The Palaeobotanist **36** : 37-50, 1987.

Karharbari : a formation or biozone

Manju Banerjee

Banerjee, Manju (1988). Karharbari : a formation or biozone. *Palaeobotanist* **36** : 37-50.

In the initial identification of the Karharbari sediment in Giridih Coalfield both litho- and bio-characters of the sediments were emphasized. Later, Karharbari has been considered as lithologically distinct unit, a definite palaeontological zone and both combined as a chronostratigraphic unit in between Talchir and Barakar. Karharbari is quite distinct in lithological composition, heavy mineral assemblage and coal seam characteristics. Stratigraphical delineation is not always distinct but from careful observation, Karharbari is identified as 'formation' in some of the basins or considered as basal member of Barakar Formation. Age of Karharbari has been suggested as Upper Sakmarian to Artinskian. The characteristic bioassemblage of Karharbari is more similar to Talchir bioassemblage in mega- and palyno-floral compositional pattern. *Botrychiopsis*, one of the characteristic members of Karharbari bioassemblage and also a dominant member of the Pre-Gondwana Botrychiopsis Flora (Middle Carboniferous-Lower Permian) of South America (Brazil, Argentina) and Australia is not recorded from any other Indian Lower Gondwana horizons so far. Karharbari environmental facies (both climatic and ecological) were initiated during Talchir sedimentation. Terminologies, e.g., Karharbari megafloral assemblage and Karharbari palynofloral assemblage are proposed in the Karharbari biozone. Macroenvironment zone for Talchir-Karharbari and microenvironment zone of Lower Karharbari are recognised considering environment of deposition. Talchir and Karharbari are considered as biostratigraphic zone. The continuation of the marine transgressional phase during Karharbari is suggested from the occurrence of brackish water acritarchs.

Key-words—Biozonation, Karharbari, Gondwana, (India).

Manju Banerjee, Department of Botany, University of Calcutta, Calcutta 700 019, India.

सारांश

करहरबारी : एक शैल-समूह अथवा जैवमंडल

मंजु बैनर्जी

गिरीडीह कोयला-क्षेत्र में करहरबारी अवसादों के प्रारम्भिक अभिनिर्धारण हेतु अवसादों के शैलिकीय एवं जैविक दोनों ही लक्षणों पर बल दिया गया। लेकिन बाद में करहरबारी को शैलिकीय दृष्टि से एक विभिन्न इकाई, एक सुनिश्चित पुरातात्विक मंडल तथा इन दोनों को मिलाकर तालचिर एवं बराकार के मध्य एक कालस्तरिक इकाई के रूप में माना गया। शैलिकीय संरचना, भारी खनिज समुच्चय तथा कोयला-सीम संलक्षणों के कारण बिल्कुल अलग है। इसका स्तरिकीय निरूपण सदैव भिन्न नहीं है परन्तु विशेष प्रेक्षणों के आधार पर कुछ द्रोणीयों में करहरबारी को एक 'शैल-समूह' की भांति अभिनिर्धारित किया गया है अथवा इसे बराकार शैल-समूह का आधारी सदस्य माना गया है। करहरबारी की आयु उपरि सकमारिअन से आर्टिन्सकिअन प्रस्तावित की गई है। गुरु-एवं परागाणविक-वनस्पतिजातीय स्वरूप में करहरबारी का लाक्षणिक जैवसमुच्चय तालचिर जैवसमुच्चय से बहुत मिलता है। **बोट्रीकिऑप्सिस**, जो करहरबारी जैवसमुच्चय के लाक्षणिक सदस्यों में से एक है तथा दक्षिण अमेरिका (ब्राजील, अर्जेन्टीना) एवं ऑस्ट्रेलिया के गोंडवाना-पूर्व बोट्रीकिऑप्सिस वनस्पतिजात (मध्य कार्बनीफ़ेरी-अधरि परमी) का भी एक प्रभावी सदस्य है, अभी तक किसी भी भारतीय अधरि गोंडवाना संस्तरों से अभिलिखित नहीं किया गया है।

करहरबारी वातावरणीय संलक्षणी (जलवायवीय एवं पारिस्थितिक) तालचिर अवसादन के समय शुरू हुई थीं। करहरबारी गुरुवनस्पतिजातीय समुच्चय एवं करहरबारी परागाणुवनस्पतिजातीय समुच्चय नामक शब्द करहरबारी जैवमंडल में प्रस्तावित किये गये हैं। अवसादन के वातावरण की दृष्टि से तालचिर-करहरबारी हेतु गुरुवातावरण मंडल तथा अधरि करहरबारी हेतु सूक्ष्म वातावरण मंडल बनाये गये हैं। तालचिर एवं करहरबारी को एक जैवस्तरिक मंडल के रूप में माना गया है। करहरबारी के समय समुद्री धंसाव की निरंतरता लवणी-जलीय एक्रीटार्कों की उपस्थिति के आधार पर प्रस्तावित की गई है।

Concepts, limits and extension of the Indian Gondwana
(Editors : B. S Venkatachala & Hari K. Maheshwari)
Publisher : Birbal Sahni Institute of Palaeobotany, Lucknow

KARHARBARI has remained a controversial unit in the stratigraphic classification of Indian Lower Gondwana since Blanford (1878) suggested separate identity of a typical lithosuccession including coal seams distinct from Talchir and Barakar in the Karharbari Village (lat. 24°14′—24°14′ long. 88°16′—86°23′) of Giridih Coalfield, Bihar (Map 1). Blanford's observation was strongly supported by Feistmantel (1876, 1879, 1882, 1886) through evidence of a distinct plant fossil assemblage recovered from the typical sediments of Karharbari Village in Giridih Coalfield and also from Hutar, Umaria, Mohpani and Shahpur coalfields. McClelland (1848) mentioned about the distinctness and similarity of the basal coal seams of the field with that of Deoghar, Kurao (Kundit Kuraia) and Itkhuri which lie nearly in the same latitude but did not identify the strata separately. Recognition of this sedimentary sequence as the formal stratigraphic unit 'formation' has been often questioned due to indistinct delineation for geological mapping of the strata in most of the basins although the lithocharacters are very much distinct from underlying Talchir and overlying Barakar sediments.

The bioassemblage recovered from the sediments, however, has significant characteristics and distinctness from other Lower Gondwana assemblages suggesting a definite biostratigraphic zone. Since the strata with this characteristic assemblage have not been deposited uniformly and also with sharp delineation in all the basins the identification of the sedimentary sequence in a higher lithostratigraphic rank has been considered variously.

LITHOCHARACTERS OF KARHARBARI

The lithocharacteristics to identify Karharbari as separate lithostratigraphic unit described by Ghosh and Basu (1969) are: (i) the dominance of reworked Talchir materials in the matrix, (ii) composition of sandstone which is greywacke to sub-greywacke, and (iii) distinctive heavy mineral assemblages.

Pareek (1969) also distinguished Karharbari for the lithocharacteristics of polymictic pebble bed usually containing Talchir pebbles which occur at the base of Karharbari. This rock unit is considered as a prominent unit for separating the strata from Talchir. The observations reveal that the sandstone of Karharbari is mature, soft and yellowish or light grey in colour and characterised by the presence of greenish yellow material similar to that of Talchir; the gritty and pebbly sandstones contain angular pieces and fragments of quartz, feldspar partly or wholly kaolinised. The lowest coal seams of Indian Lower Gondwana are associated with such sandstones. The coal seams are also very much characteristic in the non-laminated and dull nature of coal.

DEPOSITIONAL CHARACTERISTICS

Ghosh and Basu (1969) have strongly suggested that although gradational, careful observations in the field distinguish Karharbari as a mappable unit. The lower contact, i.e., with Talchir is marked by erosional unconformity but the upper contact is not so well-marked only excepting the more or less common occurrence of a pebbly conglomeratic zone at the base of Barakar. In the Son Valley, Karharbari has been deposited conformably over the Umaria marine bed. The stratigraphic position of the Umaria marine bed over Talchir has been suggested as both unconformable (Gee, 1928; Fox, 1931; Ghosh & Basu, 1969) and conformable (Ahmad, 1957). Karharbari sediments are suggested to have been deposited in the glacially denuded valleys encircled by high topographic relief; high gradient streams with high width and depth ratio carried down the course, clastic detritus from the high relief through the characteristically braided channels; unstable tectonic environment has been suggested to be responsible for the lesser thickness of Karharbari coalseams; the sediments were being accumulated in the embryonic basins during Karharbari after deglaciation at the end of Talchir sedimentation (Laskar, 1977).

DISTINCTION OF KARHARBARI FROM BARAKAR

Karharbari Sandstone is greywacke to sub-greywayke and composed of angular to sub-angular fragments. Barakar Sandstone is arkosic, dominated by gritty to pebbly and coarse-grained varieties with rounded to subrounded nature of the fragments.

In heavy mineral composition, Zircon and Rutile are dominant in Karharbari Sandstone and occur as common to rare component of Barakar Sandstone. Whereas Tourmaline is dominant in the Barakar Sandstone but occur in negligible ratio in Karharbari Sandstone.

PRESENT STATUS OF KARHARBARI IN LITHOSTRATIGRAPHIC CLASSIFICATION

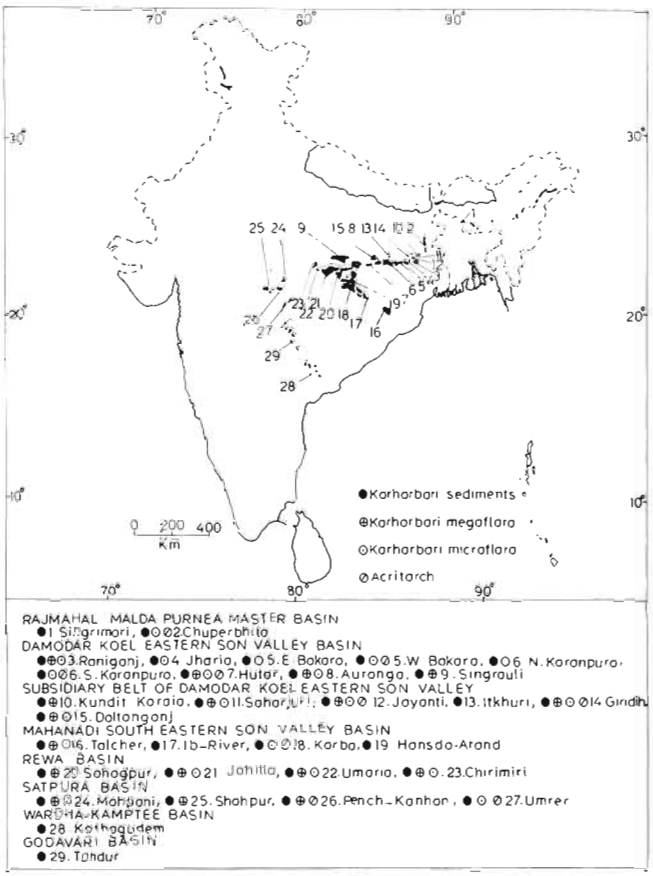
Definition—Sastry *et al.* (1977a) have defined Karharbari as consisting of grey to brown and mottled carbonaceous sandstones, grit and conglomerates with occasional coalseams of non-banded, dull type and fire clays. The sandstones are with angular to sub-angular quartz and mostly

Table 1—Stratigraphic sequence of Lower Gondwana showing biozone in Karharbari Formation

Geologic Time			KARHARBARI BIOZONE: Megafloral zones: CENO-zone	KARHARBARI BIOZONE: Megafloral zones: ACME Zone	KARHARBARI BIOZONE: Miofloral zones: CENO-Zone	KARHARBARI BIOZONE: Miofloral zones: ACME Zone	BIOSTRATIGRAPHIC CLASSIFICATION: Faunal Zones	BIOSTRATIGRAPHIC CLASSIFICATION: Biozone and Macroenvironment Zone	Damodar Valley	Rajmahal Hills	Koel Valley	Mahanandi Son Valley	Narmada Valley: Upper	Narmada Valley: Lower	Wardha-Pranhita Godavari Valley	East coast Krishna Godavari	Rajasthan
P															V Kamthi Fm Gl	Kamthi Fm	
E	U P P E R	Tatarian							Gl Raniganj Fm. Kulti Fm.Gl. (Barren Measures) Gl Barakar Fm.	Plant beds (Raniganj Fm) Barakar Fm	Gl. Raniganj Fm Gl Barakar Fm.	Gl Raniganj Fm Gl. Kulti Fm (Barren Measures) Gl. Barakar Fm	Bijori Fm. Motur Fm	Barakar Fm	V Motur Fm. Gl Barakar Fm.		
R	L O W E R	Artinskian	1) Gangamopteris 2) Noeggerathiopsis 3) Glossopteris 4) Botrychiopsis 5) Buriadia 6) Ottokaria	1) Gangamopteris 2) Noeggerathiopsis 3) Botrychiopsis 4) Buriadia 5) Ottokaria	Callumispora Parasaccites Plicatipollenites	Callumispora		Gangamopteris Glossopteris Neoggerathiopsis Parasaccites	Gl. Karharbari Fm/Mb A Jharia West Bokaro* S. Karanpura Giridih	Gl. Karharbari Mb Fm A* Chuperbhita	Gl. Karharbari Mb Fm A* Hutar	Gl. Karharbari Mb A. Korba Umaria bed at base Sr Ch ?-discontormity—	Karharbari Mb. A Pench kanhan				
P		Sakmarian					Streptorhyncus A. Zone	Plicatipollenites Callumispora Diverse	Rikba bed at top Gl		Eu.Gl Rajhara bed near top Ch	Gl. near top					
		Asselian					Eurydesma A. Zone	Acritarch				Eu. Manendragarh bed at base	Talchir Fm.		Talchir Fm		Sr Badhaura
Precambrian Metamorphites																	

Damuda Group ... Talchir Fm ... Talchir Fm ... Talchir Fm

Stratigraphic classification and faunal records (after Sastry et al. 1977a; Acharyya et al. 1977) Acritarch occurrence is added in the table from reported records and present study
Gl. = Occurrence of Glossopteris; **Eu.** = eurydesma dominated fauna; **Sr.** = Streptorhynchus fauna; **Ch.** = Chitinozoa; **V.** = Continental vertebrate fauna; **A.** = Acritarch; * = Present record, **Mb.** = Member; **Fm.** = Formation.



Map 1—Showing records of Karharbari sediments, megaflora, microflora and acritarch from different coalfields of Indian Lower Gondwana. The coalfields are considered under basins according to Datta *et al.*, 1983 and Mitra and Raja Rao, 1987.

unaltered, fresh feldspar. It overlies unconformably the Talchir Formation in the type area, Karharbari Village, Giridih Coalfield (Ghosh & Basu, 1969) and conformably over Umaria marine bed at Rewa Basin. Karharbari has been defined as formation by Ghosh and Basu (1969), in type area and by different workers in other basins and also as member within basal part of Barakar Formation due to ill-defined lithological distinction (Table 1).

Age—Artinskian to Upper Sakmarian age of Karharbari has been considered from comparative analysis of the faunal assemblages recorded from Marine bed at Umaria which lies conformably below Karharbari. Lower limit has been suggested from the faunal records of Umaria which is correlated with the marine bed of Salt Range and upper limit of Karharbari has been ascertained through extrapolation of evidences of megaplant fossils similar to peninsular Karharbari assemblage recorded from Lower Gondwana Bed at Kashmir which is overlain by the marine Zewan Bed.

BIOASSEMBLAGE OF KARHARBARI SEDIMENTS

Identification of a very typical plant fossil assemblage by Feistmantel (1876, 1879, 1882, 1886) in the carbonaceous shales associated with the Lower Karharbari seams in the Giridih Coalfield (Map 1) strongly suggested a distinct phase of deposition immediately after Talchir glaciation and before the coal-bearing Barakar Formation. Since then plant fossil assemblage has become successful parameter to identify the Karharbari rocks than lithostratigraphic consideration. With the introduction of palynological study, the palynofloral composition of Karharbari sediments has been worked out and found to be very much distinctive and useful in identifying Karharbari rocks. The mega- and palyno-floral evidences explore a typical assemblage from Karharbari sediments.

Zeiller (1902) contributed some additional plant fossils of the strata from the type area. Sen (1953) first tried to apply palynological data for identification and correlation of coalseams and distinguished the Lower Karharbari seams in the type area Giridih Coalfield with dominance of trilete, smooth types of spores (? *Callumispora*) and more monosaccates compared to the disaccate dominance in the younger Bhaddoah seam. Further mega- and palyno-floral records from the type area have been made by Guhasarkar (1956), Maithy (1965a-g, 1966, 1969a, 1977), Srivastava (1973), Maithy and Misra (1984), Bharadwaj (1966), Pant and Nautiyal (1965, 1966, 1967, 1984), Pant and Gupta (1968), Pant and Kidwai (1968), Pant and Singh (1976, 1979), Pant, Nautiyal and Misra (1981), and Maheshwari and Tewari (1986).

Megaplant Assemblage

So far 31 genera and about 100 species of megaplant fossils are recorded from Karharbari

PLATE 1 →

1. *Glossopteris decipiens*, G.S.I. specimen no. 5026. × 4/5.
2. *G. longicaulis*, G.S.I. specimen no. 5086. × Nat. Size.
3. *Noeggerathiopsis hislopi*, G.S.I. specimen no. 5065. × Nat. Size.

4,5. Portion of the big fronds of *Botrychiopsis valida* illustrated by Feistmantel, 1881, pl. VI.

6. *Ottokaria bengalensis*, G.S.I. specimen no. 7288. × Nat. Size.
7. *Rubidgea obovata* Maithy, BSIP specimen no. 32793/604. × Nat. Size.

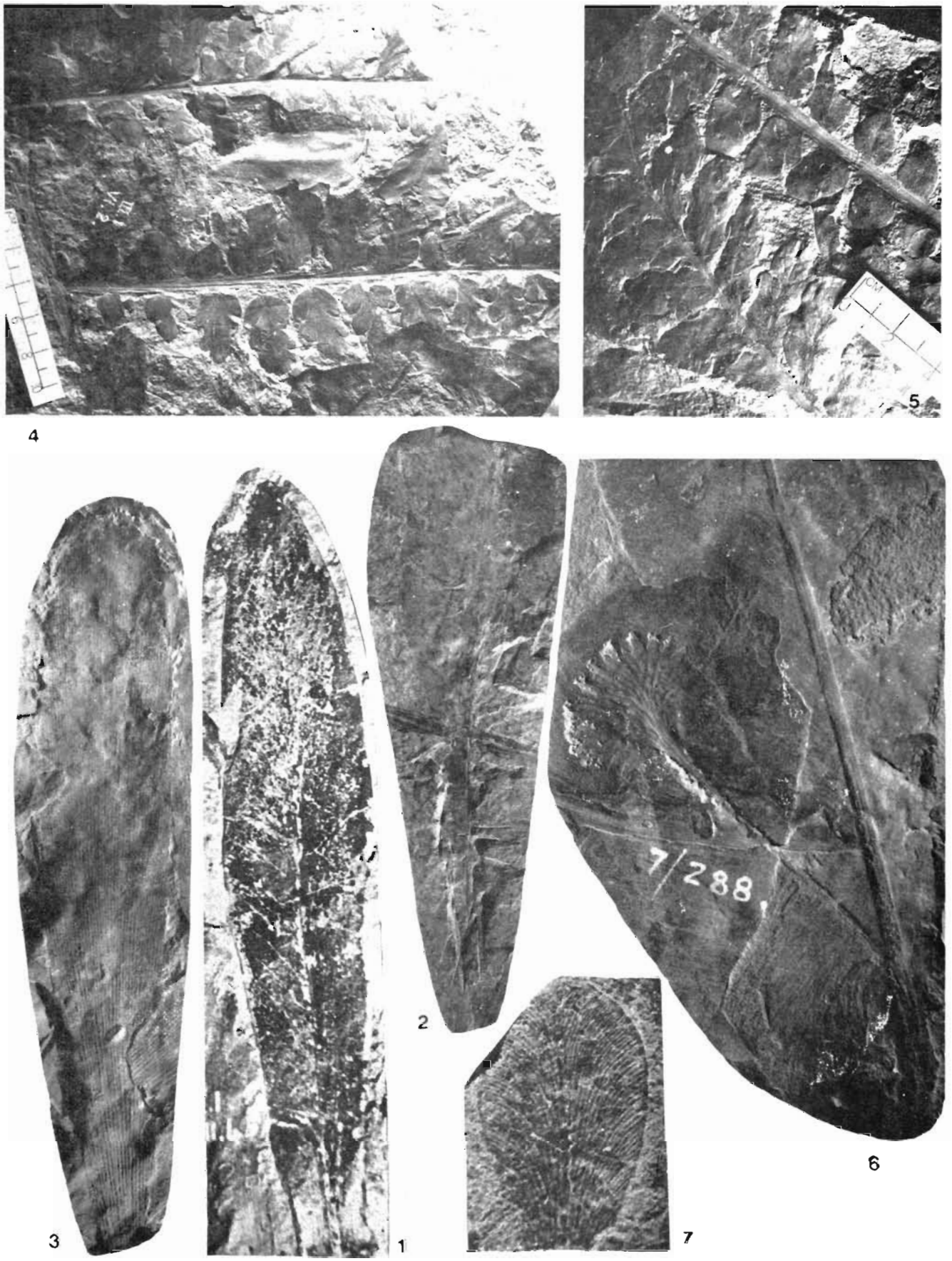


PLATE 1

sediments of different coalfields. The common occurrence of *Glossopteris* identifies the assemblages as Lower Gondwana Glossopteris flora. Most of the species of the genus are with fine venation pattern; medium mesh species are also encountered in moderate frequency. Feistmantel (1879, 1882, 1886) recognised a number of species including some new records, the lectotypes for which have been identified later (Banerjee, 1978). The species are *G. decipiens* (Pl. 1, fig. 1), *G. longicaulis* (Pl. 1, fig. 2), *G. taenioides* (Pl. 2, fig. 1), and *G. communis* (Pl. 2, fig. 2). *G. decipiens, G. indica* and *G. communis* are much frequent in the Karharbari assemblage

Plant assemblages from Karharbari sediments show very common occurrence of the *Gangamopteris* type of leaves. The leaves are apparently without any distinct midvein, but the veins in the middle part of the lamina often concentrate simulating a midrib. The lamina is covered with fine veins forming crowded meshes similar to that of *Glossopteris*. The closer similarity of fine mesh *Glossopteris* species and *Gangamopteris* species will be clearly understood when the ecofacies of the strata with such fossils is explored. About 15 species of *Gangamopteris* are recorded from Karharbari sediments of which *G. cyclopteroides* (Pl. 2, figs 3,4) is the most common which again is a common species of Talchir flora.

Common occurrence of *Noeggerathiopsis* in the assemblages of Karharbari sediments indicates similarity with the Talchir flora. But similar to *Gangamopteris* this genus also exhibits maximum species variation indicating proliferating growth of the group of plants during the deposition. *N. hislopi* (Pl. 1, fig. 3) is the most common species of the assemblages of Karharbari among about 10 to 11 species so far known.

Glossopteris, Gangamopteris and *Noeggerathiopsis* are common genera of both Talchir and Karharbari which either flourish in the younger horizon of Raniganj Formation, viz., *Glossopteris* (Banerjee, 1987) or continue up to the younger horizon of Indian Lower Gondwana, viz., *Gangamopteris* in Raniganj Formation (Banerjee, 1987) or occur sporadically in Barakar and Raniganj formations (Lakhanpal *et al.*, 1970), viz., *Noeggerathiopsis*.

However, the occurrence of *Botrychiopsis* (=*Gondwanidium*—Pl. 1, figs 4,5), *Buriadia* (Pl. 2, fig. 6), *Ottokaria* (Pl. 1, fig. 6), *Euryphyllum* (Pl. 2, fig. 7), *Rubidgea* (Pl. 1, fig. 7) in addition to *Glossopteris, Gangamopteris* and *Noeggerathiopsis* distinguishes the assemblage of Karharbari sediments from the other Lower Gondwana megaplant assemblages. *Buriadia, Ottokaria* although recorded sporadically from younger horizons (Banerjee, 1973, 1978b; Srivastava, 1973), *Botrychiopsis* is recorded from Karharbari sediments only. The less known genera *Euryphyllum, Rubidgea* are also reported from Karharbari only. The Cenozone and Acmezone representatives of megafloral assemblages are enumerated in Table 2. *Botrychiopsis valida* Feistmantel (1879) shows a luxuriant growth of the plant with profuse pinnately branched axis, bearing apparently rounded pinnule of considerable thickness indicating a tree-like habit of the plants. The genus is recorded both from Lower Karharbari and Upper Karharbari (Bandopadhyaya, 1959). Monopodially branched *Buriadia heterophylla* also occurs in the same association of *Botrychiopsis, Gangamopteris* and *Glossopteris* leaves in the type area.

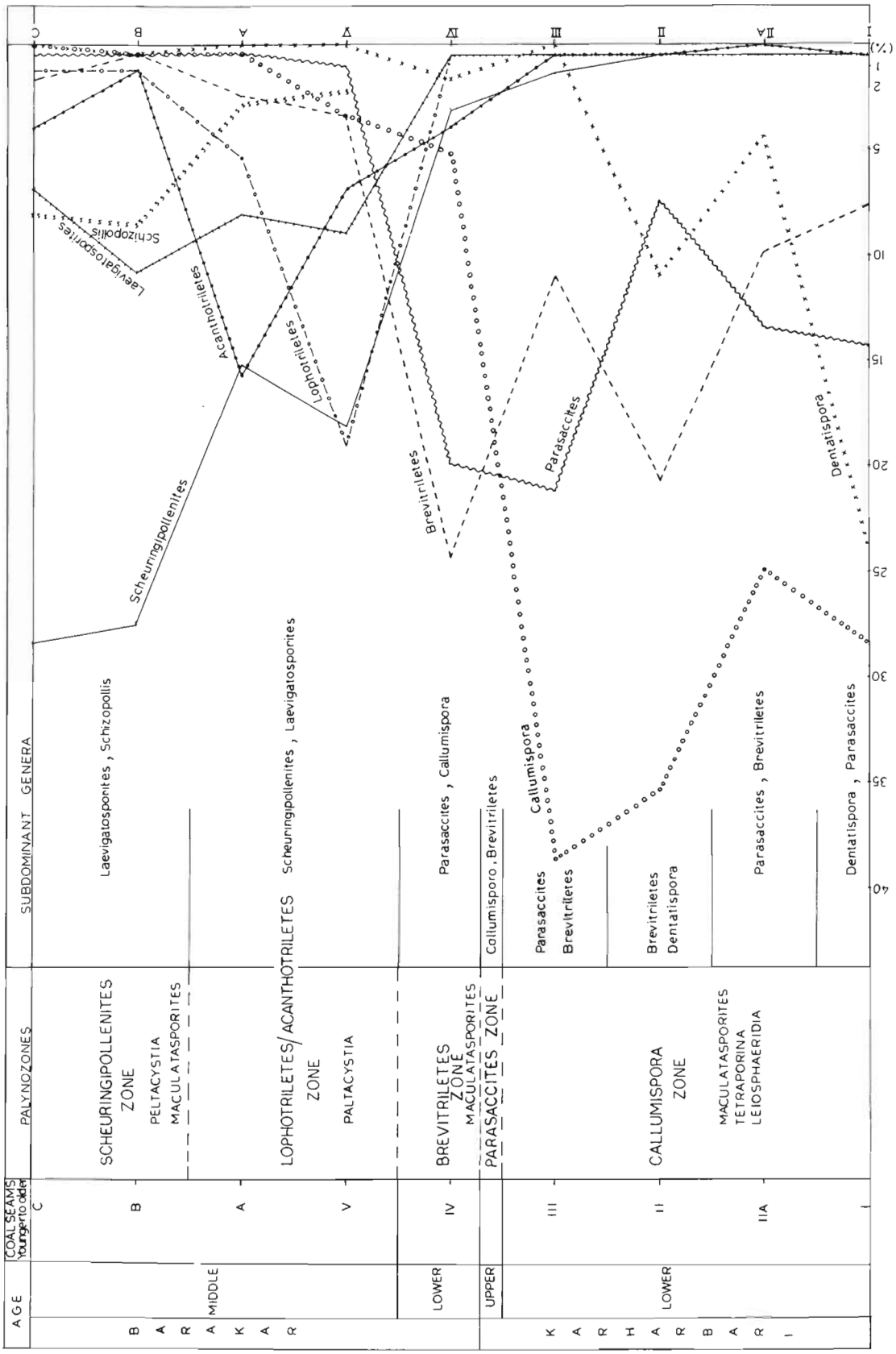
Affinity as well as environmental analysis of the characteristic representatives of Karharbari sediments are not yet known sufficiently. *Glossopteris* and *Gangamopteris* leaves are generally grouped as Glossopteridales or Glossopteridopsida and have been analysed so far considering the climatic factor only; the ecological factor analysis of the species remains still unattended. Critical analysis of the species occurring at the basal coal-bearing strata of Lower Gondwana will reveal the depositional characteristics. *Botrychiopsis* is

Table 2—Megafloral assemblage from Karharbari sediments

GENUS	QUALITATIVE ANALYSIS	RELATIVE ABUNDANCE OF OCCURRENCE
Glossopteris	Mostly fine mesh form and also medium mesh form	Common
Gangamopteris	Diverse	Dominant
Noeggerathiopsis	Diverse	Dominant
Botrychiopsis	Three species	Occur in Karharbari only
Ottokaria	Three species	Dominant
Buriadia	Diverse	Dominant
Euryphyllum	Two species	Occur in this horizon only.
Rubidgea	Three species	Occur in this horizon only
Gymnospermic seed	Diverse	Frequent
Vertebraria	Two species	Frequent
Schizoneura and Equisetaceous stem	Diverse	Frequent
Neomariopteris	Three species	Frequent

KARHARBARI MEGAFLORAL ASSEMBLAGE

CENOZONE	ACMEZONE
Gangamopteris	*Gangamopteris*
Noeggerathiopsis	*Noeggerathiopsis*
Glossopteris	*Botrychiopsis*
Botrychiopsis	*Buriadia*
Buriadia	*Ottokaria*
Ottokaria	



Text-figure 1—Shows the frequency of occurrence of mioflora in the lithosuccession of Lower Gondwana sediments in Hurilong and Hutar colliery blocks of Hutar Coalfield (after Banerjee & Ganguly, 1986; Ganguly & Banerjee, 1986 a, b).

suggested to be a progymnosperm which grew in the periglacial environment (Retallack, 1980; Meyen, 1987). *Buriadia* is the southern hemisphere Permian conifer and resembles the northern hemisphere conifer in the forked leaves but differs in the ovule bearing character (Pant & Nautiyal, 1967). *Noeggerathiopsis* is considered under Noeggerathiopsidales, suggested to be a cordaitalean plant (Pant, 1982). Northern hemisphere cordaitales, however, show characteristics of mangrove plants.

Microfossil Assemblage

Palynoassemblages were recorded from the type area Giridih Coalfield with the Lower Karharbari seams and also of the younger horizons in the type area (Sen, 1953; Maithy, 1965f; Bharadwaj, 1966; Srivastava, 1973). Similar assemblages are recovered from channel, bore-core or traverse samples from a number of coalfields of the different basins (Map 1). The assemblages recorded are also reviewed from time to time (Bharadwaj, 1966, 1971, 1974; Maithy, 1969b; Tiwari, 1974a). About 67 genera and more than 200 species are now on record from Karharbari sediments. Mostly trilete spores and monosaccate pollen grains dominate the assemblages.

Callumispora (=*Punctatisporites*) (Pl. 3, figs 1-2), *Cyclogranisporites* (Pl. 3, fig. 3), *Granulatisporites, Brevitriletes* (Pl. 3, fig. 4), *Microbaculispora* (Pl. 3, fig. 5), *Lophotriletes, Microfoveolatispora* (Pl. 3, fig. 6) are the more common trilete taxa of which *Callumispora* exhibits highest frequency; predominant occurrence of the monosaccate pollen grains, viz., *Parasaccites* (Pl. 3, fig. 7), *Plicatipollenites* (Pl. 3, fig. 8), *Virkkipollenites*, etc. accounts for the climatic condition of glacial influence.

Frequency study of channel and bore-core samples from the type as well as other coalfields has revealed a distinctive microfloral assemblage pattern from Karharbari sediments. Assemblage zone representatives, however, have differential frequency of occurrence in the lower and upper horizons of Karharbari (Text-fig. 1; Table 3). Combination of taxa with same higher frequency of monosaccates in the Upper Karharbari indicates influence of cooler climate and the trilete dominance with *Callumispora* indicates more humid and swampy ecological condition with lesser influence of climate indicator taxa. Climatic variation continued since Talchir up to the end of Karharbari approaching towards the closing phase of glaciation and deglaciation. From the relative frequency of occurrence in stratigraphic sequence of the monosaccate pollen grains in Lower Gondwana, the climatic transformation is apparent. But the dominance of *Callumispora* during *Botrychiopsis* phase of deposition in Karharbari and again during *Dicroidium* phase Triassic sedimentation (Tiwari, 1979) might be due to similar ecological condition.

Affinity of the miofloral taxa of Indian Lower Gondwana is very much conjectural as the spores and pollen have rarely been recorded *in situ* (Banerjee, 1969). The monosaccate pollen grains are assigned to the gymnospermous coniferous plants supposed to be of cool climate habitat. *Callumispora* has been suggested as a gymnosperm pollen grain (Bharadwaj, 1987 during the workshop discussion); the allied taxa *Punctatisporites* of Lower Carboniferous (northern hemisphere) dominance is known to be the prepollen of Pteridosperms (Meyen, 1987).

OTHER SIGNIFICANT BIOTA RECORDED FROM KARHARBARI SEDIMENTS

Megaspores, algae, fungal spores, acritarchs, Tasmanids and microcrystals similar to sponge spicules are recorded along with palynoflora from Karharbari sediments (Map 1; Table 3; Pl. 3, figs 14-18). The frequent occurrence of megaspores indicates the occurrence of luxuriant swampy vegetation and the fungal spores are indicator of humid condition. *Alternaria* sp. has records of fresh and brackish water environment (Jarzen & Elsik, 1986). *Quadrisporites* of the Lower Karharbari, (Shukla, 1983) is regarded as a common form of Talchir (Bharadwaj, 1966). The acritarch and tasmanids recorded in the Karharbari assemblage are now considered as brackish water biota (Tappan, 1980). Microcrystals, although not exactly similar but with some morphological similarity with the sponge spicules have been recorded from Talchir sediments of Daltonganj (Lele & Srivastava, 1974), are recorded from West Bokaro Coalfield along with palynofloral assemblages similar to that of Karharbari and Lower

PLATE 2 →

1. *Glossopteris taenioides*, G.S.I. specimen no. 5490. × Nat. Size.
2. *G. communis*, G.S.I. specimen no. 5267 (slightly reduced).
3. *Gangamopteris cyclopteroides*, G.S.I. specimen no. 5016 × Nat. Size.
4. *G. cyclopteroides*, G.S.I. specimen no. 5464. × Nat. Size.
5. *G. buriadica*, G.S.I. specimen no. 5025. × Nat. Size.
6. *Buriadia heterophylla*, G.S.I. specimen no. 5050. × Nat. Size.
7. *Euryphyllum whittianum*, G.S.I. specimen no. 5036. × Nat. Size.

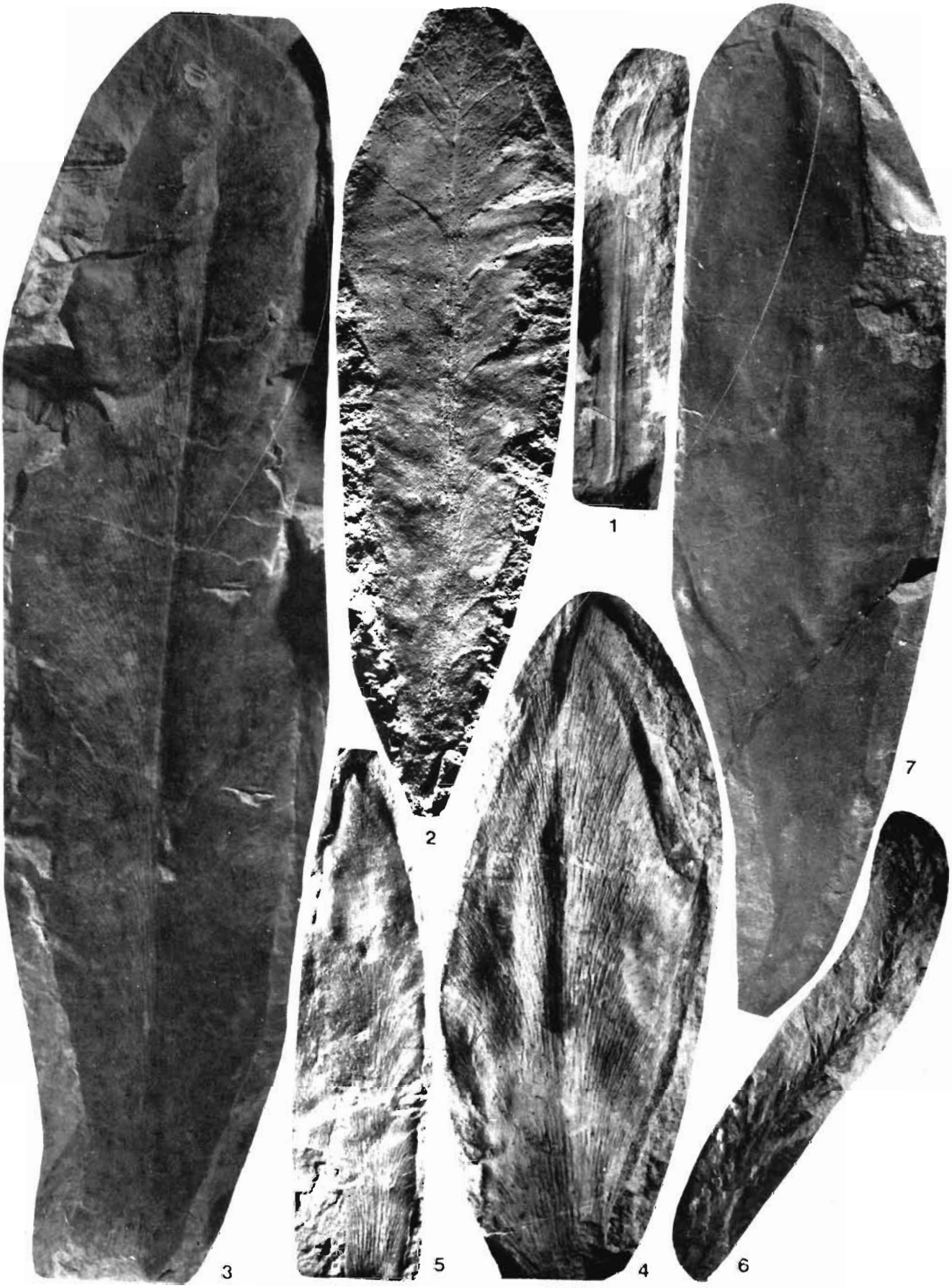


PLATE 2

Table 3—Palynoflora from Karharbari sediments

	GENUS	QUANTITATIVE ANALYSIS
Upper Karharbari	*Parasaccites*	Dominant
	Plicatipollenites	Dominant
	Callumispora	Frequent
	Brevitriletes	Frequent
	Scheuringipollenites	Common
Lower Karharbari	*Callumispora*	Dominant
	Parasaccites	Frequent
	Plicatipollenites	Frequent
	Brevitriletes	Frequent
	Cyclogranisporites	Frequent
	Microbaculispora	Frequent
	Microfoveolatispora	Frequent

Karharbari palynofloral Assemblage
Callumispora-Parasaccites-Plicatipollenites

Other microbiota—Some occur both in Upper and Lower Karharbari

ACRITARCHS
Balmeella
Brazilea
Foveofusa
Leiosphaeridea
Maculatasporites
Pilasporites
Spongocystia
Spinose and non-spinose
Tetraporina

FUNGI
Alternaria and others
Other fungal spores
Micro-crystals cf. sponge spicule
Megaspores

Barakar and also spinose and non-spinose type of acritarchs (Banerjee & Das, 1983, 1986a,b). This assemblage of biota other than microflora recorded from Karharbari sediments of type and a number of other coalfields is significant enough to consider the environment of deposition during Karharbari sedimentation.

PRESENT STATUS OF KARHARBARI

A distinctive bioassemblage both of megaflora (Table 2) and microflora (Table 3) is revealed by analysing all the megaplant and spores, pollen records from the Karharbari sediments (Map 1). The assemblages are recognised as Karharbari megafloral assemblage and Karharbari palynofloral assemblage. Besides, a number of acritarch forms are common in the assemblages as the fungal spores (Table 3). All these evidences suggest a typical biozone of Karharbari as follows:

Karharbari Biozone

Gangamopteris-Noeggerathiopsis-Glossopteris-Botrychiopsis-Buriadia-Ottokaria-Callumispora-Parasaccites-Plicatipollenites-diverse, brackish water Acritarchs, fungal spores.

The floristic pattern of Karharbari biozone and relative abundance of the taxa in Talchir, Barakar, Kulti (Barren Measure) and Raniganj formations indicate continuation of a uniformly composite pattern of vegetation that differed in the frequency of occurrences and specific variations of the genera and species according to change of climate and ecofacies (Text-fig. 2). The bioassemblage of Karharbari is more similar to that of Talchir. However, *Botrychiopsis*, one of the characteristic members of Karharbari biozone and also a dominant member of the pre-Gondwana Botrychiopsis flora during Middle Carboniferous-Lower Permian of South America (Brazil, Argentina—Archangelsky, 1986) and Australia (Retallack, 1980) is not encountered in any of the assemblages of other Lower Gondwana horizons of peninsular India except in an assemblage of extrapeninsular Permian deposit (Tewari & Singh, 1980) along with *Glossopteris, Gangamopteris, Lepidodendron* and *Calamites*.

Karharbari and Talchir are considered as the *Gangamopteris-Noeggerathiopsis-Glossopteris-Parasaccites-Plicatipollenites-Callumispora* macro-environment and biostratigraphic zone. The dominance of other taxa within this zone

PLATE 3 →

Some of the microfossils encountered from Karharbari sediments of Hutar, West Bokaro and Chuperbhita coalfields. (figs. 1-16 × 700).

1. *Callumispora tenuis*
2. *Callumispora barakarensis*
3. *Cyclogranisporites gondwanensis*
4. *Brevitriletes levis*
5. *Microbaculispora tentula*
6. *Microfoveolatispora indica*
7. *Parasaccites talchirensis*
8. *Plicatipollenites gondwanensis*
9. *Laevigatosporites flexus*
10. *Jayantisporites pseudozonatus*
11. *Didecitriletes horridus*
12. *Marsupipollenites triradiatus*
13. *Gnetaceaepollenites sinuosus*
14. *Quadrisporites horridus*
15. *Tetraporina* sp.
16. *Maculatasporites indicus*
17. *Alternaria* sp. × 1000
18. Microcrystals cf. sponge spicule. × 250

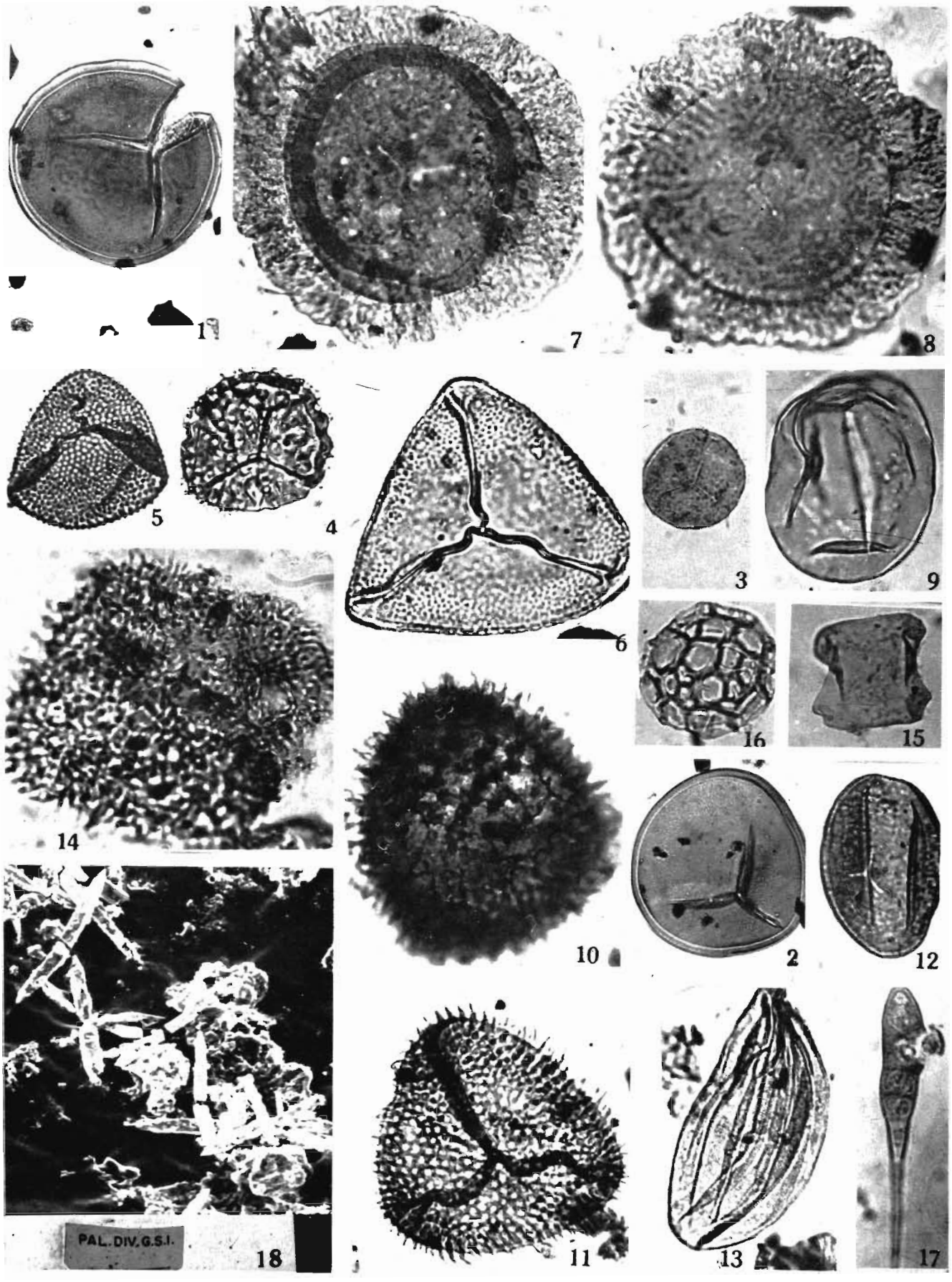
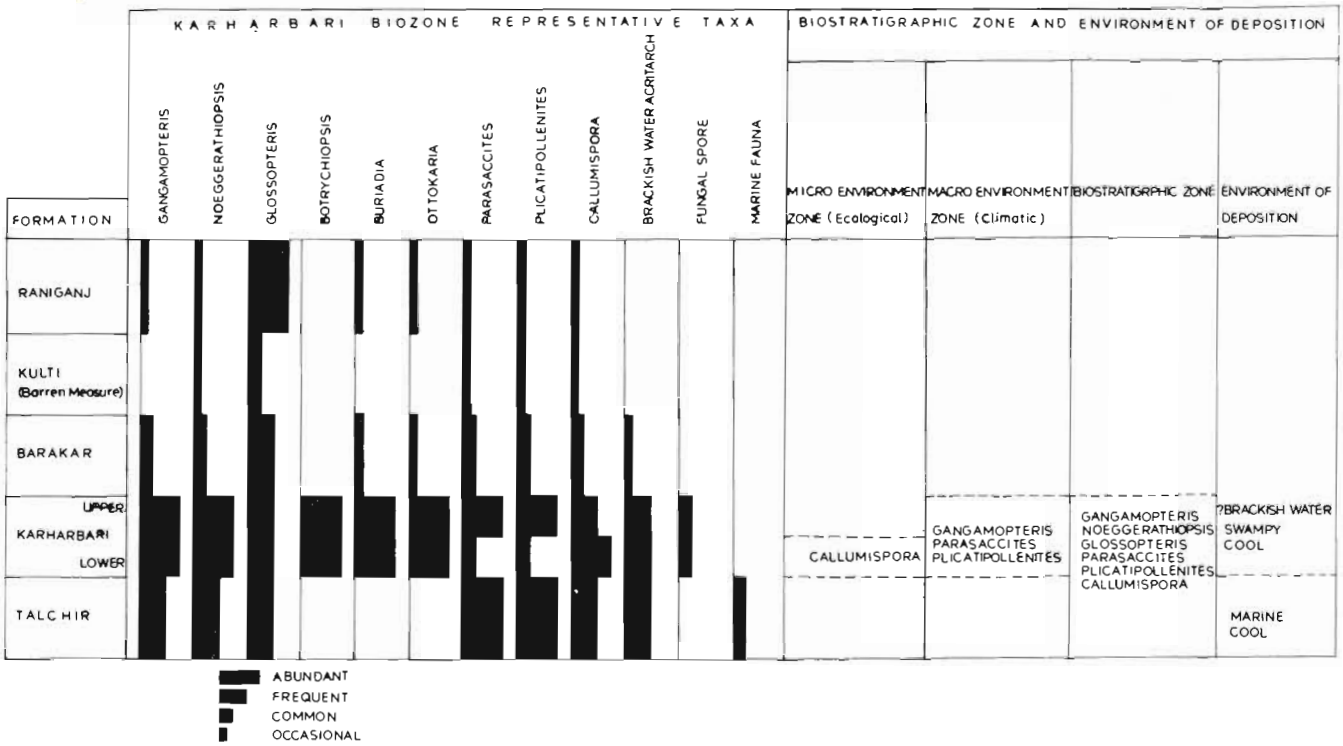


PLATE 3



Text-figure 2—Relative abundance of Karharbari biozone taxa and acritarch in Lower Gondwana horizons and macroenvironment, microenvironment zone.

(microenvironment zone) may be considered as subzones of the macroenvironment and biostratigraphic zone.

KARHARBARI BIOASSEMBLAGE REPRESENTATIVES FROM OTHER PARTS OF THE SUBCONTINENT

Salt Range

As early as in 1938, Virkki recorded megafossil assemblage from Salt Range that includes several species of *Glossopteris, Schizoneura, Ottokaria* and *Cordaicarpus*. Later Virkki (1945) described a monosaccate rich palynoassemblage. Kar (1965 *in*: Maithy, 1969b) on the basis of miospore analysis regarded the age of the beds as equivalent to Karharbari.

Kashmir and other extra-peninsular area

Gangamopteris kashmirensis, Cordaites (Noeggerathiopsis hislopi) and *Psygmophyllum (Ginkgophyton)* are recorded from the Nishatbag and Vihi beds of Kashmir (Kapoor, 1979; Singh *et al.*, 1982; Lele & Maithy, 1982). The assemblage does not contain any typical Karharbari form and is more similar to Talchir assemblage of Peninsula. But the faunal record of the marine bed below this *Gangamopteris* bed is similar to that of the Umaria marine bed lying conformably below Karharbari in peninsular Gondwana. Evidently Karharbari affinity of the Kashmir Bed has been suggested.

Mega- and palyno-floral assemblage recorded from the Permian sediments of Uttar Pradesh by Tewari and Singh (1980) and Tiwari *et al.* (1980) is quite interesting. *Gangamopteris, Glossopteris, Botrychiopsis, Lepidodendron, Calamites, Callumispora* combination is very much significant and perhaps will throw light in analysing the introduction of Glossopteris flora in the Lower Gondwana of the subcontinent.

Records of *Callumispora* and other monosaccate pollen grains with acritarch, Chitinozoan assemblage from the Tethyan Sequence is, however, from Upper Permian horizons (Tiwari *et al.*, 1984).

Arunachal Pradesh

Singh (1979) described *Callumispora* rich palynoassemblage from the Bomte Member of Garu Formation in Siang District of Arunachal Pradesh, eastern Himalaya. The assemblage is similar to the Karharbari palynofloral assemblage (Lower Karharbari) of the peninsular basins. The age of the sediments has been suggested as Asselian to Sakmarian from marine faunal evidences (Singh, 1979). Srivastava and Dutta (1978) described Karharbari miofloral assemblage from Siang District. The palynological assemblages of Karharbari from

Arunachal Pradesh also recorded occurrence of diverse acritarch, *Botryococcus*, etc.

CONCLUSION

The observations of Ghosh and Basu (1969) on Karharbari as a definite lithological unit, palaeontological zone and both combined as a chronostratigraphic unit in between Talchir and Barakar is now supported by data in many of the coalfields (Map 1). However, identification of the strata as a mappable unit in the field has not been found as comfortable as it should be. Nevertheless, the lithological, petrological constituents with strong mega- and palyno-floral records distinguish the sedimentary sequence from the rest of the Indian Lower Gondwana Succession. Karharbari deposition occurred during the same macroenvironment phase as Talchirs, in which Lower Karharbari depicts a distinct microenvironment phase. Marine transgression during Karharbari is apparent from the occurrence of brackish water acritarchs in the bioassemblage.

ACKNOWLEDGEMENT

Kind permission by the Director General and Mr S. C. Shah, Director, Palaeobotany Division, Geological Survey of India for taking photographs of Feistmantel and Zeiller's collection of megaplants from the Karharbari type area is thankfully acknowledged.

REFERENCES

Acharyya, S. K., Ghosh, S. C., Singh, Gopal 1977. Limits of stratigraphic distribution of *Glossopteris* in India: discussion. *Rev. palaeobot. Palynol.* **23** : 145-158.

Ahmad, F. 1957. Observations on Umaria marine bed. *Rec. geol. Surv. India* **84**(4) : 469-479.

Archangelsky, S. 1986. Late Palaeozoic floras of the southern hemisphere: distribution, composition, palaeoecology. *in* : Broadhead, T W. (Ed.)—*Short course on land plants*, The Palaeont. Soc. Texas. Univ. Tenn. Dept. Geol. Sci. Geol. **15** : 128-142.

Bandopadhyay, S. 1959. On the palaeontology of the Lower Barakar rocks around Palasthali, Raniganj Coalfield. *Q. Jl geol. Min. metall. Soc. India* **31**(1) : 53.

Banerjee, Manju 1969. *Senotheca murulidihensis*, a new glossopteridean fructification from India associated with *Glossopteris taeniopteroides* Feist. *in*: Santapau, H. *et al.* (eds)—*J. Sen Memorial Vol.* Bot. Soc. Bengal, Calcutta : 359-368.

Banerjee, Manju 1973. On the occurrence of *Buriadia heterophylla* (Feistm.) Seward & Sahni in the Raniganj Stage (Upper Permian) of Indian Lower Gondwana. *J. geol. Soc. India* **14**(4) : 428-431.

Banerjee, Manju 1978a. Genus *Glossopteris* Brongniart and its stratigraphic significance in the Palaeozoics of India. Part I—A revisional study of some species of the genus *Glossopteris*. *Bull. bot. Soc. Bengal* **32** : 81-125.

Banerjee, Manju 1978b. Glossopteridean fructification: 2. On the revision of *Ottokaria* Zeiller and the occurrence of *O. raniganjensis* Banerjee from the Raniganj Formation (Upper Permian) of India. *Indian Jl Earth Sci.* **5**(2) : 129-140.

Banerjee, Manju 1987. A study of the frequency of megaplant fossils in Raniganj Formation (Upper Permian) of Raniganj Coalfield. *Geol. Surv. India Spl. Publ.* (1) : 261-288.

Banerjee, Manju & Das, S. 1983. Occurrence of microspore megaspore assemblage alongwith fungal spores, acritarchs and some microcrystals from West Bokaro Coalfield (Abstract). *V Indian geophytol. Conf., Lucknow.*

Banerjee, Manju & Das, Sanghamitra 1986a. On the occurrence of *Callumispora* rich palynoassemblage from Dudhinala and Bokaro Nadi traverse samples (Abstract). *Special Indian geophytol. Conf., Lucknow.*

Banerjee, Manju & Das, Sanghamitra 1986b. Palaeobiology and environment of deposition of Lower Gondwana sediments in West Bokaro Coalfield, Damuda Basin, Bihar. (Abstract). *National Seminar on Coal Resources of India.*

Bharadwaj, D. C. 1966. Distribution of spores and pollen grains dispersed in the Lower Gondwana formations of India. *in* : *Symposium on Floristics and Stratigraphy Gondwanaland (Special session)*, Birbal Sahni Institute of Palaeobotany, Lucknow, pp. 69-84.

Bharadwaj, D. C. 1971. Palynostratigraphy of Lower Gondwana Succession in India. *Annals Geol. Dept., A.M.U., Aligarh* **5-6** : 390-419.

Bharadwaj, D. C. 1974. Palaeobotany of Talchir and Karharbari formations and Lower Gondwana glaciation. *in* : Surange, *K. R. et al.* (eds)—*Aspects and appraisal of Indian palaeobotany*, Birbal Sahni Institute of Palaeobotany, Lucknow, pp. 369-385.

Blanford, W. T. 1878. The palaeontological relations of the Gondwana System: a reply to Dr Feistmantel. *Rec. geol. Surv. India* **11**(1) : 1-160.

Feistmantel, O. 1876. Notes on the age of some fossil floras in India. *Rec. geol. Surv. India* **9**(3) : 1-80.

Feistmantel, O. 1879. The fossil flora of the Gondwana System: Lower Gondwana. The flora of the Talchir-Karharbari beds. *Mem. geol. Surv. India Palaeont. Indica*, ser. 12, **3** : 1-48, Suppl. 1881 : 49-64.

Feistmantel, O. 1882. The fossil flora of the Gondwana System—The fossil flora of the South Rewa Gondwana Basin. *Mem. geol. Surv. India Palaeont. indica*, ser. 12, **4**(1) : 1-52.

Feistmantel, O. 1886. The fossil flora of the Gondwana System: Fossil flora of some of the coalfields in West Bengal. *Mem. geol. Surv. India Palaeont indica*, ser. 12, **4**(2) : 1-66.

Fox, C. S. 1931. The Gondwana System and related formations. *Mem. geol. Surv. India* **58** : 1-241.

Gee, E. R. 1928. The geology of the Umaria Coalfield, Rewa State, central India. *Rec. geol. Surv. India* **63**(2) : 189-280.

Ghosh, P. K. & Basu, Abhijit 1969. Stratigraphic position of the Karharbaris in the Lower Gondwanas of India. *Gondwana Stratigraphy (1967) IUGS.* Unesco, Paris, pp. 407-417.

Guhasarkar, J. K. 1956. Note on the microfloral contents of the Karharbari and Barakar coals of the Giridih Coalfield. *Q. Jl geol. Min. metall. Soc. India* **28** : 141-142.

Jarzen, David M. & Elsik, William, C. 1986. Fungal palynomorphs recovered from recent river deposits, Luangwa Valley, Zambia. *Palynology* **10** : 35-60.

Lakhanpal, R. N., Maheshwari, H. K. & Awasthi, N. 1970. *A catalogue of Indian fossil plants.* Birbal Sahni Institute of Palaeobotany, Lucknow.

Laskar, B. 1977. Evolution of Gondwana coal basins. *4th int. Gond. Symp. Calcutta. Section IV: Environment and origin of coal deposits* : 1-21.

Lele, K. M. & Maithy, P. K. 1982. Precambrian and Palaeozoic floras from the Himalaya : a review. *Palaeobotanist* **30**(3) : 233-241.

Lele, K. M. & Srivastava, A. K. 1974. Spicule-like microfossils from the Talchir Formation, Daltonganj Coalfield, Bihar. *Geophytology* **4**(1) : 25-34.

Maheshwari, H. K. & Tewari, R. 1986. *Mebeshwariella spinicornuta*, a new gymnospermous seed from the Karharbari Formation. *Palaeobotanist* **35**(1) : 69-72.

Maithy, P. K. 1965a. Studies in the Glossopteris flora of India—17. On the genus *Rubidgea* Tate. *Palaeobotanist* **13**(1) : 42-44.

Maithy, P. K. 1965b. Studies in the Glossopteris flora of India—18. Gymnospermic seeds and seed-bearing organs from the Karharbari beds of the Giridih Coalfield, Bihar. *Palaeobotanist* **13**(1) : 45-56.

Maithy, P. K. 1965c. Studies in the Glossopteris flora of India—20. *Noeggerathiopsis* and allied remains from the Karharbari beds, Giridih Coalfield, India. *Palaeobotanist* **13**(1) : 94-100.

Maithy, P. K. 1965d. Studies in the *Glossopteris* flora of India—25. Pteridophytic and ginkgoalean remains from the Karharbari beds, Giridih Coalfield, India. *Palaeobotanist* **13**(3) : 239-247.

Maithy, P. K. 1965e. Studies in the Glossopteris flora of India—26. Glossopteridales from the Karharbari beds, Giridih Coalfield, India. *Palaeobotanist* **13**(3) : 248-263.

Maithy, P. K. 1965f. Studies in the Glossopteris flora of India—27. Sporae dispersae from the Karharbari beds in the Giridih Coalfield, Bihar. *Palaeobotanist* **13**(3) : 291-307.

Maithy, P. K. 1965g. Studies in the Glossopteris flora of India—32. On the genus *Gangamopteris* McCoy. *Palaeobotanist* **14**(1-3) : 46-51.

Maithy, P. K. 1966. Palaeobotany and stratigraphy of the Karharbari Stage with special references to the Giridih Coalfield, India. *in* : *Symposium on Floristics and Stratigraphy of Gondwanaland*, Birbal Sahni Institute of Palaeobotany, Lucknow, pp. 102-109.

Maithy, P. K. 1969a. Studies in the Glossopteris flora of India—39. On some new plant fossils from the Karharbari beds, Giridih Coalfields Bihar, India. *Palaeobotanist* **18**(2) : 167-172.

Maithy, P. K. 1969b. The contemporaneity of the Karharbari flora in Gondwana. *in*: Santapau, H. *et al.* (eds)—*J. Sen Mem. Vol.*, Bot. Soc. Bengal, Calcutta : 274-298.

Maithy, P. K. 1977. Revision of some fossil plants from the Karharbari Formation, Giridih Coalfield, Bihar. *Palaeobotanist* **23**(3) : 220-222.

Maithy, P. K. & Misra, P. K. 1984. A new Cyanophycean remain from the Karharbari Formation, Giridih Coalfield, Bihar. *Palaeobotanist* **32**(2) : 130-133.

McClelland, J. 1848. Report Geol. Surv. India 1848-49 : *in* Fox, 1934.

Meyen, S. V. 1987. *Fundamentals of Palaeobotany*. Chapman & Hall, London and New York.

Pant, D. D. 1982. The Lower Gondwana Gymnosperms and their relationships. *Rev. Palaeobot. Palynol.* **37** : 55-70.

Pant, D. D. & Gupta, K. L. 1968. Cuticular structure of some Indian Lower Gondwana species of *Glossopteris*. *Palaeontographica* **124B** : 45-81.

Pant, D. D. & Kidwai, Parveen 1968. On the structure of stem and leaves of *Phyllotheca indica* Bunbury. *Palaeontographica* **121B** : 102-121.

Pant, D. D. & Nautiyal, D. D. 1965. Seed bearing *Ottokaria*-like fructification from India. *Nature* **207**(4997) : 623-624.

Pant, D. D. & Nautiyal, D. D. 1966. On two peculiar fossils of Karharbari Stage, India. *in* : *Symposium on Floristics & Stratigraphy of Gondwanaland*, Birbal Sahni Institute of Palaeobotany, Lucknow, pp. 98-101.

Pant, D. D. & Nautiyal, D. D. 1967 On the structure of *Buriadia heterophylla* (Feistmantel) Seward & Sahni and its fructification. *Phil. Trans. R. Soc. Lond.* **252B**(774) : 27-48.

Pant, D. D. & Nautiyal, D. D. 1984. On the morphology and structure of *Ottokaria zeilleri* sp. nov.—a female fructification of *Glossopteris*. *Palaeontographica* **193B** : 127-152.

Pant, D. D., Nautiyal, D. D. & Misra, L. 1981. *Giridia indica* gen. et sp. nov., the possible cone of *Phyllotheca* Bunbury. *Palaeontographica* **176B** : 174-178.

Pant, D. D. & Singh, Sudha 1976. Cuticular structure and affinities of *Cheirophyllum lacerata* (Feistmantel) n. Comb. *Palaeobotanist* **25** : 353-359.

Pant, D. D. & Singh, Sudha 1979. *Canlophyllites indica* gen. et sp. nov. from the Giridih Coalfield, India. *Palaeontographica* **169B** : 107-115.

Pareek, H. S. 1969. Some observations on the lithology of coal-bearing beds and the nature of coal of the major Gondwana basins of India. *in* : *Gondwana Stratigraphy I.U.G.S.* Unesco, Paris 883-904.

Retallack, G. J. 1980. Late Carb. to Mid. Triassic megafossil floras from the Sydney Basin. *in* : Harbert, C. & Helby, R. (eds)—A guide to the Sydney Basin. *Geol. Surv. N.S.W. Bull.* **26** : 384-430.

Sastry, M. V. A., Acharyya, S. K., Shah, S. C., Satsangi, P. P., Ghosh, S. C., Raha, P. K., Singh, G. & Ghosh, R. N. 1977a. Stratigraphic lexicon of Gondwana formations of India. *Geol. Surv. India Misc. Publ.* (36) : 1-99.

Sastry, M. V. A., Acharyya, S. K., Shah, S. C., Satsangi, P. P., Ghosh, S. C. & Singh, Gopal 1977b. Classification of Indian Gondwana Sequence—A reappraisal. *4th int. Gondw. Symp., Calcutta* **2** : 502-509.

Sen, J. 1953. Principles and problems of microfloral correlation of Indian coal seams with special reference to Karharbari. *Bull. natn. Inst. Sci. India* **2** : 129-140.

Sah, S. C., Singh, Gopal & Sastry, M. V. A. 1971. *Annls Geol. Dept. A.M.U., Aligarh* **5-6** : 306-326.

Shukla, Manoj 1983. Lithostratigraphy and palynostratigraphy of the Lower Gondwana formations in the Hutar Coalfield, Bihar, India. *Palaeobotanist* **31**(2) : 176-190.

Singh, Gopal, Maithy, P. K. & Bose, M. N. 1982. Upper Palaeozoic flora of Kashmir Himalaya. *Palaeobotanist* **30**(2) : 185-232.

Singh, Trilochan 1979. Palynostratigraphy of the Permian rocks of Siang District, Arunachal Pradesh. *in* : Verma & Bagchi (eds)—*Metamorphic rock sequences of the Eastern Himalaya* : 100-113.

Srivastava, S. C. 1973. Palyno-stratigraphy of the Giridih Coalfield. *Geophytology* **3**(2) : 184-194.

Srivastava, S. C. & Dutta, S. K. 1978. A note on the palynology of Siang District, Arunachal Pradesh. *Geophytology* **7**(2) : 281-284.

Tappan, Helen 1980. *The palaeobiology of plant protists*. Freeman and Company. San Francisco, pp. 1-1028.

Tewari, B. S. & Singh, R. Y. 1980. The significance and occurrence of the Late Palaeozoic plant remains in the Infrakrol sequence of Nainital, U. P. *Bull. Indian Geol. Assoc.* **12**(2) : 263-266.

Tiwari, R. S. 1974. Inter-relationship of palynofloras in the Barakar Stage (Lower Gondwana), India. *Geophytology* **4**(2) : 111-129.

Tiwari, R. S. 1979. Palynostratigraphy of Permo-Triassic transition in India. *Proc. IV int. palynol. Conf., Lucknow (1976-77)* **2** : 199-207, Birbal Sahni Institute of Palaeobotany, Lucknow.

Tiwari, R. S., Singh, Vijaya, Kumar, S. & Singh, I. B. 1984. Palynological studies of the Tethyan Sequence in Malla Johar area, Kumaon Himalaya, India. *Palaeobotanist* **32**(3) : 341-367.

Tiwari, R. S., Tripathi, A., Kumar, S., Singh, I. B. & Singh, S. K. 1980. Gondwana plant microfossils from the Tethyan sediments, Malla Johar area, Uttar Pradesh. *J. palaeont. Soc. India* **23**, **24** : 39-42.

Virkki, C. 1938. A Lower Gondwana flora from the Salt Range, Punjab. *Proc. 25th. Indian Sci. Congr.* pt. III : 150.

Virkki, C. 1945. Spores from the Lower Gondwana of India and Australia, *Proc. natn. Acad. Sci. India* **15** : 93-176.