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Petrographic evaluation of coal seams from Rampuram area, Kothagudem Sub-basin, Godavari Valley Coalfield, Andhra Pradesh, India

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ABSTRACT

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The study incorporates petrographic (maceral and reflectance) features of the entire stratigraphic sequence of two bore-holes, SR94 and SR94-A, drilled in Rampuram area of Kothagudem sub-basin, Godavari Valley, Andhra Pradesh. This sequence includes the following coal seams: I Seam, Index below I Seam, Queen Seam (Sections I, II and III) and the top part of King Seam. The King Seam has profusion of inertinite group of macerals which signifies the prevalence of dry and oxidizing depositional scenario. However, vitrinite rich constitution, recorded from the Queen Seam and overlying Index below I and the topmost I seams, denotes a gradual shift in the climatic conditions from dry oxidizing (King Seam) to cold and humid conditions. The coal of Queen Seam has also recorded higher random reflectance (R_o mean%) values of 0.70 to 0.72%, which suggests the attainment of high volatile bituminous B stage of rank. Similarly, the Queen, Index below I and the topmost I seams depicted comparatively lower vitrinite reflectivity of 0.51 to 0.61% and therefore, they have attained high volatile bituminous C stage. The facies diagram also depicts the existence of wet moor with intermittent moderate to high flooding during the deposition of vegetal resource of King Seam and the prevalence of alternate oxic and anoxic moor when the younger seams were being deposited. The mineral matter free (m.m.f.) maceral study reveals that coal of King Seam is fusic (inertinite rich) in nature whereas the younger seams contain vitric (vitrinite rich) type of coal. Mostly, the coal seams of Rampuram area have low mineral matter association and vitrinite and inertinite rich constitution, which suggests that the study area has economically viable coal deposits.

Key-words: Petrographic evaluation, reflectance, maceral, Lower Gondwana coal, Rampuram area, Kothagudem Sub-Basin, Godavari Valley Coalfield, Andhra Pradesh.

INTRODUCTION

Little information is available about petrographic constitution of the coal seams of Kothagudem Sub-basin in Godavari Valley, Andhra Pradesh. Rizwi and Ramana Rao (1969) worked on the existence of resins in coals of Kothagudem area. Navale et al. (1983) analyzed some coal samples from King Seam which has inertinite as the dominant maceral group. Pareek (1986) demonstrated vitrinite dominance from the King and Queen seams. Sarate (2012) provided a detailed petrographic account of topmost I Seam and underlying Queen and King seams.

The study area (Rampuram Shaft Block) is the virgin tract which has been recently taken up by The Singareni Collieries Company Limited, Kothagudem, Andhra Pradesh to estimate nature

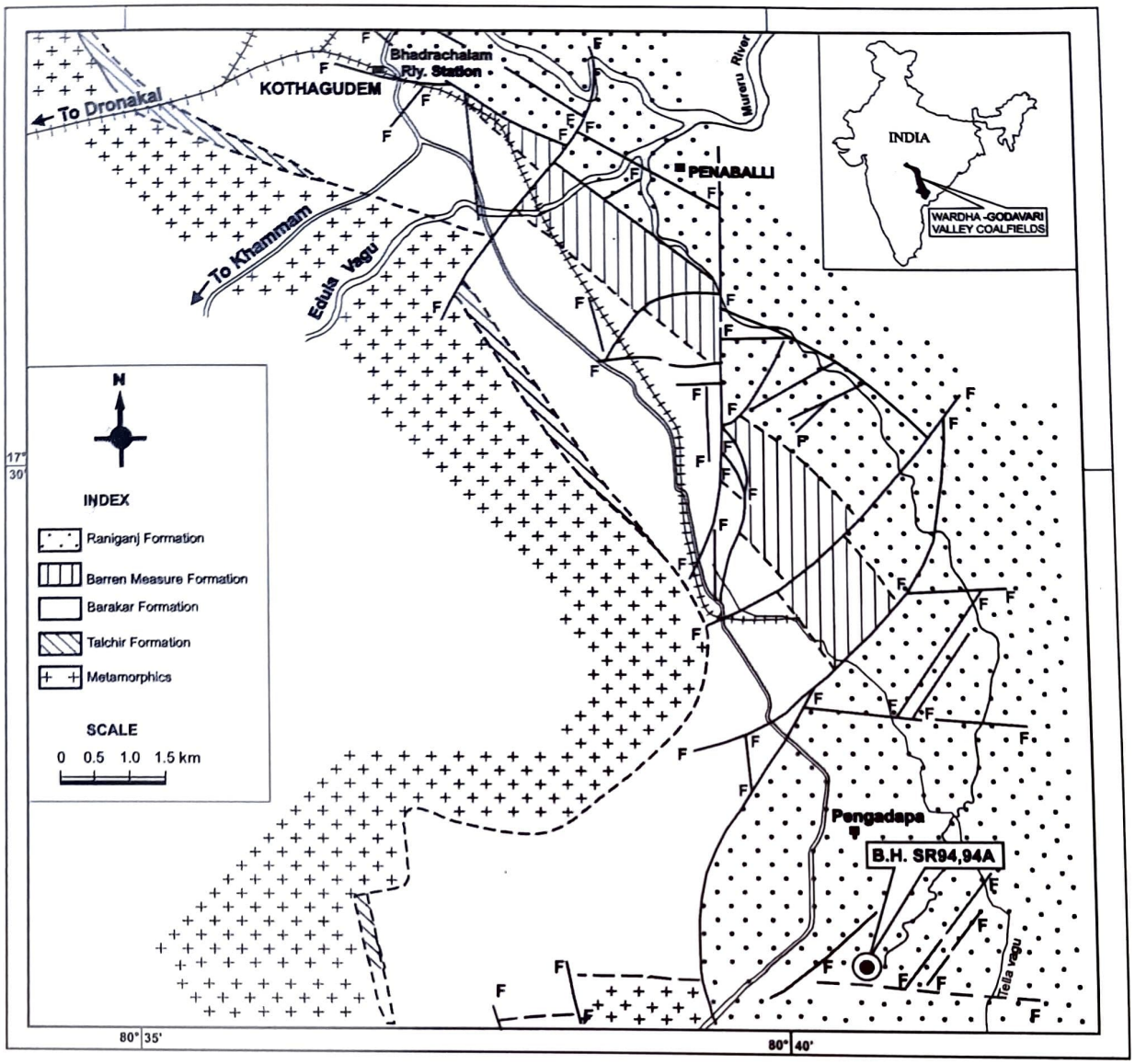
and extent of the sub-surface coal seams. This Shaft Block is named after Rampuram village and has aerial extent of about 9 km^2 (Lat. 17°24'45"N to 17°25'22"N and Long. 80°40'29"E to 80°42'20"E). The topmost I Seam of this bore-hole belongs to Kamthi Formatiom whereas the Queen and the King seams intersected in Bore-hole No. SR-94A are confined to Barakar Formation. The present petrographic study of the coal deposits from this Shaft Block will be useful in estimating their commercial prospective.

GENERAL GEOLOGY

Godavari basin demonstrates a rift valley configuration where the sediments were deposited successively in block faulted troughs. It displays NNW-SSE trend covering about 1700 km^2 area which is marked between north latitudes 16°38' and 19°32' and east longitudes 79°12' and 81°39' and spread in Adilabad, Karimnagar, Warangal and Khammam districts of Andhra Pradesh. The Godavari Valley displays more or less uninterrupted sediments of Permian to Cretaceous periods along with microfossils, biozones, faunal as well as the tectonic activities (Raja Rao 1982). The Gondwana sediments have been accumulated on the Archaen and Proterozoic basement. Talchir Formation represents the oldest stratigraphic unit of Gondwana succession in the Valley which is deposited in patches marked by deposition of tillites with thickness of more than 1 m., with overlying green shale and siltstone sequence. Recurrence of tillites along with overlying medium to coarse grained sandstones mixed with pebbles is frequently noticed. The margins of the basin are occupied by the Barakar Formation. The basal arenaceous member contains coarse grained sandstones along with lenses, conglomerates and no workable coal seams. The upper member has displayed repetition of cross-stratified sandstones, shale and coal seams with variation in thickness from place to place. The strata overlying the Barakar

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

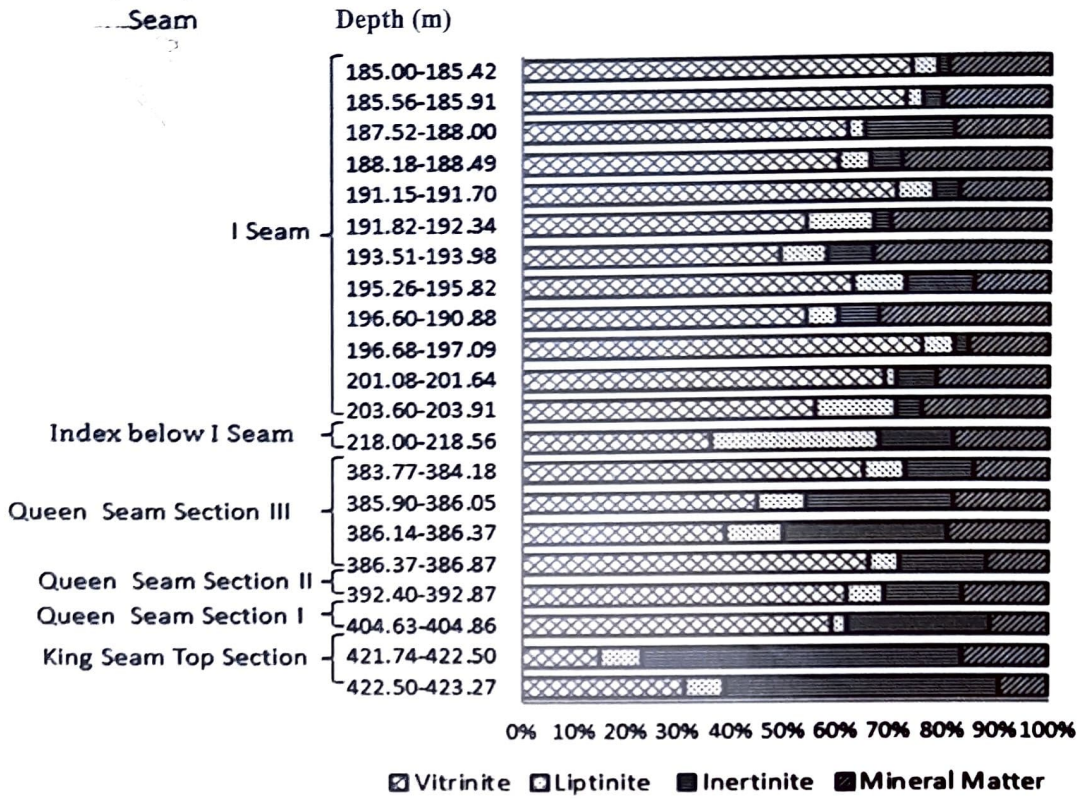
Age	Group	Formation	Maximum thickness (m)	Lithology
			500	Upper Member: Coarse grained, ferruginous sandstones with clay clasts and pebbles and subordinate violet cherty siltstones and pebble beds.
Late Permian to Early Triassic		Kamthi	600	Middle Member: Alternating sequence of medium grained white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



Text-figure 1. Geological map of the Kothagudem Sub-basin and location of bore holes SR94 and SR94-A (Courtesy, SCCL, Kothagudem).

Table 2. Lithological details of the coal seam succession intersected in Bore-hole No. SR94, Rampuram Shaft Block, Kothagudem Sub-basin, Godavari Valley Coalfield, Andhra Pradesh.

Sr. No.	Pellet No.	Depth (m)	Coal Seam	Lithology
1.	SR94-1	185.00-185.42	I Seam	Shaly Coal
2.	SR94-2	185.56-185.91	I Seam	Coal
3.	SR94-3	187.52-188.00	I Seam	Coal
4.	SR94-4	188.18-188.49	I Seam	Shaly Coal
5.	SR94-5	190.60-190.88	I Seam	Shaly Coal
6.	SR94-6	191.15-191.70	I Seam	Shaly Coal
7.	SR94-7	191.82-192.34	I Seam	Coal
8.	SR94-8	193.51-193.98	I Seam	Shaly Coal
9.	SR94-9	195.26-195.82	I Seam	Coal
10.	SR94-10	196.68-197.09	I Seam	Coal
11.	SR94-11	201.08-201.64	I Seam	Coal
12.	SR94-12	203.60-203.91	I Seam	Shaly Coal
13.	SR94-13	218.00-218.56	Index below I Seam	Coal



Text-figure 2. Maceral constitution of the coal seams intersected intersected in Bore-hole Nos. SR94 and SR94-A, from Rampuram area.

Formation is designated as Barren Measures Formation which includes medium to coarse grained, felspathic and ferruginous, cross bedded sandstones with greenish to grey-white colouration and occasional shale units. Kamthi Formation attains maximum thickness in the Valley. The lower member is represented by medium grained calcareous sandstones with greyish-white colour, while the middle and the upper members display existence of alternate sequences of ferruginous sandstone, brick red siltstone, greenish shales (occasional) and variegated clay units (Table 1). Ramanamurthy (1979) recorded existence of a persistent coal seam from Kamthi Formation of Ramagundam area.

MATERIAL AND METHODS

Both the bore-holes (SR94 and SR94A) were drilled very close to each other with a spacing of about 10 m (Lat. 17°26'41"N: Long. 80°41'11"E). Therefore, they are shown at the same place in Text-figure 1. These bore holes are located at a distance of about 12.5 km south-east of Kothagudem and 1.0 km east of Rampuram village (Text-figure 1). Complete sequence of the coal seams could not be collected from Bore hole No. SR94 because of its location in faulted zone. Only the samples representing the topmost I and underlying Index below I seams could be collected. The older coal seams were found missing from this bore-hole

Table 3. Lithological details of the coal seam succession intersected in Bore-hole No. SR94-A, Rampur Shaft Block, Kothagudem Sub-basin, Godavari Valley Coalfield, Andhra Pradesh.

Pellet No.	Coal Seam	Depth (m)	Lithology
SR94A-1	Queen Seam (Section III)	383.77-384.18	Shaly Coal
SR94A-2	Queen Seam (Section III)	385.90-386.05	Shaly Coal
SR94A-3	Queen Seam (Section III)	386.14-386.37	Shaly Coal
SR94A-4	Queen Seam (Section III)	386.37-386.87	Coal
SR94A-5	Queen Seam (Section II)	392.40-392.87	Coal
SR94A-6	Queen Seam (Section I)	404.63-404.86	Coal
SR94A-7	King Seam (Top Section)	421.74-422.50	Coal
SR 94A-8	King Seam (Top Section)	422.50-423.27	Coal

and therefore another Bore-hole SR94-A was drilled in closer vicinity. The samples of the King Seam (Top Section) and overlying Queen Seam have been collected from Bore-hole No. SR94-A. Queen Seam in this area has further been divided into three sections. The top, middle and bottom parts of the Queen Seam are referred as Sections I, II and III respectively. The coal seams in these bore-holes are intersected between 185.00 m and 423.27 m depths (Tables 2 and 3).

Different coal seam samples were crushed to get ±1-2 mm grain size particles. Adequate amount of the crushed material was transmitted into the plastic moulds already applied with a thin film of releasing agent. A mixture of releasing agent and hardener in the ratio 5:1 was added to the plastic moulds containing crushed material and mixed properly. The pellets were numbered to ascertain their identity. The mixture was allowed to settle for 10-12 hours at room temperature. The hardened pellets were removed from the plastic moulds and ground using different grades of carborundum powder in order to expose the coal particles to the surface. These pellets were then polished on silicon cloth successively using polishing alumina following the procedure laid down by the International Committee for Coal Petrology (1971, 1975, 1988) and Stach et al. (1982). The polished pellets were kept in desiccator containing crystals of $CuSO_4$ for 24 hours to make them moisture free before observation. The maceral and reflectance study has been carried out on Leica DM4500P

Table 4. Maceral constitution and reflectance (R_o mean %) analysis of the coal seams intersected in Bore-hole No SR-94, Rampuram Area, Kothagudem Sub-basin, Godavari Valley Coalfield, Andhra Pradesh (Values in the bracket indicate the m.m.f. (mineral matter free) percentage distribution.

Sr. No.	Coal Seam	Depth (m)	Pellet Nos.	Vitrinite vol. %	Liptinite vol. %	Inertinite vol. %	Mineral Matter vol. %	Reflectance (R_o mean %)
1	I Seam	185.00-185.42	SR94-1	74 (91)	5 (6)	2 (3)	19	0.51
2	I Seam	185.56-185.91	SR94-2	73 (91)	3 (4)	4 (5)	20	0.52
3	I Seam	187.52-188.00	SR94-3	62 (75)	3 (4)	17 (21)	18	0.52
4	I Seam	188.18-188.49	SR94-4	60 (84)	6 (8)	6 (8)	28	0.51
5	I Seam	196.60-190.88	SR94-5	54 (79)	6 (9)	8 (12)	32	0.51
6	I Seam	191.15-191.70	SR94-6	71 (86)	7 (8)	5 (6)	17	0.51
7	I Seam	191.82-192.34	SR94-7	54 (77)	13 (19)	3 (4)	30	0.52
8	I Seam	193.51-193.98	SR94-8	49 (74)	9 (13)	9 (13)	33	0.51
9	I Seam	195.26-195.82	SR94-9	63 (73)	10 (12)	13 (15)	14	0.51
10	I Seam	196.68-197.09	SR94-10	76 (89)	6 (7)	3 (4)	15	0.50
11	I Seam	201.08-201.64	SR94-11	69 (87)	2 (3)	8 (10)	21	0.51
12	I Seam	203.60-203.91	SR94-12	56 (74)	15 (20)	5 (06)	24	0.51
13	Index below I Seam	218.00-218.56	SR94-13	36 (44)	32 (39)	14 (17)	18	0.51

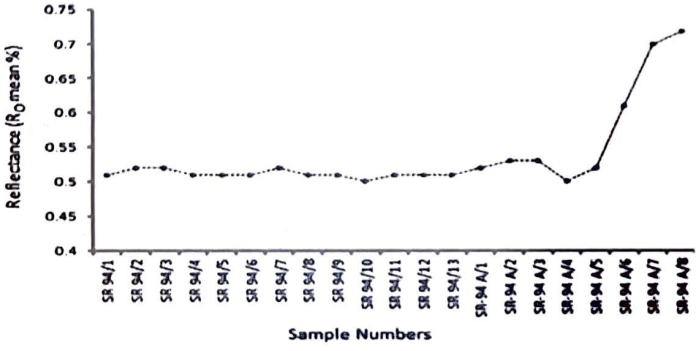
Table 5. Maceral constitution and reflectance (R_o mean %) analysis of the coal seams intersected in Bore-hole No SR-94A, Rampuram Area, Kothagudem Sub-basin, Godavari Valley Coalfield, Andhra Pradesh (Values in the bracket indicate the m.m.f. (mineral matter free) percentage distribution.

Sr. No.	Coal Seam	Depth (m)	Pellet Nos.	Vitrinite %	Liptinite %	Inertinite %	Mineral Matter %	Reflectance (R_o mean %)
1	Queen Seam Section III	383.77-384.18	SR 94A-1	65 (76)	8 (9)	13 (15)	14	0.52
2	Queen Seam Section III	385.90-386.05	SR 94A-2	45 (55)	9 (11)	28 (34)	18	0.53
3	Queen Seam Section III	386.14-386.37	SR 94A-3	39 (48)	11 (14)	31 (38)	19	0.53
4	Queen Seam Section III	386.37-386.87	SR 94A-4	68 (77)	3 (4)	17 (19)	12	0.50
5	Queen Seam Section II	392.40-392.87	SR 94A-5	62 (74)	7 (8)	15 (18)	16	0.52
6	Queen Seam Section I	404.63-404.86	SR 94A-6	59 (66)	3 (4)	27 (30)	11	0.61
7	King Seam Top Section	421.74-422.50	SR 94A-7	15 (18)	8 (10)	61 (72)	16	0.70
8	King Seam Top Section	422.50-423.27	SR 94A-8	31 (34)	8 (9)	52 (57)	9	0.72

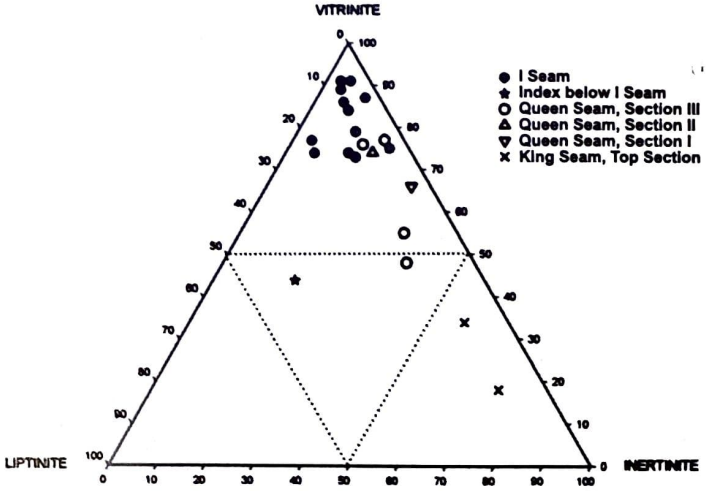
microscope. For random vitrinite reflectance (R_o mean %), Microscope photometery System (PMT III) and software MSP 200 have been used. However, the quantitative maceral estimation is done with the help of 2.35 version of the Petrolight software. Different types of macerals were photomicrographed through software tool Leica applications suit (LAS).

DESCRIPTION OF MACERALS

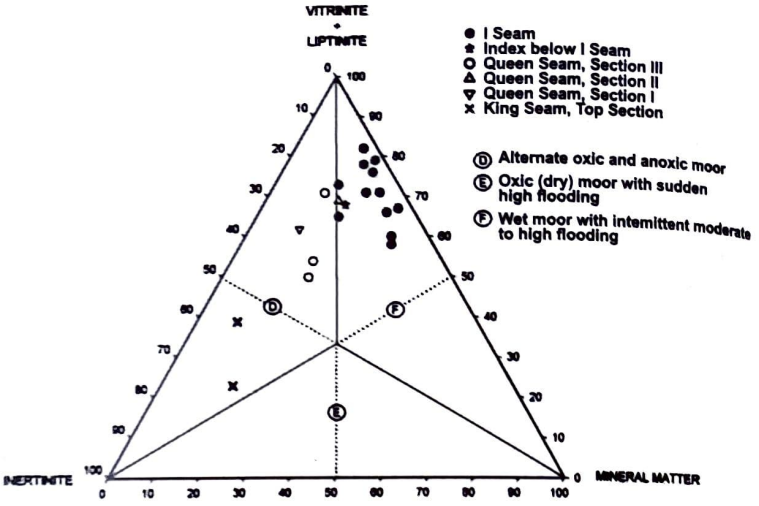
The sub-surface coal seam petrography from Rampuram area indicates that the King seam contains dominant association of inertinite group of macerals whereas, the Queen Seam, Index below I Seam and I Seam are characterized by the dominance of vitrinite maceral group. Liptinite maceral group, however, is poorly distributed.



Text-figure 3. Variation recorded in random vitrinite reflectance (R_o mean %) of the coal seams intersected in Bore-hole Nos. SR94 and SR94-A from Rampuram area.



Text-figure 4. Ternary diagram showing mineral matter free (m.m.f.) maceral constitution and coal types recognized from different coal seams intersected in Bore-hole Nos. SR94 and SR94-A from Rampuram area.



Text-figure 5. Facies diagram indicating the depositional environment for the coal seams intersected in Bore-hole Nos. SR94 and SR94-A from Rampuram area (Singh & Singh 1986).

All the coal macerals have shown invariable association with mineral matter. The details of the individual maceral groups are given below.

Vitrinite: The macerals of this group have abundance of collotelinite, illustrated by almost homogenized thick and thin bands of vitrinite having light grey to dark grey colour (Plate 1, figures 1, 2, 7) with ill-defined cellular preservation. Sometimes collotellinite have displayed dark grey to faint grey shades (Plate 1, figure 8). Vitrodetrinite is recorded as discrete, small isolated vitrinite fragments with variation in size and shape. Telinte with well preserved cellular organization has also been recorded in these coals, though its frequency is quite low. Corpogelinite occur as individual bodies, mostly as cell infillings. However, gelinite is commonly recorded from the cracks and fissures of the vitrinite, which at times trickles out as exudatinite (Plate 1, figures 3-4).

Liptinite: Sporinite is most common maceral of this group which is represented by both thin (tenuispores) and thick (crassispores) walled microspores (Stach 1964). However, the former are found in plenty and exist as thread like structures or appear in spindle form either linearly arranged or randomly distributed in the vitrinitic ground mass and display dark grey or blackish colour. Megaspores are larger in shape and display orange, yellow or brownish colour. Cutinites are

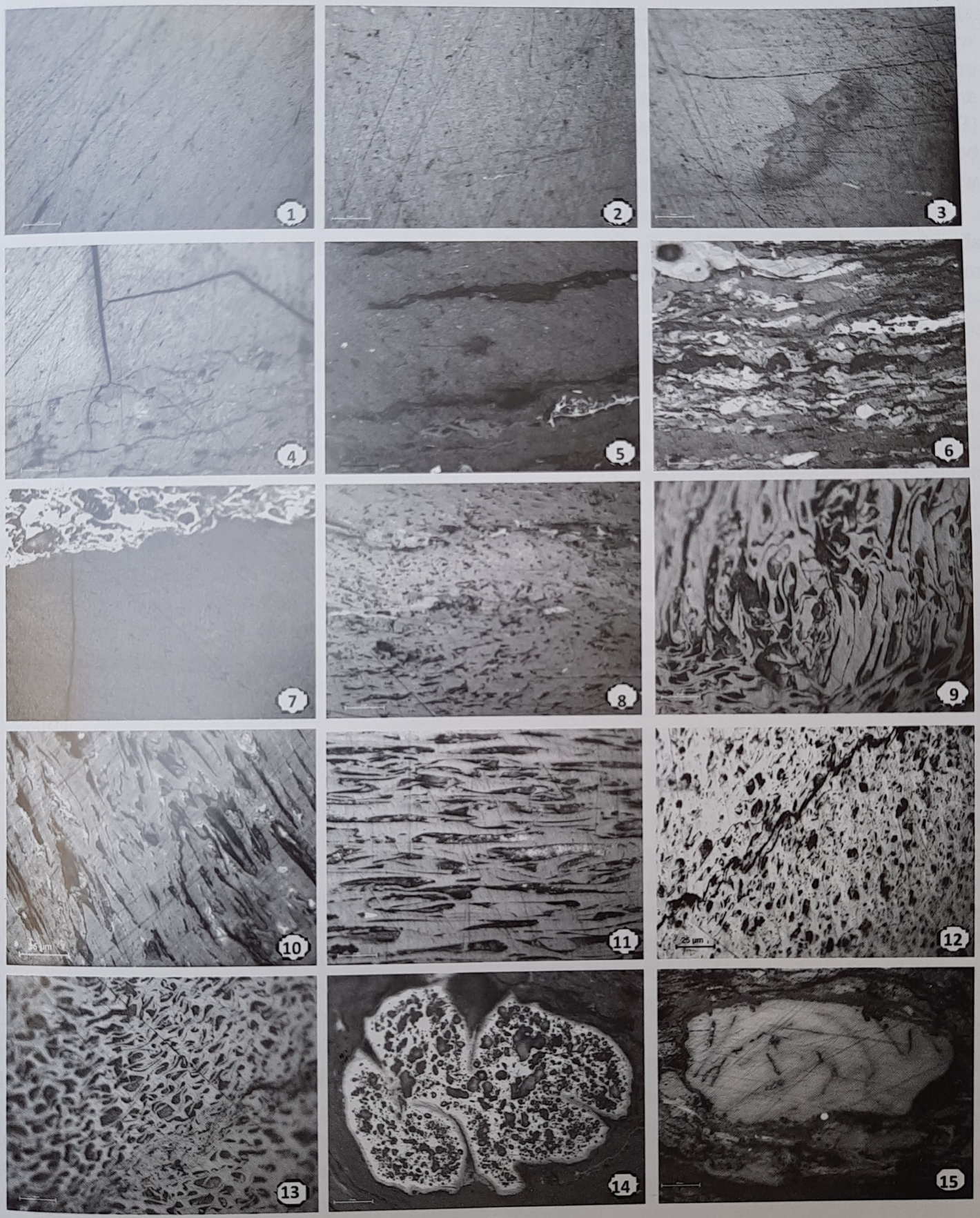


Plate 1

1-2, 7. Collotelenite. 3-4. Exudatinite. 5-6. Crassicutinite with cuticular ledges. 8. Collotelinite with rank variation. 9-13. Fusinite showing cellular compression and degradation. 14-15. Secretinite.

also recorded frequently in thin walled forms, with dark grey colouration. However, thick walled crassi-cutinites with prominent cuticular ledges and serrated margins are also randomly noticed (Plate 1, figures 5-6). Resins are noticed as isolated bodies with oval shape and also occur as infillings with dark grey or black colour.

Inertinite: The King Seam contains abundance of fusinite (Plate 1, figures 9-13) maceral, characterized by its highly reflecting white to yellowish colouration, well preserved cellular organization and a large degree of cellular compression as well as disintegration. It holds richest carbon contents of all the other coal macerals. Teichmüler (1950) divided fusinite into pyro-fusinite, having healthy cellular organization and yellow colouration and degrado-fusinite displaying white colour and bad cellular preservation. Fusinites are displaying bogen structures due to the disintegration of the cell lumens are also commonly found. Semi-fusinite is occasionally recorded as the transitional phase between vitrinite and fusinite. Secretinites (Plate 1, figures 14-15) are believed to be the oxidized derivative of resins and are recorded as isolated bodies as well as in groups, showing variability in their shape and size. Micrinites and macrinites are also recorded in these coals. The evidences of fungal bodies, i.e. funginite, are noticed as randomly distributed hyphae or mycelia with thick dark black colour. Unicellular and multicellular fungal spores are also frequently noticed in these coals. Similarly, sclerotia are mostly recorded from the inertinite fraction.

Mineral Matter: The middle part of the I Seam contains high proportion of mineral matter association. The minerals display granular appearance and black colour, and are found in abundance from the cracks, fissures or cavities. The most commonly noticed minerals are carbonate, clay and sulphide. Pyrite is mostly recorded as discrete grains and also as framboids, found associated with the vitrinite and inertinite groundmass.

MACERAL CONSTITUTION

I Seam: This is the youngest seam of Rampuram area which has shown vitrinite group of macerals in abundance (60-76 vol. %) barring a few samples where its frequency is comparatively lower (49-54 vol. %) but retain its dominance over the other maceral groups. Inertinite and liptinite are sparsely represented (2-10 vol. %), with occasional increase of 15-17 vol. % . Mineral matter association is recorded to be quite low (18-20 vol. %) in the upper part of the seam, which has been increased (28-30 vol. %) in the middle region and again declined (14-24 vol. %) towards the bottom, which indicates that middle part of the seam contains inferior quality coal as compared to the top and the bottom parts (Tables 4 and 5, Text-figure 2).

Index below I Seam: As observed in the overlying I Seam, the coal of this seam also contains dominance of vitrinite group of maceral (36 vol. %), but differs from the former in having sub-dominance of liptinite (32 vol. %). Inertinite is recorded to be 14 vol. %, besides quite low mineral matter association (18 vol. %), as compared to the I Seam.

Queen Seam (Section III): The top part of Queen Seam, referred as Section III, indicates overall vitrinite (39-68 vol. %) dominance with minimum representation (39 vol. %) in the middle part. Inertinite is recorded to be 13 vol. % in the upper part which increases to 28-31 vol. % in middle region and again declined (15-17 vol. %) at the bottom. Liptinite, however, has meagre representation (3-11 vol. %) along with significantly low mineral matter (12-19 vol. %) association.

Queen Seam (Section II): The middle part of the Queen Seam also shows dominance of vitrinite (62 vol. %) in association with inertinite and mineral matter (15-16 vol. %) and quite low representation of liptinite (7 vol. %) group of macerals.

Queen Seam (Section I): The basal part of the Queen Seam also displays similar maceral

configuration as observed in overlying II and III sections. Vitrinite has been recorded to be 59 vol. % along with inertinite (27 vol. %), mineral matter (11 vol. %) and very low liptinite (3%) contents.

Thus the entire Queen Seam shows dominance of vitrinite (39-68 vol. %) maceral group along with inertinite (15-31 vol. %) and liptinite (3-11 vol. %). Mineral matter in this seam is also recorded to be quite low (11-19%).

King Seam (Top Section): Coal of this Section has quite different maceral configuration than the overlying seams. It contains inertinite (52-61 vol. %) dominance which decreases towards bottom. However, vitrinite (15-31 vol. %) shows increasing trend towards the bottom part and scanty representation of liptinite (8%) group of macerals. Mineral matter association is recorded between 16% and 9%, with marked decreasing trend towards the bottom.

REFLECTANCE STUDY

The reflectance study shows that the coals of the topmost I and Index below I seams display random vitrinite reflectance (R_o mean %) ranging between 0.51% and 0.52%. Similarly, Sections III and II of Queen Seam have shown slight variation in vitrinite reflectance which ranges between 0.50% and 0.53%. However, the coal from Section I of the Queen Seam indicates higher vitrinte reflectance (0.61%). Thus, the coals of I Seam, Index below I Seam and the entire Queen Seam attained high volatile bituminous C stage of rank.

Similarly, the coal representing the top part of the King Seam has shown vitrinite reflectance variation between 0.70% and 0.72%. Therefore, the coal from this part of the seam attained high volatile bituminous B stage of rank (Text-figure 3).

The mineral matter free (m.m.f.) maceral study has revealed that the coals of I Seam and sections I and II of Queen Seam contain vitric (vitrinite rich) type of coal, however, the King Seam (Top Section) has fusic (inertinite rich) coal constitution. Index below I Seam contains mixed type of coal and Section III of the Queen Seam is characterized by both the vitric and mixed coal types (Text-figure 4).

The facies diagram (Text-figure 5) drawn for the entire subsurface coal seam sequence intersected in the two bore-holes (Bore-hole nos. SR94 and SR94-A) from Rampuram area has shown that Seam I and the Section II of the Queen Seam were deposited during the prevalence of wet moor with intermittent moderate to high flooding. However, sections I and II of the Queen Seam and top section of the King Seam have experienced alternate oxic and anoxic moor conditions (Singh & Singh 1996).

DISCUSSION AND CONCLUSIONS

Godavari Valley Coalfield structurally depicts the configuration of a rift valley (Qureshy et. al. 1968, Bhaskar Rao et al. 1971), which evolved between successively developed block faulted troughs. The active nature of these faults and continuous sinking of the basin made possible uninterrupted sedimentation in the Valley from Permian to Triassic. The gathering of coal forming resource (peat) in the basin appears to have been initiated with existence of dry and oxidizing conditions (King Seam), as evidenced by charred nature of maceral (inertinite). However, a gradual shift towards the cold and humid conditions has been depicted by the enrichment of vitrinite group of macerals recorded from the younger seams. King (1958) suggested that the Gondwana sediments were deposited in cold climate with seasonal change to alternate dry and oxidizing spells. Kräusel (1961), King (1961) and Plumstead (1961) also expressed similar views for the Gondwana deposits. The megafloral records from Gondwana deposits have also displayed striking morphological similarity with the flora presently growing in the sub-arctic regions (Chandra & Chandra 1987). Stach et al. (1982) pointed out that the similarity of the Gondwana megafossils with the flora existing today in the sub-arctic region is because of the fact that the Indian plate was also holding similar palaeo-latitudinal position (sub-arctic) and therefore, similar palaeo-environmental

conditions induced similar morphological features in floral elements that flourished during the Gondwana regime.

Thus, the coals of the King and Queen seams are of better quality than the topmost I Seam. It is also inferred that good quality coal horizones can be identified for selective commercial exploration from the I Seam.

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