

Lower Gondwana marine incursions : periods and pathways

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Marine nature of sediments in the Talchir Formation and its equivalent horizons is well-established by the occurrence of invertebrate faunas in Umaria, Manendragarh, Daltonganj, Rajhara, Ranjit Pebble Slate, Subansiri and Bap Boulder Bed. Most of these sediments also contain acritarchs, leiosphaerids and other palynofossils of marine origin in association with spores and pollen. The terrestrial palynofossil assemblage attributes an Early Permian age to these sequences. Leiosphaerids in the Karharbari and Barakar formations are, so far, known only in the Son Graben, indicating continuation of marginal marine environments. The discovery of phosphorite in the Barren Measures of Kelo-River, Son Graben and of palynofossils in these sediments confirm marine influence also in the Late Permian. Thus, the so-far accepted model of a predominantly continental facies for the Lower Gondwana stands challenged. It appears that during the Early Permian, almost all the low-lying embryonic basinal depressions experienced marine transgression from an eastern bay. To the west and north-west the network of marine pathways was connected with Arabian Sea and the Salt Range Sea. The evidences for continuation of marine transgression in the Middle and Late Permian of central India further demand a search for such signatures which could establish the remnant pathways to the heart of the peninsula. The marine leiosphaerid group of palynofossils can be purposefully utilized for palaeoenvironmental reconstructions.

Key-words—Lower Gondwana, Marine incursions, Acritarchs, Leiosphaerids, Continental facies (India).

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सारांश

अधरि गोंडवाना समुद्री अतिक्रमण : विभिन्न काल एवं मार्ग

बेंगलूर श्रीनिवासा वेंकटाचाला एवं राम शंकर तिवारी

उमरिया, मनेन्द्रगढ़, डाल्टनगंज, रजारा, रंजीत बालूकाश्म स्लेट, सुबनसिरी एवं बाप गोलाश्म संस्तर में अरीदुधारी जीवजातों की उपस्थिति से तालचिर शैल-समूह एवं इसके समतुल्य संस्तरों में अवसादों की समुद्री प्रकृति व्यक्त होती है। इनमें से अधिकतर अवसादों में एंक्रिटाक, लिओस्फेरिड तथा बीजाणुओं एवं परागकणों के साहचर्य में समुद्री उद्भव वाले अधिमत् परागणु भी विद्यमान हैं। स्थलीय परागणु समुच्चय में इन अवसादों की प्रारंभिक परमी आयु प्रस्तावित होती है। करहरबारी एवं बराकार शैल-समूहों में लिओस्फेरिड अभी तक केवल सोन द्रोणिका से ही ज्ञात हैं जिससे तटीय समुद्री परिस्थितियां इंगित होती हैं। केलो नदी के बैरन मेजर्स, सोन द्रोणिका एवं इन अवसादों में अधिमत् परागणुओं के अन्वेषण से अर्नात्म परमी कल्प में समुद्री प्रभाव की पुष्टि होती है। अतएव अधरि गोंडवाना हेतु पूर्व प्रभावी फ़ेसीज का अभी तक मान्य मॉडल अब एक प्रश्न बन गया है। ऐसा प्रतीत होता है कि प्रारंभिक परमी कल्प में प्रायः सभी कम गहरे प्राथमिक द्रोणीय दबावों ने पूर्वी खाड़ी से उत्पन्न समुद्री अतिक्रमण का अनुभव किया है। पश्चिम एवं उत्तर-पश्चिम में समुद्री मार्ग अरब सागर एवं साल्ट रेंज से जुड़ा हुआ था। मध्य भारत के मध्य एवं अर्नात्म परमी कल्प में समुद्री घँसाव की निरन्तरता के कारण इन पर और अनुसन्धान की आवश्यकता है जिससे प्रायद्वीप के केन्द्र में अवशिष्ट मार्ग स्थापित किया जा सके। पुरावातावरणीय व्याख्याओं में परागणविकल्पों के समुद्री लिओस्फेरिड समूह का महत्वपूर्ण उपयोग किया जा सकता है।

THE first data input for the recognition of marine signature in the otherwise non-marine package of Gondwana Sequence, was through the discovery of Umaria Marine Bed by Sinor as far back as 1923. He based this find on the occurrence of *Eurydesma* and *Productus*. The *Eurydesma-Productus-Conularia* assemblage has been subsequently found from Manendragarh (Ghosh, 1954), Subansiri (Sahni & Dutta, 1959), Badhaura in western Rajasthan (Mishra *et al.*, 1961; Shah, 1963) and Daltonganj (Dutt, 1965) associated with the Talchir Formation which initiated the Gondwana deposition in the peninsular as well as in extra-peninsular regions. Palynological, sedimentological and geochemical data have accrued to supplement records of marine sedimentation during the Permian, necessitating a rethinking on the Gondwana depositional environment. These records, earlier considered with scepticism, as they were few in number, have been authenticated by additional information.

In the configuration of eastern Gondwanaland, India finds its placement between eastern margin of Africa in the west and Antarctica in the east; Australia being offset towards north-eastern direction with reference to India (Smith *et al.*, 1981). The time-span involved in the deposition of Gondwana Sequence in India is conventionally considered as earliest Permian to Early Cretaceous. The latter limit as well as the nomenclature of spatially extended occurrence of these deposits is debatable.

Hercynian orogeny initiated the formation of Gondwana basins in the early Early Permian along the ancient weaker zones, which are presently aligned with the major river courses (Datta & Mitra, 1982). The embryonic basins were narrow as well as shallow in the earliest Permian giving rise to tectonically active grabens (or half grabens) which accumulated large sedimentary piles, including coals, during most of the Permian Period.

MARINE SIGNATURES

The invertebrate fossil fauna characterised by *Eurydesma-Productus-Conularia* assemblage is an unequivocal evidence for interpreting marine environment in the Permian. Palynoassemblages containing alete palynofossils—variously labelled as leiosphaerids, leiofusids, smooth-walled acritarchs, apiculate-spinate globular bodies, etc.—and land plant spores and pollen are associated with this fauna in several horizons. The leiosphaerid group of palynofossils has thus emerged as an indicator of marine environment. Their close association with the rocks containing marine fauna and phosphoritic nodules provides a high degree of confidence in their utility for environmental determination even

for those strata which are devoid of other evidences. The associated spore-pollen assemblages, mostly allochthonous, render age connotation to the whole assemblage because the Talchir, Karharbari, Barakar, Kulti and Raniganj formations have their own distinct index spore-pollen floras.

Recent discovery of phosphoritic beds, along with some evidence of bioturbidites in the Barren Measures of Son Valley is important in extending the marine influence in the Lower Gondwana (Datta, 1986).

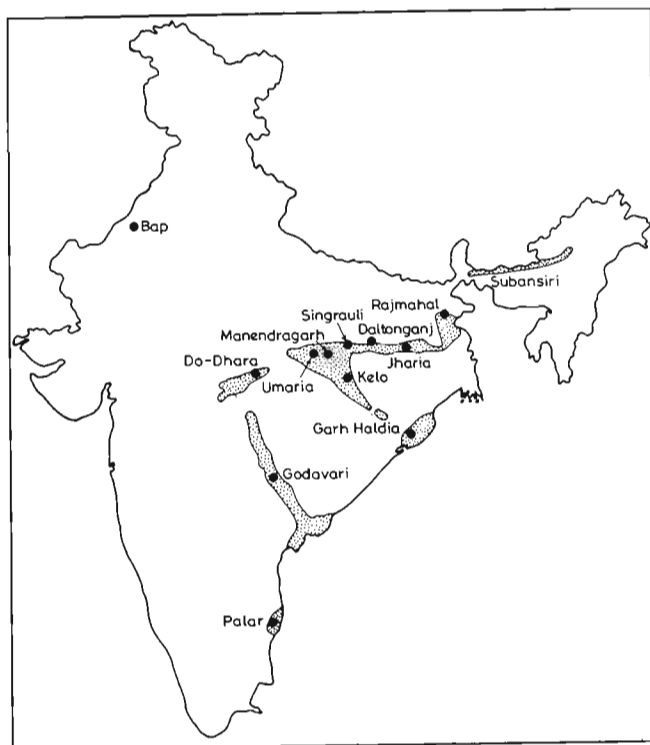
The finding of algal limestones in the Motur Formation of Satpura Basin and concentration of boron and sulphur in Damodar Graben (Datta, 1986) are important geochemical evidences suggestive of marine regimes.

These biological and geochemical marine indicators have to be considered for deciphering marine incursion in the 'Lower Gondwana' sediments.

Talchir Formation— This formation, the lowermost lithostratigraphic unit of Gondwana in India, is well known for its fluvio-glacial nature of deposition with tillite, varves, needle shales and other glacial sedimentary features. Intensive palynological studies during the last three decades in the Gondwana grabens of peninsular India establish the palynofloral suite that distinguishes the Talchir Formation (Tiwari, 1975; Tiwari & Tripathi, 1988, in this Volume). The index fossils of this assemblage are—*Plicatipollenites*, *Parasaccites*, *Virkkipollenites*, *Callumispora* and *Quadrisporites*. These are associated with few striate-disaccate pollen. This flora exemplifies expansion in radial monosaccate pollen.

A careful evaluation of spore-pollen data considered in conjunction with faunal data permits an earliest Permian age assignment to the Talchir Formation. This conclusion is further supported by the absence of typical Carboniferous taxa, such as *Raistrickia*, *Microreticulatisporites*, *Cirratriradites*, *Crassispora*, *Vestispora*, *Alatisporites*, etc. and the dominance of radial monosaccate pollen and the significant incidence of *Callumispora*. The subsequent Karharbari palynoflora is, in fact, a continuation of the older Talchir palynoflora which fact also substantiates the Permian age assignment (Tiwari & Tripathi, 1988, in this Volume). It is not pertinent to correlate the glacial events occurring in various Gondwana continents as they are not coeval.

Sequel to the record of marine fossils from Umaria and Manendragarh (see Lele & Chandra, 1969, 1972, 1973) several new occurrences have been reported. Leiosphaerid assemblage was not considered as an infallible evidence of marine environment, till Venkatachala and Rawat (1973)



Text-figure 1—Records of leiosphaerids and other acritarchs in the Early Permian.

stated that “the dominance of *Leiosphaerids* and other acritarchs suggests a marine influence” in the Talchir sediments of Chingleput area, Palar Basin, from where they recorded (along with a *Plicatipollenites*-assemblage) the genera *Leiosphaeridia*, *Leiofusa* and *Dactylofusa*. They further confirmed the marine connotation of this acritarch assemblage by finding them in the *Eurydesma*-bearing Bap Boulder Bed in Rajasthan (Venkatachala & Rawat, 1984).

Leiosphaerids recorded from the Dodhara area of Satpura Basin (Bharadwaj, Tiwari & Anand-Prakash, 1978) allow an extension of the marine arm from Umariya and Manendragarh into the central part of the Indian Peninsula. Similarly, the presence of leiosphaerids and other such fossils and unidentified vesicles in the Talchir sediments of Jharia Coalfield (Tiwari *et al.*, 1981) and leiosphaerids in the Talchir of Dudhi River Section of Bokaro Coalfield (unpublished data) are records of marine transgression in the Damodar Graben.

Venkatachala and Rawat (1984) recorded an Early Permian palynological assemblage from Bap Formation of Rajasthan which also contains *Leiosphaeridia* in association with a rich marine invertebrate fauna of Permian age (Rao *et al.*, 1977). Rawat and Jain (1985) studied the palynoflora of Talchir sediments from Pranhita-Godavari Graben and identified a monosaccate dominant assemblage

along with *Leiosphaeridia*. On this basis, a cold, brackish water or shallow-marine condition was deduced for the Early Permian deposits of this area (Raiverman *et al.*, 1985).

Recently, Tiwari *et al.* (1987) have recorded a Talchir palynoflora in the khaki-green shales which are unconformably overlain by the Athgarh Sandstone, in the south-west Athgarh Basin. This palynoflora, besides *Plicatipollenites*, contains *Leiosphaeridia* and unornamented acritarch-like fossils. Urn-shaped structures, apparently comparable to Chitinozoa, are also recorded. The stratigraphic setting and palynoflora in this sequence are comparable to that of Palar Basin. A monosaccate pollen rich palynoflora containing leiosphaerids has also been discovered from the Talchir sediments in Chuperbhita Coalfield, Rajmahal Basin (Banerjee & D’Rozario, 1987).

These records of marine incursions in Talchir of Palar Basin, Pranhita-Godavari, Satpura, Son-Mahanadi and Damodar grabens, Mahanadi (Athgarh) and Rajasthan basins (Bap Boulder Bed) support the conclusion that an epicontinental, shallow transgressive sea was present all along the tracks of graben-lineaments. The palaeotopographic low in which the Talchir Formation was deposited apparently made way for marine incursions.

In the extra-peninsular region, there are well-established evidences of marine regimes in the Early Permian of Salt Range, Kashmir, and the North-East. Palynological studies have further provided evidences of marine incursions in the Permian sediments of Upper Assam and Arunachal Pradesh (Srivastava & Dutta, 1977; Singh, 1979). Recently, Sharma *et al.* (1986) have reported an Early Permian *Plicatipollenites-Parasaccites* rich pollen assemblage with *Leiosphaeridia* in the subsurface of the Bara Pathar area, Upper Assam. This is yet another record of Early Permian marine sequence in the Assam Basin. Reworked Permian palynofossils in the Tertiary sediments have been extensively recorded.

Karharbari Formation—This formation exhibits comparatively more diversified palynoflora than the Talchir Formation. A varied radial monosaccate and striate-disaccate pollen assemblage distinguishes the Karharbari palynoflora. Marine leiosphaerids are recorded from the Umariya Coalfield in the Son Graben.

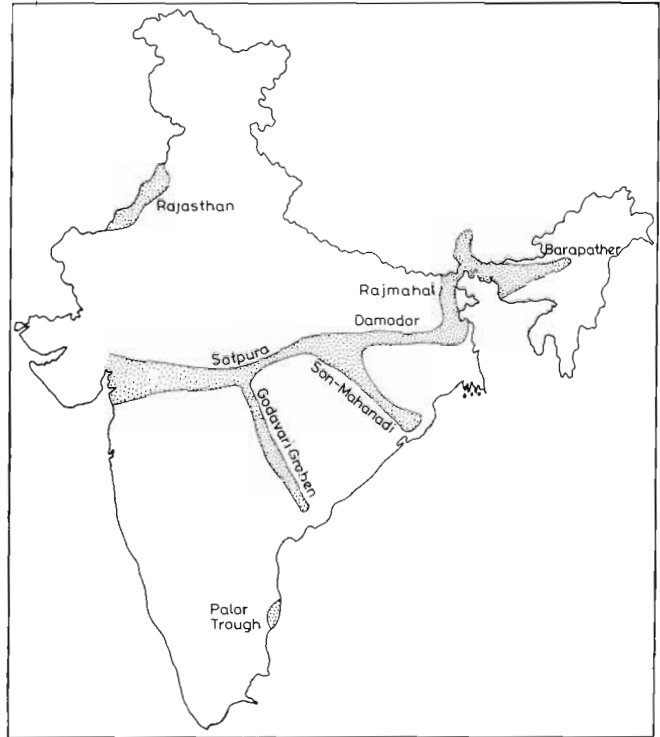
Barakar Formation—Exhaustive Barakar palynofloras are known from all the grabens which are dominated by non-striate disaccate and striate-disaccate pollen and zonate spores. Leiosphaerids indicative of a marine influence are known from Umariya Coalfield (Srivastava & Anand-Prakash, 1984). A diversified acritarch assemblage containing

Leiosphaeridia, *Peltacystia*, *Hindisporis*, *Circulisporites* and *Brazilea* is known from Johilla Coalfield (Anand-Prakash & Srivastava, 1984). The Purewa seam in the Singrauli Coalfield contains a number of smooth-walled as well as ornamented alete palynofossils, such as, *Balmeela*, *Kagulubeites*, *Brazilea* and *Peltacystia*, whose affinities are uncertain. They exhibit similar morphologies comparable to the marine acritarch fossils listed earlier (Tiwari, 1969). *Gondisphaeridium* and *Globulaesphaeridium*, recorded from the Barakar sediments of Godavari Basin, also show similar affinities (Tiwari & Moiz, 1971). *Hemisphaerium* recorded from Pench-Kanhan and Pathakhera coalfields of Satpura Basin may also belong to this group (Anand-Prakash, 1972). These fossils show advanced morphologies as compared to *Leiosphaeridium*. A detailed comparative morphological study is needed. However, a marine influence in all these grabens in the Barakar is significant.

Kulti Formation (Barren Measures)—This formation contains a well-diversified striate-disaccate rich palynoflora. *Densipollenites*, an important marker fossil, appears at this stratigraphic level.

Recent discovery of phosphoritic deposits in the Barren Measure sequence on the Kelo River Section of Ib-River Coalfield, Madhya Pradesh by the Coal Division of the Geological Survey of India is significant and indicates a marine influence in this area (Datta, 1986). Maceration of these phosphorite-bearing sediments has yielded a fairly well-preserved Late Permian spore-pollen assemblage in association with *Leiosphaeridia*, confirming the marine influence. The Barren Measures in the type area, i.e., Raniganj Coalfield, has also been reported to contain phosphorite. Palynofossils described as alete spores (Kar, 1968; Tiwari *et al.*, 1981) from the Jharia Coalfield are probably leiosphaerids. A detailed study is underway. Algal limestones are also recorded in the Motur Formation (= Kulti Formation) in the Satpura Basin.

Raniganj Formation—This Upper Permian sequence exemplifies maximum diversification of striate-disaccate pollen. The Raniganj palynoflora is an extension of the Barren Measure flora. An acritarch assemblage composed of *Leiosphaeridia* and allied forms, such as—*Greinervillites*, *Hemisphaerium*, *Circulisporites*, *Singraulipollenites* has been recorded from the Jhingurdah seam in Singrauli Coalfield (Sinha, 1969). This Seam earlier considered as Barakar is now correlated with Raniganj Formation (Tiwari & Srivastava, 1984).



Text-figure 2—Marine incursion and pathways in the Early Permian.

PATHWAYS

The Talchir Formation experienced marine incursions of a much greater spatial extent than earlier considered. Several propositions have been put forward to indicate the paths of marine incursions in the Indian Peninsula during the time of deposition of Talchir Formation. Fox (1931) proposed a pathway from Salt Range reaching up to Umaria, while Krishnan (1968) proposed a westward connection through Narmada Valley. Ahmad (1961) envisaged a connecting channel of central India with the eastern sea-bay. Sastry and Shah (1964) concluded that the Umaria fauna dominated by productids belonged to a warm-water realm, and postulated a linkage with Badhaura and Salt Range areas. *Per contra* the Manendragarh and Sikkim (Khemgaon) faunas with *Eurydesma* are considered cold-water faunas. They proposed two arms of the Tethys reaching up to the heart of the Peninsula. Jhingran (1967) postulated that there could have been a very wide gulf from the north (i.e., Tethys shore) which encompassed all the areas from where marine fauna has been found. Ahmad (1970) visualized an incursion of sea from south-east through Mahanadi Valley during Early Permian. On the basis of palaeocurrent data, he suggested that an

outlet must have existed for the Barakar drainage in the area south of the Narmada Valley, now covered by basalt.

Several new evidences have come to light during the last two decades, which suggest a new line of thinking in reconstructing marine pathways. Palynological evidences establish marine Permian occurrences in Palar Basin, Godavari, Son-Mahanadi, Satpura and Damodar grabens in the east and Rajasthan in the west and in north-eastern basins, in addition to the earlier known records in the Salt Range, Pakistan. It is now possible to postulate a network of pathways in the Early Permian connecting major depressions which were formed along the weaker zones of lineaments. The gateway of these incursions could have been from the eastern sea-bay for the peninsular area. The general trend of direction of palaeodrainage was south-east north-west, from east coast up to central India and then towards north-east connecting with the Tethys (Casshyap & Tewari, 1984). The preposition of a connection of this network with western sea-bay through Narmada lineament still requires support. However, such a situation has been already proposed by Ahmad (1970) who opined that an outlet must have existed for the Barakar drainage in the area south of Narmada Valley, now covered by basalts. It is pertinent at this juncture to emphasize marine influence in the Talchir of Shahpur and Dodhara area in central Satpura Graben on the basis of palynological studies. This evidence enhances the chances of westerly continuation of the pathway postulated here.

Marine occurrences in the Karharbari, Barakar, Barren Measures and Raniganj sequences, as discussed earlier in this paper, need attention. As evidences are still forthcoming, it is premature to put forth any conclusive postulation. However, it is possible that the pathways suggested for the Talchir marine incursion continued into the younger Permian. Marine signatures in the Son Graben are evident in all the Permian formations of this area. This feature in the central part of peninsular India needs consideration and careful study.

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