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Petrography of coal seams from Wislon area, Chandrapur District, Maharashtra and their depositional history

Omprakash S. Sarate*

Birbal Sahni Institute of Palaeosciences, 53, University Road, Lucknow 226 007, India.
*Corresponding author's e-mail: ossarate@yahoo.co.in

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ABSTRACT

Critical coal petrographic analysis (maceral and rank) has been carried out of two sub-surface seams, namely I (Top) and II (Bottom) intersected in Bore-hole No. DWL-14, representing Wislon area of the Wardha Valley Coalfield, Maharashtra to comprehend the depositional environment and their economic potentials. The topmost Seam I has shown the predominance of inertinite group of macerals, which indicates fusic type coal; whereas, Seam II contains coal of heterogeneous nature, as displayed by the existence of vitric (vitrinite rich), fusic (inertinite rich) and the mixed (both vitric and fusic) coal types. The random vitrinite reflectance (R_o mean %) variation between 0.40% and 0.49% is recorded at the top and bottom parts of Seam II, indicating the attainment of sub-bituminous B rank; whereas, a slightly higher reflectance of 0.50-0.53% is observed in the middle region of this seam, which indicates the attainment of high volatile bituminous C (sub-bituminous A) stage. Seam I, however, contains insignificant proportion of vitrinite group of macerals, therefore rank evaluation could not be done. From the coal petrographic evaluation it has been inferred that the coal constitution as well as rank remains almost same as we move eastwardly; whereas, considerable improvement in the constitution and rank has been noticed as we move towards south-east. The coal macerals and their association with mineral matter suggest that the Seam I has been deposited during the prevalence of oxic (dry) moor conditions with sudden high flooding. Seam II has witnessed alternate oxic and anoxic spells for prolonged period of time, with a few intervening short spells of wet moor conditions supplemented by moderate to high floods.

Key-words: Coal, Depositional environment, Maceral, Maharashtra, Reflectance, Wardha Valley, Wislon.

INTRODUCTION

Wardha Valley Coalfield in the state of Maharashtra occupies nearly 5576 million tonnes of coal reserves. Recently, the existence of coal has also been recorded from Wislon area of Chandrapur District. Considering the huge and increasingly growing demand of coal for the industry sector as well as in thermal power generation, emphasis has therefore been given to initiate coal petrographic analysis of the seams intersected from Wislon area of Chandrapur District to understand their maceral composition, rank and the depositional environment. Existence of coal was noticed from the bank of Wardha river near Kumbhari Village, long back in 1831 (Raja Rao 1982). Blanford (1868), Fox (1931; 1934) and Hughes (1877) have done pioneering work in the valley and provided valuable geological data of the region. The coal petrographic research contributors mainly include Anand-Prakash & Khare (1974), Agashe & Suresh (1979), Pareek & Pande (1971), Sarate (2000, 2001, 2004, 2005, 2009, 2010, 2013 and 2016)

GENERAL GEOLOGY

The coal bearing Gondwana sediments of Wardha Valley cover approximately 4150 km² area, marked between 19°30' and 20°27' latitudes and 78°50' and 79°45' longitudes and occupy almost entire areas of Chandrapur District, besides a small south-western encroachment that exists in Yeotmal District (Table 1).

Table 1. General Geological succession recorded from Wardha Valley Coalfield, Maharashtra, (after, Raja Rao 1982).

Age	Group/Formation	Lithology
Recent	-	Alluvial gravel beds, black cotton soil
? Eocene	Deccan Trap	Basalts
	----------- Unconformity----------	
Cretaceous	Lameta Formation	Limestones, cherts and silicified sandstones
	----------- Unconformity----------	
Late Triassic	Maleri Formation (only in the south eastern extremity)	Fine to medium-grained sandstone and red shales
Late Permian-Early Triassic	Kamthi Formation	Red, brown and variegated sandstones, reddish siltstones and variegated shales
	----------- Unconformity----------	
Early Permian	Barakar Formation	Light grey to white sandstones, shales and coal seams
? Late Carboniferous-Early Permian	Talchir Formation	Tillites, turbidites, varves, needle shales and sandstones
	----------- Unconformity----------	
Precambrian	Sullavai Sandstones	White to light brown quartzitic sandstones, conglomerates
	----------- Overlap----------	
	Pakhal Limestone	Grey, bluish or pinkish limestones and cherts
	----------- Unconformity----------	
Archaean		Quartzites, granite gneisses, etc.

Besides this, sub-surface Gondwana deposits have also been found concealed below the Deccan Traps in some parts of Wardha District. Structurally, Wardha Valley displays an anticline feature with NNW plunge. On the eastern limb of the anticline are situated some important coal mines, viz. Durgapur, Mahakali, Lalpeth, Ballarpur, etc. whereas, the western limb is marked by Ghugus, Majri, Telwasa and several other open cast mines.

Wardha Valley Coalfield has only one persistent coal seam, known as the Composite Seam/Main Seam, which is confined only to Barakar Formation, having thickness variation of 15-16 m. The intervening carbonaceous shale, grey shale and thin coal partings of the Composite Seam makes it divisible into top, middle and bottom sections. Besides this, 6-7 non persistent coal bands having thickness range between 0.48 & 1.31 m are also recorded from the Barakar Sequence overlying the Main Seam. A distinct similarity in the depositional pattern of different formations is observed both in the Wardha and Godavari Valley coalfields, therefore Wardha Valley is considered as the north-western continuation of the Godavari Valley Coalfield (Raja Rao 1982).

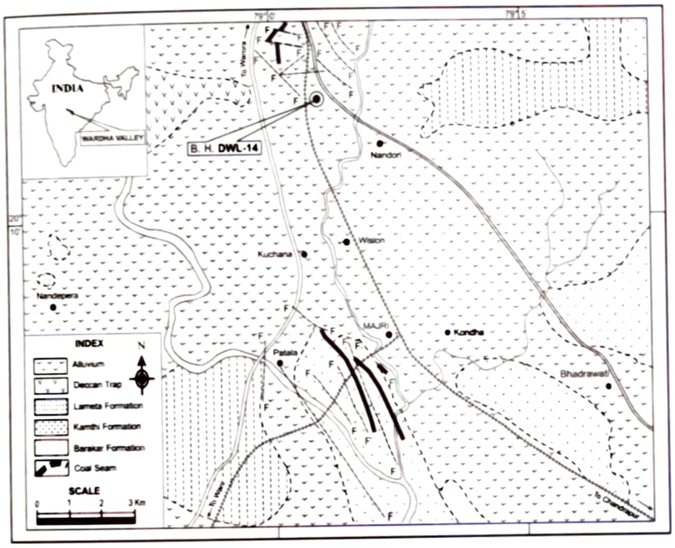
METHODOLOGY

For coal pellet preparation, maceral analysis, vitrinite reflectance (R_o mean %) and classification of coal, the recommendations of ISO 7404-2 (2009); ISO 7404-3 (2009); ISO 7404-5 (2009); ISO-11760 (2005); Taylor et al. (1998); ICCP (2001) and Stach et al. (1982) have been applied. The microscopic observations (maceral) were carried out on Leica DM4500P microscope. Reflectance (vitrinite) analysis was done using Microscopephotometry System (PMT III) and software MSP 200. The quantitative maceral analysis was performed using 2.35 version of the Petroglite software and for micro-photography, the software tool of Leica applications suit (LAS) was used.

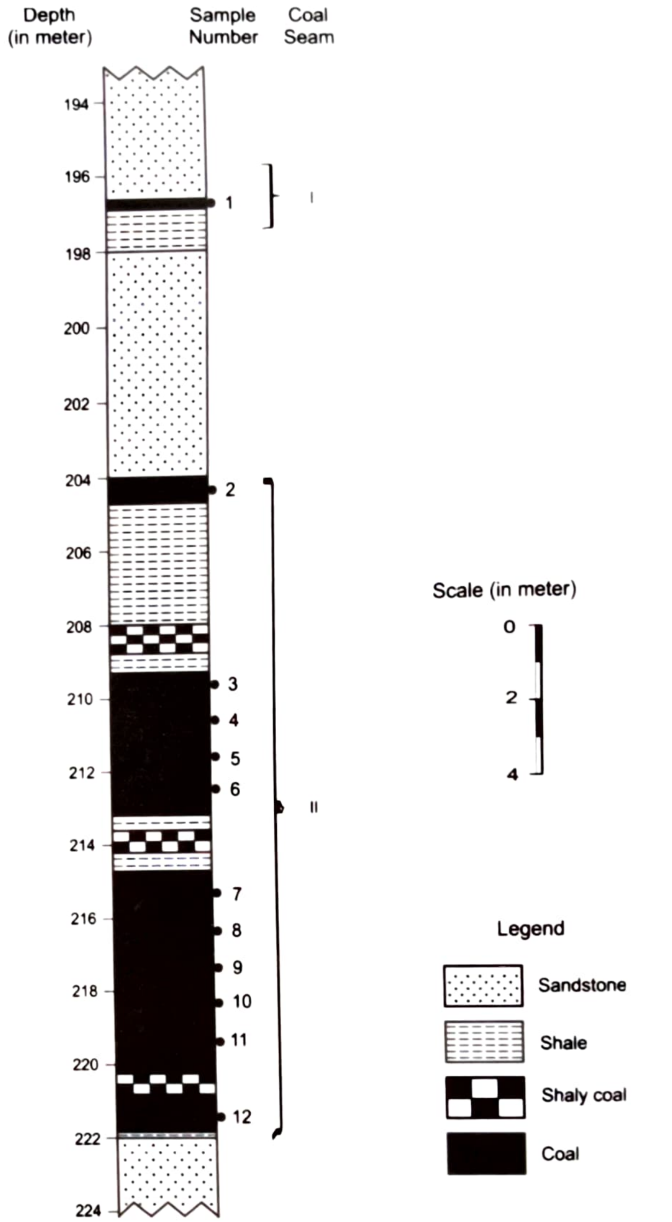
Collection Site : Wislon area covers approximately 8 km^2 area demarcated between 20°09' 45" to 20°13' 30" N latitudes and 78°50' and 79°00' 15" to 79°02' 00" E longitudes. Two sub-surface coal seams, namely Seam I (Top Seam) and Seam II (Bottom Seam) have been encountered from this area. The samples for coal petrographic study have been collected from Bore-hole No. DWL-14, which is located approximately 2.5 km north-west of Nandori Village in Bhadrawati Tehsil, Chandrapur District, Maharashtra. This Bore-hole is situated nearly 4.2 km north-west of Wislon Village (Text-figs. 1 & 2).

DESCRIPTION OF COAL MACERALS

The petrographic study has revealed that the coal of Seams I and II has predominance of three maceral groups, vitrinite, liptinite and inertinite, with invariable association of mineral matter contents. Each individual maceral group displays unique, distinctive features as described below.



Text-Figure 1. Geological map showing location of Bore-hole DWL-14, Wislon area, Wardha Valley Coalfield (after Raja Rao 1982).



Text-Figure 2. Litholog Bore-hole DWL-14, Wislon area, Wardha Valley Coalfield.

VITRINITE

The macerals of this group exhibit dark grey colouration and play a significant role in evaluating the rank of coal due to their moderate reflectance characteristics. They are mainly derived from the cellulose and lignin extracted from different plant parts of the heterogeneous and arborescent nature such as, stem, root, woody tissues, parenchymatous cell walls, etc. in the form of biodegraded humic and aromatic compounds, which are rich in O_2 contents. Telovitrinite is the sub-group of vitrinite maceral, which displays distinct cellular preservation. Collotelinite (Plate 1, Figs. 1-4.) is another dominant sub-maceral that is frequently noticed in these coals, and mainly includes homogeneous, amorphous particles of less than 10 mm size with indistinct cellular display. All the rank measurements are carried out on these collotelinite bands. Similarly, vitrinized relief-less, small, detached and amorphous plant remnants are termed as detrovitrinite, which are commonly observed in these coals. Detrovitrinite sub-maceral is further divided into vitrodetrinite, which exists as discrete, small vitrinite fragments with variable shapes and size; whereas, collodetrinite acts as mottled ground mass which binds other coal macerals. Gelovitrinite is another colloidal form of vitrinite sub-group maceral, which is further subdivided into corpogelinite and gelinite. Corpogelinite is derived from the cellular secretions and is found as secondary filling, it has homogeneous nature and exhibits oval, spherical or elongated shape, with pale yellow colour and higher reflectance than collotelinite and

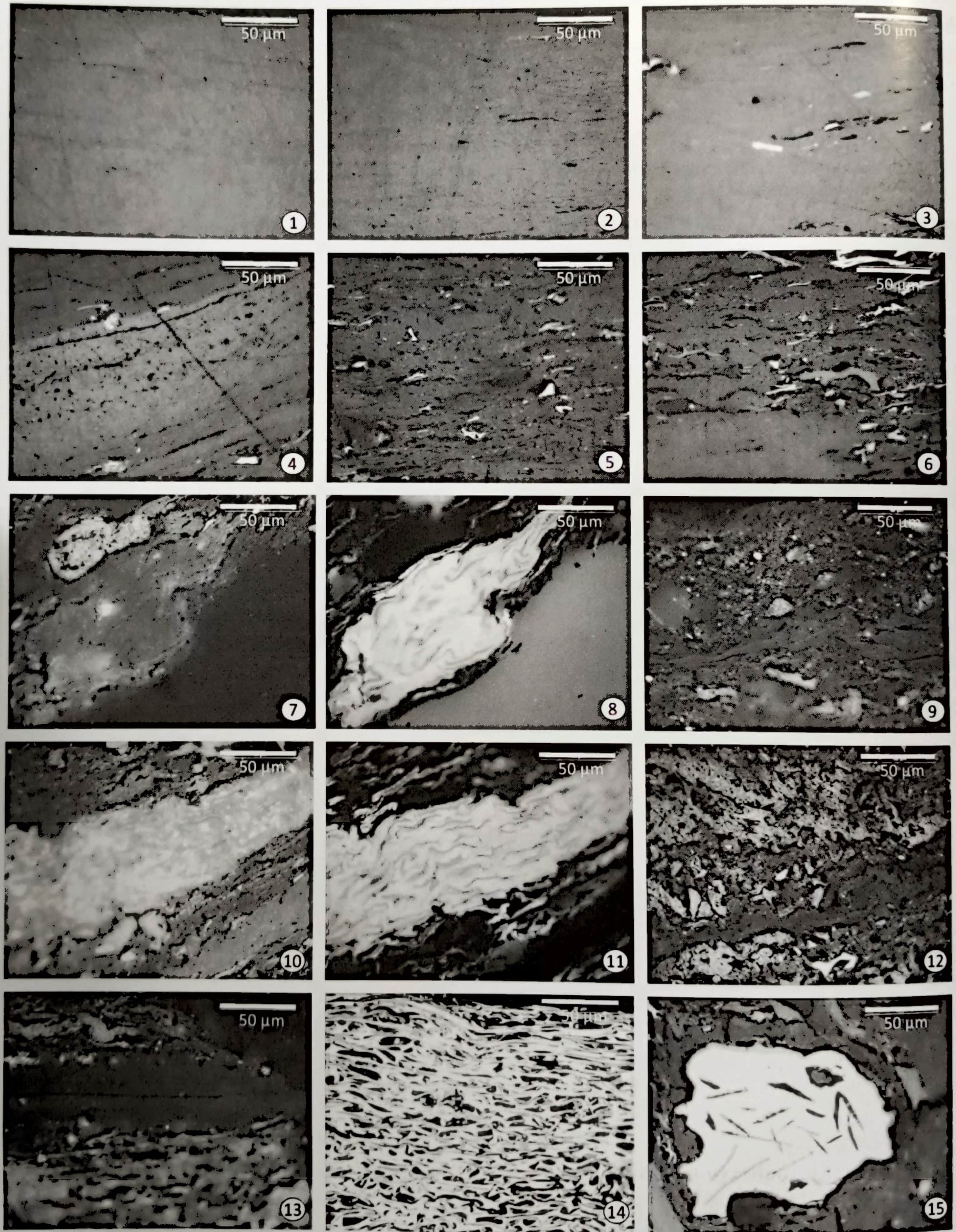


PLATE 1

1-4. Collotelinite; **5-6.** Microsporinites disbursed in vitrinitic ground mass; **7, 8, 10, 11.** Sporangia containing microspores (Fluorescence Mode); **9 & 12.** Crassicutinite; **13.** Broken Megaspore; **14.** Fusinite (bogen structure); **15.** Secretinite.

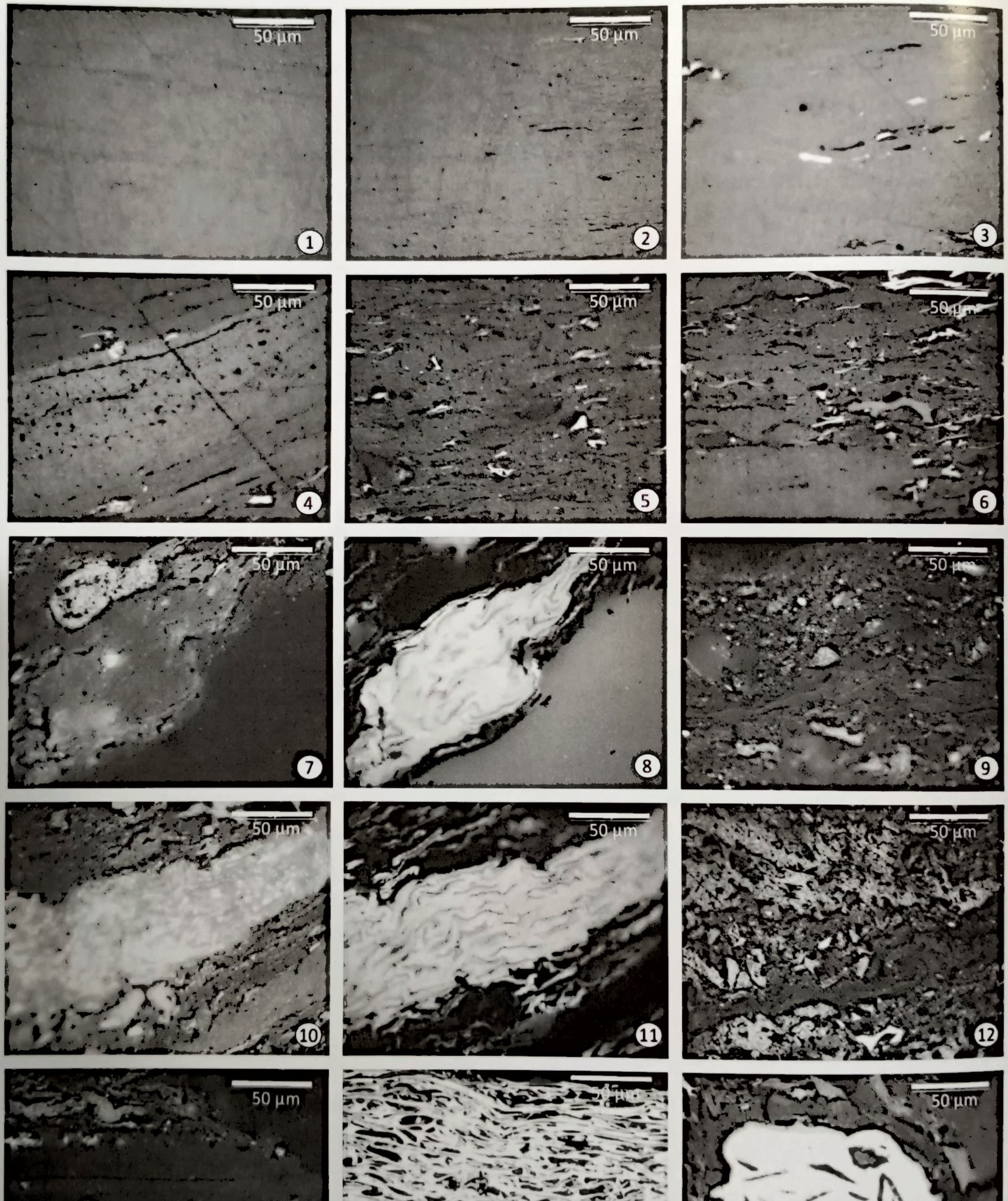


PLATE 1

1-4. Collotelinite; **5-6.** Microsporinites disbursed in vitrinitic ground mass; **7, 8, 10, 11.** Sporangia containing microspores (Fluorescence Mode); **9 & 12.** Crassicutinite; **13.** Broken Megaspore; **14.** Fusinite (bogen structure); **15.** Secretinite.

collodetrinite which acts as in-situ cavity fillings, whereas, gelinite is also homogeneous but generally exists as structureless infillings of the cracks and fissures.

LIPTINITE

This maceral group includes aliphatic (paraffin), non-humic compounds, having higher hydrogen contents, which are mainly derived from the sporopollenin, fats, waxes, resins, etc. Micro-sporinite (Plate 1, Figs. 5-6.) is the most frequently observed maceral sub-group and is present either in linearly arranged rows or is noticed in randomly distributed pattern. Micro-sporinite displays thread like appearance with much darker colouration than the vitrinite, generally they are found interspersed in the vitrinitic and/or inertinitic ground mass. Both the thin walled (Tenuispores) as well as thick walled (Crassispores) spores, exist in these coals, however, thick walled crassispores are rarely observed. Similarly, broken sporangia containing numerous spores (Plate 1, Figs. 7-8; 10-11) and megaspores (Plate 1, Fig. 13) assuming dark grey or black colour and having a wide range of variation in shape and size as well as ornamentation are also sporadically noticed. However, exudatinite exists as secondary infillings in the cracks and cell lumens, has also been occasionally noticed. Cutinites, both the smooth walled forms and also having serrated margins displaying dark black or grey colouration are rarely seen. The thin walled forms are described as tenuicutinites, whereas, the thick walled variety as crassi-cutinite (Plate 1, Figs. 9 & 12). Similarly, randomly distributed dark grey or black coloured resinites with oval or spherical appearance are also observed as cell fillings. Liptodetrinite has been occasionally recorded in fragmentary forms with considerable variation in appearance.

INERTINITE

This maceral group exhibits richest carbon contents. Seam I has shown preponderance of fusinite sub-maceral (Plate 1, Fig. 14). Both genetic categories of fusinite, i.e. pyro-fusinite and degrade-fusinites are commonly noticed in the seam, the former has strong relief, distinct cellular organization and yellow colour display, due to high carbon content; whereas, the later emits white colour, has indistinct cellular representation and shows weak relief. The existence of light grey coloured semifusinite, which is a transitionary stage between vitrinite and fusinite has also been frequently observed. Similarly, inertodetrinite in these coals is recorded in fragmentary forms, as broken remains, mainly derived from inertinite macerals and show a wide variation in their shape and size. Macrinite grains however, exist as discrete amorphous, fine grained ($> 10\ \mu m$), non-granular shining particles like fusinite. Funginites are recorded in the form of single and multicellular spores, mycelia and fungal hyphae as well as sclerotia and fungal remains with higher reflectivity having distributed haphazardly in the inertodetrinite fractions. Secretinites (Plate 1, Fig. 15) of different dimensions are also frequently recorded, mostly confined to inertinite and vitrinite fractions.

MINERAL MATTER

The most commonly recorded mineral in these coals is the detrital clay which indicates the availability of sufficient water table during deposition. Pyrite has generally been found as disseminations as well as framboidal clusters besides cavity fillings which points towards the prevalence of anoxic condition of deposition. Siderite and carbonate minerals however, exist in lesser frequency.

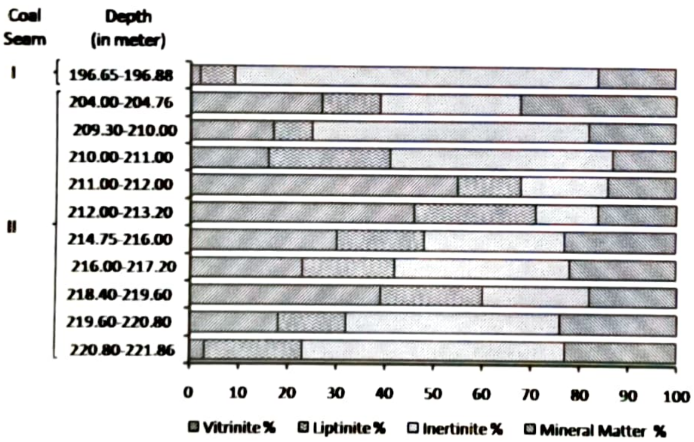
DISCUSSION

Maceral Compositon of Seam I (Top Seam)

The coal maceral study has indicated the predominance of inertinite (75%) group of macerals along with sporadic representation of liptinite (7%) and almost negligible amount of vitrinite (2%) group of macerals. Mineral matter association in this seam has been recorded to be 16%. The existence of inertinite in such a high proportion, indicates the prevalence of oxidizing condition, supplemented with occasional incidences of forest fire during the deposition. The maceral constitution further suggests that the coal of this seam is of better quality.

Maceral Compositon of Seam II (Bottom Seam)

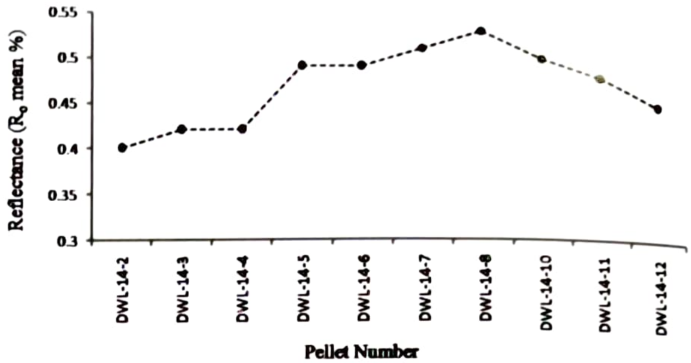
This seam has indicated distinctly different coal constitution than its overlying Seam I. The top and bottom parts are represented by inertinite dominance (29-57%) besides, vitrinite (03-27%) and liptinite (8-25%). Whereas, in middle portion of the seam, vitrinite (30-55%) gains dominance over inertinite (18-29%) group of macerals besides, liptinite (13-25%). Mineral matter association varies between 13% and 24% barring a shaly band at the top containing 32% of mineral matter association. This vitric band is in the middle part and underlain by a small inertinite rich (36%) coal sequence having vitrinite (23%), liptinite (19%) and mineral matter 22%. The existence of alternate inertinite and vitrinite coal bands in this seam indicates that there existed a gradual shift in the climate, initially from warm oxidizing to cold and humid conditions, as reflected in the maceral composition of the seam (Table 2, Text-Fig. 3).



Text-Figure 3. Maceral constitution of the coal seams intersected in Bore-hole DWL-14, Wislon area, Wardha Valley Coalfield.

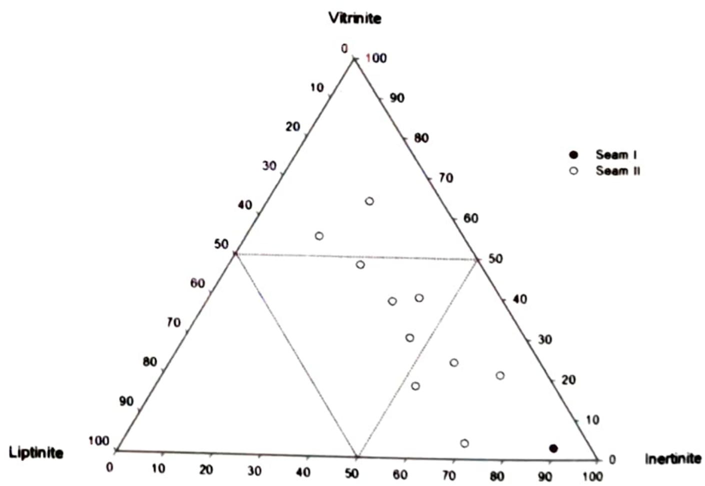
Reflectance Analysis

Seam I is exclusively comprised by the inertinite group of macerals (95%) and contains almost negligible (02%) quantity of vitrinite, therefore, the random vitrinite (R_o mean %) study could not be made. The top and the bottom parts of Seam II have indicated reflectance variation between 0.40% and 0.49%, indicating the attainment of sub-bituminous B rank; whereas, the coal in the middle region contains a slightly higher reflectance variation of 0.50-0.53%, therefore the coal in this region has reached high volatile bituminous C (sub-bituminous A) stage (Text-Fig. 4).



Text-Figure 4. Reflectance (R_o mean %) analysis of the coal seams intersected in Bore-hole DWL-14, Wislon area, Wardha Valley Coalfield.

The ternary mineral matter free (m.m.f.) maceral plotting suggests that the coal of Seam I is fusic in nature as the dominance is gained by inertinite group of macerals; whereas, the coal from Seam II is found to be of heterogeneous origin, as displayed by the presence of vitric (vitrinite rich), fusic (inertinite rich) and mixed (vitric + fusic) coal types (Text-Fig. 5).

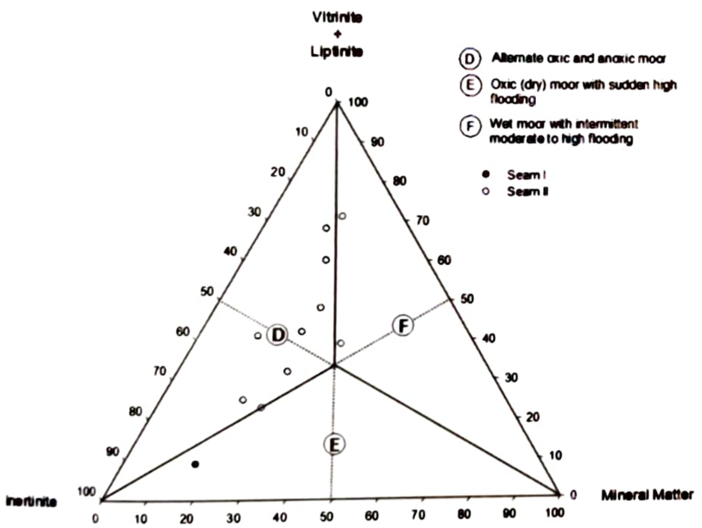


Text-Figure 5. Ternary Maceral (m.m.f.) constitution of the coal seams intersected in Bore-hole DWL-14, Wislon area, Wardha Valley Coalfield.

The facies diagram plotted, based upon the maceral and mineral matter contents within the coal seams (Singh & Singh, 1996), has revealed that Seam I has been deposited during the prevalence of oxic moor (dry) with sudden high flooding whereas, the Seam II has witnessed alternate oxic and anoxic climatic conditions for prolonged periods of time, with an intervention of wet moor with intermittent moderate to high flood situations of short durations (Text-Fig. 6).

Table 2. Maceral constitution and reflectance analysis of the coal seams intersected in Bore-hole No. DWL-14, Wislon area, Chandrapur District, Wardha Valley Coalfield, Maharashtra.

Sr. No.	Depth (in meter)	Pellet No.	Coal Seam	Vitrinite %	Liptinite %	Inertinite %	Mineral Matter %	Reflectance (R_o mean %)
1.	196.65-196.88	DWL-14-1	I	02 (03)	07 (08)	75 (89)	16	--
2.	204.00-204.76	DWL-14-2	II	27 (40)	12 (17)	29 (43)	32	0.40
3.	209.30-210.00	DWL-14-3	II	17 (21)	08 (10)	57 (69)	18	0.42
4.	210.00-211.00	DWL-14-4	II	16 (18)	25 (29)	46 (53)	13	0.42
5.	211.00-212.00	DWL-14-5	II	55 (64)	13 (15)	18 (21)	14	0.49
6.	212.00-213.20	DWL-14-6	II	46 (55)	25 (30)	13 (15)	16	0.49
7.	214.75-216.00	DWL-14-7	II	30 (39)	18 (23)	29 (38)	23	0.51
8.	216.00-217.20	DWL-14-8	II	23 (30)	19 (24)	36 (46)	22	0.53
9.	217.20-218.40	DWL-14-9	II	28	13	14	45	0.50
10.	218.40-219.60	DWL-14-10	II	39 (48)	21 (25)	22 (27)	18	0.50
11.	219.60-220.80	DWL-14-11	II	18 (24)	14 (18)	44 (58)	24	0.48
12.	220.80-221.86	DWL-14-12	II	03 (04)	20 (26)	54 (70)	23	0.45



Text-Figure 6. Facies Diagram showing depositional environment of the coal seams intersected in Bore-hole DWL-14, Wislon area, Wardha Valley Coalfield (Singh & Singh, 1996).

Comparison with other coal deposits of Wardha Valley

A comparative coal petrographic (coal maceral constitution and rank) study with deposits known from various localities of the Wardha Valley Coalfield suggests that there is not much deviation observed in the constitution as well as maturity (rank) in the deposits recovered from Nandori Village, situated nearly 2.5 km in south-eastern part of the study area, however, quite significant improvement is noticed in the quality and rank of the coals studied from Kondha area, which is located approximately 7-8 km south-east of present bore-hole (Sarate, 2000). Similarly, the coal deposits of the Telwasa (Sarate, 2005) and Junad (Sarate, 2009) open cast mines situated about 17-18 km in south-eastern extremity have shown similar composition as recorded in the coal deposits of Wislon area. A considerable improvement in the coal quality has been observed in the coal deposits of the top and middle seams of Dongargaon and the top seam of Kosar areas of Yeotmal District, Maharashtra and also from Mahadoli area of the Wardha Valley Coalfield (Sarate, 2004) whereas, the coal deposits in localities like Marki Jhari Jamni area (Sarate, 2010), situated further west of Kosar-Dongargon and the Ashtona (Sarate, 2016) area, located nearly 25-30 km north-west of Wislon, have indicated marked depletion in their coal quality and the rank as compared to the coal reserves of the Wislon area.

Depositional Environment

Gondwana during the early Permian Period was located in sub-arctic regions (Plumstead, 1961) and the Pre-Cambrian basement rocks were mounted by huge icebergs with prevalence of peri-glacial environment (Sahni, 1939). However, subsequent steady rise in the temperature not only caused melting of icebergs, but also exposed the underlying Pre-Cambrian rocks to the surface. This exposed surface has provided suitable platform for the deposition of Gondwana sediments which took place in continental and slowly sinking basins (Mackowsky, 1968), the sinking nature of the basin has facilitated continuous deposition of mainly plant derived organic matter along with mineral influx from adjoining as well as far off places to the depositional sites, which ultimately transformed into the present day coal deposits. The cold climate proved to be most conducive for the preservation as well as for the proliferation of heterogeneous plant communities, as reflected by the megafloral evidences recorded from these sequences, which mainly belongs to the terrestrial plant groups as well as from aquatic habitat flourished in and around the swamps, marshy places and large stagnant lakes (Chandra & Chandra, 1988). The flora is mainly represented by the dominant association of shrubs bearing broad tongue shaped leaves of Glossopteris plants and short-tufted Gangamopteris plants. The plants with similar morphographic features are also presently growing in the sub-arctic regions, which clearly indicates the existence of cold climatic conditions during the early Permian Period (King, 1958), which became warm-temperate in the later stages (King, 1961). Plumstead (1961) has also expressed a similar view based upon the existence of feldspar associated with the coal seams, however, the development of seasonal growth rings in the plants recorded from the coal indicate that different seasonal patterns prevailed during this regime (Kräusel, 1961).

The coal petrographic characteristics displayed suggest the prevalence of warm oxidizing conditions of deposition, which lead to the genesis of inertinite rich coal constitution; whereas, Seam II contains alternate vitrinite and inertinite rich coal that indicate a distinct change in climate from warm oxidizing to cold and humid climatic conditions, as indicated by the genesis of vitrinite rich coal constitution.

CONCLUSIONS

The coal petrographic studies carried out from the sub-surface coal seams in the vicinity of the study area (Sarate, 2000), suggest that the coal constitution as well as rank remains almost the same as we move south-east i.e., towards Nandori whereas, in Marki-Jhari Jamni area of Yeotmal District (Sarate, 2010) which is located nearly 33 km south-west of the study area and in Ashtona region (Sarate, 2016) depletion in coal quality and rank is observed. Similarly, considerable improvement in the constitution and rank has been noticed in the coal deposits of Kondha area, Dongargaon and Kosar regions (Sarate, 2004).

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