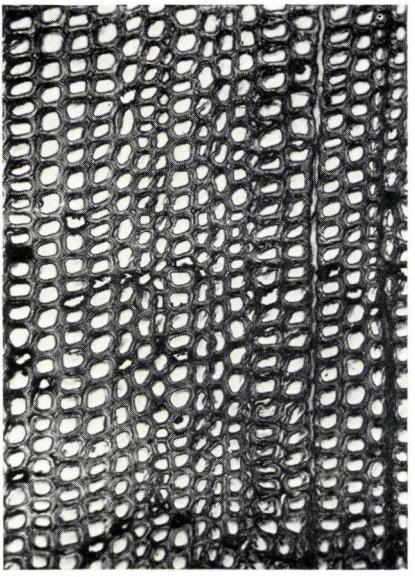
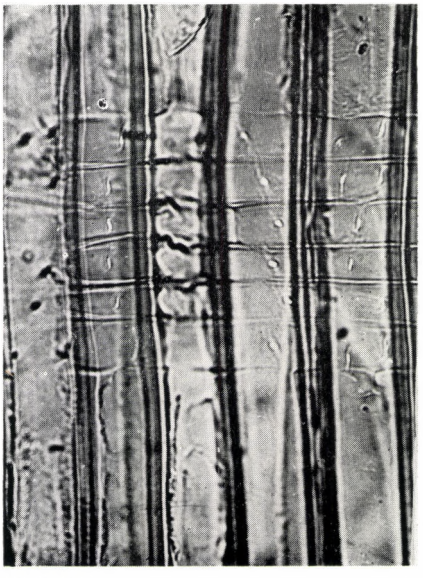


2.(x 100)



3.(x 300)

4.(x 100)

XXXII. *Dacrydium falciforme* Pilger

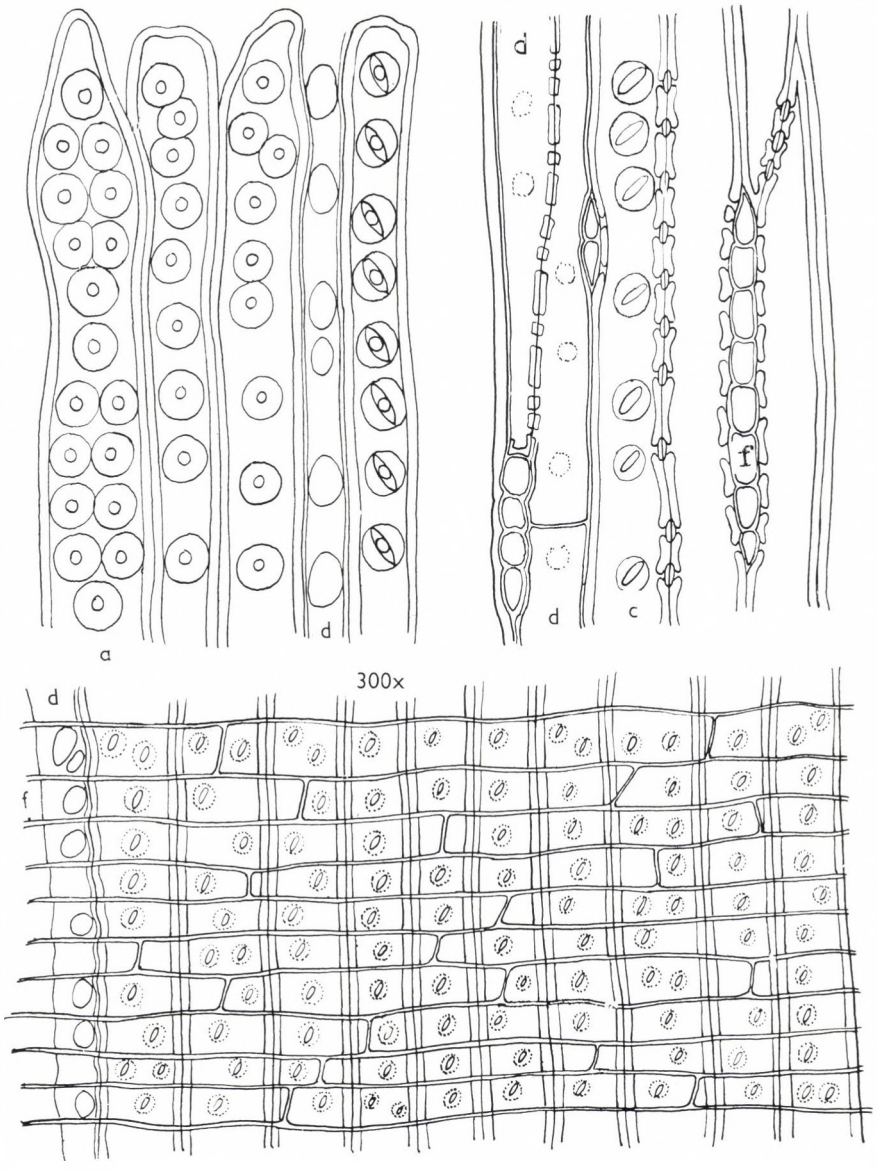
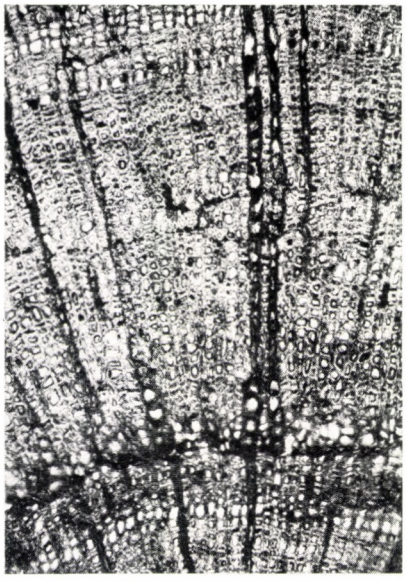
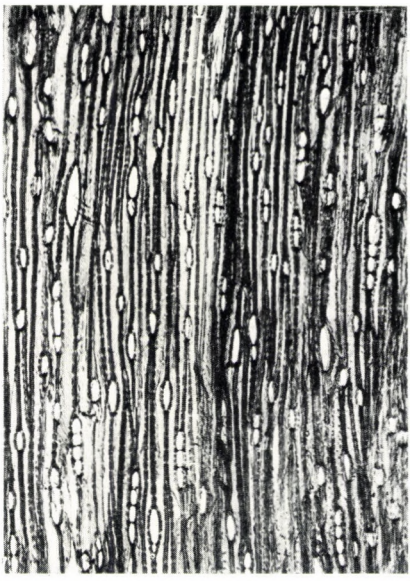


Fig. 12. *Dacrydium falciforme* Pilger



1.(× 50)



2.(×100)

3.(× 300)

4.(× 300)

XXXIII. *Dacrydium fonkii* Bentham

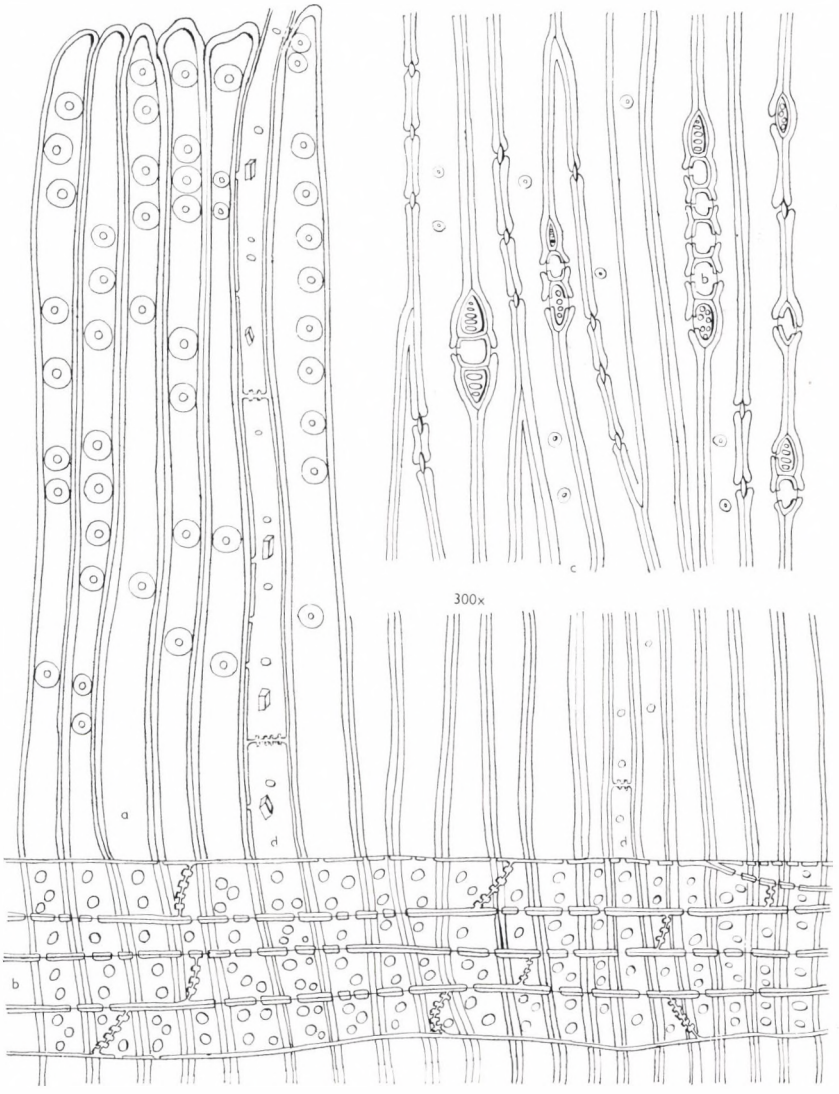
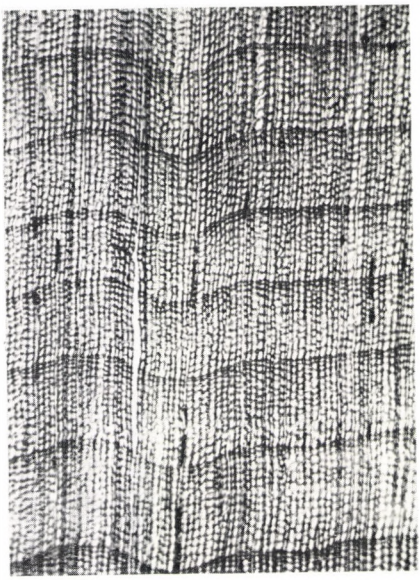
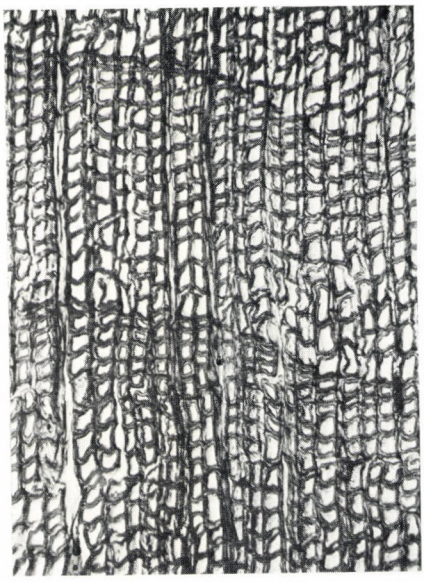


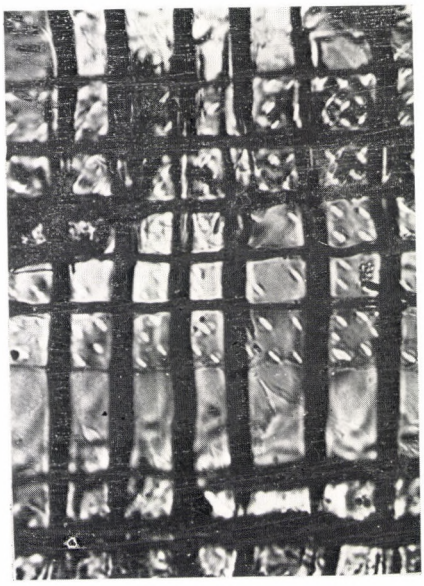
Fig. 13. *Dacrydium fonkii* Bentham



1. (×30)



2.(×100)



3.(×300)

4.(×100)

XXXIV. *Dacrydium intermedium* T. Kirk

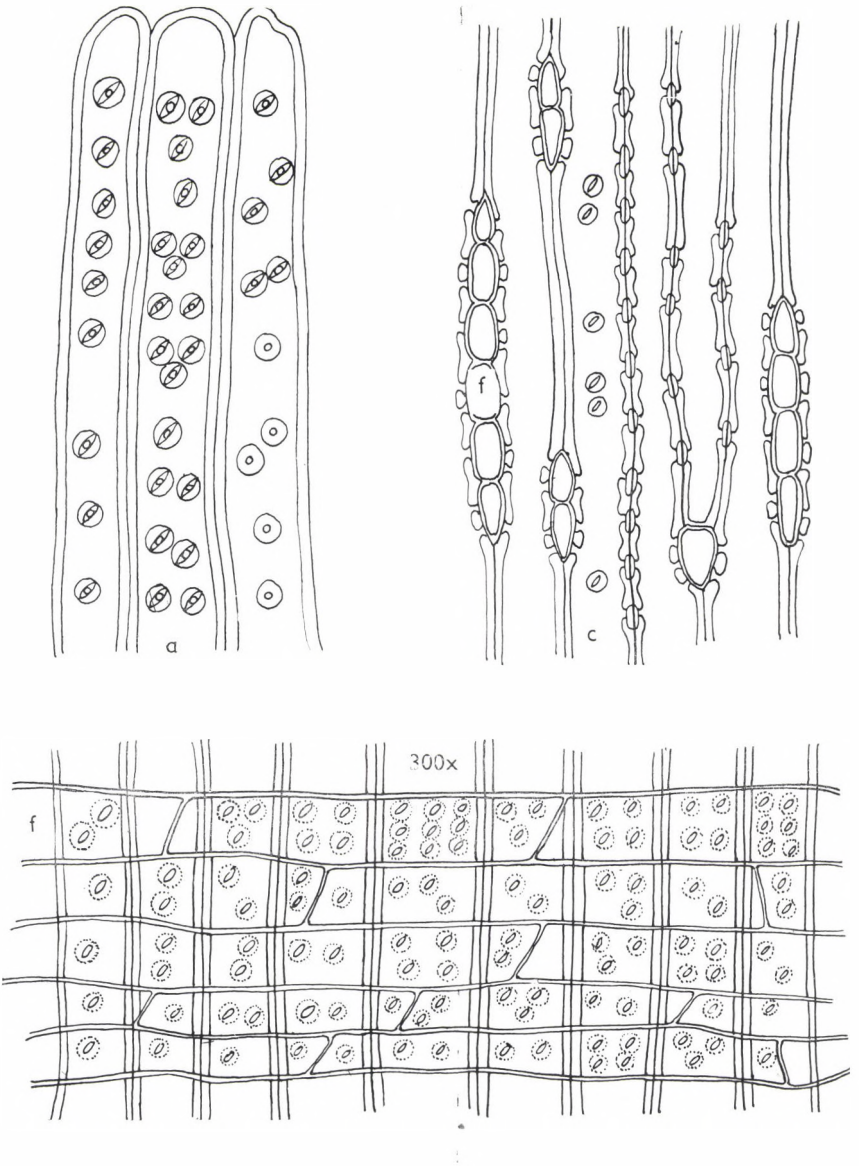
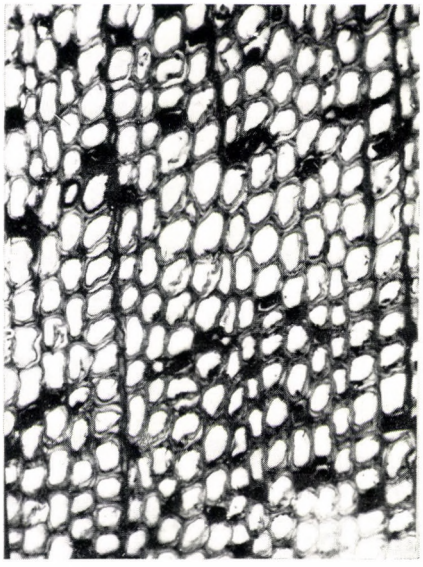
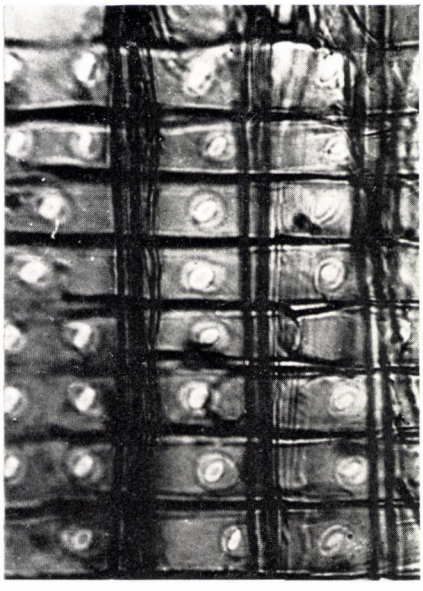


Fig. 14. *Dacrydium intermedium* T. Kirk

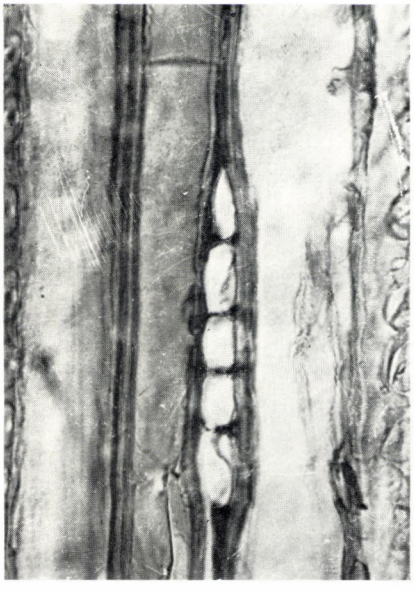


1. (× 100)

2. (× 100)



3. (× 400)



4. (× 400)

XXXV. *Dacrydium junghuhnii* Miq.

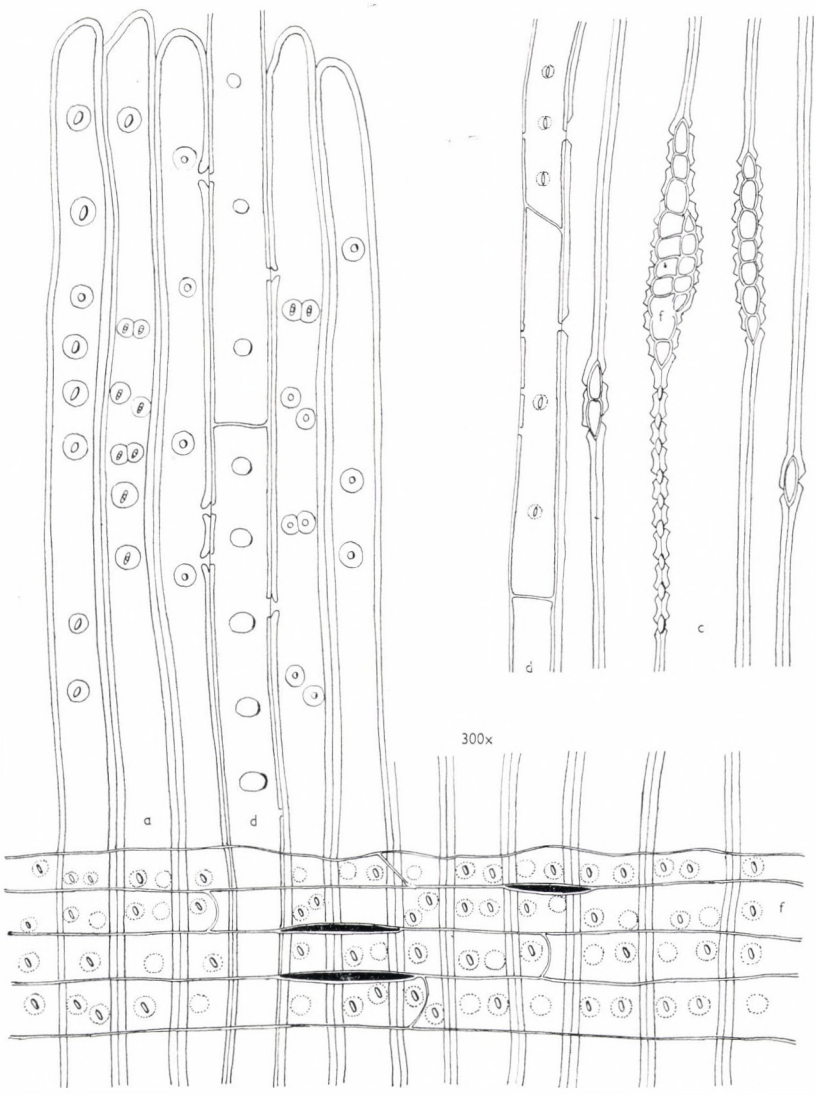
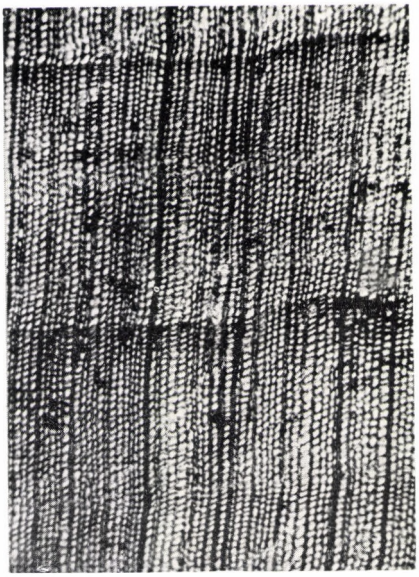
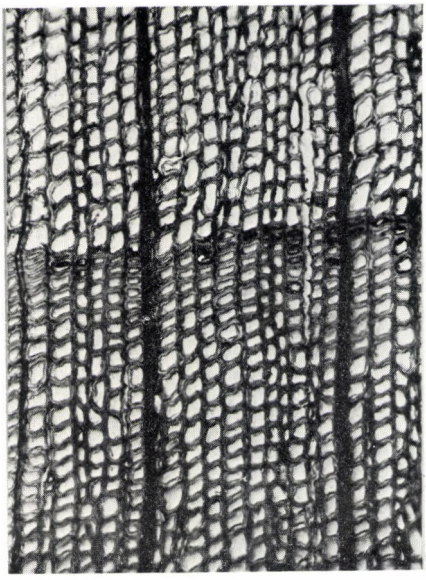


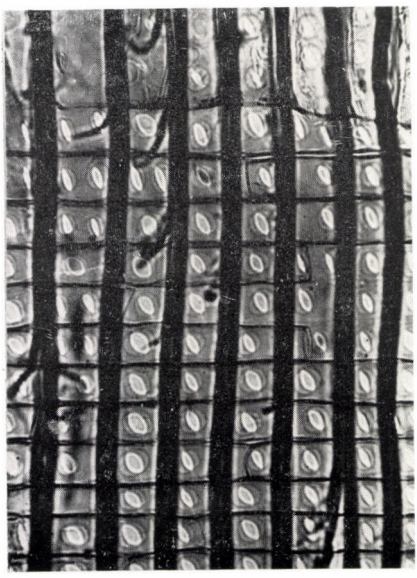
Fig. 15. *Dacrydium junghuhnii* Miq.



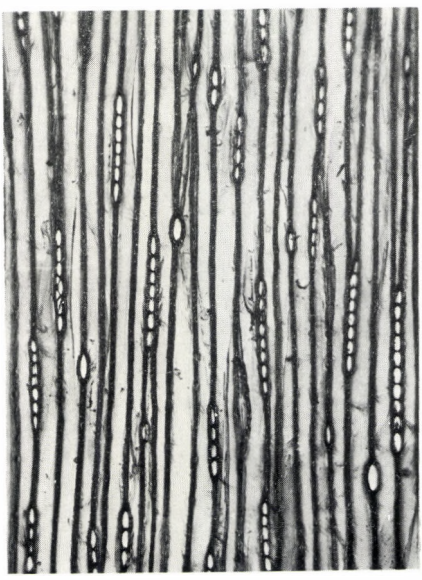
1. (x 30)



2. (x 100)



3. (x 300)



4. (x 100)

XXXVI. *Dacrydium kirkii* F. Mueller

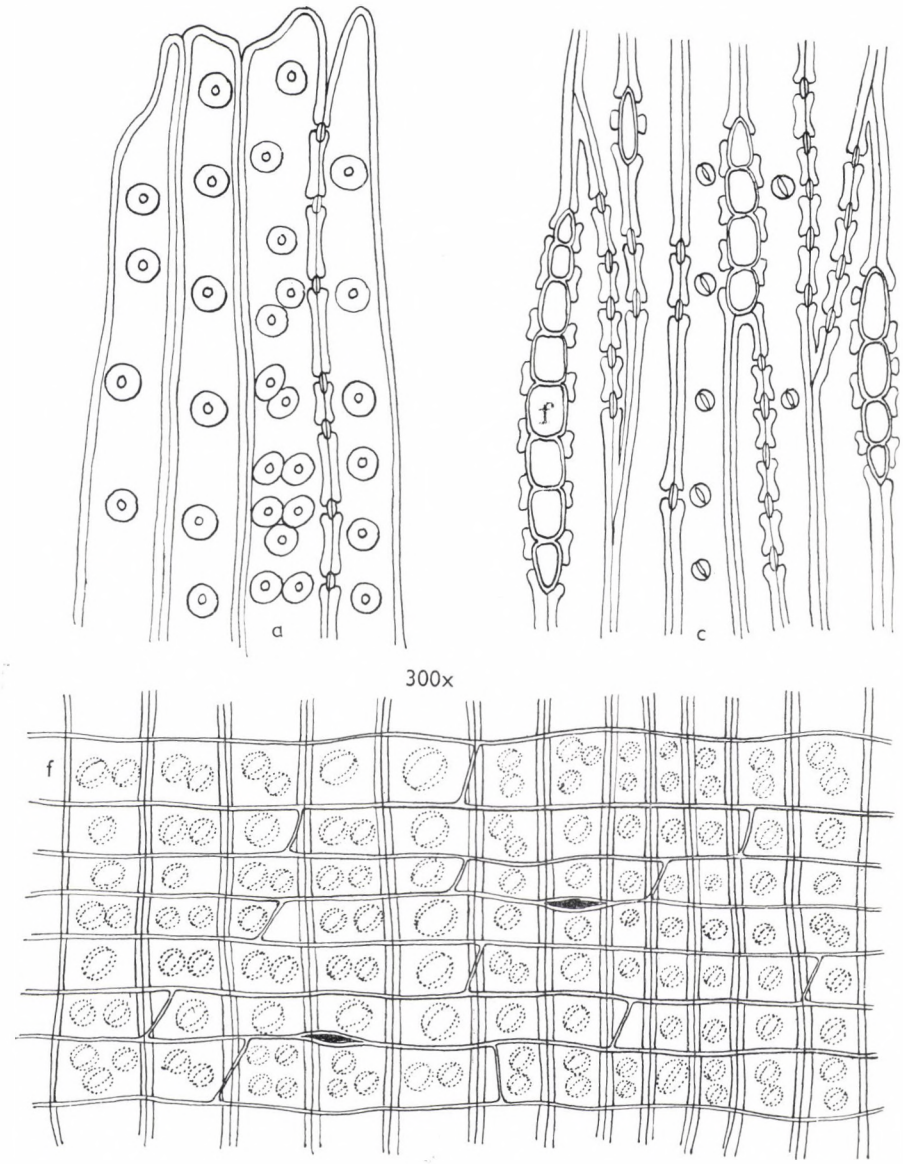
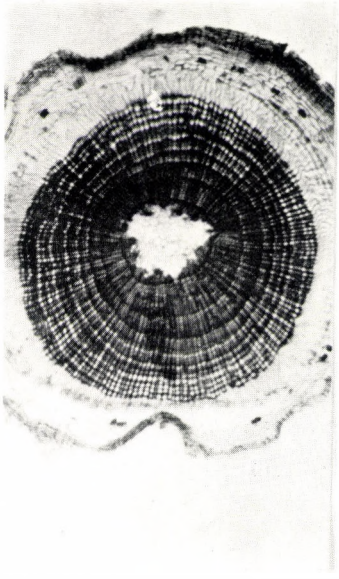
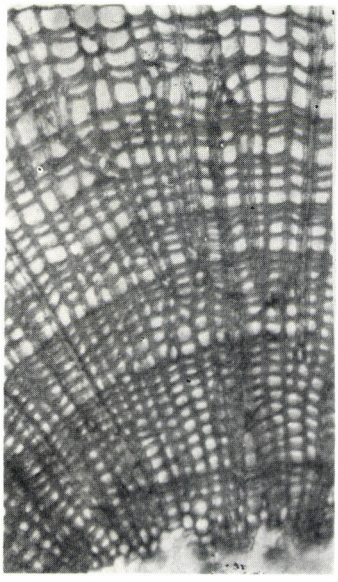


Fig. 16. *Dacrydium kirkii* F. Mueller

1. 2/3 nat. s.



2. (x 15)



3. (x 100)

4. (x 400)

5. (x 100)

XXXVII. *Dacrydium laxifolium* Hooker fil.

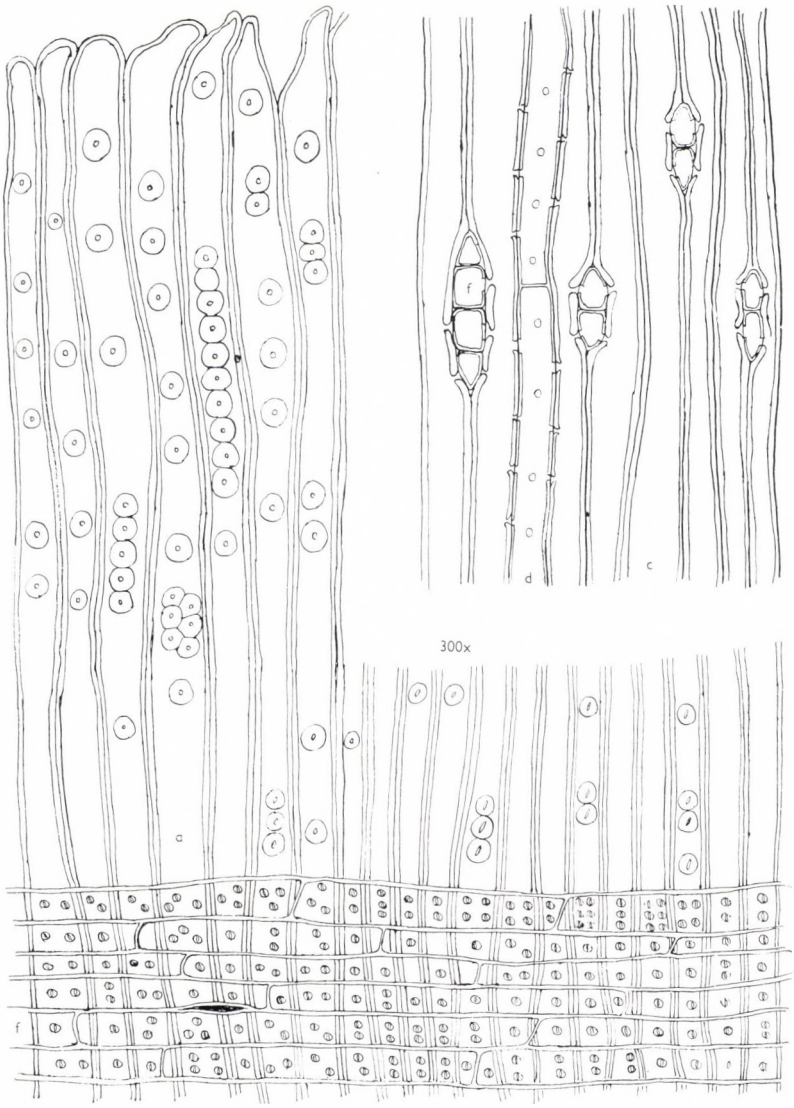
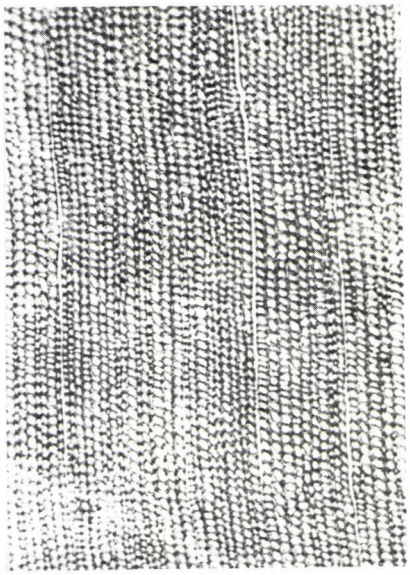
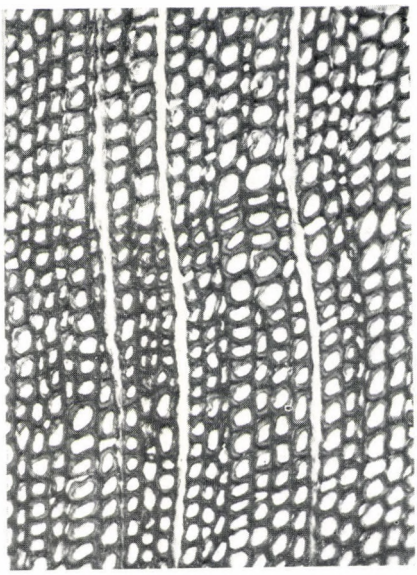


Fig. 17. *Dacrydium laxifolium* Hooker fil.



1.(×30)



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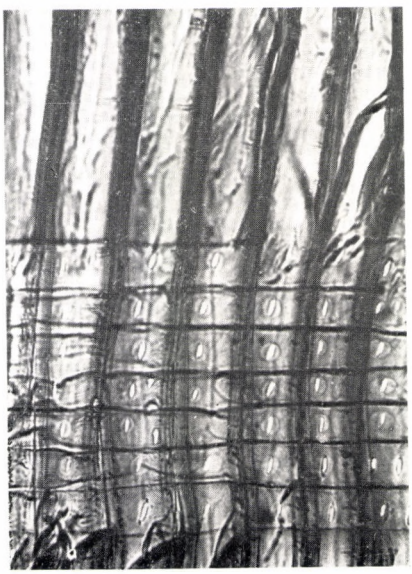


3.(×300)

4.(×100)

XXXVIII. *Dacrydium novo-guineense* Gibbs.

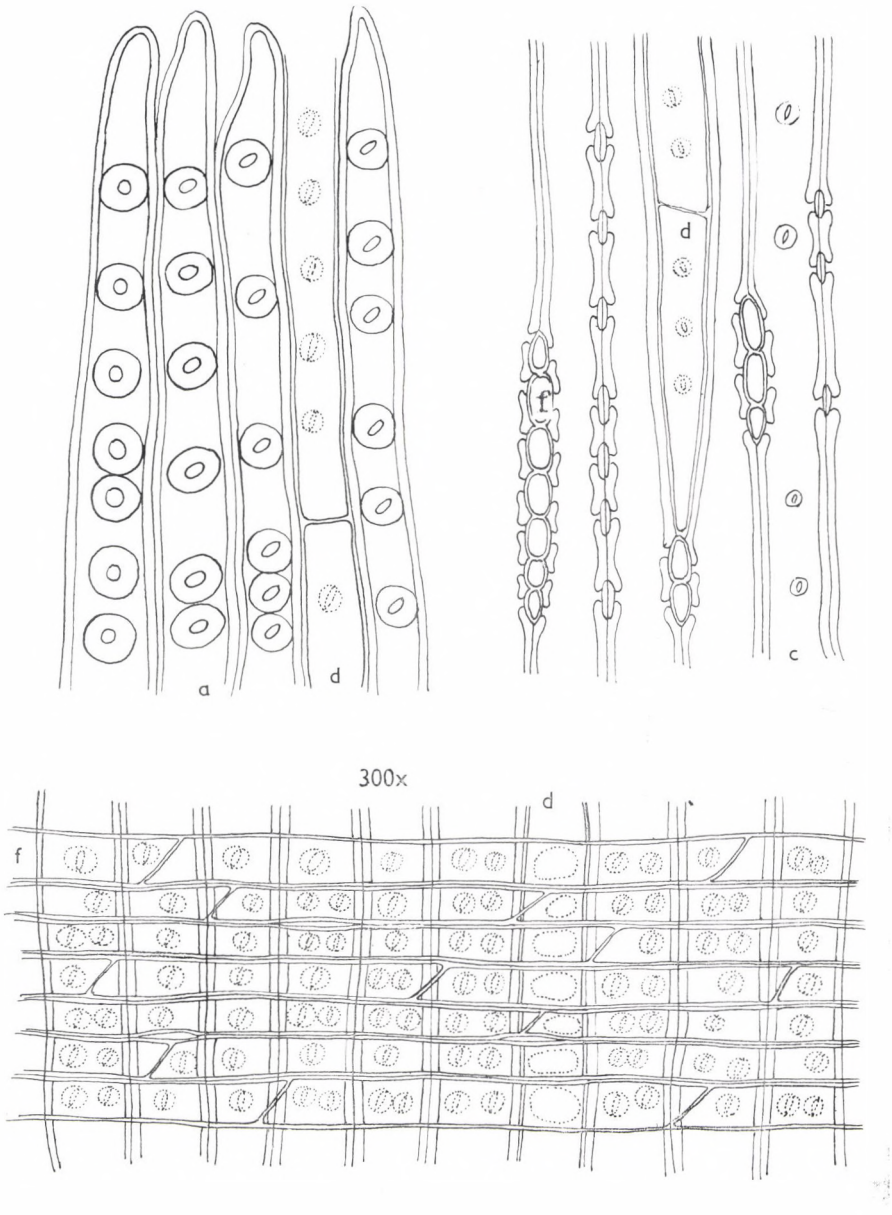
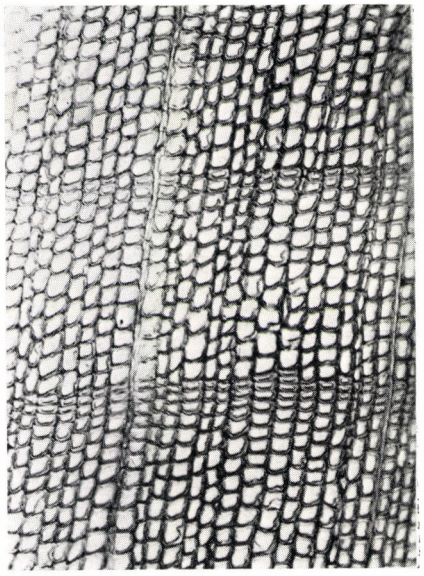
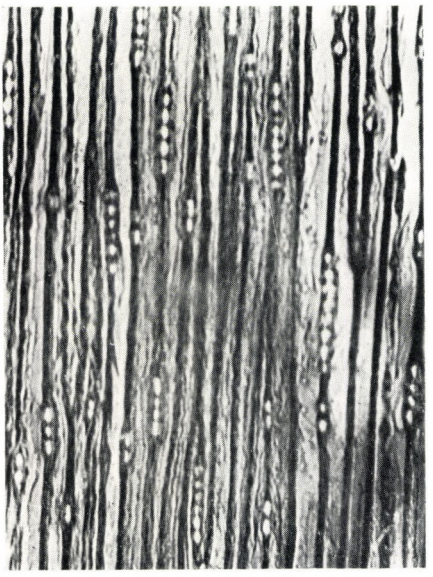


Fig. 18. *Dacrydium novo-guineense* Gibbs.



1. (×100)



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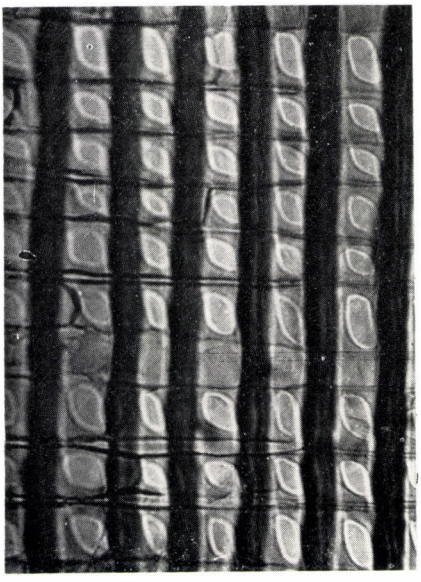
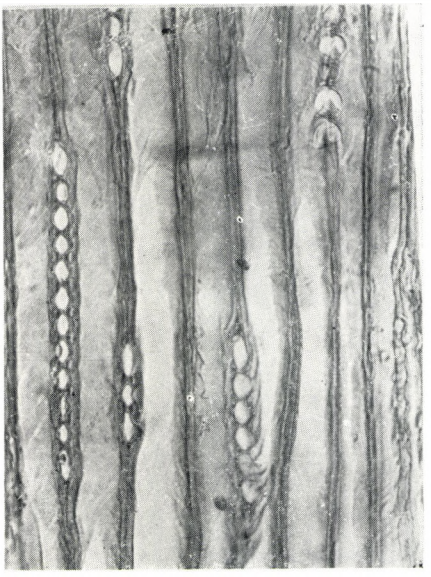


3.(×400)



4.(×200)

XXXIX. *Dacrydium westlandicum* T. Kirk

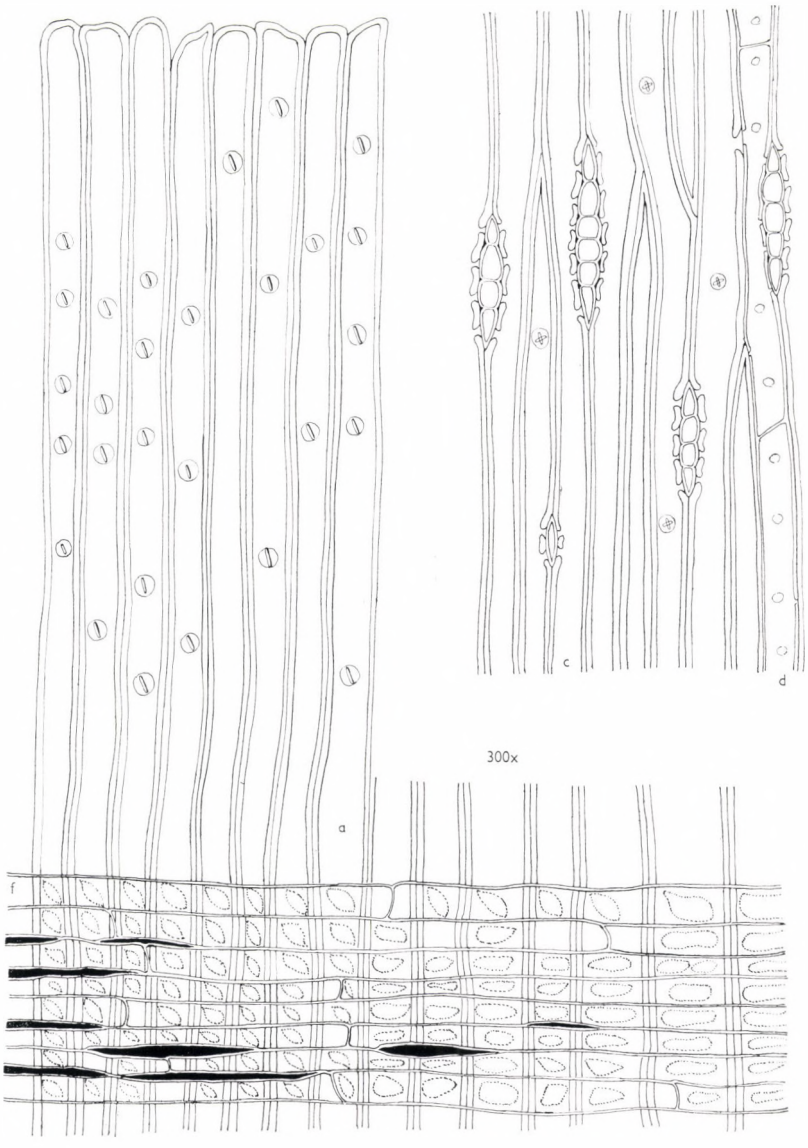
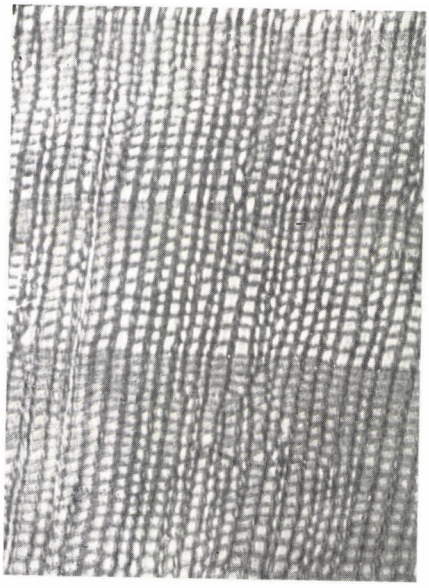
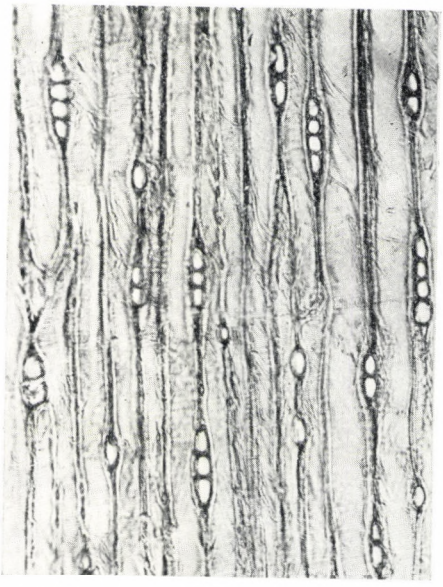


Fig. 19. *Dacrydium westlandicum* T. Kirk



1. (x100)



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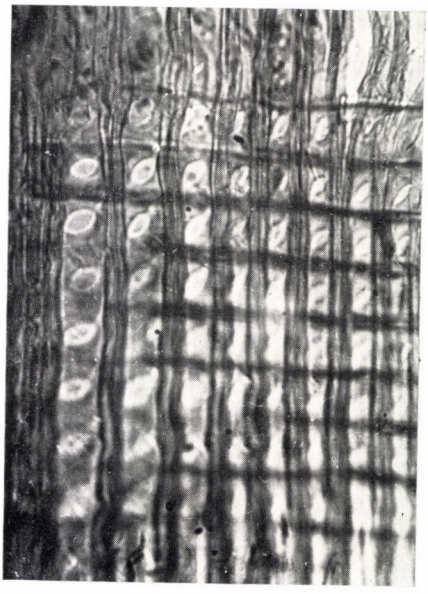

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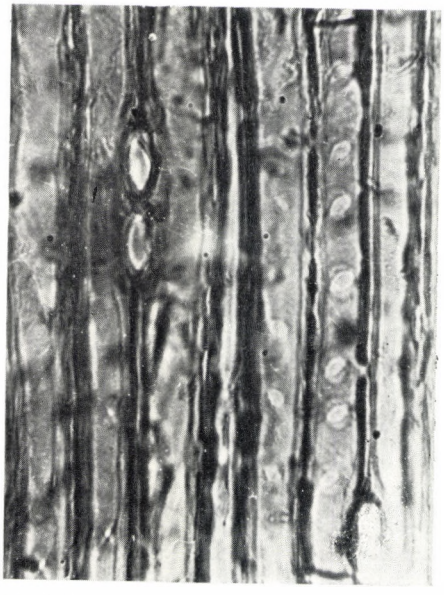


4.(x 300)

XL. *Microstrobus fizgeraldi* (F. Mueller) Gard and Johns

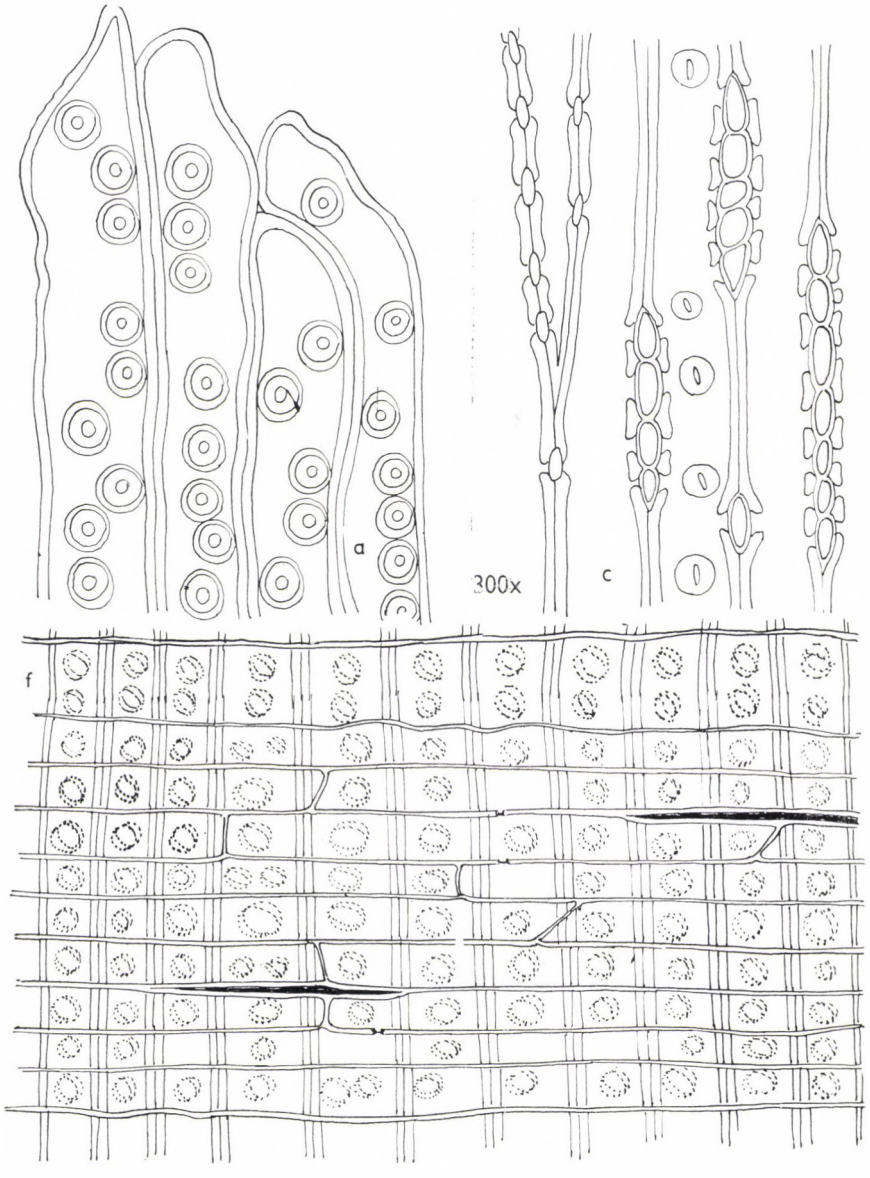
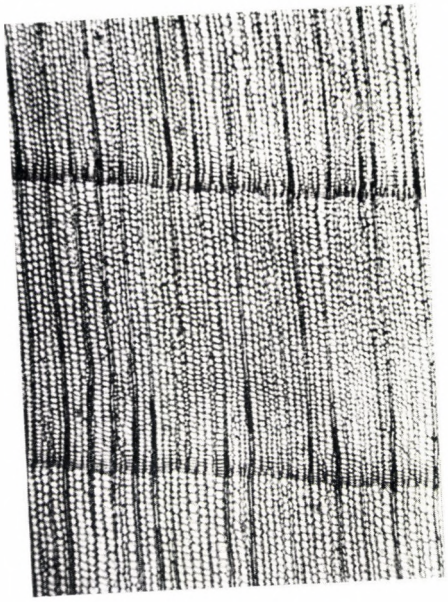
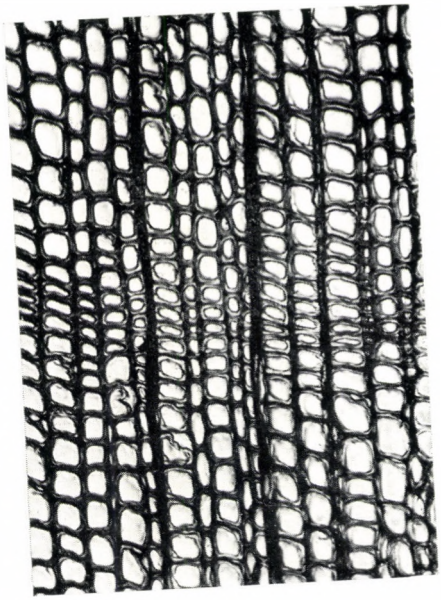


Fig. 20. *Microstrobus fizgeraldi* (F. Mueller) Gard and Johns



1. (×30)



2(×100)

3. (×300)

4. (×100)

XLI. *Phyllocladus hypophyllos* Hooker fil.

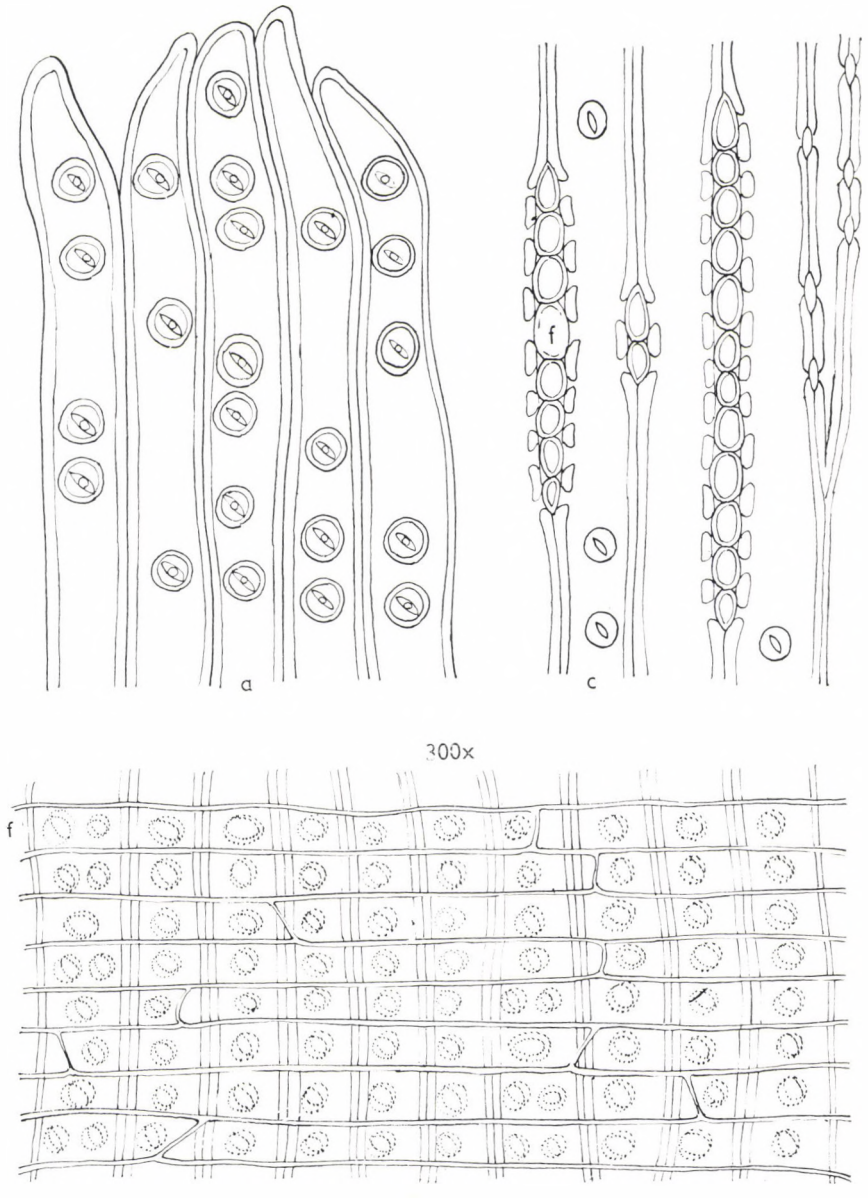
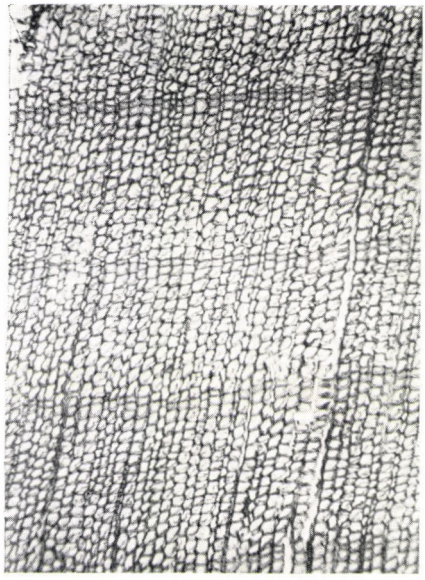
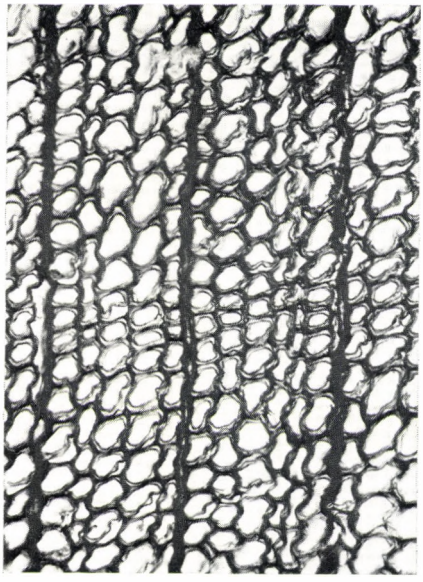


Fig. 21. *Phyllocladus hypophyllos* Hooker fil.



1. (×30)



2. (×100)

3. (×300)

4. (×100)

XLII. *Phyllocladus major* Pilger

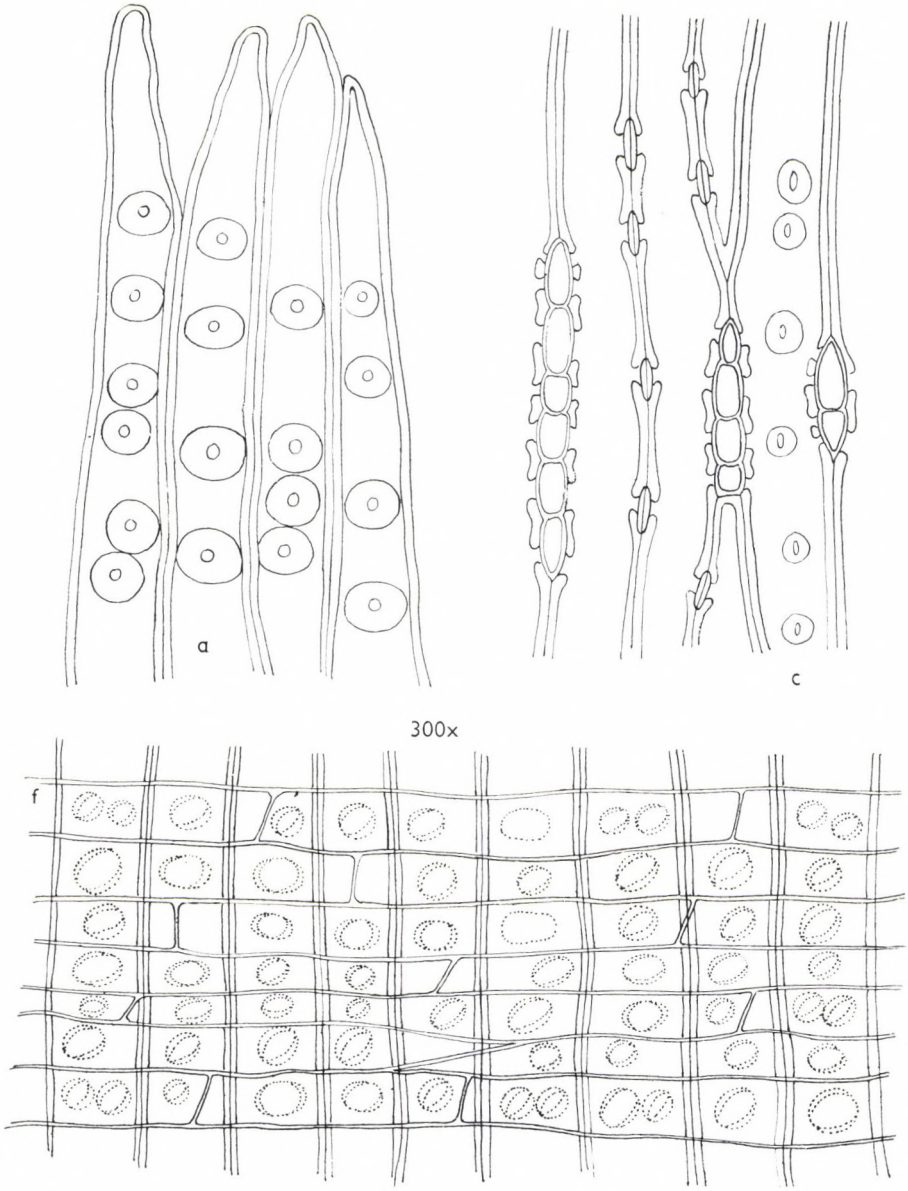
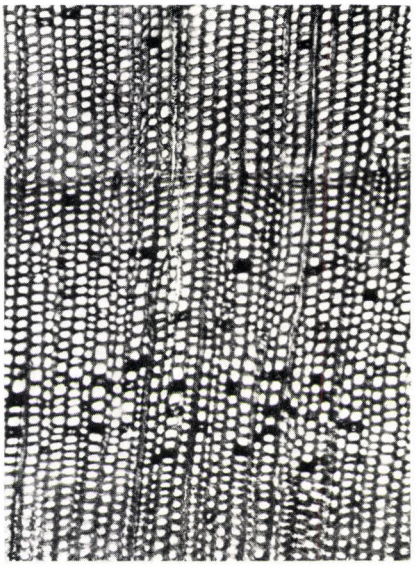
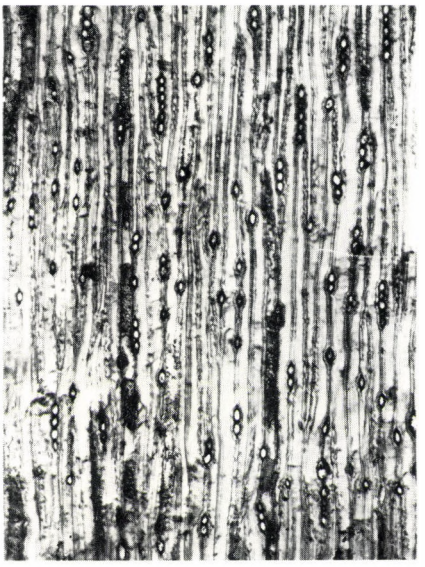


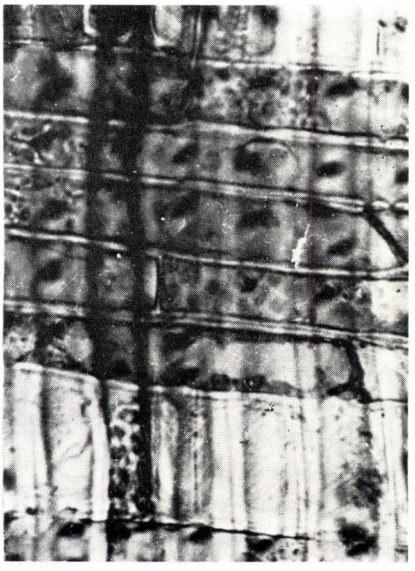
Fig. 22. *Phyllocladus major* Pilger



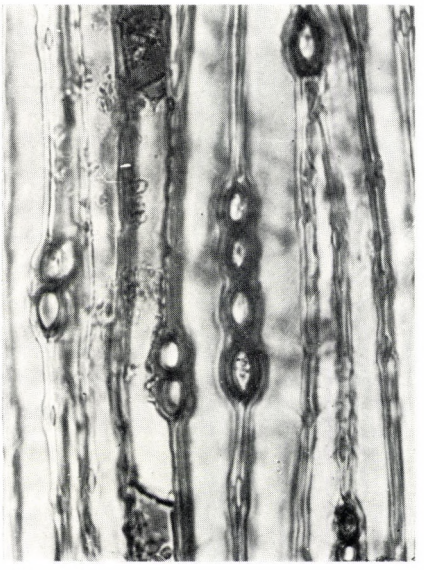
1.(x100)



2.(x100)



3.(x500)



4.(x300)

XLIII. *Podocarpus alpinus* R. Brown

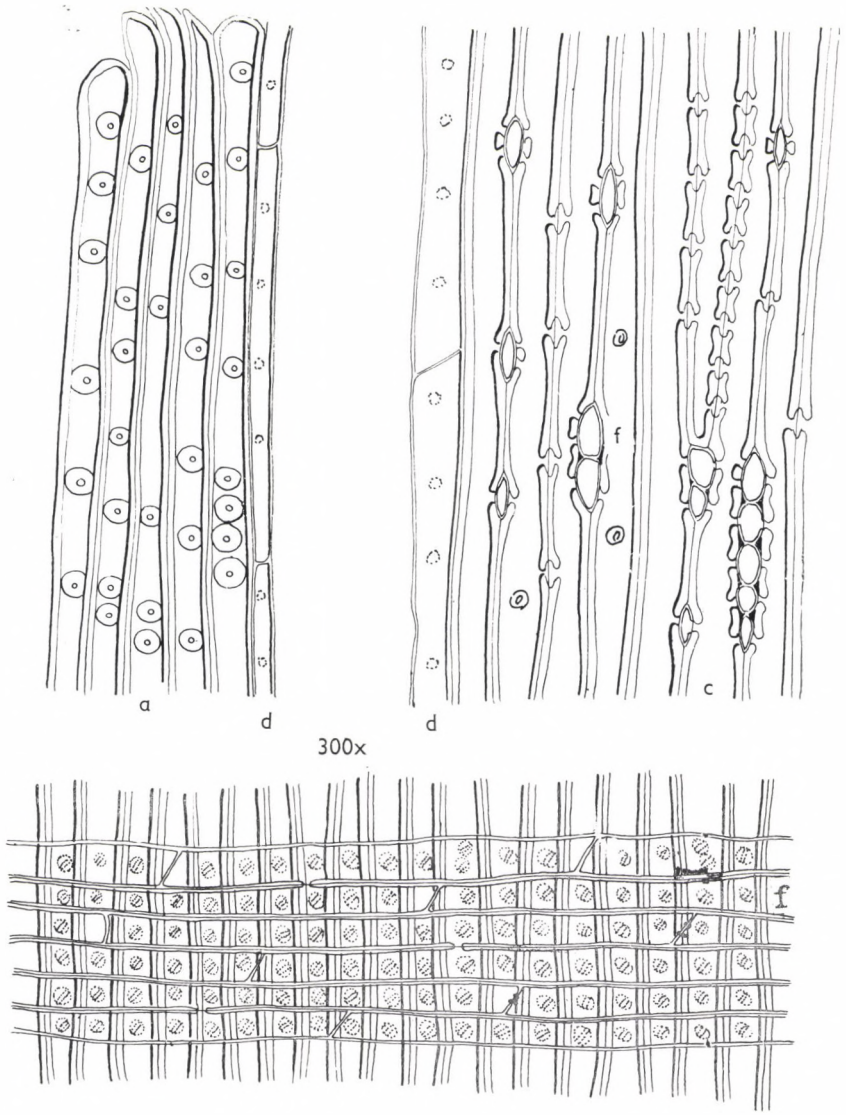
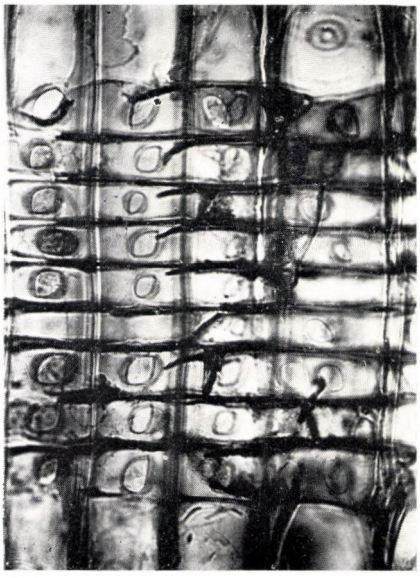


Fig. 23. *Podocarpus alpinus* R. Brown

1.(x 100)

2(x 100)



3.(x 200)

4.(x 300)

XLIV. *Podocarpus amarus* Blume

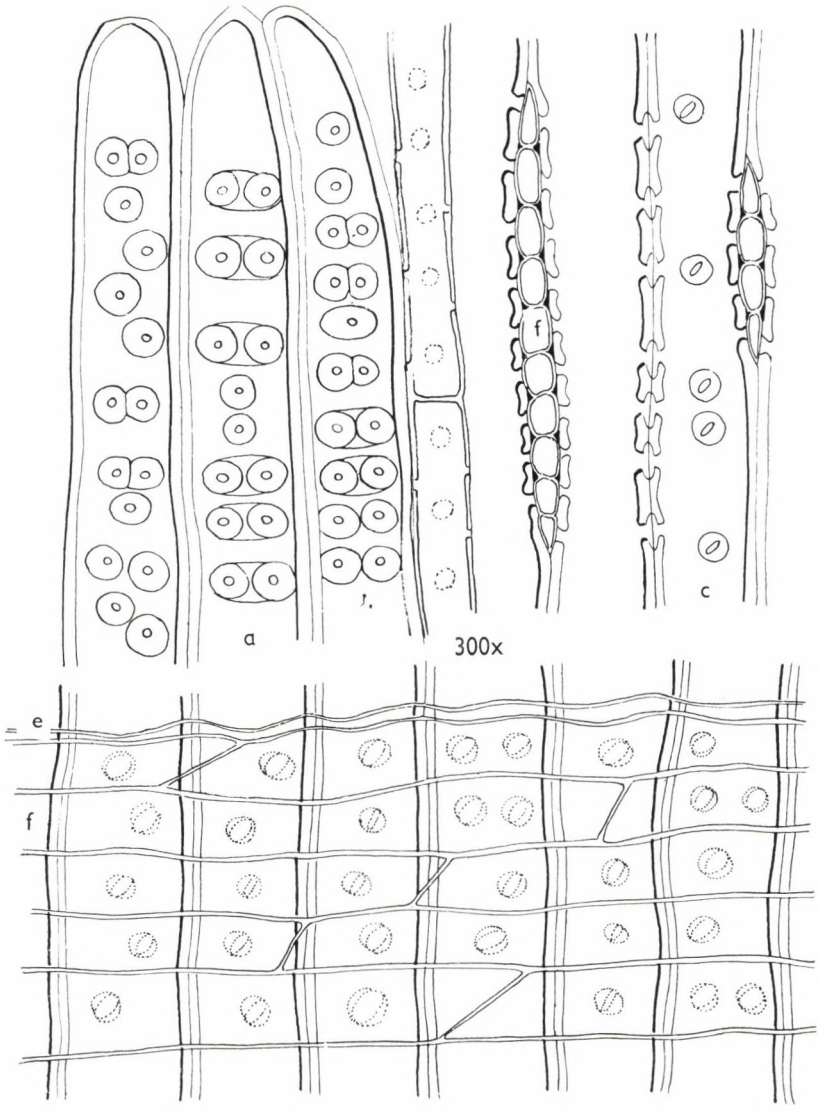
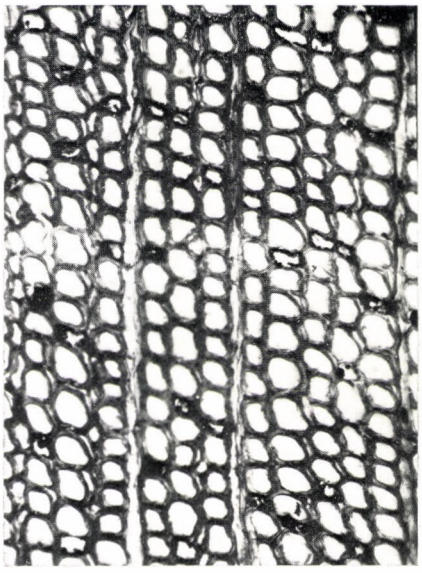
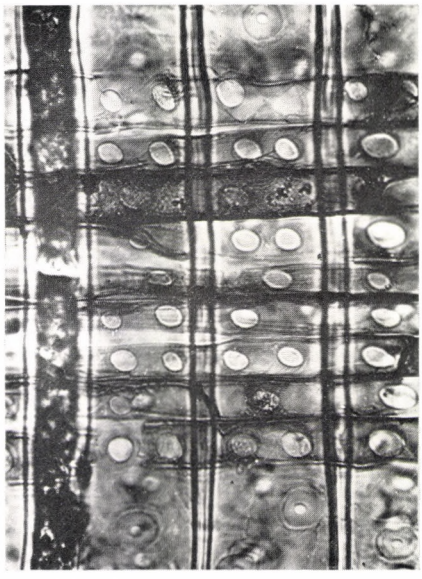


Fig. 24. *Podocarpus amarus* Blume



1. (x100)

2(x100)



3. (x300)

4. (x300)

XLV. *Podocarpus beccarii* Parlatore

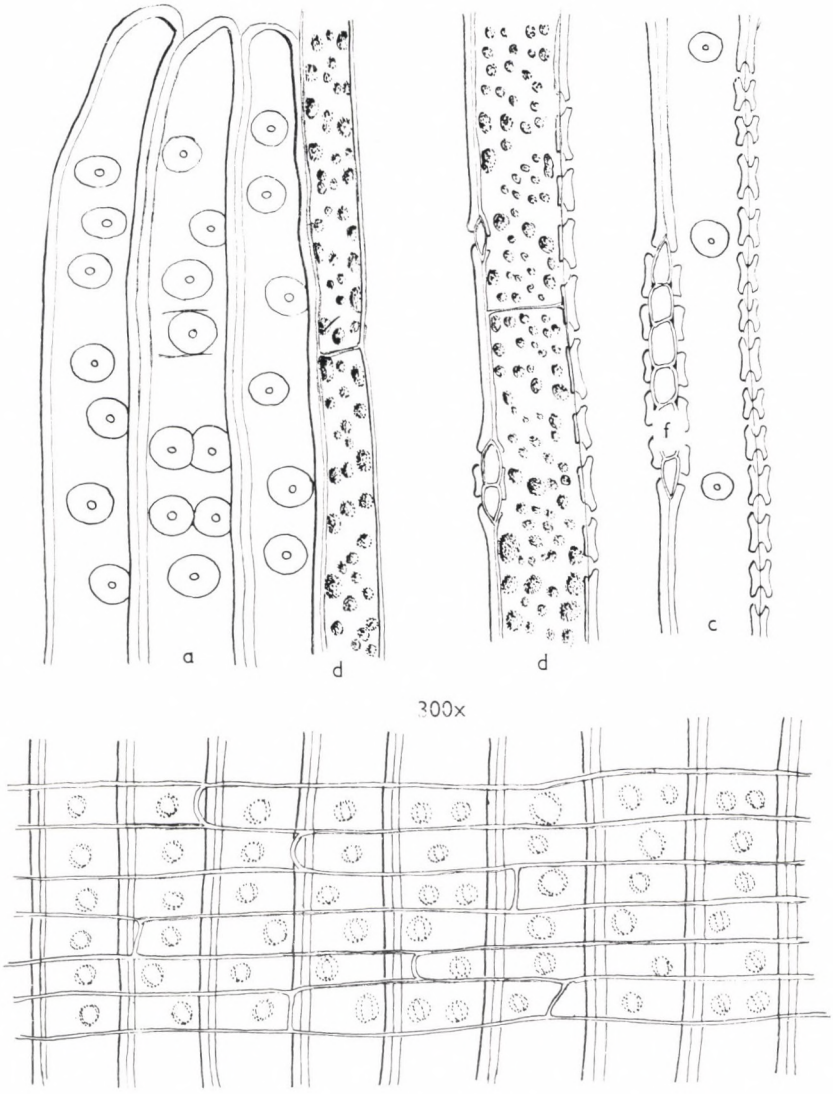
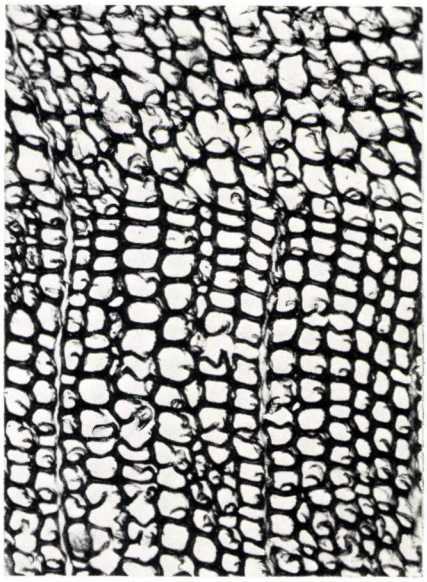


Fig. 25. *Podocarpus beccarii* Parlatore



1. (x100)

2.(x100)

3.(x300)

4.(x300)

XLVI. *Podocarpus comptonii* Buchholz

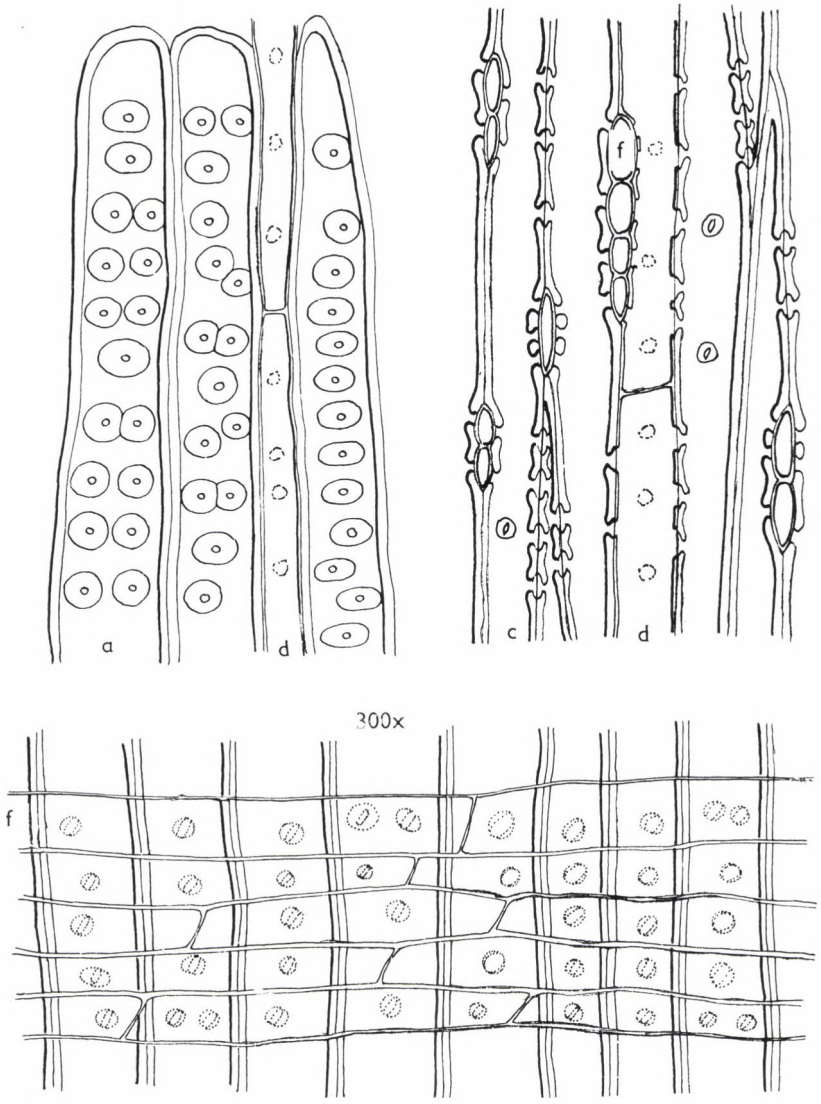
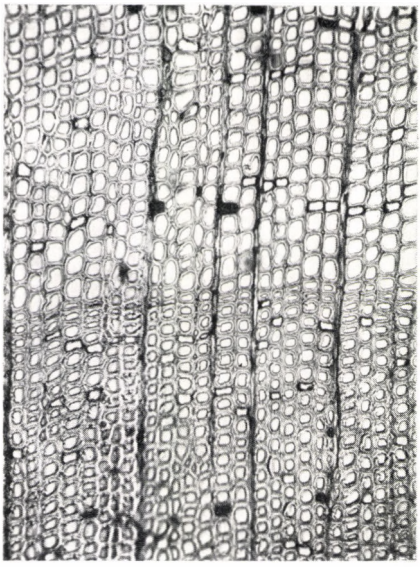
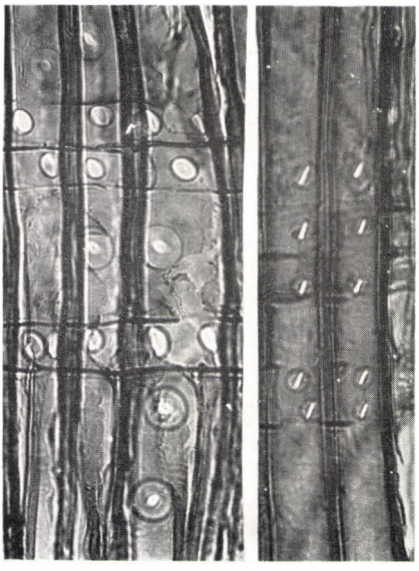


Fig. 26. *Podocarpus comptonii* Buchholz

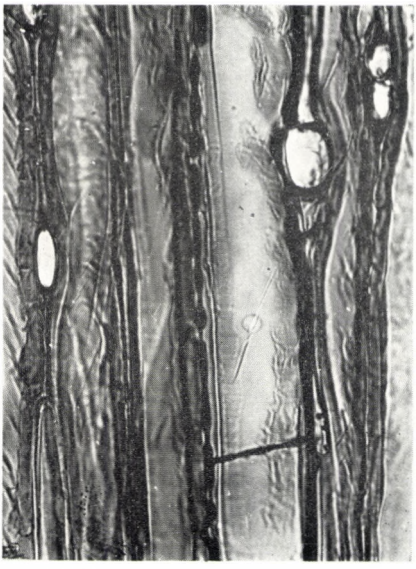


1. (×100)

2.(×100)



3.(×300)



4.(×400)

XLVII. *Podocarpus costalis* C. Presl.

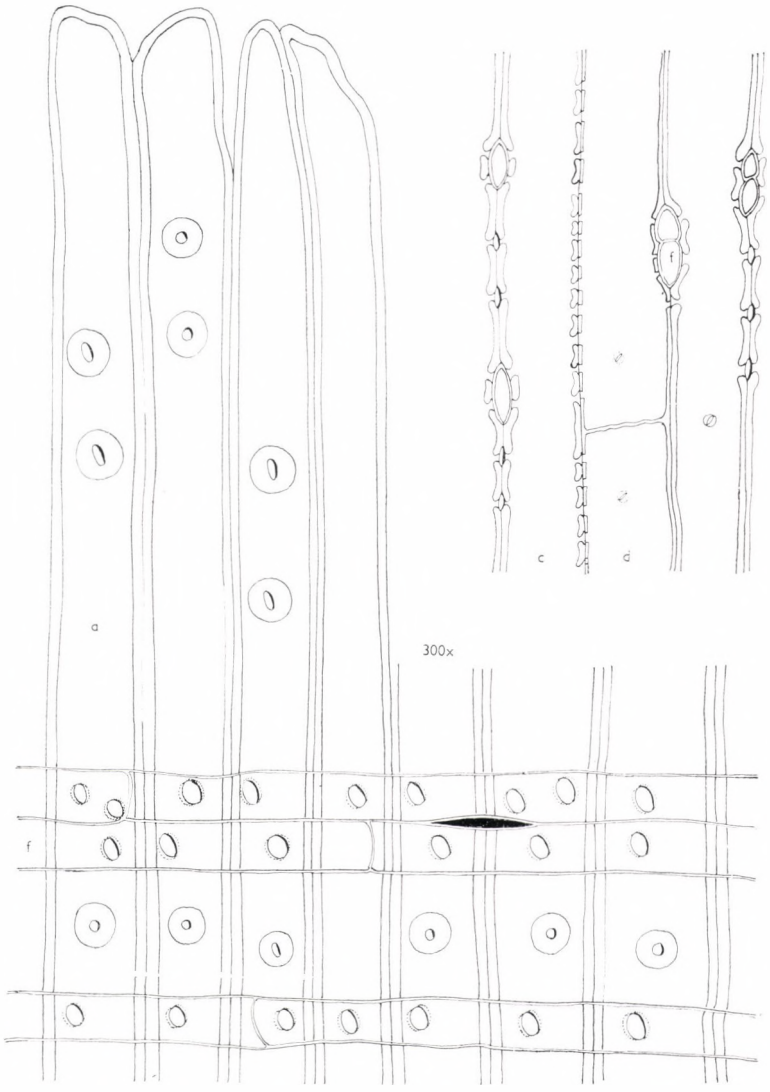
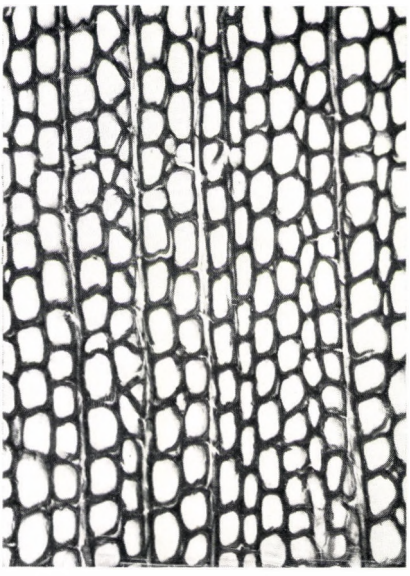


Fig. 27. *Podocarpus costalis* C. Presl.



1. (x 100)

2. (×100)

3. (x 300)

4. (x 300)

XLVIII. *Podocarpus decipiens* (Back) N. Gray

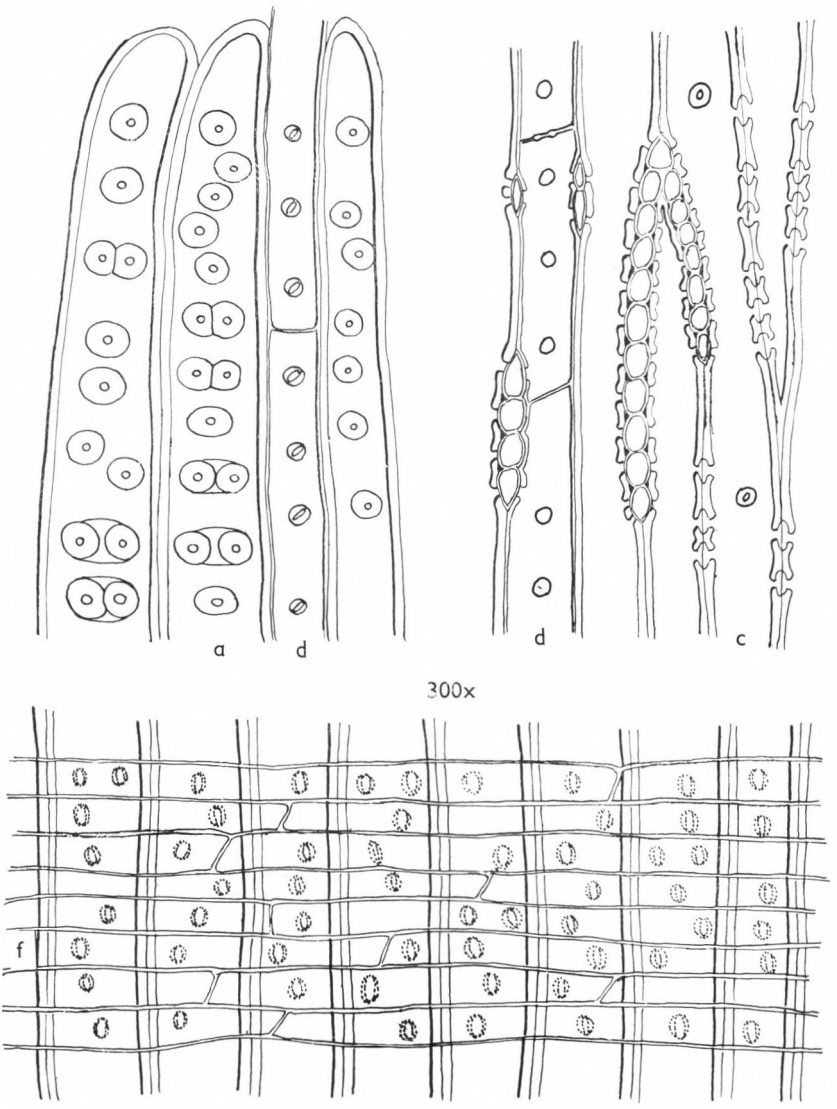
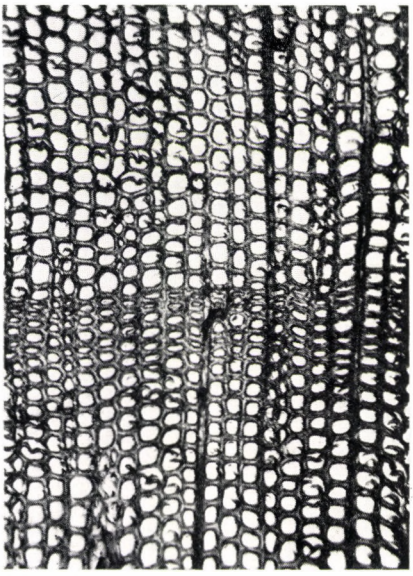
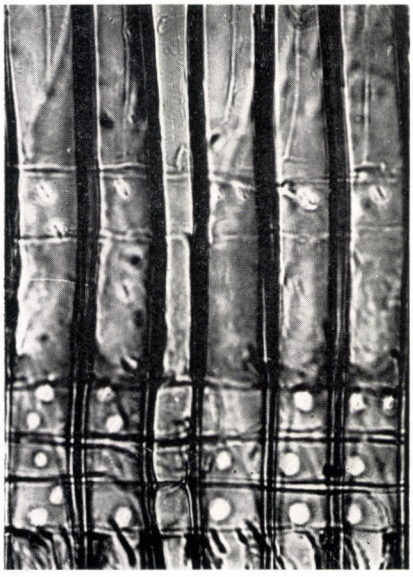


Fig. 28. *Podocarpus decipiens* (Back) N. Gray



1. (x 100)

2.(x100)



3.(x300)

4.(x 300)

XLIX. *Podocarpus dispermus* Buchholz

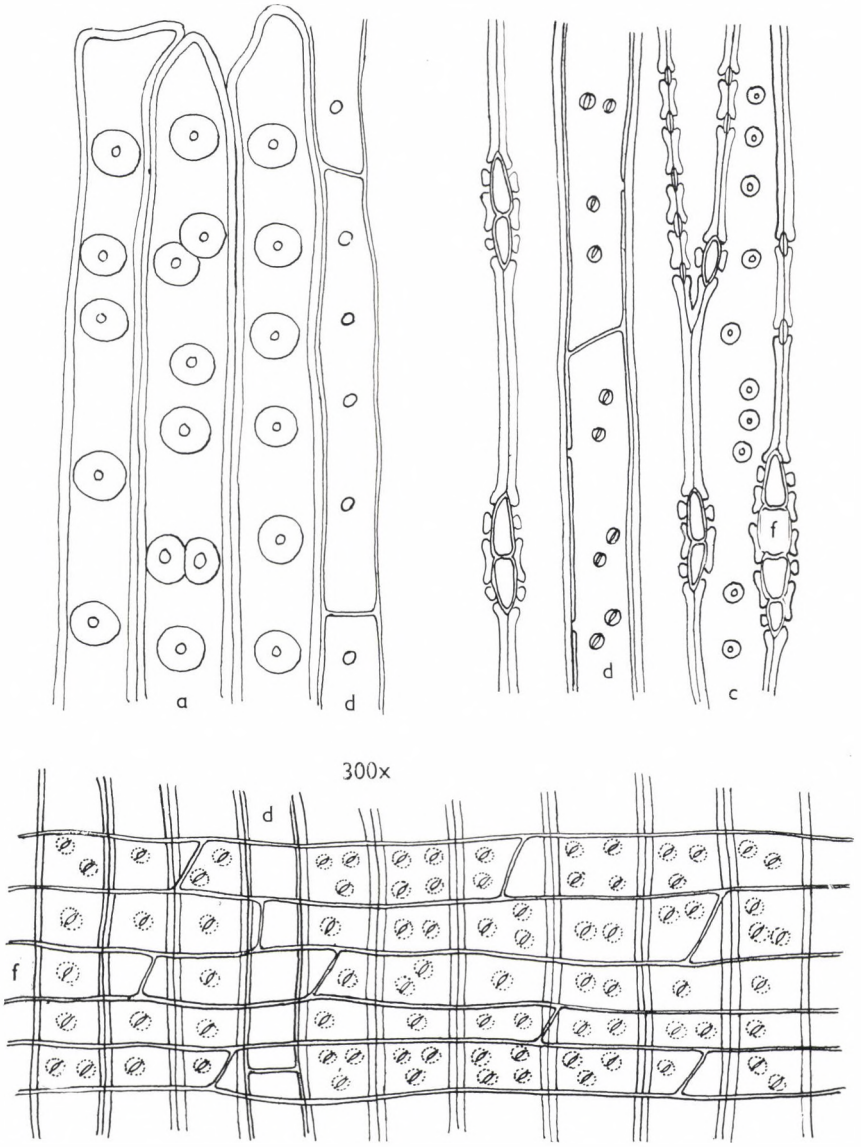
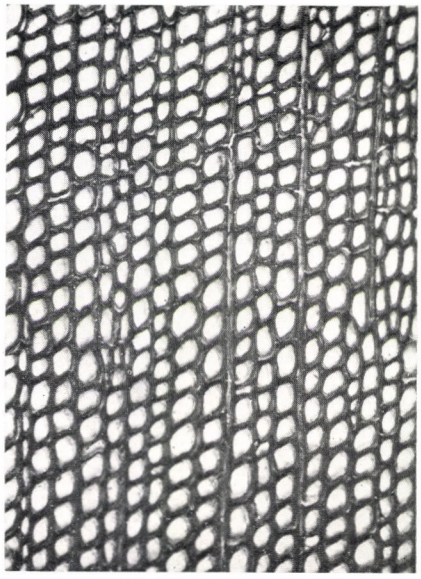
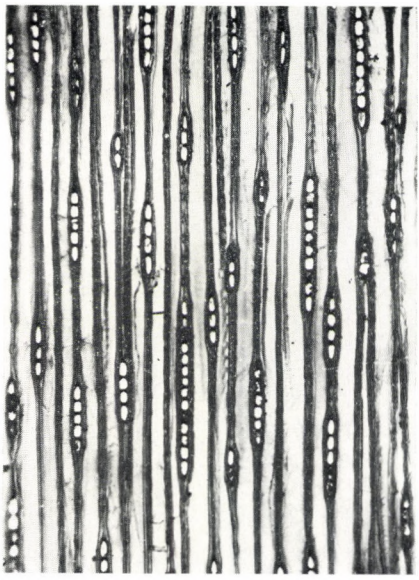


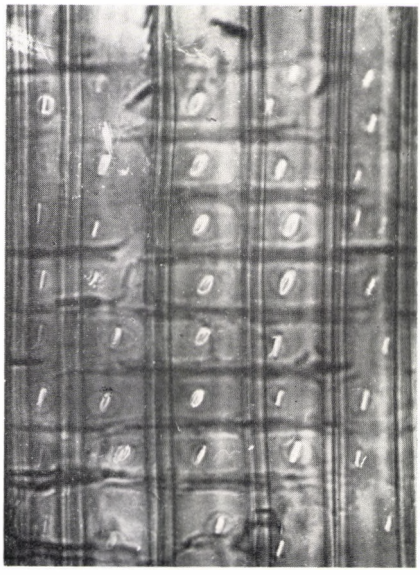
Fig. 29. *Podocarpus dispermus* Buchholz



1. (×100)



2.(×100)



3.(×300)

4. (×300)

L. *Podocarpus distichus* Buchholz

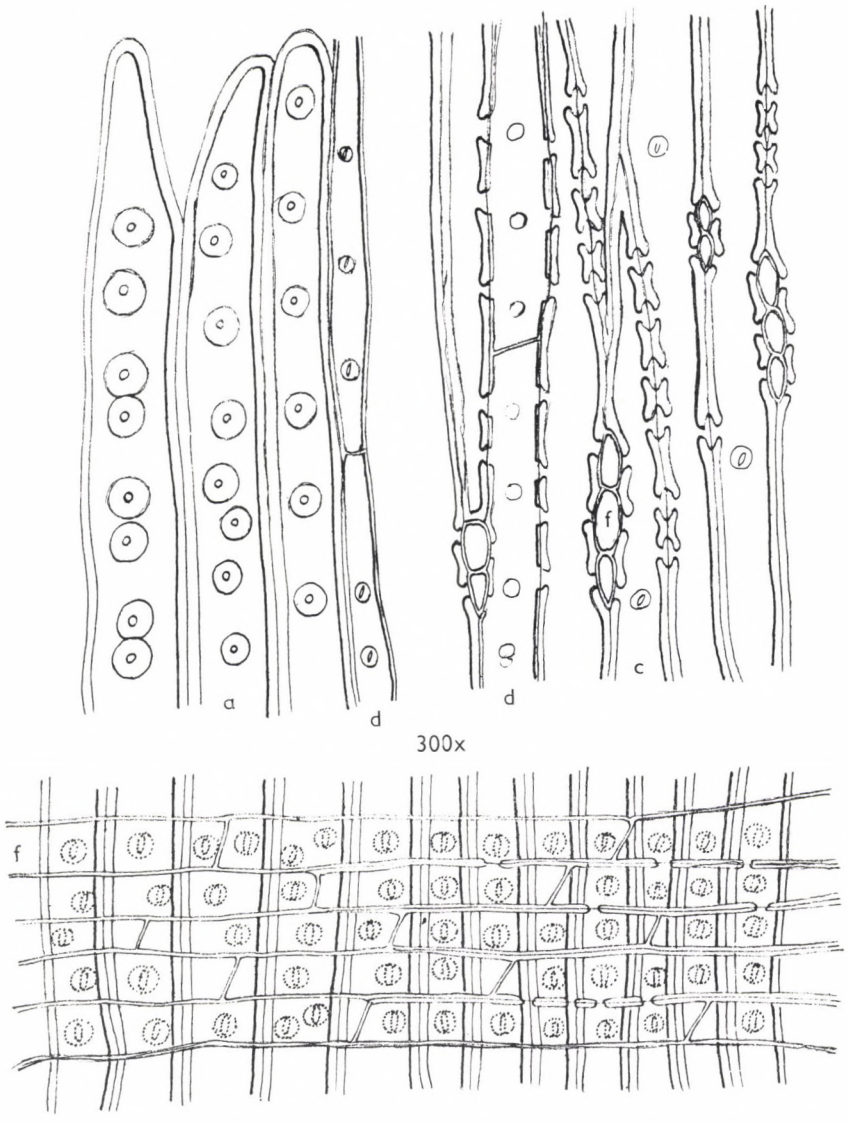
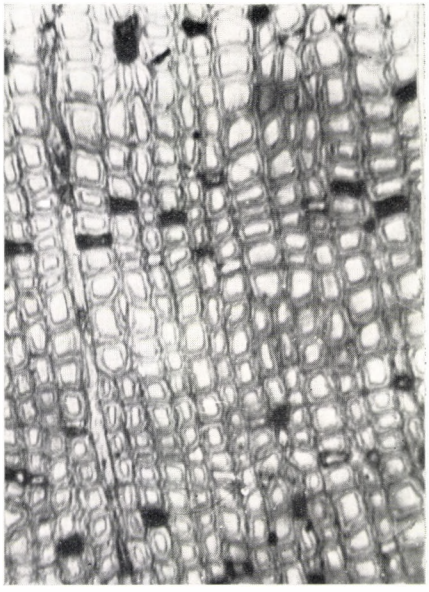
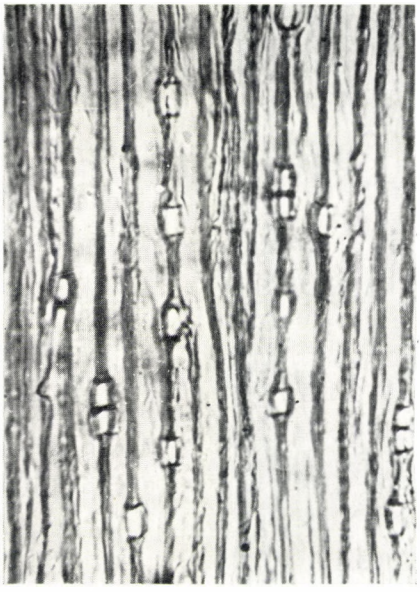


Fig. 30. *Podocarpus distichus* Buchholz

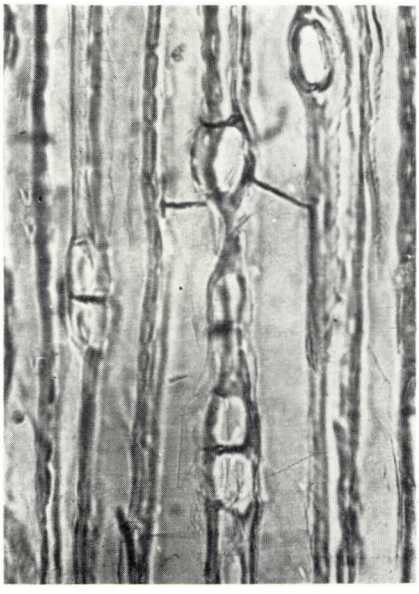


1. (×100)



2.(×100)

3.(×300)



4.(×300)

LI. *Podocarpus droynianus* F. Mueller

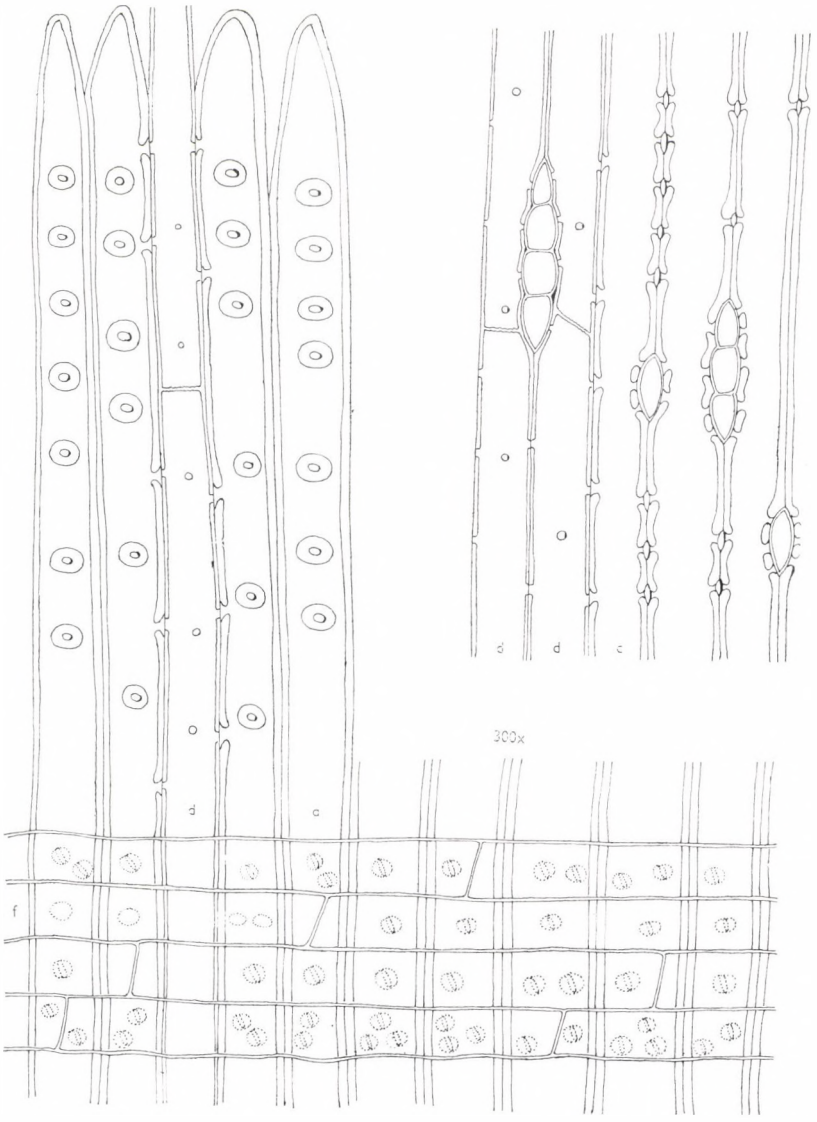
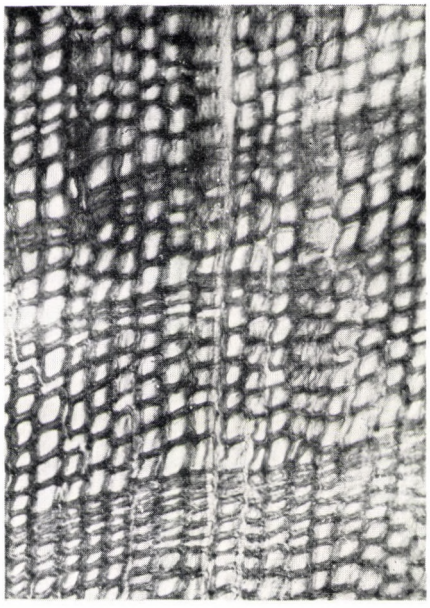


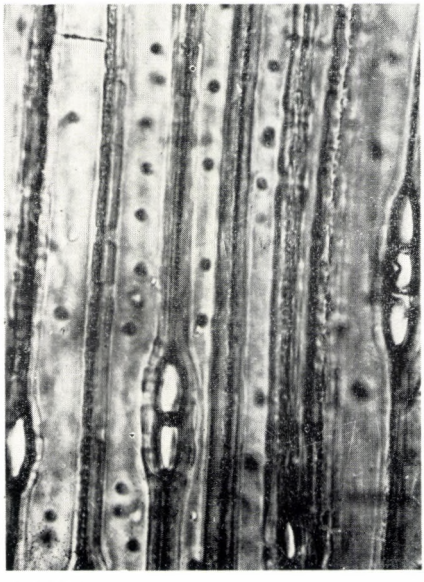
Fig. 31. *Podocarpus droynianus* F. Mueller



1. (×100)

2. (×100)

3. (×300)



4. (×300)

LII. *Podocarpus gnidioides* Carr.

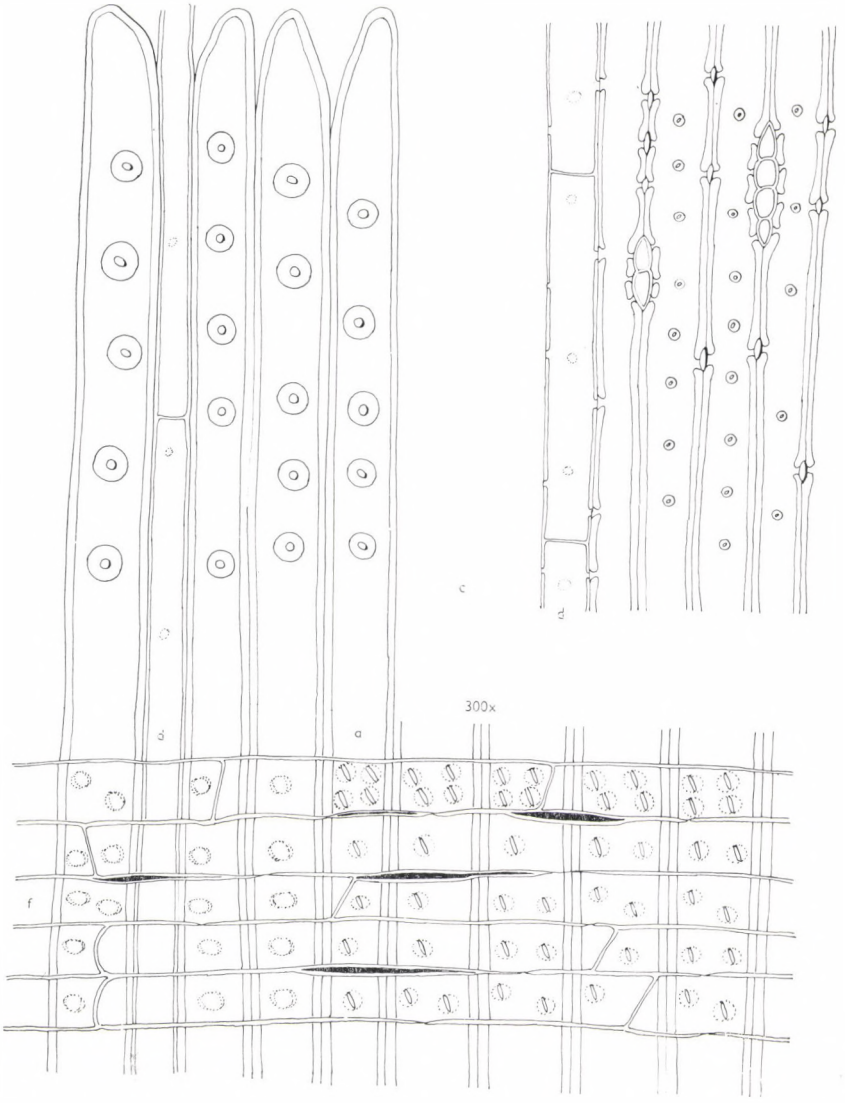
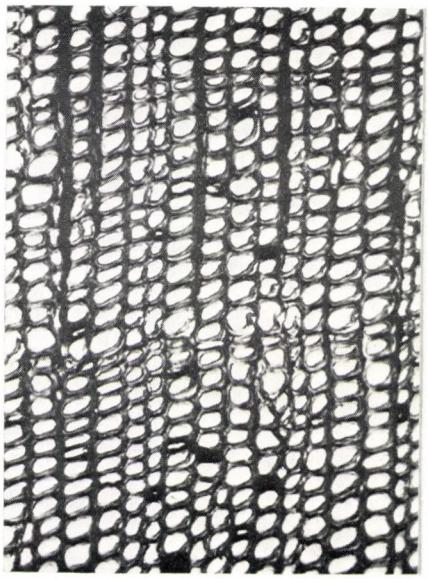
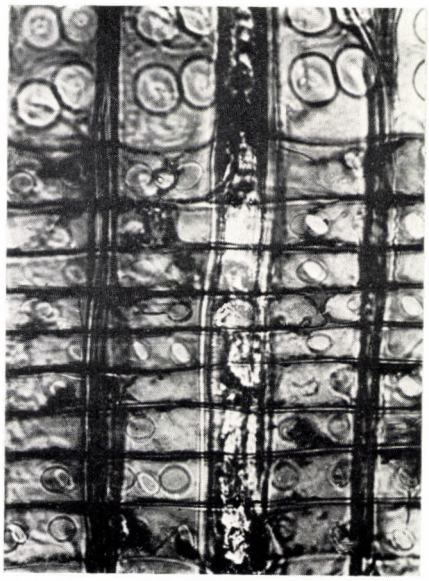


Fig. 32. *Podocarpus gnidioides* Carr.

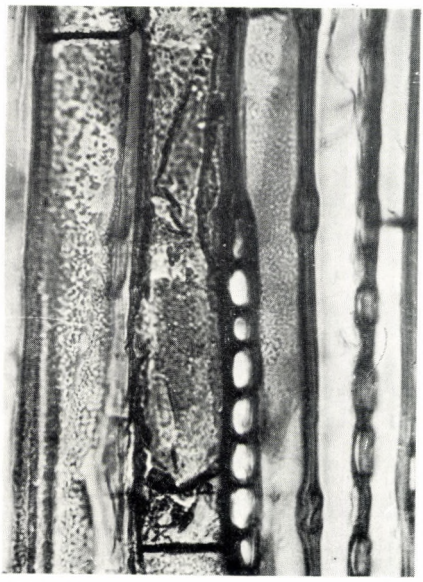


1. (x 100)

2. (x 100)



3. (x 300)



4. (x 300)

LIII. *Podocarpus guatemalensis* Standl.

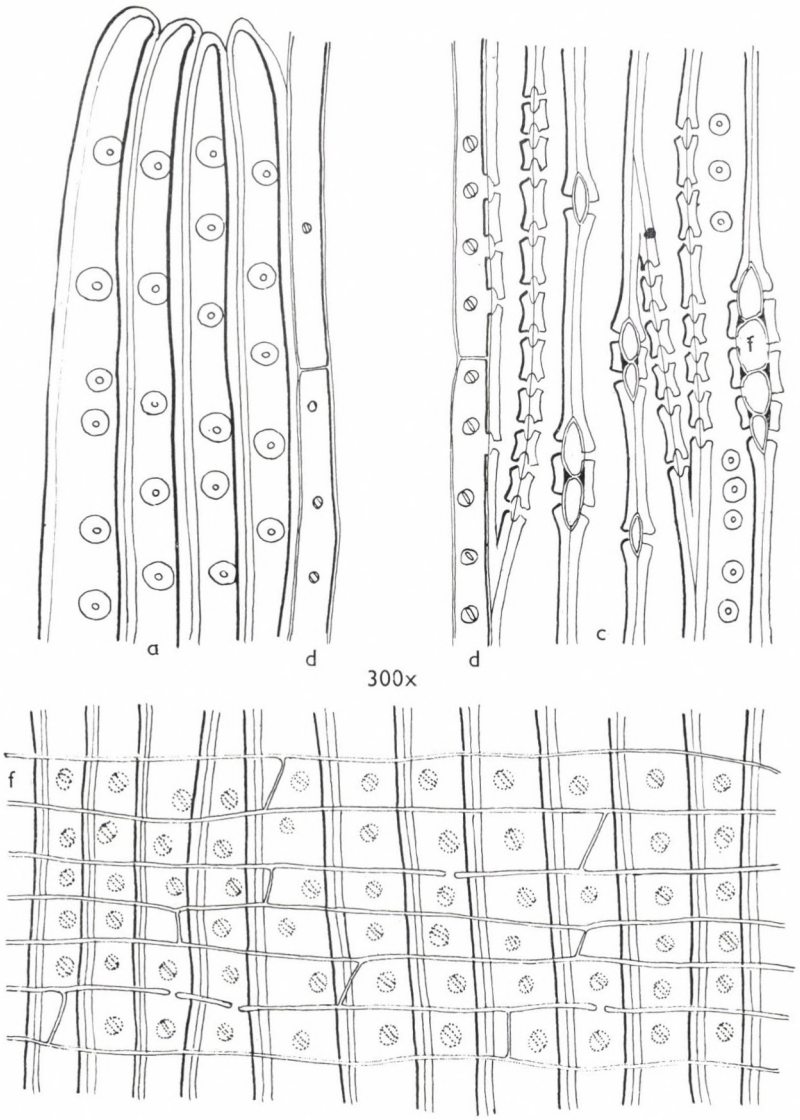
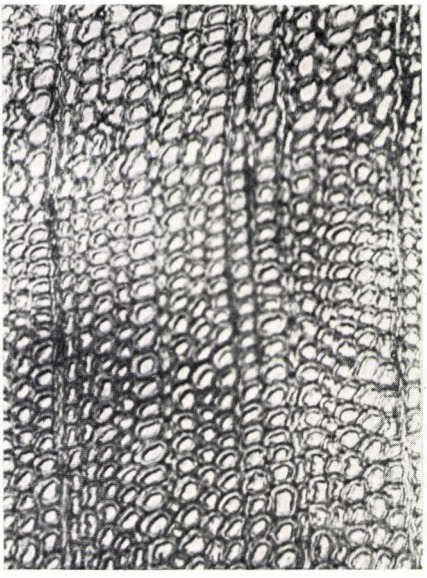
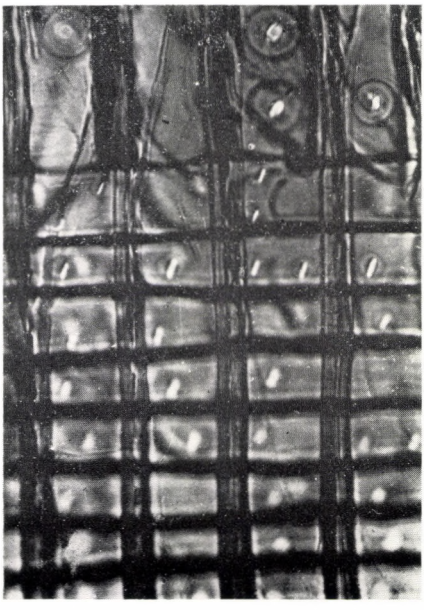


Fig. 33. *Podocarpus guatemalensis* Standl.



1. (×100)

2. (×100)



3. (×400)

4. (×400)

LIV. *Podocarpus ladei* Bailey

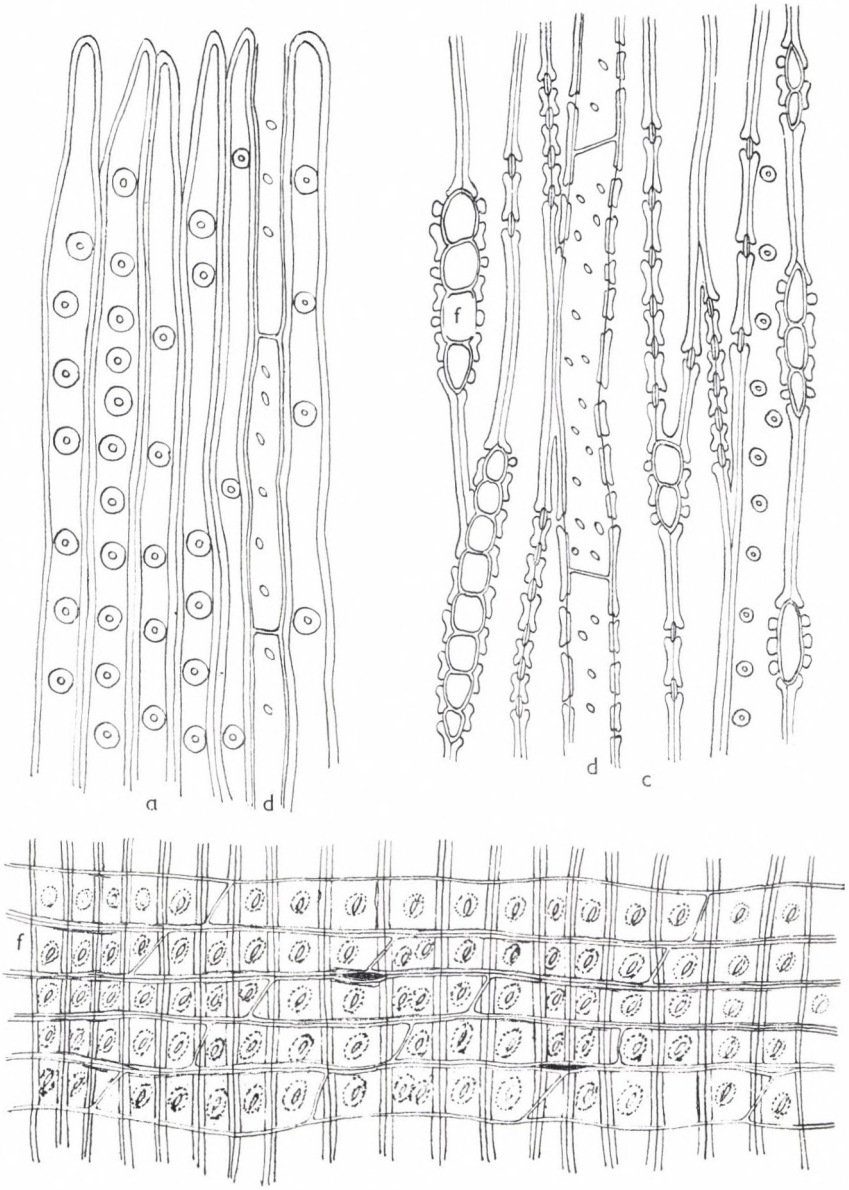
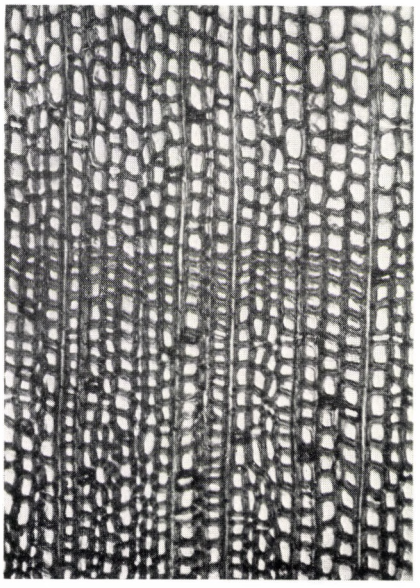
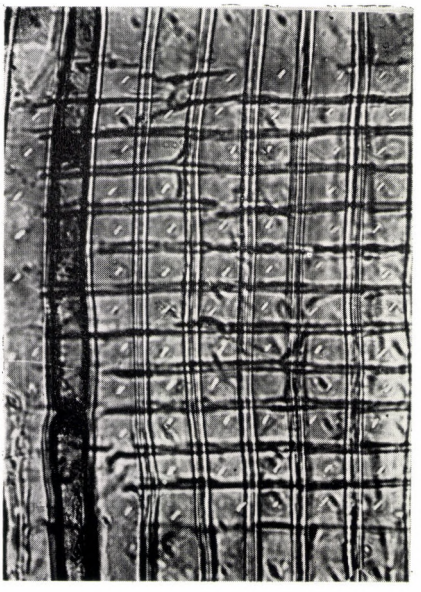


Fig. 34. *Podocarpus ladei* Bailey



1.(×100)

2.(×100)



3.(×300)

4.(×300)

LV. *Podocarpus lambertii* Klotzsch

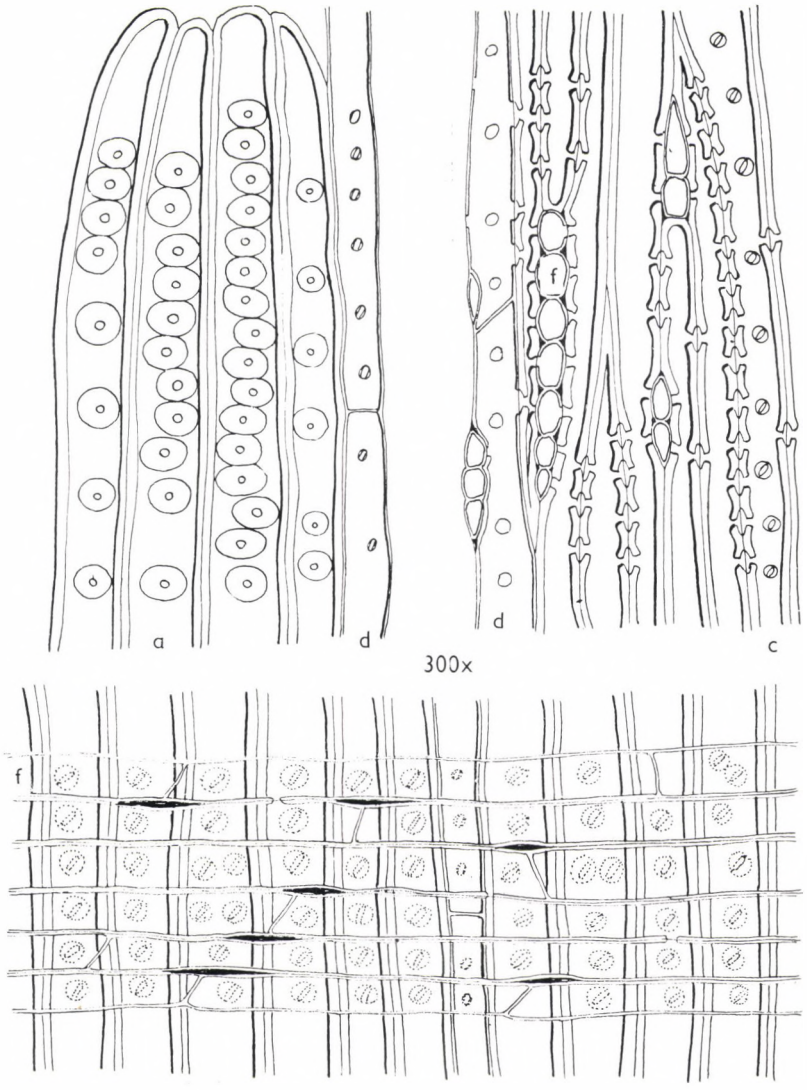
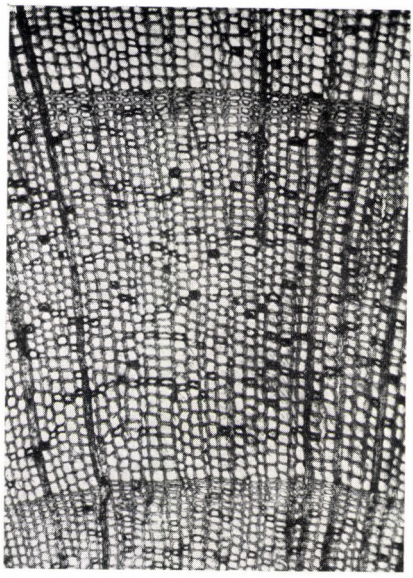
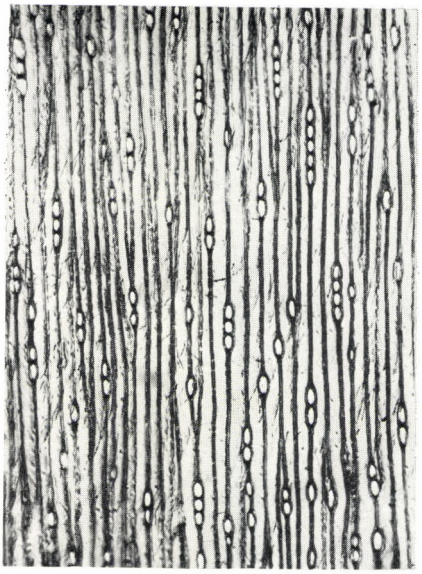


Fig. 35. *Podocarpus lambertii* Klotzsch

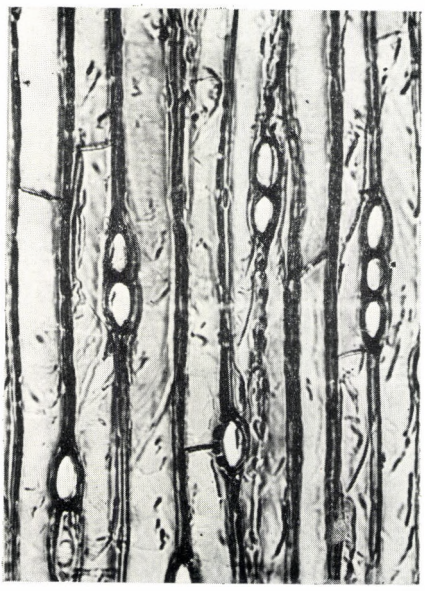


1. (×100)



2. (×100)

3. (×300)



4. (×300)

LVI. *Podocarpus macrophyllus* var. *maki* Siebold

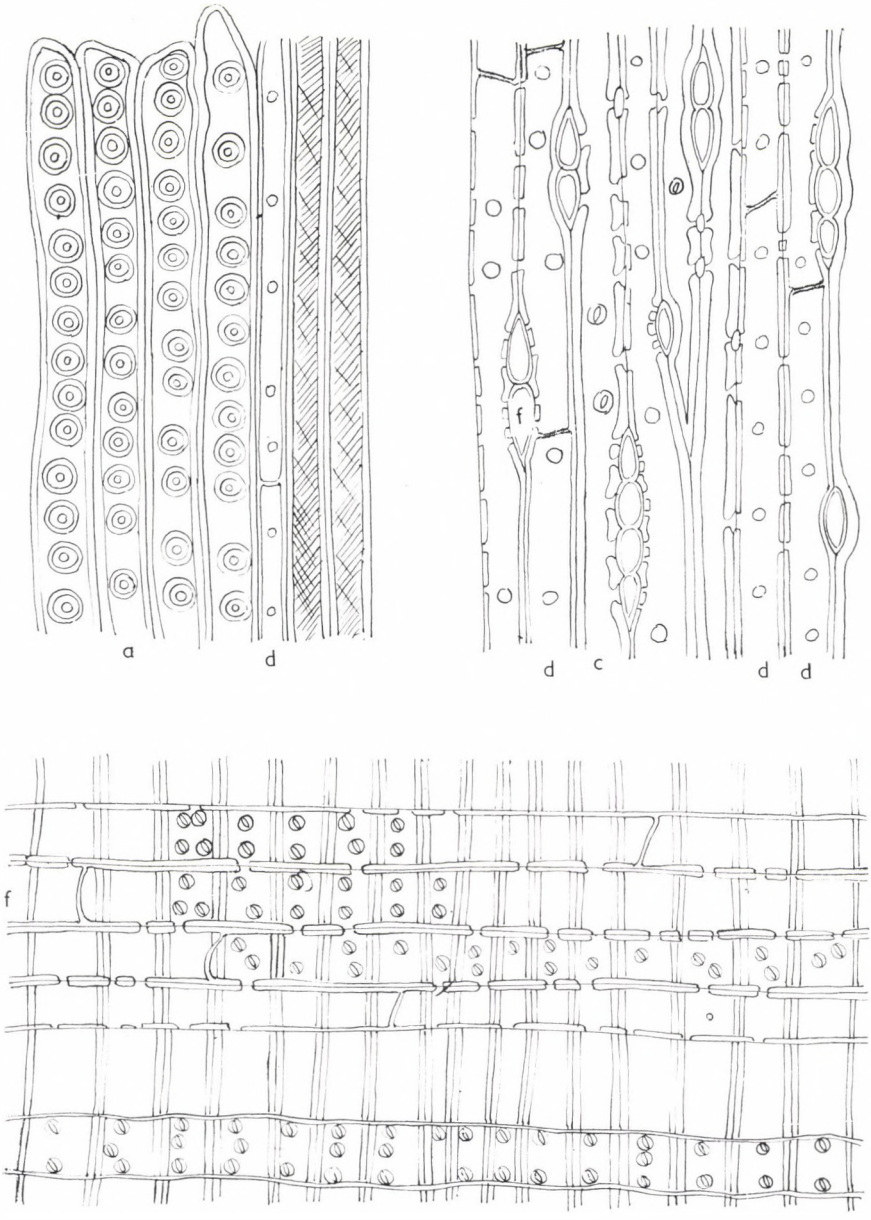
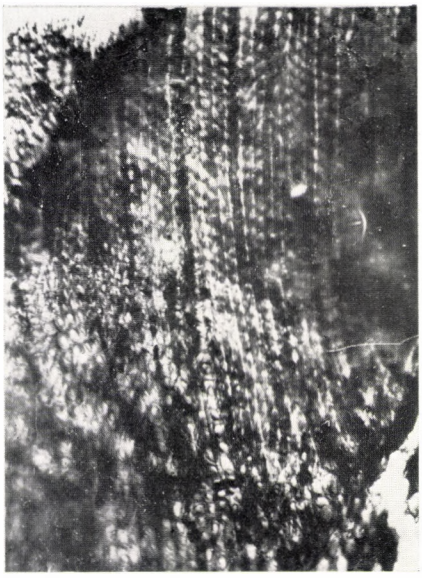
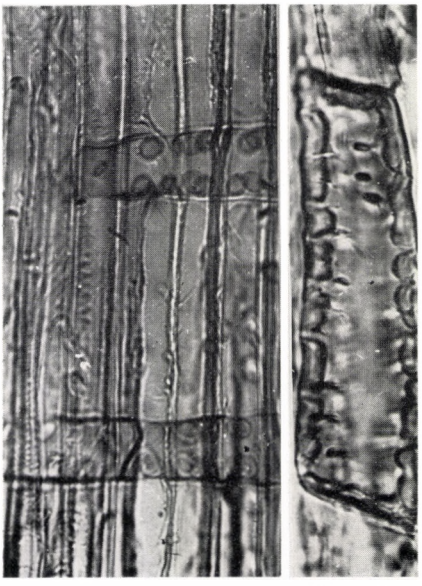


Fig. 36. *Podocarpus macrophyllus* var. *maki* Siebold



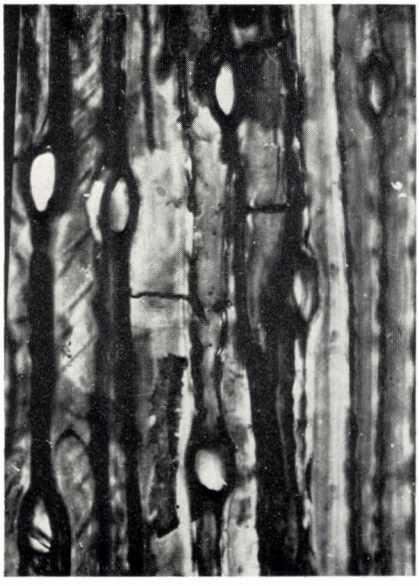
1. (x 50)

2.(x100)



3a(x 300)

b.(x 600)



4.(x 300)

LVII. *Podocarpus matudai* Lundell

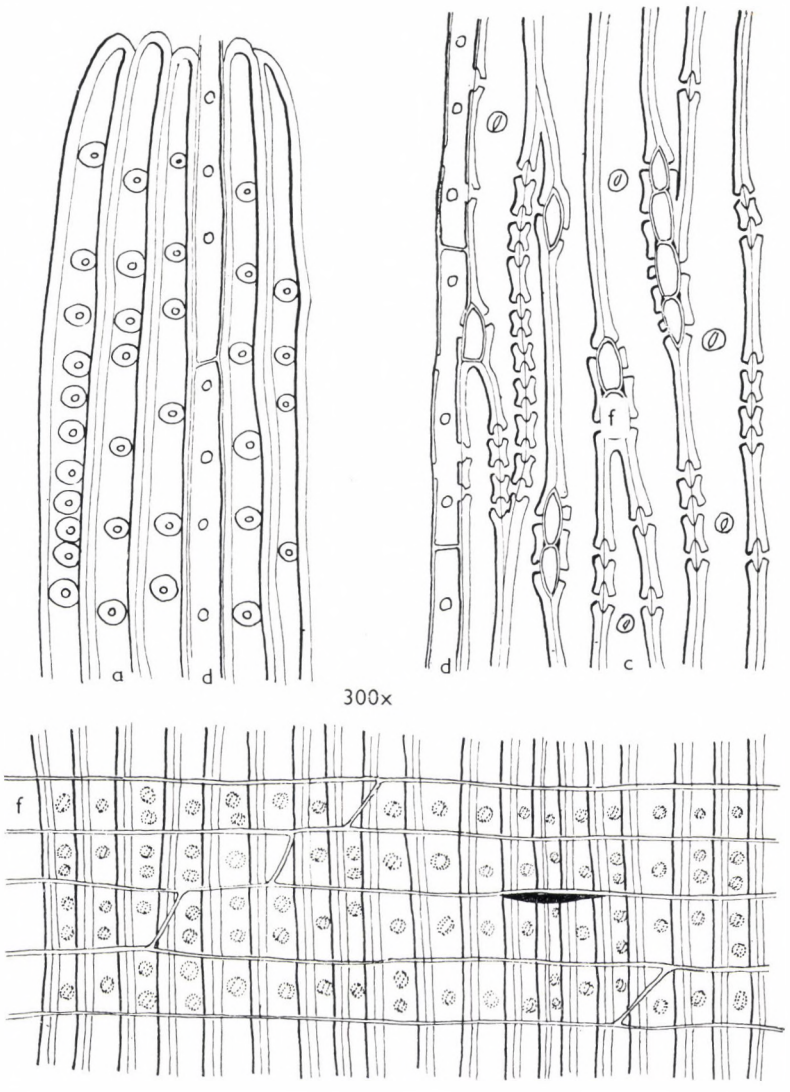
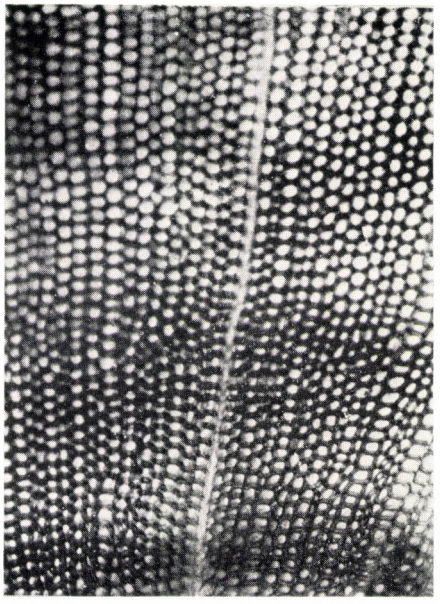
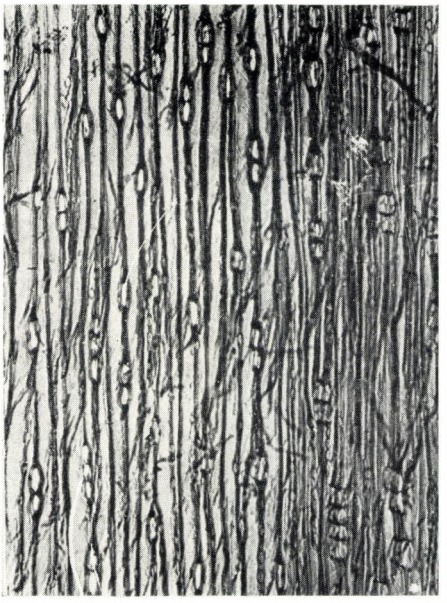


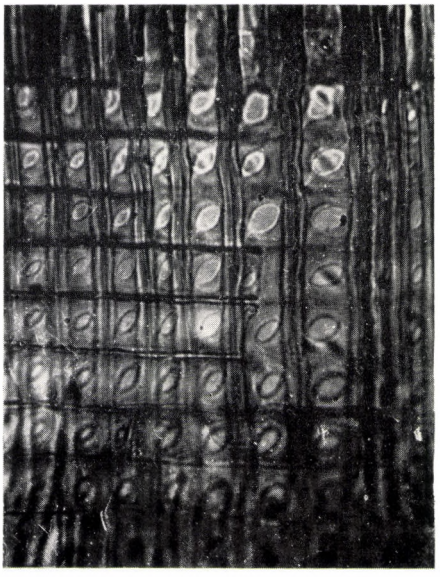
Fig. 37. *Podocarpus matudai* Lundell



1.(×100)



2.(×100)



3.(×300)

4.(×300)

LVIII. *Podocarpus montanus* var. *densifolius* Buchholz and Gray

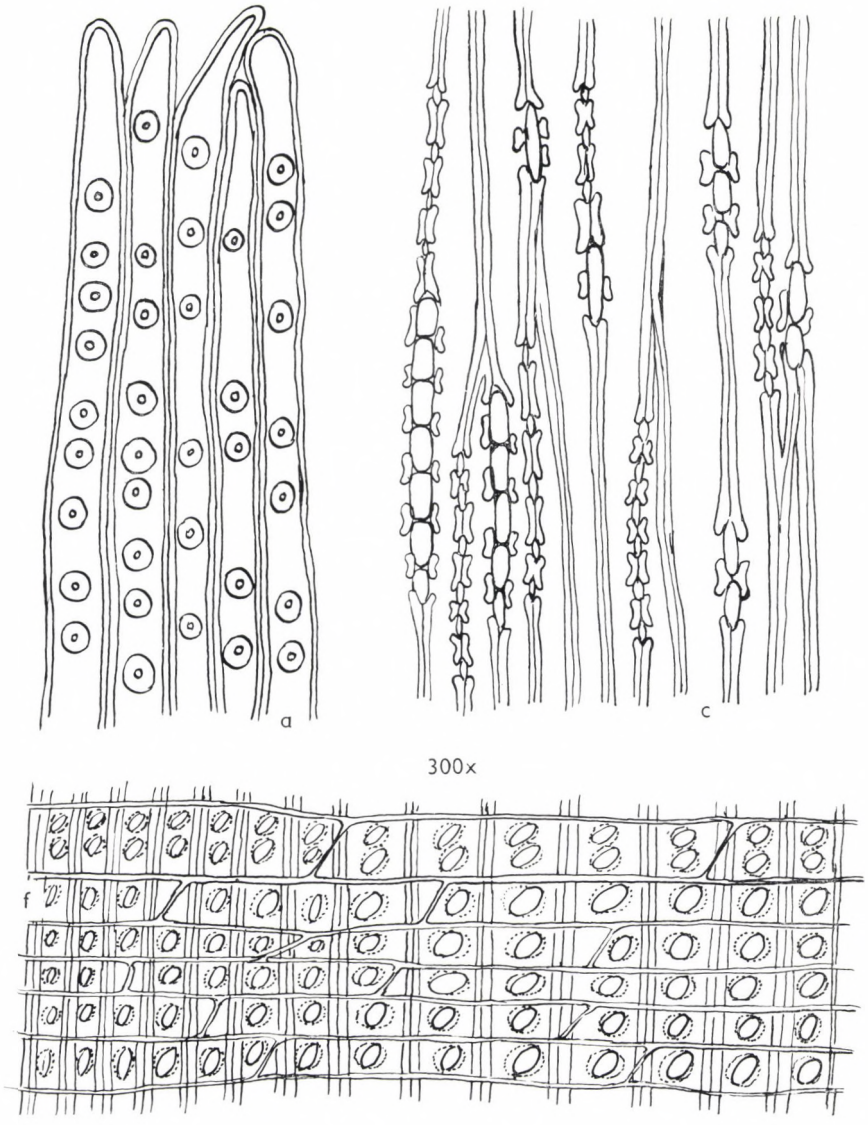
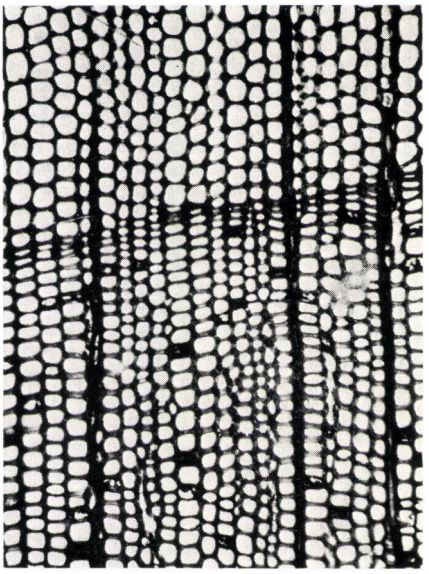


Fig. 38. *Podocarpus montanus* var. *densifolius* Buchholz and Gray



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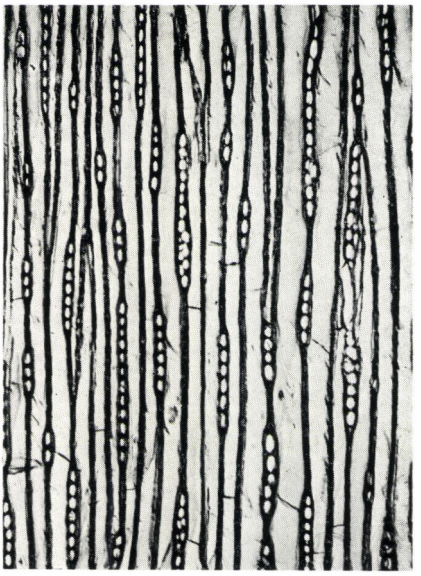

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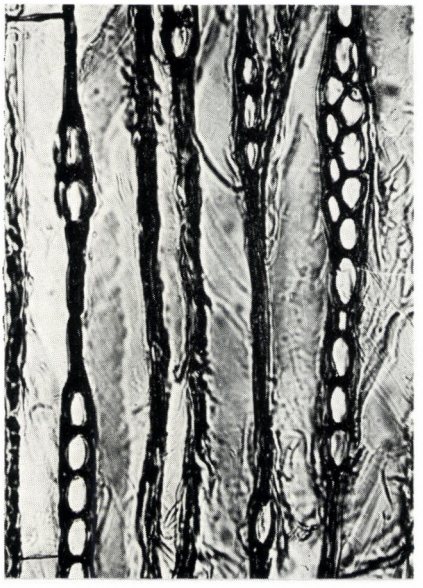
3. (×250)



4. (×300)

LIX. *Podocarpus nagi* Makino

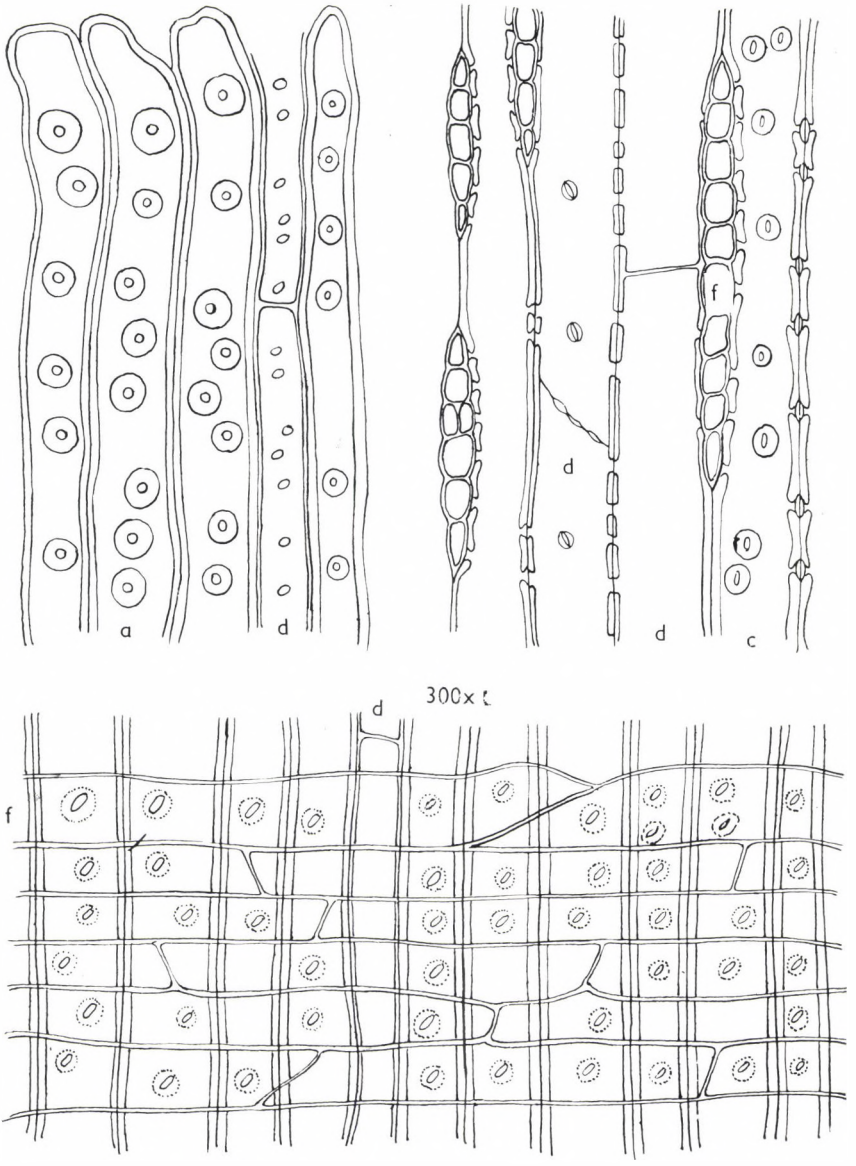
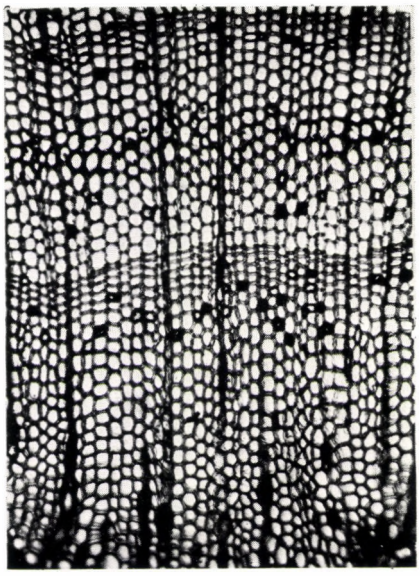


Fig. 39. *Podocarpus nagi* Makino



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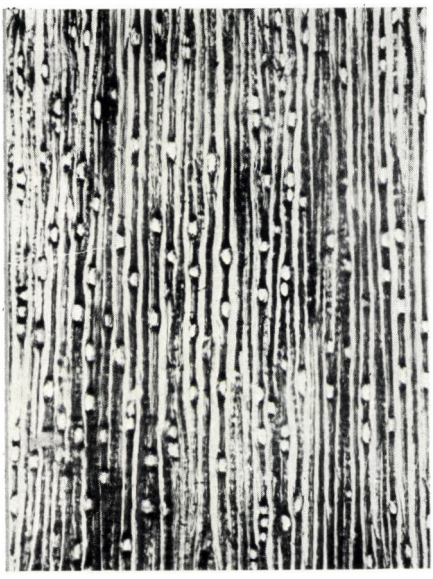

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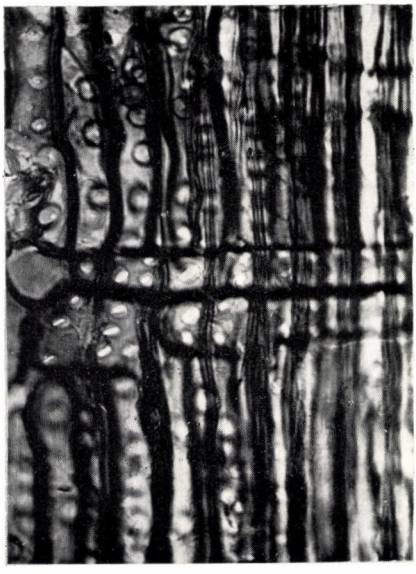

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4.(x300)

LX. *Podocarpus nakaii* Hayata

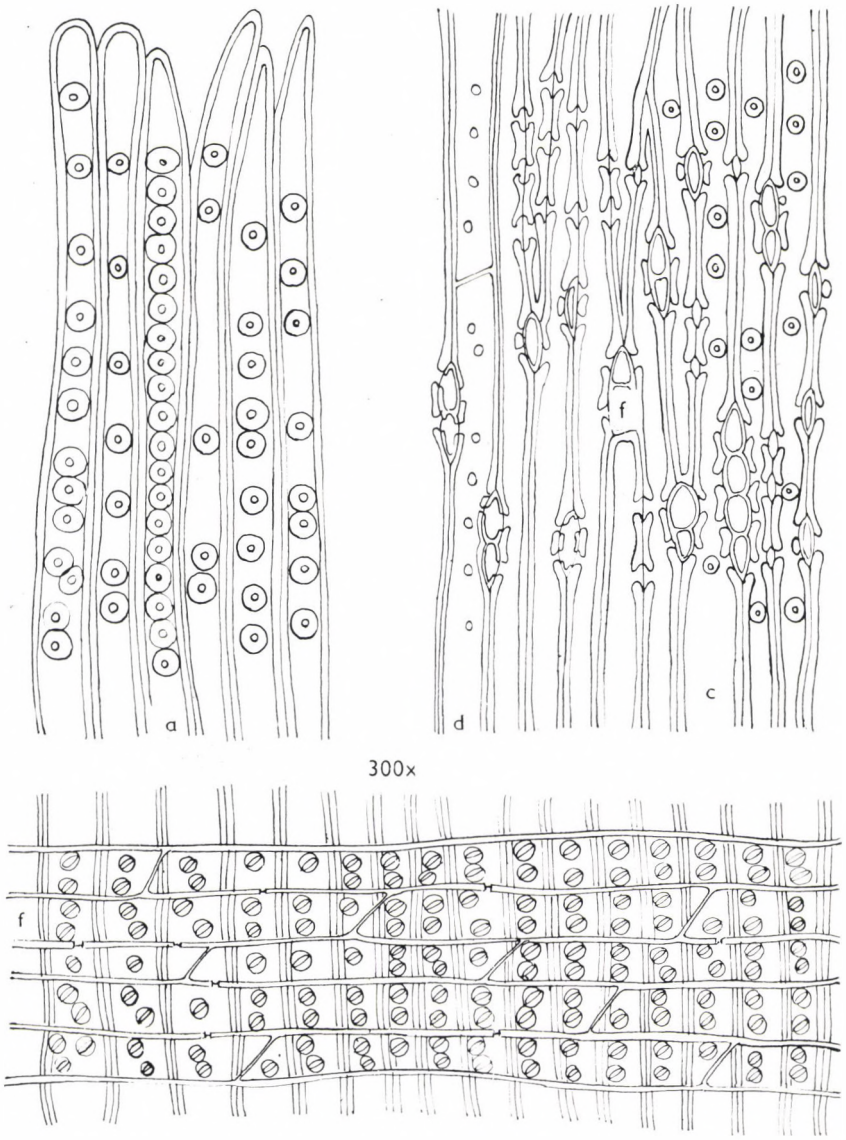
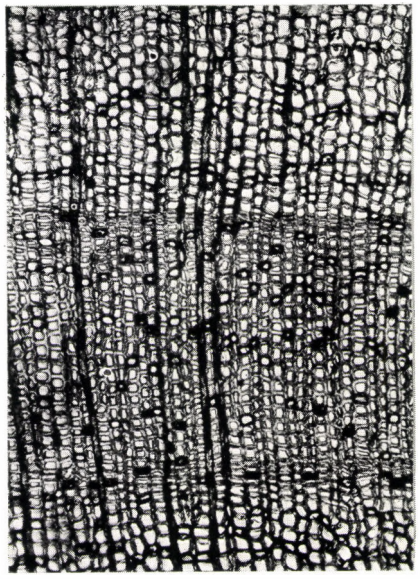


Fig. 40. *Podocarpus nakaii* Hayata



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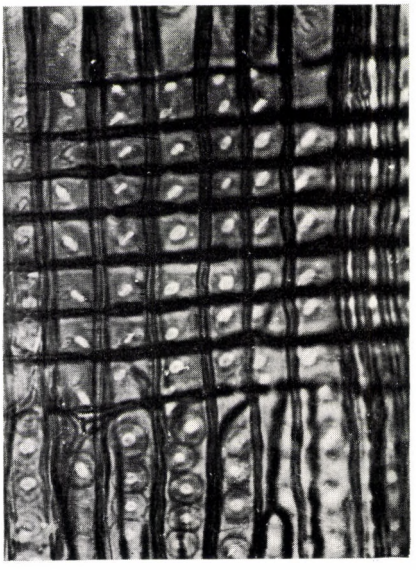
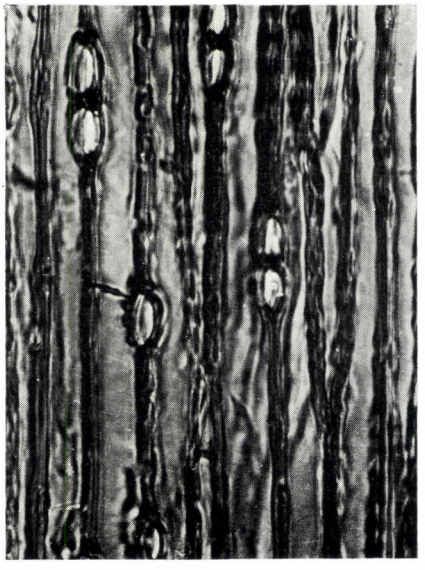
2.(×100)



3.(×300)



4.(×300)

LXI. *Podocarpus nivalis* Hooker fil.

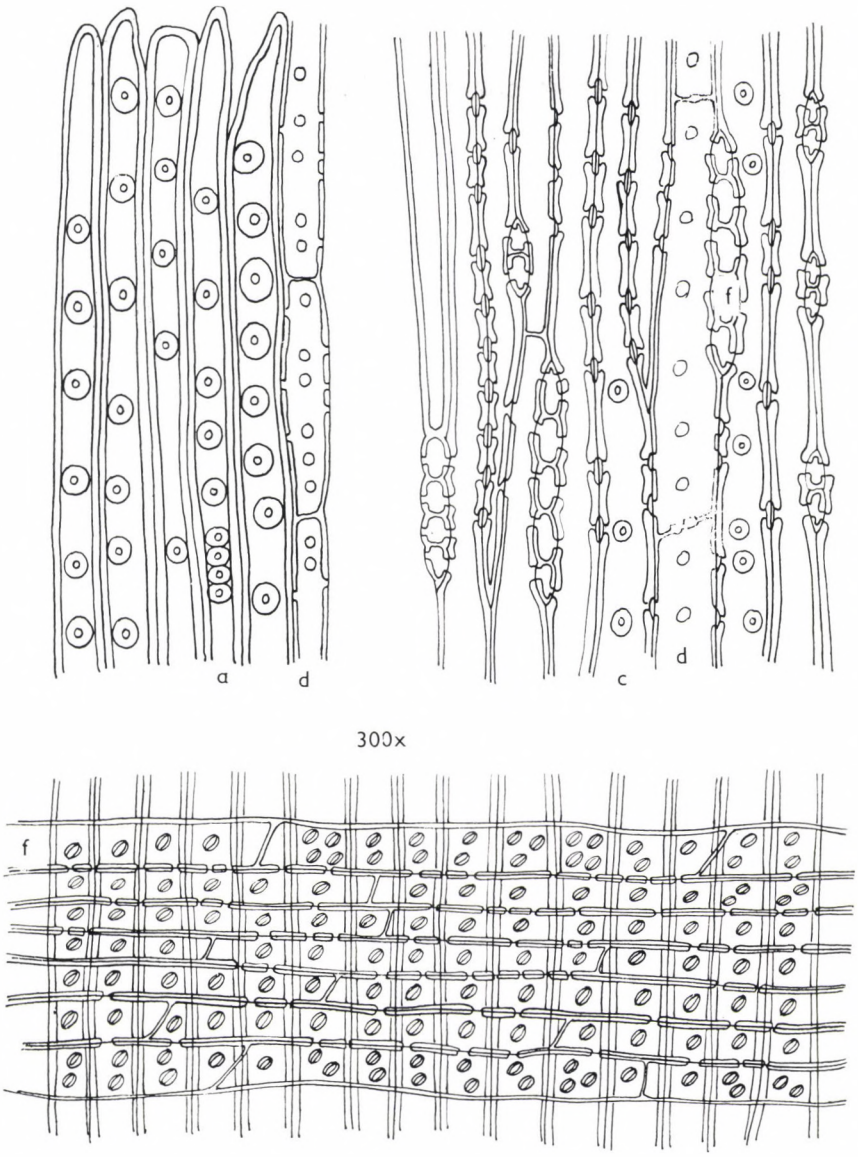


Fig. 41. *Podocarpus nivalis* Hooker fil.

1.(x100)

2.(x100)

3.(x 300)

4.(x300)

LXII. *Podocarpus novae-caledoniae* Vieillard

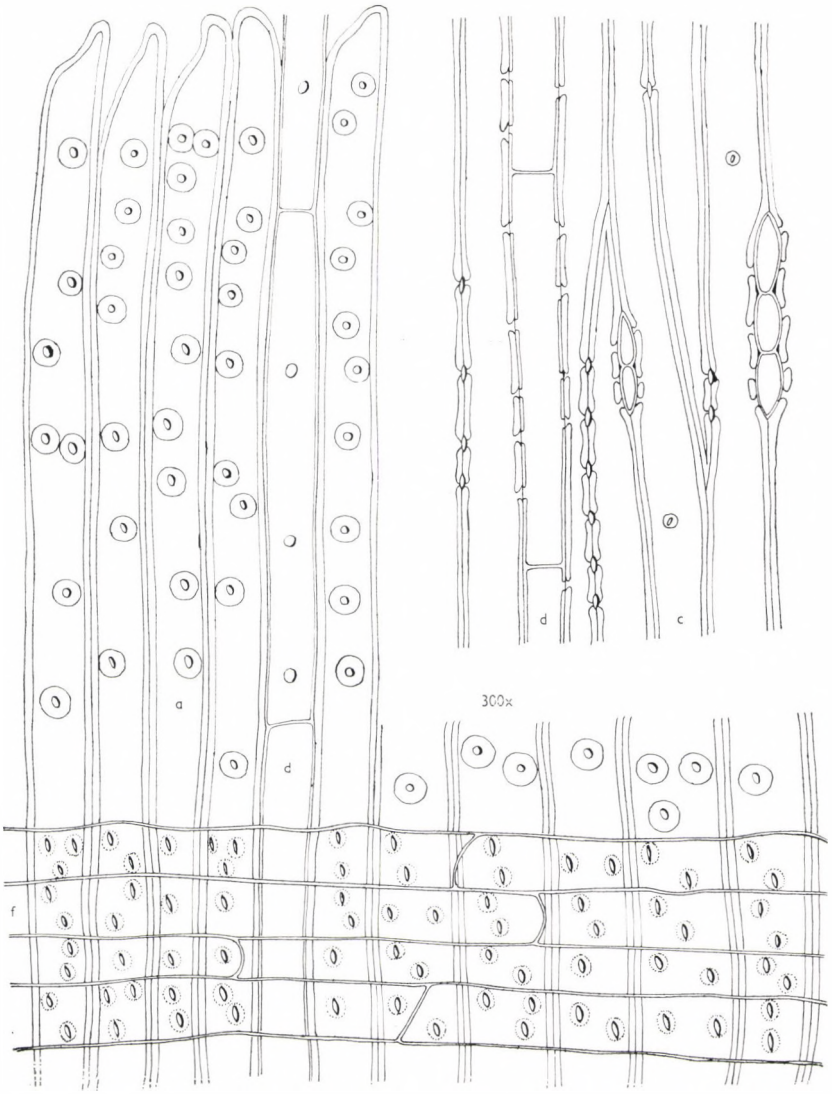
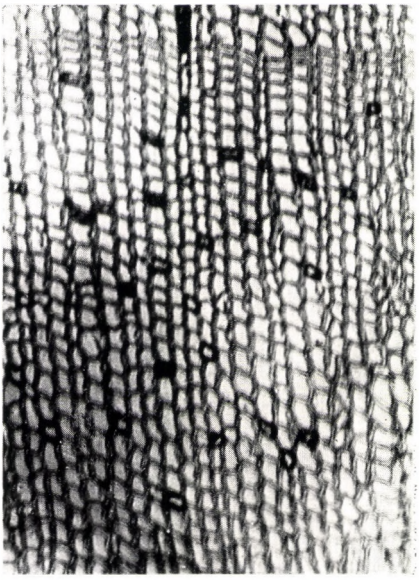


Fig. 42. *Podocarpus novae-caledoniae* Vieillard



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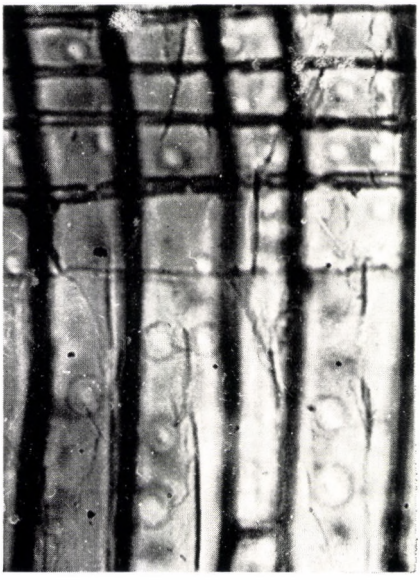
2.(x100)



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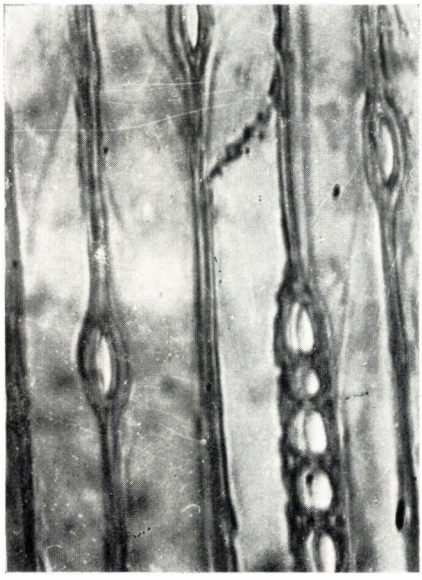


4.(x 400)

LXIII. *Podocarpus nubigenus* Lindley

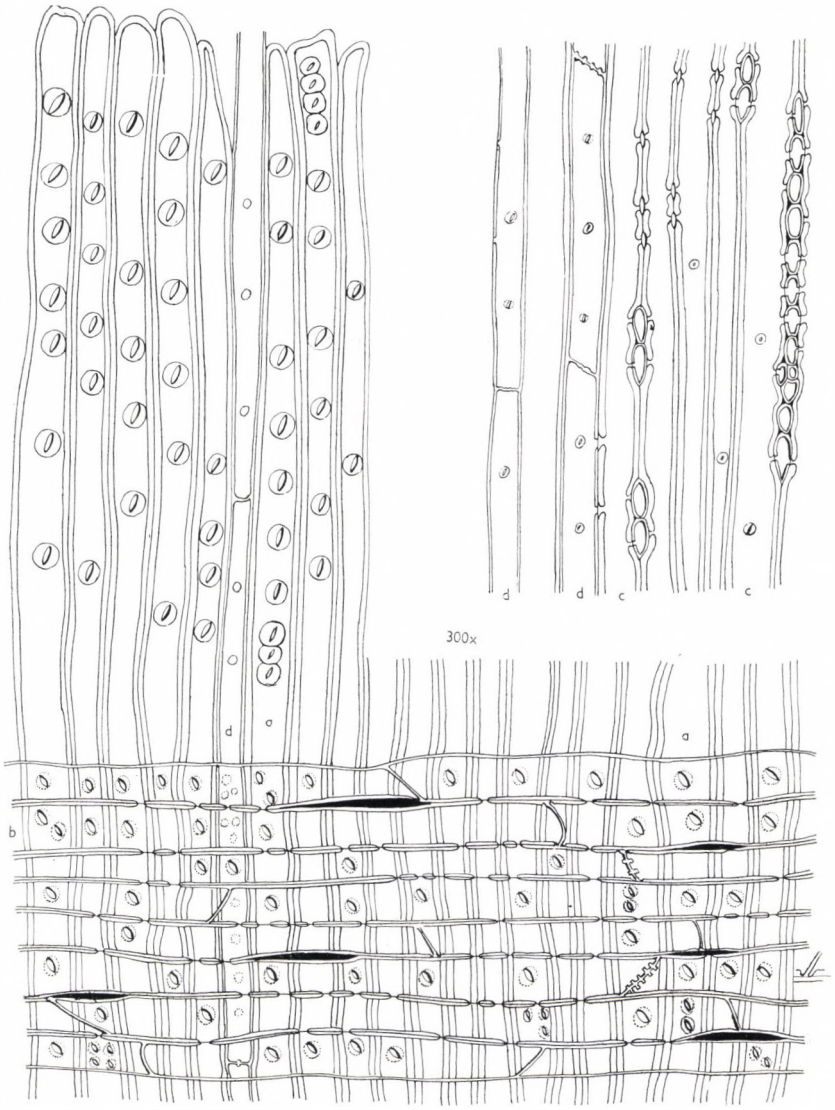
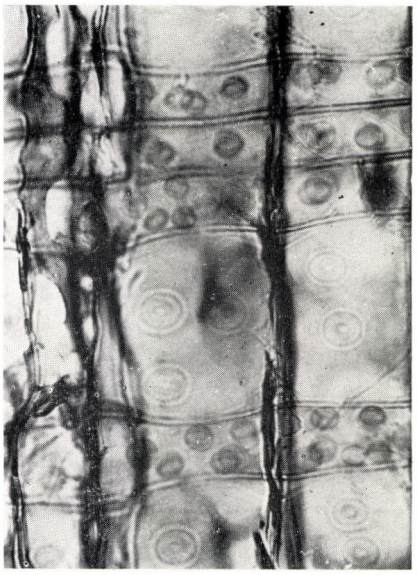
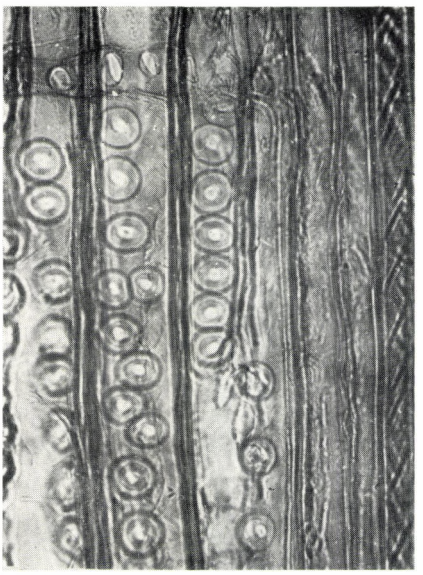


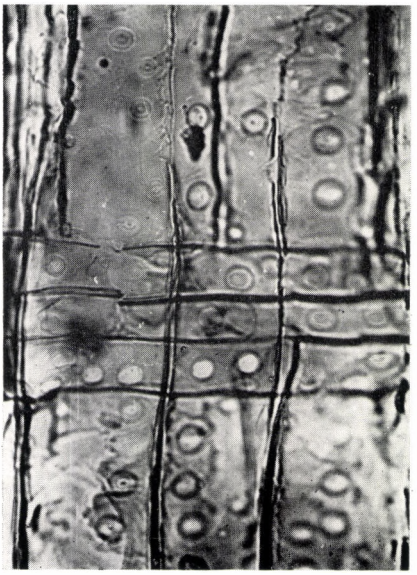
Fig. 43. *Podocarpus nubigenus* Lindley



1.(x 300)



2(x300)



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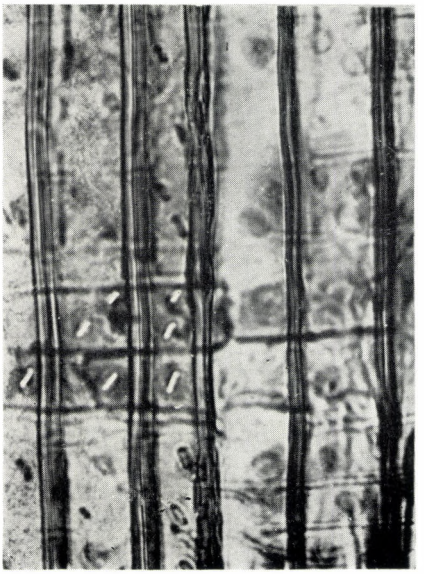


4.(x300)

LXIV. *Podocarpus palustris* Buchholz

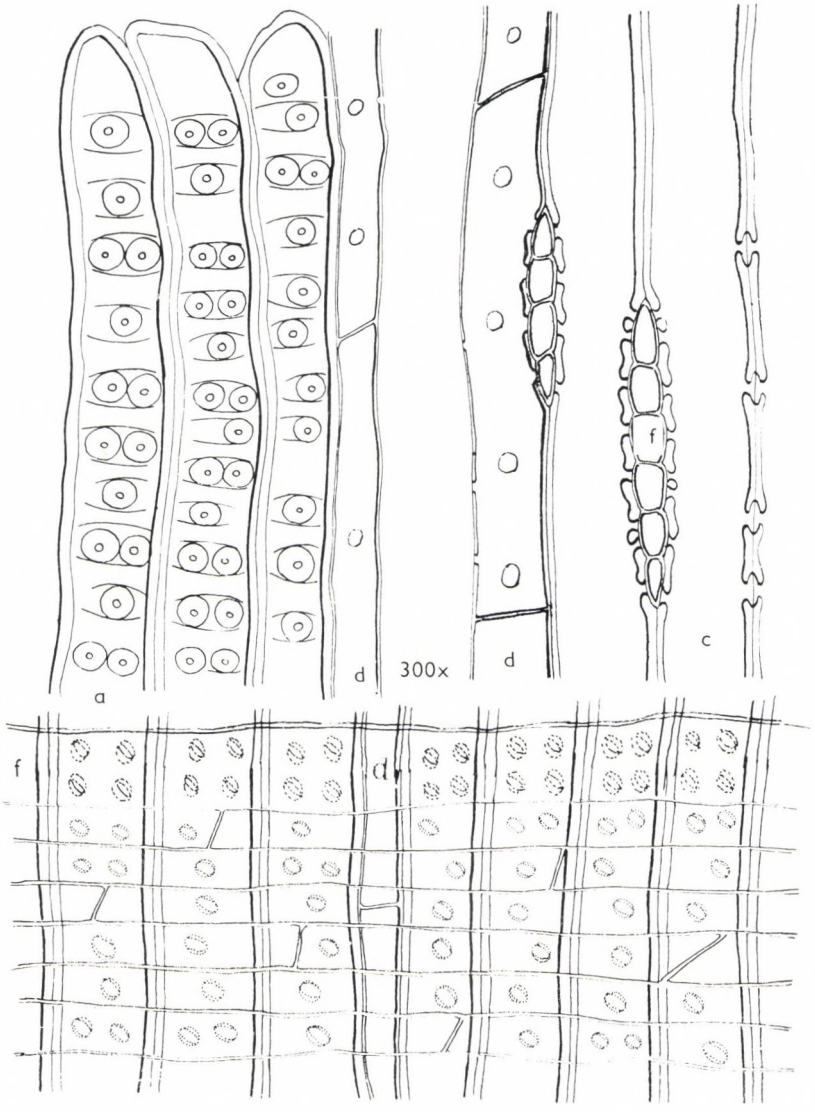
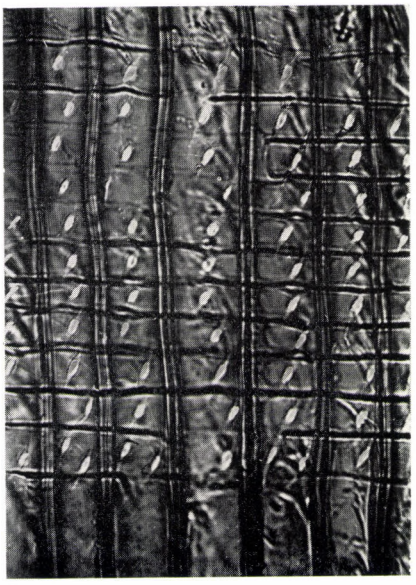


Fig. 44. *Podocarpus palustris* Buchholz

1.(×100)

2(×100)



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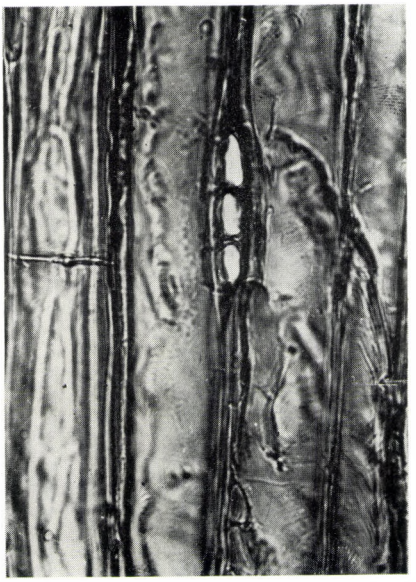


4.(×300)

LXV. *Podocarpus papuanus* Ridley

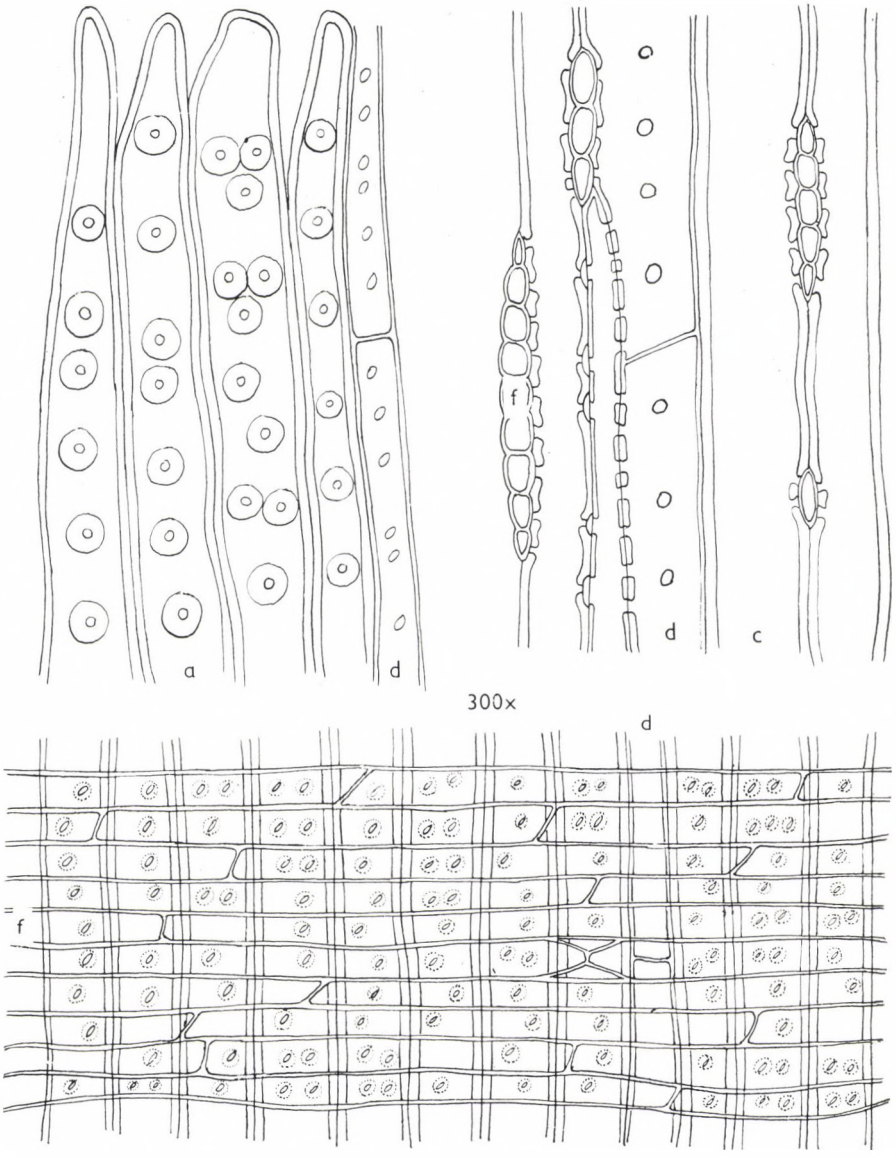
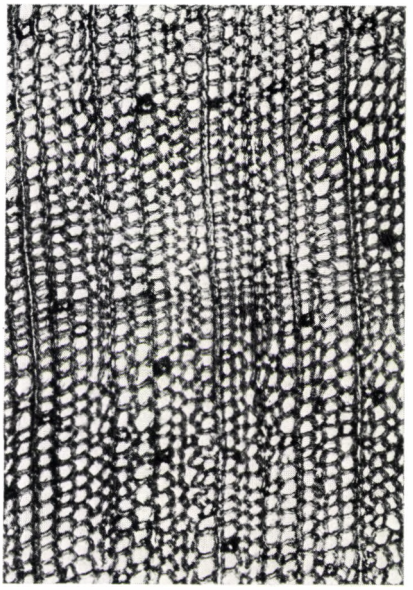


Fig. 45. *Podocarpus papuanus* Ridley



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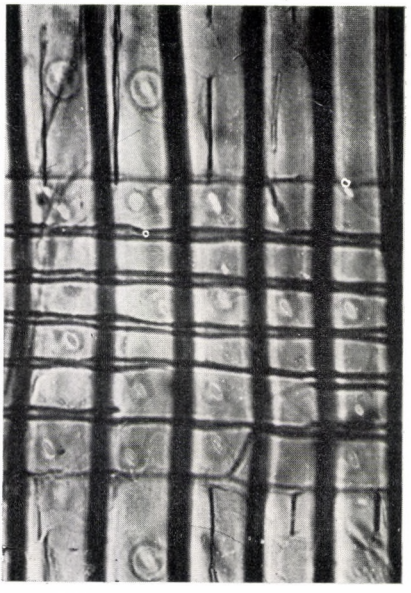
2.(×100)



3.(×400)

4.(×300)

LXVI. *Podocarpus parlatorei* Pilger

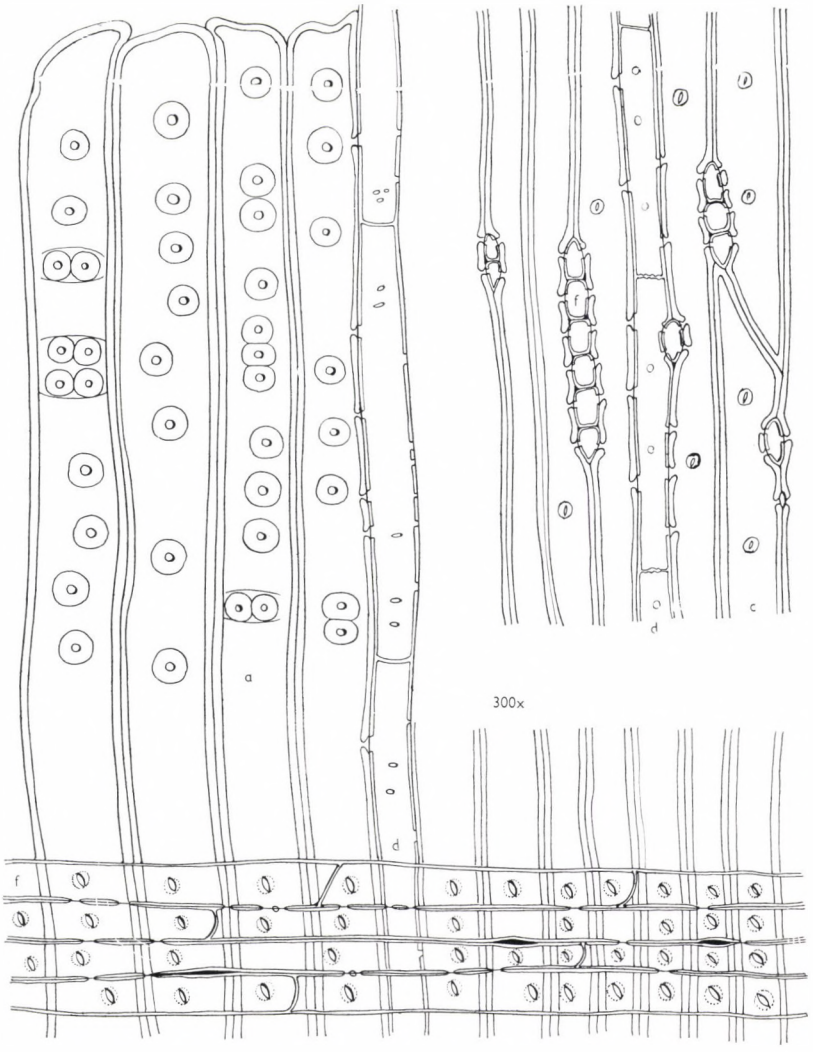
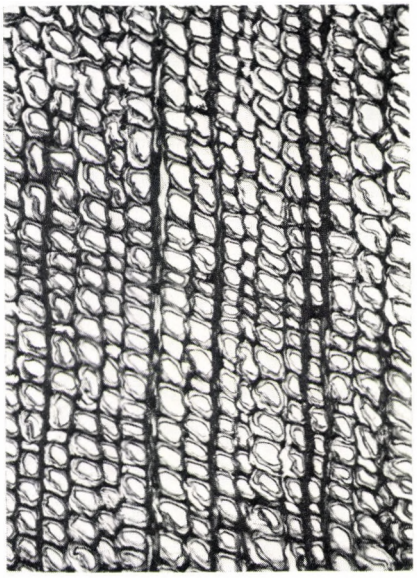


Fig. 46. *Podocarpus parlatorei* Pilger



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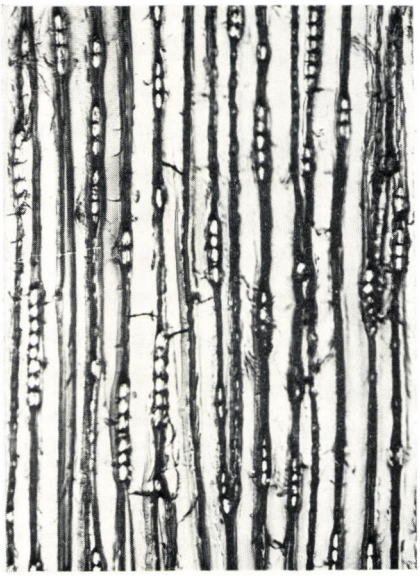
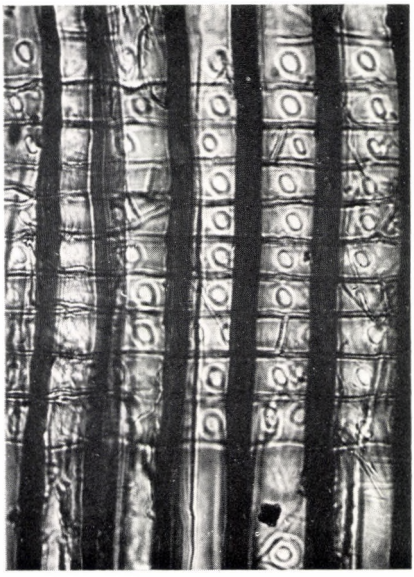


2.(×100)



3.(×300)

4(×300)

LXVII. *Podocarpus philippensis* Foxw.

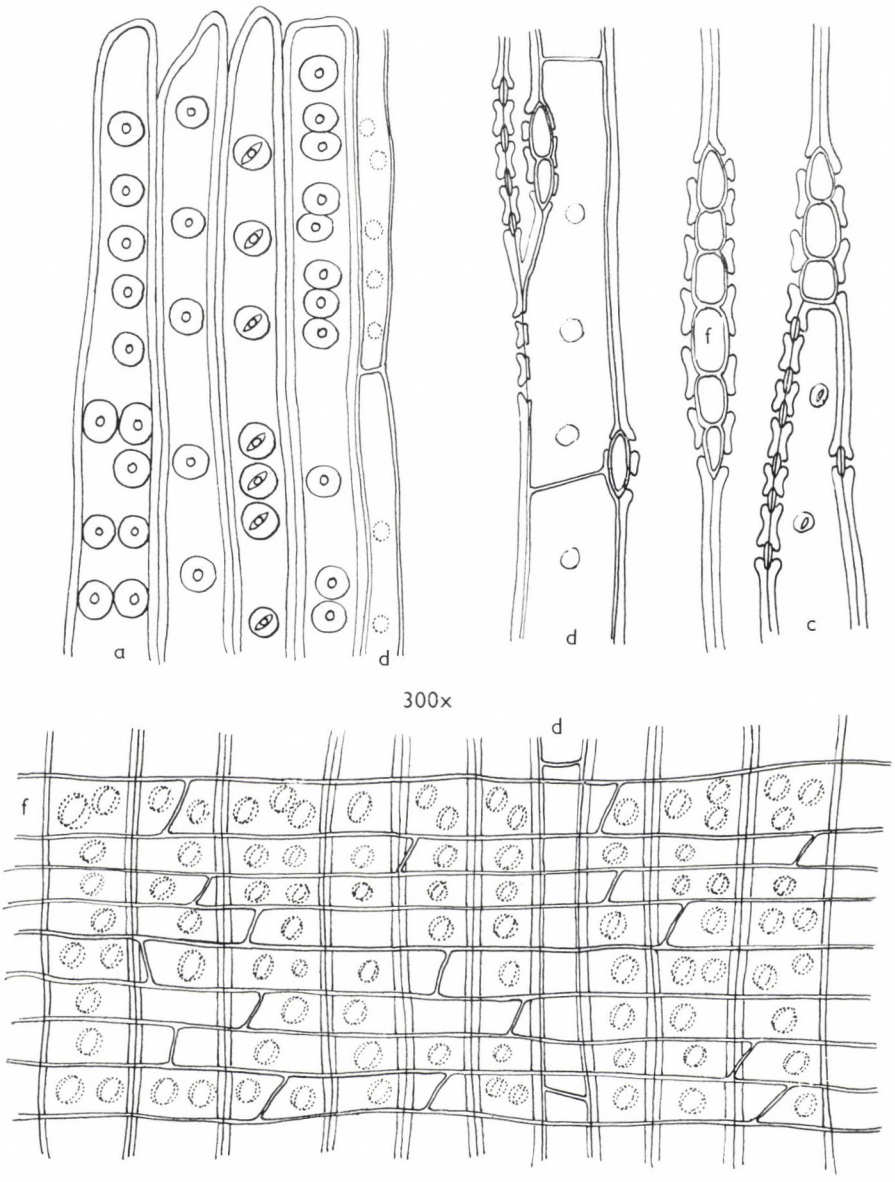
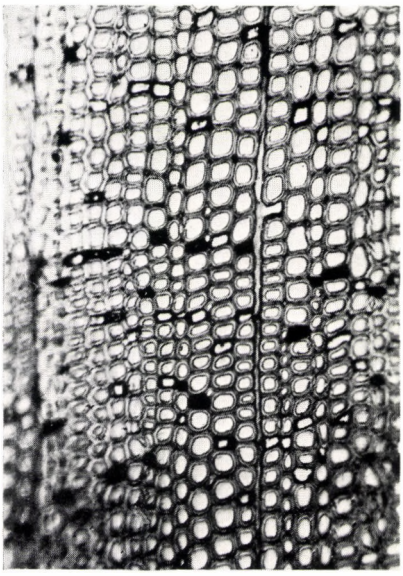
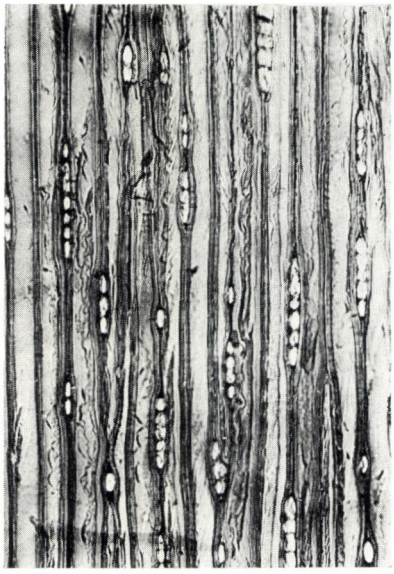


Fig. 47. *Podocarpus philippensis* Foxw.



1.(×100)



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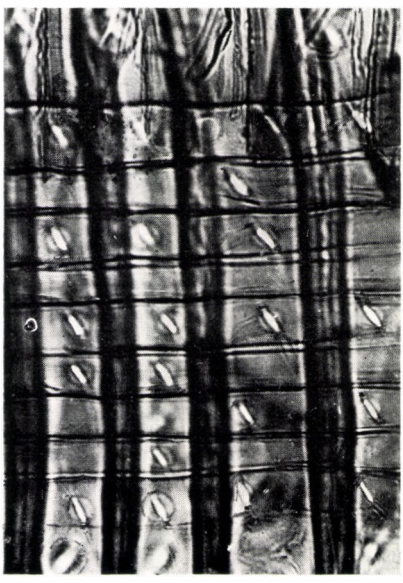
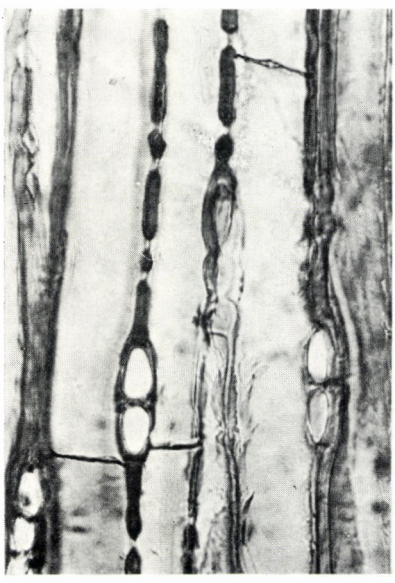


3.(× 300)



4.(×300)

LXVIII. *Podocarpus pilgeri* Foxw.

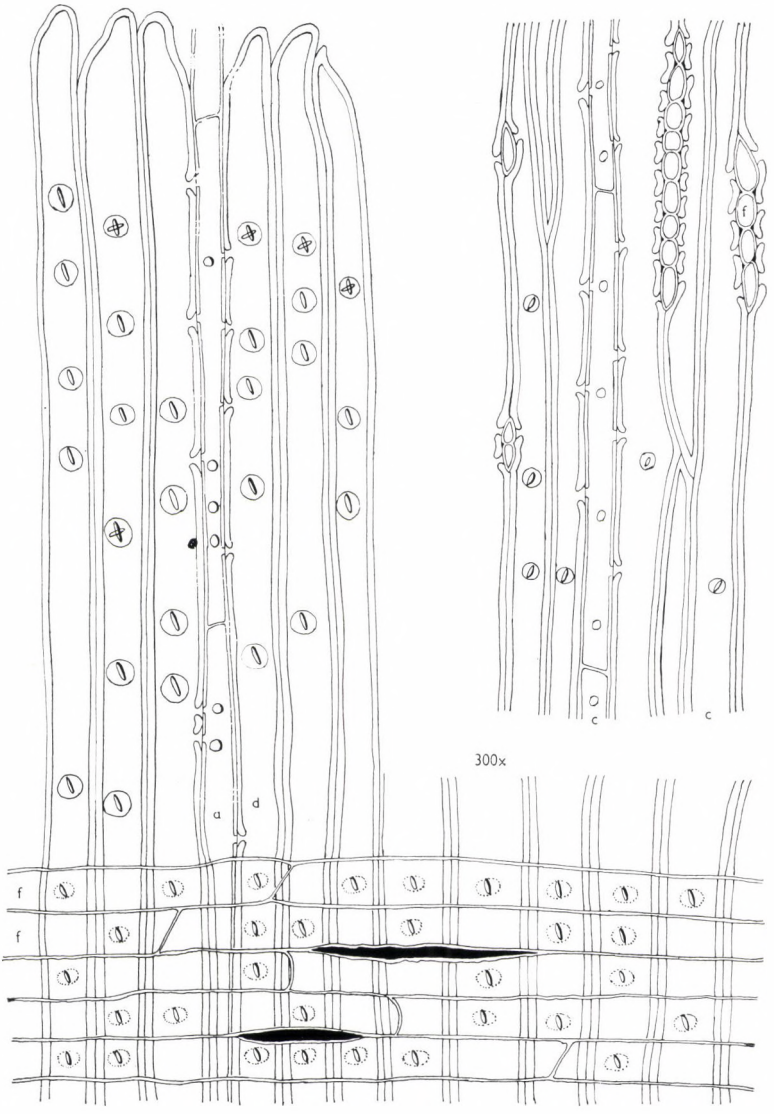
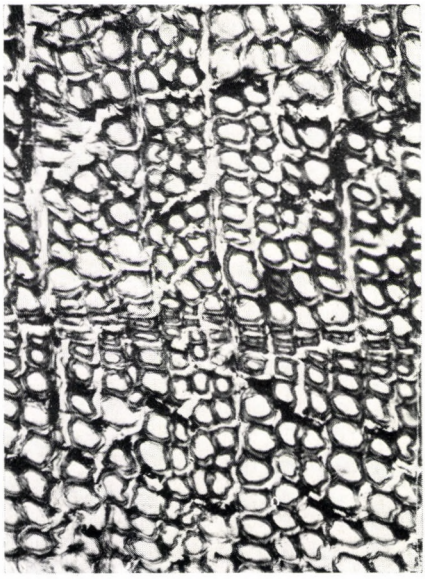


Fig. 48. *Podocarpus pilgeri* Foxw.



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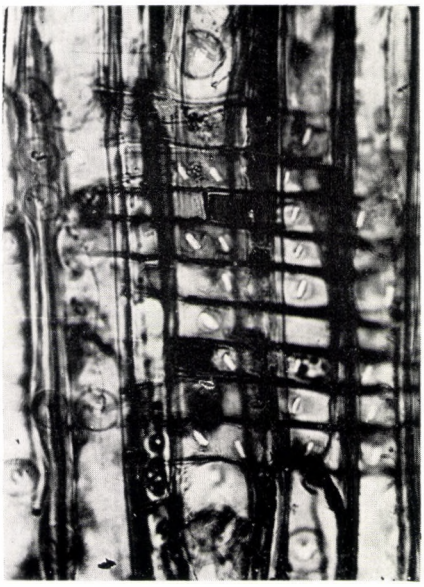
2.(×100)



3.(×300)

4.(×300)

LXIX. *Podocarpus polystachus* R. Brown

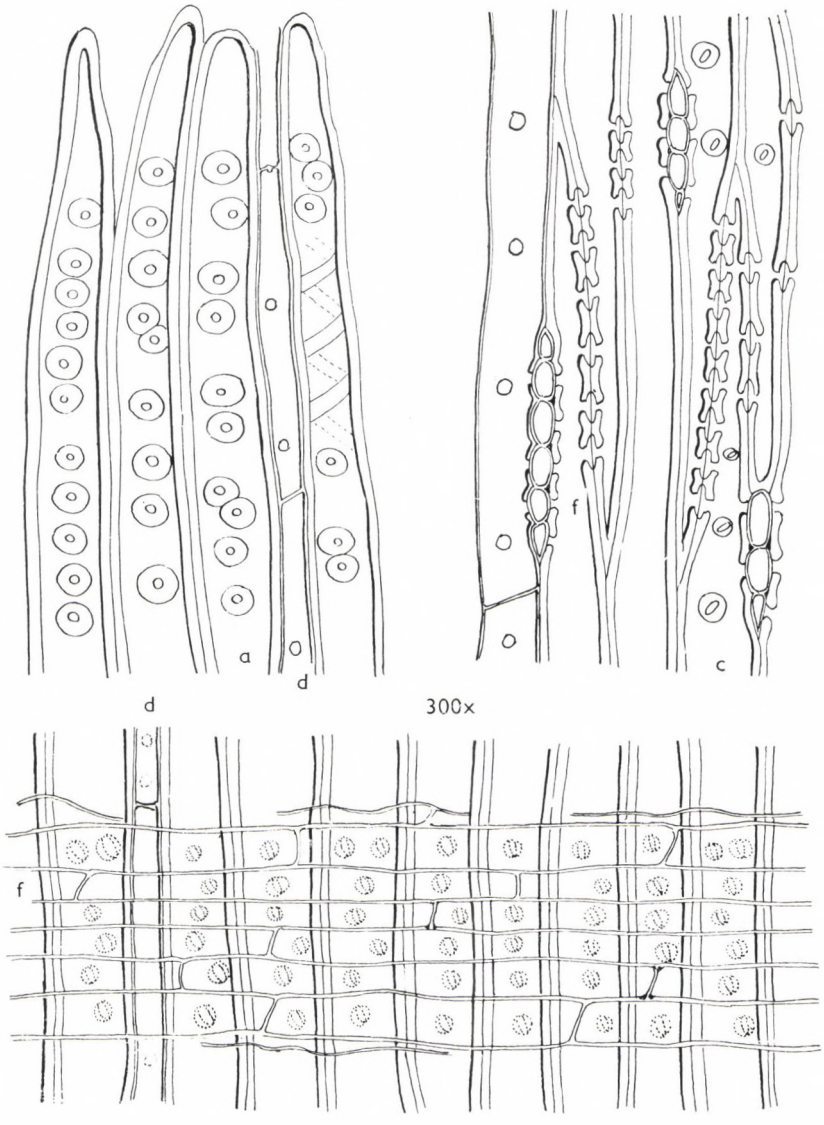
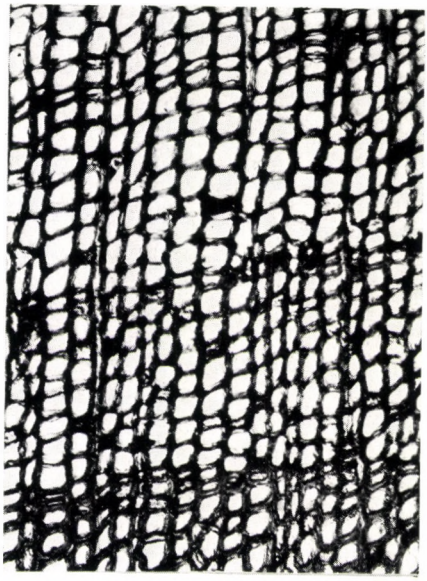


Fig. 49. *Podocarpus polystachus* R. Brown



1.(×100)

2.(×100)

3.(×300)

4.(×300)

LXX. *Podocarpus purdieanus* Hooker fil.

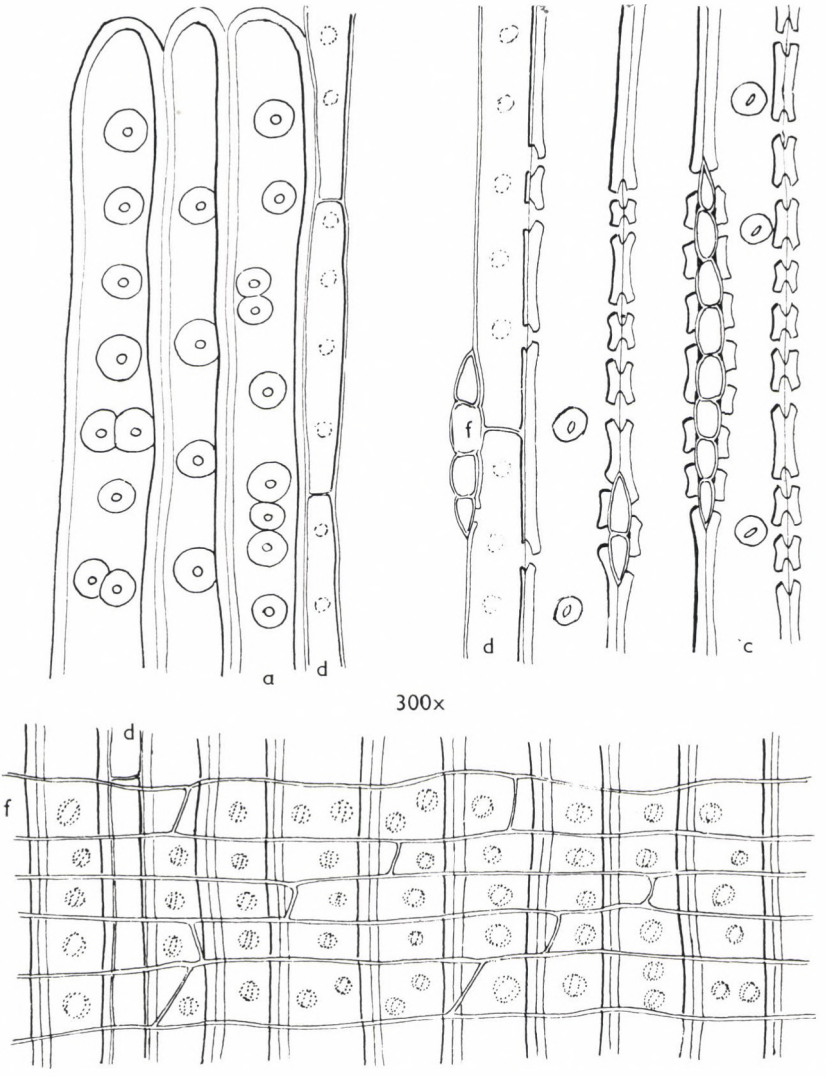
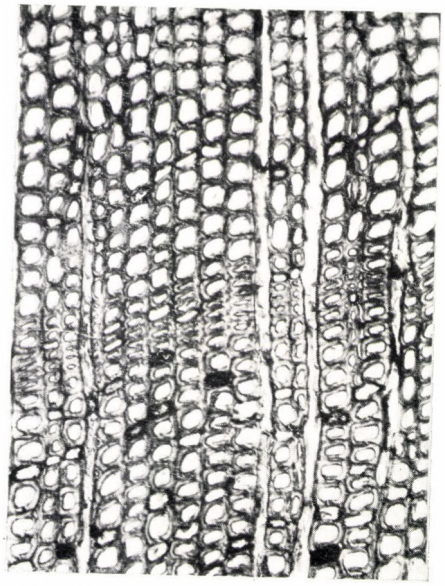


Fig. 50. *Podocarpus purdieanus* Hooker fil.



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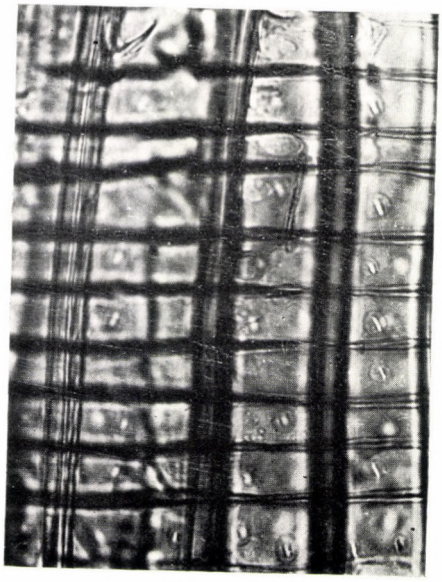
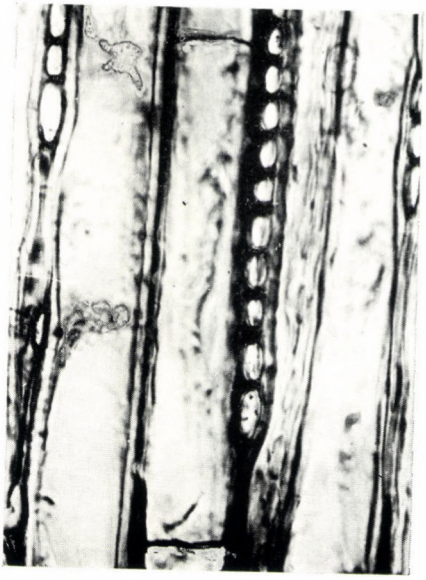
2.(×100)



3.(× 300)



4.(× 300)

LXXI. *Podocarpus rumphii* Blume

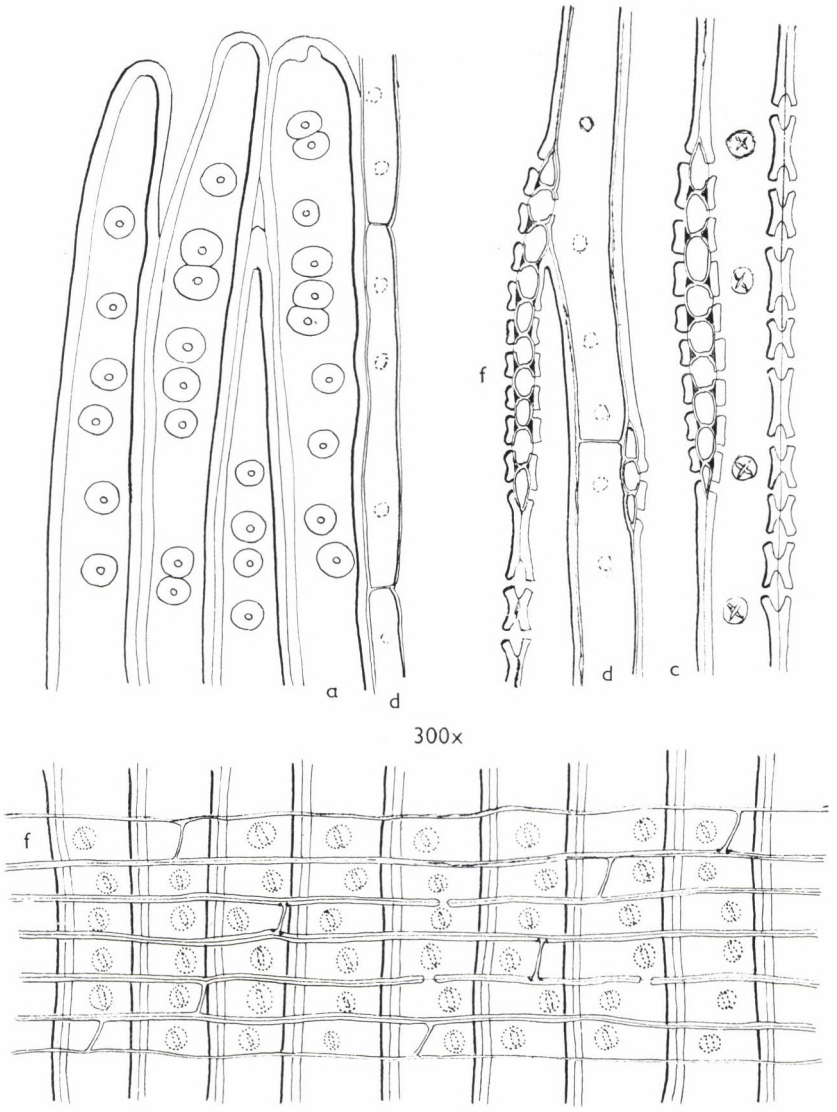
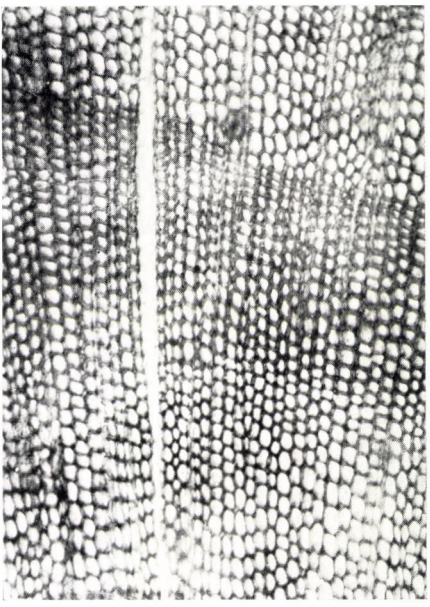


Fig. 51. *Podocarpus rumphii* Blume



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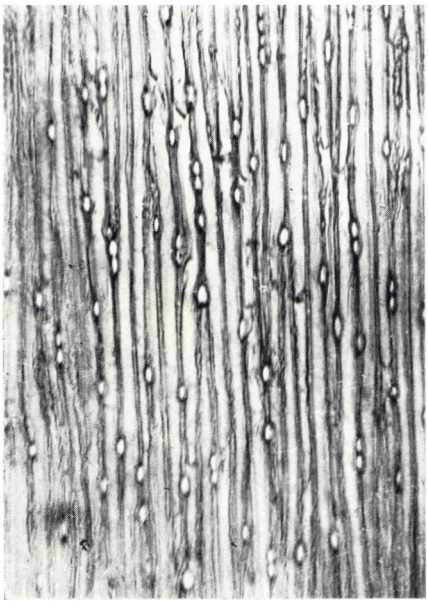
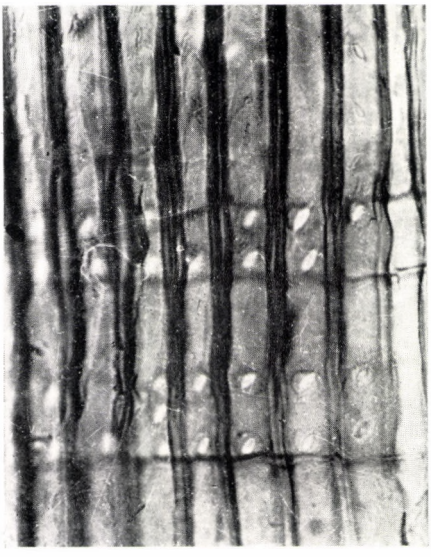


2.(x100)



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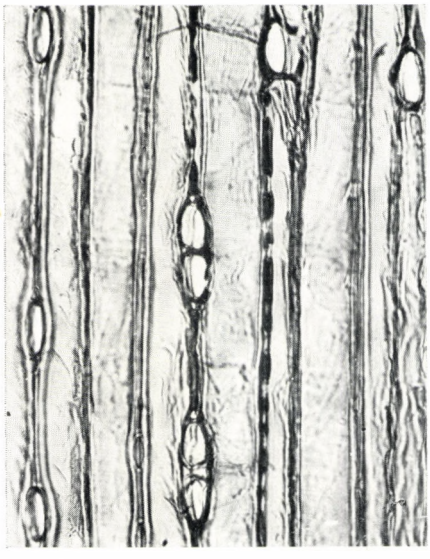

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LXXII. *Podocarpus rusbyi* Buchholz

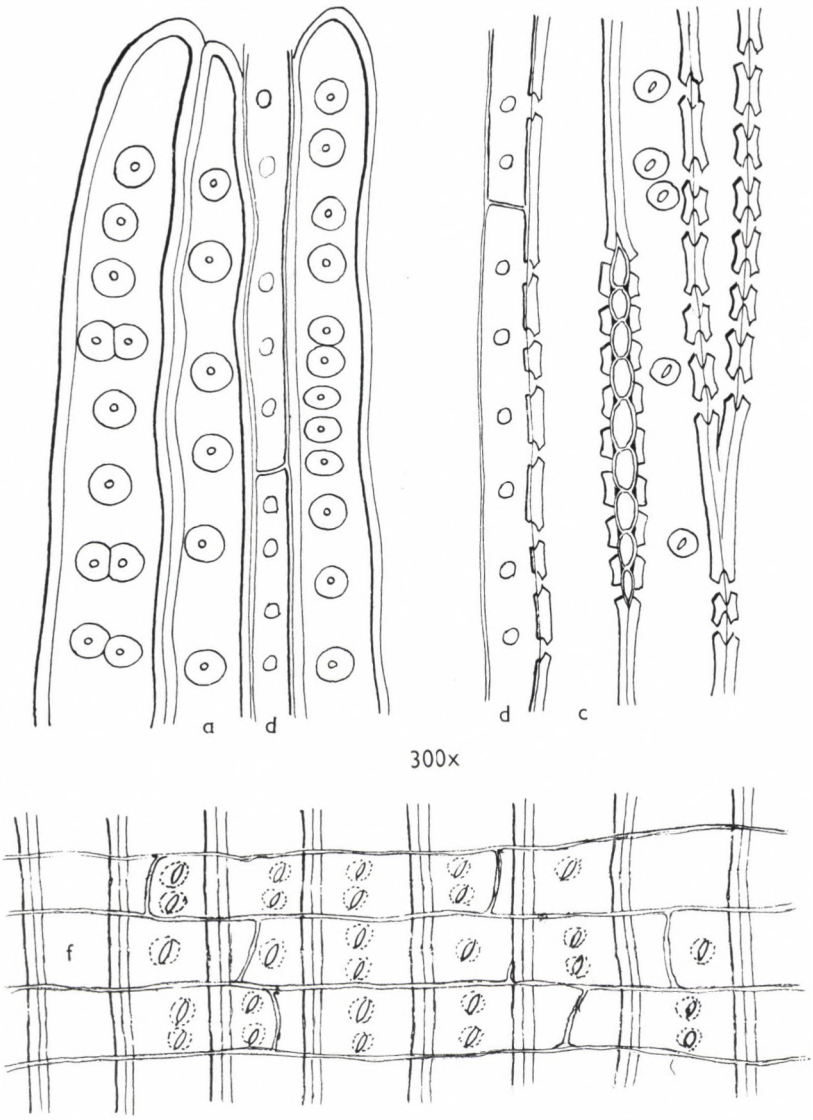
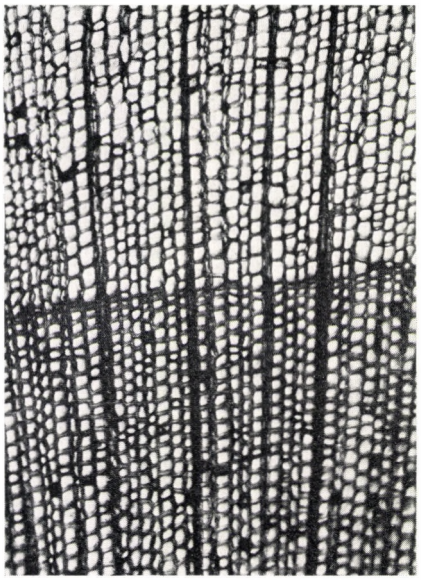


Fig. 52. *Podocarpus rusbyi* Buchholz



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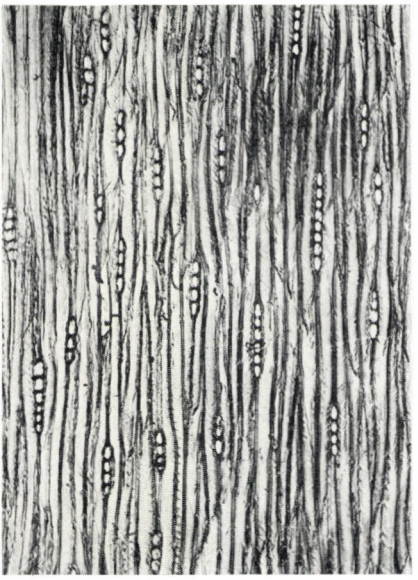

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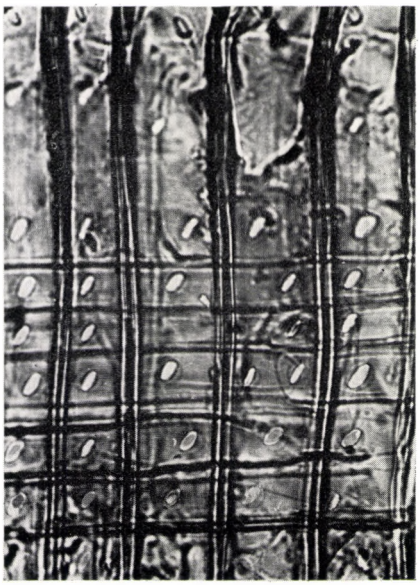

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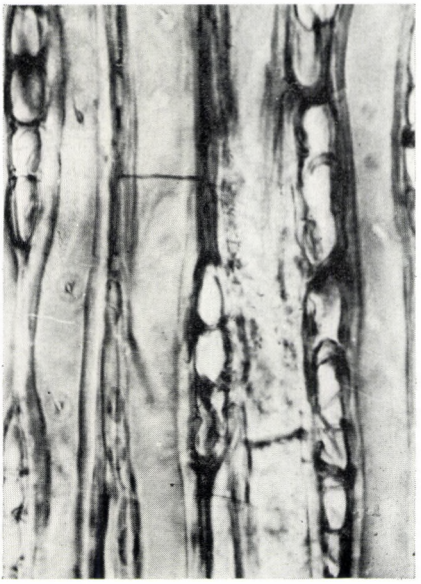

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LXXIII. *Podocarpus salomonensis* Wascher

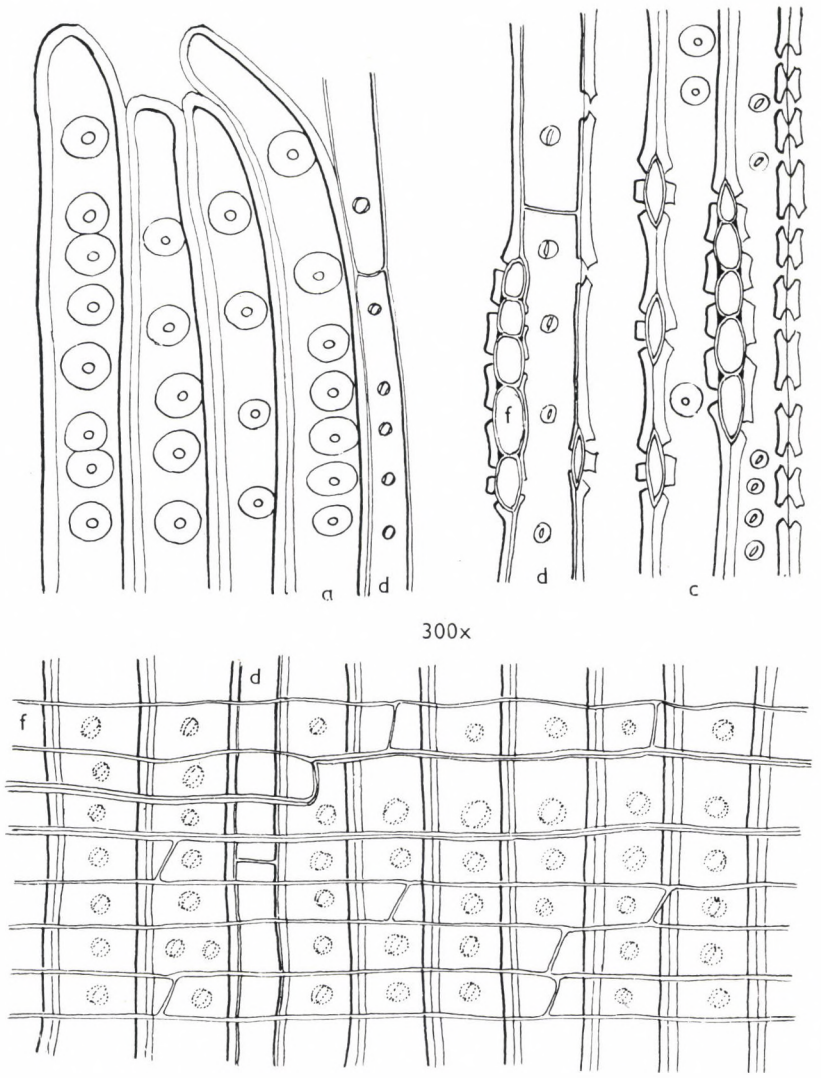
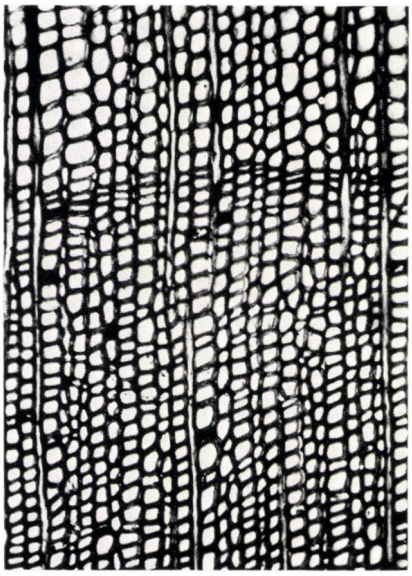


Fig. 53. *Podocarpus salomonensis* Wascher



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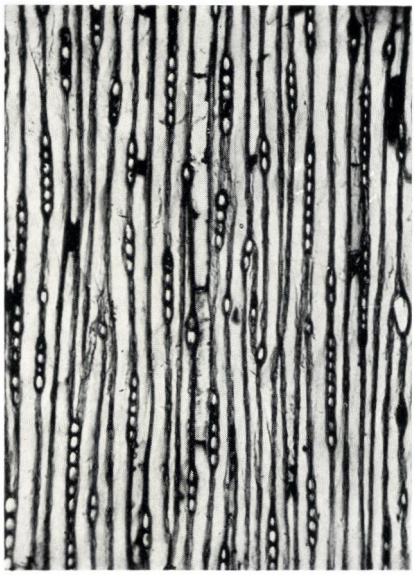

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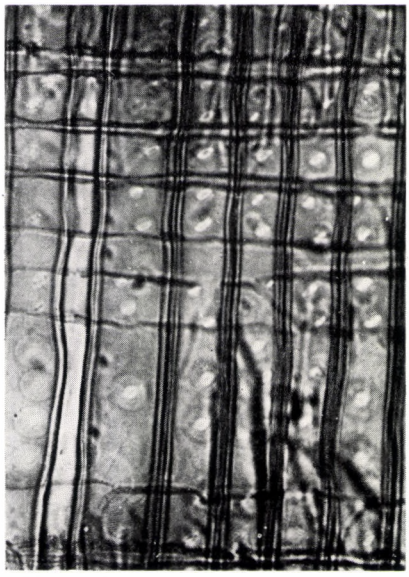

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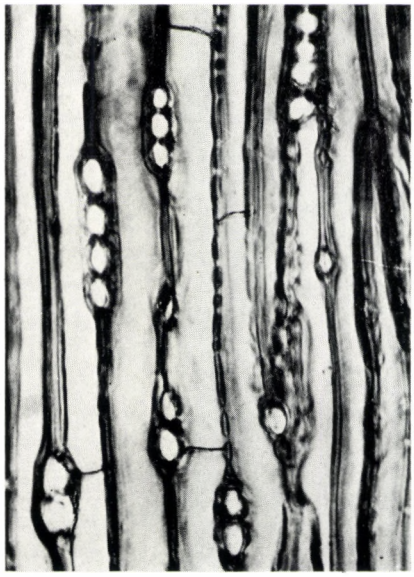

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LXXIV. *Podocarpus salignus* D. Don.

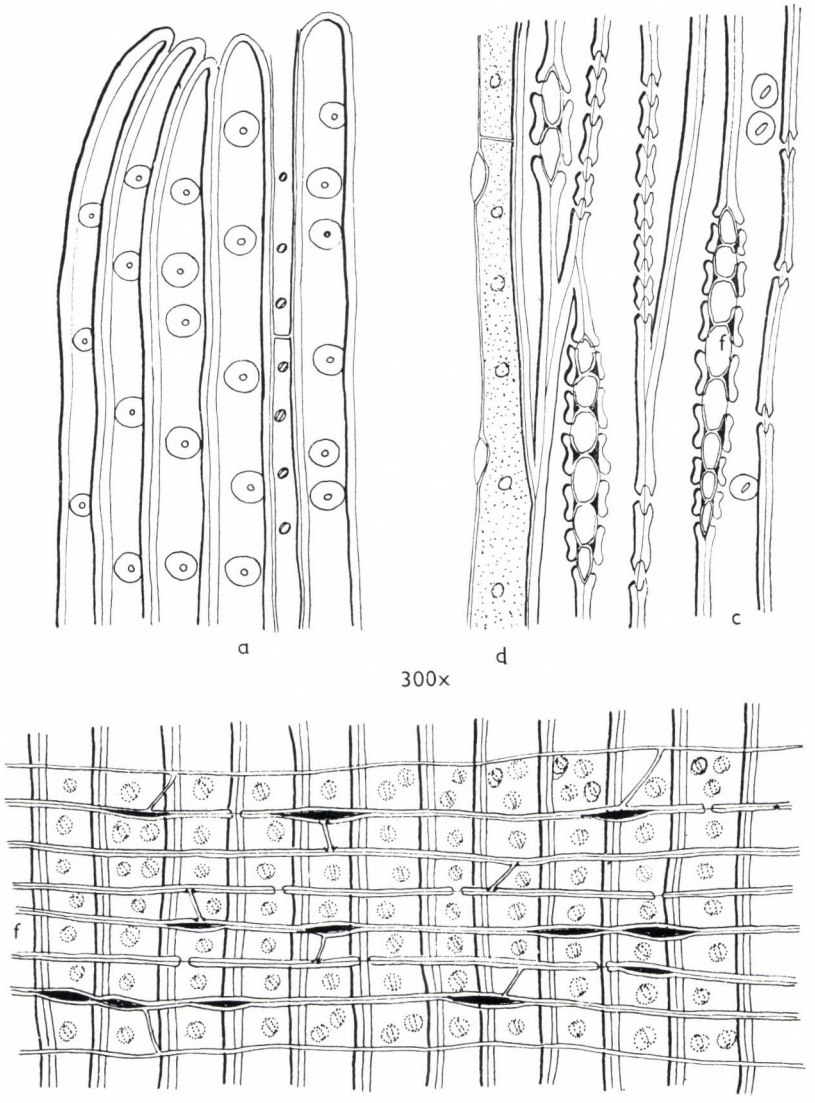
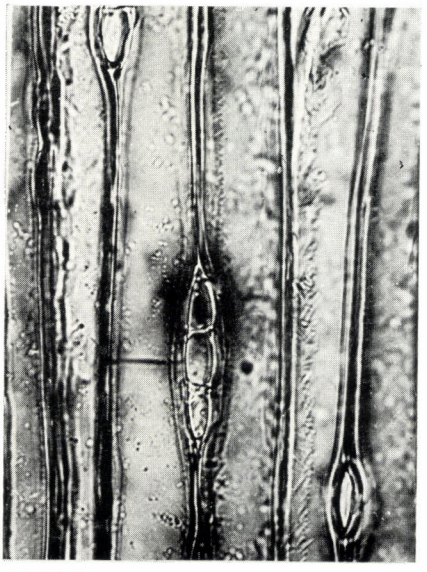


Fig. 54. *Podocarpus salignus* D. Don.

1.(×100)

2.(×100)

3.(×300)



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LXXV. *Podocarpus schlechteri* Pilger

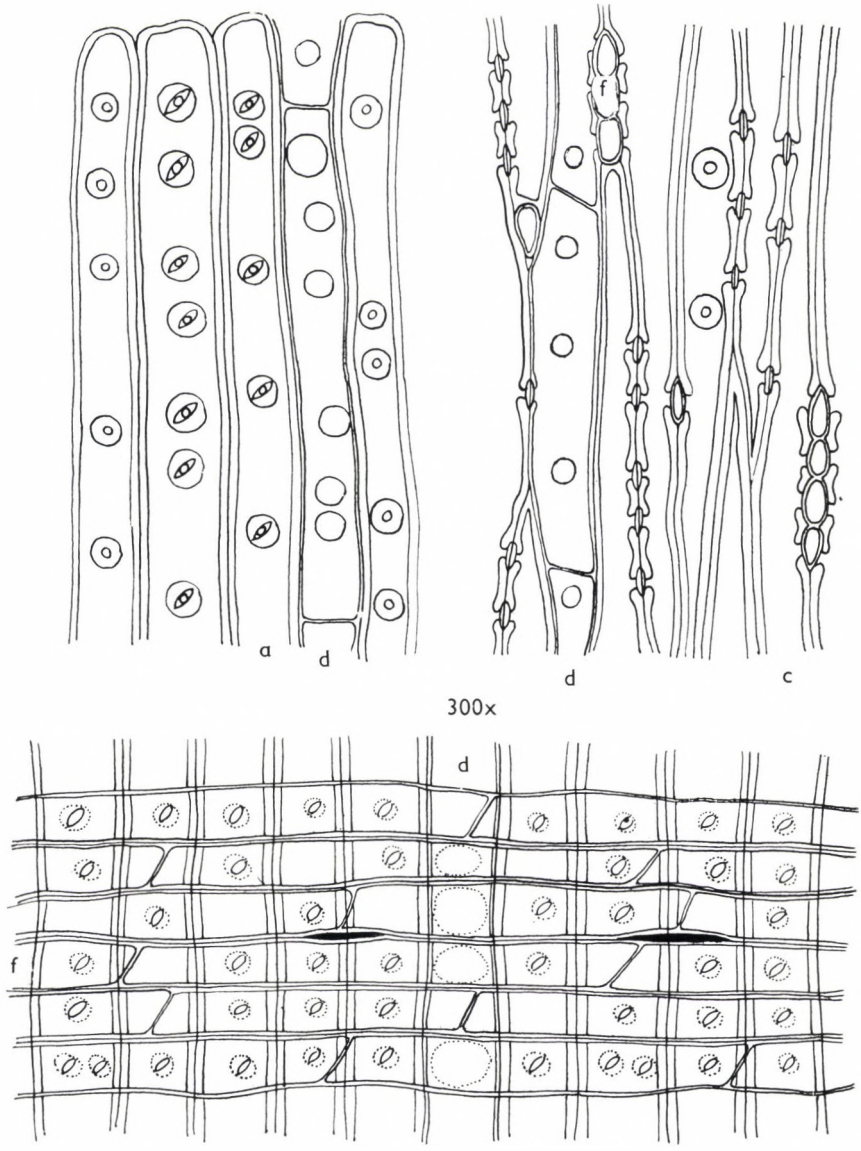
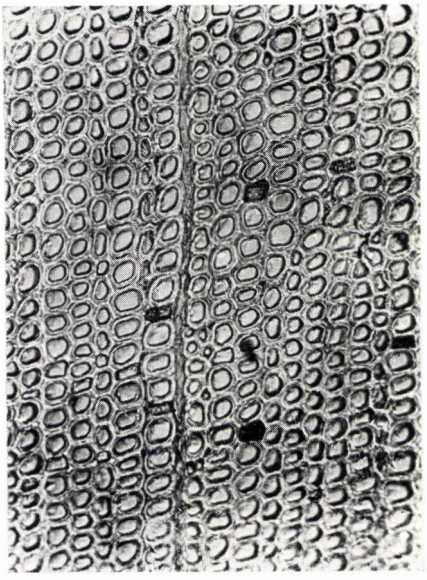


Fig. 55. *Podocarpus schlechteri* Pilger



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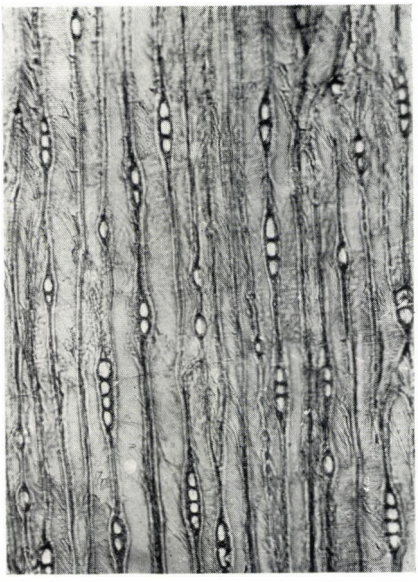

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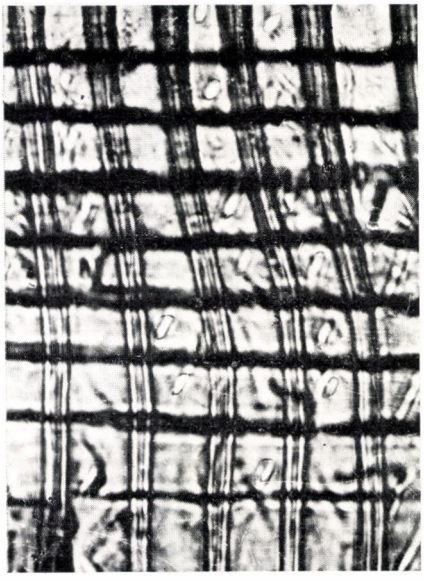

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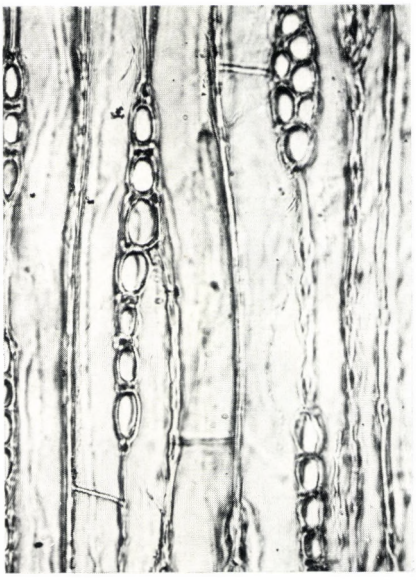

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LXXVI. *Podocarpus sellowii* Klotzsch

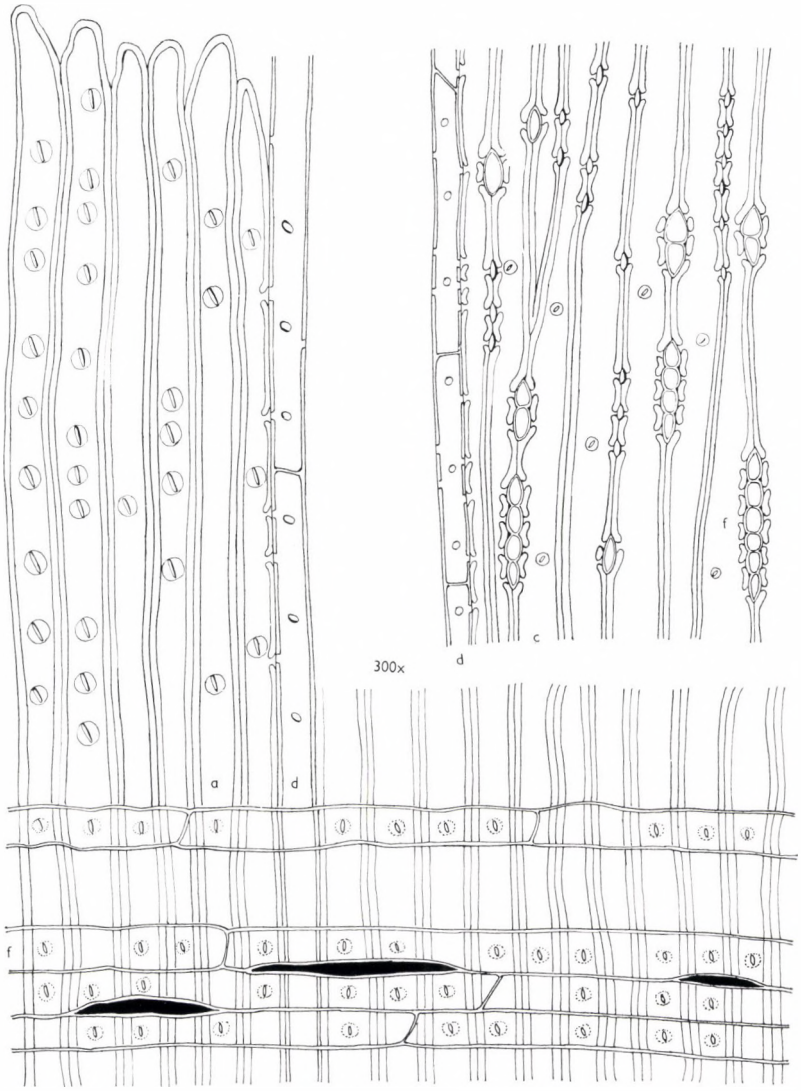
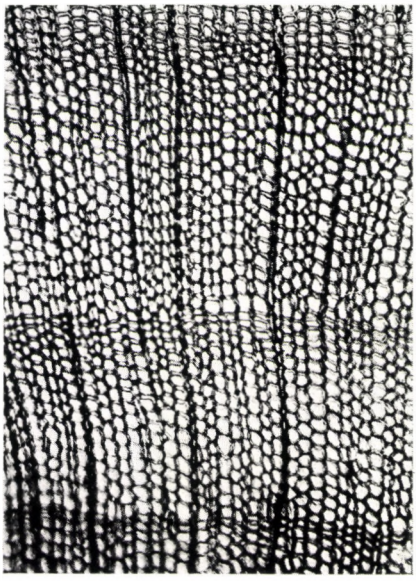


Fig. 56. *Podocarpus sellowii* Klotzsch



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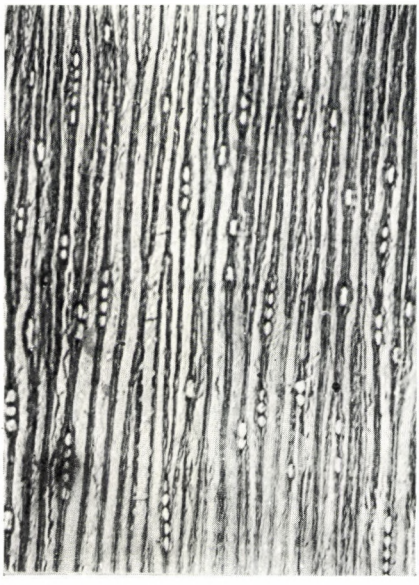

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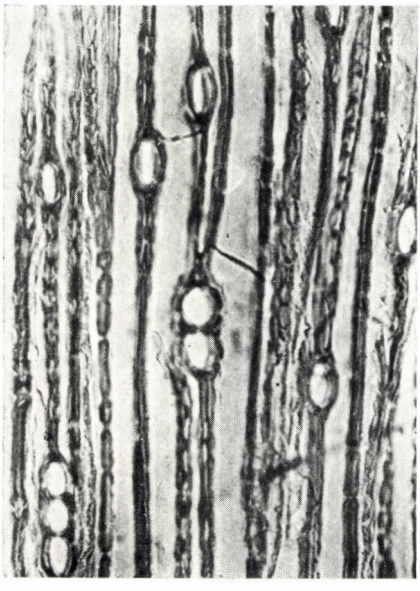
3.(×400)



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LXXVII. *Podocarpus spinulosus* R. Brown

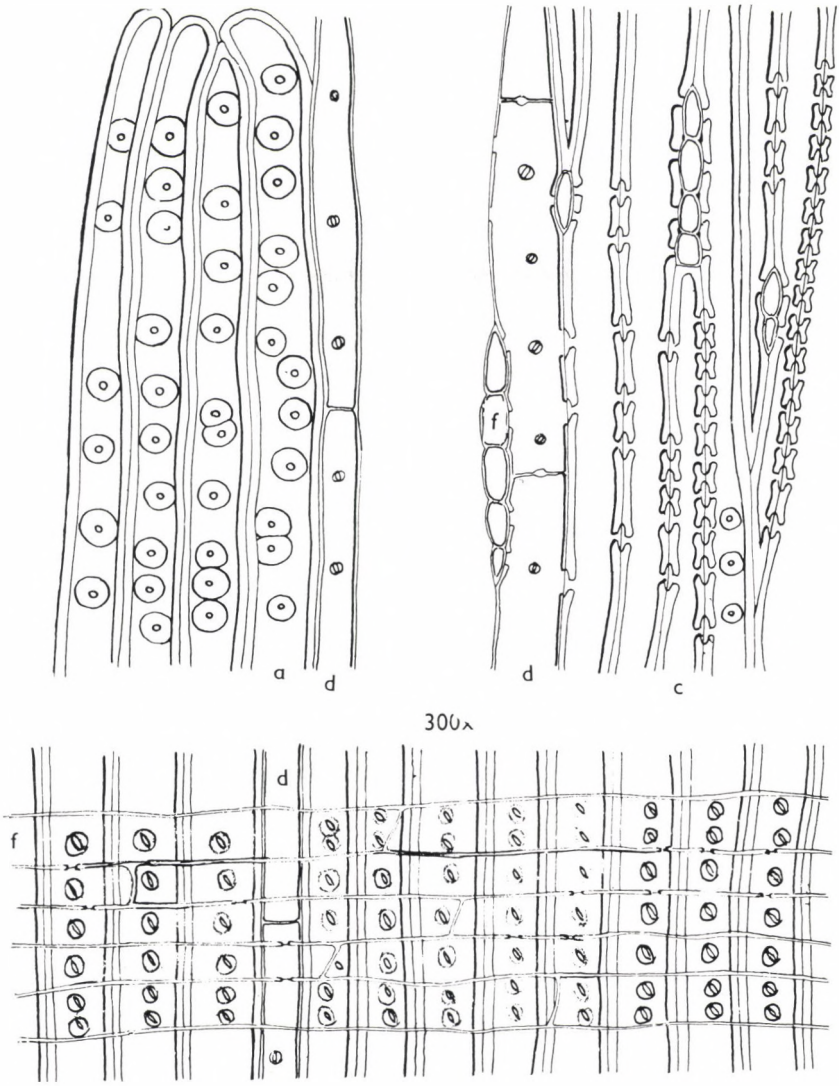
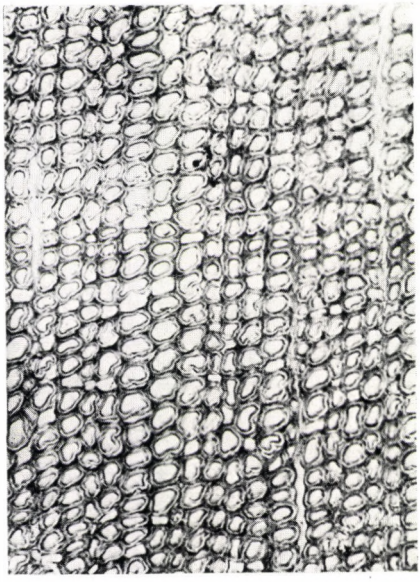


Fig. 57. *Podocarpus spinulosus* R. Brown



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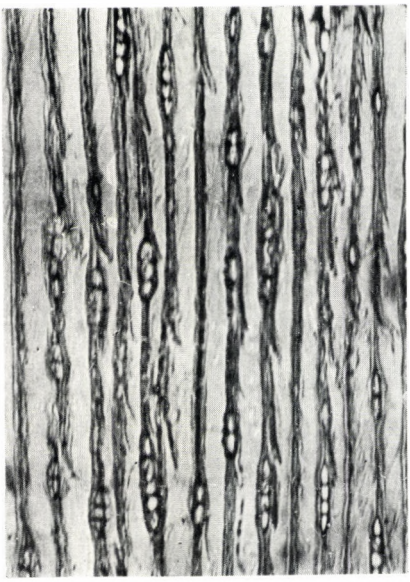

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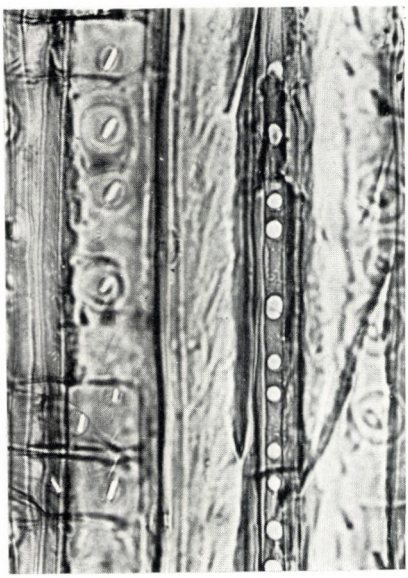

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LXXVIII. *Podocarpus sylvestris* Buchholz

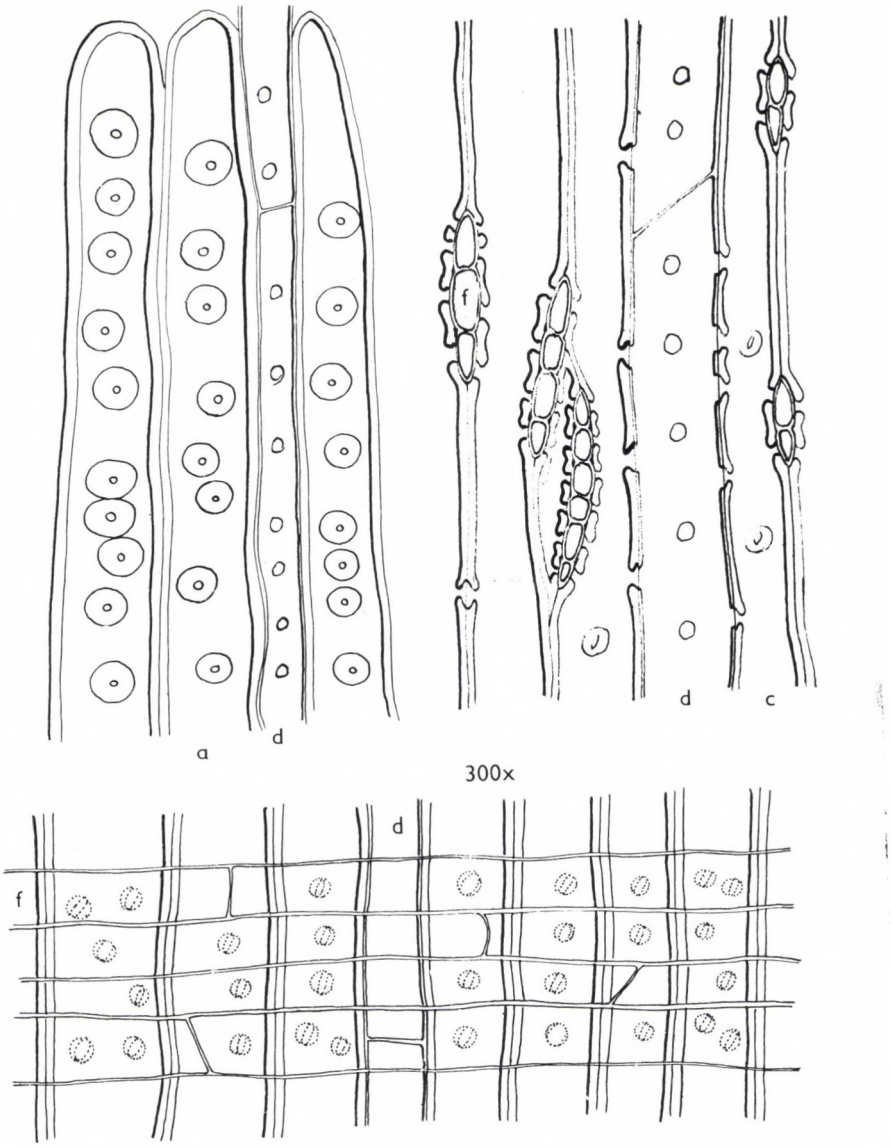
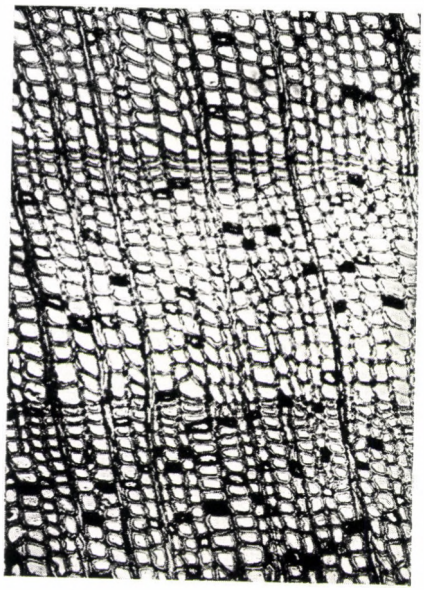


Fig. 58. *Podocarpus sylvestris* Buchholz



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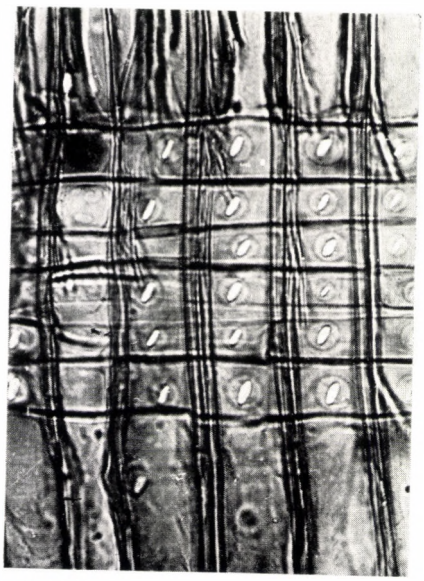

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4(x 300)

LXXIX. *Podocarpus urbanii* Pilger

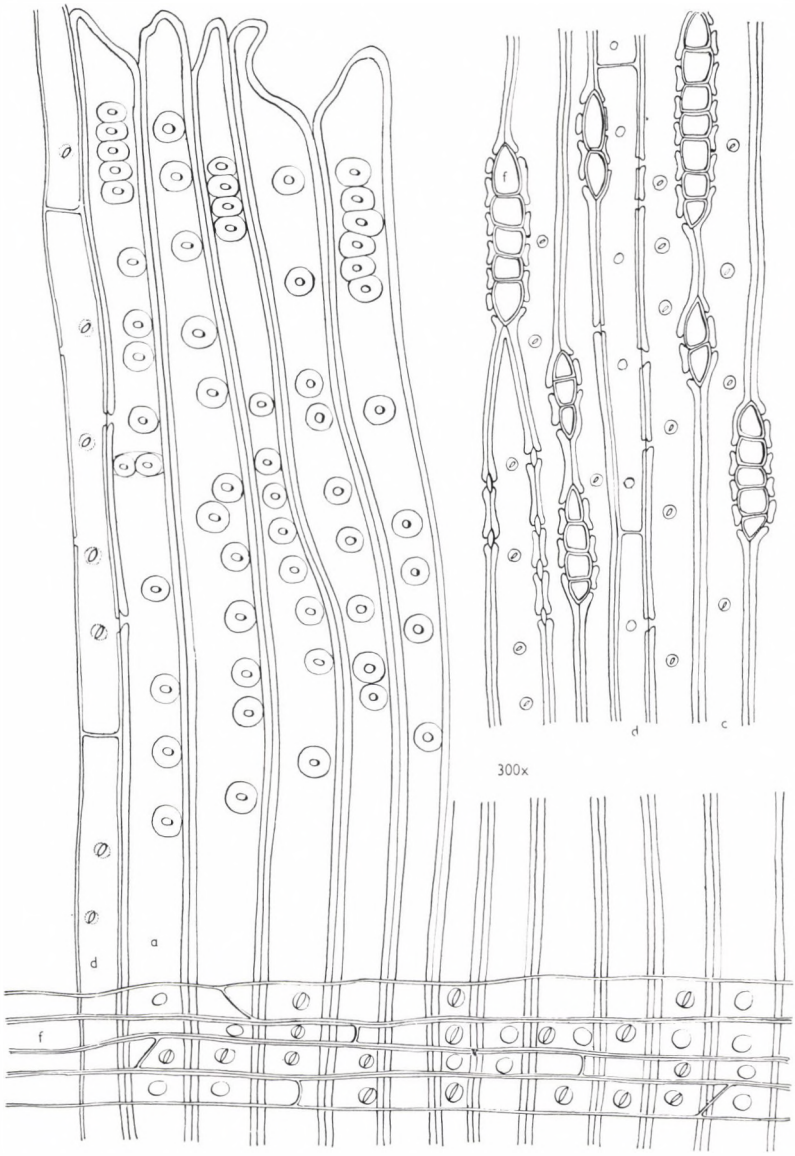
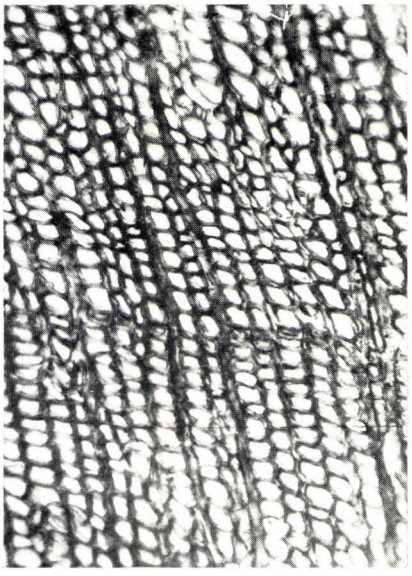


Fig. 59. *Podocarpus urbanii* Pilger



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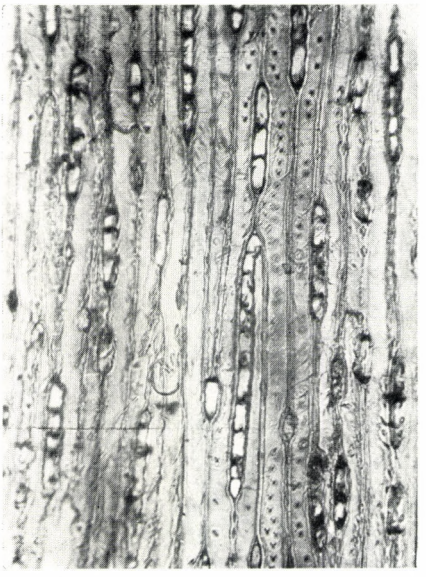
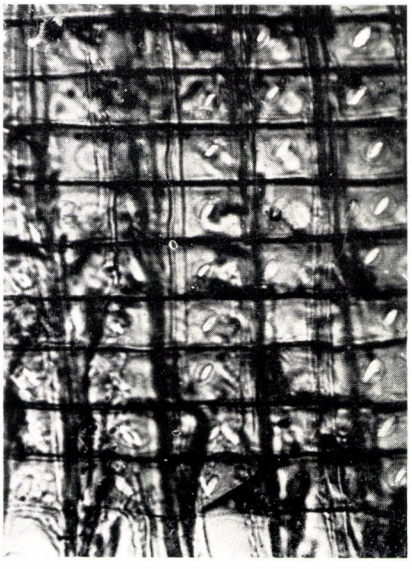


2(x 100)



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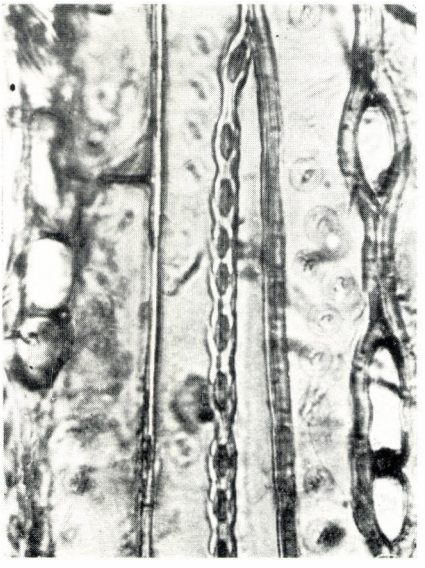

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LXXX. *Podocarpus ustus* Brongn. and Gris.

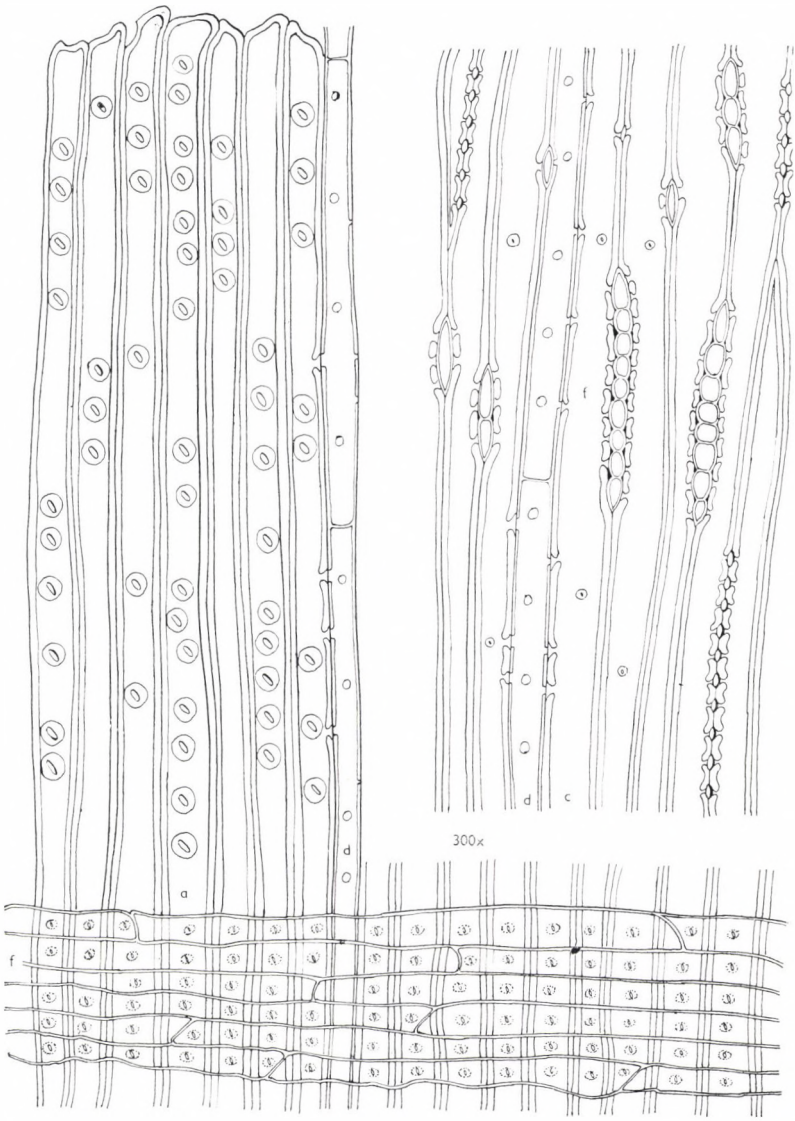
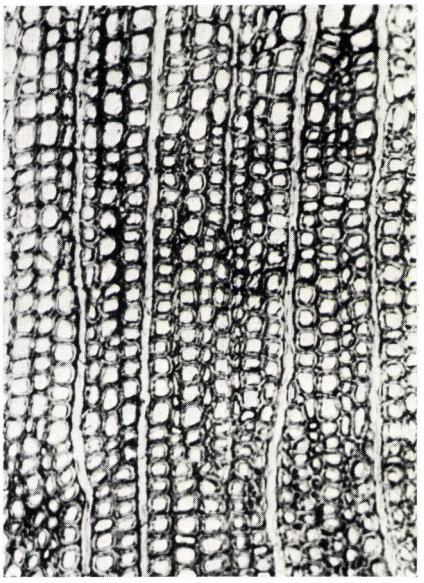


Fig. 60. *Podocarpus ustus* Brongn. and Gris.



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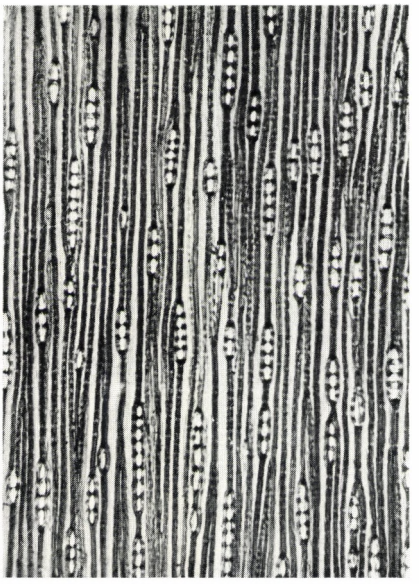

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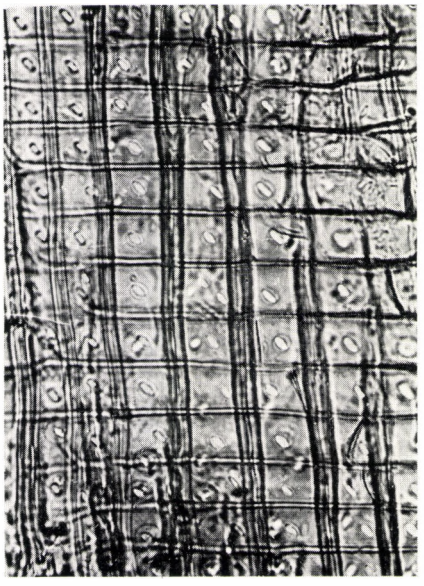

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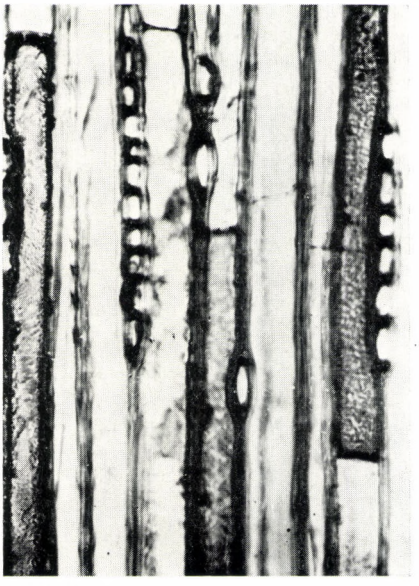


4.(×300)

LXXXI. *Podocarpus vieillardii* Parlatore

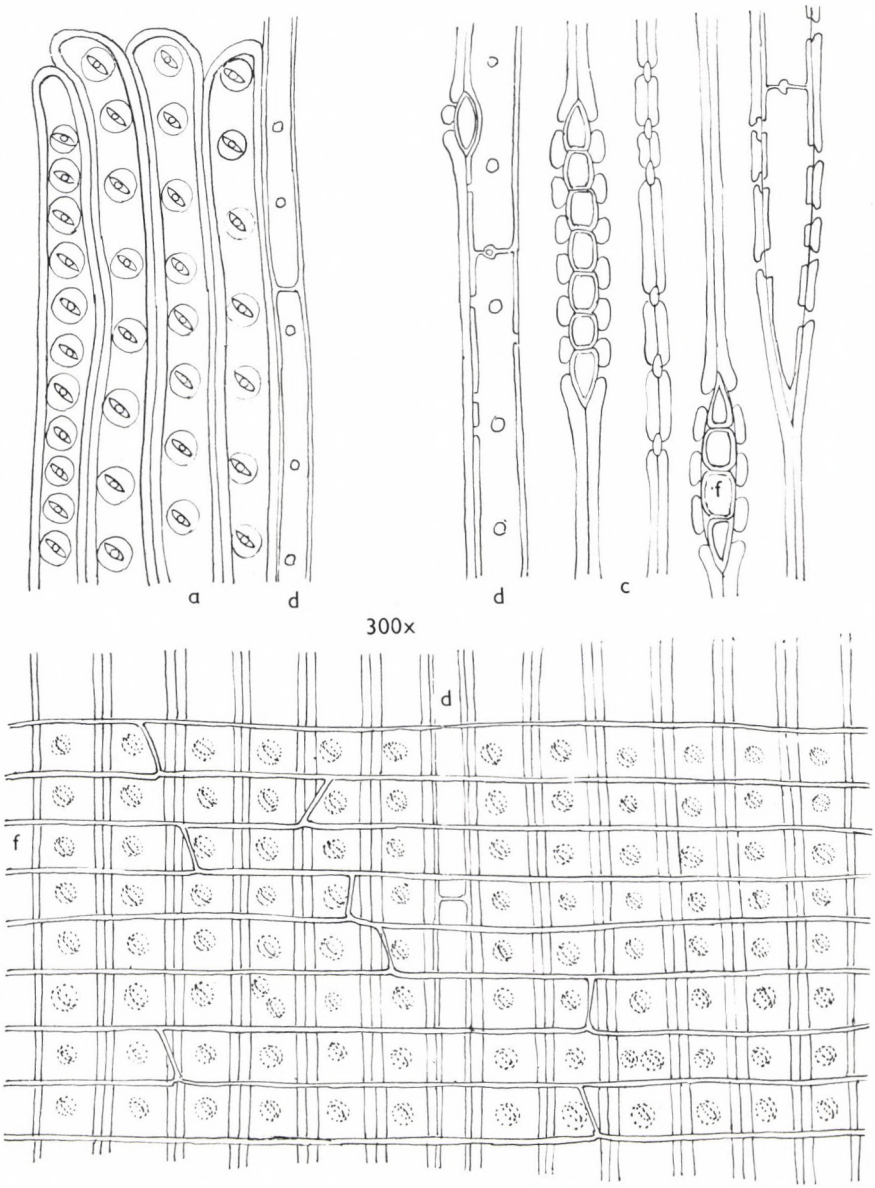
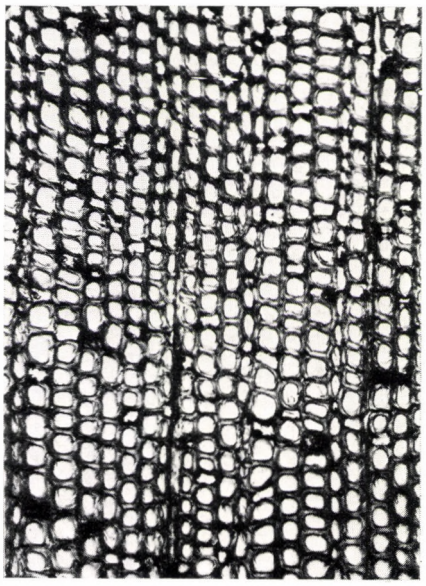


Fig. 61. *Podocarpus vieillardii* Parlatore



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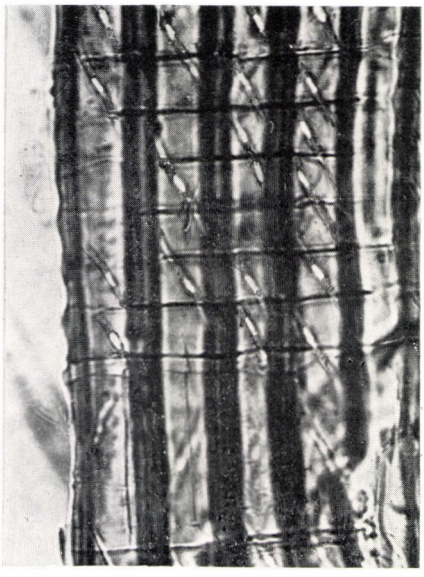
2.(×100)



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4.(×300)

LXXXII. *Podocarpus vitiensis* Seemann

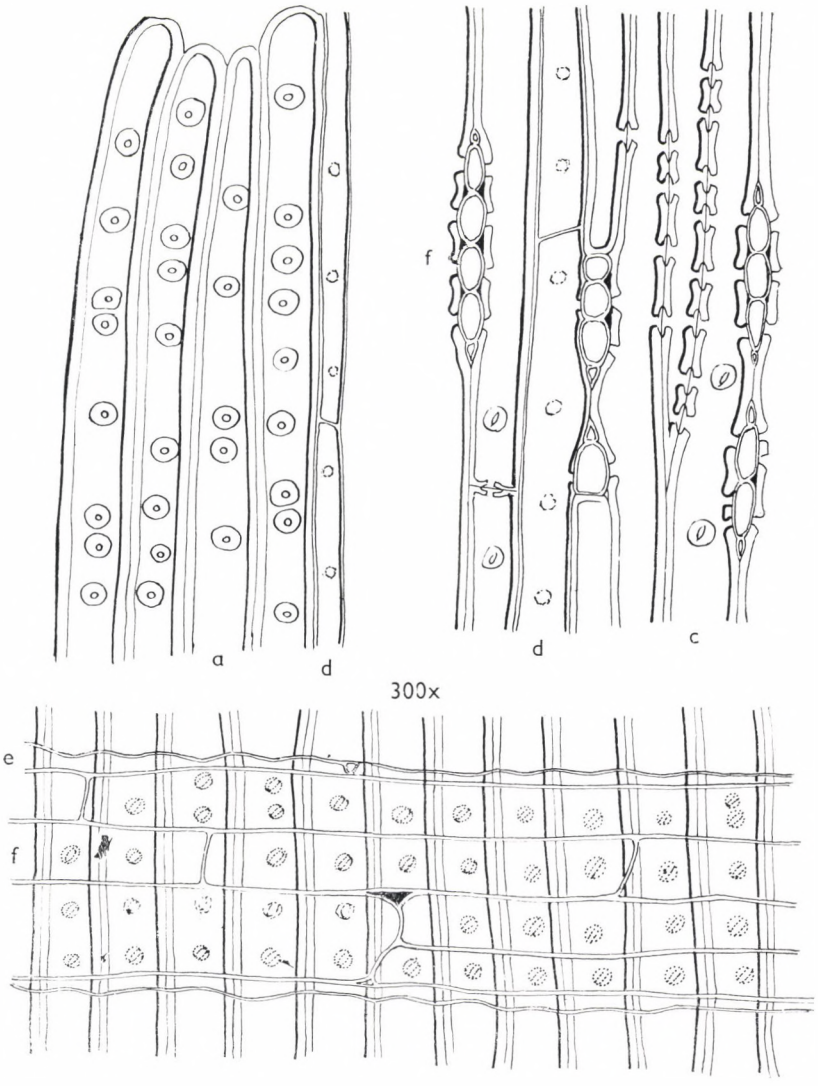
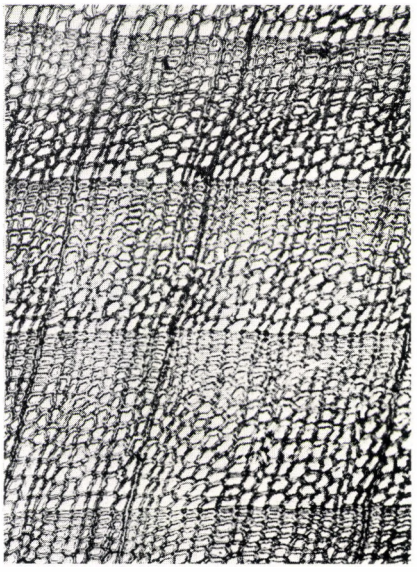


Fig. 62. *Podocarpus vitiensis* Seemann



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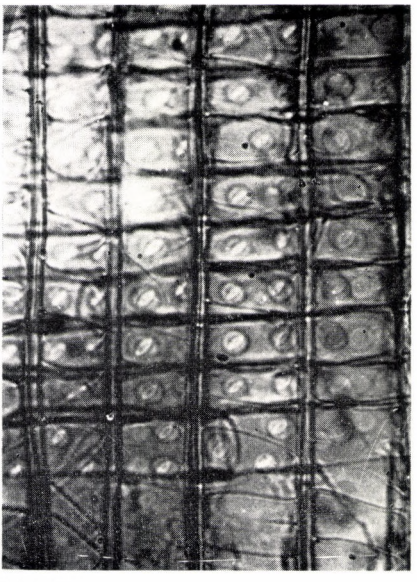

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4.(x 300)

LXXXIII. *Taxus floridana* Chapman

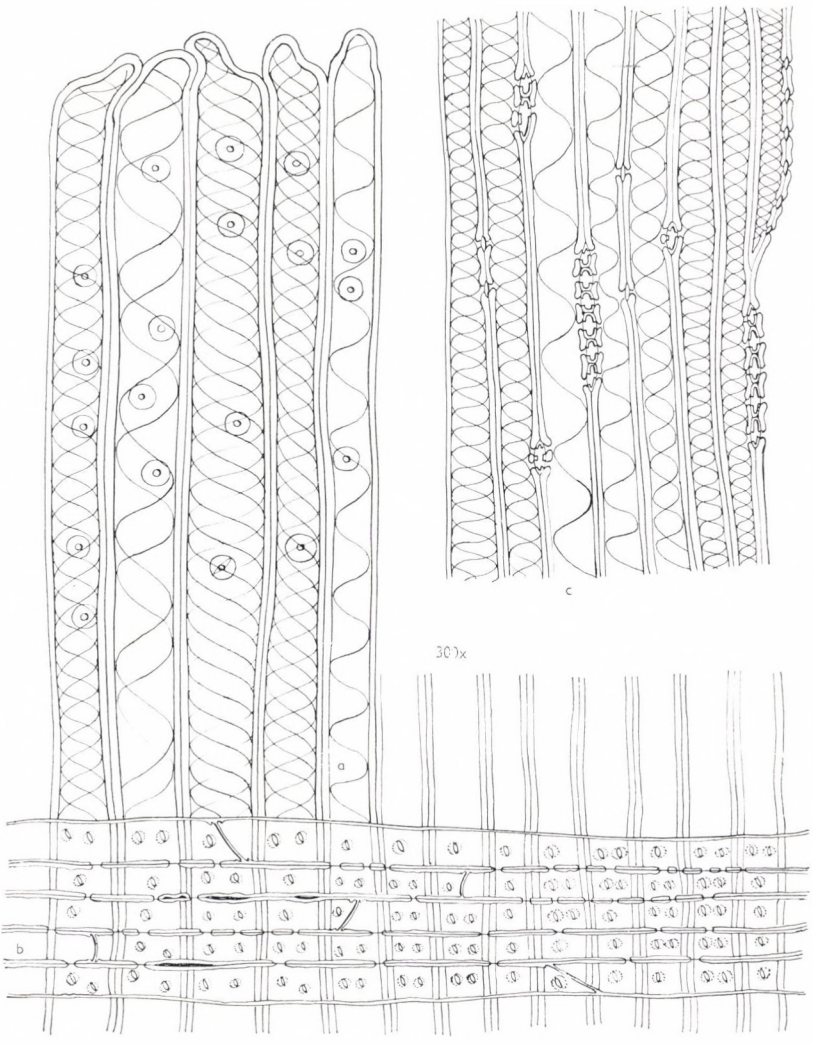
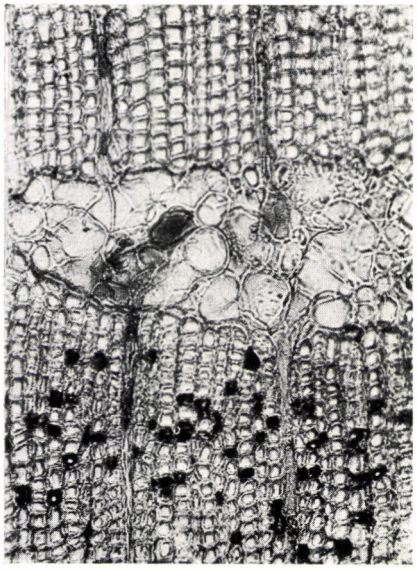


Fig. 63. *Taxus floridana* Chapman



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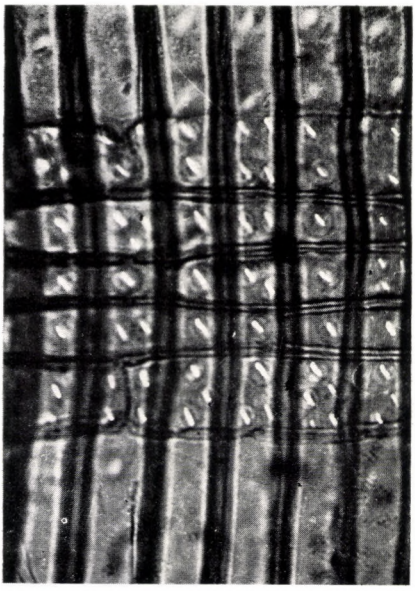

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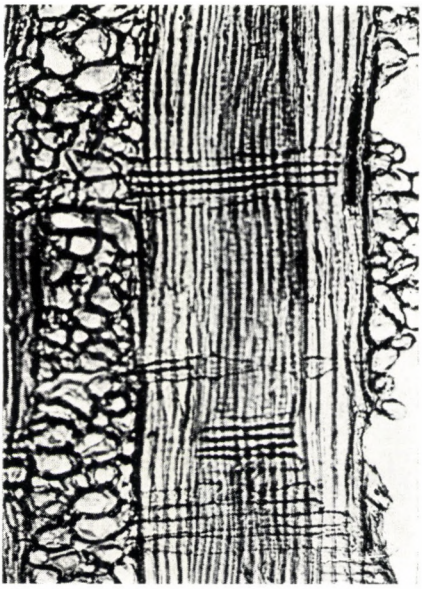

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LXXXIV. *Callitris drummondii* Benth. and Hooker fil.

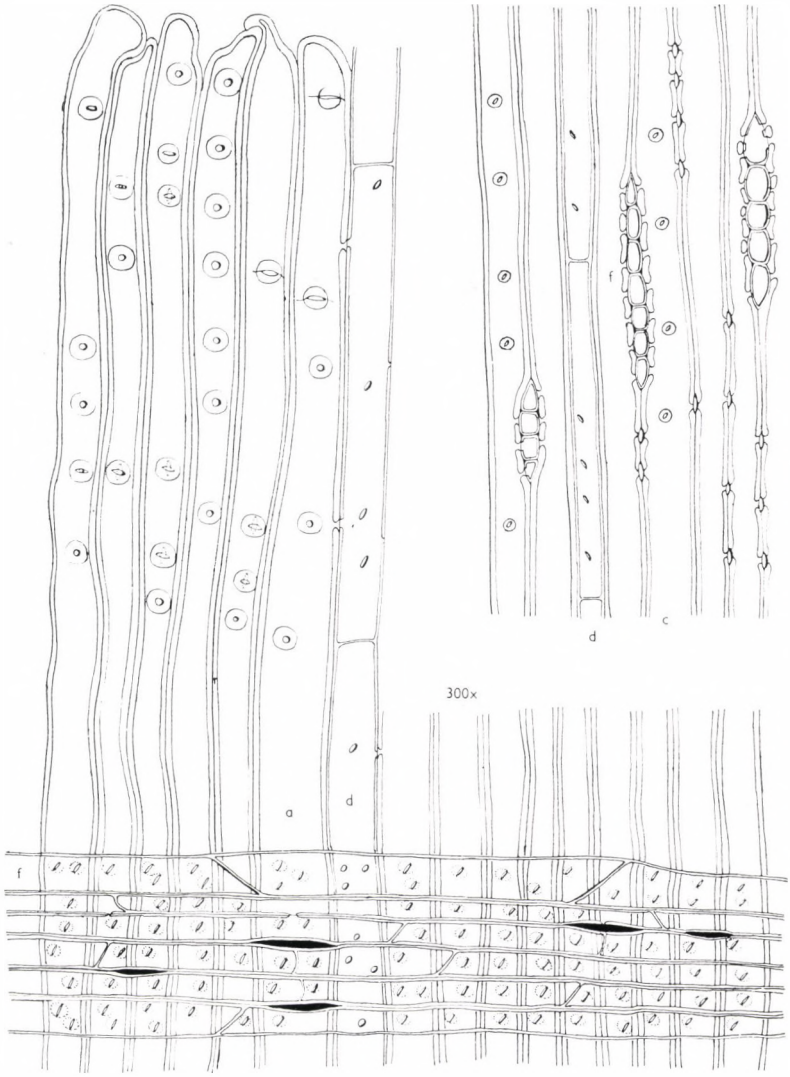
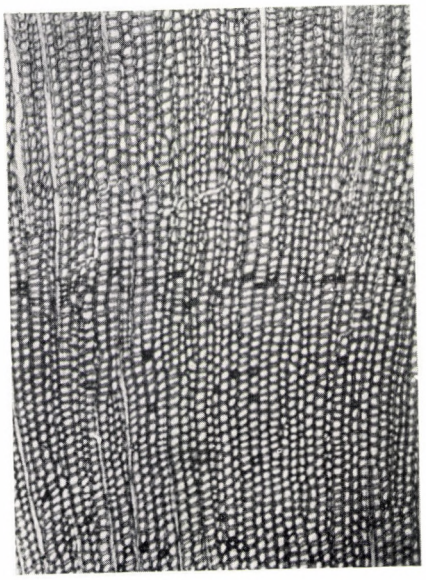


Fig. 64. *Callitris drummondii* Benth. and Hooker fil.



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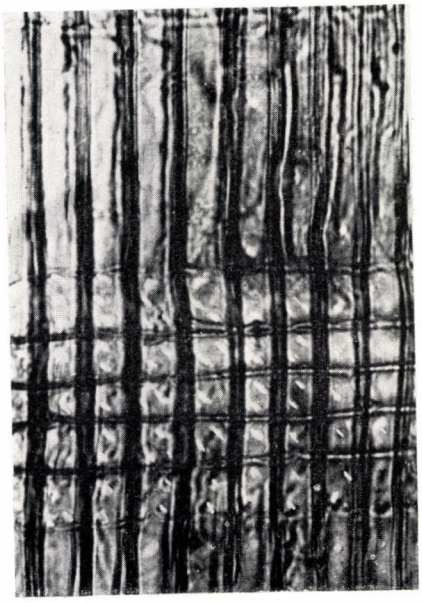


3.(x300)

4.(x350)

LXXXV. *Callitris morrisoni* R.T. Baker

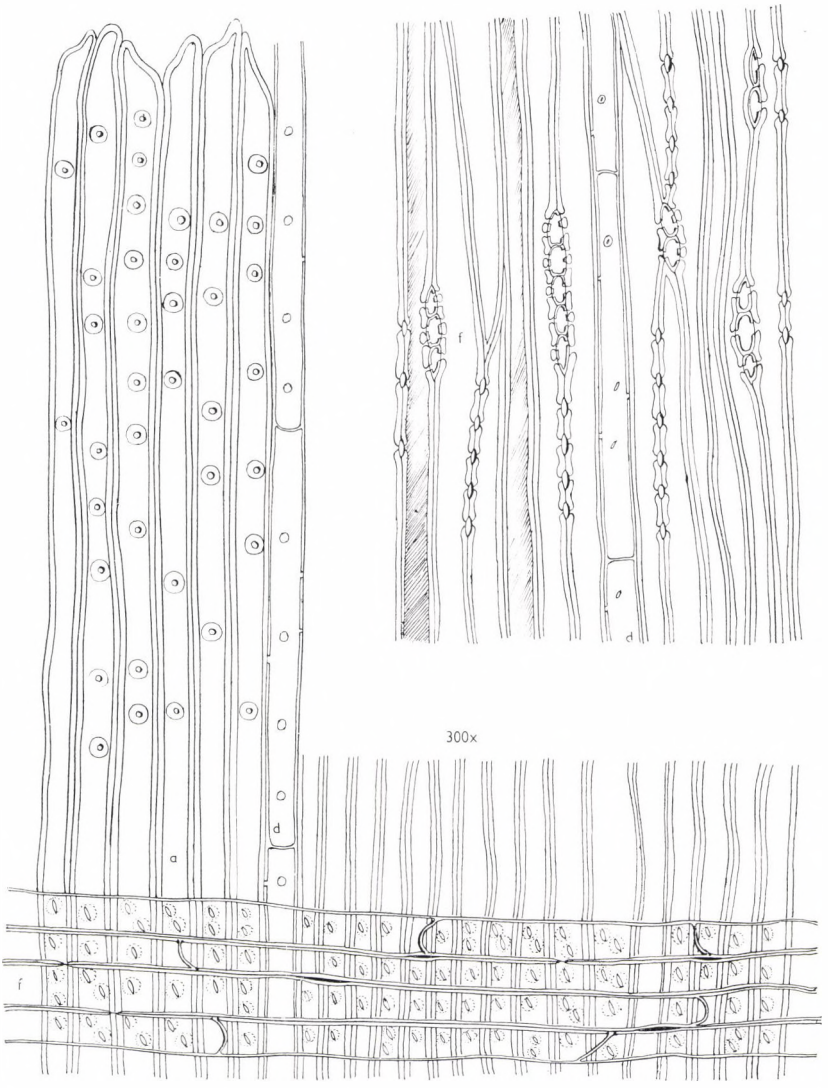
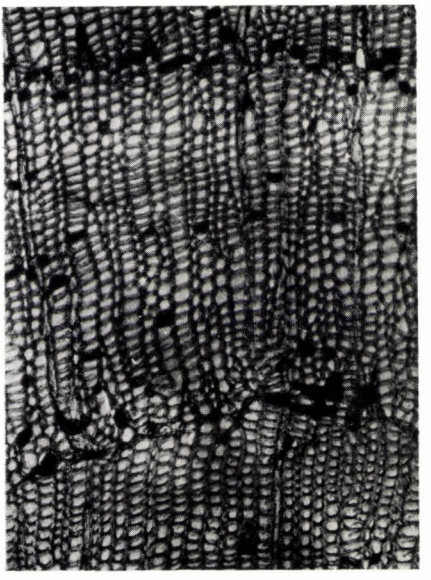


Fig. 65. *Callitris morrisoni* R.T. Baker



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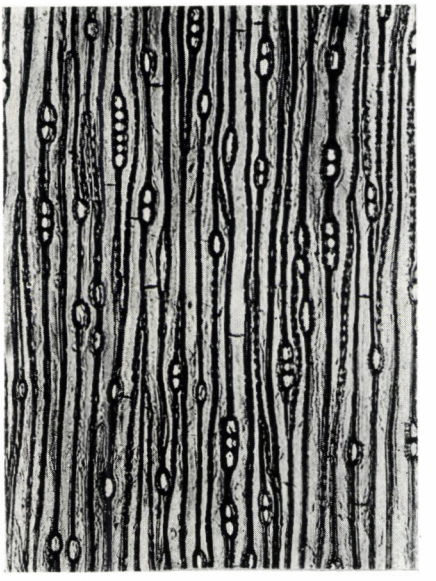

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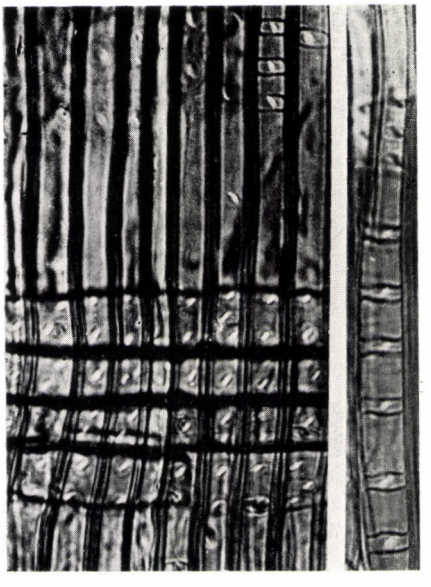

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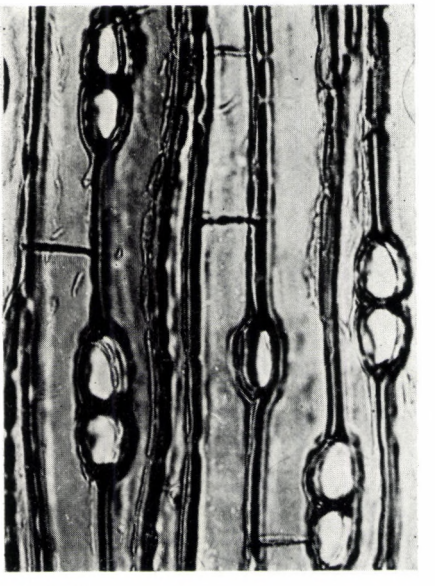


4.(× 300)

LXXXVI. *Callitris preissii* Miq.

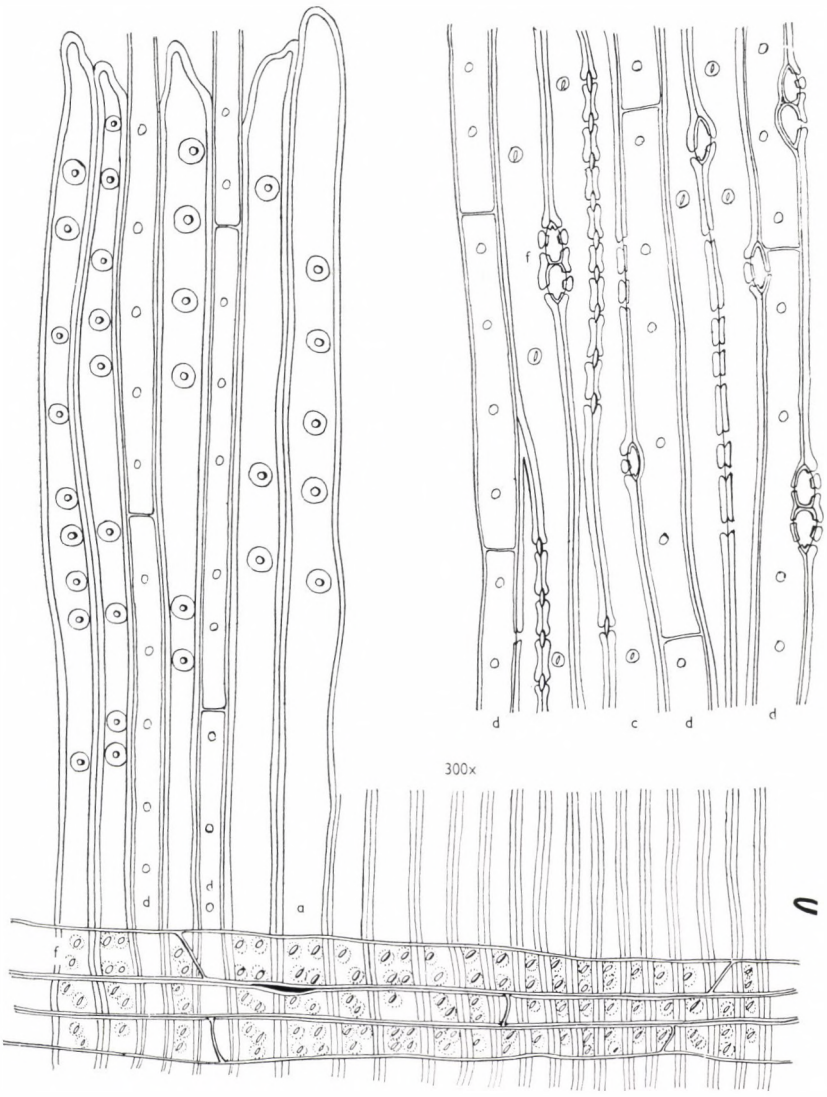
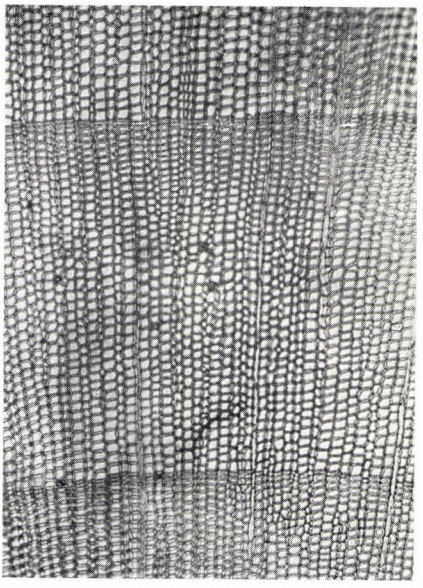


Fig. 66. *Callitris preissii* Miq.



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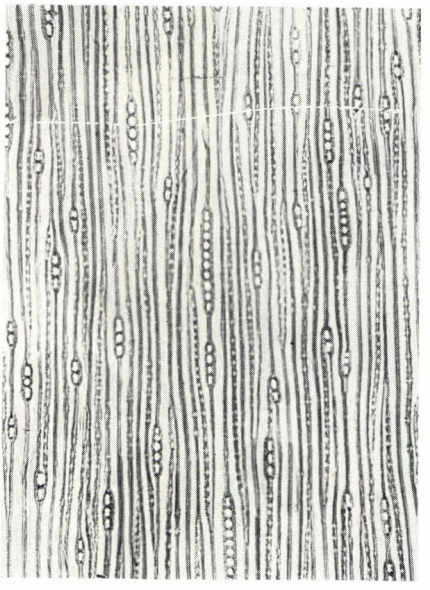

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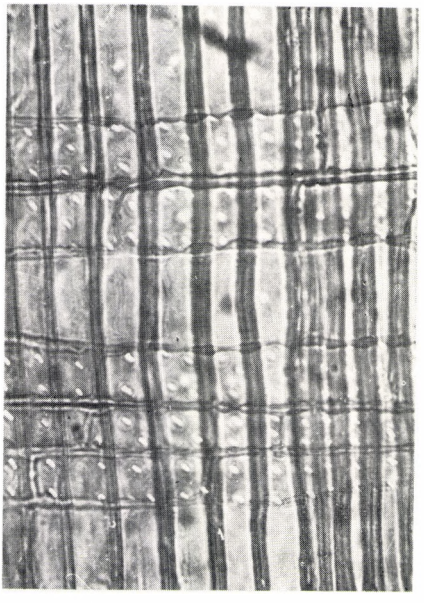

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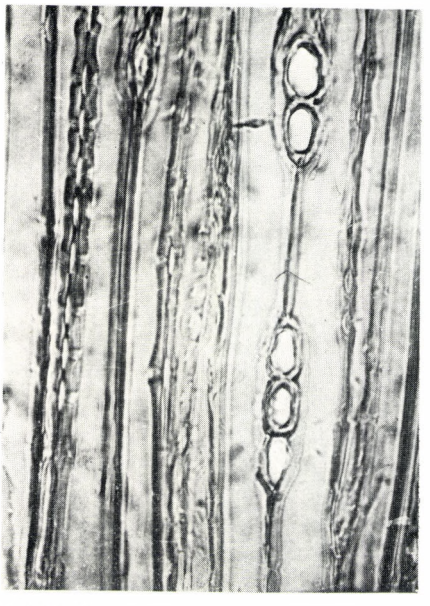

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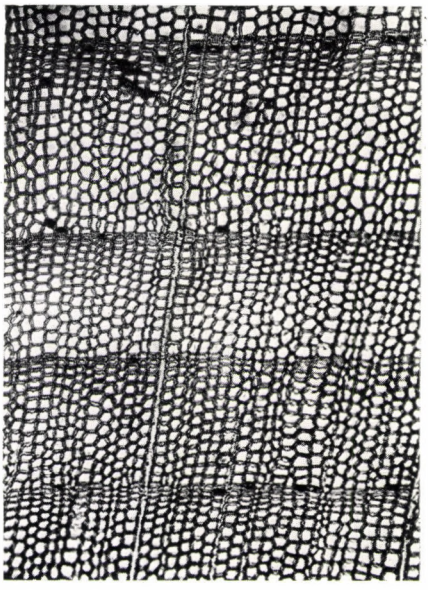
LXXXVII. *Cupressus arizonica* var. *bonita* Lemmon

Fig. 67. *Cupressus arizonica* var. *bonita* Lemmon



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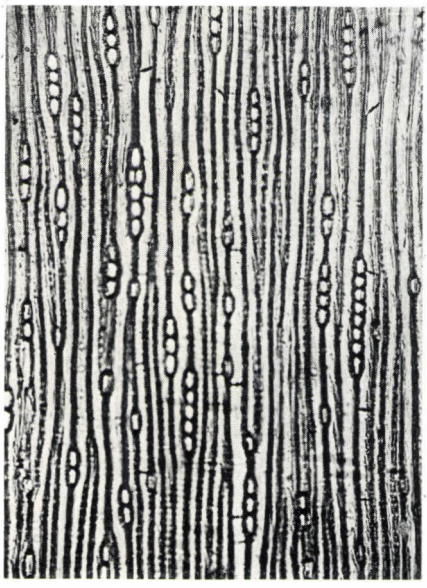

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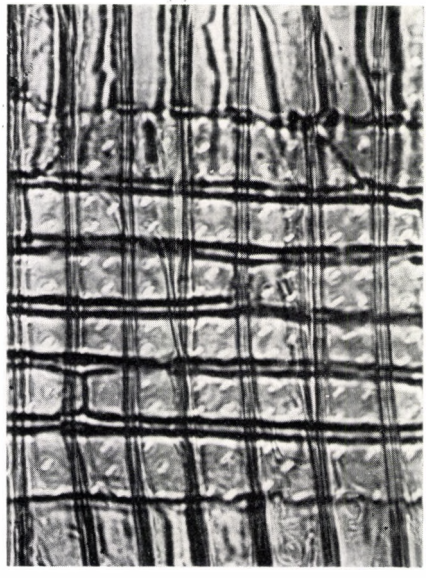

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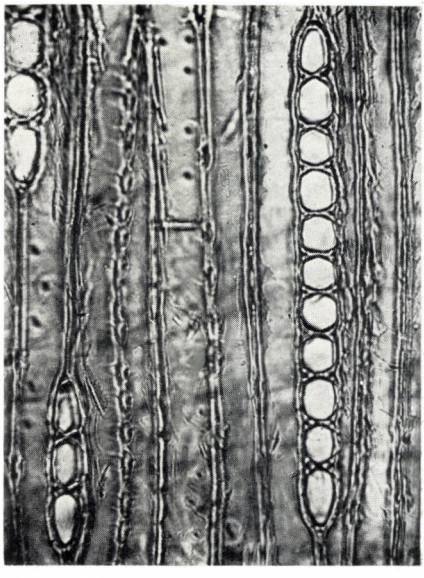


4.(x 300)

LXXXVIII. *Cupressus dupreziana* Camus

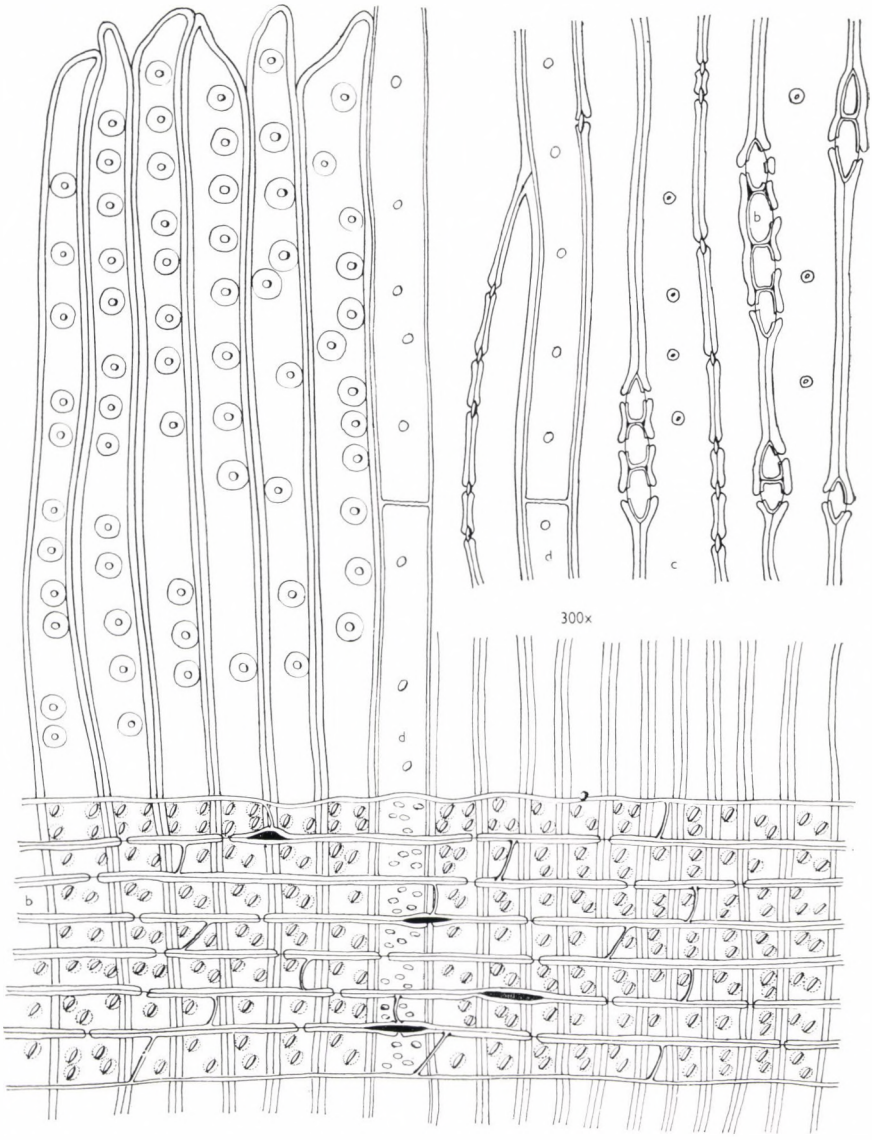
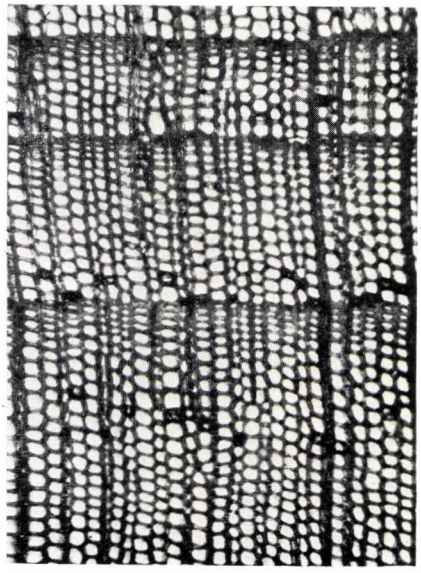


Fig. 68. *Cupressus dupreziana* Camus



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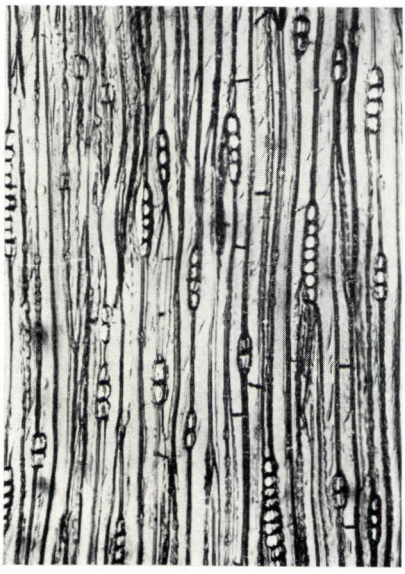

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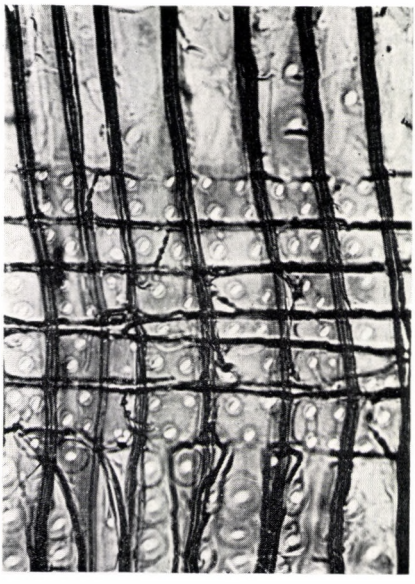

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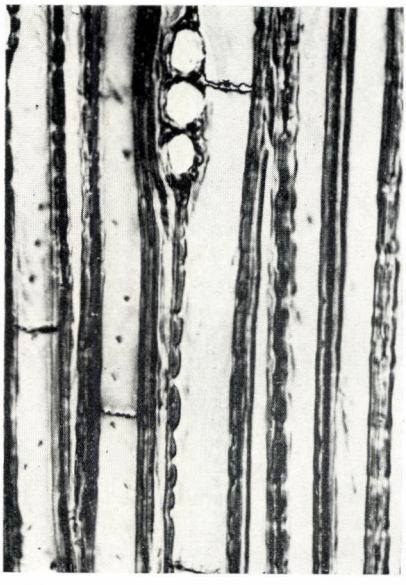

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LXXXIX. *Cupressus forbesii* Jepson

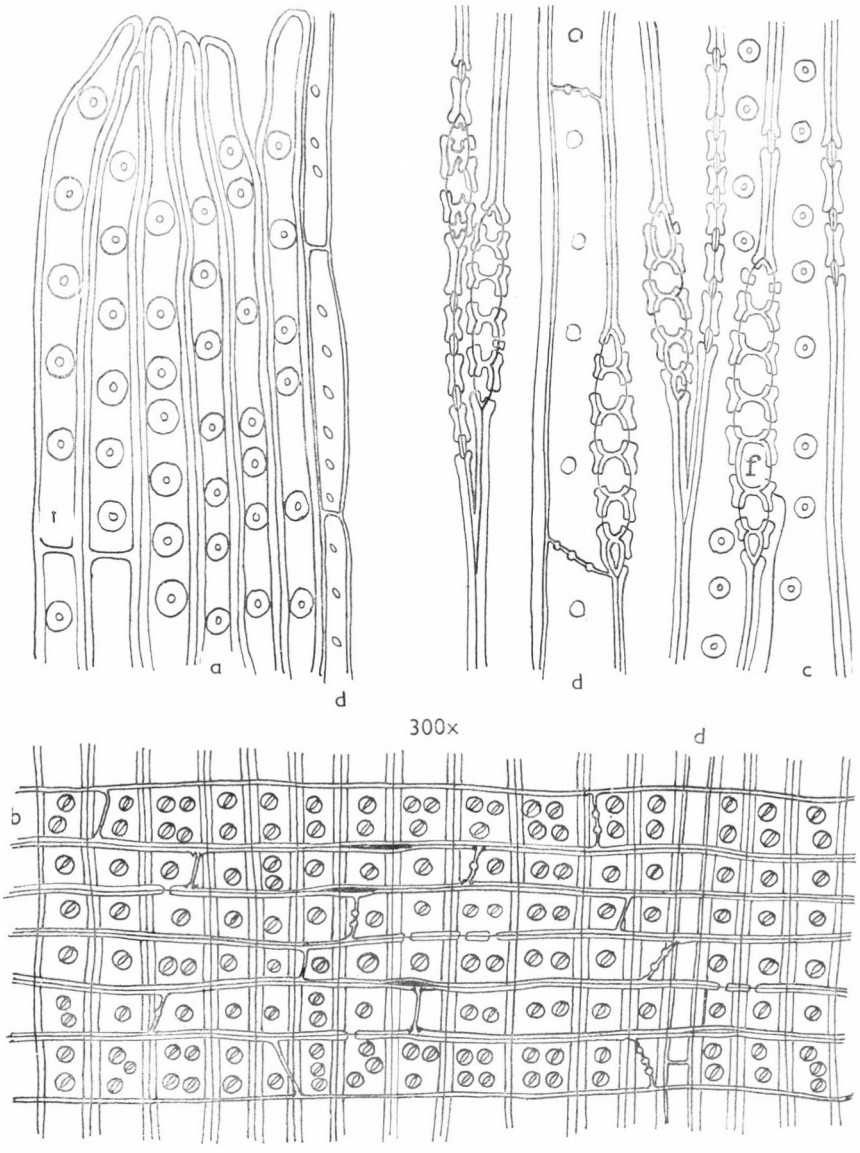
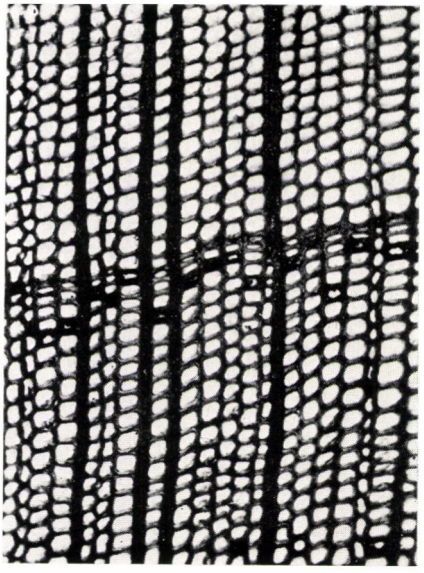


Fig. 69. *Cupressus forbesii* Jepson



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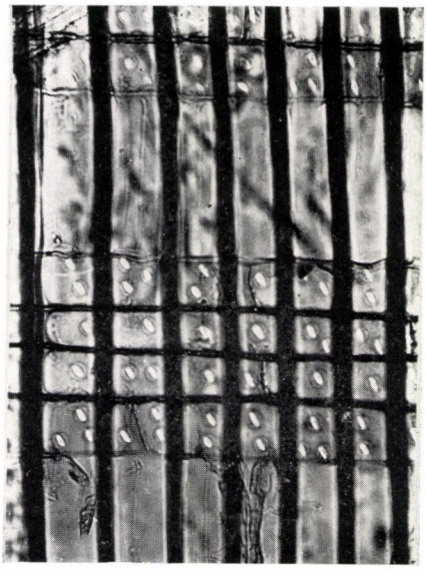
2.(x100)



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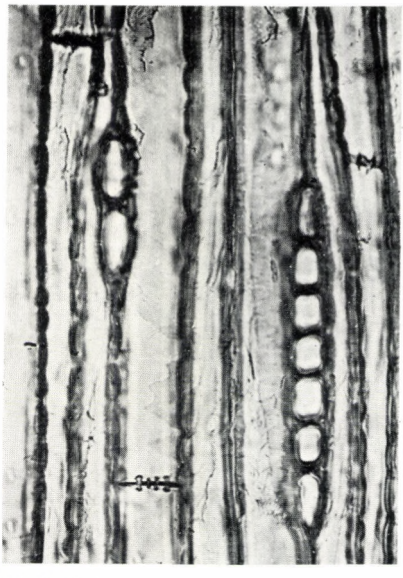


4(x300)

XC. *Heyderia formacrolepis* L.

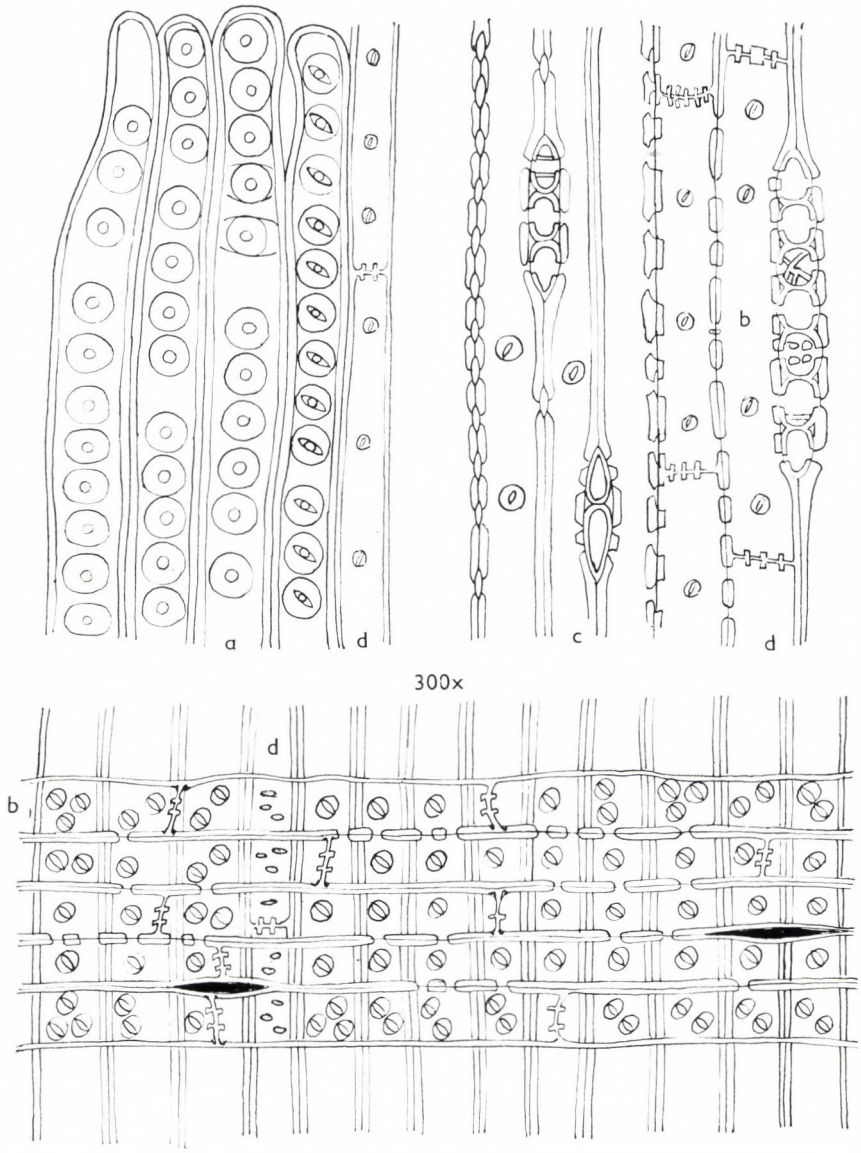
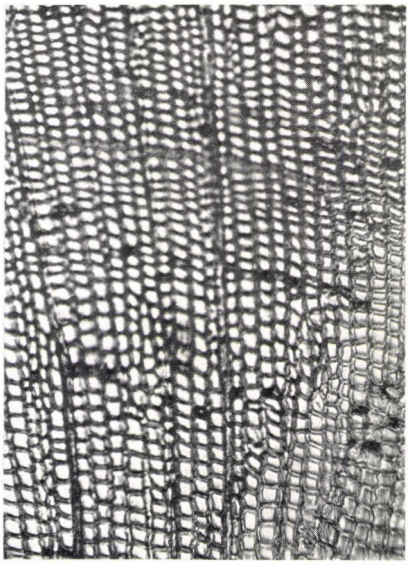


Fig. 70. *Heyderia formacrolepis* L.



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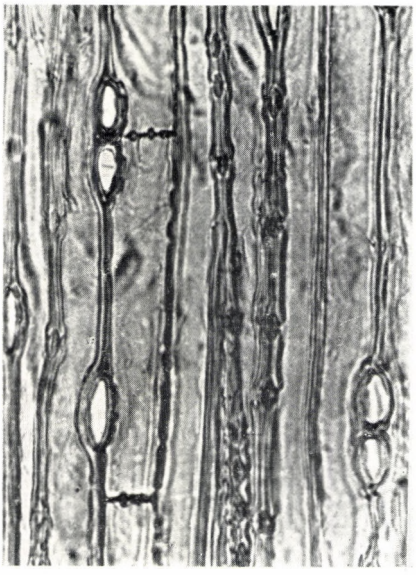
2.(×100)

3.(×300)



4.(×300)

XCI. *Juniperus brevifolia* Antoine

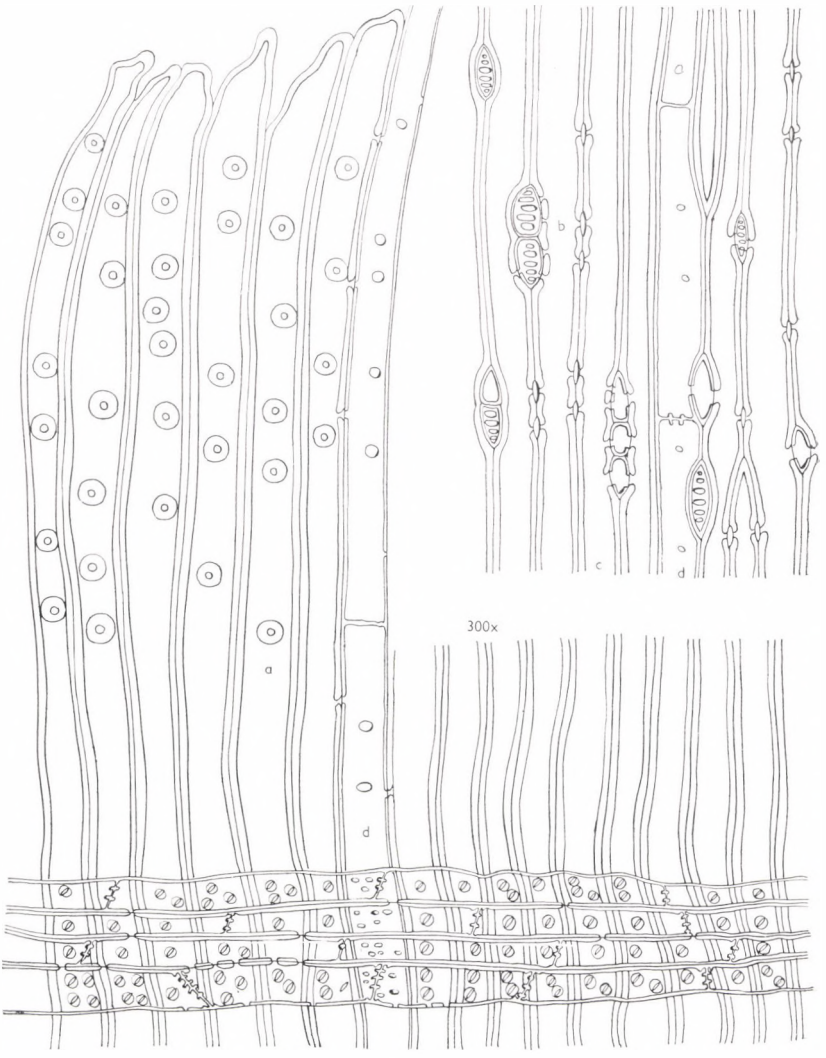
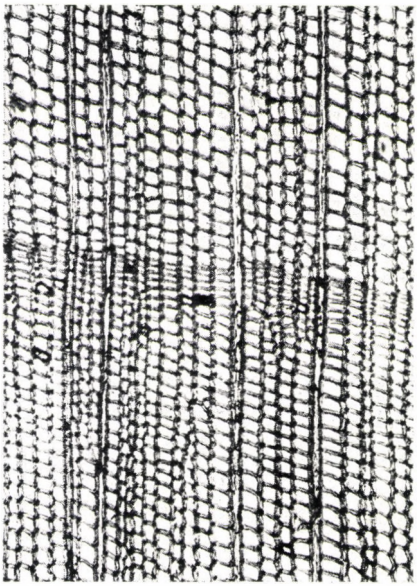


Fig. 71. *Juniperus brevifolia* Antoine



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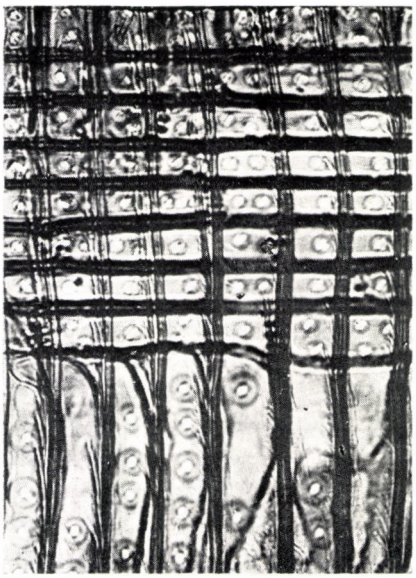
2. (x100)



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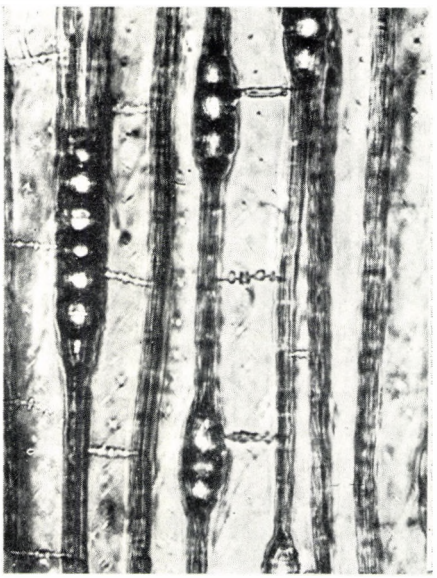


4(x300)

XCII. *Juniperus cedrus* Webb and Berthelot

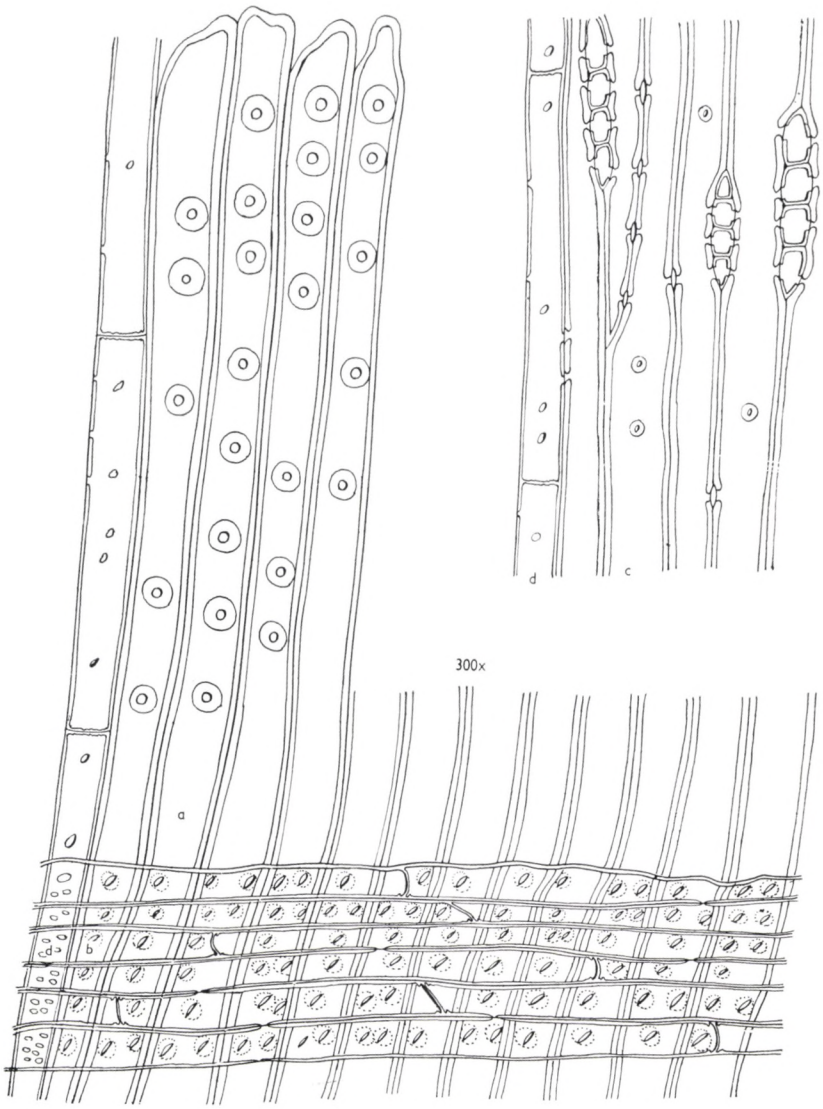
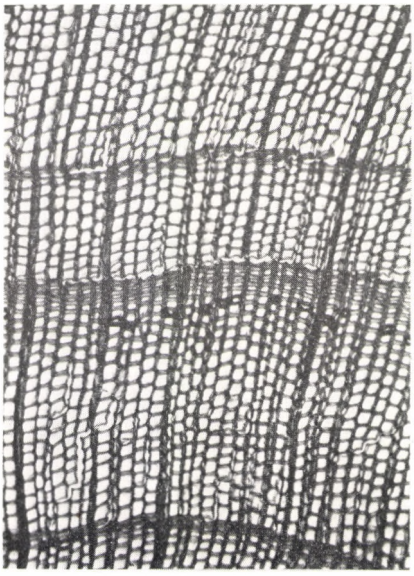


Fig. 72. *Juniperus cedrus* Webb and Berthelot



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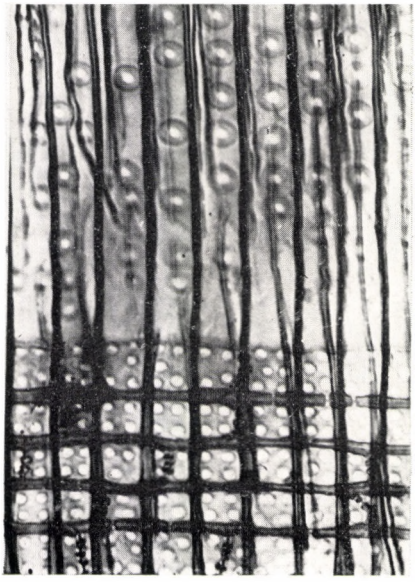
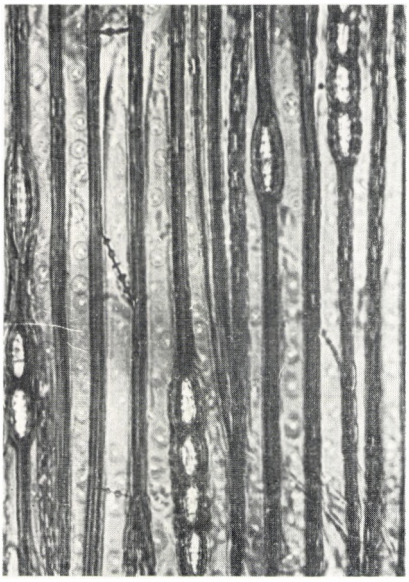
2.(×100)



3.(×300)



4.(×300)

XCIII. *Juniperus davurica* Pall.

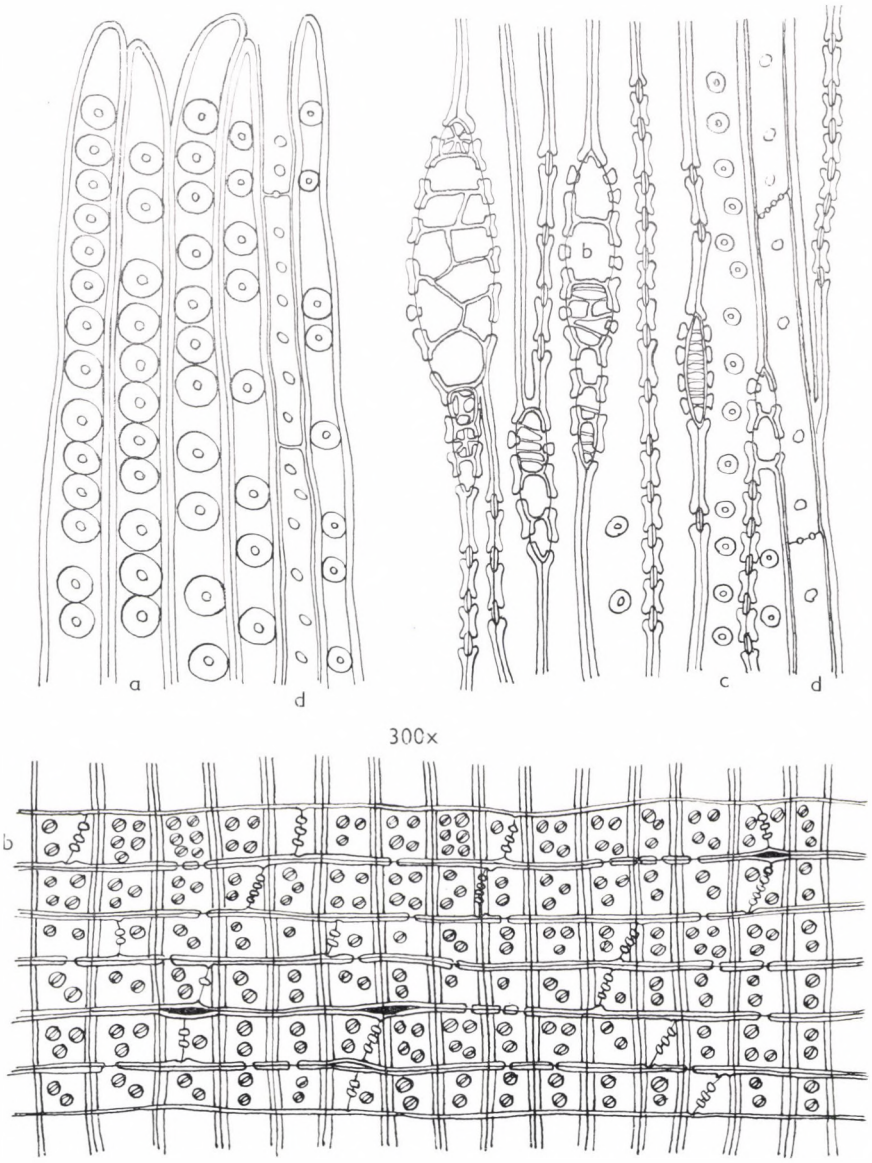
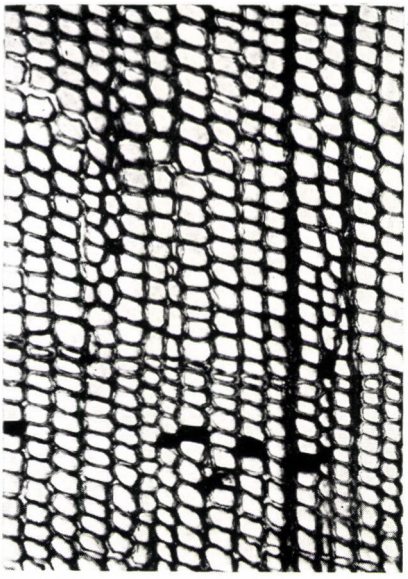


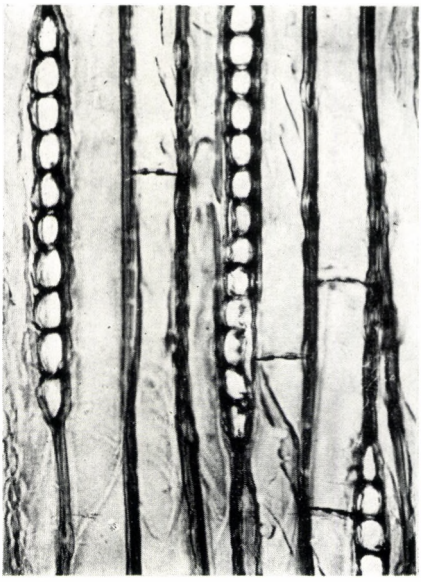
Fig. 73. *Juniperus davurica* Pall.



1. (×100)

2. (×100)

3. (×250)



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XCIV. *Juniperus flaccida* Schult.

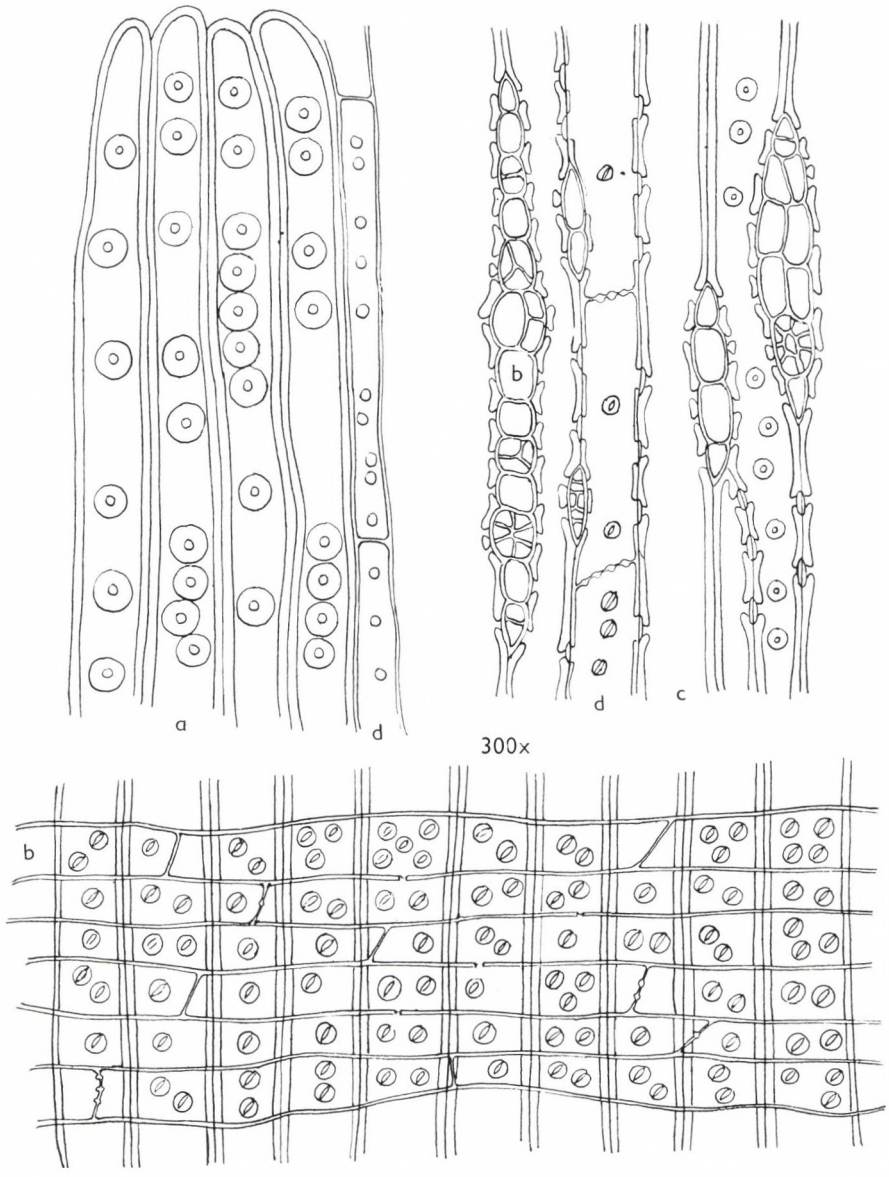
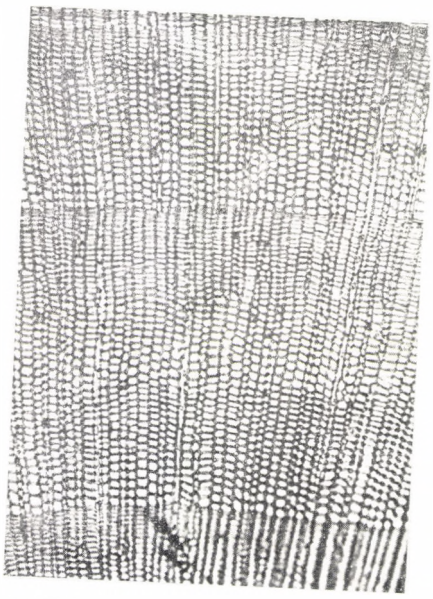


Fig. 74. *Juniperus flaccida* Schult.



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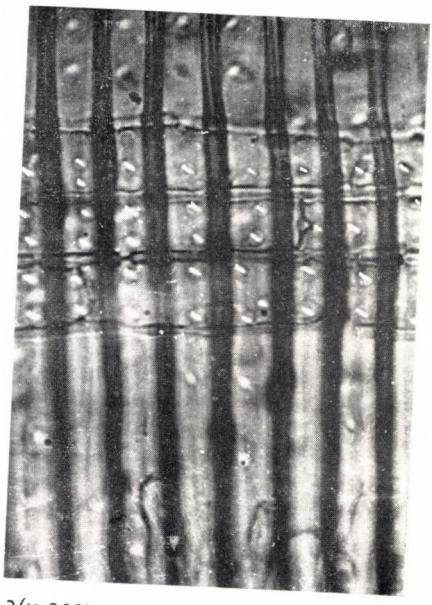
2.(×100)



3.(× 300)

4.(×300)

XCV. *Juniperus isophyllos* C. Koch

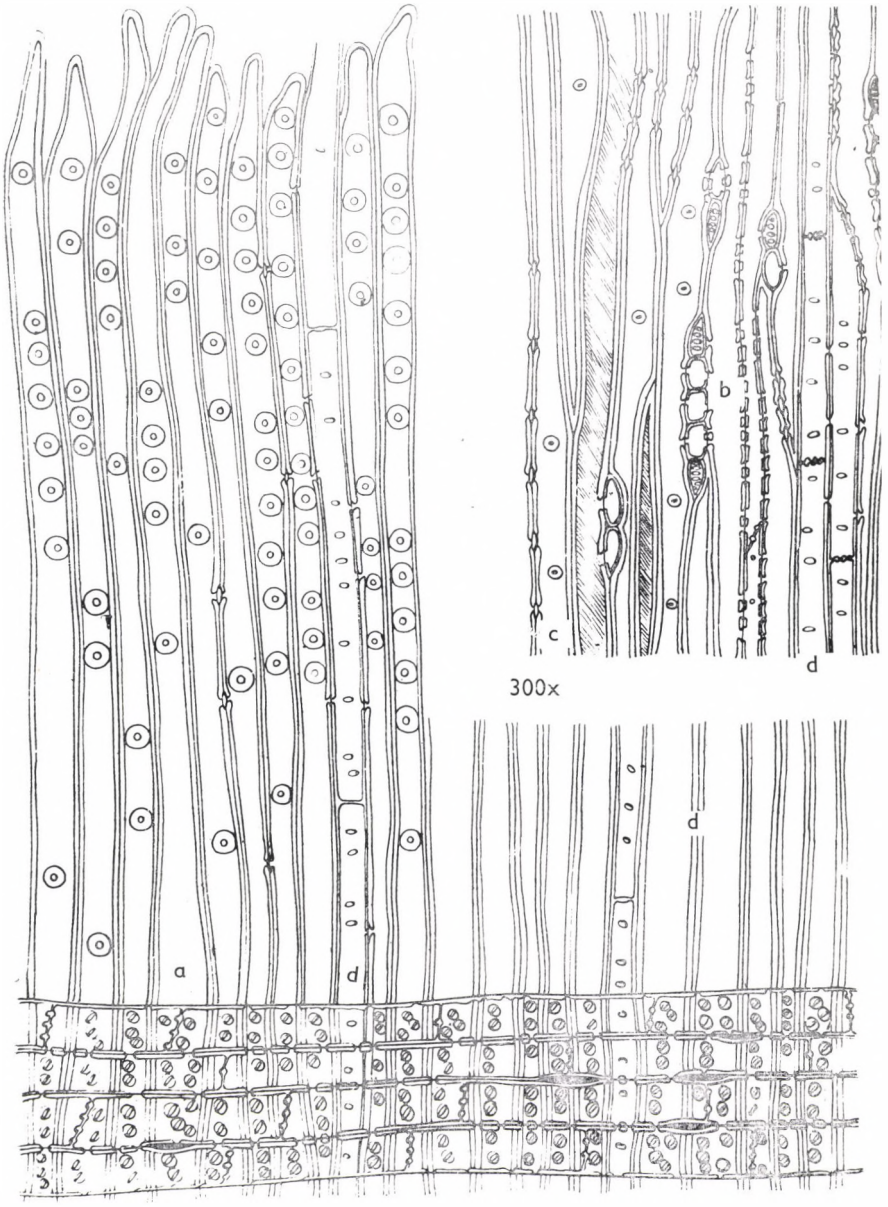
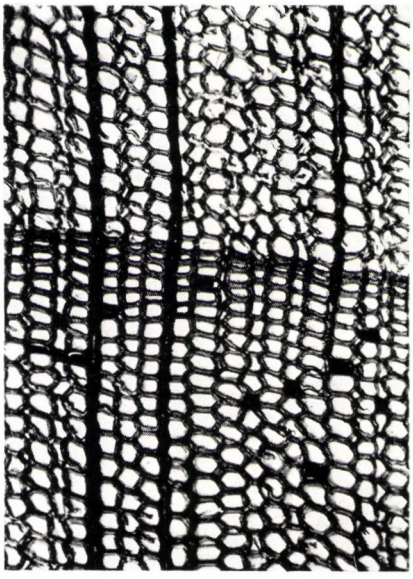


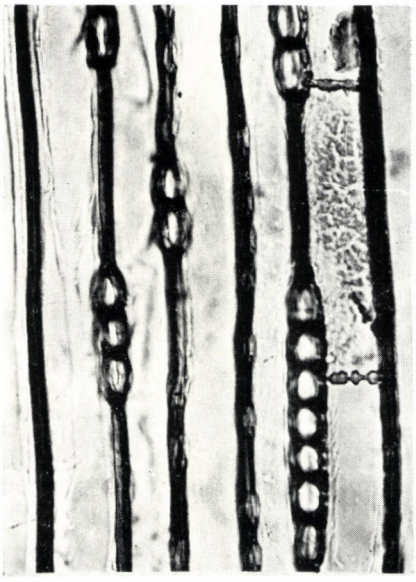
Fig. 75. *Juniperus isophyllos* C. Koch



1. (×100)

2. (×100)

3. (× 300)



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XCVI. *Juniperus lucayana* Britt.

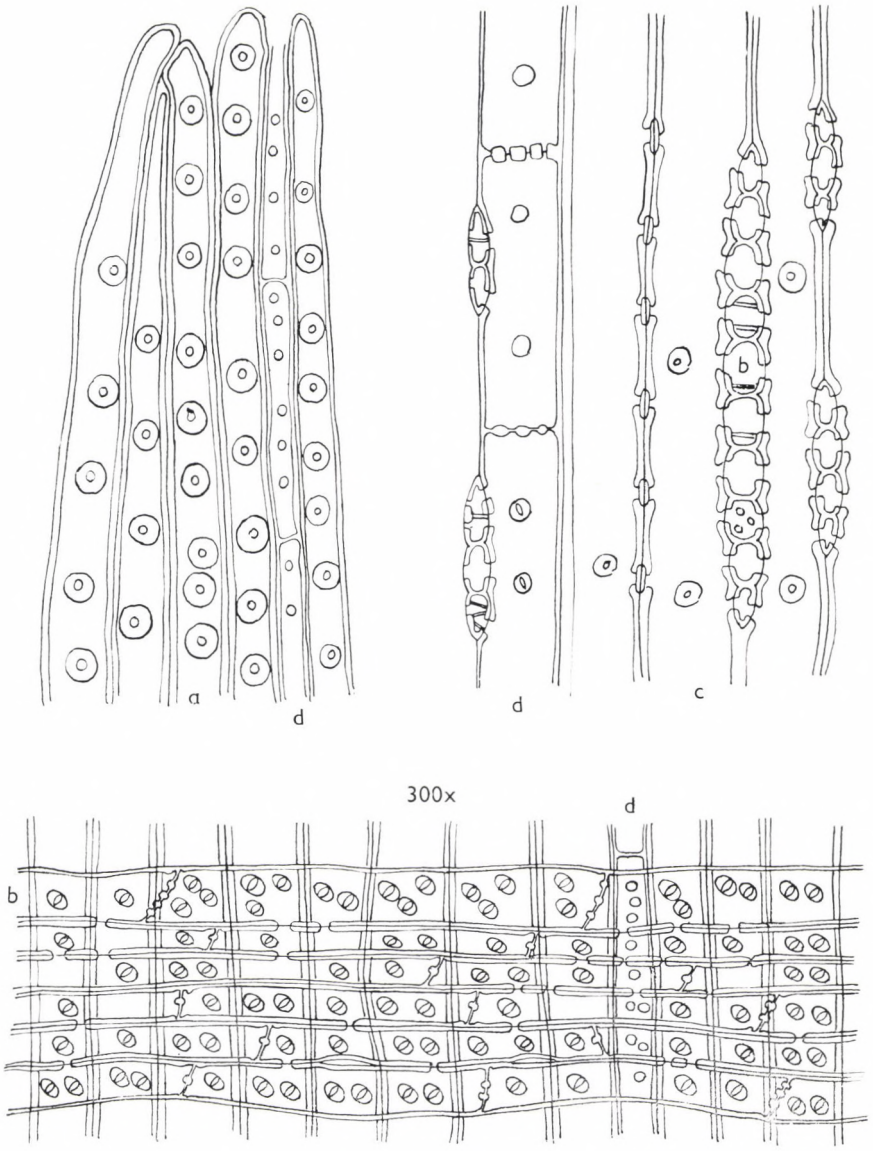
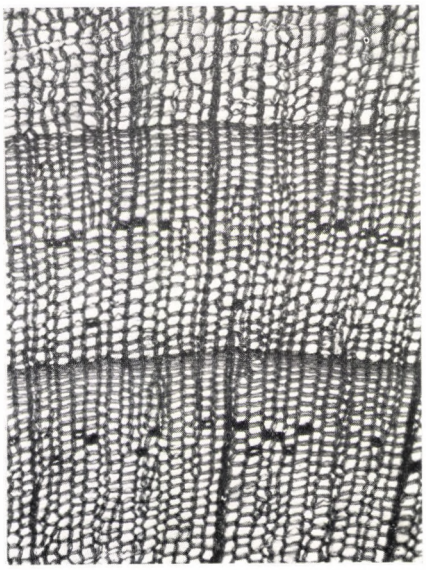


Fig. 76. *Juniperus lucayana* Britt.



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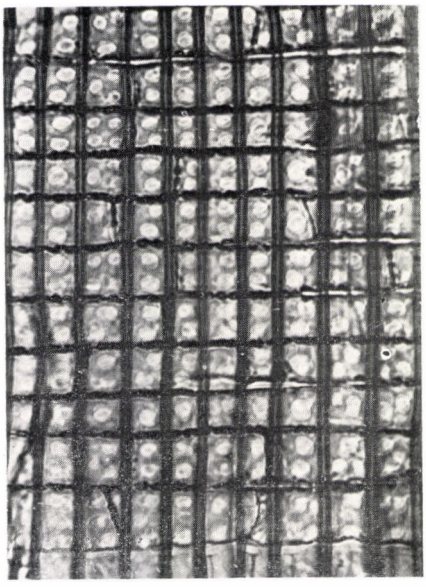
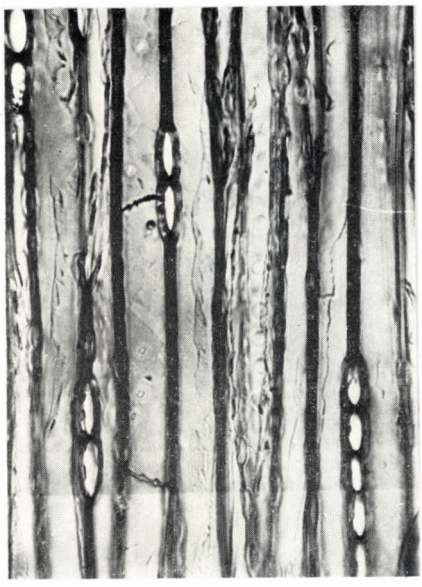
2.(x100)



3.(x 300)



4.(x300)

XCVII. *Juniperus oblonga* M.B.

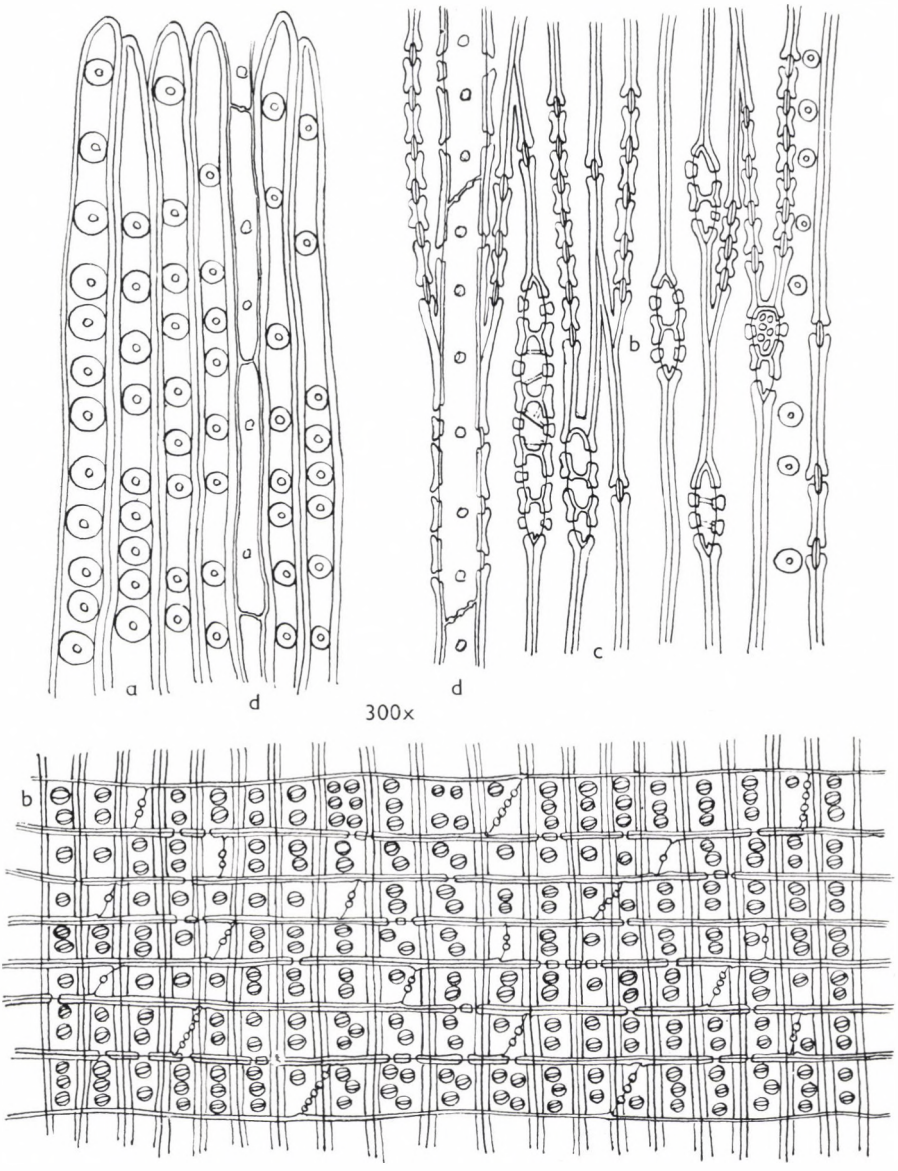


Fig. 77. *Juniperus oblonga* M.B.

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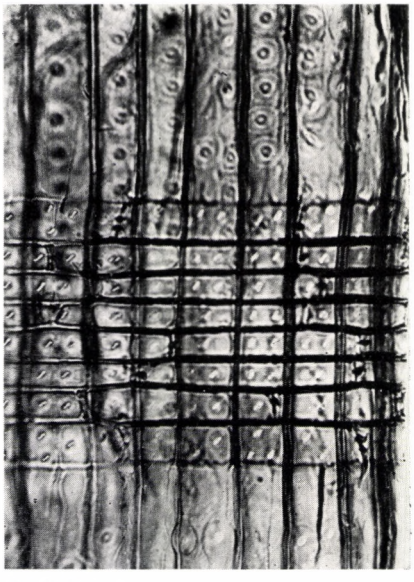
2.(×100)



3.(×300)

4.(×300)

XCVIII. *Juniperus polycarpos* C. Koch

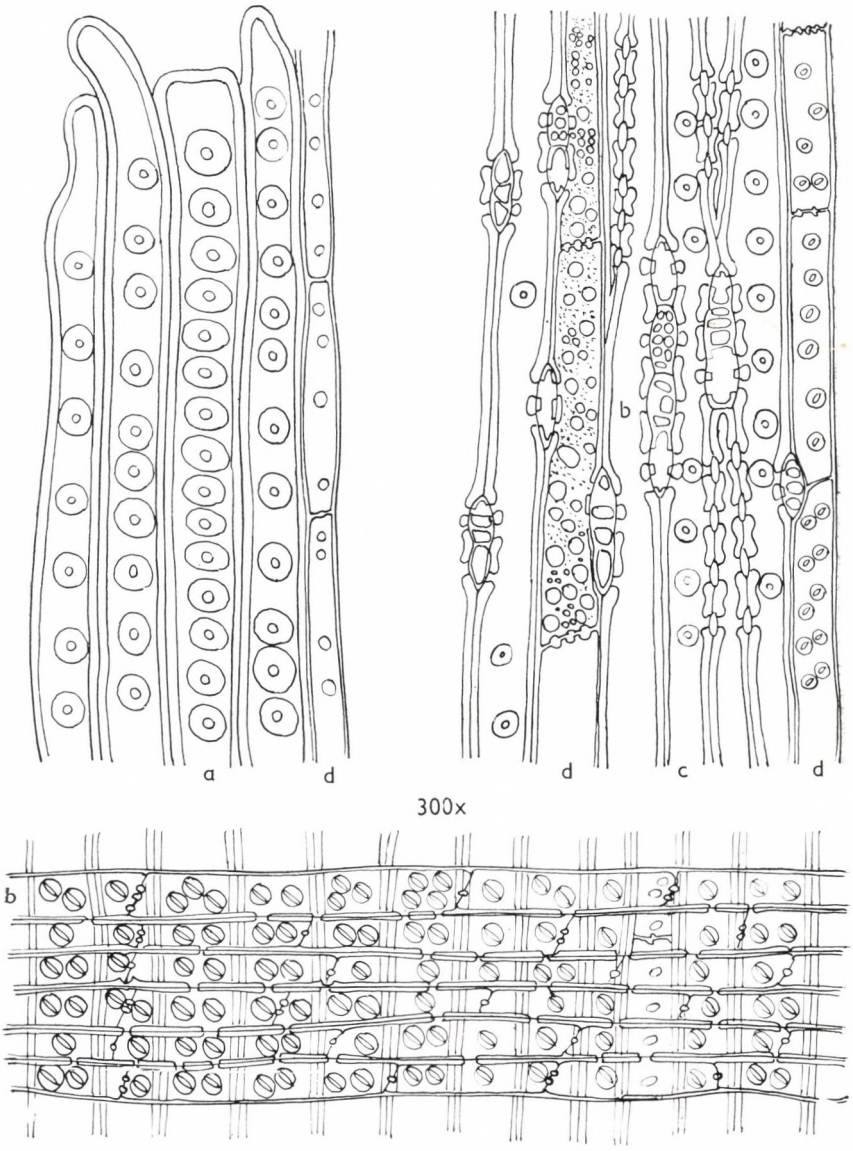
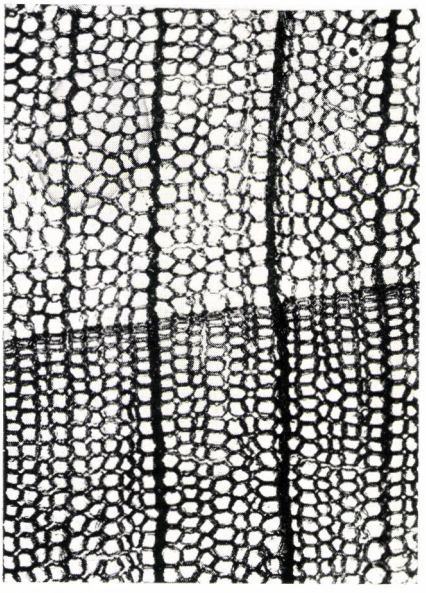


Fig. 78. *Juniperus polycarpos* C. Koch



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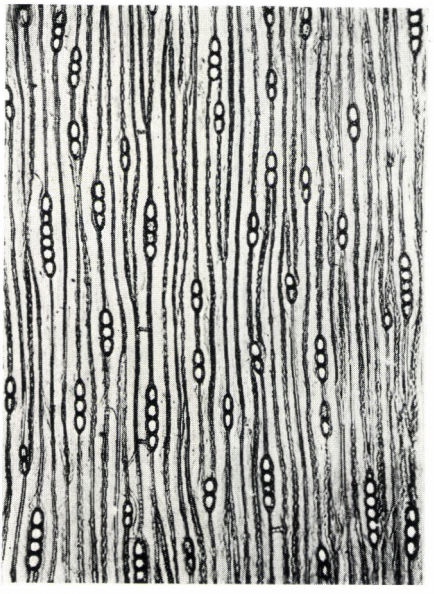

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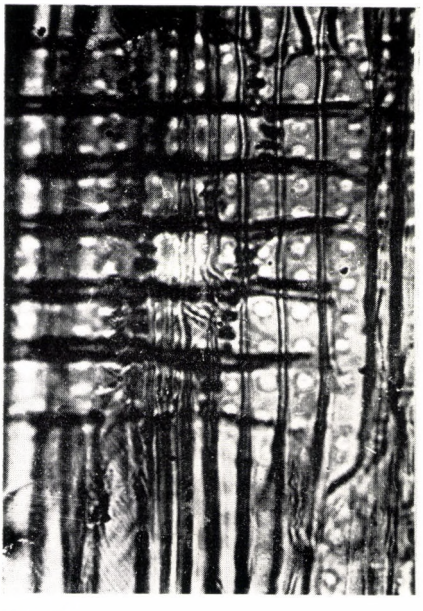

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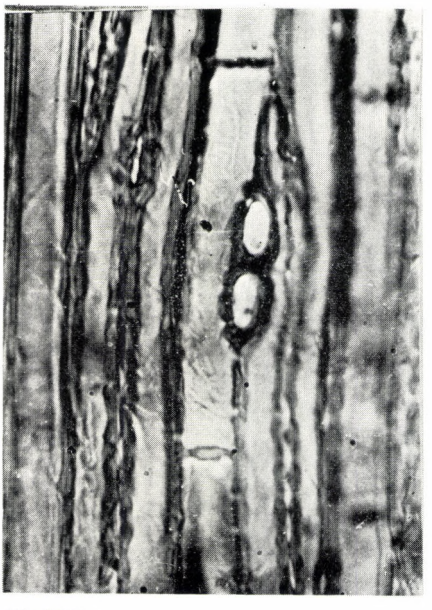


4.(×300)

XCIX. *Juniperus pseudosabina* Fisch and Meyer

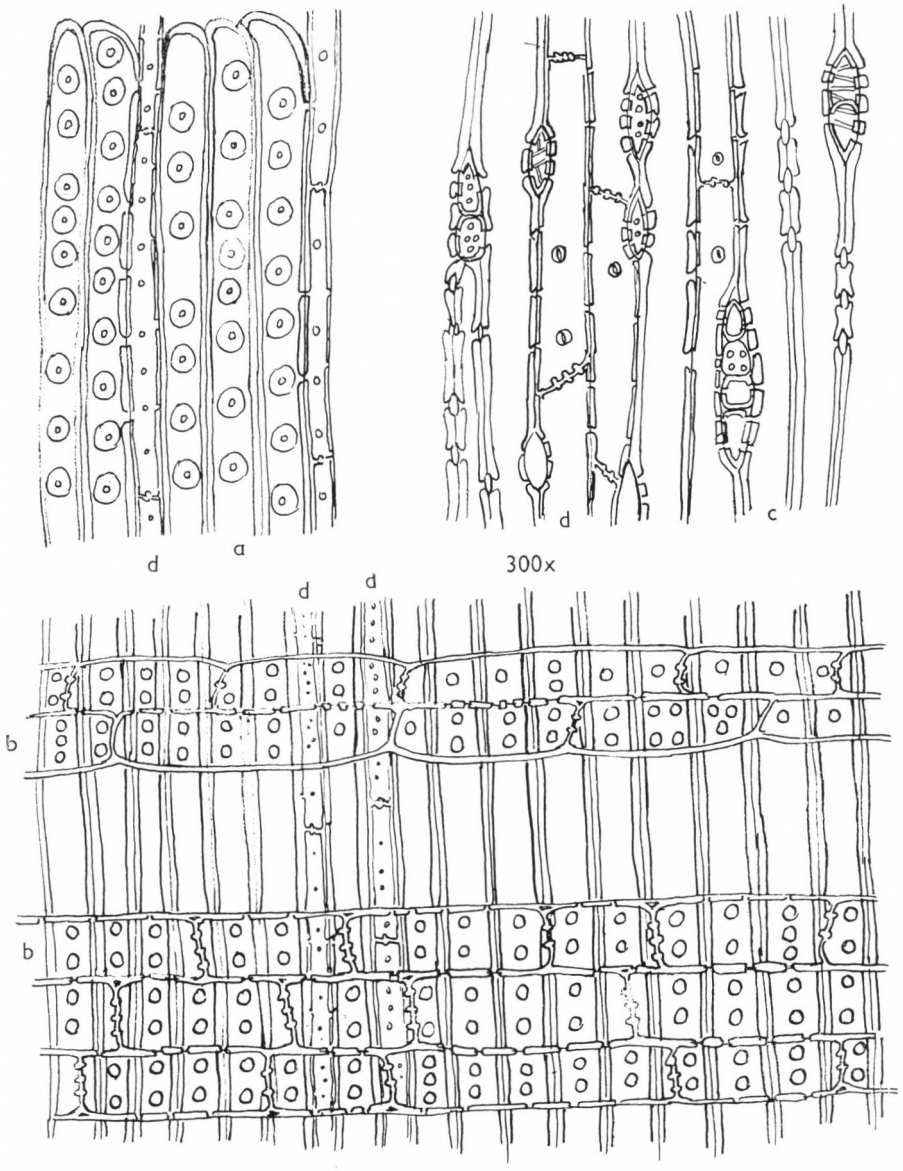
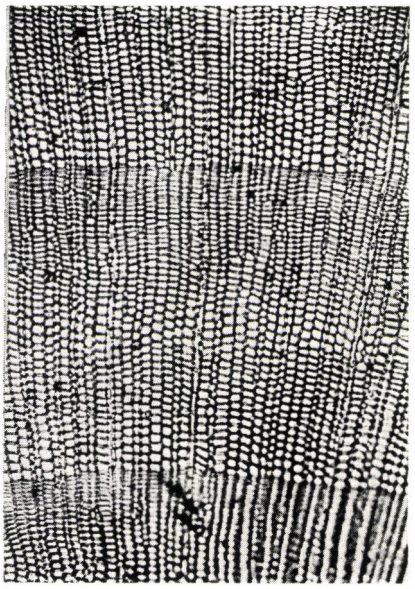


Fig. 79. *Juniperus pseudosabina* Fisch and Meyer



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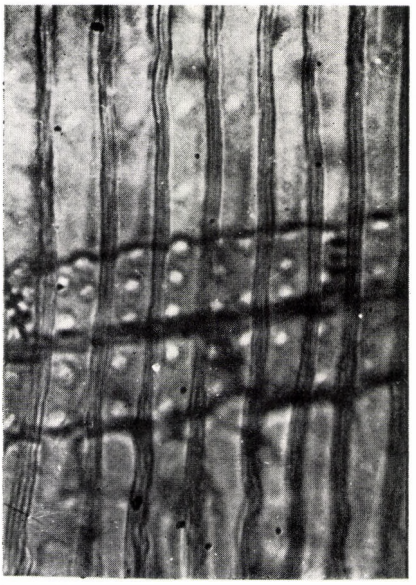
2.(×100)



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4.(×300)

C. *Juniperus sargentii* (Henry) Takeda

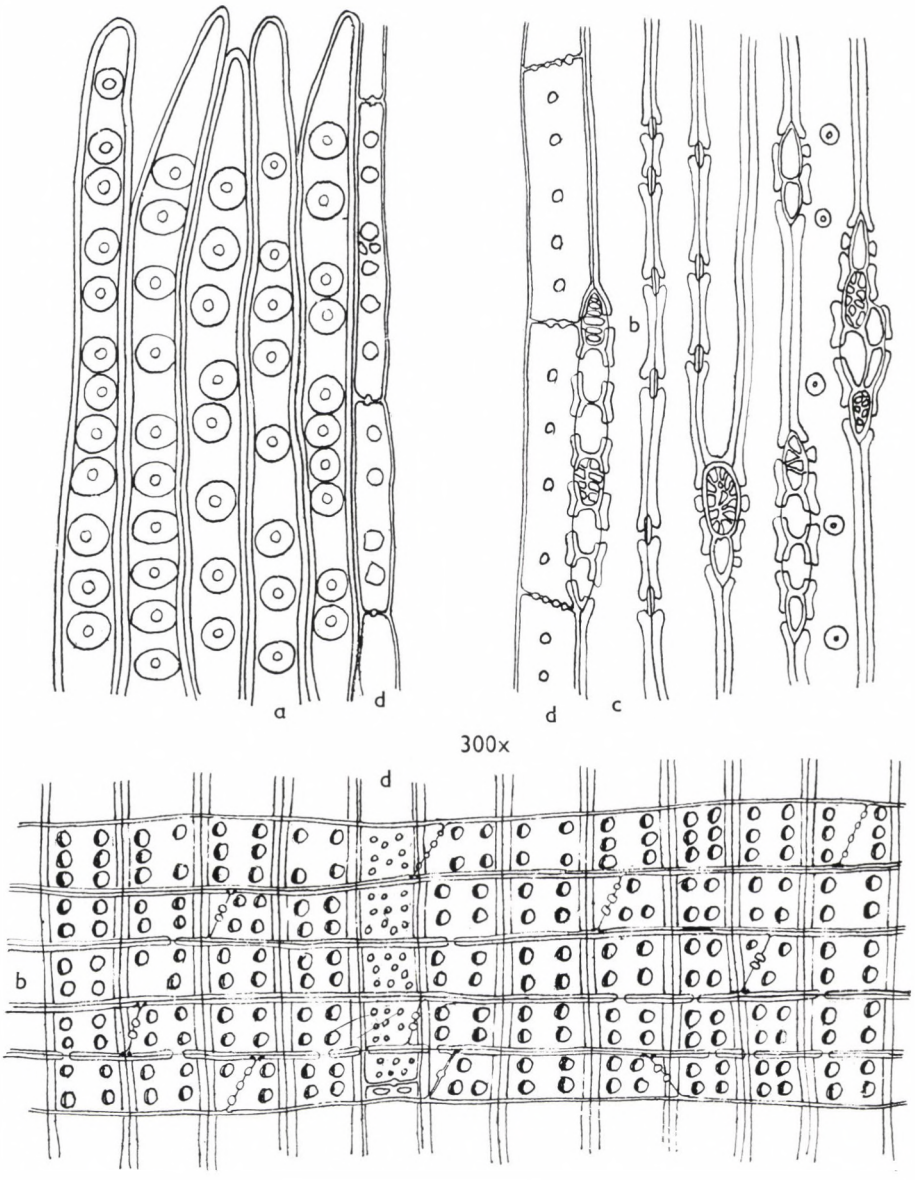
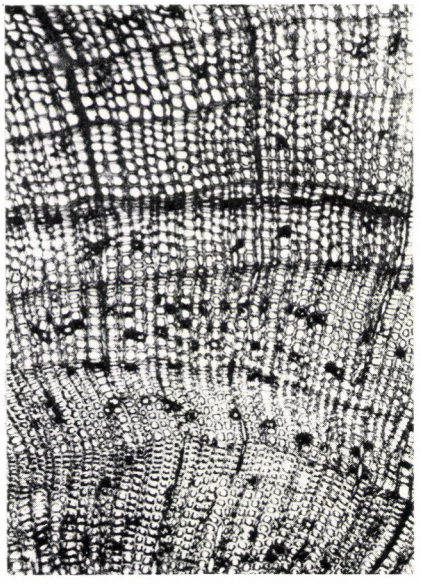


Fig. 80. *Juniperus sargentii* (Henry) Takeda



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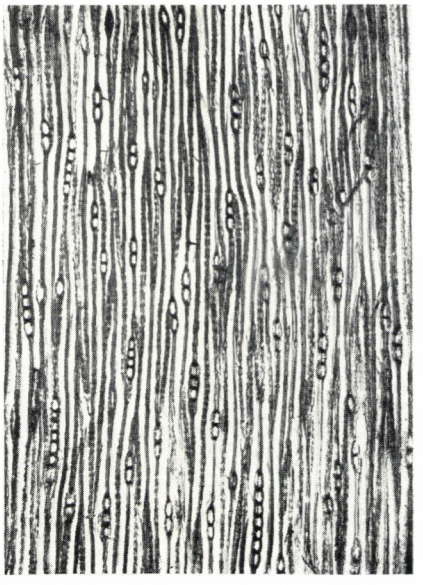

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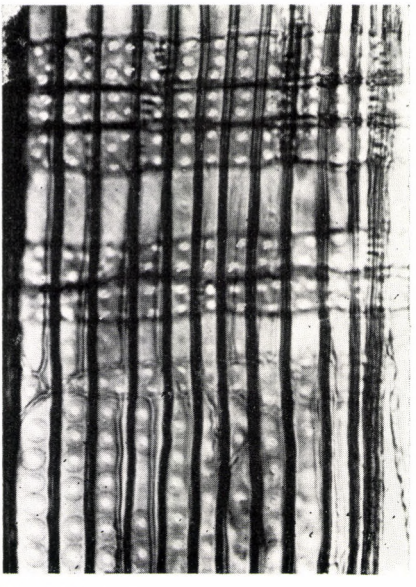

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4.(×300)

CI. *Juniperus shugnanica* Kom.

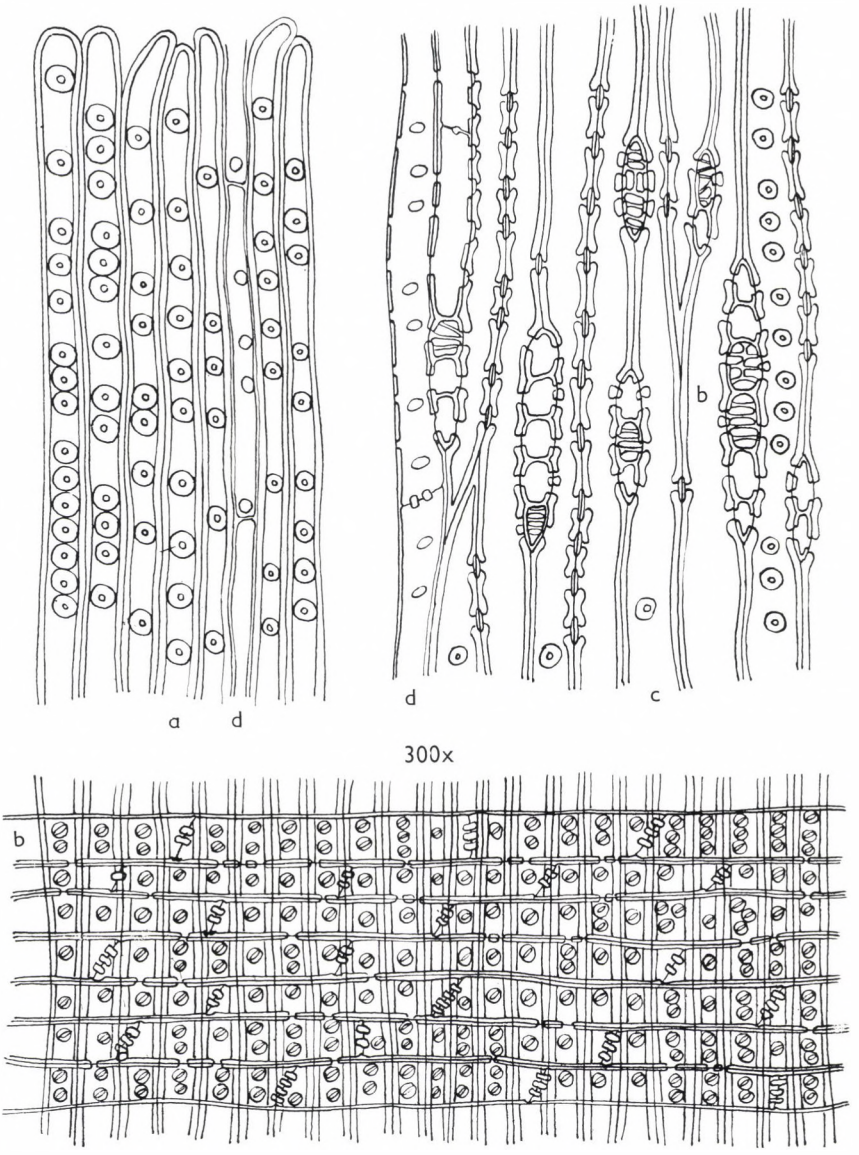
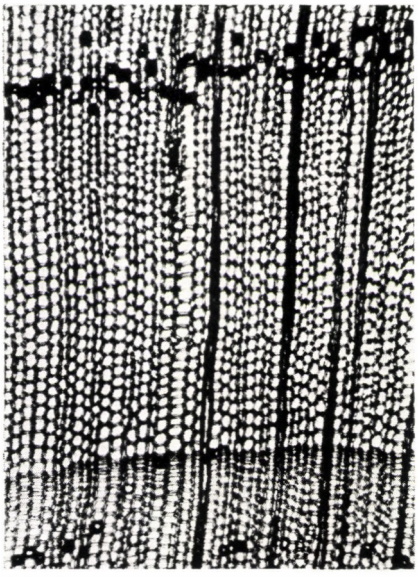


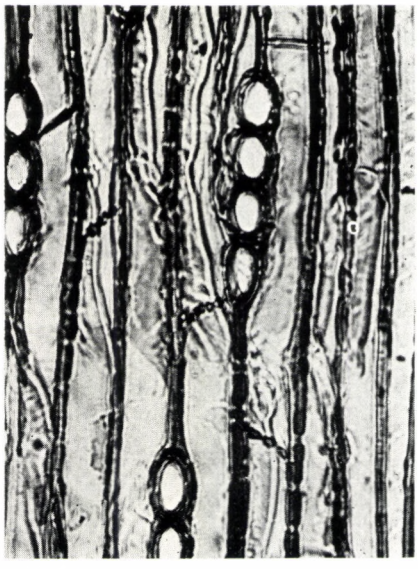
Fig. 81. *Juniperus shugnanica* Kom.



1.(x 100)

2.(×100)

3.(× 300)



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CII. *Juniperus semiglobosa* Rgl.

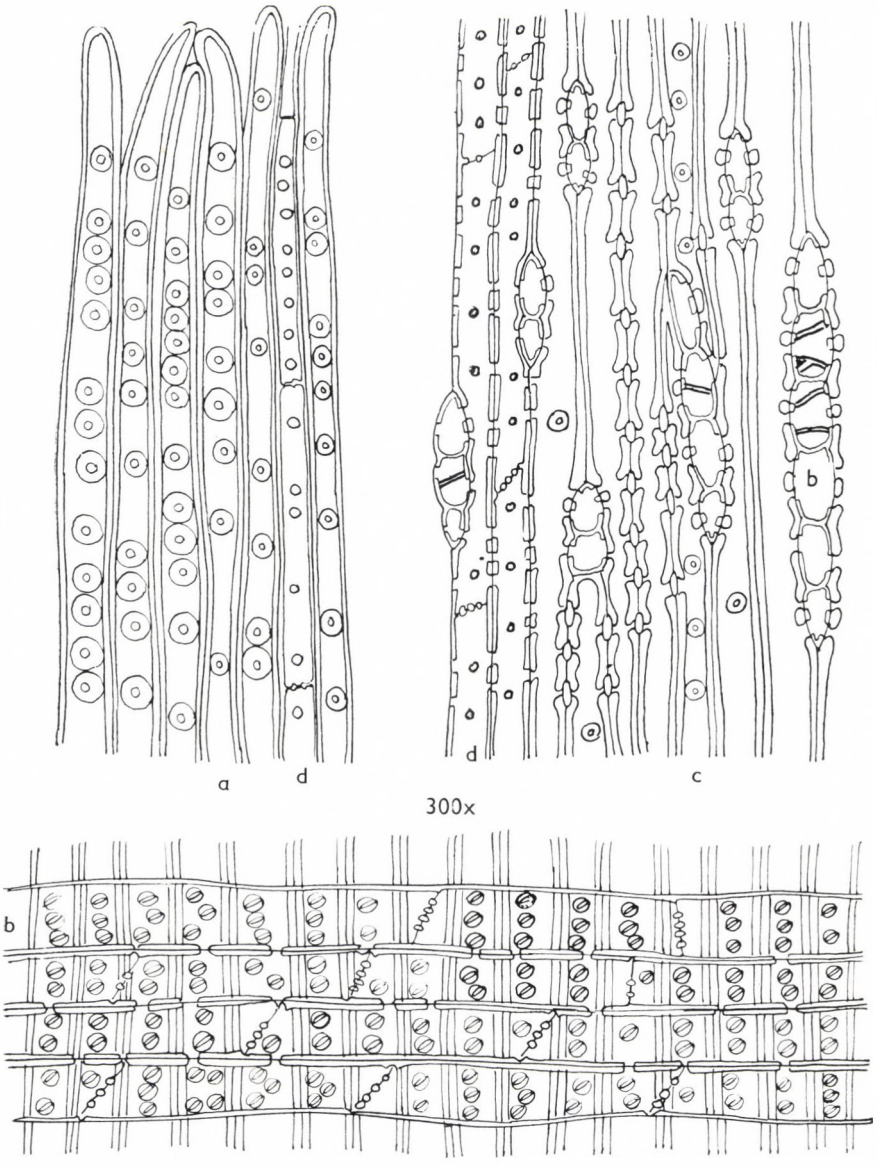
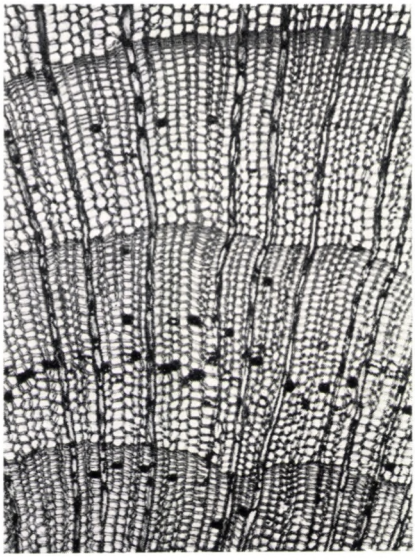


Fig. 82. *Juniperus semiglobosa* Rgl.



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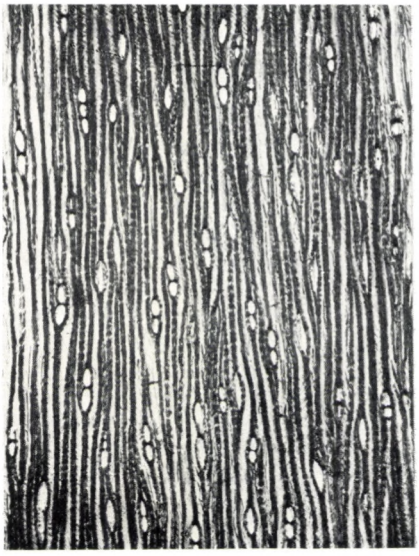


2.(x100)

3.(x 300)

4.(x 300)

CIII. *Juniperus seranschanica* Kom.

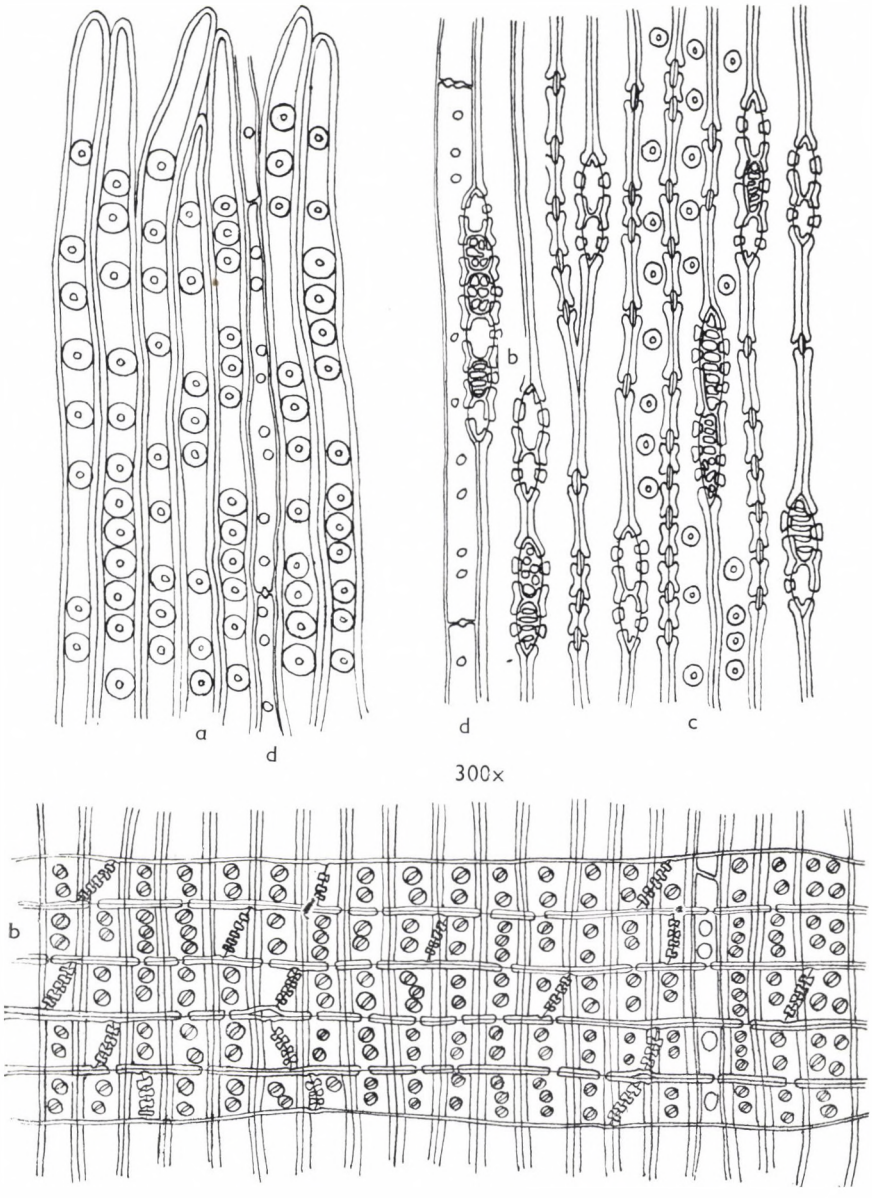
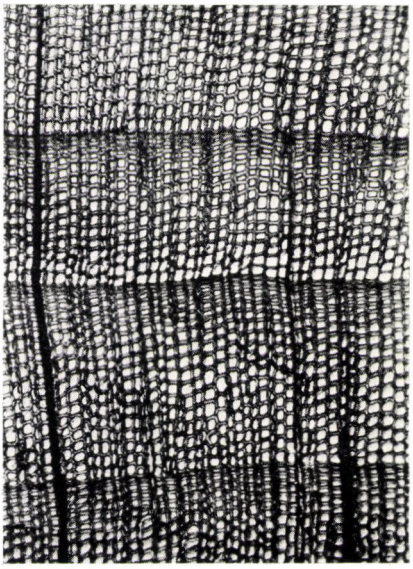


Fig. 83. *Juniperus seranschanica* Kom.



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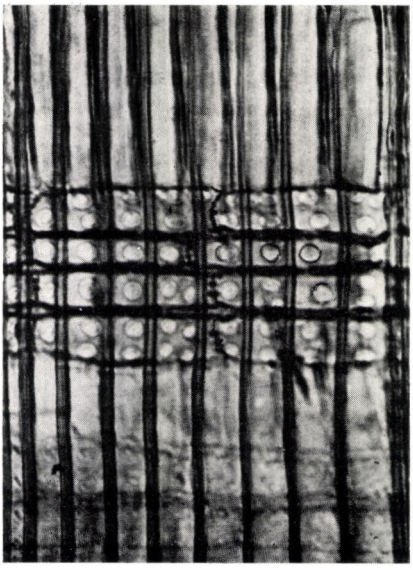
2.(x100)



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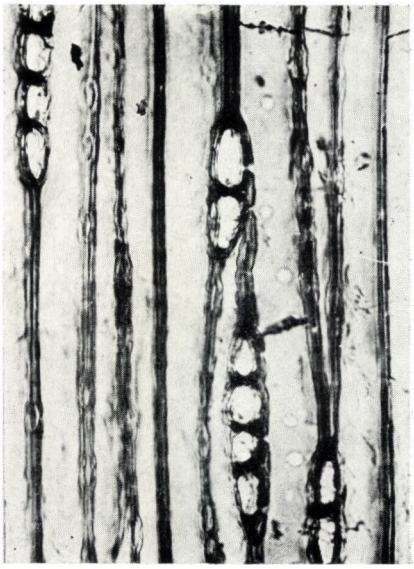


4.(x 300)

CIV. *Juniperus sibirica* Burgsd.

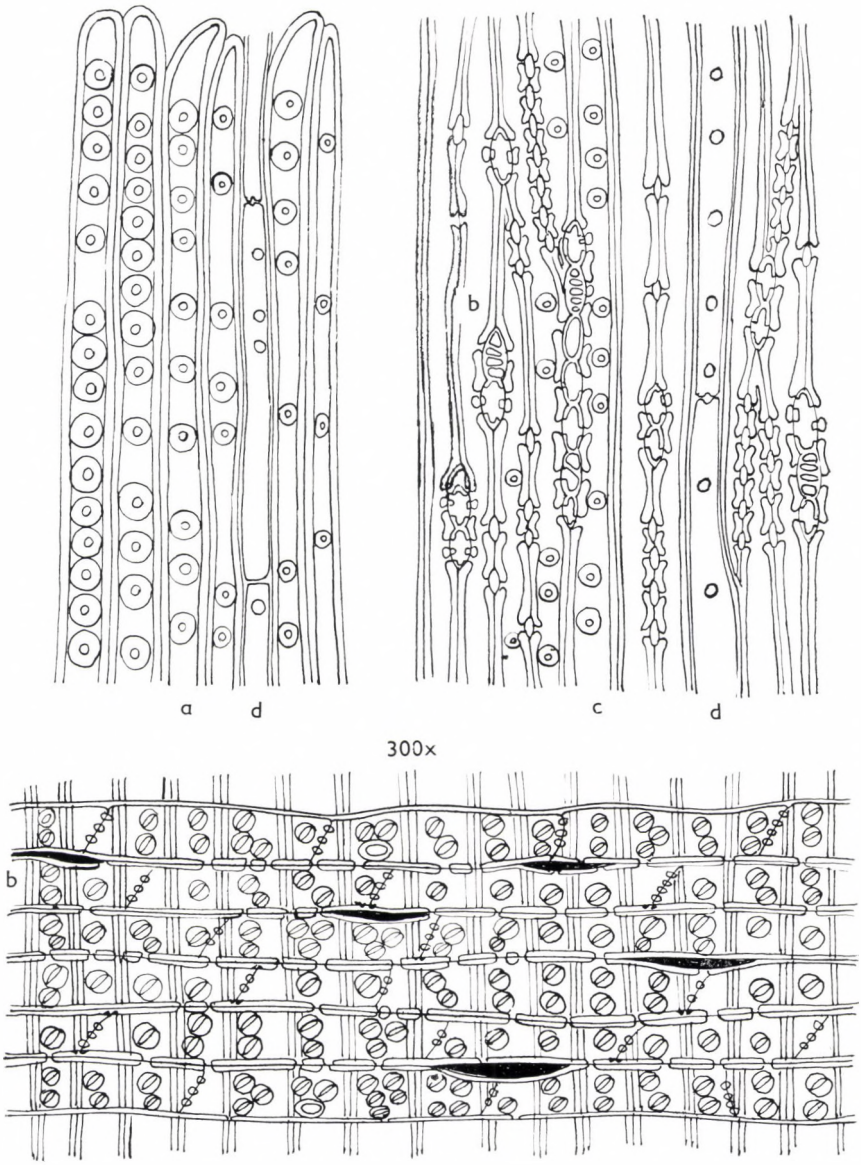
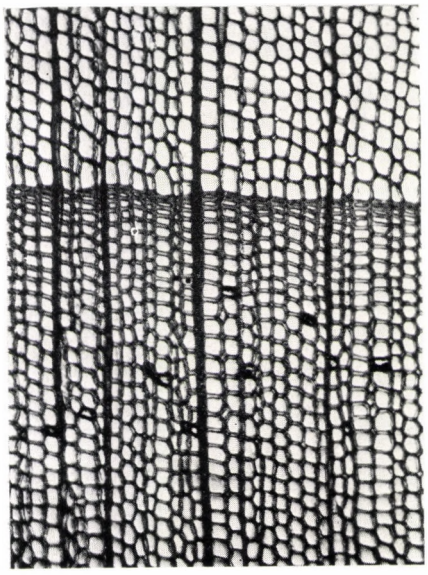


Fig. 84. *Juniperus sibirica* Burgsd.



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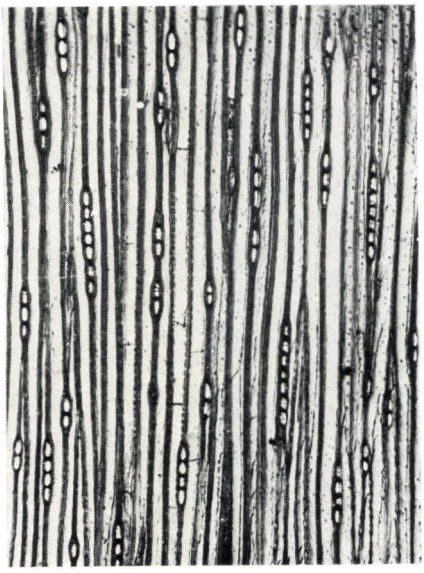

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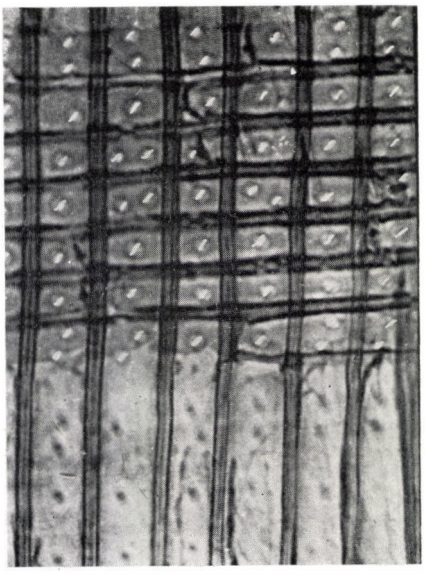
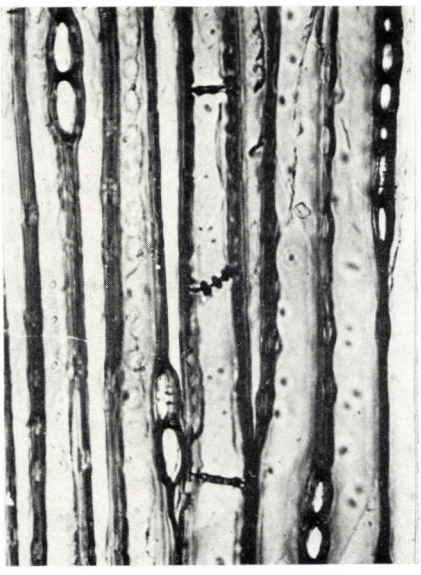


3.(×300)



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CV. *Juniperus thalassica* Lipsky

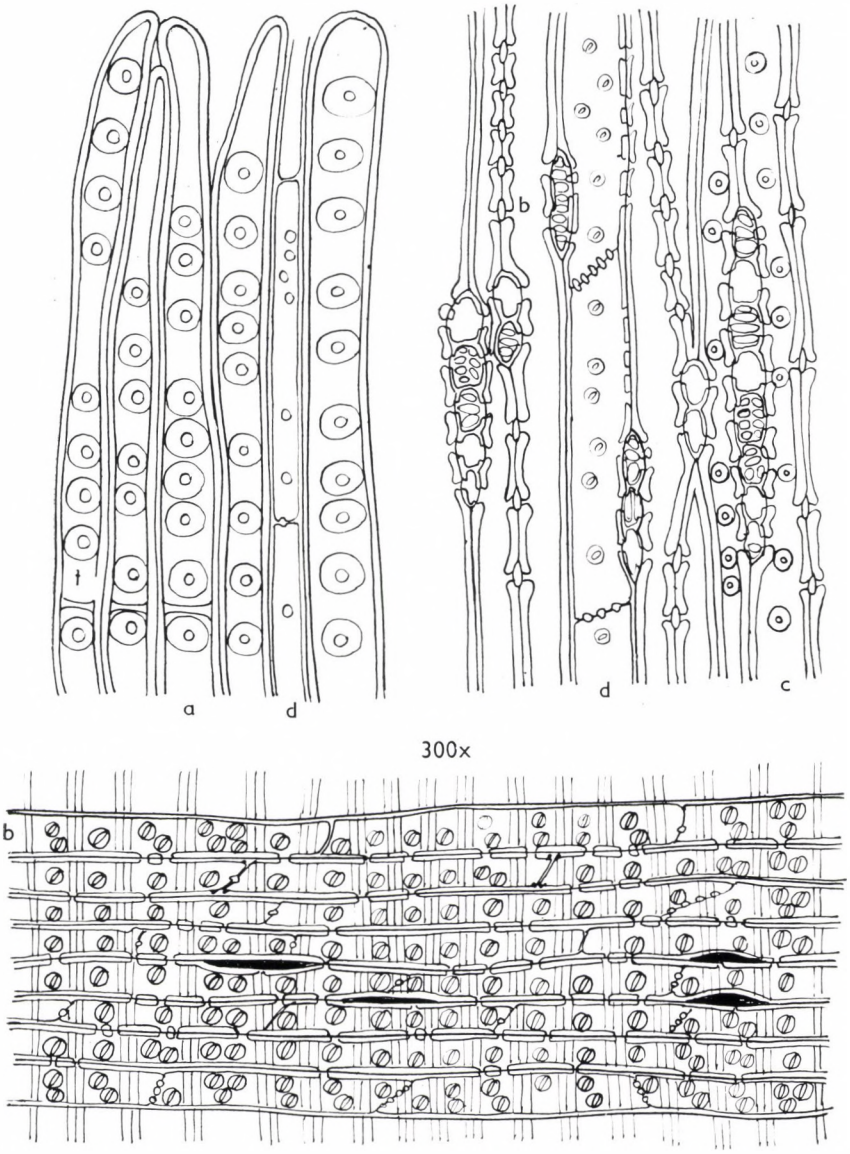
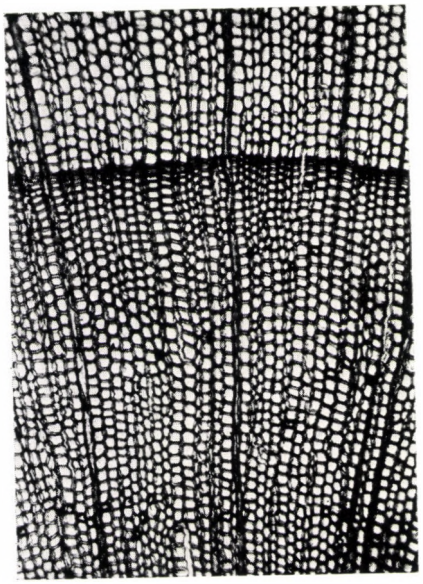


Fig. 85. *Juniperus thalassica* Lipsky



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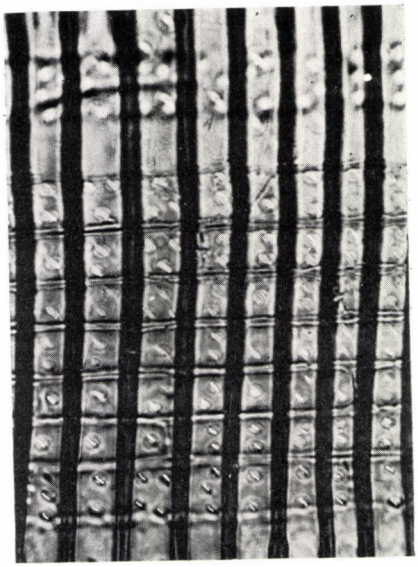
2.(x100)



3.(x 300)

4.(x 300)

CVI. *Juniperus turkestanica* Kom.

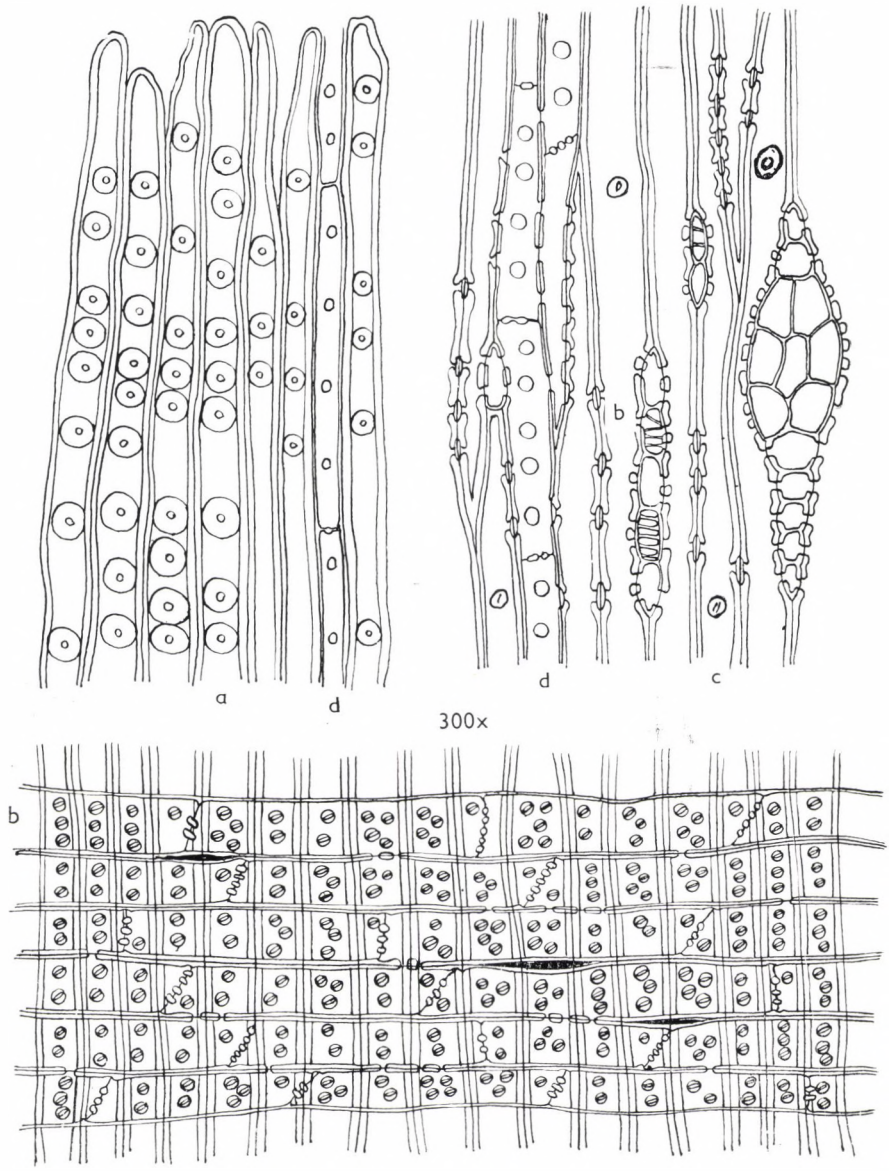
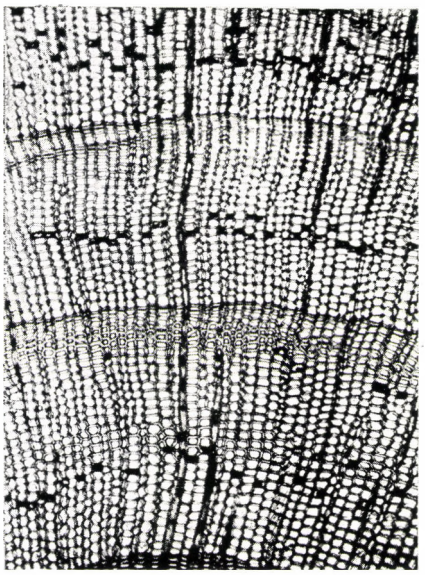


Fig 86. *Juniperus turkestanica* Kom.



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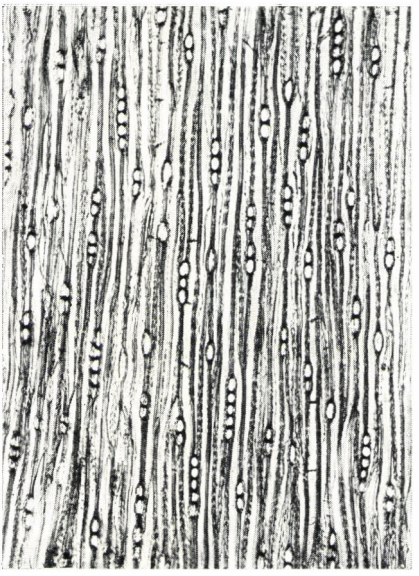

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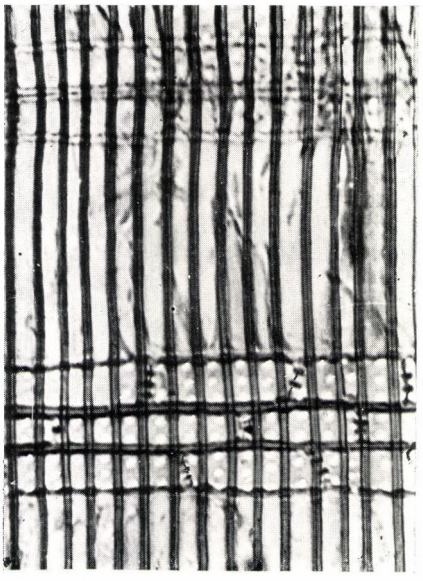


3.(x 300)

4.(x 300)

CVII. *Juniperus turcomanica* B. Fedtch.

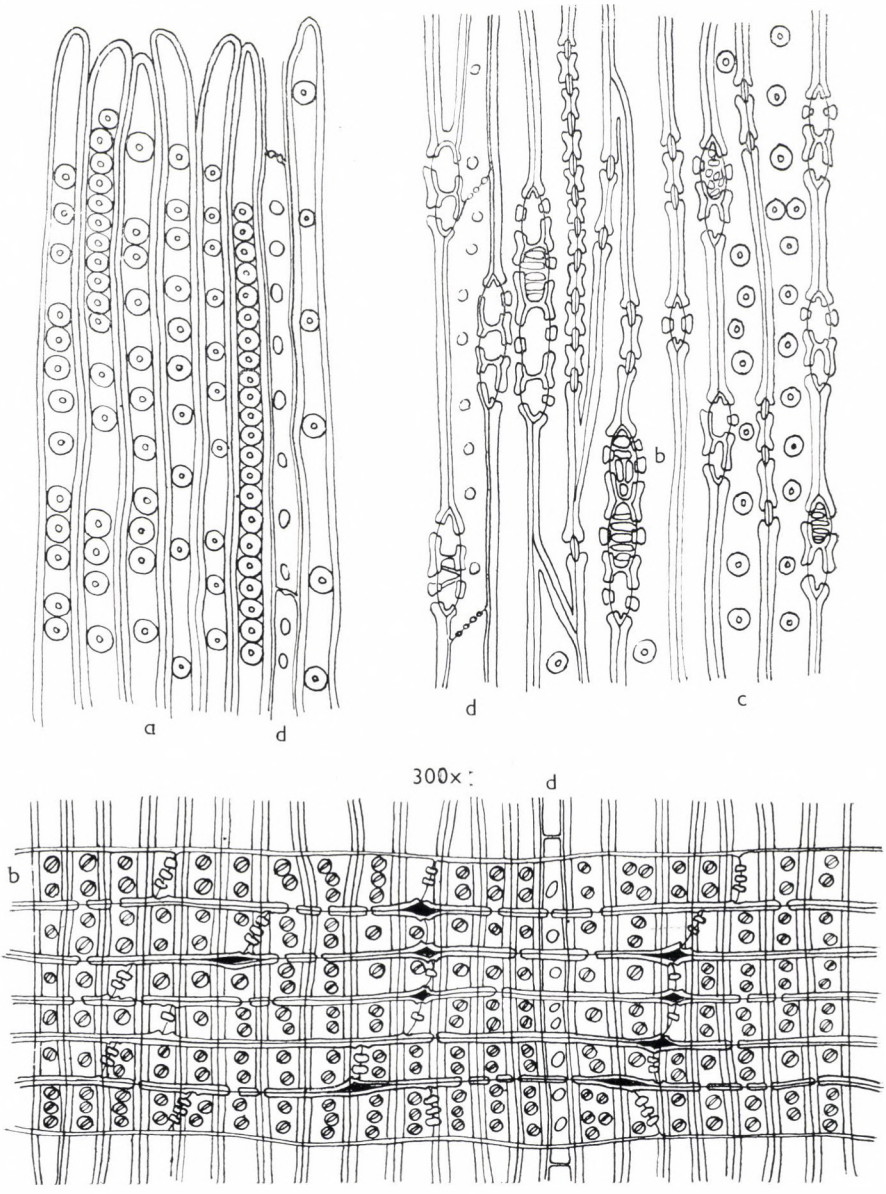
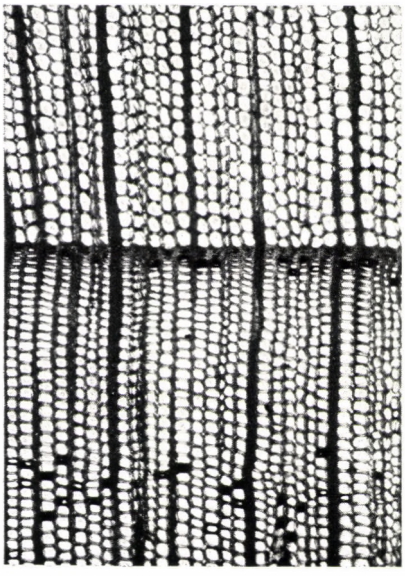


Fig. 87. *Juniperus turcomanica* B. Fedtch.



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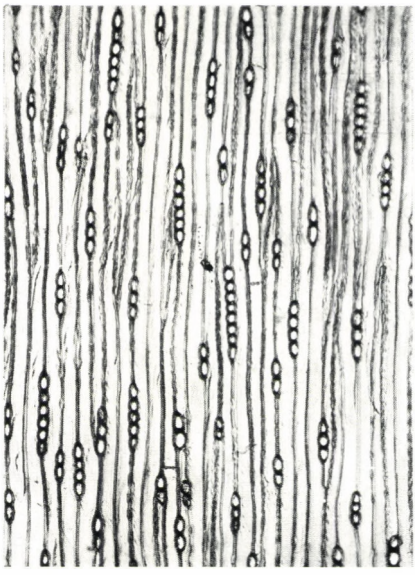

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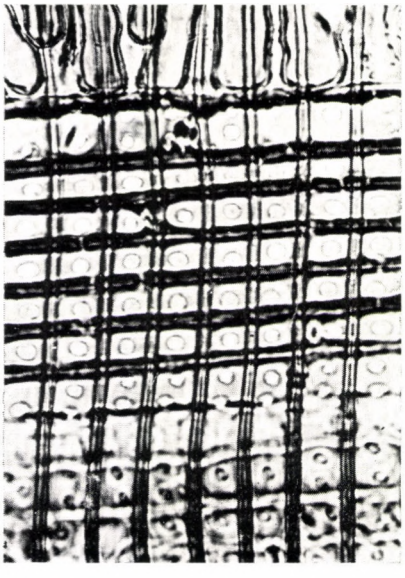

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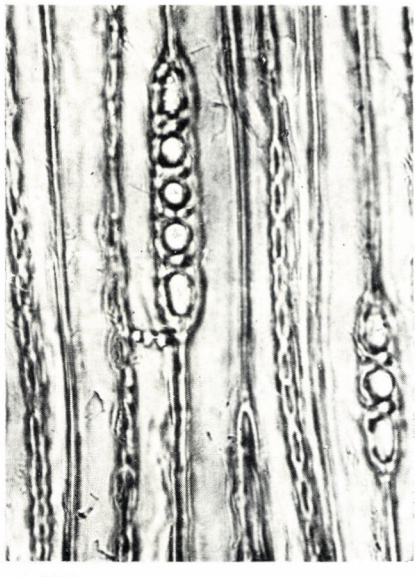


4.(x300)

CVIII. *Juniperus utahensis* Lemmon

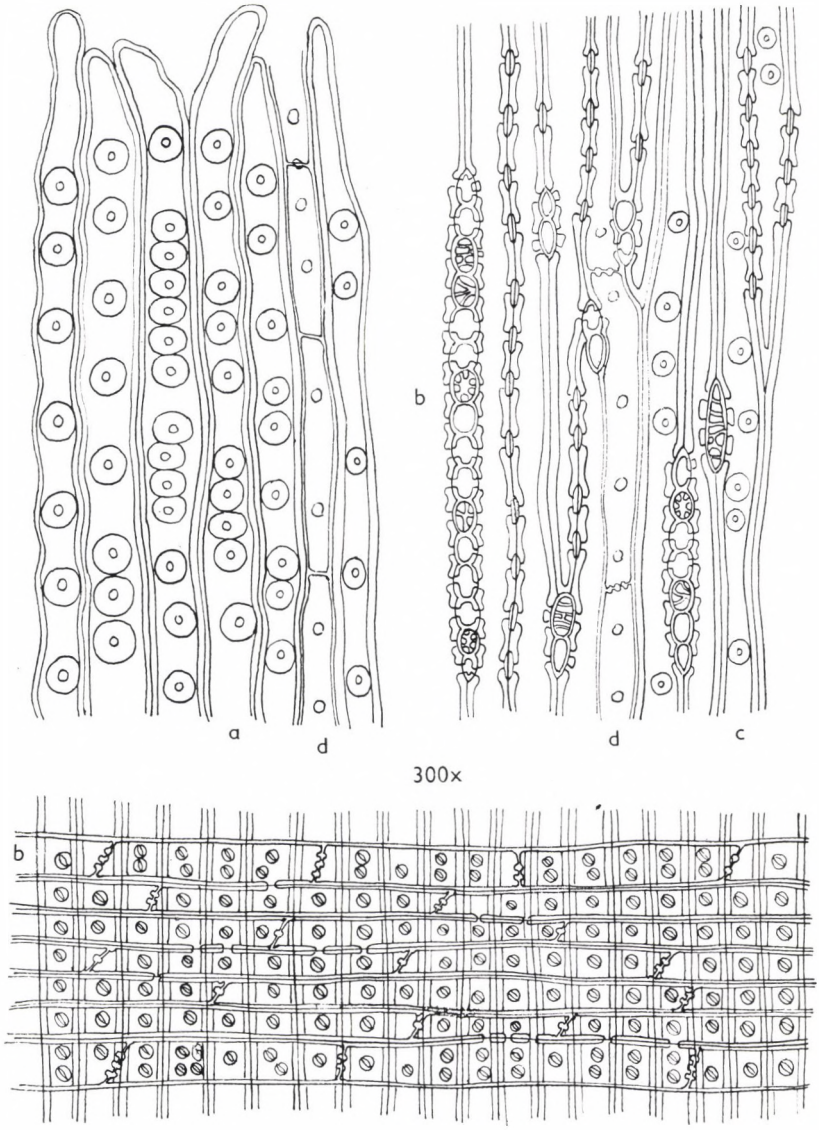
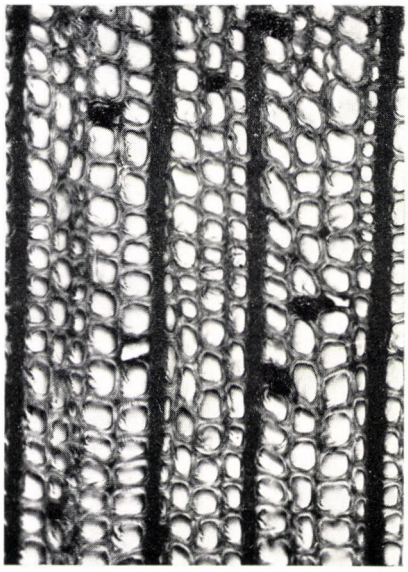


Fig. 88. *Juniperus utahensis* Lemmon



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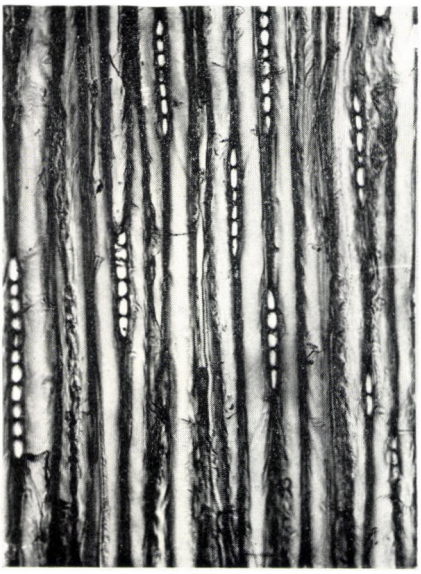

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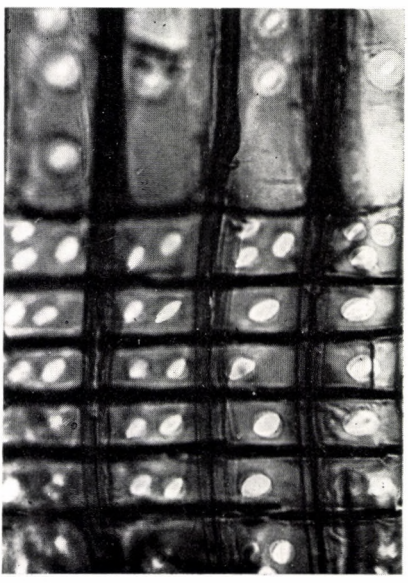

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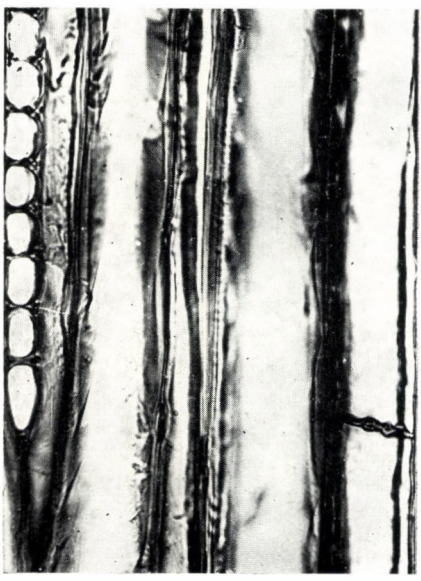

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CIX. *Libocedrus arfakensis* Gibbs.

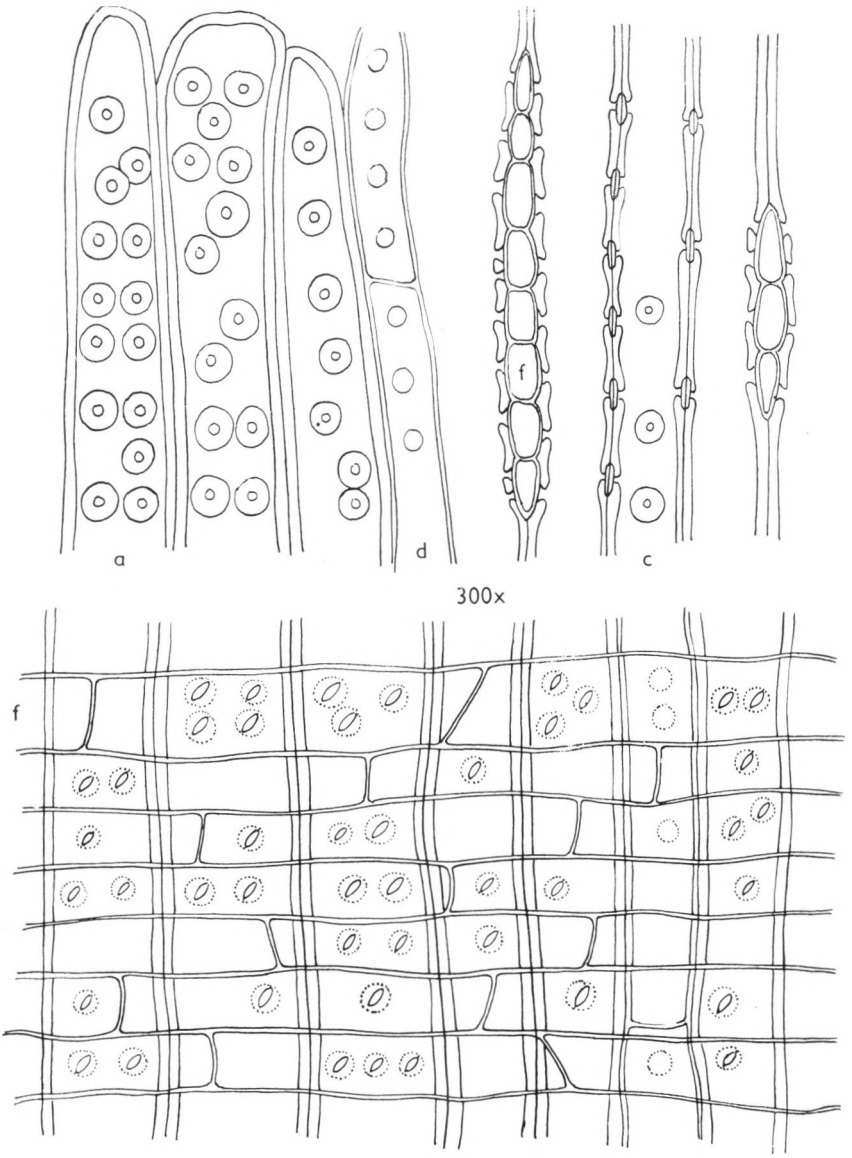

Fig. 89 *Libocedrus arfakensis* Gibbs.

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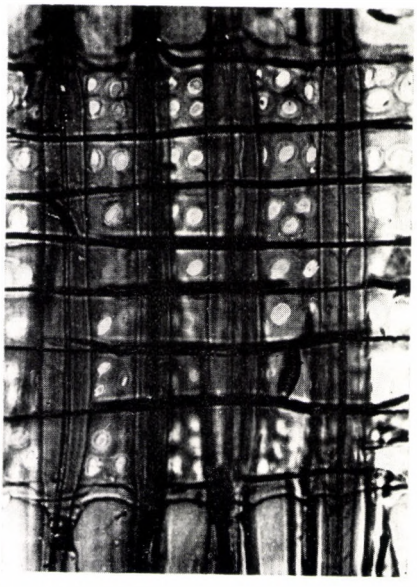
2.(×100)



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4.(×300)

CX. *Libocedrus papuana* F. Mueller

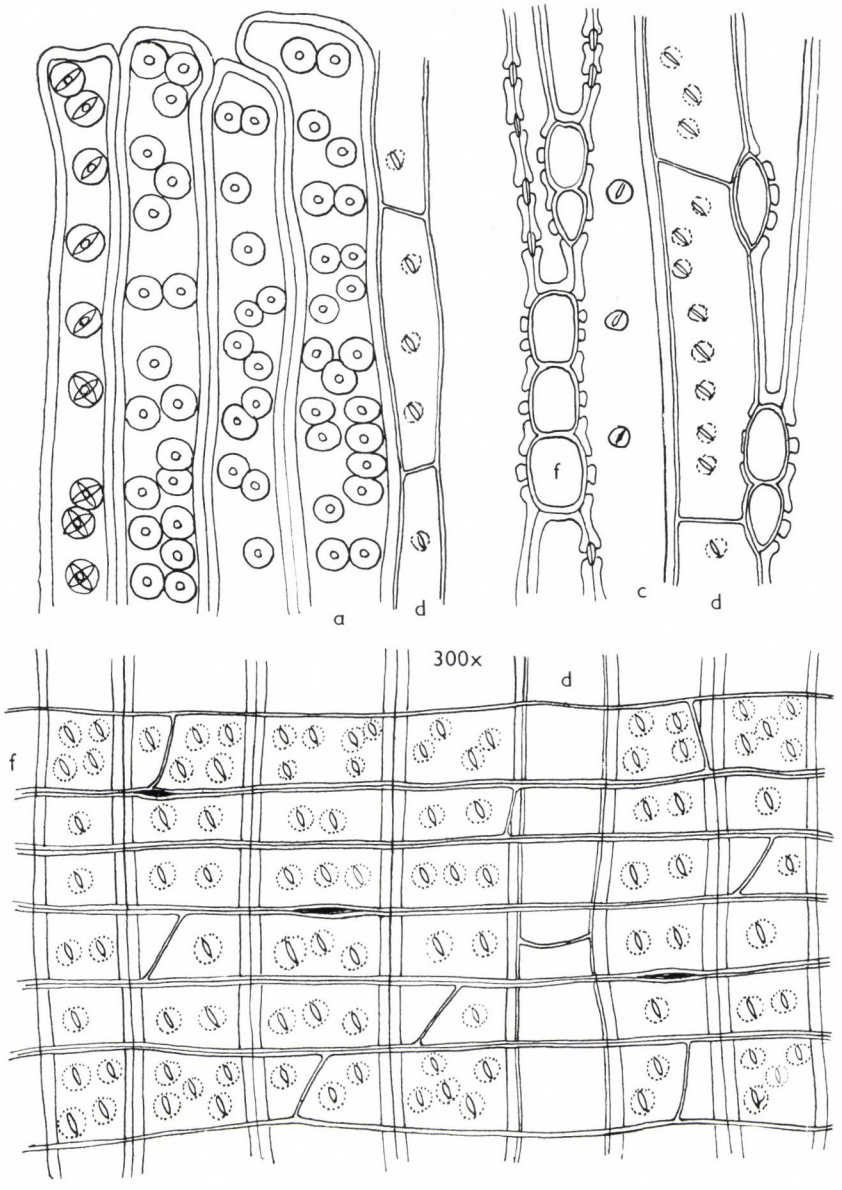
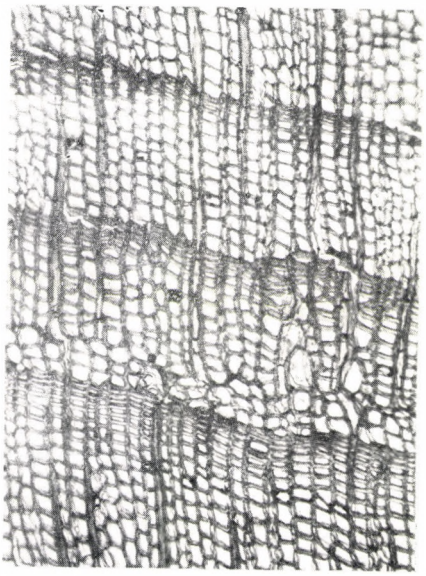


Fig. 90. *Libocedrus papuana* F. Mueller



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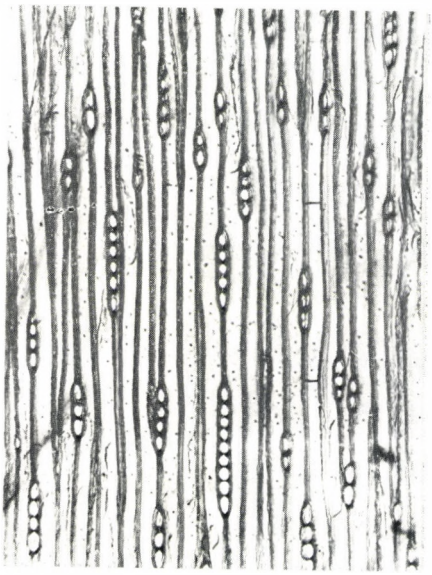

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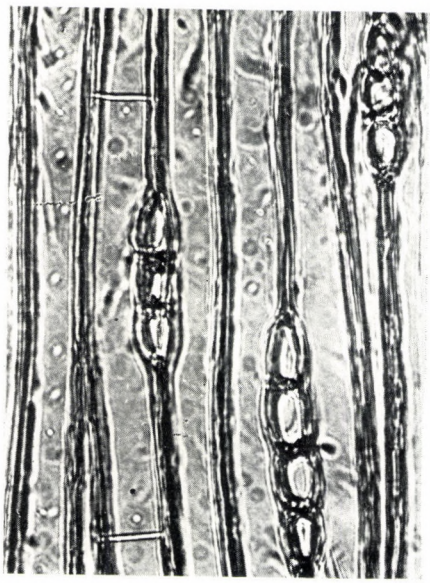
3.(× 300)



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CXI. *Athrotaxis cupressoides* Don.

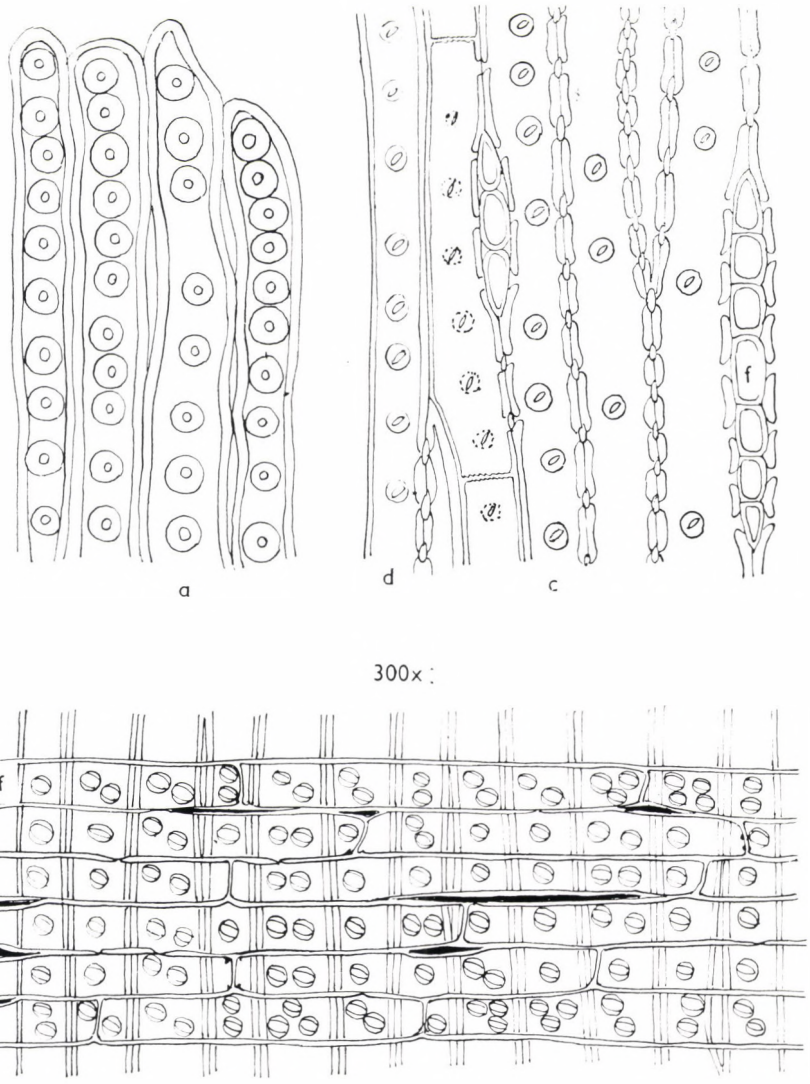
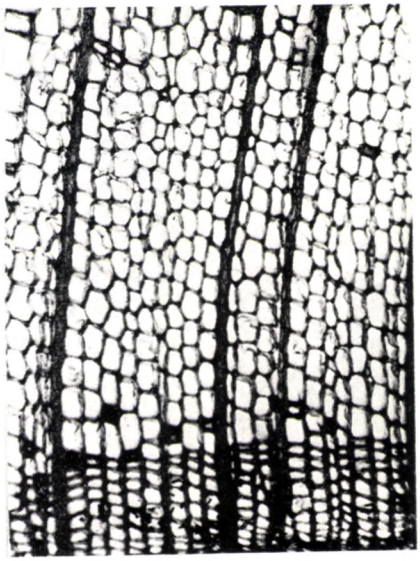


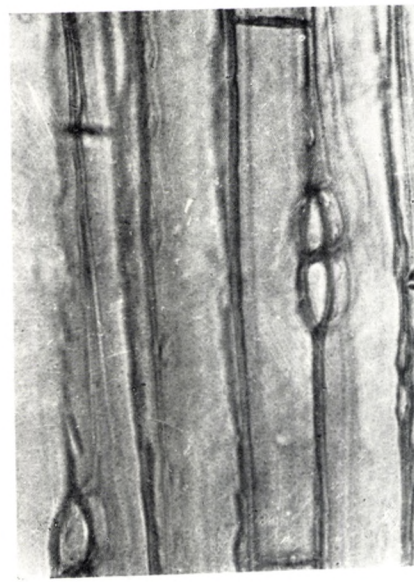
Fig. 91. *Athrotaxis cupressoides* Don.



1.(×100)

2.(×100)

3.(×300)



4.(×300)

CXII. *Cryptomeria japonica* var. *elegans* (Henkel and Hochst.) Mast.

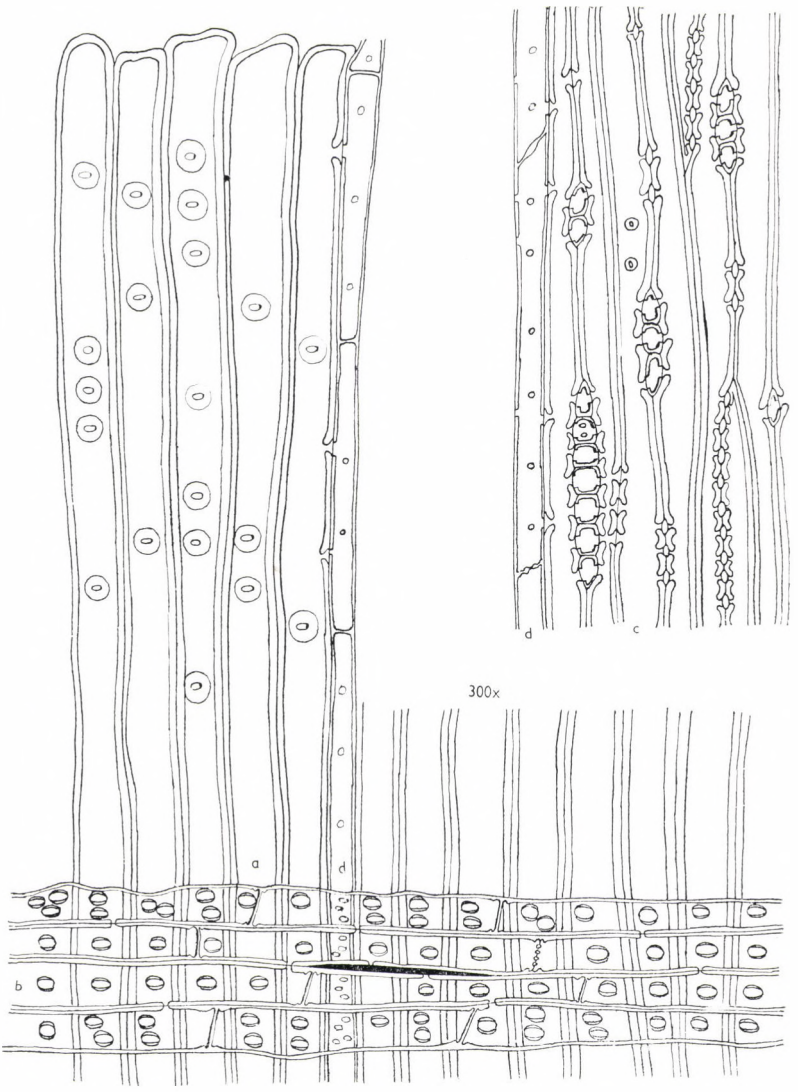
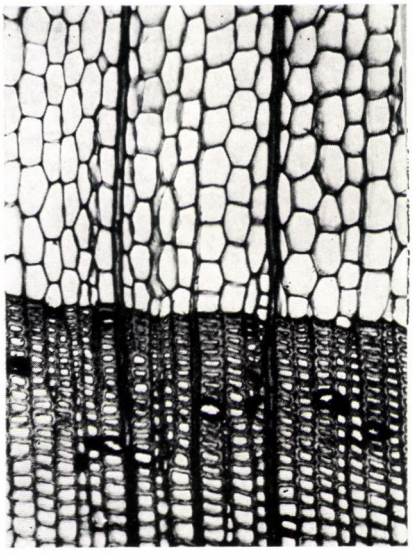


Fig. 92. *Cryptomeria japonica* var. *elegans* (Henkel and Hochst.) Mast.



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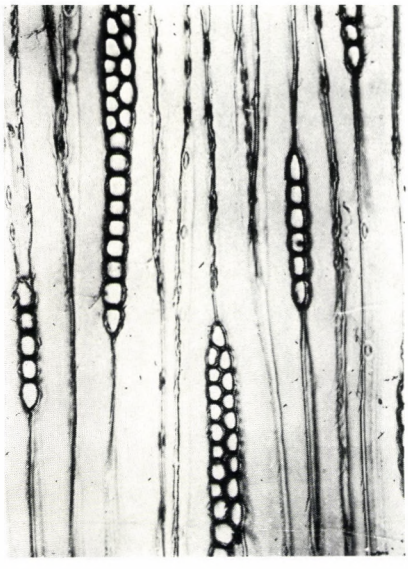
2.(x100)

3.(x 300)



4.(x300)

CXIII. *Cryptomeria japonica* var. *sinensis* Sieb. and Zucc.

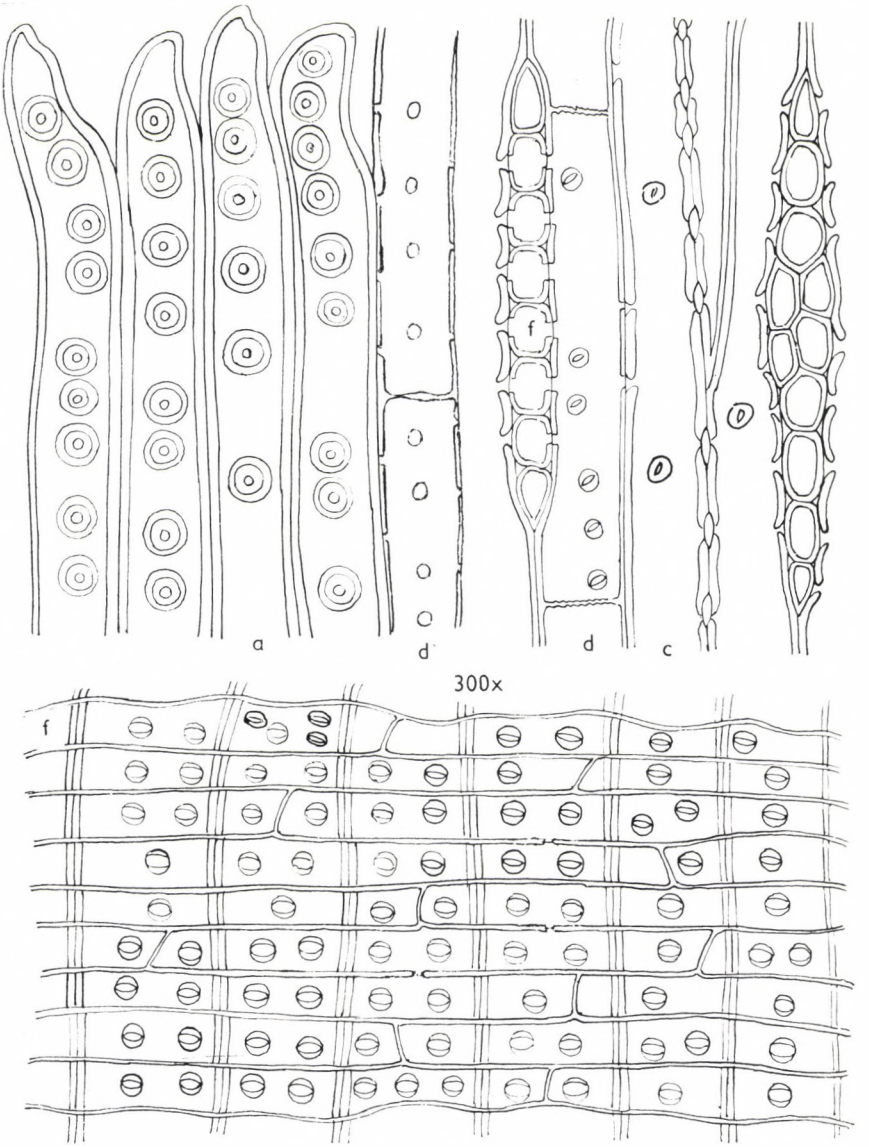
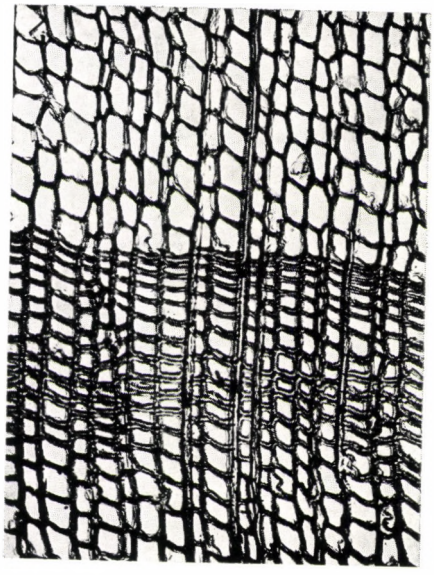


Fig. 93. *Cryptomeria japonica* var. *sinensis* Sieb. and Zucc.



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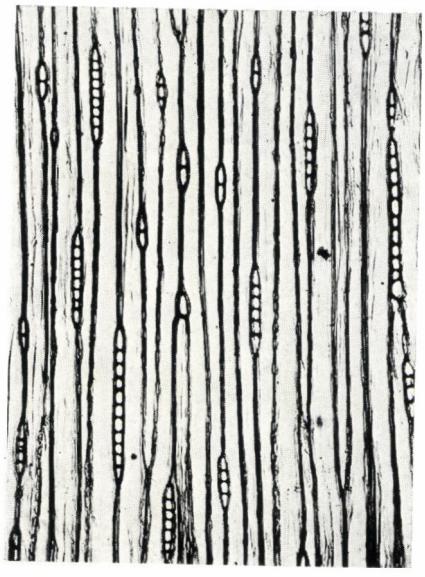

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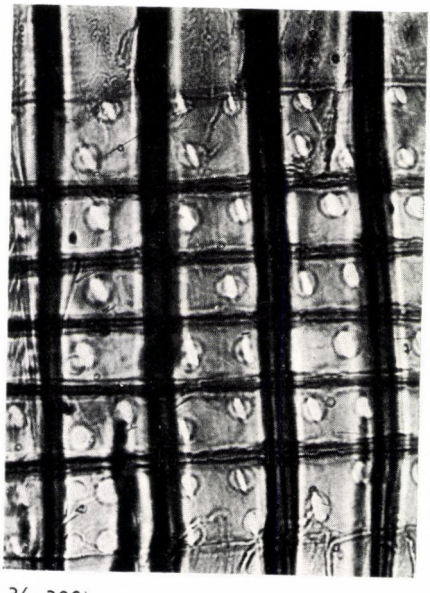

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4.(×300)

CXIV. *Cunninghamia konishii* Hayata

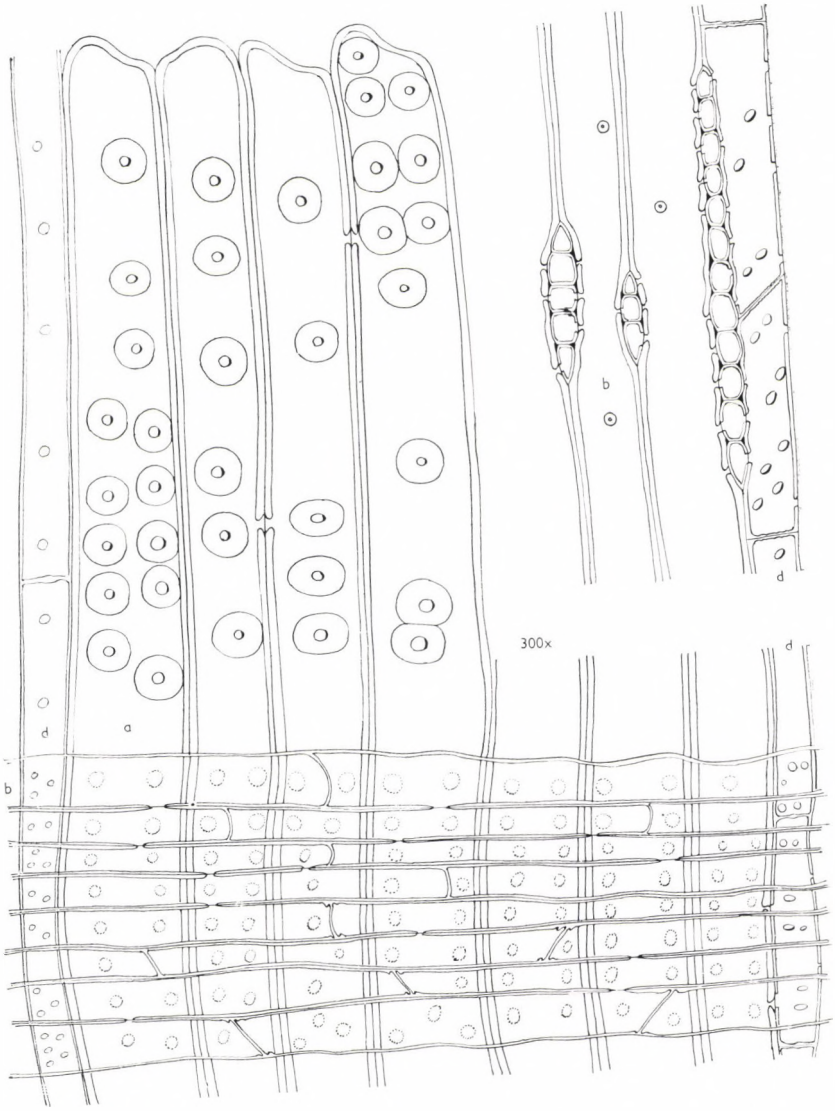
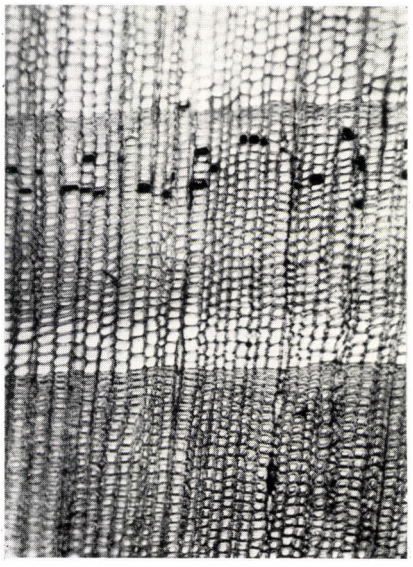


Fig. 94. *Cunninghamia konishii* Hayata



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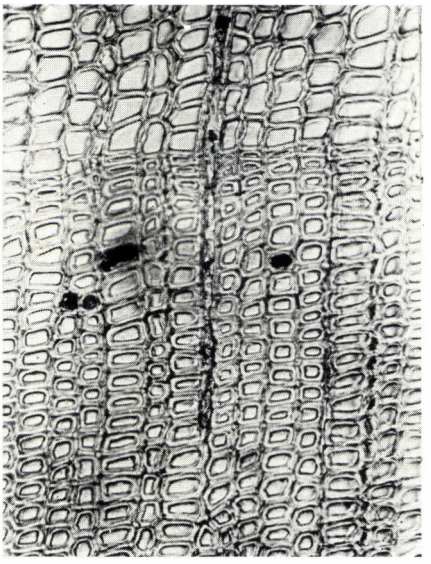

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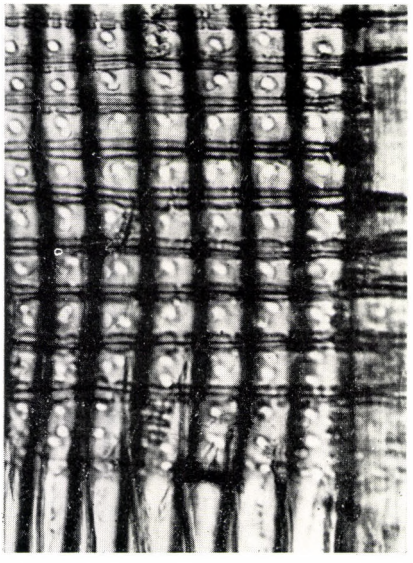

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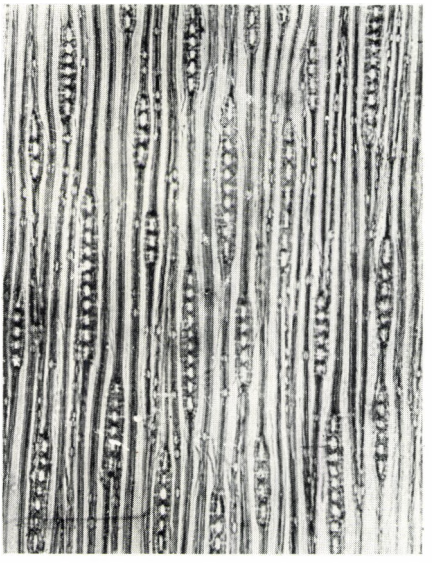

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CXV. *Abies borisii-regis* Mattfels

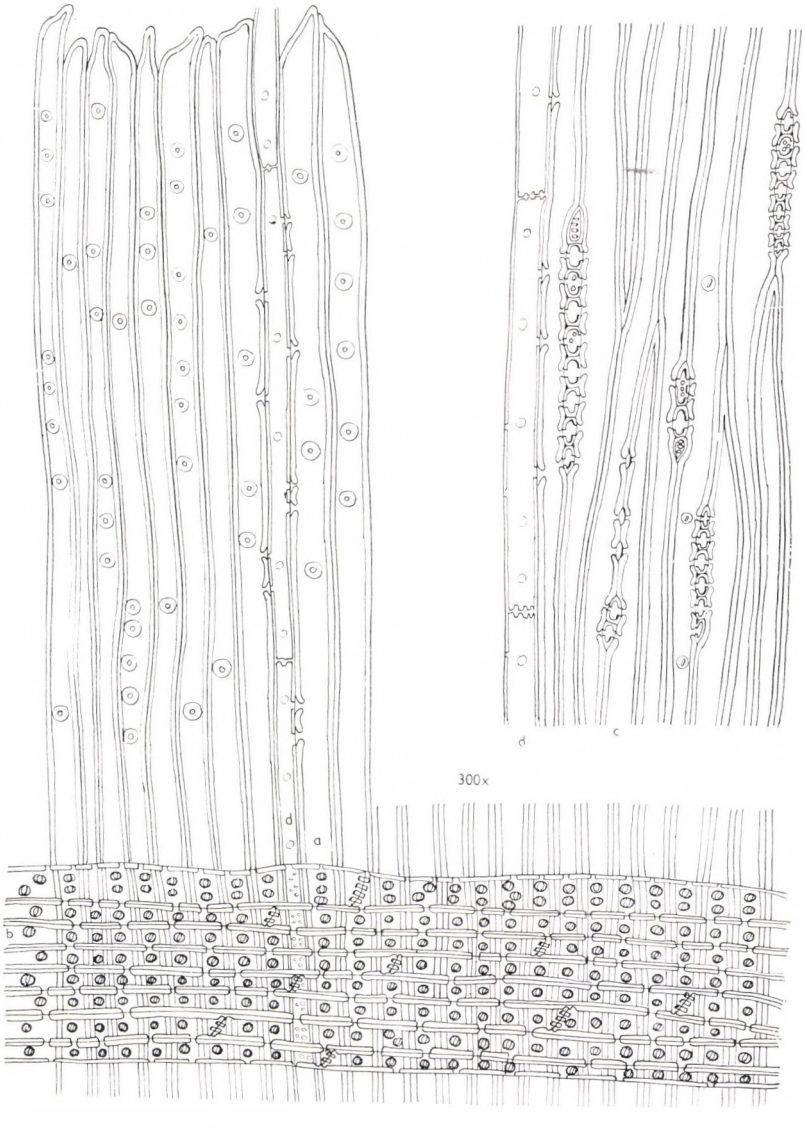
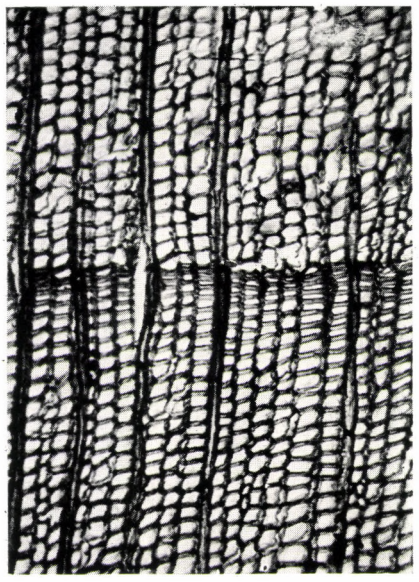


Fig. 95. *Abies borisii-regis* Mattfels



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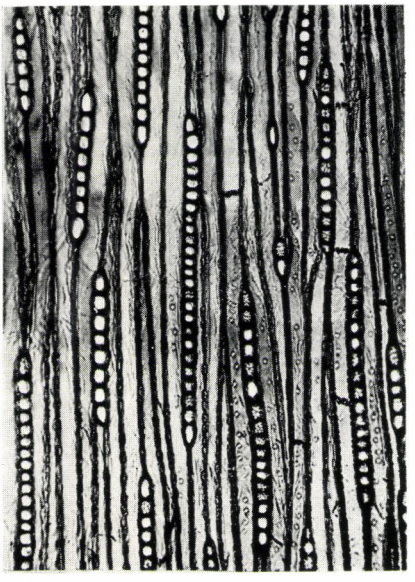

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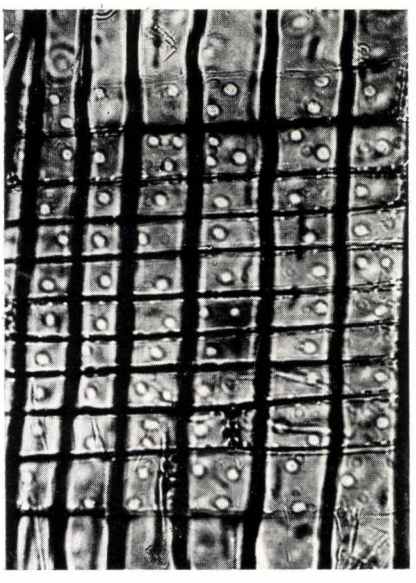


3.(×300)

4.(×300)

CXVI. *Abies delavayi* Franchet

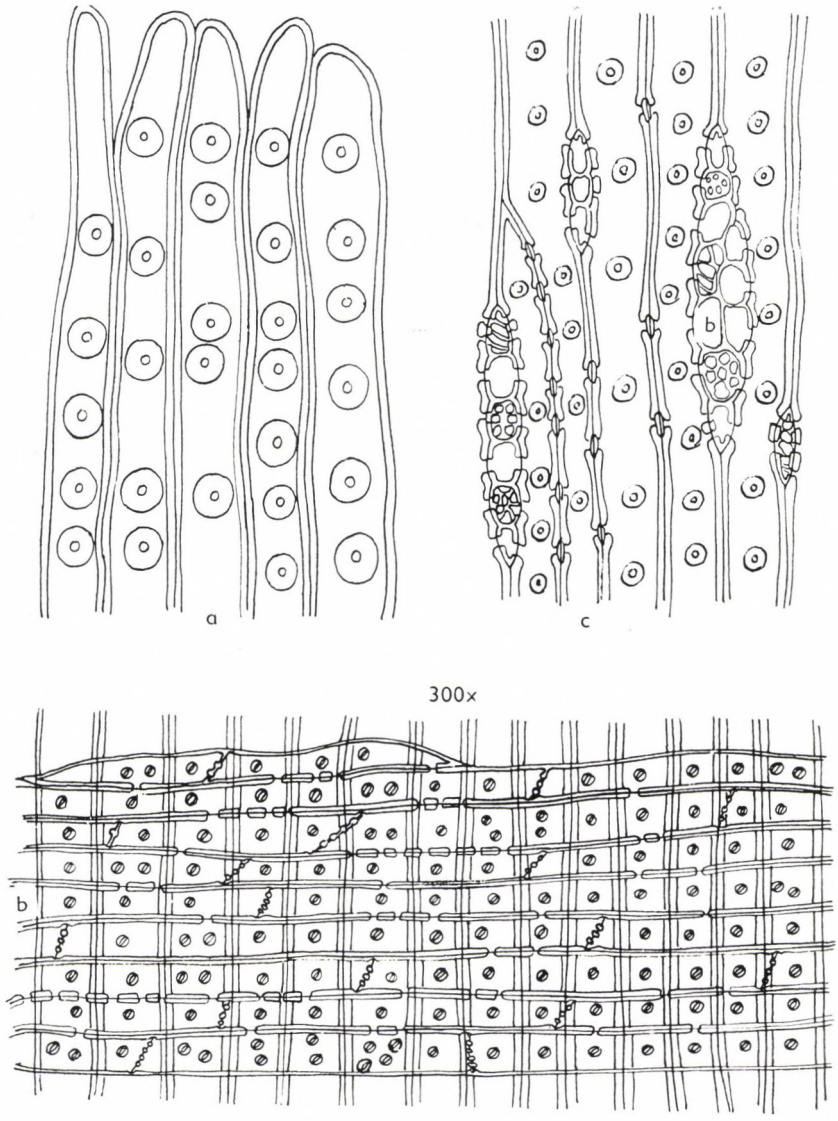
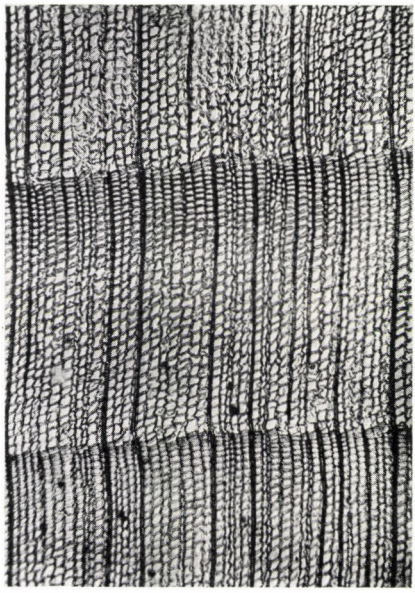


Fig. 96. *Abies delavayi* Franchet



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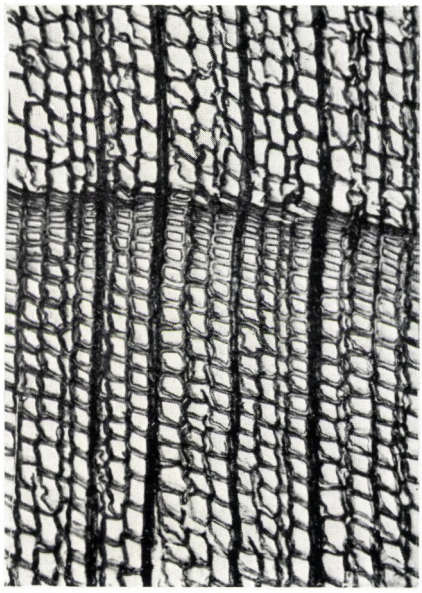

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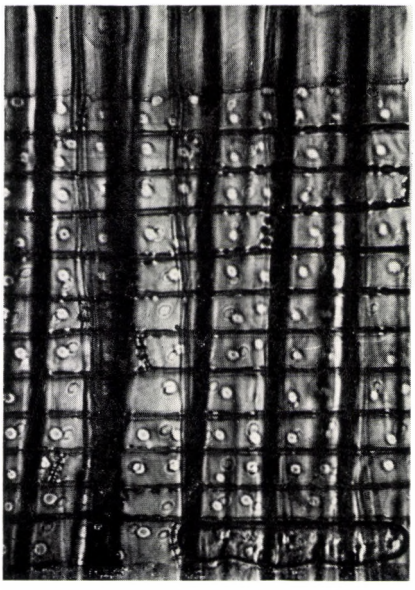

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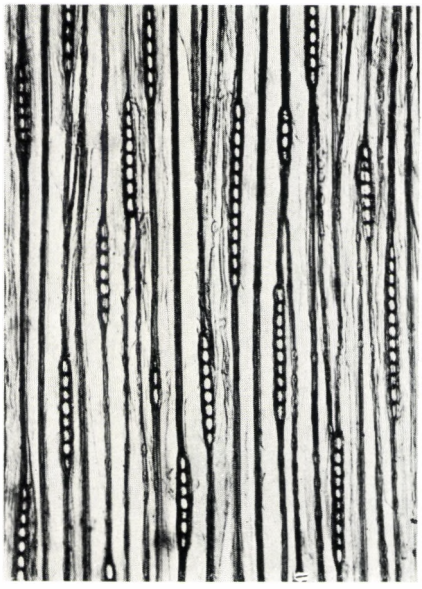

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CXVII. *Abies fargesii* Franchet

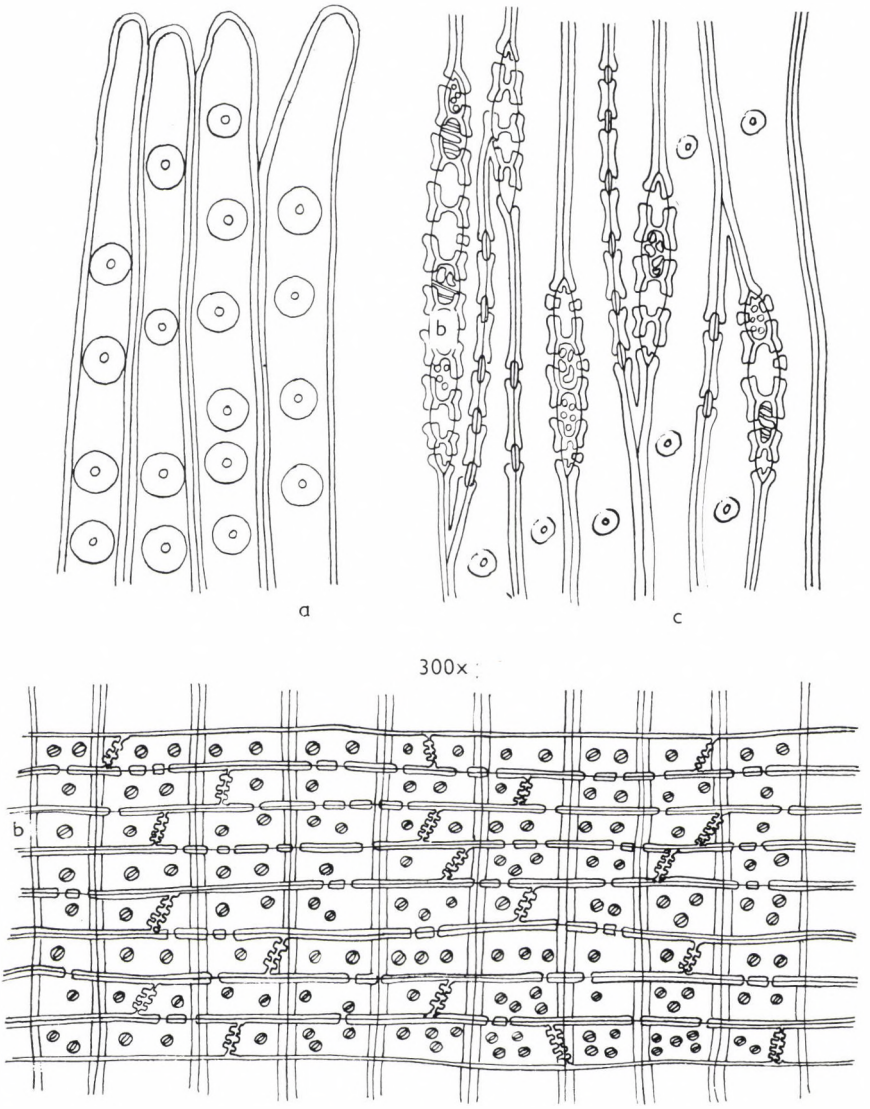
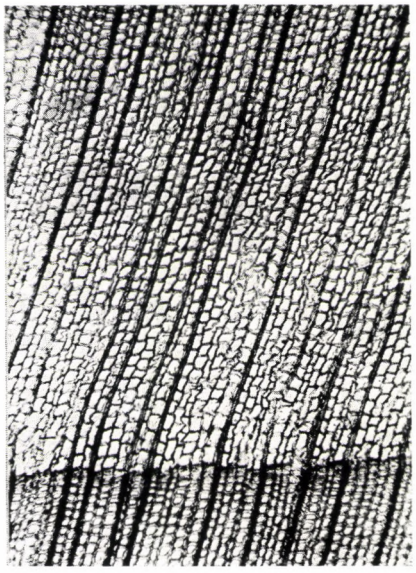
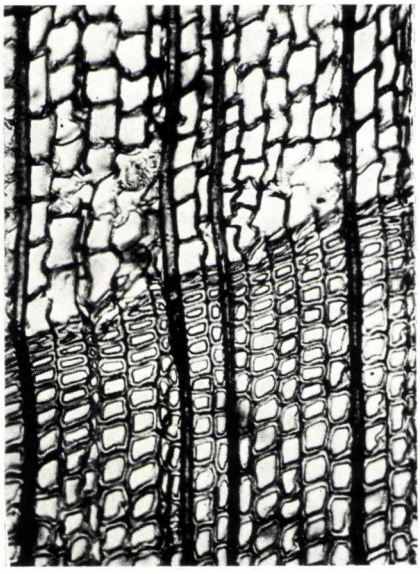


Fig. 97. *Abies fargesii* Franchet



1. (×30)



2. (×100)

3. (×300)

4. (×100)

CXVIII. *Abies faxoniana* Rehder and Wilson

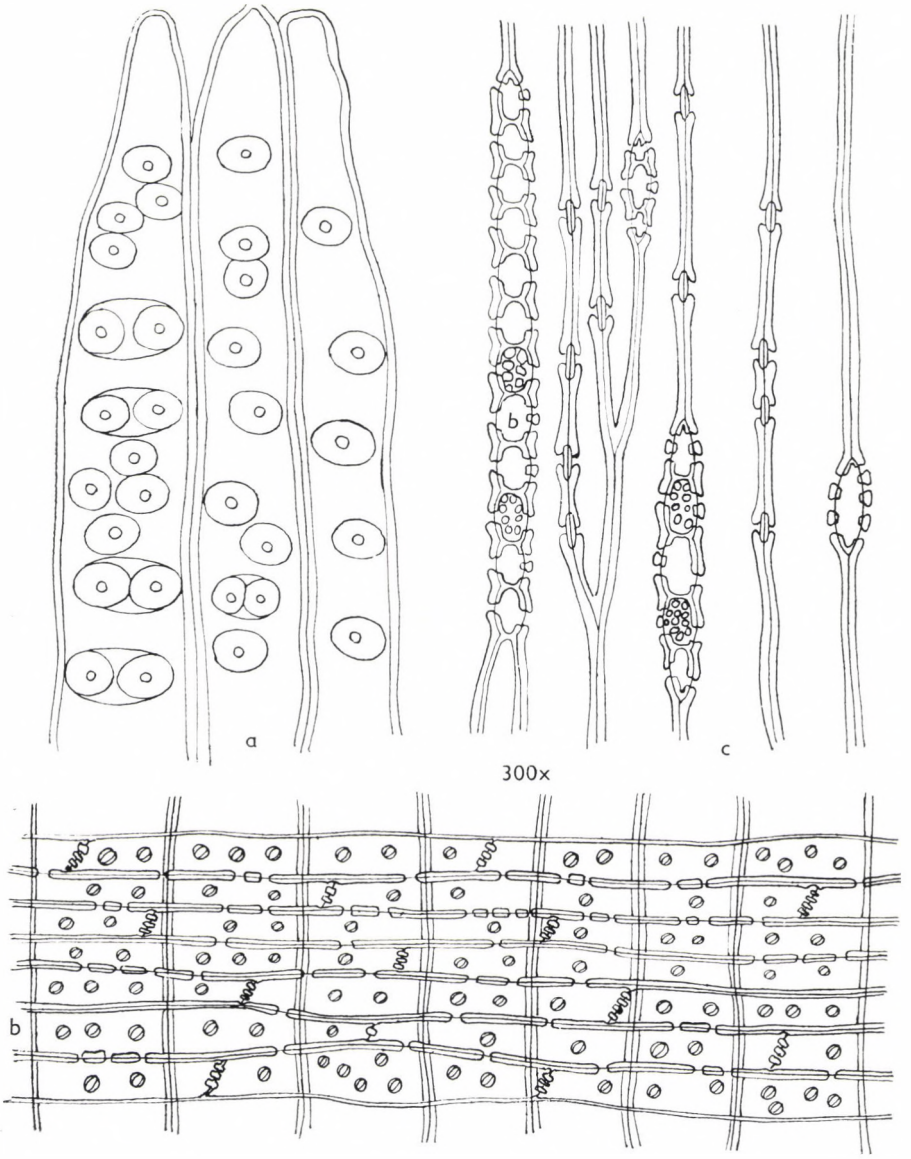
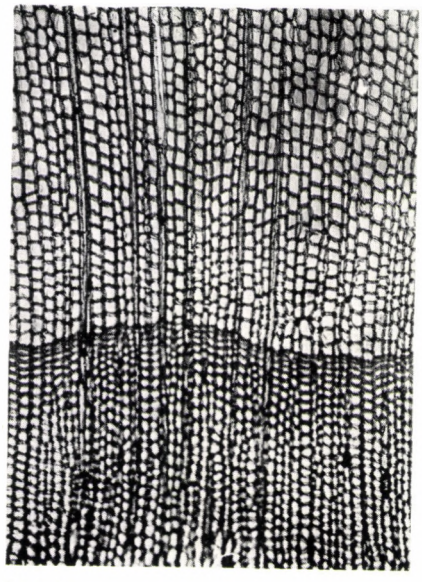


Fig. 98. *Abies faxoniana* Rehder and Wilson



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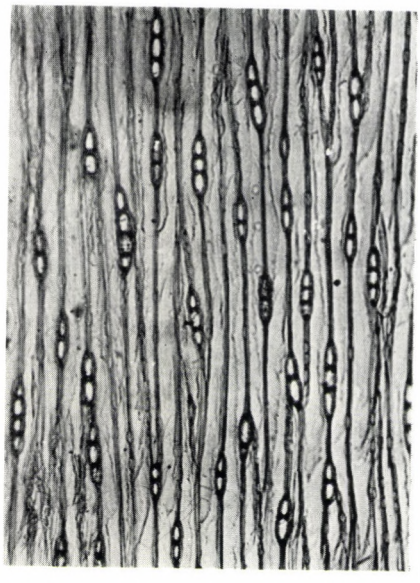


2.(x100)

3.(x 300)

4.(x300)

CXIX. *Abies forrestii* Craib.

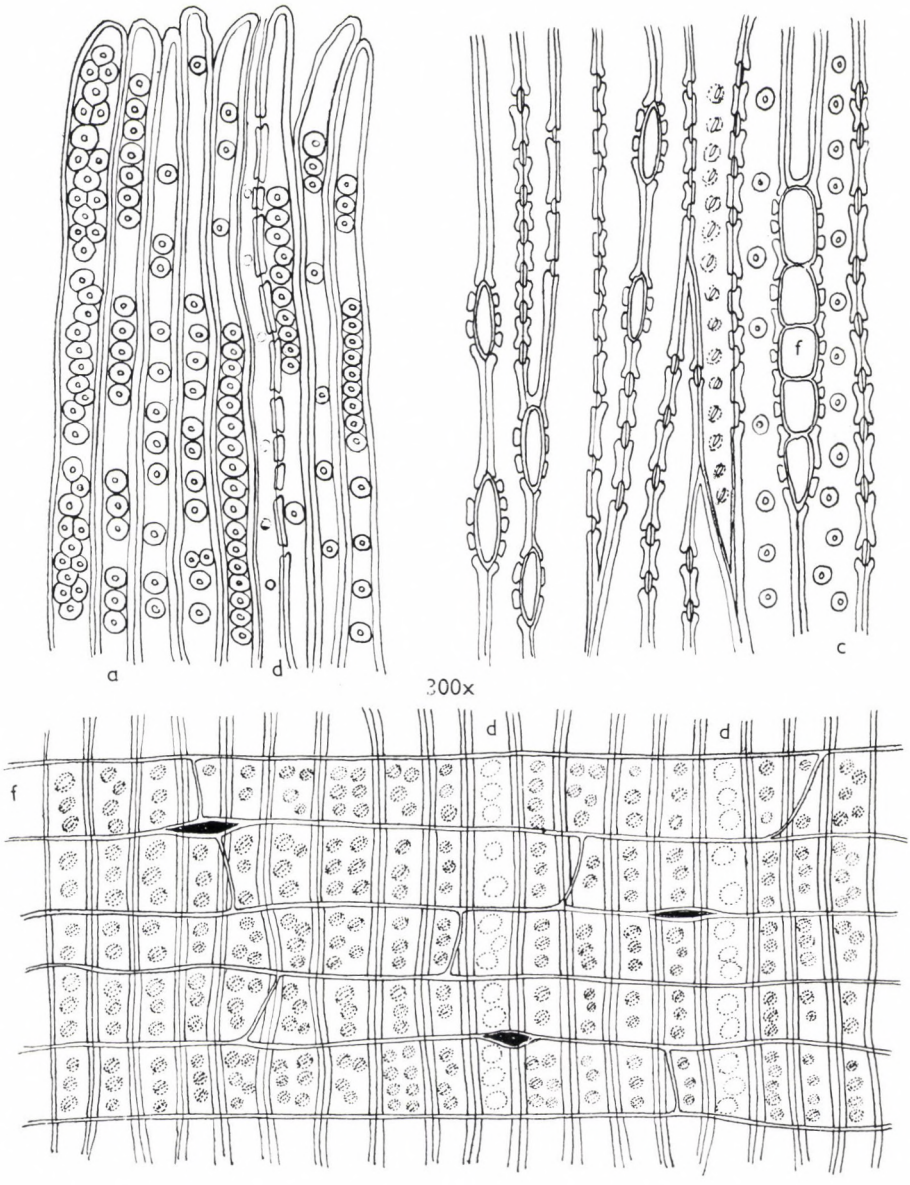
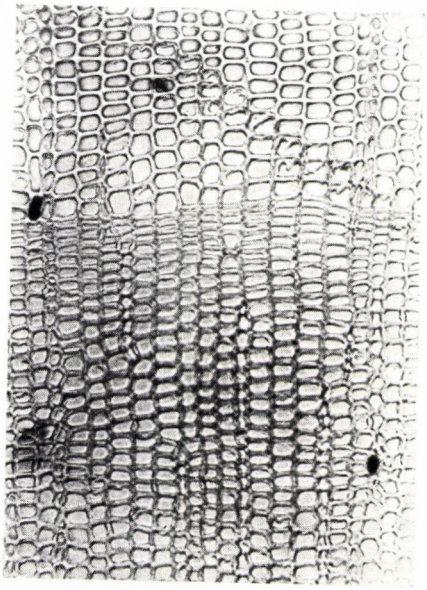


Fig. 99. *Abies forrestii* Craib.



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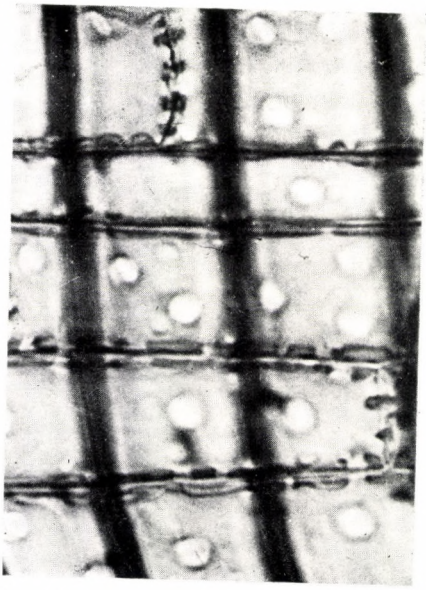

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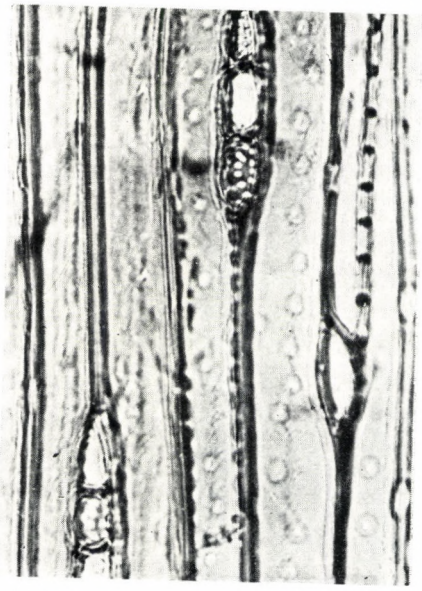

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CXX. *Abies georgei* Orr.

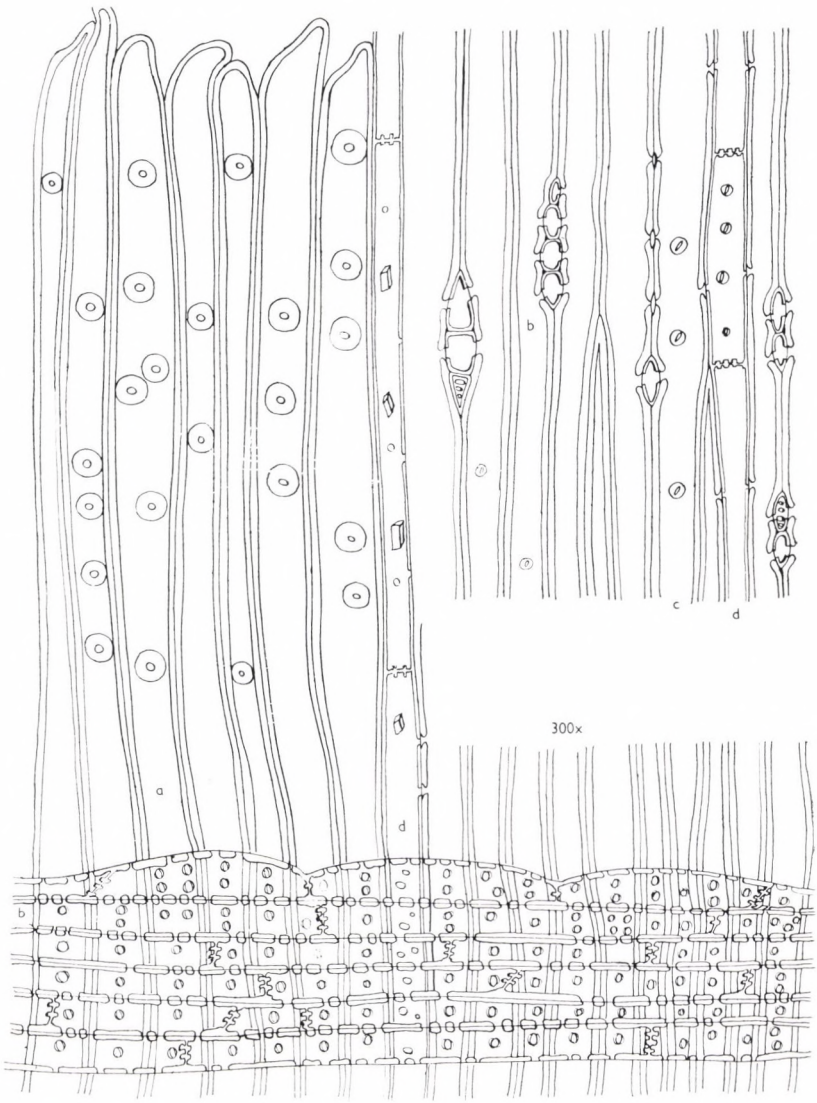
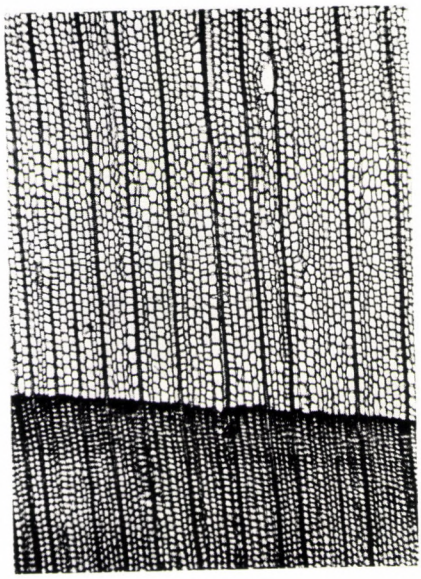
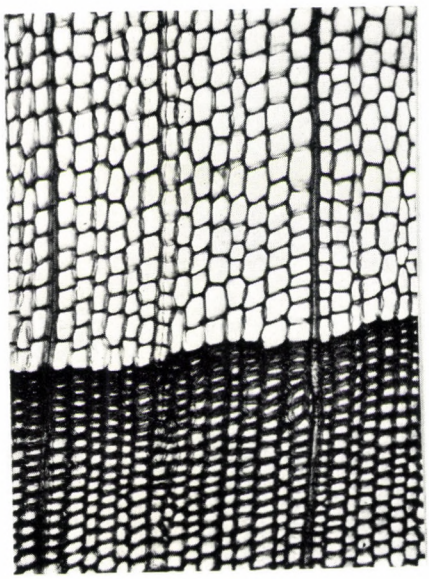


Fig. 100. *Abies georgei* Orr.



1. (×30)



2.(×100)

3.(×300)

4. (×100)

CXXI. *Abies mariesii* Mast.

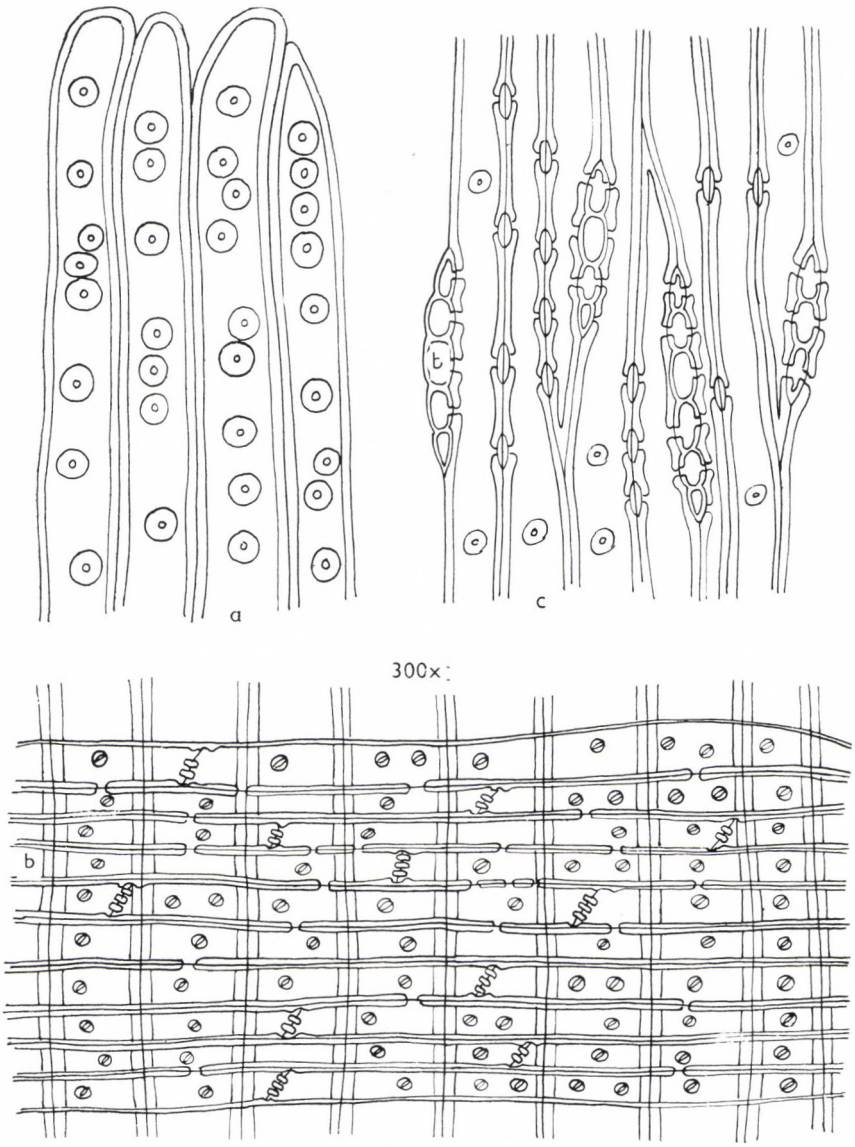
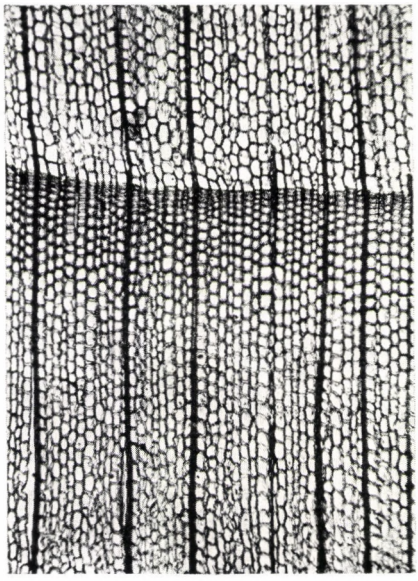


Fig. 101. *Abies mariesii* Mast.



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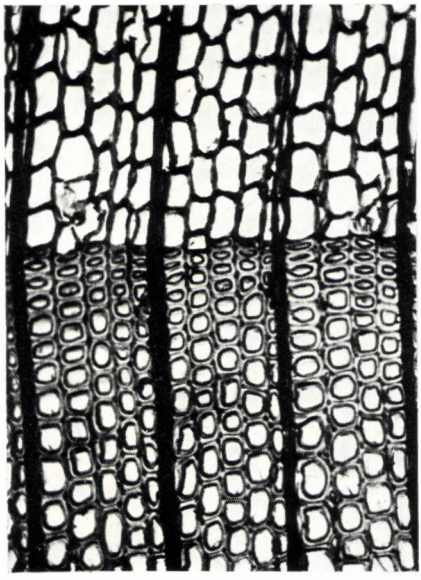

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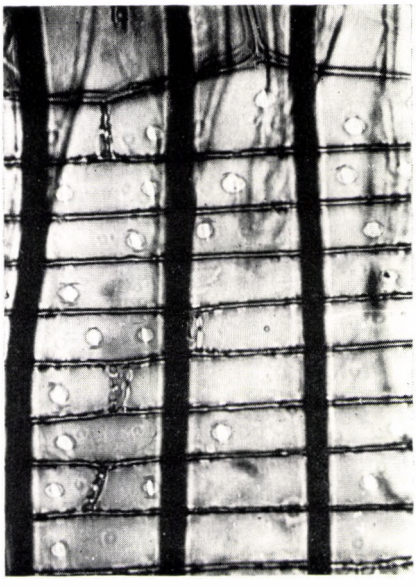

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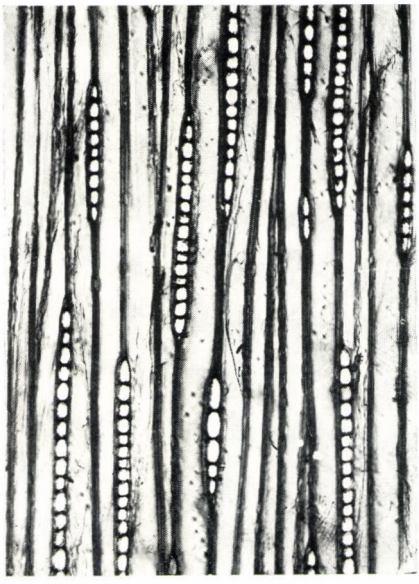


4.(×100)

CXXII. *Abies recurvata* Mast.

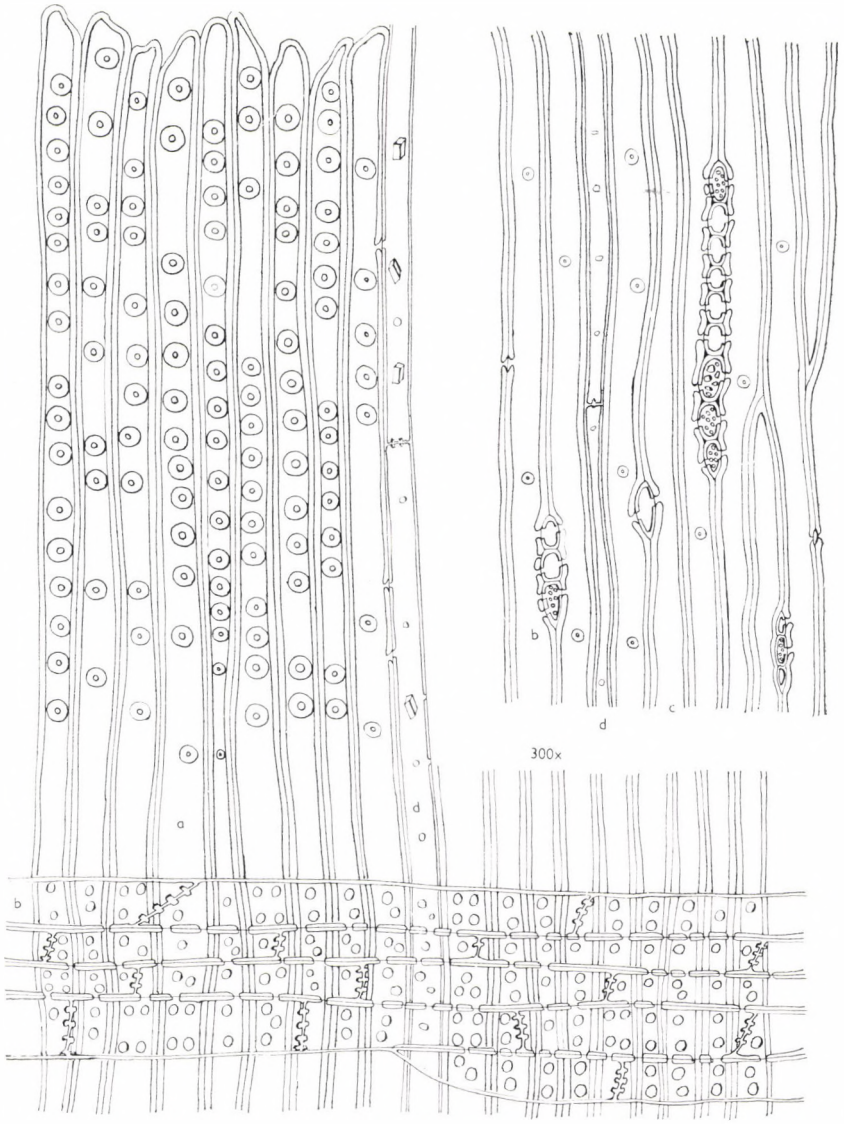
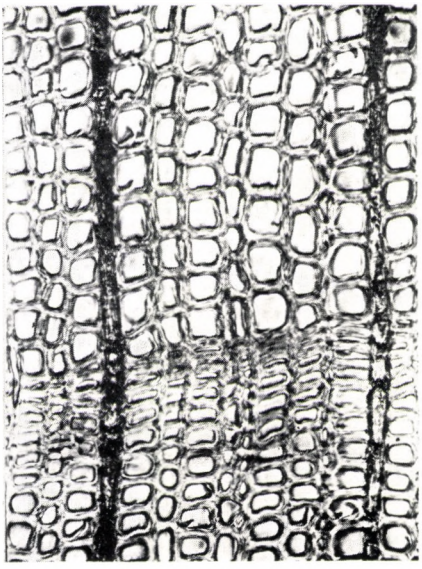


Fig. 102. *Abies recurvata* Mast.



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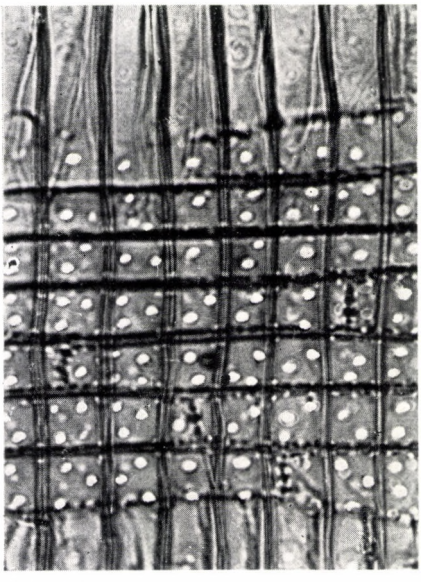
2(x100)



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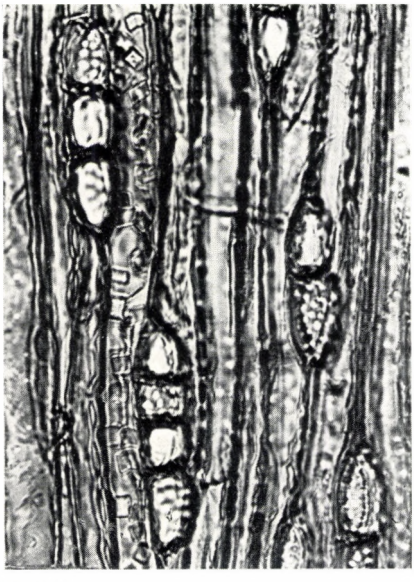

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CXXIII. *Abies religiosa* Schlecht. and Cham.

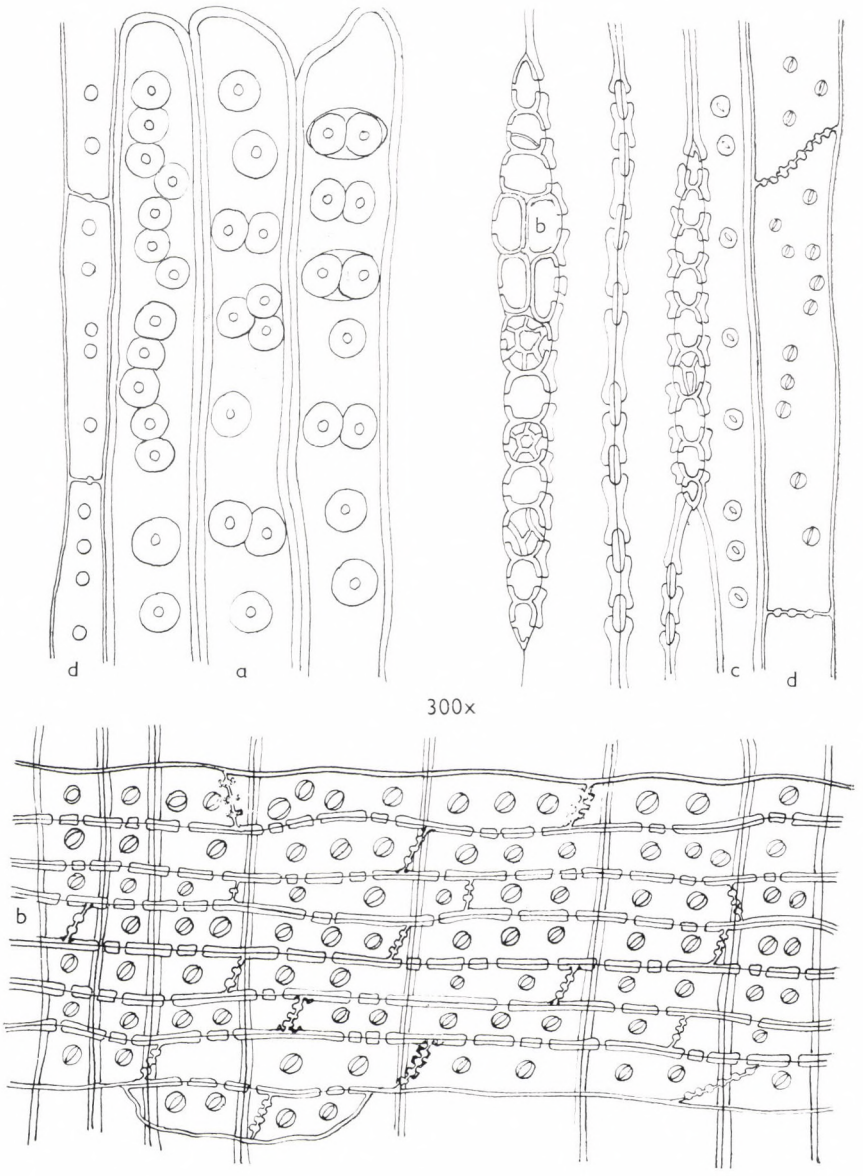
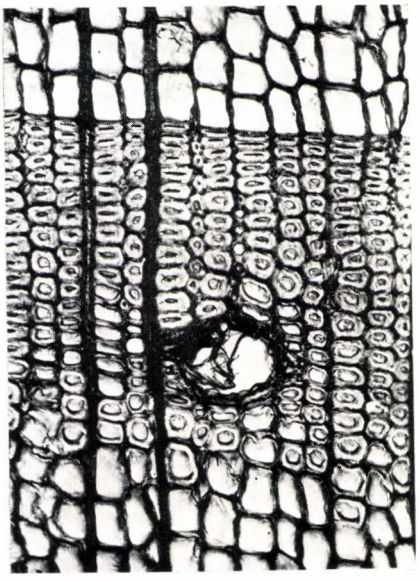


Fig. 103. *Abies religiosa* Schlecht. and Cham.



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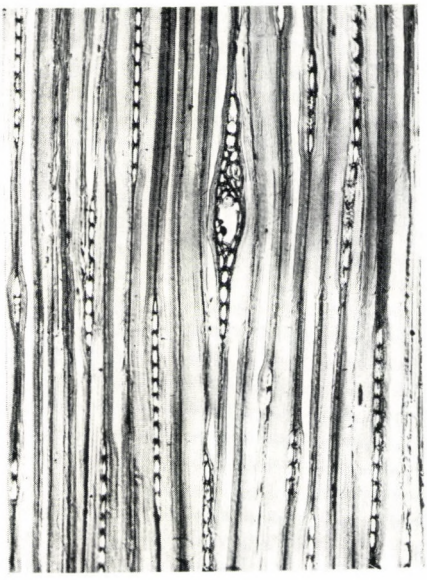

2.(×100)

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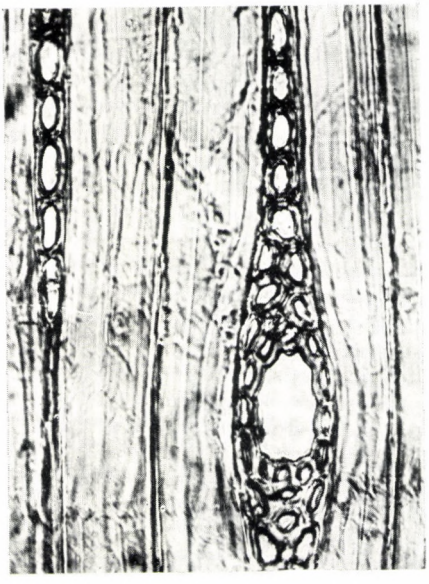


4.(×300)

CXXIV. *Larix gmelinii* var. *olgensis* Ostenfeld and Syrah

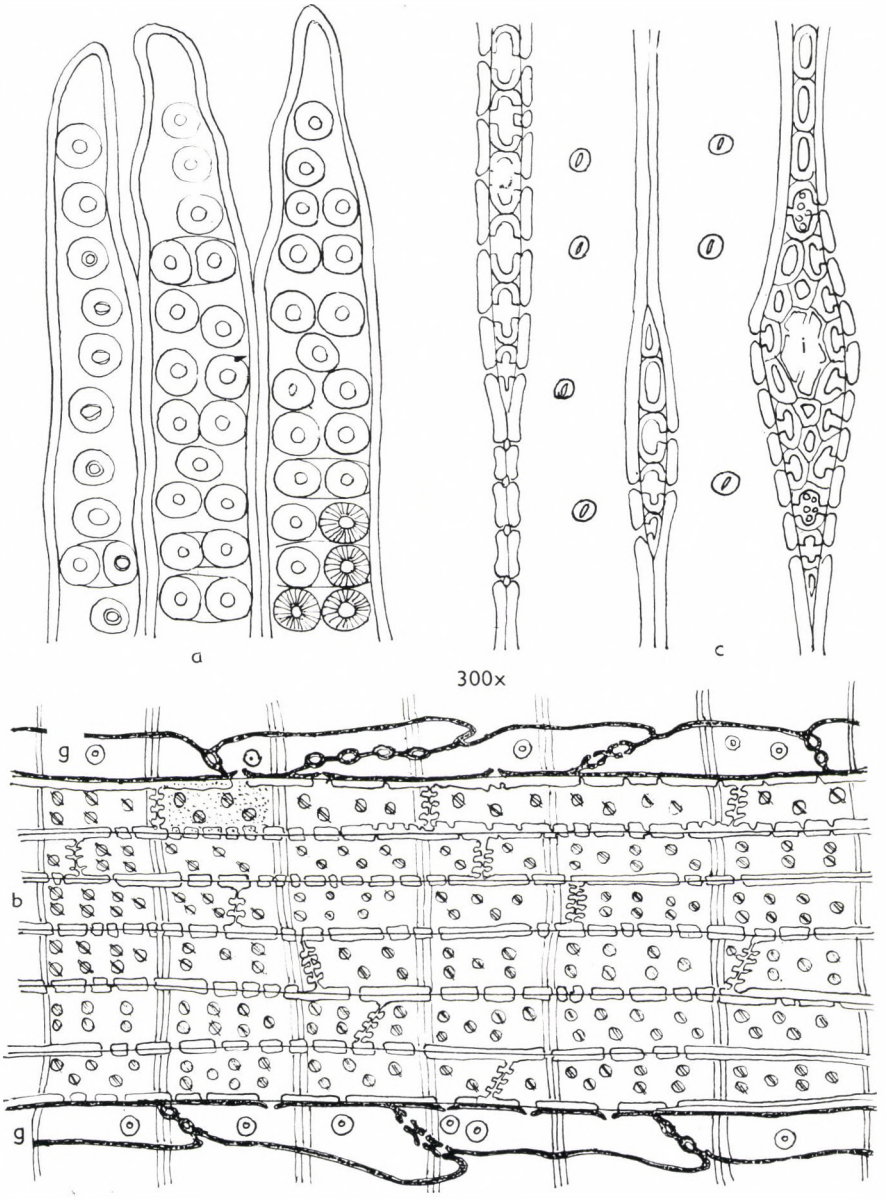
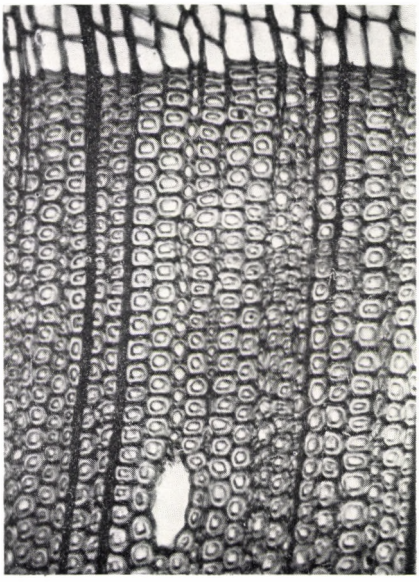


Fig. 104. *Larix gmelinii* var. *olgensis* Ostenfeld and Syrah



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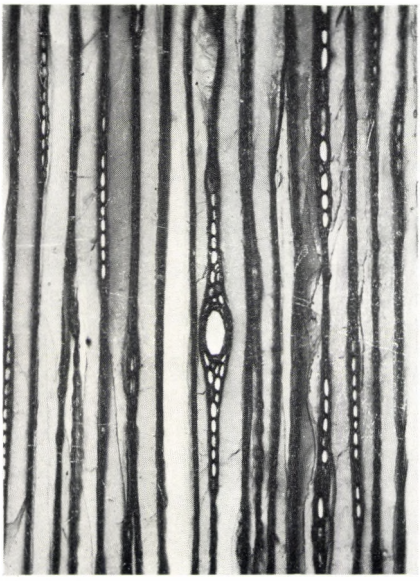

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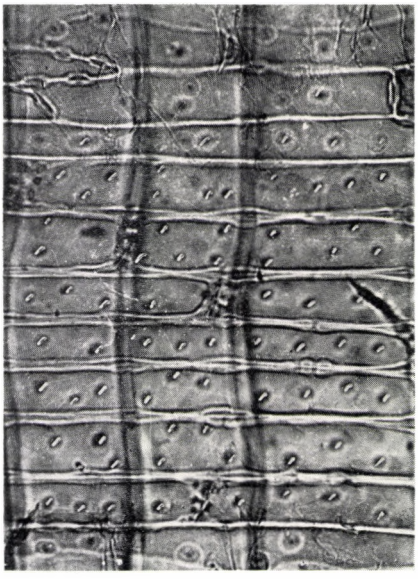


3.(×300)

4.(×300)

CXXV. *Larix gmelinii* var. *principis-rupprechtii* Pilger

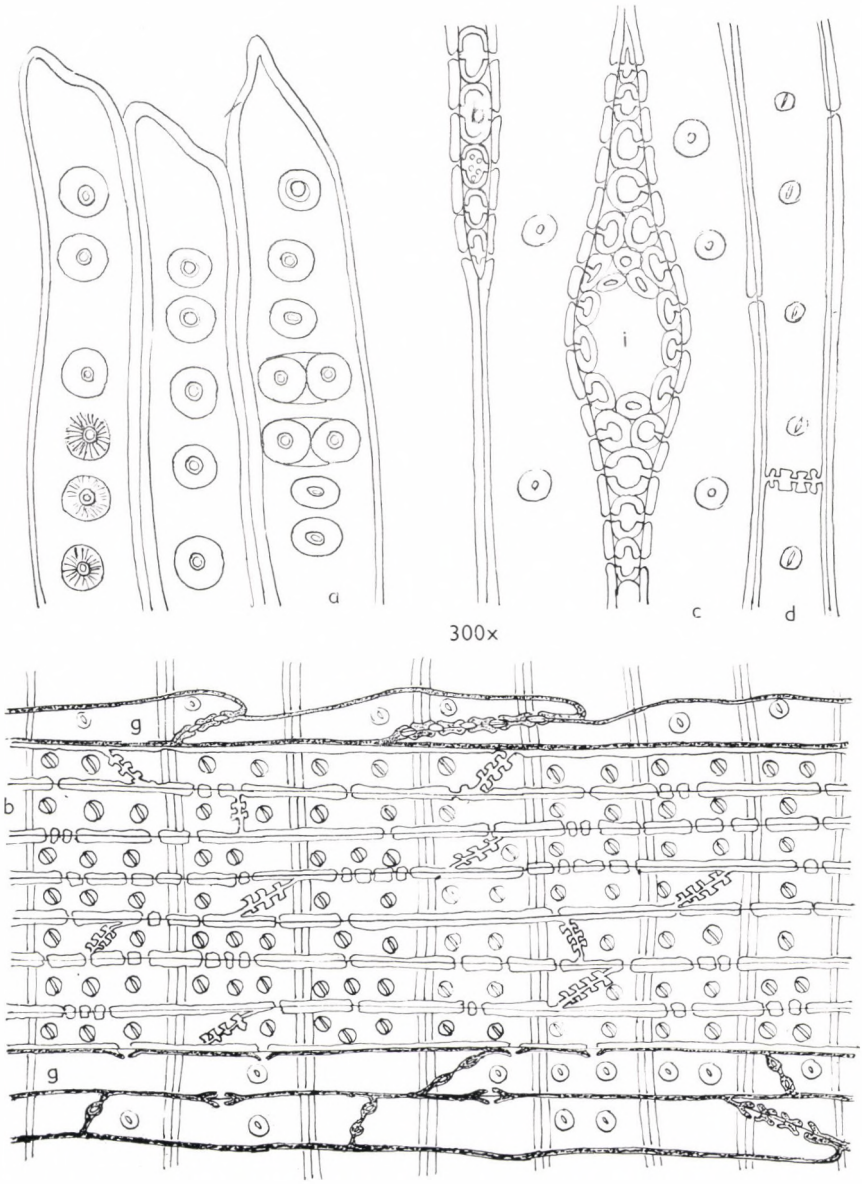
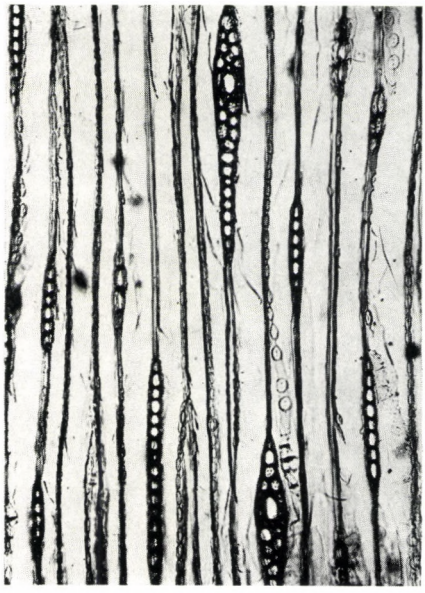
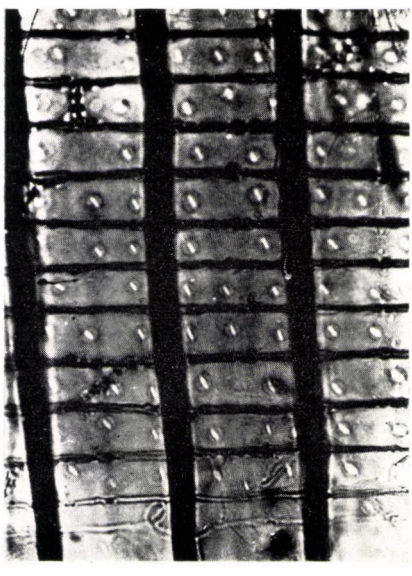


Fig. 105. *Larix gmelinii* var. *principis-rupprechtii* Pilger

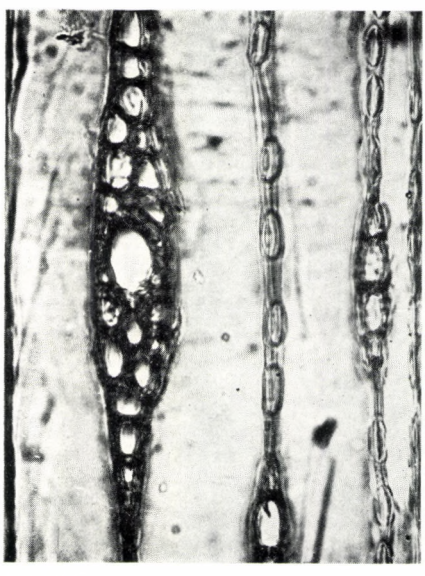
1. (x100)



2. (x100)



3. (x 300)



4. (x300)

CXXVI. *Larix griffithii* Hooker fil.

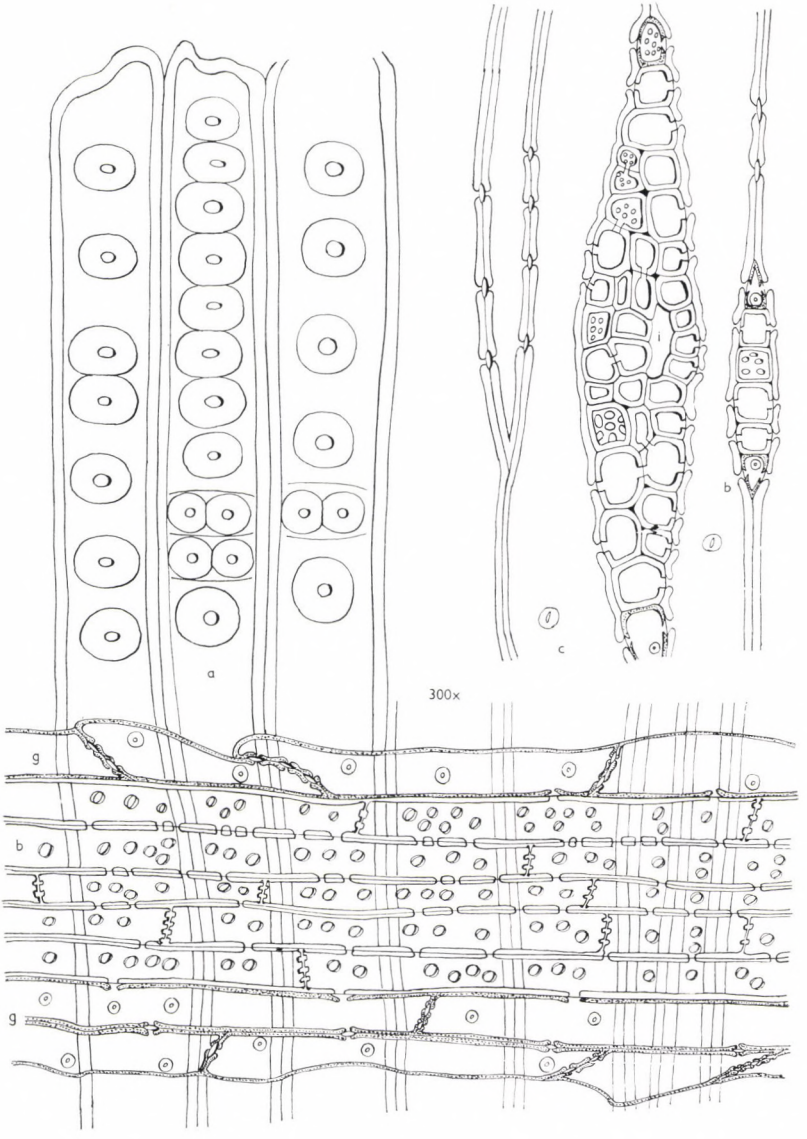
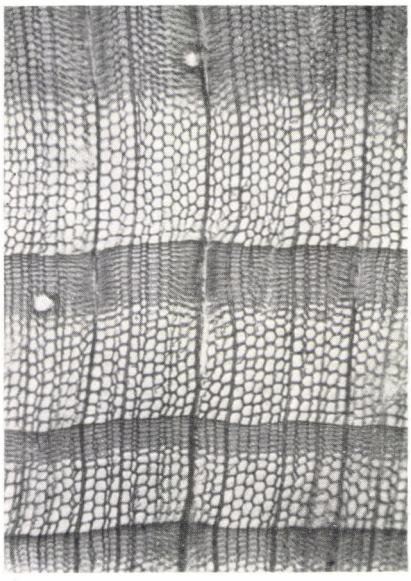
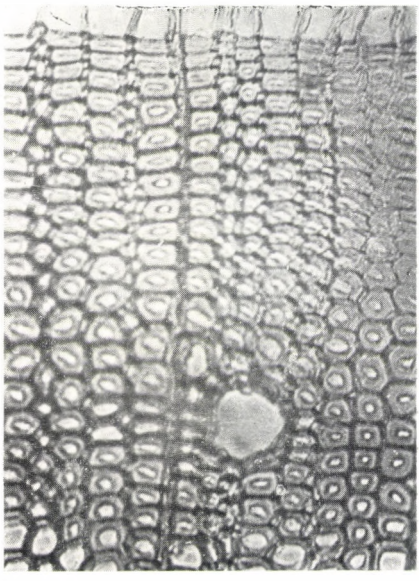


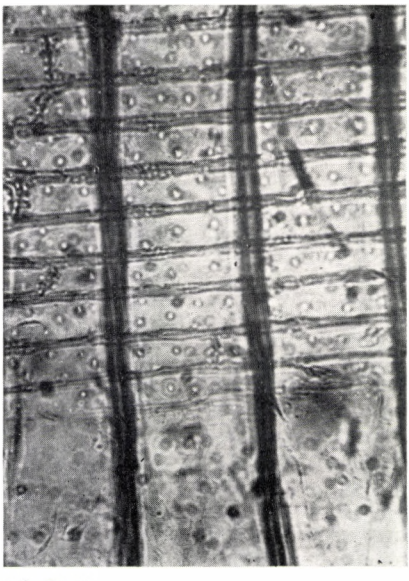
Fig. 106. *Larix griffithii* Hooker fil.



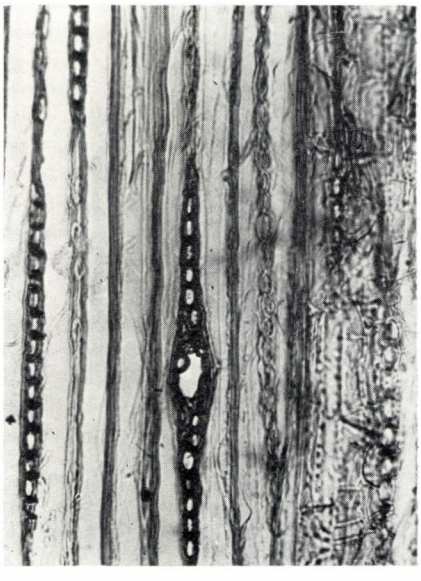
1. (x 50)



2.(x100)



3.(x 300)



4.(x 100)

CXXVII. *Larix polonica* Racib.

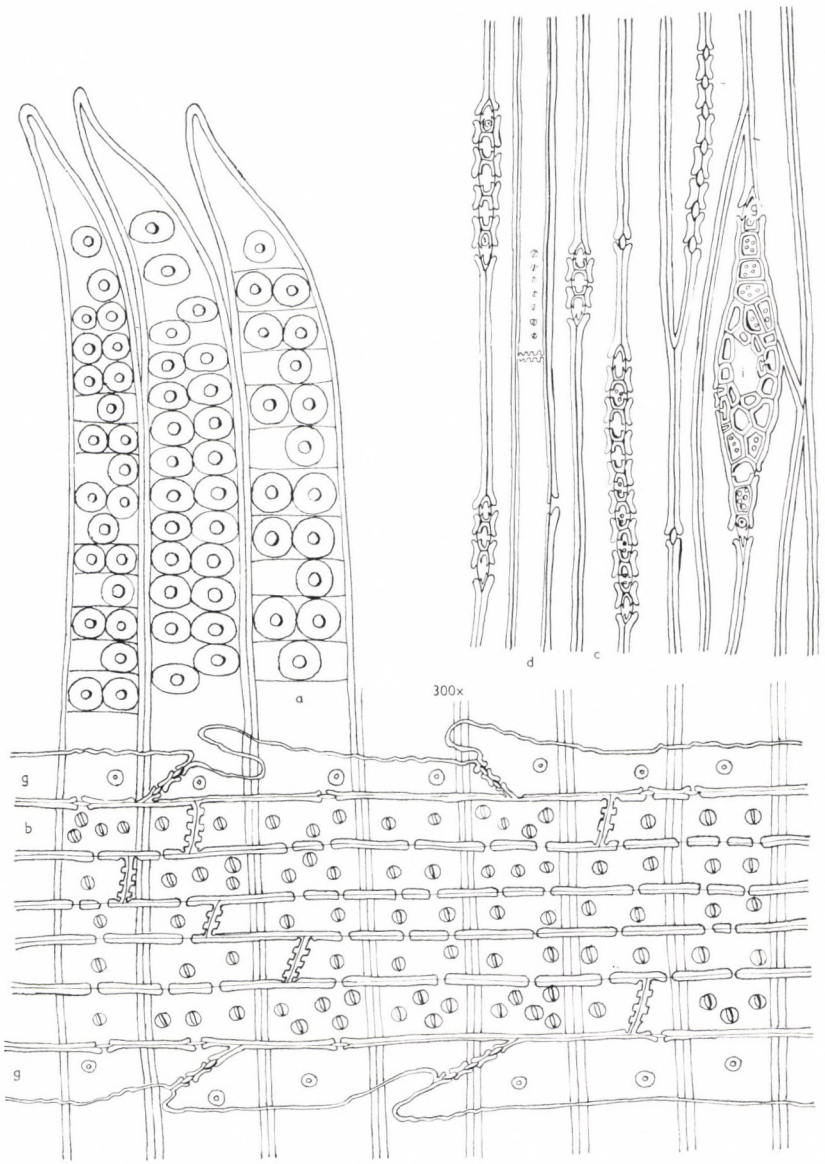
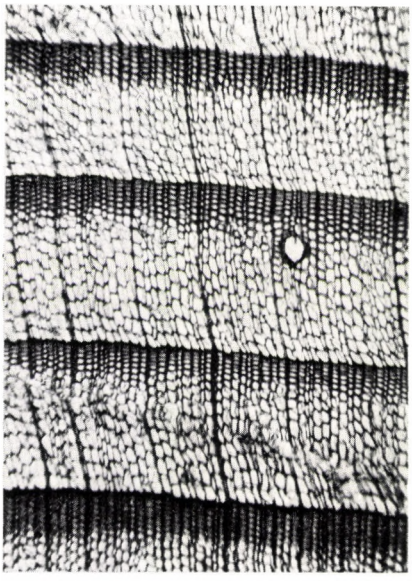
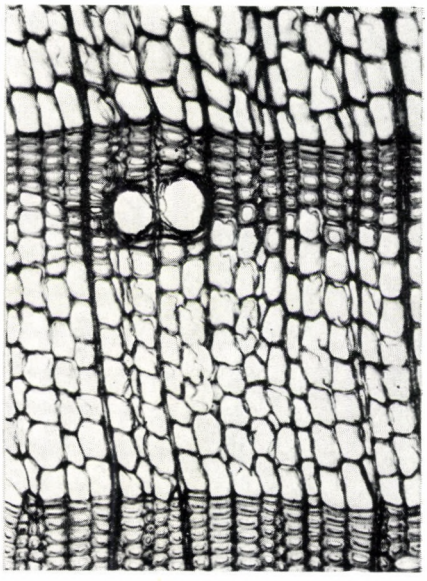


Fig. 107. *Larix polonica* Racib.

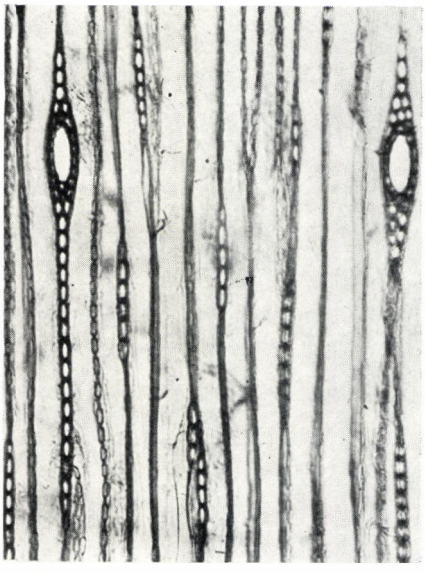


1.(× 50)



2.(×100)

3.(× 300)



4.(×100)

CXXVIII. *Larix sukaczewii* Dyer

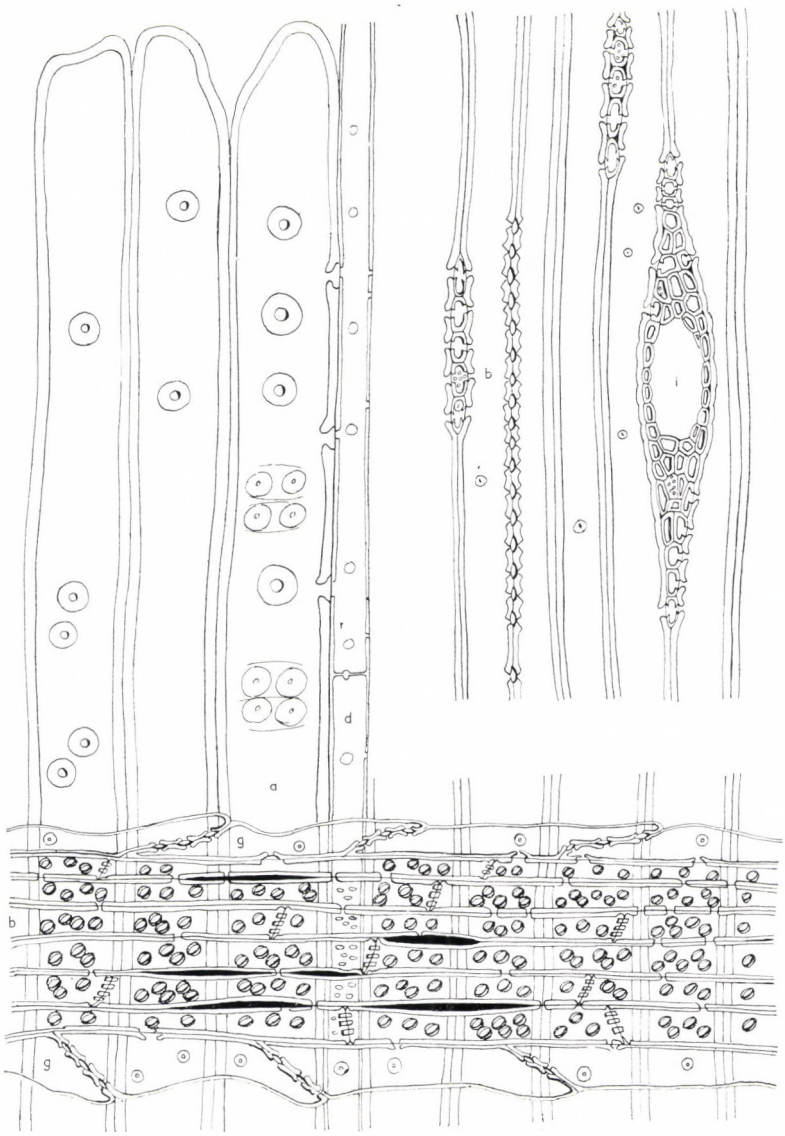
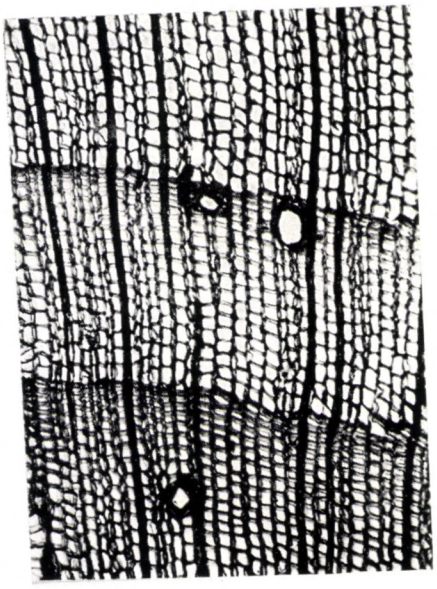
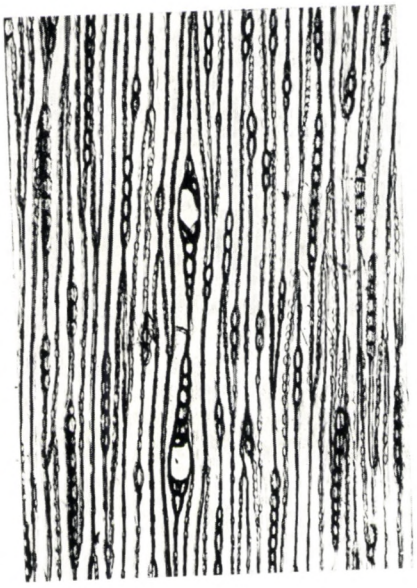


Fig. 108. *Larix sukaczewii* Dyer

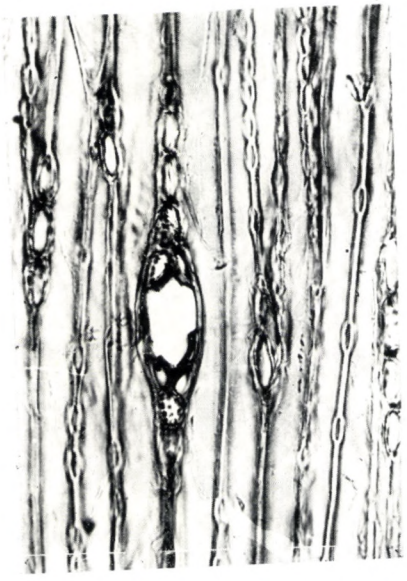


1.(x100)



2.(x100)

3.(x 200)



4.(x300)

CXXIX. *Picea fennica* Rgl.

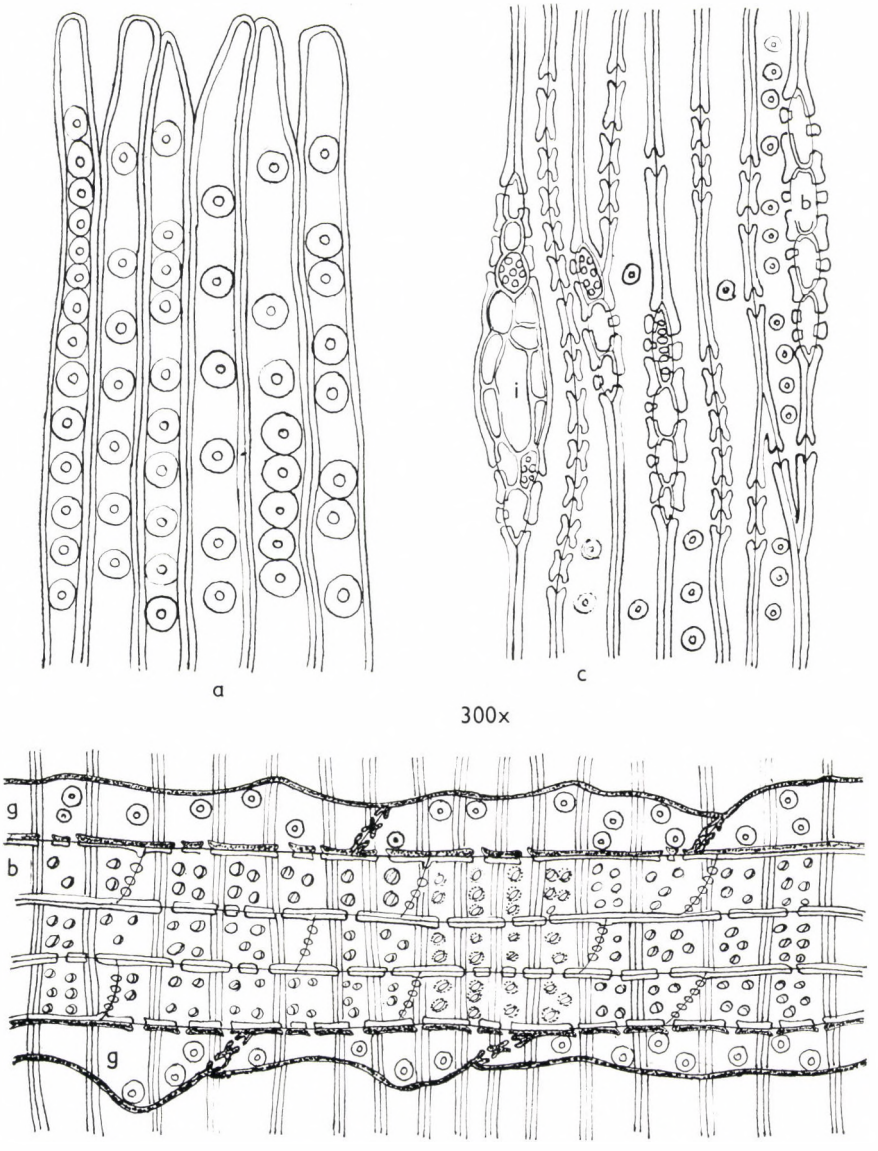
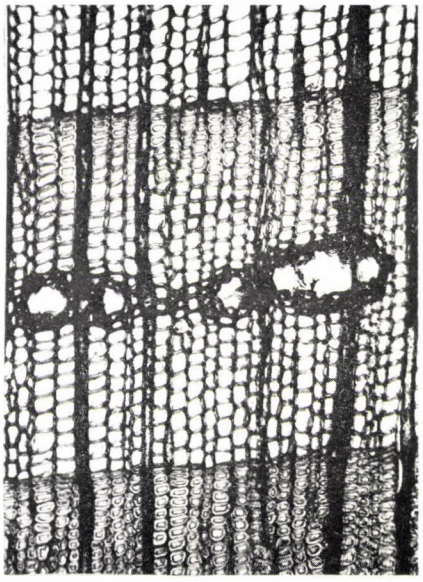
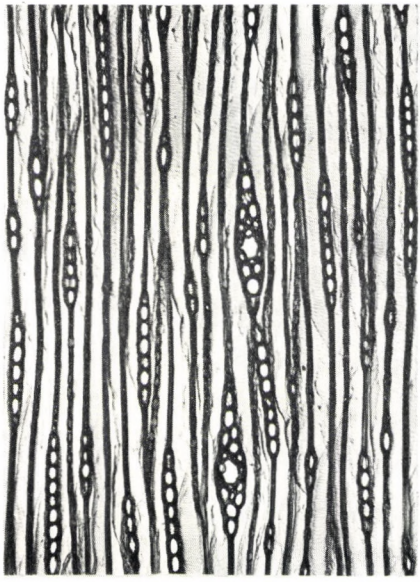


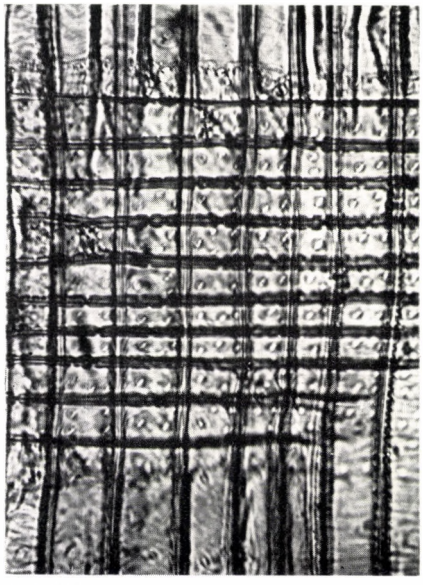
Fig. 109. *Picea fennica* Rgl.



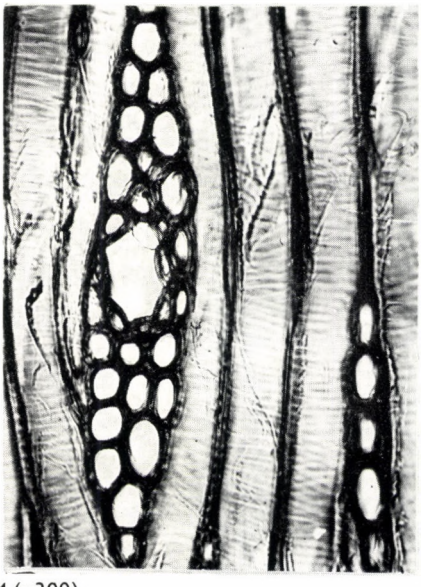
1.(x100)



2.(x100)



3.(x300)



4.(x300)

CXXX. *Picea montigena* Mast.

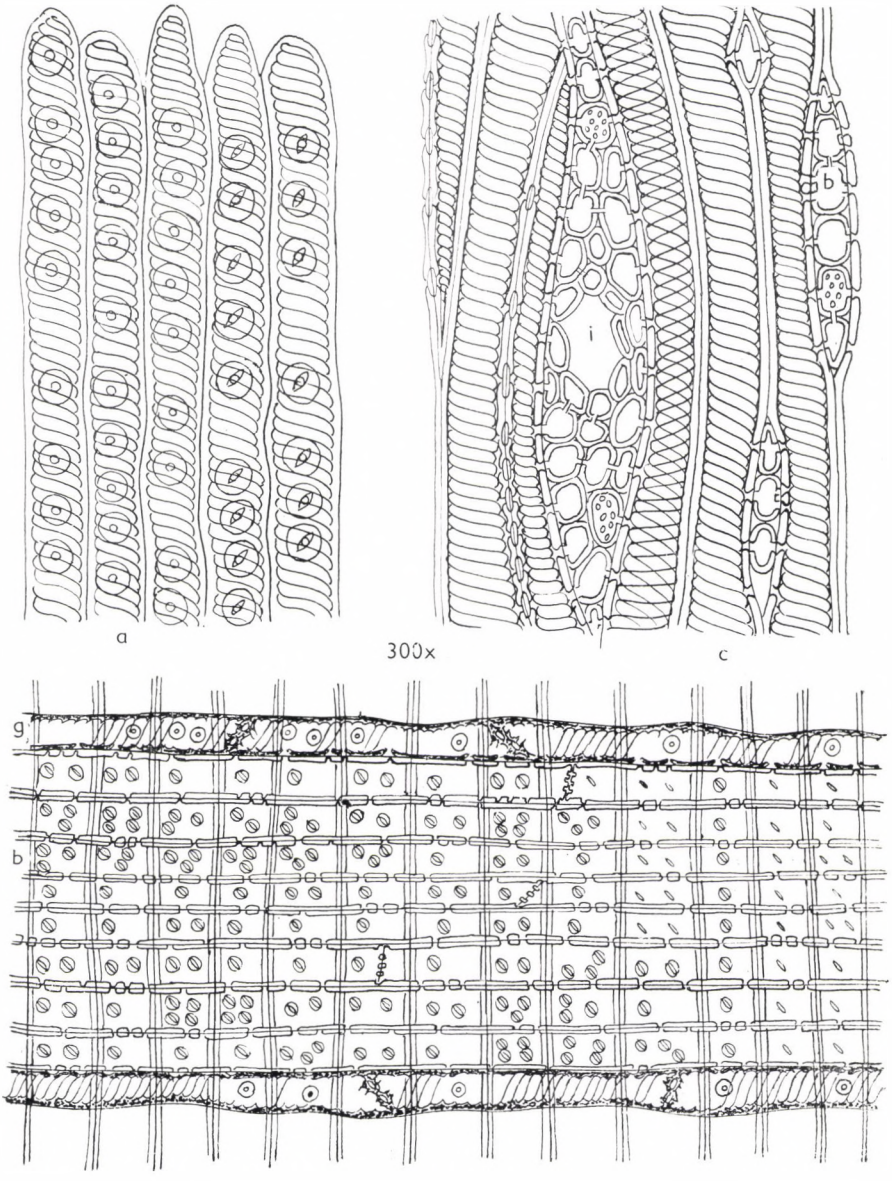


Fig. 110. *Picea montigena* Mast.

1.(×100)

2.(×100)

3.(× 300)

4.(×300)

CXXXI. *Picea rubens* Sargent

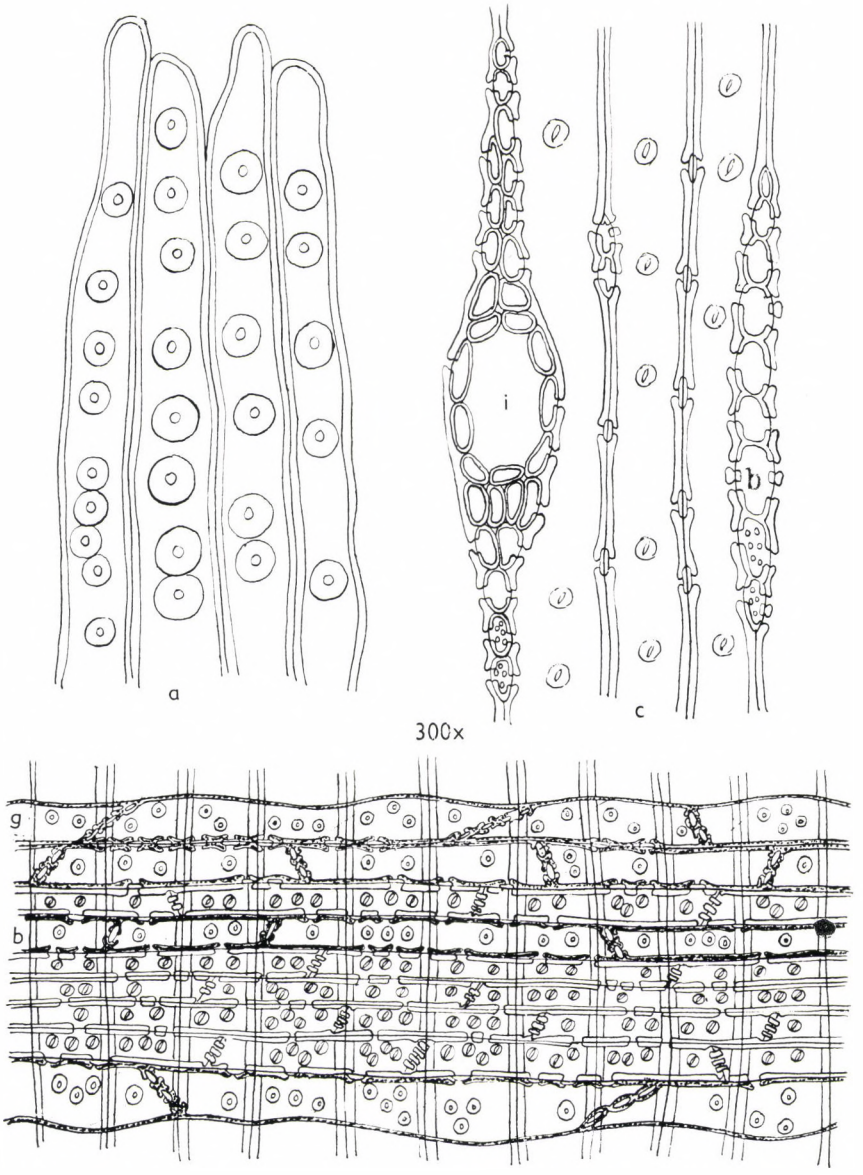
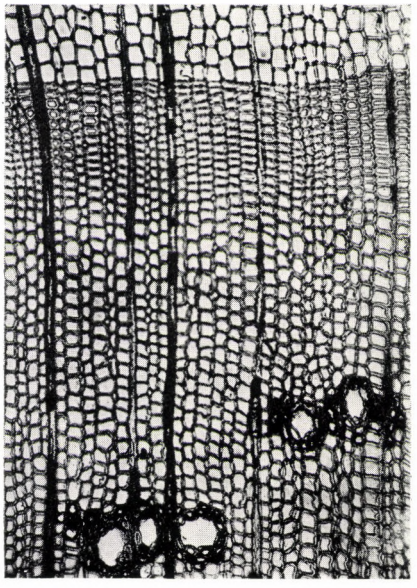
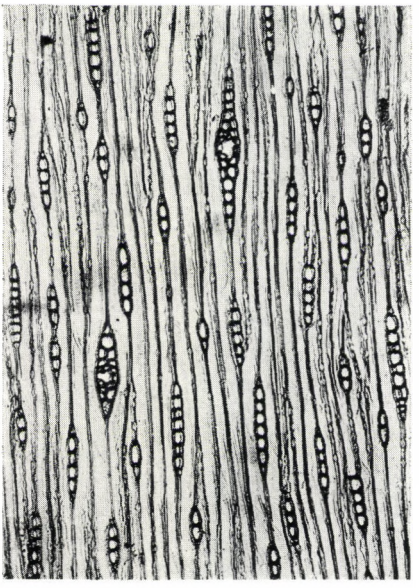


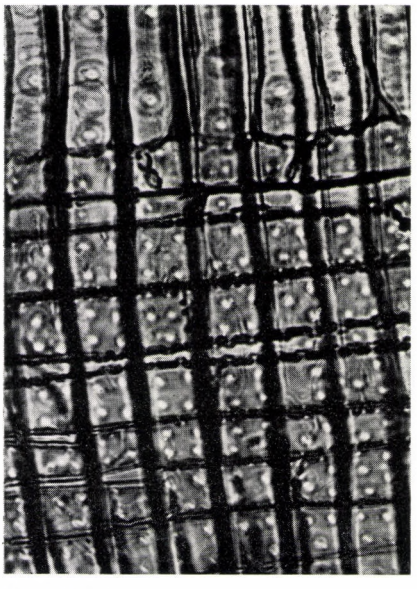
Fig. 111. *Picea rubens* Sargent



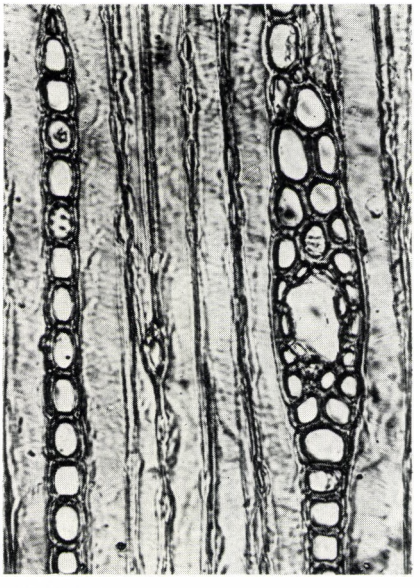
1.(x100)



2.(x100)



3.(x300)



4.(x300)

CXXXII. *Picea spinulosa* (Griffith) Henry

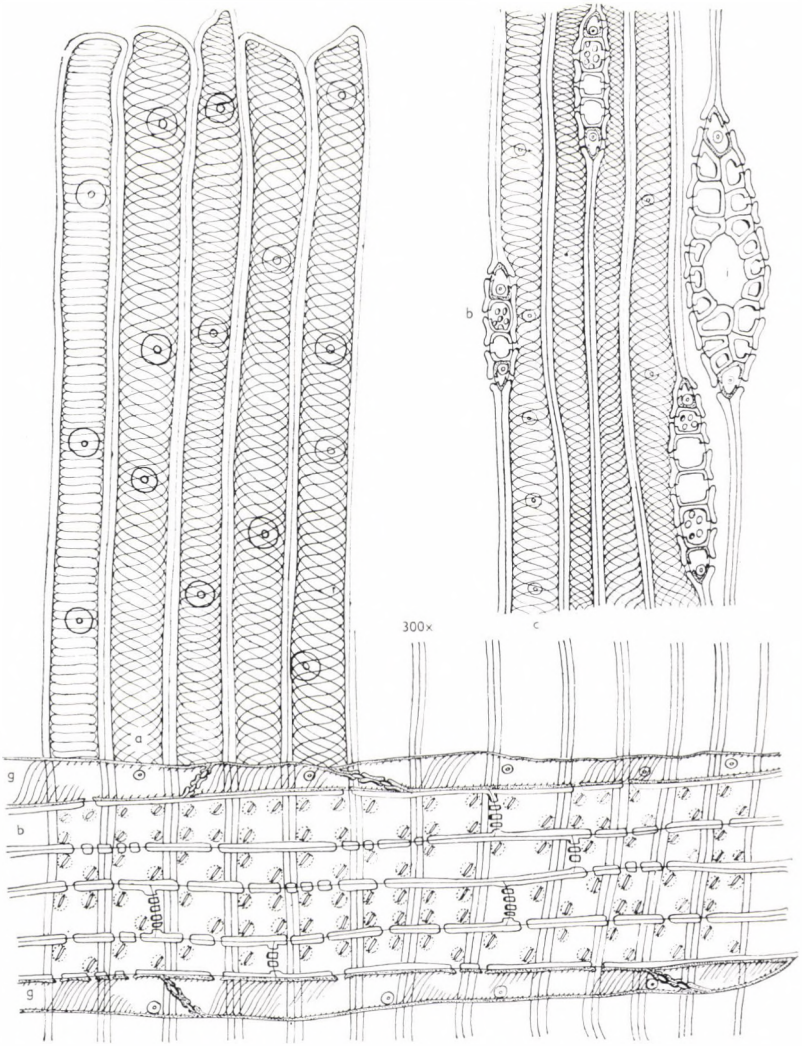
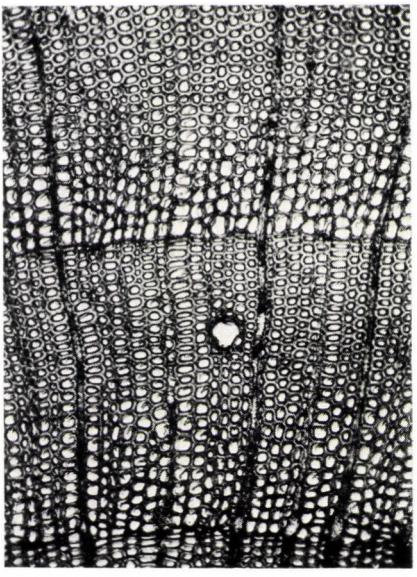
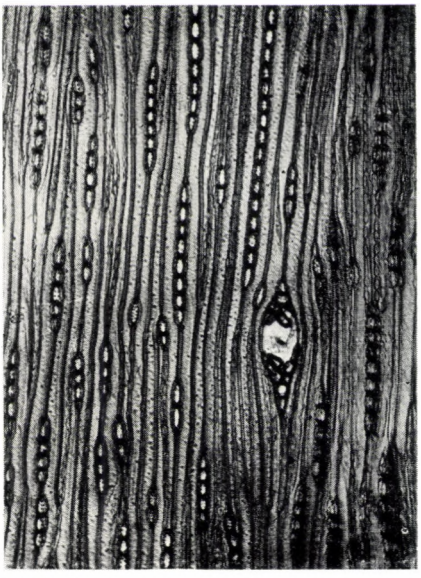


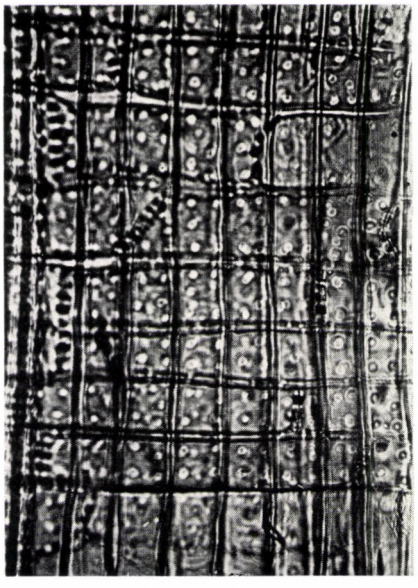
Fig. 112. *Picea spinulosa* (Griffith) Henry



1.(×100)



2.(×100)



3.(×300)

4.(×300)

CXXXIII. *Picea tianschanica* Rupr.

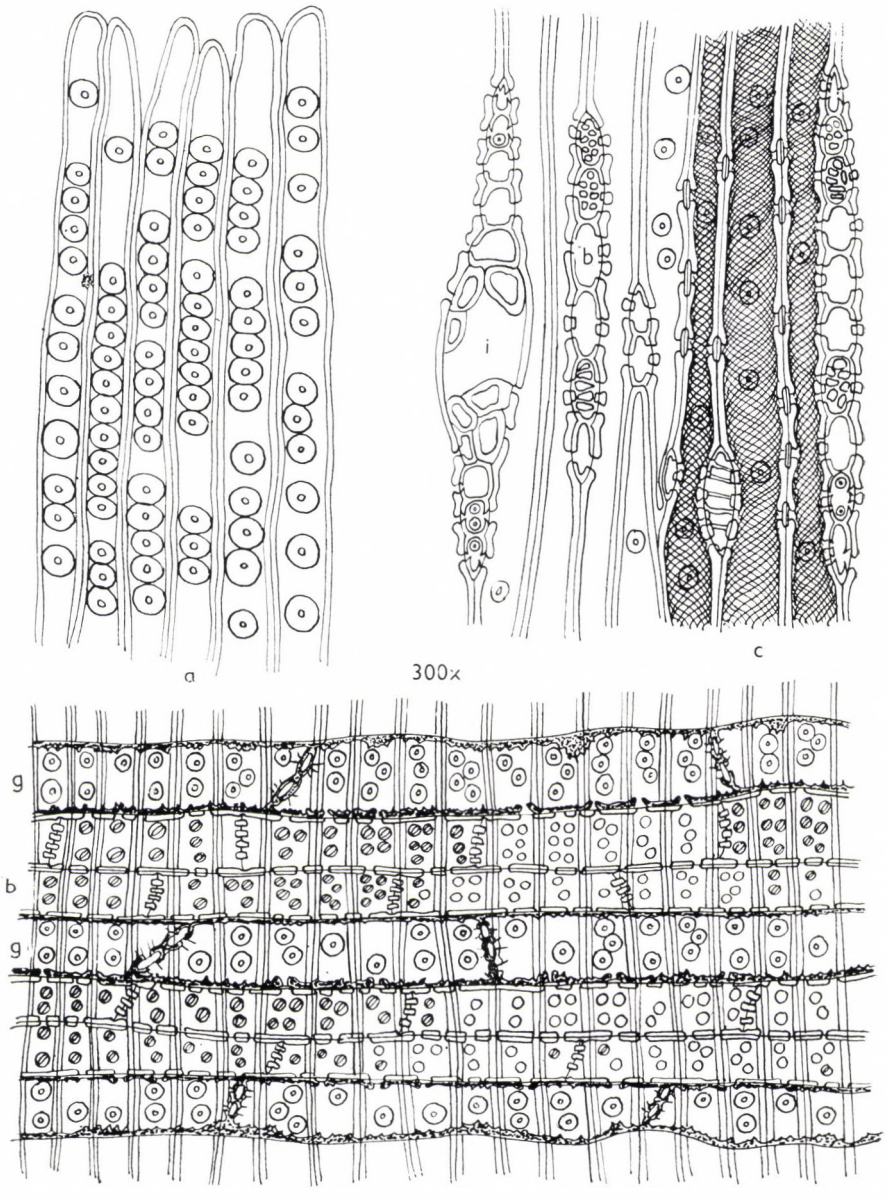
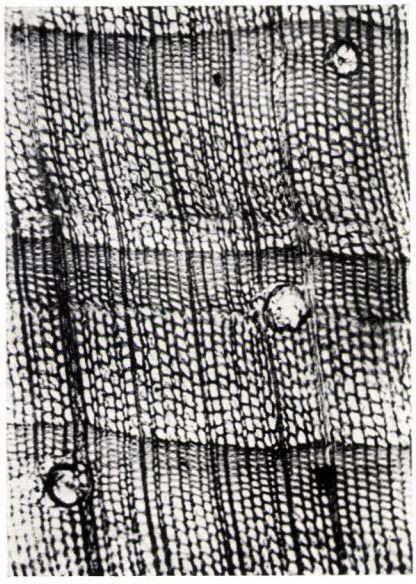
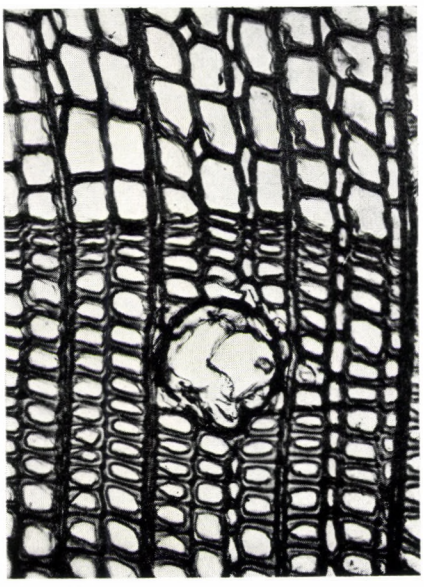


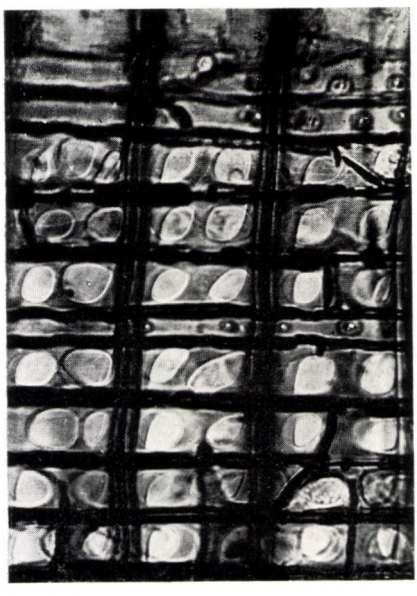
Fig. 113. *Picea tianschanica* Rupr.



1.(× 30)



2(×100)



3.(× 300)

4.(×100)

CXXXIV. *Pinus amaniana* Koidz.

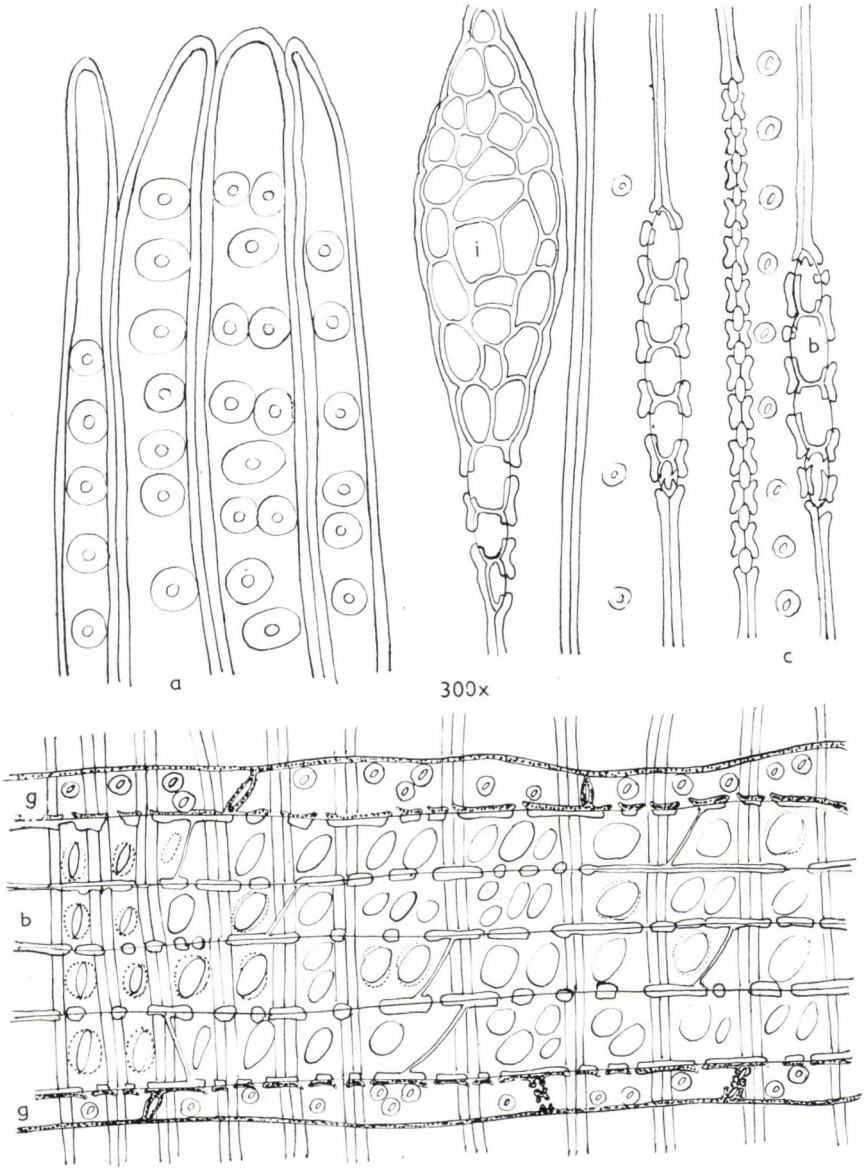
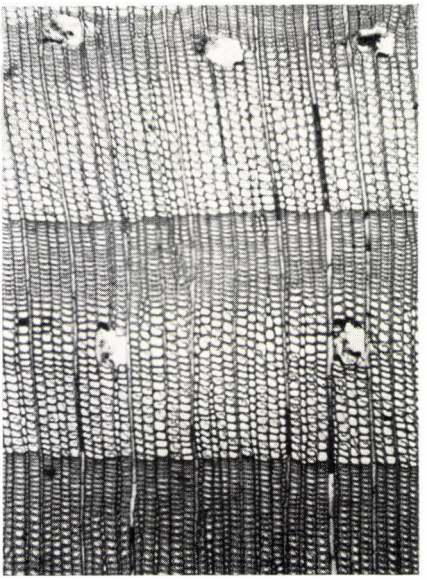
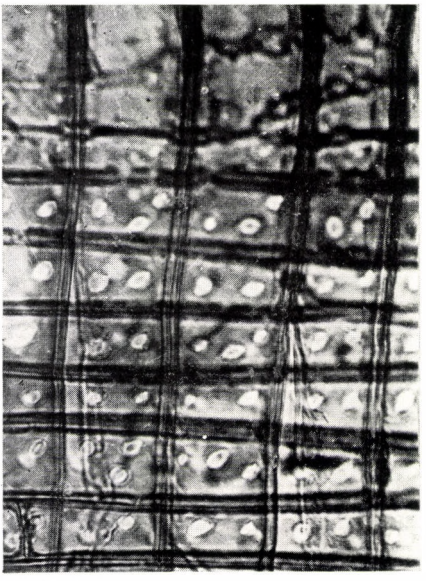


Fig. 114. *Pinus amaniana* Koidz.

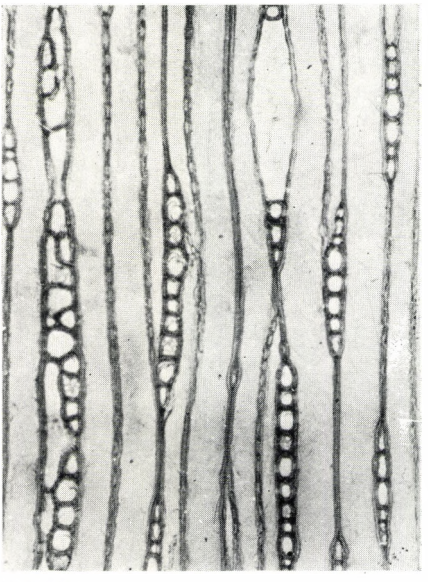


1. (×30)

2.(×100)



3. (×300)



4.(×100)

CXXXV. *Pinus brutia* var. *eldarica* Medvedjev

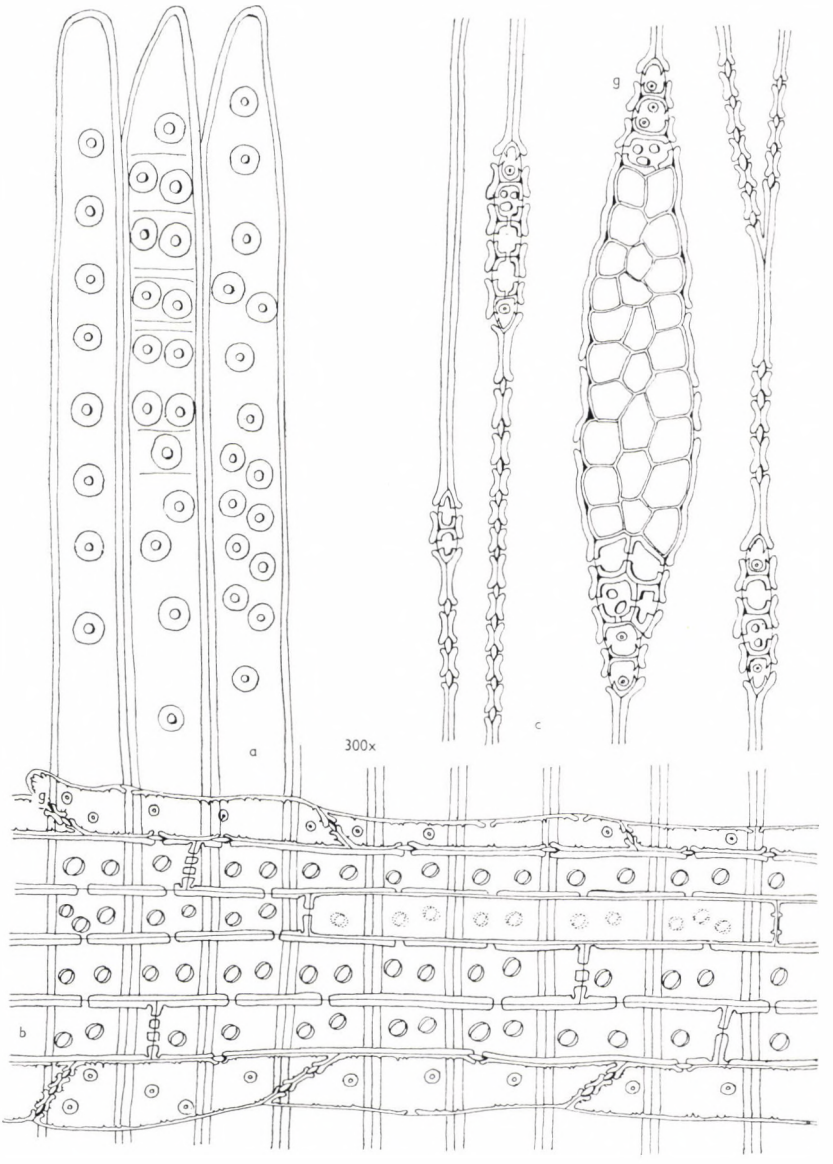
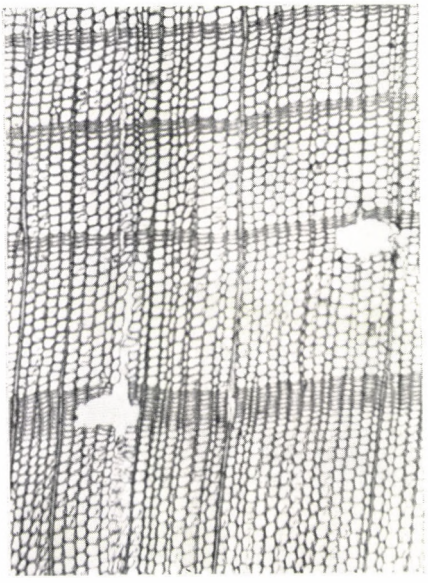
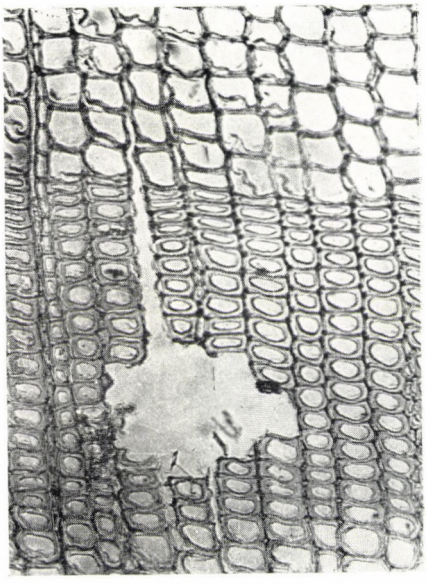


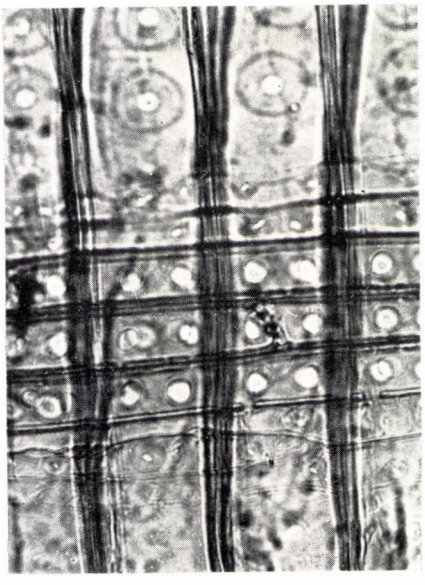
Fig. 115. *Pinus brutia* var. *eldarica* Medvedjev



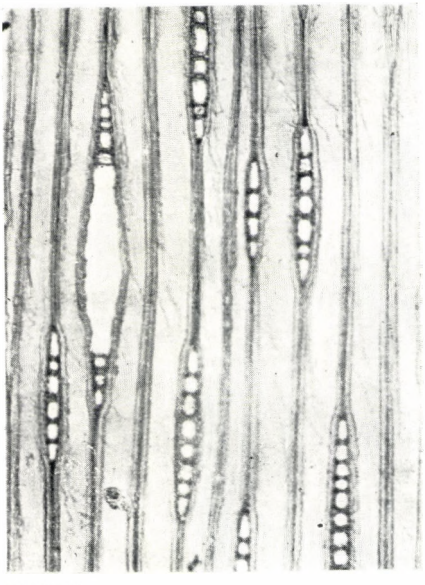
1. (×30)



2. (×100)



3. (×300)



4. (×100)

CXXXVI. *Pinus brutia* var. *pithyusa* Stev.

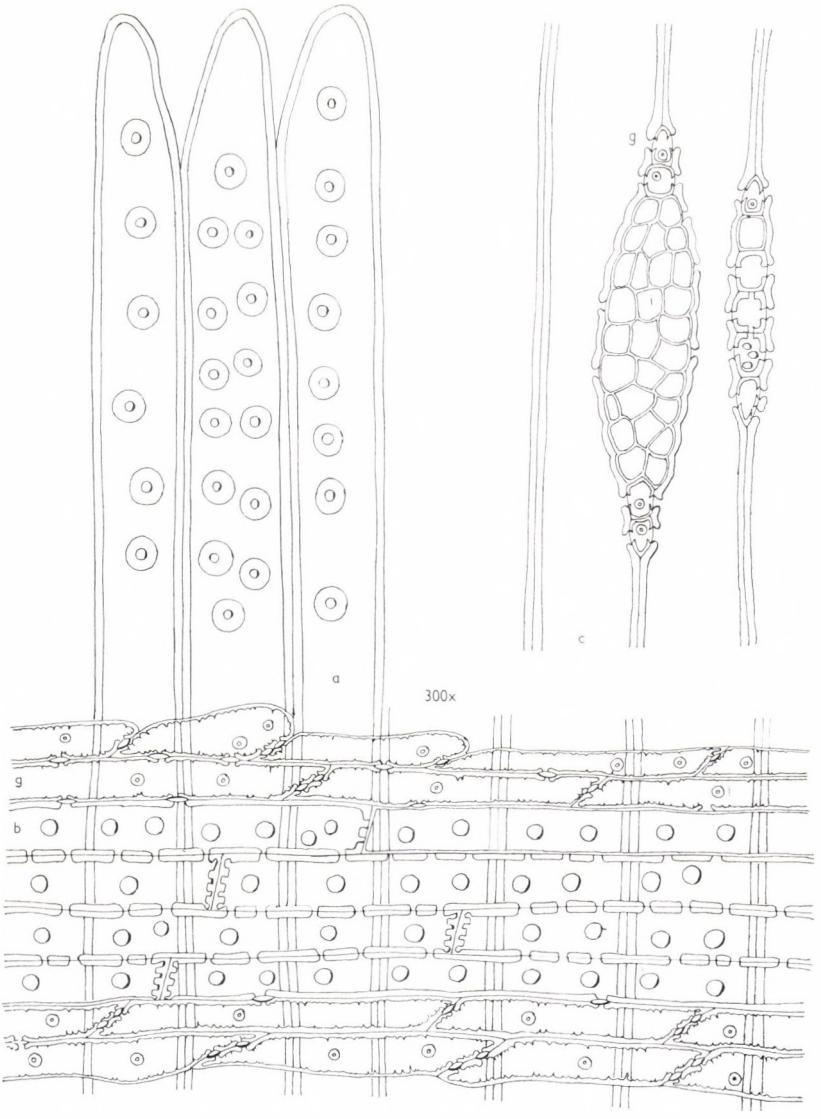
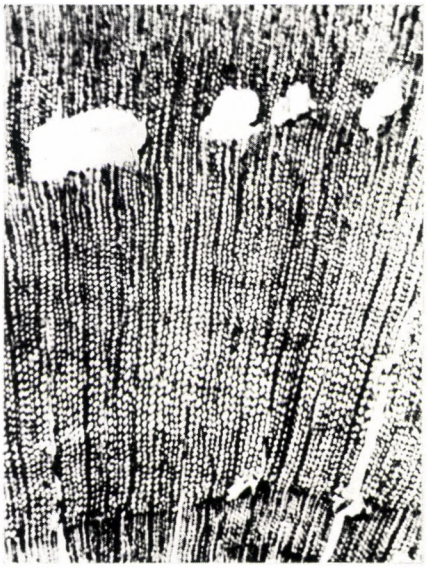
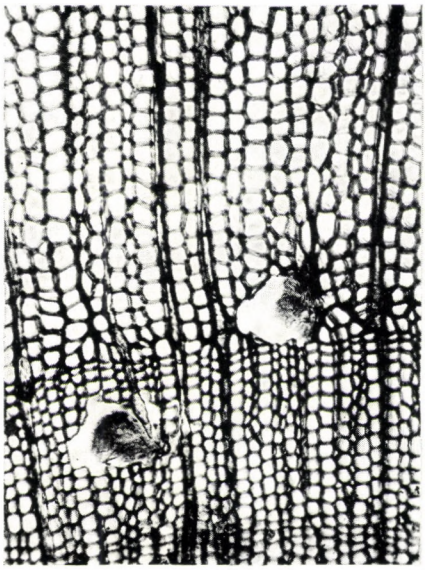


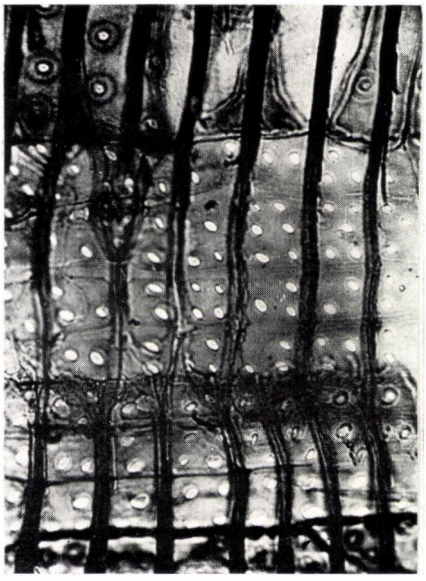
Fig. 116. *Pinus brutia* var. *pithyusa* Stev.



1.(x 30)



2.(x100)



3.(x 300)

4.(x100)

CXXXVII. *Pinus brutia* var. *stankewiczi* Sukac.

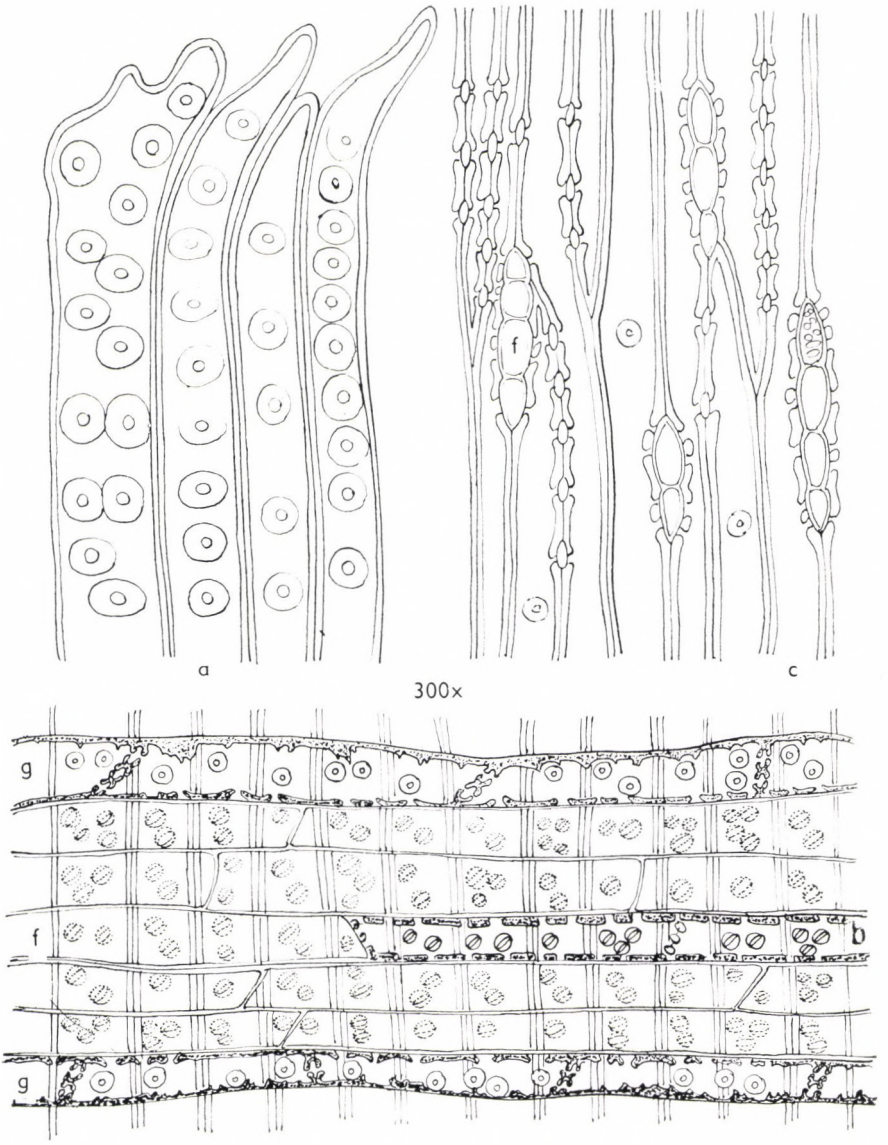
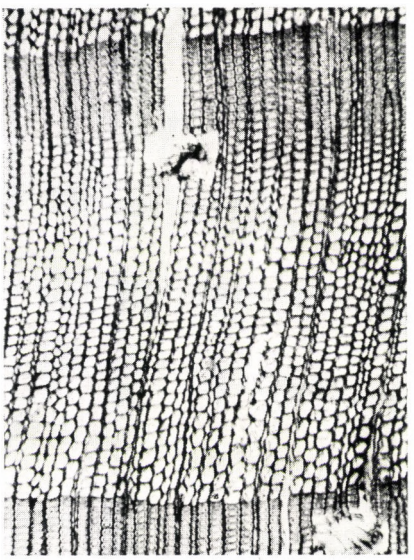
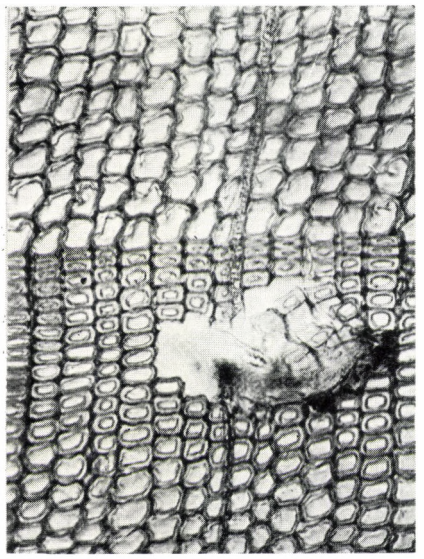


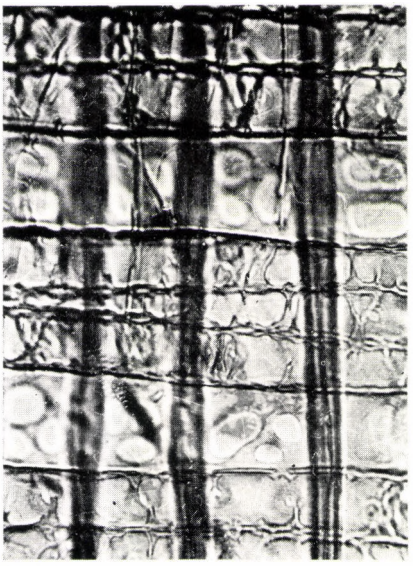
Fig. 117. *Pinus brutia* var. *stankewiczi* Sukac.



1. (x 30)



2.(x100)



3.(x 300)

4.(x100)

CXXXVIII. *Pinus cooperi* Blanco

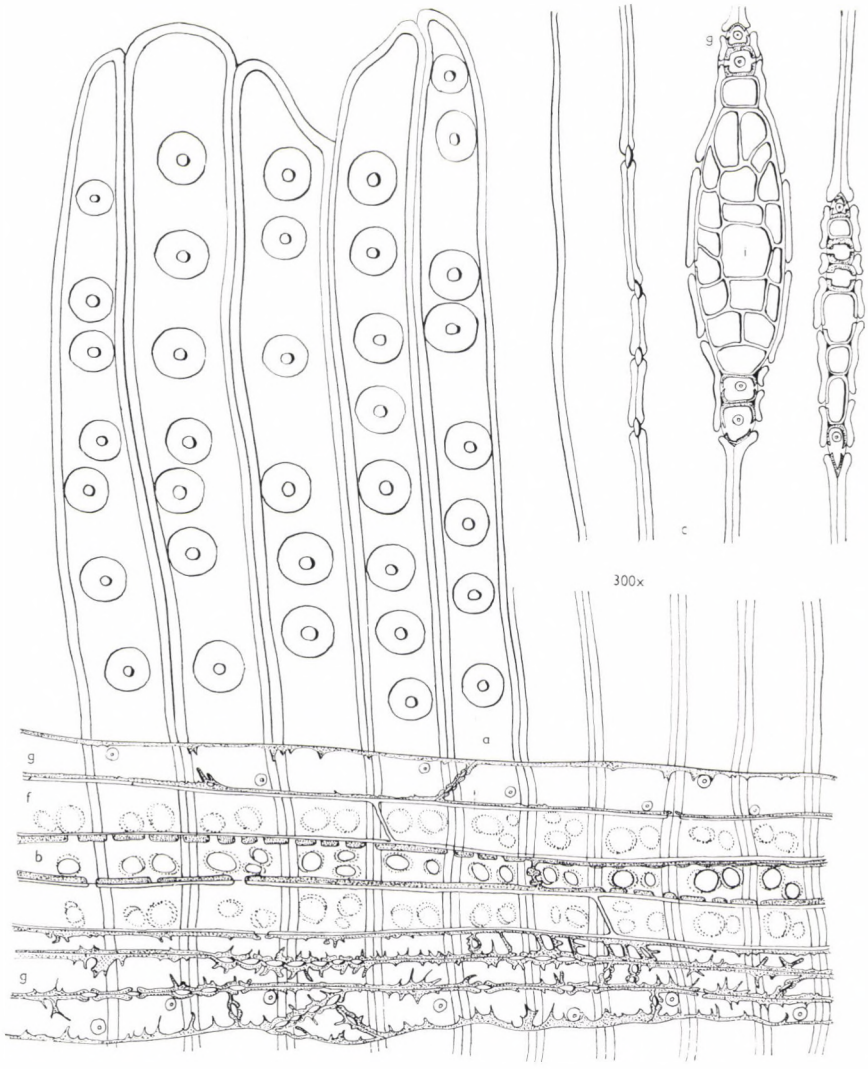
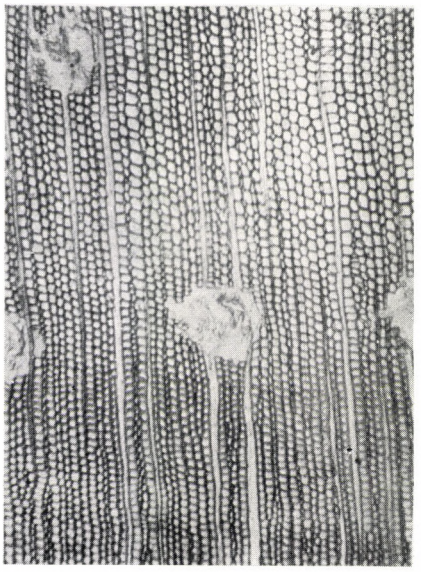


Fig. 118. *Pinus cooperi* Blanco



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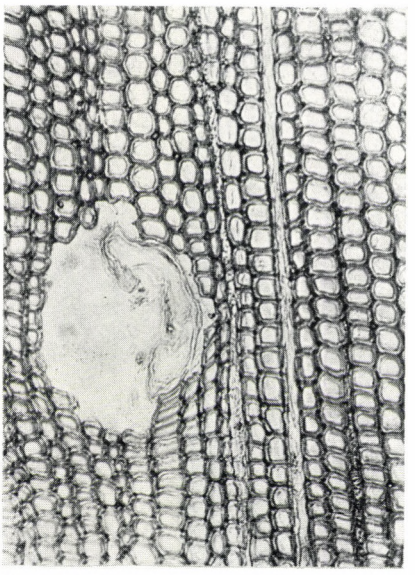

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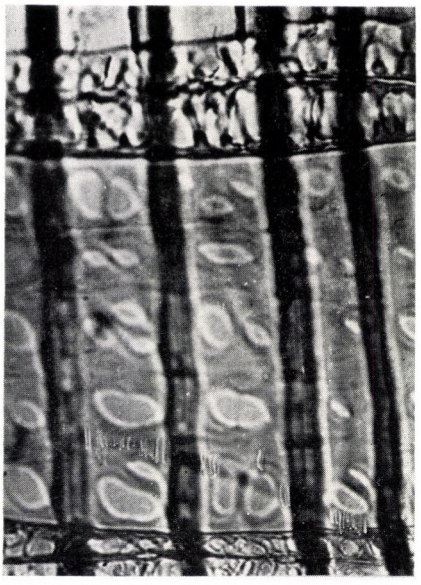


3.(× 300)

4.(×100)

CXXXIX. *Pinus elliottii* Engel.

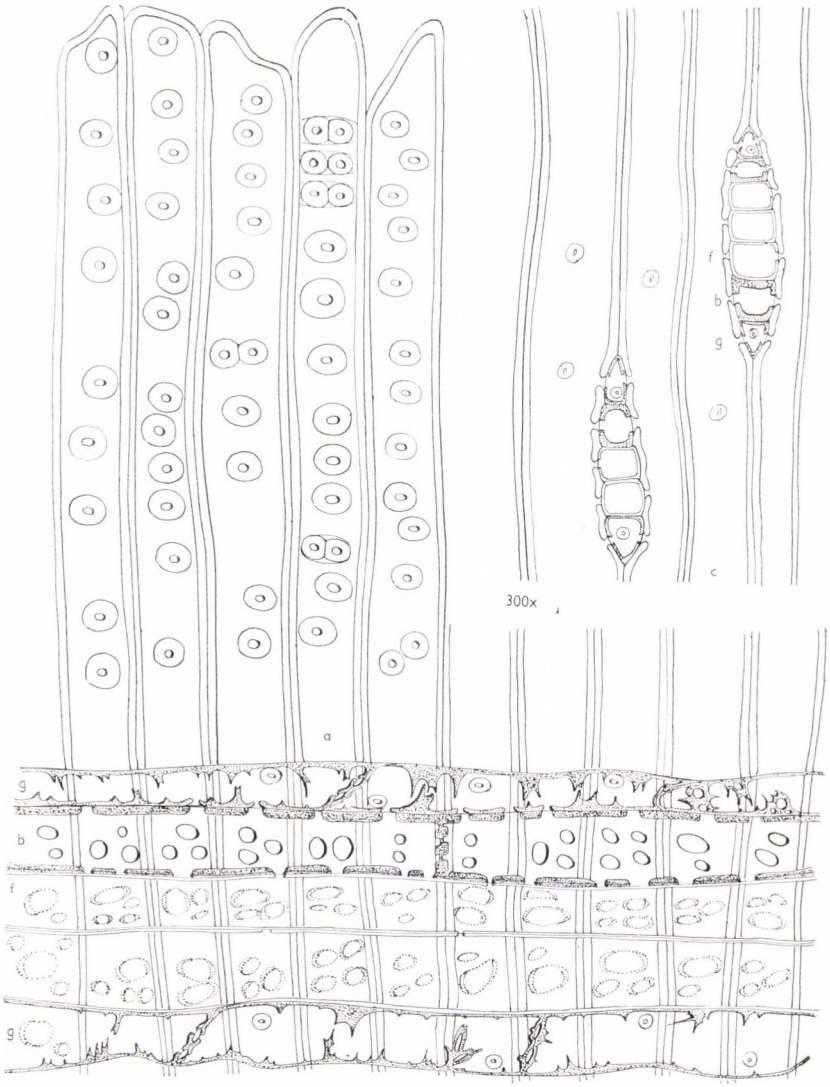
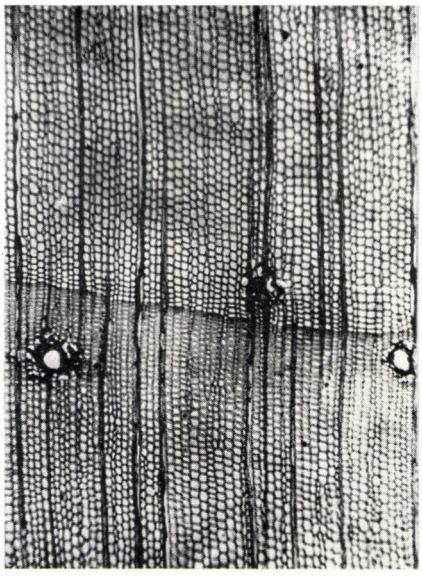


Fig. 119. *Pinus elliottii* Engel.



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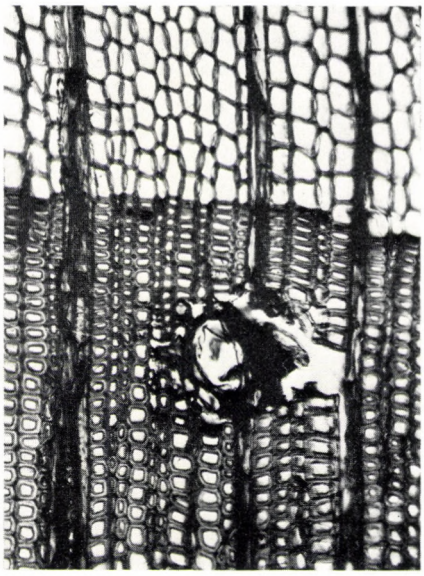

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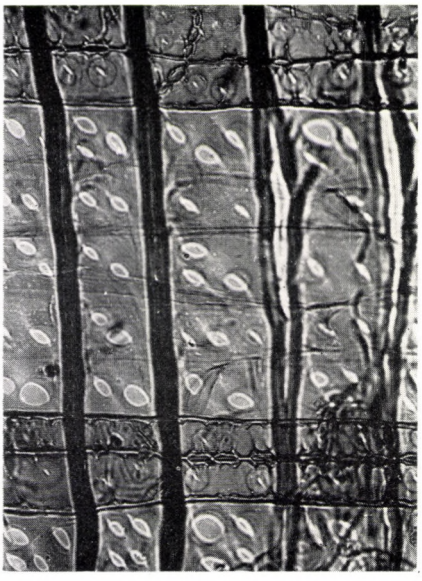
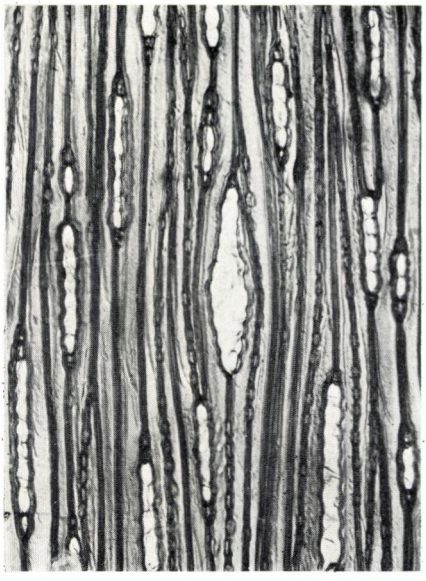


3.(× 300)



4.(×100)

CXL. *Pinus greggii* Engel.

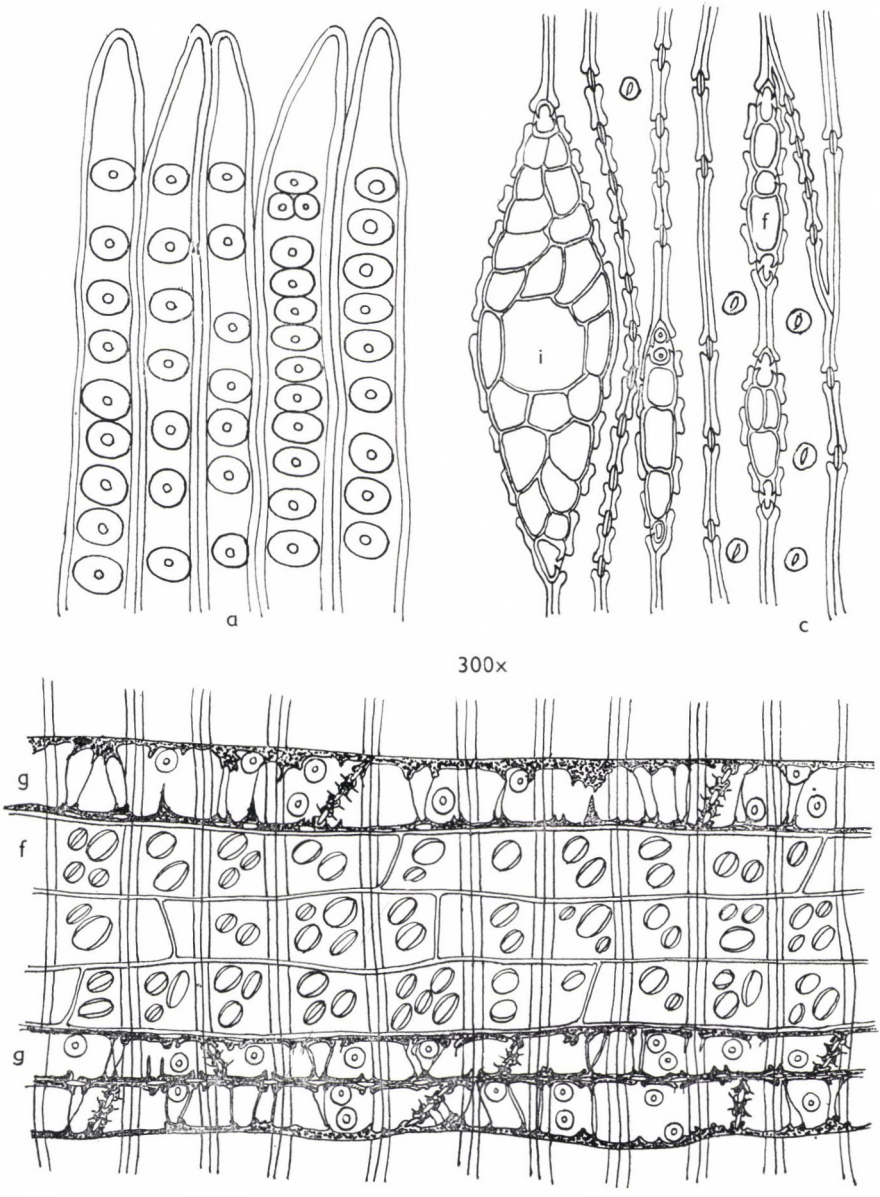
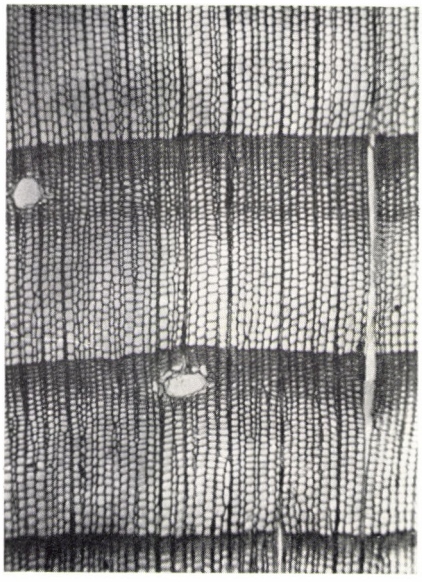


Fig. 120. *Pinus greggii* Engel.



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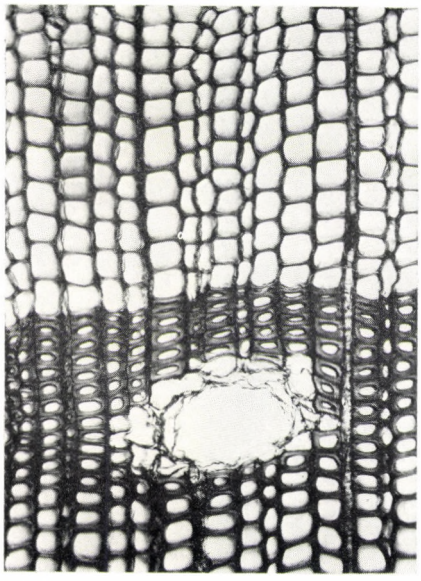

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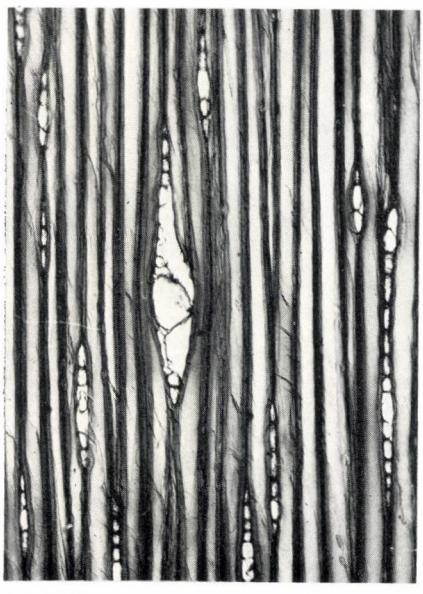
3.(×300)



4.(×100)

CXLI. *Pinus hartwegii* Lindl.

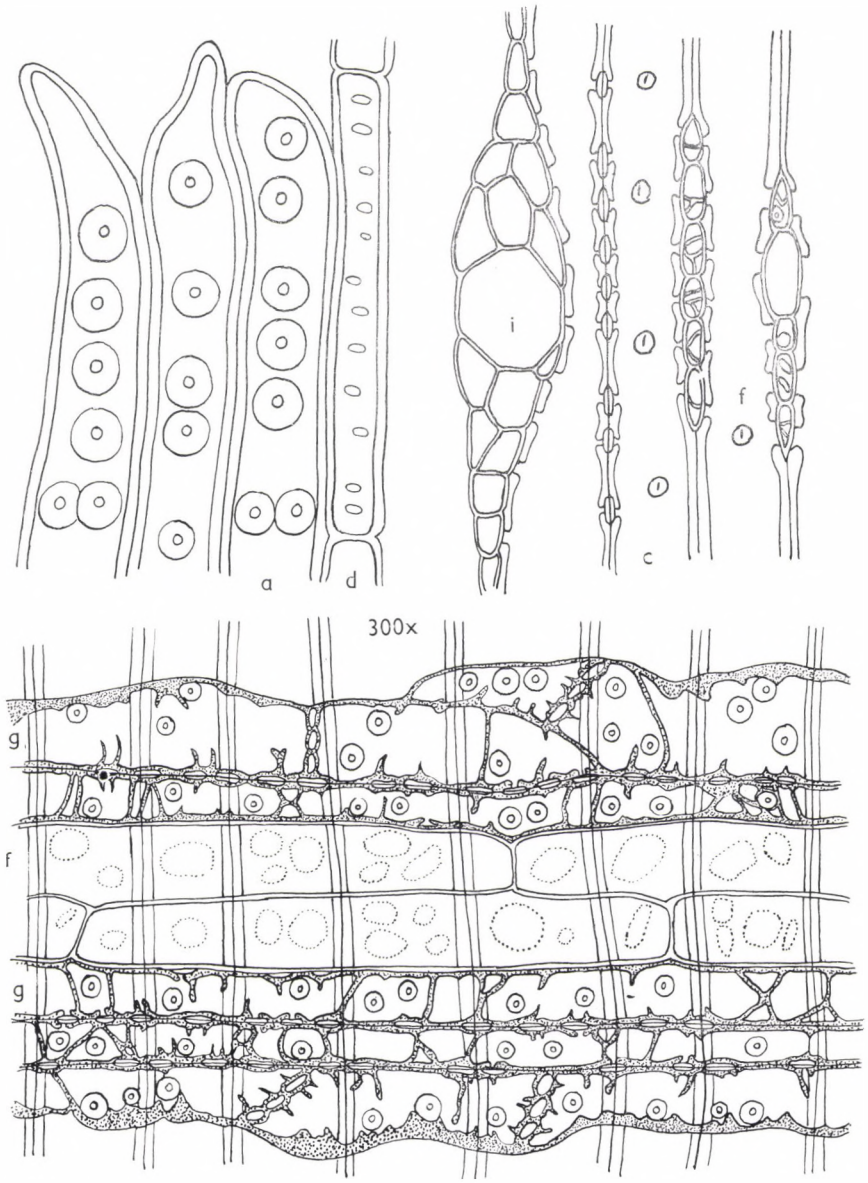
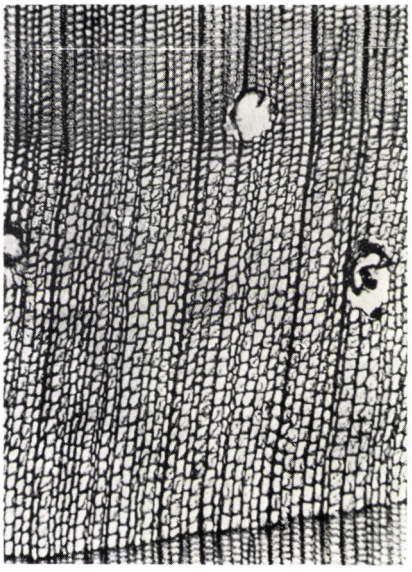


Fig. 121. *Pinus hartwegii* Lindl.



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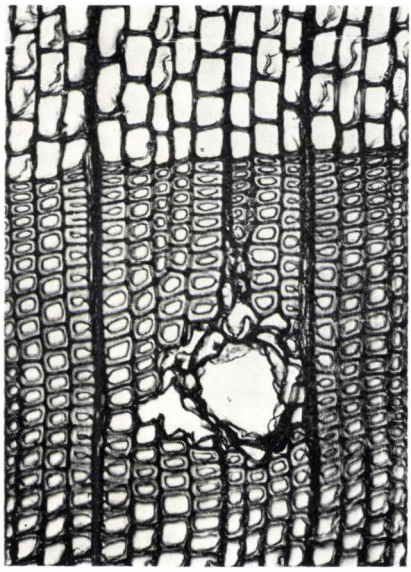

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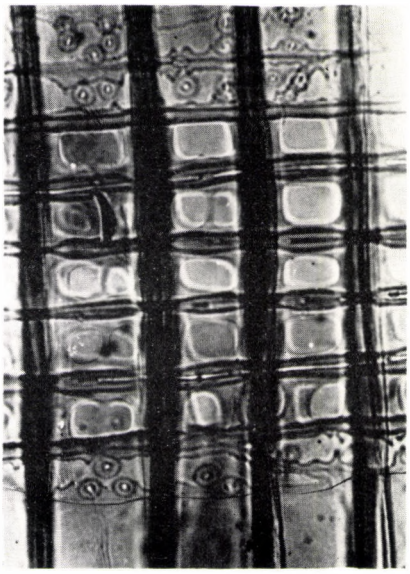
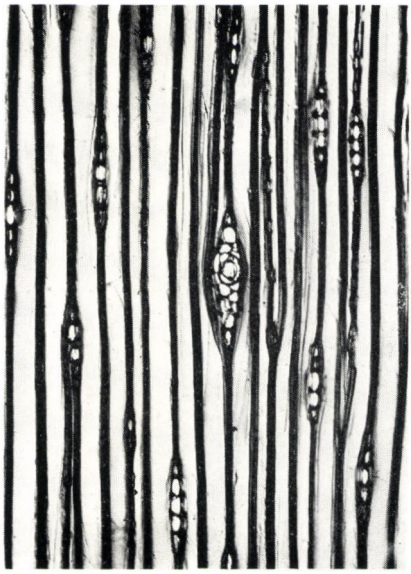


3(× 300)



4.(×100)

CXLII. *Pinus hwangshanensis* Hsia

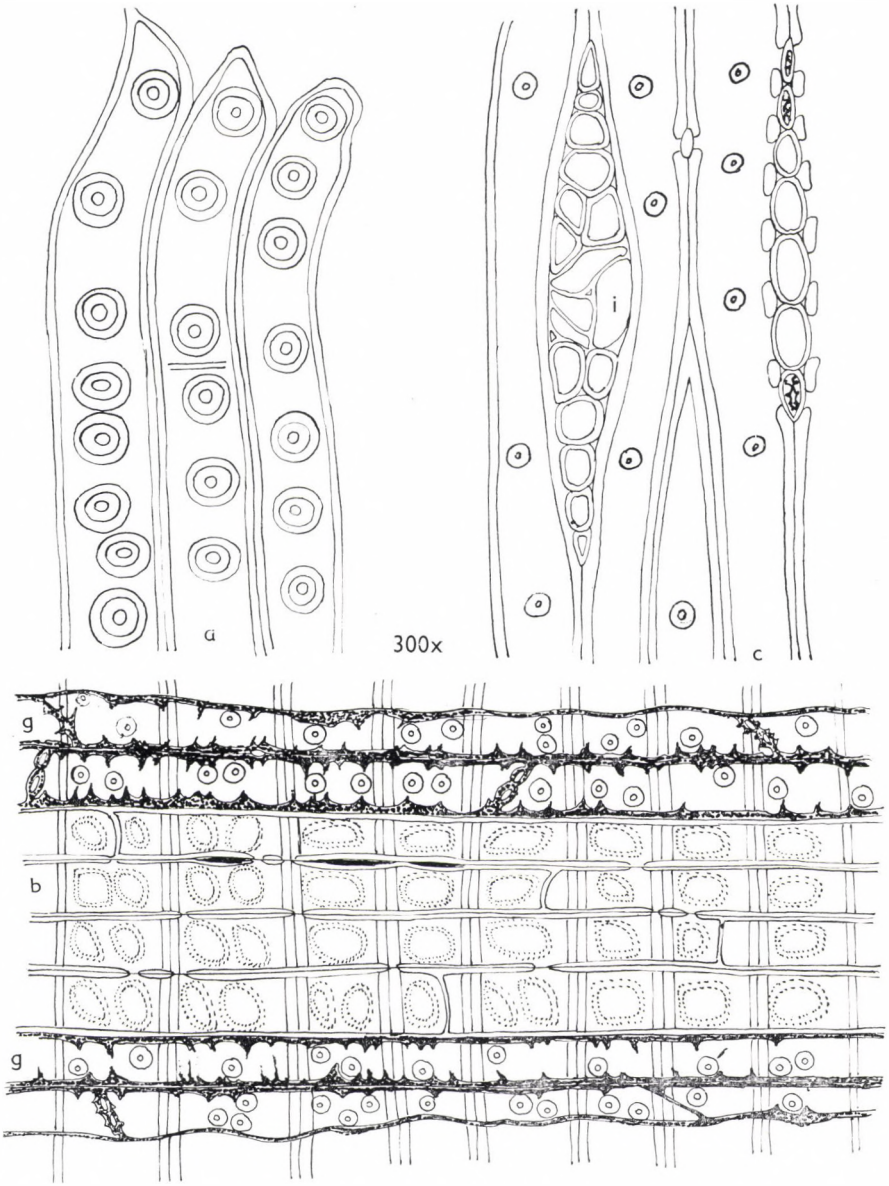
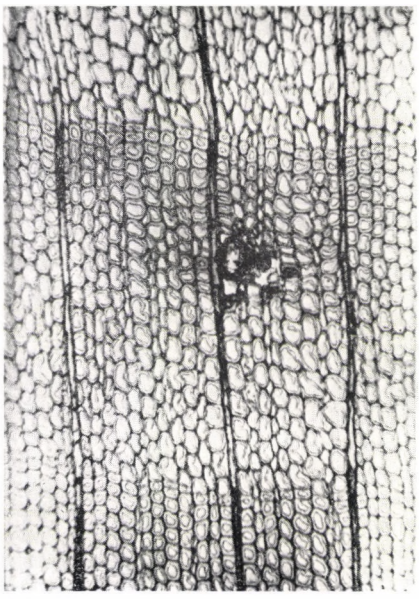


Fig. 122. *Pinus hwangshanensis* Hsia



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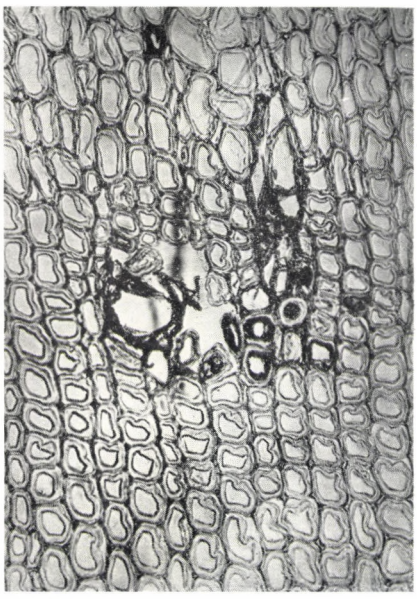

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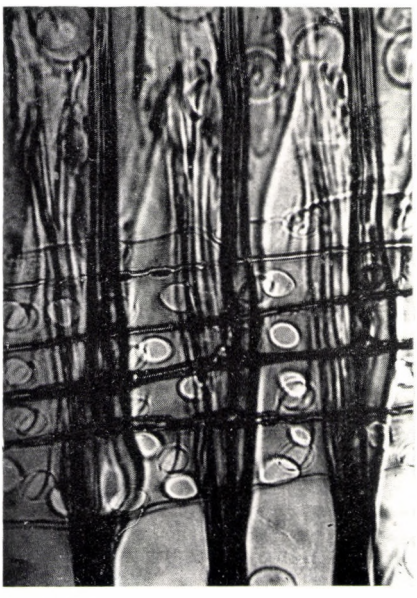


3.(× 300)

4.(x100)

CXLIII. *Pinus krempfii* Lecompte

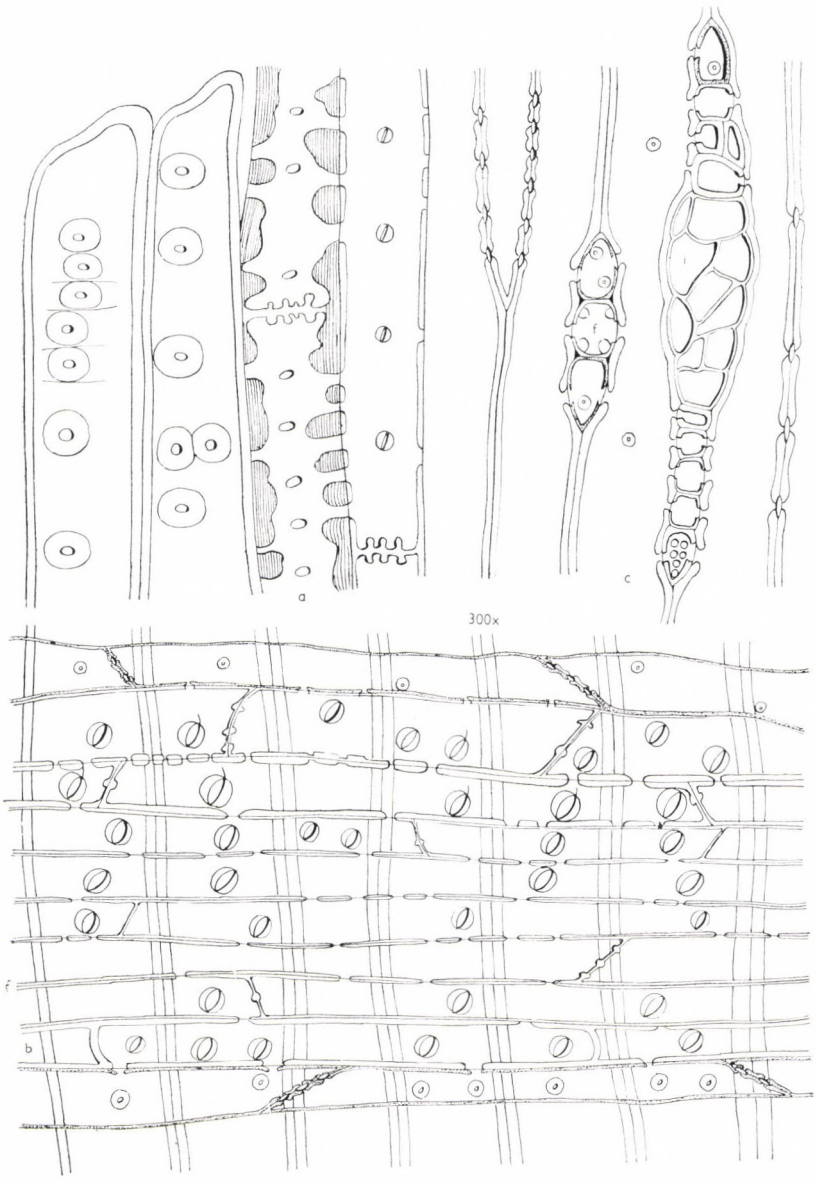
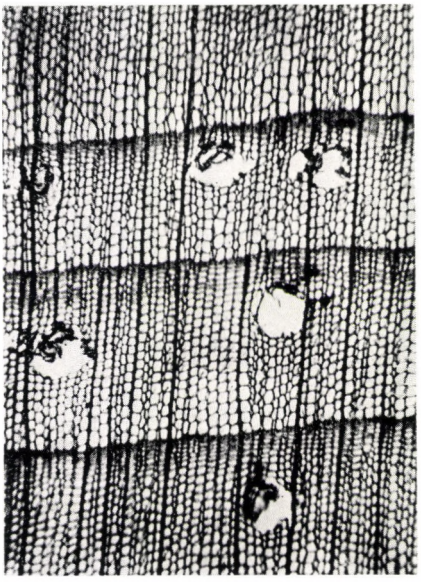


Fig. 123. *Pinus krempfii* Lecompte



1.(x 30)

2.(x100)

3.(x 300)

4.(x100)

CXLIV. *Pinus kwantungensis* Chun.

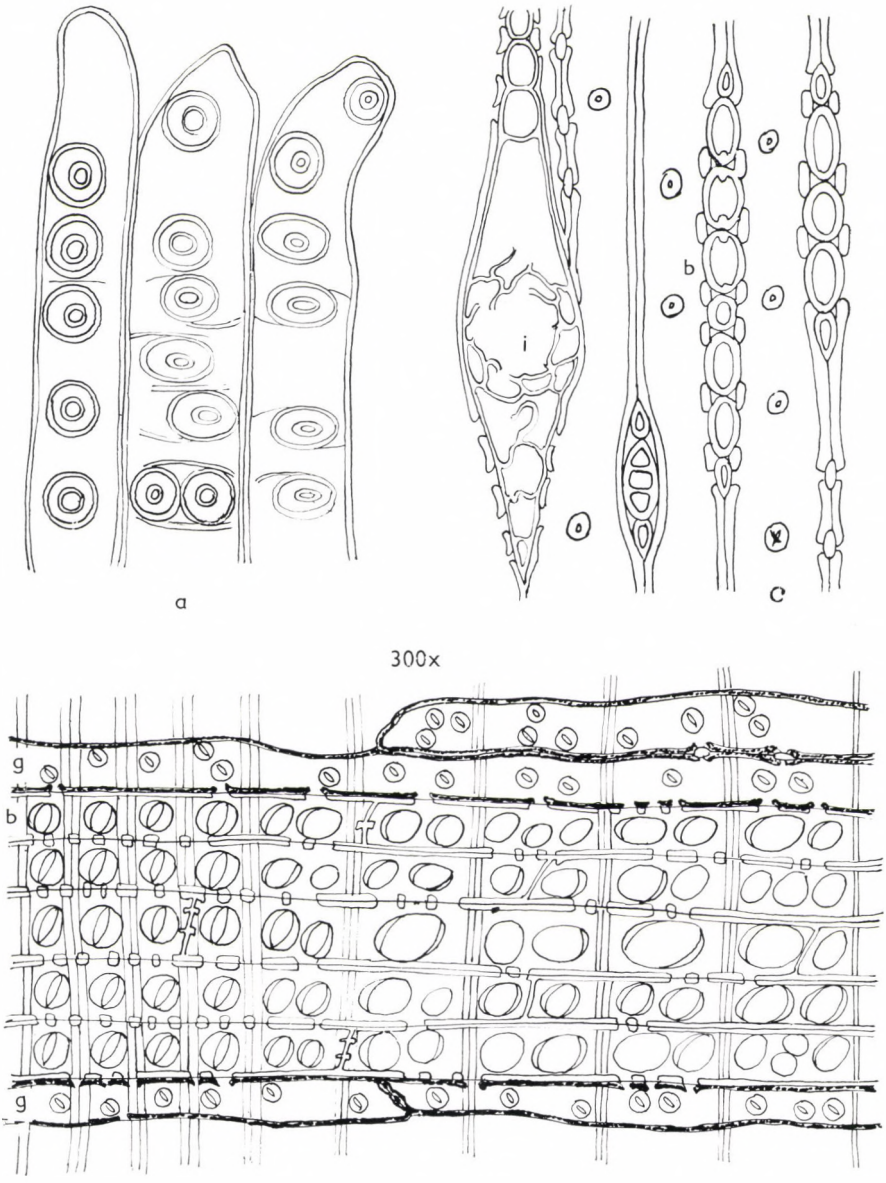
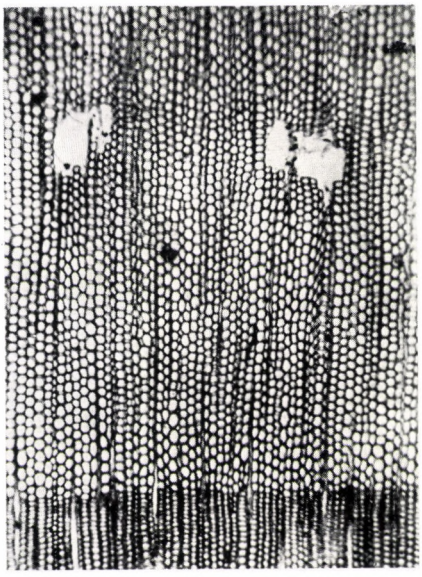


Fig. 124. *Pinus kwantungensis* Chun.



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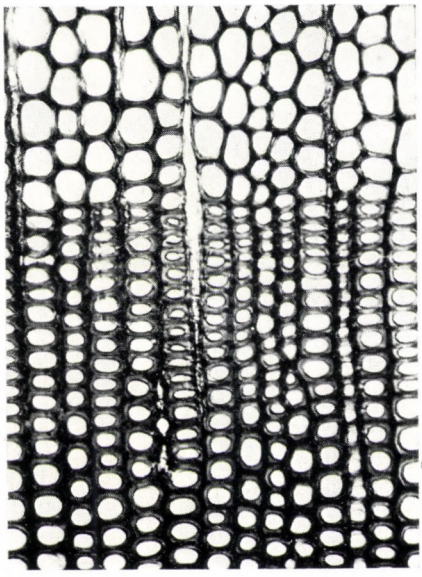


2.(×100)

3.(× 300)

4.(×100)

CXLV. *Pinus lawsoni* Roezl.

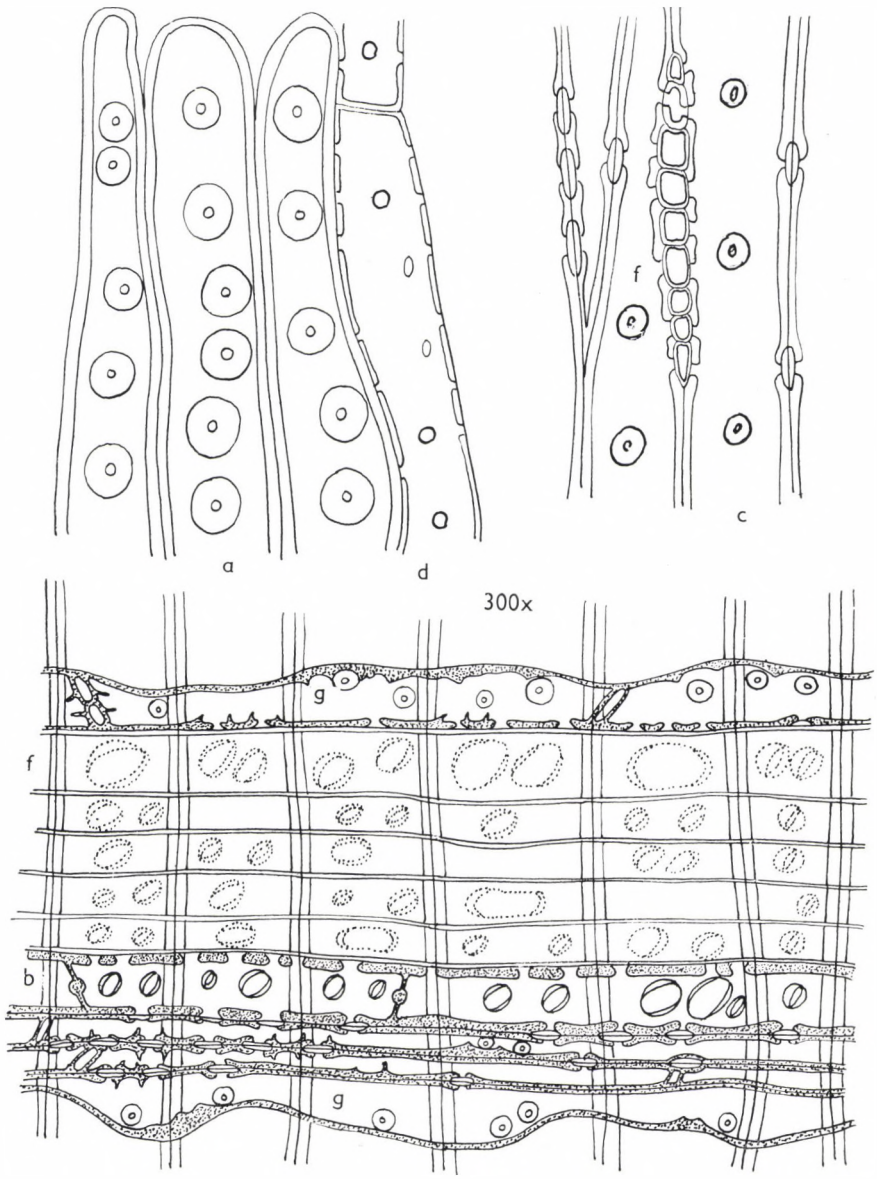
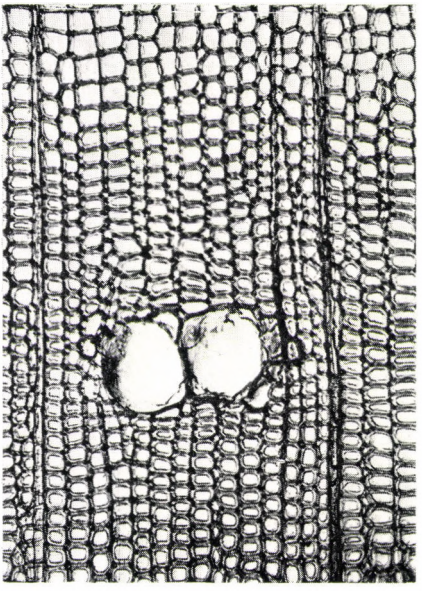


Fig. 125. *Pinus lawsoni* Roezl.



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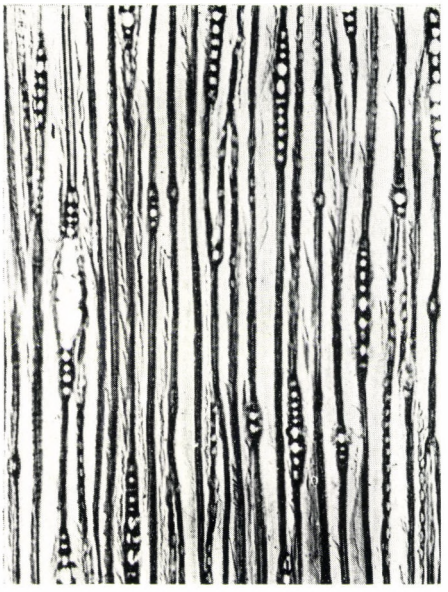

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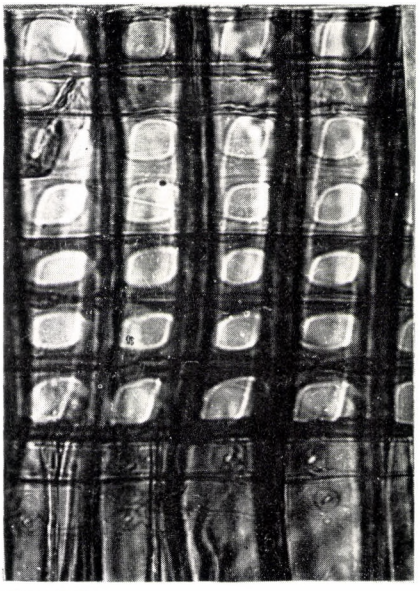


3.(× 300)

4.(×300)

CXLVI. *Pinus luchuensis* Mayr.

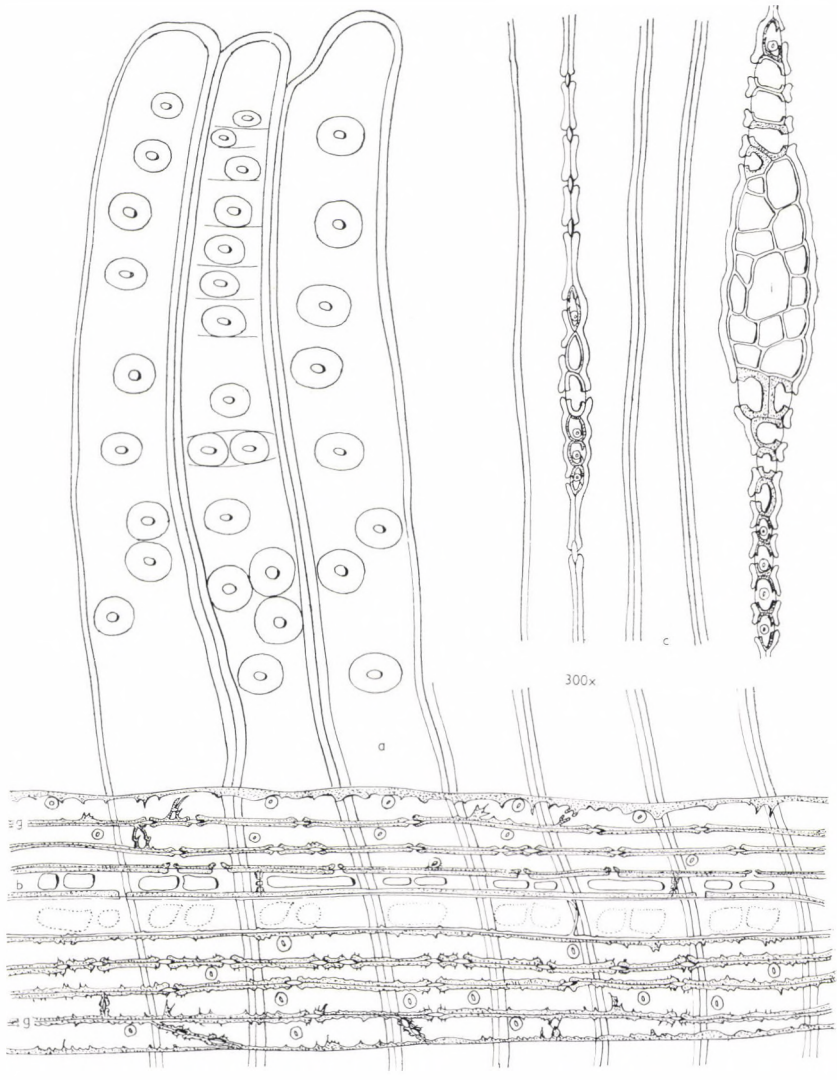
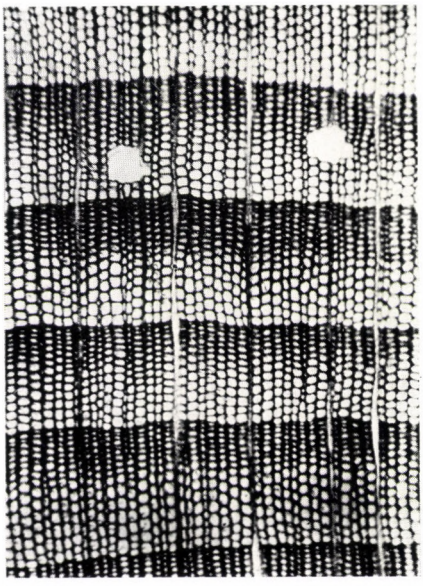


Fig. 126. *Pinus luchuensis* Mayr.



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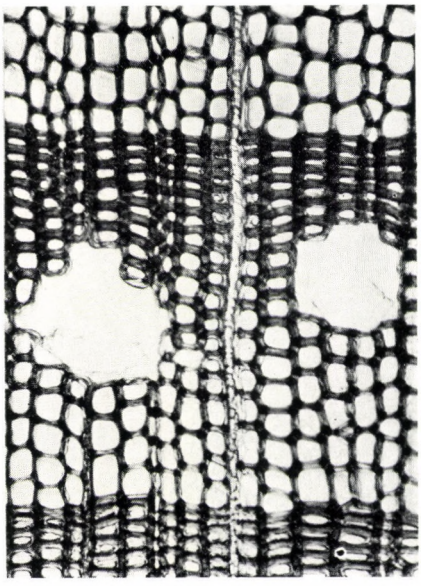
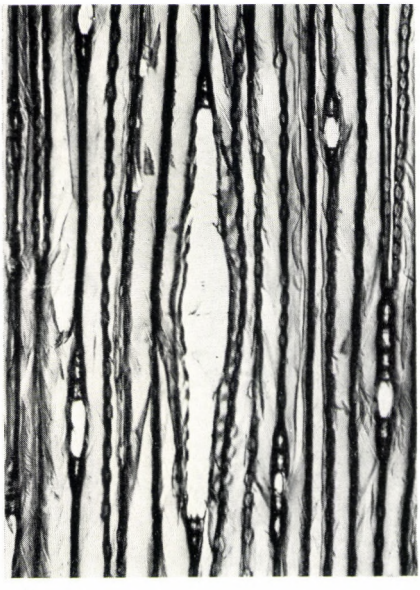


2.(×100)

3.(× 300)



4.(×100)

CXLVII. *Pinus lumholtzii* Robin and Fern

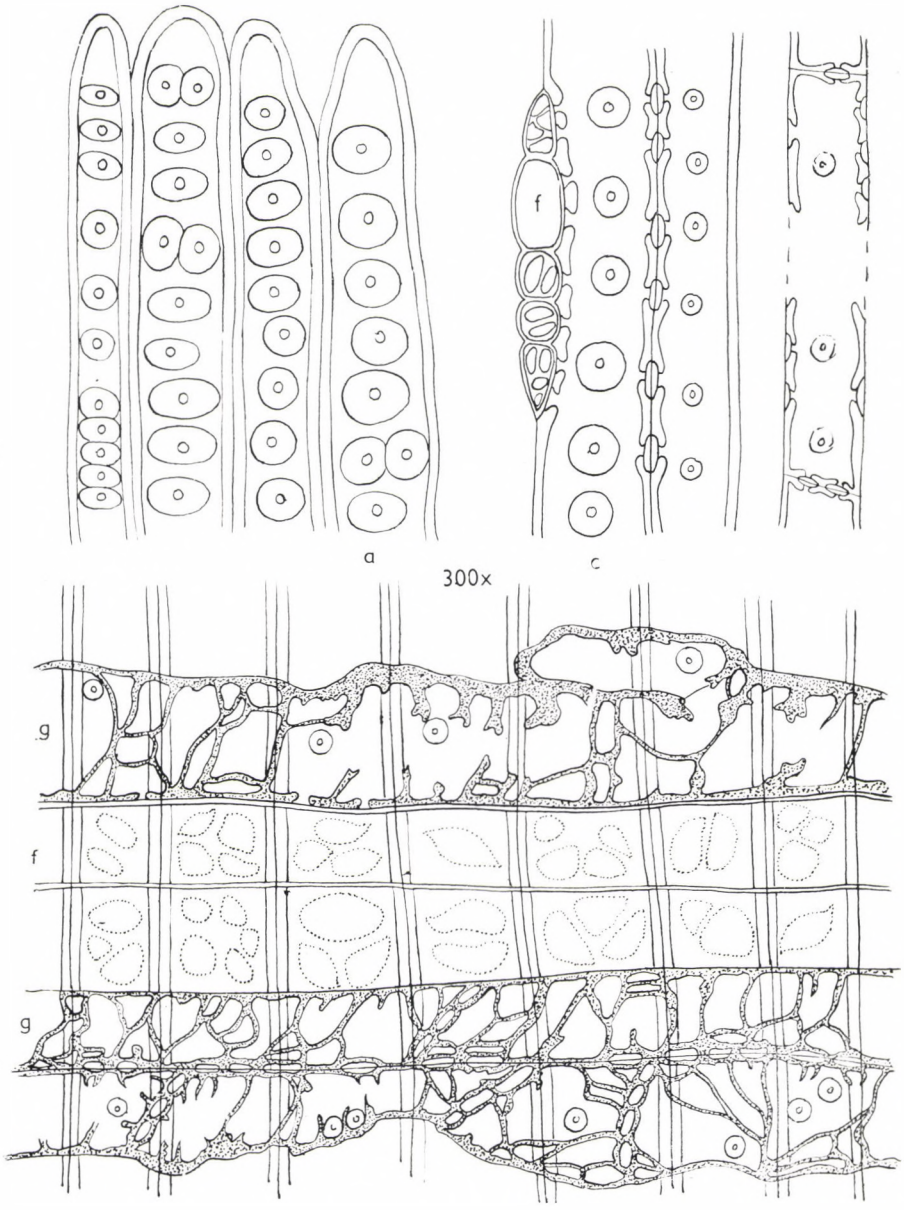
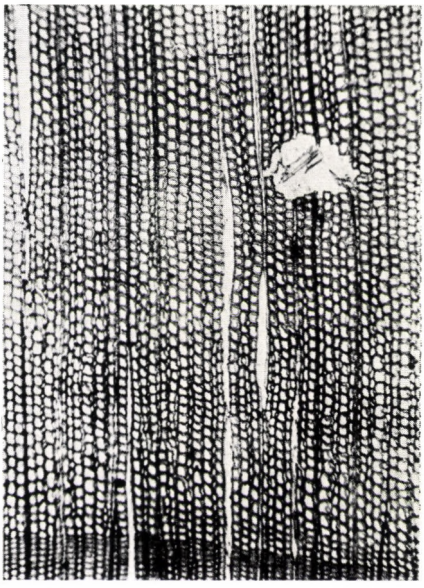


Fig. 127. *Pinus lumholtzii* Robin and Fern



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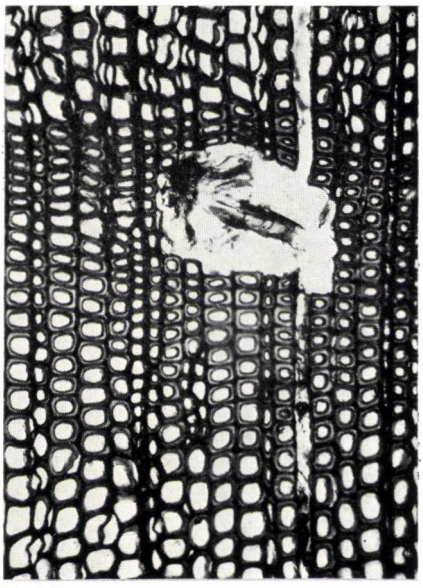
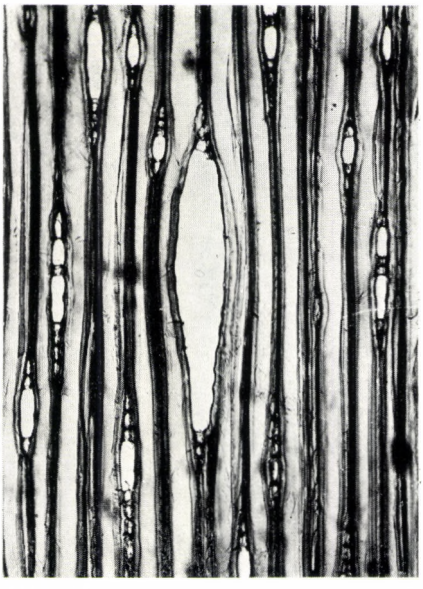


2.(×100)

3.(×300)



4.(×100)

CXLVIII. *Pinus oocarpa* Schiede

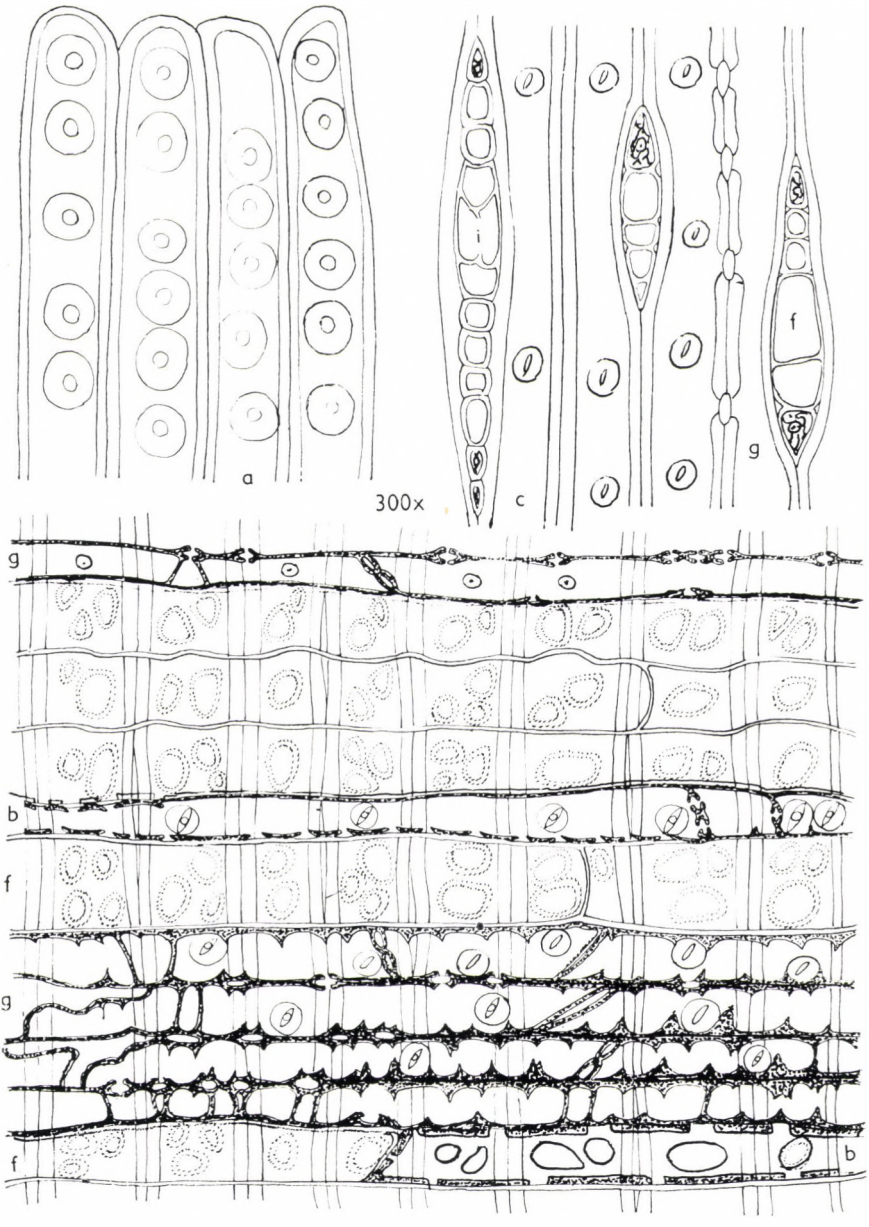
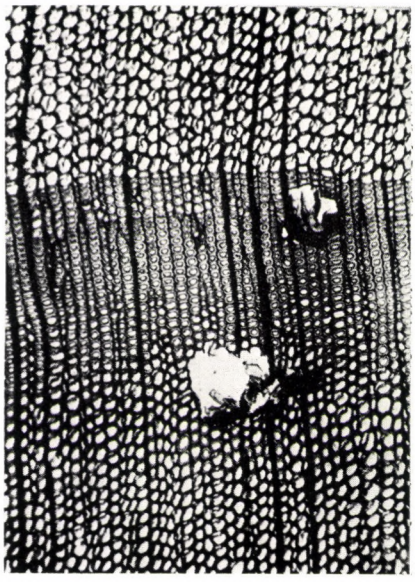


Fig. 128. *Pinus oocarpa* Schiede



1.(×30)

2.(×100)

3.(× 300)

4.(×100)

CXLIX. *Pinus pringlei* Shaw

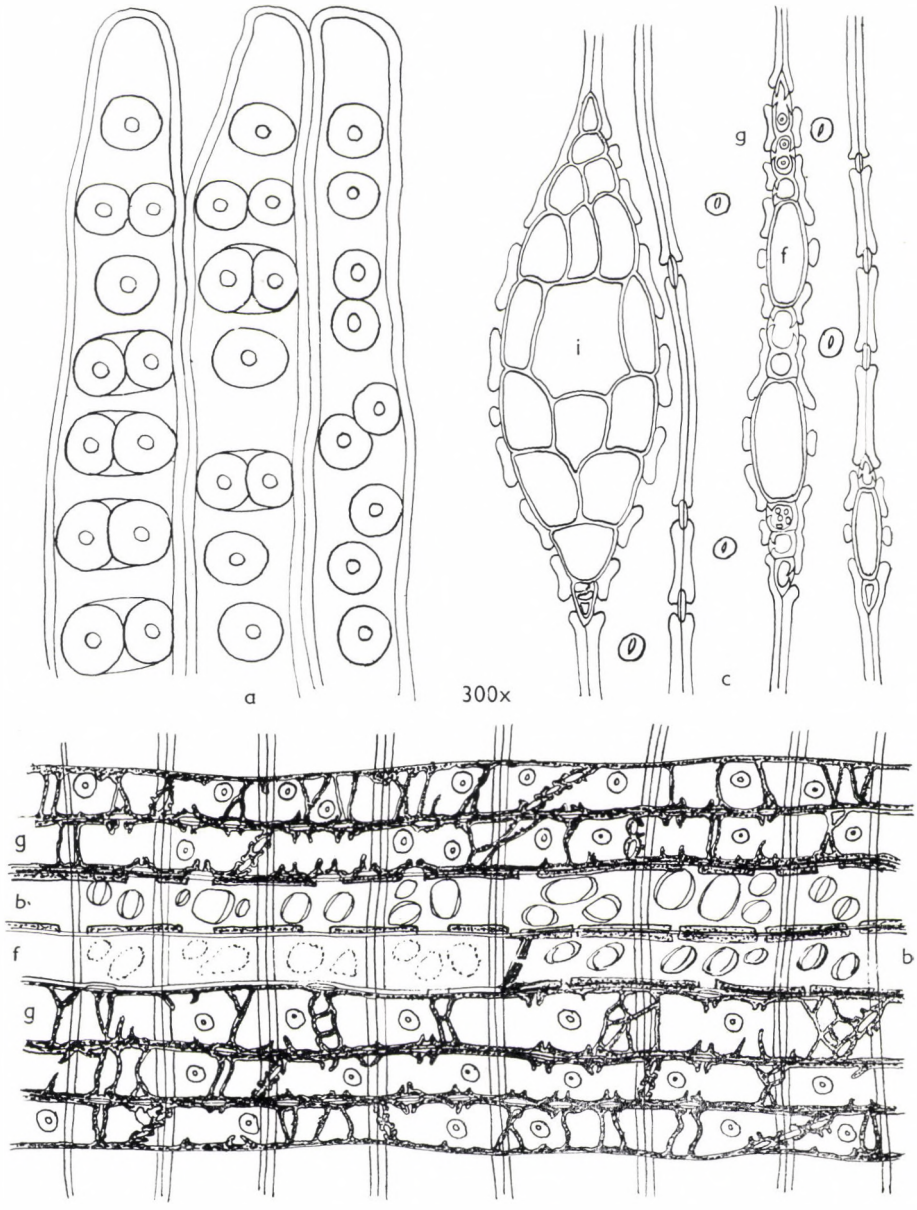
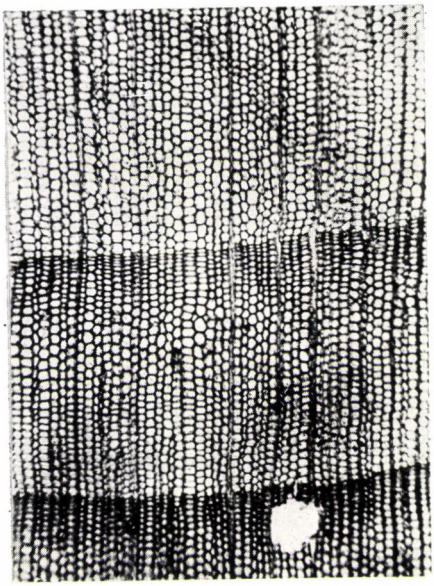


Fig. 129. *Pinus pringlei* Shaw



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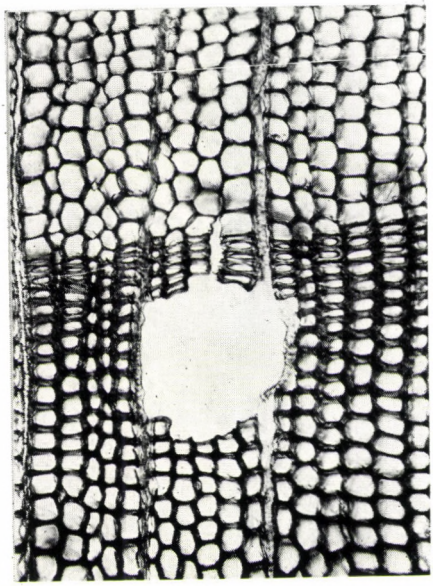


2.(×100)

3.(×300)

4.(×100)

CL. *Pinus rudis* Endl.

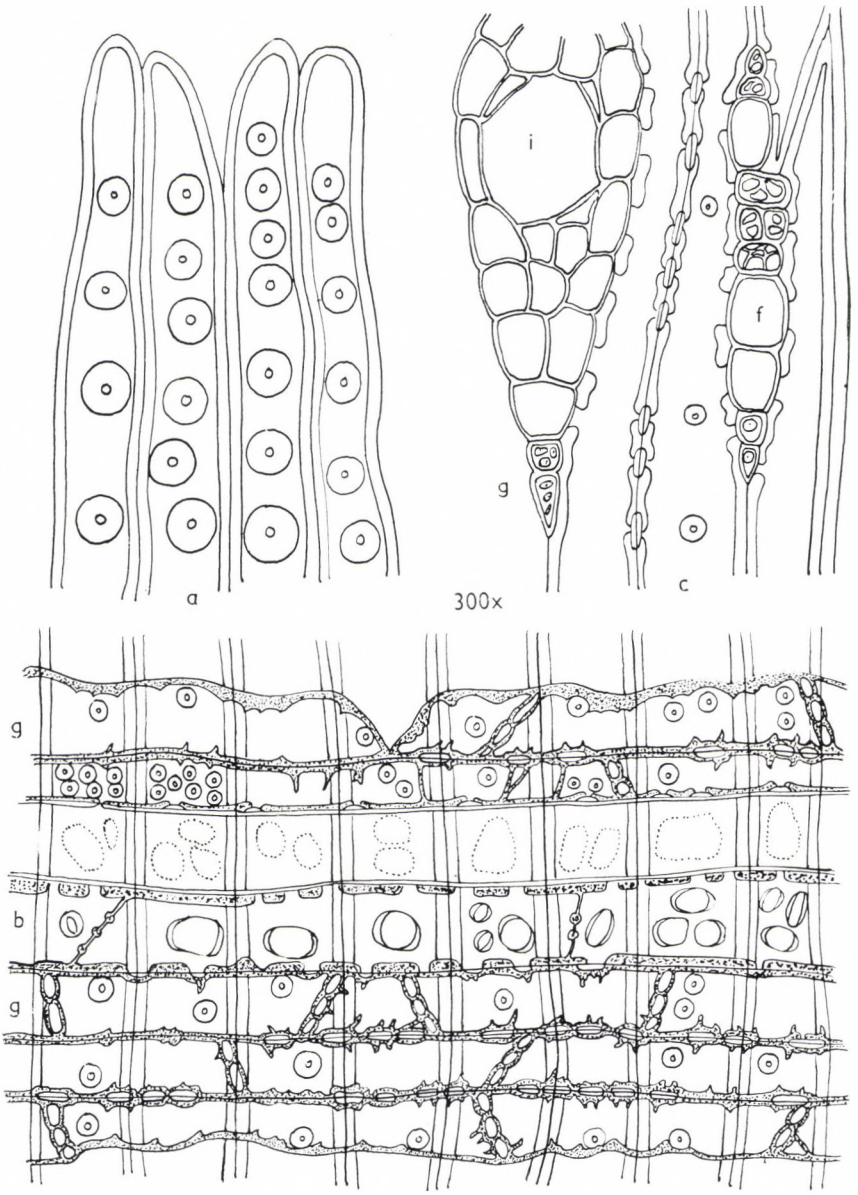
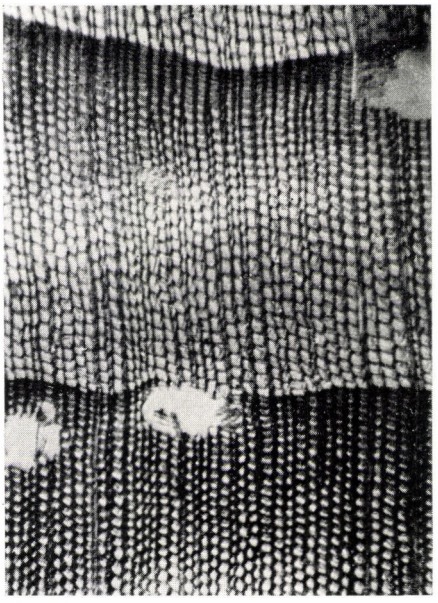


Fig. 130. *Pinus rudis* Endl.



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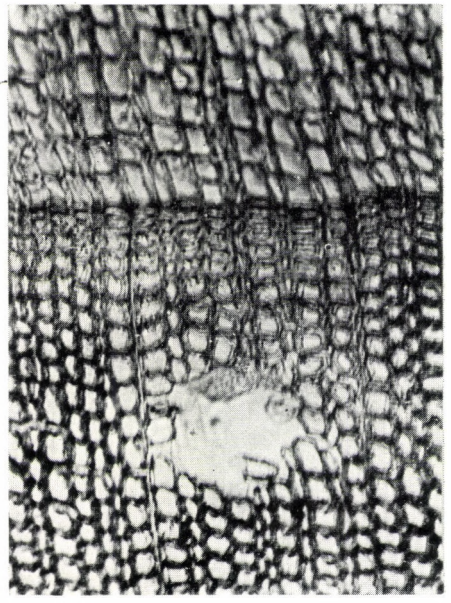

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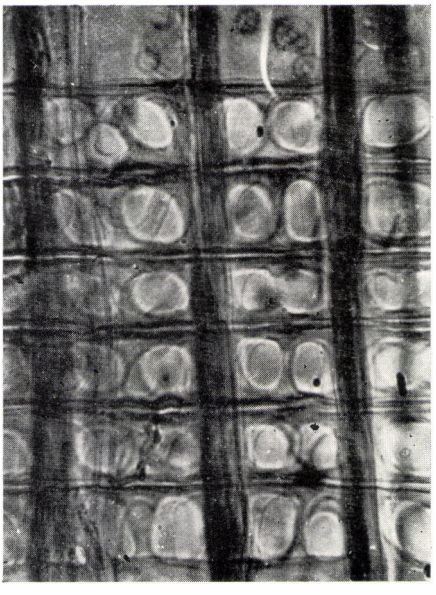

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4.(×100)

CLI. *Pinus sibirica* (Rupr.) Mayr.

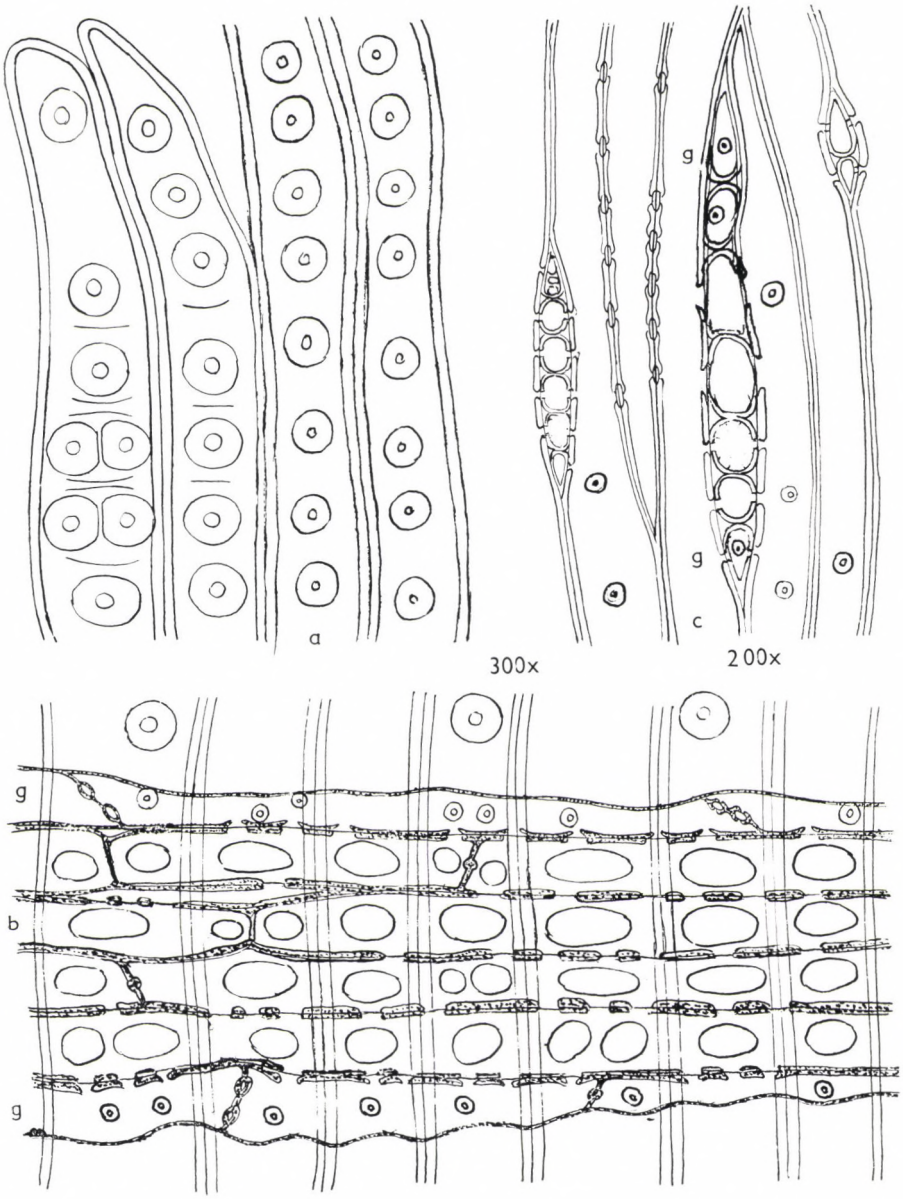
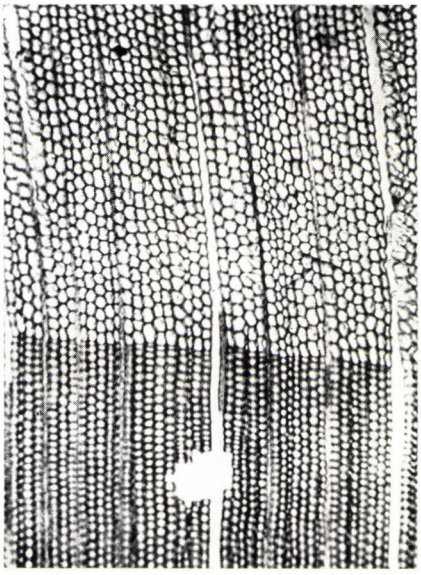


Fig. 131. *Pinus sibirica* (Rupr.) Mayr.



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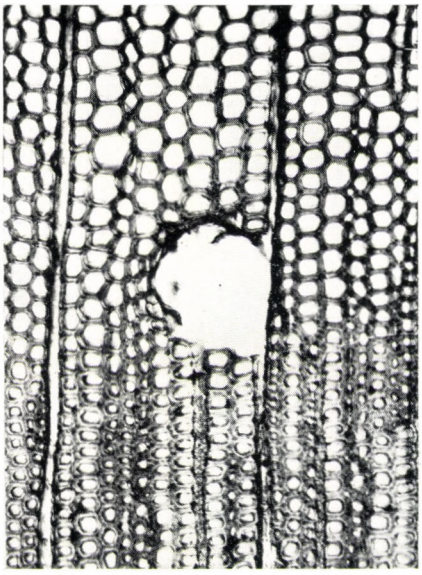

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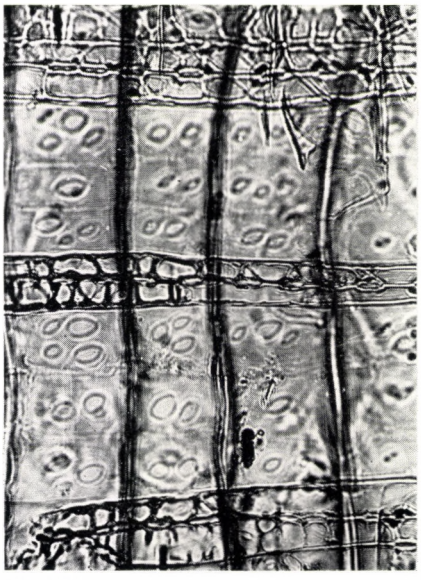


3.(x 300)

4.(x100)

CLII. *Pinus sondereggeri* H. H. Chapman

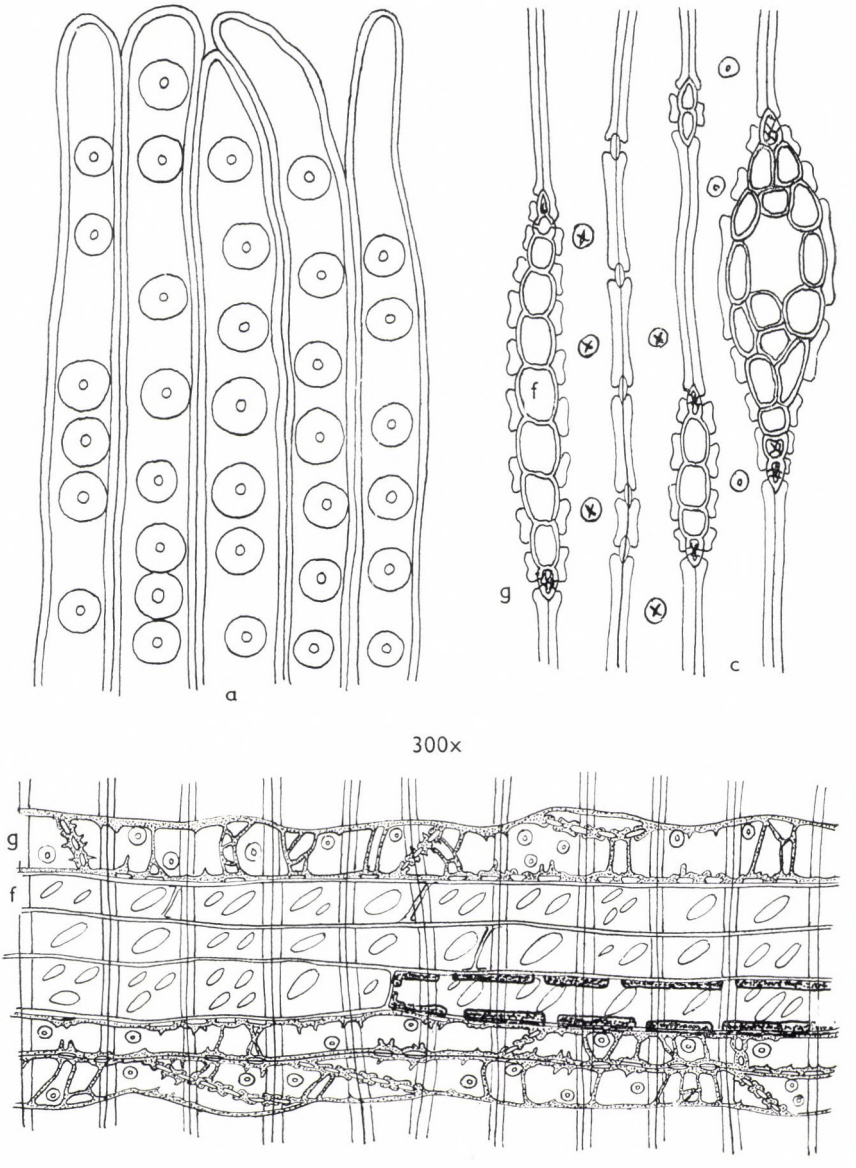
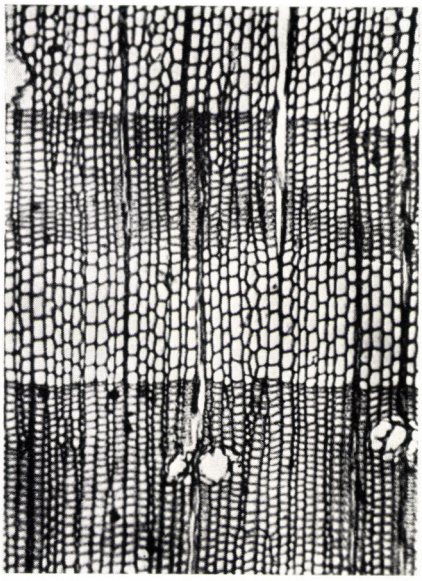


Fig. 132. *Pinus sondereggeri* H. H. Chapman



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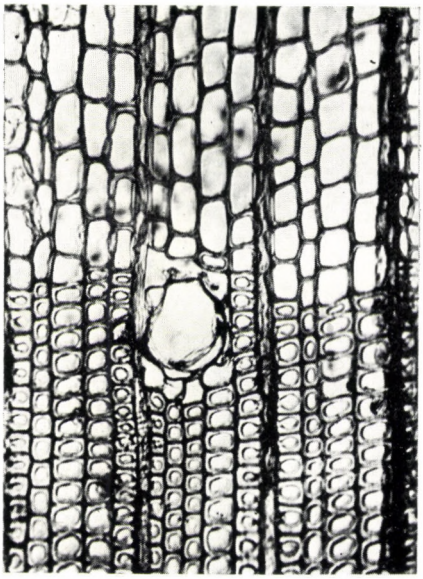

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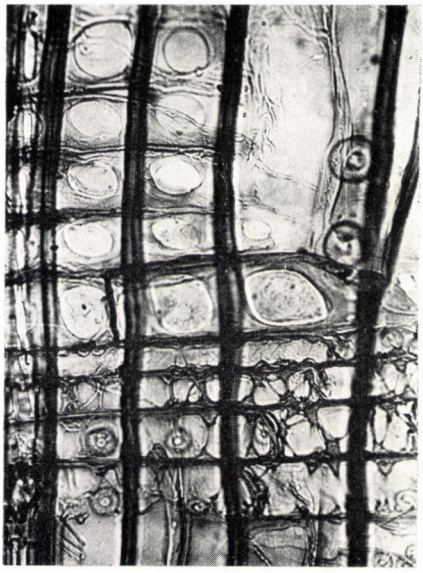

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4.(×100)

CLIII. *Pinus taiwanensis* Hayata

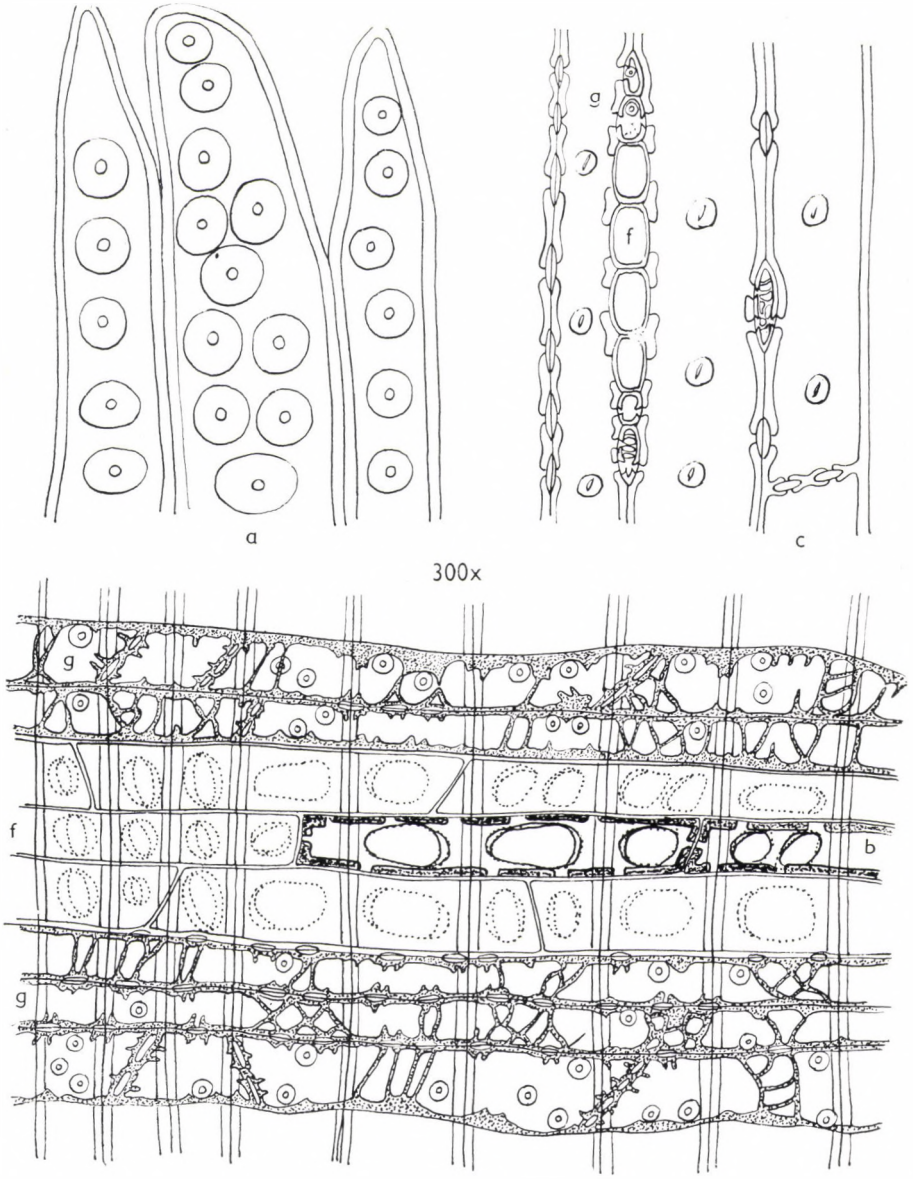
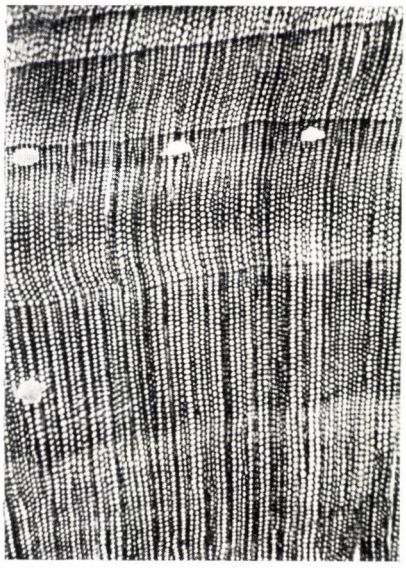


Fig. 133. *Pinus taiwanensis* Hayata



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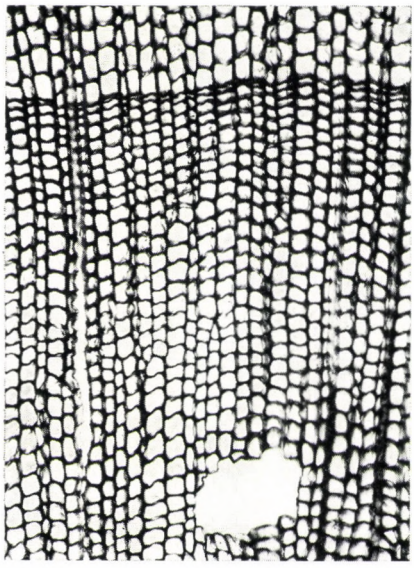


2.(×100)

3.(×300)

4.(×100)

CLIV. *Pinus tenuifolia* Bentham

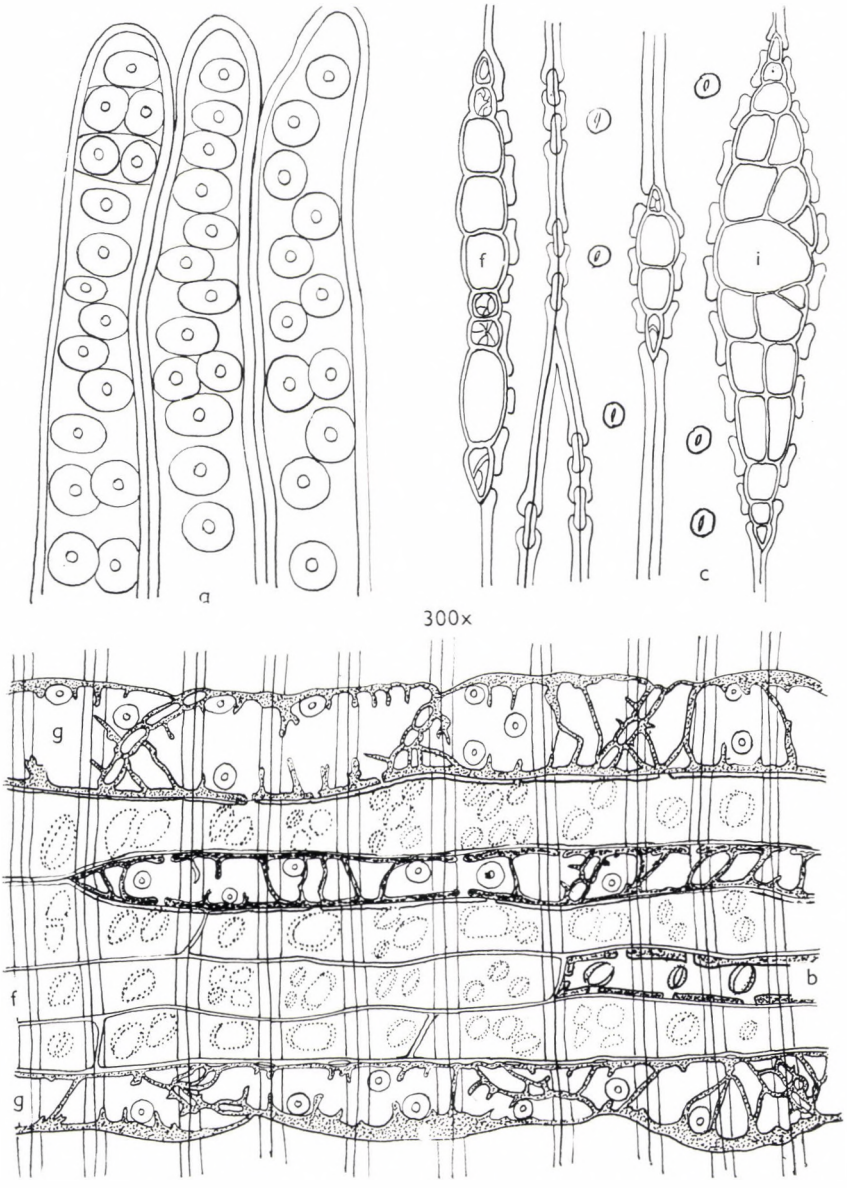
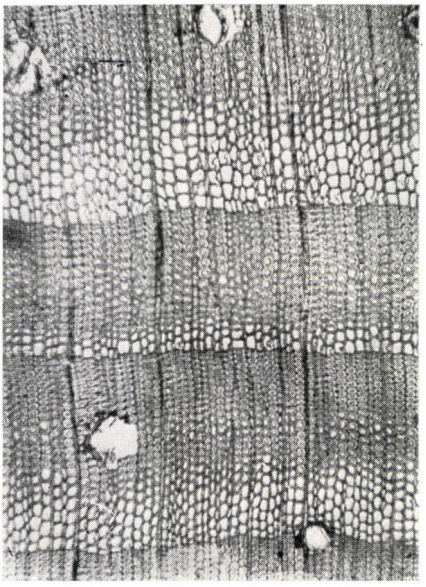


Fig. 134. *Pinus tenuifolia* Bentham



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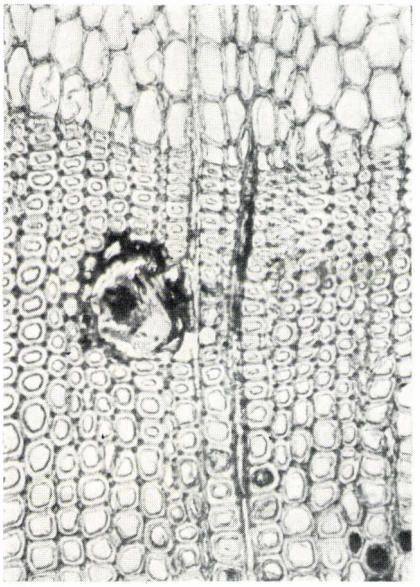

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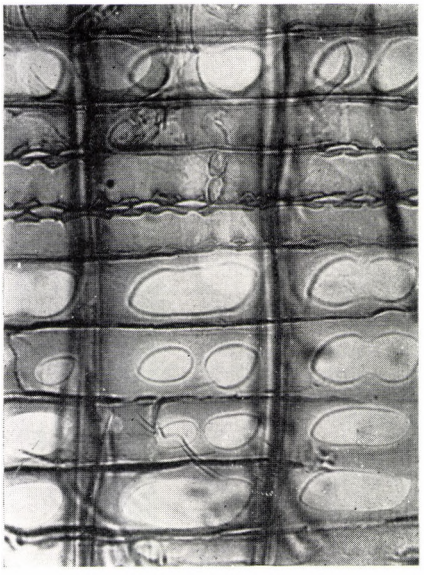

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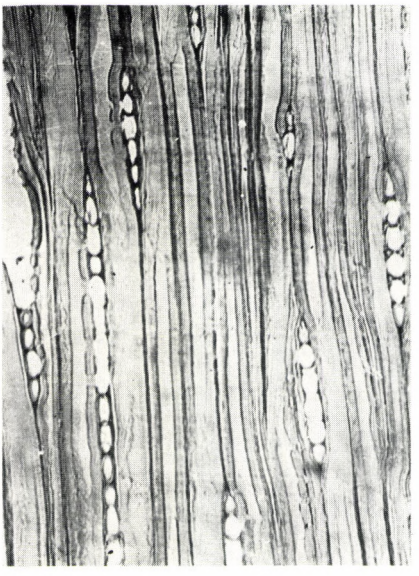


4.(×100)

CLV. *Pinus tropicalis* Morelet

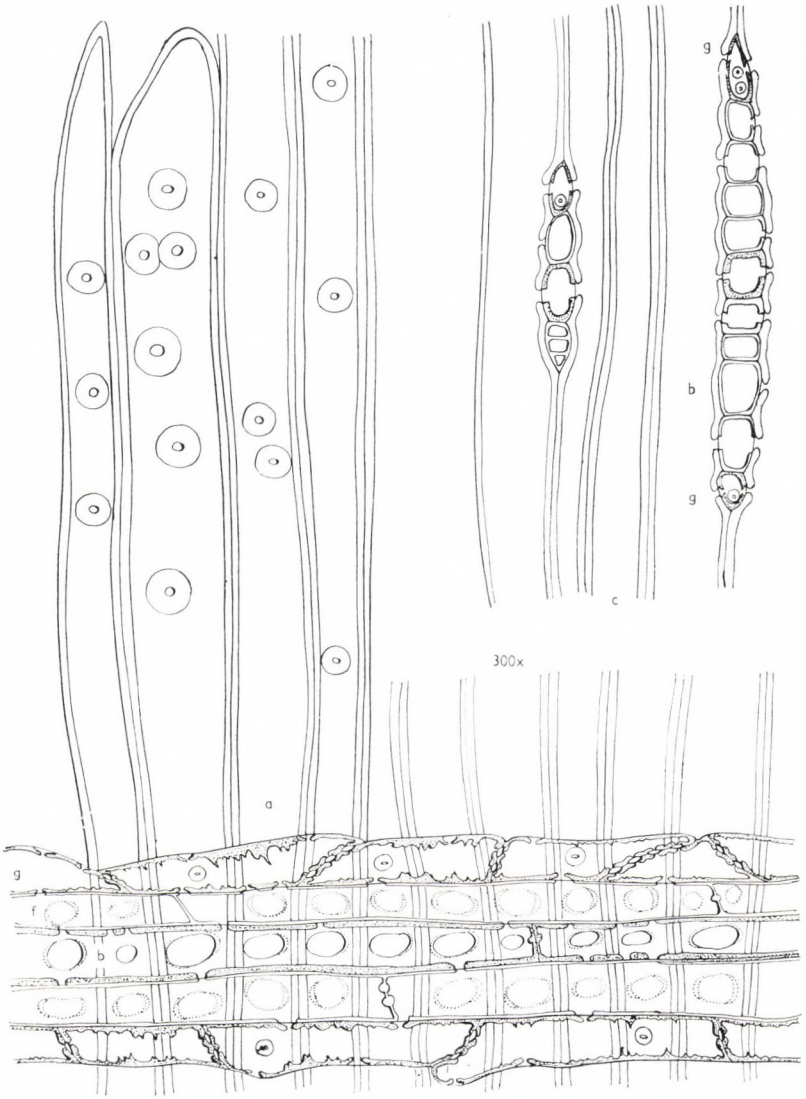
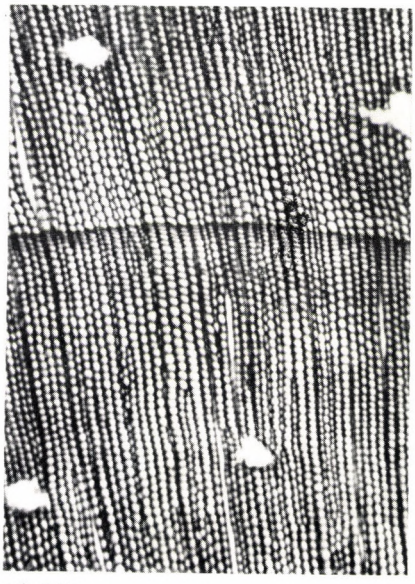


Fig. 135. *Pinus tropicalis* Morelet



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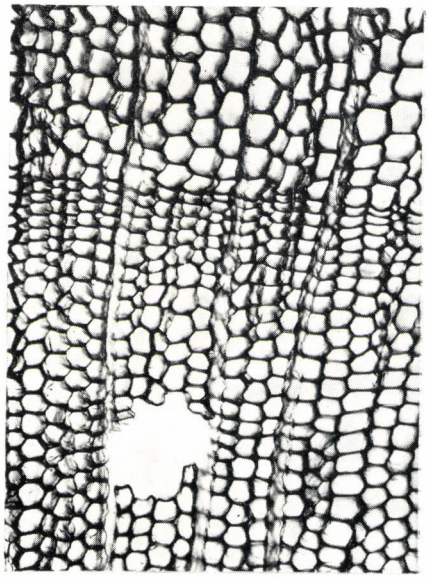


2.(×100)

3.(×300)

4.(×100)

CLVI. *Pinus uncinata* Ramond

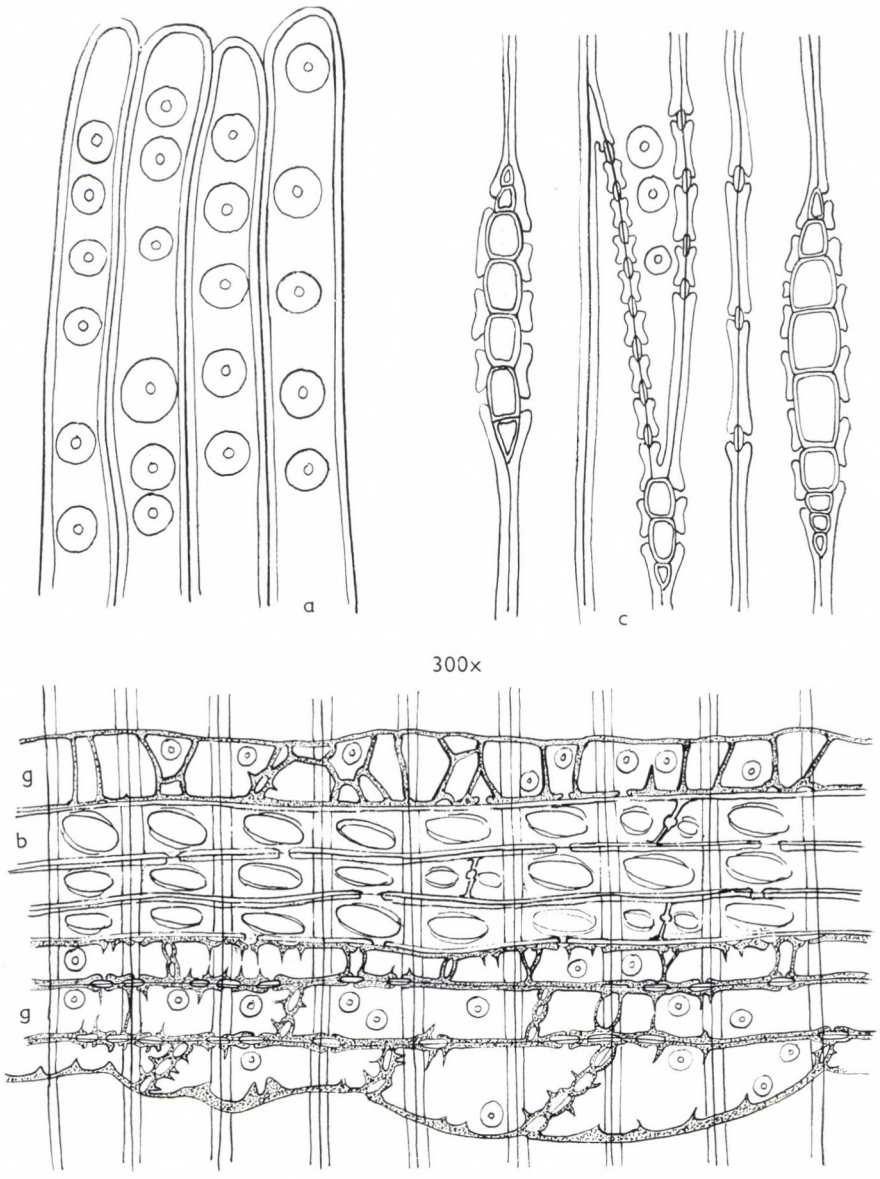
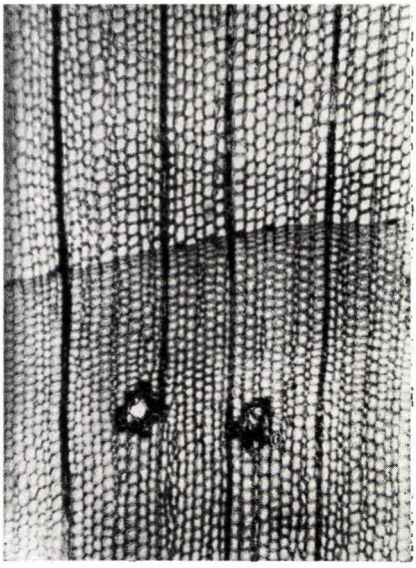


Fig. 136. *Pinus uncinata* Ramond



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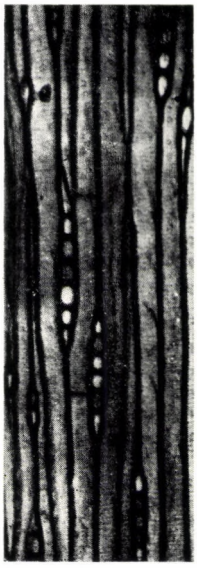

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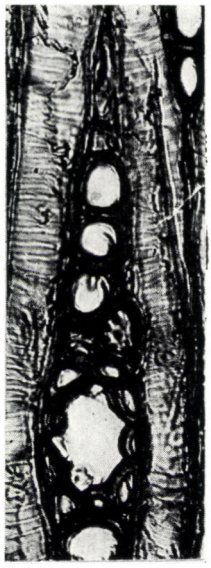

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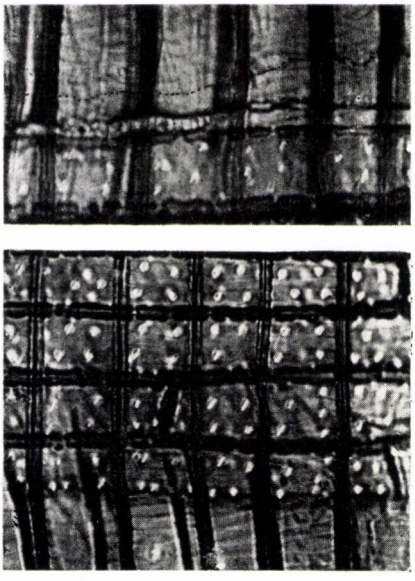

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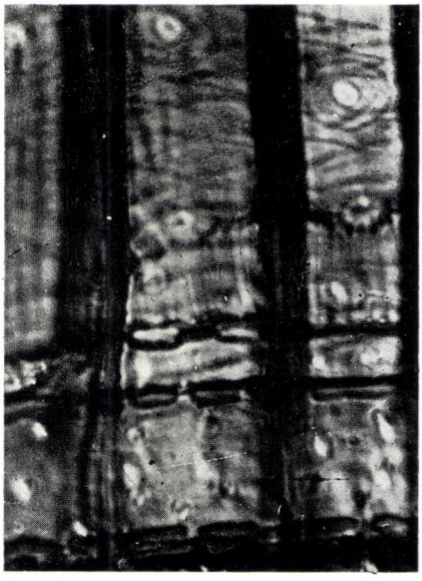


4.(×600)

CLVII. *Cathaya argyrophylla* Chun and Kuang

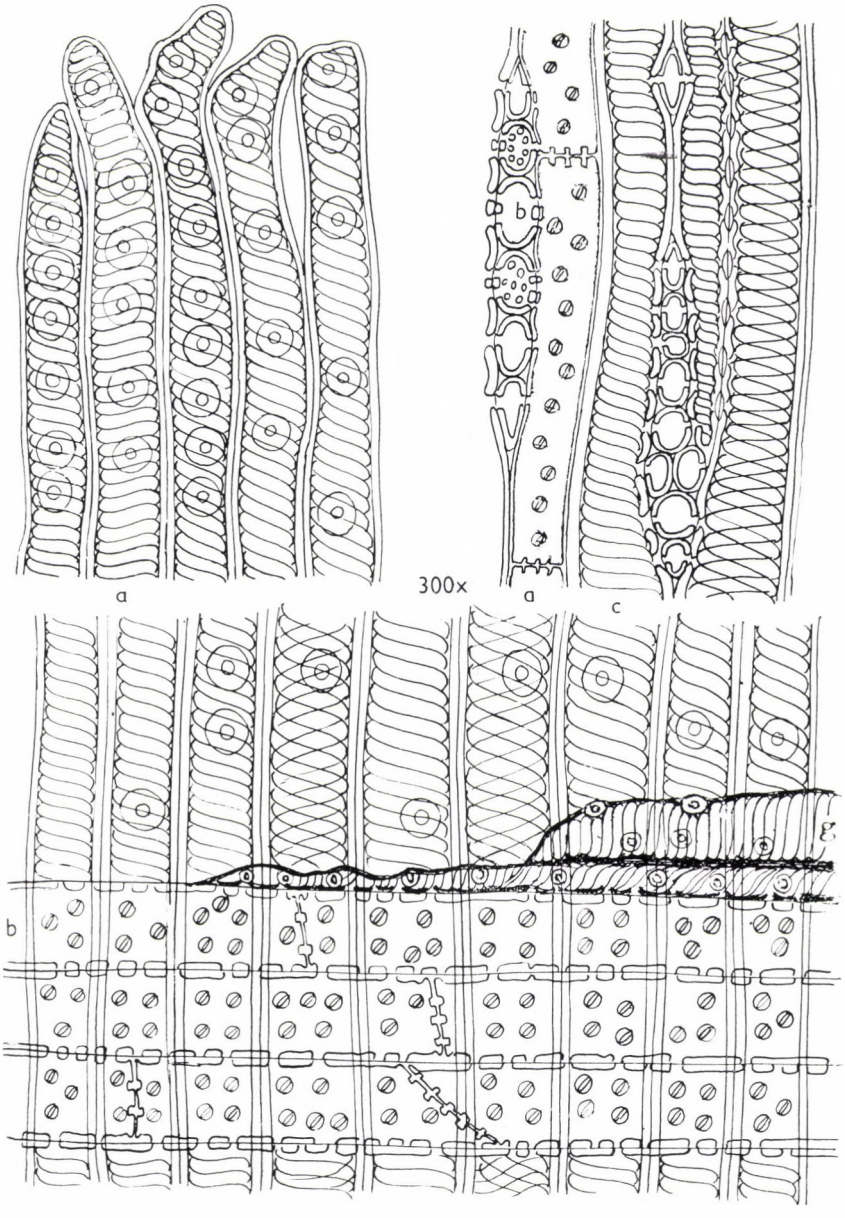
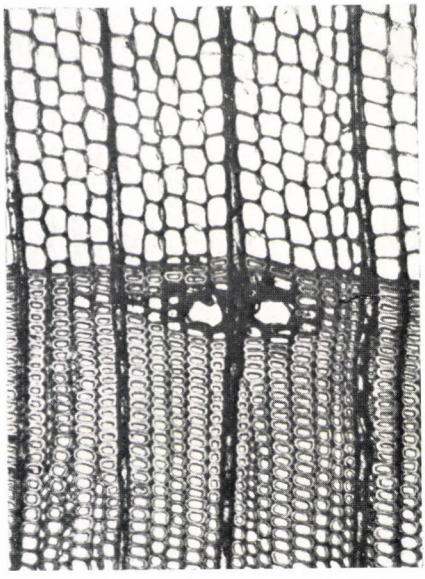


Fig. 137. *Cathaya argyrophylla* Chun and Kuang



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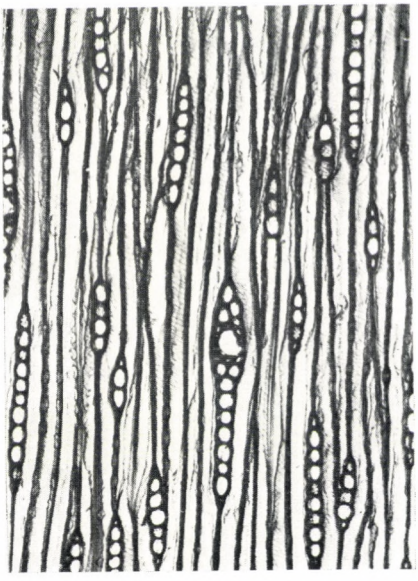

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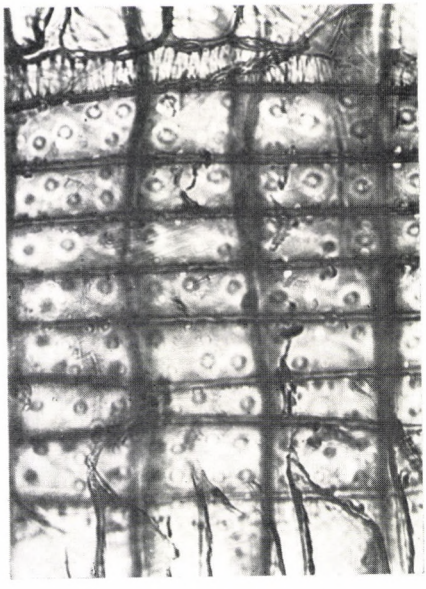

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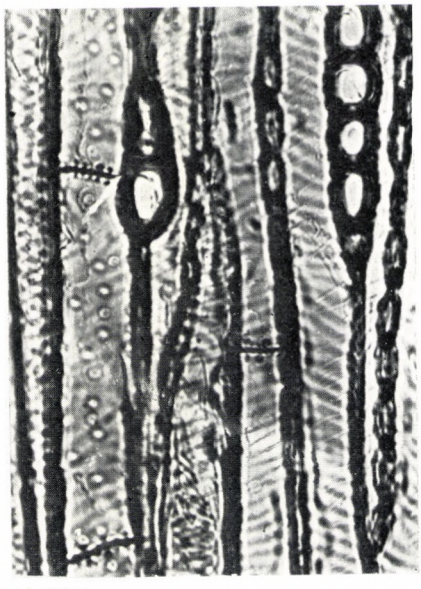


4.(×300)

CLVIII. *Pseudotsuga gausseni* Flous

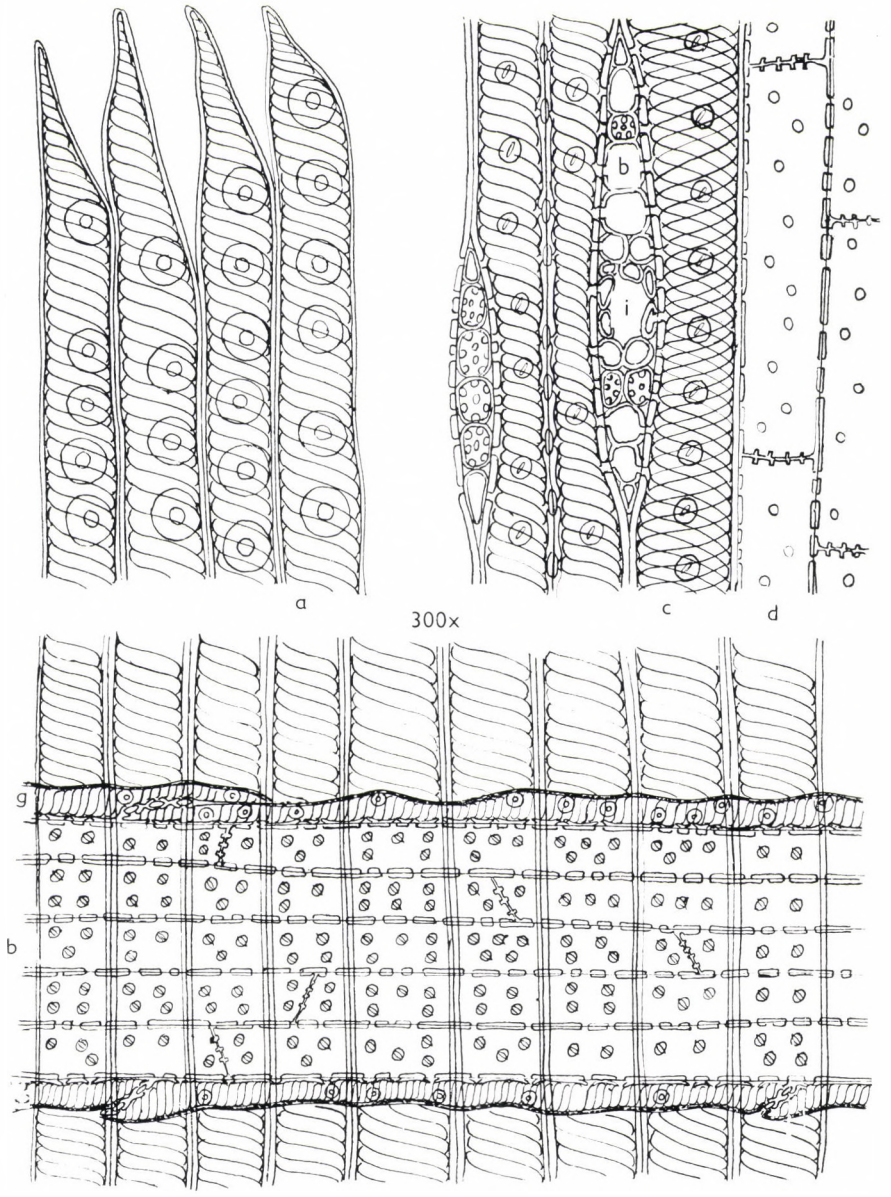
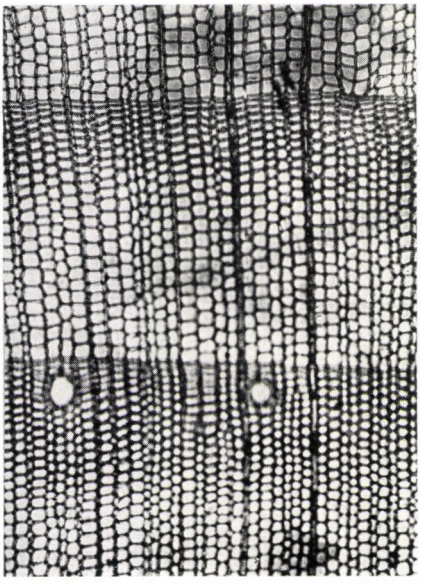


Fig. 138. *Pseudotsuga gausseni* Flous



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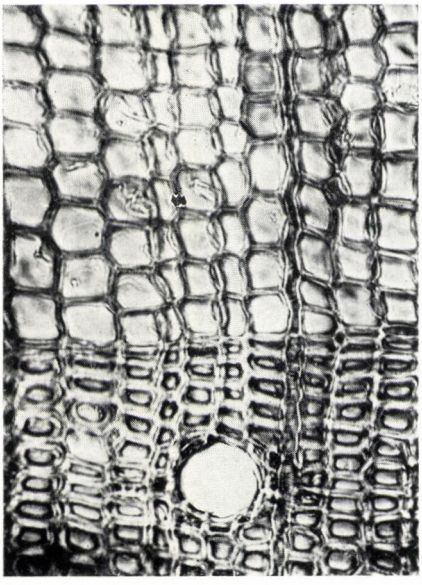
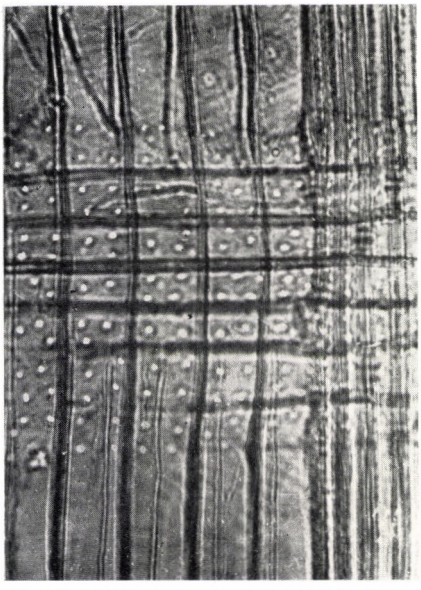


2.(x100)



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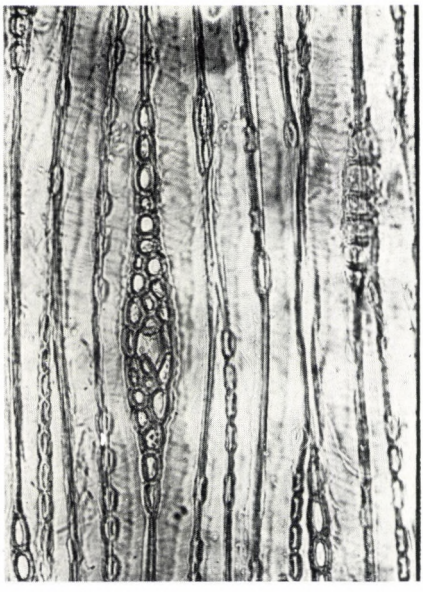

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CLIX. *Pseudotsuga glauca* Mayr.

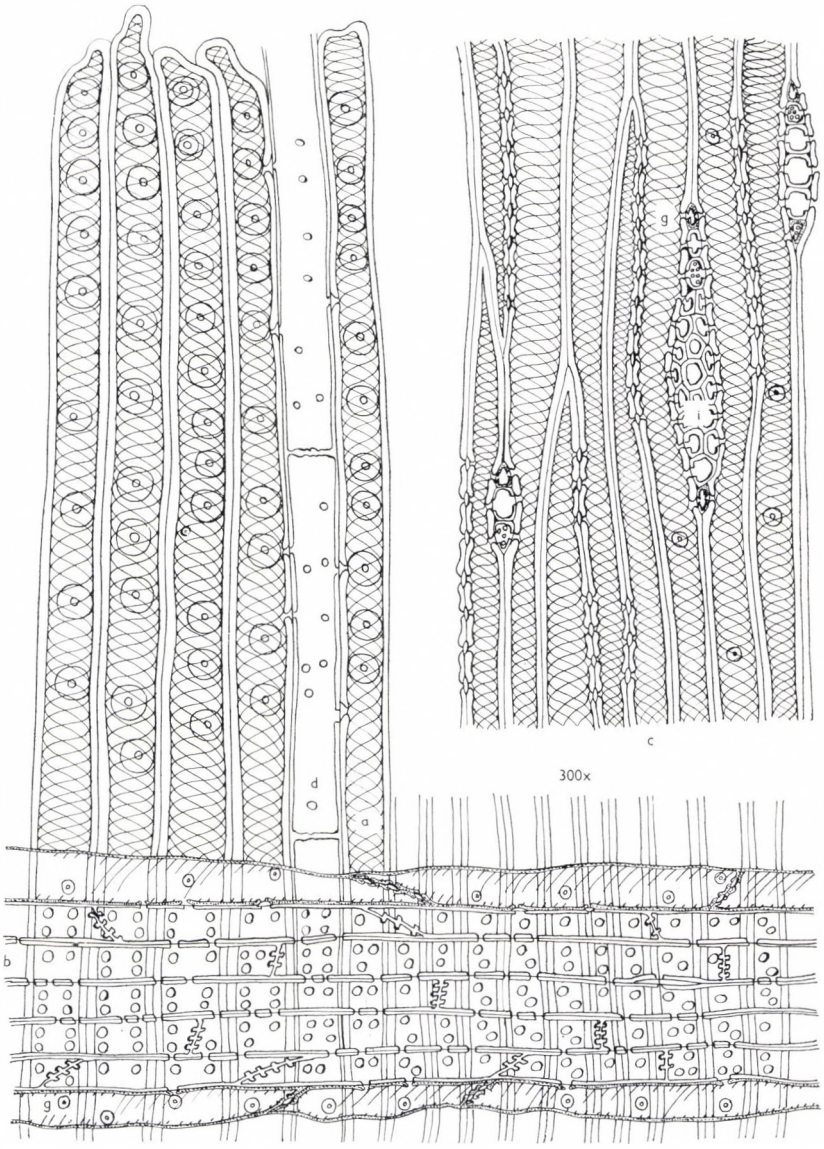
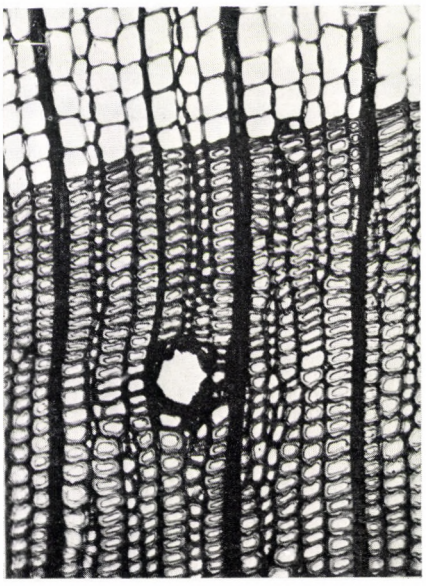


Fig. 139. *Pseudotsuga glauca* Mayr.



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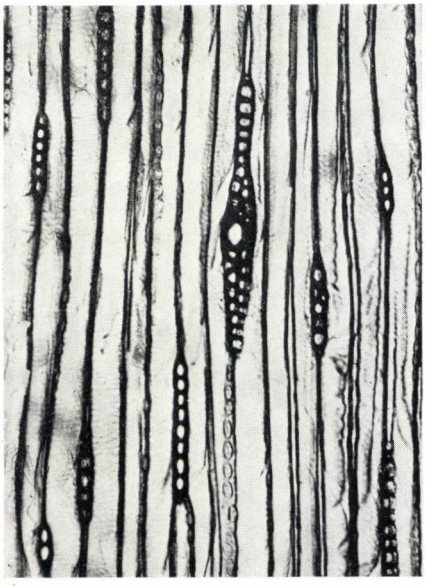
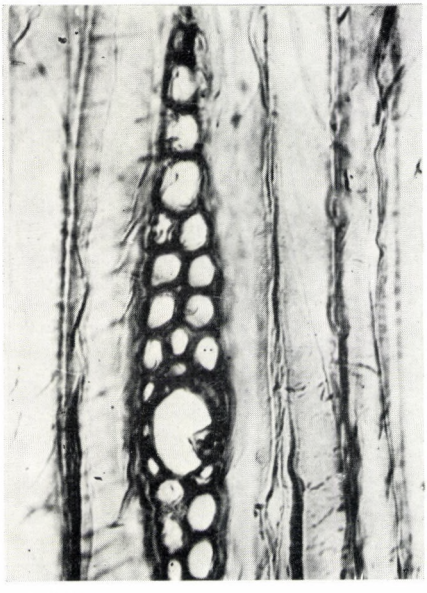


2.(×100)

3.(×300)



4.(×300)

CLX. *Pseudotsuga japonica* (Shirasawa) Beissner

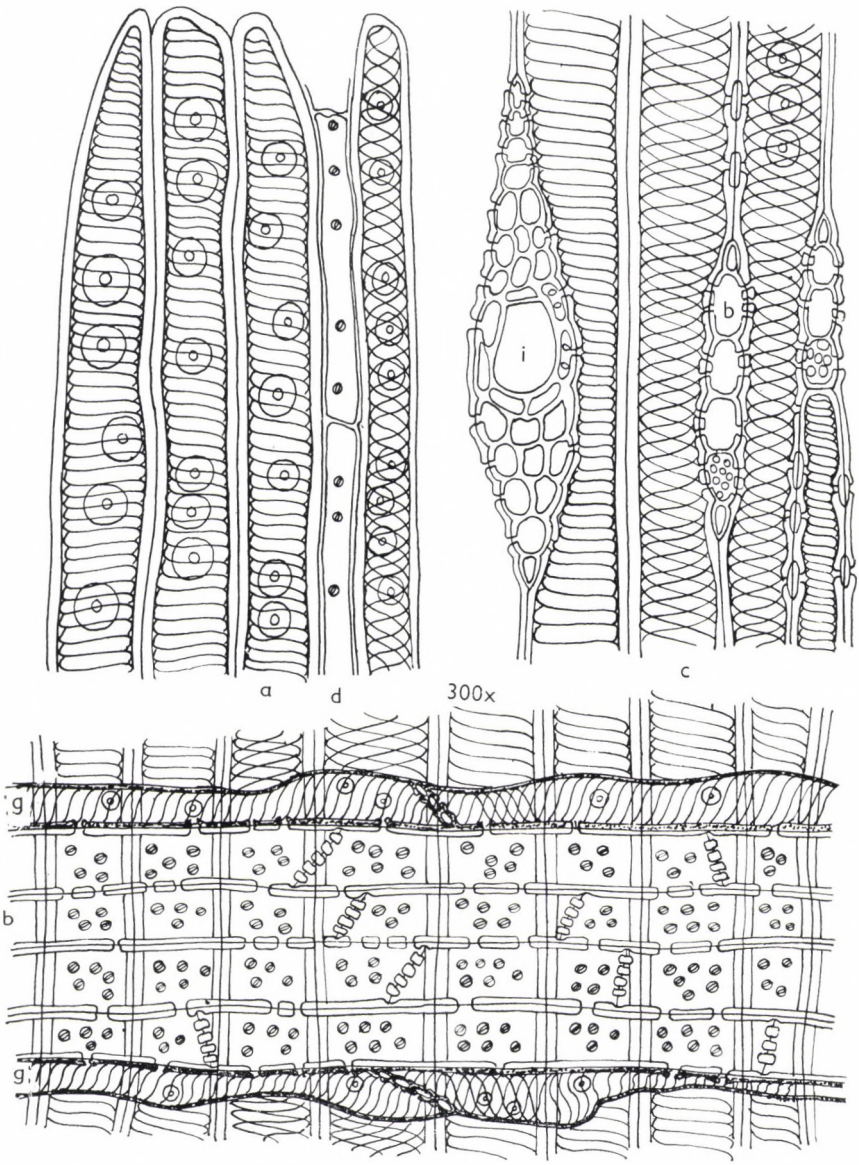
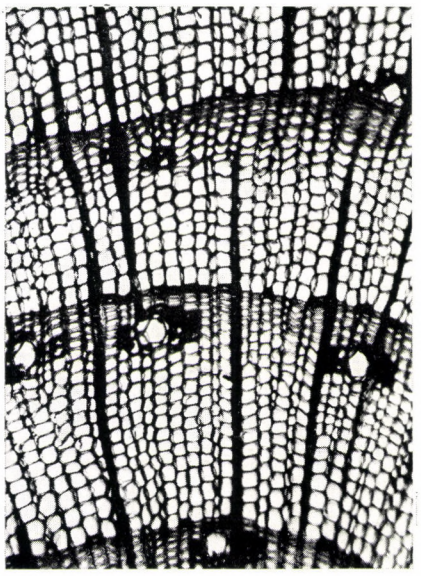


Fig. 140. *Pseudotsuga japonica* (Shirasawa) Beissner



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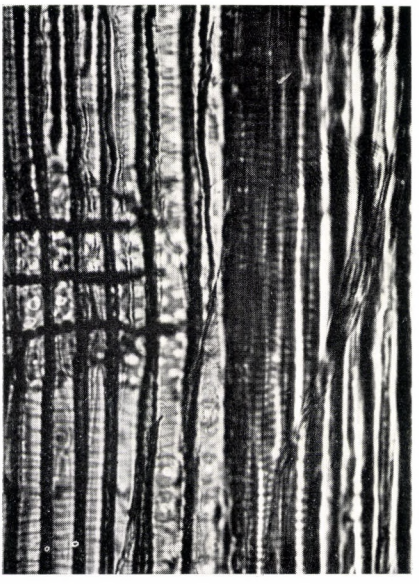
2.(×100)



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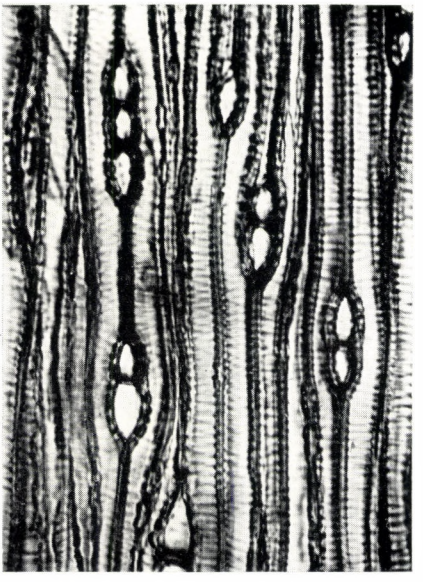


4.(×300)

CLXI. *Pseudotsuga wilsoniana* Hayata

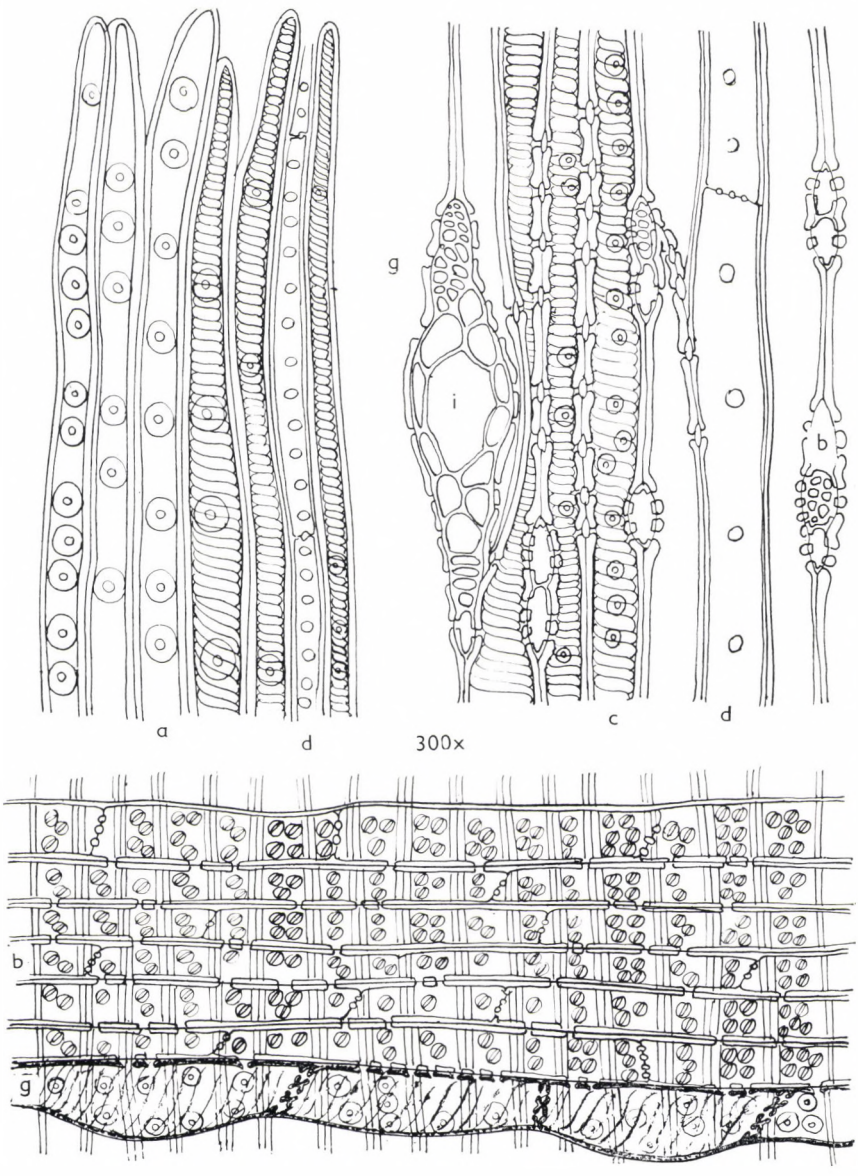
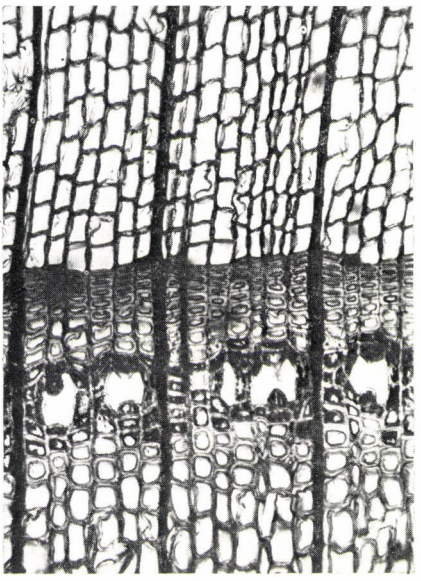


Fig. 141. *Pseudotsuga wilsoniana* Hayata



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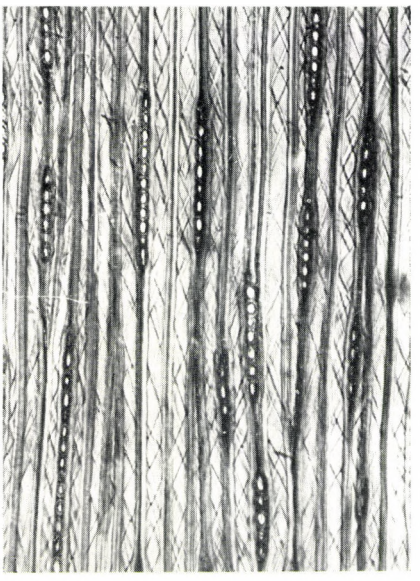
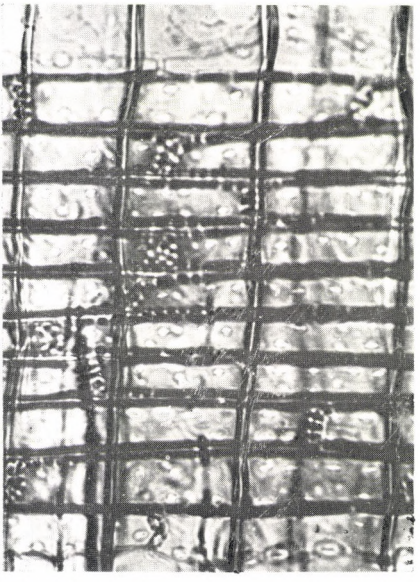
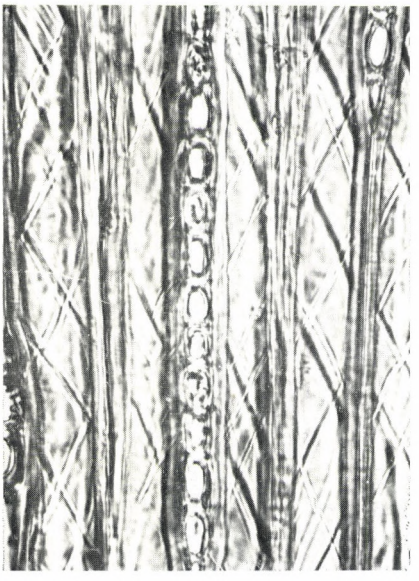


2(x100)



3(x 300)



4.(x300)

CLXII. *Tsuga caroliniana* Engel.

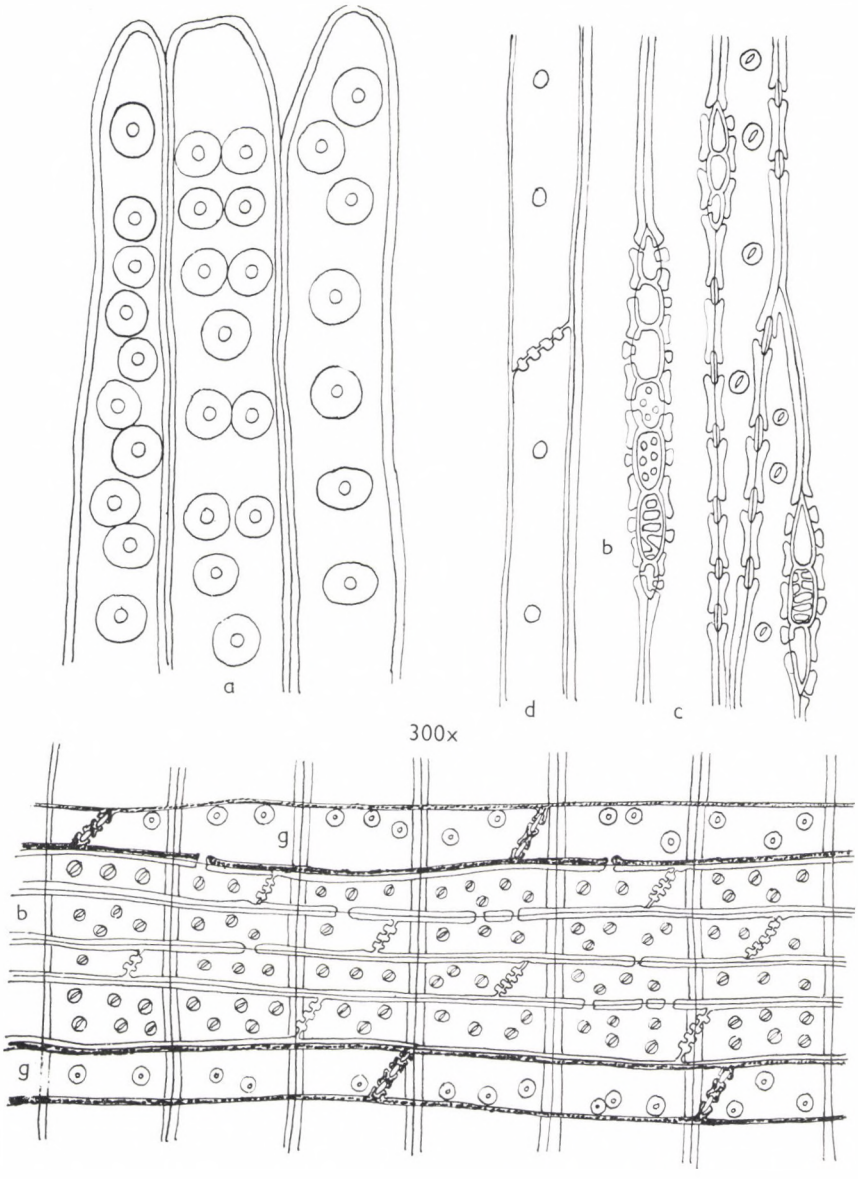
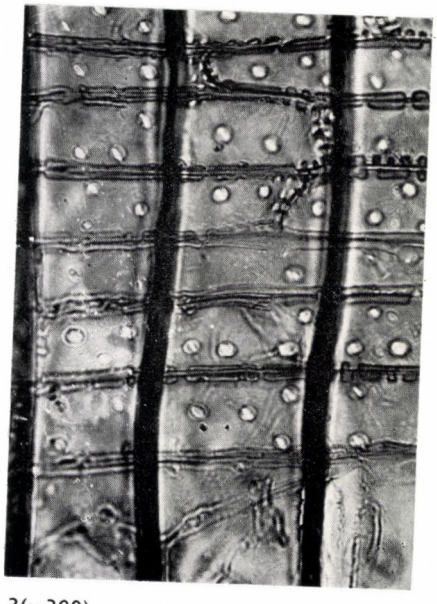


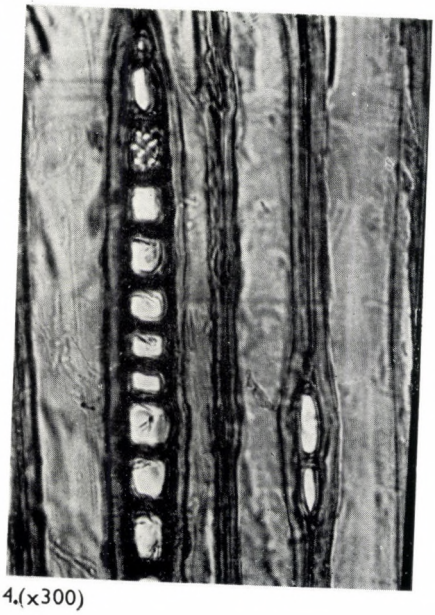
Fig. 142. *Tsuga caroliniana* Engel.

1.(×100)

2.(×100)



3.(×300)



4.(×300)

CLXIII. *Tsuga formosana* Hayata

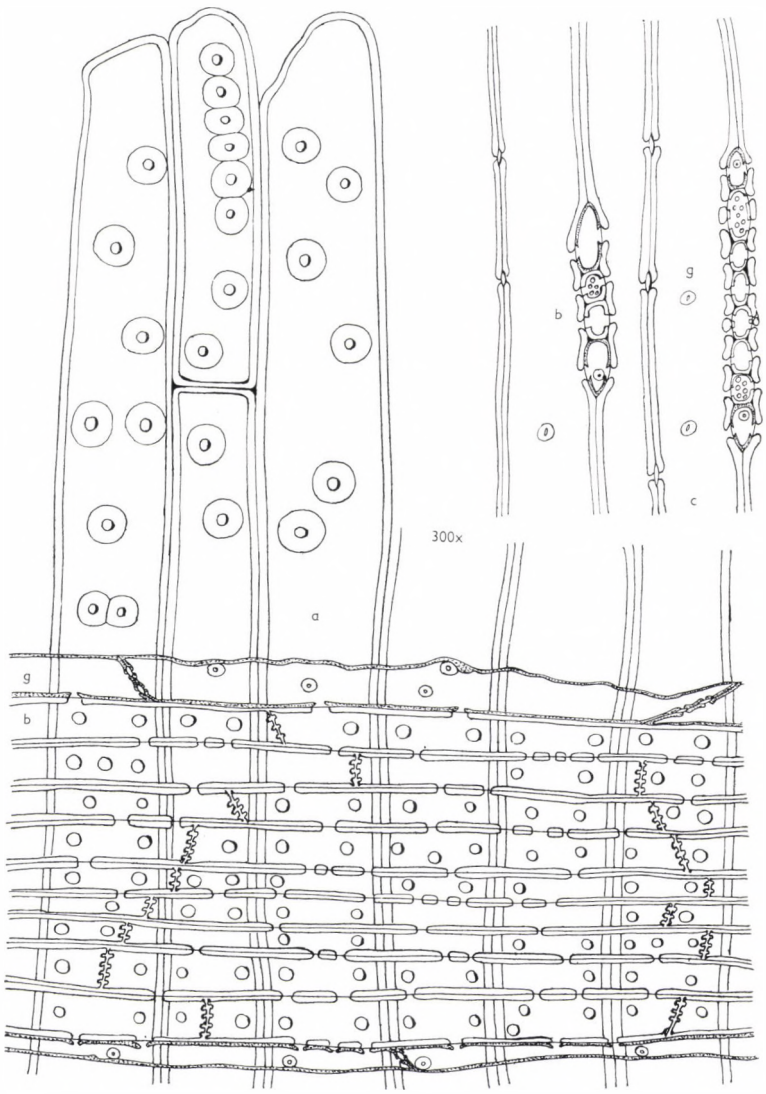
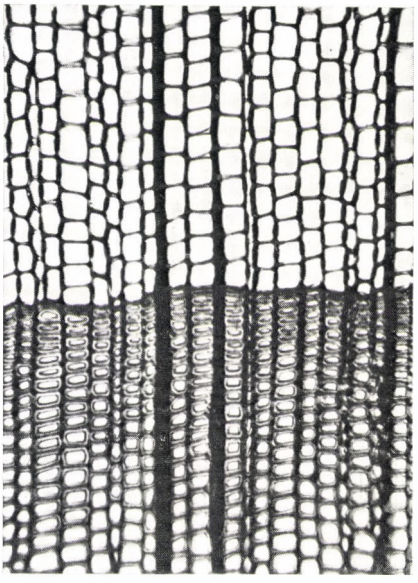
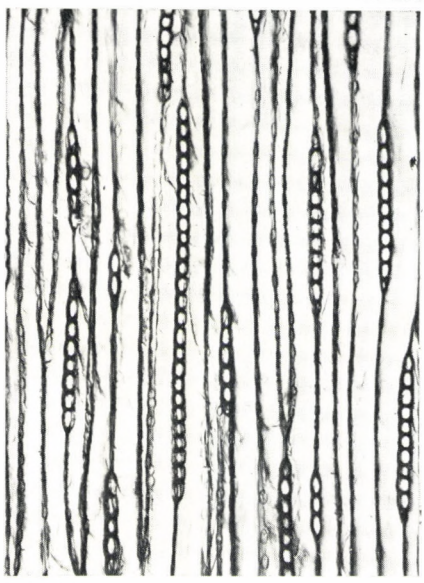


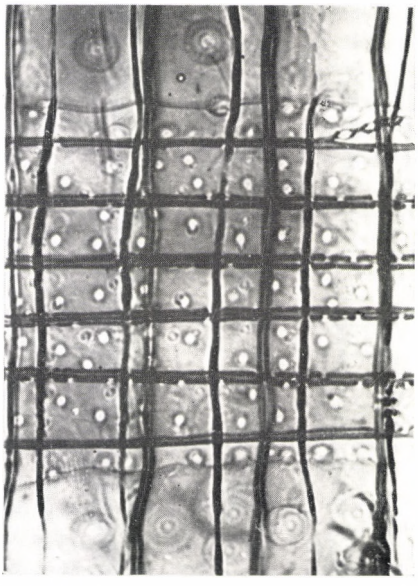
Fig. 143. *Tsuga formosana* Hayata



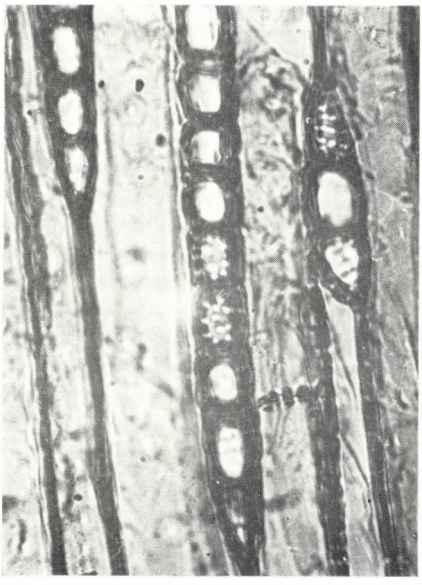
1. (×100)



2.(×100)



3.(x 300)



4.(x 300)

CLXIV. *Tsuga sieboldii* Carr.

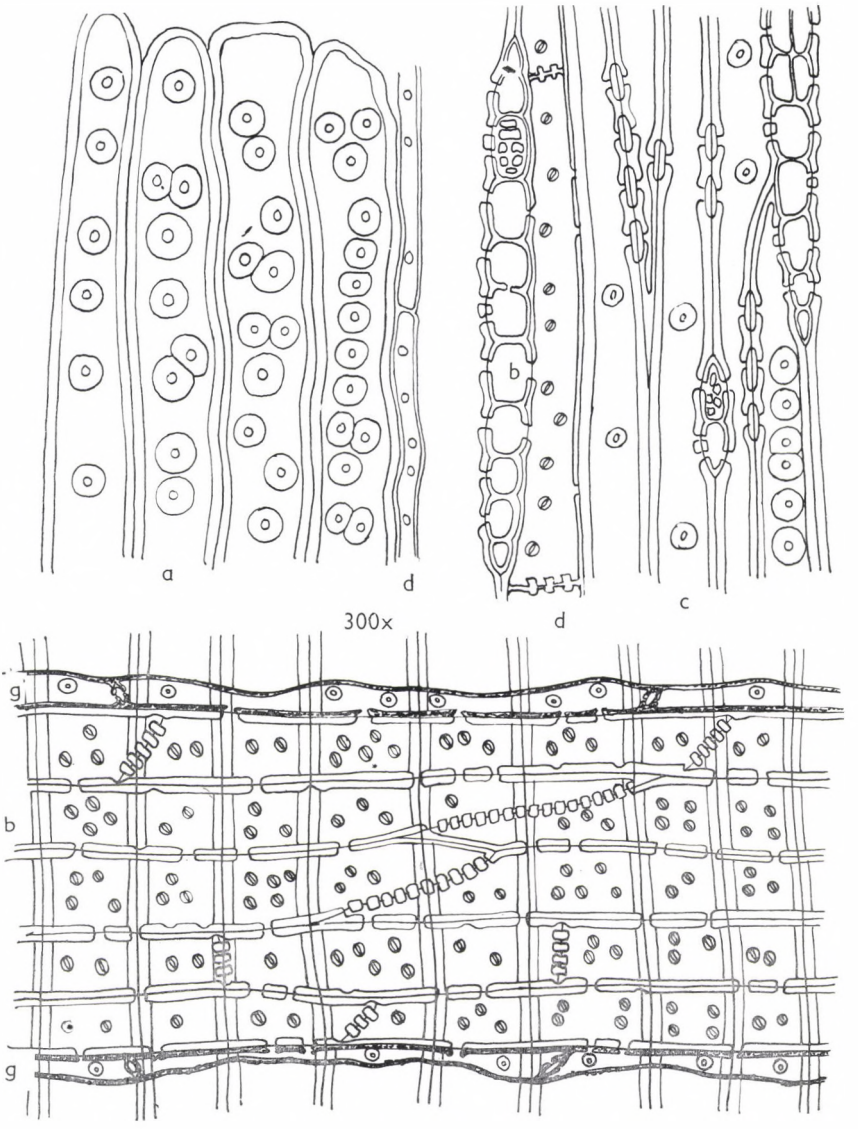
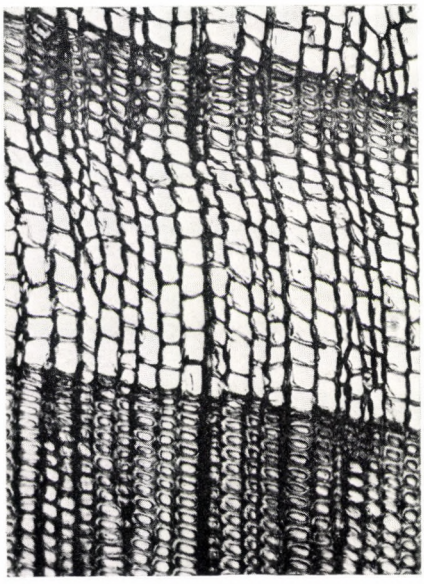


Fig. 144. *Tsuga sieboldii* Carr.



1.(×100)

2.(×100)

3.(×300)

4.(×300)

CLXV. *Tsuga yunnanensis* Mast.

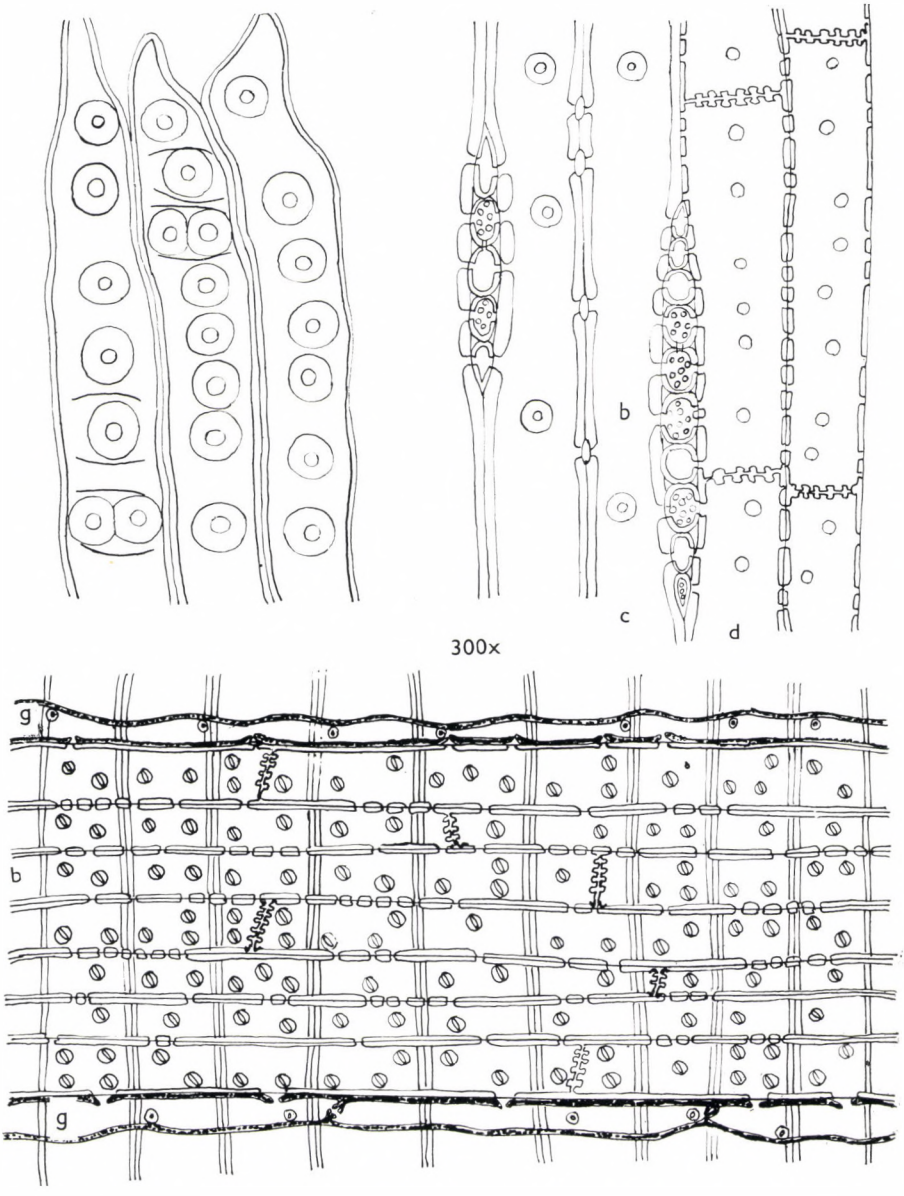


Fig. 145. *Tsuga yunnanensis* Mast.

Prof. Pál Greguss D. Sci. (biol.) made his mark as a scientist in his youth, more than sixty years ago and attained the peak of his activity in the last decade crowning his oeuvre by publishing in quick succession several comprehensive works on his special field of study which is xylotomy. He has published some 300 books, educational writings and papers altogether. His exceptional working capacity made him known the world over as a botanist, winner of various prizes and member of several learned societies both in and outside his country. He delivered lectures not only in Szeged University, Hungary, where he held the Chair of Botany, but also led courses in many European, Asian, American and African cities. He has enriched with new results the diverse fields of botany (plant biology, morphology, taxonomy, phylogenetics, palynology, ecology, bio-physics, etc.). Recently he has been preoccupied with wood anatomy, evolution history and paleontology.