Status of gymnosperms in the Indian Tertiary flora

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Gymnosperms, the most dominant group of plants during Mesozoic, were meagrely represented in the Indian Tertiary flora. The Tertiary gymnosperms occur in the form of petrified woods, cones and leaf-impressions, besides pollen, referable to the families Podocarpaceae, Araucariaceae and Cycadaceae. Until Late Cretaceous-Early Palaeocene the gymnosperms were widely distributed in the Indian peninsula. However, during Tertiary they declined to such an extent that towards the close of Pliocene Araucariaceae totally disappeared from the Indian subcontinent. The Podocarpaceae too, is now on the verge of extinction as it occurs in the restricted areas in northeast India and Nilgiri Hills in southern India. The causes of decline of these tropical gymnosperms and advent of the northern temperate members in the Indian subcontinent during Tertiary are discussed.

Key-words — Palaeobotany, Gymnosperms, Tertiary (India).

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सारांश

भारतीय तृतीयक युगीन वनस्पतिजात में अनावृतबीजीयों की स्थिति

राकेश चन्द्र मेहरोत्रा एवं नीलाम्बर अवस्थी

अनावृतबीजी पौधे, जो कि मध्यजीवी कल्प में सबसे अधिक प्रभावी पौधों का समूह था, भारतीय तृतीयक युगीन वनस्पतिजात में संख्या में बहुत कम थे। परागकणों के अतिरिक्त, तृतीयक कल्प में अनावृतबीजी पौधे अश्मीभूत काष्ठों, कोनों एवं पर्ण-छापों के रूप में मिलते हैं। ये सभी अश्मित अवयव पोडोकार्पेसी, अराकेरिएसी एवं साइकेडेसी नामक कुलों से सम्बद्ध हैं। तथापि, तृतीयक कल्प में इनकी संख्या इतनी कम हो गई थी कि अतिनूतन कल्प की समाप्ति तक अराकेरिएसी कुल भारतीय महाद्वीप से पूर्णतः विलुप्त हो गया था। पोडोकार्पेसी कुल भी अब लगभग विलुप्त ही होने वाला है क्योंकि इस कुल के प्रतिनिधि अब उत्तरी भारत के कुछ स्थानों तथा दक्षिणी भारत में नीलगिरि पहाड़ियों में ही पाये जाते हैं। इस शोध-पत्र में तृतीयक कल्प में भारतीय उपमहाद्वीप में उत्तरी शीतोष्ण सदस्यों के प्रादुर्भाव एवं उष्णकटिबन्धीय अनावृतबीजीयों के ह्रास के कारणों की विवेचना की गई है।

GYMNOSPERMS were dominant during Palaeozoic and Mesozoic times. The Lower Gondwana period was dominated by *Glossopteris* and its allies. The Middle Gondwana was dominated by *Dicroidium* which was associated with some Lower Gondwana elements in the early part of Triassic. During its middle and upper parts it was associated with Ginkgoales, Bennettitales, Cycadales and Coniferales. The Upper Gondwana Period is said to be the best period for Indian gymnosperms, when the flora was dominated by diverse members of Ginkgoales, Pentoxylales, Cycadales, Bennettitales, Coniferales and Taxales and seemingly had covered extensive areas in the Peninsular India.

During the early part of the Post Gondwana, probably during Middle to Late Cretaceous, the gymnosperms as a group suffered a drastic decline both numerically and geographically from which they never recovered to regain their former pristine position (Ramanujam, 1976). There are only a few reports of gymnospermous remains from the Late Cretaceous of Trichinopoly area of Tamil Nadu (Aiyengar & Jacob, 1952; Varma, 1955). The paper is mainly aimed to bring together all the unequivocal megafossil records of gymnosperms known from various Tertiary localities of India (see Map 1).

TERTIARY GYMNOSPERMS

Gymnosperms, occupying a subordinate posi-

tion in the Indian Tertiary flora, were represented by Cycadales and Coniferales (see Table 1).

Cycadales

There is a solitary record of fossil cycad. Paradkar (1976) described a petrified ovule as *Gymnovulites deccanii* from the Deccan Intertrappean beds (Early Tertiary) of Mohgaonkalan showing resemblance with the ovules of *Cycas*. The ovule is characterized by narrow curved neck, a flask-shaped lower part and two layered integuments.

Coniferales

The Coniferales were represented by the members of Podocarpaceae, Araucariaceae, Pinaceae and Cupressaceae.

Podocarpaceae

The fossils of Podocarpaceae comprise leaf, ovule and woods. There is only one record of fossil leaf of *Podocarpus* — *P. oligocenicus* described by Awasthi *et al.* (1992) from the Oligocene of Makum Coalfield near Ledo, Assam. Among modern species of *Podocarpus* the fossil leaf is very similar to that of *Podocarpus neriifolius* D. Don.

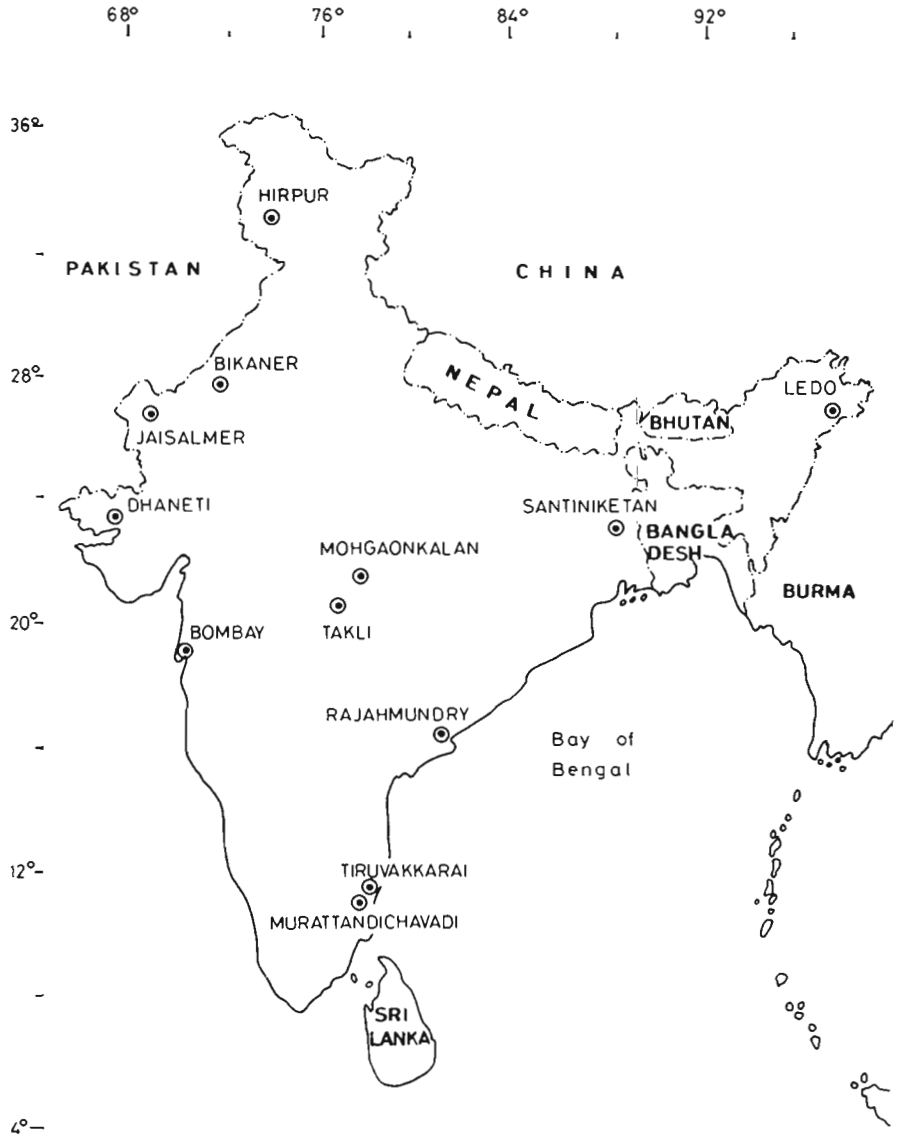
The only fossil ovule, *Podocarpoovulites chitaleyi* Sheikh & Kolhe 1982 of the family Podocarpaceae was described from the Deccan Intertrappean beds of Nagpur. The woods of this family commonly occur in the Indian Tertiary sediments. They have been described under the genus *Podocarpoxylon* or *Mesembrioxylon* from the Deccan Intertrappean beds (Mahabale & Rao, 1973; Lakhanpal *et al.*, 1975; Bande & Prakash, 1984; Trivedi & Srivastava, 1989), Mio-Pliocene of Cuddalore Sandstones (Kräusel, 1949; Ramanujam, 1953, 1954; Agashe, 1969; Trivedi & Srivastava, 1989), ? Oligo-Miocene of Rajahmundry area (Mahabale & Satyanarayana, 1978) and Neogene of Kachchh (Lakhanpal *et al.*, 1975) and Rajasthan (Guleria, 1986). Gothan (1905) instituted the genus *Podocarpoxylon* for the fossil woods of *Podocarpus* and *Dacrydium*, while Seward (1919) instituted another genus *Mesembrioxylon* saying that the use of

Table 1—List of gymnosperm megafossils from the Tertiary of India

Taxa	Modern comparable form	Formation, Locality & Age	Reference
Cycadales			
Gymnovulites deccanii Paradkar	Cycadaceae	Deccan Intertrappean beds of Mohgaon Kalan; Early Tertiary	Paradkar, 1976
Coniferales			
Taxodioxylon cuddalorense Ramanujam	?Taxodiaceae	Cuddalore Series of Tiruvakkarai; Mio-Pliocene	Ramanujam, 1960, 1976
Cupressus sp. cf. *C. torulosa*	Cupressaceae	Lower Karewa beds of Hirpur; Mio-Upper Pliocene	Awasthi & Guleria, 1982
Mesembrioxylon fusiforme Sahni	Podocarpaceae	Deccan Intertrappeans of Rajahmundry; Early Tertiary	Mahabale & Rao, 1973
M. dudukurense Mahabale & Rao	Podocarpaceae	Deccan Intertrappeans of Rajahmundry; Early Tertiary	Mahabale & Rao, 1973
M. rajmahalense Jain	Podocarpaceae	Rajahmundry area; ?Oligo-Miocene	Mahabale & Satyanarayana, 1978
Mesembrioxylon sp. cf. *M. dudukurense* Mahabale & Rao	Podocarpaceae	Rajahmundry area; ?Oligo-Miocene	Mahabale & Satyanarayana, 1978
Podocarpoxylon vikramii Bande & Prakash	Podocarpaceae	Deccan Intertrappeans of Bombay; Early Tertiary	Bande & Prakash, 1984
P. deccanensis Trivedi & Srivastava	Podocarpaceae	Deccan Intertrappean beds of Mohgaon Kalan; Early Tertiary	Trivedi & Srivastava, 1989
P. kutchensis Lakhanpal *et al.*	Podocarpaceae	Kankawati Series of Dhaneti (Kutch); Pliocene	Lakhanpal *et al.*, 1975

Contd.

Podocarpus	Podocarpaceae	Shumar Formation of Jaisalmer, Rajasthan; Miocene	Guleria, 1986
Podocarpoxylon schmidianum (Sahni) Kräusel Syn. *M. schmidianum* Sahni	Podocarpaceae	Cuddalore Series of Tiruvakkarai; Mio-Pliocene	Kräusel, 1949
P. tiruvakkarainum (Ramanujam) Trivedi & Srivastava Syn. *M. tiruvakkarainum* Ramanujam	Podocarpaceae	Cuddalore Series of Tiruvakkarai; Mio-Pliocene	Trivedi & Srivastava, 1989
P. sahnii (Ramanujam) Trivedi & Srivastava Syn. *M. Sahnii* Ramanujam	Podocarpaceae	Cuddalore Series of Tiruvakkarai; Mio-Pliocene	Trivedi & Srivastava, 1989
P. speciosum (Ramanujam) Trivedi & Srivastava Syn. *M. speciosum* Ramanujam	Podocarpaceae	Cuddalore Series of Murattandichavadi; Mio-Pliocene	Trivedi & Srivastava, 1989
P. mahabalei (Agashe) Trivedi & Srivastava Syn. *M. mahabalei* Agashe	Podocarpaceae	Cuddalore Series of Tiruvakkarai; Mio-Pliocene	Trivedi & Srivastava, 1989
Podocarpoovulites chitaleyi Sheikh & Kolhe	Podocarpaceae	Deccan Intertrappean beds of Nagpur; Early Tertiary	Sheikh & Kolhe, 1982
Podocarpus oligocenicus Awasthi *et al.*	*Podocarpus*	Makum Coalfield near Ledo Assam; Oligocene	Awasthi *et al.* 1992
Araucarioxylon deccani (Shukla) Trivedi & Srivastava Syn. *Dadoxylon deccani* Shukla	*Araucaria-Agathis*	Deccan Intertrappeans; Early Tertiary	Trivedi & Srivastava, 1989
A. resinosum (Shukla) Trivedi & Srivastava Syn. *D. resinosum* Shukla	*Araucaria-Agathis*	Deccan Intertrappeans; Early Tertiary	Trivedi & Srivastava, 1989
A. eocenum (Chitaley) Trivedi & Srivastava Syn. *D. eocenum* Chitaley	*Araucaria-Agathis*	Deccan Intertrappeans of Mohgaonkalan; Early Tertiary	Trivedi & Srivastava, 1989
A. Chhindwarensis (Billimoria) Trivedi & Srivastava Syn. *D. chhindwarensis* Billimoria	*Araucaria-Agathis*	Deccan Intertrappeans of Mohgaonkalan; Early Tertiary	Trivedi & Srivastava, 1989
A. shuklae (Singhai) Trivedi & Srivastava Syn. *D. shuklae* Singhai	*Araucaria-Agathis*	Deccan Intertrappeans of Mohgaonkalan; Early Tertiary	Trivedi & Srivastava, 1989
A. keriense Trivedi & Srivastava	*Araucaria- Agathis*	Deccan Intertrappean beds of Keria; Early Tertiary	Trivedi & Srivastava, 1989
A. mohgaoensis Lakhanpal *et al.*	*Araucaria- Agathis*	Deccan Intertrappean beds of Mohgaonkalan; Early Tertiary	Lakhanpal *et al.*, 1977
A. bikanerense Harsh & Sharma	*Araucaria-Agathis*	Mar Formation of Bikaner, Rajasthan; Pliocene	Harsh & Sharma, 1988
Araucarioxylon sp. Srivastava & Prakash	*Araucaria- Agathis*	Shantiniketan near Bolpur, West Bengal; Miocene	Srivastava & Prakash, 1984
Araucaria - Agathis	*Araucaria-Agathis*	Shumar Formation of Jaisalmer, Rajasthan; Pliocene	Guleria, 1986
Dadoxylon sp. cf. *D. harakarense* Surange & Saxena	*Araucaria-Agathis*	Rajahmundry area; ? Oligo-Miocene	Mahabale & Satyanarayana, 1978
Dadoxylon sp. cf. *D. jamudhiense* Maheshwari	*Araucaria-Agathis*	Rajahmundry area; ? Oligo-Miocene	Mahabale & Satyanarayana, 1978
Mohgaostrobus sahnii Prakash	Araucariaceae	Deccan Intertrappeans of Mohgaonkalan; Early Tertiary	Prakash, 1957 1962
Indostrobus bifidolepis Sahni	Araucariaceae	Deccan Intertrappean beds; Early Tertiary	Sahni, 1931
Takliostrobus alatus Sahni	Araucariaceae	Deccan Intertrappean beds of Takli; Early Tertiary	Sahni, 1931
Pityostrobus crassitesta Sahni	Araucariaceae	Deccan Intertrappean beds of Takli; Early Tertiary	Sahni, 1931
Harrisostrobus intertrappea Chitaley & Sheikh	Araucariaceae	Deccan Intertrappeans of Mohgaonkalan; Early Tertiary	Chitaley & Sheikh, 1973
Pinus wallichiana	*Pinus*	Lower Karewa beds of Hirpur; Mid- Upper Pliocene	Awasthi & Guleria, 1982
Abies sp. cf. *A. pindrow*	*Abies*	Lower Karewa beds of Hirpur; Mid- Upper Pliocene	Awasthi & Guleria, 1982



Map — Showing distribution of gymnosperms in India during Tertiary.

Gothan's name implied affinities to recent genera for which there were no adequate reasons. Further, Bose and Maheshwari (1974) pointed out that since *Podocarpoxylon* of Gothan is a validly and legitimately published name, it is inadvisable to replace it by *Mesembrioxylon*. Therefore, recently Trivedi and Srivastava (1989) transferred the Indian species of *Mesembrioxylon* to *Podocarpoxylon* excepting a few which probably they forgot to do so. Podocarpaceous woods are generally characterized by growth rings, wood parenchyma mostly without resin contents, predominantly uniseriate xylem rays, number of cross-field pits 1-2 with apertures vertical or oblique, radial pits bordered and 1-2 seriate, opposite and rounded.

Araucariaceae

In the Indian Tertiary rocks the remains of Araucariaceae consist of woods and cones. The woods are described as *Araucarioxylon* Kraus or *Dadoxylon* Endlicher (Table 1) from the Deccan In-

tertrappeans (Lakhanpal *et al.*, 1977; Trivedi & Srivastava, 1989), Neogene of Rajasthan (Guleria, 1986; Harsh & Sharma, 1988), West Bengal (Srivastava & Prakash, 1984) and Rajahmundry area (Mahabale & Satyanarayana, 1978). The important features of these woods are the presence of growth rings, 1-2 seriate xylem rays, absence of resin canals, bar of Sanio and xylem parenchyma, cross-field pits 1-10, radial pitting 1-3 or 4 seriate, bordered, alternate and hexagonal. For a long time all the fossil woods having such characters from Palaeozoic were assigned to *Dadoxylon*, while those from the younger formations were placed under *Araucarioxylon*, because the former were thought to belong to Cordaitales and the latter to Araucariaceae. According to Potonié (1902) and Gothan (1905) the name *Dadoxylon* should be used for the secondary wood with araucaroid type of tracheidal pitting irrespective of the age of fossil woods. Lepekhina (1972) has given a classification of fossil woods with araucaroid pitting. According to her there is no difference in the secondary wood of *Araucarioxylon* and *Dadoxylon*. *Dadoxylon* shows endarch primary xylem and rather large non-septate pith without secretory canals, while *Araucarioxylon* is based on secondary wood only. On this basis Trivedi and Srivastava (1989) transferred some of the species of *Dadoxylon* to *Araucarioxylon*.

The fossil comparable to that of *Araucaria* of Araucariaceae is represented by *Mohgaostrobus sahnii* Prakash 1957, 1962, described from the Deccan Intertrappean beds of Mohgaonkalan.

Pinaceae and Cupressaceae

There are no fossil record of Pinaceae and Cupressaceae from any Tertiary sediments of peninsular India. However, from extra-peninsular India Awasthi and Guleria (1982) have reported the woods of *Pinus*, *Cupressus* and *Abies* from the Lower Karewa beds (Upper Pliocene) of Kashmir.

Gymnosperms of uncertain affinities

Besides, there are cones of uncertain affinities described from the Deccan Intertrappean beds. These are *Indostrobus bifidolepis, Takliostrobus alatus, Pityostrobus crassitesta* (Sahni, 1931) and *Harrisostrobus intertrappea* (Chitaley & Sheikh, 1973). *Indostrobus* is characterized by distinct bract and ovuliferous scale bearing a pair of inverted ovules at a distance from the cone axis. The locality from where it was collected is not known. *Takliostrobus* and *Pityostrobus* have been reported from Takli near Nagpur. In the former, the bract is fused with the expanded ovuliferous scale along the midline but laterally free and each ovuliferous scale has two ovules. The latter possesses double cone scales and cylindrical ovules with extremely thick integument, the greater part of which is sclerotesta. *Harrisostrobus* is another cone described from the Mohgaonkalan chert of the Deccan Intertrappean beds. The unique character of this cone is the presence of six ovuliferous scales per bract scale, one attached on bract scale and the rest on cone axis. The cone is compact, not woody and bears protecting scales and two ovules per ovuliferous scale. The affinities of all these cones with those of the extant conifers are not definitely known.

In addition, a wood of Taxodiaceae, *Taxodioxylon cuddalorense*, was described by Ramanujam (1960) from Cuddalore Sandstones. But the author (1976) later on was doubtful about its affinities with Taxodiaceae.

DISTRIBUTION OF MODERN GYMNOSPERMS IN INDIA

Gymnosperms occupy extensive tracts all along the subtropical and temperate areas of Himalaya and hilly areas of Kashmir, Assam and Arunachal Pradesh. They are represented by the members of Cycadales, Coniferales, Taxales and Gnetales. Ginkgoales do not occur in India. Among nine modern genera of Cycadaceae, only *Cycas* is found in India. The conifers are found predominantly in the Himalayas and are particularly rich in north-west Himalayas. The important genera are *Abies, Cedrus, Larix, Picea, Pinus, Tsuga* (Pinaceae), *Cephalotaxus* (Cephalotaxaceae), *Cupressus, Juniperus* (Cupressaceae) and *Podocarpus* (Podocarpaceae). Taxodiaceae is totally absent. The only conifer of Southern Hemisphere origin found in India is *Podocarpus*. The order Taxales is represented by *Taxus* and *Amentotaxus*, while Gnetales includes

Ephedra and *Gnetum*. Most of these taxa are of Northern Hemisphere. The Southern Hemisphere forms mostly introduced are only *Araucaria* and *Agathis* (Sahni, 1990).

DISCUSSION

Even a cursory comparison of the Tertiary conifers of peninsular India with the modern conifers of the extra-peninsular Himalayan region would not fail to indicate a sharp difference between the two. The former were dominated by Podocarpaceae and Araucariaceae, while the latter by Pinaceae. The cumulative effect of the following factors could be ascertained for it:

(a) Appearance of angiosperms
(b) Northward movement of the Indian Plate and uplift of Himalayas.

The Indian landmass (Peninsular India) was the integral part of the then Southern Hemisphere Supercontinent "Gondwanaland" for the major part of the Mesozoic Era (Smith & Briden, 1979). However, during Late Cretaceous the Indian Plate got separated from the main landmass and started moving northward. This was the time when the angiosperm flora started appearing in India. During Palaeogene angiosperms became quite dominant as a result of their progressive diversification and expansion all over the peninsula thus reducing the gymnosperms to an extent that only Cycadaceae, Podocarpaceae and Araucariaceae could be observed. Towards the end of Palaeogene the Indian Plate collided with the Asian Plate resulting in the formation of mighty Himalayas which had adversely affected the gymnosperm population of peninsular India as they could not survive under changing conditions. As a result Araucariaceae suffered most and became totally extinct from India after Neogene (Ramanujam, 1978) while Podocarpaceae too is at the verge of its extinction (Rao, 1963) as it occurs in restricted areas only, especially in northeast India and Nilgiri Hills in southern India. However, establishment of land connections between India and neighbouring continents and the orogeny of Himalayas after Palaeogene also facilitated the entry of northern temperate conifers to the extra-Peninsular region. The palynological data from Siwaliks do suggest that the conifers, such as *Pinus, Abies, Cedrus, Picea* and *Tsuga*, etc. (Banerjee, 1968; Lukose, 1969; Nandi, 1972, 1975; Mathur, 1973; Saxena & Bhattacharyya, 1987; Singh & Saxena, 1980, 1981; Saxena and Singh, 1980, 1982a,b; Singh & Sarkar, 1984; Saxena *et al.*, 1982) had already reached the higher reaches of the newly emerged Himalayas from central and west Asian mainland by Miocene times (Ramanujam, 1976). There is also a report of pinaceous pollen in the Oligocene sediments of Himachal Pradesh (Mathur, 1984). However, absence of their megafossil record in the Siwalik sediments clearly indicates that they did not descend to the foot-hills zone. Thus it is evident that their pollen might have been transported from higher reaches in the north down into the Siwalik Basin. The occurrence of a northern temperate gymnosperm wood of Pinaceae from the Lower Karewa beds (Late Pliocene) of Kashmir (Awasthi & Guleria, 1982) suggests that by this time the Himalayas attained sufficient altitude to provide hospitable climate for rapid spread of this family.

REFERENCES

Agashe SN 1969. Studies on the fossil gymnosperms of India-Part I. A new species of *Mesembrioxylon, M. mahabalei* sp. nov. *Palaeobotanist* **17**(3) : 312-316.

Aiyengar NKN & Jacob K 1952. A preliminary notes on *Pseudocycadeoidea*, a new genus of plant fossils from the Trichinopoly District, Madras. *Rec .geol. Surv. India* **82** (2) : 325-341.

Awasthi N & Guleria JS 1982. Megaplant remains from the Lower Karewas of Kashmir. *Abstract Int. Workshop on the Late Cenozoic Palaeoclimatic changes in Kashmir and Central Asia*. Ahmedabad.

Awasthi N, Mehrotra RC & Lakhanpal RN 1992. Occurrence of *Podocarpus* and *Mesua* in the Oligocene sediments of Makum Coalfield, Assam, India. *Geophytology* **22** : 193- 198.

Bande MB & Prakash U 1984. A podocarpaceous fossil wood from the Deccan Intertrappean beds of Malabar Hills, Bombay. *Geophytology* **14** (2) : 171-178.

Banerjee D 1968. Siwalik microflora from Punjab, India. *Rev. Palaeobot. Palynol.* **6** : 171-178.

Bose MN & Maheshwari HK 1974. Mesozoic conifers. *In* Surange KR, Lakhanpal RN & Bharadwaj DC (Editors) — *Aspects & appraisal of Indian palaeobotany* : 212-223. Birbal Sahni Institute of Palaeobotany, Lucknow.

Chitaley SD & Sheikh MT 1973. *Harrisostrobus intertrappea* gen. et sp. nov., a petrified gymnospermous cone from the Deccan Intertrappean beds of India. *Palaeontographica* **144**B : 25-30.

Gothan W 1905. Zur Anatomie lebender und fossiler, Gymnospermen-Hölzer. *Abh. preuss. geol. Landesanst* **44** : 1-108.

Guleria JS 1986. Fossil woods from the Tertiary sediments near Jaisalmer, Rajasthan and their bearing on the age of Shumar Formation. *Spec. Indian Geophytological Conf.*, (Abstract), Pune.

Guleria JS 1992. Neogene vegetation of peninsular India. *Palaeobotanist* **40** : 285-311.

Harsh R & Sharma BD 1988. *Araucarioxylon bikanerense* sp. nov. from the Tertiary of Bikaner, Rajasthan, India. *Phytomorphology* **38** (2-3) : 111-115.

Kräusel R 1949. Die fossilen Koniferen-Hölzer (unter ausschluss von *Araucarioxylon* Kraus) II. Teill Kritische untersuchungen Zur diagnostik lebender und fossiler Koniferen- Hölzer. *Palaeontographica* **89B** : 83-203.

Lakhanpal RN, Guleria JS & Awasthi N 1975. A podocarpaceous wood from the Pliocene of Kutch. *Geophytology* **5** : 172-177

Lakhanpal RN, Prakash U & Bande MB 1977. An araucarian fossil wood from the Deccan Intertrappean beds of Mohgaonkalan. *Palaeobotanist* **24**(2) : 125-131

Lepekhina VG 1972. Woods of Palaeozoic pycnoxylic gymnosperms with special reference to North Eurasia representatives. *Palaeontographica* **138B** (1-4) : 44-106.

Lukose NG 1968. Microfossils from the Middle Siwalik of Bihar, India. *J. Palynol.* **4**(2) : 107-112.

Mahabale TS & Rao SV 1973. Fossil flora of Rajahmundry area. *Proc. Symp. Deccan Trap Country, Indian natn. Sci. Acad. Bull.* **45** : 192-214.

Mahabale TS & Satyanarayana T 1978. Fossil flora of Andhra Pradesh (India-1). Petrified gymnospermous woods from Godavari District. *Biovigyanam* **4** : 53-73.

Mathur K 1973. Studies in the palaeoflora of the Himalayan foot- hills on the palynoflora in the Lower Siwalik sediments of Nepal. *J Palynol.* **8** : 54-62.

Mathur YK 1984. Cenozoic palynofossils, vegetation, ecology and climate of the north and north western sub-Himalayan region, India. *In* White RO (Editor) — *The evolution of the East Asian environment-II. Occasional papers and monographs* **59** : 504-551. Centre of Asian Studies, Univ. of Hong Kong.

Nandi B 1972. Some observations on the microflora of Middle Siwalik sediments of Mohand (East) Field, Himachal Pradesh. *In : Proc. Sem. Palaeopalynol. Indian Stratigr. 1971* : 375-383. Department of Botany, Univ. of Calcutta, Calcutta.

Nandi B 1975. Palynostratigraphy of the Siwalik group of Punjab. *Himalayan Geol.* **5** : 411-423.

Paradkar SA 1976. Pollination in a fossil ovule from the Deccan Intertrappean of Mohgaonkalan. *Botanique* **7** (2-3) : 95-100.

Potonié H 1902. Fossil Hölzer aus der oberen Kreide Deutsch- Ostafrikas. *Wiss. Beih. Dtsch. Koloniabl.* **15** (4) : 227-229.

Prakash U 1957. Studies in the Deccan Intertrappean flora-1 On a petrified ovuliferous cone from Mohgaon cherts in the Deccan. *Pa aeobotanist* **5** : 91-94.

Prakash U 1962. Further observations on a petrified ovuliferous cone (*Mohgaostrobus sahnii* gen. et sp. nov.) from Mohgaon cherts in the Deccan. *Palaeobotanist* **10** : 1-5.

Ramanujam CGK 1953. On two species of *Mesembrioxylon* from the vicinity of Pondicherry, south India. *Palaeobotanist* **2** : 101-106.

Ramanujam CGK 1954. On some silicified woods from near Pondicherry, south India. *Palaeobotanist* **3** : 40-50.

Ramanujam CGK 1960. Silicified woods from the Tertiary rocks of south India. *Palaeontographica* **106B** : 99-104.

Ramanujam CGK 1976. Indian gymnosperms in time and space. *Aspects of Plant Sci.* **1** : 73-126.

Ramanujam CGK 1978. Geological history of Araucariaceae in India. *Botanique* **9** (1-4) 1-12.

Rao AR 1963. The Podocarpaceae in India. *Mem. Indian bot. Soc.* no. **4** : 150-157.

Sahni B 1931. Revision of Indian fossil plants. Pt 2- Coniferales (petrifactions). *Mem. geol. Surv. India Palaeont. indica* n. ser. **11**: 51-124.

Sahni KC 1990. *Gymnosperms of India and adjacent countries*. Bishen Singh Mahendra Pal Singh, Dehradun.

Saxena RK & Bhattacharyya AP 1987. Palynology of the Siwalik sediments of Kala Amb-Nahan area in Sirmaur District, Himachal Pradesh. *Palaeobotanist* **35** 187-195.

Saxena RK, Sarkar S & Singh HP 1984. Palynological investigation of Siwalik sediments of Bhakra Nangal area, Himachal Pradesh. *Geophytology* **14** : 178-198.

Saxena RK & Singh HP 1980. Occurrence of palynofossils from the Pinjor Formation (Upper Siwalik) exposed near Chandigarh. *Curr. Sci.* **49** (12) : 479-480.

Saxena RK & Singh HP 1982a. Palynology of the Pinjor Formation (Upper Siwalik) exposed near Chandigarh, India. *Palaeobotanist* **30** : 325-339.

Saxena RK & Singh HP 1982b. Palynological investigation of the Upper Siwalik sediments exposed along Hoshiarpur-Una Road Section in Punjab and Himachal Pradesh. *Geophytology* **12** : 287-306.

Seward AC 1919. *Fossil Plants*. **4**. New York, London.

Sheikh MT & Kolhe PD 1982. A new petrified ovule *Podocarpoovulites chitaleyi* from a new locality of Nagpur, Deccan, Maharashtra (India). *Botanique* **10** : 99-108.

Singh HP & Sarkar S 1984. A Kasauli palynoflora from Benethi area of Himachal Pradesh, India. *Geophytology* **14** : 40-51

Singh HP & Saxena RK 1980. Upper Siwalik palynoflora from Gagret-Bharwain Road Section, Himachal Pradesh. *Geophytology* **10** : 278-279.

Singh HP & Saxena RK 1981. Palynology of the Upper Siwalik sediments in the Una District, Himachal Pradesh. *Geophytology* **11** : 173-181.

Smith AG & Briden JC 1979. *Mesozoic and Cenozoic palaeocontinental maps*. Cambridge Univ. Press, Cambridge, London, New York.

Srivastava GP & Prakash U 1984. Occurrence of araucarian wood from the Neogene of West Bengal, India. *Palaeobotanist* **32** : 236-242.

Trivedi BS & Srivastava R 1989. Gymnospermous woods from Early Tertiary of Chhindwara District of Madhya Pradesh. *Phytomorphology* **39** (1) : 61-68.

Varma CP 1955. On two new species of *Mesembrioxylon* from the Cretaceous rocks of Trichinopoly District, Madras. *Palaeobotanist* **3** : 97-102.