SPIROXYLON INDICUM SP. NOV., A TAXINEAN WOOD FROM THE LOWER GONDWANAS OF INDIA

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ABSTRACT

Spiroxylon indicum is the first record of Taxinean wood from the Lower Gondwanas of India and establishes the existence of plants showing Taxoidean anatomy in the Lower Permian strata. It is described from small fragments obtained from some carbonaceous shales and is characterized by the presence of Taxinean spirals in addition to the bordered pits on the walls of its tracheides. It is closely allied to *Spiroxylon africanum* described by Walton (1925) from South Africa, but differs from that species in certain important details. It is, therefore, described here as a new species. The structure of *Spiroxylon indicum* lends support to the view that the Taxads may possibly have originated from some Cordaitean ancestors.

INTRODUCTION

THE fragments of wood and tracheides on which this species is based form a part of a rich microflora released from some carbonaceous shales from the Singrauli coalfield in the south-west corner of Mirzapur district, Uttar Pradesh. The shales were collected by Dr. R. C. Misra of the Department of Geology, Lucknow University, from near Kota (lat. 24°6′, long. 82°45′) and presented to the late Professor B. Sahni who passed it on to the writer for investigation. Preliminary reports on the nature of the microfossils obtained from the material appeared in *Palaeobotany in India*, III (p. 218) and IV (pp. 173-174; PL. 7, FIGS. 17-26). The present communication is the first of the series which will describe the entire microflora in detail.

The coal-bearing strata of the region are at present assigned to the Barakar (Lower Permian?) stage of the Indian Gondwanas (FOX, 1934, p. 179; COULSON, 1939, pp. 433-466; SAHNI, 1926, CHART II).

The genus *Spiroxylon* was instituted by Walton (1925, pp. 18-22) from a South African petrified wood exhibiting "a type of secondary wood structure very similar in some respects to that of the Taxoideae Pilger". As in the living genera *Taxus*, *Cephalotaxus*[1] and *Torreya*, the tracheides of *Spiroxylon* bear spiral thickening bands — 'Spiralverdickung' of Gothan (1905, p. 54) — in addition to the bordered pits on their walls. "These bands in size bear the same relation to the tracheides as do those in the living genus *Taxus*" (WALTON, loc. cit., p. 19). But while the tracheidal pits in the living genera are distant (separate) and opposite when in more than one series, in *Spiroxylon* they are contiguous and alternate (only occasionally opposite). The latter type of radial pitting is normal in the Araucarineae and the Cordaitales. Walton (loc. cit., p. 20) and Seward (1919, p. 134) quote other authors like Gothan (1905), Bailey (1909, pp. 51-53) and Jones (1912) who have recorded the sporadic occurrence of spiral bands on the secondary wood tracheides of several other conifers such as *Phyllocladus*, *Larix leptolepis* Murray, species of *Abies*, *Picea*, *Cupressus*, and *Pseudotsuga*. But all these as well as the fossil wood *Taxoxylon* Unger (SEWARD, 1919, pp. 202-203) normally possess distant and opposite pits. Other differences between the living Taxads and *Spiroxylon* are indicated by Walton (loc. cit., table on p. 21) in the average vertical diameter of ray cells, the number of pits in the field and the diameter of the bordered pits.

DESCRIPTION

Altogether seven fragments are described here to bring out the structural details of the Indian species.

Fragment 1 (FIG. 1) — Fragment with parts of two wood rays, each one cell deep, the lower showing pits in the field. Average maximum breadth of tracheides *ca.* 22·5 μ. Pits uniseriate, but in wider parts of tracheides irregularly biseriate, and then alternate or opposite; mostly elliptical, horizontal and

1. *Cephalotaxus* is now placed by some authors, e.g. Florin, in a separate family.

contiguous, occasionally separate. Smallest pits more or less circular in outline and *ca.* 4 μ across, mouths 2-3 μ across; largest *ca.* 14 × 10 μ, mouths *ca.* 10 × 6 μ. Ray cells thick-walled, squarish, each side *ca.* 20 μ in length, without pits in the horizontal and tangential walls. Pits in the field 6 or 7, bordered, elliptical, horizontal, 7-8 × 3-4 μ in diameter including border. Spiral bands mostly double, particularly in those parts of the tracheides which are either without pits or where the pits are far apart.

A feature of somewhat more than passing interest is provided by the truncated ends of tracheides which abut on the ray cells. Transverse endings of tracheides abutting on the ray cells or otherwise were first noted by Sahni and Singh (1926, p. 108) to be of frequent occurrence in their New South Wales and Queensland specimens of *Dadoxylon Arberi* Sew., renamed later by Prof. Sahni (1933, p. 424) as *D. krauseli*. The same authors also noticed a few similar tracheides in Miss Holden's sections of *D. indicum* (HOLDEN, 1917). They have, in addition, pointed out this feature in a South African specimen of *D. Arberi* worked out by Walton (1925, PL. 1, FIG. 3) as well as in *Callixylon Oweni* described by Elkins and Wieland (1914, TEXT-FIGS. 4, 5, 11). Without speculating on the possible phylogenetic significance of this apparently insignificant character it might be stated here that, as indicated in the concluding part of this account, the genera *Dadoxylon* and *Spiroxylon* now appear to stand closer, and that the secondary wood alone does not always distinguish *Callixylon* Zalessky from *Dadoxylon* (SEWARD, 1917, p. 293; HOLDEN, 1917, p. 323).

Fragment 2 (FIG. 2) — Tracheides mostly wide, up to *ca.* 23 μ in radial diameter, marked with spiral bands as in the last specimen. Pits up to *ca.* 14·5 × 9 μ, mouths *ca.* 11·5 × 6 μ, elliptical, horizontal, mostly contiguous and in a single more or less discontinuous series. Borders of smaller pits in two of the tracheides on the extreme left are comparatively broader as compared with others.

Fragment 3 (FIG. 3)— Part of a tracheide with a discontinuous row of mostly elliptical, horizontal and contiguous pits up to *ca.* 11·5 × 8·5 μ diameter, mouths *ca.* 7 × 4 μ. Radial width of the element *ca.* 22·5 μ in the widest portion although the limiting walls on either side are not intact. Some of the spirals run across the borders of the pits.

Fragment 4 (FIG. 4) — Tracheides of various calibres. Widest *ca.* 23 μ across, with double spirals and rather sparsely pitted — the piece intact contains only one small circular pit *ca.* 6 μ in diameter. Narrower elements (also marked with spiral bands) vary from *ca.* 5·5 to 12 μ in radial width, mostly with a single series of elliptical and horizontal pits ranging from *ca.* 5·5 (circular) to 14·5 × 11·5 μ diameter including border.

Fragment 5 (FIG. 5) — Parts of two tracheides, one with a single row of elliptical and horizontal pits up to *ca.* 14·5 × 8·7 μ across including border, the other with two series of similar but slightly smaller and alternate pits. Spiral bands run across the pit border in several cases. Tracheides *ca.* 20·5 μ across in the widest part.

Fragment 6 (FIG. 6) — Parts of unpitted elements with very clear double spirals. Radial diameters *ca.* 3, 6-8 and 14 μ respectively. The right-hand wall of the widest element is not intact.

Fragment 7 (FIG. 7) — Tracheides comparatively very narrow, the narrowest hardly 3 μ in radial width and without pits. Others *ca.* 8 μ across in the widest portions, their pits uniseriate, separate, frequently a long distance apart, more or less circular or slightly elliptical (vertical), small *ca.* 4-6 μ, mouth *ca.* 3-4·5 μ across. Parts of two wider elements (extreme left) 14-16 μ, across, their pits uniseriate, elliptical, horizontal, more or less contiguous, *ca.* 12 × 8 μ with mouths 8 × 4 μ. Spiral bands on the walls of all the elements.

All these pieces appear to be radial strips from some coniferous secondary wood and, in spite of their apparent differences, they fit in with one and the same plan of structure. The spiral thickening bands, mostly double, are common to all. The width of elements ranges from less than 3 to *ca.* 23 μ and likewise the bordered pits show a wide range in size, form, distribution, etc. Thus the fragments, when studied together, show a clear gradation in structural features and most probably represent the secondary wood components of the same species. When examined in the order in which they are described here, they seem to indicate the presence of growth rings. The so-called spring wood is made up of wider tracheides with large pits, and autumn wood of narrow

tracheides with much smaller pits or none at all. The change in radial diameters from the wider to the narrower elements of the same ring was probably gradual except in the last phase of development when the width fell suddenly from *ca.* 14-16 to *ca.* 8 μ, 3 μ or even less (FIG. 7).

DIAGNOSIS

In the light of the above observations we may sum up the provisional diagnosis of the species as follows:

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Coniferous wood, probably with well-marked growth rings. Radial diameter of tracheides varying from ca. 23 μ *in the spring wood to* ca. 3 μ (*or less*) *in the autumn wood. Radial pits very variable in size, outline and distribution, with narrow borders averaging* ca. 2 μ *in width. Pit mouth comparatively very wide, its diameter approximately two-thirds of the outer diameter of the pit. Spiral thickening bands present over all the elements, single or double, extending in between the pits, or, not infrequently, across their borders, particularly when the pits are closer together.*

Spring Wood—*Larger pits up to* ca. 14·5 × 11·5 μ *in diameter including border; uniseriate or irregularly biseriate and then opposite or alternate; elliptical, horizontal and contiguous, occasionally separate. Smaller pits only about* 4 μ *across, almost circular and uniseriate. Some of the wider elements only sparsely pitted or even altogether unpitted. Wood rays uniseriate (?), one (or more?) cell deep. Ray cells fairly thick walled, squarish, each side* ca. 20 μ, *without pits in the horizontal and tangential walls. Pits in the field* 6 *or* 7, *bordered; elliptical,* 6-8 × 3-4 μ *in diameter including border.*

Autumn Wood—*Narrowest elements almost without pits. Pits on other tracheides more or less circular or only slightly elliptical (vertical), small,* ca. 4-6 μ *across including border, uniseriate (frequently long distance apart).*

Locality — Singrauli coalfield, Mirzapur district.

Horizon—Barakar stage, Lower Permian(?) of India.

COMPARISON AND DISCUSSION

The presence of spiral thickenings in the tracheides seems to be a constant feature of this wood, and as such it at once limits the circle of its affinities to the Taxineae. The absence of pits from the horizontal and the tangential walls of the ray cells, and the number and character of the field pits distinguish it from other members of the Coniferales which show a sporadic development of spiral thickenings (*see* p. 330 above, and SEWARD, 1919, pp. 136-139). Table I below taken from Walton (1925) and added to by the author gives a comprehensive idea of the comparative anatomy and histology of this wood and its probable relationships.

It shows that *Spiroxylon indicum* combines within itself the characters of several members of the Taxineae, living and fossil. It approaches the living members in the average vertical diameter of its ray cells, the size of pits, and the position of spiral bands with respect to the borders of its pits. It

TABLE I — SHOWING THE COMPARATIVE STRUCTURE OF *SPIROXYLON INDICUM* AND RELATED WOODS

NAME OF WOOD	AVERAGE VERTICAL DIAMETER OF RAY CELLS	PITS IN THE FIELD	DIAMETER OF BORDERED PITS	ARRANGEMENT OF PITS IN TRACHEIDES	NATURE OF SPIRAL BANDS
Taxus	19 μ	1-4	13-17 μ	Opposite. Distant	Usually confined to the wall between the pits, occasionally pass across the border
Cephalotaxus	...	2-4	13 μ	,, ,,	May be so far over the border as to become tangential to the margin of the pore
Torreya	21 μ	1-5	13-15 μ	,, ,,	Sometimes in pairs; one member of the pair may be thinner and may terminate at the margin of the pore
Taxoxylon Unger (*T. scalariforme.* Goep.)	...	1-several	...	Circular. Separate	...
Spiroxylon africanum	31 μ	2-8	11-13 μ	Alternate (occasionally opposite). Contiguous	Confined to the wall between the pits
Spiroxylon indicum	20 μ	6 or 7	Various. Circular 4-6 μ. Elliptical up to 14·5 × 11·5 μ	Mostly separate in autumn tracheides. Contiguous in spring tracheides, then alternate or opposite	Over the wall between the pits, not infrequently passing across the border

covers *S. africanum* Walton and *Taxoxylon scalariforme* (Geop.) in the number of pits in the field and the size and (or) arrangement of pits in the tracheides. But in the sum total of its characters it stands easily distinguishable from all, and is, therefore, described as a new species. That it presents a synthesis of the anatomical features of the different members of the Taxineae is probably in keeping with its older geological age. The age of the African species is not known with certainty, but Walton (1925, p. 22) suggests that it could not be earlier than the Mesozoic, and may quite possibly be Tertiary. The same author also remarks that there is as yet no unequivocal record of any Taxoidean wood earlier than the Tertiary. *S. indicum*, however, shows that such a wood existed in the Palaeozoic.

Walton (loc. cit., p. 21) further suggests that the type of radial pitting in *Spiroxylon* furnishes an " additional, though somewhat slender, evidence in favour of a possibly Cordaitean ancestry for the Taxoideae ". The Cordaitean ancestry for the Taxads had been advocated by Professor Sahni (1920, 1920 a & 1921) on the basis of their seed structure. The presence of *S. indicum* in the Lower Gondwana rocks of India with its more strongly pronounced Araucarian (Cordaitean) type of tracheidal pits brings the Taxineae nearer to the Cordaitales.

Walton (loc. cit., pp. 15 and 20) also refers to a specimen of South African fossil wood in the British Museum (sections 12637-8-9) briefly described by Arber (1910) as *Dadoxylon sp.* The specimen is of exceptional interest on account of the presence of " spiral thickening, in addition to the normal secondary wall thickening with bordered pits in certain zones of the wood ". It was collected from the Ekka shales, Intombi camp, Ladysmith — a horizon regarded as homotaxial with the Permian of India (SAHNI, 1926, CHART II). The specimen needs a fuller examination and should it turn out to be a species of *Dadoxylon* with true spiral bands and not spiral striations (*Spiralstreifung* of Gothan), it will fill the gap between the Cordaitales and the Taxineae still further and support Professor Sahni's theory on the anatomical evidence as well.

Spiroxylon is here regarded as a form genus like *Dadoxylon* in the Cordaitean-Araucarian alliance or *Mesembrioxylon* in the Podocarpoid circle of affinity.

ACKNOWLEDGEMENTS

It is a matter of profound grief to the author that this communication cannot be offered to Professor Sahni in person but must take its place, among others, as a humble tribute to his sacred memory and an acknowledgement of his constant help and guidance during the course of the investigation of the microflora. Professor Sahni's untimely and sudden demise has created a void in the palaeobotanical world. In him the author has lost not only a preceptor and a guide, but also a real benefactor. The author joins his late Professor's innumerable friends and admirers all over the world in paying his humble tribute to the memory of the noble soul that inspired so many workers in the field of palaeobotany with the ideals of a devoted scientist.

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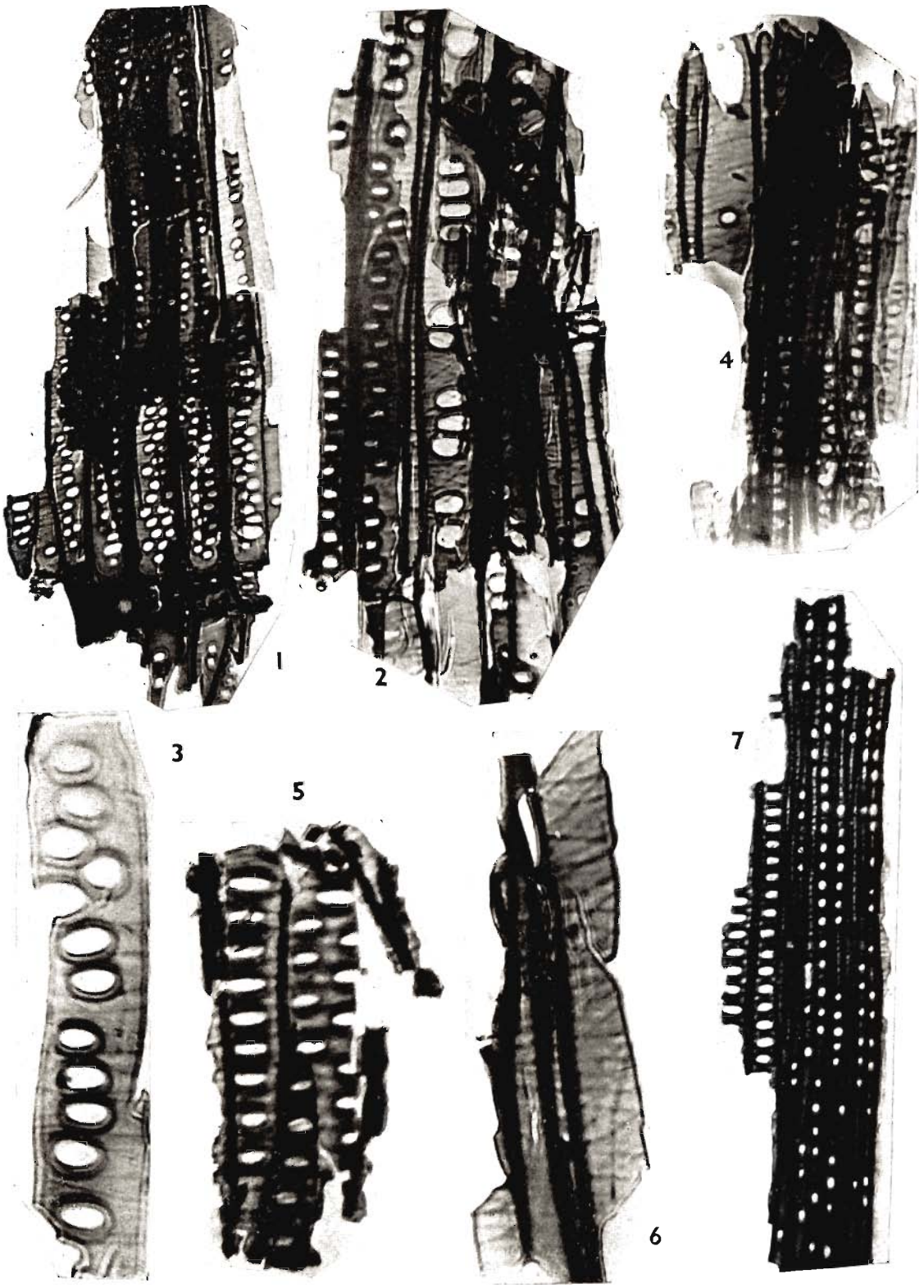
EXPLANATION OF PLATE 1

Spiroxylon indicum sp. nov.

1. Radial strip with two wood rays. Field pits in the lower one. × 324.
2. Radial strip with wide tracheides. Double spirals. × 415.
3. Part of a single tracheide. Some of the spirals run across the pit borders. × 860.
4. Radial strip showing elements of various calibres. × 415.
5. Parts of two tracheides. Elliptical pits biseriate and alternate in one of the elements. × 650.
6. Unpitted elements showing double spirals. × 790.
7. Radial strip with very narrow tracheides and small uniseriate and separate pits. Probably represents a part of the autumn wood. Elements on the extreme left tend to become wider, recalling the structure of those shown in Fig. 5 above. × 324.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