PALYNOSTRATIGRAPHY AND PETROLOGY OF LOWER GONDWANA COALS IN PENCH-KANHAN COALFIELD, SATPURA GONDWANA BASIN, M. P., INDIA

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ABSTRACT

The present paper contains an account of the palynostratigraphy including correlation of coal seams in the Lower Gondwana sediments of Pench-Kanhan Coalfield, and an evaluation of coal types based on biopetrological studies of the coals collected from the various coal mines of the coalfield. Some useful field observations and petrological details of the important rock types have also been presented.

Six biozones (cenozones) have been recognised by detailed statistical palynological study of the characteristic miospore assemblages recovered from the Talchir rocks and overlying Coal beds of the area. The lower two biozones (A and B) characterised by the dominance of radial monosaccate miospores but with or without *Callumispora*, are placed in the Talchir Stage. This placement is also corroborated by the associated Talchir lithology. The next two younger biozones (C and D), characterised by the dominance of *Microbaculispora* and *Microfoveolatispora*, in various percentages recovered from the coal and associated shales are placed in the Karharbari Stage.

The upper most biozones (E and F) characterised by the dominance of *Brevitriltes* and *Sulcatisporites* are placed in the Lower Barakar Stage. Palynologically, four coal seams are distinguishable. The correlation of coal seams and their lateral extension from Rawanwara Khas Colliery in the east and Rakhikol Colliery in the west have been established palynologically.

The ultimate coal composition derived from various organic and inorganic material has been described in detail. Statistical maceral and microlithotype analysis of the coals has revealed four distinct coal types corresponding to the four younger palynological zones.

The age, nature and formation of the coals, and the climatic conditions prevailing during the time of deposition of the Lower Gondwana sediments in the area have also been discussed.

INTRODUCTION

Pench-Kanhan Coalfield named after the Pench and Kanhan rivers in the area, is situated in the southern part of the Satpura Gondwana Basin. Presently, this is the most important coal producing area of the Satpura region. The Lower Gondwana Formations comprising Talchir sediments, Coal beds and Motur rocks, occur in the area as a continuous band from Sirgora in the east (22° 12′ : 78° 53') up to nankarak in the west (22° 11' : 78° 10'). Talchir beds are exposed in the extreme south (Map-I) of the area resting on an uneven basement of the Archean gneisses and granites. Coal beds are exposed in the central portion of the area overlying the Talchirs. In the north, Motur clays and sandstones are seen overlying the coal beds covered by the traps at places. Three main coal seams are known in the area mainly on lithological basis. As the coal is being extensively mined in the area, the entire Lower Gondwana tract of rocks has many shafts and inclines which are named after the local names of the villages and thus, is divided in several mining sectors. The well known mines are Rakhikol, Kalichhapur, Ghorawari, Datla West, Eklehra, Ambara, Barkuhi, Chandameta, Dongarchikli, Rawanwara and Rawanwara Khas etc. (Map-I). Some of the coal in the area is of good quality and is also semicaking in nature. The coal of the western area (Kanhan side) is better in quality as compared to the coal of the eastern parts (Pench side). The area has been marked by the presence of many faults and dykes which have complicated the basin structure leading to problems concerning nature, stratigraphy and correlation of the coal seams. In the present work an attempt has been made to determine the stratigraphy, correlation and lateral extension of the coal seems with the help of palyno-fossils and to evaluate the physical and petrographical characteristics of the coals for the elucidation of their nature and formation.

The samples were collected from the basal Talchir boulder bed up to Motur clay and sandstones below the traps. Palynological study of all the samples has been done and the microfloral zones from the various formations are described. Freshly blasted faces of the coal seams from various coal mines were studied for the megascopic petrological characters of the coal. Coal blocks collected from the various seams were cut to suitable sizes and polished for the microscopical study of the lithotypes. Coal pellets prepared from the representative coal samples crushed up to 18 mesh size were used for the statistical maceral and microlithotype analysis. The maceral and microlithotype composition of the coals were studied in order to determine the coal types present in the area.

GENERAL GEOLOGY

The area of the Lower Gondwana formations lying south of Pachmarhi range is traversed by Pench and Kanhan rivers and hence, derives its name as Pench-Kanhan Coalfield. In the east near Sirgora, the Lower Gondwana sediments occur as a small patch and from Dhingawani (22° 12′ : 78° 49′) to Nonkarak (22° 11′ 30″ : 78° 10′) in the west, they form a continuous strip 63 km long and 8-10 km wide. As the formations are affected by faults at many places, the division of Pench and Kanhan areas is difficult to mark. The present knowledge of the geology of this area has been mainly contributed by BLANFORD (1882), JONES (1 91), FOX (1934) and PAREEK (1970).

Geological Succession: (After PAREEK, 1970)

Recent—Alluvium

Upper Cretaceous—Lava flows (Deccan Trap) and dykes of dolerite, sometimes olivine bearing

Unconformity

Upper Gondwana .. *Jabalpur Stage*—Clays, massive sandstones, often grity and carbonaceous shales.

Unconformity

Lower Gondwana—*Motur Stage*—Yellowish sandstones, mottled red, buff, yellow and green clays, often with calcareous nodules.

Barakar Stage—Medium to coarse grained sandstones, shales, carbonaceous shales and interbedded coal seams.

Talchir Stage—Greyish, greenish to olive green shales, mudstones and boulder beds.

Unconformity

Archean .. Metamorphics, granites often porphyritic, hornblende gneiss, schists and amphibolites.

The total thickness of the Lower Gondwana sediments is about, 100 meters, but it is not uniformily so throughout the area as it has become less thick towards west in Kanhan area. The general strike is ENE-WSW and the beds are dipping towards north on low angles between 5° to 12°. The Talchirs have been laid down unconformably over the metamorphics. Their lateral contact is marked by a prominent fault forming the southern boundary of the Gondwana sediments in the area. Talchirs are overlain by the coal beds. The entire succession of Lower Gondwana sediments is exposed in Pench and Kanhan river sections. The Kanhan section is better than the Pench as the latter is covered by the alluvium at places. Coal beds are succeeded by the Motur sandstones and clays towards the north of the coalfield. Jabalpur beds overlie the Moturs uncomformably, but are present only in the extreme east in Sirgora area. In the rest of the coalfield area the Moturs are covered by the traps. the area has also been affected by many strike faults and intruded by many dolerite dykes which are spread throughout the coalfield.

In all, three workable coal seams are present in the area except in Rawanwara Khas (Map-I) where four seams have been marked. The coal seams are mostly concealed and they rarely crop out on the surface. Therefore, the entire data about the coal measures mainly depend upon the underground workings. The locations of the various coal producing collieries are given in Map-I. Thickness of the seams varies at places.

The Top Seam (No. 1 seam) has been extensively worked in Kanhan Valley area. The second and third coal seams are being worked in the Ghorawari and other areas. These seams have been recorded from many parts of the coalfield. At many places these seams are associated with their leaders. The thickness of the leader seams varies from $1\frac{1}{2}$ to 3′ and these are present just above the main seams. The number of seams is constantly three up to Rawanawara area but it increases to four in Rawanwara Khas. This is the only part of the Pench-Kanhan Coalfield where four coal seams are present and coal is extracted from all of them.

The upper portion of the Top Seam is more or less shaly in nature but the lower portion has good coal. The thickness of this seam is about 8.5 meters in Sirgora area and 7.3 meters in Rakhikol area. It is 2.42 meters in Chandameta, 1.22 meters in East Dongarchikli and 1.22 meters in Rawanwara areas.

The second seam has a thickness of 0.60 meters in Rakhikol, 0.98 meters in Datla, 1.82 meters in Dongarchikli and 3.42 meters in Rawanwara.

The third seam has a thickness of 0.60 meters in Kanhan Valley region, but is thicker in the Pench Valley areas. It has the thickness of 2.44 meters at Chandameta and 2.5 meters at Rawanawara.

The fourth seam so far known from Rawanwara Khas area is only 0.95 meters thick.

TALCHIRS—A good succession of Talchir beds is exposed in the Kanhan River section, south of the road leading to Damua. The road almost runs along the contact between the Talchirs and the coal beds near the Kanhan River. Here, the Talchirs are represented by the boulder beds, needle shales, sandstones and mudstones. Boulder bed is composed of assorted boulders of different size and shape imbedded in the clayey matrix. A good exposure of boulder bed is seen in a nala cutting about $\frac{1}{2}$ km south of the railway crossing on Parasia-Damua Road near Tomra Village. The boulder bed is overlain by the needle shales and sandstones. Further south in the nala section, the Talchir sandstones have come in sharp contact with the metamorphics due to the fault which forms the southern margin of the Lower Gondwana Formations in the area. Various exposures of needle shales of varying thicknesses are seen in the Kanhan section alternating with the sandstones. These are mostly greenish and khaki in colour often containing thick bands (up to 2′) of mudstones. Sandstones are light green to yellow in colour. Grain size varies from grit to medium grained sandstones. Felspar and quartz are the dominant mineral constituents imbedded in clayey and ferruginous matrix.

Coal beds

Coal beds are composed of coal, carbonaceous shales and coarse to fine grained sandstones. In the river section the sandstones exposed are thickly bedded, showing pot holes. These are often micaceous having quartz grains, felspars and limonitic contents. Shales are greyish in colour grading into carbonaceous and coaly shales. In all, three main coal seams which are economically important have been proved in the area. Plant fossils are common in these beds.

Moturs

Moturs represent the Barren Measures of the area and are lithologically very different in composition from the other coalfields. These are composed of coarse grained to gritty yellow and reddish sandstones, shales and clays which are associated with calcareous nodules.

MATERIAL AND METHODS

Two excursions were made to the Pench-Kanhan Coalfield in the years 1968 and 1971 for field studies and collection of coal samples from the various collieries and surface exposures of the area. The complete thickness of each seam as well as some block coal samples of different lithotype bands were collected from the working collieries of the area (Tables I, II, III & IV).

Table—I

Sample Nos.	*Colliery*	*Seam No.*	*Overall Samples*	*Block Samples*
1.	Rawanwara Khas	1	One	Three
2.	,,	2	One	Two
3.	,,	3	One	One
4.	,,	4	One	Two
5.	Rawanwara	2	One	Three
6.	,,	3	One	Two
7.	Dongar Chikkli	1	One	Two
8.	,,	2	One	Two
9.	Chandameta	1	One	Two
10.	,,	Leader of 1	One	One
11.	,,	2	One	Four
12.	,,	Leader of 2	One	Two
13.	,,	3	One	Three
14.	,,	Leader of 3	One	One
15.	Eklehra	3 (Top Section)	One	Three
16.	,,	3 (Bottom Section)	One	Three
17.	Ambara	1	One	Two
18.	,,	3	One	Three
19.	Dalta West	Illiot pit	One	Four
20.	,,	No. 6 incline	One	Two

Section in a stream below Tomra Village

Table—II

Sample Nos. (Bottom to top)	
1.	Talchir boulder bed
2.	Talchir needle shale
3.	Grey shale
4.	Talchir needle shale
5.	Grey shales
6.	Talchir needle shales

Kanhan River Section

Table—III

7.	Talchir sandstone
8.	Talchir siltstone
9.	Talchir needle shales.
10.	Talchir needle shales
11.	Talchir needle shales
12.	Talchir siltstone.

In addition to these, some colliery and bore hole samples from the other areas were also supplied by the Regional Coal Survey Station, Nagpur, the details of which are given below.

Pench-Kanhan Colliery Samples

Table—IV

Sample No.	Location	CFRI sample		Thickness of foot section (m)	Remarks
	(Damua Colliery)				
1.	No. 9 incline	No. CAN-S			
2.	,,	152/F-1		0.40	Foot numbers from the floor of the seam.
3.	,,	152/F-2		0.30	
4.	,,	152/F-3		0.30	
5.	,,	152/F-4		0.30	
6.	,,	152/F-5		0·30	
7.	,,	152/F-6		0.30	
8.	,,	152/F-7		0.30	
		152/F-8	(Carb. shale)		
9.	,,	152/F-9		0.31	
10.	,,	152/10+F-11)		0.33	
11.	,,	152/F-12		0·30	
12.	,,	152/F-13		0.30	
			Total ..	3.54	
	(Kalichhapar Colliery) No. 6 Incline				
1.	,,	169/F-1		0.30	Foot numbers from the floor of the seam.
2.	,,	169/F-2		0.30	
3.	,,	169/F-3		0.30	
4.	,,	169/F-4		0.30	
5.	,,	169/F-5		0.30	
6.	,,	169/F-6		0.30	
7.	,,	169/F-7		0.30	
8.	,,	169/F-8		0.42	
9.	,,	169/F-9	(Carb. shale)		
10.	,,	169/F-10		0.18	
			Total ..	2.80	

Sample No.	Location	CFRI sample		Thickness of foot section (m)	Remarks
	Rakhikol Colliery No. 20 Incline				
1.	,,	172/F-1		0.30	Foot numbers from the floor of the seam.
2.	,,	172/F-2		0.30	
3.	,,	172/F-3		0.30	
4.	,,	172/F-4		0.30	
5.	,,	172/F-5		0.30	
6.	,,	172/F-6		0.30	
7.	,,	172/F-7	(Carb. shale)	0.10	
8.	,,	172/F-8		0.30	
9.	,,	172/F-9		0.30	
10.	,,	172/F-10		0.21	
			Total ..	2.71	

Before actual collection of the coal samples in the case of surface exposures, the entire exposed surface of the coal seam was dug up to one foot or so in order to remove the weathered and oxidised material. A 6″ inches wide channel was cut through the entire thickness of the seam and the coal samples were collected representing each band exposed in the entire thickness of the seam. The area having working mines, the samples were collected from the freshly blasted faces of the seams. Special care was taken to collect the coal layers present in the seams. These samples were used for palynological and petrological study of the coals. The collection of coal blocks has been done according to the lithotype bands present in the coal seams. These samples were used in the study of the general petrological constituents of the coals. The material for overall samples was crushed in a pestle to small pieces of approximately 18 B.S. size and was mixed thoroughly.

All the coal samples were subjected to similar maceration technique. About 5 gms. of the material from each sample was treated with commercial nitric acid for three days followed by the treatment with 10% potassium hydroxide, after thorough washing with water as suggested by Bharadwaj (1962) and Bharadwaj AND Salujha (1964). The macerates were placed in glycerine jelly and slides were prepared. 200 microspores were counted from each sample at generic level for statistical palynological analysis.

In the case of shale samples the treatment of hydrofloric acid has also been done before the digestion of the material in KOH.

For petrological study the technique of examining the coal in polished samples through incident light has been applied in the present investigation of microconstituents of Pench-Kanhan coals.

5-10 gm. of the overall coal samples, crushed to ± 18 B.S. size were utilised for preparation of coal pellets for quantitative estimation of different macerals and microlithotypes. Representative lithotype blocks were suitably cut into 8 cm.×4 cm. size, embedded and polished for general observation of the microstructure of the microconstituents. Preparation of coal blocks and pellets have been done according to the procedures suggested by Navale (1964, 1969) and Navale AND Srivastava (1967).

The proportions of various macerals and microlithotypes were evaluated through the planimetric survey method, i.e. the point counter method. It is assumed that the thickness of various components measured along a vertical transect is directly proportional to volume relationship. The macerals were analysed by using specially designed, electrically operated mechanical stage over the microscope and a counting unit. The pellet was mounted over the stage which was adjusted to move 0.3 mm. along the fixed pattern of traverse line at every stroke of the counting unit. Only the macerals falling under the intersection of the cross-wires and for microlithotypes falling in the square after each movement of the stage were counted as representative units. Similarly one thousand points were counted in each pellet with a view to minimise errors.

All the 12 samples from Damua colliery, 10 samples each from Kalichhapar and Rakhikol collieries were mixed to make one representative sample of each for the entir working seams (Table- IV). Two samples from Ghorawari Top and Bottom Seamsc were sent to us separately by Regional Coal Survey Station, Nagpur.

PALYNOLOGICAL CHARACTERISTICS

The samples from Talchir and Coal beds succession in the Pench-Kanhan Coalfield have been investigated sporologically and in the mioflora obtained 37 genera and 62 species could be recognized. The miospores include a number of trilete, monolete, monosaccate, disaccate, monocolpate and alete forms. Most important amongst these are the triletes, monosaccates and disaccates. Qualitative and quantitative evaluation of the above miospores reveals that the following genera form the characteristic associations in the Talchirs and the Coal beds successively.

Talchirs—(Prominent genera, Histogram-I)

Callumispora Bharadwaj & Srivastava, *Parasaccites* Bharadwaj & Tiwari, *Plicatiopollenites* Lele, *Virkkipollenites* Lele, *Pilasporites* Balme & Hennelly.

The following genera are also present but in rare amounts.

Potonieisporites Bharadwaj emend. Bharadwaj, *Caheniasaccites* Bose & Kar, *Crucisaccites* Lele & Maithy, *Striatites* Pant emend. Bharadwaj, *Striatpodocarpites* Soritch & Sed. emend. Bharadwaj, *Illinites* Kosanke emend. Potonié & Kremp, *Sulcatisporites* Leschik emend. Bharadwaj, *Tiwariasporis* Maheshwari & Kar.

The percentage frequencies of the dominant spore genera reveal two distinct assemblages in the Talchir succession.

Assemblage-A recovered from the older sample, is characterised by *Parasaccites* 54%, *Plicatipollenites* 23%, *Virkkipollenites* 11% and *Pilasporites* 10%. The assemblage is dominated by radial monosaccate spores.

Assemblage-B recovered from the samples slightly higher in position in the Talchir succession than the one containing assemblage-A, is characterised by *Callumispora* 7%, *Parasaccites* 47%, *Plicatipollenites* 29%, *Virkkipollenites* 8% and *Pilasporites* 6%. This assemblage is also dominated by the radial monosaccates with the addition of *Callumispora*. The occurrence of *Callumispora* also suggests a younger position of the assemblage.

Coal beds—(Prominent genera, Histogram -II)

Hennellysporites Tiwari, *Brevitriletes* Bharadwaj & Srivastava, *Microbaculispora* Bharadwaj, *Microfoveolatispora* Bharadwaj, *Parasaccites*, *Vesicaspora* Schemel, *Sulcatisporites* & *Pilasporites*.

The undermentioned miospores occur consistently in all the samples closely following the quantitatively more prominent genera:

Callumispora, *Lophotriletes* Naum. emend. Potonié & Kremp, *Indotriradites* Tiwari, *Cuneatisporites* Leschik, *Striatites*, *Faunipollenites* Bharadwaj, *Illinites*, *Ibisporites* Tiwari.

In addition to these, the following genera are also present in the assemblage but in rare amounts.

Leiotriletes Naum. emend Potonié & Kremp, *Cyclogranisporites* Potonié & Kremp, *Horriditriletes* Bharadwaj & Salujha, *Latosporites* Potonié & Kremp, *Caheniasaccites* Bose & Kar, *Potonieisporites*, *Virkkipollenites*, *Plicatipollenites*, *Crucisaccites*, *Platysaccus* Potoniè & Klaus, *Primuspollenites* Tiwari, *Rhizomaspora* Wilson, *Lahirites* Bharadwaj, *Lunatisporites* Bharadwaj, *Striatopodocarpites*, *Tiwariasporis*, *Ginkgocycadophytus* Lub. emend. Samoil.

The distribution of the prominantly represented components reveal four different assemblages in various combinations, each characteristic of one seam in the Pench-Kanhan Coalfield. These assemblages have been illustrated as Assemblages—C, D, E, and F in histogram-I.

Assemblage—C

Assemblage-C is represented in only one sample of Rawanwara Khas IV Seam (Fig. 1). This is characterised by the dominance of *Microfoveolatispora* which is present up to 23.5%. The others to follow it are *Microbaculispora* 16.5%, *Brevitriletes* 15.0%, *Hennellysporites* 11.5%, *Callumispora* 9.5%, *Pilasporites* 8.0%

Thus, the trilete miospores outnumber the rest and form 86.5% of the total population. The next group to follow the triletes are alete miospores which are present up to 8%.

Assemblage-D

Assemblage D is also represented in Rawanwara Khas III Seam only (Fig. 1) and is marked by the dominance of *Brevitriletes* being present up to 24%. The other subdominant genera are *Pilasporites* 17.0%, *Hennellysporites* 12.0%, *Microbaculispora* 10.%.

Like Assemblage-C, this also has the dominance of trilete miospores totalling up to 76.0%. It may be noted that *Microfoveolatispora* unlike the former assemblage, is decreased considerably. The alete genus *Pilasporites* shows a considerable increase. The monosaccates (5.5%) and disaccates (9.0%) show an increase in percentage over Assemblage-C.

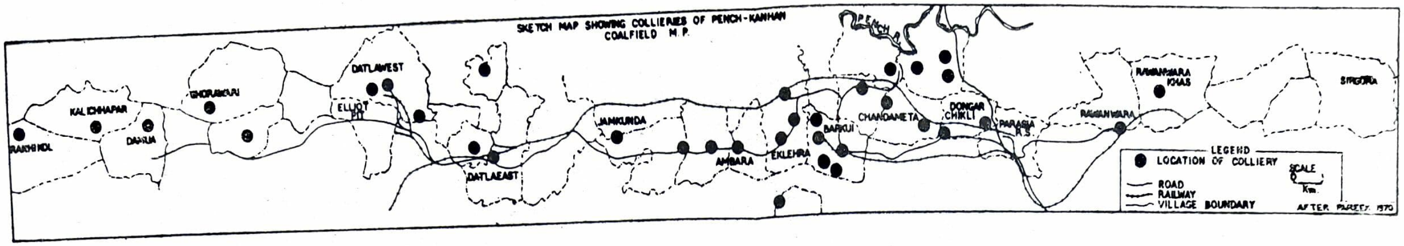
Assemblage-E

This is the third assemblage in order of succession and is represented in four samples viz. Rawanwara Khas II and I, Dongarchikli II and Chandmeta III seams (Fig. 1). The most characteristic feature of this assemblage is the high percentage representation of *Brevitriletes* 21%, *Sulcatisporites* 18%, *Pilasporites* 15%, *Hennellysporites* 9%.

The other consistent genera are *Parasaccites* 6%, *Vesicaspora* 4%, *Illinites* 4%, *Striatites* 3%, *Microbaculispora* 3%, *Indotriradites* 3%, *Faunipollenites* 2.5%, *Ibisporites* 2%, *Tiwariasporis* 2%& *Microfoveolatispora* 2%.

It is interesting to note here that the dominance of *Brevitriletes* in assemblage-E is similar to assemblage—D but the total percentage of trilete miospores has decreased considerably (43%). On the other hand, monosaccate and disaccate miospores have further increased to 7% and 36% respectively. Incoming of *Sulcatisporites* among the disaccates is significant in this assemblage.

In Dongarchikli-II Seam *Indotriradites* is present significantly and thus shows a slight variation from other samples of assemblage-E.



Map I. Sketch map showing collieries of Pench-Kanhan Coalfield, M. P.

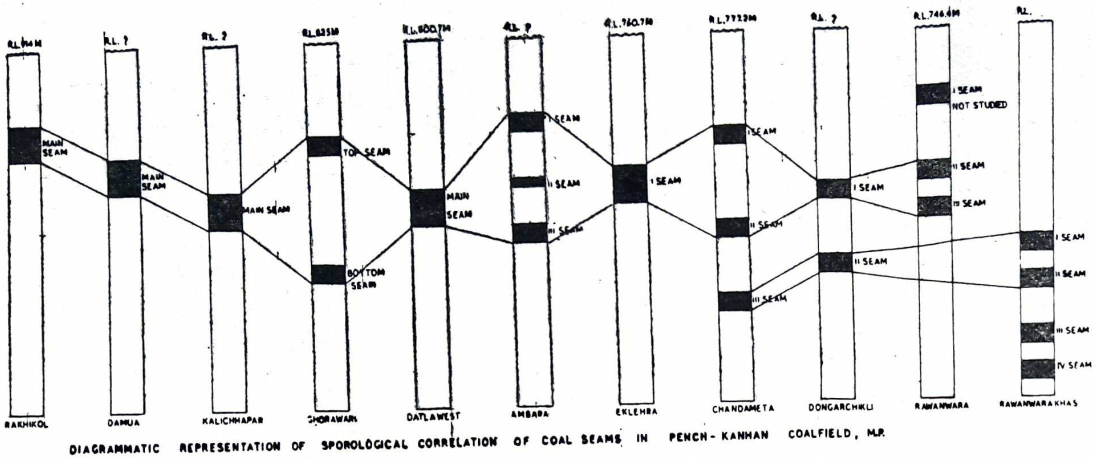
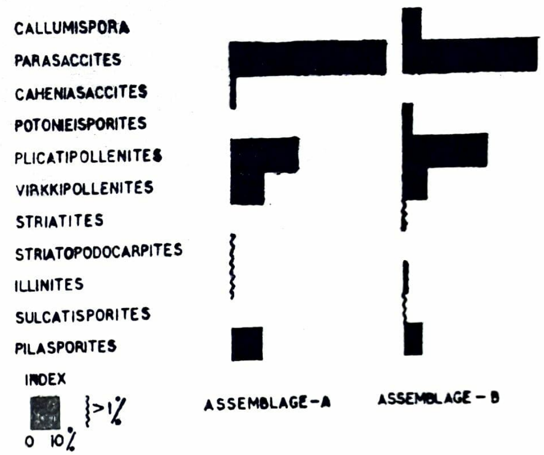
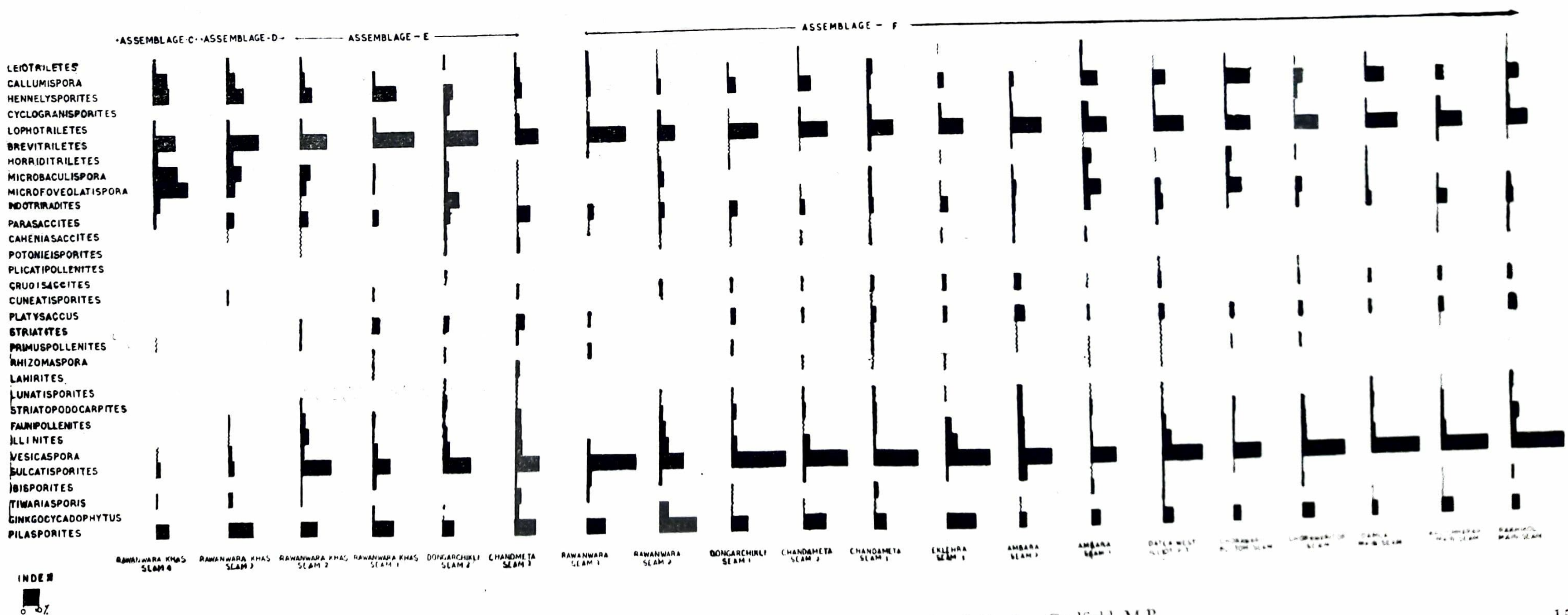


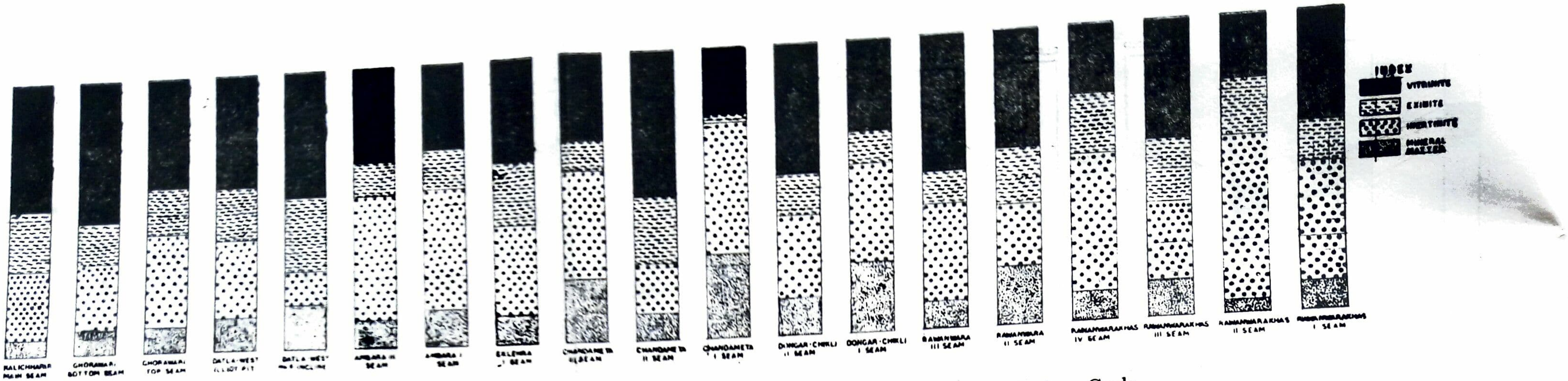
Fig. I. Diagrammatic representation of sporological correlation of coal seams in Pench- Kanhan coalfield, M. P.



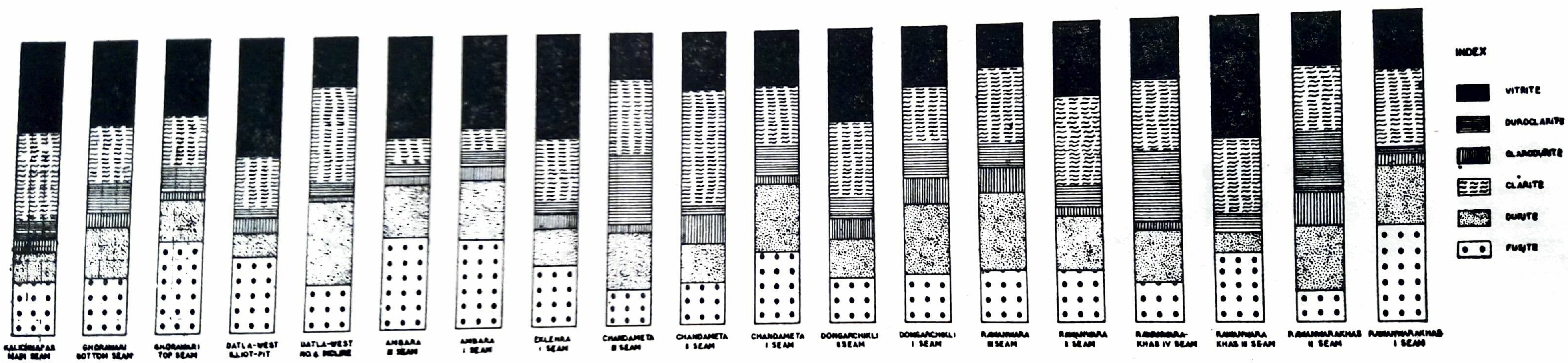
Histogram I. Percentage frequency histogram of miospore genera in Talchir sediments, Pench Kanhan Coalfield, M.P.



Histogram II. Percentage frequency histogram of miospore genera, Pench-Kanhan Coalfield, M.P.



Histogram III. Distribution of organic and inorganic microconstituents of Pench-Kanhan Coals.



Histogram IV. Percentage frequency Histogram of microlithotypes in Pench-Kanhan Coalfield, M.P.

Assemblage-F

Assemblage-F is most widely distributed assemblage in Panch-Kanhan Coalfield. It is represented in 14 samples viz., Rawanwara-II and III; Dongarchikli-I; Chandameta-I and II, Eklehra-I; Ambara-I, Datla West-Illiot Pit; Ghorawari-Top and Bottom, and main seams of Damua, Kalichappar and Rakhikol Collieries (Fig.-1). *Brevitriletes* continues to be present almost in the same amounts (19%) as in assemblages D and E but its dominance has been superceded by *Sulcatisporites* with an average percentage up to 29%. The miospores to follow next are *Pilasporites* 9.5%, *Hennellysporites* 8%, *Parasaccites* 4%, *Vesicaspora* 4%, *Indotriradites* 3%, *Illinites* 3%, *Lophotriletes* 2%, *Faunipollenites* 2%, *Microbaculispora* 1%& *Ibisporites* 1%.

The general occurence of trilete miospores is almost similar to assemblage-E and these are present up to 37%. It may be worth while to indicate that *Indotriradites* occurs in all the samples consistently but in low percentages. The alete miospores, decrease from assemblage E to F. The disaccate miospores, however, show a considerable increase over assemblage-E and become the largest group by their presence up to 45%.

The pollen spectra among the samples of assemblage-F do not exhibit appreciable variation from one another except few of them. However, the rhythmic fluctuations in *Brevitriletes* deserves special mention here. This genus is present in higher amounts in Rawanwara III seam while in overlying seam (i.e. Rawanwara II) it has reduced considerably. Similar variations are also to be observed in cases of Chandemata II and I seams, Ambara III and I seams, Ghorawari Bottom and Top seams. The genus *Sulcatisporites* shows a parallelism with *Brevitriletes* by having a similar variation as observed in the seams mentioned above. Such variations appear to be a constant character in this assemblage and thus are considered to be insignificant. Alete miospores viz. *Pilasporites* has been observed for the first time in the present assemblage and as such does not show any consistency in its occurrence. Moreover, the affinity and stratigraphic significance of such spores are not known and therefore, they have not been considered for correlation.

A critical apparaisal of all the assemblages reveals some very characteristic and prominent differences between them. *Microfoveolatispora* is dominant only in assemblage-C while in the rest, it is represented by less than 5%. *Brevitriletes* is a dominant component in assemblage-D but becomes subdominant in assemblage E and F. Assemblage-E bears a closer relationship with assemblage-F in view of its morphographically similar components. However, in the former *Brevitriletes* is quantitatively more than *Sulcatisporites* and in the latter their positions are reversed. Apart from this the total representation of disaccate pollen grains is more in assemblage-F than in E.

PETROLOGICAL CHARACTERISTICS

Petrological characteristics of the Pench-Kanhan coals were first studied by Ganju (1960). Pareek (1966) has made some critical observations on the nature of resin bodies present in these coals. Later in 1970 he presented a detailed correlation of coal seams based on lithological characteristics. Ray (1968) has studied the Ghorawari seam in Hirdagarh Quarry No. 11 C. in Kanhan Valley Coalfield with regard to its petrographic components. However, none of these authors attempted to differentiate the characteristic coal types based on petrological analysis. It is therefore, intended to give stress in this paper on the determination of coal types.

The coal lithotypes duroclarain and durain with significant proportion of mineral matter, dominate in all coal seams. Quite conspicuous feature is the rapid alternation of microbands of contrasted coal lithotypes. Although the principal coal types are described separately yet they are intimately associated and also the possible gradation and intermediate conditions occur commonly. In general, the coal seams are characterised by fine state of maceral division and by the presence of significant proportion of mineral matter finely dispersed and intimately associated with organic constituents of the seams (Histogram-III). The proportion of mineral matter generally increases with that of organic inserts making the change of coal type from clarain through duroclarain to durain. As evident from microanalysis, vitrinite and inertinite maceral groups are dominant microconstituents. Exinite is locally abundant. The micro and megaspores dominate as bands at irregular intervals along the seams. Fusinized resins occur in a variety of forms indicating large quantity of gums produced by the source material. Lenticular bodies of fusain are quite common in which cell cavities commonly contain either clay material or carbonate. Coalified wood and bark tissues commonly exhibit transition between the condition of vitrain and fusain.

The statistical maceral (Histogram-III) and microlithotype (Histogram-IV) analysis of organic and inorganic microconstituents and their assemblage pattern indicates considerable variation in the coals suggesting differentiation of Pench-Kanhan coals into four distinct types. The petrological characters of these types have not only profound influence on coal preparation and utilization but also aid in correlation of coal seams and their quality assessment.

Coal Type A

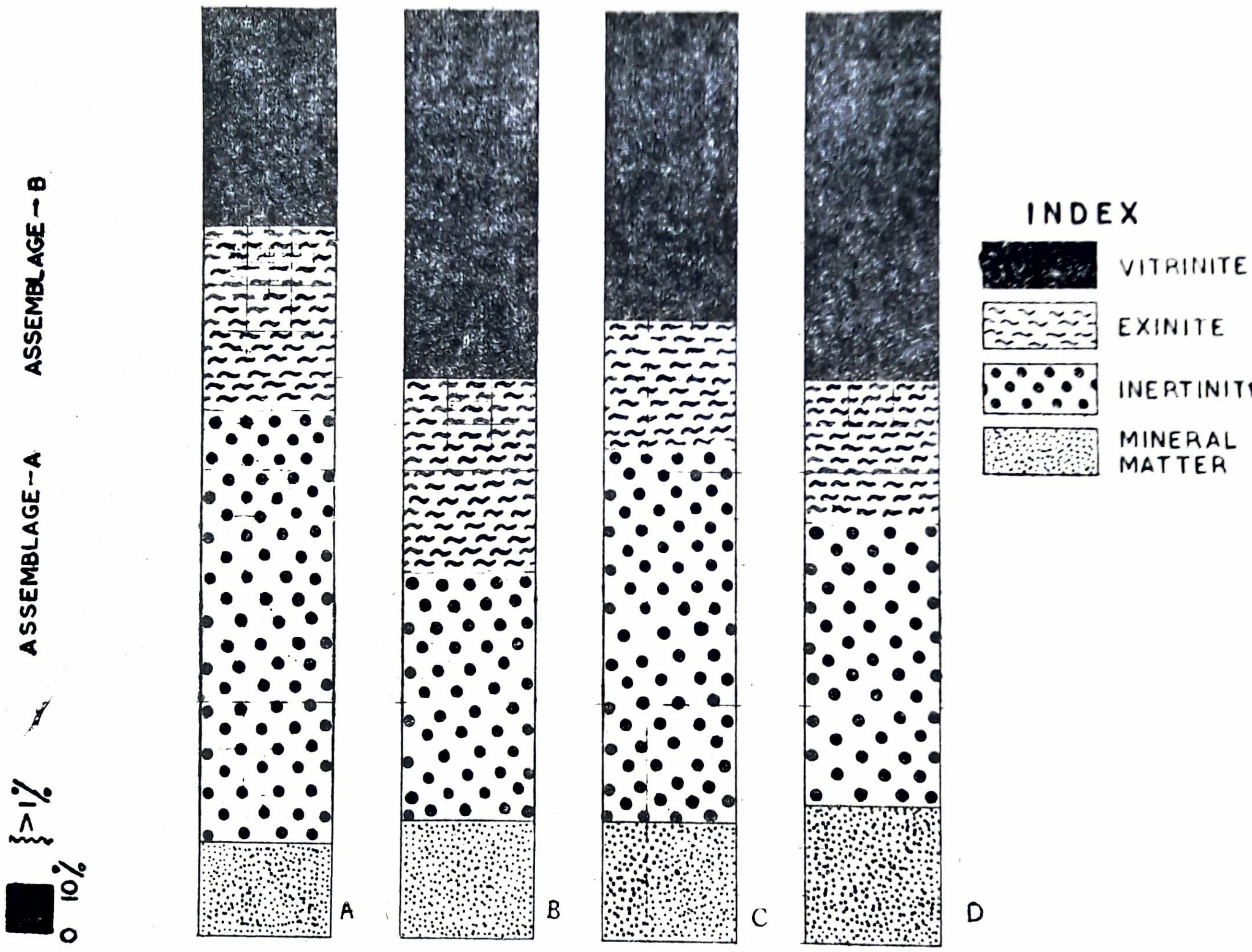
This type is characterised by rich fusinised and trimacerite entities of the lignogene and liptogene materials of the peat (Histogram-V). It comprises contrasted microbands of ultimate coal constituents of the source material. Some of the common ones are semi-brights, fusinites, dull carbargillate and those of trimaceral group components. Exinite constituents are not dominant nevertheless, on maceration it has been found that the microspores of *Microfoveolatispora* along with *Callumispora*, *Hennellysporites*, *Brevitriletes* and *Microbaculispora* form the main exines of this maceral group. The petropalynological analysis indicates that the coal type 'A' might have been mainly derived from the peat composed of prominent cryptogamic vegetation (cf. trilete miospores, prominent among them being *Microfoveolatispora*) under comparatively drier conditions as indicated by rich fusinised or disintegrated lignogene microconstituents. This type has been recognised only in Rawanwara Khas Colliery, Seam No. IV (Fig. 1) at the base of the sequence.

Coal Type B

This type is characterised by clarain microconstituents, mainly of vitrinite and exinite maceral groups (Histogram-V). There is a general increase in the "Vitrinization" and "Exinization" processes in the metamorphic alternation of the phyterals along with mineral matter. The constrasted microbands are mainly of fusinite and carbargillite constituents. They are quite distinct from coal type 'A'. Localized exinites and vitrinites are common. Both macrofragmental and attrital organic remains have played an important role in transformation of this coal type. On maceration of exinite maceral group, it has been found that trilete forms have dominated the assemblage but with diminished percentage of *Microfoveolatispora* suggesting a change in the source material of the type. Likewise decrease in fusinization is very characteristic in this coal type, suggesting increase in the water level of the basin in the peat stage. This type has also been recognized only in Rawanwara-Khas Colliery Seam No. 3 (Fig. 1).

COAL TYPE C

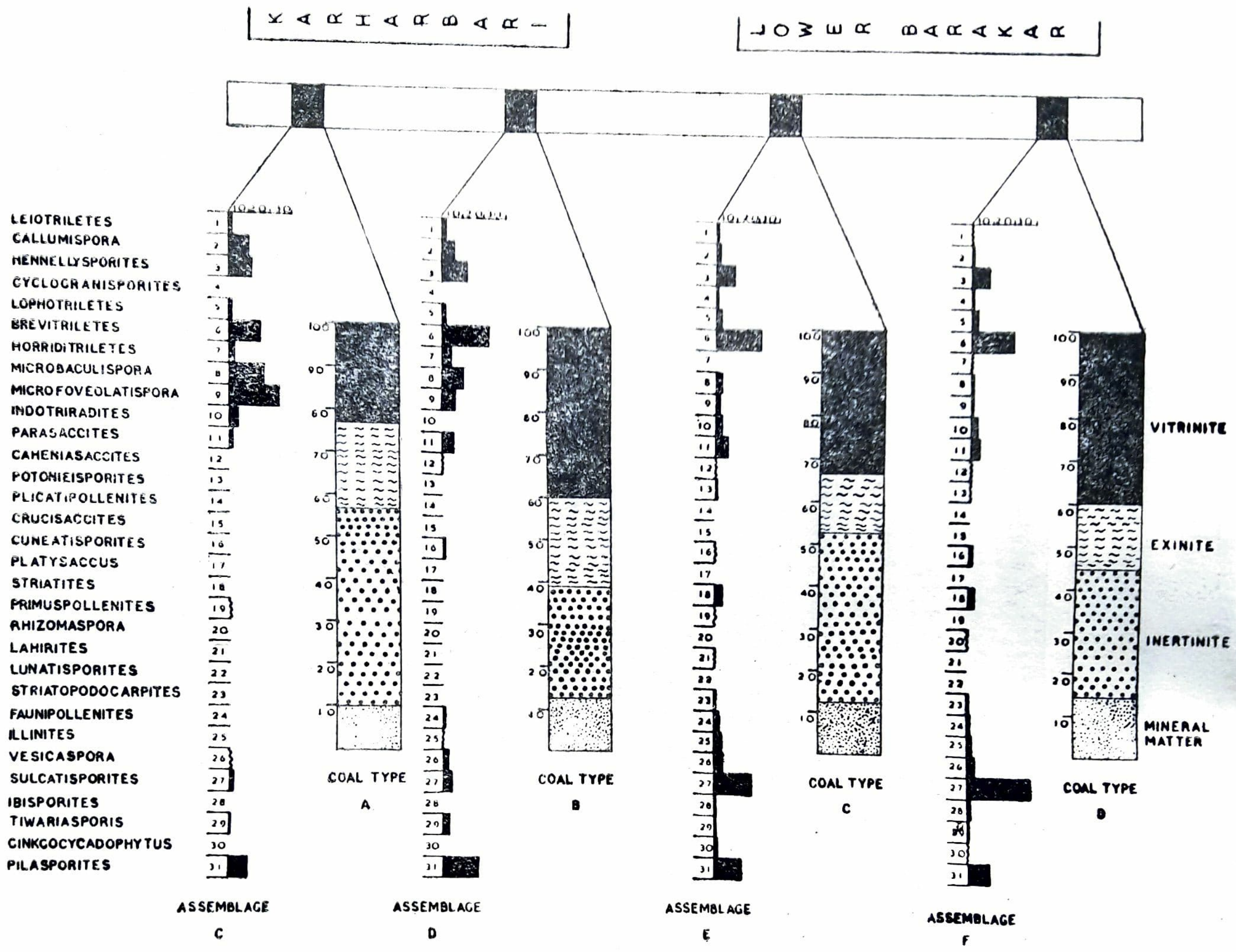
This is characterised by trimaceral organic constituents (Histogram-V). The characteristic microbandings of this type are fusinised bright, dull, semibright and shaly layers associated with inorganic matter. Among the trimaceral group components inertinite constituents dominate the type. Semifusinites are characteristic components of inertinites. Exinite is locally abundant and on maceration it has been found that *revitriletes*, *Hennellysporites* and *Sulcatisporites* form the main assemblage. Although broad general similarities are shown with the coal type 'A' and 'B' in overall maceral association yet the distinct, contrasted microlayers mainly of semifusinised and transitional nature of the source material and the composition of exinites are distinctly different. This type shows general increase in organic and inorganic microconstituents which are intricately associated. This type has been recognised in, Rawanwara Khas II and I, Chandameta III and Dongarchikli II seams (Fig. 1).



Histogram—V. Characteristic coal types.

COAL TYPE D

This type is characterised by "Vitrinite-Fusinite Series" of organic maceral group (Histogram-V). There is a general increase in vitrinization as compared to previous ones. It comprises a number of contrasted layers. Some of them are fusinised dull, bright, semi bright, shaly and rich in resinite. Woody elements have dominated in forming vitrinization, fusinization and transitional conditions of vitrinization in this coal type. Exinite is locally present yet has a chracteristic miospore assemblage dominated by *Sulcatisporites* along with *Brevitriletes*, *Hennellysporites*, *Lophotriletes*, *Microbaculispora*, *Indotriradites* and *Parasaccites* etc. The woody elements, the distinct microlayers and the source material of exinite group are characteristic of this type. Type-D is most widely distributed in Pench-Kanhan Coalfield. It is represented by 14 samples viz. Rawanwara-II and III; Dongarchikli-I, Chandameta-I and II, Eklehra-I; Datla West-Illiot Pit; Ghorawari-Top and Bottom and main seams of Damua, Kalichappar and Rakhikol (Fig. 1).



Histogram—II. Palynological assemblages and corresponding coal types in Pench-Kanhan coals.

BIOSTRATIGRAPHY OF PENCH-KANHAN COALS

Miofloral comparison provides evidence that the four different assemblages, as discussed earlier represent four different seams. Assemblage-C is oldest while assemblage-F is the youngest. *Microfoveolatispora* is dominant and *Microbaculispora* and *Brevitriletes* are subdominant in assemblage-C. But in assemblage-D *Brevitriletes* is dominant and the other two above mentioned genera are subdominant. *Microbaculispora* has been reported to be dominant in Chirimiri Coalfield (assemblage-A) and Bisrampur Coalfield by Bharadwaj and Srivastava (1969). *Microfoveolatispora* and *Microbaculispora* are sister genera, both, together with *Brevitriletes* and other similar genera constitute the Subinfraturma *Varitrileti* Venkatachala and kar (1965).

According to VENKATACHALA AND KAR (1968), varitriletes are characteristically dominant in the oldest horizon of Barakar Stage in North Karanpura Coalfield. However, in the palynological study of a bore hole sequence in N. Karanpura Coalfield, KAR (1973) has found a varitriletes-rich coaly horizon in Karharbari Stage. The latter finding being more conclusive, assemblages-C and D of Pench-Kanhan Coalfield are presumed to represent Karharbari Stage. *Sulcatisporites* is the prominant genus in the two younger seams of Pench-Kanhan Coalfield. *Sulcatisporites,* as known now (SRIVASTAVA, 1973; TIWARI, 1973) is richly present in the coals of Lower Barakar Stage from Giridih and Raniganj Coalfields. Thus, on the basis of above comparison it may safely be concluded that assemblages C and D represent Karharbari Stage and that assemblages E and F belong to Lower Barakar Stage in Pench-Kanhan Coalfield. Also there is a distinct change in the ratio of cryptogamic and gymnospermic miospores between the bottom pair and top pair of seams. The percentage of cryptogamic miospores is higher in the older while the percentage of gymnospermic pollen grains is higher in the younger.

DEPOSITIONAL HISTORY

After the deposition of the sediments belonging to the Talchir Stage characterised by the boulder beds, grits, needle shales, sandstones and mudstones the nature of sediments deposited in the basin show a distinct change. Appreciable quantities of plant parts along with the inorganic mineral matter formed the bulk of the sediments, thus, resulting into the formation of coal seams, carbonaceous shales and sandstones. As described earlier the coal seams occurring in the area are characterised by four petrographic types derived from fairly distinct organic suits of peat material forming four different seams.

The Coal type A derived from a swamp dominated by a vegetation constituting the miospore assemblage 'C' (Fig.-II) is characterised by the fusinised anthraxylous coal components, inertinite 46.5%, vitrinite 23%., exinite 20% and mineral matter 10%. Coal type 'B' derived from the vegetation dominated by the miospore assemblage 'D' (Fig.-II) is distinguished by the microfragmental components forming trimacerite constituents, vitrinite 40%, inertinite 26.5%, exinite 21% and mineral matter 12.5%. Similarly, Coal types 'C' and 'D' (Fig. II) are derived from the vegetation dominated by the miospore assemblages 'E' and 'F' characterised by inertinite 35%, vitrinite 33%, exinite 14% mineral matter 12.5% and vitrinite 40%, inertinite 30%, exinite 15.5%, mineral matter 19.5% respectively.

The percentage composition of these maceral groups suggests that coal types 'A' and 'C' and Coal types 'B' and 'D' bear close similarities. The inertinite is the dominant component in Types A and C followed by vitrinite, whereas, in types B and D vitrinite forms the dominant constituent followed by inertinite. Higher representation of inertinite is indicative of drier conditions in the basin of deposition leaving the coal forming peat exposed to atmospheric decomposition, resulting into the formation of fusains. Contrary to this, higher representation of vitrinite indicates comparatively wet and submerged conditions suitable for jellification resulting into the formation of vitrain in coal types B and D. Therefore, the water level in the basin must have been low during the formation of coal types A and C and high during the formation of coal types B and D. In view of this fact it can be safely concluded that the formation of coal in Pench-Kanhan Coalfield has taken place in two different cycles of deposition, each starting with drier conditions or low water level and ending with wet conditions or higher water level in the basin. During the first cycle the two lower seams and during the second cycle the two upper seams were deposited. The qualitative change in the miospore assemblages of the two lower seams and the two upper seams also provides additional evidence in support of this view. The first cycle shows the dominance of cryptogamic plants in the source area which was later replaced by gymnospermous vegetation during the second cycle of deposition.

DISCUSSION AND CONCLUSION

The palynopetrological study of Lower Gondwana coals of Pench-Kanhan Coalfield has enabled us to infer some important conclusions regarding stratigraphy and nature as well as formation of coal in this basin. Palynological study has been utilized in the present work, to conclude on correlation and lateral extension of the coal seams in the coalfield. The other aspect studied, is the determination of the biopetrological constituents in conjunction with sporological assemblages which have helped to evaluate the nature, formation and distribution of coal types along with their utilization characteristics.

Palynologically six biozones (cenozones) have been suggested in the Talchir and Coal beds of the area. The oldest biozone (A) dominated by the radial monosaccate miospores and the next zone (B) also dominated by the radial monosaccates with some *Callumispora* are placed in the Talchir Stage.

The younger four zones recovered from the coals suggest that four coal seams are present in this area. The eastern sector of the area known as Pench-Valley Coalfield has more complete sequence. As described earlier it is suggested that the deposition of coal seams has taken place in two different sedimentary cycles resolved on the basis of petrological analysis of the coal types. Each cycle is represented by two coal seams. Miofloristically also a distinct change between the assemblages of the two lower seams and the two upper seams has been noticed. The former are characterised by the dominance of varitriletes group of presumably pteridophytic spores while the latter by that of gymnospermous non-striate disaccates (*Sulcatisporites*). Thus, each sedimentary cycle is associated with different source material (vegetal matter) in the basin presumably due to changing ecology and progressive evolution.

Kar (1973) has described a Varitriletes rich zone from the Karharbari Stage in North Karanpura Coalfield. In view of this discovery and the evidences suggesting the change in the sedimentary cycle as well as in the vegetation the varitriletes rich zones (C and D) of the area have been kept in the Karharbari Stage, while the youngest two zones (E and F) characterised by the dominance of *Sulcatisporites* are placed in the Lower Barakar Stage.

In addition to the stratigraphic position the correlation of coal seams based on palynology has shown that the fourth seam (oldest seam) and the third seam have yielded the oldest mioflora in the area and hence, have been considered as the bottom seams. These seams are not represented in any other colliery of the area except at Rawanwara Khas. The next to these seams i.e., No. II seam has been represented in Dongarchikli colliery (No. II seam) Chandameta Colliery (Bottom seam) and Rawanawara Khas Colliery (No. I and II seams). The first seam or the youngest seam (miofloritically) is the main working seam of the area. This is represented in almost all the collieries of the basin. In certain sectors some seams also have their leader seams. The miofloral assemblage of the leader seams and the main seams is mostly the same. Therefore, leader seams are regarded as a part of the main seams.

The detailed petrological study of Pench-Kanhan coals has shown the presence of anthraxylous, attrital and intermediate group of macerals as ultimate coal components derived from the swamps. In the attrital group, microspores, magaspores and resin bodies form the main organic components of coal. The over all maceral and microlithotype composition of all the seams has been studied in terms of the percentages of two broad maceral groups, namely, anthraxylous (vitrinite, semivitrinite, fusinite, semifusinite) and attrital (sporinite, resinite, cutinite) components and mineral matter. The trend of variation in the percentage of vitrinite is very characteristic in these coals. It is less in bottom seam (IV) thence it increases in the III Seam but decreases in the II seam to rise again ultimately in the I seam. These facts have also been supported by the microlithotype analysis and indicate a cyclic deposition in the basin. It seems that, first, the rate of deposition of the vegetal matter in the basin was slow or the coal forming vegetal matter was fragmentary, so that the vitrinite content is less in the IV seam. Improved conditions during the deposition of the III seam and the increase of woody material in the vegetal matter resulted in fairly good percentage of vitrinite in the seam. The same type of depositional changes were represented again to form the II and I seams. The other main feature in the deposition of these seams in the basin seems to have been alternating fluctuations of water level in the coal swamps which caused the formation of more or less fusain due to the exposure of a larger or smaller part of peat to the atmosphere. This is represented in all the coal seams of the area suggesting oscillations of dry and wet conditions during the peat stage.

High proportions of sedimentary mineral matter generally, finely dispersed and intimately associated with organic constituents, are characteristic of Pench-Kanhan coal seams and have significant influence on coal types and their utilization properties. Common ingredients are clay minerals, quartz, mica, silica, pyrite etc. The proportions of these minerals generally increase with organic inerts, making a change in coal type from clarain through duroclarain to durain. The inorganic matter occurs as finely divided sedimentary particles interstitial to organic constituents. Such clastic materials occur even in the bright layers (clarain) of coal. Higher proportions are however, associated with the dull layers of coal (durain).

The combinations of organic and inorganic constituents categorize Pench-Kanhan coals into generally dull to semibright, not well banded, relatively high ash and low rank type. Some local variations in the coal seams were also observed in the area due to metamorphism caused by the igneous intrusions.

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