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Petrographic appraisal of coals of sub–surface seams from Belampalli Coalfield, Godavari Valley, Andhra Pradesh

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ABSTRACT

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The present paper incorporates a detailed information about the maceral composition and the rank (reflectance R_o mean %) assessment of eight sub–surface coal seams, viz. IB, IA, I, IIB, II, III, IV and V encountered in Bore–hole No. 561 from Belampalli Coalfield of the Godavari Valley. The mineral matter free (m.m.f.) maceral study has suggested that the seam IB contain vitrinite rich coal or vitric type of coal where as, the seam IIB has inertinite affluent or fusic coal. However, the seams IV and V have shown almost similar proportion of vitrinite and inertinite maceral groups, thus their coal is of mixed type. The seams I and III are represented by vitric and mixed coal types, whereas, IA and II seams are marked by the presence of vitric, fusic and mixed coal types. Most of the coal seams in general have reached high volatile bituminous C rank, barring the basal portion of the seams IV and V which have reached high volatile bituminous B stage. Similarly, a wide range of variation in vitrinite reflectance (R_o mean%) 0.53–1.1% has been recorded in seam II and thus the coal is of heterogeneous nature, having reached high volatile bituminous C, B and A stage of rank. The facies model (based upon the maceral and mineral matter association) drawn for these coal seams has indicated that the depositional site has primarily experienced alternate oxic and anoxic moor conditions. Since the seams in Belampalli Coalfield have consistency in thickness, vitrinite and inertinite rich constitution, low mineral matter association and has shown wide range of rank (reflectance) variation, therefore, the study area has potential to emerge as a productive centre of economically viable and commercially exploitable Coalfield of the Godavari Valley in near future.

Key–words—Sub–surface, Belampalli Coalfield, Maceral, Reflectance, Depositional environment.

आंध्र प्रदेश में गोदावरी घाटी के बेलमपल्ली कोयलाक्षेत्र से प्राप्त उप–पृष्ठीय सीमों के कोयलों का शैलविज्ञानसंबंधी मूल्यांकन

ओमप्रकाश एस. सराटे

सारांश

मौजूदा शोध–पत्र गोदावरी घाटी के बेलमपल्ली कोयलाक्षेत्र से प्राप्त वेध छिद्र संख्या 561 में समागमित आठ उप–पृष्ठीय कोयला सीमों अर्थात Iबी, Iए, I, IIबी, II, III, IV एवं V के मैसेरल संघटन एवं कोटि (परावर्तकता R_o माध्यः) के बारे में विस्तृत जानकारी देता है। खनिज द्रव्य मुक्त (एम.एम.एफ.) मैसेरल अध्ययन ने सुझाया है कि सीम Iबी, में विट्रीनाइट प्रचुर कोयला या कोयले का विट्रिक प्रकार है जबकि सीम IIबी में इनर्टीनाइट विपुल या फ्यूजिक कोयला है। फिर भी, IV एवं V सीमों ने विट्रीनाइट एवं इनर्टीनाइट मैसेरल समूहों के लगभग सदृश समानुपात दर्शाएं हैं इस प्रकार उनका कोयला मिश्रित प्रकार का है। I एवं III सीमें विट्रिक एवं मिश्रित कोयला प्रकारों से रुपायित हैं, जबकि, Iए और II सीमें विट्रिक फ्यूजिक एवं मिश्रित कोयला प्रकारों की विद्यमानता से चिह्नित हैं। सामान्यतः ज्यादातर कोयला सीमें उच्च वाष्पशील बिटुमेनी सी कोटि तक पहुंच चुकी हैं, IV एवं V सीमों के आधारीय भाग को छोड़कर जो कि उच्च वाष्पशील बिटुमेनी बी अवस्था तक पहुंच चुकी हैं। इसी तरह II सीम में विट्रीनाइट परावर्तकता (R_o माध्य%) 0.53-1.1% में वैभिन्य का विस्तृत प्रक्षेत्र अभिलिखित किया गया है और इस प्रकार कोटि की उच्च वाष्पशील बिटुमेनी सी, बी एवं ए अवस्था तक पहुंच चुका, कोयला विषम प्रकृति का है। इन कोयला सीमों के लिए बनाए गए संलक्षणी मॉडल (मैसेरल एवं खनिज पदार्थ संगुणन के आधार पर) ने इंगित किया है कि निक्षेपणीय स्थल ने प्राथमिक रूप से विकल्पी ऑक्सी और अनॉक्सी मूर

स्थितियां अनुभव की हैं। चूंकि बेलमपल्ली कोयलाक्षेत्र में सीमों की मोटाई, विट्रीनाइट व इनर्टीनाइट प्रचुर संघटन, अल्प खनिज पदार्थ संगुणन संगति है तथा कोटि (परावर्तकता) परिवर्तन का विस्तृत प्रक्षेत्र दर्शाया है। अतः अध्ययन क्षेत्र निकट भविष्य में गोदावरी घाटी का आर्थिक रूप से लाभप्रद और वाणिज्यिक रूप से समुपयोज्य कोयलाक्षेत्र का उत्पादी केंद्र के रूप में उभरने की संभावना रखता है।

सूचक शब्द—उप–पृष्ठीय, बेलमपल्ली कोयलाक्षेत्र, मैसेरल, परावर्तकता, निक्षेपणीय, पर्यावरण।

INTRODUCTION

BELAMPALLI Coalfield of Adilabad District, Andhra Pradesh represents the north–western edge of Godavari Valley Coalfield, which extends over strike length of 45 km and marked between 19º03'21" N latitude 79º29'35" E longitudes respectively. The Coalfield is located at a distance of 16 km both from Manceral and Tandur areas having a century old legacy of coal mining. Since this Coalfield contain a number of persistent coal seams, detailed sub–surface explorations have been taken up by the Governmental agencies such as, Singareni Colliery Company Limited, Kothagudem and Geological Survey of India to generate detailed information regarding their nature and the extent. The basal Seam in Belampalli area is popularly known as Ross Seam, which has thickness variation between 1.8 m and 3.1 m, elsewhere, this Seam it is referred as No. IV Seam. However, in southernmost extremity, near Shanti Khani, I Incline, Ross Seam splits into top (1.3 m) and bottom (0.9 m) sections with sandstone partition of about 5.5 m. It has shown increasing trend in the thickness towards NNW (Boipalli Block), which reaches up to 4 m. Variation in the thickness is the regular feature of the Ross Seam, its thickness is not only persistent but also is dirt free. It has roof marked by carbonaceous shale whereas, the floor is marked by greyish white carbonaceous sandstones, Raja Rao (1982). Since very little information,

Age	Group	Formation	Maximum Thickness (meters)	Lithology
			500	Upper Member: Coarse–grained, ferruginous sandstones with clay clasts and pebbles and subordinate violet cherty siltstones and pebble beds.
Upper Permian to Lower Triassic		Kamthi	600	Middle Member: Alternating sequence of medium–grained white to greenish grey white sandstones and buff to greenish grey clays.
	LOWER		200	Lower Member: Medium– to coarse–grained, greyish white calcareous sandstones with a few coal seams.
Upper Permian		Barren Measures	500	Medium– to coarse–grained, greenish grey to greyish white felspathic sandstones with subordinate variegated and micaceous sandstones.
Upper part of Lower Permian		Barakar	300	Upper Member: Coarse, white sandstones with subordinate shales and coal seams.
	GONDWANA			Lower Member: Coarse–grained sandstones with lenses of conglomerates, subordinate shales/clays and a few thin bands of coal.
Lower Permian		Talchir	350	Fine–grained sandstones, splintery green clays/shales, chocolate coloured clays, pebble beds and tillite. ——Unconformity——
? Upper Proterozoic		Sullavai	545	Medium– to coarse–grained, white to brick red sandstones, at places quartzitic and mottled shales. ——Unconformity——
Lower Proterozoic		Pakhal	3335	Greyish white to buff quartzites, grey shales, phyllites and marble. ——Unconformity——
Precambrian		–	–	Granites, banded gneisses, biotite gneisses, hornblende gneisses, quartz magnetite schists, biotite schists, quartz and pegmatite veins.

Table 1—General Geological succession of the Permian sediments exposed in the Godavari Valley Coalfield, Andhra Pradesh, India (after, Raja Rao, 1982).

Navale *et al.,* (1983) and Sarate (2001) is known regarding the coal petrographic constitution of the coals of this area. The present study has been initiated to enrich more detailed information regarding the nature and constitution of the sub–surface coal seams of Belampalli Coalfield to ascertain its economic potentials.

GENERAL GEOLOGY

Godavari Valley Coalfield encompasses cumulative areal extent measuring 17,400 km^2 marked between 16º38' and 19º32' latitudes and 79º12' and 81º39' longitudes. The coal bearing horizons cover 11,000 km^2 area, however, the coal horizons that can be commercially explored covers an area of 1700 km^2. Godavari Valley Coalfield is significant because of its geographic location and represents the entire southern peninsular region. It also depicts almost entire litho– and chrono–stratigraphic sequence of the Permo–Triassic sediments, besides the signatures of well marked biozones, floral, faunal as well as the tectonic events (Table 1).

Qureshy *et al.,* (1968) and Bhaskar Rao *et al.,* (1971) studied the gravity anomaly of Gondwana deposits from Godavari Valley, they have inferred that huge piles of sediments were deposited on the several ice–radiation centres in the valley, e.g. Mailaram high and Kanneri hill ranges representing the southern part, Pakhal and Sullavai uplands

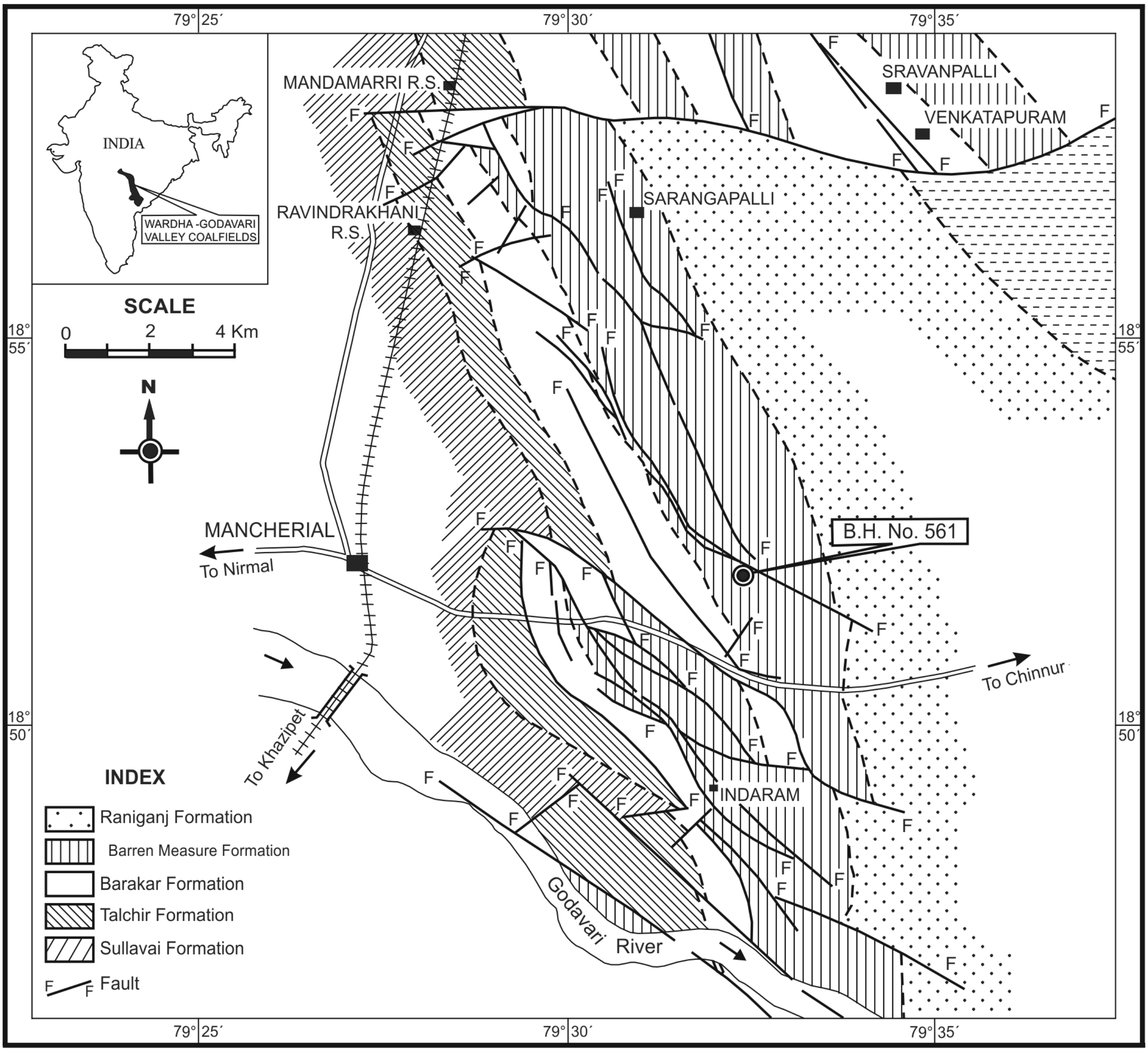

Fig. 1—Geological map showing location of Bore–hole No. 561, Belampalli Coalfield (Courtesy, SCCL, Kothagudem).

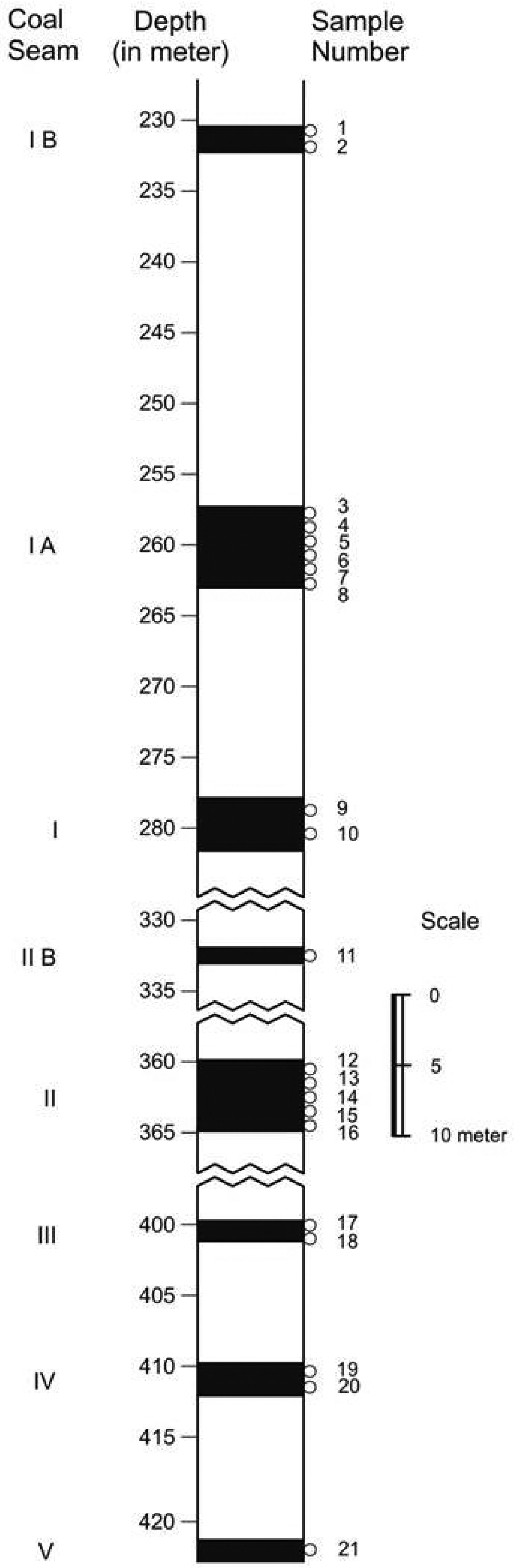

Fig. 2—Litholog showing different coal seams intersected in Bore–hole No. 561 from Belampalli Coalfield.

in the western part, Lingala area of the central part and Golet area in the northern region. The melting icebergs moved in different directions, Bose and Ramanamurthy (1977). Due to liquefaction of the icebergs the valley transformed into proglacial lakes wherein, the fluvio–glacial Gondwana sedimentation took place. The floating icebergs rafted huge amount of clasts and deposited their load into silt clay facies, however, the sandstone and conglomerate denotes the existence of glacio–fluvial environmental set up. Tillites marks the basal most unit of this Formation, which are mainly comprised by polymictic clast, that includes dolomite pebbles and boulders derived from the Pakhal succession, having variation in their size and shape. Recurrence of tillites is caused by the oscillation of the icebergs during the glacier movement. The Talchir sediments have also indicated regional variation in their lithofacies. Clay and laminated siltstones having tendency of coarsening towards the top is frequently noticed. However, drop stones are noticed in the eastern edge of the basin. The upper part of the Talchir Formation is marked by sandstones containing conglomerates. Increase in the rate of sedimentation, supplemented with the widening in areal extent has been noticed during the Barakar deposition. The basal most arenaceous member has the predominance of coarse–grained sandstones which contains lenses of conglomerates and is devoid of any coal seam, its thickness also varies from place to place. The upper member mainly includes cross stratified sandstones as the dominant lithofacies with interbands of shales and well developed coal seams. A wide range of cyclic repetition and also variation in depositional pattern is noticed at different places in the valley. The cyclic sedimentation pattern has brought course–grained sandstones load which infilled the stream channels. Repetition in channel wandering and their migration caused splitting of the seams which indicates slowly sinking nature of the depositional site, Raja Rao (1982). Similar pattern of sedimentation and the fluvial conditions continued during the deposition of the Barren Measures Formation. Greenish coloration of the sequence suggests the prevalence of reducing conditions during this regime. Kamthi sediments however, are characterised by the dominance of coarse–grained prismatic or lenticular argillaceous sandstones, along with clay and siltstone deposits; however, finer sediments are recorded from the flood plain. In Ramagundam, Kundaram and Jaipuram areas, existence of coal seam is also reported, Ramanamurthy (1979). The upper part of the Kamthi succession contains inter–bedded conglomerates which suggest that the south–western part of the basin might have suffered from tectonic disturbances.

LOCATION

The representative coal samples from sub–surface coal seams encountered in Bore–hole No 561, Belampalli Coalfield

Sr. No.	Depth in meters	Name of Coal Seam	Lithology	Pellet No.
1.	230.40–231.20	I B Seam	Coal	1
2.	231.20–232.00	I B Seam	Coal	2
3.	257.16–257.57	I A Seam	Coal	3
4.	257.57–258.58	I A Seam	Coal	4
5.	259.12–259.82	I A Seam	Coal	5
6.	259.98–260.88	I A Seam	Coal	6
7.	260.88–261.71	I A Seam	Coal	7
8.	261.78–262.76	I A Seam	Coal	8
9.	278.20–279.81	I Seam	Coal	9
10.	279.81–281.42	I Seam	Coal	10
11.	331.73–332.78	II B Seam	Coal	11
12.	359.86–360.33	II Seam	Coal	12
13.	361.13–361.88	II Seam	Coal	13
14.	361.88–362.88	II Seam	Coal	14
15	362.88–363.88	II Seam	Coal	15
16.	363.88–364.90	II Seam	Coal	16
17.	399.87–400.44	III Seam	Coal	17
18.	400.44–401.00	III Seam	Coal	18
19.	409.92–410.92	IV Seam	Coal	19
20.	410.92–411.89	IV Seam	Coal	20
21.	422.22–423.36	V Seam	Coal	21

Table 2 — Showing the details about the coal samples collected from B.H. No. 561, Belampalli Coalfield.

have been collected for the coal petrographic investigations. This bore hole is located at a distance of about 5 to 6 km east of Mancherial Town located on southern rail route. Eight coal seams have been intersected in this Bore–hole between 230.40 and 423.36 m depth range. The coal seam sequence from top to bottom is designated as IB, IA, I, IIB, II, III, IV and V respectively (Table 2; Figs 1, 2).

METHODOLOGY

For petrographic analysis coal samples have been crushed to the size of 1–2 mm to be used for pellet preparation. Approximately 15–20 gm of the crushed sample has been utilised for pellet preparation. A mixture of hardener and releasing agent in the ration 1:5 was then poured in these moulds and mixed properly before hardening. The hardened coal pellets were removed from the moulds and were grounded and then polished on silicon cloth by using different grades of polishing alumina, following the procedure laid down by ICCP (1971, 1975, 1998, 2001) and Stach *et al.,* (1982). The maceral and reflectance study has been done using Leica DM 4500P microscope. Random vitrinite reflectance measurements (R_o mean %) were done on Microscopephotometry System (PMT III) and Software MSP 200. Quantitative maceral study computerised point counter and 2.35 version of Petroglite Software has been used and for microphotography Software tool Leica applications suit (LAS) is utilised.

DESCRIPTION OF MACERALS

Macerals are the microscopically recognisable coal constituents. All the three maceral groups, vitrinite, liptinite and inertinite are well represented in these coals. Vitrinite group of macerals are homogenous, amorphous or colloidal and viscous forms with relatively higher oxygen contents than the other two macerals. Liptinite exhibits fragmentary structure with high hydrogen contents, where as inertinite displays maximum carbon contents.

Vitrinite—Vitrinite group of maceral are most frequently noticed in these coals. They represent humic fraction mainly derived from tree trunks, branches, stems and leaves, etc. The sub maceral occurs as thick and thin bands. Collotelinite is the most frequent maceral recorded in these coals (Pl. 1.1, 2). Telinite with distinct cellular preservation is also occasionally

Sr. No.	Name of the coal seam	Vitrinite %	Liptinite %	Inertinite %	Mineral Matter %	Reflectance (R_o mean %)
1.	I B	51 (58)	11 (12)	26 (30)	12	0.54
2.	I B	53 (55)	18 (19)	25 (26)	4	0.51
3.	I A	65 (67)	27 (28)	5 (5)	3	0.52
4.	I A	57 (65)	10 (11)	21 (24)	12	0.53
5.	I A	33 (39)	24 (29)	27 (32)	16	0.55
6.	I A	41 (47)	17 (19)	30 (34)	12	0.57
7.	I A	17 (23)	16 (21)	42 (56)	25	0.52
8.	I A	14 (18)	8 (10)	56 (72)	22	0.51
9.	I	50 (58)	8 (9)	29 (33)	13	0.54
10.	I	30 (37)	16 (20)	35 (43)	19	0.52
11.	II B	18 (22)	15 (18)	50 (60)	17	0.58
12.	II	58 (62)	12 (13)	23 (25)	7	0.61
13.	II	13 (16)	6 (7)	62 (77)	19	1.1
14.	II	13 (15)	26 (29)	50 (56)	11	0.69
15.	II	45 (51)	11 (13)	32 (36)	12	0.65
16.	II	34 (37)	20 (22)	39 (41)	7	0.53
17.	III	56 (63)	17 (19)	16 (18)	11	0.56
18.	III	41 (44)	22 (24)	30 (32)	7	0.63
19.	IV	36 (44)	8 (10)	38 (46)	18	0.62
20.	IV	39 (46)	18 (21)	28 (33)	15	0.68
21.	V	39 (45)	9 (11)	38 (44)	14	0.67

Table 3—Maceral composition and the reflectance (R_o mean %) analysis of the coal seams intersected in Bore–hole No. 561, Belampalli Coalfield.

recorded (Pl. 1.8). Sometimes expulsion of oil from the cracks and fissures of the telocollinite bands (Pl. 1.3, 5) is also recorded. Gelocollinite appears to be grey or dark grey in colour and exists in jellified and colloidal forms, which help in binding or holding together the other coal constituents. When observed as isolated bodies with oval or circular shape then is termed as Corpocollinite.

Liptinite—This maceral group includes golden yellow or golden brown coloured sporinite, represented by both the thick (crassispores) and thin (tenuispores) walled spores, along with some large sized megaspores displaying dark grey colour (Pl. 1.11). Cutinites, however, have serrated margins and display darker colour than the microspores (Pl.1.9, 10). Resinite has sporadic representation and is mostly recorded as isolated bodies with spheroidal or elliptical shape and is noticed as cell fillings with dark grey or black colour.

Inertinite—Fusinite is most commonly recorded as pyro– and degrado–fusinite. Pyrofusinite are rich in carbon content and display yellowish colour and has well defined cellular organization and is believed to be the derivatives of coal fire. However, degrado–fusinite contains deformed or disintegrating cells due to the fungal activity and display white coloration and weak relief. The cellular compression (Pl. 1.12, 14) at times results in the formation of bogen structures (Pl. 1.13). Semifusinite displaying intermediate stage between the vitrinite and fusinite is also recorded in these coals, their cells are poorly preserved with light grey or white colour. Funginite and Secretinite (Pl. 1.15) are also recorded in these coals but there intensity is quite low (Lyons, 2000).

PLATE 1 ⟶

1, 2. Collotelinite bands.
3, 5. Collotelinite showing oil expulsion.
4, 6, 7. Framboidal pyrite.
8. Cellular preservation.
9, 10. Cutinite displaying cuticular ledges.
11. Broken megaspore.
12, 14. Fusinite with cellular compression and disintegration.
13. Fusinite showing bogen structure.
15. Secretinite.

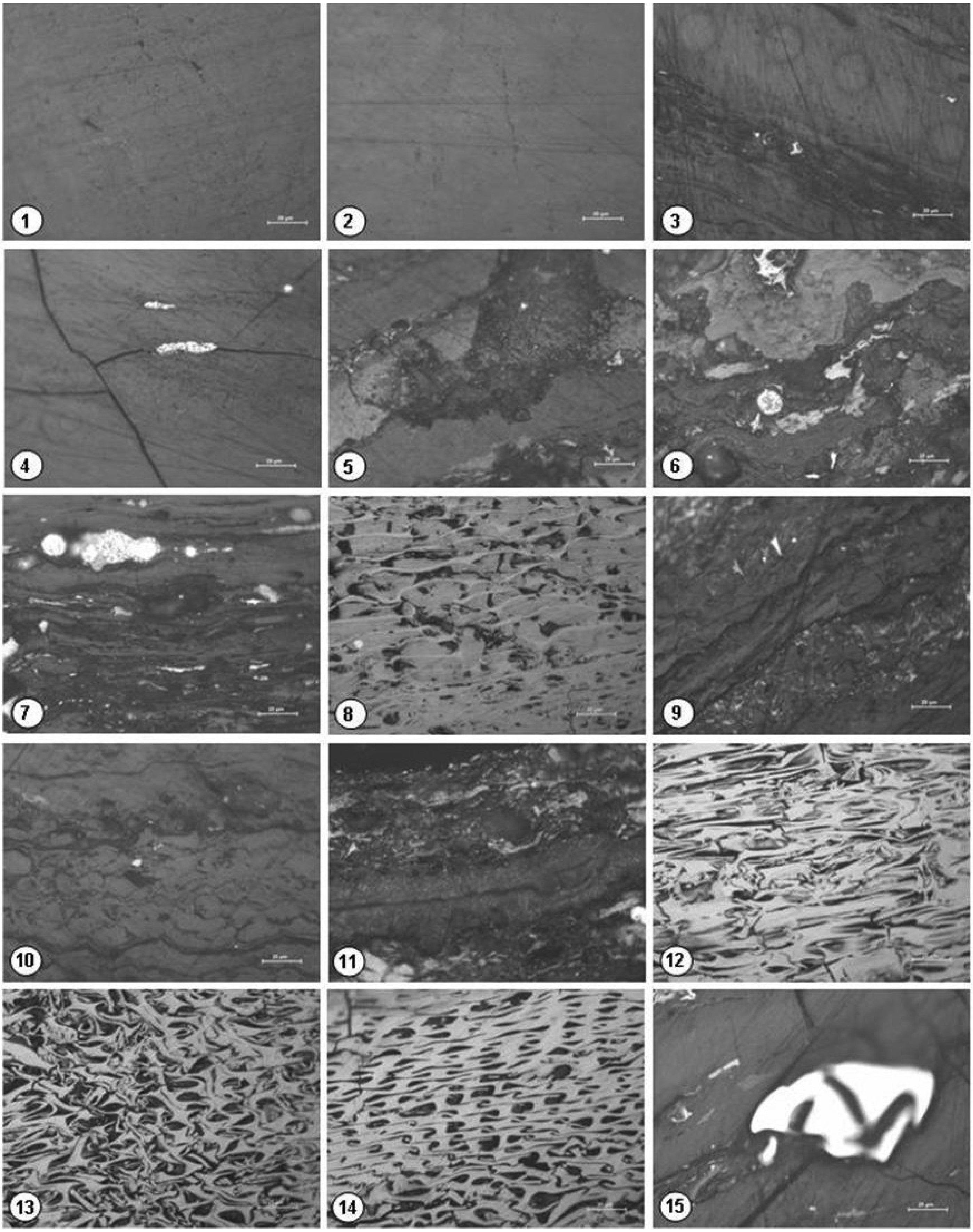

PLATE 1

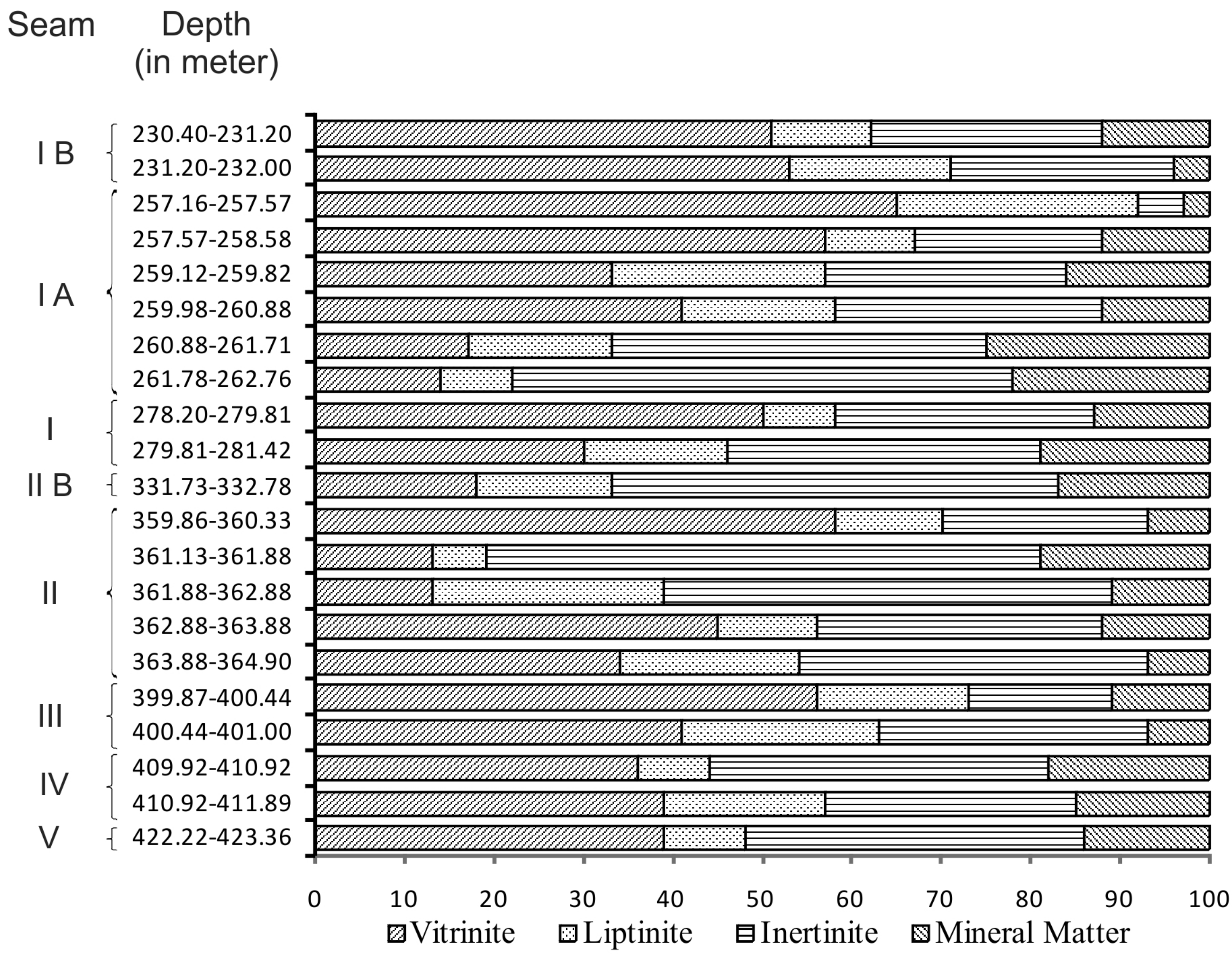

Fig. 3—Maceral constitution of the coals from B. H. No. 561, Belampalli Coalfield.

Mineral Matter—Most of the coal seams have recorded dominant association of clay minerals, mostly they exist as cell and crack fillings as well as in the cleats of the vitrinitic ground mass and infilled in the fusinised tissues. They display granular appearance with black colour. Pyrite in framboidal form (Pl. 1.4, 6, 7) as well as in the isolated granular form is noticed from the cracks and fissures of the vitrinite and inertinite macerals. Carbonates also exist in the form of ground mass and as crack fillings.

MACERAL CONSTITUTION

Vitrinite group of macerals have recorded dominance in the topmost IB and III seams, with frequency range between 41 and 56 vol. %, which is declined to 39 vol. % in V seam. Similarly, the liptinitic contents range between 11 and 18 vol. % in IB seam, increased to 17–22 vol. % in III seam and reduced to 9 vol. % in the V seam. Inertinite, however, is recorded to be 25–26 vol. % in IB, 16–30 vol. % in III seam and recorded its maximum of 38% in V seam. Mineral matter distribution in these coal seams in general ranges between 11 and 14 vol. % which has reduced to 4–7 %, in bottom part of seam IB and III seams respectively.

II B seam is the only seam containing fusic coal with inertinite 50 vol. %., in association with vitrinite 18 vol. %, liptinite 15 vol. % and mineral matter 17 vol. %.

Seam II contain two alternate bands of vitrinite and inertinite rich coal bands. The coal at the top is vitric in nature. The coal at the top and in the middle region contain vitrinite 45–58 vol. % with decreasing trend of frequency distribution towards the bottom part. Liptinite 11–12 vol. %, inertinite 23–32 vol. % and mineral matter 7–12 vol. % however, have shown increase in their frequency distribution towards the bottom part. The uppermost fusic coal band is represented by inertinite 50–62 vol. % with decreasing tendency towards the bottom part, besides vitrinite 13 vol. %. However, liptinite 6–26 vol. has indicated considerable increase towards the bottom part whereas, mineral matter 19–11 vol. % has shown

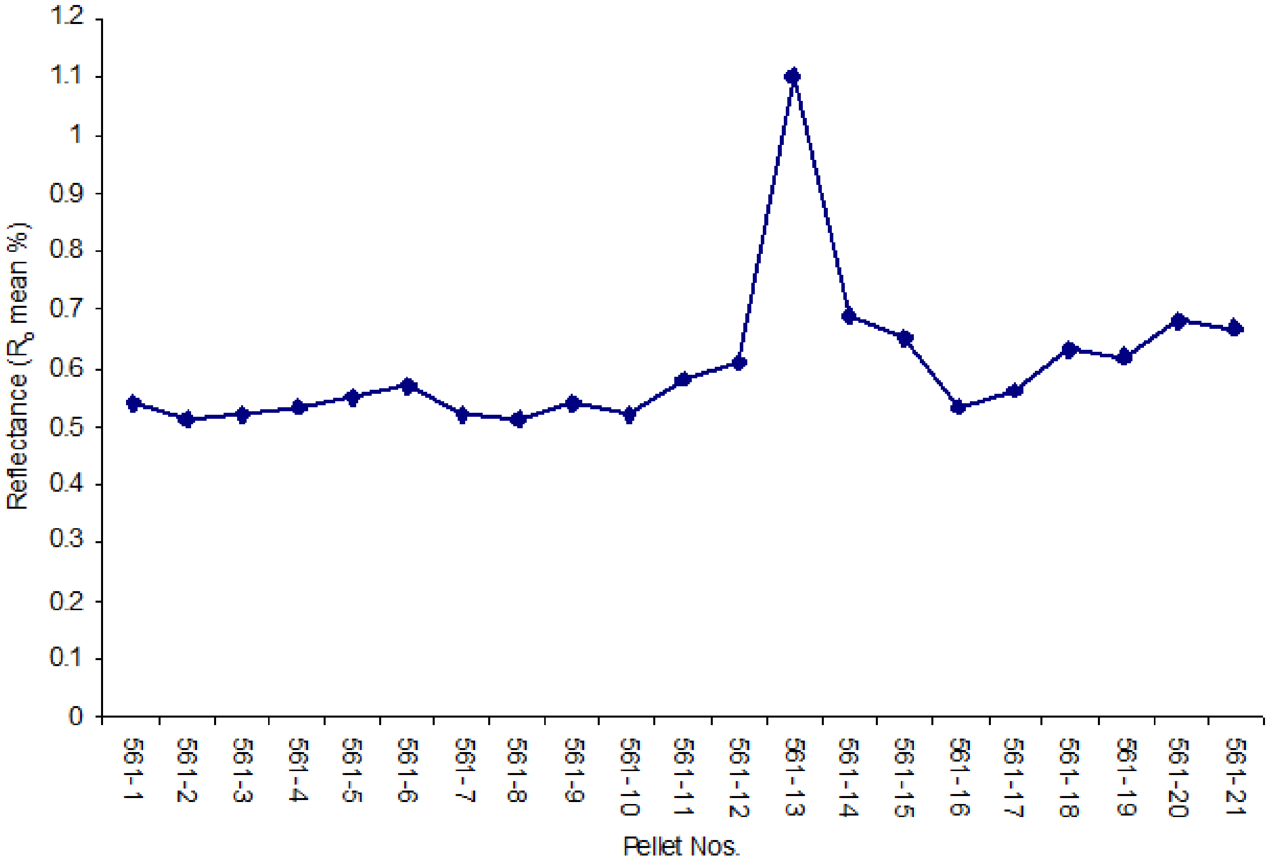

Fig 4—Reflectance (R_o mean%) analysis of the coal seams intersected in B. H. No. 561, Belampalli Coalfield.

decreasing trend towards the bottom part of this seam. The basal fusic coal band, however, contain inertinite 39 vol. % , in association with vitrinite 34 vol. %, liptinite 20 vol. % along with significantly low 7 vol. % mineral matter association.

IA and its underlying I seams are characterised by the presence of vitrinite rich 33–65 vol. % (vitric) coal at the top having liptinite 10–27 vol. %, inertinite 21–30 vol. % and mineral matter 12–25% apart from the coal at the top of IA seam which has scanty distribution of 3% vol. and 5% vol. of inertinite and mineral matter respectively. The alternating fusic coal bands in these seams contain inertinite 35-42 vol. %, besides, liptinite 16 vol. % and vitrinite 17 to 30 vol. %.

As observed in IA and I seams the seam IV is also represented by alternate bands fusic and vitric coal constituents but at the top it has inertinite rich (fusic) coal having inertinite 38 vol. % besides, vitrinite 36 vol. % and meagre representation of liptinite 8 vol. %. The underlying coal sequence has the dominance of vitrinite 39 vol. % in association with inertinite 28 vol. % and liptinite 18 vol. %. Mineral matter association in this seam ranges between 18 and 15 vol. % with slight decrease at its bottom (Table 3; Fig. 3).

REFLECTANCE STUDY

The vitrinite reflectance (R_o mean %) of IA and I seams has been recorded between 0.51% and 0.54%, except for a coal band in seam I with higher reflectance of 0.57%. Similarly, the seam IIB has shown vitrinite reflectance 0.58% which indicates that these seams have attained high volatile bituminous C stage. In seam II a wide range of variation in vitrinite reflectance has been noticed, which ranges between 0.53 and 1.1% indicating the attainment of high volatile bituminous C, B and A stages of rank. Seam III and upper part of the seam IV has depicted vitrinite reflectance from 0.56% to 0.63% indicating the attainment of high volatile bituminous C stage of rank. However, the lower part of IV seam and the V seam showed vitrinite reflectance between 0.67% and 0.68% and thus they have attained high volatile bituminous B rank (Table 3; Fig. 4).

The ternary mineral matter free (m.m.f.) maceral plotting has revealed that the seam IB contains vitrinite rich or vitric type of coal whereas, seam IIB has inertinite rich or fusic coal. The seams IV and V have displayed the existence of mixed coal type, whereas, the seams I and III are represented

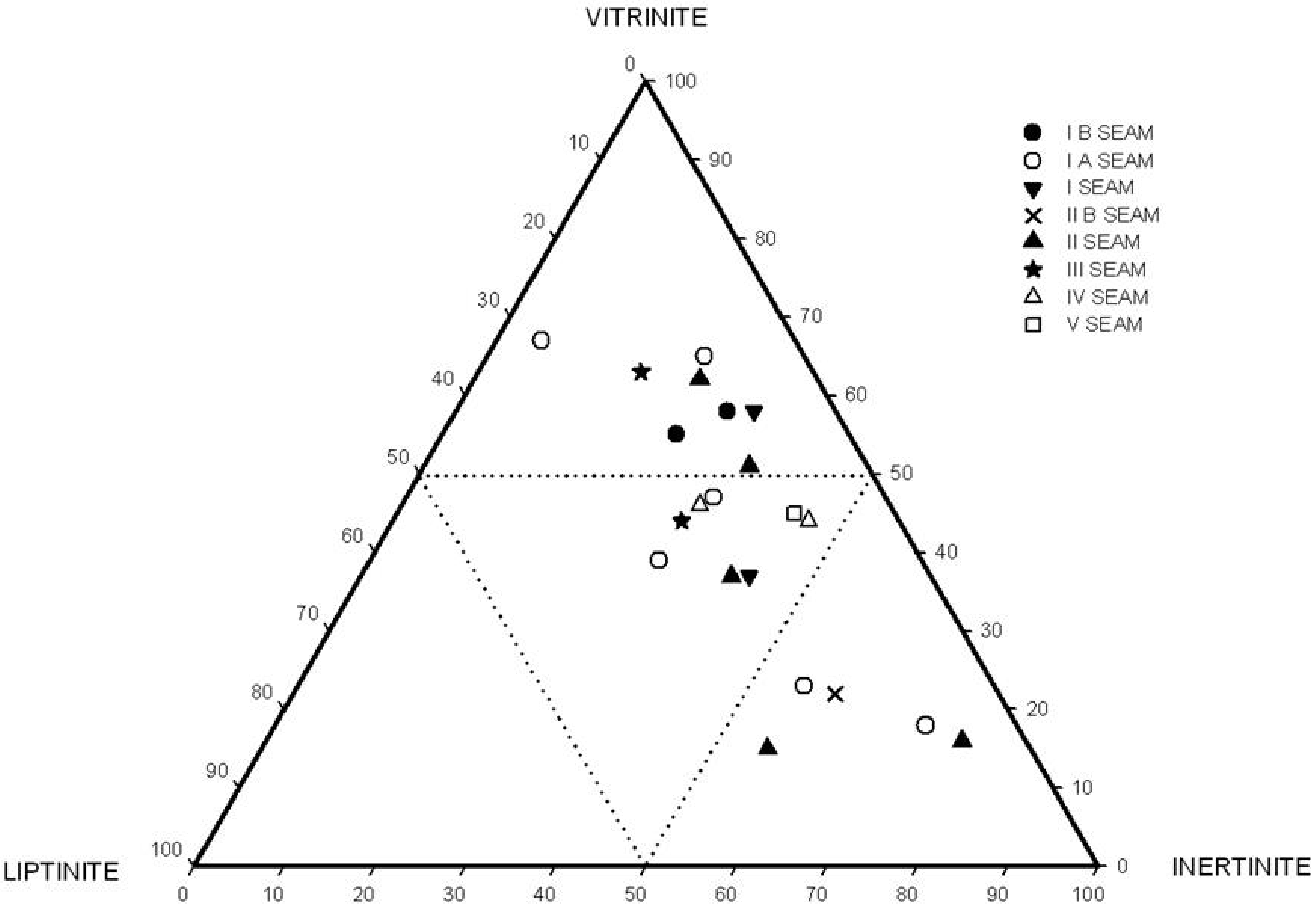

Fig 5—Ternary diagram showing maceral (m.m.f.) constitution of the coal seams intersected in B.H. No. 561, Belampalli Coalfield.

by vitric and mixed coal types. Similarly, the seams IA and II have been found containing vitric, fusic as well as mixed type of coal (Fig. 5).

The facies diagram (Fig. 6) based upon the maceral and mineral matter contents of these coal seams has displayed that the entire coal seam sequence of Belampalli Coalfield area by and large has been deposited with the prevalence of alternate oxic and anoxic moor conditions, Singh & Singh (1996).

DISCUSSION AND CONCLUSIONS

The study area represents a part of the tectonically controlled and slowly sinking basin in which the vegetal matter rich influx (organic debris) derived from luxuriantly growing vegetation of the closer vicinity and also from the far off sites, has been brought continuously for a prolonged period of time through the agencies like wind, rain water, river channels and also the periodic floods and deposited. The organic matter (peat) accumulated in the basin has undergone biodegradation by anaerobic bacteria and fungal action (putrefaction), which caused enhancement in its carbon contents whereas, humification gave it a brownish tint. The overburden of incoming organic and inorganic matter load in the basin resulted in compaction and water loss of the underlying semi–degraded peat deposit and thus converted it into the lignite stage. The diagenetic or biochemical changes took place in the peat swamp mainly through the bacterial and fungal activity at the very shallow depths. At the increased of burial depth, i.e. < 10 m, the bacterial activity is ceased. Further geothermal and geochemical changes (i.e. the alterations) caused in the organic material of the brown coal (lignite) stage are severe and can be termed as metamorphism, Thomas (2002), coal is more susceptible to the changes temperature and pressure than the mineral contents, therefore coal has tendency to indicate metamorphism.

The climatic conditions prevailing at the depositional site play decisive role in conversion of the organic debris finally into different group of coal macerals such as vitrinite, liptinite and inertinite. Prevalence of the cold climatic condition plays important role in the genesis of vitrinite group of macerals

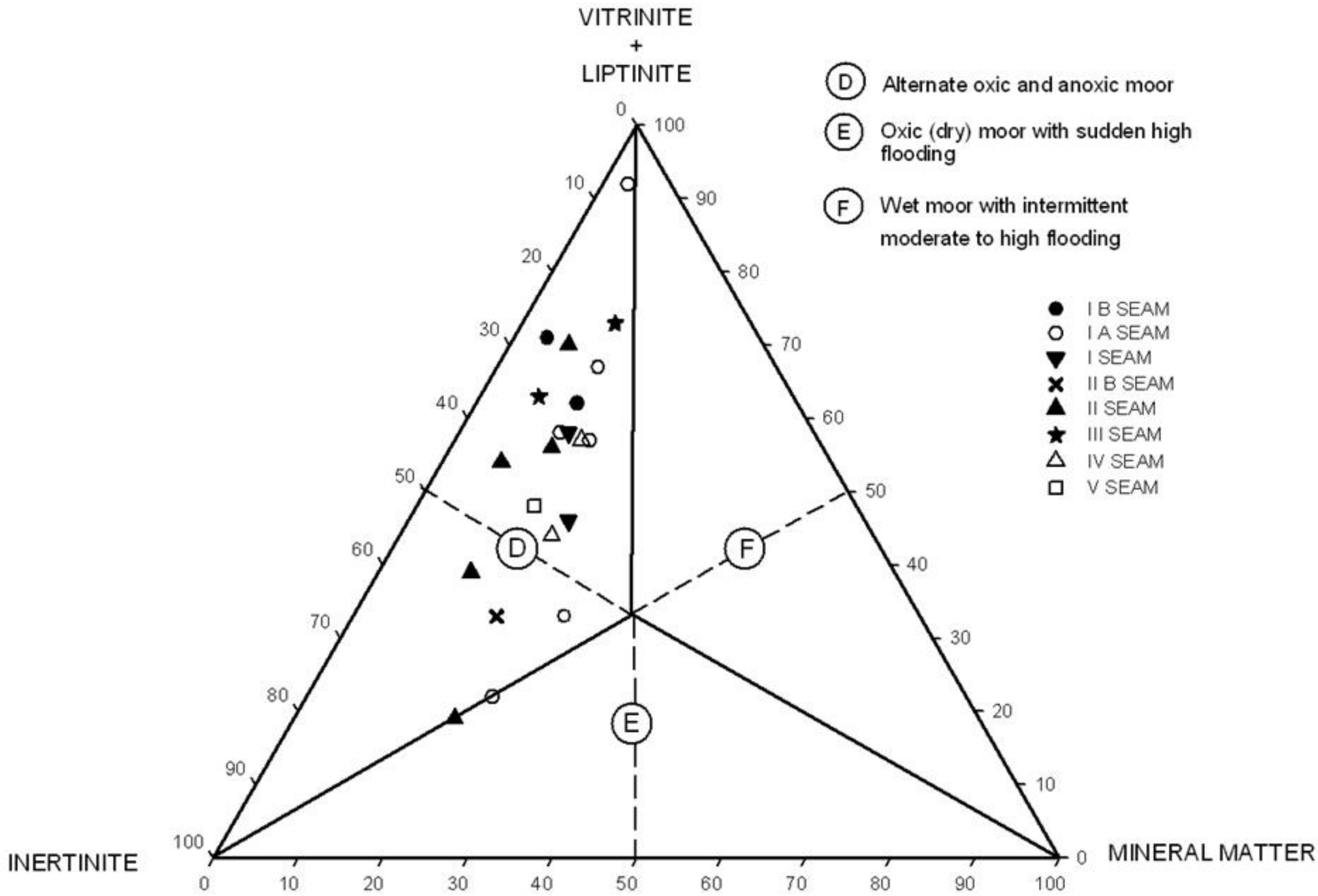

Fig. 6—Facies model showing depositional conditions of the coal seams intersected in B. H. No. 561, Belampalli Coalfield (after Singh & Singh, 1996).

whereas inernite macerals require warm and oxidizing conditions. Based upon the maceral analysis an attempt has been made to deduce depositional scenario for different coal seams of Belampalli Coalfield.

The coals of the V and IV seam contain mixed type of coal indicating the prevalence of moderate climate during their deposition. However, existence of mixed and vitric type of coal from III and I seams denote change in the climatic conditions from moderate to cold. Seams II and IA contain vitric, fusic and the mixed coal types, thus have experienced moderate, cold as well as dry and oxidizing environmental conditions. Existence of inertinite rich coal in IIB seam indicates the prevalence of oxidizing depositional environment, whereas seam IB has vitrinite rich or vitric type of coal which suggests the incidence of cold climatic conditions (Fig. 5).

Thus, the coal petrographic study of the seam succession in Belampalli Coalfield, in nut shell suggests that mostly climate remain moderate and cold with alternating dry and oxidizing spells. Significantly high proportion of pyro–fusinites has been recorded in one of the samples of seam II which demonstrates the possible occurrence of a short term coal fire event at this stage Teichmüller (1950, 1962), Glasspool (2000) and Taylor *et al.* (1998). Similarly, rise in the vitrinite reflectance is also observed in the coal of this horizon.

If we look at the flora that exists today in the subarctic (boreal climate) we see that the vegetation is mostly dominated by the Conifers along with the broad leaved trees which are flourishing in the prevalence of cold climatic conditions. During Permian Period Indian Plate was holding similar palaeogeographic position (i.e. located in the subarctic region Stach *et al.,* 1982). Similarly, the fossil megafloral evidences recovered the Permian (Indian Lower Gondwana) deposits also depicts the existence of plants having closer morphological similarity with the plant groups that exist today in sub–arctic region. These, extinct plants flourished as climax vegetation represented by stunted trees (*Glossopteris forests*) with characteristic tongue shaped leaves of *Glossopteris, Gangamopteris, Lepidodendron* and *Sigillaria* (Glossopteris forests) along with the aquatic plants of the family Calamariaceae, which suggests the prevalence of cold climatic conditions during Permian Period, Chandra and Chandra (1987), King (1958), Plumstead (1961) with alternate dry and rainy seasons Kräusel (1961). The climate became warm and temperate in the later stages, King (1961).

In Belampalli Coalfield the sub–surface coal seams have consistency in thickness and contain vitrinite or inertinite rich configuration, besides significantly low mineral matter association, therefore, they display better quality coal, thus this Coalfield has potential to emerge as one of the most significant and economically exploitable coal production centres of the Godavari Valley.

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