Nature, composition and rank of Lower Gondwana Coals from Pathakhera Coalfield, Satpura Graben*

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The maceral, microlithotype and reflectance analyses of Bagdona, Lower and Upper Workable coal seams of Pathakhera Coalfield have been carried out in detail. The coal seams are characterized by the bright, semibright and dull bands of variable thickness. Vitrinite, inertinite and exinite maceral groups form the major fraction of coal microconstituents. These macerals generally occur as part of durite, clarodurite and duroclarite microlithotypes. The inorganic mineral matter is invariably associated with almost all the microconstituents.

On the basis of quantitative representation of microconstituents, the Pathakhera coals have been divided into three types: 1. Vitrinite rich (vitric) type. 2. Intermediate (fusovitric and vitrofusic) type and 3. Inertinite rich (fusic) type. The rank of the coals has been estimated by the measurement of maximum reflectance of vitrinite in oil. It ranges between 0.6% to 0.9% which indicates that these coals can be grouped with the high volatile bituminous C to B stage coals according to the ASTM classification. However, the coal from lower workable seam of PK-2 Incline shows sudden rise (1.5%) in reflectance which seems to have been caused by the presence of an igneous intrusion.

Key-words—Organic petrology, coals, Lower Gondwana, Satpura Graben, India.

INTRODUCTION

PATHAKHERA Coalfield is located in Betul District, Madhya Pradesh and forms the southern part of Satpura Graben. The area is characterized by the presence of low hills of basement metamorphic rocks and Gondwana sediments.

The history of the discovery of coal in the area dates back to 1867 when Major Ashburner discovered a coal seam and named it Mohadongri seam. The area was later described as Pathakhera Coalfield by Jones (1887). Recently, Raja Rao (1983) has provided a detailed account of the geology and coal resources of Pathakhera Coalfield (Map 1). The lithostratigraphic succession in Satpura Basin is given below.

Lithostratigraphic set up of Satpura Basin (after Raja Rao, 1983)

Age	Formation	Lithology (Thickness)
Recent	Alluvium	
Up.Cretaceous to Eocene	Deccan Traps basic flows, dykes & sills	Basalt
Up. Cretaceous	Lameta	Conglomerate, limestones and clays
Lr. Cretaceous	Jabalpur	Massive sandstones with Jasper conglomerates, white clays, red clays, carbonaceous shales and coal lenses (50 m to 100 m)
----------	Unconformity	----------
Rhaetic(?)	Bagra	Predominantly coarse conglomerates with bands of calcareous sandstones, variegated clays, limestone and dolomite (180 m to 240 m)

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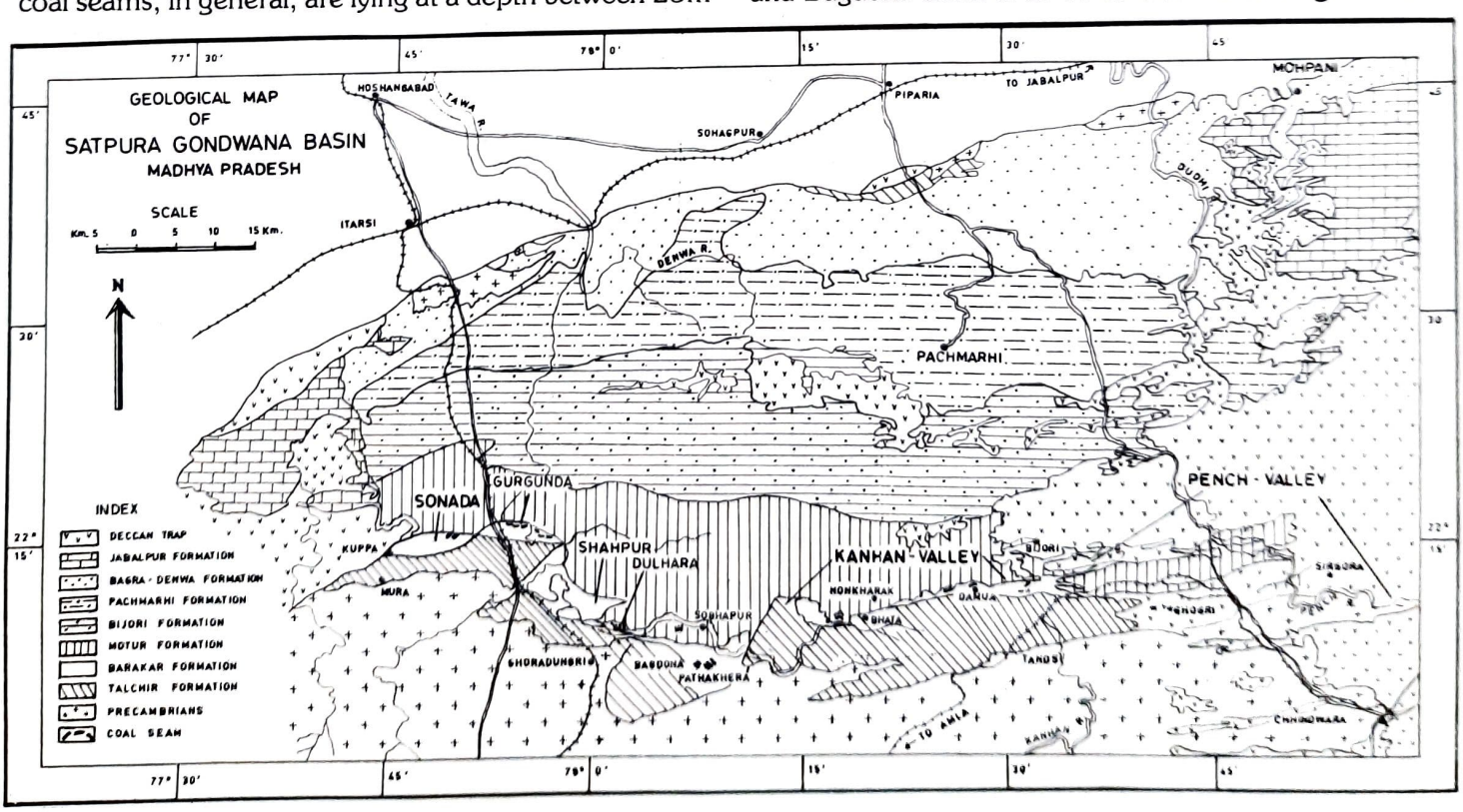
Age	Formation	Lithology (Thickness)
	-Unconformity-	
Upper part of Lower Triassic to Middle Triassic	Denwa	Soft variegated clays interbedded with sandstone bands, conglomeratic at places (about 350 m).
Lr. Triassic	Panchmari	White-coarse grained crossbedded sandstones with lenses of sub-angular quartz pebbles (about 750 m).
Upper Premian	Bijori	Micaceous, flaggy sandstones and shales, at places micaceous (180 m to 250 m).
	Motur	Buff, green and variegated clays with coarse to very coarse grainded sandstones (about 600 m).
Lower Permian	Barkar	Coarse to medium grained sandstones shales, carbonaceous shales and coal seams (250 m to 450 m).
Upper carboniferous (?)	Talchir	Diamictites, sandstones, grey and olive green needle shales, varves and rhythmites (about 490 m).
	-Unconformity-	
Precambrian		Gneiss, schists, quartzites, limestones etc.

The coal-bearing Barakar sediments in this coalfield have attained their maximum thickness upto 500 m spread in about 350 sq km (Map-1). In all nine coal seams are known, but only three workable coal seams have been indentified in the area, viz., Upper Workable seam, Lower Workable and the lowermost Bagdona seam. However, the Bagdona seam is not workable throughout the area. Where it is not being worked, only the lower and upper workable seams are identified. In the areas, the Bagdona seam is being worked, sometimes the Lower Workable seam is also called Middle Workable seam, locally. The coal seams, in general, are lying at a depth between 25m to 150m below the surface. At present the coal is being mined in sectors I, II and III towards south, north-west and north of the area.

The Bagdona seam is the lowermost seam of Pathakhera Coalfield and has attained a maximum thickness of 3m. The Middle Workable seam shows its maximum thickness upto 5.64 m (average 1.5-3.5 m). The Upper Workable seam shows variation in its thickness ranging from 0.75 m to 3.29 m. The seam has several dirt (shale) bands. Parting between Upper and Lower Workable seams is of about 20m. while between Lower Workable and Bagdona seam is of 40 to 50m. The Bagdona coal



Map 1. Geological map of Satpura Gondwana Basin, Madhya Pradesh.

seam is also interbedded with dirt bands. The Barakar sediments in the southern portion have a faulted contact with Talchir sediments and gneisses, whereas, a large number of dolerite dykes are present affecting the Barakar sediments in the eastern region. The rest of the Barakar sediments are represented by fine to medium grained sandstones.

MATERIAL AND METHOD

The coal samples (67) for petrological analyses were collected from fresh cut-mine faces of PK-1 Incline, PK-2 Incline, SP-1 Incline, SP-2 Incline and three Boreholes (CMPS-35, 38 & 43) from Shobhapur Block of the Pathakhera Coalfield. Details of the samples investigated have been given in Tables 1,2,3,4,5 and 6.

The particulate pallets were prepared from crushed and sieved (± 18 mesh) coal samples by embedding in Epoxy risin using suitable hardener. These pellets were then polished using standard polishing techniques.

Maceral and microlithotype analyses were carried out according to the recommendations of I.C.C.P. (1963, 1971) under the low power oil immersion objective (20) on Leitz Orthoplan microscope. An automative point counter was attached to the microscope stage to control the pellet movement. The eyepiece cross wire and square grid were used for counting maceral points and microlithotype areas respectively. For rank evaluation, reflectance measurements (Max.Reflectance with polarizer) were taken on vitrinite maceral at 548 nm wave band. An EMI 520 photomultiplier and a sensitive light spot galvanometer were used for recording the reflectance measurements. A glass prism standard with reflectance (1.23% in oil) was utilized for caliberating the photometric apparatus. The details of the samples are given below.

Table 1. PK-I Incline

Sl.no.	Sample no.	Lithology	Combinations	Pellet no.
Upper Workable coal seam				
1.	PK-1	Shale		
2.	PK-2	Semi bright coal	PK-1 (PK-1+PK-2)	1
3.	PK-3	-do-	–	–
4.	PK-4	Shale	–	–
5.	PK-5	Semi bright coal	PK-2	2
6.	PK-6	Dull coal	–	
7.	PK-7	Dull coal	PK-4	3
8.	PK-8	-do-	–	
9.	PK-9	-do-	PK 5 (PK-6 to 9)	4
Middle Workable coal seam				
1.	M-1	Semi bright coal	M-I	5
2.	M-2	-do-		
3.	M-3	Shale lense	-	-
4.	M-4	Bright coal	M-2	6
5.	M-5	Semi bright coal		
6.	M-6	-do-		
7.	M-7	-do-	M-3	7
8.	M-8	-do-	(M6 to M9)	
9.	M-9	-do-		
10.	M-10	Dull coal	M-4	8
Lowermost Workable coal seam (Bagdona)				
1.	B-1	Roof shale		
2.	B-2	Shale		
3.	B-3	Semi bright coal		
4.	B-4	-do-	B-1	9
5.	B-5	-do-	(B-3-B-7)	
6.	B-6	-do-		
7.	B-7	-do-		

Table 2. PK-II Incline

Table 2. PK-II Incline

Upper Workable coal seam				
1.	UP-1	Semi bright coal	UP-1	10
2.	UP-2	Shale		
3.	UP-3	Semi bright coal		
4.	UP-4	-do-	UP-2	11
5.	UP-5	-do-	(UP-3 to 6)	
6.	UP-6	-do-		
7.	UP-7	Dull coal	UP-3	12
8.	UP-8	Shale	–	
Lower Workable coal seam				
1.	LR-1	Semi bright coal	LR-1	13
2.	LR-2	-do-	(LR-1 & LR-2)	
3.	LR-3	Shale		
4.	LR-4	Semi bright coal		
5.	LR-5	-do-		
6.	LR-6	-do-	LR-2	
7.	LR-7	-do-	(LR- 3 to – 8)	14
8.	LR-8	-do-		

Table 3 . SP-II Incline

Upper Workable coal seam				
1.	U-1	Shale		
2.	U-2	Sandstone		
3.	U-3	Semi bright coal	U-1	15
4.	U-4	-do-	(U-3 to U-6)	
5.	U-5	-do-		
6.	U-6	-do-		
7.	U-7	Dull coal	U-2	16
8.	U-8	Semi bright coal	U-8	17
Lower Workable coal seam				
1.	L-1	Semi bright coal	L-1	18
2.	L-2	Dull coal	L-2	19
3.	L-3	Semi bright coal	L-3	
4.	L-4	-do-	(L-3 & L-4)	20
5.	L-5	Dull coal	L-4	21
6.	L-6	Semi bright coal	L-5	22
7.	L-7	-do-	(L-6 & L-7)	
8.	L-8	Dull coal	L-6	23
9.	L-9	Semi bright coal	L-7	
10.	L-10	-do-	(L-9 & L-10)	24

Table 4.Shobhapur Block

B.H. No. CMPS-43

Upper Workable coal seam				
1.	A-1	Coal (shaly)	A-2	25
2.	A-2	Coal	A-3	26
3.	A-3	Shale		

Middle Workable coal seam				
1.	B-1	Coal		
2.	B-2	Carbonaceous shale		
3.	B-3	Coal		
4.	B-4	Coal	(B-3 & B-4)	27
5.	B-5	Shale		
6.	B-6	Coal (shaly)		
7.	B-7	Coaly shale		
Lower most Workable coal seam (Bagdona)				
1.	BG-1	Coal	BG-1	28
2.	BG-2	Sandy shale		
3.	BG-3	Sandstone		
4.	BG-4	Coal	BG-4	29

Table 5. B.H. No. CMPS-35

Upper Workable coal seam				
1.	X-1	Coal	X-1	30
2.	X-2	Shale		
3.	X-3	Shale		
Lower Workable coal seam				
4.	X-4	Shale		
5.	X-5	Coal	X-3	31
6.	X-6	Shale		
7.	X-7	Coal	X-4	32
8.	X-8	Shale		

Table 6. B.H. No. CMPS-38

Upper Workable coal seam				
1.	Z-1	Coal	Z-1	33
2.	Z-2	Shale		
3.	Z-3	Coal	Z-2	34
4.	Z-4	Shale		
Lower Workable coal seam				
5.	Z-5	Coal	Z-3	35
6.	Z-6	Shale		
7.	Z-7	Coal	Z-4	36
8.	Z-8	Shale		
9.	Z-9	Coal		

MACROSCOPIC CHARACTERISTICS OF COAL

In general, Pathakhera coals are the combination of durain, vitrain, clarain and fusain lithotypes. In otherwWords they are the mixture of dull and bright coal layers. The coal of the bottom seam (Bagdona seam) is dominated by the bright constituents followed by the dull bands and occasional thin fusain layers. Middle Workable seam shows a mixture of both dull and bright constituents. The vitrain and durain in this seam are almost evenly represented. The Upper Workable seam shows the dominance of dull constituents followed by the bright layers. Durain seems to be the major constituent of this seam showing dull and earthy lustre. The details of the characteristic lithotypes present in the coal seam are given below.

PK-I Incline

Upper Workable coal seam—The Upper Workable coal seam of PK-I Incline at the place of collection is about 2 m thick. The thickness of the coal seam shows variation

when traced laterally. In general, the coal seam is characterized by the alternating bands of bright and semibright coal of variable thickness. A prominent carbonaceous shale band is seen running below the topmost semibright coal band. The basal part of the coal seam is also marked by the presence of a prominent dull coal band (durain). A persistent thin shale band overlies the coal seam. The base and top of the coal seam is represented by the coarse grained sandstone.

Middle Workable coal seam—The coal seam is present at about 20 to 25 m below the upper workable seam and is about 2.5 m thick. It closely resembles with the upper workable coal seam in having prominent bands of bright and semibright coal. A carbonaceous shale lense of about 15 cm thickness in the middle part occurs below the topmost semibright coal band. Number of such lenses have been observed in this coal seam. The basal part of the seam is characterized by the presence of a prominent dull coal band.

Lowermost Workable coal (Bagdona) seam—The coal seam is also locally known as Bagdona seam, as it is located near the Bagdona village. It is about 2-3m in thickness. The coal seam is almost exclusively composed of semibright coal. A carbonaceous shale band of variable thickness marks the top of the coal seam. The coal seam is present at about 45 to 50 m below the Middle Workable seam.

PK-II Incline

Upper Workable coal seam—The seam is mainly composed of semibright coal at the upper part, while the lower and middle parts contain a mixture of dull and bright coal with a prominent carbonaceous shale band at the base which also marks the end of the coal seam.

Lower Workable coal seam—Like at PK-I Incline the coal seam is almost completely composed of semibright coal. However, a prominent carbonaceous shale band of about 25 cm thickness is seen running parallel to the bedding plane in the seam. The coal seam is underlain by the sandstone.

SP-II Incline

Upper Workable coal seam—The seam mainly contains semibright and dull coal bands. A prominent dull band is seen above the lowermost 30 cm thick semibright coal band. This seam is overlain by thin sandstone and carbonaceous shale layers.

Lower Workable coal seam—The coal seam is mainly composed of semibright and dull coal bands. The top and bottom of the coal seam is represented by semibright coal, whereas, dull coal is present between semibright coal layers.

Shobhapur Block
B.H. No. CMPS-35

Upper Workable coal seam—The coal seam is encountered at a depth of 165 m below the surface and is about 1.64 m in thickness. It contains mainly semibright coal. At the bottom part it has a thick carbonaceous shale band.

Lower Workable coal seam—The coal seam is found at a depth of 182 m below the surface and is about 2.40 m in thickness.

The seam mainly contains semibright coal which is interbedded by thin coaly shale bands. The carbonaceous shale bands also occur at the top and bottom of the seam.

B.H. No. CMPS-38

Upper Workable coal seam—Like the upper workable coal seam found in bore-hole CMPS-35 here also this coal seam is encountered at a depth of 165 m but has attained comparatively greater thickness of 1.83 m. It mainly contains bands of semibright and dull coal. However, the coal seam also contains a prominent carbonaceous shale layer below the topmost semibright coal band.

Lower Workable coal seam—The coal seam is present at a depth of 183 m overlain by a 18 m thick band of coarse grained sandstone. The thickness of the seam is 4.23 m which indicates that the coal seam has attained its maximum thickness in this area. The semibright and dull coal bands mainly characterize the coal seam. It also contains two thin carbonaceous shale bands in the middle part.

B.H. No. CMPS-43

Upper Workable coal seam- The coal seam is 1.5 m thick and mainly contains semibright coal. At the top the coal seam contains shaly coal, while the bottom of the seam is represented by a carbonaceous shale band. This coal seam is encountered at the depth of 189 m and is overlain by a coarse grained sandstone.

Middle Workable coal seam—This coal seam is encountered at a depth of 211.53 m and is about 2.87 m in thickness. The coal is mainly semibright in nature. The top and bottom parts of the seam are marked by carbonaceous shale layers.

Lowermost Workable coal seam (Bagdona)—The coal seam is about 1.64 m in thickness and is encountered

Table 7. Showing Maceral distribution and Reflectance values in different coal seams of Pathakhera Coalfield

Description of coal seam	Pellet No.	Sample No.	Vitrinite %	Exinite %	Inertinite %	Mineral matter %	Reflectance %
Pk-1 Incline							
Upper Workable Coal Seam	1	PK-1	32.0	10.2	42.4	15.4	0.63
	2	PK-2	19.2	7.2	27.8	45.8	0.71
	3	PK-4	23.8	5.8	24.8	45.6	0.73
	4	PK-5	13.4	2.6	42.4	41.6	0.634
Middle Workable Coal Seam	5	M-1	65.5	8.5	16.5	9.5	0.73
	6	M-2	75.5	6.0	9.5	9.0	0.685
	7	M-3	26.5	11	21	41.5	0.874
	8	M-4	15.5	-	9.0	75.5	
Lower Most Workable Seam (Bagdona)	9	B-1	46.8	16.8	18.4	18	0.793
PK-II Incline							
Upper Workable Coal Seam	10	UP-1	60.5	5.0	19.5	15	0.74
	11	UP-2	42	1.0	16	41	0.74
	12	UP-3	18	1.0	11.5	69.5	0.716
Lower Workable Coal Seam	13	LR-1	32.5	-	385	29	1.488
	14	LR-2	36.5	-	34.5	29	1.184
SP-II Incline							
Upper Workable Coal Seam	15	U-1	1.5	-	3	95.5	-
	16	U-2	44.4	15.2	20.8	19.6	0.699
	17	U-3	28	9.5	15.5	47	0.744
Lower Workable Coal Seam	18	L-1	17	-	57.5	25.5	-
	19	L-2	5	-	1	95.5	-
	20	L-3	-	-	48	52	-
	21	L-4	5	-	12	83	-
	22	L-5	3	1	21	75	-
	23	L-6	15.5	0.5	19.5	64.5	-
	24	L-7	39	5	13.5	42.5	-
SHOBHAPUR BLOCK							
B.H.NO Cmps-35							
Upper Workable Coal Seam	25	X-1	29.75	7.8	23.05	39.40	0.66
Lower Workable Coal Seam	26	X-3	6.4	2.5	38.15	52.95	-
	27	X-4	23.75	4.08	20.42	51.75	0.676
B.H.NO.CMPS-38							
Upper Workable Coal Seam	28	Z-1	38.8	11.30	20	29.90	0.66
	29	Z-2	20.4	12.4	31.2	36	0.68
Lower Workable Coal Seam	30	Z-3	38	4	22.4	35.6	0.61
	31	Z-4	17.2	14	36	32.8	0.70
B.H.. No. Cmps-43	32	A-2	36	9.2	26.4	28.4	0.525
Upper Workable Coal Seam	33	A-3	30.8	19.6	15.2	34.4	0.71
Lower Workable Coal Seam	34	B-3	19.2	9.6	45.6	25.6	0.61
	35	BG-1	40.4	17.2	16.4	26	0.71
Bagdona Coal Seam	36	BG-2	16.4	18.8	16.4	48.4	0.63

at a depth of 226 m below the ground level. It contains mainly semibright coal but the presence of a carbonaceous shale band in the middle portion has considerably reduced the quality of the coal.

MICROSCOPIC CHARACTERISTICS

All the three workable coal seams of Pathakhera Coalfield consist of three maceral groups; the Vitrinite, Exinite and Inertinite (Table 7). Among these the vitrinite and inertinite are the dominant groups. The coal of lower seam and the upper seam are characterized by the dominance of the macerals of vitrinite and inertinite groups respectively. However, the coal of middle seam is of intermediate type, comprising almost equal proportions of vitrinite and inertinite macerals. Mineral matter is the next constituent in order of dominance. It is intimately associated with the coal microconstituents, particularly durite microlithotype.

VITRINITE GROUP

The macerals of vitrinite group in Pathakhera coals occur as finely divided irregular shreds, fragments, thin and thick bands and sheets. It is also associated with the durite, clarite trimacerite and vitrinertite microlithotypes. A considerable proportion of vitrinite is found associated with these microlithotypes. (Pl.1, figs 1–3).

Telocollinite is the most common maceral of vitrinite group found in the Pathakhera coals. It is generally represented by thick persistent bands and sheets which are characterized by shining light grey colour. The clean, uniform and scratch free portions of this maceral were used for reflectance measurements to determine the rank of the coal. The other common varieties of vitrinite are desmocollinite and carpocollinite which are found associated with the durite, clarite and trimacerite microlithotypes.

The maceral tellinite is rare in Pathakhera coals. However, at a few places it has been observed having cell lumens generally filled with the collinitic material.

Black argillaceous mineral matter, quartz grains, pyrite and carbonate minerals are frequently present associated with the vitrinites. Pyrite is the most common mineral present in the vitrinites mostly as infillings in fissures and cracks.

Exinite (Liptinite) Group

The exinite group in Pathakhera coals is chiefly constituted by the maceral sporinite (Pl. 1,fig. 6). The cutinite and resinite macerals are relatively less common. Among the sporinite, the major fraction is represented by microsporinite. Megasporinite is sporadic and comparatively much less represented.

Distinctly consistent proportions of sporinite are present in association with the durite, clarite and trimacerite microlithotypes. Often densely packed, microspore exines are seen in the clarite bands.

The cutinites are long and slender with serrated margins and often folded. Resin bodies, though present, are in small amount. Rarely resin also occurs as infillings of cell cavites in tellinites.

Inertinite Group

The inertinite group in Pathakhera coals is represented by semifusinite, fusinite, inertodetrinite, resinoinertinite, macrinite and micrinite macerals. The term resinoinertinite has been recently introduced by Misra *et al.* (1990) for the fusinised resin bodies described earlier. It is also a dominant maceral group present in the Pathakhera coals (Pl.2, figs 7-10).

Semifusinite is a common maceral in Pathakhera coal. It occurs mainly in the form of isolated fragments, bands and as part of durite and trimacerite (Clarodurite and Duroclarite) microlithotypes (Pl.2, figs 5-6). The cellular structures seen in the semifusinite are generally not well preserved. Only rarely well preserved cell structures were observed. The presence of broken cell walls is common feature of semifusinite forming bogen structures. Microfolds are often seen in the semifusinite showing the effect of compressional forces over the vegetal matter during the early diagenetic stages. The transitional stages from semifusinite to fusinite and vitrinite to semifusinite have been observed frequently. This shows fluctuations in the water level of the basin from low to high resulting into the oxidising and reducing environments. This also indicates that the processess of fusinization, jelifusinization and jelification were active during the peat stage resulting into the formation of fusinite, semifusinite and vitrinite macerals respectively.

Fusinite is one of the most common maceral of inertinite group, and is fairly well represented in Pathakhera coals (Pl 2, fig. 4,11). It is present as thin to thick bands, shreds, irregular isolated fragments and part of inertodetrinite maceral. Like semifusinite most of the fusinite seems to be the product of fusinization as rank fusinite is rarely seen. The cellular structures in the fusinised tissues are generally well preserved, but where the coals are affected by the intense compressional forces they form bogen and folded structures. The cell cavities of the tissues are mostly filled with black argillaceous mineral matter and carbonate minerals. The fusinite also shows a shining white to yellowish white colour in Pathakhera coals.

Besides true fusinite, the transition from vitrinite to fusinite through semifusinite have also been observed. In number of coal particles the macerals vitrinite, semifusinite and fusinite are seen occurring together. The line of demarcation between them is always distinct and sharp. This clearly indicates the fluctuations in the water level of the depositional basin.

Micrinite in Pathakhera coals is usually present in the form of finely dispersed matter in the durites. At a few places macrinites have also been observed which are characterized by a bright whitish yellow colour.

Plate 1

(All photomicrographs are taken in reflected light, oil immersion, x200)

1 & 3. Telocollinite (vitrinite)

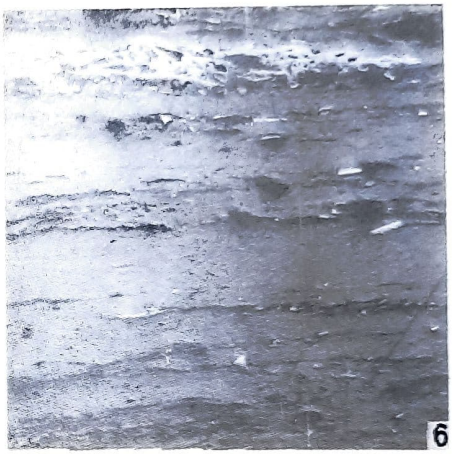
2. Vitrinite (vitrite) band, showing cleats filled with inorganic mineral matter.

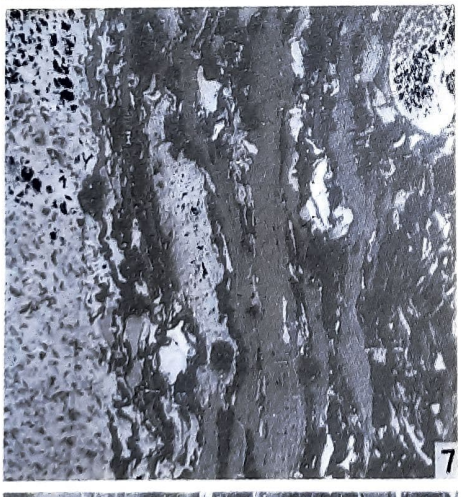
4. A transition from vitrinite to semifusinite

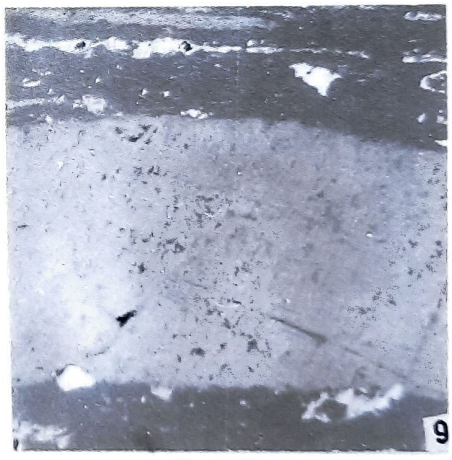
5,7. Clarodurite, showing bands of vitrinite, fusinite and 10, 11 & 12 exinite.

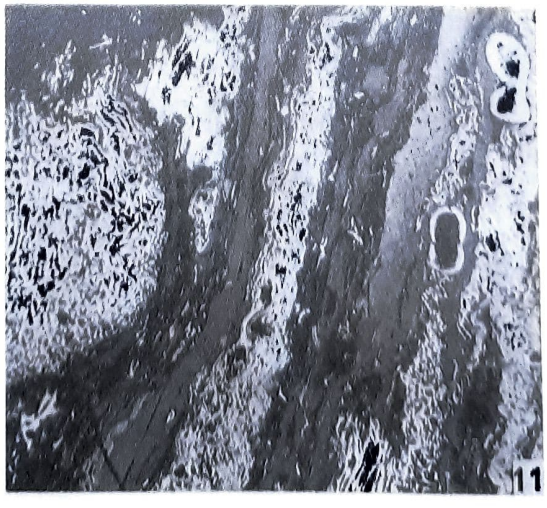
6 & 8. Duroclartie, showing bands of vitrinite and fusinite. Microsporinite is also seen.

9. A thick band of semifusinite and mineral matter.









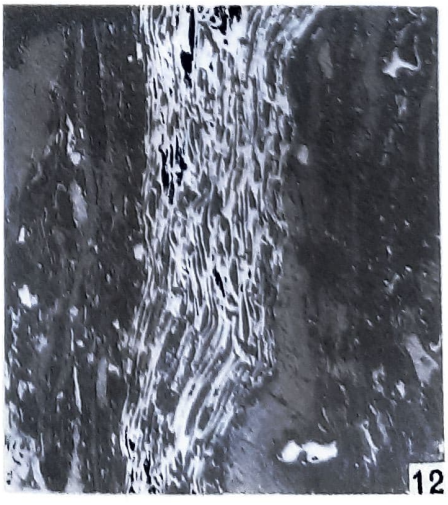


Plate 1

Inertodetrinite is also present in Pathakhera coals usually associated with the vitrite and durite microlithotypes. This is characterized by relatively higher reflectivity.

Another maceral of inertinite group present in the Pathakhera coals is *resinoinertinite* (Pl.2, figs 7-10). This is a common maceral and can be recognized by its characteristic form and relatively high reflectivity. It is present in different shapes and sizes, with or without resin canals.

Mineral matter—It directly affects the quality of the coal and reflects upon the depositional conditions prevailed during the accumulation of source material in the basin. In general, the coals are characterized by the medium to high proportions of mineral matter, which can be divided into four groups, viz., i) clay minerals, ii) silica minerals, iii) carbonate minerals and iv) sulphide and other minerals.

Argillaceous matter—It represents the most dominant mineral group in Pathakhera coals. It is associated with almost every microconstituent present in the coals. Mostly, it occurs as finely dispersed matter in the groundmass of coal constituents and as thin to thick bands forming shaly coal or carbargillite. Occasionally, clay minerals also occur as infillings in fusinitic cell cavities.

Silica minerals—Small quartz grains are often found in association with various macerals. They are clastic in nature and seems to be introduced during the sedimentation along with the vegetal matter.

Carbonate minerals—Siderite is a common carbonate mineral observed in these coals. Generally, it occurs as rounded and subrounded concretions associated with vitrinite and inertinite macerals. It seems to be syngenetic in origin and formed under reducing environment.

Sulphide minerals—Pyrite is a frequently occurring sulphide mineral in the Pathakhera coals (Pl.2, fig.12). It is generally present as crack and fissure infillings in vitrinite maceral as shining yellowish white matter. It also indicates the presence of reducing environment in the basin of deposition.

Maceral composition

The quantitative distribution of macerals in Pathakhera coals from different inclines and bore-holes investigated here is given below:

PK-I Incline—The Upper Workable coal seam contains high percentage of Inertinite (42.4%). Vitrinite has a frequency range of (19%-32%) and Exinite, (2.5%-10%). Exinite is almost exclusively composed of pollen, spores, cuticles and megaspores of various shapes and sizes. The mineral matter and inertinite maceral group shows an increasing tendency towards the bottom part of the seam.

The Middle Workable seam contains (65%-75.5%) vitrinite in the top and middle portions. This maceral group shows gradually decreasing tendency towards the bottom. Inertinite (9%-16%) is in low percentage as compared to upper seam. The mineral matter, like upper seam has increasing tendency towards bottom. Exinite (6%-11%) is less in middle portion. The resinoinertinites are common in this seam, whereas, megaspores are rarely observed.

The lowermost Bagdona seam is rich in vitrinite (46.8%) like Middle Workable seam. The exinitic contents have high percentage (16.8%) than the Upper and Middle Workable seams. Inertinite (18.4%) and mineral matter (18%) are also low in quantity than the Upper and Middle Workable seams. Thus, the quality of the coal in Bagdona seam is better than the overlying two seams.

PK-II Incline—The overall maceral composition of the Upper Workable seam here is closely comparable with the Middle Workable and Bagdona seams of PK-I Incline in having high percentages of vitrinite (42.60%) and subordinate amount of inertinite (16%-19.5%). Mineral matter is recorded to be (15%) at the top, but shows an increasing tendency towards the bottom. Exinite in this seam is reduced to (1%-5%) only.

The lower seam of this incline is rich in vitrinite and inertinite being (32%) and(38.5%) respectively. Mineral matter is also comparatively high (29%).

SP-II Incline—The Upper Workable seam is vitrinite rich (28%-44.4%) like the Middle and Bagdona seams of PK-I Incline and Upper seam of PK-II Incline. Exinite is present here in fairly high amount (9%-15%). Thus, it has

Plate 2 →

(All photomicrographs are taken in reflected light, oil immersion, x200)

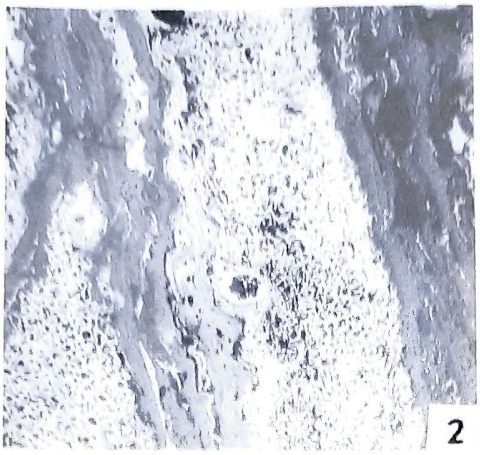
1-3. Clarodurite, a fungal body can be seen in the fusinite band.

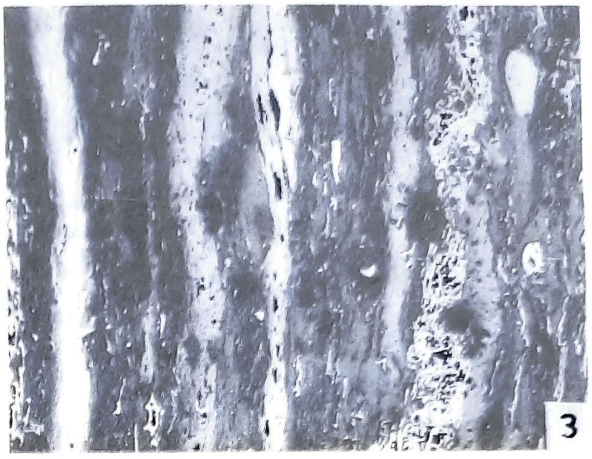
4-6. Fusinite (fusite), showing compressed cells of woody tissues.

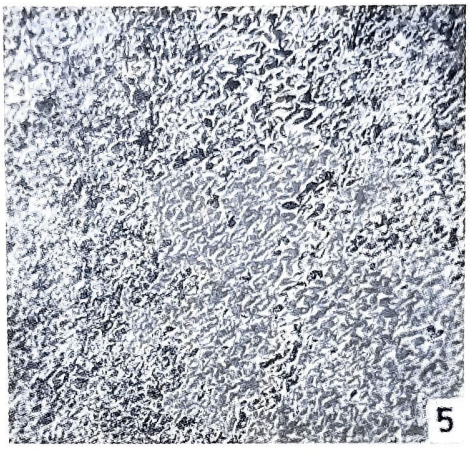
7-10. Durite, showing prominent resinoinertinite bodies with canals and shrinkage cracks.

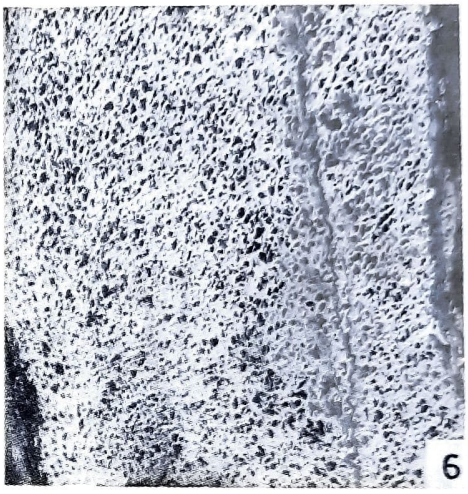
11. Fusinite showing highly degraded cellular tissue.

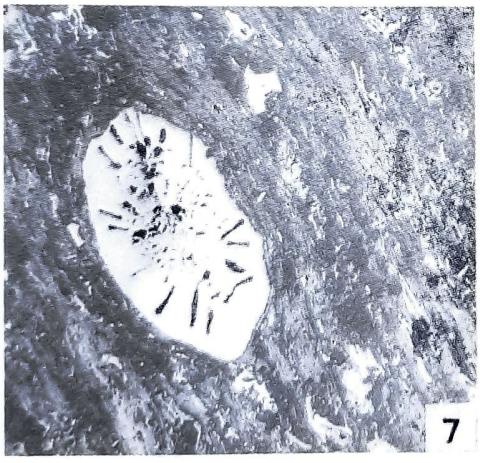
12. Durite, showing pyrite concretions and argillaceous mineral matter.

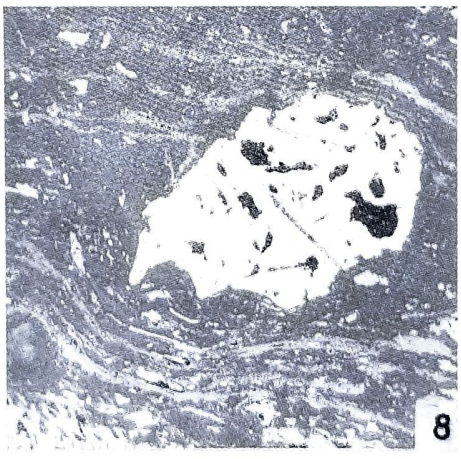


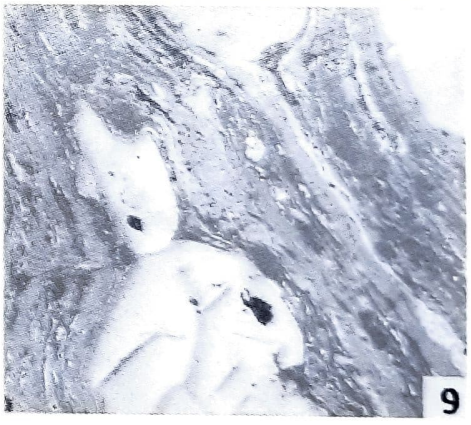


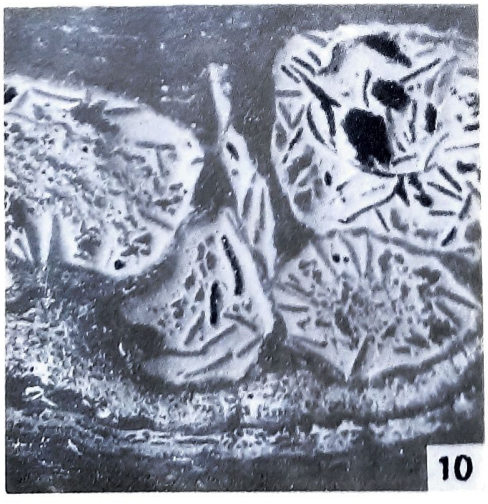


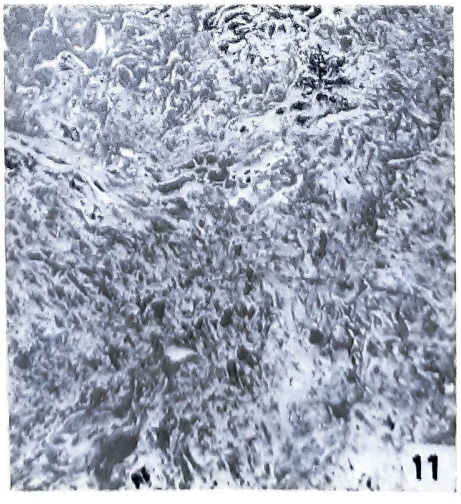












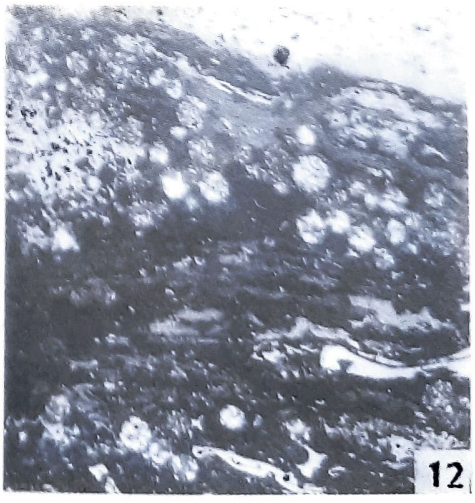


Plate 2

closer resemblance with Bagdona seam of PK-I Incline. The middle part of the seam is of better quality, as it contains only (19.6%) mineral matter. Whereas, the mineral matter is present in higher amount at upper and lower parts of the seam. Inertinite has a percentage distribution of (15%-20.8%).

The coal of Lower Workable seam is different than the Upper Workable seam in having high inertinite percentage (47%-57.5%), particularly, in top portion. In upper and middle parts the vitrinite is (15%-17%), whereas, it is much higher (39%) at the bottom part. The coal bands are intermixed with high amount of mineral matter.

Shobhapur Block

B.H. No. CMPS-35—The coal of Upper and Lower Workable seams is vitrinite rich (23%-29.75%) followed by inertinite (23%-23.75%). Exinite is recorded to be (2%-7.8%) with the maximum representation in the upper part. The coal of these seams show close similarity with the coal of upper seam of PK-I Incline in over all maceral composition.

B.H. No. CMPS-38—The Upper and the Lower Workable seams contain almost (17 to 38%) vitrinite and (11% to 14%) Exinite. The exinitic contents are mostly restricted to basal part of the Lower Workable seam. Inertinite macerals are present upto (20%-36%) and their maximum representation is seen in the lower seam. Thus, the upper and lower seams of B.H. No. CMPS-38 are closely comparable to the upper and lower seams of B.H. No. CMPS-35 in coal constituents.The coal is also comparable to Bagdona seam of PK-I Incline in having rich exinitic contents.

B.H.No. CMPS-43—The Upper Workable seam closely resembles with the upper seam of PK-I Incline in its vitrinite content. However, it contains higher amount of exinite and inertinite macerals as compared to the upper seam of PK-I Incline.

The Middle Workable seam is rich in inertinite macerals (45.6%), while the vitrinite and mineral matter are recorded to be (19.2%) and (25.6%) respectively.

The lowermost coal (Bagdona) seam in this bore hole shows close similarity in maceral composition with the Bagdona seam of PK-I Incline, particularly, with the upper part. An increasing tendency of mineral matter has been recorded towards the bottom part of the coal seam.

Microlithotype composition

PK-I Incline—The coal of Upper Workable seam is rich in trimacerite (54% to 59%) with (9% to 17%) vitrite and (4% to 9%) clarite. Semifusite and fusite are recorded upto (1% to 4%) and (2.5% to 15.3%) respectively. Vitrinertite (14.1%) and Durite (7.4%) are restricted only in the topmost portion. Trimacerite is (16.3%) in the upper part but suddenly increases to (59%) in the middle part and continues to be in higher percentage in the lower portion.

The Middle Workable seam like upper seam contains (25.5% to 51%) trimacerite. Vitrite (11% to 32%) is subdominant. Clarite is recorded upto (6.5% to 28.5%). Semifusite and fusite have small representation of (0.5%-6%) only. Carbominerite is recorded upto (3-16%). It is maximum in the basal part of the seam.

The lowermost Bagdona seam is also trimacerite rich like the upper and middle seams. Inertodetrite is significantly higher in proportion like the upper seam (12.4%). Fusite and carbominerite are (7.2%) and (6.8%) respectively.

PK-II Incline—The Upper Workable seam contains high percentage of trimacerite (50-56.5%) followed by the vitrite (11-18.5%). Clarite is (18%) and its maximum representation is seen in the middle part. Carbominerite has been recorded upto (15-16%), whereas, fusite is only (2% to 3.5%). Vitrinertite is restricted to middle part only and is (9.8%). Thus, the coal of this seam has close similarity with the upper and lower seams of PK-I Incline.

The Lower Workable seam towards upper portion is dominated by semifusite (37%) and fusite (22.5%). Durite and carbominerite are represented upto (20%) and(27%) respectively. The bottom portion contains trimacerite (36.5%) & carbominerite (27.5%). Fusite is reduced to (13%) only. Vitrite and clarite which are absent in topmost part are recorded upto (13.5%) and(6.5%) respectively in the bottom part. It suggests that the coal is of mixed quality.

SP-II Incline—The Upper Workable seam is dominated by the trimacerite microlithotype (31%-40%). It is maximum in the topmost part. Carbominerite is recorded upto (20%-36%) in this seam. Vitrite (15%) is restricted only to middle and lower portions. Semifusite & fusite are (7.5%-10.5%) and (4.15%) respectively. Clarite is represented by (3% to 4%) and remains restricted to middle and lower parts only.

The Lower Workable seam contains mixed type of coal. In the upper part, the coal contains (74%) Fusite, (21.5%) semifusite and(4.5%) carbominerite. The lowermost portion of the seam is characterized by a carbonaceous shale layer as it contains (75% to 90%) carbominerite.Fusite (9-25%), semifusite (8-9%), durite (18%) and clarite (4.5%) are represented in the middle part of the seam.

Table 8. Microlithotype distribution of different coal seams of Pathakhera Coalfield

Description of coal seam	Pellet No.	Sample No.	Vitrite %	Clarite %	Semifusite %	Fusite %	Inertodetrinite %	Vitrinertite %	Durite %	Trimacerite %	Carbominerite %
PK-I Incline											
Upper Workable Coal Seam	1	PK-1	13.8	0.9	3.8	15.3	0.9	14.1	7.4	16.3	30.6
	2	PK-2	9	9	2.5	7.5	-	-	-	59	13
	3	PK-4	17	4.5	1.5	6	-	-	-	56.5	14.5
	4	PK-5	2	-	2	2.5	-	-	-	54	17
Middle Workable Coal Seam	5	M-1	32	13.5	4	6.5	-	-	-	40.5	3.5
	6	M-2	37.5	28.5	0.5	0.5	-	-	-	20.5	5
	7	M-3	11.5	6.5	-	-	-	-	10	51	16
	8	M-4	2	-	0.5	0.5	-	-	-	3	92
Lower Most Workable Seam (Bagdona)	9	B-1	20.8	-	0.4	7.2	1.2	12.4	-	51.2	6.8
PK-II Incline											
Upper Workable Coal Seam	10	UP-1	18.5	4.5	1	3.5	-	-	-	56.5	16
	11	UP-2	13.6	8	0.4	2.4	-	9.8	-	50.6	15.2
	12	UP-3	11	1	1	11	-	-	-	14.5	61.5
Lower Workable Coal Seam	13	LR-1	-	-	37	22.5	-	-	20	-	20.5
	14	LR-2	13.5	6.5	3	13	-	-	-	36.5	27.5
SP-II Incline											
Upper Workable Coal Seam	15	U-1	-	-	1	1	-	-	-	6	96.5
	16	U-2	15	3.5	7.5	4	-	-	-	40	20
	17	U-3	3	4	10.5	15.5	-	-	-	31	36
Lower Workable Coal Seam	18	L-1	-	-	21.5	74	-	-	-	-	4.5
	19	L-2	-	-	-	10	-	-	-	-	90
	20	L-3	-	-	1	11.5	-	-	-	-	87.5
	21	L-4	-	-	-	25	-	-	-	-	75
	22	L-5	2.5	0.5	8.5	13.5	-	-	-	-	73.5
	23	L-6	0.5	-	9	9.5	-	-	-	-	80
	24	L-7	9	4.5	26	6	1.5	1.0	18	-	25.5
Shobhapur Block B.H. No. CMPS-35											
Upper Workable Coal Seam	25	X-1	8.8	21.2	-	2.8	9.8	0.4	1.6	47.6	8
Lower Workable Seam	26	X-3	0.4	3.2	4.8	22.4	9.6	1.2	1.2	18.8	39.2
	27	X-4	3.2	14.4	2.8	15.6	10	9.6	9.6	17.6	6.4
B.H. NO. CMPS-38											
Upper Workable Coal Seam	28	Z-1	6.4	14	2	8.8	1.6	-	-	26.8	40
	29	Z-2	1.2	10	0.8	8.4	1.6	12.4	-	41.6	24
Lower Workable Coal Seam	30	Z-3	17.6	1.6	0.8	3.2	0.4	22.8	-	18.4	35.2
	31	Z-4	4.4	8	4.0	18.4	2.4	8.4	-	30	26.8
B.H. NO. CMPS-43											
Upper Workable Coal Seam	32	A-2	14	5	1.0	10	-	-	3	42.5	24.5
Lower Workable Coal Seam	33	A-3	9.2	13.2	-	6.4	-	7.6	-	35.2	28
	34	B-3	0.8	5.6	1.6	5.6	25.2	8.4	-	34	18.8
Lower Most Workable	35	BG-1	7.6	15.6	-	4.4	-	12	-	31.6	28.8
Seam (Bagdona)	36	BG-1	4.4	10	0.4	2	4	9.2	-	30.8	39.2

Shobhapur Block

B.H. No. CMPS-35—The Upper Workable coal seam contains high percentage of trimacerite (47.6%). Clarite with (21.2%) and inertodetrite with (9.8%) distribution are the subdominant microlithotypes. Vitrite is also recorded upto (8.8%). Fusite and Durite occur in low percentage of (1.5% to 3%) and carbominerite is present upto (8%). Thus, the coal of this seam has close similarity with the upper coal seams of PK-1, PK-II and SP-II Inclines. The overall microlithotype composition of this seam is also comparable with the rest of the coal seams of PK-I Incline.

The coal of Lower Workable seam has distinctly different microlithotype composition at the top and bottom portions. The topmost coal is rich in carbominerite (39.2%), followed by fusite (22.4%). Inertodetrite (9.6%) and vitrinertite and durite are reduced to (1%) only. Semifusite is recorded upto (4.8%). The coal of bottom part contains clarite, fusite and trimacerite in almost similar frequency range between (14%-17%). Whereas, vitrite and semifusite are (1%) and (3%) respectively. Durite is having the percentage frequency of (10%) and carbominerite is (6.4%).Thus, the coal is of mixed type like the coal of lower seam of PK-II Incline.

B.H. No. CMPS-38 —The Upper Workable seam is also characterized by the microlithotype composition similar to that of the lower seam of B.H. No. CMPS-35. The carbominerite (40%) is dominant in the upper coal horizon followed by the trimacerite (26%) which is subdominant. At the bottom portion the composition is different, clarite (14%) Fusite (8.8%), Vitrite (6.4%) and semifusite (2%) represent the main constituents. It also contains Vitrinertite (12.4%) which is almost absent in the upper part.

The Lower Workable seam is carbominerite rich (20%-35.2%). Trimacerite (18-20%) is subdominant with maximum representation in the bottom part. Vitrinertite is recorded to be (22.8%) in the top portion but is reduced to (8.4%) in the bottom. Fusite is (3.2%) in the top and (18.4%) in the bottom. The bottom portion also contains (8%) clarite and (4%) semifusite.Vitrite has been recorded to be (17.6%) at the top but is reduced to (4.4%) at the bottom.

B.H. No. CMPS-43—The Upper Workable seam contains high amount of trimacerite (35.2%). Carbominerite follows next in the order of abundance. Vitrite (9.2%-14%) and clarite (5%-13.2%) have maximum representation in the top and bottom parts of the coal seam respectively. Fusite is recorded to be (10%) in the upper part, whereas, it is reduced to (6.4%) in lower portion. Vitrinertite is restricted to bottom portion only (7.6%) and durite to the topmost portion (3%). Thus, the coal is comparable with the upper, middle and Bagdona seams of PK-I Incline in its trimacerite composition, particularly, with the middle seam and upper seams of SP-II Incline. The upper seam of BH.No. CMPS-35 and lower seam of BH.No. CMPS-38 can also be compared with this seam.

Similar to upper seam the Lower Workable seam is also characterized by the dominance of trimacerite (34%). Inertodetrite unlike the upper seam is in subdominance (25.6%). Carbominerite (18.8%) is next in the order of abundance. Thus, this seam has distinctly higher inertodetrite frequency which is not recorded in any other seam of the area. Clarite and vitrite are also present in low percentages.

The lowermost Bagdona seam like the above seams is also trimacerite rich (31.6%). Carbominerite subdominates at the top (28.8%), but has an increasing tendency towards the bottom. The clarite (10-15%), vitrinertite (9.2%), Vitrite (4%) and inertodetrite (7%) are also recorded with their higher representation towards the top portion of the coal seam.

RANK (MATURITY)

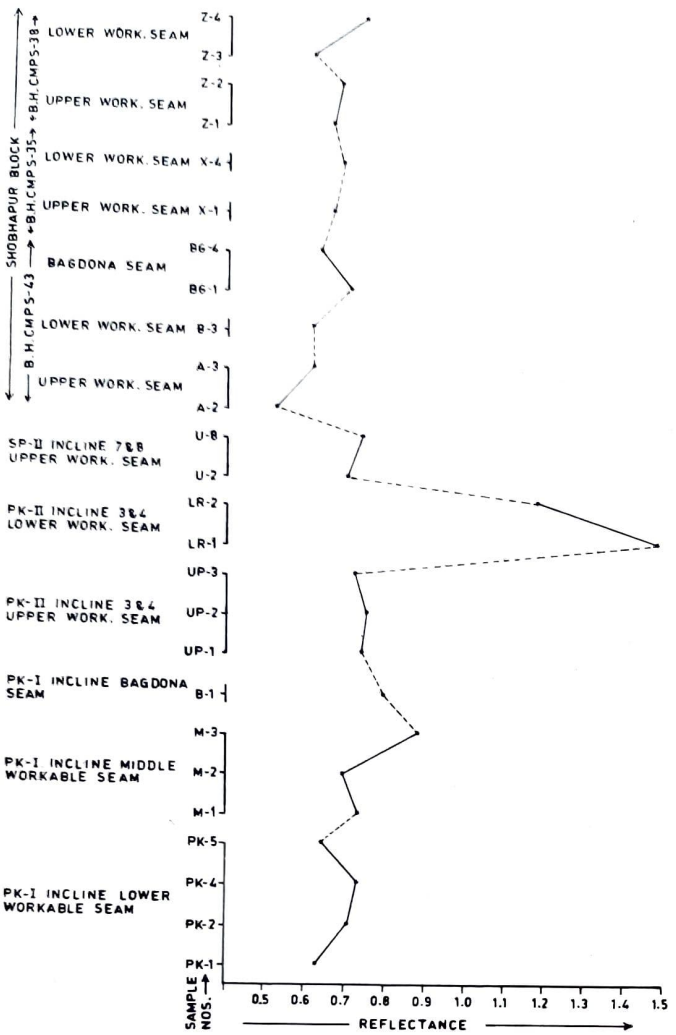
The Pathakhera coals exhibit a reflectance range between (0.525% to 1.48%, Text-fig. 1). The highest reflectance values were recorded only from the coals of Lower Workable seam of PK-II Incline. These values show unusually higher maturity as compared to the coals of other inclines and bore-holes. This has resulted due to the considerable amount of heat generated by the igneous intrusions present in this area. The rest of the coals from other areas show reflectance between (0.6% to 0.7%). which indicates that these coals can be grouped with the high volatile bituminous-C to B stage coals according to the A.S.T.M. system of coal classification. The lower reflectance values (0.5% to 0.55%) were recorded mostly from the desmocollinite fraction of the vitrinite group generally found associated with the trimacerite and durite microlithotypes.

The trend of maturation appears to have been uniform throughout the coal basin except at PK-II Incline where sudden rise in maturity has been observed mainly due to the presence of igneous intrusion. In other places coal katagenesis seems to have been controlled only by the time and depth of burial. The geothermal gradient seems to have remained relatively low during the geological past to cause the present rank to Pathakhera coals.

Coal Types

Text-figs 2–3

A critical evaluation of microconstituents (macerals and microlithotypes) suggests that there are three distinct coal types present in the coal seams of Pathakhera Coalfield. These coal types are designated as, Vitric,



Text-figure 1. Showing rank variation in the Pathakhera region.

Mixed (fusovitric and vitrofusic) and Fusic according to the lines suggested by Navale and Mishra (1983). The majority of the coal samples analysed for the present study belong to the mixed type. Whereas, the vitric and fusic coal types are represented by a few samples only.

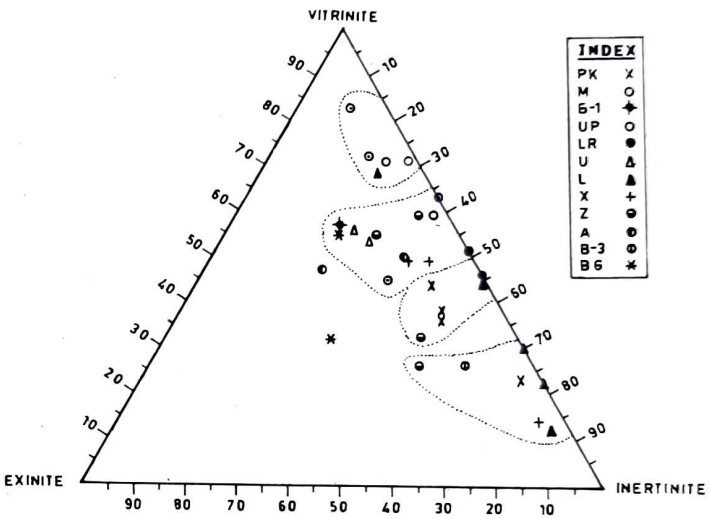
PK-I Incline—The Upper Workable seam in PK-I Incline is characterized by the presence of vitrofusic, vitric and fusic coal types in upper, middle and lower parts respectively. The Middle Workable seam is represented by vitric coal type in upper part and vitrofusic coal type in the lower part. Whereas, the lowermost Bagdona seam is almost exclusively composed of vitric coal type.

PK-II Incline—The Upper Workable seam in PK-II incline is characterized by vitric coal type at the top and vitrofusic coal type at bottom portions. The Lower Workable seam contains fusovitric and vitrofusic coal types in the upper and lower parts respectively.

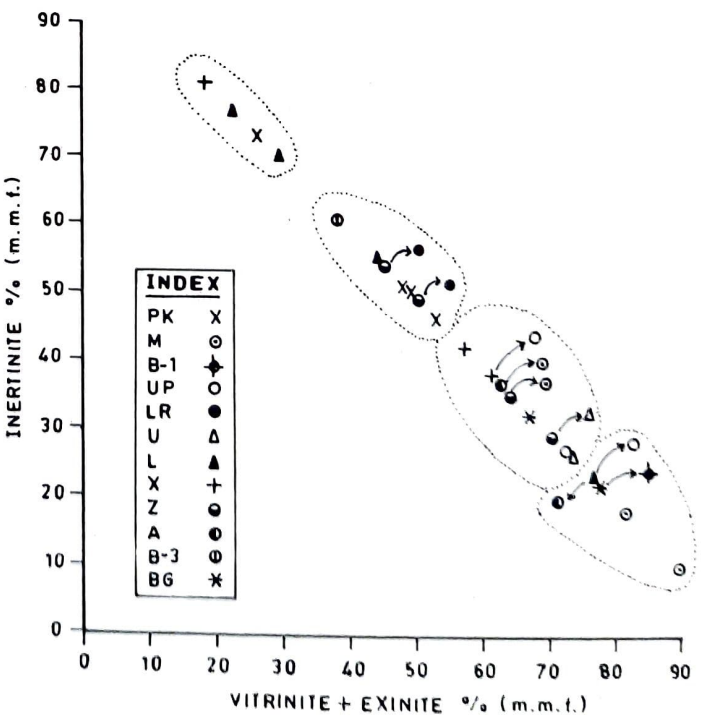
SP-II Incline— The Upper Workable seam in SP-II incline contains fusic coal type in the top portion. While, the rest of the seam is represented by the fusovitric coal type. The Lower Workable seam is characterized by the fusic coal type in the upper and lower parts. Whereas, the middle part contains vitric coal type.

Shobhapur Block

B.H.No. CMPS-35—The Upper Workable seam in this bore hole is represented by the fusovitric coal type. Whereas, the Lower Workable seam is characterized by fusovitric and fusic coal types at the top and bottom halves respectively.



Text-figure 2. Showing relation between vitrinite, inertinite and exinite contents and the coal types in Pathakhera Coalfield.



Text-figure 3. Showing different coal types present in Pathakhera Coalfield.

B.H.No. CMPS-38—The Upper Workable seam in this bore hole contains fusovitric coal type at the top and vitrofusic coal type at the bottom portions. The Lower Workable seam contains fusovitric coal type in the upper and fusic coal type in the lower part.

B.H.No. CMPS-43—The Upper Workable seam in this bore hole is characterized by fusic and vitric coal types in the upper and lower halves respectively. The Lower Workable seam is represented by the fusic coal type. The lowermost (Bagdona) seam in this area has fusic coal type in the upper and mixed coal type in the lower portions.

In general, the Pathakhera coals are closely comparable to those of Pench-Kanhan Coalfield, Satpura Basin, Bharadwaj *et al.* (1974), and Navale and Misra (1980) and Ramagundam coals of Godavari Basin, Navale *et al.* (1983) in overall Petrological and rank characteristics.

The similarity of coal between Pench- Kanhan and Pathakhera coalfields seems to be the effect of similar depositional conditions, as both these coalfields lie in the southern part of Satpura Gondwana Basin. Pench-Kanhan Coalfield represents the eastern part of the coal belt which extends from Handipani in the west to Rawanwara khas in the east. Its similarity with the coal of Ramagundam area of Godavari Basin also indicates that the similar depositional conditions seems to have existed further southwards atleast upto Godavari area. Some similarity between the Pathakhera and Korar coals, Singh (1989) has also been observed.

An abrupt increase in the rank (Ro max. 1.48%) of the coal from Lower workable seam of PK-II Incline has been caused due to an igneous intrusion in this area. The intrusion increased the rank of coal upto the medium volatile bituminous stage indicating that considerable amount of heat was supplied during igneous activity.

UTILIZATION PROSPECTS

On the basis of present petrological investigations, it has been suggested that the vitric coal of Pathakhera area can be suitably utilized for blending purposes. This will help in enhancing the life of fast depleting high quality coal reserves of the country. The rest of the coal from this area can find its use in steam raising and in thermal power plants.

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