CLIMATES DURING GONDWANA ERA IN PENINSULAR INDIA : FAUNAL EVIDENCES

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ABSTRACT

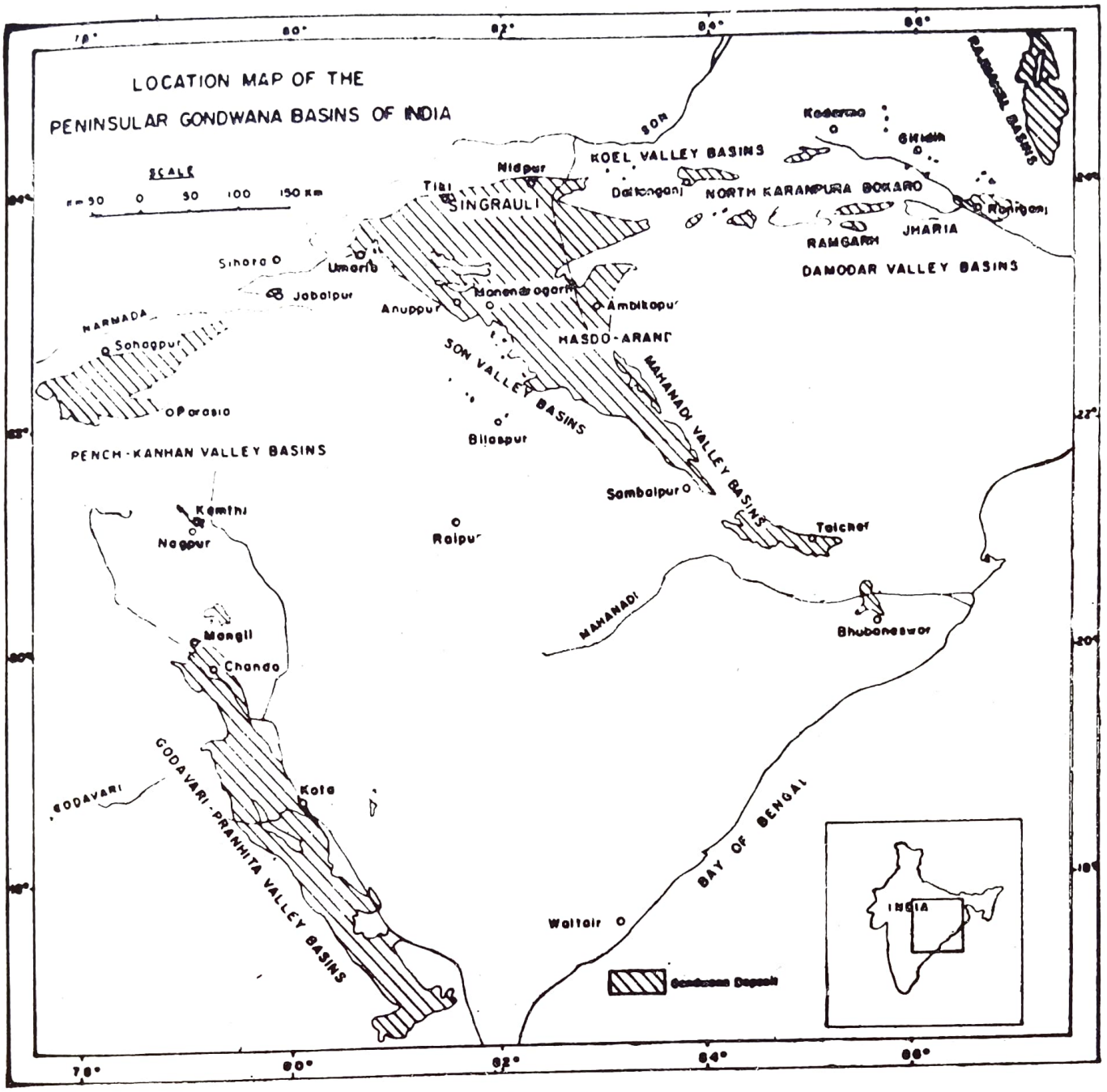
In India, the Gondwana era encompasses later part of the Palaeozoic (Permian) and the major portion of the Mesozoic eras (upto the end of the Albian) and covers a time span of nearly 180 million years. This period commenced after the glacial condition of the late Carboniferous. During the Permian, the climate was mainly cool to cool-temperate with an intermittent spell of warm and moist during the later part of the early Permian. During the Triassic, the climate was warm and moist with subarid condition at times. The Jurassic and early Cretaceous witnessed a very favourable climate for the organic world with seasonal variations in the early Jurassic only. But in the later part of the period, i.e. in early Cretaceous, it was slightly warmer.

INTRODUCTION

In India, the Gondwana era represents a long span of time during which 6,000 m thick Gondwana deposit of essentially fresh water sediments rich in vegetable detritus and ironstone were laid down. These sediments are mostly in the Peninsular India (Map. 1). Though a few patches of early Permian Gondwana are found in Kashmir and Arunachal Pradesh of the Extra-Peninsular region, they are excluded from the present paper. Since the views differ regarding the definiton of the lower and upper limits of the Gondwana, the era it represents denotes a varying time interval. However, the author holds that it encompasses a duration of time from the base of the Permian to the top of the early Cretaceous (Shah & Sastry, 1975; Shah *et al.*, 1972). The present paper deals with the animal fossils only and the discussion regarding the palaeoclimates.

Neumayr (1833) was the pioneer who made climatic zones of the Jurassic on the basis of fossils. The climate, the net result of temperature, pressure, wind and the rainfall, has a direct bearing on the animals whether aquatic or terrestrial. The latter reflect the change of climate better than the marine animals as the water in the sea has a great buffering effect between the animal and the climate. This data, together with evidences from other organic remains etc., will enable us to have the palaeoclimatic reconstructions. The latter can give us the definite clues to the distribution of sedimentary deposits like coal and clay.

The climate which was responsible for existence and/or extinction of the animal can be inferred from the deductions made on similar or related living animals; but in case of animals during the Gondwana era, such inferences are less significant; however, from most of the animals indirect analogies can be drawn, from which reasonably valid conclusions can be established. Moreover, the animals have been evolving with time, hence their tolerance to climatic changes are difficult to judge. But the evolution itself suggests the faunal adaptation to new living conditions, and the physical and anatomical changes suggest the type of new climate. Faunal lists by themselves are not very useful from the present point of view



Map. 1

unless there are some climatic indicators in them. Though statistical study is an ideal one where the fossils are numerically present as in the case of microfossils. Otherwise the abundance of the animals in the assemblage serves a great purpose. But, sometimes, two different assemblages denoting the same time interval are assigned to one biozone. In such cases, the vertical climatic zoning of a particular period in the area are of great importance and should not be lost sight of. It would indicate the same relationship as the different facies of the marine to fluviatile deposits.

The Gondwana contains the remains of animals from the base to the top of this Supergroup; but they formed an important part of the organic world in the Triassic only. The animals during the Gondwana era thrived in sea and in continental water. They roamed on the land and flew in the air. The evidences from these animals together with surrounding vegetation are very useful in the interpretations of the palaeoclimates.

It may be pointed out here that the total thickness of the beds bearing animal remains is much less in proportion to that of the entire Gondwana sediments. Hence the climatic fluctuations deduced from the animal remains are the minimum that had occur-

red during the Gondwana era, though there might have been, but not necessarily were, additional climatic changes. Further in deducing the sequence of climate fluctuations during the era in question, a well established and non-controversial Gondwana sequence having a chronostratigraphic status should be taken into considerations. But for the Permain, no unquestionable sequence has been established so far. Hence the biostratigraphical sequence should be used instead. The correlation of the various Gondwana units along with biostratigraphical sequence is given in Chart I A-C and the faunal assemblages from the various units are given in the Appendix—A (prepared from sources listed in the references).

The climate during the Gondwana era was discussed earlier in a symposium on palaeoclimates by Fox (1937) and SAHNI (1957). Later on, ROBINSON (1963) also discussed the palaeoclimates. With the advance of the knowledge regarding fauna, the palaeoclimates during the Gondwana era are being discussed afresh here.

The world had witnessed three major glacial periods after the Precambrian times, i.e. in Eocambrian, late Carboniferous and Quaternary. The second glaciation, i.e. of late Carboniferous times, was just prior to the Gondwana era and even the last phase had its effect in the earliest Talchir Formation at some places, and there are definite evidences of this undoubted glacial climate (a type of climate of prolonged ice sheet of some appreciable thickness). The whole of the Gondwana era, thus, was essentially of post-glacial nature.

CLIMATE DURING PERMIAN

The lower limit of the Gondwana Supergroup is taken at the base of the Permian and the oldest unit of Gondwana is the Talchir Formation. Associated with the Talchir Formation is the marine Eurydesma Fauna, known from Manendragarh, Rajhara, Darjeeling and Sikkim—the dominant genus in all above mentioned assemblages being *Eurydesma*. At Rajhara, the fauna is very poor and is represented by 3 species of *Eurydesma*, one specimen of *Streblopteria* and a few specimens of *Praeundolomya*. At Manendragarh, the marine fauna consists of foraminifera (5 genera), bryozoan (1 genus; few specimens), brachiopod (1 genus; few specimens), gastropods (good number of specimens, 2 genera) pelecypods (4 genera of which *Eurydesma* and *Deltopecten* are abundant) and few crinoids. At Manendragarh the fauna occurs in the lower part of the Talchir while at Rajhara, higher up in the unit. *Eurydesma*, a peculiar thick shelled pelecypod, occurs in the peripheral Gondwana sea (Gondwana shelf) and is known from all Gondwanaland region except Antartica. The palaeoecological conditions indicated by *Eurydesma* are cool water conditions as worked out for the Australian eurydesmids (DICKINS, 1957). Similar conditions can be deduced for Indian Eurydesma fauna. The size of the *Eurydesma* from India is small than that from the Eastern Australia which witnessed the glacial conditions 3-4 times during Permain. The climate enjoyed by Manendragarh and Rajhara might not be as cool as that of Eastern Australia though the small size of eurydesmids may also be due to the closed nature of the sea in the Peninsular India, as opposed to the open sea in the Eastern Australia or may be even due to its geographical position, i.e. nearer the equator. The region from Manendragarh to Sikkim along the present Son drainage, along which the sea was present in that distant past, witnessed cool condition but what condition prevailed inland cannot be deduced as no faunal remains are known from the Talchir Formation of such areas. But in view of the lithological similarities of the Talchir throughout the Peninsular region, one can safely infer that during the deposition of this unit, the Peninsular India witnessed a cool climate. This deduction is quite in conformity with the glacial climate just at the beginning of the Talchir Formation.

Chart I : Correlation of Gondwana in India

A : Permian Gondwana with fauna

	Biostratigraphic sequence	Damodar valley	Upper Narmada valley		Koel valley	Wardha-Pranhita Godavari valley	Rajasthan
			Satpura	Bansa-Parsora			
Glossopteris Assemblage zone	*Glossopteris conspicua—G. retifera* A. subzone	Raniganj Fm. (i, v)	Bijori Fm. (v)	Pali Fm.		Kamathi Fm. (i)	
	Cyclodendron A. subzone	Kulti shale (i)	Motur Fm.	Kulti Shale (v)		Motur-like Fm.	
	Barakaria dichotoma—Walkomiella indica. A. subzone	Barakar Fm. (i)	Barakar Fm.	Barakar Fm.	Barakar Fm.	Barakar Fm.	
Gangamopteris Assemblage zone	*Gondwanidium—Buriadia* A. subzone	Karharbari Fm.	Karharbari Fm.	Karharbari Fm. (M, i)	Karharbari Fm.		Badhaura Fm. (M, i)
	Noeggerathiopsis—Paranocladus A. subzone	Talchir Fm.	Talchir Fm.	Talchir Fm. (M, i)	Talchir Fm. (M, i)	Talchir Fm.	Bap Fm.

Note—M—wholly marine or brackish; i—*invertebrate bearing;* v—*vertebrate bearing* : (*common to chart IA-C*)

Chart I : Correlation of Gondwana in India

B : Triassic Gondwana with fauna

	Biostratigraphic sequence	Raniganj Coalfield	North Karanpura Coalfield	Bokaro Coalfield	Singrauli Coalfield (Nidpur)	Tiki-Parsora	Satpura	Pranhita Godavari valley	Wardha valley
Late	Flora IV	?	?	?		Parsora Fm. Tiki Fm. (v, i)	Denwa Fm. (v)	Dharmaram Fm. (v,i) Maleri Fm (v,i)	
Lepidopteris—Dicroidium Assemblage Zone	Flora III	Supra-Panchet	Mahadeva (i)	Mahadeva	Mahadeva (i) ? Beds (v) Nidpur bed		Pachmarhi (?, i)	Bhimaram Fm. (v) Yerrapalli (v)	
	Flora II	Upper Panchet (i , v)	Panchet Fm. (i, v)	Panchet Fm. (i)			?		Mangli beds (i, v)
Early	Flora I	Lower Panchet (i, v)					Almod beds (i)		

Chart I : Correlation of Gondwana in India

C : Jurassic-Early Cretaceous Gondwana with fauna

		Biostratigraphic sequence	Rajmahal hills	Satpura	Pranhita-Godavari basin	East Coast			
						Ongole	Ellore	Madras	Trichinopoly
Early Cretaceous	Pillophyllum Assemblage zone	*Weichselia*				Pavalur Fm.	Tirupati Fm. (M, i)	Satyavedu Fm.	
		Onychiopsis	?	Bansa Fm. (i)		Vemavaram Fm, (M, v, i)	Raghavapuram Mudstone (M, v, i).	Sriperumatur (M, i)	Terani Beds (M, i) Sivaganga Fm. (i)
		A. subzone				Budavada Fm. ((M, i)			
Late Jurassic		*Pagiophyllum—Brachyphyllum* A. subzone	Nipania beds	Jabalpur Fm.	Gangapur Fm. (v) Chikiala Sst.		?		
Early Jurassic		*Dictyozamites* *Pterophyllum* A. subzone	Rajmahal Plant beds (v)/ Up. part of Dubrajpur Fm. (i)	Chaugan Fm. (i)	Kota Lat. (v, i)		?Golapilli Fm.		

Next higher up is the Karharbari Formation which has not yielded any fauna. But associated with the Karharbari are the marine intercalations at Umaria. The marine faunal assemblage is dominatd by *Stepanoviella* (represented by one species) though *Amibkella*, *Cleithyridina* are also represented. Pelecypods are represented by few specimens of *Deltopecten* and small sized *Eurydesma*. The fauna is referred to as *Stepanoviella* fauna and is quite well studied from various parts of the world. The palaeo-ecological deductions indicate that it was thriving in cool temperate climate (WATERHOUSE, 1970). At Badhaura, the *Stepanoviella* fauna is represented by plecypods (11 genera), brachiopods (14 genera, abundant,) gastropods (5 genera) and others. The fauna is closely comparable to one from the Callythara Formation of Carnarvon basin, Western Australia and the climate as deduced is of cool temperate nature. The presence of *Ambikella* also indicate cool climate. The absence of corals, cephalopods and the fusulinids indicate the climate was cool and not warm enough for their thriving.

In the Umaria Coalfield, the Umaria marine bed laterally passes into the fresh water deposits having a characteristic mio- -and macroflora which have been one of the criteria for recognizing the Karharbari Formation or Member throughout the Peninsular India. Hence it seems quite reasonable to expect that during the deposition of the Karharbari, India still continued to have a cool temperate conditions.

Overlying the Karharbari is the Barakar Formation which is extensively devloped and contains the valuable reserves of coal. The fauna consists of anthracocids whch are known from the Mand-Raigarh Coalfield, Madhya Pradesh, and the Damodar basin. No climatic deduction is possible.

Overlying the Barakar are the Kulti Formation in the Damodar basin and Motur-like formation in the Pranhita-Godavari basin. In the Damodar basin, the Kulti Formation in the North Karanpura Coalfield has 4 thin mudstone bands containing the anthracocids. Nothing definite can be deduced from this fauna. But there was prolific bacterial activity during this period which is evident from the distribution of siderite (hydrous iron carbonate) which occurs as lenses and nodules. Bacterial activity will be at its optimum under warm and humid condition and reducing environment (restricted circulation of water, i.e. in lakes or partially closed lakes). This activity will also be responsible for the decaying of vegetable matter rather being allowed to be preserved as carbonaceous matter. The general absence of carbonaceous matter will also support the bacterial activity at its optimum. In the northern part of the Pranhita-Godavari basin, the reptilian fauna has been discovered (KUTTY, 1972) in the hard and ferruginous nodules of the Motur-like formation. More than 30 skulls are recovered and the fauna consists essentially of dicynodonts with only one non-dicynodont member. Similar fauna is known from the upper part of the early Permain of South Africa (i.e. from Karroo beds), America and Europe. The presence of this fauna suggests that in the Pranhita-Godavari basin warm and moist climate prevailed. In view of the lithological similarities of this unit, it can be postulated that warm and moist climate was being experienced throughout the Peninsular India during the last phase of the early Permian.

The youngest unit in the Permian Gondwana is the Raniganj Formation in the Damodar basin and its equivalents elsewhere. A single specimen of ? *Amblypterus* fish and some shells of *Anthraconauta* are reported from the Damodar valley. Nothing significant can be deduced from this fauna regarding the climate. But the few layers of siderite (indicating bacterial activity) are seen associated in the basal Raniganj Formation (Poniati coalseam in the Raniganj Coalfield) suggesting that the bacterial activity, though may not be continuous, was seasonal during the basal part of the Raniganj For-

mation. The Kamthi Formation, an equivalent of the Raniganj, in the Wardha-Prahnita-Godavari basin is lithologically quite different and few estheriids have been recorded from one locality (Kawarsa) from the upper part of the formation. This may be suggestive of warmer climate. "Inland basins with a hot season temperature of 20° to 30°C provide the optimum conditions of living estherians", (KOBAYASHI & SHIKAMA, 1961; p. 298) and can survive seasonal droughts when estheriids can survive and other form of life (except lungfishes etc.) are rare. In the Satpura basin, the Bijori Formation is equivalent to the Raniganj Formation and a single specimen of amphibian, *Gondwanosaurus bijoriensis* is believed to have come from this unit which is floristically of late Permian age. The amphibian is suggestive of Triassic age (ROMER, 1947). In the Singrauli Coalfield, the youngest Permain unit is referred to as the Raniganj Formation and the amphibian, viz. *Rhinesuchus* is believed to have come from this unit. The fauna by itself cannot give any indication about the climate except that it shows there was water for some part of the year.

There has been a notable absence of reptilian vertebrates from the early to late Permain deposits of India except for the last phase of the early Permian. In Australia also, the Permian is devoid of any vertebrate remains. But the reptiles were quite dominant part in the northern hemisphere and also in South Africa during the Permian. The absence in Australia was attributed to its geographical isolation or to unsuitable climatic conditions (TEICHERT, 1950). Australia witnessed cool to cool-temperate climate during the Permian. India also seems to have witnessed cool to cool-temperate climate (but warmer than Australia). This is supported by the depauperate Glossopteris flora, represented by few genera and species as compared to the northern flora which had a warmer climate.

CLIMATE DURING TRIASSIC

The Triassic Gondwana of Pranhita-Godavari, Damodar, South Rewa, Satpura and the Wardha basins have yielded fauna. The first area presents nearly a complete sedimentary sequence of the Triassic except the earliest Triassic; the second one, however, has the earliest Triassic; the third and fourth basins have the fossiliferous beds of Carnian-Norian age only, while the last one had also the earliest Triassic fossil record.

In the Damodar basin, the earliest Triassic beds are known as the Panchet Formation and are well developed in the Raniganj, Bokaro and North Karanpura Coalfields. The Raniganj Coalfield has a well developed Lystrosaurus fauna and North Karanpura Coalfield has yielded so far two skulls and few bone fragments of *Lystrosaurus*. The characteristic element of fauna is the abundance of *Lystrosaurus*, a theraspaid reptile (highly specialized reptile of acquatic habit). "This animal was a sort of reptilian hippopotamous of small size and its prevalence is a fair indicator of widespread moist conditions duing early Triassic times with an abundance of rivers, and lakes streams and ponds" (COLBERT, 1964). The *Lystrosaurus* is known from practically all the Gondwanaland countries except Australia. In addition to this small-sized reptile, there are also large-sized reptiles—*Proterosuchus* (*Chasmatosaurus*) which is suggestive of climate, though "not completely subtropical, certainly were not severe" (COLBERT, 1964). There are 6 genera of amphibians; the group ". . is difficult to imagine as existing very far from water—atleast for a part of each year" (ROMER, 1953). The existence of fresh water fish (as known by 1 genus) supports the existence of ponds and lakes.

The elements of the Lystrosaurus fauna are known from the Panchet together with the occurrence of the estheriids which form an important part of the fauna. The estheriids

indicate the warm and moist climate and can survive in seasonal droughts. The small size of the estheriids confirm the seasonal droughts during Scythian.

Hence, it can be surmised that the climate during the Panchet in the Raniganj Coalfield was warm and moist with seasonal droughts. Similar climatic conditions can be implied in the other parts of the Damodar basin because of the similar faunal contents and the lithological similarities.

In the Peninsular India, the Wardha basin is another area where the earliest Triassic bed bearing fauna is recorded. The vertebrate fauna consists of the solitary record of one amphibian specimen of *Brachyops laticeps* and invertebrate fauna which is abundantly known. The latter consists of estheriids only. Hence, the climate might have been warm and moist with seasonal droughts quite often.

For the rest of the Triassic, the discussion will centre around the Pranhita-Godavari basin, where the sequence seems to be entire (KUTTY & ROY CHOWDHURY, 1970).

The oldest unit in the sequence is the Yerrapalli Formation which has yielded the vertebrate fauna only. The fauna is essentially a dicynodont one, and the assemblage consists of dipnoid fish (1 genus), amphibians (2 genera) and reptiles (6 genera). On the basis of the amphibians and reptiles, as discussed above, warm and moist climate might have been prevailing. The presence of dipnoid fish genus, though not in abundance, "is an indication that the water in which they lived were subjected to frequent periods of great reduction or drying up. The dipnoid fish can bury itself in the mud and withstand several months of complete dryness as air breathing vertebrates" (COLBERT, 1953). Such drying up was frequent. The rock unit equivalent to the Yerrapalli Formation is not known elsewhere in India.

Higher up in the sequence in Pranhita-Godavari basin, is the Bhimaram sandstone bearing only bone fragments, which give no indication of the climate. Probably equivalent to the Bhimaram Formation are the Pachmarhi Formation in the Satpura and Mahadeva Formation in the Damodar basins. In the latter basin, estheriids are known from the base of Mahadeva in the Bokaro coalfield. The exposure is small and consists of 2-3 bands containing numerous estheriids. Hence, during the deposition of the lower part of the Mahadeva in this area, the climate seems to have been warm and moist with frequent drying up of the basins. The overlying Maleri formation has yielded vertebrates and invertebrates representing low land fauna. Among the vertebrates numerous dental plates of dipnoid fish have been found (1 genus). The amphibians are recorded by one genus and the reptiles by 4 genera. The emphibians and reptiles indicate warm and moist climate and the abundance of the lungfish indicates frequent drying up of rivers and lakes, streams and ponds where the fishes were thriving. The invertebrate fauna does not contradict the climatic deductions. The equivalent beds to Maleri is the Tiki Formation in the South Rewa basin and compares closely with the former, both in the fauna and lithology. Only one dental plate of dipnoid fish is known so far.

In Satpura basin, the Denwa Formation, so far considered as equivalent to Maleri, is older than Maleri (CHATTERJEE & ROY CHOWDHURY, 1974) and the fauna is still under study.

In the Pranhita-Godavari basin, the Maleri is overlain by Dharmaram Formation from which the vertebrate and invertebrate remains are known. The vertebrate fauna is poorly known but is essentially an archosaur fauna with one large probably plateosaurid and one small prosauropods (thecodontosaurid) and two archosaurs (CHATTERJEE & ROY CHOWDHURY, 1974). According to COLBERT (1974) "The archosaurians were obviously very active reptiles, certainly living with optimum efficiency, in tropical and sub-

tropical climate." Hence the climate during the deposition of the vertebrate fauna in this formation was tropical to subtropical. The invertebrate fauna (1 genus) also does not contradict it. There are no other equivalent fossiliferous beds elsewhere in India.

The climate was warm and moist for the entire Triassic Period and there were seasonal droughts which were absent during the Rhaetian when it was again warm and moist.

CLIMATE DURING JURASSIC—EARLY CRETACEOUS

The oldest unit of this time range is the Kota Formation, known for its fossil fishes since 1878. The assemblge includes actinopterygian genera namely *Lepidotes* (abundant), *Tetragonolepis* (rare), *Paradapedium* (uncommon), *Pholidophorus* (one species) and crossosterygian genus of coelecanth fish (one specimen). Though *Lepidotes* and *Pholidophorus* are known from the freshwater deposits elsewhere, the *Tetragonolepsis* and *Paradapedium* are also known from the marine habitat outside India. Since the Kota Formation is of freshwater origin, the marine genera seem to have adapted to the freshwater conditions. Thus marine fishes, which are subsidiary in number to the freshwater fish, might have come upstream and settled there. These fishes indicate warm water conditions. "Abundance of actinopterygian fishes suggests year round rainfall so that the swamp water remains oxygen rich" (ROMER, 1961, p. 189). The insect fauna consists essentially of cockroaches (blattids), beettles (coloeptera), and plant bugs (hemiptera). These insects are primarily vegetarians. The climatic condition indicated by them is tropical. Associated with these, is also the abundance of estheriids which thrive at the optimum temperature of 20°-30°C. Their presence suggests that these basins of deposition might be drying up temporarily during which period the eggs of estheriids could remain dormant and could be dispersed away by the wind to more favourable areas where they can resume their life history. The Kota Formation has also yielded two specimens of pterosaur but these have been known elsewhere from the marine sediments (SAINT-SEINE, 1955). Though the pterosaurs are widely distributed in Laurasian continents, nothing is known of this group from the Gondwanaland.

The above assemblage can thrive better in the tropical to subtropical climate only, and this fact is supported by the numerous dinosaurian remains in the Kota Formation. The larger dinosaur might have been 23 m in length and 6 m in height while the medium sized herbivorous sauropod dinosaurs were also present. (ANON, 1975). The warm climate will not be suitable for their thriving. There might have been good vegetation all round for the herbivorous-dinosaurs to feed. These evidences support the tropical climate during the deposition of Kota Formation with seasonal droughts (cf. COLBERT, 1966; p. 632).

Equivalent beds to the Kota Formation are the Rajmahal plant beds which have yielded one specimen of fossil fish, *Jhingrennia roonwali*, the genus and species being both new. The fish belongs to the clupeidae and favours warm climate, though the evidence is based on a single specimen.

During late Jurassic, the sea on the west coast of India had a marine reptile plesiosaur which is indicative of a warm climate (cf. COLBERT, 1964).

In the Pranhita-Godavari basin, the Gangapur Formation which overlies the Kota Formation has yielded fish scales only.

In the Satpura basin, Jurassic-early Cretaceous Gondwana sequence has few scattered uninoid shells of no significance for assessing the climate.

During the early Cretaceous times, the fauna is represented in the East Coast Gondwana only. The faunal elements except that of forams/brachipods and the ammonites

(which are fragmentary and poor) have not been well studied. These depositions have taken place in the brackish water condition. The assemblage of the forams and the ammonites is suggestive of a warm climate. Summing up, the Peninsular India witnessed tropical climate during Jurassic-early Cretaceous with few seasonal droughts in the Liassic.

CONCLUSIONS

During the Gondwana era, the climatic sequence (Chart II) witnessed by the Peninsular India is as follows :

1. There has been a cold to cool-temperate climate for the major part of the Permian Period except for the spell of warm and moist one in the latter part of the early Permian.
2. During the Triassic, the climate was warm and moist with seasonal droughts in the Lower and Middle Triassic. There was not any permanent desertic condition. The climate was subtropical.
3. During the Jurassic-early Cretaceous, the climate was very favourable for the organic world with few seasonal droughts in the Liassic. The climate was tropical.

Chart II : Climatic sequence in Gondwana Era : Based on Fauna

Era	System	Series	Fromation	Climate inferred
GONDWANA ERA	Cretaceous	Early	Tirupati Satyavedu/Vemavaram/Raghavapuram/Sriperumbudur Fm.	Warm and moist
	Jurassic	Late	Jabalpur Fm.	Warm and moist
		Early	Rajmahal plant beds/Kota Fm.	
	Triassic	Late	Parosora Fm.	
			Maleri	Warm humid with seasonal variations
		Middle	Pachmarhi Fm.	
			Beds with Vertebrate (Nidpur beds)	Warm humid
		Early	Panchet Fm.	Warm humid with seasonal variations
	Permian	Late	Raniganj Fm. (Rare)	Temperate
			Motur-like Fm. (Vertebrate)	Warm and moist
		Early	Barakar Fm. (Vertebrate absent)	Cool temperate
			Karharbari Fm. (Vertebrate absent)	Cool temperate
			Talchir Fm. (Vertebrate absent)	Cool to cold
	Carboniferous	Late	Glacial	Cold

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APPENDIX– A

LIST OF FAUNA IN INDIAN GONDWANA

(Compiled from various sources)

EARLY PERMIAN

(Gangamopteris Assemblage Zone)

A. Talchir Formation at Manendragarh

Invertebrate (Marine)

Foraminifers :	*Hyperammina gracilis*, *H.* cf. *bulbosa*, *H.* aff. *clevatula*, *Hyperammina* sp. indet. *Glomospira articulosa*, ? *Lituotuba* sp. indet., *Tolypammina polyverta*, *Trochammina hesdoensis*
Bryozonas :	*Polypora* sp.
Brachiopods :	*Trigonotreta narsarhensis*
Gastropods :	*Peruvispira umariensis*, *Cycloscena* sp.
Pelecypods :	*Myonia* ? sp. (or *Astartella* ? sp.), *Eurydesma mytiloides*, *E. playfordi*, *E. hobartense*, *Eurydesma* spp., *Deltopecten lyonensis*, *Streblopteria* sp.

B. Talchir Formation at Rajhara

Invertebrate (Marine)

Bryozonas :	*Fenestella* sp.
Pelecypods :	*Praeundolomya subelongata*, *Eurydesma mytiloides*, *E. playfordi*, *E. hobartense*, *Streblopteria* sp.
Insecta :	Blattoid wing (Fresh water)

C. Rangit pebble-slate at Darjeeling (Marine)

Invertebrate

Pelecypods :	*Eurydesma* sp., *Sanguinolites* sp. (or *Praeundolomya* sp.,), *Wilkingia* sp., *Leptodesma* sp., (or *Merismopteris* sp.)

D. Umaria Marine Bed

Invertebrate

Ostracods :	*Cytherella* sp., *Jonesina* sp., *Healdia umariensis*, *Palaeocyris* sp.
Bryozoans :	*Rhombopora* sp., *Fenestella* sp.
Foraminifers :	*Hyperammina gracilis*, *H.* aff. *elongata*
Brachiopods :	*Stepanoviella umariensis*, *Trigonotreta narsarhensis*, *Ambikella barakarensis*, *Cleithyridinia protea*
Gastropods :	*Peruvispira umariensis*, *Keeneia ocula*
Pelecypods :	*Eurydesma mytiloides*, *E. hobartense* (Juvenile) *Deltopecten lyonensis*, *D. limaeformis*
Crinoides :	*Jimbacrinus* sp.

E. Badhaura Formation

Invertebrate

Bryozoans :	*Polypora* sp.
Conulariids :	*Paraconularia indica*, *P. punjabica*, *Paraconularia* sp.
Brachiopods :	*Lingula* sp., *Streptorhynchus mistus*, *S.* cf. *praeceps*, *Streptorhynchus* spp. *Derbyia* cf. *buriensis*, *Aulosteges trimuensis*, *Aulosteges* sp., *Wyndhamia sublamellata*, *W. densispinosa*, *Wyndhamia* sp., *Cyrtella nagmargensis*,

	Neospirifer trimuensis, Fusispirifer plicatus, Ambikella spp., *Hoskingia dedanensis, Gilledia homevalensis, Fletcherithyris farleyensis, F. hardmani*
Gastropods :	*Ptychomphalina* sp., *Naticopsis* sp., *Mourlonia* ? cf. *lyndonensis, Warthia* cf. *micromphala, Stachella* cf. *crucilirata*
Pelecypods :	*Nuculopsis bongarraensis, Phestia thompsoni, P. darwini, Parallelodon* sp., *Magadesmus* sp., *Arartila blatchfordi, Chaenomya* ? cf. *nurraensis, Aviculopecten tenuicollis, Cypricardinia* sp., *Schizodus* cf. *fitzroyensis, S.* cf. *sandimanensis, Oriocrassatella* sp.
Crinoids :	Crinoid stems

EARLY TO LATE PERMIAN
(Glossopteris Assemblage Zone)

A. **Barakar Formation, Mand Raigarh Coalfield (Fresh water)**

Invertebrate

Pelecypods : *Anthraconauta* sp.

B. **Barakar Formation, Jharia Coalfield (Fresh water)**

Invertebrate

Pelecypods : Anthracocids

C. **Kulti Shale, North Karanpura Coalfield (Fresh water)**

Invertebrate

Pelecypods : *Anthraconauta* spp.

D. **Kulti Formation Raniganj Coalfield (Fresh water)**

Invertebrate

Pelecypod : *Anthrococids*

E. **Motur-like Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Reptiles : Dicynodont assemblage consisting of skulls of two medium to large sized endothidontids and include *Endothiodon;* small dicynodonts of which one is tusked endothiodontid and a few are tuskless. (Possibly *Kistecephalus*). Nondicynodont also presented by small captorhinomorph.

F. **Bijori Formation, Satpura Basin (Fresh water)**

Vertebrate

Amphibia : *Gondwanosaurus bijoriensis*

G. **Raniganj Formation, Singrauli Coalfield (Fresh water)**

Vertebrate :

Amphibia : *Rhinesuchus wadii, Rhinesuchus* sp.

H. **Raniganj Formation, Raniganj Coalfield (Fresh water)**

Vertebrate

Fishes : ? *Amblypterus* sp.

Invertebrate

Pelecypods : *Anthraconauta* spp.

I. **Kamthi Formation, Wardha Basin (Fresh water)**

Invertebrate

Branchiopoda : Estheriids

TRIASSIC

(Lepidopteris—Dicroidium Assemblage zone)

A. **Panchet Formation, Raniganj Coalfield (Fresh water)**

Vertebrate

Fishes : *Amblypterus* sp.

Amphibians : *Indobrachyops panchetensis, Labyrinthodon panchetensis, Indobenthosuchus panchetensis, Gonioglyptus longirostris, Indolyrocephalus panchetensis, I. huxleyi, Lydekkerina panchetensis, Panchetosaurus panchetensis*

Reptiles : *Lystrosaurus orientalis, Proterosuchus indicus*

Invertebrate

Pelecypods : Unionid

Decapoda : Brachyurous crab

Branchiopods : *Euestheria minuta*, Estheriids

Insecta : Blattoid wing

B. **Mangli Beds, Wardha Basin (Fresh water)**

Vertebrate

Amphibians : *Brachyops laticeps*

Invertebrate

Branchiopods : *Euestheria mangaliensis, Corpia* sp.

C. **Panchet Formation, North Karanpura Coalfield (Fresh water)**

Vertebrate

Amphibians : *Lystrosaurus* sp.

Invertebrate

Branchiopods : Estheriids

D. **Panchet Formation, Bokaro Coalfield (Fresh water)**

Invertebrate

Branchiopods : *Estheriella taschi, Cyzicus* sp.

E. **Unnamed bed, Singrauli Coalfield (Fresh water)**

Vertebrate

Fishes : under study

Other vertebrates :

F. **Mahadeva Group, Singrauli Coalfield (Fresh water)**

Invertebrate

Insecta : ? Dragon fly

G. **Mahadeva Group, Bokaro Coalfield (Fresh water)**

Invertebrate

Branchiopods : Estheriids

H. **Yerrapalli Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Fishes :	*Ceratodus* sp.
Amphibians	*Paratosaurus rajareddyi*, Brachyopoid gen. *et* sp. indet.
Reptiles :	*Wadiasurus indicus*, *Rechnisaurus*, *Cristarhynchus*, a stahleckerid; triractodonlid teeth; unnamed genera and species of Erythrosuchid and that of pretosuchid

I. **Bhimaram Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Bone fragments

J. **Maleri Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Fishes :	*Ceratodus hunterianus* , *C. hislopianus*, *C. virapa*, *C. nageswarii*, unnamed genus and species of subholostei, teeth resembling *Pleuracanthus parvidens*
Amphibians :	*Metaposaur maleriensis*
Reptiles :	*Paradapedon huxlayi*, *Parasuchus hislopi*, ? *Brachysuchus maleriensis*, scutes of ? *Typothorax*, unnamed genus and species of *Coeleurosaurs*

Invertebrate

Pelecypods :	*Tihkia corruguta*

K. **Tiki Formation, South Rewa Basin (Fresh water)**

Vertebrate

Fishes :	*Ceratodus* sp.
Amphibians :	*Metaposaur* sp.
Reptiles :	Rhynchosaur, Phytosaur, an aetosaur

Invertebrate

Pelecypods :	*Tihkia navis*, *T. compressa*, *T. subangulata*

L. **Denwa Formation, Satpura Basin (Fresh water)**

Vertebrate

Reptiles :	? *Paratosaurus* sp.

M. **Bhimaram Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Reptiles :	Prosauropods, (including Plateosaurid, thecodosurid) Archosaur

Invertebrate

Pelecypods :	Unionids

JURASSIC-EARLY CRETACEOUS

(Ptilophyllum Assemblage zone)

A. **Rajmahal plant beds, Rajmahal Hills (Fresh water)**

Vertebrate

Fishes :	*Jhingrennia roonwali*

B. **Kota Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Fishes :	*Lepidotus deccanensis, Paradapedium egerteni, Tetragonolepsis oldhami, Pholidophorus* sp., *Indocoelacanthus robustus*
Reptiles :	*Campylognathoides indicus*, Sauropod dinosaurs Carnosaur, Undetermined scutes of Crocodiles

Invertebrate

Ostracords :	*Candona kotaensis, Darwinula* cf. *sarytirmensis, Timiria-sevia digitalis, Limnocythera* sp.
Branchiopods :	*Cyzicus kotanesis, Palaeolimnadia* sp.
Insecta :	Blattoid, Coleoptera, Orthoptera, Hemiptera
Annelids :	Undetermined worm tracks

C. **Gangapur Formation, Pranhita-Godavari Basin (Fresh water)**

Vertebrate

Fish :	Scales

D. **Chaugan, Jabalpur & Bansa Formation, Satpura Basin (Fresh water)**

Invertebrate

Pelecypods :	unionids

E. **Budavada Formation, East Coast**

Invertebrate

Foraminifers :	*Dentalina* sp., *Bathysiphon*, sp., *Lenticulina* sp.
Ammonites :	*Pascoeites budavadensis, P. crassus, Holodiscus* cf. *perezianus*
Gastropods :	? *Natica* sp., *Cerithium* sp., ? *Turritella* sp., ? *Eucylus sp.*, ? *Turbo* sp., ? *Trochus* sp., *Patella* sp.
Bryozoan :	Indet.
Annelids :	*Serpula*

F. **Vemavaram Shale, East Coast (Brackish)**

Vertebrate

Mammals :	Rib impression of ? mamalian
Fishes :	Cycloid fish scutes, Indeterminate fihses

Invertebrate

Cephalopods :	*Hemihoplites baskidensis, H.* cf. *borrowae*
Gastropods :	Indeterminate
Pelecypods :	species of Inoceramus, *Pecten, Exogyra, Leda*, ? Loldia, ? *Tellina*
Brachiopods :	(*Eschara, Ophiura*), *Rectithyris expansa, R. recurvata*
Decapoda :	*Eryon* cf. *barrovensis*

G. **Raghavapuram Mudstone, East Coast (Brackish)**

Vertebrate

Fishes :	*Cluparus neocamiensis*

Invertebrate

Foraminifers :	*Saccamina lagenoides*, ? *Ammopemphix* sp. *Ammodiscus* cf. *cretaceus, Ammobaculites funicularis, A. fisheri* var. *tripathiensis, A. hofkeri, A. indicus, A. raghavapuramensis, A. sahnii, Haplophragmoides concava, H.*

chapmani H. cf. *dickinsoni, H. kirki, H. witgunyaensis, Trochammina hagni, T. stellifera, T.* cf. *whittininagtoni, Nonion presublaeve, N. barakendai*

Ammonites : *Gymnoplits simplex, Holodiscus* cf. *caillaundianus, Pascocites crassus*

Pelecypods : (*Leda, Mytilus, Trigonia* ? *interlaevigata, Solen, Telina, Pecten*)

H. **Tirupati Sandstone, East Coast (Brackish)**

Invertebrate

Ammonites : *Belemnite, Ammonite, Relicoceras*

Pelecypods : *Trigonia ventricosa, T. smeei, Inoceramus, Pseudomonotis, Lima, Pecten*

I. **Sriperumatur Shale, East Coast (Brackish)**

Invertebrate

Foraminifers : *Bathysiphon* cf. *taurinensis, Pelosina complanata, Ammodiscus cretacens, Lituotuba* sp., *Haplophragmoides dickinsonii, H. concava, H. footei, H. indicus, Ammobaculites* sp., *Spiroplectommina indica*

Cephalopods : *Pascocites crassus*

Pelecypods : *Leda, Yoldia, Tellina, Lima, Pecten*

J. **Terani Formation, East Coast (Brackish)**

Invertebrate

Ammonites : *Gymnoplites* cf. *simplex, Pascocites* cf. *simplex*

Pelecypods : ? *Inoceramus* sp.

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