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A brief account of Cenozoic (Tertiary) flora of India: its development, significance and future considerations

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ABSTRACT

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The paper is based on megafossil records of which the angiosperms provide the bulk of data and are represented by various plant parts such as roots, woods, leaves, fruits, flowers, etc. The modern flora of India is one of the richest and diverse floras of the world. The roots of extant flora of India can be traced back to base of the Palaeocene or just below the K/Pg boundary. The development or history of primarily Cenozoic flora in India can be divided into three periods, viz., (i) Pre-Sahni Period (1782-1920), (ii) Prof. Sahni's Period (1920-1949) and (iii) Post-Sahni Period (1950 onwards).The first period can be called as the age of colonial or pioneer explorers. It was a period when Cenozoic plant fossils were largely collected as curios and were purely viewed with a geological bias. The second period was the most momentous period in the history of Indian Palaeobotany in general and Cenozoic Palaeobotany in particular. It began with the return of Prof. Birbal Sahni in 1920 from Cambridge, when he took stock of the existing position of Palaeobotany in India and eventually laid the foundation of Indian Palaeobotany. During the third period, Indian Palaeobotany made far reaching progress in all spheres. A large amount of data was accumulated and synthesized for the proper evaluation of the Cenozoic flora. However, many problems are still to be tackled and neglected aspects of the flora need to be looked into to get fuller picture of the Cenozoic flora.

Key-words—Megafossils, Cenozoic (Tertiary) flora, India, Future considerations.

भारत के सीनोजोइक (टर्शियरी) वनस्पतिजात का संक्षिप्त लेखा : इसके विकास, महत्व एवं भावी विचार

जे.एस. गुलेरिया

सारांश

यह शोध-पत्र गुरूजीवाश्म लेखा पर आधारित है जिसमें आवृतबीजी अधिक आँकड़े प्रदान करता है और विभिन्न पादप भागों जैसे जड़े, तना, पत्तियाँ, फलों, फूलों, इत्यादि का प्रतिनिधित्व करता है। भारत की आधुनिक वनस्पति दुनियाँ में सबसे प्रचुर तथा विविध है। भारत की मौजूदा वनस्पति की जड़े पेलियोसीन के आधार के नीचे या के/पीसी सीमा के थोड़ा नीचे से ढूँढ सकते हैं। भारत की प्राथमिक सीनोजोइक वनस्पति के विकास या इतिहास को तीन कालों में विभाजित कर सकते हैं, अर्थात (i) साहनी-पूर्व काल (1782-1920), (ii) प्रो. साहनी काल (1920-1949) एवं (iii) साहनी-पश्च काल (1950 से आगे)। प्रथम काल को उपनिवेशी या अग्रणी खोजकर्त्ता का युग कह सकते हैं। यह ऐसा काल था जब सीनोजोइक पादप जीवाश्मों का दुर्लभ वस्तु के रूप में अधिक मात्रा में संग्रहीत किया था तथा भूवैज्ञानिक प्रवृत्ति से पूर्णतया देखा गया था। द्वितीय काल भारतीय पुरावनस्पतिविज्ञान के इतिहास में साधारण तथा सीनोजोइक पुरावनस्पतिविज्ञान के इतिहास में विशेष रूप से सबसे महत्वपूर्ण काल था। यह काल प्रो. बीरबल साहनी के सन् 1920 में कैम्ब्रिज से लौटने के साथ ही शुरू हुआ था। जब उन्होंने भारत में पुरावनस्पतिविज्ञान की मौजूदा स्थिति का कार्यभार संभाला था और भारतीय पुरावनस्पतिविज्ञान की संभावित नींव रखी। तृतीय काल के दौरान, भारतीय पुरावनस्पतिविज्ञान ने हर क्षेत्र में अधिक प्रगति की। अधिक संख्या में आँकड़े सीनोजोइक वनस्पति के उचित मूल्याँकन हेतु संचित एवं संयोजित किए गए थे। यद्यपि कई समस्याएं अभी भी सुलझानी हैं और वनस्पति के उपेक्षित पहलूओं को सीनोजोइक वनस्पति की पूर्ण तस्वीर प्राप्त करने के लिए देखने की आवश्यकता है।

संकेत-शब्द—गुरूजीवाश्म, सीनोजोइक (टर्शियरी) वनस्पति, भारत, भावी विचार।

Challenges in Indian Palaeobiology: Current Status, Recent Development and Future Directions
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DEVELOPMENT OR HISTORY OF CENOZOIC (TERTIARY) FLORA OF INDIA

The paper deals with the development of largely Cenozoic flora of India based on megafossils recovered from the rocks ranging from Late Maastrichtian to Pliocene-Pleistocene Epoch covering approximately a time span of 66 my. Dealing with the Cenozoic (Tertiary) flora of India it is difficult to draw a clear cut line on the commencement and end of the Tertiary flora. This is evident when we consider the age of Deccan Intertrappean sediments and Karewa beds of Kashmir. The age of Deccan Intertraps ranges from Late Maastrichtian to Early Palaeocene and that of Karewa beds ranges from Pliocene to Pleistocene.

The modern flora of India is one of the richest and diverse floras of the world. The immediate ancestors of the dominant vegetation of today can be traced in the Early Cenozoic (Tertiary) Era. The dominance of angiosperms, their close similarity with extant plants and with the plants of other Early Tertiary sediments and almost complete lack of typical Mesozoic forms in the Deccan Intertrappean flora has forced us to include K/Pg boundary flora known as the Deccan Intertrappean and Infratrappean flora under the Cenozoic (Tertiary) flora. Likewise, the late Tertiary flora of Karewa of Kashmir which transgresses into Pleistocene has also been considered here as part of Cenozoic (Tertiary) flora of India.

The development or history of Cenozoic (Tertiary) flora or Palaeobotany in India can be divided into three periods, viz., (i) Pre-Sahni Period (1782-1920), (ii) Prof. Sahni's Period (1920-1949) and (iii) Post-Sahni Period (1950 onwards):

(i) **Pre-Sahni Period (1782-1920)**—This period can be called as the age of colonial or pioneer explorers. Most of them were Christian missionaries, medical and army officers. The period began with the work of a French naturalist who reported the occurrence of petrified woods near Pondicherry in the last quarter of the eighteenth century (Sonnerat, 1782). However, Warren (1810) gave the first illustrative account of these fossils. Similarly, Brongniant as early as 1837, reported the occurrence of fossil plants in the Deccan Intertrappean sediments. A number of subsequent inquisitive explorers and geologists contributed towards the rudimentary development of Cenozoic (Tertiary) Palaeobotany of India. Some of the important contributors of this period were:- Coulthard (1829), Spilsbury (1829), Sleeman (1830), Spry (1833), *Brongniart (1837), Malcolmson (1837), Sowerby (1840), Hislop (1853), *Hislop & Hunter (1855), *Schmid and Schleiden (1855), Carter (1857, 1862), Nicolls (1857), Medlicott (1860), *Bunbury (1861), Blanford (1862), Godwin-Austin (1864), Stoliczka (1869), Wynne (1872), *Feistmantel (1882), *Schenk (1882, *1890), Lydekker (1883), Fedden (1884), Noetling (1893), La Touche (1902), Pilgrim (1910), *Middlemiss (1911), *Seward (1912), Wadia (1919) and many more. As a Cenozoic (Tertiary) palaeobotanist I pay my humble tribute to these pioneers for their untiring efforts and for working in the remotest and inhospitable areas of the country. Their pioneering efforts have provided the glimpses of Cenozoic (Tertiary) fossil localities spread far and wide in the country. Inspite of their contributions, practically no taxonomic work was carried out during this period and the knowledge of Tertiary plant fossils remained very poor. It was a period when plant fossils were collected as curios or mere samples and were largely viewed with a geological bias.

(ii) **Prof. Sahni's Period (1920-1949)**—It was the most momentous period in the history of Indian palaeobotany in general and Cenozoic (Tertiary) Palaeobotany in particular. Prof. Birbal Sahni soon after returning from Cambridge took a stock of the existing position of Palaeobotany in India (Sahni, 1921). He showed special interest in the Deccan Intertrappean plant fossils, the occurrence of which was reported by Brongniart as early in 1837. Prof. Sahni initiated work on the Cenozoic plant fossils (*Sahni, 1931a, b; *1932; 1937; *1938; 1940; *1943a, b; *1944; 1946; *Sahni & Rao, 1934; *Sahni & Rao, 1943a, b; *Sahni & Rode, 1937; *Sahni & Surange, 1944). Prof. Sahni was a visionary and he evinced keen interest in the fossil plants of Karewas of Kashmir. The Karewa flora has provided evidence of uplift of Himalaya (*Sahni, 1936). One of his students, G.S. Puri, subsequently investigated the Karewa megaflora in detail in a series of papers (*Puri, 1943-1949). Prof. Sahni did considerable work on the Deccan Intertrappean fossils and trained many of his students to work on plant fossils and laid the foundation of Indian Cenozoic (Tertiary) Palaeobotany. Under his able guidance, work on Tertiary microfossils and cuticular studies was also carried out (Sahni *et al.*, 1948; *Rao & Vimal, 1950; *Jacob & Jacob, 1950). The early work on microfossils laid the foundation of Palaeopalynology which eventually proved an asset in stratigraphy and hydrocarbon exploration. Other important workers of this period were Gee (1927); De Terra (1935); *Rode (1933a, b, 1934, 1935, 1936); *Chowdhury (1934, 1936, 1938); Kaul (1935, 1938); *De Terra and Peterson (1939); *Rao and Rao (1939); *Shukla (1939, 1941, 1944, 1946); *Chowdhury and Ghosh (1946); *Sen 1948; *Mahadavan (1944); *Mahadavan and Sarma 1948; *Chowdhury and Tandon (1949); *Chitaley (1949). *Rode (1934) was the first to report the occurrence of dicotyledonous wood at Mohgaon Kalan, a classical intertrappean locality in district Chhindwara of Madhya Pradesh (For references marked with *, Please see Lakhanpal *et al.*, 1976).

Most significant contribution of Prof. Sahni was the formation of the Palaeobotanical Society for the advancement of Palaeobotany which culminated in the establishment of Institute of Palaeobotany in 1946. The Institute was renamed in 1949 as Birbal Sahni Institute of Palaeobotany on the untimely death of Prof. Sahni. Ever since the institute has proved the most active centre of palaeobotanical researches in India.

The major achievements of this period can be summed up as: Initiation of systematic taxonomic work on the Cenozoic (Tertiary) plant fossils from various parts of India, e.g. Karewa, Siwalik, Assam, Andamans, Rajasthan, Deccan Intertrappeans, and south India. The impetus provided by Sahni opened up numerous possibilities for Tertiary workers.

(iii) **Post-Sahni Period (1950 onwards)—**Indian Palaeobotany suffered a big jolt due to sudden demise of Prof. Birbal Sahni in 1949. However, his devoted team of students and successor carried forward successfully the flag of Palaeobotany. During this period Indian Palaeobotany made far reaching progress in all spheres both on account of large fossil collections and newly discovered localities and of improved methods of investigations. More and more fossil plants were studied with a point of view of their taxonomy so that the antiquity of the taxon could be traced which may throw light on the evolution of particular taxon. A large amount of data was accumulated and synthesized for the proper evaluation of the Cenozoic (Tertiary) flora (Awasthi, 1974, 1982, 1992; Bande, 1992; Bande *et al*., 1988; Bonde, 2008; Bonde & Kumaran, 2002a, b; Bera & Banerjee, 2001; *Chitaley, *1950, 1974; Guleria, 1992, 2005; Guleria & Srivastava, 2001; Guleria *et al*., 2002; Gupta *et al.,* 2002; *Mahabale, 1950a, b, 1959, 1963, 1965, 1968; Prakash, 1974; Lakhanpal, 1970, 1988, 1991, 1998; Mehrotra, 2003; Roy & Mukhopadhyay, 2005; Prasad, 2008; Prasad & Pandey, 2008; Puri, 1957; *Sahni, 1953, 1964; Trivedi, 1974; Vishnu Mittre, 1965; Kar *et al*., 2004; Banerjee *et al*., 2005) and many more. For further references and details readers may consult Srivastava 1990; Srivastava and Guleria 2006. Moreover, beginning on the amber studies and stomatal frequency responses in the fossil leaves have been made (Shukla *et al*., 2000a, b; Mehrotra *et al*., 2003). However, lately the Palaeobotany is lagging behind in India than some of the advanced countries in the world.

CENOZOIC (TERTIARY) FLORA AND ITS SIGNIFICANCE

The Indian Cenozoic (Tertiary) flora can easily be divided into two parts, viz. (1) The Palaeogene or Lower Tertiary flora and (2) The Neogene or Upper Tertiary flora.

(1) THE PALAEOGENE OR LOWER TERTIARY FLORA

The Deccan Intertrappean flora has largely been considered to be basal Tertiary (Late Maastrichtian-Early Palaeocene) and is well documented from various intertrappean sites of Madhya Pradesh, Maharashtra, Andhra Pradesh and Gujarat. Lately, some additions have been made to the equivalent infratrappean flora of Madhya Pradesh and Maharashtra . The Deccan Intertrappean flora is unique in the sense that a large number of plant fossils representing almost all groups of the Plant Kingdom have been reported from various intertrappean localities. The inter or infratrappean flora can be considered as the parental stock of the modern Indian flora. Some of the important taxa reported from various intertrappean/ infratrappean sites are:

Rajahmundry Area

Algal taxa - *Helimeda, Dissocladella, Terquemella, Acetabularia, Neomaris, Holosporella* and *Acicularia.* The occurrence of estuarine algae along with *Cocos (Palmoxylon sundaram)* and *Sonneratia* indicates near shore tropical conditions around Rajahmundary at the time of their deposition.

Central India (Mandla, Chhindwara, Sagar, Nagpur-Wardha Area)

Algal taxa, viz. *Peyssonnelia, Distichoplax* and *Solenopora.* Pteridophytes – *Acrostichum, Azolla, Salvinia, Marsilea* and *Rodeites* cf. *Regnellidium.* Representative of gymnosperms are *Araucaria-Agathis* and *Podocarpus.* In addition, a number of angiospermous genera such as *Ailanthus, Amoora, Anamitra, Aristolochia, Artocarpus, Atalantia-Limonia, Barringtonia, Bursera, Canarium, Cocos, Dracontomelum, Elaeocarpus-Echinocarpus, Eucalyptus, Euphoria, Evodia, Flacourtia, Garcinia, Gmelina, Grewia, Heterophragma, Homalium, Hydnocarpus, Hyphaene, Lagerstroemia, Leea, Livistona, Lophopetalum, Mallotus, Melaleuca-Tristania, Musa, Nymphaea, Nypa, Polyalthia, Simarouba, Sonneratia, Stemonuras* (= *Gomphandra), Sterculia, Syzygium, Walsura,* etc. and a number of palms.

Kachchh, Gujarat (Anjar)

Homalium, Hydnocarpus, Stemonurs (= *Gomphandra), Bischofia, Mallotus* and some palms.

Significant Conclusions

- The taxa reported in the fossil form are all inhabitant of tropical forests and most of the genera exist in the evergreen to semi-evergreen to moist deciduous forests of Western Ghats and North-east India.
- The abundance and variety of palms (which form the characteristic features of vegetation of the tropics) in the intertrappeans and other moisture loving dicotyledonous taxa together with those confined and belonging to Gondwanaland continents of tropical America, Africa and Australia *(Regnellidium,* a water fern of Brazil, *Simarouba; Hyphaene, Chrysalidocarpus; Eucalyptus)* provide strong evidence to infer that palaeoposition of the Indian landmass during the intertrappean time was within the equatorial zone south of equator.
- The abundance of palms and lack of legumes distinguishes the intertrappean flora from the Neogene flora.
- An analysis of the intertrappean woods has shown that they possess more primitive anatomical features than the Neogene woods.

Other Palaeocene Floras

Upper Palaeocene flora of India is known from Meghalaya, Eocene flora from Rajasthan and Gujarat, late Eocene-early Oligocene flora from Ladakh and Manipur, Oligocene flora from Assam and Arunachal Pradesh. The Palaeogene flora from north-east, Rajasthan and Gujarat shows the presence of estuarine or littoral elements such as *Avicennia, Barringtonia, Calophyllum, Cocos, Nypa, Pandanus, Terminalia catappa, Sonneratia, Rhizophora,* palms along with other moist tropical taxa indicating swampy, littoral/deltaic depositional conditions with close proximity of sea as far deep in the north-east as Dibrugarh in Assam, Tirap District of Arunachal Pradesh and in the west near Bharuch-Surat and Kachchh in Gujarat and Barmer in Rajasthan. The occurrence of tropical palm genus *Livistona* in the Hemis – Conglomerate horizon of Ladakh indicates that climate of Ladakh was tropical till the Oligocene Epoch. The composition of the flora shows that it is largely a continuation of the Deccan Intertrappean flora.

(2) NEOGENE FLORA OR UPPER TERTIARY FLORA

The Neogene flora of India is fairly well known and consists of typical hardwood assemblages of broad leaf types and in many instances they show close resemblance to existing species. The commonest plant fossils found in the Neogene deposits are petrified and carbonized woods and leaf impressions.

The Neogene flora has been divided for the sake of convenience into two parts, viz. (A) Neogene flora of peninsular India (B) Neogene flora of extra-peninsular India.

(**A**) **Neogene flora of peninsular India**—For the purpose of study it has been divided into five parts.

(i) Western Indian flora—includes floras of Gujarat, Rajasthan, Konkan and Kerala
(ii) East Coast flora—includes floras of Rajahmundary, Neyveli and Cuddalore.
(iii) North-eastern flora.
(iv) Central Indian flora.
(v) Andaman and Nicobar Islands flora.

(B) Neogene flora of extra-peninsular India—It can be divided into four parts : (i) Pre-Siwalik flora—The flora is poorly documented except for the flora of Kasauli Formation (Sahni, 1953; Mathur *et al*., 1996; Guleria *et al*., 2000 a, b; Srivastava & Guleria, 2004). (ii) Siwalik flora—includes floras of Siwalik sediments extending from Jammu in the West to Arunachal Pradesh in the East. A number of assemblages of megafossils are known from the Lower, Middle and Upper Siwalik sediments. The assemblages of Lower and Middle Siwaliks do not show much difference in terms of floral composition. However, records of megafossils from the Upper Siwalik are poor. (iii) Higher Himalayan flora— A very limited work has been done on the Higher Himalayan megaflora and only three genera, viz. *Populus, Prunus* and *Trachycarpus* (Lakhanpal, 1988) have been reported so far. This shows that cooler conditions had set in the higher Himalaya during Neogene. (iv) Karewa flora— (equivalent to Upper Siwalik)—A rich flora from the Lower Karewa beds of Kashmir is known.

A survey of the Neogene taxa reported from different parts of the peninsular and extra-peninsular India and their comparison with the extant taxa which are largely distributed in lowland evergreen, semi-evergreen to moist deciduous forests indicate that the Neogene flora was more or less uniform indicating the prevalence of tropical moist climate throughout the Indian landmass. The flora also shows immigration of plants from the South-east *(Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Koompassia, Swintonia,* etc.), Africa and Arabia *(Baphia, Chlorophora, Entandrophragma, Khaya, Isoberlinia,* etc.) and from the North *(Populus, Prunus, Trachycarpus)* (Lakhanpal, 1988; Guleria, 1992*).* The flora remained nearly unchanged in its overall composition until the close of Pliocene. At the end of Pliocene a distinct change in the vegetation (from tropical to warm temperate-temperate) has been observed in the Kashmir Valley (Karewa beds) due to final uplift of Himalaya *(Puri, 1943-1949, 1957; Vishnu-Mittre, 1965).

Significant Conclusions

- All the floras from different basins show close similarity in their composition as most of the genera are common to them.
- The wide distribution of the tropical rain forest family Dipterocarpaceae along with other associated genera, indicates more or less uniform tropical moist climate throughout the Indian landmass during the Neogene.
- There were large scale migrations and admixture of floras over Malaysia, India, Arabia-Africa and north of India during the Neogene times due to establishment of land connections.
- The complete absence of any megafossil of northern conifers in 2400 km long Siwalik belt indicates that prevailing climatic conditions remained tropical in the Himalayan foot hills up to Lower Pliocene in contrast to the cooler climatic conditions observed in the higher Himalaya during Neogene and later at the end of Pliocene in Kashmir.
- The presence of some families and genera such as Dipterocarpaceae, Ebenaceae, Sapotaceae, Rosaceae, *Afzelia-Intsia, Swintonia,* dominance of legumes and paucity of palms distinguishes the Neogene flora from the Palaeogene flora of India.

Thus to understand the history and evolution of the modern flora of India and its phytogeography it is important to study and build up the Cenozoic flora of India.

FUTURE CONSIDERATIONS

♦ The occurrence of reported coastal and estuarine mangrove taxa belonging to higher plants such as *Acrostichum, Barringtonia, Cocos, Nypa, Sonneratia* along with number of palms and the marine algal taxa *Peyssonnelia, Distichoplax,* and *Solenopora* indicate the existence of at least estuarine and coastal conditions in the central India (Mohgaon Kalan, etc.) during the Deccan Intertrappean time. However, the question of marine influence in the Deccan Intertrappean sediments deep inside central India has to be settled in view of the doubts raised by some geologists in the absence of any definite palaeontological supporting evidences. Microfossil studies can play an important role to settle this issue.

♦ To trace the exact affinities of some of the reported problematic taxa in the intertrappean sediments.

♦ Despite the occurrence of a large number of arborescent palms (Guleria, 2005; Guleria & Mehrotra, 1999; Bonde, in press) there is no definite record of cane/rattan palms (*Calamus*) and bamboos in the intertrappean or equivalent sediments. Remains of cane palms and bamboos must be searched to trace their antiquity in the Indian flora.

♦ Study of mesofossils has been largely neglected / ignored. Their morphological and anatomical study should be taken up on priority basis as there is no dearth of material (e.g. fruits, seeds, flowers, etc.) in the Deccan Intertrappeans sediments as well as in the lignite mines.

♦ To investigate higher Himalayan Cenozoic flora as it remained largely unexplored due to difficult terrain and inaccessibility of the area. The investigation will throw light on the immigration of northern elements in India.

♦ To study stomatal frequency responses in fossil leaves.

♦ Emphasis be given on the investigations of amber (fossil resin) found in Tertiary lignite mines.

♦ Evaluation of climate and temperature changes be made on the basis of megafossil studies through the Cenozoic vis-á-vis changes seen in global context. In this direction work on climate modelling and CLAMP analysis be taken up.

♦ To study the evolution and establishment of monsoon system.

♦ Efforts be made for molecular studies and extraction of DNA from the mummified leaves found in Cenozoic sediments and to integrate fossils into molecular phylogenies.

♦ To assess Tertiary vegetation in broader biological and evolutionary perspectives involving interdisciplinary approach.

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