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Petrochemical characterization of Argada seam of South Karanpura Coalfield, Jharkhand, India

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Abstract: South Karanpura Coalfield is a part of the master Gondwana basins of India. It is semi-elliptical in shape and located in the western part of the Damodar Valley, Ramgarh district, Jharkhand. The area comprises different formations of Lower Gondwana. Pillar coal samples have been collected from the working mine face of Argada coal seam. On the basis of megascopic study, coal samples having similar characteristics were clubbed together to form a single composite sample. The petrographic analysis shows that these coals are vitrinite rich followed by inertinite and liptinite maceral group. Mineral matters are represented by carbonates, followed by argillaceous minerals and pyrite. At microlithotype level, these coals are vitrinertite rich followed by vitrite, duroclarite and inertite. Carbominerites are represented by carbankerite followed by carbargillite, while the concentration of carbopolyminerite and carbopyrite are insignificant. The vitrinite reflectance characterizes these coals as sub-bituminous 'B' to high volatile bituminous 'C' in rank. The maceral and microlithotypes concentration suggests that the coals of Argada seam have evolved under alternate oxic to anoxic moor conditions.

Keywords: Petrography, Maceral, Microlithotype, Rank , South Karanpura, Argada Seam

Introduction

The lower Gondwana system has a unique importance in the Indian energy scenario due to the presence of significant coal reserves in different coal bearing sedimentary basins. Main coal bearing basins of India are Damodar Valley, Mahanadi Valley, Son Valley, Satpura, Pranhita - Godavari Valley, Wardha Valley etc. South Karanpura is one of the major coalfields of Damodar valley and it is located in Ramgarh district of Jharkhand (Figure 1). This coalfield covers an area of 195 square kilometers (Raja Rao, 1987). There are 13 coal seams exposed in the area. In the present study, Argada coal seam has been taken into consideration for the detail petrochemical characterization, which is the thickest coal seam of this coalfield. Studies of South Karanpura Coalfield and adjoining areas are mainly attempted by Sedimentologists, paleontologists and paleobotanists but studies on coal deposits of the area are least attended by the researchers. Although few petrographic and geochemical data on South Karanpura coals were published by Ganju (1955), Marshall (1959) and Pareek, (1969) but these data were generated by the workers based on sporadic samples. The previous studies lack a systematic sampling collection and a detailed regional approach. In the present study, an endeavor has been made to find out the detailed organic petrographic and geochemical variation along the vertical section of Argada seam and based on the petrographic constituents depositional condition of the coals have been discussed. This study reveals vital information about

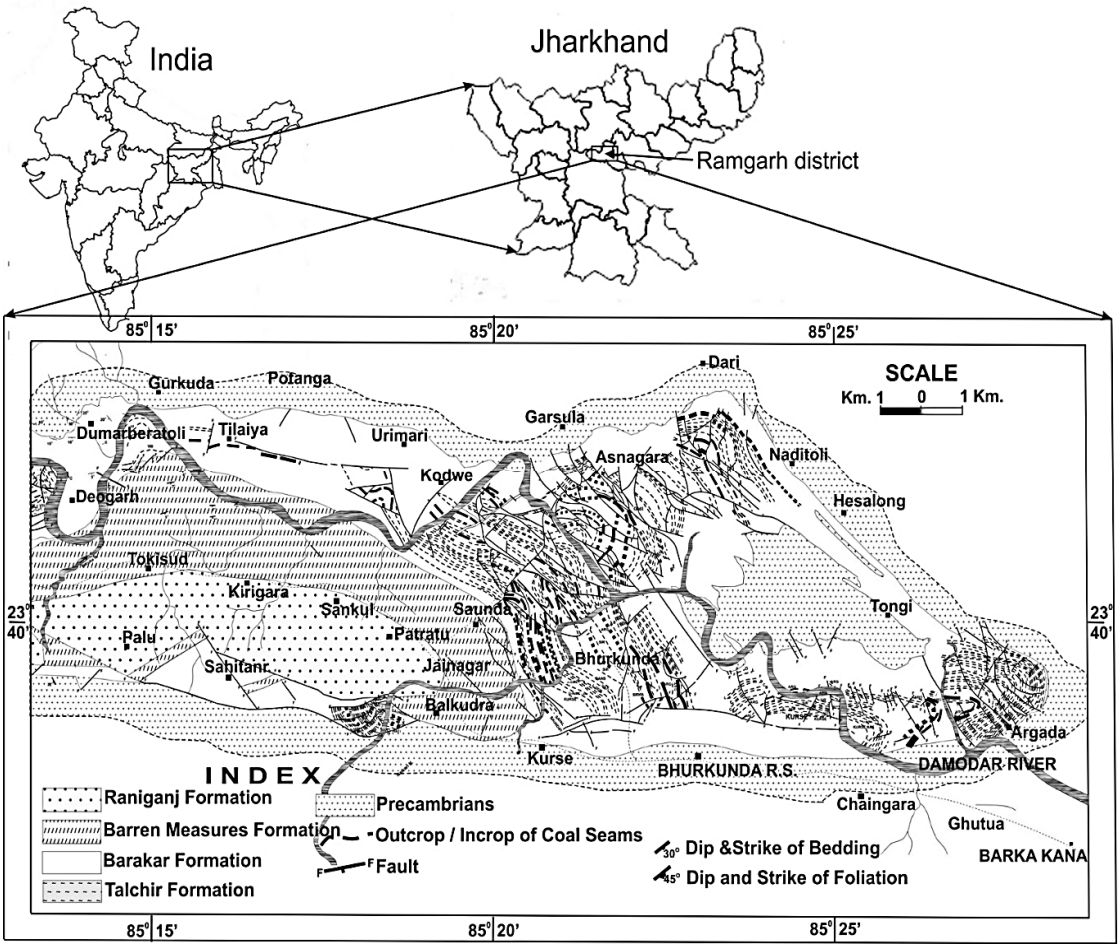

Figure 1. Geological map of Argada area, South Karanpura Coalfield, Jharkhand (Modified after Raja Rao, 1987).

the coal of the area and it can also be helpful for suggesting the proper utilization of these coals.

Geological setting

South Karanpura Coalfield is a part of the east-west aligned Damodar-Koel group of basins and contains different formations of Lower Gondwana (Figure1). The metamorphics forming the basement rock, which are exposed all along the periphery of the area. It includes rocks such as granite, gneisses, mica schist, quartzite and very few occurrences of limestone. Talchir rocks composing of greenish shales and tillites conformably lie on the basement. The Talchir tillites are made up of angular to sub-angular pebbles of quartz, quartzite or granite. Karharbari formation having main rock type as pebbly to coarse-grained sandstone forms an unconformable contact with Talchir formation. Barakar is the main coal-bearing horizon of the area. According to the stratigraphic order it is above Karharbari, but at most places it directly overlies on metamorphics. It covers the most part of the coalfield. The barren measure is exposed at the central part of the coalfield and comprises of medium grained sandstones, siltstones, ironstone, micaceous and carbonaceous shale. It forms a gradational contact with Barakar formation. Raniganj formation resides in the south-central part of the coalfield and forms a conformable contact with Barren measure. There are several faults present in the area. The Barakar formation is the main coal-bearing horizon and contains several coal seams. There are few coal seams also present in the underlying Karharbari formation. Raniganj formation does not contain significant coal seams. Argada seam is the most important and thickest seam of this coalfield, it is a

part of the Barakar formation. At different parts of the area, thickness of Argada seam varies from 12.1 m to 30.7 m. The lithological succession of the area is described in Table 1 (after Raja Rao, 1987).

Age	Series	Formation	Lithology	Approximate thickness in (m)
Early Cretaceous		Intrusive	Lamprophyre and dolerite dykes and sills.	
Late Permian	Damuda	Raniganj	Fine-grained sandstones; grey, medium to coarse grained, calcareous sandstones; mudstones; carbonaceous shale; a few thin coal seams	610
Middle Permian		Barren Measures	Medium grained sandstones; siltstones; micaceous and carbonaceous shales; ironstone shales.	304-457
Early Permian		Barakar	Coarse-grained sandstone, shales; various economic coal seams	1053
Early Permian		Karharbari	Pebbly to coarse-grained sandstones, shales and coal seams	74
Early Permian to Late Carboniferous	Talchir	Talchir	Olive green shales/ green mudstones; fine to medium-grained sandstones; conglomerate; rhythmites and diamictites.	3-16
Precambrian		Basement	Granite, gneisses, mica-schist, quartzite and limestone	

Table 1. Generalized stratigraphy sequence of South Karanpura Coalfield (after Raja Rao, 1987).

Methodology

During the present investigation coal samples (more than 60 samples) have been collected from the working faces of Argada main coal seam following the pillar sampling method. The megascopic characterization of the coal samples has been done according to Diessel's classification of banded coal (Diessel, 1965). Coal samples having the similar megascopic characteristics have been clubbed together and form the composite band. The coal samples were crushed to < 18-mesh size for petrography and < 72-mesh size for chemical analysis. The polished particulate coal mounts were prepared by using cold setting compound, without pressure. The study was carried out on an advanced petrological microscope with fluorescence attachment and MSP 200 photometry system. The identification of maceral has been carried out as per the recommendation of the International Committee for Coal Petrology (1963, 1971, 1975, 1998, 2001), Stach et al. (1982) and Taylor et al. (1998). To identify different macerals such as dark vitrinite and unstructured liptinite more precisely, the macerals analysis was carried out in both incident white light as well as under fluorescence light. Qualitative and quantitative analysis of

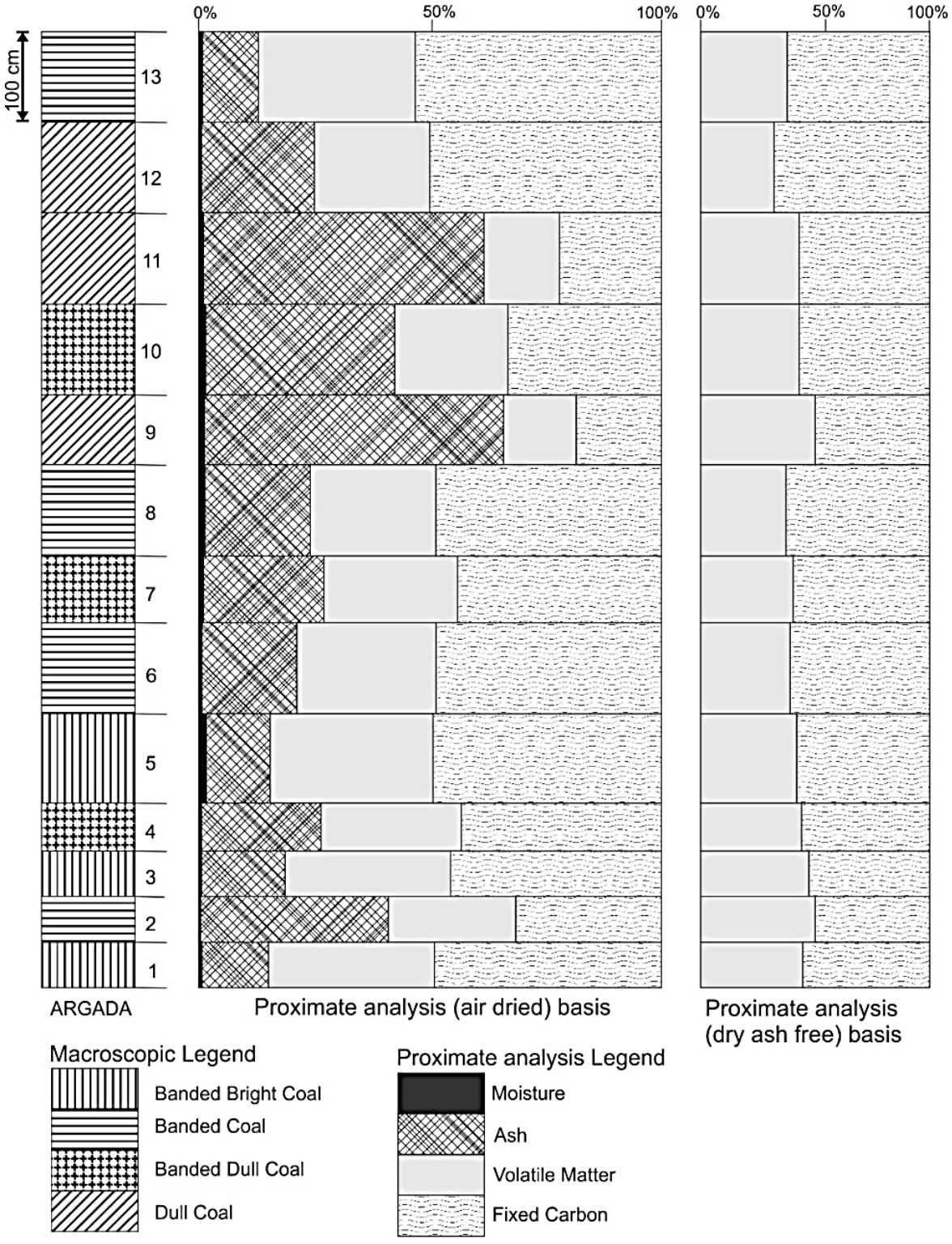

Figure: 2. Macropetrographic section and proximate analysis (air-dried basis and dry ash free basis) seam profiles of Argada Seam, South Karanpura Coalfield, Jharkhand.

maceral and microlithotype counting was done simultaneously. The random virtinite reflectance measurement was carried out as per the ISO standard (ISO 7404-5, 2009) on the scratch free collotelinite patches. All the coal samples were subjected to proximate analysis using Indian Standard (1984).

Chemical characteristics of argada coal seam

Coals of Argada seam exhibit low moisture (0.19 to 1.51 %) and moderately high ash (12.77 to 64.99 %) contents. In these coals, volatile matter varies between 15.99 and 36.63 % (32.62 to 48.57 % daf basis) while the fixed carbon ranges from 17.74 to 53.19 wt% (51.43 to 67.38% daf basis) (Table 2) and (Figure 2).

Proximate Analysis	**Range**		**Mean**
	Minimum	**Maximum**	
Moisture	0.19	1.51	0.76
Ash	12.77	64.99	29.62
Volatile Matter	15.99	36.63	28.16
Fixed Carbon	17.74	53.19	41.47
Volatile Matter (daf basis)	32.62	48.57	41.01
Fixed Carbon (daf basis)	51.43	67.38	58.99

Table 2. Proximate analysis result (in wt%) of coals of Argada seam, South Karanpura Coalfield, Jharkhand.

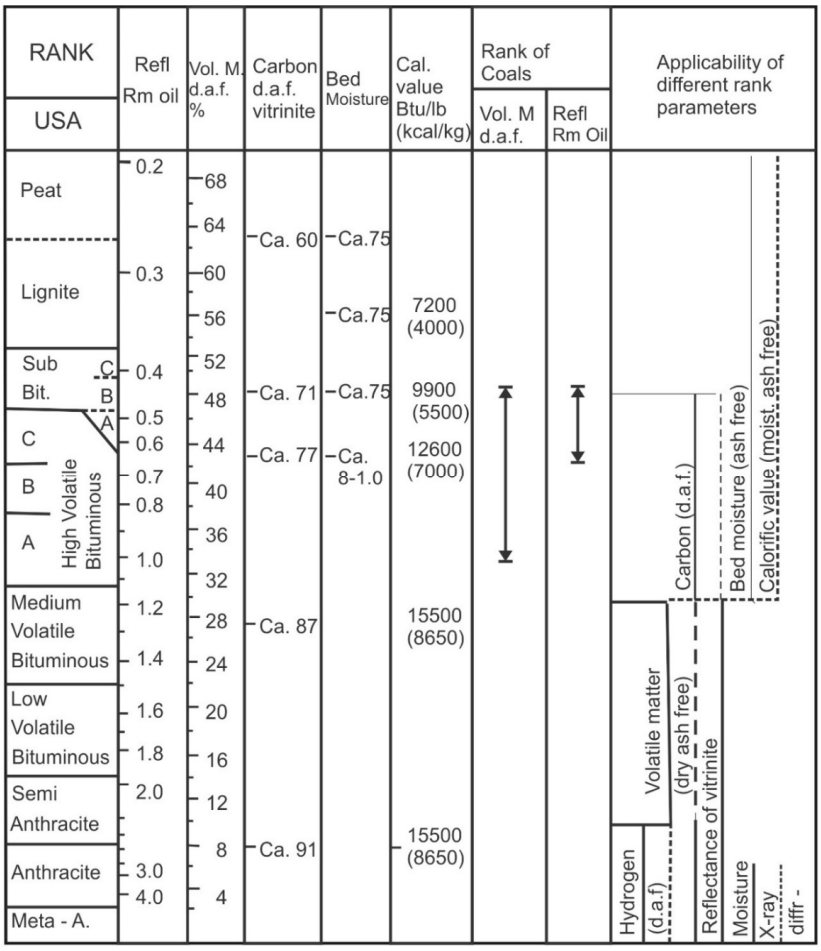

Figure 3. Rank of coals of the Argada seam, South Karanpura coalfield, Jharkhand on the basis of V.M. (d.a.f.) and vitrinite reflectance in the scheme representing the different stages of coalification according to North American (ASTM) classification and their distinction on the baiss of different physical and chemical parameters. The last column shows the applicability of various rank parameters to different coalfication stage (modified after Stach et al., 1982).

Petrographic characteristics of coal

Macropetrographic characteristics

The coals of Argada seam are banded in nature. The megascopic characteristics of this coal seam have been described using the classification of Diessel (1965) for banded coals. Banded coal is the dominant band followed by dull coal, banded dull coal and banded bright coal in Argada coal seam (Figure 4). Banded coals are present all over the seam and contribute to the major portion of the thickness of the seam. Dull coals are generally limited to the top of the seam. These bands are hard and compact in nature and dull appearance with a higher specific gravity than other lithotypes. Banded bright coal and Banded dull coal occurs approximately in equal proportion. In the Argada seam, generally banded bright coals are present at the bottom of the seam sections whereas banded dull coal is found in intervals from bottom to top.

Micropetrographic characteristics

Maceral analysis

All the three group of macerals vitrinite, liptinite and inertinite are present in these coals. Quantitative analysis of the microscopic constituents is given in Table 3. The Figure 4 represents the variation of macerals along the macropetrographic seam profile of Argada seam.

Vitrinite group

Coals of Argada seam are vitrinite rich. All the sub-macerals of the vitrinite group (telinite, collotelinite, vitrodetrinite, collodetrinite, gelinite and corpogelinite) occur in these coals. Telinite is present in good amount. The cell cavities/lumens of telinite are generally found to be filled with gelinite but sometimes with resin and mineral matter (Figure 5A). Collotelinite is the most dominant maceral of this group (Table 3). Its colour varies from light grey to moderate grey. It occurs as thick and thin bands and commonly shows a fragmentary nature and cracks (Figure 5B). The gelinite in these coals are found acting as infilling material within the cell lumens or cracks and cavities. Oval to crescentic shaped corpogelinites has also been detected. These generally exhibit the same colour as collotelinite but comparatively higher relief and reflectance. Vitrodetrinites are found in high concentration commonly associated with other macerals showing attrital nature. Collodetrinite is found sometimes forming groundmass for other macerals (inertodetrinite, sporinite etc.) and dispersed nature minerals such as argillaceous minerals and carbonates (Figure 5C). In some samples pseudovitrinite is also found, having very light grey colour and higher reflectance than collotelinite in the same coal. Few occurrences of dark vitrinite are also detected showing darker colour and low reflectance. They exhibit orange to brown fluorescence due to impregnation by hydrogen rich bituminous substances.

Liptinite group

Sporinite is the most dominant maceral of the liptinite group. They occur as elongated thread-like bodies. Tenui (thin walled) (Figure 5D), sporinite are dominant than crassi sporinite (thick walled) (Figure 5E and 5F). Both mega and micro spores are observed but microspores are more common. Under white light, they look darker while under fluorescence light they show yellow to orange colour of moderate intensity. Generally, thick wall of the spore is generated as a protective cover against dehydration, hence thin wall of sporinite represent wet environment (Diessel, 1992). Cutinite also occurs in these coals as thread-like bodies with serrated margins. They exhibit colour of dark grey in incident white light but show a yellowish orange to light brown colour under fluorescence light (Figure 5G). Round to oval shaped resinite of variable size are found as isolated or as cell fillings (Figure 5H). They are dark grey to black under

white light but show greenish yellow colour under fluorescence light. Detrital remains of structured liptinites (sporinite, cutinite and resinite) form a significant amount of liptodetrinite in the sample. Unstructured liptinites are represented by bituminite, fluorinite and exsudatinite. Exsudatinite is found occupying few voids and cracks. They exhibit black colour under white incident light and greenish yellow colour under fluorescence light. Teichmüller, (1986) marks it, as an indicator of first coalification jump and beginning of bituminization. Fluorinite is rarely present in coals of the Argada seam.

Inertinite group

Coals of Argada seam contains appreciable amounts of inertinites. Inetrodetrinite followed by semifusinite are the most dominant macerals of this group present in the samples. Fusinite is characterized by very high reflectance as well as very well-preserved cellular structure. Most of the times cell cavities are empty, sometimes they are filled with mineral matter (Figure 6A). Both pyro-and degrado-fusinite have been recorded. Bogen structure formed due to collapsed cell cavities and sieve structures are seen at various instances (Figure 6B). Semifusinites are having colour variation from light grey to white and recognized by their poorly preserved cell structure (Figure 6C). Macrinite occurs mostly as rounded to oval bodies showing white colour with reflectance as like fusinite (Figure 6D). In these coals, inertodetrinite is a common maceral constituting less than 10 micrometer fragments of other inertinites such as fusinite, semifusinite and macrinite (Figure 5C). Micrinite having a characteristic white dot-like appearance with size less than 2 microns are also observed in few samples (Figure 5A). The quantitative occurrence of inertinite macerals is shown in Table 3.

Mineral matter

Coals of Argada seam contain a significant portion of visible mineral matter. Argillaceous, carbonate and various sulphide minerals are easily recognizable mineral constituent of this seam. In general, the carbonate minerals are more dominant mineral matter and occurs as a dispersed form, as groundmass (Figure 6G) whereas various carbonate nodules are also observed (Figure 6H). Argillaceous minerals are also present in a high amount and characterized by their dark black colour. They occur as lenticular bodies, microbands and as infillings of fissure, crack, cleat and cell cavities of fusinite (Figure 6F). Pyrites are found as disseminated particles as well as discrete grains sometimes they also occur as fissure fillings.

Microlithotype analysis

At the microlithotype level, coals of Argada seam are vitrinertite rich, followed by vitrite, duroclarite and inertite. Vitrinertite-V is more common than vitrinertite-I and forms most of the vitrinertite microlithotype. In these coals, duroclarite is generally represented by a combination of vitrinite, inertinite and liptinite group of macerals, among which vitrinite macerals are more dominant than liptinite and inertinite combined. Variation of different microlithotype along the seam profile is represented in Figure 4.

Carbominerite represents a combination of macerals and mineral matter (Mukhopadhyay & Hatcher, 1993). Coals of the study area are marked by carbankerite followed by carbargillite while the concentration of carbopolyminerite and carbopyrite are insignificant. Frequency distribution of microlithotype composition (in vol. %) is given in Table 4.

MACERAL	Range	Mean

	Minimum	Maximum	
VITRINITE	20.20	68.60	39.51
Telinite	0.80	12.20	5.15
Collotelinite	2.60	41.60	18.65
Vitrodetrinite	6.00	21.40	11.17
Collodetrinite	1.00	6.00	3.55
Corpogelinite	0.20	1.80	0.69
Gelinite	0.00	0.80	0.24
Dark Vitrinite	0.00	1.20	0.43
Pseudovitrinite	0.00	0.20	0.04
LIPTINITE	5.80	12.20	8.88
Sporinite	1.80	7.80	4.49
Cutinite	0.40	1.80	0.82
Resinite	0.20	1.80	0.86
Alginite	0.00	0.00	0.00
Suberinite	0.00	0.20	0.03
Liptodetrinite	1.20	3.60	2.08
Fluorinite	0.00	0.20	0.02
Exsudatinite	0.00	1.80	0.55
Bituminite	0.00	0.40	0.14
INERTINITE	21.40	53.60	35.55
Micrinite	0.00	2.80	0.98
Macrinite	0.00	2.60	0.95
Semifusinite	3.00	20.20	8.77
Fusinite	2.60	19.80	7.23
Sclerotinite	0.00	0.00	0.00
Inertodetrinite	8.40	34.60	17.77
MINERAL MATTER	20.20	68.60	39.51
Argillaceous mineral matter	0.40	19.20	6.74
Carbonate mineral matter	0.20	40.80	8.71

Table 3. Maceral and mineral matter composition (in vol. %) in coals of Argada seam, South Karanpura Coalfield, Jharkhand.

Pyrite	0.20	1.40	0.73

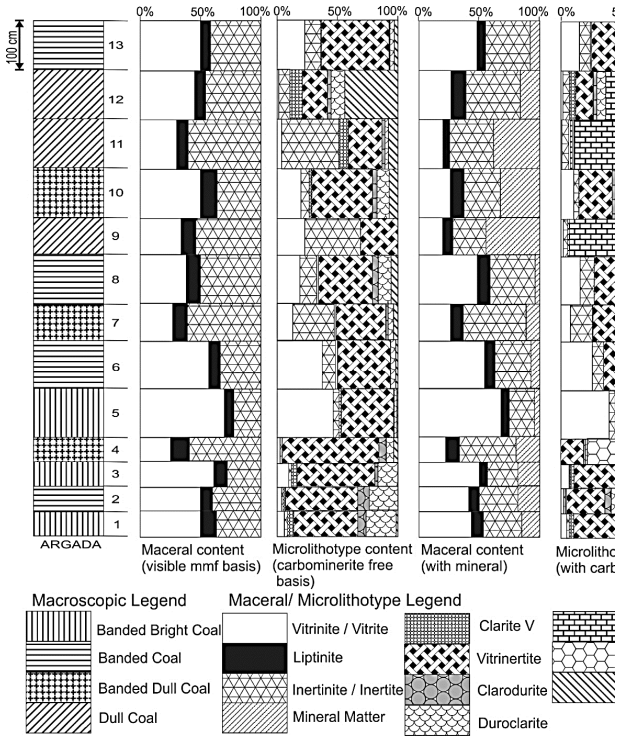

Figure 4. Macropetrographic section and microscopic (maceral and microlithotype) seam profiles of Argada seam, South Karanpura coalfield, Jharkhand

Microlithotype group	Range		Mean	Range (mmf basis*)		Mean (mmf basis)
	Minimum	Maximum		Minimum	Maximum	
Monomaceral	0.81	43.53	16.72	3.51	70.04	30.47
Vitrite	0.40	39.06	11.37	1.56	45.81	15.78
Liptite	0.00	0.22	0.03	0.00	0.31	0.02
Inertite	0.40	18.02	6.23	1.02	47.07	14.66
Bimaceral	1.92	53.22	32.07	26.68	83.33	55.96
Clarite V	0.00	7.32	2.00	0.00	10.31	2.96
Clarite E(L)	0.00	0.94	0.24	0.00	1.25	0.28
Vitrinertite V	1.44	37.20	19.91	10.00	55.19	33.82
Vitrinertite I	0.24	12.20	7.21	3.34	29.82	12.96
Durite I	0.00	29.05	4.59	0.00	40.94	5.39
Durite E(L)	0.00	1.65	0.44	0.00	1.94	0.54
Trimaceral	0.24	26.80	9.21	3.14	34.81	13.58
Vitrinertoliptite	0.00	2.00	0.60	0.00	3.34	1.07
Clarodurite	0.00	5.40	2.07	0.00	9.22	3.31
Duroclarite	0.00	19.60	6.54	0.00	25.26	9.20
Carbominerite	14.73	92.81	44.27			
Carbankerite	0.23	86.09	26.94			
Carbopyrite	0.00	1.60	0.50			
Carbopolymineritе	0.47	5.13	2.40			
Carbargilite	0.60	72.73	18.38			

Table 4. Microlithotype and carbominerite composition (in vol. %) in coals of Argada seam, South Karanpura Coalfield, Jharkhand

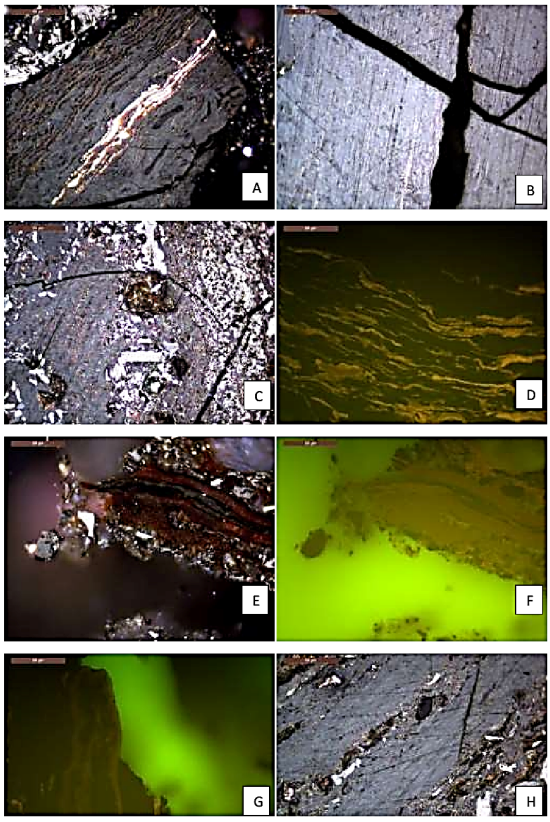

Figure 5. Representative photomicrographs of macerals of Argada seam (scale bar= 50 µm). A) Telinite, cell lumens filled with micrinite, B) Collotelinite with mineral matter filled in crackes, C) Collotelinite and collodetrinite with inertodetrinite, D) Tenui-type sporinite in fluoresecence light, E) Megasporinite in white incident light, F) Megasporinite in fluoresecence light, G) Cutinite with serrated margin in fluorescence light, H) Oval shaper resinite occurring with collotelinite

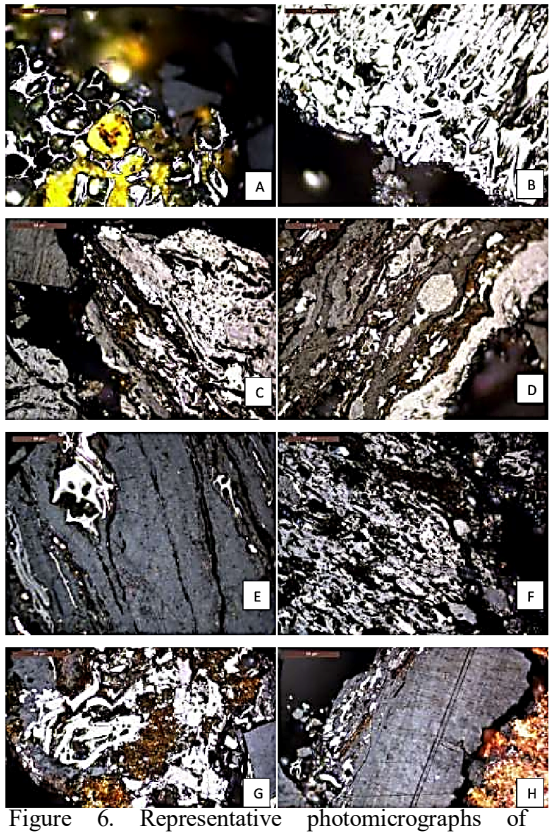

Figure 6. Representative photomicrographs of macerals of Argada seam (scale bar= 50 µm). A) Fusinite cell cavities filled with carbonate minerals, B) Pyro-fusinite, C) Semifusinite occurring with sporinite, D) Oval shaped macrinite with inertodetrinite and collotelinite, E) Secretinite, F) Semifusinite cell cavities filled with argillaceous minerals, G) Dispersed nature carbonate minerals, H) Part of a carbonate nodule at bottom left surrounded by collotelinite.

Evolution of coals of argada seam

An attempt has been made to discuss the evolution of coals of the Argada seam. Since these coals are minerals rich and minerals are directly related with the paleodepositional condition. Hence, the coal petrography-based depositional model proposed by Singh & Singh, (1996) for Permian coal is chosen to discuss the evolutionary condition of these coals. This model suggests that the most of the coals of Argada seam have evolved under alternate oxic to anoxic moor conditions (Figure 7). Few of the samples present at the top of the seam lies outside the zone of alternate oxic to anoxic moor condition and suggest an oxic (dry) moor with a rapid influx of water. The model is also justified by the alternate formation of more and less inertinite due to the fluctuation of the water table.

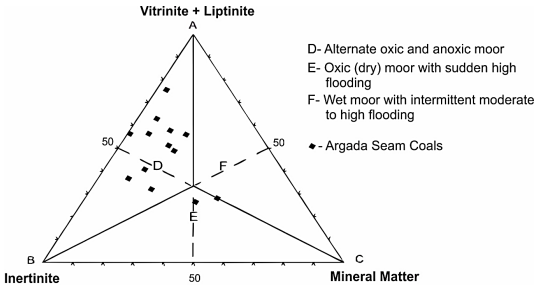

Figure 7. Depositional conditions of Argada coal seam based on maceral and mineral matter content (after Singh and Singh, 1996).

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Conclusion

Coals of Argada seam of South Karanpura Coalfield are vitrinite-rich followed by inertinite and liptinite. The vitrinite reflectance indicates these coal as to sub-bituminous 'B' to high volatile bituminous 'C' in rank. Disseminated nature clay and carbonate minerals, carbonate nodules and few fragments of pyrite are the main visible mineral matter found in these coals. At microlithotype level, these coals are characterized by a high amount of vitrinertite followed by vitrite, duroclarite and inertite. Carbominerite is characterized by carbankerite followed by carbargillite while the concentration of carbopolyminerite and carbopyrite is insignificant. The microscopic constituents of these coals suggest its evolution in an alternate oxic and anoxic moor condition due to repeated seasonal variation.

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