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Floristic zones in the Mesozoic formations and their relative age

Sukh-Dev

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Through a comprehensive analytical study of the Indian Mesozoic flora and synthesis of the available data 12 assemblage zones and a floral succession are established. These assemblage zones also extend into the Early Cretaceous flora in the neighbouring countries: Pakistan, Nepal, Bhutan and Sri Lanka. The Gondwana Triassic elements and the European Jurassic-Cretaceous elements in the flora are highlighted. The inter-relationship of the Mesozoic floras of Gondwanaland, European and Asian countries is examined. The relative age of the biozones is worked out on the basis of plant megafossils, palynology, palaeontology, stratigraphy and radiometry. It is suggested that the concept of Gondwana be replaced by chronostratigraphic terms, viz., Triassic, Jurassic and Cretaceous for the Indian Mesozoic sediments.

Key-words—Floristics, Biostratigraphy, Phytogeography, Mesozoic (India).

सारांश

मध्यजीवी शैल-समूहों में वनस्पतिजातीय मंडल तथा इनकी आयु

सुख-देव

भारतीय मध्यजीवी वनस्पतिजात के गहन विश्लेषणात्मक अध्ययन तथा उपलब्ध आँकड़ों के संश्लेषण से 12 समुच्चय मंडल एवं एक वनस्पतिजातीय अनुक्रम स्थापित किये गये हैं। ये समुच्चय मंडल पड़ोसी देशों—पाकिस्तान, नेपाल, भूटान एवं श्रीलंका—के प्रारंभिक क्रीटेशी वनस्पतिजातों में भी विस्तृत हैं। उपलब्ध वनस्पतिजात में गोंडवाना त्रिसंधी अवयवों एवं यूरोपीय जूराई-क्रीटेशी अवयवों पर भी प्रकाश डाला गया है। गोंडवानाभूमि, यूरोपीय एवं एशियाई देशों के मध्यजीवी वनस्पतिजातों की अन्तरबन्धुता का अध्ययन किया गया है। गुरु-पादपाश्मों, परागाणविक अध्ययन, पुरातात्विक अध्ययन, स्तरिकी एवं रेडियोमितीय कालनिर्धारण के आधार पर जैवमंडलों की आयु भी प्रस्तावित की गई है। यह प्रस्तावित किया गया है कि भारतीय मध्यजीवी अवसादों के लिए गोंडवाना अवधारणा को कालानुक्रमिक शब्दों अर्थात् त्रिसंधी, जूराई एवं क्रीटेशी से प्रस्थापित किया जाना चाहिये।

SINCE the initiation of study of the Indian Mesozoic flora in the middle of the 19th Century plant megafossils have been systematically described and illustrated from Early Triassic to Early Cretaceous sediments. These plants represent algae, bryophytes, pteridophytes (Isoetaceae, Equisetaceae, Marattiaceae, Osmundaceae, Matoniaceae, Weichseliaceae, Dipteridaceae, Aspidiaceae, Cyatheaceae, Dicksoniaceae, Dennstaedtiaceae, Gleicheniaceae, Schizaeaceae and Azollaceae), pteridosperms, glossopterids, cycadophytes, ginkgophytes, Caytoniales, Pentoxyleae and conifers. From time to time biozonation of the Mesozoic sediments based on plant megafossils has been attempted (Shah *et al.*, 1971) but with limited success. Here a synergistic analysis of Indian Mesozoic floral assemblages has been attempted to clearly demarcate the floristic zones and their relative age.

Anomalies regarding the age and position of various formations are resolved to a great extent. The Bhuj, Gangapur, Jabalpur, Rajmahal and East

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Coast sediments, hitherto considered Jurassic on the evidence of megaflora, are assigned an Early Cretaceous age on the basis of palynology, palaeontology and radiometric dating (Biswas, 1977; Venkatachala & Kar, 1970; Bose *et al.*, 1982; Mc Dougall & McElhinny, 1970; Agarwal & Rama, 1976; Arkell, 1956; Bose & Dev, 1959; Singh, 1966). The presence of *Weichselia* and *Onychiopsis* plants in the Bansa sediments indicating an Early Cretaceous age is confirmed.

FLORISTIC ZONES AND THEIR AGE

1. Lepidopteris-Dicroidium-Glossopteris Assemblage Zone

The Panchet Group assemblage is characterized by the appearance of the genera *Lepidopteris* and *Dicroidium*. The other elements of the assemblage are *Trizygia, Schizoneura, Cladophlebis, Neomariopteris, Cyclopteris, Sphenopteris, Glossopteris, Vertebraria, Taeniopteris, Macrotaeniopteris, Podozamites, Pseudoctenis, ?Pterophyllum, Noeggerathiopsis, Samaropsis*, etc. In this assemblage *Glossopteris* is represented by about 5 species. Species of *Lepidopteris* and *Dicroidium* increase in number in the upper part of the group.

Age—Early Triassic

Occurrence :

—Raniganj Coalfield (Banerji & Bose, 1977).

—Auranga Coalfield (Bose & Banerji, 1976).

—Ramkola-Tatapani Coalfield (Bose *et al.*, 1977).

—Daigaon Formation, Madhya Pradesh (Lele, 1969).

2. Gopadia-Glottolepis-Dicroidium Assemblage Zone

The Triassic rocks on the west bank of Gopad River near Nidpur Village (24°7′N : 81°54′E) comprise mainly of carbonaceous shales with micaflakes and micaceous fine grained sandstones. Plant fossils from these beds were first reported by Satsangi (1964). Subsequently an interesting rich flora preserved as compressions has been described by various workers. This plant assemblage is dominated by leaves of *Dicroidium*. *Glossopteris* is less common, represented by smaller and narrower forms. Scale-leaf *Glottolepis* and *Taeniopteris* are quite common. The other elements are *Algacites, Hepaticites, Sphagnophyllites, Rhabdotaenia, Lepidopteris, Bosea, Pteruchus, Marhwaseaphyllum, Rewaphyllum, Nidia, Sidhiphyllites, Nidistrobus, Nidpuria, Lelestrobus, Conites, Gopadia, Satsangia, Chakrea, Rugatheca, Rugaspermum*, etc. (for references see Srivastava, 1988, this Volume).

Age—Middle Triassic.

Remarks—The plant assemblage from Nidpur represents a more evolved flora than that of the Panchet. The palynoflora also corroborates the magaflora (Bharadwaj & Srivastava, 1969) in having dominance of nonstriate-bisaccate pollen grains.

3. Pagiophyllum-Elatocladus-Dicroidium Assemblage Zone

In the plant assemblage of Tiki Formation (named after the village Tiki (23°56′N : 81°22′E) the genus *Dicroidium* is commonly met with. This assemblage is marked by the appearance of new elements like *Pagiophyllum, Elatocladus, Yabeiella, Xylopteris, Sphenobaiera* and *Baiera*. Other elements are *Lepidopteris* and *Desmiophyllum* (Pal, 1984b).

Age—Late Triassic.

Remarks—In the plant assemblage recovered from near Giar from Son River Section the genera *Elatocladus* and *Pagiophyllum* are commonly found, whereas these are absent in the Harai plant assemblage obtained from Janar River Section. The Giar Assemblage seems to be younger than that from Harai. In the Tiki Formation are also found *Mesembrioxylon malerianum* woods, vertebrates and unionid *Tikkia* (Shah *et al.*, 1971).

4. Marattiopsis-Pterophyllum-Dicroidium Assemblage Zone

This assemblage comes from the Parsora Formation, named after the village Parsora (23°26′ N : 81°06′ E) in Shahdol District, Madhya Pradesh. It is characterized by the appearance of the genera *Marattiopsis, Danaeopsis* and *Parsorophyllum*. The genus *Dicroidium* is fairly well-represented. The other constituents are *Pterophyllum, Ginkgoites* and *Desmiophyllum*, etc. (Lele, 1956, 1962a-b, 1969).

Age—Late Triassic.

Remarks—The Parsora Formation overlies Tiki Formation as observed in Bamandev Hill Section (Sahni & Rao, 1956).

5. Brachyphyllum-Pagiophyllum-Desmiophyllum Assemblage Zone

The plant assemblage of Hartala Formation developed near Hartala Village (23°49′29″ N : 81°15′11″ E), Shahdol District, Madhya Pradesh comprises *Brachyphyllum, Pagiophyllum* and *Desmiophyllum*.

Age—Early Jurassic.

Remarks—The Hartala Formation overlies the Tiki Formation. The plant fossils are preserved in white or pinkish white shales (Pal, 1984a). So far, the Triassic genera *Lepidopteris* and *Dicroidium* are

not known in the Hartala Formation. *Pagiophyllum* is most common. The genus *Brachyphyllum* is not found in Tiki and Parsora formations. On the basis of plant fossils and lithology of sediments the Hartala Formation is considered as Early Jurassic.

6. *Hausmannia-Ptilophyllum-Araucarioxylon* Assemblage Zone

The floral assemblage of the Kota Formation named after the village Kota (18°55′N : 80°02′ E) on the east bank of the river Pranhita, is rich in conifer woods comprising *Araucarioxylon, Podocarpoxylon, Cupressinoxylon* and *Taxaceoxylon*. Among them Ginkgoalean wood, *Ginkgoxylon* is also present. The other constituents of the flora are represented by impressions of *Equisetites, Cladophlebis, Hausmannia, Sphenopteris, Otozamites, Ptilophyllum, Elatocladus, Brachyphyllum* and *Pagiophyllum*.

The significance of presence of Rajmahal woods *Araucarioxylon santalense, Podocarpoxylon rajmahalense* and *Taxaceoxylon* cf. *T. rajmahalense* in the Kota flora can not be fully assessed at present.

Age—Middle Jurassic (or slightly younger).

Remarks—The Kota Formation is characterised by limestone band, grits of light brown colour with red clay bands and sandstones. Carbonaceous clays are also present. It underlies Early Cretaceous Gangapur Formation. The age of the Kota Formation is considered Liassic on fish evidence, but on discovery of Ostracod the age is extended to Early Middle Jurassic (Govindan, 1975). Palaeobotanical data, particularly the fossil woods show clear affinity with the Rajmahal flora (Rajanikanth & Sukh-Dev, in Press). In view of the present palaeobotanical findings more work is called for on the Kota Formation for knowing its real position.

7. *Pachypteris-Cladophlebis daradensis* Assemblage Zone

The Jhuran Formation in Kutch Basin has yielded an assemblage of plant fossils consisting of *Cladophlebis daradensis, Pachypteris indica, P. specifica, Pagiophyllum chawadensis* and *Cladophlebis* species. At present the flora of the Jhuran Formation is not sufficiently known for dating purpose.

Age—Late Jurassic (Tithonian).

8. *Dictyozamites-Pterophyllum-Anomozamites* Assemblage Zone

The Chaugan sediments of Jabalpur Formation in Madhya Pradesh exposed from Morand River to Imjhiri show dominance of cycadophytes over pteridophytes and conifers. The cycadophytes are constituted by *Ptilophyllum, Pterophyllum, Dictyozamites, Anomozamites, Ctenis* and Taeniopteris.

The pteridophytes are represented by *Equisetites Gleichenites, Hausmannia Cladophlebis*, pteridosperms by *Pachypteris*; ginkgophytes by *Ginkgo* and conifers *Araucaria, Pagiophyllum, Brachyphyllum, Elatocladus, Moranocladus* and *Araucarites* (Bose & Banerji, 1981; Bose & Zeba-Bano, 1978; Sukh-Dev & Zeba-Bano, 1980, 1981b; Zeba-Bano 1979).

Age—Early Cretaceous.

Occurrence:

—Chaugan Reserve Forest, Madhya Pradesh (Crookshank, 1936).

—Bhuj Formation—Assemblage 1, Kutch (Bose & Banerji, 1984).

—Pariwar Formation, Rajasthan (Bose *et al.*, 1982).

—Sarnu Hill Formation, Rajasthan (Baksi & Naskar, 1981; Banerji & Pal, 1986).

—Dubrajpur Formation (Upper beds); Rajmahal Formation—Assemblage 1, Bihar (lower 3 intertrappean beds between lava flow 1-4) (Bose & Sah, 1968; Sharma, 1969, 1971, 1975; Zeba-Bano *et al.*, 1979).

—Sivaganga Formation, Tamil Nadu (Maheshwari, 1986; Sukh-Dev & Rajanikanth, in Press);

—Kagbeni beds, Thakkhola Valley, Nepal (Barale *et al.*, 1978).

—Taltung Formation, Palpa District (Kimura *et al.*, 1985).

—Tabbowa beds, Sri Lanka (Sitholey, 1944).

Remarks—The Chaugan sediments lie unconformably over Triassic Denwa and Bagra sediments and are overlain unconformably by the Deccan Traps or the Lametas (Crookshank, 1936). The plant assemblage of the Chaugan sediments is essentially similar to Assemblage 1 of Rajmahal Formation, the lower traps of which are dated 100-105 million years (reliable minimum age, McDougall & McElhinny, 1970). Considering that this is the minimum age limit, it is not inconsistent with the present conclusion in as much as the age may be older than 105 Ma. McDougall and McElhinny (1970, p. 374) have admitted the possibility of the Early Cretaceous age for these traps. Further, no angiosperm is obtained so far from the floras of these intertrappean sediments nor from the similar floras as mentioned above in other parts of the country under the assemblage no. 8. Therefore lack

of angiosperm also indicates that these floras are older than 105 Ma, i.e., Albian. Moreover, this assemblage no. 8 is also older than the succeeding assemblages nos. 9 and 10 which also lack angiosperms.

9. Allocladus-Brachyphyllum-Pagiophyllum Assemblage Zone

The plant assemblage recovered from the sediments exposed on the Sher River near the village Sehora (22°52′ N : 79°21′ E), Narsinghpur District, Madhya Pradesh shows richness of conifers, less cycadophytes and pteridophytes. In this assemblage *Onychiopsis, Doratophyllum, Allocladus* and *Satpuria* are new entrants. This assemblage includes flora of closeby areas of Hard River near Hasnapur and Jabalpur as well. This assemblage has rich representation of *Pachypteris, Ptilophyllum, Allocladus, Brachyphyllum* and *Pagiophyllum* (Sukh-Dev & Zeba-Bano, 1978, 1979, 1081a,b).

Age—Early Cretaceous

Occurrence :

—Jabalpur Formation, Sehora on Sher River, Narsinghpur District, Madhya Pradesh.

—Bhuj Formation—Assemblage 2, Kutch (Bose & Banerji, 1984) (Trambau, Sukhpur, Dharesi)

—Gangapur Formation—Assemblage 1, Andhra Pradesh (Bose *et al.*, 1982; Sukh-Dev & Rajanikanth, 1988).

—Rajmahal Formation—Assemblage 2, Bihar (Nipania flora, between lava flows 4-5) (Mittre, 1957-1958a-b).

—Golapalli, Raghavapuram, Budavada and Vemavaram formations, Andhra Pradesh (Feistmantel, 1877, 1879; Baksi, 1964, 1968; Sastri *et al.*, 1977).

—Sriperumbudur Formation, Tamil Nadu (Feistmantel, 1877, 1879; Baksi, 1964, 1968; Sastry *et al.*, 1977).

—Sakesar beds, Salt Range, Punjab, Pakistan (Sahni & Sitholey, 1945).

—Lingshi Group—Bhutan (Ganesan & Bose, 1982).

Remarks—In this assemblage genus *Onychiopsis* is an important taxon as it was of world-wide distribution during the Early Cretaceous time. A caution is to be exercised in assigning Wealden age on the basis of *Onychiopsis* as it occurs in the Middle Jurassic in Israel (Lorch, 1967), Late Jurassic in Madagascar (Appert, 1973), Middle Jurassic to Early Cretaceous in Japan (Kimura & Aiba, 1986) and Late Cretaceous (Cenomanian, Velenovsky, 1888) in Czechoslovakia. Regarding the age of the present assemblage the Bhuj Formation (Ukra Member) is dated 112 ± 15 million years (Srivastava & Rajagopalan, 1985) which covers this assemblage. On the basis of foraminifera Raghavapuram Formation is considered Barremian, similar to Vemavaram and Sriperumbudur formations (Sastry *et al.*, 1977).

10. Weichselia-Onychiopsis-Gleichenia Assemblage Zone

The sediments around the village Bansa (23°36′45″ N : 80°39′20″ E) of Jabalpur Formation in Shahdol District, Madhya Pradesh are marked by richness of pteridophytes and conifers, reduction of cycadophytes and pteridosperms. This plant assemblage is characterized by frequent occurrence of *Weichselia, Onychiopsis, Phlebopteris, Hausmannia, Cycadopteris* and proliferation of *Gleichenia, Araucaria, Allocladus, Brachyphyllum* and *Pagiophyllum* (Bose & Dev, 1960, 1972; Sukh-Dev, 1970; Sukh-Dev & Bose, 1974; Sukh-Dev & Zeba-Bano, 1977).

Age—Early Cretaceous (Aptian-Albian)

Occurrence :

—Jabalpur Formation, Bansa, Shahdol District, Madhya Pradesh.

—Dhrangadhra Formation (Borkar & Chiplonkar, 1973; Kumaran *et al.*, 1983).

—Gardeshwar Formation (Bose *et al.*, 1983).

—Himmatnagar Formation (Banerji *et al.*, 1983).

—Gangapur Formation—Assemblage 2, Andhra Pradesh (Sukh-Dev & Rajanikanth, 1988).

—Athgarh Formation, Orissa (Patra, 1973, 1980).

—Tirupati Formation, Andhra Pradesh.

—Pavalur Formation, Andhra Pradesh.

—Satyavedu Formation, Tamil Nadu.

Remarks—Genus *Weichselia* is an important Early Cretceous plant. In Europe, this genus occurs from Neocomian to Albian. The *Weichselia*-bearing floras are known mostly from Early Cretaceous, then tropical-subtropical regions as southern Europe, Moscow Basin, western Siberia Depression, Chuskhakul Hills, southern Primorye, North America, Peru, Middle East, China, India and Japan (Vakhrameev, 1964; Sukh-Dev, 1970; Kimura & Aiba, 1985). In India *Weichselia* is known from Bansa (Madhya Pradesh), Himmatnagar and Songad (Gujarat).

The Pavalur, Satyavedu and Tirupati formations are considered Aptian on the faunal evidence and their stratigraphical position (Sastry *et al.*, 1977).

11. Azolla Assemblage Zone

The Lameta Group developed near the village Dongargaon in Chandrapur District, Maharashtra has yielded a couple of fertile organs of *Azolla* and some other plant remains.

Age—Late Cretaceous (Maastrichtian).

Remarks—From the Lameta clays near the village Dongargaon in Maharashtra fertile organs of *Azolla* and some fragmentary plant remains have been recovered. The clay samples were collected by Dr S. L. Jain. Spores of *Azolla* (*A. cretacea*) are reported from the Maastrichtian subsurface samples in Cauvery Basin (Venkatachala & Sharma, 1982). *Azolla* is also known from the Deccan Intertrappeans (Sahni, 1941; Trivedi & Verma, 1971). The trap samples overlying the fauna and plant-bearing beds are dated 66.2 ± 3.9 million years (Besse *et al.*, 1985). Thus the age of these Lameta sediments is Maastrichtian. Vertebrates including fish, turtles and dinosaurs have been reported from these sediments indicating a probable continental facies (Berman & Jain, 1982). The presence of *Azolla* plants in the clay beds indicates a fresh-water lacustrine environment.

12. Raphaelia-Piazopteris-Acrostichopteris Assemblage Zone

The plant assemblage from Fukche, Ladakh in Kashmir is constituted by *Raphaelia, Piazopteris, Acrostichopteris, Taeniopteris, Nilssonia, Cycadites, Pterophyllum, Anomozamites, Ptilophyllum* and few other plants (Bose *et al.*, 1983).

Age—Middle-Late Jurassic.

Remarks—The plant assemblage does not resemble any one known from India, Pakistan, Nepal, Bhutan or Sri Lanka. It rather resembles Eurasian flora. Therefore it is treated here separately from the mainstream Indian floras.

DISCUSSION

A study of Indian Mesozoic plant assemblages clearly demonstrates that the Indian Mesozoic flora owes its origin to two stocks; namely the Gondwana Stock and the Eurasia Stock. Most of the elements of the flora are of the Gondwana Stock that flourished in central, western and eastern parts of India and extended into Pakistan, Nepal, Bhutan and Sri Lanka. Contemporary flora of Ladakh (Middle-Late Jurassic) also flourished on the southern edge of Eurasia.

The development of the Mesozoic flora from the Gondwana Stock has been gradual as is evidenced by the rise, climax and fall of *Dicroidium* and its associates. The *Glossopteris* and its associates also disappeared from the scene in Late Triassic. At this time the floral elements in the Indian Triassic, viz., *Marattiopsis, Danaeopsis, Cladophlebis, Sphenopteris, Taeniopteris, Macrotaeniopteris, Pseudoctenis, Pterophyllum, Ginkgoites, Desmiophyllum, Baiera, Pagiophyllum, Elatocladus*, etc. (Assemblages 1, 2, 3 and 4) rapidly underwent the process of diversification and amplification and gained prominence in the Jurassic-Early Cretaceous times (Interestingly, these Triassic elements were also world-wide in distribution, though their representations varied). As the Indian Plate moved from southward towards North and came in close proximity of the European flora, a distinct Indo-European Palaeofloristic Province emerged, extending from Europe via India, South China, Far East to Japan during Jurassic to Early Cretaceous. At that time the European elements like *Thinnfeldia, Cycadopteris, Weichselia*, etc. entered the Gondwana flora of India, through the European, Middle East and closeby African lands and later possibly from Far East on coming closer to these countries. Many plants or plant groups common to both the regions as mentioned above during the Triassic Period developed possibly by homoplasy and later by intermingling of their floras. This Indo-European Palaeofloristic Province had predominant development of Marattiaceae, Osmundaceae, Gleicheniaceae, Matoniaceae, Dipteridaceae, numerous Cycadales, Bennettitales, conifers with scale-like leaves and some ginkgophytes. The exclusive elements of the European flora were members of the family Pinaceae, and that of the Indian flora were members of Podocarpaceae and Pentoxyleae (Pentoxyleae were also present in Australia and New Zealand), whereas Araucariaceae, Taxaceae and possibly Cupressaceae were common to both the floras. Palaeogeographically this flora flourished in the tropical to subtropical climate. The xeric characters of the plants are indicated by the presence of small dissected leaves, thick cuticle, leathery texture of leaves with sunken stomata, hairs and papillae. The dry conditions are also exhibited by the presence of red beds in the Indo-European Palaeofloristic Province. Thus the Jurassic-Early Cretaceous flora of India contains a mixture of European as well as Gondwana elements. Precise determination of the Gondwanic and European elements in the mixed floras poses a big problem as identifications in several cases are doubtful and the floras are not adequately known. Therefore it is necessary to study the mixed floras in depth, keeping in mind the palaeogeographic position of the plates affecting global migration of floras before a tangible conclusion can be drawn on the Gondwanic and non-Gondwanic elements in the Indian flora.

By the end of Early Cretaceous the complexion of the Indo-European Palaeofloristic Province distinctly changed. A large majority of the elements of this flora suddenly vanished and paved a way for the rise and spread of the angiosperms. The Late Cretaceous flora of India then assumed a new

dimension, leading to the development of the modern flora. It is interesting to note that this flora has continued to maintain its Indo-European heritage till today, i.e., it has the following families still growing in India: Lycopodiaceae, Selaginellaceae, Isoetaceae, Equisetaceae, Marattiaceae, Osmundaceae, Matoniaceae, Dipteridaceae, Gleicheniaceae, Aspidaceae, Cyatheaceae, Dicksoniaceae, Dennstaedtiaceae, Schizaeaceae and Azollaceae among pteridophytes: Cycadaceae (*Cycas*) among cycadophytes; Podocarpaceae (*Podocarpus*) and Cupressaceae (*Cupressus* and *Juniperus*) among conifers; and Taxaceae (*Taxus*) among taxads.

A restudy of the Indian Mesozoic flora clearly shows that it has been recovered from the continental, marine and transitional strata of the so-called 'Gondwana'. This prompts me to review the original definition of the 'Gondwana' according to which these sediments were laid under continental conditions (fluvitiale/lacustrine). Subsequently several marine intercalations have also been included in the Gondwana System expanding its original concept to a degree of its being untenable. Therefore, it is concluded that the term 'Gondwana' be replaced by the chronostratigraphic units, viz., Triassic, Jurassic, and Cretaceous for the Indian Gondwanic sediments.

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