Palaeobotanist 54(2005) . 107-113
0031-0174/2005/107-113 $2.00

Evaluation of earliest Permian flora of India and its equivalents in other Gondwana continents

KAMAL JEET SINGH, ANIL CHANDRA AND SHAILA CHANDRA

Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow - 226007, India
E: Mail - kamaljeet31@hotmail.com

(Received 26 April 2004; revised version accepted 07 October 2005)

ABSTRACT

Singh KJ, Chandra A & Chandra S 2005. Evaluation of earliest Permian flora of India and its equivalents in other Gondwana continents. Palaeobotanist 54 : 107-113.

The Talchir Formation occurs at the base of the Indian Gondwana sequence resting directly on the Precambrian basement and is conformably overlain by the coal bearing Damuda Group. It is a treasure trove of plant fossils and holds clue to the origin and subsequent rise of Glossopteris flora. Mega and palynofossils of the Talchir Formation reported from various basins of peninsular India are reviewed in the light of new researches. A comparative study of homotaxial flora from other Gondwana continents indicates uniformity and similarity in plant types at the generic level. The flora reconfirms an Early Permian age equivalent to Asselian-Sakmarian for the Talchir Formation.

Key words—Talchir Formation, Gondwana, Early Permian, Floral evaluation.

सारांश

भारत के प्रारम्भिक परमियन वनस्पतिजात तथा प्राणिजात का मूल्यांकन और अन्य गोंडवाना महाद्वीपों में इनका सहसम्बन्धन

कमलजीत सिंह, अनिल चन्द्रा एवं शैला चन्द्रा

तलचीर शैलसमूह, पूर्व-कैम्ब्रिय तलघर पर प्रत्यक्ष रूप से टिकी हुई भारतीय गोंडवाना अनुक्रम के आधार पर पायी जाती है तथा यह कोयलाधारी स्तरी द्वारा अनुकूलन उपरिशायी है। यह पादप पादपाश्मों की निखातनिधि है तथा ग्लोसॉप्टेरिस वनस्पतिजात के मूल तथा अनुवर्ती उन्नति के सुराग को बनाए रखती है। प्रायद्विपीय भारत के तलचीर शैलसमूह की विभिन्न द्रोणियों से अंकित गुरु तथा परागकण पादपाश्मों के नए शोधों को ध्यान में रखते हुए पुनर्विचार किये गये हैं। अन्य गोंडवाना महाद्वीपों से प्राप्त समकालक्रमी वनस्पतिजात का तुलनात्मक अध्ययन वंश आधार पर पादप प्रकारों में एकसमानता तथा समरूपता का संकेत करता है। यह पुनःपुष्टि करता है कि तलचीर शैलसमूह हेतु प्रारम्भिक परमियन आयु एसेलियन सकमेरियन के समतुल्य है।

संकेत शब्द—तलचीर शैलसमूह, गोंडवाना, प्रारम्भिक परमियन, वनस्पतिजात मूल्यांकन।

INTRODUCTION

THE lowermost unit of the Gondwana sequence exposed in India was named the Talchir Beds by Blanford *et al.* in 1859 and now re-defined as the Talchir Formation. Subsequently the formation has been discovered in all the Indian Permian coalfields. This Formation rests directly on the Precambrian basement and is conformably overlain by the coal bearing Damuda Group. At the base, it consists of the Talchir boulder bed, followed by the Talchir needle shales and siltstones and capped by the Rikba beds. The formation generally attains a thickness of 100 to 200 meters in various basins though in some basins of eastern part of the Damuda Valley the maximum thickness of 300 meters have also been reported (Ghosh & Mitra, 1967). The thickness shows progressive decrease towards the west. The lithological characters of the Talchirs are remarkably uniform and can easily be recognised in widely separated basins of the Indian peninsula.

The base of the Talchir Formation i.e., the boulder bed is believed to have been laid down under fluvio-glacial conditions attending the Carbo-Permian Ice Age. The overlying khaki-green to variegated needle shales associated with siltstones and calcareous bands are characteristics of the Talchirs. The upper part of the Talchir Formation consists mainly of greenish sandstones. Rikba beds exposed in the South Rewa Gondwana Basin form the top of the Talchir Formation.

The Talchir sediments are very significant from the palaeobotanical point of view because in these sediments one looks for evidences relating to the advent and spread of various plant groups of the Glossopteris flora. The inter-relationship of the Glossopteris flora and the Carbo-Permian glaciation is one of the most significant aspect and palaeobotanical study involving megafossil and spore / pollen recovered from the Talchir and its equivalent formations, can provide such evidences.

MEGA FOSSIL DATA

The plant fossils of the Talchir Formation are meagrely recorded, mostly from the shale band from various basins of India (Fig. 1). Recently, Chandra and Singh (1996) reported plant fossils along with some insect wings and other animal impressions from the type section of the Talchir Formation in the Talcher Coalfield. They also provided a list of all the known records from this Formation. Other records are by Blanford *et al.* (1859) and Roy and Bhattacharyya (1967). Feistmantel (1879) gave detailed description of plant fossils from the Talchir Formation exposed in Deogarh, Karanpura, Auranga and Hutar Coalfields and also from South Rewa Gondwana Basin. Surange and Lele (1956, 1957) reported Talchir plant fossils from Johilla River section in South Rewa Gondwana Basin and Giridih Coalfield. Lele *et al.* (1968) reported ill preserved plant fossils from Singrauli Coalfield, South Rewa Gondwana Basin. From this basin there are plant fossil records by various workers (Biswas, 1955; Ganguly, 1959; Chandra & Srivastava 1982; Chandra *et al.*, 1992). A significant assemblage of bryophytes representing Hepaticae and Musci groups reported from this Basin by Chandra (1995) is the first ever record of such plants from the earliest Permian strata of India. Upadhyay *et al.*(1999) discovered a rare fossil assemblage of both micro and mega floras from the Chhongtash Formation located near the Chhongtash locality in Eastern Karakoram, Kashmir Himalaya, and correlated the floras with the Talchir assemblages. Recently Tewari and Srivastava (2000) observed a rich specific diversity in the genera *Gangamopteris* and *Glossopteris* (seven and six species respectively) from the Jaitri River section near Latehar Town, Auranga Coalfield.

A synthesis of megafloral studies of the Talchir Formation reveals that more or less similar type of flora were present in all the Gondwana basins of India. The maximum specific diversity is observed in the genus *Gangamopteris* (16 species) followed by *Glossopteris* (7 species; see Fig. 1). Equisetales are generally represented by stems and very rarely by leaflets. Ferns are absent in any assemblage whereas the conifers are represented by the genus *Paranocladus*. It has also been observed that the typical Carboniferous genera like *Lepidodendron*, *Rhacopteris*, *Botrychiopsis* and *Triphyllopteris* have never been recorded in India from the Talchir sediments.

PALYNOLOGICAL DATA

Palynological study of the Talchir Formation was initiated by Lele way back in 1964 and later followed by his associates and other workers (Lele, 1964, 1966; Tiwari, 1975; Chandra & Lele, 1979; Tiwari & Tripathi, 1988). Contrary to megafossil occurence, palynological assemblages are known from boulder bed of the Palar Basin, South Rewa Gondwana Basin, Athgarh Sandstone beds of Mahanadi Basin, Jayanti Coalfield and Penganga River section. All these palynological assemblages are considered to be the earliest representatives of plants of the Indian Gondwana. A complete list of palynotaxa recorded from different basins of Talchir Formation has been tabulated by Vijaya (1996).

The index palynofossils of the Talchir Formation are *Plicatipollenites, Parasaccites, Virkkipollenites, Calumispora* and *Quadrisporites*. These are also associated with few striate disaccate pollen. The flora exemplifies expansion in the radial monosaccate pollen. Typical Carboniferous palynotaxa like *Raistrickea, Microreticulatisporites, Cirratriradites, Crassispora, Vestispora, Alatisporites* etc. are absent in the Talchir sediments. The palynoflora of the overlying Karharbari Formation is in fact a continuation of the Talchir palynoflora.

Fossil Remains ▼ Locality No. ▶	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. *Arberia umbellata* Surange & Lele												+			
2. *Arberia* sp.													+		
3. *Gangamopteris angustifolia* McCoy	+						+		+			+			
4. *G.* cf. *angustifolia* McCoy												+			
5. *G. buriadica* Feistmantel									+						
6. *G. clarkeana* Feistmantel	+	+										+	+		
7. *G. cyclopteroides* Feistmantel	+	+		+	+		+	+	+	+	+	+	+		
8. *G. cyclopteroides* var. *acuminata* Feistmantel	+								+						
9. *G. cyclopteroides* var. *areolata* Feistmantel								+							
10. *G. cyclopteroides* var. *attenuata* Feistmantel	+							+	+			+			
11. *G. cyclopteroides* var. *cordifolia* Feistmantel	+								+						
12. *G. cyclopteroides* var. *crassinervis* Feistmantel									+						
13. *G. cyclopteroides* var. *subauriculata* Feistmantel	+				+			+	+						
14. *G. intermedia* Maithy												+			
15. *G. major* Feistmantel	+	+							+		+	+	+		
16. *G. obliqua* McCoy									+			+			
17. *G.* cf. *spathulata* McCoy	+											+			
18. *G. fibrosa* Maithy	+														
19. *G. karharbariensis* Maithy	+														
20. *Gangamopteris* sp.	+														+
21. *Glossopteris communis* Feistmantel	+	+							+						
22. *G. indica* Schimper	+								+						
23. *G. longicaulis* Feistmantel													+		
24. *G. talchirensis* Chandra & Surange	+											+			
25. *G. stenoneura* Feistmantel	+														
26. *G. tenuifolia* Pant & Gupta	+														
27. *G. spatulata* Pant & Singh	+														
28. *Glossopteris* sp.						+		+				+			
29. *Vertebraria indica* Royle												+	+		
30. *Maheshwariella furcata* Maheshwari & Tewari												+			
31. *Noeggerathiopsis hislopii* (Bunbury) Feistmantel	+			+			+		+		+	+	+		
32. *Noeggerathiopsis* sp.															+
33. *Ottokaria bengalensis* Zeiller													+		
34. ?*Paranocladus indica* Surange & Lele												+			
35. *Phyllotheca* sp.									+	+					
36. *Cordaicarpus* sp.		+													
37. *Samaropsis goraiensis* Surange & Lele											+	+			
38. *Samaropsis* sp.	+	+							+			+			+
39. ?*Schizoneura* sp.							+								
40. *Talchirospermum indicum* Srivastava & Chandra												+			
41. *Bryothallites talchirensis* Chandra												+			
42. *Hepaticites umariaensis* Chandra												+			
43. *Saksenaphyllites saksenae* Chandra												+			
44. *Talchirophyllites indicus* Chandra												+			

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
45. *Umariaphyllites acutus* Chandra												+			
46. Bryophytic remains													+		
47. *Neuropterous* insect wing														+	
48. Insect wing													+		
49. Tubular impression of Annelids													+		
50. Acicular specimens of Nematodes													+		
51 Circular bodied specimens													+		
52. Equisetalean stems / stalks	+	+			+				+			+	+		+
53. Indistinct carbonaceous markings	+			+		+									
54. Annelid track marking on thin bed of sandstone													+		
55. Fragments of stems		+				+	+				+		+		
56. Seed vessels														+	
57. Petiole or rachis impressions				+											
58. Barks of Cordaitales		+													
59. Secondary wood with rectangular to pentagonal cells			+												

(1. Auranga Coalfield, 2. Chirimiri Coalfield, 3. Daltonganj Coalfield, 4. Giridih Coalfield, 5. Hutar Coalfield, 6. Jharia Coalfield, 7. Jainti Coalfield, (Karaon C.F.), 8. Karanpura Coalfield, 9. North-Karanpura Coalfield(Chano Basin), 10. Rajmahal Hills, 11. Singrauli Coalfield, 12. South Rewa Gondwana Basin, 13. Talcher Coalfield, 14. WardhaValley Coalfield, 15. Karakoram Block, Kashmir Himalayas)

Fig. 1—Fossil remains belonging to Talchir Formation in various localities / coalfields in India.

Lele (1966) envisaged the possibility of two miofloral zones in the Talchir Formation, which were later substantiated by the study of Chandra and Lele (1979). It was found that *Parasaccites* increases from older to younger horizons while *Plicatipollenites*, which existed at the same time as *Parasaccites*, shows a definite decline upward. Tiwari and Tripathi (1988) also recognized two palyno suites; suite-1, the older one is characterized by radial monosaccates having dense central body and the presence of genus *Callumispora*. Suite -2, the younger one, is characterized by radial monosaccates having thin central body and the presence of tetrads. Thus it establishes a fact that the two miofloral zones suggested by Chandra and Lele (1979), Suite 1 and 2 of Tiwari and Tripathi (1988), Biozone I and II proposed by Vijaya and Tiwari (1992) and Palynoevent 1 of Tiwari (1996) are dichronous. Tiwari and Tripathi (1992) suggested three palynoassemblage zones for the entire Talchir sequence. First is the *Potonieisporites neglectus* Asssemblage Zone for the basal most bed, which is recognised by the absence of striate-disaccate pollen and preponderance of *Plicatipollenites*, *Parasaccites* and *Potonieisporites*. The reference section is within the siltstone units above the first boulder bed in the Dudhi River section, West Bokaro Coalfield, Bihar. The second is the *Plicatipollenites gondwanensis* Asssemblage Zone, characterized by first appearance of a variety of striate-disaccates, monosaccates and zonate spores-pollen taxa and is dominated by the genera *Parasaccites* and *Plicatipollenites*. The reference section is also in the Dudhi River section, but the siltstone units are placed below the last boulder bed. The third and youngest zone is the *Parasaccites korbaensis* Assemblage Zone depicting further diversification of spores and pollen with several new entrants such as pteridophytic including lycopsid and apiculate spores, ginkgo-cycadoid pollen and several monosaccate species. Reference section of this zone is exposed in the Patharjore Nala, Jayanti Coalfield, Bihar.

PALAEOBOTANICAL ANALYSIS

A comprehensive analysis of micro - and megafossil assemblages (which are found separately or in association with each other) at various levels of the Talchir Formation, seems interesting and prompts one to enquire as to what extent these mega and micro fossils compliment each other with respect to the question of their mutual derivation, relationship and affinities. For example, in the entire Talchirs the persistent number of trilete spores generally reflects a pteridophytic affinity. As is evident from the plant fossil records, except for ribbed stem axis and few records of *Phyllotheca* and *Trizygia* there are no evidences of such megafossils, which could have produced spores. Likewise it is not possible to correlate *Ginkgocycadophytes* with some fossil Ginkgocycadophyte or Cycadophyte. Similarly the presence of bryophytic plant fossils reported from the Talchir Formation in the South Rewa

Gondwana Basin (Chandra, 1995) is not supplemented by spores in the palynoassemblages.

In the back drop of this knowledge one would like to seek the answer to a major question regarding the origin of Talchir flora, as Sahni (1935) put it to "ascertain" how far down into the Talchir Formation it was possible to push our knowledge of the Glossopteris flora of India and in particular to look for the traces of this flora in the glacial matrix itself.

The evidences of megafossils and spores/pollen demonstrate the presence of the Glossopteris flora at different levels just above the base of the Talchirs (Lele, 1966; Surange & Lele, 1957). There is thus good reason to visualise that the Glossopteris flora was probably also present at the commencement of the Gondwana sedimentation i.e., during the deposition of the boulder bed, which indicates glacial conditions. *Gangamopteris* and *Noeggerathiopsis* recorded from the Giridih and West Bokaro Coalfields indicate that these were amongst the pioneer elements of the Glossopteris flora of India, which survived well in some refugia during the early severe cold phase - the Permo-Carboniferous glaciation (Lele, 1976; Chandra & Chandra, 1988). These plant forms steadily evolved and developed as the climate ameliorated towards the latter part of the Talchirs which is evidenced by the relatively greater abundance and variety of species especially within *Gangamopteris*. The maximum proliferation in the Talchir flora is indicated by the assemblages recovered mainly from three localities i.e., Rikba beds, needle shales near Sarang Village, Talcher Coalfield (Chandra & Singh, 1996) and near Latehar Town, Auranga Coalfield (Tewari & Srivastava, 2000). These are believed to represent the uppermost part of the Talchir Formation. Unlike *Gangamopteris*, *Glossopteris* appears to have responded favourably to the progressively warmer climate in the younger horizons of Talchir Formation as is reflected in the proliferation of *Glossopteris* species with a definite midrib. The *Glossopteris* evolved steadily through the Karharbari, attained greater prominence in younger formations (Barakar and Raniganj) and even continued during the arid conditions of the Triassic Period. On the contrary midrib-less forms like *Gangamopteris, Noeggerathiopsis, Euryphyllum* and *Rubidgea,* which were closely associated with relatively colder phases (during Talchir and Karharbari time), show a rapid decline after the Karharbari stage.

A close look at the collective plant types from the Talchir Formation reveals that the vegetation was poor with strikingly small leaves, sometimes fleshy, curled or folded up, having mostly very fine and dense venation. The plants bearing these leaves were dwarf and were growing only at selected niches (Chandra 1992).

AGE OF THE TALCHIR FORMATION

Oldham (1893), Cotter (1917), Fox (1931) and Holland (1933) postulated Carboniferous age of the Talchir Formation on the basis of palaeontological, lithological and palaeobotanical evidences. Medlicott and Blanford (1879), Vredenburg (1914), Reed (1928), Ahmad and Ahmad (1962), Sastry and Sah (1964), Lele (1966), Chandra and Lele (1979), Shah *et al.* (1971) and Tiwari (1996) suggested Early Permian (Late Asselian-Early Sakmarian) age on palaeontological, palaeobotanical and palynological evidences. In peninsular India, Talchir glaciation is widely accepted as of Early Permian age based on the following evidences:

1. A marine invertebrate fauna - *Eurydesma* of definite Early Permian age in the basal boulder bed of the Talchir Formation at Manendragarh.
2. Microfossils from shales and boulder bed matrices in several localities collectively indicate Early Permian age.
3. Absence of typical Carboniferous genera like *Rhacopteris, Botrychiopsis, Triphyllopteris* and several lycopods in the Talchir Formation.
4. Absence of typical Carboniferous palynotaxa *Raistrickia,* Microreticulatisporites, Cirratriradites, Crassispora, Vestispora, *Alatisporites* etc. in these beds.

CORRELATION IN INDIA

The Talchir boulder beds are correlated to several boulder beds of extra-Peninsular India. Agglomeratic Slate of Kashmir (Middlemiss, 1910), Tanakki Boulder Bed of Hazra and Rangit Pebble-Slate of the Eastern Himalaya (Acharyya, 1971) are considered equivalent to Talchir Formation. Marine fossils from these extra-Peninsular beds are considered faunistically closely related to the marine intercalations within the Talchir Formation of the peninsular region from the Manendragarh and Daltonganj Coalfields. The Bap boulder beds of Rajasthan are considered equivalent to the Talchir Formation (Oldham, 1886).

CORRELATION WITH OTHER GONDWANA CONTINENTS

Feistmantel (1888) while discussing the fossil flora of Australia concluded that the Bacchus Marsh Sandstone in Australia could be correlated with the Talchir Group of India. Rigby and Chandra (1990) reported a variety of plant fossils including *Glossopteris douglasii* Rigby & Chandra, *Glossopteris* sp. A, *Glossopteris* sp. B, *Glossopteris* sp. C, *Gangamopteris augustifolia* McCoy, *Gangamopteris cyclopteroides* Feistmantel, *Gangamopteris obliqua* McCoy, *Gangamopteris spathulata* McCoy and an indeterminate plant fragment from the Bacchus Marsh Sandstones and assigned it an Early Permian age.

The fossil flora reported from the right bank of the river Mavonono in the Sakoa Basin, Madagascar (Appert, 1977) includes *Gangamopteris cyclopteroids, Gangamopteris oblanceolata*, a few *Glossopteris*, some leaves identified as cf. *Lesleya*, several stems of articulates, animal remains and insect wings. This is the oldest record of fossil flora from

Madagascar and corresponds in age with Talchir Formation of India.

Archangelsky and Cúneo (1991) recognised four floral zones during Carboniferous and Permian in North West Argentina. The lower member of the *Gangamopteris* zone comprising of *Botrychiopsis plantiana, Paranocladus ?fallax, Samaropsis* sp., *Samaropsis kurtzii, Cordaites hislopii, Feruglíocladus riojanum, Euryphyllum whittianum, Glossopteris occidentalis, G. wilsonii, Asterotheca feruglioi, Gangamopteris obovata, Phyllotheca* sp. and *Sphenopteris* sp. This zone marks the extinction of *Botrychiopsis* and is referred to the Lubeckense stage by the authors. In Brazil, Tafoflora A-B and Itararé flora in the Parana Basin represent the Early Permian assemblage (Frakes & Crowell, 1969).

An Antarctic flora reported from Whichaway Nunataks, Theron Mountains has been referred to the Early Permian age by Plumstead (1962). This flora is dominated by Glossopterids, however, the specific variability and the presence of some taxa found in younger strata suggest that the biostratigraphy is not properly established.

Leslie (1921) reported *Gangamopteris* from glacial conglomerate at Vereeniging, South Africa. The identification has been confirmed by Pant (1988). This is the only confirmed occurrence of the Glossopteris flora underlying the glacial horizon.

Acknowledgements—*The authors are thankful to the Director, Birbal Sahni Institute of Palaeobotany, Lucknow for permission to publish this research paper. We are also grateful to Dr. John F. Rigby, Queensland University of Technology, Brisbane, Queensland and to anonymous referee who suggested many alterations to improve the final manuscript.*

REFERENCES

Acharyya, SK 1971. Rangit Pebble-Slate, a new formation from Darjeeling foothills. Indian Mineral 25: 61-64.

Ahmad F & Ahmad N 1962. The age of the Gondwana glaciation. Proceedings of the National Institute of Sciences of India 28 : 16-56.

Appert O 1977. Die Glossopteris flora der Sakoa in Südwest-Madagaskar. Palaeontographica B 162 : 1-50.

Archangelsky S & Cúneo R 1991. The neopalcozoic floristic succession from Northwestern Argentina.A new perspective. *In* : Ulbrich H & Campos AC(Editors)- Gondwana Seven, Proceedings, Seventh International Gondwana Symposium, São Paulo: 469 – 481.

Biswas B 1955. Geology of the Kurasia Coalfield around Chirimiri area, South Rewa Gondwana Basin, Madhya Pradesh. Quarterly Journal of the Geological, Mining and Metallurgical Society of India 27: 39 -65.

Blanford WT, Blanford HF& Theobald WM 1859. On the geological structure and relations of the Talchir Coalfield in the District of Cuttack. Memoirs of Geological Survey of India 1: 33 - 88.

Chandra S 1992. Changing patterns of the Permian Gondwana vegetation. Palaeobotanist 40: 73 -100.

Chandra S 1995. Bryophytic remains from the Early Permian sediments of India. Palaeobotanist 43: 16 - 48.

Chandra S & Chandra A 1988. Vegetational changes and their climatic implications in coal - bearing Gondwana. Palaeobotanist 36: 74 - 86.

Chandra A & Lele KM 1979. Talchir miofloras from South Rewa Gondwana Basin, India and their biostratigraphical significance. Proceeding of IXth International Palynological Conference, Lucknow (1976-1977) 2: 117 -151.

Chandra S & Singh KJ 1996. Plant fossils from the Type locality of Talchir Formation and evidence of earliest Plant / Animal activity in Gondwana of India. *In*: Gondwana Nine, Vol.1, Mitra, N. D. *et al.*, (Editors), Ninth International Gondwana Symposium, Hyderabad 1994: 397 - 414.

Chandra A & Srivastava AK 1982. Plant fossils from the Talchir and Coal-bearing formations of South Rewa Gondwana Basin, India and their biostratigraphical significance. Palaeobotanist 30: 143 - 167.

Chandra S, Srivastava AK & Singh KJ 1992. Lower Permian plant fossils from India and early developmental history of the Glossopteris flora. Acta Palaeobotanica 32 : 5 - 19.

Cotter G DeP 1917. A revised classification of the Gondwana system. Records of Geological Survey of India 48: 23 - 33.

Feistmantel O 1879. The fossil flora of the Lower Gondwana - 1. The flora of the Talchir-Karharbari beds. Memoirs of the Geological Survey of India. Palaeontologica indica, Ser.12 (3): 1 - 64.

Feistmantel O 1888. Nachtrag zu: Über die pflanzen-und kohlenführenden Schichten in Indien (beziehungsw. Asien), Afrika und Australien etc. Sitzungsberichte der Königlich Böhmischen Gesellschaft der Wissenschaften, Mathematisch-naturwissenschaftliche Klasse, Prague. 1887: 570-576.

Fox CS 1931. Coal in India. 2 -The Gondwana system and related formations. Memoirs of the Geological Survey of India 58: 1 - 241.

Frakes LA & Crowell JC 1969. Late Palaeozoic glaciation 1: South America. Bulletin of Geological Society of America 8: 1007-1042.

Ganguly S 1959. Palaeontological study of Lower Gondwana rocks including the coal seams around Chirimiri of Sarguja District, Madhya Pradesh. Quarterly Journal of the Geological, Mining and Metallurgical Society of India 31: 155 - 166.

Ghosh PK & Mitra ND 1967. Recent studies on the Talchir glaciation in India. International Symposium on Gondwana, Stratigraphy and Palaeontology, Mar del Plata Argentina : 537 - 550.

Holland TH 1933. The geological age of the glacial horizon at the base of the Gondwana System. Presidential Address. Quarterly Journal of the Geological Society of London : 67 - 70.

Lele KM 1964. Studies in the Talchir flora of India -2. Resolution of the spore genus *Nuskoisporites* Pot. & K I. Palaeobotanist 12: 147 - 168.

Lele KM 1966. Studies in the Talchir flora of India-4. Quest for the Early traces and subsequent development of the Glossopteris flora in the Talchir stage. *In* . Anonymous (Editor) - Symposium on floristics and stratigraphy of Gondwanaland. Birbal Sahni Institute of Palaeobotany, Lucknow : 85 - 97

Lele KM 1976. Palaeoclimatic implications of Gondwana floras. Geophytology 6: 207 - 229.

Lele KM, Swarup P & Singh JN 1968. Occurence of plant fossils in the Lower Gondwana succession of Singrauli Coalfield, Uttar

Pradesh. Journal of the Palaeontological Society of India 11 : 8 - 17.

Leslie TN 1921. Observations on some fossil plants from the Permo – Carboniferous of Vereeniging (Pres.Addr.). Proceedings of the Geological Society of South Africa, Johannesburg : 29-30.

Medlicott HB & Blanford WT 1879. A manual of the geology of India .Compiled from the observations of the Geological Survey of India.1 : 1 -144, 2 : 445-817.

Middlemiss, CS 1910. Revision of Silurian-Triassic sequence in Kashmir. Records of Geological Survey of India 10: 232.

Oldham RD 1886. Correlation of Indian and Australian coal-bearing beds. Records of Geological Survey of India 19: 39-47.

Oldham RD 1893. A manual of the geology of India. Stratigraphical and structural geology, 2nd Edition. Geological Survey Office, Calcutta. 543p.

Pant DD 1988. The origin, rise and decline of Glossopteris flora : with notes on its palaeogeographical northern boundary and age.*In*: Venkatachala BS & Maheshwari HK (Editors) - Concepts, limits and extension of the Indian Gondwana. Palaeobotanist 36: 106 - 117.

Plumstead EP 1962. Fossil floras of Antarctica. Scientific Reports on Trans Antarctic Expedition 9 : 1 - 154.

Reed FRC 1928. A Permo - Carboniferous marine fauna from the Umaria Coalfield. Records of the Geological Survey of India 60: 367-398.

Rigby JF & Chandra S 1990. Revision of the Permian Gondwana flora from Bacchus Marsh, Victoria. Proceedings of 3rd International Organisation of Palaeobotanists Conference, Melbourne, 1988: 107-113.

Roy R & Bhattacharya C 1967. Palaeontology of the Gondwana rocks with a note on the correlation of coal seams of Talchir Coalfield,Orissa. Quarterly Journal of the Geological, Mining and Metallurgical Society of India 39: 27 - 34.

Sahni, B 1935. Permo-Carboniferous life provinces with special reference to India. Current Science 4 : 385-390.

Sastry MVA & Shah SC 1964. Permian marine transgression in Peninsular India. Abstract Volume, 22nd International Geological Congress, Part. 19, New Delhi: 139 - 150.

Shah SC, Singh G & Sastry MVA 1971. Biostratigraphic classification of Indian Gondwana. International Symposium on Stratigraphy, Minining, Research and Coordination Systems. Annals of Geology Department, Aligarh Muslim University V & VI: 306 - 326.

Surange KR & Lele KM 1956. Studies in the Glossopteris flora of India -3. Plant fossils from the Talchir Needle Shales from Giridih Coalfield. Palaeobotanist 4 : 153 - 157.

Surange KR & Lele KM 1957. Studies in the Glossopteris flora of India - 6. Plant fossils from Talchir Beds of South Rewa Gondwana Basin. Palaeobotanist 5 : 82 -90.

Tewari Rajni & Srivastava AK 2000. Plant fossil assemblage from the Talchir Formation, Auranga Coalfield, Bihar, India. Palaeobotanist 49: 23-30.

Tiwari RS 1975. Palynological composition of the basal Gondwana in India. Bulletin de la Société belge de géologie, de paléontologie et d' hydrologie, Bruxelles 84 : 11 - 17.

Tiwari RS 1996. Palynoevent stratigraphy in Gondwana sequence of India. *In*: Gondwana Nine, Vol.1, Mitra, N. D. *et al.*, (Editors), Ninth International Gondwana Symposium, Hyderabad,1994 : 3 - 20.

Tiwari RS & Tripathi A 1988. Palynological zones and their climatic inference in the coal-bearing Gondwana of Peninsular India. Palaeobotanist 36 : 87 – 101.

Tiwari RS & Tripathi A 1992. Marker Assemblage-Zones of spores and pollen species through Gondwana Palaeozoic and Mesozoic sequence in India. Palaeobotanist 40: 194-236.

Upadhyay R, Chandra R, Sinha AK, Kar RK, Chandra S, Jha N & Rai H 1999. Discovery of Gondwana plant fossils and palynomorphs of Late Asselian (Early Permian) age in the Karakoram Block. Terra Nova 11 : 278-283.

Vijaya 1996. Advent of Gondwana deposition on Indian Peninsula : A palynological reflection and relationship. *In*: Gondwana Nine, Vol.1, Mitra, N. D. *et al.*, (Editors), Ninth International Gondwana Symposium, Hyderabad, 1994 : 283 - 298.

Vijaya & Tiwari R S 1992. Morpho - evolutionary biohorizon stratigraphy and cladistics in saccate pollen through Gondwana sequence of India. Palaeobotanist 40 : 157 - 193.

Vredenburg EW 1914. The classification of the Gondwana System. Proceedings of 1st.Session, Indian Science Congress. Pt.3.