SUBSURFACE PALYNOLOGICAL SUCCESSION IN KORBA COALFIELD, M.P., INDIA*

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ABSTRACT

Seventy-nine samples of various lithologies, e.g. coal, shale, shaly sandstone and boulder bed from a 689 meters long continuous core out of a deep borehole in Korba Coalfield have been palynologically investigated. The succession is palynologically divisible into three major zones. The oldest zone commencing with the glacial boulder beds and the greenish tinted rocks overlying it, is dominated by radial monosaccates (*Parasaccites* + *Plicatipollenites*) and *Callumispora* along with progressively increased presence of striated saccates and pteridophytic spores. The middle zone is dominated by *Parasaccites*. The pteridophytic spores increase and appear more consistently while the striated saccates continue to be sporadic. The top zone is characterized by overall prominence of nonstriated saccates (chiefly *Sulcatisporites*), increased and consistent presence of striated saccates but similar incidence of pteridophytic spores as in the middle zone. The succession represents Talchir Stage from the base at 689 meters up to 668·57 meters level constituting the basal subzone and the Karharbari Stage above it. The climate during three zones, as presumable on the basis of quantitative representation of spore kinds, seems to have been cold and dry followed by cool and humid in the basal zone, cold and humid followed by cool and dry in the middle zone and progressively warm and humid in the top zone.

INTRODUCTION

THE general palynology of the coal-bearing formations of Korba Coalfield is known through the investigations made by Bharadwaj & Tiwari (1964) and Tiwari (1964, 1965). Recently, core from a 689 meters deep borehole No. NCKB-19, was supplied to us by National Coal Development Corporation Ltd., from the Korba Coalfield which includes rocks of various lithologies, e.g. coal, coaly shale, grey shale, shaly sandstone and boulder bed. Such a thick continuous succession of sediments has provided a good opportunity to establish the miofloral succession from the oldest to the youngest part in the Lower Gondwana deposits of the area and has also enabled us to find out the variation pattern in the miospore assemblages with respect to differing lithologies and the climatic sequence.

The details of the lithological characteristics and the spore-pollen recovery of the stratigraphical succession which includes 145 samples covering 18·28-689·51 metres of thickness, are given in Table 1. The oldest rock encountered in borehole No. NCKB-19 is a grey, shaly sandstone with greenish tint having assorted pebbles of different size and shapes. The pebbles are mainly rounded, small and embedded in a clayey matrix along with grains of felspar. This typical sandstone, characteristic of the Talchir sediments, continues up to 687·10 meters. Thereafter the sediments become finer. The greenish tint occurs last at 674·55 meters and the conglomeratic nature is accosted last at 668·90 meters. At 666·15 meter level, megascopic occurrence of carbonaceous matter is noted for the first time. The first occurrence of coal is observed at 612·05 meters. Thereafter coal seams are seen to occur at intervals throughout the succession. Between the coal seams the sandstones are often conglomeratic or pebbly, interbedded with finer sandstones or shales. Within the succession, after the coal seam at 495·86 meters, up to 254·90 meters, a sequence of about 241 meters is virtually devoid of coal but for thin layers of shaly coal or streaks of coal at intervals.

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MATERIALS AND METHODS

Of all the 145 samples listed in Table 1, 79 samples including various lithologies, which were expected to represent all the possible range of variations in the mioflora, were selected for maceration. The coal samples were macerated according to Bharadwaj and Salujha (1964).

However, a different technique was employed for shales and sandstones. They were treated with 40 per cent Hydrofluoric acid in polythene jars for about 48 hours or

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TABLE 1 — BOREHOLE NO. NCKB-19 KORBA COALFIELD, MADHYA PRADESH

SAMPLE No.	DEPTH (IN METERS) from	to	THICKNESS	LITHOLOGY	INCIDENCE OF SPORES
1-3	G.L.	3·04	3·04	Soil and sandy sub-soil	—
4	3·04	39·54	36·50	Weathered sandstone. Loose and friable	—
5-8C	39·54	59·63	20·09	Medium to coarse and very coarse grained sandstone	—
8B	59·63	59·79	0·16	Clay shale with coal streaks and fine grained sandstone lenses	—
8A	59·79	92·37	33·48	*Shaly Coal-Jartaj Seam*	Spores poorer than tracheids and cuticles
9	93·27	93·59	0·32	Sandy shale	—
	93·59	95·34	1·75	Alternating bands of shale and sandstone	—
10-11	95·34	109·20	13·86	Medium and coarse to very coarse grained sandstone	—
11A	109·20	114·30	5·10	*Shaly Coal — L.J.I. Seam*	Spores poorer than tracheids and cuticles
12	114·30	115·23	0·93	Sandy Shale	—
13	115·23	116·04	0·81	Intercalations of shale and sandstone	—
14	116·04	120·37	4·33	Coarse grained sandstone	—
14A	120·37	124·73	4·36	*Shaly Coal — L.J.II Seam*	Good
	124·73	125·88	1·15	Clay shale	—
	125·88	126·66	0·78	Carbonaceous shale with thin coal bands at places	—
	126·66	126·79	0·13	Shaly coal	—
	126·79	127·30	0·51	Coal	—
	127·30	127·91	0·61	Grey to dark grey shale	—
	127·91	128·57	0·66	Coal interspersed with thin bands of carbonaceous shale	—
15	128·57	129·08	0·51	Clay shale/Shale	—
	129·08	129·23	0·15	Shaly coal	—
	129·23	129·38	0·15	Carbonaceous clay shale	—
	129·38	129·84	0·46	Shale	—
16-20	129·84	148·66	18·82	Medium and coarse grained sandstone	—
	148·66	148·76	0·10	Coal	
	148·76	148·99	0·23	Sandy shale	—
	148·99	149·35	0·36	Intercalations of shale and sandstone	—
	149·35	150·54	1·19	Mdedium grained sandstone	—
	150·54	150·64	0·10	Intercalations of shale and sandstone	—
21	150·64	150·92	0·28	Shaly Coal	Good
	150·92	151·18	0·26	Carbonaceous shale	—
	151·18	151·84	0·66	Coal interspersed with thin bands of carbonaceous shale	—
	151·84	151·94	0·10	Sandy shale	—
22-24	151·94	168·50	16·56	Medium to coarse and very coarse grained sandstone with pebbles at places	—
25	168·50	169·97	1·47	Coal/shaly coal	Poor
26	169·97	188·43	18·46	Medium and coarse grained sandstone	—
27	188·43	189·48	1·05	Coal/shaly coal	Fair
28	189·48	189·65	0·17	Sandy carbonaceous shale	Acicular bodies and miospores
29-37	189·65	229·56	39·91	Medium and coarse grained sandstone with quartz pebbles at places	Good
	229·56	254·89	25·33	Medium to coarse and very coarse grained sandstone	—

Continued

TABLE 1 — BOREHOLE NO. NCKB-19 KORBA COALEIELD, MADHYA PRACESH
(Continued)

SAMPLE No.	DEPTH (IN METERS) from	to	THICKNESS	LITHOLOGY	INCIDENCE OF SPORES
38	254·89	255·05	0·16	Coal	Good
	255·05	255·43	0·38	Grey shale	—
	255·43	256·49	1·06	Coal shaly and coaly shale. 0·05 m shale band at 255·72 m	—
39	256·49	256·77	0·28	Shaly sandstone	Poor
	256·77	271·15	14·38	Medium and coarse grained sandstone, occasionally very coarse grained at places	—
40-41	271·15	271·44	0·29	Sandy shale	—
	271·44	271·68	0·24	Coal Shaly	—
42-43	271·68	271·79	0·11	Sandy Shale	Fair/Good
	271·79	271·87	0·08	Intercalations of shale and sandstone	—
44-51	271·87	312·77	40·90	Medium to coarse and very coarse grained sandstone	—
52	312·77	312·97	0·20	Sandy shale	Good
53	212·97	315·47	2·50	Coarse grained sandstone	—
	315·47	315·63	0·16	Clay shale	—
54	315·63	315·99	0·36	Shaly coal interspersed with thin sandstone lenses	Good
55-56	315·99	316·97	0·98	Shaly sandstone grading to arenaceous shale	—
57-59	316·97	336·34	19·37	Medium to coarse and very coarse grained sandstone	—
60	336·34	336·72	0·38	Shaly coal	Good
61	336·72	337·72	1·00	Sandy shale	—
62-66	337·72	360·35	22·63	Medium and coarse grained sandstone partially gritty at places	—
67	360·35	360·53	0·18	Shaly coal	—
68	360·53	361·56	1·03	Clay shale carbonaceous at places	—
69	361·56	364·57	3·01	Grey shale	Acicular bodies and miospores
70	364·57	365·47	0·90	Shaly sandstone	—
71-91	365·47	472·35	106·88	Medium and coarse grained sandstone, partially gritty at places	Good spores at 461·10 meters
92	472·35	472·51	0·16	Carbonaceous shale	Acicular bodies and miospores
	472·51	472·66	0·15	Coal	—
93-94	472·66	473·79	1·13	Interbanded shale and sandstone	Good/Acicular bodies and miospores
95-98	473·79	495·06	21·27	Medium to coarse and very coarse grained sandstone with pebbles at places	—
98A	495·06	495·86	0·80	*Coal Seam G. IV*	Spores poorer than tracheids and cuticles
99-100	495·86	518·96	23·10	Medium and coarse grained sandstone partially to semi gritty with quartz pebbles at places	—
101	518·96	519·09	0·13	Coal	Good
102	519·09	519·12	0·03	Carbonaceous shale	—
103	519·12	519·37	0·25	Grey arenaceous shale-carbonaceous	Acicular bodies
104	519·37	519·65	0·28	Medium grained sandstone	—
105	519·65	519·75	0·10	Grey sandy shale	—
	519·75	519·98	0·23	Medium grained sandstone	—
	519·98	520·30	0·32	Grey shale	—
	520·30	520·40	0·10	Shaly coal	—
	520·40	520·46	0·06	Grey shale	—
	520·46	520·84	0·38	Medium grained sandstone	—
	520·84	521·03	0·19	Grey shale/shaly sandstone	—
	521·03	521·09	0·06	Coal	—

TABLE 1 — BOREHOLE NO. NCKB-19 KORBA COALFIELD, MADHYA PRADESH
(Continued)

SAMPLE No.	DEPTH (IN METERS) from	to	THICKNESS	LITHOLOGY	INCIDENCE OF SPORES
	521·09	521·15	0·06	Carbonaceous shale	—
	521·15	521·43	0·28	Medium grained sandstone	—
	521·43	521·60	0·17	Dark grey shale carbonaceous	—
	521·60	521·79	0·19	Intercalations of fine grained shaly sandstone/shale	—
	521·79	523·05	1·26	Grey arenaceous shale	—
	523·05	523·13	0·08	Shaly coal	—
	523·13	523·16	0·03	Grey arenaceous shale	—
106	523·16	523·30	0·14	Medium grained sandstone	—
107a	523·30	523·39	0·09	Grey shale	—
107b	523·39	523·44	0·05	Medium grained sandstone	—
108	523·44	523·47	0·03	Grey shale	Acicular bodies
	523·47	523·67	0·20	Coal partially shaly at places	—
109	523·67	524·04	0·37	Grey arenaceous shale	Poor
	524·04	524·10	0·06	Medium grained sandstone	—
	524·10	524·54	0·44	Grey arenaceous shale	—
	524·54	524·70	0·16	Medium grained sandstone	—
	524·70	524·77	0·07	Grey shale	—
110	524·77	524·81	0·04	Coal shaly	Good
	524·81	525·35	0·54	Grey arenaceous shale	—
	525·35	525·52	0·17	Coal	—
	525·52	525·83	0·31	Arenaceous shale	—
111	525·83	525·99	0·16	Medium grained sandstone	—
	525·99	526·05	0·06	Grey arenaceous shale	—
	526·05	526·15	0·10	Shaly sandstone	—
112	526·15	526·35	0·20	Coal with broken pieces of shale	Good
113-114	526·35	527·25	0·90	Interbanded shale/sandstone	Acicular bodies and miospores
115-117	527·25	576·55	9·30	Medium and coarse grained sandstone, partially gritty at places	—
117A	576·55	577·53	0·98	Grey shale	Good
	577·53	587·87	10·34	Fine, medium and coarse grained sandstone	—
	587·87	588·32	0·45	Sandy shale	—
118	588·32	611·96	23·64	Medium and coarse grained sandstone	—
119	611·96	612·04	0·08	Coal	Good
120	612·04	621·12	0·08	Medium and coarse grained sandstone	—
121	621·12	621·28	0·16	Grey shale	Poor
122	621·28	646·75	25·75	Fine and medium grained sandstone, coarse grained at places	—
123	646·75	647·38	0·63	Grey shale	Good
124	647·38	647·98	0·60	Intercalations of shale and sandstone	Good
125	647·98	648·19	0·21	Medium grained sandstone	—
126	648·19	648·98	0·79	Grey shale	Good
127-128	648·98	658·51	0·53	Medium grained sandstone	—
129	658·51	659·60	1·09	Intercalations of shale and sandstone	—
130	569·60	660·58	0·98	Grey shale (carbonaceous)	Good
131	660·58	662·22	1·64	Fine to coarse grained sandstone and shale	—
	662·22	663·34	0·88	Interbanded fine grained shaly sandstone and shale	—
132	663·34	666·98	3·64	Intercalations of shale and sandstone (carbonaceous shale with indeterminate plant impressions)	Good
133	666·98	668·57	1·59	Whitish grey fine grained shaly sandstone	—

TABLE 1 — BOREHOLE NO. NCKB-19, KORBA COALFIELD, MADHYA PRADESH
(*Continued*)

SAMPLE No.	DEPTH (IN METERS) from	to	THICKNESS	LITHOLOGY	INCIDENCE OF SPORES
134-136	668·57	674·55	5·98	Black and grey shale with disseminations of small rounded and subrounded pebbles	Poor/Absent/Good
137-138	674·55	683·62	9·07	Grey shale	Good
139	683·62	684·63	1·01	Fine and medium grained sandstone	Poor
140-145	684·63	689·51	4·88	Grey shaly sandstone with greenish tint at places and inclusions of pebbles of assorted size (maximum dimensions being 0·35 × 0·07 meters) of gneissic, quartzitic etc. compositions	Poor

BOREHOLE CLOSED AT 689·51 METERS

even more till the silicates dissolved completely. Some of the samples, chiefly the shaly sandstone and boulder bed, yielded spores after the treatment with Hydrofluoric acid but grey shale and carbonaceous shales, rich in organic content, required further treatment and were oxidized on the lines similar to that followed for coal samples.

Out of the 79 samples macerated, as indicated in Table 1, only 49 of them contained microfossils. Amongst these, sample nos. 108 and 103 contained large number of acicular bodies while sample nos. 113, 94, 92, 69, 28, contained acicular bodies and miospores both. Sample nos. 145-141, 139, 134, 121, 114, 109, 39 and 25 contained few miospores whereas in sample nos. 8A, 11A and 98A woody tracheids and cuticles were more common than the miospores. Quantitative estimation of miospores was possible only in 37 samples as they contained sufficient amount of palynofossils in them while the counting was not possible in sample nos. 145-141, 109, 39 due to paucity of the miospores and hence, are not represented in the histograms.

MIOFLORAL COMPOSITION

The miofloral assemblage investigated in the borehole No. NCKB-19 consists of 50 genera which are listed below.

*Leiotriletes, Callumispora, Hennellysporites, Cyclogranisporites, *Verrucosisporites, *Acanthotriletes, Lophotriletes, Brevitriletes, Horriditriletes, Microbaculispora, *Pseudoreticulatispora, *Lacinitriletes, Microfoveolatispora, *Cyclobaculisporites, Potonieitriradites, Indotriradites, *Dentatispora, *Latosporites, Barakarites, *Divarisaccus, Parasaccites, *Crucisaccites, *Stellapollenites, *Cannanoropollis, Caheniasaccites, Potonieisporites, Plicatipollenites, *Cuneatisporites, Platysaccus, Lueckisporites, Striatites, Rhizomaspora, Primuspollenites, Lahirites, Striatopodocarpites, Faunipollenites, Illinites, Vesicaspora, Sulcatisporites, Ibisporites, Tiwariasporis, *Decussatisporites, Ginkgocycadophytus, *Peltacystia, Maculatasporites, *Hemisphaerium, *Greinervillites, Pilasporites, Leiosphaeridia.*

Amongst these the genera marked with an asterisk occur sporadically and are rarely encountered during counting and hence, have been excluded or merged with the group nearest to their morphographic similarity. The general behaviour of rest of the genera which characterise the pollen spectrum at various levels of the bore core is described in detail here under and has been listed in Table 2.

Leiotriletes commences from sample no. 132 and continues to rise up to 119 whereafter it declines sharply. In younger levels it is present only sporadically till it becomes consistent from sample no. 25 and up to 8A.

The genus *Callumispora* forms one of the dominant constituents of the mioflora in the lower part of the bore core. In sample nos. 145-141 it is present in very small amounts and continues to rise up to 55 per cent in sample no. 132. Beyond sample no. 130 it declines gradually up to sample no. 124 whereafter it marks another dominance in sample nos. 121 and 117A. In sample no. 114 and those younger, it diminishes significantly.

Hennellysporites is represented poorly and sporadically throughout the whole length of the bore core. From sample no. 130 to 98A it occurs up to 5 per cent.

Cyclogranisporites seems to have a restricted occurrence in the upper zone of the bore core as it is present from sample nos. 38 to 8A. It is present up to 7 per cent and remains as a subdominant miospore.

Lophotriletes appears first in sample no. 132, increases up to 11 per cent in sample no. 130, declines and remains insignificant up to sample no. 42. However, from sample no. 38 to 8A it occurs almost consistently between 1-7 per cent.

Brevitriletes is present almost regularly from sample nos. 132 to 98A with a maximum of 31 per cent in sample no. 112. This genus is significantly associated with the coal facies whereas in shales and sandstones it is either reduced considerably or absent.

Horriditriletes occurs almost uniformly right from sample no. 134 to 52 from where it rises to attain dominance in sample no. 25 and finally decreases in younger samples.

Microbaculispora is noteworthy only between sample nos. 132 and 121 reaching 16% in 130. In the rest of the core it occurs only sporadically.

Microfoveolatispora is a straggler but in sample nos. 119 and 117A it is 12%.

Potonieitriradites is a genus associated with the coal facies except in the sample no. 130, although it is a straggler like *Microfoveolatispora*.

The occurrence of *Indotriradites* is marked in sample nos. 130, 98A, 25 and 21 but it is a very inconsistent element in the assemblage.

Latosporites occurs in the younger zones of the bore core. It appears first in sample no. 87 but becomes consistent from sample nos. 38 to 8A.

Parasaccites characterises the older sediments of the bore core. It is dominantly present (up to 55 per cent) in sample nos. 145-136, whereafter it decreases gradually up to 117A. It again rises to dominance in sample no. 114, decreases almost uniformly up to sample no. 69 and looses its significance in still younger samples. The sudden decline in sample nos. 130 and 117A and the rise in sample nos. 129 and 121 significantly interrupts the regularity of the pollen curve. These fluctuations are noticeable in the sandy shales.

Caheniasaccites occurs in very low percentages (2-4%) and is inconsistently present in sample nos. 140-126.

Potonieisporites, unlike *Caheniasaccites*, occurs inconsistently in the older horizons of the bore core, i.e. sample no. 140 to 121. In still younger beds it is consistent but low in percentage (1-5%).

Plicatipollenites which appears to be closely related to *Parasaccites* is restricted to the older horizons of the bore core. Its frequency is high in sample no. 145 to 132 whereafter it declines appreciably but continues to exist as a subdominant element up to sample no. 92.

Platysaccus has shown its existence early in sample no. 134 but remains as a straggler till it starts rising consistently from sample no. 98A, attaining highest percentage in sample no. 52 and finally decreasing in the younger samples.

Lueckisporites occurs sporadically in sample nos. 54 to 8A thus, restricting itself to the younger sediments in the bore core. It forms one of the rare elements of the miofloral assemblage, being present from 0·5-4 per cent.

Striatites is present inconsistently from sample nos. 124 to 93 but from sample no. 92 it consistently rises up to 9 per cent in sample no. 52. It decreases in younger sample to rise slightly again in sample nos. 11A and 8A.

The occurrence of *Primuspollenites* is marked between sample nos. 94-8A. It rises up to 10 per cent in sample no. 92 and then decreases gradually upwards. In sample no. 28 it is absent.

Striatopodocarpites has shown its existence early in sample no. 136 but could not establish itself up to sample no. 52. From sample no. 42 up to 8A it behaves as a subdominant genus rising up to its maximum (19%) in sample no. 27.

The genus *Faunipollenites* occurs sporadically between sample nos. 140-112 but in sample no. 110 and the younger ones, it rises consistently reaching its maximum (28%) in sample no. 27.

TABLE 2 — SHOWING THE PERCENTAGE DISTRIBUTION OF MIOSPORES IN VARIOUS LITHOLOGIES OF THE BOREHOLE NO. NCKB-19, KORBA COALFIELD, M.P.

General Sample No.	*Leiotriletes*	*Callumispora*	*Hennellysporites*	*Cyclogranisporites*	*Lophotriletes*	*Brevitriletes*	*Horriditriletes*	*Microbaculispora*	*Microfoveolatispora*	*Indotriradites*	*Potonieitriradites*	*Latosporites*	*Divarisaccus*	*Parasaccites*	*Caheniasaccites*	*Potonieisporites*	*Plicatipollenites*	*Cuneatisporites*	*Platyacus*	*Lueckisporites*	*Striatites*	*Rhizomaspora*	*Primuspollenites*	*Lahirites*	*Striatopodocarpites*	*Faunipollenites*	*Illinites*	*Vesicaspora*	*Sulcatisporites*	*Tiwariasporis*	*Ginkgocycadophytus*	*Maculatasporites*	*Pilasoporites*	*Leiosphaeridia*
8A	4·0	0·5	0·5	7·0	0·5	4·0	5·0	0·5	1·5	—	3·0	2·5	—	1·0	—	—	—	—	5·0	0·5	6·0	—	3·0	7·0	7·0	11·0	—	3·0	19·5	1·0	1·5	0·5	5·0	—
11A	5·0	0·5	—	4·0	1·0	7·5	4·0	4·0	—	0·5	0·5	1·5	—	—	—	—	—	1·0	8·0	0·5	7·0	—	6·0	4·0	6·0	8·0	—	7·0	20·5	—	1·0	—	1·5	1·0
14A	2·5	1·5	0·5	2·0	2·0	5·0	6·0	2·0	0·5	—	2·0	2·0	—	0·5	—	0·5	—	—	7·0	1·5	2·5	—	2·0	6·5	7·0	12·0	0·5	3·5	23·5	1·5	1·5	—	2·0	2·0
21	2·0	1·5	0·5	2·0	3·0	9·5	10·5	3·5	—	1·5	0·5	3·0	0·5	—	—	—	—	—	4·0	4·5	1·0	—	3·0	5·0	3·5	10·5	—	2·5	21·0	1·0	0·5	—	4·0	—
25	2·0	1·0	—	2·0	1·0	2·0	25·0	—	1·0	2·0	—	3·0	—	—	—	—	—	—	7·0	—	2·0	—	2·0	5·0	2·0	5·0	—	2·0	31·5	—	—	—	1·5	2·5
27	0·5	0·5	—	3·5	6·0	1·0	2·0	—	1·0	0·5	—	1·0	—	—	—	1·0	—	—	3·5	3·0	1·5	—	0·5	5·0	19·0	28·0	—	4·5	16·0	0·5	—	—	1·0	0·5
28	0·5	0·5	—	—	—	—	—	—	—	—	—	0·5	—	2·0	—	—	—	—	3·0	1·5	3·0	—	—	7·0	14·0	13·5	0·5	7·0	42·0	1·0	—	—	1·0	3·0
34	3·0	1·0	—	3·0	2·5	6·0	9·5	1·5	—	—	—	6·0	—	0·5	—	0·5	—	—	3·0	1·5	1·0	—	3·0	3·0	5·0	15·0	—	5·0	21·0	1·0	1·0	—	3·0	4·0
38	2·0	2·0	1·0	2·0	7·0	8·0	7·0	—	—	—	—	3·0	—	—	—	—	—	—	3·0	—	3·0	1·5	3·5	3·0	6·0	8·0	—	2·0	25·5	1·5	1·0	1·5	1·0	7·5
42	—	1·0	—	—	0·5	1·0	1·0	—	—	0·5	—	0·5	—	11·0	—	1·0	0·5	—	5·0	0·5	5·0	—	2·0	3·0	7·0	16·0	—	11·0	28·5	2·5	—	—	1·5	1·0
52	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·0	24·0	—	9·0	—	6·0	3·0	—	8·0	—	5·0	42·0	2·0	—	—	—	—
54	1·0	—	—	—	1·0	6·0	2·5	—	—	—	—	—	—	4·5	—	1·5	—	—	9·0	0·5	2·0	—	7·0	1·0	1·0	3·0	—	3·0	43·0	1·0	1·0	—	2·0	10·0
60	3·0	1·0	1·0	—	1·0	7·0	4·0	—	0·5	—	—	2·0	—	0·5	—	—	—	2·0	7·0	—	6·0	—	7·0	3·0	1·0	10·0	—	1·0	34·5	0·5	0·5	0·5	—	7·0
69	—	—	—	—	1·0	8·0	2·0	1·0	—	—	—	—	—	5·0	—	—	—	2·0	6·0	—	5·0	—	7·0	4·0	5·0	—	—	1·0	45·0	—	5·0	—	2·0	1·0
87	2·5	2·0	1·0	—	0·5	19·0	5·0	—	4·0	—	0·5	7·0	0·5	4·5	—	—	—	—	4·0	—	2·0	—	1·0	1·0	2·0	4·0	—	0·5	29·0	3·0	3·5	—	2·0	1·5
92	—	0·5	—	—	—	6·0	—	—	—	—	—	—	—	26·0	—	—	3·5	—	6·0	—	4·0	—	10·0	0·5	—	2·0	—	1·5	37·5	0·5	0·5	—	1·0	0·5
93	—	2·0	—	—	—	3·5	2·0	—	0·5	0·5	—	—	—	20·0	—	0·5	6·5	1·5	5·5	—	0·5	—	7·5	2·0	—	5·0	—	—	36·0	2·0	0·5	—	1·0	3·0
94	—	0·5	—	—	—	0·5	—	—	—	—	—	—	—	40·0	—	4·0	8·5	1·5	3·0	—	1·0	—	6·5	1·0	2·0	2·0	—	—	26·0	2·0	1·0	—	0·5	—
98A	1·0	5·0	2·5	—	2·5	14·0	3·0	3·0	2·0	7·0	—	—	—	12·0	—	—	5·0	—	3·0	—	2·0	—	—	2·5	3·0	2·0	2·0	5·0	18·0	1·0	—	—	4·5	—
101	—	—	1·0	1·0	1·0	8·0	1·0	—	—	—	—	—	3·0	47·0	—	1·0	9·0	—	—	—	—	—	—	—	9·0	2·0	1·0	0·5	2·0	12·5	—	—	1·0	—
110	1·0	21·5	—	—	—	23·0	5·0	—	—	—	—	—	—	35·0	—	—	2·0	—	—	—	1·0	—	—	0·5	0·5	1·0	1·0	0·5	5·0	0·5	—	—	0·5	2·0
112	0·5	3·0	3·0	—	—	31·0	2·0	—	1·5	—	1·5	—	—	45·0	—	—	—	—	—	—	—	—	—	—	2·0	—	1·0	—	3·0	0·5	0·5	0·5	3·0	2·0
114	—	2·0	—	—	—	—	3·0	—	—	—	—	—	—	63·0	—	1·0	8·0	3·0	3·0	—	1·0	—	—	—	—	—	—	—	13·0	—	—	—	—	3·0
117A	2·0	34·5	1·5	0·5	—	12·5	2·0	4·5	11·5	0·5	10·5	—	—	3·0	—	—	7·0	—	—	—	—	—	—	—	—	—	—	2·0	0·5	1·0	2·0	1·5	1·5	2·0
119	6·5	17·5	3·5	—	—	18·5	—	—	13·0	—	—	—	—	13·0	—	—	0·5	—	1·5	—	0·5	—	0·5	—	—	—	1·0	5·0	—	—	12·0	—	2·0	5·0
121	2·0	38·0	—	—	—	1·0	1·0	2·0	—	—	—	—	—	42·0	—	2·0	2·0	—	—	—	—	—	—	—	—	2·0	—	—	2·0	—	—	—	2·0	4·0
123	3·5	25·0	1·5	—	4·5	1·0	2·0	6·0	—	—	—	—	—	24·0	—	2·0	8·0	0·5	1·5	—	1·0	—	—	—	0·5	0·5	—	0·5	2·0	—	4·0	—	6·0	6·0
124	—	14·0	—	—	—	2·0	4·0	—	—	—	—	—	—	54·0	—	2·0	2·0	—	2·0	—	—	—	—	—	—	2·0	—	—	4·0	—	—	—	4·0	10·0
126	—	28·0	—	—	—	—	3·0	1·0	—	—	—	—	—	43·0	—	4·0	—	—	1·5	—	—	—	—	—	0·5	2·0	—	—	5·0	—	—	—	4·0	10·0
129	2·0	16·0	—	—	2·0	—	2·0	2·0	—	—	—	—	1·0	54·0	2·0	5·0	14·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
130	4·5	27·5	5·0	—	11·0	—	2·5	16·0	6·5	1·0	4·5	—	—	16·0	—	1·0	3·5	—	—	—	—	—	—	—	—	—	—	0·5	—	—	0·5	—	—	—
132	1·0	55·0	0·5	—	6·0	2·0	0·5	2·0	3·5	—	—	—	—	25·0	—	1·0	2·0	—	0·5	—	—	—	—	—	—	—	—	0·5	—	0·5	—	—	—	—
134	—	8·0	—	—	—	—	2·0	—	—	—	—	—	—	40·0	4·0	4·0	36·0	—	4·0	—	—	—	—	—	—	—	—	—	—	—	—	—	2·0	—
136	—	9·0	—	—	—	—	—	1·0	—	—	—	—	—	50·0	1·0	5·0	30·0	—	—	—	—	—	—	—	1·0	1·0	1·0	—	—	—	1·0	1·0	—	—
137	—	22·0	0·5	—	—	—	0·5	—	3·0	—	—	—	0·5	45·0	0·5	5·0	22·0	—	—	—	—	—	—	—	—	—	—	0·5	0·5	—	—	—	—	—
138	—	6·5	1·0	—	1·0	—	—	—	6·5	—	—	—	5·0	54·0	3·0	1·5	14·5	—	—	—	—	—	—	—	—	1·5	1·0	1·5	2·0	—	0·5	—	0·5	—
140	—	1·0	—	—	—	—	—	0·5	0·5	—	—	—	—	46·0	1·5	1·0	47·0	—	—	—	—	—	—	—	—	0·5	—	—	1·5	—	—	0·5	—	—

Illinites behaves inconsistently between sample nos. 138 and 98A and is always rare in occurrence.

Vesicaspora although present as early as sample no. 138, appears irregularly but later it is consistent in the younger samples. It rises up to its maximum in sample no. 42 (11%) and then declines gradually.

Sulcatisporites appears quite early, as in sample no. 140, but remains a straggler till sample no. 117A. This genus becomes the most dominant constituent in sample no. 98A and the younger samples, reaching its maximum of 45 per cent in sample no. 69. Subsequently it declines gradually. This way it characterises the upper half of the borehole NCKB-19 along with the other disaccate pollen genera.

Tiwariasporis occurs sporadically from 2-12 per cent throughout the whole length of the bore core.

The genus *Ginkgocycadophytus* behaves similarly as *Tiwariasporis* and is present from 1-12 per cent.

Maculatasporites is very rare in occurrence and has been observed in very low percentages (1-2%).

Pilasporites is present in appreciable amounts (2-6%) and is regularly distributed from the oldest to the youngest sample and thus, its occurrence is more consistent than other rare palynomorphs.

Leiosphaeridia is very much similar to *Pilasporites* in its occurrence. It is present almost consistently from sample no. 126 and the younger ones, being present from 2-10 per cent.

PALYNOLOGICAL SUCCESSION

The succession of the forest, as represented by miofloral assemblages through 689 meters deep sediments of the borehole NCKB-19 in Korba Coalfield, has been investigated with reference to their qualitative composition and quantitative abundance after a count of nearly 200 miospores in each sample. As shown in Table 2, *Parasaccites, Plicatipollenites, Callumispora* and *Sulcatisporites* form the dominant constituents of the forest associations. Among the subdominants are *Leiotriletes, Lophotriletes, Brevitriletes, Horriditriletes, Platysaccus, Striatites, Primuspollenites, Lahirites, Striatopodocarpites, Faunipollenites* and *Vesicaspora*. Arpat from these, the genera viz. *Cyclogranisporites, Latosporites, Lueckisporites* and *Caheniasaccites*, although present in very low percentages, are considered important because their occurrence is restricted to a set of samples thus, signifying themselves as important and consistent member of the forest association at one time or the other. On the other hand some other miospores viz. *Hennellysporites, Microbaculispora, Microfoveolatispora, Potonieitriradites, Indotriradites, Divarisaccus, Cuneatisporites, Illinites, Tiwariasporis* and *Ginkgocycadophytus*, are present in considerable amounts at various levels of the borehole but their occurrence is not consistent either in a particular set of samples or throughout the whole length of the bore core. Such miospores have been considered as sporadic elements of the forest association and have been excluded from the rest of the population. Their percentages have been merged with the consistently occurring units to calculate the absolute percentages of the latter which have been diagrammatically represented in Histogram 1.

The palynological distribution shows that the succession has essentially gone through one major change with a zone of transition in between the two major phases.

In the older phase, represented by the Zone No. 1, the miofloral assemblage is chiefly dominated by *Parasaccites, Plicatipollenites* and *Callumispora*. This zone is further divisible into two subzones. The older subzone is constituted by sample nos. 145-134. The pollen spectra of sample nos. 145-141 have not been represented in the histograms due to sporadic occurrence of miospores, but whatever were observed, represented a mioflora similar to that from sample nos. 140-134. *Parasaccites* and *Plicatipollenites* constitute 51 per cent and 31 per cent of the total association respectively. *Callumispora* is present up to 10 per cent approximately. *Potonieisporites* and *Caheniasaccites* follow next to the above (3% and 2% respectively). However, while the disaccate pollen grains are present only sporadically, pteridophytic triletes are totally absent.

The younger subzone constituted by sample nos. 132-117A, has the characteristic association of *Parasaccites* and *Callumispora*. *Plicatipollenites* shows a considerable decrease while *Callumispora* increases correspondingly. This genus seems to have been

HISTOGRAM I - PERCENTAGE CALCULATED AFTER MERGING THE PERCENTAGES OF INCONSISTENT GENERA INTO THOSE OF THE CONSISTENT ONES IN KORBA COALFIELD

HISTOGRAM 1

fighting for its dominance ever since the forest was formed and grew under a sort of intergeneric competition with *Plicatipollenites*. Amongst the trilete miospores, *Brevitriletes, Lophotriletes, Leiotriletes* and *Horriditriletes*, which are supposed to have been produced by pteridophytes, increase considerably making up a total of 14 per cent in the assemblage. Disaccate pollen grains continue to be sporadic in occurrence. It may be concluded that at the cost of decline of radial monosaccates, *Callumispora*, presumably pteridospermous, came up along with sufficient undergrowth of pteridophytic elements.

In the transition phase represented by Zone No. 2, comprized of sample nos. 114-92, *Callumispora* declines and the dominant association is composed of *Parasaccites, Sulcatisporites* and *Brevitriletes*. Within this zone, *Parasaccites* is associated with *Brevitriletes* in the older subzone and with *Sulcatisporites* in the younger subzone. The striate disaccates become prominent in the younger subzone. The pteridophytic triletes consisting mostly of *Brevitriletes* are up to 20 per cent in the older sub-zone. Sample nos. 98A to 92 contain a mixed mioflora, representing the dying phase of *Parasaccites, Plicatipollenites, Callumispora* and incoming of *Sulcatisporites* and other disaccate pollen grains.

In the younger phase, i.e. Zone No. 3, represented by sample nos. 87-8A, the disaccate pollen grains which are low in the earlier two zones, become abundant, being represented up to 72 per cent. *Parascacites* and *Callumispora* decline drastically while trilete miospores maintain their representation almost similar to that in Zone No. 2. *Sulcatisporites*, which appears to have originated in the younger part of Zone No. 1, could establish itself only when the radial monosaccates and *Callumispora* gave way to it. In sample no. 87 and the younger ones, *Sulcatisporites* dominates in general (average 32%). *Faunipollenites* (10%), *Striatopodocarpites* (5%), *Platysaccus* (6%), *Primuspollenites* (5%), *Striatites* (3%) and *Lahirites* (3%) constitute the subdominant association of the miofloral assemblage. Like others, this zone is divisible into two subzones, the older with lesser striate disaccates (17%) and pteridophytic triletes (14%) than those in the younger (30%, 24% respectively).

LITHOLOGICAL SUCCESSION

The base of the bore core is characterized by grey, shaly sandstone with greenish tint and pebbles of assorted size (maximum dimensions being 0·35 × 0·07 m) from 689·51 m to 684·63 m level. Above this occur shaly to conglomeratic sandstones, and sandy shales which are usually grey with rare blackish inclusions, but greenish too, at 674·55 m level. The first coal seam occurs between 611·96 and 612·04 m depth. The strata which consist mostly of fine to medium grained sediments with rare carbonaceous matter, end up at 576·55 m level. Overlying this occurs a 49·30 m thick medium to coarse grained, gritty as well as pebbly sandstone. Subsequently thin-banded sandstones, shales and coal occur till 518·96 m level followed by another 45 m thick medium to coarse grained pebbly sandstone with a 0·80 m thick coal parting in its middle region. Overlying this, after thin beds of sandstone, shale and coal, totalling less than two meters in thickness, at 472·35 m level commences a medium and coarse grained sandstone, partially gritty or pebbly and with thick coal bands at places, up to 365·47 m level. Similar sandstones occur between 360·35-337·72 m, 312·77-271·87 m, 271·15-256·77 m, 254·89-189·65 m and 168·50-151·94 m in the bore core. The intervening strata are composed of shaly sandstone, shales and coal as usual. In the younger levels, medium to very coarse sandstones occur roofing the youngest three coal seams including the Jatraj seam which lies between 93·27-59·79 m.

LITHOPALYNOLOGY

As apparent from Table 1, in the oldest rocks represented by sample nos. 145 to 141, which are pebbly, grey with greenish tint at places, shaly sandstones, the spores are poor in quantity. Good spore recovery is noted from greenish-grey shale sample nos. 138-136. However, the dark grey to black shales in sample nos. 135 and 134 either lack spores or contain only some. Commencing from sample no. 132, good spore assemblages have been generally recovered in carbonaceous, grey and sandy shales as well as coal from the younger levels. Medium and coarse grained sandstones usually lack spores. From some grey shales only acicular, spicule like bodies have been recovered.

Such bodies have also been found in sample no. 92 which is a carbonaceous shale/coal. By and large, finer grained and organic sediments are richer in spores than the coarser grained.

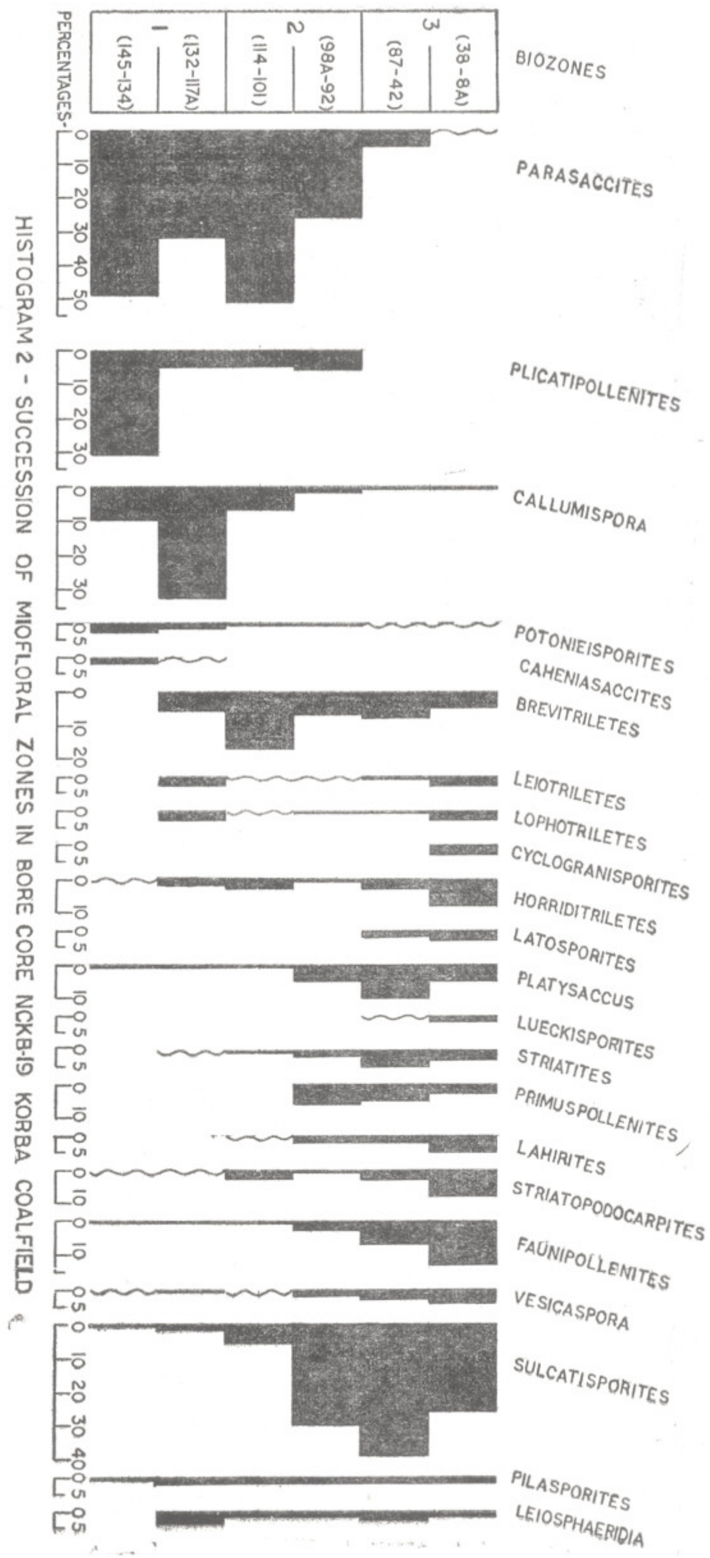
It is interesting to note that continuous samples coming from the younger and older levels in the same bed (Histogram 1 — sample nos. 136, 137, 138, 129, 130, 93, 94) show some difference in the quantitative representation of the spore genera in their assemblages. Likewise, closely bedded different lithologies (Histogram 1— sample nos. 123, 124, 27, 28) show differences in the quantitative generic composition of their assemblages. Evidently the resultant similar effect on the spore assemblages under two, different lithological conditions suggest that different factors independent of lithological differences account for the miofloral compositions. Comparing the effect of conglomeratic lithologies on the palynological succession (Histogram 1) one finds that four out of the seven beds (576·55-527·25 m; 518·96-473·79 m; 472·35-365·47 m; 271·15-256·77 m) coincide with changes in the miofloral composition. It seems that the miofloral changes have been accentuated to some extent by these gritty, pebbly beds but they also do not represent a significant time gap because in spite of such thick intervening beds, the miofloral spectrum above and below shows some continuity. Moreover, between samples 132 and 134 a miofloral change is as clearly depicted as elsewhere while the intervening stratum is a fine grained shaly sandstone, and that between samples 69 and 87, 42 and 38 and 34, there is hardly any miofloral difference in spite of the intervening strata being gritty and pebbly.

BIOSTRATIGRAPHY

The qualitative as well as quantitative distribution of various palynotaxa among the samples of the bore core No. NCKB-19 in Korba Coalfield suggests that the succession of the mioflora is divisible into dominant phases of *Callumispora* and *Sulcatisporites* indicating one major miofloral change (Histogram 2). The level of this major change between *Callumispora* phase and *Sulcatisporites* phase lies above sample no. 117A. Lithologically the same level separates the comparatively finer grained scarcely carbonaceous strata lying below from the coarser grained, gritty and richly carbonaceous sediments above.

The older phase commences with a pebbly bed with such characteristics as suggest it to be of periglacial origin. The mioflora in this phase has the dominant association between *Parasaccites* and *Callumispora* which is also said to be characteristic of the glacigene sediments in Australia (Evans 1969). In India, the glacial, periglacial or fluvioglacial sediments at the base of the Lower Gondwana System are usually assigned to the Talchir Stage. Evidently the sequence of strata encompassed by the older subzone in Zone No. 1 is assignable to the Talchir Stage. In the younger subzone of Zone 1 carbonaceous matter appears at the base and finally a thin (8 cm) coal layer occurs in the younger portion. This subzone being in a conformable contact with the older subzone, which is unmistakably Talchir Stage, corresponds to the Karharbari Stage.

The younger phase encompassed by miofloral Zones 2 and 3 is lithologically characterized by gritty and pebbly sediments along with interbedded, carbonaceous sediments including coal. Palynologically Zone 2 shows the dominance of *Parasaccites*. Similar dominance is known from the mioflora in shales of Karharbari Stage in Giridih Coalfield (Maithy, 1965). The mioflora of Zone 3 is rich in *Sulcatisporites* and the striated disaccates. Somewhat similar miofloral composition is now known from the coals of Mohpani Coalfield (Bharadwaj & Anand-Prakash, 1972a) and the basal seams in Argada Sector of South Karanpura Coalfield (Bharadwaj & Anand-Prakash, 1972b), both of which are placed on lithostratigraphic grounds in the Karharbari Stage. Evidently, the Karharbari Stage in Korba Coalfield tends to encompass palynologically the younger subzone in Zone 1 and Zones 2 and 3 as deducible from the information available at present. But palynofloristically the younger subzone of Zone 1 is definitely closer to the older subzone and as the major floral change commences just above Zone 1, Zones 2 and 3 are separate from it. Thus, the younger subzone of Zone-1, which conformably overlies the lithopalynologically undoubted Talchir Stage, is the older part of Karharbari Stage and the strata of palynological Zones 2 and 3 represent the younger part of Karharbari Stage, as deducible so far.


HISTOGRAM 2 - SUCCESSION OF MIOFLORAL ZONES IN BORE CORE NCKB-19 KORBA COALFIELD
BIOZONES
1
(145-134)
(132-117A)
2
(114-101)
(98A-92)
3
(87-42)
(38-8A)
PERCENTAGES-1
PARASACCITES
PLICATIPOLLENITES
CALLUMISPORA
POTONIEISPORITES
CAHENIASACCITES
BREVITRILETES
LEIOTRILETES
LOPHOTRILETES
CYCLOGRANISPORITES
HORRIDITRILETES
LATOSPORITES
PLATYSACCUS
LUECKISPORITES
STRIATITES
PRIMUSPOLLENITES
LAHIRITES
STRIATOPODOCARPITES
FAUNIPOLLENITES
VESICASPORA
SULCATISPORITES
PILASPORITES
LEIOSPHAERIDIA

HISTOGRAM 2

In the subsurface of Korba Coalfield, the Karharbari Stage is represented by three palynological assemblages viz. *Callumispora* rich, *Parasaccites* rich and *Sulcatisporites* rich in progressive succession and out of these one (*Parasaccites* rich) assemblage is known so far from the type area of Karharbari Stage in Giridih Coalfield. It is still unknown if the other two assemblages occur also in the type area. In case they do, it will have to be decided whether all the three constitute the Karharbari Stage or only one or two of them.

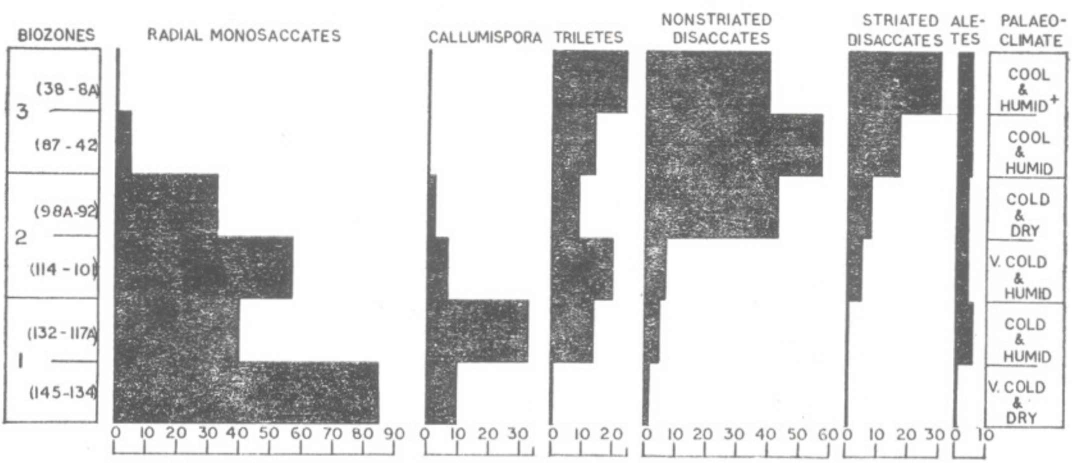
PALYNO-PALAEOCLIMATE

The base of the bore core consists of greenish tinted pebbly, grey shaly sandstone, which along with the prevalence of radial monosaccates dominated mioflora characteristic of glacigene sediments, suggests that sedimentation in the basin started under periglacial conditions and continued so till the deposition of black and grey shale with pebbles of black schist up to 668·57 m level. The miofloral assemblage of this zone lacks pteridophytic triletes suggesting thereby that the climate while being cold was also dry.

In the strata between 668·57 and 576·55 m level, there is no lithological evidence regarding the climatic conditions. Miofloristically the assemblage becomes progressively richer in the representation of pteridophytic triletes. *Parasaccites* which continues to be more or less dominant throughout, is associated with equally dominating *Callumispora* in this section of the zone. The *Parasaccites* + *Callumispora* association has been reported to be prevalent in glacigene sediments (cf. Evans 1969) and its occurrence in close stratigraphic proximity of conformably underlying glacigene sediments in the Korba basin suggests that the climate during the deposition of this younger section of Zone No. 1 continued to be cold but ameliorated due to rise in humidity as indicated by a progressive increase in the pteridophytic triletes, i.e. humidity, and consequently density of vegetation, culminating into the formation of a thin coal seam at 612 m level.

In the older section of Zone No. 2, *Parasaccites* is singly dominant associated with low *Sulcatisporites* and *Callumispora*. The representation of pteridophytic triletes increases to 20 per cent. This increase could be somewhat exaggerated because most of the samples studied are coal. However, in view of the high *Parasaccites*, it seems that the climate again receded to become colder but the increase in humidity proved conducive to richer vegetation resulting into formation of a number of thin coal seams at short intervals. The duration of this climate was rather short.

Above the 518·96 m level, the younger subzone commences with the residual climate, progressively ameliorated in respect of temperature and drier as compared to



HISTOGRAM 3 - SHOWING THE PALAEOCLIMATE IN THE BIOZONES

HISTOGRAM 3

the older subzone. The reversion to colder climate at the commencement of Zone No. 2 as suggested palynologically, seems to have been due to a cyclic glacial advance of a shorter duration and less intense than the earlier one supposed to be operating during the deposition of the basal subzone in Zone No. 1.

In Zone No. 3, the miofloral assemblage assumes its *Sulcatisporites* dominating and striated disaccates rich character. The triletes also increase and become more diversified. Although the temperature tolerance of the plants producing *Sulcatisporites* and striated disaccates is not precisely known, yet conjecturing that they were primitive gymnosperms and that the change from the preceding cooler climate in the sequence could only be towards being warmer, it is postulated that the climate of the youngest zone was comparatively much less cold but humid, subtending a vegetation rich in gymnosperms with reasonable pteridophytic undergrowth which resulted into formation of thick coal seams.

Histogram 3 sums up the palyno-palaeoclimatic interpretations.

CONCLUSIONS

NCKB-19 has provided a detailed, sequential, palyno-stratigraphical-climatological investigation of the older part of Lower Gondwana horizon in India. Palynologically the sequence reveals the existence of three miofloral zones. In the oldest zone, the basal part is interpreted to be representing the Talchir Stage and the younger subzone and the two younger zones, the Karharbari Stage. The youngest zone is homotaxial with the coal bearing beds in Mohpani Coalfield and the Argada 'S' seam in Argada Sector of South Karanpura Coalfield.

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