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Stratigraphic implication of 'Late Gondwana' floras in the East Coast

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The Cauvery, Palar, Krishna-Godavari and Mahanadi basins in the East Coast of India include coeval, paralic, lagoonal and deltaic Mesozoic ('Late Gondwana') deposits distributed in detached outcrops. The 'Ptilophyllum Flora' characterising these sediments was earlier considered Jurassic in age. Considerable floristic and stratigraphic data have accrued necessitating a relook on earlier age assignments and stratigraphic placements. Biostratigraphic evidences considered *in toto* suggest an Early Cretaceous age to the flora found in these sediments. Sedimentation of these sediments is attributed to rifting of Indian Plate coupled with a reactivation phase. It is recommended that the term 'Gondwana' should either be recircumscribed to include marine coastal sediments or discontinued in favour of usage of chronostratigraphic terminology.

Key-words—Stratigraphy, 'Late Gondwana' Flora, East Coast, Early Cretaceous (India).

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सारांश

पूर्व तट में 'अनंतिम गोंडवाना' वनस्पतिजातों का स्तरिक महत्त्व

बेंगलूर श्रीनिवासा वेंकटाचाला एवं अन्नमराजु रजनीकान्थ

भारत के पूर्व तट में कावेरी, पलार, कृष्णा-गोदावरी एवं महानदी द्रोणीयों में तटांचली, समकालीन, लैगूनी एवं डेल्टीय मध्यजीवी ('अनंतिम गोंडवाना') निक्षेप विद्यमान हैं जो कि अलग-अलग दृश्यांशों में वितरित हैं। इन अवसादों को अभिलक्षणित करने वाले 'टाइलोफ़िल्लम् वनस्पतिजात' की आयु पहले जूराई मानी गयी थी। परन्तु पर्याप्त उपलब्ध वनस्पतिजातीय एवं स्तरिकीय आँकड़ों के कारण अब इनकी आयु एवं इनके स्तरिक स्थान पुनः विचारणीय हैं। समस्त जैवस्तरिकीय प्रमाणों से इन अवसादों में उपलब्ध वनस्पतिजात की प्रारम्भिक क्रीटेशी आयु इंगित होती है। इन अवसादों के अवसादन से भारतीय प्लेट का विस्थापन इंगित होता है। यह भी प्रस्तावित किया गया है कि 'गोंडवाना' नामक शब्द समुद्री तटीय अवसादों के लिए परिसीमित अथवा कालानुक्रमिक शब्दों के लिए प्रयुक्त नहीं किया जाना चाहिये।

FLUVIAL-LACUSTRINE successions ranging in age from Upper Palaeozoic to Jurassic in the peninsular India were termed "Gondwana" by Medlicott in 1872. The term appeared in print only in 1876 (Feistmantel, 1876). These are characterised by conglomerates, sandstones, shales and coal measures (Fox 1931). The upper limit of the 'Gondwana' Sequence and the nomenclature of spatially extended occurrence of these deposits in the East Coast of India is debatable. Thin marine beds discovered along the East Coast were considered as marine intercalations in the 'Late Gondwana'. These deposits include coeval, paralic, lagoonal Mesozoic sediments distributed in detached outcrops parallel to the shoreline. An analogy between the east coast sedimentary basins

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and those on the west coast of Australia has been observed by Sastry *et al.* (1974) on the basis of faunal and palynological comparisons.

The 'Ptilophyllum Flora' characterises the east coast sediments and has been traditionally considered Jurassic in age. Considerable floristic and stratigraphic data has accumulated, which necessitates a reassessment of earlier age assignments and stratigraphic placements. Additional records of Lower Cretaceous marine sediments have been reported from shallow, structural and deep wells drilled by the ONGC (Sastry *et al.*, 1974, 1975, 1981; Rao & Venkatachala, 1971; Venkatachala & Sinha, 1986). An objective analysis of this data demonstrates that the quantitative differentiation and age assignments based on megaflora are not tenable for east coast sediments.

The east coast 'Late Gondwana' sediments are distributed in Cauvery, Palar, Krishna-Godavari and Mahanadi basins. The ecological regimes of these sediments vary from nonmarine to paralic through marginal marine environments (Murthy & Sastry, 1961, 1962; Sastry & Mamgain, 1971; Venkatachala & Sinha, 1986). These represent a transition zone where continental and marine facies interdigitate. Palynological evidences suggest an environmental realm consisting of 'upland flora' characterised by allochthonous saccate gymnosperm pollen; autochthonous swampy environments marked by non-saccate palynoassemblage and phytoplankton denoting marine environments in Early Cretaceous sequence of the Krishna-Godavari Basin (Venkatachala & Sinha, 1986). This is also true with regard to the other basins under discussion (Venkatachala, 1977). Consequent to this observation the noticeable differences in the floral composition (Ferns/Cycadophytes/Conifers) of different basins have to be reassessed to understand the depositional environment and stratigraphic implications. A comparative analysis of mega- and palynofloral records from the sediments confirms an Early Cretaceous age. An overview and assessment of east coast 'Late Gondwana' floras help understand geological and climatic factors involved.

CAUVERY BASIN

Sivaganga Formation

'Late Gondwana' deposits occur near and around Uttatur, Terani, Naicolam, Karai, Rayani, Kattipuliyar and Sivaganga areas. The Sivaganga Formation, which is considered to be the southern most 'Late Gondwana' unit, comprises coarse pebbly and gritty sandstones. The subsurface facies equivalents comprise paralic shales and argillaceous sandstones. This formation underlies the well-known marine Upper Cretaceous fossiliferous sequences. Some thin beds within this formation contain plant fossils, arenaceous foraminifera and ostracods.

Megaflora—Megaflora has been studied by Feistmantel (1879), Gopal, Jacob and Jacob (1957), Chowdhury (1958), Mamgain, Sastry and Subbaraman (1973), Ayyaswami and Gururaja (1977), Jeyasingh and Sudhersan (1985) and Maheshwari (1986). Cycadophytes constitute the dominant group followed by conifers and ferns. The flora is characterised by *Marattiopsis, Taeniopteris, Thinnfeldia, Anomozamites, Ptilophyllum, Otozamites, Dictyozamites; Elatocladus, Brachyphyllum, Ginkgoites* and *Araucarites* (Table 1). The megafloral assemblage has been variously dated as Middle-Upper Jurassic (Feistmantel, 1879; Gopal, Jacob & Jacob, 1957; Bose, 1966). Studies by Ayyaswami and Gururaja (1977) and Maheshwari (1986) suggest an Early Cretaceous affinity.

Blanford (1862) remarked that the Uttatur plant beds appeared both on stratigraphical and lithological grounds "....to be not very widely separated in time from Cretaceous rocks immediately overlying them". Later, Chowdhury (1958) suggested that "...the plant beds are homotaxial with the Jabalpur—Tirupati group" These suggestions veer round a Lower Cretaceous age assignment.

Palynoflora—Palynology of subsurface sediments are known through the studies of Rao and Venkatachala (1971), Venkatachala *et al.* (1972) and Venkatachala (1973, 1974). Maheshwari (1986) also recorded some palynotaxa. The *Microcachryidites antarcticus* Zone (Neocomian) is recognised in the Karaikal, Karaikudi, Nagapattinam, Tirutturaipundi and Vridhachalam areas. This palynoflora comprises distinct markers such as *Cooksonites, Neoraistrickia, Aequitriradites, Polycingulatisporites, Impardecispora, Staplinisporites, Ischyosporites, Crybelosporites, Klukisporites* and *Contignisporites* (Table 2). Palynological evidences recorded in the subsurface of the Sivaganga area, as evidenced by a study of subsurface sequence met within the Karaikudi well, confirm marine influence during the Early Cretaceous.

Fauna—Mamgain, Sastry and Subbaraman (1973) recorded ammonites such as *Gymnoplites* cf. *simplex* Spath, *Pascoites* cf. *crassus* Spath and *?Inoceramus* sp. from the Terani beds. Venkatachala (1977) lists *Ammodiscus cretaceous, Ammobaculites humei, Spiroplectammina* sp., *Haplophragmoides sluzari* and *Bathysiphon taurinensis.* Arenaceous foraminifera like *Ammobaculites, Ammodiscus, Bathysiphon, Haplophragmoides* and *Trachammina*

Table 1—Distribution of megaflora

Taxa	Cauvery Sivaganga	Palar		Krishna-Godavari		Mahanadi Athgarh
		Sriperumbudur	Satyavedu	Krishna Depression	Godavari Depression	
	1	2a	2b	3a	3b	4
PTERIDOPHYTES						
Cladophlebis	sp.		sp.	sp.	sp.	sp.
C. indica	+	+	+	+	–	+
C. srivastavae	+	–	–	–	–	+
C. reversa	+	–	–	–	–	–
C. whitbyensis	–	+	–	+	+	+
C. denticulata	–	–	–	–	–	+
Sphenopteris	sp.	–	–	–	sp.	sp.
S. tiruchirapalliense	+	–	–	–	–	–
Onychiopsis paradoxus	–	–	–	–	–	+
Coniopteris	–	–	–	–	–	sp.
Rhizomopteris	sp.	–	–	–	–	–
R. balli	–	–	–	–	–	+
Marattiopsis macrocarpus	+	–	–	–	–	+
Phlebopteris athgarhensis	–	–	–	–	–	+
P. polypodioides	–	–	–	–	–	+
Gleichenia	–	–	–	–	–	sp.
G. gleichenoides	–	–	–	–	–	+
G. nordenskioldii	–	–	–	–	–	+
Hausmannia	–	–	–	–	–	sp.
Eboracia	–	–	–	–	–	sp.
Equisetites	sp.	–	sp.	–	–	sp.
PTERIDOSPERMS						
Cycadopteris	–	–	–	–	–	sp.
Pachypteris	–	–	–	–	–	sp.
P. ellorensis	–	–	–	+	–	–
Thinnfeldia	–	sp.	–	sp.	–	sp.
T. indica	+	–	–	–	–	–
T. subtrigona	–	–	–	–	+	–
T. feistmantelii	–	–	–	–	+	–
CYCADOPHYTES						
Taeniopteris	sp.	–	sp.	–	–	–
T. spatulata	+	+	+	+	+	+
T. ovata	+	–	–	–	–	–
T. lata	+	–	–	–	–	–
T. mcClellandii	–	+	–	+	+	–
T. ensis	–	–	–	+	–	–
Anomozamites	sp.	–	sp.	–	sp.	–
A. haburensis	+	–	–	–	–	–
A. lindleyanus	–	+	–	–	–	–
A. fissa	+	–	–	–	–	+
Pterophyllum	sp.	sp.	–	sp.	sp.	–
P. footeanum	–	+	–	–	+	–
P. morrisiana	+	–	–	+	–	–
P. carterianum	–	–	–	+	–	–
P. kingianum	–	–	–	+	–	–
P. distans	–	–	–	+	–	–
Ptilophyllum	sp.	–	–	sp.	sp.	–
P. acutifolium	+	+	+	+	+	+
P. cutchense	+	+	–	+	+	+
P. rarinervis	+	–	–	+	–	–
P. tenerrimum	–	–	–	+	–	–
Dictyozamites	–	sp.	sp.	–	–	–
D. indica	+	–	–	+	+	–
D. falcatus	+	–	–	+	+	–
D. feistmantelii	+	–	–	–	+	–

Contd.

D. sahnii	–	–	–	–	+	–
Otozamites	–	–	–	–	sp.	sp.
O. angustatus	+	–	–	–	–	–
O. rarinervis	+	+	–	+	+	–
O. exhislopii	–	–	–	–	+	–
O. vemavaramensis	–	–	–	–	+	–
O. gondwanaensis	–	–	–	–	+	–
Cycadites	–	–	–	–	sp.	–
Cycadolepis	–	–	–	sp.	sp.	sp.
Williamsonia	–	–	–	sp.	–	–
W. blanfordii	–	–	–	+	–	–
W. gigas	–	–	–	+	–	–
Pseudoctenis	sp.	–	–	–	–	–
P. footeana	+	–	–	–	+	–
Bucklandia	–	–	–	sp.	–	–
CONIFERALES						
Elatocladus	–	–	–	–	sp.	sp.
E. plana	+	+	–	+	+	–
E. tenerrima	+	+	–	+	–	–
E. conferta	+	+	–	+	–	+
Pagiophyllum	sp.	–	–	–	sp.	sp.
P. marwarensis	+	–	–	–	–	–
P. peregrinum	–	+	–	+	+	–
Brachyphyllum	sp.	–	sp.	–	–	sp.
B. regularis	+	–	–	–	–	–
B. rhombicum	–	+	–	+	–	–
B. rajmahalensis	–	+	–	–	–	–
B. feistmantelii	–	–	–	+	+	–
Araucarites	–	–	–	–	–	sp.
A. cutchensis	+	+	–	–	+	+
A. minutus	+	+	–	–	–	+
A. macropterus	–	+	–	+	–	cf.
Podozamites lanceolatus	+	–	–	+	–	+
Desmiophyllum	sp.	–	–	–	sp.	–
Conites	–	–	–	sp.	sp.	–
C. sessiles	–	+	–	–	+	–
C. sripermaturensis	–	+	–	–	–	–
C. verticillatus	–	+	–	–	–	–
Torreyites constricta	–	–	–	–	+	–
Araucarioxylon rajmahalense	–	+	–	–	–	–
A. agathioides	–	–	–	+	–	–
Podocarpoxylon parthasarathyi	–	+	–	–	–	–
P. tirumangalense	–	+	–	–	–	–
Cupressinoxylon coromandelinum	–	+	–	–	–	–
C. alternans	–	–	–	+	–	–
GINKGOALES						
Ginkgoites	sp.	sp.	–	sp.	–	–
G. rajmahalensis	cf.	–	–	–	–	–
G. crassipes	–	+	–	+	+	–
G. feistmantelii	–	–	–	+	–	–
Baiera	–	–	–	–	–	sp.

(+) Present; (–) Absent; (sp.) Species not attributed; (cf.) Comparable form

were recorded by Banerji and Sastry (1979). Banerji (1982) reported some arenaceous foraminifera from the Sivaganga Formation which include *Lituola* sp., *Miliammina* sp., *Pelosina* sp., *Polychasmina* sp., *Pseudoreophax* sp., *Saccamina* sp. and *Textularia* sp. These evidences ascribe an Early Cretaceous age.

Dalmiapuram Formation

This formation succeeds Sivaganga Formation and comprises a sequence of marine limestones with intervening shales containing ammonoids, foraminifera, ostracods and palynofossils (Banerji, 1972; Bhatia & Jain, 1969; Jain, 1968; Jain, 1977; Venkatachala, 1972). Plant megaflora is not known.

Palynoflora—The palynoflora is known through the studies of Jain and Subbaraman (1969), Rao and Venkatachala (1971), Venkatachala *et al.*, 1972; Jain and Taugourdeau Lantz (1973) and Jain (1977). Rich and diversified phytoplankton known from this

Table 2—Distribution of palynoflora

Taxa	*Cauvery*	*Palar*	*Krishna-Godavari*	*Mahanadi*
Cyathidites australis	+	+	+	+
C. minor	+	+	+	+
C. punctatus	–	–	+	–
C. pseudopunctatus	–	–	+	–
C. cutchensis	–	–	+	–
C. trilobatus	–	–	+	–
C. jurassicus	–	–	+	–
C. asper	–	–	cf.	–
C. cancavus	–	–	–	+
Deltoidospora	Sp.	–	Sp.	Sp.
D. haltiminor	+	–	–	–
D. rhytisma	+	–	–	–
D. juncta	–	+	–	–
D. diaplana	–	+	–	–
Stereisporites antiquasporites	+	+	+	–
Biretisporites	sp.	sp.	+	–
B. spectabilis	+	+	+	–
B. potoniaiae	–	+	cf.	–
Concavisporites	sp.	–	–	–
C. juriensis	+	–	–	–
C. cutchensis	–	+	–	–
Leptolepidites	sp.	–	sp.	–
L. major	–	–	–	–
L. verrucatus	–	+	–	–
Triletes	–	–	–	sp.
T. verrucosus	+	+	+	–
T. tuberculiformis	+	+	–	–
T. orikkaiense	–	+	–	–
T. grandiverrucosus	–	–	+	–
T. rugosus	–	–	+	–
Osmundacidites	sp.	–	–	–
O. singhii	–	+	–	–
O. wellmanii	–	+	+	+
Baculatisporites comaumensis	+	+	–	–
B. claveoides	–	+	–	–
B. baculatus	–	+	+	–
Concavissimisporites	sp.	–	sp.	–
C. veriverrucatus	–	+	–	–
C. crassatus	–	–	–	+
Impardecispora	–	–	–	sp.
I. purverulentus	+	–	+	–
I. apiverrucata	–	+	–	+
I. trioreticulosus	–	+	+	–
I. marylandensis	–	+	–	–
I. tribotrys	–	–	+	–
Neoraistrickia	sp.	–	–	sp.
N. truncatus	+	+	+	–
Ceratosporites	sp.	sp.	–	–
C. acutus	+	–	+	–
C. equalis	+	+	+	–
C. couliensis	–	+	–	–
Foveotriletes	sp.	–	–	–
F. crassipunctatus	–	–	+	–
Lycopodiumsporites eminulus	+	+	+	–
L. austroclavatidites	+	+	+	+
L. reticulumsporities	+	–	–	–
L. sp. cf. *trambauensis*	–	+	–	–
L. reticulum	–	–	+	–
L. regulatus	–	–	+	–
L. crassireticulatus	–	–	+	–
L. circolumeus	–	–	+	–
Lycopodiacidites	sp.	–	–	–

Contd.

Klukisporites	sp.	–	–	–
K. scaberis	+	–	+	–
K. faveolatus	–	+	–	–
K. areolatus	–	+	–	+
K. pseudoreticulatus	–	–	–	+
Staplinisporites caminus	+	+	+	–
Converrucosisporites	sp.	sp.	–	–
Laevigatosporites	sp.	–	–	sp.
Corrugatisporites	sp.	–	–	–
Lygoditites laevigatus	+	–	–	–
Pilosisporites	sp.	sp.	–	–
Cicatricosisporites	sp.	–	–	–
C. hughesii	+	–	+	–
C. metrioides	–	+	–	–
C. ludbrookei	+	+	–	–
C. australiensis	+	+	+	–
C. hallei	–	+	–	–
C. augustus	–	+	–	–
C. gonidontos	–	+	–	–
C. apicaulis	–	+	–	–
C. mohriodes	–	+	–	–
Matonisporites	sp.	sp.	sp.	–
M. phlebopteroides	–	+	–	–
M. crassiangulatus	–	+	–	+
M. discoidalis	–	+	–	–
M. cooksonae	–	+	–	–
M. sahnii	–	+	–	–
Ischyosporites crateris	+	+	+	+
I. punctatus	–	+	–	–
Gleichenidites	sp.	sp.	sp.	–
G. senonicus	–	+	+	–
G. circinidites	–	+	–	+
Clavifera	sp.	sp.	–	–
Appendicisporites	–	sp.	–	–
A. sp. cf. *A. tricornitatus*	+	–	–	–
A. sp. cf. *A. irregularis*	+	–	–	–
A. verrucosa	–	+	–	–
A. sellingii	–	–	+	–
Taurocusporites	sp.	–	–	–
T. segmentatus	–	+	–	–
Plicifera	sp.	–	–	–
P. minutus	–	+	–	–
P. senonicus	–	–	+	–
Cingulatisporites	sp.	–	–	–
Coptospora	sp.	sp.	–	–
C. cauveriana	+	+	–	–
C. kutchensis	–	+	–	–
Contignisporites	sp.	sp.	–	–
C. glebulentus	+	+	+	+
C. multimuratus	+	+	+	–
C. cooksonii	+	+	+	–
C. fornicatus	+	–	+	+
C. crenatus	–	+	–	–
C. dorsostriatus	–	+	–	–
C. problematicus	–	+	–	–
Kraeuselisporites linearis	+	+	+	–
Psilospora	sp.	–	–	–
Polycingulatisporites roduncus	+	+	+	–
Crybelosporites stylosus	+	–	+	–
C. punctatus	–	+	–	–
Densosporites	–	sp.	–	–
D. velatus	+	–	+	–
D. indicus	–	–	–	+
Monoletes	–	sp.	–	–
M. indicus	–	+	–	+
M. grandis	+	–	–	–

Contd.

M. intragranulatus	–	+	–	–
Thymospora	sp.	–	sp.	–
Cooksonites	sp.	sp.	–	–
C. variabilis	–	+	+	–
Aequitriradites	–	sp.	–	–
A. spinulosus	+	+	+	–
Polypodiisporites	sp.	–	sp.	–
Callialasporites trilobatus	+	+	+	+
C. lenticularis	+	–	–	–
C. triletes	+	+	+	+
C. segmentatus	+	+	+	+
C. dempieri	+	+	+	+
C. monoalasporus	+	–	+	–
C. kattavakuamense	–	+	–	–
C. reticulatus	–	+	–	–
C. discoidalis	–	+	–	+
C. punctatus	–	+	–	–
C. lucidus	–	–	+	+
C. doeringii	–	–	–	+
C. enigmatus	–	–	–	+
Cornamessifera	sp.	–	–	–
Coronatispora	sp.	sp.	–	–
C. perforata	–	+	–	–
Sestrosporites	sp.	–	–	–
S. pseudoalveolatus	–	+	–	sp.
Auritulinasporites	sp.	–	–	–
Tripartina	sp.	–	–	–
Undulatisporites pannuceus	–	+	–	–
Dictyophyllidites	–	–	–	sp.
D. venkatachalae	–	+	–	–
D. harrisii	–	–	–	+
Todisporites rotundiformis	–	+	–	–
T. crassus	–	+	–	–
T. minor	–	+	–	+
Echinatisporis varispinosus	–	+	–	–
E. vembanii	–	+	–	–
Foveosporites	–	sp.	–	–
F. canalis	–	+	–	–
F. subtriangularis	–	+	–	–
Dictyosporites complex	–	+	–	–
Callispora faveolata	–	+	–	–
C. potoniei	–	+	–	–
Ornamentifera	–	–	–	sp.
O. echninata	–	+	–	–
O. granulosa	–	–	+	–
Murospora sp. cf. *mesozoica*	–	+	–	–
M. florida	–	–	+	–
Verrucosisporites	–	–	–	sp.
V. rotundus	–	+	–	–
Foraminisporis cf. *dailyi*	–	+	–	–
Distalanulisporites verrucatus	–	+	–	–
Crassimonoletes	–	–	–	sp.
C. surangei	–	+	–	–
Metamonolites haradensis	–	+	–	–
Bbujiasporites	–	–	sp.	–
Conbacculatisporites densibaculatus	–	–	+	–
Boseisporites	–	–	sp.	–
B. praeclarus	–	–	–	+
Vitreisporites	sp.	–	–	sp.
V. pallidus	+	+	+	+
Lametatriletes indicus	–	–	–	+
Dettmannites	–	–	–	sp.
Reticulatisporites pudens	–	–	–	+
Alisporites	sp.	–	–	sp.
A. grandis	+	+	–	+

Contd.

A. ovalis	–	+	–	+
A. rotundus	–	+	–	–
A. ellipticus	–	–	+	–
Podocarpidites ellipticus	+	+	–	+
P. multesimus	+	–	+	–
P. major	–	+	–	–
P. minisculus	–	+	–	–
P. grandis	–	–	+	–
P. crisilleximus	–	–	+	–
P. typicus	–	–	+	–
P. magnus	–	–	–	+
P. novus	–	–	–	+
Microcachryidites	sp.	–	–	–
M. antarcticus	+	+	+	+
Podosporites tripakshii	+	+	+	+
P. raoi	–	–	+	–
Classopollis	sp.	sp.	–	–
C. classoides	+	+	+	+
C. obidonensis	–	+	–	–
C. torosus	–	–	+	–
C. indicus	–	–	–	+
Cedripites nudis	+	+	–	+
C. cretaceous	–	+	–	–
Parvisaccites	sp.	–	–	–
Ginkgocycadophytes	–	–	–	sp.
G. asymmetricus	–	–	+	–
G. detritus	–	–	+	–
G. nitidus	+	+	–	–
G. srivastavae	–	–	+	–
Araucariacites	sp.	–	–	–
A. australis	+	+	+	+
A. ghuneriensis	–	–	–	+
Spheripollenites scabratus	+	+	+	–
S. psilatus	+	–	–	–
Phyllocladidites	–	–	sp.	–
Ramanujamiaspora reticulata	–	–	+	–
Leschikiasporis rudis	–	–	+	–
Singhiapollis triletes	–	–	+	–
S. rudis	–	–	+	–
Indusiisporites microsaccatus	–	–	+	–
Inaperturopollenites	–	–	–	sp.
Araucariapollenites	–	–	–	sp.
Platysaccus densus	–	+	–	–
Phyllocladites inchoatus	–	+	–	–
Dacrycarpites australiensis	–	+	–	–
Laricoidites commiensis	–	+	–	–
L. indicus	–	+	+	–
Granuloperculatipollis	–	sp.	–	–
G. subcircularis	–	–	+	–
G. triletus	–	–	+	–
G. flavatus	–	–	+	–
Schizosporis regulatus	–	+	–	–
Properinopollenites monoalasporus	–	–	–	+
Sehoripollenites	–	–	–	+
Abiespollenites	–	–	–	+
Cycadopites couperii	–	+	–	+
C. gracilis	–	+	–	–
C. sakrigaliensis	–	+	–	–

(+) Present; (–) Absent; (sp.) Species not attributed; (cf.) Comparable form.

formation suggest an Early Albian age (Jain, 1977). The palynoflora is assigned to *Coptospora cauveriana* Zone of Aptian—Early Albian age (Venkatachala *et al.*, 1972). It is characterised by *Ceratosporites, Coptospora, Cooksonites, Aequitriradites, Staplinisporites, Foveotriletes, Sestrosporites, Krauselisporites, Foveosporites, Baculatisporites, Klukisporites, Ischyosporites, Trilites, Impardecispora, Polypodiaceoisporites, Appendecisporites, Pilosisporites, Polycingulati-*

sporites, Contignisporites, Crybelosporites, Podosporites and *Classopollis* (Table 2). The occurrence of *Classopollis* and corroded nature of spore and pollen suggest long transportation of palynofossils before deposition. A marine depositional environment is ascribed on the basis of phytoplankton and foraminifera. Foraminiferal evidences suggest that the depositional environment was marine and the depositional site was probably away from the main continental landmass.

Fauna—Rich foraminiferal assemblages recovered from this unit help recognise different biozones like *Lenticulina macrodisca* Zone and *Hedbergella planispira* Zone (Banerji, 1972). They ascribe Aptian—Early Albian and Early Albian age (Jain, 1968; Bhatia & Jain, 1969; Banerji, 1972). Significant fauna include *Lytoceras, Puzosia, Pascoeites, Engonoceras* (ammonoids) and *Lenticulina, Trestix, Gavelinella, Vagunilina, Nodosaria, Gavellinopsis* and *Glandolina* (foraminifers) (Jaikrishna, 1983). Trace fossil *Chondrites* Sternberg was also recorded (Chiplonkar & Tapaswi, 1975).

PALAR BASIN

Sriperumbudur beds

These are characterised by arenaceous and argillaceous rock units comprising splintery green shale, clays and sandstones with ironstone intercalations and unconformably overlaying either the Precambrian basement or Permian boulder beds and green shales. The beds contain marine intercalations (Murthy & Sastri, 1961). Their lithologic suites and fossil fauna are suggestive of deposition under shallow and brackish conditions, probably close to the shoreline (Sastry *et al.*, 1974).

Megaflora—The megaflora comprises species of *Cladophlebis, Dictyozamites, Taeniopteris, Pterophyllum, Otozamites, Ptilophyllum, Elatocladus, Brachyphyllum, Araucarites, Conites, Ginkgoites* and some conifer woods (Feistmantel, 1879; Seward & Sahni, 1920; Sahni, 1928, 1931; Suryanarayana, 1954, 1955). The floral assemblage in general is dominated by conifers followed by cycadophytes and ferns. Pteridosperms and Ginkgoales are poorly represented (Table 2). Foote (1868) compared Sriperumbudur megaflora with that of Rajmahal. A Jurassic affinity to this flora was also suggested (Feistmantel, 1879).

Palynoflora—Palynoflora is known both from surface and subsurface (Ramanujam & Srisailam, 1974; Ramanujam & Varma, 1977, 1981; Venkatachala, 1977; Varma & Ramanujam, 1984). The characteristic fossils include *Aequitriradites, Coptospora, Cooksonites, Foraminisporis, Staplinisporites, Sestrosporites, Ornamentifera, Klukisporites, Impardecispora, Cicatricosisporites, Appendicisporites, Contignisporites, Undulatisporites, Coronatispora, Polycingulatisporites, Taurocusporites, Crybelosporites, Murospora* and *Microcachrydites* (Table 2). Sriperumbudur palynoflora shows significant resemblance with the Early Cretaceous palynoflora from Cauvery and Krishna-Godavari basins.

Fauna—Murthy and Sastry (1961) recorded an Early Cretaceous fauna consisting of ammonite *Pascoites crassus* and foraminifera—*Pelosina complaneta, Haplophragmoides concava, H. footei, H. indicus, Bathysiphon* cf. *taurinensis, Ammodiscus cretaceous, Lituotuba* sp. and *Spiroplectammina indica.*

Satyavedu beds

These overlie the Sriperumbudur beds and are characterised by grits, sandstones and conglomerates. Fragmentary plant fossils are recorded which include *Equisetites, Cladophlebis, Taeniopteris, Nilssonia, Ptilophyllum, Dictyozamites, Elatocladus* and *Brachyphyllum* (Murthy & Ahmed, 1971; Sastry *et al.*, 1977). Faunal and palynological records are wanting. These beds are often correlated with Tirupati and Pavalur beds of Krishna-Godavari Basin.

KRISHNA-GODAVARI BASIN

'Late Gondwana' sediments in this basin are mainly exposed near the western fringes of the Krishna and West Godavari depressions. These unconformably overlie either the Precambrian basement or Permian sediments. These sediments contain few plant and animal fossils. Data derived through surface and subsurface sediments from wells drilled by ONGC suggest that the tripartite classification in the outcrop is not tenable in the subsurface and the respective units are probably lithofacial variants of major argillaceous sequence (Venkatachala & Sinha, 1986).

Krishna Depression

This includes three lithologic units, viz., Budavada Sandstone, Vemavaram Shale and Pavalur Sandstone. The Budavada Sandstone comprises sandstones on the surface and mostly shales in the subsurface. These contain both plant and marine invertebrate fossils. Plant megaflora mainly comprises *Taeniopteris, Otozamites, Dictyozamites, Ptilophyllum* and some conifer woods (Sastry *et al.*,

1977). Marine fossils include ammonites *Pascoeites budavadensis, Gymnoplites simplex* and associated foraminifera, bryozoans, lamellibranchs, gastropods and brachypods (Sastry *et al.*, 1977). These indicate an Early Cretaceous age (Spath, 1933; Sahni, 1960; Bhalla, 1969). Wells drilled on the outcrops of Budavada unit near Nutalapadu and Inkollu yielded shale sections similar to other equivalent units within the basin (Venkatachala & Sinha, 1986). This unit is often correlated with Gollapalli unit in West Godavari depression and Athgarh Sandstone in Mahanadi Basin.

The Vemavaram Shale comprises light grey shales. The subsurface sediments in Uppugunduru well comprise sandstones and silty shales. The plant fossils include *Cladophlebis, Thinnfeldia, Taeniopteris, Ptilophyllum, Otozamites, Elatocladus, Brachyphyllum* and *Araucarites* (Feistmantel, 1879; Seward & Sahni, 1920; Sahni, 1928; Suryanarayana, 1954; Rao, 1959; Bose & Jain, 1967; Jain, 1968; Bose, 1974; Bose & Bano, 1978). This assemblage, dominated by cycadophytes followed by conifers and pteridophytes, has been compared with the Sriperumbudur flora and was considered as Jurassic in age (Feistmantel, 1879). Palynoflora was studied by Ramanujam (1957) and Kar and Sah (1970) and a reassessment suggests an Early Cretaceous age. Animal remains from Vemavaram Shale were identified by Spath (1933) and consist of ammonites, brachipods, lamellibranchs, fish scales and mammalian ribs. The evidences considered *in toto* confirm Early Cretaceous age assignment.

The Pavalur Sandstone conformably overlies the Vemavaram Shale and is composed of sandstones and has been correlated with Tirupati Sandstone in the West Godavari depression. Fossil records are wanting.

West Godavari Depression

'Late Gondwana' sediments are once again represented by three units, viz., Gollapalli Sandstone, Raghavapuram Shale and Tirupati Sandstone. The Gollapalli Sandstone unconformably overlies the Chintalpudi Sandstone and underlies unconformably the Raghavapuram Shale. It comprises sandstones, grits and conglomerates with thin clay intercalations containing plant fossils and arenaceous foraminifera. Some of the important plant fossils include *Gleichenia, Marattiopsis, Pachypteris, Ptilophyllum, Dictyozamites, Taeniopteris, Pterophyllum, Williamsonia, Elatocladus* and *Araucarites* (Table 1) (King, 1880; Feistmantel, 1877a; Sahni, 1928; Sarma, 1957; Baksi, 1964; Mahabale & Satyanarayana, 1979). While discussing the tectonics, sedimentation and marine transgression in this sub-basin, Baksi (1977) inferred a marginal marine to fluvial environment to Gollapalli Sandstone.

The Raghavapuram Shale is characterised by white and buff shales, sandstones, variegated and purplish arenaceous shales. Due to lack of fissility in these rocks the term shale has been replaced by mudstone (Baksi, 1967a).

Megaflora chiefly comprises *Cladophlebis, Taeniopteris, Williamsonia, Ptilophyllum, Otozamites, Dictyozamites, Ginkgoites, Brachyphyllum, Elatocladus* and *Araucarites* (Table 1) (Feistmantel, 1879; Seward & Sahni, 1920; Sahni, 1931; Baksi, 1967a, 1967b). This assemblage was considered Jurassic (Feistmantel, 1879).

Arenaceous foraminifera dominated by *Ammobaculites* associated with *Haplophragmoides* suggest an Early Cretaceous age (Baksi, 1966; Sastry *et al.*, 1963; Bhalla, 1969a, 1972). Other fossils include fish scales and molluscs.

The Tirupati Sandstone comprises clayey, friable and lateritised sandstones. In the subsurface it consists of shales and sandstones. These contain fragmentary plant remains and marine invertebrate fossils like *Holocoleras, Trigonia ventioxa, T. smeei, Pseudomonotis, Limia pecten, Belemnite* and considered to be of Aptian age (Sastry *et al.*, 1977).

Palynological studies from the subsurface sequences from different wells drilled throughout the basin indicate Neocomian-Aptian age (Sastry *et al.*, 1977; Venkatachala & Sinha, 1986). Palynoassemblages encountered in the Krishna-Godavari Basin are enumerated in Table 2. The important fossils include *Staplinisporites, Contignisporites, Triletes, Impardecispora, Crybelosporites, Appendicisporites, Aequitriradites* and *Microcachryidites.*

It may be concluded that the tripartite classification of the exposed 'Late Gondwana' sediments in the Krishna-Godavari Basin is not tenable as the three lithological units identified in the outcrops give place to major argillaceous sequence in the near subsurface and indicate an Early Cretaceous age (Venkatachala & Sinha, 1986). Both palynological and faunal evidences support this age assignment. The major palaeoecological regimes deduced from these evidences indicate nonmarine-paralic through swampy environments.

MAHANADI BASIN

Athgarh Sandstone of 'Late Gondwana' affinity, exposed near the western margin of the basin, consists mainly of white to grey, hard sandstones with intercalations of lenticular greyish-white to pinkish clays and carbonaceous shales bearing plant megafossils.

Megaflora—Some important taxa include *Marattiopsis, Gleichenia, Phlebopteris, Cladophlebis, Eboracia, Hausmannia, Cycadopteris, Onychiopsis, Anomozamites, Ptilophyllum, Araucarites* and *Brachyphyllum* (Table 1) (Feistmantel, 1877b; Adyalkar & Rao, 1963; Jain, 1968; Pandya & Patra, 1968; Patra, 1973, 1980; Patra & Patnaik, 1974). Predominance of pteridophytes helps to compare this with other known Early Cretaceous assemblages of western and central India.

Palynoflora—Presence of important palynotaxa *Ischyosporites, Impardecispora, Klukisporites, Sestrosporites* and *Contignisporites* allows an Early Cretaceous age assignment (Table 2) (Maheshwari, 1975; Jana & Tiwari, 1987).

DISCUSSION

'Late Gondwana' plant beds associated with primarily marine sediments have been well-documented from the east coast basins. A critical reassessment of the 'Late Gondwana' flora in the east coast suggests that floral differentiation and variations in several basins and sub-basins can be attributed to ecological parameters and preservational factors. These floras are homotaxial, though, minor variations are evident. Fallible evidences like presence or absence of Wealden ferns may not hold good for age assignment. The discrepancy between palynological evidences supported by faunal records on one hand and megaflora on the other is due to incompleteness of evidence. Biostratigraphic evidences should be considered *in toto*.

East coast Early Cretaceous sediments embody significant plant fossils such as *Onychiopsis paradoxus, Hausmannia* sp., *Pagiophyllum marwarensis* and *Brachyphyllum regularis*. These plant fossils are also known from some of the Early Cretaceous sequences of central and western India. Predominance of pteridophytes characterises Athgarh megaflora. Likewise equivalent sediments in other basins of east coast also contain more or less similar floral components. Relative dominance of one group of plants over the other in different basins can be ascribed to different ecological niches which are conducive to preservation of megafossils. Available evidences strongly indicate that floral differentiation observed is due to lack of understanding and incompleteness of data rather than their actual absence. Similarly mere occurrence of terrestrial fossils does not imply a continental deposition. This has to be supplemented with data from other disciplines.

An evaluation of palynoflora from the four east coast sedimentary basins suports an Early Cretaceous age assignment. This flora is represented by upland, near basinal as well as marginal floral components. Cosmopolitan palynotaxa such as *Cicatricosisporites, Aequitriradites, Foraminisporis, Crybelosporites, Trilobosporites, Densoisporites, Coptospora* and *Coronatispora* are mostly known from these basins. Distinct palynological zones of the Early Cretaceous subsurface sequence in the Cauvery Basin, viz., *Microcachryidites antarcticus* Zone, *Coptospora cauveriana* Zone and *Triporoletes reticulatus* Zone (in parts) show a characteristic vertical range. These palynofloras containing spore pollen as well as phytoplankton assemblages are Neocomian and Aptian—Early Albian in age (Venkatachala *et al.*, 1972).

Distinct Early Cretaceous palynofossil suites in the Palar Basin from Conjeevaram, Kattavakam, Avadi and Orikkai areas are recognised through the presence of *Contignisporites, Impardecispora, Sestrosporites, Ornamentifera, Klukisporites, Coptospora, Aequitriradites* and *Cooksonites*.

Neocomian—Aptian palynofossil suites (Sharma *et al.*, 1977; Venkatachala & Sinha, 1986) in the subsurface sediments of the Krishna-Godavari Basin are closely comparable to those of the *Crybelosporites stylosus* and the *Dictyotosporites speciosus* zones (Dettmann & Playford, 1969) in Australia. Some of the common palynotaxa include *Crybelosporites stylosus, Murospora florida, Aequitriradites hispidus, Cyclosporites hughesii, Contignisporites cooksoniae, Kraeuselisporites linearis, Biretisporites spectabilis, Dictyotosporites speciosus, Cooksonites variabilis, Foraminisporis asymmetricus, Cicatricosisporites australiensis* and *C. ludbrookii*.

Palynoassemblages recorded from the 'Late Gondwana' sediments of the Mahanadi Basin also contain important Early Cretaceous palynotaxa such as *Impardecispora, Klukisporites, Ischyosporites, Sestrosporites* and *Contignisporites*.

Well documented Early Cretaceous palynofloral assemblages (Neocomian-Aptian) of Kutch and Jabalpur are closely comparable with east coast palynoflora.

As early as 1871, Waagen remarked that cephalopod evidences suggest an Early Cretaceous (Neocomian) age to the marine deposits found in the east coast. Striking similarity of the arenaceous foraminifera of the basins on the east coast of India with those of Australia was also suggested (Sastry *et al.*, 1974, 1981).

Sedimentation of the 'Late Gondwana' on the east coast is attributed to rifting of the Indian Plate during Early Cretaceous (Datta *et al.*, 1983). Both Lower and Upper Cretaceous marine sediments along the east coast were deposited by one and the same marine transgression. An absence of Jurassic

sedimentation is possible taking into consideration major reactivation phase coupled with rifting history of 'Gondwana'.

Environment of sedimentation in the east coast is paralic. These sequences consist mainly of sandstones and shales laid down under shallow marine environments. Marine and non-marine 'Late Gondwana' units are contemporary and interdigitate. Similar flora and fauna can be observed in intracratonic and coastal sediments.

The presence of marine fossils and terrestrial plant remains rather suggests that the deposition probably took place in a tranquil, open marine basin near to the shore line. The occurrence of 'Late Gondwana' sediments along the east coast indicates similar depositional mileau. Occurrence of both autochthonous and allochthonous floral components and phytoplankton indicates an ecosystem consisting of non-marine to paralic through swampy environments. Abundance of ferns, cycadophytes and conifers in these floral assemblages also supports this conclusion.

Thus, it is necessary to consider the entire set of stratigraphic, tectonic, palynologic, palaeontologic and environmental evidences to understand the stratigraphic implication of the east coast 'Late Gondwana' flora. Megafossil evidences need be tied up with others for a meaningful interpretation. The occurrence of marine intercalations, earlier considered sporadic, is more a rule than an exception. In view of this, stratigraphic usage of the term 'Gondwana' needs to be reviewed. The term could be recircumscribed to include marine sequences or discontinued to be used.

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