
Fossil woods from the Siwalik sediments of Darjeeling District, West Bengal, India

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The fossil woods described in this paper form the first report from the Himalayan foot-hills near Oodlabari, a small town on Siliguri-Guwahati Highway, Darjeeling District, West Bengal. These belong to the extant genera *Bauhinia* Linn. and *Diospyros* Linn. of the families Fabaceae and Ebenaceae, respectively and have been described as *Bauhinium palaeo malabaricum* Prakash & Prasad and *Ebenoxylon miocenicum* Prakash. They indicate the prevalence of tropical humid climate in the foot-hills during Siwalik sedimentation.

Key-words—Fossil woods, Anatomy, *Bauhinia*, *Diospyros*, Lower and Middle Siwalik, West Bengal (India).

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सारांश

भारत में पश्चिम बंगाल के दार्जिलिंग जनपद के शिवालिक अवसादों से अश्मित काष्ठ

जसवन्तसिंह अन्तल, महेश प्रसाद एवं एकनाथ गवजी खरे

पश्चिम बंगाल में दार्जिलिंग जनपद में ऊदलाबाड़ी, जो कि सिलीगुड़ी-गुवाहाटी मार्ग पर एक छोटा सा कस्बा है, के समीपस्थ हिमालयी गिरि-पादों से पहली बार अश्मित काष्ठों का इस शोध-पत्र में वर्णन किया गया है। ये काष्ठ *बाँहीनिया* लित्रे एवं *डायसपायरॉस* लित्रे नामक वर्तमान प्रजातियों से, जो कि क्रमशः फैबेसी एवं एबीनेसी कुलों की हैं, से सजातीयता व्यक्त करती हैं तथा इन्हें *बाँहीनियम मालाबारिकम्* प्रकाश व प्रसाद एवं *एँबीनॉक्सिलॉन मायोसेनिकम्* प्रकाश से नामांकित किया गया है। हिमालयी गिरि-पादों में इन पौधों के काष्ठाश्मों की उपस्थिति से अवसादन के समय उष्णकटिबन्धीय नम जलवायु का होना इंगित होता है।

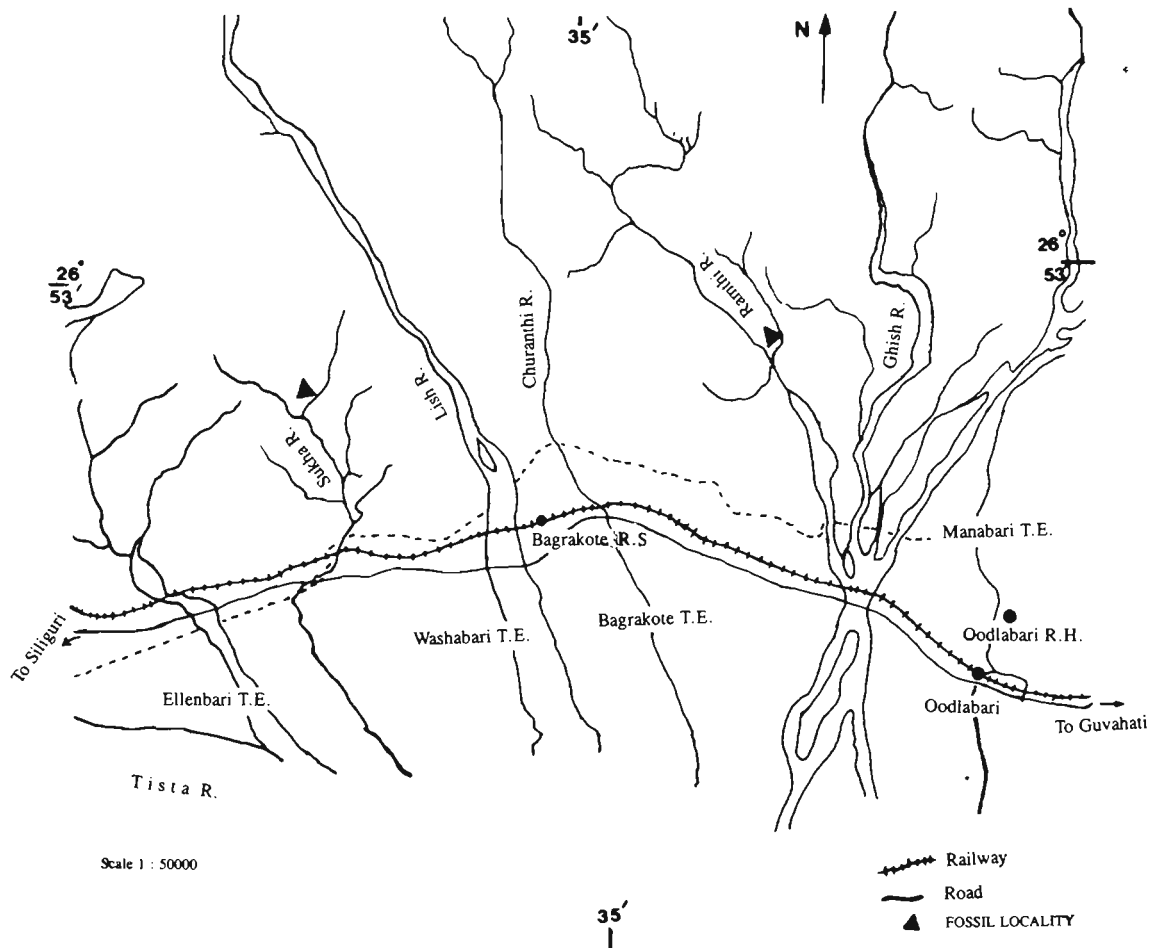
ONE of the most important episodes in the mountain building process during Middle Miocene was the formation of a long and narrow depression on the northern border of India. This depression became the site of deposition of the Siwalik sediments which extend from the Indus in the West to Brahmaputra in the East and are composed of massive alluvial detritus derived from the subaerial waste of mountains brought down by rains, numerous rivers and streams. It covers a distance of about 2,400 km in length and 20-25 km in width and ranges in age from the Middle Miocene to the Middle Pleistocene.

The fossil localities, from where the fossil woods have been collected, are situated near Oodlabari, a small town on Siliguri-Guwahati Highway in the Dar-

jeeling District, West Bengal, where the Siwaliks occur in north-east direction. The geology of the area was investigated earlier by Mallet (1875), Bose (1890), Auden (1935), Heim and Gansser (1939), Kurien (1962), Pawde (1966, 1972), and Acharyya (1972). Misra (1984) also surveyed the area and drawn a geological map. According to him the site in the Ramthi River belongs to Lower Siwalik while the other site in the Sukha River is of Middle Siwalik (Map 1).

The Siwalik sediments of West Bengal are rich in angiospermic plant remains comprising leaf-impresions, rarely fruits and seeds, and a flower (Antal & Awasthi, 1993; Antal & Prasad, 1995, 1996a, b, c).

Recently, three semi-carbonised fossil woods were collected *in situ* from the area. Of them, two



Map 1—Showing the fossiliferous localities.

are from the right bank of Ramthi River (about 2 km upstream) and one from Sukha River near Oodlabari. Ramthi River is about 3 km west while Sukha River is about 8 km further north-west from Oodlabari. The anatomical study of these fossil woods shows that one of the woods from Ramthi River is satisfactorily preserved, while the other wood is poorly preserved with no anatomical details. Another wood from Sukha River shows reasonably good preservation. It is worth mentioning here that the wood from Ramthi River is semi-carbonised and brittle in nature, while that from Sukha River is hard. These woods show closest similarity with the extant woods of *Bauhinia malabarica* and *Diospyros kurzii* of the families Fabaceae and Ebenaceae, respectively. These have been described and discussed in the present communication.

SYSTEMATIC DESCRIPTION

Family—Fabaceae

Genus—*Baubinium* Prakash & Prasad 1984

Baubinium palaeomalabaricum Prakash & Prasad 1984

The specimen consists of several somewhat well-preserved semi-carbonised secondary wood pieces measuring less than 4 X 2 cm.

Description—Wood diffuse porous. Growth rings indistinct. Vessels small to large, solitary as well as in radial rows of 2-5 (Pl. 1, fig. 1), t.d. 75-210 μ m, r.d. 100-280 μ m, 5-12 per sq mm, rays contiguous on one or both sides; vessels filled with brownish black deposits, round to oval in shape when solitary, tangentially compressed due to pressure during fossili-

zation (Pl. 1, figs 1, 2), vessel segments 140-800 μm in length with truncate ends and irregularly storied, perforation simple; intervessel pit pairs alternate, vested, round to oval in shape, 6-8 μm in diameter with linear to lenticular apertures. *Parenchyma* paratracheal forming mostly sinuate, confluent concentric bands, alternating broader bands of fibres (Pl. 1, fig. 2), parenchyma cells thin-walled, 10-25 μm in diameter and 50-120 μm in length, strands irregularly storied. *Xylem rays* fine, 1-2 (mostly 1) seriate, 15-50 μm in length, 5-30 cells or 135-690 μm in height and storied (Pl. 1, fig. 3), ray tissue heterogeneous, consisting of homo- to-heterocellular rays, heterocellular rays with procumbent cells mostly in the median portion, upright cells at the ends (Pl. 1, figs 3, 4); ray cells thin-walled, tangential height 22-38 μm , radial length 12-20 μm ; procumbent cells 15-25 μm in tangential height and 32-60 μm in radial length (Pl. 1, fig. 4). *Fibres* not aligned in radial rows, libriform to semi-libriform, moderately thick-walled, non-septate, 8-16 μm in diameter and 390-1260 μm in length, interfibre pits could not be seen. *Ripple marks* present due to storied arrangement of vessel members, parenchyma strands and xylem rays.

Specimen—No. BSIP 37616.

Locality—Right bank of Ramthi River (about 2 km upstream) near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower Siwalik.

Affinities—The important anatomical features of the present fossil such as small to large vessels, confluent banded parenchyma, 1-2 seriate storied xylem rays and irregularly storied parenchyma strands and vessel segments are found in the modern woods of *Bauhinia*, *Millettia*, *Pterocarpus*, *Dialium*, *Swartzia*, *Dalbergia* and *Crabia* of the family Fabaceae. Of these, the woods of *Millettia* can be distinguished from the present fossil in being possessing relatively broad, 1-3 seriate xylem rays and almost straight and continuous bands of apotracheal parenchyma. Moreover, the xylem rays are regularly storied as compared to slightly irregularly storied in the present

fossil wood. *Pterocarpus*, *Dialium* and *Dalbergia* can be differentiated from this fossil wood in having predominantly narrow bands of parenchyma and homogeneous to almost homogeneous xylem rays as compared to broader bands of parenchyma and heterogeneous xylem rays in the present fossil wood. The woods of *Swartzia* and *Crabia* differ from the present fossil wood in possessing predominantly narrow bands of parenchyma and regularly arranged storied parenchyma strands and vessel segments. Whereas, the vessel segments and the parenchyma strands are somewhat irregularly storied in the fossil wood. Thus, the present fossil shows closest affinity with the modern woods of the genus *Bauhinia*. In order to find out the nearest resembling species, thin sections of extant woods of eight species of *Bauhinia*, viz., *B. foveolata* Dalz., *B. malabarica* Roxb., *B. mirandica* Pitter, *B. purpurea* Linn., *B. racemosa* Linn., *B. reticulata* D.C., *B. retusa* Ham., *B. variegata* Linn., were carefully examined. Besides, the published anatomical descriptions and photographs of *Bauhinia angusta* Roxb., *B. malabarica* Roxb., *B. purpurea* Linn., *B. racemosa* Linn., *B. retusa* Ham., *B. vahlii* W. & A. and *B. variegata* Linn. were also consulted (Moll & Janssonius, 1914, pp. 112-119, fig. 158; Pearson & Brown, 1932, pp. 417-425, figs 144-146; Metcalfe & Chalk, 1950, pp. 493-501; Gamble, 1972, pp. 280-284; Ramesh Rao & Purkayastha, 1972, pp. 64-68, pl. 72, figs 428-432; pl. 73, fig. 433). It was found that the present fossil shows closest resemblance with the modern woods of *Bauhinia malabarica* Roxb.

A fossil wood resembling *Bauhinia* was first reported by Rawat (1964) from the Siwalik sediments of Mohand, Saharanpur, Uttar Pradesh under *Bauhinioxylon indicum* gen. et sp. nov. but it became an invalid publication since he did not give any description and figures (Article 38 of the ICBN). Similarly, another fossil wood showing resemblance with *Bauhinia* is also known from the Cuddalore Series of south India but no generic name was as-

PLATE 1

Bauhinium palaeomalabaricum Prakash & Prasad 1984

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| 1. Cross section in low power microscope showing vessel distribution and banded parenchyma X 40. Slide no. BSIP 37616/I. | 3. Tangential longitudinal section magnified to show the nature of xylem rays X 100. Slide no. BSIP 37616/III. |
| 2. Cross section magnified to show the nature and distribution of vessels and parenchyma X 100. Slide no. BSIP 37616/II. | 4. Radial longitudinal section magnified to show heterocellular xylem rays X 100. Slide no. BSIP 37616/IV. |

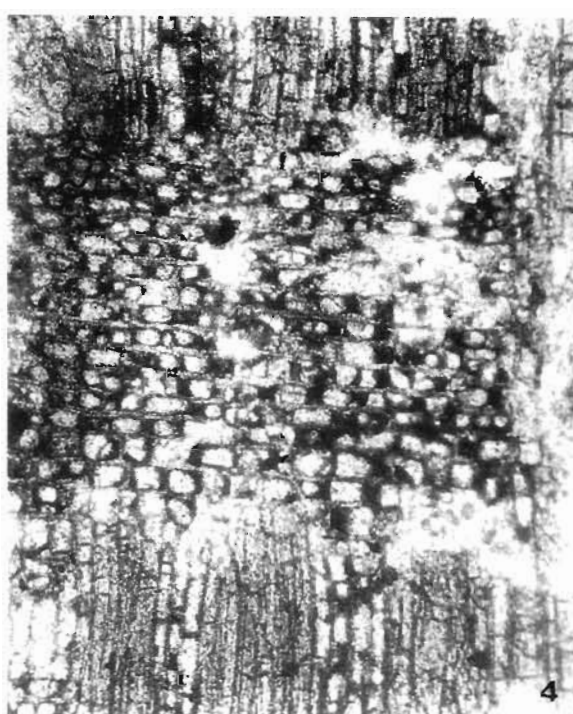
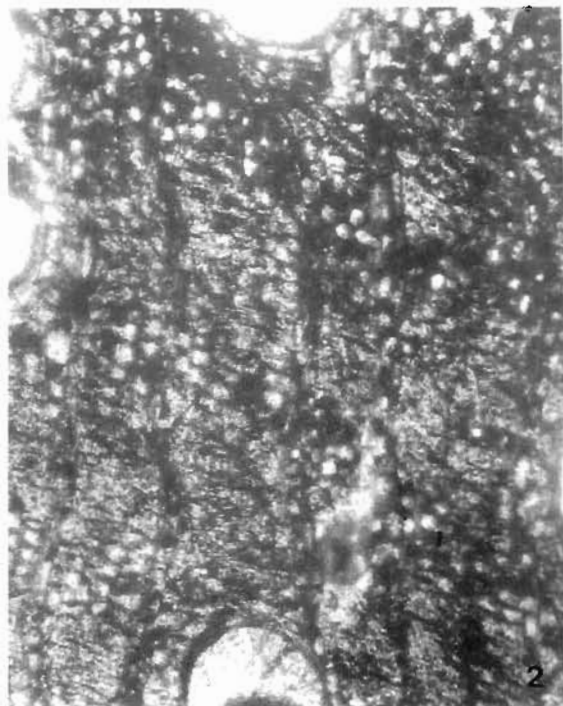
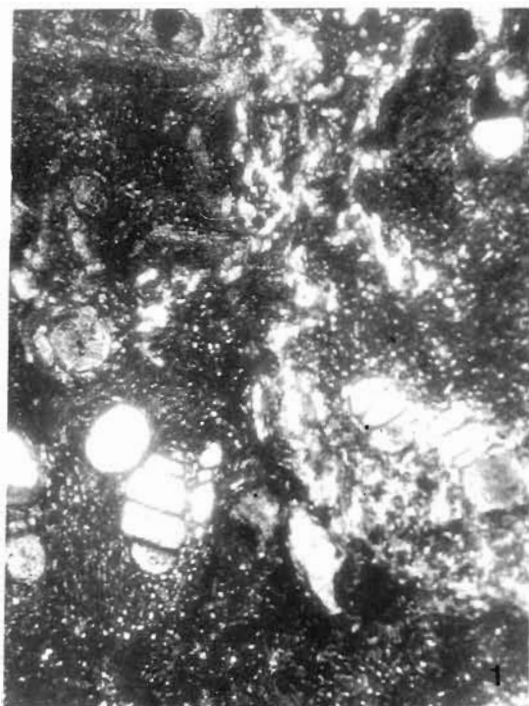


PLATE 1

signed to this fossil wood (Ramanujam & Rao, 1966). Trivedi and Panjwani instituted an organ genus *Baubinium* to include the fossil woods of *Baubinia* and described as *Baubinium miocenica* from the Siwalik beds of Kalagarh, Uttar Pradesh, India but it was published in 1986; while Prakash and Prasad inadvertently described a fossil wood under the genus *Baubinium*, after Trivedi and Panjwani, from the Siwalik beds of Kalagarh, Pauri Garhwal, Uttar Pradesh and it was published in 1984. Obviously it has the priority, so the credit of establishing the genus *Baubinium* goes to Prakash and Prasad (1984) and the same is retained herewith. Subsequently, Awasthi and Prakash (1987) described a fossil wood of *Baubinia* from the Namsang beds of Deomali, Arunachal Pradesh, India as *Baubinia deomalica*. Further in 1991, Agarwal also described a fossil wood under the same species *Baubinia deomalica* Awasthi & Prakash from Neyveli lignite, south India. Besides, a fossil wood resembling the extant genus *Baubinia* has also been reported from the Pliocene of Jaisalmer, Rajasthan (Guleria, 1986).

From the above account it is clear that two generic names, viz., *Baubinium* and *Baubinia* have been given to the fossil woods of *Baubinia*. This has happened because no uniform policy on nomenclature is being followed. This creates some kind of confusion in the mind of workers. In view of this it is suggested that a uniform policy should be followed. The present fossil wood has been compared with all the known fossil woods of *Baubinia* and found that the fossil wood—*Baubinium palaeomalabaricum* described by Prakash & Prasad (1984) from Kalagarh Siwalik, Uttar Pradesh as well as the present fossil wood both possess similar anatomical features and hence described under the same species *Baubinium palaeomalabaricum* Prakash & Prasad.

Baubinia malabarica Roxb., with which the fossil wood shows closest affinity, is a moderate-sized tree occurring from Ravi eastward to Assam through the Himalaya. It also grows in Bengal, the central

Provinces, Gujarat, Bihar and West Coast down to south India and in the mixed forests of Pegu Yama and south Myanmar (Pearson & Brown, 1932).

Family—Ebenaceae

Genus—*Ebenoxylon* Felix

Ebenoxylon miocenicum Prakash 1978

Pl. 2, figs 1-4

The fossil wood is a small piece of secondary wood measuring about 10 cm in length and 15 cm in diameter. The preservation is satisfactory.

Description—Wood diffuse porous. *Growth rings* indistinct. *Vessels* small to medium, t.d. 50-125 μm , r.d. 65-190 μm , solitary as well as radial multiples of 2-4, 8-14 per sq mm, plugged with dark contents (Pl. 2, figs 1, 2). Vessel members 220 μm in length with usually truncate to tailed ends, perforation simple; intervessel pits small to medium, 6-8 μm in diameter, bordered, alternate with linear to lenticular apertures. *Parenchyma* apotracheal, irregular, 1-2 (mostly 1) seriate, concentric tangential lines about 10-12 lines per sq mm, paratracheal parenchyma scanty, few cells associated with vessels (Pl. 2, fig. 2), parenchyma cells thin-walled, 15-18 μm in diameter, 45-60 μm in length. *Xylem rays* fine, 1-2, mostly uniseriate, 12-18 μm in width, 4-20 cells and 50-600 μm in height (Pl. 2, fig. 3), ray tissue heterogeneous, rays composed of both upright and procumbent cells, procumbent cells 18-25 μm in tangential height, 38-50 μm in radial length; upright cells 34-38 μm in tangential height and 25 μm in radial length, upright cells sometimes swollen and crystalliferous (Pl. 2, fig. 4). *Fibres* aligned in radial rows, semi-libriform, moderately thick-walled, non-septate, 10-14 μm in diameter and 690-980 μm in length.

Specimen—No. BSIP 37617.

Locality—Sukha River (about 4 km upstream), near Oodlabari, Darjeeling District, West Bengal.

PLATE 2

Ebenoxylon miocenicum Prakash 1978

1. Cross section in low power microscope showing vessel distribution and concentric lines of parenchyma X 40. Slide no. BSIP 37617/I.
2. Cross section magnified to show vessels and parenchyma distribution X 100. Slide no. BSIP 37617/II.
3. Tangential longitudinal section showing predominantly uniseriate xylem rays X 100. Slide no. BSIP 37617/III.
4. Radial longitudinal section showing heterocellular xylem rays X 100. Slide no. BSIP 37617/IV.

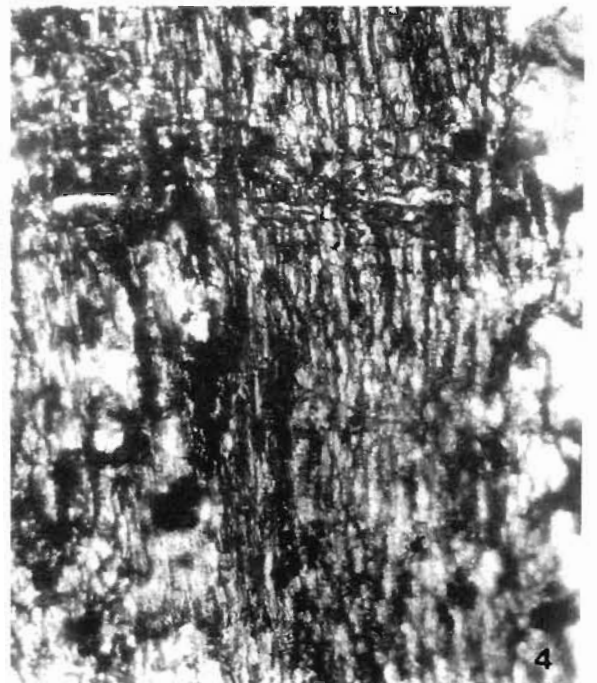
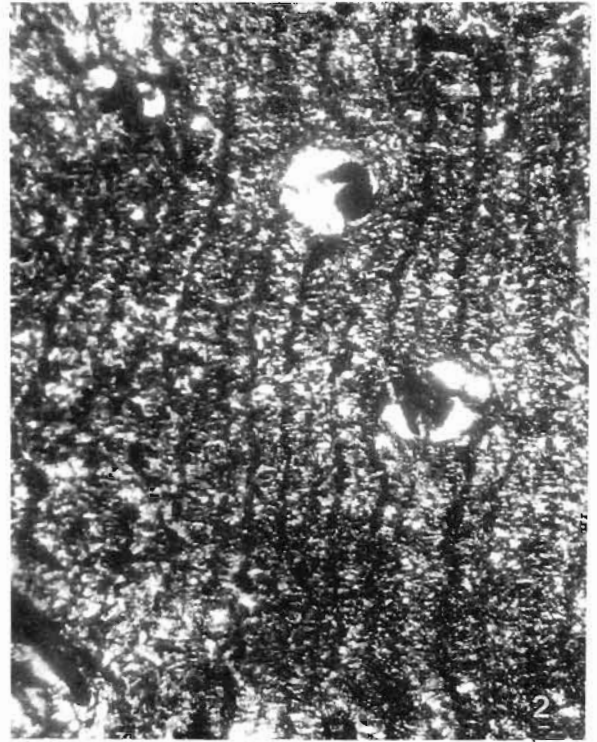
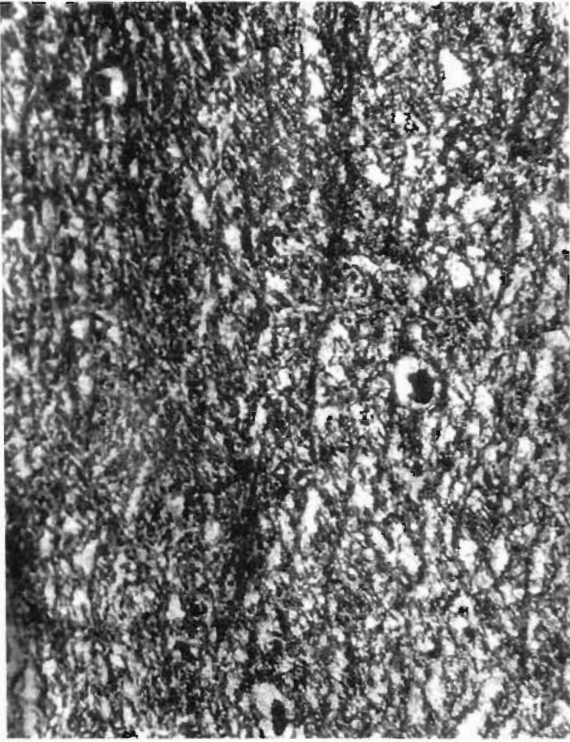


PLATE 2

Horizon—Middle Siwalik.

Affinities—The most characteristic features of the present fossil are apotracheal parenchyma in 1-2 seriate, concentric tangential lines and 1-2 seriate heterogeneous xylem rays. These features are found in the modern woods of the families Apocynaceae, Ebenaceae, Rubiaceae and Sapotaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950). The woods of the family Sapotaceae differ in possessing vasicentric tracheids which are absent in the present fossil. Similarly, woods of both the families Apocynaceae and Rubiaceae can be differentiated from the present fossil in having vested pit pairs and comparatively broader xylem rays. Thus the present fossil shows resemblance with the woods of family Ebenaceae. On comparing the fossil with the ebenaceous woods it was found that the fossil indicates close affinity in all its characters with the modern wood of *Diospyros* Linn. (= *Maba* Forst).

A critical examination of all available wood slides of the genera *Diospyros* and *Maba* together with the survey of available literature it was found that the present fossil wood has closest affinity with *Diospyros kurzii* Heim. (Kanehira, 1924, pp. 40-42, fig. 10; Lecomte, 1926, pl. 61; Pearson & Brown, 1932, pp. 693-697, 700-708, figs 224-225, 227-229; Chowdhury, 1945, pl. 29; Metcalfe & Chalk, 1950, pp. 883-885, fig. 204A, B, E, G, H; Henderson, 1953, pp. 24, figs 98 A, B, C, 99; Desch. 1957, pp. 150-157, pl. 46, fig. 1, table 25; Kribs, 1959, pp. 37, 38, figs 127, 129, 358; Normand, 1960, pls 143-145; Brazier & Franklin, 1961, pp. 34, 38, 39, fig. 359).

The fossil woods showing close resemblance with that of *Diospyros* and *Maba* are assigned to the form genus *Ebenoxylon* Felix 1882. So far, a number of fossil woods are known from the Tertiary sediments of India, which have already been listed by Prakash and Tripathi (1970, pp. 165; Awasthi & Panjwani, 1982, pp. 252, 253). Those which have not been included by them in the list are *Ebenoxylon deccanensis* Trivedi & Srivastava 1982 from the Deccan Intertrappean beds of Madhya Pradesh, *Ebenoxylon obliquiporosus* Awasthi & Ahuja 1982 from the Neogene of Varkala in Kerala Coast, south India, and *Ebenoxylon palaeocandoleana* Prasad 1993 from the Siwalik sediments of Kalagarh, Uttar Pradesh, India. Of these, four species, viz., *Ebenoxylon miocenicum* Prakash 1978, *E. siwalicus*

Prakash 1981, *E. kalagarbensis* Prasad 1988 and *E. candoleana* Prasad 1993 are known from the Siwalik sediments of India. On comparison of present fossil wood with the above known fossil woods from Siwalik sediments it has been found that *Ebenoxylon siwalicus* Prakash differs in having 1-3 seriate xylem rays as compared to 1-2 (mostly 1) seriate in the present fossil wood. *Ebenoxylon kalagarbensis* Prasad can be differentiated in possessing closely placed regular concentric parenchyma band and comparatively smaller vessels. However, *E. palaeocandoleana* can be distinguished from the present fossil wood in possessing spacely arranged parenchyma bands. Thus, *Ebenoxylon miocenicum* Prakash is the only known fossil wood with which the present fossil wood shows closest similarity in almost all anatomical characters like shape, size and distribution of vessels, nature and distribution of parenchyma and xylem rays. Therefore, the present fossil wood has been described under *Ebenoxylon miocenicum* Prakash 1978.

The modern equivalent taxon *Diospyros kurzii* Heim, with which the present fossil wood closely resembles, is an evergreen tree growing in tropical and moister upper mixed forests of the Andamans (Gamble, 1972).

It is significant to mention here that the leaf-impression of *Bauhinia* has earlier been reported from the same bed from where the present *in situ* fossil wood has been reported here (Antal & Awasthi, 1993). The fossil leaves belonging to the genus *Diospyros* are known from Ghish River which is about 6 km away from Sukha River locality. Thus the occurrence of leaf-impressions as well as fossil woods of these genera collectively indicates that they were present in the area during Siwalik sedimentation.

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