Palynostratigraphy and palynofacies analysis of subsurface Permian sediments in Talcher Coalfield, Orissa

Archana Tripathi

Tripathi Archana 1997. Palynostratigraphy and palynofacies analysis of subsurface Permian sediments in Talcher Coalfield, Orissa. *Palaeobotanist* **46**(3) : 79-88.

Palynological analysis of subsurface sediments in bore-hole TCC-19 near Chhendipada, Talcher Coalfield, Orissa reveals the presence of a Permian palynoflora both below and above the key marker horizon—a conglomeratic pebble bed. The presence of acritarchs in the assemblage suggests brackish water conditions; the palynofacies analysis indicates low energy lacustrine conditions during the deposition of these sediments.

Key-words—Palynology, Palynostratigraphy, Palynofacies, Palaeoenvironment, Early Permian, India.

Archana Tripathi, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

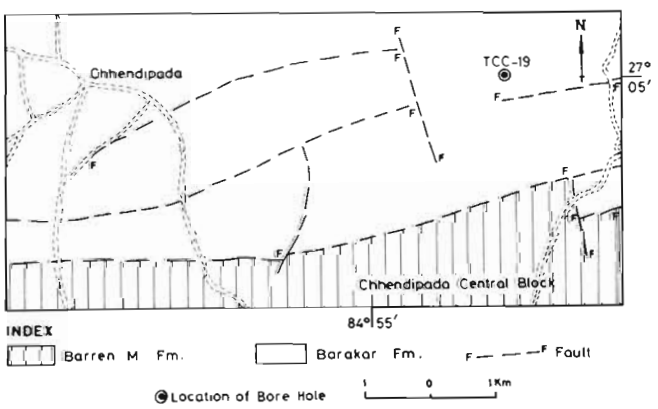
सारांश

उड़ीसा के तलचीर कोयला-क्षेत्र में उपसतही परमियन अवसादों का परागाणुस्तरविन्यास एवं परागाणविक विश्लेषण

अर्चना त्रिपाठी

उड़ीसा के तलचीर कोयला-क्षेत्र में उपसतही परमियन अवसादों के परागाणुस्तरविन्यास एवं परागाणु संलक्षणी विश्लेषण से व्यक्त होता है कि मुख्य संस्तर के नीचे और ऊपर परमियन कालीन परागाणुवनस्पतिजात विद्यमान है। इस समुच्चय में एक्रीटार्कों की उपस्थिति से खारे जल वाली परिस्थितियों का होना इंगित होता है जबकि परागाणु संलक्षणी विश्लेषण से इन अवसादों के निक्षेपण के समय कम शक्ति वाली सरोवरी परिस्थतियों का होना व्यक्त होता है।

RECENT palynological studies in the Talcher Coalfield have revealed the presence of a Late Permian palynoassemblage in coal-bearing sediments cropping out in Madalia River near Patrapara (Tiwari *et al.*, 1991). In an attempt to understand the palynostratigraphy of these Gondwana sediments core samples from bore-hole TCC-19 were studied. This 318 m deep bore-hole was drilled by the Geological Survey of India near Chhendipada (Map 1) and intersected about five metres of conglomeratic pebble bed, sandwitched between the Lower Gondwana coal horizon pertaining to Barakar Formation.



Map 1—Showing location of bore-hole TCC-19 in the Talcher Coalfield, Orissa.

OBSERVATIONS

Seventeen samples were palynologically analysed (Table 1), all but one (greenish shale, 318 m depth) represented coal beds. Most of the samples were rich in organic matter, including spore-pollen, acritarch, wood, cuticle; three samples had a high spore-pollen content. These were used for detailed palynological analysis. The richness of organic material in most of

Table 1—List of samples in bore-hole TCC-19, Chhendipada Block, Talcher Coalfield, Orissa

Depth	Lithology	Remarks
10.75 - 27.85	Coal	full of wood pieces, spore-pollen rare
47.41 - 60.47	Coal	rich in other plant tissues, spore-pollen and wood pieces comparatively less
about 5 m thick conglomeratic bed ————		
65.60 - 67.21	Coal	rich in spore-pollen and plant tissues, wood pieces comparatively less
70.86 - 79.12	Coal	full of wood pieces, spore-pollen rare
80.50 - 87.83	Coal	full of wood pieces, spore-pollen rare
91.81 - 92.51	Coal	full of wood pieces, spore-pollen rare
103.30 - 104.05	Coal	full of wood pieces, spore-pollen absent
113.60 - 115.30	Coal	full of wood pieces, spore-pollen rare
117.60 - 118.35	Coal	full of wood pieces, spore-pollen comparatively less
132.43 - 133.15	Coal	full of wood pieces, spore-pollen comparatively less
154.37 - 155.42	Coal	full of wood pieces, spore-pollen rare and broken
159.91 - 162.52	Coal	full of wood pieces, spore-pollen rare
167.29 - 167.81	Coal	full of wood pieces, spore-pollen rare
168.28 - 169.22	Coal	full of wood pieces, spore-pollen comparatively less
170.96 - 172.11	Coal	rich in wood pieces and other plant tissues, spore-pollen comparatively less and broken
177.04 - 177.24	Coal	full of wood pieces, spore-pollen comparatively less
318.00	Greenish shale	spore-pollen poor

the samples allowed palynofacies analysis. In the present study the palynofacies analysis was used for palaeoenvironmental interpretation. The palynological slides have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

PALYNOSTRATIGRAPHICAL ANALYSIS

Following taxa are present in the palynoflora of bore-hole TCC-19.

Cyclogranisporites gondwanensis Bharadwaj & Salujha 1964

Cyclogranisporites optimus Bharadwaj & Salujha 1965

Cyclobaculisporites indicus Bharadwaj & Salujha 1964

Cyclobaculisporites minutus Bharadwaj & Salujha 1964

Brevitriletes communis Bharadwaj & Srivastava emend. Tiwari & Singh 1981

Brevitriletes unicus Bharadwaj & Srivastava emend. Tiwari & Singh 1981

Microfoveolatispora foveolata Tiwari emend. Tiwari & Singh 1981

Microbaculispora tentula Tiwari 1965

Microbaculispora barakarensis Tiwari 1965

Callumispora gretensis (Balme & Hennelly) Bharadwaj & Srivastava emend. Tiwari *et al.* 1989

Lacinitriletes badamensis Venkatachala & Kar 1965

Lacinitriletes minutus Venkatachala & Kar 1968

Letotriletes sp.

Indotriradites sparsus Tiwari 1965

Horriditriletes novus Tiwari 1965

Verrucosisporites sp.

Faunipollenites varius Bharadwaj emend. Tiwari *et al.*1989

Faunipollenites perexiguus Bharadwaj emend. Tiwari, *et al.*1989

Striatopodocarpites decorus Bharadwaj & Salujha 1964

Striatopodocarpites multistriatus Tiwari 1965

Crescentipollenites fuscus (Bharadwaj) Bharadwaj *et al.*1989

Verticipollenites secretus Bharadwaj 1962

Striatites altus Venkatachala & Kar 1968

Striatites solitus Bharadwaj & Salujha 1964

Striatites communis Bharadwaj & Salujha 1964

Labirites incertus Bharadwaj & Salujha 1964

Rhizomaspora indica Tiwari 1965

Primuspollenites levis Tiwari 1965

Primuspollenites obscurus Tiwari 1965

Primuspollenites dicavus Tiwari 1965

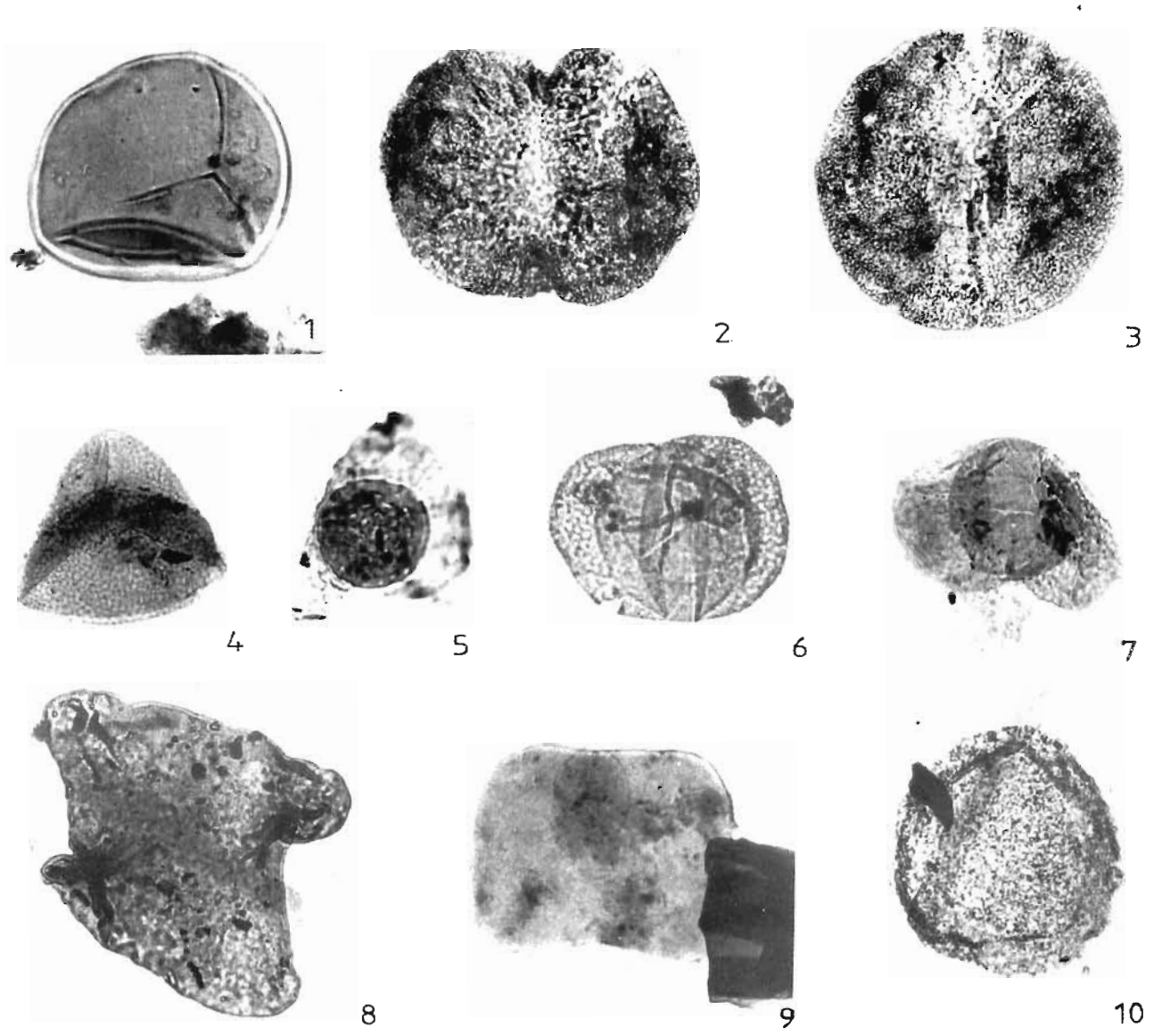


PLATE 1

(All photomicrographs are X 500)

1. *Callumispora*, Slide no. BSIP 11394
2. *Primuspollenites*, Slide no. BSIP 11392
3. *Scheuringipollenites*, Slide no. BSIP 11392
4. *Microbaculispora*, Slide no. BSIP 11394
5. *Maculatasporites*, Slide no. BSIP 11394
6. *Crescentipollenites*, Slide no. BSIP 11394
7. *Sahnites*, Slide no. BSIP 11394
8. *Tetraporina*, Slide no. BSIP 11391
9. *Balmeella*, Slide no. BSIP 11394
10. *Lophosphaeridium*, Slide no. BSIP 11392

Vestigisporites disectus Hart emend. Tiwari & Singh 1984

Vestigisporites diffusus Maithy 1965

Sahnites thomasi Pant emend. Tiwari & Singh 1984

Sahnites barrelis (Tiwari) Tiwari & Singh 1984

Sahnites methoris (Hart) Tiwari & Singh 1984

Sahnites elongatus (Lele & Karim) Tiwari & Singh 1984

Scheuringipollenites tentulus (Tiwari) Tiwari 1973

Scheuringipollenites barakarensis (Tiwari) Tiwari 1973

Scheuringipollenites maximus (Hart) Tiwari 1973

Ginkgocycadophytes sp.

Tiwariasporis gondwanensis (Tiwari) Maheshwari & Kar 1967

Parasaccites korbaensis Bharadwaj & Tiwari 1964

Parasaccites obscurus Tiwari 1965

Table 2—Relative percentage of spores and pollen in samples from bore-hole TCC-19. Presence of palynomorphs is marked with + in samples where quantitative analysis could not be done; (+) less than 5; (++) more than 5 and less than 15; (+++) more than 15. Details of Groups : I - Acritarchs; II - Striate bisaccate; III - Bisaccate with imperfect striations; IV - Nonstriate bisaccate; V - Radial monosaccate; VI - Trilete and zonate spore; VII - Others

Group		Depth in meters								
		10.75-27.85	47.41-60.47	65.60-67.21	117.60-118.35	132.40-133.15	154.37-155.42 & 159.52-162.52	168.24-169.22	170.96-172.11	177.04-177.24
	Genera									
I	*Balmeella*	-	1	4	-	-	-	+	-	-
	Leiosphaeridia	+	5	1	-	-	-	-	-	-
	Tetraporina	-	1	-	-	-	-	-	-	-
	Lophosphaeridium	-	1	1	-	-	-	-	-	-
II	*Crescentipollenites*	+	1	-	+	+	-	-	+	2
	Faunipollenites	+	38	6	++	+	+	+	+	6
	Striatopodocarpites	+	9	5	+	+	-	+	+	7
	Striatites	-	3	4	-	-	-	-	-	-
	Verticipollenites	-	1	-	-	-	-	-	-	-
III	*Primuspollenites*	-	1	5	-	+	-	-	-	-
	Rhizomaspora	-	1	2	-	-	-	-	-	-
IV	*Platysaccus*	-	2	1	-	-	-	-	-	-
	Paravesicaspora	-	-	1	-	-	-	-	+	-
	Scheuringipollenites	-	32	68	+++	++	+	++	+	8
	Vestigisporites	-	-	-	+	-	+	+	+	3
	Sahnites	+	-	-	-	+	+	++	+	6
V	*Parasaccites*	+	4	2	+	+	+	+	++	8
	Plicatipollenites	-	-	-	-	-	-	-	-	1
VI	*Microfoveolatispora*	-	-	-	-	-	-	-	-	1
	Brevitriletes	-	-	-	++	++	-	+	+++	10
	Microbaculispora	-	-	-	+	+	-	+	++	33
	Lacinitriletes	-	-	-	-	-	-	-	+	4
	Horriditriletes	-	-	-	-	-	-	-	-	1
	Cyclogranisporites	-	-	-	-	-	-	-	+	6
	Indotriradites	-	-	-	+	-	-	++	+	2
VII	*Callumispora*	-	-	-	-	+	-	+	+	1
	Tiwariasporis	-	-	-	-	+	-	-	-	1
	Quadrisporites	-	-	1	-	-	-	-	-	-

Parasaccites bilateralis Tiwari 1965

Cahentasaccites indicus Lele 1964

Potonietsporites lelei Maheshwari 1967

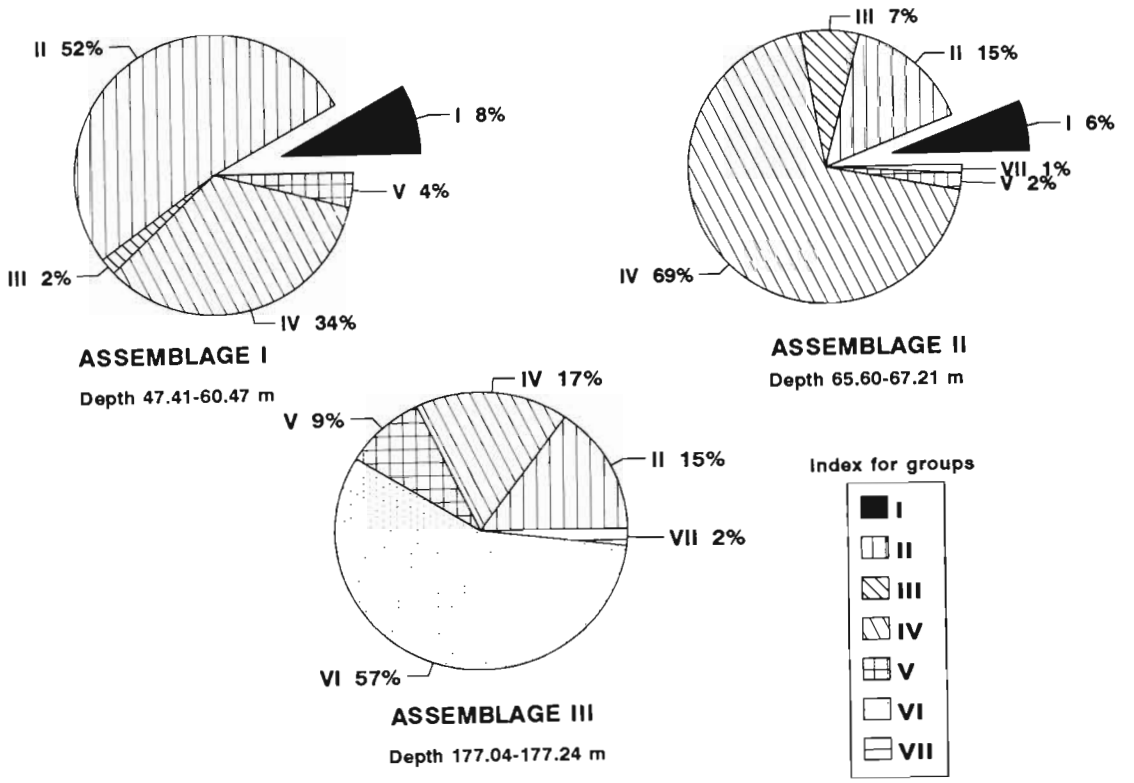
Besides the above mentioned palynomorphs, acritarch taxa, viz., *Letosphaeridia* Downie & Sarjeant 1965, *Lophosphaeridium* Timofeev ex. Downie 1963, *Balmeella* Pant & Mehra 1963, *Tetraporina* Naumova ex. Naumova emend. Kar & Bose 1976, and *Maculatasporites* Tiwari 1965 are also recorded. The quantitative analysis of spore-pollen and acritarch population (Pl. 1, figs 1-10) has been differentiated in seven groups as detailed in Table 2. Their distribution pattern reveals the presence of three assemblages (Table 2; Text-figure 1). The ordinal scale categories used for representation of the palynomorphs are : above 25% = abundant, 25% - 10% = common; and less than 10% = rare.

Assemblage I

This assemblage is recorded from the lowermost coal horizon (170.96-177.24 m depth) of the sequence. The palynoflora is dominated by the trilete spore *Microbaculispora* together with *Brevitriletes, Lacinitriletes* and *Cyclogranisporites*. The nonstriate bisaccates (*Scheuringipollenites* + *Sahnites* + *Vestigisporites*) attain the second position numerically followed by the striate bisaccates (*Faunipollenites* + *Striatopodocarpites*). Radial monosaccates are common.

Assemblage II

This assemblage is also recorded from the coal-bearing horizon (65.60-169.22 m depth) below marker conglomeratic pebbly bed. The dominance



Text-figure 1 — Relative frequency of palynomorph groups I-VII recorded in various assemblages identified in samples from bore-hole TCC-19. The frequency plotted here is the sum of percentage of various palynotaxa of a particular Group as given in Table 2.

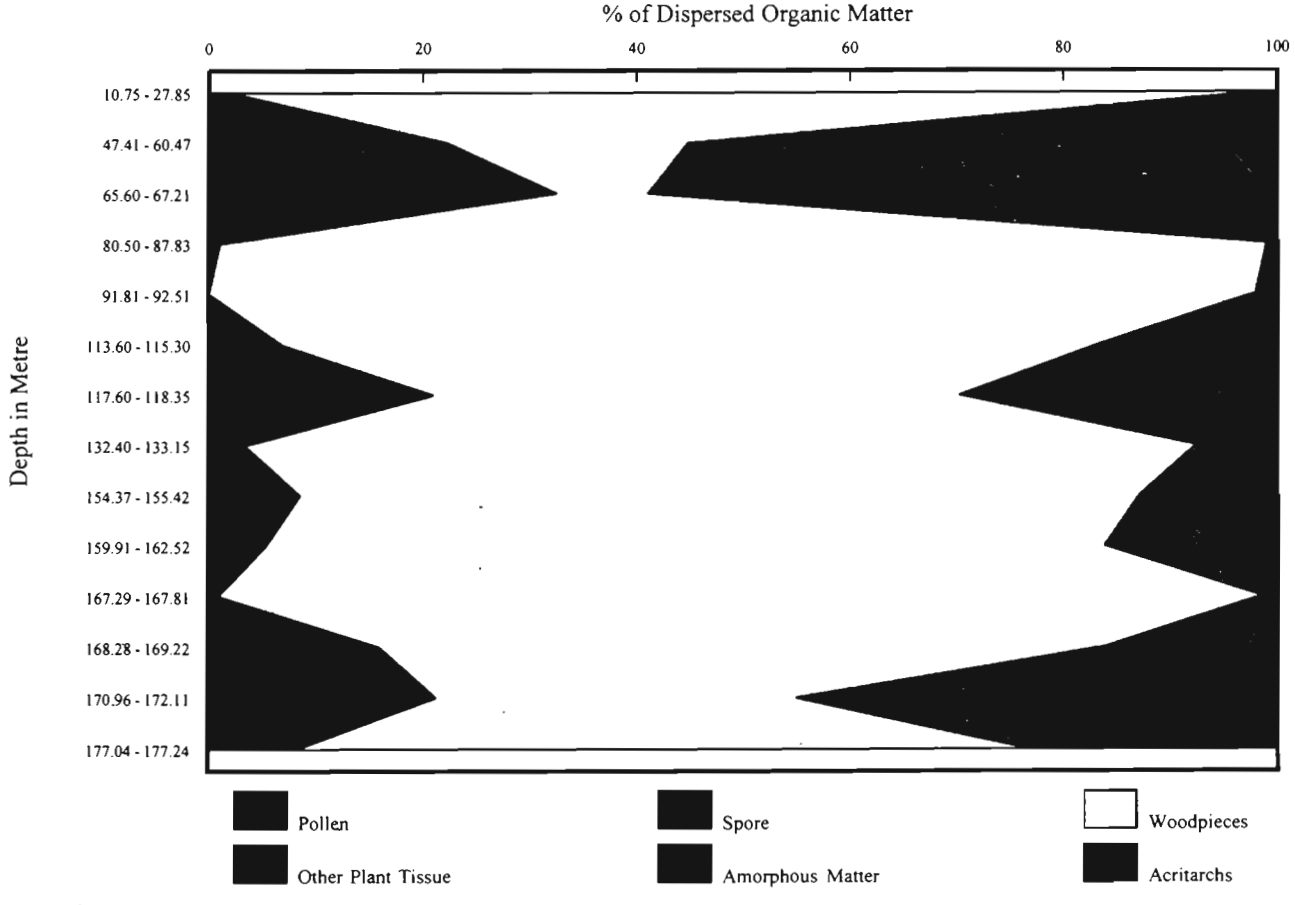
of trilete spores of Assemblage I is replaced by nonstriate bisaccate *Scheuringipollenites* and *Primuspollenites*. Common representation of trilete spores reveals continuity of the flora from Assemblage I, where they are abundant, to Assemblage II. The radial monosaccates show a declining trend. The presence of acritarchs *Balmeella, Letosphaeridia* and *Lophosphaeridium* at 65.60-67.21 m depth, although rare, is noteworthy.

Assemblage III

This assemblage is recorded from the coal-bearing horizon (10.75-60.47 m depth) above the conglomeratic pebbly bed. It has a distinct palynoflora which is dominated by striate bisaccates (*Faunipollenites* + *Striatopodocarpites*) and the nonstriate bisaccates attain second place numerically. The trilete spores are rare. The assemblage shows presence of acritarchs *Letosphaeridia, Lophosphaeridium* and *Balmeella*. At 47.41-60.47 m depth just above the conglomeratic bed all the three forms are present where as at 10.75-27.85 m depth only *Letosphaeridia* is recorded.

PALYNOFACIES ANALYSIS

The palynofacies analysis included the study of complete acid resistant organic residue, divisible into — (i) terrestrial material (spores, pollen, fresh water algae, wood and cuticle), (ii) marine algae, microforam tests, and (iii) structureless organic



Text-figure 2 — Composite diagram showing the lithocolumn of bore-hole TCC-19 along with palynological characteristics of various assemblages and palynofacies units with remarks on palaeoenvironment.

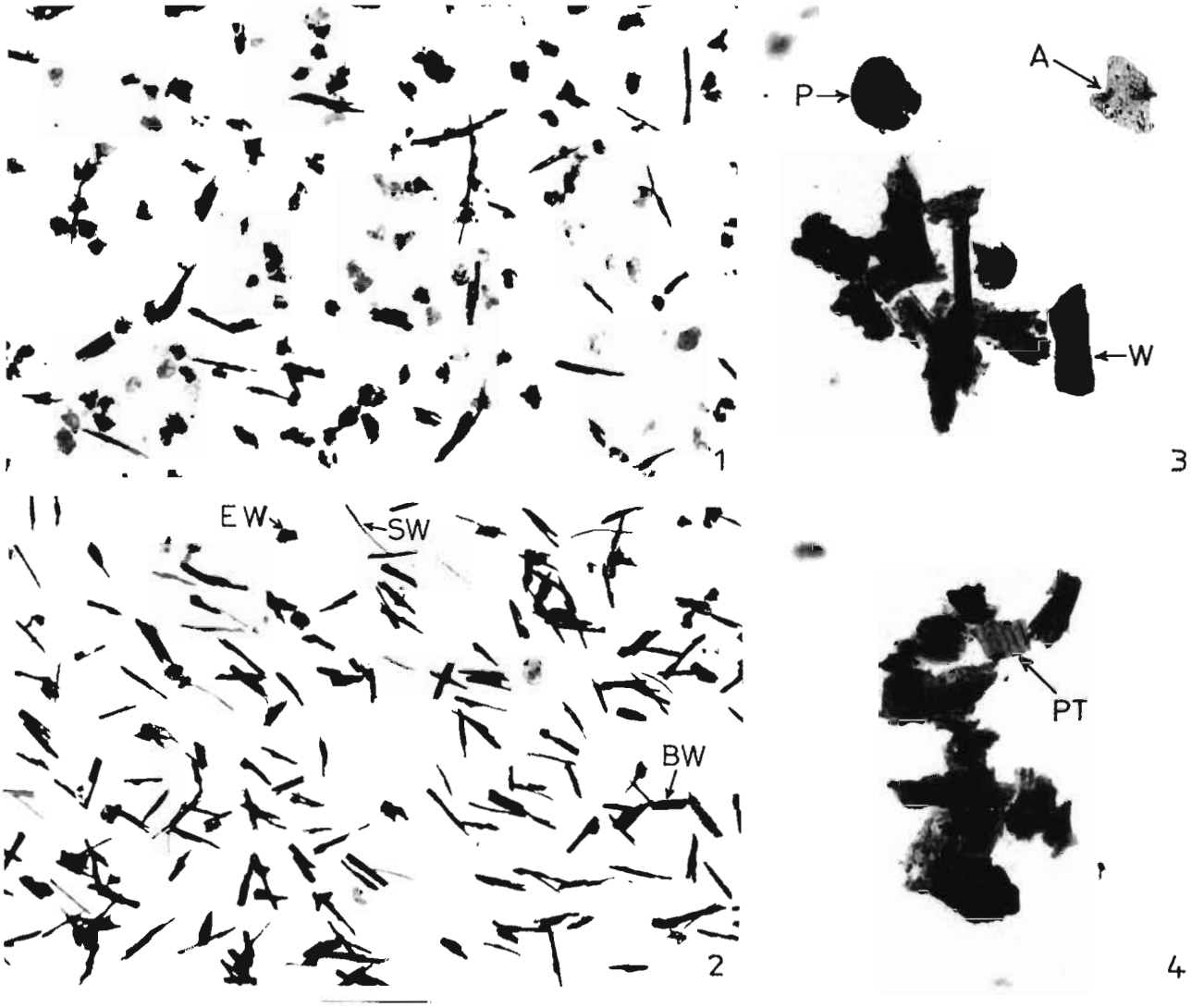


PLATE 2

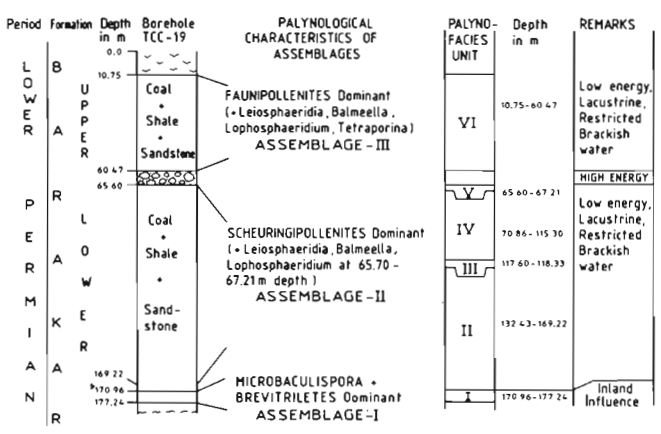
1. Spore-pollen rich contents with some structure-less brownish black wood pieces, Slide no. BSIP 11394.
2. Palynodebris rich in splintery (SW), blade shape (BW) and some equidimensional (EW), brownish black structure-less wood pieces with few palynomorphs, Slide no. BSIP 11393.
3. Structureless brownish black woody material (W) along with pollen (P) and acritarch (A), Slide no. BSIP 11391.
4. Structureless brownish black woody material along with other plant tissue (PT), Slide no. BSIP 11391.

matter-bacterially reworked biomass of laminar or granular appearance. All these entities are now termed as "Palynodebris" which was coined by Manum (1976, in Boulter, 1994). In the present study the palynodebris are identified according to the classification proposed by van Bergen *et al.* (1990).

The palynofacies analysis for acid resistant organic matter (Pl. 2, figs 1-4) was carried out for all the coal samples. They were subjected to nitric acid and mild alkali treatment for oxidation and release of the organic matter. Thereafter passed through 400 mesh sieve. This resulted in the removal of very fine matter (± 15 µm). Relative occurrences of various components were observed in at least three slides, under a 20 x 40 mm coverglass, of each sample. Text-figure 2 illustrates the distribution pattern of organic matter in the samples considered for palynofacies analysis. In general, the composition shows that most samples have dominance of woody material except at depths 170.96-172.11 m and 47.41 to 67.21 m, where other plant tissues contribute as dominant group. In none of the samples spores and pollen show dominance. On the basis of relative frequencies of various groups the sequence may be subdivided into the following palynofacies units from bottom to top (Text-figure 3).

Unit I

This is recorded in two samples. The sample at 177.04-177.24 m depth is rich in splintery, blade-



Text-figure 3 — Distribution pattern of dispersed organic matter in the samples from bore-hole TCC-19, Talcher Coalfield, Orissa, India.

shaped wood remains, and the spore-pollen are comparatively less. The sample at 170.96-172:11 m is rich in golden-yellow spore-pollen with other plant tissues. Detritus is attached to the debris. Most of the gymnospermous pollen are broken.

Unit II

It is recorded in five samples from 132.43 -169.22 m depth. The samples are rich in woody material and spore-pollen are less and broken. The wood pieces are splintery as well as equidimensional varying in colour from golden brown to dark brown and black. Few cuticle pieces are also present. Only one specimen of smooth-walled acritarch is found.

Unit III

The sample from 117.60-118.35 m depth is rich in spore-pollen and cuticle, in which the pollen are broken. Wood pieces dominant, equidimensional, brown and black in colour.

Unit IV

This unit is recorded in six samples at 70.86 - 115.30 m depth. In this unit the spore-pollen are poorly represented and the samples are rich in woody material. The wood pieces are mostly splintery and some are equidimensional, dark brown to black in colour.

Unit V

The sample (65.60-67.21 m depth) is rich in spore-pollen. Wood pieces and other plant tissues are few and big, equidimensional and dark brown in colour. The acritarch are also present, though in small numbers.

Unit VI

This unit is represented in two samples at 10.75-60.47 m depth. These are full of golden yellow to blackish brown equidimensional but not splintery wood pieces. Spore-pollen are few, mostly degraded, yellow but not hyaline and difficult to identify at species level. The acritarchs are also recorded in this unit having better representation at 47.41-60.47 m depth with dominance of other plant tissues.

DISCUSSION

Assemblages I-III in bore-hole TCC-19 can closely be identified with the palynoflora of Barakar age (Tiwari & Tripathi, 1988). Assemblage I and II show difference in the dominant and subdominant taxa but the palynofloral change is gradual, and not abrupt. These two assemblages are compositionally similar to the Lower Barakar palynoflora (Tiwari, 1974; Srivastava, 1984). Assemblage III reveals a compositional change due to dominance of striate-bisaccates and is correlatable with the Upper Barakar assemblages (Bharadwaj & Srivastava, 1969; Tiwari, 1974; Srivastava, 1984; Tripathi, 1993). The palynoflora is continuous and does not indicate any sharp break inspite of the presence of conglomeratic pebble bed. The palynoflora clearly indicates the intraformational nature, well within Barakar rather than at the base of Barakar, of this marker bed.

The occurrence of acritarchs in Assemblage II at 65.70-67.21 m depth, which also continues in Assemblage III at 47.41-60.47 m depth is significant. The acritarchs are also recorded below and above the conglomeratic pebble bed (56.60-180.70 m depth) in the bore-hole NCTB-288 (Srivastava, 1984). The presence of acritarchs indicates brackish water condition (Tappan, 1980) which evidently started before the deposition of conglomeratic pebble bed and existed even after its deposition in this coalfield. The acritarchs are also on record from the Barakar assemblage of bore-hole TCW-25 in north-western part of the Talcher Coalfield (Tripathi, 1993). Acritarchs have been reported from early Late Barakar assemblages from areas of Damodar, Son-Mahanadi, Krishna-Godavari and Rajmahal Basins (Tiwari *et al.*, 1995; Prasad *et al.*, 1996).

The oval-shaped pebbles suggest their transportation over a long distance (Roy, 1963). Their unsorted nature in the bed suggests high energy conditions. The area of provenance might be from Antarctica, as during Permian the Eastern Antarctica have shown palaeodrainage system towards north through Son-Mahanadi Graben of India (Casshyap & Tewari, 1984; Webb & Fielding, 1993).

The palynofacies analysis reveals good preservation of organic matter, except in Units I and VI where black specks are attached to the matter which could not be separated through chemical treatments by HCl. The spore and pollen are yellow but not hyaline. However, the structureless amorphous organic matter is comparatively less. The sequence is characteristic in having abundance of blade-shaped splintery wood pieces and relatively low frequency of palynomorphs except at 170.96-172.11 m and 47.41-67.21 m depths where the woody material is replaced by high incidence of other plant tissue. This indicates low to medium energy conditions and fluvial environment. The amorphous organic matter is present in very low percentage throughout. This together with high incidence of woody material and other plant tissue is suggestive of the lacustrine environment (Boulter, 1994). The high incidence of plant tissues at depth levels 170.96-172.11 m and 47.41-67.21 m is interpreted as indicative of a near shore environment (Pocock *et al.*, 1988; Traverse, 1988). The presence of smooth-walled acritarchs suggests restricted brackish water condition. The high influx of pteridophytic spore content within the coal at 168.28-172.11 m depth indicates the influence of inland flora growing in and around the basin and in the provenance area as undergrowth. The high frequency of the splintery and blade-shaped black wood pieces in the coal samples suggests terrigenous input and fluvial conditions (Boulter & Riddick, 1986; van Bergen & Kerp, 1990). The brownish black to black colour of the wood components may be the result of oxidation during transportation (Pocock *et al.*, 1988).

From the present state of observation it is clear that the coal bed sequence studied in this paper was deposited in low energy conditions with a short spell of high energy during deposition of the conglomeratic pebble bed and fluvial lacustrine palaeoenvironment with restricted brackish water conditions.

CONCLUSION

1. Palynological Assemblages I and II from the coal horizon below the conglomeratic pebblebed are comparable to the Early Barakar

palynoflora while the Assemblage III is comparable to Late Barakar palynoflora of Damodar Valley coalfields.

2. The presence of acritarch indicates a brackish water depositional environment.

3. The palynofacies analysis reveals that low energy, lacustrine conditions with a short spell of high energy prevailed during the deposition of these sedimentaries.

ACKNOWLEDGEMENTS

My sincere thanks are due to Dr R.S. Tiwari, Former Director, BSIP, Lucknow for discussions during the progress of this work. I am also thankful to Sri P.K. Mohanty, Senior Geologist, Geological Survey of India for the help rendered during the collection of the bore-core material. I extend my thanks to Dr George F. Hart, Professor Emeritus, Louisiana State University, USA and other referees for going through paper.

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