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Biological evidence for better appreciation of the Indian Gondwana

Jai Krishna

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The Gondwana sequences in India are located in intraplate graben or semi graben basins along Narmada-Son-Damodar, Son-Mahanadi and Pranhita-Godavari ancient fracture zones. The basal glacial tillite of these sequences as also their diverse geological similarities, specially the coal-bearing lower part, was well and uniformly understood very widely even beyond the frontiers of India in distant Africa, South America, Australia, Madagascar and Antarctica which are now separated by several thousand kilometers of intervening land, sea or oceanic distances. Obviously, it did not take many years for the Gondwana as a stratigraphic unit of super-order to receive wide acceptance through the length and breadth of the southern hemisphere. With refinement in stratigraphic terminology over the last several decades and growing information about the dissimilarities which were not so evident in the beginning, the usage of the term Gondwana inspite of such spectacular and sound foundation as stratigraphic unit went into disuse in other Gondwanaland constituents in favour of local names while the term Gondwanaland as a supercontinent became firmly entrenched in global geological literature. Moreover, in view of the multidimensional nature of the Indian Gondwana stratigraphic units, viz., their physical, lithological, climatic, tectonic, stratigraphic, facies floral, faunal and other expressions added often to lack of their precise comprehension and usage in line with modern stratigraphic nomenclature there has crept in lot of misunderstanding, contradictions and confusions. An effort has been made to resolve problems concerning classification, definition, distribution, dating and correlation using biological evidences and geological information from the Indian Gondwana and coeval units.

Key-words—Stratigraphy, Palaeoclimate, Lithology, Biological evidence, Gondwana (India).

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साराँश

भारतीय गोंडवाना के परिबोधन हेतु जैविकीय प्रमाण

जय कृष्ण

भारत में गोंडवाना अनुक्रम नर्मदा-सोन-दामोदर, सोन-महानदी एवं प्रणहिता-गोदावरी के प्राचीन क्रमभंग मंडलों के संग-संग अन्तर-प्लेट द्रोणिका अथवा अर्ध-द्रोणिकाओं में विद्यमान हैं। इन अनुक्रमों का आधारी हिमानी टिलाइट, विशेषतया कोयला-धारक अधरि भाग, दूर-दूर तक समान रूप से फैला हुआ था यहाँ तक कि यह भारतीय सीमा से परे दूर स्थित अफ्रीका, दक्षिण अमेरिका, ऑस्ट्रेलिया, मेडागास्कर एवं अंटार्कटिका में भी विद्यमान था। निस्संदेह दक्षिणी गोलार्ध के देशों में गोंडवाना को एक स्तरिकीय इकाई के रूप में स्वीकार किए जाने में बहुत वर्ष नहीं लगे। पिछले कई दशकों में हुए स्तरिकीय अनुसंधान तथा विजातीयताओं के आधार पर एकस्तरिक इकाई के रूप में स्थानीय अन्य गोंडवाना सम्बन्धी देशों में अब प्रयोग नहीं किया जा रहा है जबकि ग्लोबीय भूवैज्ञानिक साहित्य में एक महा-महाद्वीप के रूप में 'गोंडवानाभूमि' शब्द का प्रयोग इतनी शीघ्रता से गभीरकृत हो गया। अपितु, भारतीय गोंडवाना स्तरिकीय इकाइयों की बहुआयामी प्रकृति अर्थात् उनकी भौतिक, शैलिकीय, जलवायवी, विवर्तनिक, स्तरिकीय, फ़ेसीज वनस्पतिजातीय, जीवजातीय आदि के कारण आधुनिक स्तरिकीय नामपद्धति के दृष्टिकोण से इनकी यथार्थ अवधारणा एवं प्रयोग में कुछ कमीयाँ रह गई हैं जिनके फलस्वरूप अनेक भ्रान्तियाँ, असंगतियाँ एवं भ्रम पैदा हो गये हैं। भारतीय गोंडवाना एवं समकालीन इकाईयों से उपलब्ध जैविकीय प्रमाण एवं भूवैज्ञानिक जानकारी का उपयोग करके वर्गीकरण, परिभाषा, वितरण, कालनिर्धारण एवं सहसम्बन्धन से सम्बन्धित समस्याओं को सुलझाने का प्रयास किया गया है।

Concepts, limits and extension of the Indian Gondwana
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MEDLICOTT understood and named the Gondwana Sequence in a lithostratigraphic sense, although, the modern three tier concept of stratigraphic units had then not developed. Moreover, not much distinction was then in vogue among litho-, bio- and chronostratigraphic units. In recent years, the Indian Gondwana Sequence and its subdivisions have been formalised as lithostratigraphic units (Gondwana Lexicon, Sastry *et al.*, 1977). The Gondwana stratigraphic units on account of similar origin of depositional basins, climate, tectonic control, source rocks, etc. exhibit exemplary similarity of lithology, coal content, facies, cyclicity, fauna, flora, etc. However, the most striking similarity catching the eyes of the Gondwana specialists has been the megafloral similarity. Over the decades, the megaflora has received prime consideration for identification, definition or inclusion of contemporary Indian stratigraphic units into Gondwana fold, for the principal reason that in the classical sense presence of rich land flora also guaranteed non-marine origin to the stratigraphic units which happened to be one of the major features of the Gondwana stratigraphic units as per original definition. As a consequence, all contemporary units enclosing the characteristic Gondwana floral elements whether fulfiling basic conceptual requirements of Gondwana by original definition or not were brought to the Gondwana fold as 'coastal/pericratonic/mixed/marine Gondwana, viz., Agglomeratic Formation of Kashmir, Ranjit Formation of Sikkim, Subansiri Formation of Assam, Umaria Formation of Madhya Pradesh, Umia Formation of Kachchh, Vemavaram Formation of East Coast, Kagbeni Formation of Nepal.

An analysis of Medlicott's original definition of Gondwana as stratigraphic unit, clearly projects forth their essential requisites as also many auxiliary features as follows:

Essential requisites of Gondwana lithostratigraphic units:

1. Lithological similarity in the form of substantial coal-bearing lower part in a glacial boulder/conglomerate, coal and red sand ascending sequence.
2. Preservation and/or deposition in intracratonic narrow linear faulted basins.
3. Largely fluvio-lacustrine depositional environment, except for the glacio-marine influence near the base.

Additional or auxiliary features of Gondwana lithostratigraphic units:

1. Presence of a large unconformable gap below the base of the Indian Gondwana Sequence from latest Precambrian (plus doubtful lowest Cambrian) to Upper Carboniferous (Table 4).
2. Absence of marine body fossils in view of their largely non-marine origin as per original definition except in the glacio-marine basal part.
3. Spectacular megafloral and land vertebrate similarity.
4. Cyclic fining upward sequences with sandstone shale and coal repetition in that order.
5. Northwest pointing palaeocurrent and palaeoslopes throughout the span of Gondwana Sequence.
6. Major unconformity above the Gondwana Sequence.
7. Presence of regional discontinuities within the sequence.

It is emphasised here that any of the above additional characteristics is no guarantee for recognition of lithostratigraphic units as Gondwana. However, these auxiliary characteristics can often be objectively used to resolve disputes and confusions about the Gondwana units. The only obligation or condition is that the auxiliary feature used must be in line with the essential requisites. The true Gondwana units need be recognised on the basis of their characteristic lithology (glaciogene boulder bed at the base followed by rich coal-bearing sediments with a cap of red sandstones) and other physical attributes observable by naked eyes in the field. Floral or faunal characteristics have no relevance in defining or recognising a lithostratigraphic unit.

Looking at the so-called 'Gondwana lithostratigraphic units' of Lesser Himalaya and many marginal areas in the west, north and east, it becomes amply clear that the said units do not exhibit the true Gondwana lithological characteristics. For example, the units like Agglomeratic Formation of Kashmir or Subansiri Formation of Assam or Badhaura Formation of Rajasthan or Umaria Formation of Madhya Pradesh are all largely neither rich in coal nor capped by red sandstones nor thick like the true Gondwana. In fact these units although containing the characteristic Lower Gondwana *Glossopteris* floral elements are otherwise products of different tectonic, stratigraphic and depositional setting, from that of true Gondwana as detailed in Tables 1 and 4. It is clear from the elaborate tables that the true Gondwana units are largely non-marine and differ markedly from, florally similar but, largely marine contemporaneous non-Gondwana stratigraphic units in origin of the basins, stratigraphic set-up below, above and within, lithology, faunal elements (both land and sea, micro or mega), trace fossils, physical structures, thickness, sedimentation cycles,

Table 1—Diverse similarities/differences between largely non-marine true Gondwana and largely marine non-Gondwana

TRUE GONDWANA UNITS	*OTHER FLORALLY SIMILAR CONTEMPORARY UNITS*			
	Lesser Himalaya	*High Himalaya*	*Western India*	*Indian East Coast*
1. Glacial conglomerate, at the base like Talchir Boulder Member	Glacial sediments mostly lacking, e.g., in Dogadda (U.P.)	Glacial sediments lacking, e.g., Productus Shale Formation in Spiti or Krinkrong Formation of Kumaon	Glacial sediments present, e.g., Bap Formation	Glacial sediments absent, e.g., Palar Formation
2. Rich coal content in the Permian part, e.g., Damuda Group or its equivalents	Thin carbonaceous shales or coal present but never very rich as in true Gondwana mostly Lower Permian only	Thin carbonaceous shales or coal present but never very rich	Thin carbonaceous shales or coal present but never rich, mostly Lower Permian only	Thin carbonaceous shales or coal present but never rich
3. Coal rich Permian part invariably followed by coal devoid red sandstones of Triassic age	Except for the lower part rest of the Permian and Triassic is unrepresented	Permian and Triassic nearly complete but without coal and red sandstones respectively	Permian and Triassic absent except Lower Permian excluding western Rajasthan where Triassic is known in subsurface	Permian and Triassic absent except for Lower Permian at Palar
4. Thickness of the sequence (Permian & Triassic) large, several thousand meters	Florally similar units always thin	Florally similar intercalations always very thin	Florally similar part very thin	Florally similar part very thin
5. Sedimentation mostly fluvio-lacustrine non-marine except for glacio-marine influence in Lower Permian	Sediments formed mostly by marine depositional processes	Sediments exclusively marine	Sediments exclusively largely marine	Sediments exclusively largely marine
6. Stratigraphic units marine fossil devoid except the basal lower Permian part	Units with marine fossils	Sediments with abundant marine fossils	Sediments with rich marine body or trace fossils	Sediments with rich marine body or trace fossils
7. Abundance of *Glossopteris* and *Dicroidium* floral elements respectively characterising the Permian and Triassic	*Glossopteris* floral elements present	Megaflora present only occassionally during Permian and Triassic	Glossopteris flora present in Lower Permian	
8. Exclusively found in inland, narrow linear faulted basins which originated from a wide regional tectonic event at the start of Permian, by reactivation of Precambrian weak fracture zones	Along narrow linear tracks near the tectonic contact of Lesser Himalaya and Outer Himalaya	Along the High Himalaya in basins existing since Precambrian	In Kutch the basin originated only near the base of the Triassic/Jurassic/ boundary	The basins except Palar originated only near the Jurassic/Cretaceous boundary
9. Palaeodrainage and palaeoslope in general converging towards the north west, west or north for the entire Permian and Triassic	Westerly or north westerly palaeoslopes	Northerly, northwesterly or westerly palaeoslopes	Westerly or north westerly palaeoslopes	South-easterly palaeocurrent and palaeoslopes during Lower Cretaceous

(*Contd.*)

10. "Upper Gondwana" of inland Gondwana basins included later into the Gondwana Sequence as per original definition of Medlicott characterised by *Ptilophyllum* megafloral elements in non-marine sediments at Jabalpur, Bansa, Rajmahal, etc. of Lower Cretaceous age unconformably overlying Triassic sandstones	Mostly absent or very rare unconformably over mostly Precambrian	Exclusively marine with abundance of marine body fossils and only locally containing *Ptilophyllum* floral elements conformably overlying Palaeozoic to Mesozoic (nearly continuous sequence)	Exclusively or largely marine with abundant marine trace fossils and also *Ptilophyllum* megafloral elements conformably overlying the Jurassic	Exclusively or largely marine with the marine body fossils only in thin bands but rich in *Ptilophyllum* megafloral elements unconformably overlying Precambrians mostly linear basins along the East Coast originating near the Jurassic/Cretaceous boundary

palaeodrainage/palaeoslope, palaeocurrent, etc. These largely marine non-Gondwana equivalents are found in the peninsular linear basins, Lesser Himalaya, High Himalaya, western India and East Coast. Unlike the Permian to Triassic span of the largely non-marine Gondwana Sequence these marine equivalents are largely of Lower Permian and Lower Cretaceous ages; major part of the Permian and entire Triassic is mostly absent.

These non-Gondwana units not only fail to qualify as true Gondwana units in terms of the essential physical requisites (lithology and others) but also fail in exhibiting most of the auxiliary true Gondwana features. It seems that the striking floral similarity of *Glossopteris* elements in Lower Permian and *Ptilophyllum* elements in Lower Cretaceous has been the only binding force for the erroneous admission of largely marine Lower Permian and Lower Cretaceous non-Gondwana stratigraphic units into their largely non-marine equivalents (Gondwana or others). It is also very necessary now to objectively analyse the relevance of land flora for differentiating a sedimentary rock formed by non-marine or marine depositional processes. At the same time it is also desirable to use other evidences like physical and biogenic structures specially in less obvious or disputed apparently marine body fossil devoid, land plant fossil rich, coarse clastic dominated units. We need to remind ourselves that coastal land plants or animals very characteristic of fluvio-lacustrine depositional systems could always be transported or drifted in a nearby marine paralic or allied depositional system. Thus similar floral characteristics could well be displayed both in non-marine and marine sediments. On the contrary, members of an exclusively marine fossil group like Brachiopoda or Cephalopoda can hardly ever be transported from a marine to non-marine depositional system. Thus presence of plant fossils in any stratigraphic unit can neither guarantee non-marine origin nor provide exclusive right for admission into Gondwana fold, while presence of marine body or trace fossils provides guarantee of marine depositional framework. Another crucial application of biogenic evidence is in deciphering the depositional processes of rock formation through the study of the traces made by animals while living. In recent years, many prolificly plant-bearing but marine body fossil devoid, coarse clastic dominating Lower Cretaceous stratigraphic sequences in western India, East Coast and elsewhere traditionally understood as non-marine have been interpreted as having been essentially formed by marine depositional processes (Bhalla, 1972; Baksi, 1977; Biswas, 1977; Casshyap, 1979; Krishna, 1983a, b, 1987; Krishna *et al.*, 1983; Bose *et al.*, 1986). Their *Ptilophyllum*-bearing floral similarity with inland non-marine units can not qualify them as non-marine. On the other hand, looking at the Gondwana lithostratigraphic units in the above perspective, their inland coal-bearing, largely non-marine conceptual characteristics by original definition become very obvious, hardly leaving any scope for confusion or misunderstanding in their recognition and distinction from contemporary largely marine non-Gondwana units. Adhering to the above understanding, it is here recommended that largely marine coal devoid/deficient sequences in Lesser Himalaya or marginal areas in the north, east and west of mostly Lower Permian and Lower Cretaceous, be excluded from the Gondwana fold. Also should be excluded the Lower Cretaceous non-marine stratigraphic units of Gondwana basins for neither being part of the Gondwana lithological or of tectonostratigraphic framework (Table 2).

DATING AND CORRELATION

Many of the Gondwana litho-and biostratigraphic units are mostly diachronous. The boundaries of such units, specially biostratigraphic

Table 2—Lower Cretaceous part of traditional Gondwana Sequence here recommended for exclusion from true Gondwana as per original definition of Gondwana Sequence by Medlicott.

PERIOD		REWA	GODAVARI	NARMADA	RAJMAHAL
CRETACEOUS (LR.)	ALB. APT.				
	UPP. NEOC.	BANSA FN.	GANGPUR FN. CHIKIALA FN.	JABALPUR FN.	RAJMAHAL FN.
	LR. NEOC.				
JURASSIC			? KOTA FN.↓		

units, are often ill-defined in measured lithocolumns. Also the lithological and floral changes are mostly not simultaneous, some time lag seems to be always involved. For example, the flora of the Karharbari Formation (Damuda Group) is similar to that of the underlying Talchir Group-much different from that of the overlying Damuda Group Many a times, the Gondwana lithostratigraphic unit names have also been used for biostratigraphic units with change of suffix, viz., Barakar Formation as Barakar 'Series/Stage'. This has led to lot of confusion. The Talchir/Damuda lithostratigraphic boundary is defined by a lithologic change at the base of Karharbari Formation, while the floral change is at the top of Karharbari Formation. If duplication of the same name with different suffix like Formation and Stage is ignored, the biostratigraphic boundary between Talchir and Damuda 'Series' becomes altogether different from the lithostratigraphic boundary between the two lithostratigraphic units. The flora of the Barakar 'Series/Stage' excludes the flora of the Karharbari Formation which is otherwise allied and included with the flora of the Talchir Group. This is greatly confusing and such usages must be abandoned. As a rule, florally based biostratigraphic units must be named after single taxon or assemblage of fossil taxa instead of locality names already employed and occupied for lithostratigraphic nomenclature. Similarly, usage of expressions like 'Rajmahal flora' or 'Barakar flora' must also be abandoned because that does not precisely clarify as to whether the flora refers to the same or different sequence of beds constituting the Rajmahal or Barakar Formation. Better would be to specify the range of a particular flora in the section. It is worth while to comment here on Banerjee's (this workshop) question as to whether Karharbari is a formation or biozone. Her answer is correct except that name of the megafloral or microfloral biozone has to be after fossil taxa instead of the duplication of Karharbari which is already occupied for lithostratigraphic unit.

Another significant aspect of most of the land plants and animals, mega- or micro-, is their relatively long ranging nature. As a consequence chronology and correlation of Gondwana litho- or bio-stratigraphic units have been far from satisfactory. Floral and vertebrate control on geological time is comparably either much less or little understood than control on time provided by many marine elements. Dating and correlation based on floral elements alone has led to gross absurdities specially with regard to dating of Gondwana lithostratigraphic units. For example, Rajmahal Formation used to be dated on the strength of *Ptilophyllum* and allied floral elements independently as Lower Jurassic since similar floral

Table 3—Revised lithostratigraphic scheme proposed here

PERIOD			DAMODAR	SONE-MAHANADI	REWA	GODAWARI	NARMADA	RAJMAHAL
GONDWANA	TRIASSIC	UPPER	MAHADEVA FN. (SUPRA PANCHET FN.)	SUPRA PANCHET FN.	PARSORA FN.	KOTA FN. DHARMARAM FN. MALERI FN.	BAGRA FN.	DABRAJPUR FN.
		MIDDLE				BHIMARAM FN. YERAPALLI FN.	DENWA FN.	
		LOWER	PANCHET FN.	PANCHET FN.			PACHMARHI FN.	
	PERMIAN	UPPER	RANIGANJ FN. BARREN MEASURES	RANIGANJ KAMTHI FN. B. MEASURES	PALI-TIKI FN.	KAMTHI FN. MANGLI FN.	BIJOURI FN. MOTUR FN.	RANIGANJ FN.
		LOWER	BARAKAR FN. KARHARBARI FN. TALCHIR FN.	BARAKAR FN. KARHARBARI FN. TALCHIR FN.	BARAKAR FN. KARHARBARI FN. TALCHIR FN.	BARAKAR FN. TALCHIR FN.	BARAKAR FN. TALCHIR FN.	BARAKAR FN. TALCHIR FN.

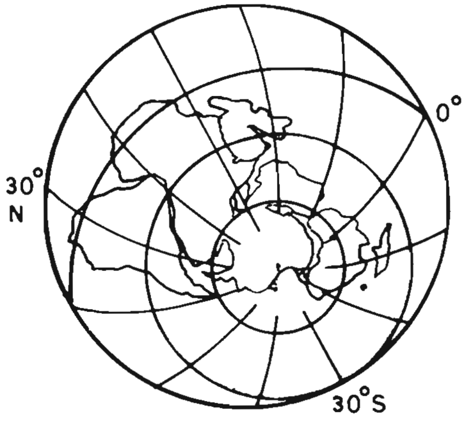
Table 4—Stratigraphic set-up in Gondwana and non-Gondwana basins (Cambrian to Lower Cretaceous)

Period	*Gondwana Basins*	*Non-Gondwana Basins*			
		Lesser Himalaya	*Tethys Himalaya*	*Western India*	*East Coast*
Cretaceous (Lower)	Rajmahal Trap	Mostly stratigr. gap or marine	Marine	Marine	Marine
Jurassic	Stratigr. gap			Marine	
Triassic	Non-Marine without coal	Stratigr. gap	Nearly continuous Marine		Stratigr. gap
Permian	Coal bearing	Marine		Stratigr. gap	Locally marine at Palar
Carboniferous Cambrian	Stratigr. gap	Stratigr. gap			Stratigr. gap

elements were found in the Lower Jurassic of England. This was in utter disregard of the fact that *Ptilophyllum* and allied floral elements range from Triassic to Cretaceous. In a recent lexicon on Indian Gondwana (Sastry *et al.*, 1977) essentially Lower Cretaceous lithostratigraphic units have been dated from Upper Triassic to late Lower Cretaceous by different palaeobotanists. To a present day stratigrapher, such plant fossil based vague/broad independent dating amounts to a futile exercise completely lacking any time control in real sense. Another example of a different kind is the similarity of flora of Lathi Formation of Lower Jurassic age and Lower Cretaceous units which age wise should have been entirely different (Lexicon, 1977) like Rajmahal Formation. The non-marine sequences of Gondwana grabens involving a time span of about 180 million years (including the disputed Lower Cretaceous) have been ambitiously split into 13 floral assemblage (Shah *et al.*, 1971) with an average assemblage duration of about 15 million years without actual correlation with universal marine stages and zones. This was entirely unrealistic as proved later. The ones referred to Jurassic turned out to be Cretaceous, the ones referred to as successive turned out to be coeval, the variation in floral content being possibly due to climatic and geographic considerations. The whole exercise seems to have been based on circular argument/presumption like that Rajmahal, Jabalpur and Umia units are in ascending stratigraphic order. Nobody thought that the said units being located far apart do not show any such stratigraphic relationship. Thus such a difficult situation warrants dating of the plant-bearing units only with the help of short ranging index fossils or assemblages based on precise data on taxa ranges. Moreover, the Gondwana stratigraphic units lacking index taxa can be better dated by relating them to their marine contemporary non-Gondwana units, both being products of the same tectonic framework. Wherever possible indirect temporal control provided by marine index fossils from the underlying or overlying units in contemporary pericratonic units needs also be made use of. In addition, absolute radiometric dates can be obtained for igneous rocks, stratigraphically/structurally related to Gondwana units. Fission-Track dating of apatite and glauconite bearing rocks has shown excellent promise in recent years (Radiometric Dating Laboratory, Birbal Sahni Institute of Palaeobotany). Microfloral elements over the years have shown increasing potential in terms of their quantitative distribution through time, still the boundaries resulting from such statistical counts of microfloral elements are difficult to correlate with standard universally applicable inter and intra stage time divisions. There is grave allround need to investigate quantitative aspects of microfloral assemblages in marine units for the integration of the two. The best bets for Permian and Triassic appear to be Salt Range and Kashmir for such integration, since these areas, compared to High Himalaya sequences, had similar climatic framework specially temperature conditions as those of true Gondwana units. For the Lower Cretaceous or the Jurassic/Cretaceous boundary Kachchh appears to be a good proposition for relating to non-marine Lower Cretaceous of Gondwana grabens, although recommended here for exclusion from true Gondwana units for various other reasons.

TECTONO-STRATIGRAPHIC FRAMEWORK

It is generally agreed that several early Precambrian orogenies in succession expressed in the form of the Dharwar, Aravalli, Eastern Ghat, Satpura and Delhi fold belts assimilated to constitute the basement of the Indian plateform, the Indian Plate for a long duration from Upper Precambrian to close of Cretaceous did not again witness mountain

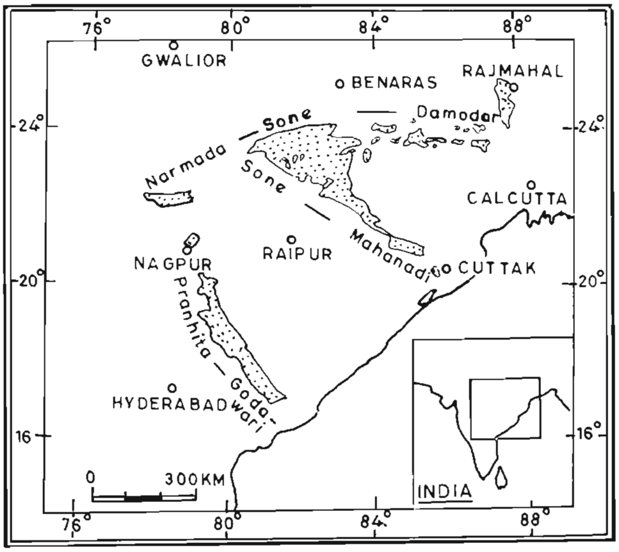


Text-figure 1—Gondwanaland at the start of Gondwana sedimentation at Carboniferous/Permian boundary.

building activity. On the other hand vertical epierogenic tectonics dominated the scene in this part of the world. Thus the span of time during which Gondwana sequences were deposited, the Indian subcontinent witnessed several major or significant vertical tectonic events. These events invariably resulted in reactivation of the major ancient basement fracture zones, prior, concomitant and subsequent to the Gondwana sedimentation. Thus reactivation along ancient fracture zones seems to have played crucial role not only in the deposition and preservation of Gondwana sequences but also has been responsible for the creation of some linear faulted basins or closure of some other such basins irrespective of their marine or non-marine nature and intra or pericratonic location. These events affected the marine and non-marine basins simultaneously in similar or different manner. These reactivation events have proved very helpful in understanding the time relationship of stratigraphic events from one basin to the other, towards formulation of a sort of composite stratigraphy and correlation. Some stratigraphers have termed this composite understanding of geological events as Event Stratigraphy. The major tectonic events of Late Palaeozoic and Mesozoic of relevance to Gondwana sedimentation and dated mostly on fossil evidence can be summarised as follows:

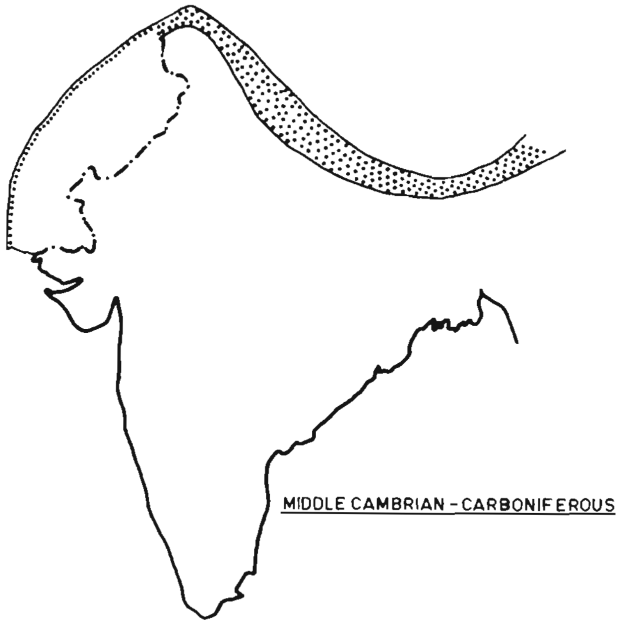
Basal Permian (Tatarian/Asselian Boundary) event (Text-figs 3, 4)—This was a very widely spread event reflected specially in the form of vertical tectonics in the Indian subcontinent. This event also signalled the initiation of protorifting/fracturing, etc. which later during Late Mesozoic caused the break-up of Gondwanaland. Before this event peninsular India, or better to say the major part of the Indian Plate was beyond the reach of the Tethys Sea from Middle Cambrian to close of Carboniferous except the High Himalaya belt undergoing almost continuous sedimentation since Late Precambrian. The basal Permian event caused reactivation in Bikaner and Jaisalmer, along narrow linear zones in Lesser Himalaya, along Narmada-Son-Damodar, Pranhita-Godavari and Son-Mahanadi fracture zones, and Palar Basin along East Coast. Several linear faulted basins were created in these areas. Except for few such basins which were in the heart of the Indian Plate the rest of the basins were transgressed by the Tethys on account of a global sea level rise. The basins located in the high relief region in the heart of India and in general beyond the reach of the Tethys witnessed non-marine sedimentation. Central and southeast India being relatively closer to the spread of polar ice caps had in its basins sedimentation influenced by glacial processes resulting in glaciogene tillite sedimentaries. A significant aspect of the Permian intracratonic true Gondwana units is the increasing physical, biological and chemical evidence of marine influence up to stratigraphically as high as Barren Measures or equivalents or even younger Raniganj Formation (Chaudhri, 1988 Venkatachala & Tiwari, 1988, this Volume). Most of these influences in a largely non-marine framework are probably of transient nature but still suggesting the possibility of occasional rare marine connection from Narmada to Palar through the Godavari Graben. Localised mild fracturing in Palar parallel to East Coast and incursion of very shallow paralic sea from north-east can not be altogether ruled out.

The dating of the event as Lower Permian or Asselian is based on wide spread occurrence of *Eurydesma-Conularia-Deltopecten-Productus* assemblage of Upper Asselian age besides fusulinid foraminifera, conodonts, etc. in High Himalaya. The lowest stratigraphic units of largely non-marine Gondwana sequences in all the Gondwana basins lately have provided increasing transient marine influence (Venkatachala & Tiwari, 1988 this Volume). In Gondwana grabens the basal sediments are glaciogenic. Unlike the traditional thinking that these basal beds also include some part of latest Carboniferous, no definite evidence until yet has come forth in support of a partly Upper Carboniferous age. It appears that most of the Indian literature indicating Upper Carboniferous age of the basal beds is possibly due to transfer of previously held Upper Carboniferous sediments in the Permian stratotype of USSR into basal Permian on the basis of their faunal affinity specially that of fusulinid foraminifera much after the original establishment of the Permian. Partly Upper Carboniferous age is also not supported by the present relatively refined evidence of uppermost Carboniferous representing a stratigraphic gap in all the High Himalaya areas otherwise having relatively complete upper Palaeozoic sequences. Since, the start of sedimentation in Gondwana grabens is genetically tied to the same tectonic event causing wide spread Asselian transgressive sedimentation, the origin of Gondwana grabens should not be older. Recently, Mitra (1988, this Volume) has reported substantial thickness of the sediments in an exploratory borehole in the neighbourhood of Daltonganj from even below the glaciogene conglomeratic sediments which in turn underlie the Asselian *Eurydesma-Conularia*-bearing beds, thus suggesting older than Asselian (possibly uppermost Carboniferous) age for the sediments underlying the glaciogene conglomerate. In this context probably lowest Asselian age for these lowest beds should be a better proposition in view of the Upper Carboniferous being a regressive phase in all High Himalaya basins. Such substantial thickness of clastic sediments can well be deposited in a relatively small span of time within Asselian itself. Thus the lower age limit of the Gondwana Sequence when critically evaluated in context of the regional expression in High Himalaya marine basins is basal Permian on account of the stratigraphic framework in the entire region, both being products of the same wide regional tectonic event. Florally Talchir Shale Member is characterized by radial monosaccates and absence of saccates or colpates (Bharadwaj, 1987). It is suggested to study the microflora in better dated Lower Permian of High Himalaya, for example Spiti and Kumaon areas for refining the temporal resolution of the microfloral elements. Comparison and correlation with Salt Range Lower Permian may be still better in view of similar cold subpolar climatic conditions (Singh, 1987) in Salt Range as well as Gondwana basins. Flora of Karharbari Formation shows near absence of Varitriletes and zonate Triletes while *Sulcatisporites* dominates the assemblage. According to Bharadwaj (1987) Talchir Formation and Karharbari Formation are Artinskian in age which needs confirmation by comparing the flora from these stratigraphic units with that from otherwise firmly dated Artinskian sediments. According to Shah and Dickins (1987) Talchir Formation is Asselian, Badhaura Formation is Sakmarian and Agglomeratic Formation is Asselian/Sakmarian. Shah and Dickins (1987) have suggested a break between Nilawan Group (=Speckled Sandstone Formation) and the overlying Productus Limestone Formation at the base of Amb Member in Salt Range equivalent to Sakmarian and Artinskian stages. They have dated Panjal Trap Formation and intercalated plant-bearing beds as mostly Kungurian and Ufimian (=Wordian) while Zewan Formation is assigned to Kazanian and Tatarian. According to Shah and Dickins (1987) there is another depositional break between Amb Member and overlying Virgal Formation. In addition they indicate a drastic climatic change from cold to warm between Asselian and Kungurian suggesting a climatic event. A similar climatic event has been envisaged between Talchir and Barakar Formation with a stratigraphic break at the base of Barakar Formation. On the strength of climatic event alone Amb Member can be broadly correlated with Barakar Formation. In terms of stratigraphic setting Chidru Member can be broadly correlated with Raniganj Formation. It will be worthwhile to compare the flora of Chidru Formation of Upper Permian age with that of the Raniganj Formation of Gondwana grabens. Recently, Balme (1970) has precisioned Permian/Triassic boundary to the best, possible extent in terms of floral assemblages in Pakistan comparing and correlating it with Australia, Madagascar, South Africa (*see* Wright & Askin, 1987). This line of approach appears to be promising in integrating the successive floral assemblages from Talchir and Damuda groups with standard universally understood stages and zones.

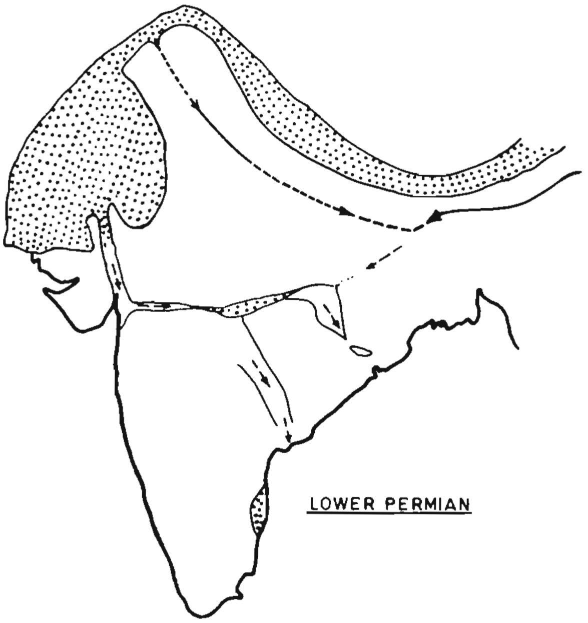


Text-figure 2—Distribution of Gondwana formations (fluvial intracratonic) in India.

Permian/Triassic Boundary event (Text-fig. 5)—Excluding at least one intra- Permian event near (the Lower/Middle Permian), the next major event supposedly occurred near the Permian/Triassic boundary. All along the High Himalaya, there is evidence of lowest Triassic (*Otoceras woodwardi* Zone of basal Schythian Stage) transgressive over the latest Permian sediments. In Gondwana grabens, the event marks the cessation of coal formation suggesting a significant climatic change from lush forest vegetation favouring climate (warm humid temperate with intermittent rainfall) to dry and arid



Text-figure 3



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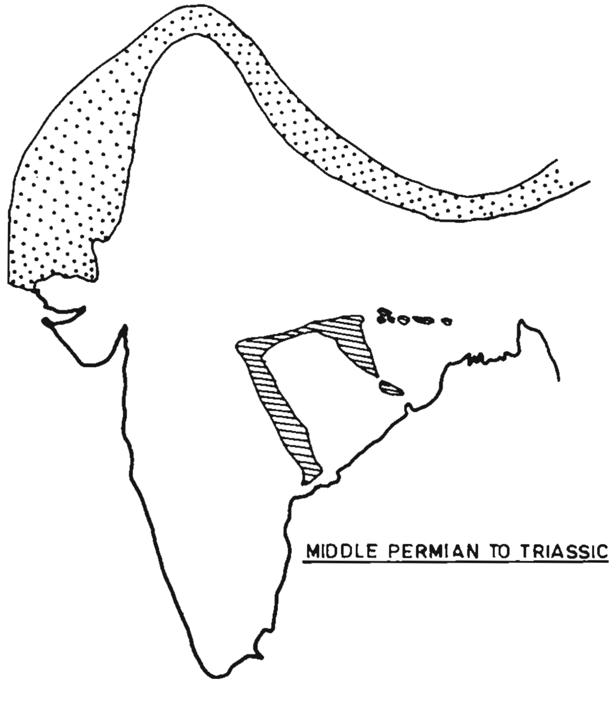

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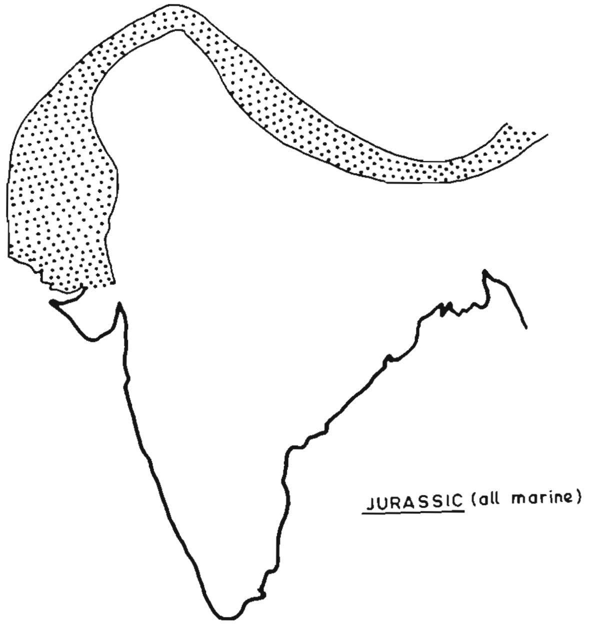
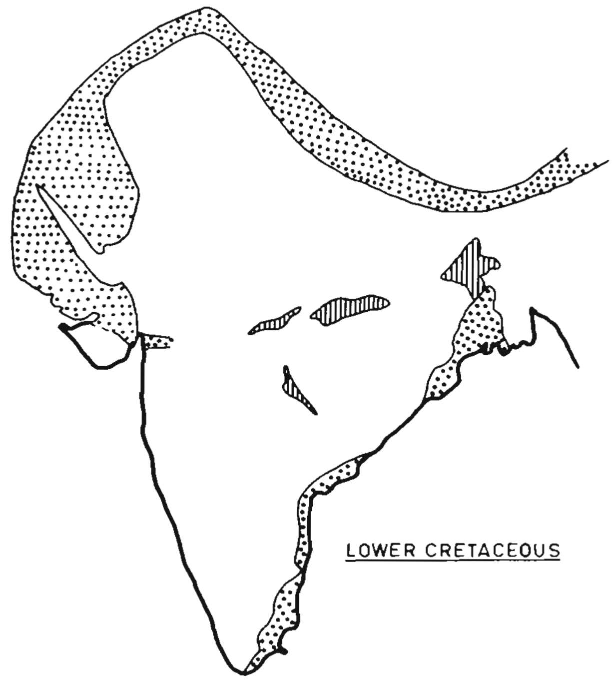


Text-figure 6

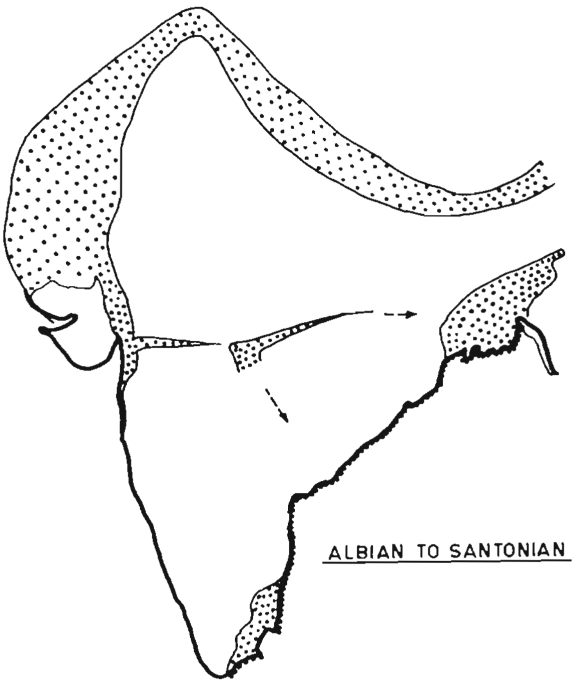
Text-figures 3 to 6—Postulated schematic distribution of land and sea along with fresh water Gondwana sediments in the Indian subcontinent during Middle Cambrian to Carboniferous, Lower Permian, Middle Permian to Triassic and Jurassic.

conditions detrimental for preservation of plants and their transformation into coal (Chandra & Chandra, 1988, this Volume). Microflorally the Triassic is dominated by Trilete spores while in marine High Himalaya basins there is noticed increasing dominance of ammonoids. Megaflorally there is only gradual transition from dominance of *Glossopteris* to that of *Dicroidium* and allied elements. The microfloral transition has been dated within or above the Dorashamian (=Tatarian) Stage of Permian near the Permian/Triassic boundary in Salt Range (Balme, 1970).

Mitra (1987) has suggested a compressional tectonic event above Panchet Formation and below



Text-figure 7



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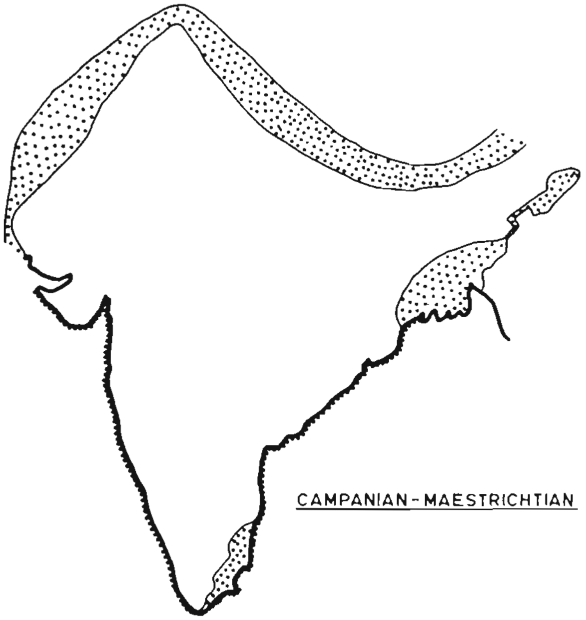
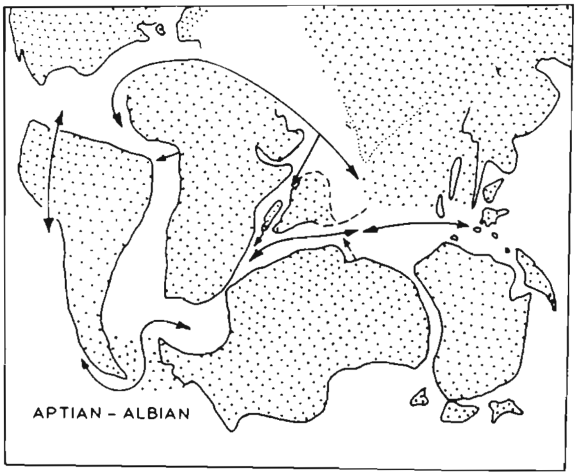


Text-figure 9

Text-figures 7 to 9—Postulated schematic distribution of land and sea along with fresh water Gondwana sediments in the Indian subcontinent during Lower Cretaceous, Albian to Santonian and during Campanian to Maestrichtian.

Supra-Panchet Formation in Pranhita-Godavari and Son-Damodar basins which is also marked by regional discontinuity. It appears that either this event was very localised or of very light intensity because there is no evidence of such a compressional event from any High Himalaya area having a nearly continuous sequence of Triassic sediments. More logical explanation is provided by Bose and Mukhopadhyay (1985) about these folds being second order domes and basins along the flanks of buried ridges somewhat similar to Jurassic domes in Kachchh and for such second order bending a compressional event is not necessary. However, there is some evidence of mountain building activity during Triassic at marginal areas of Gondwanaland as Ellsworth mountain of Antarctica, Cape fold belt of South Africa and Sierra fold belt of Argentina.

Regarding the dating of Triassic Gondwana stratigraphic units the situation is not very

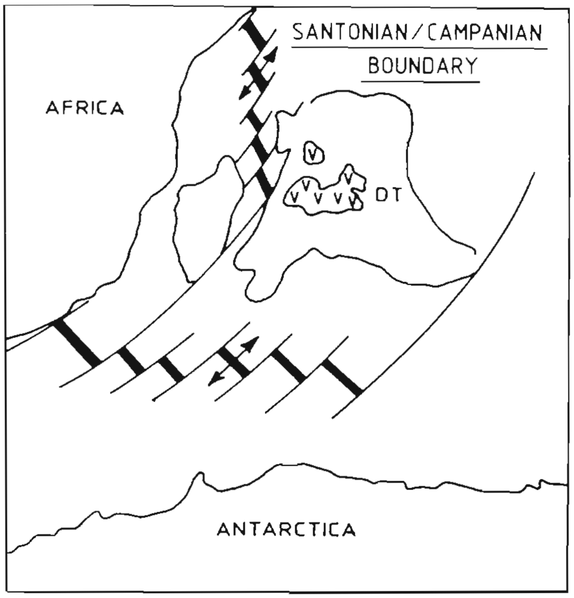


Text-figure 10—Palaeogbeographic reconstruction showing marine faunal dispersal routes to and from India in the southern hemisphere during Aptian-Albian.

satisfactory. Panchet Formation has been dated as Lower Triassic or Scythian mainly on the evidence of *Lystrosaurus* of Lower Triassic age in many Gondwanaland continents. There is regional discontinuity of unequal duration between Panchet Formation and Supra-Panchet or their equivalents in different Gondwana grabens. Sometimes this discontinuity sets in at the close of Damuda Group or its Raniganj Formation, however, the duration of this regional disconformity is not precisely known in different basins. Most of the Supra-Panchet Triassic stratigraphic units have been mostly dated as Upper Triassic or within Upper Triassic except for Pranhita-Godavari Basin where the stratigraphic gap is possibly of the shortest duration among different Gondwana grabens. In Pranhita-Godavari Valley there is succession of five lithostratigraphic units as indicated in Table 1. These supposedly range from Middle to latest Triassic or even doubtful lowest Jurassic. The topmost lithostratigraphic unit of this sequence is Kota Formation with significant fresh-water fish fauna. Among the fishes the genera *Paradapedium* and *Tetragonolepis* suggest Liassic affinity, while another fish *Lepidotes* is similar to another European Liassic species (Jain, 1987). Sauropod dinosaur remains and mammals also known from Kota Formation are also assigned Lower Jurassic age. It is significant to note that many of these faunal elements range from Rhaetian to Liassic, however, precise taxa ranges in different parts of Gondwanaland are not yet available. In context of the regional tectono-stratigraphic framework the Triassic Gondwana stratigraphic units are not known to extend into Lower Jurassic with exception of Kota Formation which prompts to favour a Rhaetian top for Kota Formation rather than Liassic until a definite conclusive evidence is available in favour of Liassic which, however, can not be altogether ruled out. There is evidence of the Tethys having advanced as for south as Jaisalmer in India (subsurface Triassic evidence in Dutta, 1983). During the Triassic, like the Permian the integration of Triassic microflora with that from better dated marine units of high Himalaya should prove rewarding. The best propositions in this aspect would be Kashmir, Spiti or Kumaon sections.

Triassic/Jurassic Boundary event (Text-fig. 6)—This is a significant event with different expressions in intracratonic Gondwana basins and pericratonic non-Gondwana areas. This event marks the origin of Kachchh Basin in western India parallel to Narmada and Delhi fracture trends as suggested by Rhaetian/Liassic microflora from the Banni exploratory well (Koshal, 1983). It also marks the closure of sedimentation in all the Gondwana basins. It is worth pointing out here that for a long time it was anticipated that the whole Jurassic Period is represented in the largely non-marine nearly continuous basal Permian to Lower Cretaceous Gondwana Sequence. Most of the 'Upper Gondwana' stratigraphic units were also for a long time assigned Lower, Middle and Upper Jurassic ages. There are still many specialists, including some palaeobotanists, who have yet not reconciled with the otherwise widely accepted absence of nearly the entire Jurassic in the Gondwana grabens based on precision dating of the floral assemblages rather indirectly from underlying and overlying units in contemporary marine sequences of western India and East Coast. There is also evidence of two generations of post Supra-Panchet Mesozoic faults in Gondwana basins. These faults are mostly high angled faults often cutting the earlier system of faults. One generation of these faults has affected Supra-Panchet sediments but predates igneous intrusives related to Rajmahal volcanic activity of Aptian-Albian being in turn affected by them. This is here broadly dated with Triassic/Jurassic or Jurassic/Cretaceous boundary events. The younger generation of Mesozoic faults are related to Deccan volcanic activity. There is evidence of gradual sea level rise during the Jurassic on a global scale. Since Jurassic is unrepresented in the Gondwana basins possibly the reactivation of the Gondwana basins resulted in their uplift to cause closure of sedimentation. On the northern margin of the Indian Plate the South Tibet micro-block seems to have separated from the parent Indian Gondwana Plate and rifted northward as suggested by sudden decrease of post-Triassic floral similarity between different basins on the Indian Plate and South Tibet, in contrast to strong earlier similarity of the Glossopteris Flora between India and South Tibet.

Jurassic/Cretaceous Boundary event (Text-fig. 7)—It needs to be understood that although the Gondwana sedimentation by and large had almost closed near the Triassic/Jurassic boundary, the Gondwana superplate as a tectonic and geographic unit remained compositely united as a single unit except for separation of micro plate on its northern margin throughout the Permian to Middle or even latest Cretaceous, when came forth the first evidence of the somewhat north-south running shallow arm of the Tethys reaching across to the southeast Pacific along the East and South African Coast (Krishna, 1983b, 1987). The evidence is in the form of sudden increase in topmost Tithonian (Micracanthum Zone) ammonoid faunal similarity between the Indo-East-African marine faunal province areas (western India, High Himalaya, East Africa, Madagascar, etc.) and southeast Pacific marine faunal province areas (Argentina, Peru, Mexico). This suddenly increased similarity is in contrast to low similarity for nearly the whole of Middle and Upper Jurassic until topmost Tithonian between the said faunal province areas (Krishna, 1987). This suggests that there has been sudden dispersal of topmost Tithonian South American ammonoid genera, viz., *Corongoceras* Spath, *Substeuroceras* Spath, *Argentiniceras* Spath, *Groebericeras* Leanza, etc. to either Kachchh or Himalaya (Krishna, 1983a; and unpublished work) due to the creation of shallow marine corridor from western India to South America. It may be particularly emphasised here that presence of such a shallow strait of the Tethys Sea almost midway between western and eastern part of Gondwanaland does not mean continental separation of the two by creation of new ocean floor which in fact took place distinctly later in latest Cretaceous. I have revised my own earlier views (Krishna, 1983a) on the continental separation between East Africa and India during Aptian-Albian in favour of later separation near the base of Campanian related to Deccan volcanic activity. The revision is in better agreement not only with the ammonoid and other shallow marine faunal distribution (Krishna, 1983a, 1987) but also with regard to general similarities of Indian and Madagascar vertebrate remains with those of Africa, Arabia, Europe, North and South America (Sahni *et al.*, 1987) allowing dispersal of land animals until high up in the Cretaceous which could not have been otherwise possible, in case the Indian Plate has had separated from Africa in Aptian-Albian. The revised model does not envisage separation of India from Gondwanaland (at least its western half) until the beginning of Campanian. Near the Jurassic/Cretaceous boundary also originated linear

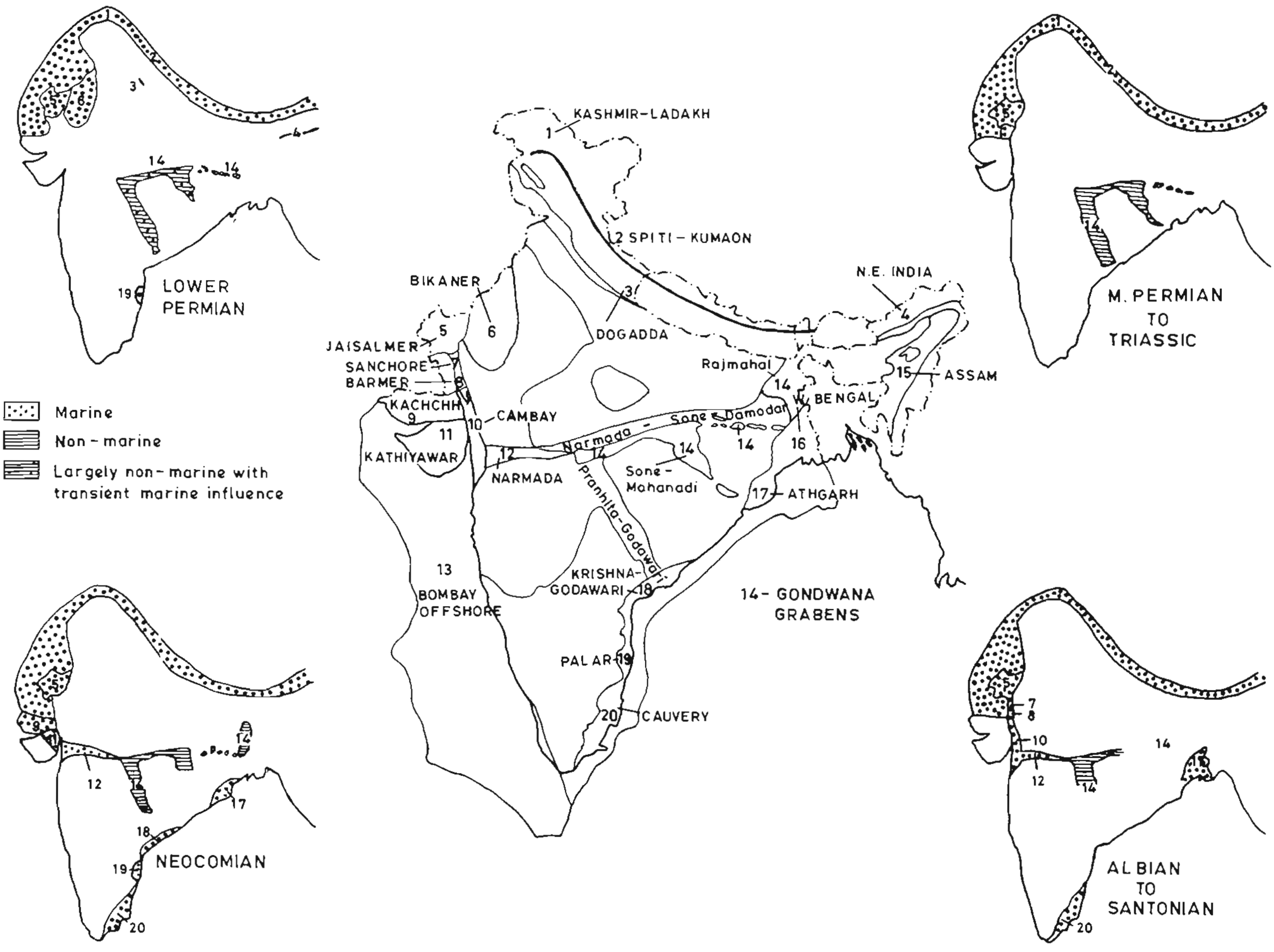


Text-figure 11—Complete isolation of the Indian Plate from its immediate neighbouring component plates of the Gondwanaland (Africa in the west and Antarctica in south or east) with continental separation/creation of new ocean floor (proto-Indian ocean) both in the west and south or east of India.

clastic basins of Kathiawar and several basins on the East Coast between Athgarh (Orissa) to Cauvery (southern Tamil Nadu). There is also witnessed renewal of non-marine sedimentation in only few of the Gondwana grabens (Narmada, Rajmahal, Rewa & Godavari) as a consequence of a fresh reactivation unconformably overlying the Late Triassic with the stratigraphic gap spanning nearly through the whole of Jurassic. The Jurassic/Cretaceous event also indicates reversal of palaeocurrents and palaeodrainage towards southeast in contrast to north-west and west during Permian and Triassic. Most of these Lower Cretaceous clastic sequences in marginal areas of India either in the east or west are sedimentologically and lithologically alike largely lacking in recognisable marine body fossils while being prolificly plant-bearing except for thin marine fossil-bearing rather localised intercalations. Several such basins arose parallel to the East Coast almost in a row from Orissa to southernmost Tamil Nadu suggesting the creation of a shallow corridor type of sea between India and eastern half of Gondwanaland near the Jurassic/Cretaceous boundary almost in a similar fashion to that in the west from India to South America. The precise dating of these Lower Cretaceous sequences whether in the west or east has been very difficult because the mega- and micro-flora as also benthonic micro-fauna are long ranging. The occasional control provided by thin marine body fossil-bearing horizons (particularly the ammonoids) has allowed indirect dating of the largely plant fossil-bearing sequences. Such broad ages of the mega- micro-floral assemblages also in turn help the dating of similar plant-bearing non-marine sequences in the intraplate Gondwana grabens. The spore and pollen assemblages from different late Upper Jurassic to Lower Cretaceous sequences of India reflect microfloral continuity near the Jurassic/Cretaceous boundary. The microflora of Vemavaram Formation of Upper Neocomian age is relatively closer to that of Katrol Formation (Tithonian) than that of Bhuj Member (post Lower Albian). The contention of many (Srivastava, 1983; and others) that the first appearance of *Cicatricosisporites australiensis* marks the Jurassic/Cretaceous boundary, does not seem to be correct in at least Indian context. In fact, the first appearance of this taxon takes place distinctly much after the Jurassic/Cretaceous time boundary as defined and understood throughout the Tethyan realm between Jaccobi and Grandis ammonoid zones. The Jurassic/Cretaceous boundary as suggested by Singh and Venkatachala (1988, this Volume) on the basis of palynomorphs between 'Jhuran' and 'Bhuj Formation' is distinctly younger than the Jurassic/Cretaceous boundary much more precisely demarcated by ammonoids within the basal Umia glauconitic/oolitic ammonitiferous Member in western Kachchh (unpublished discovery of Berriasian index ammonoid *Argentiniceras*). Similar discrepancy still continues between the age of 'Bhuj Formation' (=Umia Formation excluding the basal member) based on palynomorphs and the other based on ammonoids. Inter-area correlation of successive palynological assemblages likewise shows discrepancies with that of the correlations based on ammonoids. So also continues the fallacy of elementally quite different palynofloral assemblages of Kachchh, Jaisalmer, Rajmahal, Jabalpur and East Coast areas indirectly dated and also now widely accepted as being coeval of Neocomian. Caution needs to be observed before correlating definite ammonoid based Albian sediments with Neocomian *M. antarcticus* zone and likewise definite Lower Albian with Upper Albian-Cenomanian *Triporoletes reticulatus* Zone in Cauvery Basin. The need of the hour is to integrate the palynofloral data with ammonoid based dates wherever available in surface sections and later to extend such control to subsurface or non-marine surface sections which would permit differentiation of individual stages. It does not look satisfying to refer the entire sequence qualitatively as Lower Cretaceous. Better control on time is available from scarce ammonoids like Barremian *Holcodiscus*, from Krishna Basin in Vemavaram Formation, *Puzosia* of Lower Albian in Dalmiapuram Formation of Cauvery Basin, *Pascoeites* and *Gymnoplites* of Hauterivian-Barremian age from Sivaganga and Budavada units which should be taken help of in formulating further differentiation of Lower Cretaceous palynoflora. Efforts of integration of ammonoid and dinocysts (Garg *et al.*, unpublished work) has been quite rewarding and presents a good example in this direction which needs to be extended to other areas and microfloral groups.

Aptian-Albian event (Text-figs 8, 10)—This tectonic event has found diverse expressions in different parts of India. Several basins for example Kachchh, Jaisalmer, Kathiawar and all the East Coast basins, except for Cauvery, indicate wide-spread regression or withdrawl of the sea. However, in a few areas along ancient fractures zones like Narmada, Barmer, Sanchore, Bengal and Cambay because of reactivation linear basins were created. Cauvery Basin, on the other hand, witnessed continuous sedimentation until the close of Cretaceous with a strong transgressive impulse in Upper Albian. The Narmada and Cauvery sequences although being contemporary for a considerable length of time have little in common in terms of marine faunas particularly the ammonoids suggesting existence of separate shallow seas in western India (Tethys) and southern India (Indo-Pacific sea). Sahni (1983) has suggested the possibility of very short duration transiant marine connection between the said areas via Pranhita-Godavari ancient fracture during the early Upper Cretaceous. This activity is also expressed in terms of wide-spread volcanic activity in eastern India (Bihar, Bengal, Assam, etc.) as Rajmahal Traps and Sylhet Traps radiometrically dated around 100 to 110 million years. It is suggested here that continental separation of India from eastern part of Gondwanaland in the eastern sector is related to this volcanic activity. Early continental separation and isolation of Indian Plate as suggested in most of the plate tectonic reconstructions is found inconsistent with the distribution of both shallow, marine and land vertebrates in Madagascar, India, Africa and Laurasia. This event was also responsible for closure of sedimentation in Gondwana inland grabens in Narmada, Rewa, Rajmahal and Godavari valleys.

Santonian/Campanian Boundary event (Text-figs 9, 11)—This marks another phase of reactivation resulting in the origin of Assam Basin and closure of Narmada and Jaisalmer basins. This is the time around which began the Deccan volcanic outpouring which is related with the continental separation of India from Madagascar and Africa. Sahni *et al.* (1987) have explained the presence of dinosaurian remains



Text-figure 12—Origin of different sedimentary basins of India, intracratonic or pericratonic, marine or non-marine from basal Permian to basal Campanian.

of *Laplatosaurus, Antarctosaurus* and *Titanosaurus* in the Upper Cretaceous Lameta Formation which are otherwise known from the Upper Cretaceous of Central and South America, Madagascar, Africa and western Europe by free intermigration through a Cretaceous island are system located between the Asian Plate and the drifting Indian Plate. It could also be alternatively and rather better explained by the separation of India, Madagascar and Africa near the beginning of Campanian altogether disallowing complete isolation of India until that time. It is also interesting to note the contrast in the distribution of ammonoid family Kossmaticeratidae between pre- and post-Campanian durations of Cretaceous in various Gondwana component plates (Macellari, 1987). The family appeared in Turonian in India, spread to Indian southeast Coast, Madagascar and Africa during Coniacian, later in Santonian to New Zealand. The family rapidly diversified in Early Campanian in Madagascar and Africa. Being adapted to cold water conditions, became restricted during Campanian and Maestrichtian in the most southerly shallow seas of South America, Antarctica, New Zealand, etc. The sudden marked decrease of the family from Campanian onwards and its rapid diversity in the polar vicinity in Antarctica, South America and New Zealand appears related to continental separation and movement apart of India Madagascar and Africa from one another as also from the rest of the Gondwanaland comprising South America, Antarctica, New Zealand and Australia which for some more geological time remained united during the Cenozoic. At the same time, this also supports that India did not separate from the Gondwanaland until the Lower Campanian.

EXTENT OF INDIAN GONDWANA

In light of available data, modern concepts of depositional framework and the current international and national rules of stratigraphic nomenclature, we should strive towards uniform acceptance of the original concept of the Indian Gondwana as lithostratigraphic units although permitting qualified careful usage otherwise in plate tectonic and/or biogeographic context. The usage, however, in plate tectonic and biogeographic context, will show variation in extent with geological time.

The problem of extent reduces to resolving the age old dispute as to whether the present graben geometry is pre- or post-Gondwana which is quite complex in itself since there have been several reactivations along the said zones from time to time. Individual Gondwana basins invariably exhibit a single or only a few of the several different depositional facies developing in a composite fluvial system. The component facies represented in a fluvial complex are proximal, medial and distal, while usually the component preserved is medial one. Proximal or distal or both components are found removed by weathering and erosion. and the preserved component is found abruptly truncated by either of the faulted margins clearly suggesting the post Gondwana nature of either or both marginal faults (Casshyap, 1979; Ghosh & Upadhyay, 1985; Niyogi, 1987; Mitra, 1987; Ahmad & Ahmad, 1979). In recent years, presence of Gondwana sediments has been encountered or interpreted in subsurface wells or through geophysical investigations concealed under Deccan Traps in the west and under Bihar, Bengal, and Assam alluvium in the east suggesting much wider original extent of the Gondwana Sequence.

It is yet not clear as to whether these subsurface Gondwana sediments are also similarly fault bounded along some or other ancient fracture zones. It is also important to remember that many marine sequences of Lower Permian and post-Triassic ages are also preserved in fault bounded graben basins in western India and East Coast with all the component facies of the complex depositional system not always present. Thus partial preservation and part removal both laterally and vertically are inherent consequential aspects of vertical or epierogenic tectonics both in intracratonic and pericratonic areas. While accepting greater original extent than the now preserved, it looks rather premature to accept the original depositional extent of Indian Gondwana units as very extensive large scale platform cover like as advocated by Mitra (1987). It looks more realistic that the Gondwana basins originated as a result of a transient short-lived wide regional initial protorifting/fracturing at the base of Permian signalling the initiation of the long episodic weak zone reactivation history in India and neighbourhood which also resulted in creation of pericratonic largely marine non-Gondwana basins. The Gondwana basins indicate transient marine influences in pre-Raniganj Permian time while rest of the Permian and Triassic is exclusively non-marine although the whole span of Gondwana sedimentation is punctuated with regional discontinuities. Huge thickness and regional discontinuities clearly suggest repetitive reactivation of faults during the course of sedimentation. Truncated preservation, however, is due to post-Gondwana Late Mesozoic or Cenozoic tectonics. The presence of rather huge stable oregons (positive blocks) in between the Gondwana basins seems to have controlled the overall geodynamic evolution of the Indian Plate and these positive blocks should not have favoured continuous interconnected expanse of Gondwana Sequence from central and eastern India to Assam in the northeast. Biological evidence present in the Gondwana and contemporary non-Gondwana units also supports the above observations and interpretations about the geographic extent of the true Gondwana lithostratigraphic sequences as defined in this paper.

It is generally accepted today that Gondwanaland as a composite superplate did not come into existence at the base of Permian but existed as such right at least since late Precambrian. The Gondwana superplate existed from Late Precambrian to at least latest Cretaceous, i.e., until the time of complete continental separation of the Indian Plate from other Gondwanaland component plates. It may also be remembered that during the long Late Precambrian to latest Cretaceous duration, epierogeny dominated tectonics affected the present day Indian subcontinent which presumably allowed in succession separation of some micro block or micro-plate at its northern boundary accreting later to the Asian Plate. Thus the Indian Gondwanic Plate witnessed regular episodic truncation at its northern boundary with obvious reduction in size each time until the accretion of the entire left over Indian Plate (inclusive of South Tibet during Permian, and reduced to present High Himalaya belt) to Asia during Early Palaeogene.

The salient points that have emerged forth by way of conclusion can by summarised as follows:

1. The Indian Gondwana are unmistakably lithostratigraphic units. The term, however, can also be used in geographic context with proper clarification, e.g., the Indian Gondwana Plate or Indian Gondwana floral or faunal province at any particular geologic time. The Gondwanaland existed at least right since Late Precambrian and continued as a single geographic unit until Upper Cretaceous, i.e., for a much longer duration than the Indian Gondwana Sequence.
2. The Indian Gondwana (lithostratigraphic units) need be recognised exclusively on the basis of

their characteristic lithological set-up, i.e., glaciogene base dominantly coal-bearing lower part, and sandstones in ascending order, the coal-bearing feature being their most important lithological expression.

3. Plant fossils should not be used for recognition of Indian Gondwana.
4. Indian Gondwana exclusively located along intracratonic grabens are largely non-marine except for glaciomarine influence in the early part by original definition of Medlicott and should not be confused or mixed up with their pericratonic or otherwise largely marine non-Gondwana contemporary units having different lithological, depositional and tectonostratigraphic framework.
5. Geographic extent of the Indian Gondwana is confined to the intracratonic graben basins, the east-west running Narmada-Son-Damodar belt and northwest-southeast running Pranhita-Godavari and Son-Mahanadi belts. On the contrary extent of the Indian Gondwana Plate was inclusive of the South Tibet during Permian, but delimited by the High Himalaya or Tibetan Himalaya during the Mesozoic prior to complete continental separation during late Upper Cretaceous both in the east and west from the rest of the Gondwanaland comprising South America, Antarctica and Australia. At this time India got not only separated from Africa but also bereft of Madagascar (genetically related to Deccan volcanic activity) and the present Indian East and West Coasts took shape with creation of Bombay Off-shore Basin in the west and Assam Basin in the east.

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