Bull. Natn. Sci. Mus., Tokyo, Ser. C, **28**, pp. 1–8, December 20, 2002

Major Palynological Trends in Relation to the Development of *Glossopteris* Flora through Lower Gondwana of India

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Abstract Palynological studies of Permian sequence pertaining to *Glossopteris* flora provide a model for biostratigraphic zonation and correlation in different basins. The major episodes of changes in palynocomplexes through Permian time are determined on the basis of appearance and proliferation of various pollen morphotypes, e.g., monosaccate, bisaccate, nonsaccate sulcate, striate, non-striate and taeniate forms. A comparative assessment of such palynofloral patterns in relation to megafloral occurrences of various morphological groups of leaf genera from the Talchir Formation (Late Asselian of Early Permian) to Raniganj Formation (Late Permian) has been made. It has been found that there exists a group correlation in mega- and microfossil diversities although paucity of in-situ spores and pollen does not allow a precise tagging of forms. The relationship of these groups surmised are—(1) monosaccate pollen with leaves without midrib and with meshes, (2) nonstriate bisaccates with leaves with midrib and narrow meshes, (3) striate bisaccates with leaves with midrib and medium/broad meshes, (4) nonsaccate nonstriate sulcates with leaves without meshes and midrib, and (5) nonsaccate striate sulcates with leaves without meshes but with midrib.

Key words: Palynology, *Glossopteris* flora, Permian, India

Introduction

The imprints of Lower Gondwana Permian vegetation of Indian Peninsula are recorded as *Glossopteris* flora. This flora has been analysed extensively covering the morphological aspect, vegetational history, provincialism and palaeoclimate (Surange, 1975; Surange & Chandra, 1974; Lele, 1976; Pant, 1988; Chandra, 1992; Chandra & Chandra, 1988; Maheshwari, 1976, 1992; Srivastava, 1986, 1991). The detailed palynological studies from the Permian sequences provide a model for biostratigraphic zonation and correlation in different basins and various palynoevents and evolutionary shifts have been identified (Tiwari, 1994; Tiwari & Tripathi, 1988, 1992; Vijaya & Tiwari, 1992). These sediments exhibit more or less complete and continuous palynological sequence (Fig. 1) throughout the Lower Gondwana Group, i.e., Talchir to Raniganj formations (Tiwari & Tripathi, 1988, 1992). On otherhand the megafossil records do not provide continuous sequence for the development of flora. In the present paper major palynological trends have been compared and tagged with the trends of glossopterid megafossils and a hypothesis has been proposed to evaluate the relationship of morphological groups of pollen and glossopterid leaves.

Analysis

The morphological analysis of glossopterid palynomorphs of gymnospermous affinity provide two basic types of pollen, the saccate and nonsaccate. Among these the saccates are classified as monosaccate and bisaccate. Thus the three principle groups of palynocomplex can be further classified under the nonstriate, striate, striniate and taeniate subgroups (Fig. 2). Likewise the

PERIOD	EPOCH	AGE	FORMATION	ZONE NUMBERS	SPORE-POLLEN SPECIES ASSEMBLAGE-ZONE
TRIASSIC	EARLY	EARLY SCYTHIAN	PANCHET / DUBRAJPUR	XI	*Playfordiaspora cancellosa*
				X	*Krempipollenites schaubergerii*
PERMIAN	LATE	END PERMIAN	RANIGANJ	IX	*Densipollenites magnicorpus*
		LATE PERMIAN		VIII	*Gondisporites raniganjensis*
			KULTI	VII	*Densipollenites indicus*
		LATE EARLY PERMIAN	BARAKAR	VI	*Faunipollenites varius*
				V	*Scheuringipollenites barakarensis*
		ARTINSKIAN LATE SAKMARIAN	KARHARBARI	IV	*Crucisaccites monoletus*
	EARLY	EARLY SAKMARIAN	TALCHIR	III	*Parasaccites korbaensis*
				II	*Plicatipollenites gondwanensis*
		LATE ASSELIAN		I	*Potonieisporites neglectus*

Fig. 1. Palynostratigraphic zonation of Permian sequence on Indian Peninsula (after Tiwari & Tripathi, 1992).

basic morphological groups of glossopterid leaf complex are classified in the absence or presence of the anastomosing venation as forms without meshes and with meshes. These basic types are further grouped in the development of midrib as without midrib, with subparallel (parallel) veins, with 2/3–3/4 midrib and with solid and full length midrib (Srivastava, 1991). Further distinction in leaves with meshes are based on the presence of narrow, medium and broad meshes (Fig. 3).

Major Palynological Trends

Various trends in the palynocomplex through Permian time have been depicted in Fig. 4 based on the database given in Table 1. These palynological trends determined on the basis of relative abundance of various pollen morphotypes and appearance of various pollen organizations and their proliferation are identified as Trends 1 to 5 in ascending order. The palynoflora of the basal Gondwana deposits in the early Asselian i.e., Talchir Formation shows dominance of nonstriate radial monosaccate pollen (e.g., *Plicatipollenites*) and presence of nonstriate bisaccate pollen (e.g.,

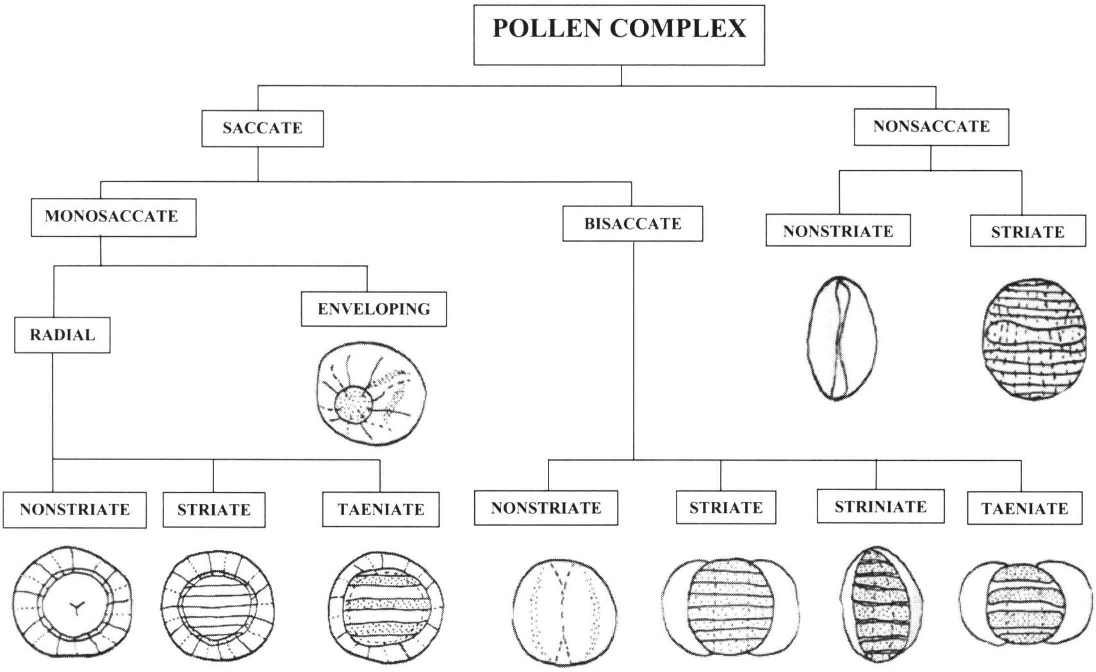

Fig. 2. Various morphotypes of pollen complex recognized in Indian Permian palynoassemblages.

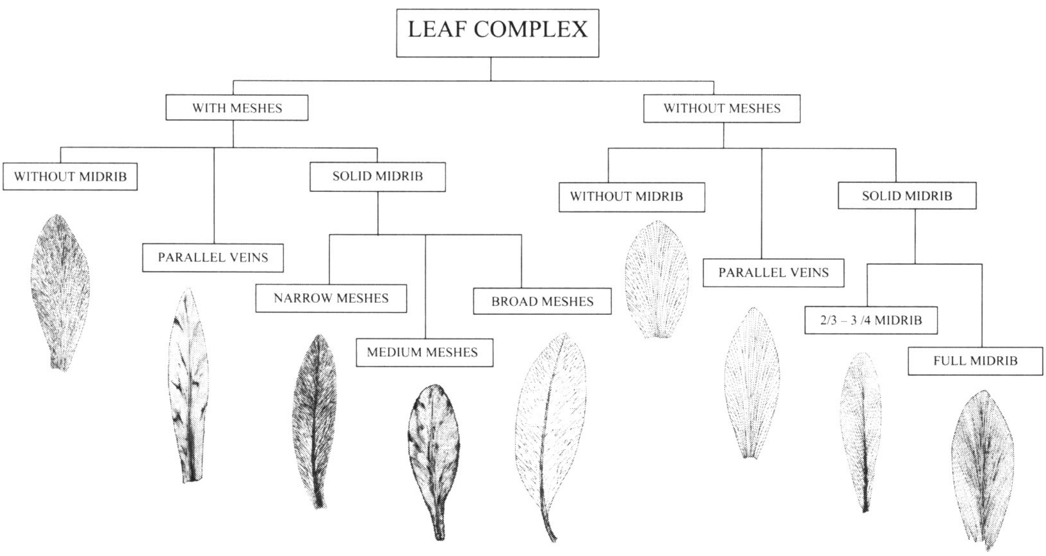

Fig. 3. Various morphotypes of leaf complex identified in gymnospermous component of *Glossopteris* flora.

Vestigisporites). The radial monosaccate and bisaccate pollen with striations (e.g., *Faunipollenites*, *Striatopodocarpites*) and simple monosulcate (e.g., *Ginkgocycadophytus*) component of nonstriate, nonsaccate pollen appear in Late Asselian (i.e. Upper Talchir Formation). This trend in the Talchir Formation has been identified as Trend I. In the next phase the dominance of non-

Table 1. Source of data for the palynological trends in pollen complex through Permian in India.

Horizon	Coalfield/Area	References
Talchir Formation	West Bokaro	Lele, 1975
	Jayanti	Lele & Karim, 1971; Lele & Makada, 1972, 1974
Talchir, Karharbari, Barakar, Kulti & Raniganj Formations	Jharria	Tiwari, Srivastava, Tripathi & Singh, 1981
Kulti & Raniganj Formations	Raniganj	Rana & Tiwari, 1980; Tiwari & Rana, 1984; Singh & Tiwari, 1982
Kulti Formation	Jharia	Kar, 1968
	North Karanpura	Kar, 1969a
Raniganj Formation	North Karanpura	Kar, 1969b
Barakar, Barren Measure & Raniganj Formations	Talcher	Tripathi & Bhattacharya, 2001
Talchir, Karharbari, Barakar & Kulti Formations	Godavari	Srivastava & Jha, 1989; Srivastava & Jha, 1995

striate radial monosaccates (e.g., *Parasaccites*, *Plicatipollenites*) continues. The striate and nonstriate bisaccates increase in number and nonsaccate striate sulcate pollen (e.g., *Marsupipollenites*, *Weylandites*) and enveloping monosaccate (e.g., *Densipollenites*) appear slightly later. This Trend II is identified in assemblages from the Karharbari Formation. The next trend recognized is the dominance of nonstriate bisaccates (e.g., *Scheuringipollenites*) which ultimately changes to the dominance of striate bisaccates (e.g., *Faunipollenites* and *Striatopodocarpites*) while the nonstriate bisaccates still maintain their subdominance. This trend has been identified as Trend III recognized in assemblage of the Barakar Formation. The trend in the dominance of striate bisaccates (e.g., *Striatopodocarpites*, *Faunipollenites*, *Striatites*) continues with an intermediate phase having dominance of enveloping monosaccates (e.g., *Densipollenites*). This Trend IV is recognized in assemblages of the Kulti Formation. Further the dominance of striate bisaccates still continues in assemblages of the Raniganj Formation of the Latest Permian. However, the trend in this time interval is revealed by the appearance of striniate and taeniate bisaccates (e.g., *Guttulapollenites*, *Arcuatipollenites*) and taeniate monosaccates (e.g., *Kamthisaccites*) and diversification of nonstriate (e.g., *Praecolpatites*) and non-saccate striate pollen (e.g. *Striasulcites*, *Ephedripites*, *Welwitschiapites*, *Marsupipollenites*). This Trend in the Raninganj Formation is identified as Trend V.

Trends in Leaf Morphotypes

The analysis of glossopterid megafloral records from the Lower Gondwana Group of India has resulted in the identification of various leaf morphotypes (Fig. 3). The trends in the stratigraphic distribution of these leaf morphotypes have been depicted in Fig. 5 based on data base given in Table 2. These trends are based on the appearance of particular morphotype and number of species. In the Talchir Formation proliferation of the leaf types with meshes and without midrib (e.g., *Gangamopteris*) is recorded and is recognized as Trend A. The species with meshes and without midrib continue to proliferate in kind. The other leaf types, e.g., forms possessing meshes and solid midrib (e.g., *Glossopteris*) and forms without meshes and midrib (e.g., *Euryphyllum*, *Rubidgia*) also increase. This trend is recognized in assemblages from the Karharbari Formation as Trend B. Succeedingly the proliferation of species with narrow, medium and broad meshes and with midrib is noticed. This trend is recorded in assemblages from the

Table 2. Source data for the trends in leaf morphotypes through Permian in India.

Horizon	Coalfield/Area	References
Kulti Formation	Jharia	Srivastava & Tewari, 2001
Talchir-Raniganj Formations	Lower Gondwana Basins	Chandra & Surange, 1979; Maheshwari, 1992; Lakhanpal, Maheshwari & Awasthi, 1976
Barakar Formation	Auranga	Srivastava & Tewari, 1996
Talchir, Karharbari, Barakar Formations	Karanpura, Bokaro	Singh, 2000

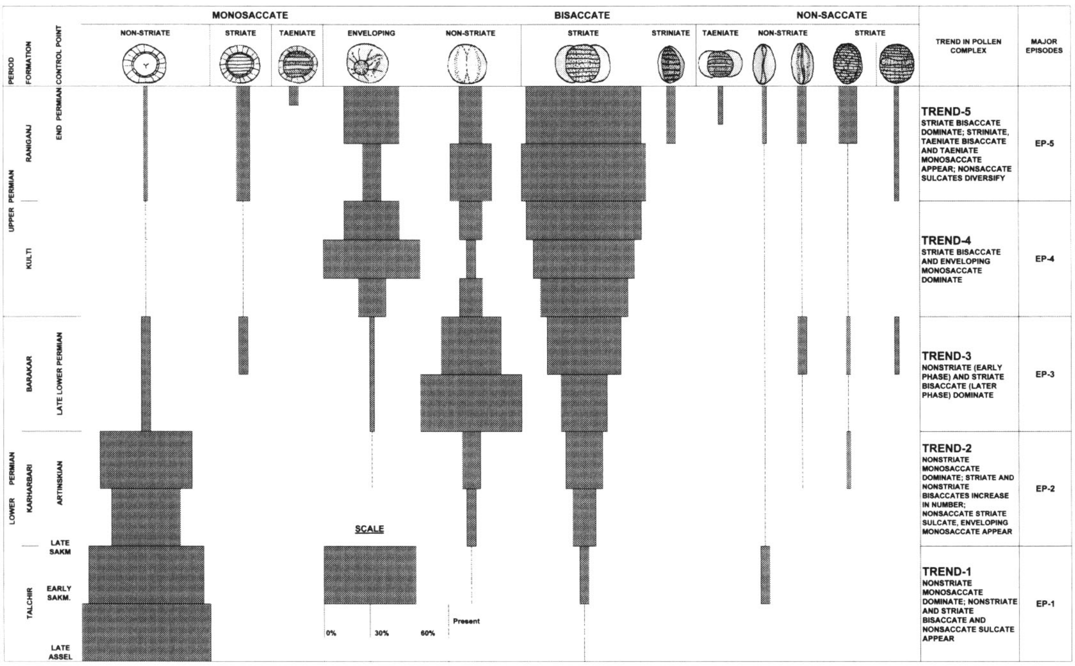

Fig. 4. Pattern of relative abundance of various pollen morphotypes through Lower Gondwana of India.

Barakar Formation as Trend C. The megaflora from the Kulti Formation is not well known hence no detailed analysis could be done. The last phase of megaflora shows proliferation of morphotypes, in kind, with meshes and midrib, forms without midrib also increase. The morphotypes without meshes also show a diversification. This trend is recognized as Trend D in megafloral assemblages from the Raniganj Formation.

Discussion and Conclusion

There are several limitations to know the relationship of various groups of pollen and leaf complex of glossopterid flora. The problem becomes all the same more difficult in the absence of in-situ pollen although number of glossopterid male fructifications have been described. Speculations have been made from time to time relating the monosaccate pollen with *Gangamopteris* phase and bisaccate pollen with *Glossopteris* phase of the *Glossopteris* flora (Virkki, 1937; Pant, 1955; Bharadwaj, 1966, 1969; Lele, 1974). The factual evidence of in-situ spore studies show presence of striate monolete spores, *Kendosporites*, from fructification of *Kendostrobus*

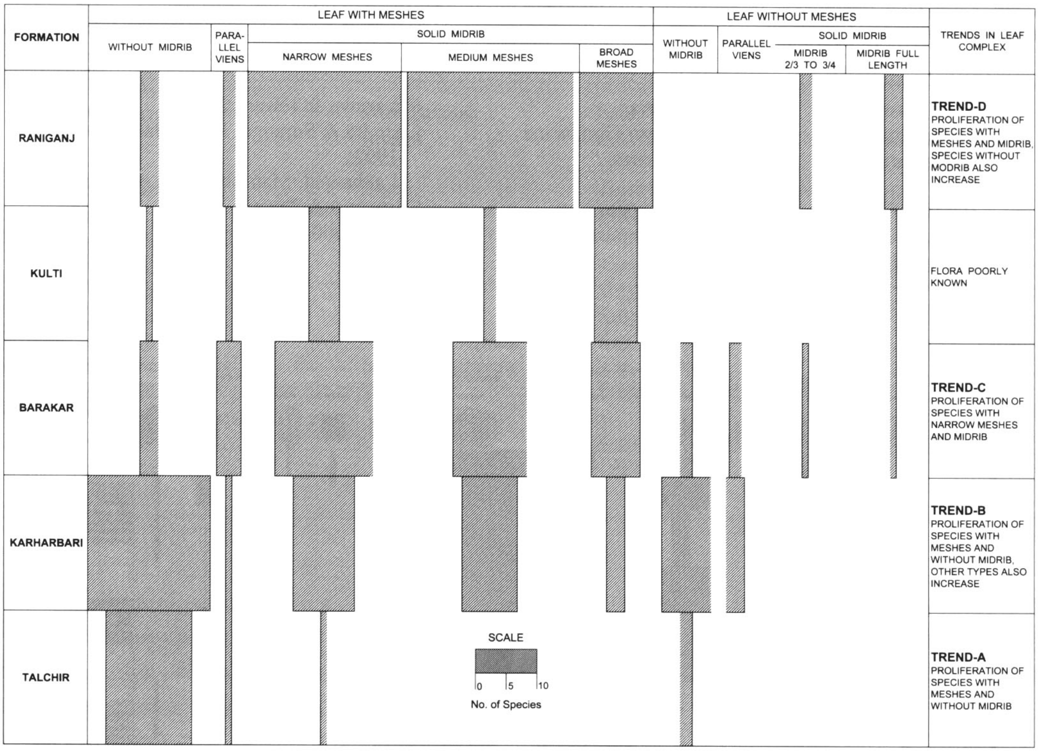

Fig. 5. Distribution pattern of number of species of various leaf morphotypes through Lower Gondwana of India.

(Surange & Chandra, 1974). The striate, nonstriate bisaccate and monosulcate pollen have been reported from the pollen chamber and micropyler canal of glossopterid seeds, e.g., *Cornuspermum penatus* by Pant and Nautiyal (1960, 1967), Banerjee (1969), and Chandra and Surange (1977). However, the direct relationship of pollen and leaf morphologies is lacking.

A comparative assessment of presently analysed palynofloral pattern in relation to megafloral occurrences of various morphological groups of leaf complex pertaining to gymnospermous component of the Permian *Glossopteris* flora of India has been made. This clearly reveals following five episodes:

Episode–1. The abundance of nonstriate radial monosaccate pollen coincides with the maximum species of leaves with meshes and without midrib in the Early Permian Talchir Formation.

Episode–2. The abundance of nonstriate radial monosaccate pollen continues and coincides with continuation of maximum species of leaves with meshes and without midrib. The increase in bisaccate pollen types coincides with an increase in number of species of leaves with meshes and midrib in the Early Permian Karharbari Formation.

Episode–3. The turn-over of nonstriate bisaccate (in early phase) and striate bisaccate pollen (in later phase) in the late Early Permian Barakar Formation coincides with the distribution pattern of species of leaves with meshes and midrib. The nonsaccate sulcate pollen occurrence matches with the increase in species of leaves without meshes and with midrib.

Episode–4. The abundance of striate bisaccate (with maximum diversity) and enveloping monosaccate component of pollen complex is well established in the early Late Permian

Kulti Formation. Matching of leaf complex is not possible due to poorly known megaflora.

Episode–5. The continuation of abundance of striate bisaccate component of pollen complex is associated with the occurrence of striniate and taeniate pollen. This trend coincides with the increase in number of species of leaves with meshes and midrib. The diversification of nonsaccate striate pollen component is also noticed at the Latest Permian. This trend coincides with the increase in species number of leaves with out meshes and with midrib.

Based on the critical assessment in the pattern of appearance and proliferation of morphological groups of pollen and glossopterid leaf complex through Permian time the relationship of pollen and leaf morphotype groups have been proposed. It has been noticed that a group correlation of the two can be traced—the saccate pollen were produced by plants having leaves with meshes and the nonsaccate pollen by plants having leaves with out meshes. The relationship within these groups proposed are (1) monosaccate pollen with leaves with meshes and without midrib, (2) bisaccate pollen with leaves with meshes and midrib; the nonstriate bisaccate forms with leaves having narrow meshes and striate bisaccate forms with leaves having medium and broad meshes, (3) nonsaccate nonstriate sulcate pollen with leaves without meshes and midrib and (4) nonsaccate striate sulcate pollen with leaves without meshes but with midrib.

Acknowledgements

The author is thankful to Dr. R. S. Tiwari, the then Director, Birbal Sahni Institute of Palaeobotany, Lucknow for his kind permission to communicate this paper in the XV International Botanical Congress held at Yokohama, Japan during August 28 to September 3, 1994 together with partial financial assistance which has generated the finance from other sources and the scientific discussions during the progress of this work. I wish to gratefully acknowledge the Hon. Governer, Uttar Pradesh and the authorities of Indian National Science Academy, New Delhi, for the financial support which had facilitated my participation to the XV IBC at Japan.

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