STUDIES ON SOME MORE CARBONISED WOODS FROM THE NEogene OF KERALA COAST, INDIA

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ABSTRACT

More carbonised woods from Varkala Cliff Section and Payangadi Clay Mine belonging to Warkalli beds (Miocene-Pliocene) have been investigated. These woods show close resemblance with the extant woods of *Leea, Gluta* and *Gonystylus* and have been named as *Leeoxylon cananaorense* sp. nov., *Glutoxylon hurmeense* (Hold.) Chowdhury, *Gonystyluxylon indicum* gen. et sp. nov. and *G. tertiarium* sp. nov. Almost all the modern taxa with which these carbonised woods show closest resemblance are confined to the tropical evergreen forests of Malayan and Indonesian archipelagoes.

Key-words — Xylotomy, Carbonised woods, *Leea, Gluta*, *Gonystylus* Miocene-Pliocene (India).

**Saraiya**

Keral tatt (भारत) के पश्च-पूर्वीय क्षेत्र से कुछ और कार्बनी काटों का प्रबन्धन — नीलाम्बर, भंसानी और मथुर वनबानी

वर्कली संस्त्री (मध्यपूर्व-पश्चिमी) से स्वाभाविक वाक्य विंश और दुर्गागढ़ी दृश्याक बार्ष में भी और एक भिन्न धातु काटों की एक श्रेणी में वर्णन किया गया है। ये काट भी, हरी और गोटवस्टोलस की वर्त-मान काटों से बनने वाली सतहों का द्वारा प्रस्तुत किया है तथा इन्हें मैक्रोक्रिस्टल जंगलों के कैटेगरी में वर्गीकृत, सुतुरास्तिमी वर्ने (होल्ट) चौकी, गोटवस्टोलस और इंडिक्यू मिलाकर तथा दृष्टि से नामांकित किया गया है। जिन वर्तमान वर्गों से ये कार्बनी काट समानता प्रदर्शित करते हैं वे सभी भारत, मथुर और इंडोनेशिया के प्राप्तव्यों के उपरीक्षित सदहरित बालों में पाये जाते हैं।

**INTRODUCTION**

I

N the Neogene of Kerala Coast the megaplant remains chiefly occur in the form of carbonised (lignitised) woods associated with lignites and carbonaceous clays. The associated lignites and carbonaceous clays have been considerably analysed by various workers (Vimal, 1953; Ramanujam, 1960, 1972; Ramanujam & Rao, 1973a, 1973b, 1977, 1978; Ramanujam & Srisailam, 1980; Ramanujam, Srisailam & Reddy, 1981; Rao & Ramanujam, 1975, 1976, 1978; Jain & Gupta, 1972; Jain & Kar, 1979; Kar & Jain, 1981) and reported the occurrence of fungal remains, spores and pollen contents mainly for stratigraphical correlations. However, keeping in view the great significance of plant megafossils in deciphering the palaeo-ecology and palaeo-phytogeography the present authors have initiated the systematic study of carbonised woods from the Neogene deposits of Kerala Coast. Awasthi and Ahuja (1982) reported six dicotyledonous woods, viz., Calophyllum, Dryobalanops, Swintonia, Cynometra, Terminalia, Diospyros and a lauraceous member having close resemblance with some of the species of Cinnamomum — Litsea and anatomically allied genera from the Varkala Coast. The material investigated here is a part of collection made from the Varkala Cliff Section and from the Payangadi Super Clay Mine in Cannanore District. The Payangadi Super Clay Mine is considered to be the extension of Warkalli beds.
SYSTEMATIC DESCRIPTION

FAMILY — AMPELIDACEAE

Genus — Leeoxylon Prakash & Dayal, 1964

Leeoxylon cannanorensis sp. nov.

Pl. 1, figs 1-6

Description — Wood diffuse-porous. Growth rings not observed. Vessels solitary and in radial multiples of 2-3 (Pl. 1, figs 1, 2), small to medium, round to oval, t.d. 96-160 μm, r.d. 114-192 μm, evenly distributed, 3-8 per sq mm; vessel-members 272-1,280 μm long with truncate to tailed ends; perforations simple; intervessel scalariform (Pl. 1, figs 5, 6); pits leading to parenchyma cells and rays opposite, large, usually with long axis placed horizontally; tyloses not seen. Parenchyma paratracheal, scanty, a few cells occurring round the vessels (Pl. 1, fig. 2). Rays broad (Pl. 1, fig. 4), up to 12-seriate and up to 225 μm wide, very high, mostly of indeterminate height, heterocellular, consisting of upright and square cells (Pl. 1, fig. 3); upright cells 40-80 μm in vertical length, 32-40 μm in radial length; square cells 32-40 μm in vertical and radial length; uniseriate rays rare, composed wholly of upright cells. Fibres aligned in radial rows in crosssection, semilibriform, moderately thick-walled and septate.

Affinities with modern woods — The salient features of the present fossil wood are small to medium vessels, scanty paratracheal parenchyma, broad, and very tall, multiserial rays with a few homocellular uniseriate rays and scalariform intervessel pitting. These may be considered as cogent features in bringing the present fossil wood closer to the genus Leeea Royen ex Linn. of the family Ampelidaceae (Hess, 1936; Dadswell & Record, 1936; Metcalfe & Chalk, 1950). Thin sections of the woods of seven species of Leeea, viz., L. sambucina Willd., L. philippinensis Merill, L. indica Merill, L. alata Edgew., L. brunoniana C. B. Clarke, L. angulata Korth, and the descriptions and illustrations of the woods of Leeea quinenzense Don. (Metcalfe & Chalk, 1950. p. 417, fig. 956), L. sundaica Miq., L. javanica Bl. (Moll & Janssonius, 1908, pp. 314, 315), L. gigantea Griff. (Desch, 1954, p. 5) were examined in order to find out the nearest living counterpart of the present fossil wood. This thorough task enabled us to put our fossil wood more close to Leeea angulata and L. philippinensis. The former shows similarity in the nature and distribution of vessels, parenchyma and fibres while the latter has similar xylem rays. But none of the above species of Leeea seems to be exactly identical to our fossil.

Affinities with fossil species — As the fossil shows closest resemblance with the modern wood of Leeea of the family Ampelidaceae, it has been placed under the genus Leeoxylon Prakash & Dayal (1964). So far only four fossil woods having close resemblance with Leeea are known. They are Leeoxylon multisieratum Prakash & Dayal (1964) from the Deccan Intertrappean beds of Mahurzari near Nagpur, India, Leeoxylon eoajaponicum (Watarai) Kramer (1974) (Leeea eoajaponica Watarai, 1951) from the Lower Miocene of Simane, Japan, Leeoxylon altiradiatum Kramer (1974) from the Tertiary of Java and Leeoxylon sp. Lemoigne (1978) from the Pliocene-Pleistocene of Omo Basin, Ethiopia. Our fossil though resembles these species in the nature and distribution of vessels, parenchyma, xylem rays and scalariform intervessel pitting, yet it can easily be differentiated in the size and frequency of vessels, height and width of xylem rays. In Leeoxylon multisieratum the vessels are relatively smaller in size, i.e. up to 120 μm in diameter and their frequency is 8-15 per sq mm; the xylem rays are up to 18 cells wide and 375-2775 μm high; whereas in the present fossil the vessels are less frequent, i.e. 3-8 per sq mm and relatively bigger, up to 192 μm in diameter and the xylem rays are up to 12 cells wide and extremely tall, so much so that the height of most of the rays is indeterminable. Leeoxylon eoajaponicum shows considerable differences from the present species particularly in the absence of uniseriate rays, presence of raphids in ray cells, relatively larger vessels and complete sheath of paratracheal parenchyma around the vessels. The broad xylem rays in Leeoxylon eoajaponicum are 2-10 (mostly 7-8) seriate and are still higher than in the present fossil. Lastly, Leeoxylon sp. Lemoigne also differs in having diffuse parenchyma. Therefore, the present fossil is named as Leeoxylon cannanorensis sp. nov.; the specific name is after Cannanore District.
Specific Diagnosis

Lecoxyylon canareense sp. nov.

Wood diffuse-porous. Growth rings not observed. Vessels solitary and in radial multiples of 2-3, small to medium, t.d. 96-160 μm, r.d. 144-192 μm; vessel-members 272-1280 μm long with truncate to tailed ends; perforations simple; intervessel pitting scalariform. Parenchyma scanty paratracheal, only a few cells associated with vessels. Rays 1-12 seriate, heterocellular, consisting of mostly upright and square cells, very tall; uniseriate rays occasionally present, homocellular, consisting of only upright cells. Fibres semilibiform and septate.

Holotype — B.S.I.P. Specimen no. 35529.
Locality — China Clay Mine, Payangadi, district Kannanore, Kerala.

Family — Thymelaeaceae

Genus — Gonystyloxyylon gen. nov.

Gonystyloxyylon indicum sp. nov.

Pl. 2, figs 7-11

Description — Wood diffuse-porous. Growth rings indistinct (Pl. 2, fig. 7) though at places narrow zones of relatively small-sized fibres indicate the annual growth marks. Vessels solitary and in radial multiples of 2-3, sometimes in tangential groups of 2-3, small to medium, somewhat angular in shape, t.d. 80-90 μm, r.d. 60-120 μm, 3-9 per sq mm; vessel-members short, up to 352 μm high with truncate or slightly tailed ends; perforations simple; intervessel pitting small, alternate, bordered (Pl. 2, fig. 9). Parenchyma abundant, paratracheal, forming 2-3 seriate, incomplete or mostly complete sheath around vessels, and frequently extending laterally across several rays forming fine tangential lines of usually 1-2 cells in width, sometimes aliform parenchyma bifurcating into fine lines (Pl. 2, fig. 7); lines about 4-5 per mm; parenchyma cells 20-42 μm in tangential diameter and up to 16 μm in radial diameter. Rays predominantly uniseriate (Pl. 2, fig. 8), occasionally biseriate due to pairing of procumbent cells through the median port
phyllus, although no where in the literature there is any report about the presence of the intraxillary phloem in this genus. So this character seems to be a variable one and it is a matter of opinion whether Gonystylus be treated in a distinct family or be retained in Thymelaeaceae.

The fossil wood was also compared with the published literature of G. bicanus Gilg and G. miquelianus Teijem et Binn. (Metcalfe & Chalk, 1950, pp. 1178-1181, fig. 283A-B), G. warburgianus Gilg (Desh. 1954, pp. 208, 209). G. macrophyllus (Miq.) Airy Shaw [(syn. G. bicanus (Miq.) Kurz], Miles, 1978, p. 66) and it was found that the fossil wood resembles all the above mentioned species in the distribution pattern of vessels, parenchyma, fibres and rays. However, it differs in having smaller vessels. Besides, the fossil can be further differentiated from G. macrophyllus in the absence of intraxillary phloem.

Since the fossil woods shows resemblance with the woods of Gonystylus, it is placed under a new genus Gonystyloxyton, instituted to include all the fossil woods having close similarity with the woods of Gonystylus of the family Thymelaeaceae. It is specifically named as Gonystyloxyton indicum sp. nov.

With regard to other fossil records of Thymelaeaceae, Ramanujam (1966) recovered the pollen grains of this family from the Neyveli Lignite and placed them under the artificial genus Olavitissiporites and named C. jacobi. He has shown their affinities with the pollen grains of Wikstroemia. This also confirms that the family Thymelaeaceae had existed in South India in the geological past.

**DIAGNOSIS**

**Gonystyloxyton** gen. nov.

Wood diffuse-porous. Growth rings present or absent. Vessels small to medium, solitary and in radial multiples of 2-4 or more, cells sometimes in double rows, vessel-members usually short in height; perforations simple; intervessel pitting alternate, small to medium, bordered. Parenchyma abundant, paratracheal, forming 2-3 seriate complete or incomplete sheath around the vessels, often extending tangentially forming narrow lines. Rays 1-2 seriate, almost homogeneous to weakly heterogeneous; crystals present in ray cells. Fibres non libriform, non-septate with simple or bordered pits on radial and tangential walls. Included phloem present or absent.

**Genotype —** Gonystyloxyton indicum sp. nov.

**Gonystyloxyton indicum** sp. nov.

Wood diffuse-porous. Growth rings indistinct. Vessels solitary and also in radial multiples of 2-3, small to medium, t.d. 80-100 μm, r.d. 60-120 μm, somewhat angular in shape; vessel-members up to 352 μm long with truncate or slightly tailed ends; perforations simple; intervessel pitting alternate, small, 4-6 μm, bordered. Parenchyma abundant, paratracheal, forming 2-3 seriate complete or incomplete sheath around vessels and extending laterally across several rays forming fine tangential lines of 2-4 cells in thickness, about 4-5 lines per mm. Rays predominantly uniseriate, occasionally biseri et, homogeneous to weakly heterogeneous, 5-17 (88-640 μm) cells high, 16-32 μm wide, about 10-12 per mm; solitary crystal sometimes present in ray cells. Fibres aligned in radial rows, hexagonal to elongated, t.d. up to 36 μm, r.d. 32-60 μm, bigger than parenchyma cells, thin-walled with numerous simple as well as bordered pits on both radial and tangential walls, non libriform, non-septate. Included phloem absent.

**Holotype —** B.S.I.P. no. 35530.

**Locality —** Varkala Cliff Section, Varkala, Kerala.

**Gonystyloxyton tertiarius** sp. nov.

Pl. 2, figs 13, 15, 16; Pl. 3, figs 17, 19, 21

**Description —** Wood diffuse-porous. Growth rings present, delimited by narrow zone of thick-walled fibres (Pl. 2, fig. 12). Vessels solitary and also in radial multiples of 2-4 as well as in double rows (Pl. 2, fig. 12), occasionally in clusters of small vessels, almost uniformly distributed, circular to oval, t.d. 40-160 μm, r.d. 50-160 μm, small to medium, 3-13 per sq mm; vessel-members 180-600 μm long with truncate to slightly inclined ends; intervessel pitting alternate, small or minute, bordered, crowded, pits 4-5 μm in diameter with circular to lenticular aperture (Pl. 2, fig. 15). Parenchyma
paratracheal, completely enclosing vessels and extending laterally forming 1-2 seriate fine lines (Pl. 2, figs 12, 13; Pl. 3, fig. 17), about 8 lines per mm; parenchyma cells oval to elongated, 16-32 µm in diameter, those occurring around vessels peripherally flattened. Rays very fine, uniseriate to rarely biseriate (Pl. 3, fig. 19), 12-18 per mm in cross-section, 4-24 cells high; ray tissue homogeneous to weakly heterogoneous (Pl. 3, fig. 21), consisting of procumbent cells, sometimes with one squarish cell; vertical height of procumbent cells 20-32 µm, radial length 40-80 µm; vertical height of squarish cells 48-52 µm, radial length 36-40 µm; crystals present in almost all the cells (Pl. 3, fig. 21). Fibres aligned in radial rows, circular to oval in cross section, about 8-30 µm in diameter, moderately thick-walled, thicker and narrower towards the close of the ring (Pl. 2, fig. 12), nonlibriform, with numerous bordered pits on the radial as well as tangential walls (Pl. 2, fig. 16). Included phloem present, thin-walled, cells irregular in shape and size. These anatomical features of the fossil wood are more or less similar as shown by the previous fossil and hence it is also being placed under the genus Gonystyloxyon.

On the basis of the studies of modern species of Gonystylus, it was found that the present fossil closely resembles G. macrophylalus in having intraxylary phloem which is absent in Gonystyloxyon indicum. However, in almost all other characters, such as distribution of vessels, parenchyma lines, rays, crystals, thickness of fibres the fossil wood is more closer to Gonystylus sp. (B.S.I.P. slide no. 1472).

The present fossil wood differs from Gonystyloxyon indicum in having interxylary phloem, relatively bigger vessels and greater frequency of xylem rays and presence of crystals in almost all ray cells. Hence it is being described here as Gonystyloxyon tertiaearum sp. nov.

**SPECIFIC DIAGNOSIS**

Gonystyloxyon tertiaearum sp. nov.

**Wood** diffuse-porous. **Growth rings** present. **Vessels** solitary and also in radial multiples of 2-4, as well as in double rows, circular to oval, t.d. 40-160 µm, r.d. 50-150 µm, small to medium, 3-13 per sq mm, vessel-members 180-600 µm long with truncate to slightly tail.d ends, intervessel pitting alternate, minute, bordered, pits 4-5 µm in diameter with circular to lenticular aperture. **Parenchyma** paratracheal completely enclosing the vessels and extending laterally forming 1-2 seriate lines, about 8 lines per mm. **Rays** uniseriate or rarely biseriate; ray tissue homogeneous to weakly heterogeneous, solitary crystals frequent in ray cells. Fibres circular to oval in cross section, moderately thick-walled, thicker and narrower towards the close of the ring, nonlibriform with numerous bordered pits on the radial walls. **Included phloem** present, thin-walled, cells irregular in shape and size.

**Holotype** — B.S.I.P. specimen no. 35531.
**Locality** — China Clay Mine, Payangadi, Cannanore District, Kerala.

**FAMILY** — ANACARDIACEAE

**Genus** — Glutoxyon Chowdhury, 1934

**Glutoxyon burmense** (Hold.) Chowdhury, 1952

Pl. 3, figs 23, 24

**Description** — Wood diffuse porous. **Growth rings** not seen. **Vessels** small to large in size, t.d. 80-160 µm, r.d. 144-240 µm, oval in shape, solitary and also in radial multiples of 2-5 (mostly 2-3), 2-8 per sq mm, heavily tylosed (Pl. 3, fig. 23); perforations simple; intervessel pits bordered, large, alternate, orbicular with lenticular aperture. **Parenchyma** both paratracheal and apotracheal; paratracheal parenchyma scanty; apotracheal in the form of 2-4 (rarely up to 5) cells wide incomplete bands (Pl. 3, fig. 23), 2-4 per mm. **Xylem rays** simple and fusiform (Pl. 3, fig. 24), simple rays fine, 1-2 (mostly 1) s:riate, homocellular, consisting of procumbent cells, up to 11 cells in height; fusiform rays 2-5 seriate with single radial gum duct in the centre (Pl. 3, fig. 24), homocellular, consisting of procumbent cells; gum ducts lined with single row of epithelial cells; rays 8-10 per mm. Fibres semilibriform, non-septate, thick-walled.

**Affinitiies** — In all its anatomical features the present carbonised wood shows closest resemblance with the woods of Gluta, and
hence placed under the genus *Glutoxylon* Chowdhury, 1934. This genus was created by Chowdhury (1934) for the fossil woods of *Gluta* and those melanorrhoeas which have thin apotracheal parenchyma lines or bands. Since then a large number of fossil woods have been described by several workers from various Neogene deposits of India and Burma and all of them have been placed under this fossil genus. However, to accommodate those fossils having broad parenchyma lines or bands as seen in a few species of *Melanorrhoea*, Prakash and Tripathi (1969) proposed a new genus *Melanorrhoeoxyylon*. Ghosh and Roy (1980) described a fossil wood under this genus as *Melanorrhoeoxyylon garbetaense* from the Tertiary of West Bengal.

Recently Ding Hou (1978), who made taxonomic study of the Malesian Anacardiaceae, has merged all the species of *Melanorrhoea* to the genus *Gluta*. As a consequence the genus *Melanorrhoeoxyylon* Prakash & Tripathi becomes superfluous and hence merged with *Glutoxylon* (Hold.) Chowdhury. Among the fossil woods referred to the genus *Glutoxylon* our carbonised wood shows the structural details similar to *Glutoxylon burmense* (Hold.) Chowdhury. It is, therefore, placed under the same species.

*Specimen* — B.S.I.P. specimen no. 35532.

**DISCUSSION**

The carbonised woods identified as *Leea, Gonystylus* and *Gluta* are quite significant from the ecological and phytogeographical point of view. The genus *Leea* Royen ex L. consists of 70 species of climbers, climbing shrubs or small trees, distributed in palaeotropical regions (Willis, 1973, p. 643). In India, the species of *Leea* are generally found in the under-growth of the forest and one or two also in open grasslands like *Leea macrophylla* Roxb. and *L. alata* Edgew. Among the forest ones *L.aspera* Wall. is very common in deciduous forest all over India. *Leea crispa* Willd. and *L. sambucina* Willd. are common in the Darjeeling Terai. *Leea umbraculifera* C. B. Clarke and *L. robusta* Roxb. are found in the forests of the Sikkim-Himalaya, Terai up to 1,000 m in the undergrowth forests, and also in North Kanara, West coast (Gamble, 1972, p. 191). Of the species comparable to the present carbonised wood, *Leea angulata* is distributed in the evergreen forests of Malay peninsula, while *L. philippinensis* is known to occur in similar forest of Philippines.

The other genus *Gluta* consists of about 30 species as a consequence of the reduction of *Melanorrhoea* to *Gluta*. It is distributed in Madagascar, India, Burma, Thailand, Indochina, China and throughout Malaysia (Ding Hou, 1978). In India this genus is represented by *Gluta travancorica*, occurring in dense moist forests on the hills of Travancore and Tinnevelly. The genus *Gonystylus* which is totally absent from the Indian subcontinent, consists of about 30 species (Willis, 1973) confined to the evergreen forests of Malayan and Indonesian archipelagoes.

Since the modern equivalents of the present fossil woods are the important elements of the tropical evergreen forests, it is thus envisaged that somewhat similar climatic conditions prevailed during Neogene times all along the Kerala Coast.

**REFERENCES**


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**EXPLANATION OF PLATES**

**PLATE 1**

*Leeoxylon kannanorensis* sp. nov.

1. Cross section showing gross features. × 40; B.S.I.P. slide no. 7016.
2. Cross section at higher magnification showing vessels and scanty paratrachel parenchyma. × 100; B.S.I.P. slide no. 7016.
3. Radial longitudinal section showing heterocellular xylem rays made up of upright and square cells. × 100; B.S.I.P. slide no. 7017.
4. Tangential longitudinal section showing broad rays of indeterminate height. × 100; B.S.I.P. slide no. 7018.
5. Tangential longitudinal section showing scalariform intervessel pitting. × 100; B.S.I.P. slide no. 7018.

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**PLATE 2**

*Gonystyloxylon indicum* gen. et sp. nov.

1. Cross section showing shape, size and distribution of vessels, parenchyma and fibres. × 40; B.S.I.P. slide no. 7020.
2. Tangential longitudinal section showing homocellular to weakly heterocellular xylem rays. × 100; B.S.I.P. slide no. 7021.
3. Tangential longitudinal section showing intervessel pits. × 400; B.S.I.P. slide no. 7021.
4. Radial longitudinal section showing crystals in ray cells. × 400; B.S.I.P. slide no. 7022.
11. Bordered pits on the radial walls of fibres. × 400; B.S.I.P. slide no. 7022.

Gonystlyoxylon tertiarum sp. nov.

12. Cross section showing growth rings and distribution of vessels and parenchyma. × 100; B.S.I.P. slide no. 7023.

13. Cross section showing nature and distribution of vessels, parenchyma and fibres. × 40; B.S.I.P. slide no. 7023.

Gonystylus sp.

14. Cross section showing similar type and distribution of vessels and parenchyma as in fossil. × 40.

15. Gonystlyoxylon tertiarum sp. nov. showing intervessel pitting. × 400; B.S.I.P. slide no. 7024.

16. G. tertiarum sp. nov. showing fibre pits. × 400; B.S.I.P. slide no. 7025.

PLATE 3

17. Gonystlyoxylon tertiarum sp. nov.: Cross section showing vessels, parenchyma and included phloem. × 40; B.S.I.P. slide no. 7023.

18. Gonystylus macrophyllus: Cross section showing similar included (interxylary) phloem, vessels and parenchyma. × 40.

19. Gonystlyoxylon tertiarum sp. nov.: Tangential longitudinal section showing homocellular to weakly heterocellular xylem rays. × 100; B.S.I.P. slide no. 7024.

20. Gonystylus sp.: Tangential longitudinal section showing similar type of rays. × 100.

21. Gonystlyoxylon tertiarum sp. nov.: Radial longitudinal section showing ray cells with crystals. × 100; B.S.I.P. slide no. 7025.

22. Gonystylus sp.: Radial longitudinal section showing similar type of ray cells with crystals as in fossil. × 100.

Gluoxylon burmense (Hold.) Chowdhury

23. Cross section showing distribution of vessels (with tyloses) and apotracheal parenchyma (dark bands or lines). × 40; B.S.I.P. slide no. 7026.

24. Tangential longitudinal section showing simple uniseriate xylem rays and a fusiform ray with gum canal. × 120; B.S.I.P. slide no. 7027.
Plate 2