A *SHOREOXYLON* AND TWO OTHER TERTIARY WOODS FROM THE GARO HILLS, ASSAM

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ABSTRACT

An examination of a collection of fossil wood specimens from the Tertiary of Assam revealed the presence of three distinct kinds of wood. Two of the woods, referable to the family Dipterocarpaceae, are described under the names *Shoreoxylon evidens* sp. nov. and *Dipterocarpoxylon kalaicharparense* sp. nov. The third is a *Terminalia* wood, very similar to one previously reported from the Cachar Hills by Prakash and Navale.

INRODUCTION

THE fossil woods described in this paper were collected by Dr. R. N. Lakhanpal during March 1954, in the Garo Hills of Assam. The locality is shown as mid-Tertiary in age on maps of the Geological Survey of India. The material is silicified and ranges in size from small hand specimens to large logs. Only limited regions in any of these specimens are sufficiently well preserved for identification; all of the woods had obviously very much deteriorated before silicification took place.

Although there are a large number of separate pieces of wood in the collection, an examination of thin sections prepared from each of them revealed that only three different kinds of wood are present. Two of these are the remains of two kinds of dipterocarpaceous trees; the third is a *Terminalia* wood. The two dipterocarp woods are somewhat different from any previously reported Assamese fossils; therefore, they have been described below under new binomials.

It is a widespread practice to designate Tertiary woods by generic names that combine the name of a modern genus with the suffix — *oxylon*. This practice can lead to considerable difficulty under the present rules of nomenclature, but it has been followed in almost all of the many papers on fossil dipterocarp woods, including the most recent monographic study of these woods by Schweitzer (1958); hence it has been followed here. The names *Shoreoxylon* and *Dipterocarpoxylon* are used in this paper in the same sense in which Schweitzer used them.

DESCRIPTION

FAMILY DIPTEROCARPACEAE

***Shoreoxylon* den Berger**
***Shoreoxylon evidens* sp. nov.**

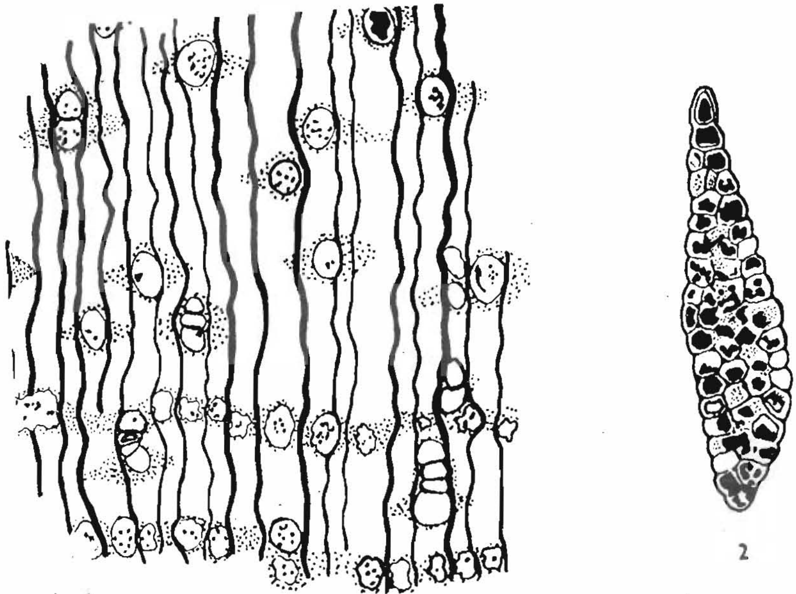
Pl. 1, Figs. 1, 2; Text-figs. 1, 2

This is the most plentiful fossil in the collection. Specimens include a large stump, a log about 100 cm. long by 28 cm. in diameter, and numerous smaller pieces, all taken from hillsides ¾ mile to 1 mile SSW of Sonamati near Garobadha. The log (B.S.I.P. No. 31804) is now on permanent display in the entrance hall of the Birbal Sahni Institute of Palaeobotany.

Concentric rings due to secretory canals are a prominent feature of this wood. These are visible to the unaided eye on the uncut ends of a log. On a transversely cut surface, the bands of canals appear as white beaded lines running the whole way around the trunk. In regions of poor preservation these become arc-shaped cavities, along which the specimen breaks very easily. The canals may be seen as white lines on the longitudinal surfaces. A conspicuous whitish deposit is also present in many modern dipterocarp woods (CHOWDHURY & GHOSH, 1958, p. 106); it would be of interest to know whether these canals of the silicified wood contain the same substance that was secreted within them millions of years ago.

The wood is diffuse porous and shows no sign of growth rings.

The vessels are visible to the naked eye and are elliptical in outline, measuring 135-345 μ in radial diameter and 105-285 μ in tangential diameter, with a wall thickness of 5-7 μ. They are widely spaced (about 3 to every 2 sq. mm.) and mostly solitary, but groups of 2 and 3 are common, and groups of 4 occur rarely. Tyloses are


1 2

TEXT-FIGS. 1, 2 — Camera lucida drawings made from thin sections of *Shoreoxylon evidens* sp. nov. 1, Transverse section showing aliform parenchyma and two rows of secretory canals. × 19. 2, a ray seen in tangential section. × 115.

rarely present, but almost all of the vessels contain the spores and filaments of a fungus (PL. 1, FIG. 1; TEXT-FIG. 1). The vessel ends are truncated, with straight end walls and simple perforations. Inter-vessel pitting has a crowded, hexagonal appearance.

Tracheids are not clearly visible in this material.

Fibres are libriform. This was established by macerating portions of the silicified wood in hydrofluoric acid and teasing out the elements with a needle. All of the 25 or so fibres and fibre-fragments obtained in this manner showed the simple, slit-like pits that are characteristic of libriform fibres. These fibres are not so thick walled, as the libriform fibres of many other woods however, and the lumina are rather large.

The longitudinal parenchyma has an aliform paratracheal distribution. Parenchyma occurs also in conspicuous apotracheal bands, 200-600 μ in width, in which the secretory canals are located. No other apotracheal parenchyma is clearly visible in this material.

Only vertical secretory canals are present. They are distributed 2-5/mm. in tangential bands of parenchyma that seem to circumscribe the stem completely (PL. 1, FIG. 1; TEXT-FIG. 1). The spacing of these bands is very irregular (1200-4200 μ between bands). The outlines of the secretory canals in cross-section are elliptical, the radial diameter ranging from 165 to 270 μ and the tangential diameter from 120 to 195 μ. The cavities are filled with a whitish substance. Epithelial cells are rarely preserved.

There are 5-7 rays per mm. in a cross-section. These are mostly 3-5 cells (55-105 μ) wide (TEXT-FIG. 2), but biseriate and, very rarely, uniseriate rays occur too. Most rays are 13-25 cells (450-690 μ) high. They are almost entirely made up of procumbent cells, but a single row of uprights is present on at least some of the margins. The ray cells are usually filled with a dark inclusion.

Comparison with Modern Dipterocarpaceous Woods — Schweitzer (1958), following the example of earlier workers, classified all fossil dipterocarpaceous woods containing long tangential bands of secretory canals either as *Shoreoxylon* or as *Dryobalanoxylon*. Woods in which fibres are libriform only are called *Shoreoxylon*. This category embraces all fossil woods resembling woods of the modern genera *Shorea, Parashorea, Hopea, Pentacme, Doona* and *Balanocarpus*. The name *Dryobalanoxylon* is used for fossils containing fibre-tracheids as well as libriform fibres, i.e. those fossils resembling woods of the modern genus *Dryobalanops*. According to Schweitzer, one other criterion may sometimes be used to distinguish between *Shoreoxylon* and *Dryobalanoxylon*. Individual pores are said to occur in groups, and the number of pores per group is used as a key character for making the separation (loc. cit., p. 7). To the present author's eye, however, the pores do not occur in discrete groups either in the fossil described here or in Schweitzer's illustrations. Moreover, the judgment as to what is a libriform fibre and what is a fibre-tracheid can be very arbitrary even in modern woods, because the two kinds of elements grade into each other; therefore, many workers have not attempted to draw this distinction between *Shoreoxylon* and *Dryobalanoxylon*. In the present instance it was possible to obtain some fibres from macerated material, and as these were all libriform fibres, the name *Shoreoxylon* is used without hesitation.

If one may judge from a survey of the modern commercial woods of *Shorea* and related genera as presented in the work of Pearson & Brown (1932, pp. 92-126), the closest resemblances to the new *Shoreoxylon* are to be found in the genus *Shorea* itself. Modern Indian woods of *Parashorea, Pentacme, Balanocarpus* and *Hopea* generally differ from this fossil with regard to the size of vessels (larger in the fossil) and/or the distribution of parenchyma. In fact, the very closest resemblances are with woods of *S. robusta* and *S. assamica*, the two species of *Shorea* that grow in Assam today (Kanjilal *et al.*, 1934); the other *Shorea* woods treated by Pearson and Brown differ in having abundant apotracheal parenchyma. However, neither *S. robusta* nor *S. assamica* has wood structure identical with the fossil, for in the fossil there is no abundance of tyloses, and the vessels are more widely spaced.

Considering the amount of variation in vessel size and parenchyma distribution that is known to occur within modern species of dipterocarps, one should not attempt to make too much of these specific comparisons. Schweitzer has shown that two wood samples from the same species can show greater differences with regard to these characters than might be shown by woods from two related species (loc. cit., pp. 7-8, Tables 1, 2).

Comparison with other Fossil Dipterocarpaceous Woods — In view of the fact that there are hundreds of species of dipterocarpaceous trees in existence today (Foxworthy, 1946) and that the woods of some of these trees are naturally very durable (Chowdhury & Gosh, 1958), it is perhaps not surprising that fossil dipterocarp woods are plentiful. Schweitzer's monograph lists about forty fossil species from Tertiary and Pleistocene deposits and one supposedly from the Cretaceous. Arguments presented by Hughes (1961, p. 93) raise considerable doubt as to the antiquity of the latter. Roughly half of the fossils included in Schweitzer's work are of the *Shoreoxylon* or *Dryobalanoxylon* type, i.e. they possess secretory canals in long tangential bands. These woods generally differ from the Garo *Shoreoxylon* in having abundant apotracheal parenchyma, in ray structure, or in regard to the size and distribution of pores. Moreover, some of them contain solitary secretory canals or secretory canals in short tangential rows along with the very long tangential rows. This latter condition has not been observed in the Garo fossil.

It may be of special interest to compare the new fossil with three other Indian fossils described under the name *Shoreoxylon* by Ramanujam. His recently published *Shoreoxylon megaporosum* (Ramanujam, 1960) differs considerably from *S. evidens* in possessing very large pores and frequent uniseriate rays. In an earlier work, Ramanujam (1955) described the woods *S. holdeni* and *S. mortandrense* (originally *mortandranse*), an orthographic error; *-ense* or *-ensis* is the correct suffix for place-names). *S. holdeni* has markedly heterogeneous rays, by which character it may be separated from the others. *S. mortandrense* is more similar to the new *Shoreoxylon* with respect to ray structure, and there was some thought of combining the two. However, an inspection of the holotype of *S. mortandrense*, which is housed in the museum of the Birbal Sahni Institute, revealed a striking difference in the frequency of vessels. There are 10-18 pores per sq. mm. in cross-sections of *S. mortandrense*; whereas *S. evidens* has only 13·5 pores to a 9 sq. mm. field (average of 43 counts).

Type Collection — The microscope slides deposited in the Birbal Sahni Institute Museum under No. 31805 are chosen as the holotype of *Shoreoxylon evidens* (PL. 1, FIG. 1). A series of slides from another stem, B.S.I.P., No. 31806 (PL. 1, FIG. 2) was also examined frequently when the description of this new fossil was composed.

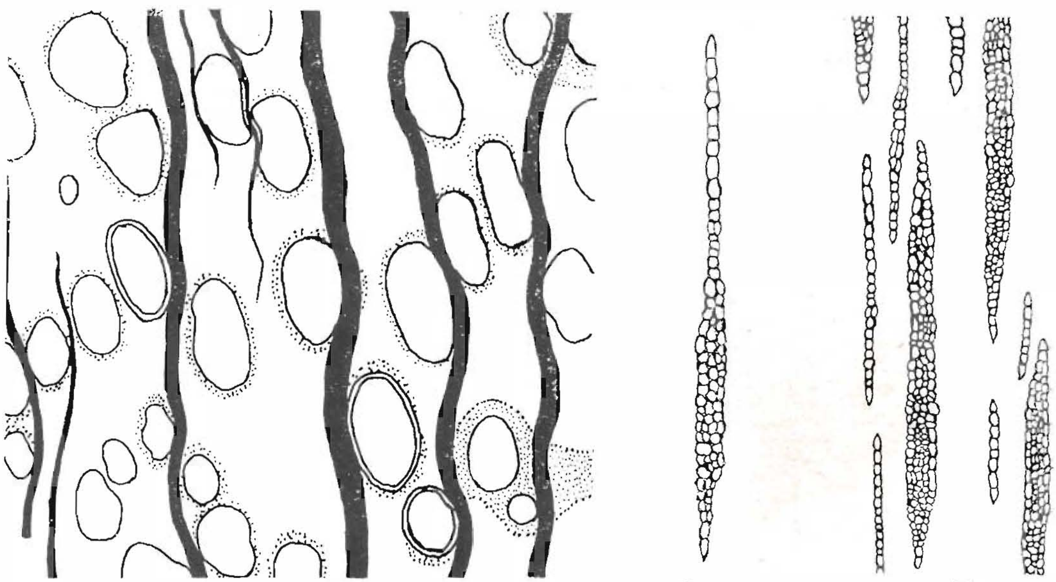
Dipterocarpoxylon Holden emend. den Berger
Dipterocarpoxylon kalaicharparense sp. nov.

Pl. 1, Figs. 3, 4; Text-figs. 3, 4

The following description is based on several small fragments and one large specimen about 30 cm. long and 20 cm. in diameter. In certain parts of the specimens the preservation is excellent, but a lack of natural staining makes it difficult to see some of the structural features of the wood in thin sections. According to Dr. Lakhanpal's field notes, the specimens were all taken " from the southern slope of the Kalaicharpara Hill in the cutting of the gully ".

The wood is diffuse porous. A transversely cut gross specimen gives an impression of faint growth rings, but these disappear under the microscope.

Most of the pores are large and easily visible to the unaided eye. They are sometimes rounded, but usually elliptical in outline and very variable in size. The radial diameter ranges from 75 to 390 μ (mostly 255-300 μ), the tangential diameter from 68 to 285 μ (mostly 180-210 μ). Some of this variability is due to the fact that the secretory canals and the vessels cannot be separated in most sections. Pore measurements, therefore, include both. The smaller pores are probably secretory canals. Where pores are elongated because of tangential compression, the radial diameter may exceed 400 μ. The pores are almost exclusively solitary and are distributed 5-7 to a sq. mm. There is a tendency for the pores to be aligned in oblique rows. Tyloses are absent, but some vessels contain a dark deposit. Vessel walls are 12-16 μ in thickness. The members are 300-675 μ in length. End walls are simply perforated, and at least some of the vessel ends have " tails ".



3 4 a 4 b

TEXT-FIGS. 3, 4 — Camera lucida drawings made from thin sections of *Dipterocarpoxylon kalaicharparense* sp. nov. 3, transverse section showing vasicentric parenchyma and one pair of secretory canals (lower right). × 37. 4a, b, rays as seen in tangential section. Both. × 47.

Vessel pairs are so rare that inter-vessel pitting was never observed.

Tracheids are not distinguishable.

The fibres have thick walls and small lumina. Pitting is not apparent on these elements.

The longitudinal parenchyma is very difficult to see, especially in cross-sections, because of the uniformly pale colour and transparency of the sections. In most cross-sections only scanty vasicentric parenchyma is distinguishable. This appears around some of the vessels as a sheath, one to a few cell thick (TEXT-FIG. 3). In the very best cross-sections apotracheal parenchyma may be seen in patches and short confluent bands enclosing secretory canals. It was not until these patches and associated canals were observed that it became possible to identify the wood. An inspection of longitudinal sections reveals that the paucity of parenchyma is, however, only apparent. Parenchyma strands are visible in these sections in abundance. Where the parenchyma strands make contact with vessels, one can see half-bordered pit pairs with elongated apertures.

Secretory canals occur singly, in tangential pairs (PL. 1, FIG. 3; TEXT-FIG. 3) or in short tangential bands. In those few places where secretory canals may be clearly distinguished from vessels, the canals are seen to be somewhat smaller in diameter than the vessels. Epithelial parenchyma is not visible in cross-sections, but there seem to be some vestiges in longitudinal sections.

Both uniseriate and multiseriate rays are present (TEXT-FIG. 4b), occurring at a frequency of 4 or 5 to each mm. in cross-section. There is a marked variation in the size of cells within both the uniseriate and the multiseriate rays (PL. 1, FIG. 4). The multiseriates bear prominent sheath cells on their flanks. They usually have 1 or 2 rows of marginal upright cells (TEXT-FIG. 4b), but uniseriate extensions, several cells in height, are not uncommon (TEXT-FIG. 4a). Multiseriate rays are 2-5 cells (37-82 μ) wide; most are 3 or 4 cells wide. Ray height varies from 7 to 43 cells (375-1500 μ).

Comparison with Similar Modern Woods — The name *Dipterocarpoxylon* has most recently been applied to fossil woods that are similar in structure to modern woods of the genera *Dipterocarpus* and *Anisoptera*, i.e., dipterocarpaceous woods in which the secretory canals are solitary or in short tangential rows and in which, in addition, the pore diameters are regularly greater than 150 μ (SCHWEITZER, 1958). In the past, *Dipterocarpoxylon* was used by some authors to designate all fossil dipterocarpaceous woods (*see* references in RAMANUJAM, 1955, p. 45). Moreover, the name was originally coined for a fossil that has since been identified as having affinities with *Gluta* in the Anacardiaceae (CHOWDHURY, 1952). Schweitzer's usage has been followed here in an effort to be understandable rather than to be nomenclaturally punctilious.

If one refers to the key for the separation of commercial woods of *Dipterocarpus* in the work of Pearson & Brown (1932, pp. 69-70), one finds that the ray width and pore diameter in the fossil wood put it closest to woods of the modern species *D. alatus*, *D. costatus*, and *D. obtusifolius*.

Through the cooperation of the Wood Anatomy Branch of the Forest Research Institute, Dehra Dun, it was possible to compare the thin sections of *Dipterocarpoxylon kalaicharparense* with sections of modern woods of *Dipterocarpus*. It was found that the fossil is very similar to the wood of *D. alatus*, a species of Burma and the Malaya Peninsula. The wood of *D. macrocarpus*, which is growing in Assam today, is only a little less similar with regard to ray height and the abundance of tyloses. Again recalling the amount of variability of minor features of xylem structure that is known to occur within dipterocarp species, no attempt will be made to draw any evolutionary inferences from these specific similarities.

Comparison with Similar Fossil Woods — A *Dipterocarpoxylon* was previously reported from the Garo Hills by Chowdhury (1938) and described under the name *D. garoense*. *D. garoense* differs from the fossil described here in possessing tyloses and banded apotracheal parenchyma. Furthermore, the vessels are not so exclusively solitary in Chowdhury's fossil, and the rays are both wider and lower than in the material from Kalaicharpara.

There are 12 other *Dipterocarpoxylon* species mentioned by Schweitzer (loc. cit., pp. 15-29). Some of these (*D. gracile*, *D. indicum*, *D. schenkii*, *D. javanicum*, *D. resiniferum*) differ from the new *Dipterocarpoxylon* with regard to vessel size, which Schweitzer uses as a key character. Others differ in having broader rays (*D. goepperti*, *D. porosum*) or more homogeneous rays (*D. anisopteroides*, *D. kraeuseli*, *D. perforatum*) than the Kalaicharpara fossil. The rays of *D. africanum* lack the uniseriate extensions frequently encountered in tangential sections of *D. kalaicharparense*. *Dipterocarpoxylon chowdhurii* (GHOSH, 1956; SCHWEITZER, loc. cit., p. 19), a fossil from the Tertiary of north-eastern Assam, has rays very much like those of the new Garo fossil. The vessels of *D. chowdhurii* are heavily tylosed however. It is difficult to compare the two with respect to parenchyma distribution, because this feature does not show up well in *D. kalaicharparense*; or to compare them with respect to vessel size, because Ghosh gave no diameter measurement in his description (1956).

Three other woods of this same general type have been described in recent years under the name *Anisopteroxylon*. This name was originally applied to some wood fragments found in an archaeological excavation in West Bengal (GHOSH & KAZMI, 1958). It has since been applied to a wood from the middle part of the Siwalik system in the Punjab (GHOSH & GHOSH, 1958) and to another wood from the Tertiary rocks of South India (RAMANUJAM, 1960). It is the belief of the authors who use this name that woods referable to *Anisoptera* are distinguishable from woods referable to *Dipterocarpus*. Distribution of secretory canals is taken as the distinguishing feature. Woods in which the secretory canals are almost exclusively solitary or in pairs are placed in *Anisopteroxylon*; those in which short tangential groups of canals also occur are placed in *Dipterocarpoxylon*. This distinction is of some importance, for modern *Anisoptera* is not found in India (GHOSH & GHOSH, 1958).

Tangential rows of several secretory canals are discernible in some sections of the Kalaicharpara fossil; therefore, it has been assigned to *Dipterocarpoxylon*. Otherwise this new fossil bears some similarity to *Anisopteroxylon* spp., notably to the Holocene wood designated as *A. bengalense* (originally *bengalensis*) by Ghosh & Kazmi (1958).

Type Collection — The material upon which the above description is based, is deposited in the Museum of the Birbal Sahni Institute as Nos. 31810 and 31811. No. 31810 has been chosen as the holotype.

FAMILY COMBRETACEAE

***Terminalioxylon* Schonfeld**

One of the specimens in Dr. Lakhanpal's collection, a piece of wood measuring 30×22×17 cm. from "a small hill about 2 furlongs SSW of Sonamati", was found to be in an exceptionally poor state of preservation. It was only in a few places in the specimen that any xylem structure could be found, and sections from the best of these places revealed only certain features such as low, mostly uniseriate rays and vasicentric to aliform-confluent parenchyma distribution. It is likely that this wood would have remained unidentified had not Dr. R. K. Jain pointed out to the author that it bore some resemblance to an Assamese fossil previously investigated by Prakash and Navale.

This work of Prakash and Navale had not been published at the time the present work was undertaken, but it was possible through the cooperation of Dr. Navale to read the description in manuscript form and to examine the thin sections of their fossil, which is not so poorly preserved as the one from Dr. Lakhanpal's collection. A comparison of the two fossils showed a marked resemblance in all observable characteristics. No differences were seen that could not be attributed to differences in preservation, and the two woods might very well have come from the same kind of tree.

The fossil investigated by Prakash and Navale was collected in the Cachar Hills, also a mid-Tertiary locality. It was identified by them as a wood of *Terminalia*, the first such fossil reported from the Tertiary of Assam, and they have given it the name *Terminalioxylon chowdhurii*. The manuscript containing a full description of this fossil and giving its affinities will have reached the press before the present paper is published; therefore, it will not be necessary to repeat these details here, but merely to report the finding of this fossil from a new locality.

Sections from this more recently discovered *Terminalia* specimen are deposited in the museum of the Birbal Sahni Institute as No. 31812.

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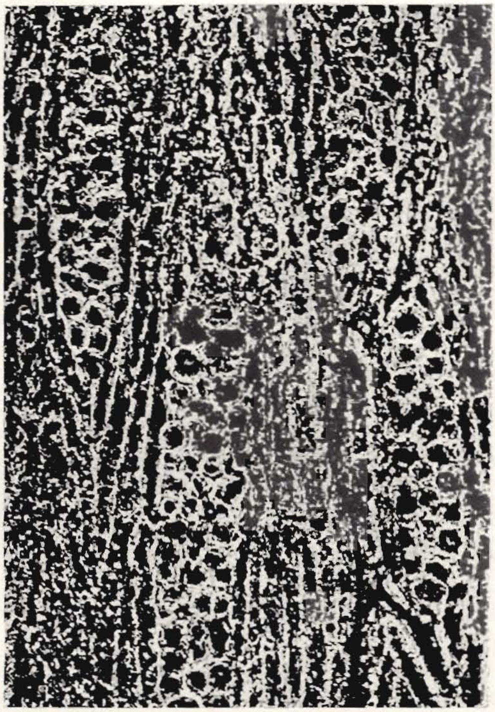

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3

4

ACKNOWLEDGEMENT

The investigation reported in this paper was carried out while the author worked at the Birbal Sahni Institute of Palaeobotany, Lucknow, as a Fulbright Student under the supervision of Dr. R. N. Lakhanpal from August 1960 to May 1961. He would like to take this opportunity to express his gratitude for the use of the Institute facilities and to thank the personnel at all levels for the many courtesies, both personal and professional, that were extended to him during his stay in India.

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EXPLANATION OF PLATE 1

1. Transverse section of *Shoreoxylon evidens* sp. nov. (B.S.I.P. 31805-1). A row of secretory canals may be seen at the bottom of the photograph. Dark spots within the pores are most probably due to the presence of a fungus. × 35.

2. Tangential section of *S. evidens* (B.S.I.P. 31806-1) enlarged to show the nature of the xylem rays. × 125.

3. Transverse section of *Dipterocarpoxylon kalaicharparense* sp. nov. (B.S.I.P. 31810-1). A pair of secretory canals may be seen just below the letters SC. × 32.

4. Tangential section of *D. kalaicharparense* (B.S.I.P. 31810-2) showing uniseriate and multiseriate rays. Note the presence of sheath cells on the flanks of the multiseriate rays. × 125.