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Jurassic and Lower Cretaceous dinoflagellate cysts from India with some remarks on the concept of Upper Gondwana

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A critical re-evaluation of the known records of dinoflagellate cyst assemblages from Jurassic and Lower Cretaceous sediments of India is made and stratigraphically significant taxa are identified and tabulated. Emphasis is laid on integration of dinocyst and ammonite evidences for stratigraphic precision. Significance of dinocysts in age determination of Kimmeridgian-Tithonian sequences of Kutch and Malla Johar is recognised. Berriasian dinocysts are not known from India. It is suggested that dinocyst assemblages documented from subsurface of East Coast of India are not older than Hauterivian as no conclusive evidence for Valanginian age, assigned by earlier workers, is available.

The traditional view of regarding coastal marine Lower Cretaceous sequences as part of Gondwana is not tenable. It is suggested that the term Gondwana be reserved for inland, predominantly non-marine, fluviatile-lacustrine sediments as a lithostratigraphic unit. In view of the lack of any definite evidence of Jurassic sediments in intracratonic basins and the prominent post-Triassic hiatus, Late Triassic be considered to mark the upper age limit of Gondwana sequences.

Key-words—Dinoflagellate cysts, Stratigraphy, Jurassic, Lower Cretaceous, Upper Gondwana (India).

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साराँश

भारत से जूराई एवं अधरि क्रीटेशी घूर्णीकशाभ पुटीयाँ तथा उपरि गोंडवाना की अवधारणा पर कुछ टिप्पणियाँ

राहुल गर्ग, खोवाज़ा अतीकुज़्ज़मा एवं कृष्ण प्रसाद जैन

भारत के जूराई एवं अधरि क्रीटेशी अवसादों से ज्ञात घूर्णीकशाभ-पुटी समुच्चयों के अभिलेखों का विशेष पुनर्मूल्याँकन किया गया है तथा स्तरिकीय दृष्टि से महत्वपूर्ण वर्गक अभिनिर्धारित एवं तालिकाबद्ध किये गये हैं। स्तरिक यथार्थता हेतु घूर्णीकशाभ पुटीयों एवं ॲमोनाइटों के प्रमाणों के एकीकरण पर बल दिया गया है। कच्छ एवं मल्ला जोहर के किम्मॅरिडजिअन-टिथोनियन अनुक्रमों की आयु-निर्धारण में घूर्णीकशाभ पुटीयों का महत्त्व अभिनिर्धारित किया गया है। भारत से बेरिएशियन कालीन घूर्णीकशाभ पुटीयाँ अभी तक विदित नहीं हैं। यह प्रस्तावित किया गया है कि भारत के पूर्व तट के उपसतह से ज्ञात घूर्णीकशाभ पुटी समुच्चय हॉटीरीवियन से अधिक पुराने नहीं हैं क्योंकि इससे पहले शोधकर्त्ताओं द्वारा निर्धारित वालेन्जीनिअन आयु का कोई प्रमाण नहीं मिलता। तटीय समुद्री अधरि क्रीटेशी अनुक्रम गोंडवाना का ही एक भाग हैं, यह दृष्टिकोण मान्य नहीं है। यह प्रस्तावित किया गया है कि 'गोंडवाना' नामक शब्द का प्रयोग एक शैल-स्तरिकीय इकाई के रूप में अंतःस्थलीय असमुद्री, नदीय-सरोवरी अवसादों हेतु होना चाहिये। अन्तःक्रेटानी द्रोणीयों में जूराई अवसादों तथा स्पष्ट पश्च-त्रिसंघी दरार के निश्चित प्रमाण की अनुपस्थिति में गोंडवाना अनुक्रमों की उपरि आयु सीमा अनंतिम त्रिसंघी मानी जानी चाहिये।

JURASSIC and Lower Cretaceous sedimentary rocks of shallow marine to paralic facies are confined primarily along the margins of the Indian Craton. A remarkably complete sequence of these rocks was laid down only in the Tethys Himalayan belt in a unique tectono-sedimentary set-up under shallow to deeper marine environment. Deposition of Middle Jurassic-Lower Cretaceous rocks in Rajasthan and

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Kutch and thick Lower Cretaceous clastic sequences along the East Coast of Peninsular India took place in marginal marine basins.

Micropalaeontological studies of these sequences have primarily been confined to microfauna and microflora (spore-pollen assemblages). Earlier records of dinoflagellate cysts from Jurassic sediments of India are sporadic and have little biostratigraphic value (Jain, 1974). Recent systematic documentation of dinocysts from richly fossiliferous Jurassic sequences of Kutch (Jain *et al.*, 1986; Kumar, 1986a, 1987a, b) and Tethys Himalaya (Jain *et al.*, 1984) has highlighted their biostratigraphic potential. For a better stratigraphic resolution, integration of dinocysts data with ammonite evidences has also been attempted (Jain *et al.*, 1984; Garg *et al.*, 1986).

In Kutch Basin, richly fossiliferous marine Jurassic rocks are extensively developed. Dinocysts are described from Jhurio (Kumar, 1987a) and Jhuran formations (Jain *et al.*, 1986; Kumar 1986a, 1987a,b). The assemblage from Jhurio Formation of Jhura Dome Section is poorly preserved and consists of 18 dinocyst species. Significant taxa of this assemblage are *Atopodinium prostratum, Chytroeisphaeridia chytroeides, C. scabrata, Ctenidodinium* sp. cf. *C. ornatum, Ctenidodinium* sp. cf. *C. tenellum, Escharisphaeridia pocockii, Pareodinia ceratophora, P. prolongata, Prolixosphaeridium granulosum, Rigaudella* sp. cf. *R. aemula* and *Tubotuberella dangeardii.* Kumar (1987a) assigned Bathonian-Callovian age, though dinocyst data is inconclusive for age determination. Most of these species are long ranging, recorded from Middle to Late Jurassic of Europe, Australia and Blake-Bahama Basin. This assemblage may extend into Oxfordian as well. Agarwal (1957) assigned Callovian-Oxfordian age to this sequence on molluscan evidence.

Jain *et al.* (1986) described 22 genera and 29 species of dinocysts from various levels of Jhuran Formation. Kumar (1986a, 1987b) recorded 35 species from a section exposed westwards of Bhuj, which according to him belongs to the Middle Member of Jhuran Formation. This section is exposed along the banks of the Khari Nadi (river) near the Cremation Ground on the western outskirts of Bhuj town. Two of us (K.P.J. & R.G.) investigated and sampled this section during a joint field trip of BSIP/ONGC in 1986 alongwith Drs S.V. Deshpande (ONGC) and H.K. Maheshwari (BSIP). The lithological sequence is characterised by thick, medium to coarse, brownish sandstone and thin siltstone alternations with very thin greyish black shale/silty shale partings in the lower part and very thick current bedded sandstone with fewer siltstone partings towards the top. This lithology is typical of the Upper Member of the Jhuran Formation (Biswas, 1977). It is our contention that the dinocyst assemblage recorded by Kumar (1986a, 1987b) is actually from the uppermost part of the Upper Member and not from the Middle Member of the Jhuran Formation. Hence, this assemblage is accordingly tabulated in the species list (Table 1) with Upper Member assemblages. Significantly, the Jhuran assemblages documented by Kumar (1986a, 1987b) and Jain *et al.* (1986) are qualitatively quite different and have only a few common elements. Dinocyst assemblages from Lower and Middle members of the Jhuran Formation documented by Jain *et al.* (1986) are quite similar. Except for *Escharisphaeridia pocockii*, all the 14 species present in the Lower Member extend into younger assemblages. Only a few species are restricted to Middle Member, viz., *Surculosphaeridium vestitum, Adnatosphaeridium filamentosum* and *A. paucispinum*, which are long ranging. However, common occurrence of *Scriniodinium dictyotum, Sentusidinium echinatum, Egmontodinium polyplacophorum, Gonyaulacysta ehrenbergii, Gonyaulacysta jurassica, Ellipsoidictyum cinctum* and *Scriniodinium luridum* in Lower and Middle members of Jhuran Formation reflects Early Kimmeridgian aspect. Dinocysts from Patasar Shale (unpublished data) have provided first hand correlation between Jhuran Formation of Kutch mainland and lower shaly part of Wagad Sandstone Formation of eastern Kutch for which no mega or microfaunal evidences are yet available except for the ammonites in the immediately underlying Dhosa Oolite and Kanthkot Ammonite band in respective regions. It is interesting to note that the two Upper Member assemblages recovered from Ugedi Well (Jain *et al.*, 1986) and Cremation Ground (Kumar, 1986, 1987) are qualitatively distinct, though there are certain common taxa amongst the two. The Ugedi assemblage has 14 significant species, only four including *G. jurassica* and *Scriniodinium dictyotum* extend from Lower and Middle members, while 10 including *Tanyosphaeridium torynum, Tubotuberella apatela* and *Broomea ramosa* are confined to this assemblage. The Cremation Ground assemblage interestingly shows seven additional species extending from Lower to Middle Member including *Egmontodinium polyplacophorum, Sentusidinium echinatum* and *Ellipsoidictyum cinctum.* Significantly *Broomea ramosa* is not recorded by Kumar (1986) but several other species are additionally documented. Presence of *Tanyosphaeridium torynum, Broomea ramosa, Pareodinia verrucosa, Chlamydophorella wallala* in Upper Member assemblages of Kumar (1986a, 1987b) and Jain *et al.* (1986), is indicative of Middle-Late Kimmeridgian (*sensu anglico*) age, not younger than *Pectinatus* Zone, probably equivalent to early-Middle Tithonian in the Tethyan realm. It should, however, be noted that stratigraphic ranges of most of the dinocyst species are primarily defined in terms of well established ammonite zonation of boreal region. The extension of European boreal dinocyst ranges to this part of the Tethyan realm is bound to be tenuous and correlations should be attempted cautiously. For this purpose, only a few selective cosmopolitan and well known species have been chosen for age determination and correlation.

A high degree of provincialism among ammonites during Late Jurassic has led to the establishment of different zonation schemes for Tethyan, boreal and Russian platform regions using Tithonian, Kimmeridgian/Portlandian and Volgian Stage names respectively (Hallam, 1975). Precise correlation of ammonite zones in these regions is still not firmly established. In view of this the age determination based on dinocysts in terms of boreal ammonite zones are difficult to integrate with Tethyan ammonite zones. Reliability in dinocyst dating and correlation can only be achieved by defining dinocyst ranges in terms of Tethyan ammonite successions and their subsequent tagging, as far as possible, with boreal ammonite schemes.

Integration of dinocyst and ammonite evidences in the Tethyan Sequence is attempted by Jain *et al.* (1984) in their study of Spiti Shale Formation sequence exposed in Malla Johar area. They proposed an informal dinocyst biozonation scheme for a part of Spiti Shale and integrated dinocyst assemblages with ammonite zones defined by Krishna *et al.* (1983) for the same succession. This assemblage is rich and diversified. In all, 67 species are recorded. A significant aspect of this assemblage is the co-occurrence of *Gonyaulacysta jurassica* and *Omatia montgomeryii* at the same stratigraphic level in the upper part of Middle Spiti Shale sequence. *G. jurassica* has its last occurrence while *O. montgomeryii* has its first appearance in the boreal *Pectinatus* Zone, of early Late Kimmeridgian which is probably equivalent to late Middle Tithonian or early Late Tithonian. Krishna *et al.* (1983) placed this part of the Spiti Shale within the *Blanfordiceras* Assemblage of late Late Tithonian. In order to resolve this controversy, Garg *et al.* (1986) investigated dinocysts recovered from ammonite specimens duly identified and provided by Dr Jai Krishna (BHU). It has been observed that ammonites from the upper part of the Middle Spiti Shale, viz., *Virgatosphinctes* and *Kossmatia* both contain *G. jurassica* and *O. montgomeryii*; *Blanfordiceras* from suprajacent levels yielded poor dinocysts containing only *Gonyaulacysta* sp. cf. *G. perforans* and cf. *Batioladinium*. On dinocyst evidence, Jain *et al.* (1986) suggested to shift the tentatively defined boundaries of ammonite assemblage, a few meter higher up. The topmost part of the Spiti Shale sequence appears to be condensed, characterised by bedded cherts and hardgrounds and is totally devoid of organic matter. It is quite likely that Late Tithonian ammonite zones may be confined within short intervals in the uppermost part of the Spiti Shale sequence.

Another stratigraphically significant event among Spiti Shale dinocysts is the first appearance of *Broomea simplex* which can be tagged with *Troquatisphinctes-Aulacosphinctes* Assemblage of Early Tithonian. In terms of boreal ammonite zones its first appearance is within the *Wheatleyensis* Zone of early Middle Kimmeridgian. However, it should be noted that several dinocyst species have different ranges in Indian sequences as compared to Europe. *Adnatosphaeridium aemulum, A. filamentosum, A. paucispinum, Lithodinia jurassica, Nannoceratopsis pellucida, Scriniodinium luridum, Prolixosphaeridium mixitispinosum, Ellipsoidictyum cinctum* and *Wanaea clathrata* are recorded from Oxfordian-Early Kimmeridgian or Early Kimmeridgian in Europe but have extended range in definite Tithonian sequence of Tethyan Himalaya. *Peridictyocysta mirabilis* which has its earliest appearance in *Scitulus* Zone is documented from definite Early Tithonian sequence referable to *Torquatisphinctes-Aulacosphinctes* assemblage.

Jurassic dinocysts known from India are tabulated (Table 1) and stratigraphically significant species are sorted out (Table 2). Late Jurassic dinocyst assemblages from Kutch and Tethyan Himalaya are quite distinct from each other. There are several common species but absence of *Omatia* species in Kutch Assemblage and *Egmontodinium* in Malla Johar Assemblage is noteworthy. Kumar (1986) suggested the possibility of some degree of provincialism among Late Jurassic dinocysts based on their differential distribution in Kutch and Tethyan Himalaya. However, *Egmontodinium polyplacophorum* as well as *Indodinium khariensis* and *Nannoceratopsis radiatus* documented from Kutch have recently been recovered from the ammonite *Kossmatia* collected from Kibber Section in Spiti (Garg *et al.*, 1986). It is, therefore, difficult at this juncture to speculate on provincialism despite some palaeobiogeographic distinction between the dinocyst assemblages of the two regions, because these are yet to be documented in detail and the observed distinction may actually be deceptive.

Records of Lower Cretaceous dinocysts are confined to the sedimentary basins along the east

Table 1—Distribution of Jurassic dinocysts from India

	KUTCH				MALLA JOHAR				
		Jhuran Formation			*Spiti Shale (Formation)*				
		Lower Member	*Middle Member*	*Upper Member*					
DINOCYST TAXA	*Jhurio Formation*				*Assemblage*				*Zones*
					A	*B*	*C*	*D*	*E*
Atopodinium prostatum	+								
Chytroeisphaeridia chytroeides	+								
C. scabrata	+								
Cleistosphaeridium cf. *C. varispinosum*	+								
Ctenidodinium cf. *C. ornatum*	+								
Ctenidodinium cf. *C. tenellum*	+								
Dichadogonyaulax sp.	+								
Dingodinium sp.	+								
Leiosphaeridia sp.	+								
Meiourogonyaulax sp.	+								
Pareodinia prolongata	+								
Prolixosphaeridium granulosum	+								
Rigaudella cf. *R. aemula*	+								
Sentusidinium sp.	+								
Xenicodinium sp.	+								
Tubotuberella dangeardii	+			+					
Escharisphaeridia pocockii	+	+	+	+					
Pareodinia ceratophora	+	+	+	+	+				+
Scriniodinium dictyotum		+							
Sentusidinium echinatum		+		+	+				
Egmontodinium polyplacophorum		+	+	+					
Ellipsoidictyum cinctum		+	+	+					+
Gonyaulacysta jurassica jurassica		+	+	+					+
Leptodinium eumorphum		+	+	+					
Gonyaulacysta ehrenbergii		+	+						
Adnatosphaeridium aemulum		+	+						+
Occisucysta sp.		+	+						
Scriniodinium luridum		+	+						
Apteodinium granulatum		+	+		+				
Nannoceratopsis pellucida		+	+			+	+		
Adnatosphaeridium filamentosum			+						
Adnatosphaeridium pausispinosum			+						
Gonyaulacysta sp. cf. *perforans*			+	+					
Systematophora orbifera			+	+	+				
Surculosphaeridium vestitum			+				+		
Nannoceratopsis radiatus				+					
Egmontodinium torynum				+					
Sentusidinium hexagonalis				+					
Oligosphaeridium pulcherrimum				+					
Sentusidinium pelionence				+					
Sentusidinium sp. A				+					
Sentusidinium creberbatum				+					
Scriniocassis downiei				+					
Parvocavatus scabratus				+					
Escharisphaeridia psilata				+					
Geiselodinium inaffectum				+					
Indodinium khariensis				+					
Indosphaera bhujensis				+					
Mendicodinium granulatum				+					
M. microreticulatum				+					
Pareodinia verrucosa				+					
P. imbatodinensis				+					
Broomea ramosa				+					
Prolixosphaeridium anasillum				+					

(*Contd.*)

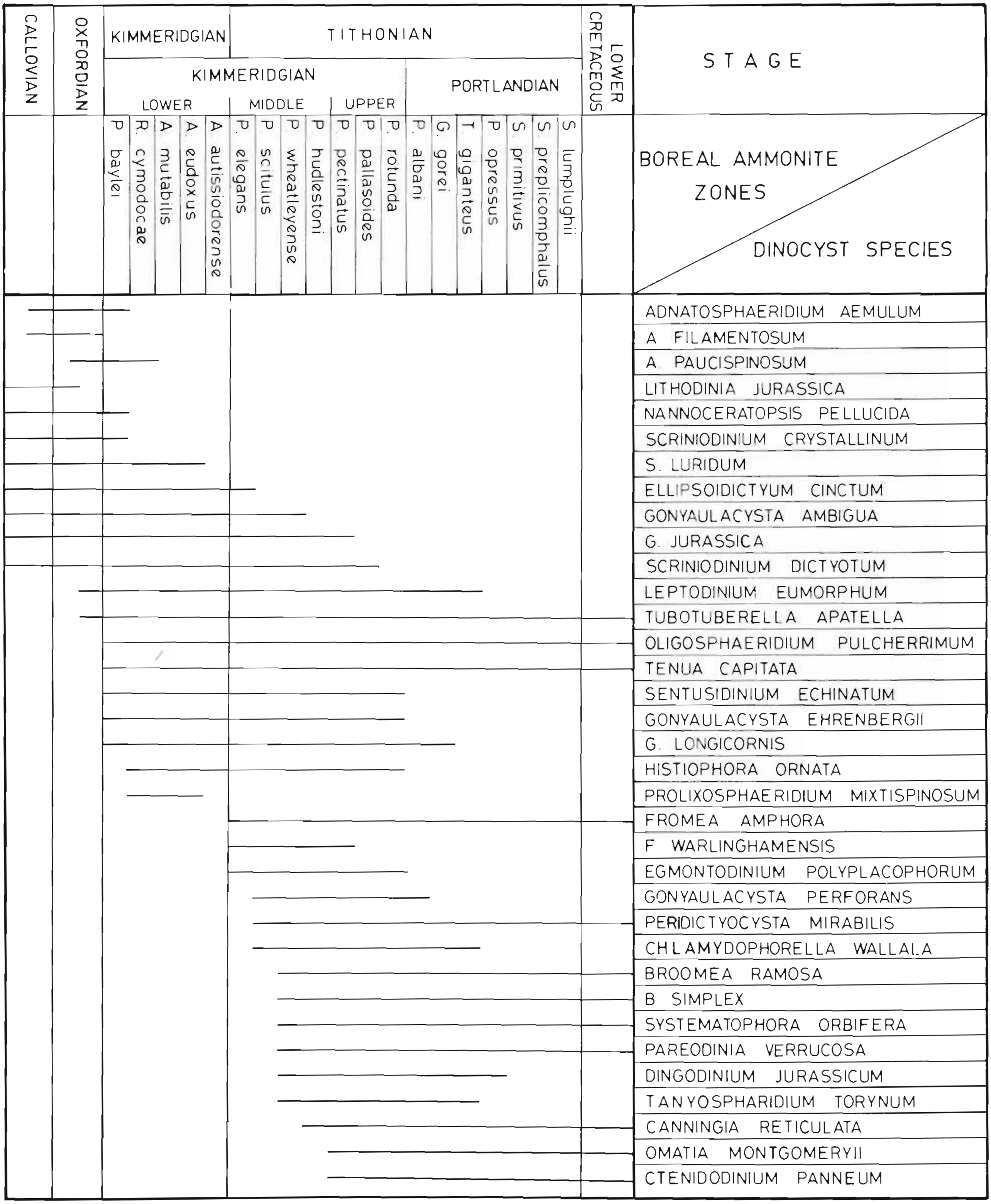
Table 1—(*Contd.*)

Chlamydophorella wallalla	+					
Ctenidodinium culmulum	+					
Scriniodinium echinatum	+		+			
Tubotuberella apatela	+	+				
Systematophora panicillata	+	+				
Canningia reticulata		+				
Chytroeisphaeridia sp. A		+				
Cribroperidinium granulatum		+				
Ellipsoidictyum sp. A		+				
Fromea amphora		+				
Lithodinia sp.		+				
Oligosphaeridium dictyophorum		+				
Oligosphaeridium sp. cf. *anthophorum*		+				
Prolixosphaeridium capitatum		+				
Scriniodinium indicum		+			+	
Prolixosphaeridium dictyophorum		+				
Oligosphaeridium sp.		+				
Broomea simplex		+	+			+
Prolixosphaeridium granulosum			+			
Cyclonephelium sp. A			+			
Lanterna sp. A			+			
Peridictyocysta mirabilis			+			
Wanaea clathrata			+			
Broomea sp. A			+			
Prolixosphaeridium sp. A			+			
Sentusidinium sp. A			+	+		
Sentusidinium sp. B			+	+		
Apteodinium nuciforme				+		
Canningia apiculata				+		
Ovoidinium waltonii				+		
Pseudoceratium spitiensis				+		
Scriniodinium galeritum				+		
Tanyosphaeridium jurassicum				+		
Chlamydophorella fenestrata						+
Emmetrocysta sarjeantii						+
Histiosphora ornata						+
Lithodinia jurassica						+
Membranilarnacia leptoderma						+
Omatia montgomeryii						+
Omatia pisciformis						+
Prolixosphaeridium mixtispinosum						+
Rhyncodiniopsis ambigua						+
Tubotuberella sp. A						+
Leptodinium sp. A						

coast of peninsular India. Sharma *et al.* (1977) referred and illustrated a few dinocysts alongwith a rich spore-pollen assemblage from the subsurface of Krishna-Godavari Basin. The same sequence was subsequently investigated in more detail for dinocysts by Kumar (1982, 1986). Khowaja-Ateequzzaman *et al.* (1985, 1988a, b) and Jain and Khowaja-Ateequzzaman (1984) have documented a rich dinocyst assemblage from subsurface Lower Cretaceous Sequence of Palar Basin besides carrying out detailed morphological studies of some taxa. Mehrotra and Sarjeant (1984a, b, c) made detailed morphological studies of some Lower Cretaceous dinocyst taxa from subsurface of Cauvery Basin. Subsequently, they (1986) documented a fairly rich dinocyst assemblage from the same sequence.

Kumar (1982, 1986b) tabulated a rich dinocyst assemblage comprising 78 species recovered from 19 core samples collected at various depths from 8 different shallow wells in Krishna-Godavari Basin. Based on a comparison with Australian and European assemblages, Valanginian to Hauterivian age is assigned with the possibility of the upper age limit extending into Barremian. In our opinion this assemblage is most closely comparable with type Barremian assemblages documented by Srivastava (1984) from southern France and Duxbury (1980) from England and also with Australian assemblage documented by Berger (1980, 1982). According to Kumar (1986), the Krishna-Godavari assemblage is most closely comparable with Australian assemblages documented by Berger (1982) from

Table 2—Stratigraphic ranges of selected Jurassic dinocysts species



DK2 and DK3 zones which are assigned to Valanginian and Hauterivian to possibly Early Barremian age respectively. Helby *et al.* (1987) recently reviewed Burger's data and extended the upper limit of DK2 Zone to the top of Zone DK3a, corresponding to their *Muderongia testudinaria* Zone of Middle Hauterivian. In our opinion, presence of *Bachidinium polypes* (now *Kiokansium*

Table 3—Distribution of Lower Cretaceous dinocysts from India

Dinocyst Species	Krishna-Godavari Basin (*Arun Kumar, 1986b*)	Cauvery Basin (Mehrotra & Sarjeant, 1986)	Palar Basin (Khowaja Ateequzzaman, 1988 a, b)
Achomosphaera ?neptunii	×		
A. ramulifera	×		
Achomosphaera cf. *sagena*		×	
Alterbidinium minor			×
Aprobolocysta sp.		×	
Aptea anaphrissa			×
Apteodinium conjunctum	×		
A. grande	×		
A. granulatum	×		
A. maculatum	×		
A. spinosum	×		
Ascodinium acrophorum	×		
Bacchidinium polypes (Now *Kiokansium polypes*)	×		
Batiacasphaera aptiense	×		
B. crassicingulata	×		
B. echinata	×		
Batiacasphaera cf. *macrogranulata*		×	
B. minor	×		
B. pilosa	×		
B. scrobiculata	×		
B. spumosa	×		
Batiacasphaera sp.	×		
Batioladinium micropodum	×		
B. jeageri			×
Callaiosphaeridium asymmetricum			×
Canningia colliveri	×		
C. reticulata	×		
Canningia sp. A (Burger, 1980)	×		
Cassiculosphaeridia magna	×		
C. reticulata	×		
Chlamydophorella nyei	×		
Chlamydophorella cf. *nyei*		×	
Cleistosphaeridium aciculare	×		
C. granulatum	×		
C. huguoniotii			×
Cleistosphaeridium sp. (Brideaux, 1977)	×		
Coronifera oceanica	×		
Cribroperidinium apione	×		
C. cornutum			×
C. muderongense	×		
Cribroperidinium cf. *orthoceras*		×	
Cribroperidinium sp.		×	
Cyclonephelium areolatum	×		
C. densebarbatum	×		
C. distinctum	×		
C distinctum subsp. *laevigatum*		×	
C. hystrix	×		
Dapsilidinium multispinosum	×		
Dingodinium cerviculum	×	×	×
Discorsia nanna	×		×
Druggidium jubatum			×
Endoscrinium luridum	×		
Ellipsodinium cf. *reticulatum*			×
Exochosphaeridium phragmites	×		
Fromea amphora	×	×	
F. fragilis	×		
F. glabella	×		
Gonyaulacysta sp. A		×	

(*Contd.*)

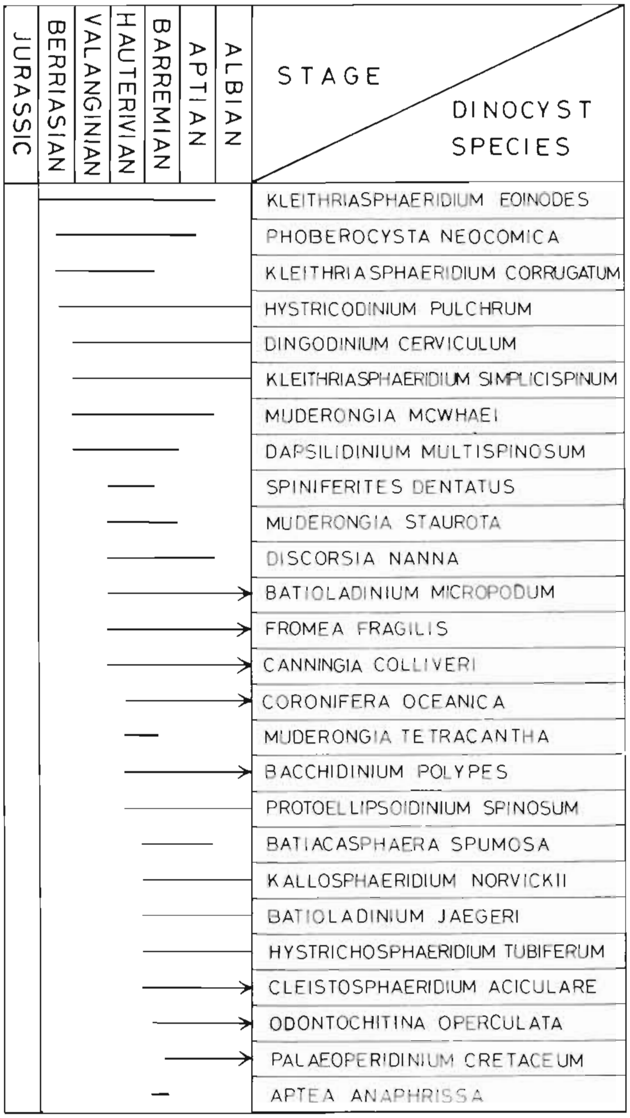
Table 3—(*Contd*)

Gonyaulacysta sp. B		×	
Hystrichodinium oligacanthum	×		
H. pulchrum	×	×	
Hystrichogonyaulax serrata	×		
Hystrichosphaeridium arborispinum	×		
H. tubiferum	×		
Imbatodinium fractum		×	
Kallosphaeridium granulatum	×		
K. norvickii	×		
K. romaense	×		
Kleithriasphaeridium eoinodes	×		
K. simplicispinum	×	×	
K. corrugatum			×
Leberidocysta chlamydata	×		
L. defloccata	×		
Leptodinium simplex	×		
Leptodinium sp.	×	×	
Lithodinia cf. *jurassica*	×		
cf. *Mendicodinium* sp.	×		
Meiourogonyaulax bulloidea			×
Muderongia mcwhaei	×	×	×
Muderongia cf. *mcwhaei*		×	
M. staurota	×		
M. tetracantha		×	×
Muderongia sp.		×	
Odontochitina operculata			×
Oligosphaeridium asterigerum		×	
O. complex	×		×
O. dictyophorum	×		
O. diluculum		×	
O. pulcherimum	×		×
O. totum totum			×
Palaeoperidinium cretaceum			×
Pareodinia cf. *ceratophora*	×		×
Phoberocysta neocomica	×		
Polygonifera eisenackii		×	
Prolixosphaeridium capitatum	×		
P. conulum	×		
P. deirense			×
Protoellipsoidinium sp.	×		
Pterodinium premnos			×
Rhynchodiniopsis aptiana	×		
R. fimbriata			×
R. hyalodermopsis	×		
Rhombodella vesca			×
Scriniodinium attadalense	×		
Spiniferites pterosus	×		
S. ramosus granomembranaceous	×		
S. ramosus ramosus	×	×	×
S. scabrosus	×		
S. dentatus		×	
Tanyosphaeridium cf. *isocalamus*	×		
T. isocalamus		×	
Trabeculidium quinquetrum			×
Wallodinium anglicum		×	
W. glaessneri	×		
Wallodinium cf. *luna*		×	

polypes), *Canningia colliveri*, *Fromea fragilis*, *Batioladinium micropodum*, *Discorsia nanna*, *Muderongia staurota*, *Cleistosphaeridium aciculare*, *Kallosphaeridum norvickii* and *Batiacasphaera spumosa* in Krishna-Godavari Assemblage indicates Hauterivian-Barremian age. Absence of *Odontochitina operculata*, though a negative evidence, suggests that this assemblage may not be younger than Lower Barremian.

Kumar (1986b, p. 33) suggested the possibility of reworking of older Jurassic sediments in view of the occurrence of *Apteodinium granulatum*,

Table 4—Stratigraphic ranges of selected dinocyst species known from Lower Cretaceous sequences of India



Batiacasphaera crassiangulata, Lithodinia sp. cf. *L. jurassica, Oligosphaeridium dictyophorum, Prolixosphaeridium capitatum* and *Pareodinia* sp. cf. *P. ceratophora.* This statement needs explanation as no marine Jurassic sequence is developed along the East Coast where sedimentation is believed to have commenced only sometimes in Late Neocomian with the development of marine sea way as a prelude to the disruption of Gondwanaland. These dinocyst species might have extended stratigraphic ranges or may need careful taxonomic reassessment.

Mehrotra and Sarjeant (1986) described 27 dinocyst species from 7 conventional core somples spread between a depth of 95 to 143 m in Priyavadavadi shallow well-1, Cauvery Basin. Of these, 13 species are provisionally assigned or identified up to generic level only, due to the unsatisfactory state of preservation. A majority of taxa range within Neocomian-Aptian which occur along with some species of Albian or younger age. The authors, however, differentiated Valanginian to Aptian sediments within a thickness of 48 metres, primarily based on meagre or dominant occurrence or absence of *Muderongia mcwhaei* (Hauterivian-Aptian) alongwith *Dingodinium cerviculum* (Valanginian to Middle Albian) and *Batiacasphaera* sp. cf. *B. macrogranulata* whose range is given by Mehrotra and Sarjeant (1986, table 1) as Neocomian. It is to be noted that the youngest assemblage shows predominance of *Achomosphaera* sp. cf. *A. sagena, Chlamydophorella* sp. cf. *C. nyei, Cyclonephelium distinctum* subsp. *laevigatum, Dingodinium cerviculum, Imbatodinium fractum, Muderongia* sp. cf. *M. mcwhaei* and *Polygonifera eiseneckii.* Except for *Muderongia* cf. *mcwhaei* all other species persist almost throughout the sequence. Further, occurrence of *Chlamydophorella* cf. *nyei* (Aptian-Maastrichtian) is noted in good numbers in the older samples while *Wallodinium anglicum* (Albian-Early Cenomanian) and *Tanyosphaeridium isocalamus* (Late Albian) occur rarely in the younger horizon. Stratigraphic range of *C. nyei* actually extends down to Late Berriasian (Burger, 1982, text-fig. 11). In view of meagre representation of *W. anglicum* and *T. isocalamus* and predominance of *M. mcwhaei*, Mehrotra and Sarjeant assigned Aptian age to younger assemblages. However, predominance of *Oligosphaeridium asterigerum*, having restricted range within Valanginian-Lower Hauterivian, as well as occurrence of *Spiniferites dentatus* (Hauterivian-Barremian) at this level is not considered by them. In our opinion, dinocyst evidence is inconclusive for precise age assignment and differentiation of various Early Cretaceous stages within 48 m of this shallow bore-hole is not acceptable. We believe that no conclusive evidence is available for Valanginian dating and the documented assemblages may range within Hauterivian-Aptian or may represent only a part of this time span.

Khowaja-Ateequzzman *et al.* (1988a, b) recorded rich and diversified dinocyst assemblages from a bore-hole drilled up to a depth of 760 m in Puduvoyal, Palar Basin. A characteristic Barremian dinocyst assemblage recovered from a conventional core at 440-444 m depth is dominated by *Odontochitina operculata, Muderongia mcwhaei, M. tetracantha, Discorsia nanna* and *Aptea anaphrissa.* Its equivalence with the European *Aptea anaphrissa* subzone of *O. operculata* Zone of Middle Barremian age (Davey, 1979) is suggested (Khowaja-Ateequzzaman *et al.*, 1988a). Other significant species in this assemblage are: *Trabeculidinium quinquetrum, Pterodinium premnos, P cingulatum, Kleithriasphaeridium simplicispinum, Rhynchodiniopsis fimbriata, Ellipsodinium reticulatum, Druggidium jubbatum, Prolixosphaeridium dierense, Batioladinium jaegeri, Cribroperidinium cornutum* and *Meiourogonyaulax bugoniotii.*

The dinocyst species known from Lower Cretaceous of India are tabulated (Table 3). Stratigraphic ranges of some key taxa are given separately (Table 4). Occurrence of some Lower Cretaceous dinocysts in the Flysch succession of Tethys Himalaya has been postulated by Jain and Garg (1986). In fact, Mehrotra and Sinha (1981) provided a brief account of dinocysts from Upper Flysch Sequence of Malla Johar area and suggested Palaeocene-Lower Eocene age for a major part of the succession. Jain and Garg (1986) reassessed the assemblage on face value as repository of type slides could not be traced, suggesting many taxonomic reallocations and considered the assemblage to be not younger than Cretaceous. Occurrence of *Endoceratium ludbrookiae* (identified as *Deflandrea* by Mehrotra & Sinha, 1981) and also *Odontochitina* sp. is probably suggestive of Lower Cretaceous reworking in younger Flysch sequence.

The only record of dinocysts from intracratonic Gondwana Basin is by Jain *et al.* (1982) from Jabalpur Formation. The carbonaceous shale sample which yielded dinocysts, spores and pollen, was collected from the lower part of Jabalpur Formation from Morand River Section near Morghat, Satpura Basin. The dinocyst assemblage consists of *Kalyptea, Sentusidinium* and *Canningia.* Jain *et al.* (1982) doubtfully placed the assemblage in Late Jurassic in view of the then available palynological evidences. *Kalyptea indica* closely resembles cysts recorded from Lower Cretaceous of Australia. Similar forms are also recorded from Lower Cretaceous of East Coast of India and Kutch (unpublished data) but are not known from Jurassic sequences. Forma A (Jain *et al.*, 1982, p. 25; pl. 1; fig. 13) resembles *Batioladinium* known from the Lower Cretaceous of East Coast of India and Australia. In the absence of any marker taxa, and in view of the recent spore-Pollen evidences (Singh & Venkatachala, 1988, in this volume) we would prefer to place the present assemblage in Lower Cretaceous.

Jain *et al.* (1982) suggested that in view of the so far believed non-marine origin of Jabalpur sediments, the dinocyst assemblage may be non-marine too. However, they kept their views open on this aspect. It is difficult to envisage any marine influence during Lower Cretaeous in Jabalpur area at this juncture as evidences for existence of any marine seaway are yet lacking. The only possible channel for marine incursion in this region seems to be the Narbada rift which is known to have undergone a transgressive event during Late Cretaceous time. Estuarine (Singh, 1981) or non-marine (Brookfield & Sahni, 1987) environment has been suggested for Late Cretaceous Lameta Group of sediments. The possibility of re-activation of Narbada rift in Early Cretaceous times, so as to bring in marine influence, albeit for a short period, during the deposition of Jabalpur Formation is a moot question. There is absolutely no sedimentologic or palaeontologic evidence as yet available supporting such an early transgressive event along Narbada rift. The discovery of dinocysts is probably the first evidence which should initiate more cautious and unbiassed approach in future biostratigraphical and palaeoenvironmental studies in this area.

REMARKS

It is our contention that so far no definitive dinocyst evidence for older than Hauterivian age is available from any of the basins along the East Coast of India. The Lower Cretaceous Sequence in these basins has traditionally been termed as coastal Gondwana and Late Jurassic or Early Cretaceous age is indiscriminately assigned on the evidence of *Ptilophyllum* floral assemblage. Their reference to coastal Gondwana stems out because of supposed non-marine origin, so considered in view of megaflora, punctuated with some definite marine ammonite bearing horizons of Barremian age. However, their supposed Gondwana affinity has been a matter of dispute among workers (Rao & Venkatachala, 1971) and it would be appropriate for us to briefly discuss the concept of Gondwana and division of Upper Gondwana at this juncture.

Concept of Upper Gondwana

The term Gondwana, has been used rather indiscriminately as a serve-all-purpose term. It has been used formally or informally to serve variously as lithostratigraphic, biostratigraphic or chronostratigraphic unit besides being used with a palaeobiogeographic and palaeogeographic connotation. The literature is replete with terms like 'Gondwana Series or System', 'Gondwana Group or Supergroup', 'Gondwana Flora', 'Gondwanaland', *Glossopteris* bearing 'Lower Gondwana', *Ptilophyllum* bearing 'Upper Gondwana', *Dicroidium* bearing 'Middle Gondwana', 'Coastal Gondwana', marine intercalations in Gondwanas; Gondwana continent, 'Gondwana time', 'Gondwana Era', 'Gondwana Period', 'Gondwana sedimentation', 'Gondwana Facies', 'Peninsular Gondwana', 'Extra-peninsular

Gondwana', or simply as 'The Gondwana', or 'The Indian Gondwana'. This amply demonstrates the urgent need to review the status and use of the term Gondwana.

The typical Gondwana succession, documented by Feistmantel (1876) and subsequent workers, is developed in peninsular India in widely separated inland basins having their own depositional history. A critical perusal of available data suggests that in Damodar Koel Basin there is a thick Permian to Lower Triassic Sequence followed unconformably by Upper Triassic sediments; in Rajmahal Basin the thick Permian Coal Measures are unconformably overlain by ?Triassic sediments and are capped unconformably by Lower Cretaceous lava flows and plant-bearing Intertrappeans; the Son-Mahanadi Basin shows the development of thick Permo-Triassic succession; the South Rewa Basin shows development of Permian and Triassic sediments followed unconformably by plant-bearing Lower Cretaceous sediments; in the Satpura Basin a Permian and Triassic sequence is overlain unconformably by Lower Cretaceous sediment while in Pranhita-Godavari Basin an almost complete Permian-Triassic sequence occurs overlain unconformably by ?Lower Jurassic and Lower Cretaceous sediments.

Based primarily on floral evidences, 2-fold or 3-fold classification of Gondwana Sequence has been proposed. In two fold classification the line of division is placed above Panchet Formation, the Lower Gondwana being characterised by the Glossopteris Flora and the Upper Gondwana by the Ptilophyllum Flora. In the tripartite division, The Panchet and Mahadeva formations are included in the Middle Gondwana which is characterised by the *Dicroidium* 'Mixed Flora' as well as Triassic vertebrate fauna. The tripartite sub-division has even been fitted into the Standard Geologic Time Scale as Permian, Triassic and Jurassic-Lower Cretaceous, attributing chronostratigraphic status to the 3 floristic units despite the fact that time relationships of stratigraphic boundaries of these divisions are yet to be established firmly and precisely. It has been observed that diachronous nature of lithologic boundaries, stratigraphic breaks and floral changes in various intracratonic basins render intrabasinal biozonation and correlation extremely difficult and rule out the feasibility of any unified, all pervasive stratigraphic framework for Gondwana sequences (Mitra *et al.*, 1979).

Occurrence of clastic sequence of Lower Cretaceous age containing 'Ptilophyllum Flora', unconformably overlying the Permo-Triassic sequence is restricted to a few intracratonic basins. However, presence of *Ptilophyllum* Flora in East Coast and western India has led to the inclusion of these sequences in the Upper Gondwana despite the fact that no typical Permo-Triassic Gondwana facies is developed in these basins. If we take note of the fact that *Ptilophyllum* is also known from the upper part of Jhuran (Katrol) Formation in Kutch, should we not include Jhuran also in Upper Gondwana?

In fact, occurrence of *Ptilophyllum* Flora in a succession, implying thereby non-marine environment of deposition, has been the most important criterion for identification of Upper Gondwana units. However, evidences based on trace fossils, facies interpretation, foraminifera and dinocysts suggest that Lower Cretaceous clastic sequences of Kutch (Krishna *et al.*, 1983), Jaisalmer (Krishna, 1982; Garg, 1983) and East Coast (Rao & Venkatachala, 1971; unpublished data) are coastal marine deposits.

According to prevailing concept Rajmahal, Jabalpur and Umia plant beds are considered to comprise the Upper Gondwana Sequence, in an ascending order. These sequences are developed in geographically widely separated and genetically different basins and their presumed order of superposition is without any substantial stratigraphic evidence. Obviously the supposed Jurassic age of Rajmahal beds and occurrence of Aptian ammonites in Umia beds led to the construction of such sequence. Subsequent to the recovery of plant megafossils from East Coast sequences, the latter were also included in Upper Gondwana but were not sandwitched between the established succession despite the fact that Barremian ammonites were found in association with plant fossils (Mamgain *et al.*, 1973) and thus deserved a logical inclusion in Upper Gondwana hierarchy. However, with precise radiometric data of Rajmahal traps available recently, all Upper Gondwana units are infact most likely coeval belonging to Lower Cretaceous time span. Thus the Upper Gondwana should now be restricted to certain Lower Cretaceous plant bearing formations in peninsular India and questionably included East Coast and western Indian sequences of a comparable age. The inclusion of these coastal marine sequences in Upper Gondwana has been questioned by several authors in past (Pascoe, 1959; Rao & Venkatachala, 1971; Casshyap, 1977; Biswas, 1977, 1983; Krishna *et al.*, 1983; Krishna, 1983).

The lower boundary of the Gondwana Sequence is clearly defined lithologically in all intracratonic basins by glacial/glaciomarine beds with more or less precise time control. However, the upper boundary has never been defined lithologically and a perusal of literature suggests that very variable and stratigraphically untenable criteria have been used for the purpose. Perhaps youngest known occurrence of Ptilophyllum Flora is one of the criteria. Its uppermost association with datable ammonite fauna is used to fix the upper limit at Neocomian in East Coast sequences and Neocomian Aptian in western as well as in peninsular regions (Sastry *et al.*, 1979). Fixation of such a broad Neocomian-Aptian age, spread over a timespan of nearly 30 Ma, as the upper limit of any lithologic sequence only on floral-faunal evidence and without any lithological attributes, is stratigraphically not tenable. Thus the boundary is supposed to lie arbitrarily within continuous coastal marine sequences. It has also been suggested that Gondwana sedimentation in southern continents generally closes with extensive development of basic Volcanic flow (Krishsnan, 1968). Though considering Rajmahal traps as the coeval event in India, the upper limit of Gondwana succession was extended well up to Middle Cretaceous due to the occurrence of similar flora in younger sediments. It should, however, be noted that in Pranhita-Godavari Graben the most complete Gondwana Sequence is unconformably overlain by Deccan Traps and associated intertrappeans which are treated separately despite having distinctive floral attributes. The upper limit of the Gondwana Sequence is also related to the timing of separation of Indian Plate from the Gondwanaland Super-continent. None of these criteria, based on floral and plate tectonic context, however, helps to place a well defined lithological boundary.

In peninsular India, accumulation of continental sedimentary sequences in intracratonic basins continued during Permian and Triassic without any major breaks. Evidences are now forthcoming that this thick succession of Gondwana facies characterised by distinctive lithological and floral attributes is punctuated with minor marine incursions during Permian at more than one level even in basins which lay well within the craton (Venkatachala & Tiwari, 1988, this Volume). It should, however, be noted that shorelines that may be defined by the distribution of marine strata of Permian age, bear little or no relationship with future continental fragments of the Gondwanaland. Towards the close of Triassic or in Early Jurassic time, the long period of tectonic quiescence in the Gondwanaland craton come to an end and initial phases of disruption of the Supercontinent were initiated. Initiation of tectonic reactivation which foreshadowed the continental breakup was accompanied by widespread cessation of sedimentation in peninsular basins near the end of Triassic with the only possible exception in Pranhita-Godavari Graben where occurrence of broadly dated Liassic sequence is suggested. As a consequence of rifting associated with fragmentation of Gondwanaland, a narrow marine though opened up during Early Jurassic on the western margin between India—Madagascar and Africa which led to the origin of Kutch and Jaisalmer basins. Marine conditions are now known to have been established along the East Coast during the Early Cretaceous with the opening of another narrow marine seaway as a sequel to rifting between India and Antarctica-Australia, leading to the deposition of a thick clastic coastal marine sequence along emerging shorelines, followed by richly fossiliferous marine Upper Cretaceous sequences.

At about the same time during Early Cretaceous, the Rajmahal volcanic activity resulted in the outpouring of basaltic flows interspersed with plant bearing intertrappeans. After a long stratigraphic gap, sedimentation within peninsular India was resumed but was much restricted in distribution and confined to only a few intracratonic basins. There are compelling reasons to believe that the marginal marine basins differ conspicuously from these earlier continental basins and are undoubtedly the first geological structures which actually defined the margins/borders of the future continental fragments.

If coastal marine sequences of pericratonic basins are excluded from the Gondwana fold, the known Upper Gondwana sedimentary sequences are then restricted only to Satpura, Rewa and Pranhita-Godavari basins. It needs to be realised that deposition of these sequences took place under regional and inter-regional tectonic control entirely different from that prevailing during that deposition of typical Gondwana facies during Permian and Triassic. The Lower Cretaceous sedimentation event in intracratonic basins is most likely contemporaneous with the coeval trap activity of Rajmahal which has been related to the initial phases of disruption/breakup of the eastern part of the Gondwanaland supercontinent (Barron *et al.*, 1981). Consideration of this localized trap activity as the event marking close of Gondwana sedimentation in the entire Indian sub-continent based only on certain floral attributes without precise correlation potential would be stratigraphically untenable. The enormous time gap between the Permian-Triassic sequences and Rajmahal trap activity and coeval sedimentation event in peninsular India needs not to be overemphasised.

It is, therefore, suggested that Lower Cretaceous sequences in intracratonic peninsular basins and coastal marine pericratonic basins should be treated separately as these can not be included in any all-pervasive stratigraphic scheme in view of their different origin and sedimentation history. The typical Gondwana facies in peninsular India is better delimited by two most remarkable and wide spread events, the glaciomarine/glacial beds of Early Permian age at the base and the post-Triassic hiatus above the continental red sandstones in almost all the intracratonic basins. The Lower Cretaceous intracratonic sequences should be treated independently as are the other continental formations of a later period, e.g., Cuddalore Formation, Siwalik Group, etc. The Rajmahal Traps and Intertrappeans should be accorded an independent status as given to the Deccan Traps. Both are now regarded to be associated with different phases of rifting history of the Gondwanaland and are characterised by diagnostic floral associations. The Deccan trap activity straddles across the Cretaceous-Tertiary boundary and contemporaneous sedimentary sequences in CauveryBasin, Simla Himalaya and in South Shillong Plateau are all treated independently in Indian stratigraphy.

It is urged that the stratigraphic status of Gondwana sequences should be properly defined and strictly adhered to. It is better to treat Gondwana as a litho-stratigraphic unit of a higher rank (Krishnan, 1968; Sastry *et al.*, 1977) rather than a biostratigraphic unit for which floral zones should be applied.

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