OBSERVATIONS ON THE POST-TRIASSIC GONDWANA SEQUENCE OF INDIA

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ABSTRACT

The post-Triassic Gondwana sequence of India is one of the well developed in the Gondwanaland. Its flora has been helpful in establishing the stratigraphy of thick continental deposits of this period. The sedimentary sequences containing this flora are developed in widely scattered Gondwana basins of the Peninsula namely, the Rajmahal hills, Bihar; Satpura and South Rewa Gondwana basins, Madhya Pradesh; Pranhita-Godavari basin of Andhra Pradesh and Maharshtra; East Coast and Gujarat. In the light of the recent studies the stratigraphic position of the floral assemblages has been reviewed in the paper.

The flora is known to continue without any break throughout the Jurassic and the Lower Cretaceous. The lower age limit of the floral sequence commences in Lower Jurassic and as such the views expressed by Spath (1933) and Arkell (1956) suggesting the absence of entire Jurassic continental deposits of India is no more tenable.

The flora associated with Lower Cretaceous marine fauna on the East Coast indicates the range of the Jurassic floral elements into the Lower Cretaceous rather than suggesting any palaeontological contradiction between the faunal and floral evidences as thought earlier.

INTRODUCTION

THE post-Triassic Gondwana sequence of India embodying a rich flora is one of the best of its kind developed in the Southern Continent. In Australia, this sequence is represented by a great development of continental deposits of Jurassic-Cretaceous age, while in Africa and South America, this was a period of enormous volcanic activity, resulting in limited deposition of continental deposits.

In India, the post-Triassic Gondwana sequence is developed in widely scattered basins: in Rajmahal hills, Bihar; South Rewa — Satpura basins, Madhya Pradesh; Pranhita — Godavari basin, Andhra Pradesh and Maharashtra; Jaisalmer, Rajasthan; Cutch, Kathiawar and Himmatnagar, Gujarat; and along the East Coast in Orissa, Andhra Pradesh and Tamil Nadu. In these basins, the Triassics, wherever they are seen, are distinguished by their characteristic lithology, vertebrate remains and rarity of plant fossils. The overlying Jurassic-Cretaceous sequence of rocks have a rich and distinct floral assemblage commonly designated as the Ptilophyllum flora and their stratigraphy is mainly based on floral evidences.

Recent studies have indicated that the sequence proposed earlier for these Jurassic-Cretaceous deposits in India is rather confusing and as such the dating done on floral evidences has been a matter of great dispute. Palaeobotanists like Oldham & Morris, Feistmantel, Sahni, Jacob, Bose and others assigned a Jurassic age to these deposits, whereas Spath, Arkell and many others on the basis of faunal evidences suggested a Lower Cretaceous age to them.

Here, the post-Triassic sequences are being dealt as developed in different basins and the problem of age of this sequence is being discussed in the light of geological history and recent palaeontological evidences.

Pranhita-Godavari Basin

The post-Triassic Gondwana sequence in this basin is as follows:

	King (1881)	Kutty (1969)
Post Triassic Gondwanas	Chikiala Kota	Gangapur formation/ ? Chikiala Kota formation Dharmaram formation
Up. Triassic	Maleri	Maleri formation

King (1881) made collection of fossils including plants from Kotas only and Chikialas were devoid of fossils. The plant fossils were studied by Feistmantel (1877):

Localities	*Fossils*
Annaram	*Elatocladus* (*Palissya*), *Chirolepis*

Localities	*Fossils*
Naogaon	*Taeniopteris* (*Angiopteridium*), *Ptilophyllum acutifolium*
Chirakunt	*Cycadites* sp., *Elatocladus* (*Palissya*) *jabalpurensis*
Between the villages Maor and Balhanpur	*Pagiophyllum peregrinum*, *Araucarites cutchensis*

Later on, Rao & Shah (1959a), listed additional plant fossils from Kota-Maleri formation and Bose (1966) observed that there is an admixture of flora in the assemblage given. To remove this confusion (Rao & Dutt, 1955-56 and Rao & Shah, 1957-60, the unpublished reports in the Geological Survey of India) the collection is being studied and the results of the preliminary study are summarized here.

The plant fossils as mentioned from Kota-Maleri formation belong to Kota 'stage' of King. The list of fossils is given in Chart I.

It is observed that there are clearly three and not two zones, as inferred earlier by Rao and Shah (1959a), namely:

Zone C — Fossils from Gangapur Sandstone and Chikiala Sandstone

Zone B — Fossils from Kota formation (as defined by Kutty, 1969)

Zone A — Fossils from Acheli and Ganaram

Zone A is characterized by few species of *Glossopteris, Thinnfeldia hughesi, Dicroidium hughesi, Dicroidium odontopteroides, Noeggerathiopsis cf. hughesi* etc. This assemblage is from the lower part of the Kota formation which is underlain by Maleri formation of Carnic-Noric age. Similar floral assemblage has also been known from the Parsora formation which is overlying the Tiki formation (Shah *et al* 1970; Dutt, P. K. pers. comm). This assemblage can easily be assigned as a part of Dicroidium flora which is prevalent in the Triassic period. Since the beds yielding the flora similar to that from Parsora formation is overlying the formation of Carnic-Noric age, it can be assigned to Rhaetic age.

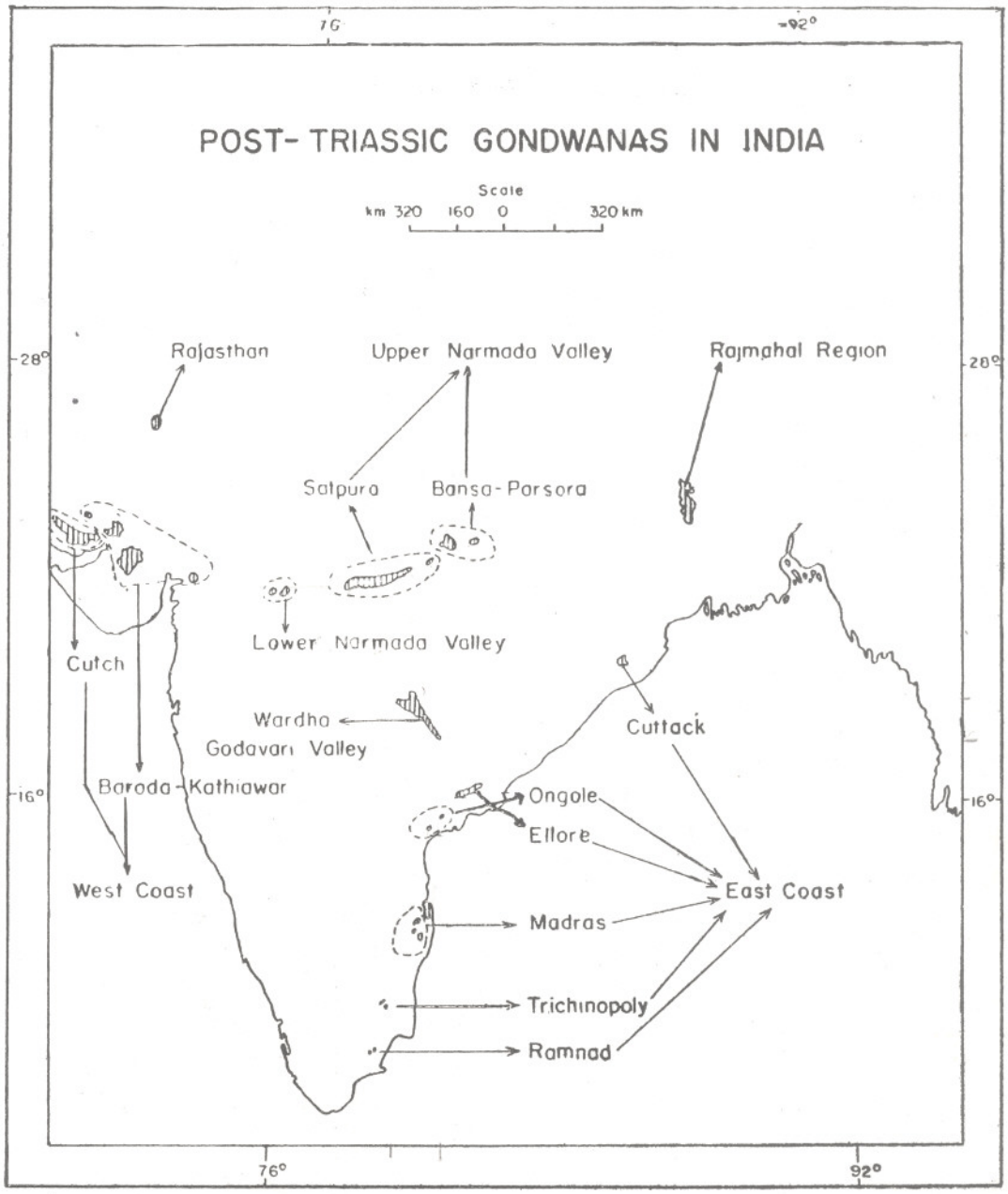
The lower Kotas have elsewhere been differentiated as Dharmaram formation (Kutty 1969) and this has not yielded any plant fossils. But it has been assigned Rhaetic on the basis of vertebrate fossils.

CHART 1 — DISTRIBUTION OF POST TRIASSIC GONDWANA FLORA FROM PRANHITA-GODAVARI BASIN

Name of Species	Kota Fm.	Gangapur (=? Chikiala Fm.)
Equisetites sp.	×	×
Gleichenites gleichenoides		×
G. rewahensis		×
G. sp.		×
Coniopteris hymenophylloides	×	
Coniopteris sp.	×	
Cladophlebis indica	×	×
Sphenopteris sp.	×	
Hausmannia sp.	×	×
Ptilophyllum acutifolium		×
Otozamites sp.	×	×
Dictyozamites sp.		×
Taeniopteris spathulata		×
? *Nilssonia* sp.		×
? *Cycadites* sp.		×
Elatocladus plana		×
E. conferta		×
E. jabalpurensis	×	×
E. ? *tenerrima*		×
Elatocladus sp.	×	×
Brachyphyllum sp.		×
Pagiophyllum peregrinum	×	×
Pagiophyllum sp.	×	
Torreyites cf. *constrictus*	×	×
Araucarites cutchensis	×	×
Araucarites sp.		×
Pagiophyllum peregrinum		×
Pagiophyllum sp.	×	
Podozamites sp.		×

Zone B has plant fossils which are represented by about a dozen genera. They are mostly found in limestone. The fossil forms are fragmentary and the assemblage consists of: *Equisetiies* sp. *Sphenopteris* sp., *Hausmannia* sp., *Coniopteris hymenophylloides, Coniopteris* sp., *Otozamites* sp., *Pagiophyllum cf. peregrium, Pagiophyllum* sp., *Araucarites cutchensis, Elatocladus* sp. The beds containing this flora overlie the lower Kotas yielding the Rhaetic flora. Associated with this flora arefishes, sauropod dinosaur and ccocodilian remains which are considered as Lower Jurassic (? early middle Jurassic). Hence this flora is of upper Liassic age or in other words the genera represented in this flora were thriving during this period.

Zone C has the assemblages of plant fossils which belongs to the Gangapur formation, Chikiala sandstone and some localities of Kota 'stage' of King. Gangapur



formation was considered by King (1881) as the basal member of the Kota 'stage' (of King) but Kutty (1969) separated them from the Kota 'stage' and considered them as overlying the Kota formation with an unconformity. Gangapur formation is developed in the western part of the basin and is provisionally considered as equivalent to Chikiala Sandstone which is developed in eastern part of the basin. Kutty had not recorded any fossils but observed that the flora of Anaram belonged only to Kota

formation and flora from other localities as given by King belonged to Gangapur formation.

Further, Chikiala Sandstone was considered to be unfossiliferous till Rao & Shah (1959b) recorded some fossils. The fossils from some localities given by Rao and Dutt (1955-56, unpublished report) seemed to belong to Gangapur formation. The assemblage, if taken as one unit, is characterized by the predominance of conifers. This is younger than Lower Jurassic and its exact age or the upper limit on the basis of considerations other than plants can not be inferred. This floral assemblage clearly resembles the flora from Nipania of Rajmahal region and also to the flora from Raghavapuram Mudstone, Vemavaram Shales and Sriperumbudur beds from east coast and Bhuj formation of west coast.

Rajmahal Region

The general sequence of the post-Triassic Gondwana strata in this area is as follows:

Alluvium
Post-Triassic Gondwanas — Rajmahal Traps (with intertrappean Rajmahal Series)
Post-Triassic Gondwanas — Dubrajpur beds
Damudas

The generalized sections of the Rajmahal volcanics and the associated intertrappeans, constructed from different sections (as given by Ramaswamy 1952-53) is as follows:

	Laterite	(*Level above sea-level in feet*)
XIII & XIV	Trap	1700
XII	Fine grained Trap ...	1420
	Red clay, sandstone	1400
XI	Trap	1250
	Ferruginous sandstone porcellanites ...	1200
X	Trap	1100
	Clay sandstone with fossil wood ...	1050
IX	Trap	1000
	White-pink, friable sandstone ...	950
VIII	Trap	800
	Bluish clay bed ...	
VII	Trap	725
	Ferruginous sandstone	700
	Laterite	(*Level above sea-level in feet*)
VI	Trap	625
	Sandstone ...	600
V	Trap	530
	Ferruginous, friable sandstone ...	500
VI	Trap	425
	Chert beds ...	420
III	Trap	320
	Oolitic iron-ore ...	310
II	Trap	250
	Plastic, white, iron-stained ...	210
I	Trap	210

The number of flows exceeds 15 in number and the total thickness of flows is around 1500 feet or so. The individual flow may vary in thickness from 50 to 300 feet. The older flows are represented in the eastern half of the Rajmahal hills while in the western half higher flows are recorded along the fringe of the plateau where the height rises from 750′-1000′. The intertrappeans vary in thickness from 5 to 25 feet but the average thickness is about 5 feet. The earlier three intertrappeans are profusely fossiliferous. They have yielded the richest flora of the world. The name Rajmahal plant beds was restricted to first three intertrappeans. However, the flora from Nipania comes from the 4th and 5th intertrappeans beds.

The flora (Chart II) from these areas can be grouped in two zones:

Zone — A: Flora from upper part of Dubrajpurs and the intertrappean beds (1-3 from below) associated with Lava flows. This is characterized by broad leaved cycads.

Zone — B: Flora from Nipania, i.e. from the 4th intertrappean associated with 4th and 5th lava flows. Earlier also, this flora was considered as younger by Vishnu-Mittre (1957). This flora is characterized by its richness in pteridophytes and conifers.

Associated with Zone A, are fish scales and a new genus of fish and some unionids. Except for the plant remains which are of course profusely known, there is no other criterion of fixing the age of these beds.

CHART 2 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA FROM RAJMAHAL HILLS, BIHAR

Name of Species	Rajmahal plant beds (including upper part of Dubrajpur)	Nipania beds	Name of Species	Rajmahal plant beds (including upper parts of Dubrajpur)	Nipania beds
	(1)	(2)		(1)	(2)
Equisetites rajmahalensis	×	×	*D. hallei*	×	
Lycoxylon indicum	×	×	*D. baghjorensis*	×	
Lycoxylon sp.		×	*Taeniopteris lata*	×	
Lycopodium gracilis	×		*T. morrisiana*	×	
Todites indicus	×		*T. ovata*	×	
Cladophlebis lobata	×		*T. crassinervis*	×	
C. sahnii	×	×	*T. musaefolia*	×	
C. srivastavii	×	×	*T. spathulata*	×	
Cladopheibis sp.	×		*T. mcclendii*	×	
Marattiopsis macrocarpa	×		*T. ensis*	×	
Gleichenia gleichenoides	×		*Microtaeniopteris lata*	×	
Coniopteris hymenophylloides	×		*Cycadites rajmahalensis*	×	
			Nilssonia morrisiana	×	
Tinpaharia sinuosa		×	*N. princeps*	×	
Sphenopteris rajmahalensis	×		*N. bindrabundensis*	×	
			N. fissa	×	
S. khairabanensis	×		*Nilssonia* sp.	×	
S. hislopi	×		*Pterophyllum distans*	×	
Sphenopteris sp.		×	*Pterophyllum* sp.		
Rhizomopteris chaksu	×		*Beaniopsis rajmahalensis*	×	
R. rajmahalensis	×		*Brachyphyllum feistmanteli*	×	
R. sahnii	×				
Solenostelopteris nipanica		×	*B. florini*		×
			B. mamillare	×	
S. sahnii		×	*B. expansum*	×	×
Dityopstelopteris rajmahalense		×	*B. expansum* var. *indicum*	×	
			B. spiroxylon	×	
D. jacobi		×	*Pagiophyllum* cf. *peregrinum*		×
D. fasciosteloides		×			
Danaeopsis rajmahalensis	×		*P. araucaroides*		×
Microphyllopteris sp.	×		*Elatocladus plana*	×	
Thinnfeldia indica	×		*E. conferta*	×	
T. chunakhalensis	×		*E. tenerima*	×	
T. nirmali	×		*E. sahnii*		×
Thinnfeldia sp.	×		*Elatocladus* sp.	×	
Pachypteris indica	×		*Mehtaia rajmahalensis*		×
Sagenopteris bhambhanii	×		*M. nipaniensis*		×
Pentoxylon sahnii		×	*M. santalensis*		×
P. tetraxyloides		×	*Sitholeya rajmahalensis*		×
Nipanioxylon guptai		×	*Nipaniogruha granthia*		×
Nipniophyllum raoi		×	*N. lanceolata*		×
Ptilophyllum acutifolium	×		*N. curvifolia*		×
P. amarjolense	×		*Indophyllum sahnii*		×
P. incisum	×		*I. raoi*		×
Otozamites bengalensis	×		*I. nipanica*		×
Bucklandia indica	×		*Coniferocaulon rajmahalensis*	×	
B. sahnii	×				
Williamsonia microps	×		*C. latisulcatum*	×	
W. indica	×		*C. amarjolense*	×	
W. sewardiana	×		*Araucarites cutchensis*	×	
W. santalensis	×		*A. nipaniensis*		×
W. harrisiana	×		*A. bindrabunensis*	×	
Williamsonia sp.	×		*Masculostrobus rajmahalensis*		×
Sahnioxylon rajmahalensis	×				
S. andrewsii	×	×			
Dictyozmites falcatus	×				

(*Continued*)

CHART 2 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA FROM RAJMAHAL HILLS, BIHAR — *Continued*

NAME OF SPECIES	RAJMAHAL PLANT BEDS (INCLUDING UPPER PART OF DUBRAJPUR)	NIPANIA BEDS
	(1)	(2)
M. podocarpoides		×
Masculostrobus sp.		×
Nipaniostrobus sahnii		×
N. pagiophylloides		×
N. aciculipholia		×
Ginkgoites rajmahalensis	×	
Ginkgoites sp.	×	
Baiera sp.	×	
Dadoxylon jurassicum	×	
D. rajmahalense	×	
Mesembrioxylon indicum	×	
Cycadospermum indicum	×	
Cycadolepis indica	×	
Rajmahalia paradoxa	×	

It has been pointed out by one of us (Shah) that the upper biozone of Dubrajpur formed as Dubrajpur equivalent to some portion of first four volcanic flows and the associated intertrappeans. The demarcation between Dubrajpurs and Barakars (lower beds Dubrajpurs are also shown to be Barakars; Ramaswamy & Shrivastava, 1952, Sah & Maheshwari, 1969) is not well defined, the lithological characters of the two units being very similar.

South Rewa — Satpura Gondwana Basin

The post-Triassic Gondwana formations are developed along the northern fringes of Satpura and occur as four isolated patches which are developed near Seoni-Malwa, Hoshangabad district; Narsinghpur, Narsinghpur district; Jabalpur, Jabalpur district and Chandia, Shahdol district, all in Madhya Pradesh. These patches stretch for about 600 km. north-southward. The stratigraphic succession of this basin is as follows as worked by the authors:

	Satpura	*South Rewa*
		Bansa formation
Post-Triassic Gondwanas	Jabalpur formation	
	Chaugan formation	
Rhaetic	—	Parsora formation
Up. Triassic	Denwa formation	Tiki formation

Crookshank (1936) divided the Jabalpur into Chaugan and Jabalpur based on floral evidences only. Jacob (1951) and Agrawal (1963) opined that the two subdivisions should be merged into one. Shah (1966) had indicated that there are three definite subdivisions of Jabalpurs and the fourth is definitely developed in South Rewa though may doubtfully be present in the western part. Recent stratigraphical and palaeobotanical studied by Gopal Singh (1967) have established three subdivisions as shown above. The distribution of the flora in these three zones as worked out by him is given in the Chart III.

CHART 3 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA FROM SATPURA AND SOUTH REWA BASINS, MADHYA PRADESH

(1=Chaugan Formation, 2=Jabalpur Formation, 3=Bansa Formation)

NAME OF SPECIES	(1)	(2)	(3)
Equisetites sp.	×		
Sphenopteris cf. *arguta*	×	×	
Sphenopteris hughesi	×	×	
S. cf. *rajmahalensis*			×
Sphenopteris sp.		×	
Cladophlebis indicus	×	×	
Cladophlebis cf. *kathiawarensis*			×
Cladophlebis cf. *longipennis*		×	
Cladophlebis sp.		×	
Cladophlebis salicifolia	×	×	
Cladophlebis cf. *lobifolia*	×	×	
Phlebopteris sp.			×
Coniopteris hymenophylloides		×	
Gleichenites rewahensis	×	×	×
G. gleichenoides			×
Onychiopsis psilotoides	×		
Onychiopsis paradoxus		×	×
Weichselia reticulata			×
Hanusmannia dichotoma	×		×
H. buchii	×		×
H. crookshanki	×		
Adiantites indicus			×
Rhizomopteris rajmahalenais	×		
Sagenopteris sp.	×	?	
? *Thinnfeldia* sp.	×		
Pachypteris indicus	×	×	×
Cycadopteris pulcherrima			×
C. auriculata			×
C. indica			×
C. majus			×
Ptilophyllum acutifolium	×	×	×

(*Continued*)

CHART 3 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA FROM SATPURA AND SOUTH REWA BASINS, MADHYA PRADESH — *Continued*

NAME OF SPECIES	(1)	(2)	(3)
P. distans	×	×	
P. cutchense	×	×	
P. jabalpurensis		×	
P. instilacallum			×
P. gladiatus			×
Dictyozamites indica	×		
D. falcatus	×		
Nilssonia fissa	×		
N. princeps	×	×	
Cycadites rajmahalensis	×		
Cycadites ? graminius	×		
Carpolithes sp.	×		
Nilssonia sp.		×	
Taeniopteris crassinervis	×		
Taeniopteris vittata	×		
Taeniopteris sp.	×		
Bucklandia indica	×		
Williamsonia indica	×		
W. microps	×		
Williamsonia sp.	×		
Ginkgoites lobata		×	×
G. feistmanteli			×
Baiera cf. *brauniana*	×		
Desmiophyllum indicum	×	×	×
Elatocladus tenerrimus	×		
E. plana	×		×
E. conferta	×	×	×
E. jabalpurensis	×	×	×
Elatocladus sp.	×		
Brachyphyllum mamillare	×	×	×
B. rhombicum	×	×	×
B. feistmanteli			×
B. expansum			×
B. expansum var. *indica*	×		
Pagiophyllum divaricatum	×	×	
P. peregrinum	×	×	×
P. cf. *peregrinum*	×		×
Coniferocaulon rajmahalensis	×		
Araucarites cutchensis	×	×	×
A. chandiansis			×
A. striatus			×
A. macropetrus		×	×
A. oldhami	×		
A. latifolius			×
Strobilites sewardi		×	
Conites cf. *Strobilites anceps*			×
hoeniocopsis	×		
Czekanowskia sp.		×	
Pityophyllum sp.		×	

Except for evidences furnished by the plants, there are no other forms to suggest the exact age of these zones. In Satpura region, the Chaugan formation is underlain conformably by Bagra-Denwa formation of Carnic-Noric age while in South Rewa those are underlain by the Parsora formation of Rhaetic age.

Western India

The post-Triassic Gondwanas show a wide development as isolated patches in Rajasthan and Gujarat and Lower Narmada valley.

Jaisalmer Area

The post-Triassic Gondwana sequence is represented by Lathi and Parihar sandstone in Jaisalmer area of Rajasthan.

At the base of thick marine sedimentaries of Jurassic age, a continental facies represented by Lathi formation is developed which is considered as Lower to Middle Jurassic. They are 60 m. thick and comprise white or red and variegated sandstone containing a few bands of limestone. Though they have not yielded any megafossil yet the miofloral evidences suggest a closer affinity with Gondwana beyond doubt. The mioflora as known after the work of Srivastava (1966) and Lukose (1971) suggest a Lower Jurassic age. They are overlain by Jaisalmer strata of Middle Jurassic age.

Higher in the sequence is Parihar sandstone of continental nature which is 800 m thick. These are unfossiliferous. Because of their stratigraphic position, they are considered of Lower Cretaceous age as they are underlain by the upper Jurassic and overlain Aptian, marine horizon, i.e. Abur beds.

Ahmednagar Area

A fresh-water sequence of strata nearly 60 m thick is developed near Ahmednagar. This is called as Himatnagar or Ahmednagar sandstone. This has yielded a Gondwana flora assemblage comparable to Than plant beds of Kathiawar. The assemblage is shown in the distribution chart IV and are thus considered of Lower Cretaceous age.

Himatnagar sandstone { Sandstone with shale and lithomerge Boulder Conglomerate

Erinpura Granite

CHART 4 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA IN WESTERN INDIA

Name of the Taxa	Bhuj beds	Than beds	Himatnagar sandstone	Lower Nimar sand-stone
	(1)	(2)	(3)	(4)
Equisetites rajmahalense	×			
Isoetites indicus	×			
I. serratifolius	×			
Phlebopteris sp.		×		
Matonidium	×	×	×	
Gleichenites sp.		×		
Onychiopsis psilotoides	×	×		
Weichselia reticulata		×		
Cladophlebis indicus		×		
C. cf. *longipennis*	×			
C. kathiawarensis	×	×		
Pacopteris tenera	×			
Pachypteris indicus	×			
Sphenopteris specifica	×			
Sphenopteris spp.	×	×		×
Otozamites imbricatus	×			
O. bengalensis	×			
Nilssonia trambauensis	×			
Taeniopteris vittata	×			
T. densinervis	×			×
Ptilophyllum cutchense	×	×		×
P. acutifolium	×	×		
Williamsonia blanfordi	×			
Brachyphyllum expansum	×			
Pagiophyllum divarisatum	×			
Araucarites cutchensis	×			
A. macropterus	×			
Elatocladus tenerrimaus	×			
Trambaus trilobata	×			
Actinopteris sp.	×			
Lorumformophyllum serratum	×			

Kathiawar Area

In Kathiawar nearly 600 m thick strata of fresh-water deposits namely Dhrangadhra sandstone is developed. The sequence developed is as follows:

Wadhwan sandstone

Dhrangadhra sandstone
- Upper — Ferruginous sandstone and conglomerates
- Lower — Pale sandstone with carbonaceous shale and coal seam

base ?

The upper part of the Lower Dhrangadhra sandstone (Than beds) has yielded floral assemblage consisting *Ptilophyllum cutchense, Cladophlebis indicus, C. kathiawarensis, Matonidium indicum, Onychiopsis psilotoides* and *Weichselia reticulata* which suggest a lower Cretaceous age.

Kutch Area

Upper Gondwana sequence is developed in Kutch which is called as Bhuj Formation. The stratigraphic position of which as follows:

Bhuj beds		Post Aptian (? Albian)
Ukra beds		Aptian
	Barren sandstone	
	Trigonia beds	Valanginian
Umia beds	Barren sandstone	
	Ammonite beds	Upper Tithonian
	Barren sandstone	
	Katrol	Portlandian

Plant bearing horizons which are now called Bhuj beds are supposed to be post Aptian and have yielded a rich assemblage as shown in the distribution charts. In field, Bhuj formation are apparently seen overlying the Katrol but are supposed to be

post Aptian on structural basis by Rajnath (1932).

EAST COAST

A number of isolated patches of post-Triassic Gondwana sediments are developed along the East Coast of India from north to south. They are represented chiefly by sandstone in the region of Mahanadi delta near Cuttack, Orissa; Golapilli sandstone, Raghavapuram shales and Tirupati sandstones in the Ellore region; Budavada sandstones, Vamavaran shales, and Pavalur sandstone in the Ongole region; between Ongole and Guntur, Andhra Pradesh, Sriperumbudur and Satyavedu formations in the vicinity of Madras; the Utatur plant beds in Trichinopoly district and the most southerly patch of Sivaganga beds in Ramnad district of Tamil Nadu.

These fossiliferous sedimentary patches represent an admixture of continental and marine conditions of deposition, reflected also in their fossil content. They have proved to be a critical area of study from the point of their stratigraphy and palaeontology.

Cuttack Area

The post-Triassic sediments of purely fresh-water origin are found at Athgarh near Cuttack. The successions of rocks in this area is as follows:

Alluvium

Post-Triassic Gondwana { Athgarh sandstone

? Metamorphics

The plant fossils from these sandstones (Chart V) have been described by Feistmantel (1879), Adyalkar & Rao (1968), Jain (1968) and Pandya & Patra (1968). Based on the floral similarity they are considered of the same age as Rajmahal plant beds.

Ellore Area

The stratigraphic succession in the area is as follows:

Post-Triassic Gondwanas { Tirupati sandstone
Raghavapuram shale
Golapilli sandstone

Lower Gondwanas — Kamthis (Chintalpudi sandstone)

Golapilli sandstone — An entirely continental deposit of about 130 m. thick, orange to brown sandstones, grits and conglomerates is developed around the village Golapilli. The palaeobotanical knowledge of these sandstones are due to Feistmantel (1877), Sarma (1957, 1958) and Baksi (1964). The plant fossils of these beds are given in the Chart (No. V). Based on flora they are considered equivalent to Rajmahals.

Raghavapuram shales — Representing the middle division of the sequence of rocks in the area they consist of 50 m. thick white and pink, bluish shales or mudstones. They contain both fresh water plants and marine invertebrates such as ammonites, bivalves and foraminifers.

The flora (Chart V) has been described by Feistmantel (1879), Sarma & Rameesam (1962) and Baksi (1967).

The foraminifers described are by Sastri & others (1963), Bhalla (1965, 1969) Bakshi (1968). They suggest a lower Cretaceous (? Neocomian age) to these shales.

Tirupati sandstones — The uppermost division of the sequence of rocks in the area, they occur at Tirupati hill, 37 km. northeast of Ellore. They consist of red to brown sandstones and conglomerates. The marine invertebrates contained in them have indicated a lower Cretaceous (Aptian) age. Coniferous woods are also recorded from these beds.

Ongole Area

The general sequence of rocks in this area is as follows:

Post-Triassic Gondwanas { Pavalur sandstone
Vemavaram shale
Budavada sandstone

Gneisses

Budavada sandstone — This is developed around the village Budavada and consists of entirely of sandstones. They are an admixture of fresh water and marine sediments. The assemblage includes plant fossils and marine invertebrates such as ammonites, brachiopods and arenaceous foraminifers. The flora is known after Feistmantel (1879) and is given in the chart (No. V).

These sandstones were treated to be marine equivalents of Golapillis. However, ammonites and foraminifers (Bhalla, 1969) indicate a lower Cretaceous age to the upper beds of these sandstones.

CHART 5 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA IN EAST COAST, INDIA

Name of the Taxa	Athgarh (Cuttack)	Golapilli (Elora)	Raghavapuram (Ellore)	Budavada (Ongole)	Vemavaram (Ongole)	Sriperumbudur (Madras)	Utatur (Trichinopoly)	Shiv Ganga (Ramnad)	Satyavedu (Madras)
Marattiopsis macrocarpa	×	×							
Gleichenites gleichenoides	×	×							
Cladophlebis lobata								×	
Cladophlebis indica	×				×	×	×		
Cladophlebis reversa			×			×		×	
Cladophlebis sp.	×	×	×						
Rhizomopteris balli	×								
Sphenopteris sp.		×							
Sphenopteris sp. ? *Thinnfeldia*								×	
Thinnfeldia sp.	×								
Dichopteris ellorenois		×							
Dicroidiun feistmanteli					×				
Dicroidium (? *Dichopteris*)			×			×			
Ptilophyllum cutchense		×	×		×	×	×	×	
Pachypteris indica	×				×	×			
Ptilophyllum acutifolium	×	×	×	×	×	×	×		
Ptilophyllum indicum	×								
Ptilophyllum oldhami	×								
Ptilophyllum tennerrimum		×	×						
Ptilophyllum sp.		×							
Cycadites cf. *conferta*	×								
Otozamites bengalensis						×			
Otozamites abbreviatus			×	×	×	×	×		
Otozamites rarinervis			×		×	×	×		
O. vemaramensis			×		×				
Otozamites bunburyanus					×	×			
O. hislopi						×			
Dictyozamites falcatus			×		×	×	×		
Dictyozamites indica		×		×	×				
Dictyozamites sp.		×							
Taeniopteris spathulata	×	×	×	×	×	×	×	×	
Taeniopteris mcclellandi			×		×	×		? ×	
Taeniopteris ovata *T. densinervis*							×		
Taeniopteris sp.		×							
Nilssonia fissa					×				

Continued

CHART 5 — DISTRIBUTION OF POST-TRIASSIC GONDWANA FLORA IN EAST COAST, INDIA — *Continued*

Name of the Taxa	Athgarh (Cuttack)	Golapilli (Elora)	Raghavapuram (Ellore)	Budavada (Ongole)	Vemavaram (Ongole)	Sriperumbudur (Madras)	Utatur (Trichinopoly)	Shiv Ganga (Ramnad)	Satyavedu (Madras)
Nilssonia morrisiniana		×						×	
Nilssonia sp.		×							
Pterophyllum distans		×							
Pterophyllum kingnianum		×							
Pterophyllum sp.					×	×			
Pseudoctenis footeana					×	×			
Williamsonia blanfordi			×						
Williamsonia indica		×							
Ginkgoites crassipes			×			×		? ×	
Ginkgoites feistmanteli			×			×			
Ginkgoites lobata						×			
Ginkgoites sp.			×						
Baiera sp.	×								
Torreyites constricta					×	×			
Cycadolepis indica			×						
Cycadolepis sp.					×				
Elatocladus confera						×			
Elatocladus plana					×	×	×	×	
Elatocladus jabalpurensis					×	×			
Elatocladus tenerrimas						×			
Elatocladus spp.		×				×			
Retinosporites sp.	×								
Brachyphyllum expansum					×	×			
Brachyphyllum mamillare						×			
Brachyphyllum rhombicum			×			×			
Brachyphyllum feistmanteli			×		×	×			
Brachyphyllum sp.		×							
Araucarites macropterus						×			
Araucarites cutchensis			×		×	×	×		
Araucarites sp.	×								
Actinopteris sp.							×		
Podozamites lanceolatus		×	×				×		
Conites sessilis					×	×			
Conites sripermaturensis						×			
Conites verticillatus						×			
Conites sp.			×						
Mesembrioxylon parthasarathyi						×			
Cupressinoxylon coromandelinum						×			

Vemavaram shales — These are too continental and marine in nature. The rocks consist of hard and soft white and grey shales containing both mega and micro plant fossils and marine invertebrates such as ammonites. Fossil fishes are also known. The flora (Chart V) is known after the work of Feistmantel (1879), Suryanarayana (1954), Ramanujam (1957), Kar & Sah (1969), Jain (1968) and Bose & Jain (1967).

On mega floral evidences they were known to be Kota (Middle Jurassic) in age. The microflora (Kar and Sah 1969) indicates an upper Jurassic age. However on the faunal evidences afforded by ammonites and fish remains, they are considered to be of lower Cretaceous (upper Neocomian) age.

Pavalur sandstone — They are developed around Pavalur. Lithologically they are essentially made up of sandstones. No fossils *in situ* are known from this horizon. Since they rest on the Vemavaram shales they are considered equivalent to Tirupati sandstones.

Madras Area

The sequence of rocks in this area is as follows:

Post-Triassic Gondwanas { Satyavedu beds / Sriperumbudur beds

Metamorphics

There are a number of small patches of upper Gondwana rocks around Madras of which only those of Sriperumbudur and Satyavedu are well known.

Sriperumbudur beds — They are developed about 15 km. west-southwest of Madras and are primarily argillaceous consisting of shales. The beds have yielded both fresh water plants and marine invertebrates including ammonites and arenaceous foraminifers. The flora (Chart V) of these shales are known through the work of Feistmantel (1879) & Suryanarayana (1953, 1955).

Based on flora they were considered Kota in age i.e. Middle Jurassic. However ammonites and arenaceous foraminifers suggest a Lower Cretaceous (Murthy & Sastry 1962) age to these shales.

Satyavedu beds — Developed in the area of Satyavedu hills northwest of Madras, these beds are mainly arenaceous, consisting of purple or pink ferruginous sandstones and conglomerates. Plant fossils from these beds are too fragmentary. An indeterminate species of *Dictyozamites* sp. is known. As these beds overlie the Sriperumbudur beds (probably homotaxial to Raghavapuram shales in Ellore area) they are considered equivalent to Tirupati Sandstone of Ellore area.

Trichinopoly Area

The post-Triassic Gondwana succession in this area is as follows:

Cretaceous — Utatur group

Post-Triassic Gondwanas — Utatur Plant beds / ? Conglomerates (at places)

Metamorphics

Utatur plant beds — These are purely continental deposits and are found near Utatur in Trichinopoly district consisting of white to reddish sandstone at times conglomeratic which alternate with beds of shales or pass into grey and white clays. The plant fossils (Chart V) are fragmentary and are known through the work of Feistmantel (1879) and Chowdhury (1958).

Blanford (1962) had remarked, despite absence of marine fossils "they appeared both on stratigraphical and lithological grounds to be not very widely separated in time from Cretaceous rocks immediately overlying them". Chowdhury (1958) pending detail work, suggests these "plant beds are homotaxial with the Jabalpur-Tirupati group".

Ramnad Area

The post-Triassic Gondwana sediments of this area show the following sequence:

Recent — Alluvium & Laterite

Post-Triassic Gondwanas { Sivaganga beds

— Unconformity —

Archaean rocks

Sivaganga beds — These are purely continental deposits and are developed around Sivaganga, made up of conglomerates, sandstones, grits and shales.

Gopal, Jacob & Jacob (1957) described these beds in detail. The plant fossils (Chart V) and undetermined lamellibranchs in them suggest a Kota (middle Jurassic) age to these beds.

TABLE 1 POST-TRIASSIC GONDWANA SUCCESSION IN INDIA

	Biostratigraphic Units		Lithostratigraphic Units													
					Uppr Narmada Valley				West Coast		East Coast					
Standard Scale		Assemblage Zone	Rajmahal Region	Wardha Godavari Valley	Satpura	Bansa Parsora	Lower Narmada Valley	Rajasthan	Cutch Region	Baroda Kathiawar	Cuttack	Ellore	Ongole	Madras	Trichinopoly	Ramnad
Lower Cretaceous	↑ Ptilophyllum Flora	Weichselia-Onychiopsis Zone	Unfossiliferous Intertrappeans associated with flows (Nos.5-11) of Rajmahal Volcanics			Bansa beds	? Lower Nimar beds/Katkot Sandstone	Parihar Sandstone	Bhuj formation (Including Narha beds)	Songir Sandstone/ Himatnagar Sst./ Wadhwan Sst./ Up.-Mid. Dhrangadhra Sandstone (including Tlian beds)		Tirupati Sandstone Raghavapuram Shales	Pavalur Sandstones/Vemavaram Shales Budavada Sst.	Satyavedu beds Sriperumbudur beds		
Upper Jurassic	Ptilophyllum Flora	Pagiophyllum-Brachyphyllum Zone	Nipania intertrappean beds between flows (Nos. 4-5) of Raj-Volcanics	? Gangapur formation/Chikiala formation	Jabalpur beds					Lowermost Dhrangdhra Sst.						? Sivganga beds
Lower Jurassic	Ptilophyllum Flora	Dictyozamites-Pterophyllum Zone	Rajmahal plant beds as Intertrappeans between flows (Nos. 1 to 4) of Rajmahal Volcanics/Dubrajpur beds (upper part)	Kota formation	Chaugan beds	↑		Lathi formation			Athgarh beds	? Golapili Sst.			? Utatur Plant beds	
Rhaetic	↓ Dicroidium Flora					Parsora beds										

DISCUSSION

In the preceding pages the stratigraphic position of the plant bearing horizons of post-Triassic sequences has been analysed. In this analysis the associated faunal evidences in some of the formations suggest the following three different ages to them.

Post-Aptian

(? Albian) Upper Neocomian — Bhuj Formation; East Coast Gondwanas (excluding Golapilli, Athgarh Utatur & Sivaganga beds)

Lower to Middle — Kota formation and Lathi formation

The Kota and Lathi formations can be considered of lower Jurassic age based on the faunal evidences. The former rocks have yielded the lower Jurassic fishes while latter are overlain by ammonite bearing Jaisalmer limestone of Callovian-Oxfordian age. Thus these two formations being Lower Jurassic in age with possibility of ranging into early part of Middle Jurassic can hardly be doubted. But these two formations are palaeobotanically very poor and no rich assemblage of mega fossils is known. The Kotas from which, most of the flora was described by Feistmantel (1877) now has been proved to come from strata younger than Kotas and as such they cannot be considered of the same age. Therefore, Kotas as defined earlier specially the term Kota floral stage looses its significance. The Lathis have not yielded any mega plants. However, microfossils have proved its upper Gondwana affinity beyond doubt. It is thus evident that the flora of Lower Jurassic age is not very well known and whatever little is known could not be of much help to correlate the other known terrestrial deposits.

The fore-runners of younger flora are represented in the fossil assemblages of Parsora formation. The climatic conditions which were unfavourable during the major part of the Triassic improved at its close, i.e. Rhaetic and thus a rich floral assemblage during the Lower Jurassic could be expected reasonably. Further there is no indication of any major climatic changes or any break in sedimentary continuity between Rhaetic and slightly younger rocks. The only undoubted Lower Jurassic plant beds containing mega plants are known in Kota formation where the plant assemblage is poor. This may perhaps be attributed to want of sufficient palaeobotanical work done in the area. The only older beds in the post-Triassic sequence where the floral assemblage is rich are the Rajmahal plant beds. This can, it seems, be reasonably equated with Kota formation. If this be true, the Rajmahal plant beds are Lower Jurassic or Lower Jurassic — Middle Jurassic in age. Since the flora from the Chaugan formation, Golapilli sandstone, and Athgarh sandstone show affinities with Rajmahal plant beds, they may be of similar age or to some part of Lower Jurassic — Middle Jurassic range. These beds may be considered roughly of the same age.

Higher up in the sequence are the floral assemblage from the East Coast Gondwanas (excluding Golapilli sandstone and Athgarh sandstone) Gangapur formation, and the Nipania beds. Wherever, the East Coast Gondwanas are associated with marine fossils they are of undoubted upper Neocomian age. The Gangapur formation which overlies the Kota formation, unconformably, possess a flora comparable to the flora of the East Coast Gondwanas. Thus the Gangapur formation may range from middle Jurassic to Lower Cretaceous (upper Neocomian). Same age can be adduced for Nipania beds. But in the latter case, the older beds in Rajmahal hills are of Lower — Middle Jurassic age. Hence the Nipania beds should be of upper Jurassic rather than Upper Neocomian in age so also the Jabalpur formation. If this is accepted, it follows that there was no floral difference between the upper Jurassic and upper Neocomian.

It may be mentioned here that recently McDougall and McElhinny, (in McElhinny, 1970) have suggested that the Rajmahal Traps of India are of Albian age on K-Ar determinations. In other words, the two biozones associated with the Rajmahal Traps become younger to the flora from Upper Neocomian East Coast Gondwanas containing ammonites also.

But the flora from the Upper Neocomian age is correlatable to the flora from upper biozone of Rajmahal hills. In view of this contradiction, K-Ar age determination is not in conformity with plant evolution.

Still higher in the sequence are the floral assemblages from the Himatnagar and Dhrangadhra sandstones, Bansa and Bhuj formations. Of these, except the last, others have yielded typical Lower Creta-

ceous plant fossils, which indicate, that Lower Cretaceous is represented in these beds. The Bhuj formation however, is of post-Aptian age based on the considerations of marine fossils and structural evidences. The typical lower Cretaceous fossils in the Dhrangadhra sandstone comes from 'Than beds' which occur in the upper portion of the Lower Dhrangadhra sandstone and the base of this formation is not known. Because of *Weichselia reticulata*, they are generally considered to be of Wealden age (=Lower Neocomian). The age of the Lower part of Nimar sandstone containing very few Gondwana plants cannot be decided. It may be anywhere in the Lower Cretaceous.

CONCLUSIONS

From the foregoing observations and the discussion on the post-Triassic Gondwana flora, the following conclusions become evident:

1. There were definite Jurassic continental deposits in India.

2. The Rajmahal hills offer a good scope for the zonation of the Jurassic-Lower Cretaceous flora and Rajmahal plant beds are of Lower Jurassic—Middle Jurassic age as observed earlier by Feistmantel (1877) and Sahni (1937).

3. The evolution of floral elements during Jurassic — Lower Cretaceous times was very slow.

4. There is no clear boundary between the Upper Jurassic and Lower Cretaceous flora as most of the plant genera continued from Jurassic to post-Aptian (? Albian) times, it is only their preponderance that varied.

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