Early Permian microfossils in faunal Coal Balls from Arunachal Pradesh, India - Phytogeographic And Palaeoenvironmental significance

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Faunal coal balls occurring in Bomte Member of the Garu Formation (Early Permian) from West Siang District, Arunachal Pradesh, India contain a rich assemblage of spores and pollen grains comprising 42 genera and 48 species. The quantitative distribtution of various palynotaxa show the dominance of radial monosaccate pollen chiefly *Parasaccites*, in association with trilete spores - *Callumispora* and *Indotriradites*. This assemblage occurs in coal balls having typical invertebrate Sakmarian fauna and is comparable with the Karharbari palynoassemblages known from Early Permian sediments of peninsular India. Presence of acritarchs, conodont, scolecodont jaws, ? Chitinozoa and foraminifera in this assemblage suggests deposition of these sediments in marginal swamps subjected to periodic marine incursions during Early Permian. The occurrence of coal balls further indicates that atleast the Permian sediments of Siang District in Arunachal Pradesh are autochthonous in nature and contrary to the Permian sediments of peninsular India which are believed largely to be allochthonous deposits. The above palynoflora alongwith the invertebrate faunal association exhibit strong similarities between India and Western Australia during Early Permian.

Key-words - Microfossils, Faunal coal balls, Early Permian, India.

INTRODUCTION

THE Permian sediments in Arunachal Pradesh are disposed in a linear belt all along the foot hills of Lesser Himalaya and are tectonically placed between the Tertiary rocks in the south and metamorphic rocks of Miri Group in the north. This sequence is often compared with the Lower Gondwana (Permian) sequence in Peninsular India on the basis of their fossil contents and gross lithological set up. These sediments exhibit; (a) continental facies with Glossopteris flora and, (b) marginal facies with typical marine fauna (Acharyya *et al.*, 1975). In Siang District the Permian sediments have been divided into the Rangit Formation overlain gradationally by the Garu Formation (Srivastava & Bhattacharyya 1996). The latter is characterised by repeated alternate sequences of sandstone, carbonaceous shale and coal. In between the coaly horizons are entombed innumerable mineral concretions of various shapes and sizes which have been recently designated as faunal coal balls (Anand - Prakash *et al.*, 1988) since they contain a varied assemblage of invertebrate fossils comprising brachiopods, gastropods, cephalopods, crinoid remains and bryozoa (Singh 1983) indicating Early Permian age.

The presence of these faunal coal balls is distinctly visible on the outcrop surface by their round to subrounded, oval-elongated shape; size varying from 1 cm to 30 cm but concretions occasionally upto 50 cm in diameter have also been recorded. They are hard, compact and massive in nature and are found embedded in sediments both along and across the bedding plane and are distributed randomly over the entire exposed surface. The faunal coal balls are more frequent and numerous in the basal horizon of the Garu Formation and occur in a linear belt from Litemari village in the west to Renging in the east of West Siang District.

In the basal horizon of the Garu Formation (Lower Member, Fig. 1) the frequency of occurrence of faunal coal balls is higher towards west between Garu and Litemari villages while it gradually decreases laterally towards Renging village in the east. In the Middle Member of the Garu

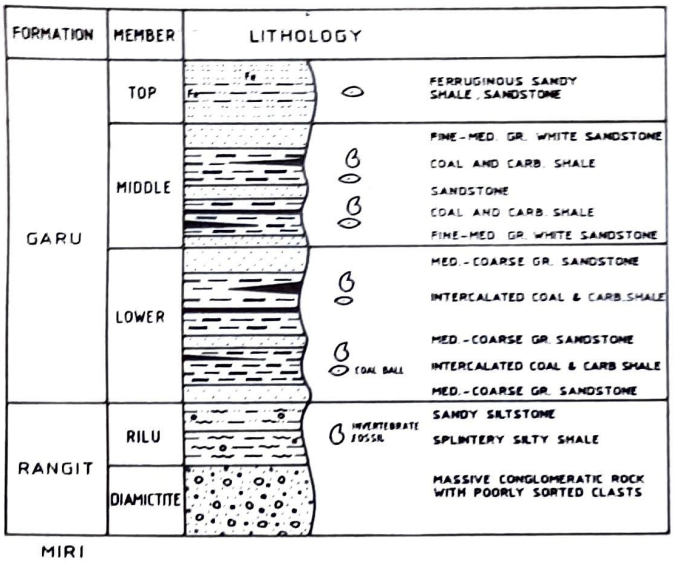


Figure 1. Lithological succession of Permian sequence in West Siang District, Arunachal Pradesh, India (Not to scale).

Formation, the frequency of occurrence of such coal balls is comparatively reduced and are present around Gensi village. Well preserved invertebrate fossils either form a nucleus or they are dispersed irregularly in the entire coal ball. It is rather difficult to isolate these fossils from the coal balls due to hardness of the matrix. The faunal coal balls are mostly composed of calcium carbonate, magnesium carbonate with varying proportions of clay and silt. Some coal balls also contain small amount of calcium phosphate and iron sulphide.

In addition to these there are concretions that exhibit concentric rings with pyrite mineralization and rarely contain fossils. In such concretions calcite often form the nucleus. These concretions are randomly distributed alongwith the faunal coal balls associated with the coal and carbonaceous shales. In younger sediments towards top of the Garu Formation, characterised by ferruginous sandy shales and sandstone, the concretions are mostly rounded and comparatively smaller in size. They are rich in iron-oxide and iron-sulphide and many of them contain crenoidal remains.

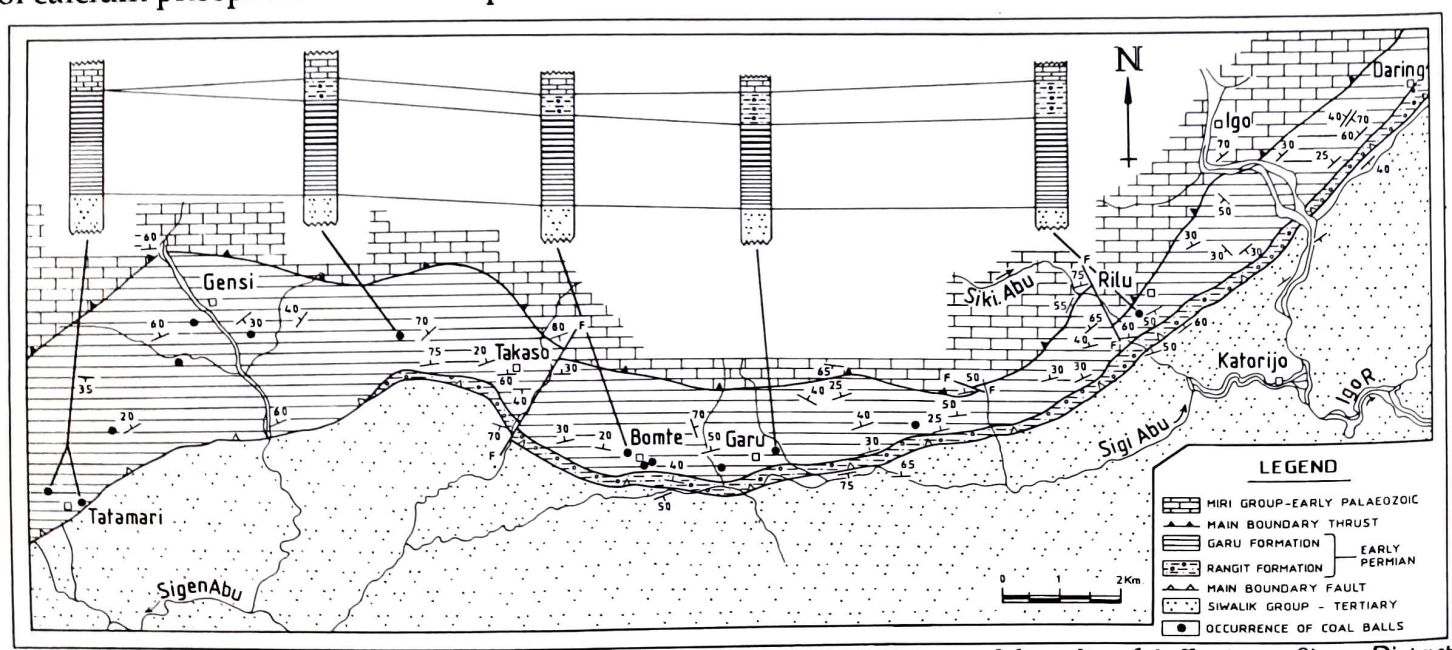
The faunal coal balls associated with the coal and carbonaceous shales of the Garu Formation, apart from yielding a variety of invertebrate fossils have also yielded a rich assemblage of spores and pollen grains, leiosphaerids, and acritarchs alongwith foraminifera, conodont and scolecodont jaws and flask shaped vesicles like chitinozoa. The present paper deals with such microremains from West Siang District of Arunachal Pradesh, India. The location of the coal balls investigated is shown in Map 1.

Palynoassemblage

The microfossils (Plate 1) recovered from the faunal coal balls are represented by 42 genera and 48 species of spores and pollen grains which are listed below:

Trilete spores

Leiotriletes erectus Kar



Map 1. Dsitribution of different lithounits of Permian sequence and occurrence of faunal coal balls, West Siang District, Arunachal Pradesh, India (Map after Singh 1987).

Apiculatisporis cornutus (Balme & Hennelly) Segroves

Brevitriletes unicus (Tiw.) Bharadwaj & Srivastava emend. Tiwari & Singh

Granulatisporites sp.

Imparitriletes korbaensis Tiwari & Singh

Lophotriletes minimus Salujha

Microbaculispora tentula Tiwari

Didecitriletes horridus (Venkatachala & Kar) Tiwari & Singh

Callumispora gretensis (Balme & Hennelly) Bharadwaj & Srivastava emend. Tiwari, Srivastava, Tripathi & Singh

Lobatisporites gondwanensis Tiwari & Moiz

Diatomozonotriletes townrowii Segroves

Horriditriletes curvibaculosus Bharadwaj & Salujha

Pseudoreticulatispora barakarensis Bharadwaj & Srivastava

Trilete-zonate/cingulate spores

Indotriradites korbaensis Tiwari

I. surangei Tiwari

Dentatispora gondwanenis Tiwari

D. crassa Tiwari

D. implicata Tiwari

Jayantisporites pseudozonatus Lele & Makada

Densoisporites solidus Segroves

Monosaccate pollen

Parasaccites korbaensis Bharadwaj & Tiwari

P. densicorpus Lele

P. obscurus Tiwari

Plicatipollenites gondwanensis (Balme & Hennelly) Lele

P. indicus Lele

Caheniasccites indicus Srivastava

C. elongatus Bose & Kar

Divarisaccus lelei Venkatachala & Kar

D. strengeri Bose & Kar

Crucisaccites indicus Srivastava

Potonieisporites novicus Bharadwaj

Sahnites congoensis (Bose & Maheshwari) Tiwari & Singh

S. thomasi (Pant) Tiwari & Singh

S. methoris (Hart) Tiwari & Singh

Vestigisporites diffusus Maithy

V. notus (Lele & Karim) Tiwari & Singh

Virkkipollenites congoensis Bose & Kar

Non-striate Disaccate pollen

Scheuringipollenites maximus (Hart) Tiwari

Paravesicaspora indica (Tiwari) Bharadwaj & Dwivedi

Striate Disaccate pollen

Striatopodocarpites decorus Bharadwaj & Salujha

Faunipollenites varius Bharadwaj

Striatites varius Kar

Tiwariasporis simplex (Tiwari) Maheshwari & Kar

Marsupipollenites sp.

Lueckisporites sp.

Monocolpate pollen grain

Ginkgocycadophytus cymbatus (Balme & Hennelly) Potonie & Lele

Incertae sedis

Quadrisporites horridus Hennelly

Spongocystia eraduica Segroves

Leiosphaeridia talchirensis Lele & Karim

Maculatasporites gondwanensis Tiwari

Botryococcus braunii Kützing

Micrhystridium sp.

Balmeella sp.

In addition to the above spores and pollen few other microfossils have also been recorded from the faunal coal balls:

Foraminifera - *Palaeotextularia* sp.

Chordata - Conodont jaw

Annelida - Scolecodont jaws

? Chitinozoa–like vesicle

Foraminifera - They are aquatic, mainly marine protocysts which secrete a shell, the TEST, which are composed of calcium cabonate. On the basis of structure and composition of these tests they have been divided into five orders. Foraminifera with agglutinated tests are characteristic of near - shore and brackish water habitats. The tests present in coal balls here are agglutinated, multilocular and biserial with chambers alternating in two series. They have been tentatively placed in the genus *Palaeotextularia*.

Conodont - These remains, generally referred to the Phylum - Chordata, are microscopic in size, tooth - like, brownish in colour and glossy in appearance. They are made up of calcium phosphate together with organic proteinaceous matter resem-

bling teeth and are normally described using terms appropriate to teeth.

Conodonts are widespread in marine rocks including limestones and are stratigraphically valuable since they show rapid evolutionary change. Such fossils are found numerously during Silurian but they reduced untill late Devonian. In late Carboniferous a decline set in and continued upto late Triassic in limited numbers.

In Garu Formation of East Siang District, their presence in calcareous faunal coal balls is rare yet significant.

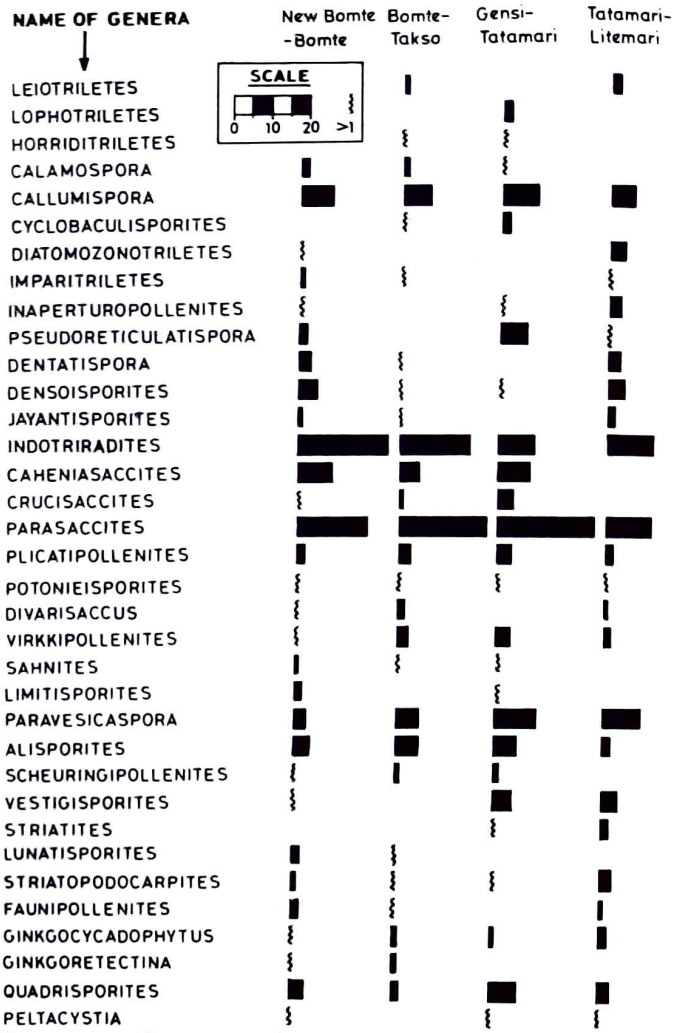
Scolecodonts - Most of the annelids are free - living, either pelagic or benthic but some of these are predators with chitinous jaws. There record is patchy and are most abundant in Silurian and Devonian.

In Permian faunal coal balls of Siang District a number of such chitinous jaws have been recorded which exhibit distinct morphological variation. However, their rare occurrence and restricted number of specimens precludes further morphotaxonomic categorisation.

? Chitinozoa - The chitinozoa-like remains are hollow flasks of bottle-shaped vesicles of unknown affinities. The vesicles are open at one end and the wall consists of a chitinous organic substance, pseudochitin. The wall is two-layered and dark coloured. Chitinozoans are confined to marine deposits of Palaeozoic age.

Such vesicles recorded in Permian coal balls of Siang District are dark brown in colour, flask-shaped with an opening through a well defined collar.

The qualitative and quantitative estimation of spores and pollen grains show that among the pteridophytic spores *Indotriradites* is most common



Histogram 1. Percentage frequency of spore-pollen grains in faunal coal balls from West Siang District, Arunachal Pradesh, India.

and occurs between 11-12 percent (Historam-1). The other zonate-cingulate trilete spores are rare in occurrence and are mostly represented by *Dentatispora, Jayantisporites* and *Densoisporites.* The trilete spore *Callumispora* is persistently represented (6%). In addition to this *Leiotriletes, Horriditriletes, Granulatisporites, Verrucosisporites, Imparitriletes* and *Lophotriletes* are also present in

Plate 1

(All photomicrographs unless stated X 500; EF = England Finder; Scale bar = 10 μm)

1. *Callumispora gretensis*, BSIP Sl No. 10731, EF No. E 40/4.
2. *Indotriradites korbaensis*, BSIP Sl No. 10722, EF No. L 35/3.
3. *Horriditriltes* sp., BSIP Sl No. 10722, EF No. V 63/4.
4. *Quadrisporits horridus*, BSIP Sl No. 10726, EF No. S 43/2.
5. *Parasaccites diffusus*, BSIP Sl No. 19734, EF No. K 25/2.
6. *Plicatipollenites gondwanensis*, BSIP Sl No. 10726, EF No. Y 42/1.
7. &10. *Foraminifera*, 7-BSIP Sl No. 10538, EF No. T 36/2 (Under Differential Interference Contrast), 10-BSIP Sl No. 10538, EF No. U 51/4.
8. *Pseudoreticulatispora barakarensis*, BSIP Sl No. 10732 EF No. N 33/1
9. *Tetraporina* sp., BSIP Sl No. 10733, EF No. J 57/2
11. ?Chitinozoa- like vesicle 11. BSIP Sl No. 10537, EF No. U 54/2
12. *Micrhystridum* sp., BSIP Sl No. 10725, EF No.K 14/2
13. *Dentatispora* sp., BSIP Sl No. 10727, EF No. Q 62/4
14-16. Scolecodont Jaws, 14- BSIP Sl No. 10723, EF No. Y 55/3; 15-BSIP 10722, EF No. R 41/2; 16- BSIP Sl No. 19736, EF No. W 57/4
17. Conodont, BSIP Sl No. 10539, EF No. S 30/4

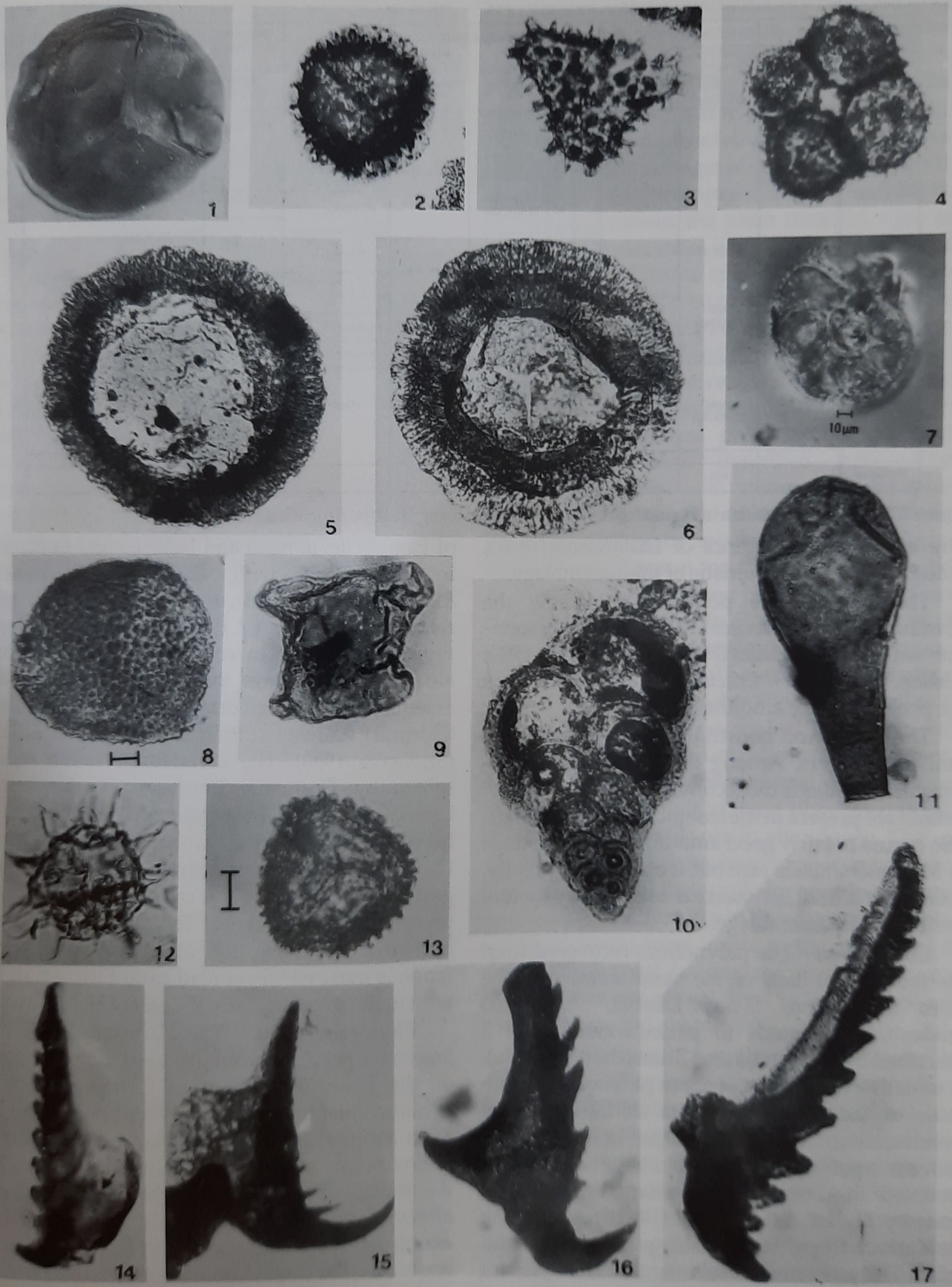


Plate 1

INDIAN GONDWANA		WEST SIANG DISTRICT		WESTERN AUSTRALIA COLLIE BASIN			INTERNATIONAL	COLLIE COALFIELD	EASTERN AUSTRALIA	KAROO BASIN	SOUTH-AFRICA KAROO-BASIN
Lithostratigraphy	Palynozones Tiwari & Tripathi-1992	Lithostratigraphy	Palynozones Srivastava & Bhattacharyya/1996	Lithostratigraphy Le Blanc Smith-1993			Stage / Substage	Palynostratigraphy Backhouse-1991	Kemp et al. 1977 Price-1983	Microfloral Zones Anderson-1977	Lithostratigraphy
BARAKAR	F.varius	GARU FORMATION	P.ovatus + R.indica P.barakarensis C.indicus C.gretensis	P2	COLLIE GROUP	PREMIER COAL MEASURES	Bigendzinian	M. villosa	Upper Stage-4b	4a 3d	VOLKRUST FORMATION
								P.sinuosus consistent occurrence	Upper Stage-4a	3c	
						ALLANSON SANDSTONE		P.sinuosus	Lower Stage-4	3b	
	S.barakarensis			P1		EWINGTON COAL MEASURES	Aktastinian	M.trisina	Stage-3b	2d	VRYHEID FORMATION
								S. fusus	Stage-3a	2c	
KARHARBARI	C.monoletus					WESTRALIA SANDSTONE	Sterlitamaklan	P.pseudoreticulata		2b 2a	
							Tastubian	P.confluence			
TALCHIR	P.korbaensis P.gondwanesis P.neglectus	RANGIT FORMATION	P.korbaensis P.stigmatus		STOCKTON GROUP	MOORHEAD FORMATION	? Asselian	Stage - 2	Stage - 2	1	PIETER MARITZBURG FORMATION
						SHOTTS FORMATION					DWYKA FORMATION
ARCHAEAN		MIRI		ARCHAEAN							

Figure 2. Tentative correlation of Permian palynozones of West Siang District, Arunachal Pradesh, India.

rare amounts. Occurrence of *Diatomozonotriletes*, though rare, is characteristic of this assemblage.

The monosaccate pollen grains show the dominance of *Parasaccites* (12.5-25.0%) in association with *Caheniasaccites* (7%), *Plicatipollenites* (3%), *Virkkipollenites* (2%). *Crucisaccites* and *Divarisaccus* are present in rare amounts.

The striate and nonstriate pollen grains are in limited numbers. Among the alete spores *Quadrisporites horridus* is most common and a number of tetrads are present in the assemblage. *Leiosphaeridia* also occurs in fairly good amounts. The percentage of *Micrhystridium* is rare but it occurs persistently. *Spongocystia* and *Botryococcus* are also frequently present in the assemblage.

Correlation - The palynoflora recovered from the faunal coal balls of the basal member of the Garu Formation, Siang District, Arunachal Pradesh, corresponds to palynozones 2 and 3 described by Srivastava and Bhattacharyya (1996). A tentative correlation of these palynozones with those of the peninsular India as well as other Gondwanic continents is attemped in figure 2. The above two palynozones together have been accommodated in *Crucisaccites monoletus* Assemblage Zone by Tiwari and Tripathi (1992) representing the Karharbari palynoassemblage in Indian peninsular Early Permian sediments. The present palynoassemblage show maximum development of *Parasaccites diffusus* and *Indotriradites korbaensis* in association with *Callumispora gretensis*, *Microbaculispora tentula*, and *Jayantisporites pseudozonatus*. *C. gretensis* + *J. pseudozonatus* assemblage representing the Lower Karharbari palynoflora also occur just above the *Quadrisporites horridus* assemblage (Talchir Formation) from Paradole - Chirimiri Railway cutting of Chirimiri Coalfield (Srivastva 1980). The invertebrate fauna represented by *Tivertonia*, *Strophalosia*, *Costatumulus*, *Cyrtella*, *Subansiria*, *Tomiopsis* and *Trigonotreta* have been recovered from the faunal coal balls of Siang District by Archbold and Singh (1993) which suggest late Tastubian age. A coquina of *Productus* is present in Leena Abu near Tatamari village. These horizons containing the above microflora and fauna is most widely spread from Litemari in the west to Renging village in the east of Siang District.

Phytogeography - The *Granulatisporites confluence* Oppel-Zone from glacio-marine sediments of the Grant Formation of Canning Basin in Western Australia (Foster & Waterhouse 1988) has been assigned to late Tastubian on the basis of palynofloral as well as faunal contents. The Australian palynoflora is highly diversified and almost all the palynotaxa share in common with the above palynoassemblage described here except *G. confluence*. The faunal contents of this zone from the above two places too share in common, viz. *Tomiop-*

sis and *Strophalosia*. It is more appropriate to compare the palynocontents of the Siang District with palynozone Unit-II of Canning Basin in Western Australia (Kemp *et al.* 1977) in view of the presence of *C. gretensis, M. tentula, J. pseudozonatus, I. korbaensis* and overwhelming presence of radial monosaccate pollen. The presence of *Densoisporites solidus* and *Diatomozonotriletes townrowii* is the first record from the Early Permian of India and its notable presence in Nangetty Formation (Late Sakmarian) of Perth Basin, Western Australia (Segroves 1970) permits correlation of two areas. The presence of *Pseudoreticulatispora barakarensis* in the coal balls is also correlatable with *P. pseudoreticulata* zone from the Collie Basin (Le Blanc Smith & Backhouse 1964) in Western Australia. The brachiopod fauna of the Garu Formation further substantiates this contention in having closer links with the Fossil Cliff Formation and Calythara Formation in Western Australia in view of the presence of *Tomiopsis, Tivertonia, Strophalosia, Costatumulus, Trigonotreta, Cyrtella* and *Subansiria*. In the continental fit proposed by Smith and Hallam (1970) the eastern edge of the Indian plate lies in Assam and is separated from Australia through an oceanic gulf known as "*Sinus Australia*". Datta and Mitra (1982) proposed that continental blocks existed in place of the oceanic gulf supporting the concept of a *Greater India* (Veevers *et al.* 1975). In this reconstruction the eastern margin of India was partly in juxtaposition with south-west Australia. With this continental fit the palynofloral and faunal links of Arunachal Pradesh with Western Australian basins get further substantiated. Strong palynofloral linkages between Indian and West Australian basins (Collie Basin) have also been advocated by Le Blanc Smith and Backhouse (1994). Truswell (1980) have made broad inter-regional palynological correlations beween the two continents. Singh (1987), Archbold and Singh (1993) have also drawn similar biogeographic relationship between India and Australia on the basis of brachiopod assemblage.

DISCUSSION

The mineral concretions, termed as "faunal coal balls" recently (Anand-Prakash *et al.* 1988) as per classification of Mamay and Yochelson (1962), occurring in the coal and associated sediments of the Garu Formation, Siang District, Arunachal Pradesh are massive, calcareous, generally rounded to subrounded and are composed of homogeneous matrix. In the sense of Mamay and Yochelson (1962), Eggert and Phillips (1982) a true "coal ball" signifies permineralised masses of peat embedded in coal seams and preserving the plant and animal remains in various stages of decay or disintegration in more or less uncompressed state. In these permineralised masses the plant material were embedded in a peat mass early in the history of the peat deposition before compaction or coalificaion beyond the level of peat or, at the most lignite, had occurred. In the Garu Formation well preserved invertebrate marine fossils entombed in these concretions exhibit no observable sign of compression. These fossil-bearing concretions also contain well preserved spores and pollen grains alongwith other microremains described here. These microfossils are also well preserved, more spherical and show little effect of bilateral compression. All these concretions appear to have been formed *in situ* during the peat forming stage in near shore lagoons which were being periodically influenced by marine incursions. In Siang District workable coal seams are nearly absent and the coal occurs as thin seams or stringers. These faunal coal balls are present haphazardly within the coal as well as the associated carbonaceous shales. These coal balls compare with the true coal balls to greater extent as explained above. The true faunal coal balls considered here have not yielded plant megafossils, however, microfossils are in abundance. The true coal balls appear to have been formed in very short interval in view of their uniform permineralisation and there is no difference in the magnitude of plant / animal fossils from inside to the margin of the coal balls. The coal / carbonaceous shale beds containing them are also aligned in accordance with the curvature and shape of the coal balls.

There are many concretions found associated with the black/carbonaceous shales which do not contain invertebrate/plant megafossils but have yielded extensively degraded plant microfossils. Calcareous concretions having concentric rings and associated with carbonaceous shales have not yielded fossils of any kind. All such concretions have been exluded from the category of true faunal coal balls considered above. Similarly, the concretions associated with ferruginous shales containing

highly degraded crinoidal remains at the top of the Garu Formation have been considered as simple concretions.

The presence of faunal coal balls indicate seaward exension of the peat swamps that were off and on being inundated by the sea across the off-shore barriers. The marine invertebrates might have invaded the swamps during high tides. The enrichment of salt water in the swamps favoured conditions for the coal ball petrifaction and preservation of animal remains unabatedly. The basin also appears to have been fed by some channels supplying fresh water and land-drived sediments along with spores and pollen grains to the coal-forming swamp. The palynoassemblages of the coal balls are similar and also the sediments entombing them suggesting contemporaneity.

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