

# Petrographic analysis and depositional environment of subsurface coal seams of Koyagudem area, Godavari Valley Coalfield, Telangana, India

OMPRAKASH S. SARATE

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.  
Email: ossarate@yahoo.co.in

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## ABSTRACT

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The study area marks the south-eastern extremity of the Mulug Coal Belt of Godavari Valley Coalfield, Telangana. The Bore-hole No. KYG-353, containing Index above Queen and Queen seams, is located in north-western direction from Kothagudem Town of Khammam District. The petrographic analysis has been done to ascertain their rank by random vitrinite reflectance ( $R_o$  mean %) measurements and quality estimation through maceral analysis, in order to interpret the environment of deposition as well as economic significance. The Index above Queen Seam has vitrinite group of maceral in dominance therefore, contains vitric type of coal whereas; the top and a band in the middle part of the Queen Seam contain coal which is fusic (inertinite rich) in nature. The bottom part of this seam has shown vitrinite in abundance indicating its vitric nature. The random vitrinite reflectance ( $R_o$  mean %) study has revealed that the coals of Index above Queen and the Queen seams have attained high volatile bituminous C stage of rank, except for a coal band located between 161.44 m and 162.44 m depth range, which has reached high volatile bituminous B rank. It is also inferred that the vegetal resource of Index above Queen Seam has been deposited during oxic and anoxic moor conditions; however, a distinct change in the climatic conditions to oxic moor with intermittent moderate to high flood situation occurred in the depositional phase of the Queen Seam. The study also suggests that coal deposits in this region have significantly high economic potentials.

**Key-words**—Petrography, Maceral, Reflectance, Depositional Environment, Gondwana sediments, Koyagudem, Godavari Valley, Telangana, India.

## कोयागुडेम क्षेत्र, गोदावरी घाटी कोयलाक्षेत्र, तेलंगाना, भारत में उप-पृष्ठीय कोयला संस्तरों का शैलविज्ञानसंबंधी विश्लेषण एवं निक्षेपणीय पर्यावरण

ओमप्रकाश एस. सराटे

### सारांश

अध्ययन क्षेत्र गोदावरी घाटी कोयलाक्षेत्र, तेलंगाना के मुलुग कोयला पट्टी का दक्षिण-पूर्वी छोर चिह्नित करता है। क्वीन के ऊपर एवं क्वीन संस्तरों सन्निहित सूचक, वेध-छिद्र संख्या के वाई जी-353, खम्मम जिले के कोटागुडेम कस्बे से उत्तर-पश्चिमी दिशा में स्थित है। निक्षेपण का पर्यावरण एवं आर्थिक महत्ता व्याख्या करने हेतु मैसेरल विश्लेषण के माध्यम से यादृच्छिक विट्रीनाइट परावर्तकता ( $R_o$  माध्य %) मापनों एवं गुणवत्ता आकलन से उनकी कोटि अभिनिश्चित करने के लिए शैलविज्ञानसंबंधी विश्लेषण किया गया है। क्वीन संस्तर उपरि सूचक बहुलता में मैसेरल का विट्रीनाइट समूह है अतैव, कोयले की विट्रिक टाइप सन्निहित है। जबकि, क्वीन संस्तर के शीर्ष और मध्य भाग में पट्टी कोयला सन्निहित है जो कि प्रकृति में फ्यूजिक (इनर्टीनाइट प्रचुर) है। इस संस्तर के निचले (अधो) भाग ने विट्रिक प्रकृति इंगित करते हुए बहुलता में विट्रीनाइट दर्शाया है। यादृच्छिक विट्रीनाइट परावर्तकता ( $R_o$  माध्य %) अध्ययन ने खुलासा किया है कि 161.44 मीटर एवं 162.44 मीटर गहराई के बीच स्थित कोयला पट्टी के अलावा, क्वीन उपरि एवं क्वीन संस्तरों सूचक के कोयलों में कोटि की उच्च सी प्रावस्था प्राप्त करती है, जो कि उच्च वोल्टीय बिटुमेनी बी कोटि तक पहुंच गई है। यह भी निष्कर्षित किया जाता है कि उपरि क्वीन संस्तर का वनस्पति स्रोत ऑक्सिक एवं अनॉक्सी मूर दशाओं के दरम्यान निक्षेपित हो गया है; फिर भी, क्वीन संस्तर की निक्षेपणीय प्रावस्था में आंतरायिक मध्यम से उच्च बाढ़ स्थिति सहित ऑक्सिक मूर को जलवायवी स्थितियों में विशेष परिवर्तन हुआ। यह अध्ययन सुझाता है कि इस अंचल में कोयला निक्षेपों में सार्थक रूप से उच्च आर्थिक संभावनाएं भी हैं।

**सूचक शब्द**—शैलवर्णना, मैसेरल, परावर्तकता, निक्षेपणीय पर्यावरण, गोंडवाना अवसाद, कोयागुडेम, गोदावरी घाटी, तेलंगाना, भारत।

## INTRODUCTION

THE recent sub-surface explorations in Koyagudem Sector have proved it to be a much geologically disturbed area as it has interventions by several faults, which have not only resulted in displacement but also have hampered the continuity of both the Index above Queen and the Queen seams of this area at several places. As a result of these agonies the coal seams in this sector are encountered at much shallower depths, which have considerably increased their chances of exploration through Open Cast Mining.

So far, not much is known regarding the petrographic constitution of both the Index above Queen and the Queen seams of this region. However, Sarate (1998) has done petrographic study of these coal seams encountered in a bore-

hole situated in the north-eastern extremity of Koyagudem Sector. The present work however provides additional information regarding the change, if any in coal composition of the Queen Seam, as we move towards the south-western direction of this sector.

## GENERAL GEOLOGY

Godavari Valley Coalfield is located in the southern peninsular region, spread in Adilabad, Karimnagar, Khammam, Warangal and West-Godavari districts of states Telangana and Andhra Pradesh. It has vast area coverage of approximately 17 000 km<sup>2</sup>, which displays strike length of about 350 km and width of nearly 50 km, marked between 16°38' and 19°32' latitudes and 79°12' and 81°39' longitudes. The geophysical

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.
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 E R	Barren Measures	500	Medium to coarse grained, greenish grey to greyish white felspathic sandstones with subordinate variegated clays and micaceous sandstones.
Later part of Early Permian	G O N D W A N A	Barakar	300	Upper Member: Coarse, white sandstones with subordinate shales and coal seams. Lower Member: Coarse-grained sandstones with lenses of conglomerates, subordinate shales/clays and a few thin bands of coal.
Early Permian	W A N A	Talchir	350	Fine-grained sandstones, splintery green clays/shales, chocolate coloured clays, pebble beds and tillite.
? Late Proterozoic		Sullavai	545	-----Unconformity----- Medium to coarse grained, white to brick red sandstones, at places quartzitic and mottled shales. -----Unconformity-----
Early 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 (after Raja Rao, 1982).

and gravity data provided by Qureshy *et al.* (1968), Bhaskar Rao *et al.* (1970) suggest that the Gondwana deposits of Pranhita–Godavari rift valley took place in a fault controlled NW–SE trending troughs. However, the Mulug Basin (i.e. the study area), has been originated because of the development of faults in the Archaean rock during Middle Proterozoic Era. The initial work regarding the geological features of the Godavari Valley Coalfield has been carried out by Blanford (1871a, b), Fox (1931) and King (1872a, b, 1873, 1877). Raja Rao (1982) provided the geological details of the Godavari Valley and also proposed division of the Godavari Valley Coalfield into four sub-basins, based upon the tectonic configuration and lithic fill parameters, namely (1) Godavari sub-basin (2) Kothagudem sub-basin (3) Chintalapudi sub-basin and (4) Krishna Godavari coastal sub-basin (Table 1). Prachiti *et al.* (2011) however, have carried out geochemical and petrographic study of the coal and shaly horizons of the Sattupalli area of the Godavari Valley and inferred that the basin has been developed due to the marked downwarping of the basal floor. Similarly, Lakshminarayana (1995a, b) has dealt with the stratigraphic studies of the Valley with special reference to the Chintalapudi sub-basin. Similarly, Mishra *et al.* (1987) have provided the geophysical details of the Godavari Valley coalfields. The Gondwana sediments of the Godavari Valley in the study area have been laid down on the Archaean and Pakhal basement and attained a maximum

thickness of about 1100 m. Talchir Formation represents the basal most member of the Gondwana succession in this area, which displays the predominance of shale facies with several interventions of the thin limestone bands. The succeeding sequence is of Barakar Formation containing sandstones with disruption of thin shale and siltstone partings. The coal seam deposited in this Formation is known as “Queen Seam” which exists at a very shallow depth and its overlying seam is designated as Index above Queen Seam. The overlying formations are known as Barren Measures Formation and Kamthi Formation respectively, the former has occasional thin shale or coal bands and the later contains several shale and coal bands. The area has also shown the existence of several faulted zones.

Koyagudem Sector represents the south–eastern continuity of the Mulug Coal belt located in the central part of the Godavari Basin. A detailed geological information of the Koyagudem Sector has been provided by Sarolkar & Sabale (1990) and Bhattacharjee & Sabale (1990).

## MATERIAL AND METHODOLOGY

The samples of both the Queen and Index above Queen Seam for the petrographic investigations have been collected from a Bore-hole No. KYG-353 drilled at the distance of approximately 8–9 km north–west of the Koyagudem Village

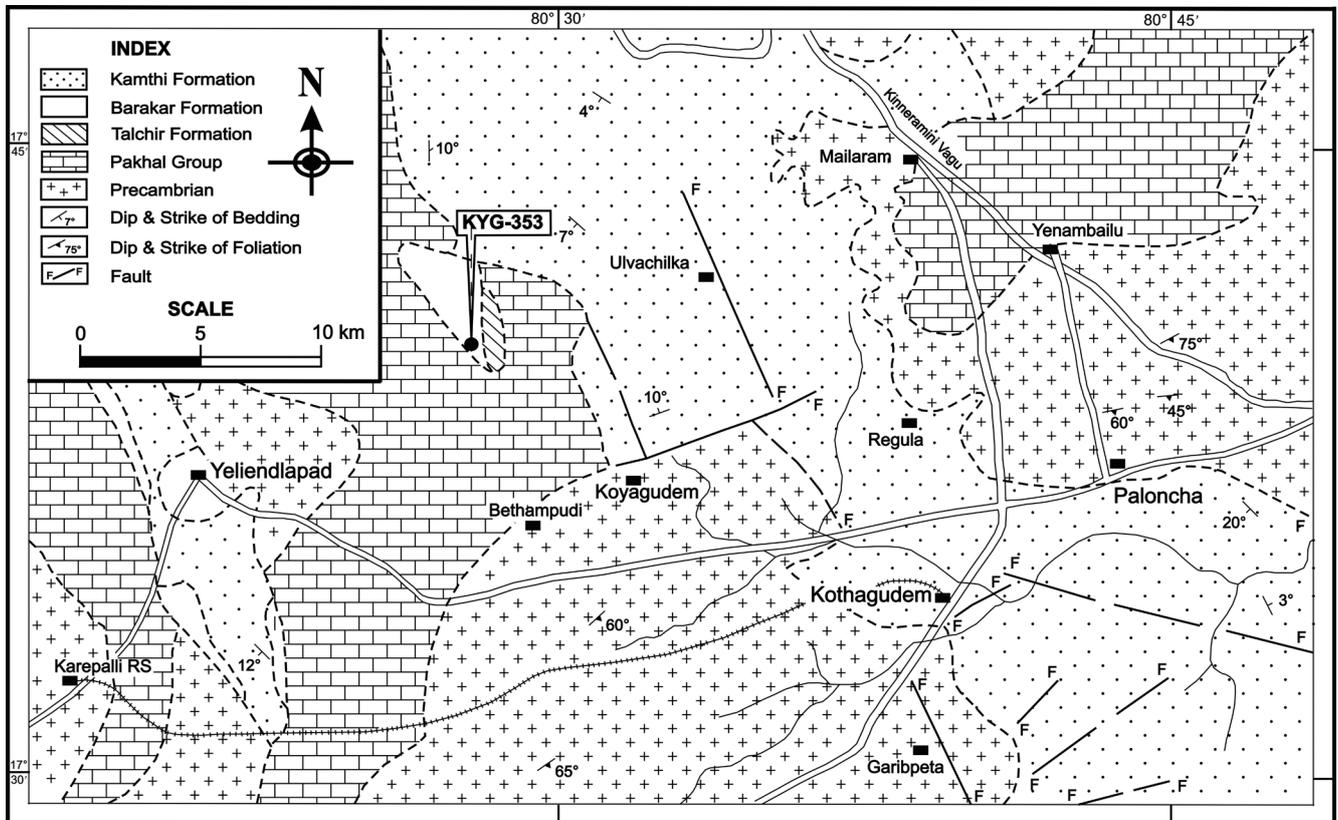


Fig. 1—Geological map showing location of Bore-hole No. KYG-353.

Table 2—Details of samples collected from Bore-hole No. KYG-353 in Koyagudem area, Godavari Valley Coalfield, Telangana.

Sr. No.	Pellet No.	Depth (in meter)	Coal Seam	Lithology
1.	KYG 353/1	105.53–106.07	Index above Queen Seam	Shaly Coal
2.	KYG 353/2	153.10–153.51	Queen Seam	Shaly Coal
3.	KYG 353/3	157.38–157.67	Queen Seam	Shaly Coal
4.	KYG 353/4	158.04–158.30	Queen Seam	Shaly Coal
5.	KYG 353/5	159.32–159.55	Queen Seam	Shaly Coal
6.	KYG 353/6	160.94–161.44	Queen Seam	Shaly Coal
7.	KYG 353/7	161.44–161.94	Queen Seam	Shaly Coal
8.	KYG 353/8	161.94–162.44	Queen Seam	Shaly Coal
9.	KYG 353/9	162.44–163.00	Queen Seam	Shaly Coal
10.	KYG 353/10	163.00–163.90	Queen Seam	Shaly Coal
11.	KYG 353/11	164.22–164.92	Queen Seam	Shaly Coal
12.	KYG 353/12	165.12–165.54	Queen Seam	Shaly Coal
13.	KYG 353/13	166.00–166.75	Queen Seam	Shaly Coal
14.	KYG 353/14	179.93–180.46	Queen Seam	Shaly Coal
15.	KYG 353/15	185.15–185.50	Queen Seam	Shaly Coal

of Bhadrachalam Tehsil, Khammam District, by authorities of the Singareni Collieries Company limited, Kothagudem. This bore-hole has intersected through a patch of Barakar Formation exposure, which is surrounded by the sediments of Pakhal Formation along with a small Talchir exposure located on the eastern side of this Barakar Formation (Fig. 1, Table 2).

About 15–10 gm of the each crushed (to 1-mm size) representative coal seam sample was taken into the plastic mould and properly mixed with solution of hardener and resin (in 1:5 ratio) for pellet preparation. Similarly, the methodology and the coal petrographic parameters for reflectance and maceral study have been followed as recommended by ICCP (1971, 1975, 1998, 2001), Taylor *et al.* (1998) and Stach *et al.* (1982). The equipment Leica DM 4500P has been used for coal petrographic study. The reflectance measurements have been done on Microscope photometry System (PMT III) along with Software MSP 200, whereas, 2.35 version of Petroglite Software is used during the Quantitative maceral analysis. The microphotographs of the macerals have been taken through software Leica Application Suit (LAS).

## DESCRIPTION OF MACERALS

Coal is considered to be the most complex heterogeneous rock which underwent several bio-chemical, geological and geothermal alterations and is constituted by a group of entities designated as coal macerals, which are considered as dehydrogenated plant fragments found in abundance along with lesser amount of inorganic substances (i.e. mineral matter). The three basic group of macerals recorded from the coals under investigation are the vitrinite, which has its origin from the woody precursors. Liptinite maceral group is derived from resinous waxy plant parts, e.g. spores, pollens and cuticles, etc. Inertinite however, represents the charred plant tissues, which have undergone biochemical alterations.

*Vitrinite*—The coal deposits of the study area have shown dominant association of the vitrinite group of macerals which are recognized mostly in the form of thick bands of collotelinite and display light or dark grey colouration. Telinite, however has sporadic existence the cell walls containing dark grey colour and has lower reflectance than the collotelinite (Pl. 1.1, 2). The cell lumens and the cracks and

## PLATE 1

- |       |   |        |   |
|-------|---|--------|---|
| 1, 2. | Collotelinite                                       | 8.     | Gelinite under Fluorescence mode  |
| 3.    | Transition from telinite to collotelinite           | 9.     | Crassi-cutinite displaying cuticular ledges                               |
| 4.    | Gelinite expulsion (transmitted light)              | 10.    | Sporinite dispersed in the collotelinite band                             |
| 5.    | Gelinite under Fluorescence mode                    | 11–14. | Fusinite showing varied degree of cellular compression and disintegration |
| 6.    | Collotelinite showing tendency towards semifusinite | 15.    | Secretinite.  |
| 7.    | Gelinite expulsion (transmitted light)              |        |   |



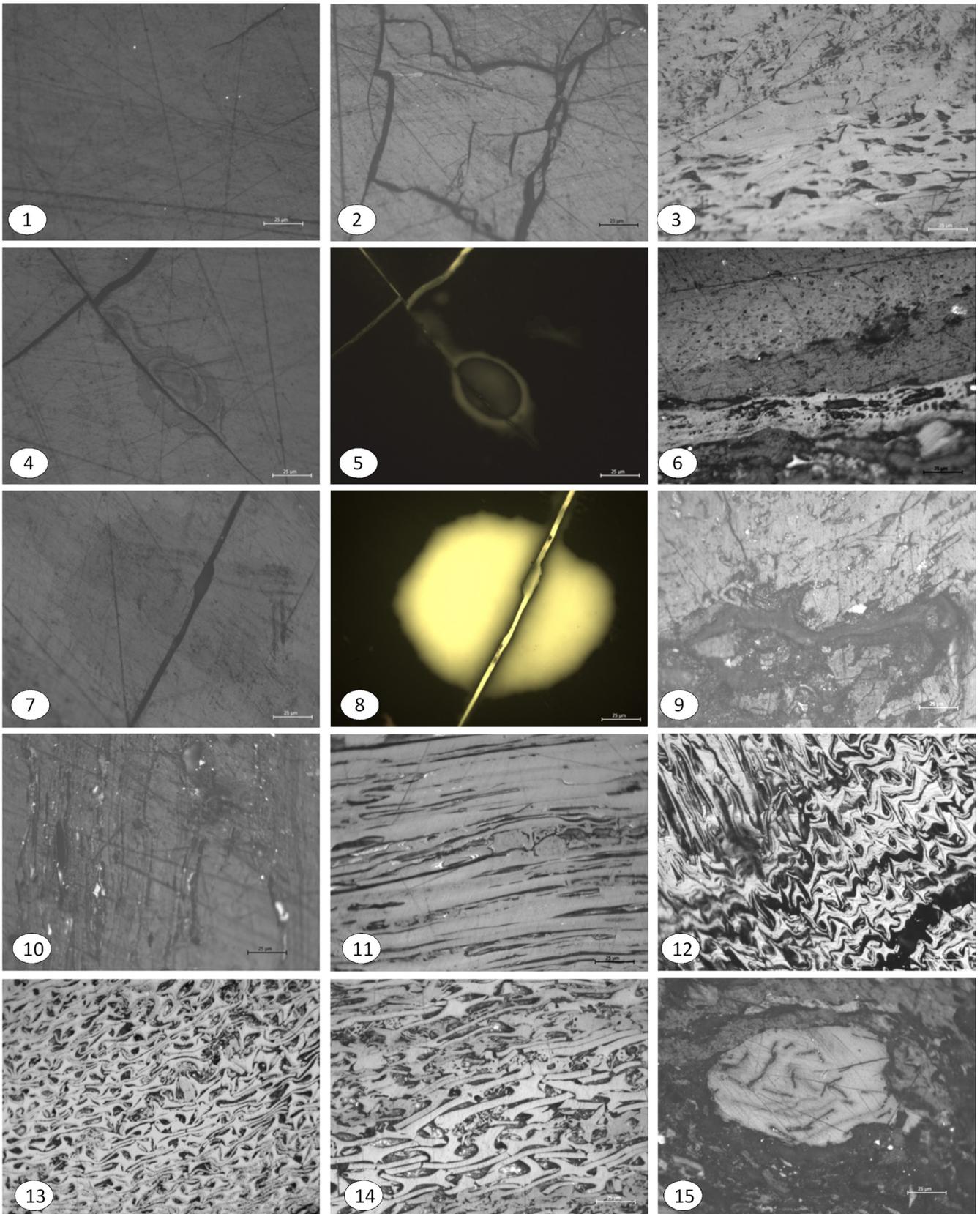


PLATE 1

the fissures in general are filled either by resinites or gelinite. Transitional stages from telinite to collotelinite (Pl. 1.3) and then form collotelinite to semifusinite (Pl. 1.6) are also occasionally noticed. Cracks in the collotelinites have also shown expulsion of gelinite which has shown fluorescence property (Pl. 1.4, 5, 7, 8). Oval or spheroid isolated as well as clusters of corpogelinite have also been recorded in some of the samples. Inclusion of liptinite macerals are also frequently noticed in the collotelinite bands, whereas, their cracks and fissures has been filled by mineral matter.

*Liptinite*—Sporinite mainly includes the microspores, which are most profusely recognized in these coals and are observed as linearly arranged rows of thin walled tenuisporites (Pl. 1.10) and the thick walled crassisporites, displaying spindle like appearance and dark grey or black colouration. Crassisporites have comparatively lesser frequency distribution than the tenuisporites and mostly they are randomly distributed. Mostly the microspores are seen associated with the vitrinitic ground mass however, they are also frequently recognized from the inertinite fractions also. Large sized and dark grey coloured megasporites with beautiful ornamentation patterns are also recorded in these coals. Cuticles with serrated margins (Pl. 1.9) are also frequently noticed. Thin walled tenuicutinites are abundantly found whereas, the thick walled crassicutinites are occasionally witnessed. Similarly, isolated as well as groups of resin bodies with large variation in shape and

size have sporadic representation. Secondary liptinites have also been recorded as bituminites and exudatinite, generally they are found associated with the cracks and fissures of the vitrinite.

*Inertinite*—This maceral group contains predominance of yellow coloured pyrofusinites with well documented cellular organization and white coloured degradofusinite with less preserved cellular structures than pyrofusinites and their reflectance is also comparatively lower. The Fusinites display a wide range of cellular degradation and deformation (Pl. 1.11, 12, 14) due to the compression which at times is displayed in the form of bogen structure (Pl. 1.13). Their intercellular spaces are generally filled with the mineral matter. Semifusinite demonstrates the intermediate stage between fusinite and telinite, with ill-preserved cells and white or dark grey colouration, their reflectance is also comparatively lower than the fusinite but higher than vitrinite. Micrinites in these coals are recorded as highly reflecting non-granular isolated spherical contours. Inertodetrinite is also recorded in quite high proportion and exists as fragments which are mainly form derived either from fusinite, semifusinite or macrinites macerals, but have lost their identity in the present form, they are generally found associated with the vitrinite and liptinite group of macerals. Transformation vitrinite to fusinite via semifusinite in the same band is also occasionally noticed. Funginite mainly includes fungal spores in different

Table 3—The maceral constitution and reflectance ( $R_0$  mean %) analysis of the coal seams intersected in Bore-hole No. KYG-353, Koyagudem area, Godavari Valley Coalfield, Telangana.

Sr. No.	Pellet No.	Depth (in meter)	Name of Coal Seam	Vitrinite %	Liptinite %	Inertinite %	Mineral Matter %	Reflectance ( $R_0$ mean %)
1.	KYG 353-1	105.53-106.07	Index above Queen Seam	34 (47)	12 (16)	27 (37)	27	0.62
2.	KYG 353-2	153.10-153.51	Queen Seam	34 (39)	15 (17)	38 (44)	13	0.52
3.	KYG 353-3	157.38-157.67	Queen Seam	27 (30)	10 (11)	52 (59)	11	0.64
4.	KYG 353-4	158.04-158.30	Queen Seam	10 (11)	18 (21)	60 (68)	12	0.72
5.	KYG 353-5	159.32-159.55	Queen Seam	3 (3)	23 (25)	66 (72)	8	0.57
6.	KYG 353-6	160.94-161.44	Queen Seam	—	7 (8)	77 (92)	16	—
7.	KYG 353-7	161.44-161.94	Queen Seam	21 (26)	11 (13)	50 (61)	18	0.72
8.	KYG 353-8	161.94-162.44	Queen Seam	16 (19)	13 (15)	57 (66)	14	0.72
9.	KYG 353-9	162.44-163.00	Queen Seam	21 (25)	15 (17)	50 (58)	14	0.61
10.	KYG 353-10	163.00-163.90	Queen Seam	45 (51)	10 (11)	34 (38)	11	0.63
11.	KYG 353-11	164.22-164.92	Queen Seam	28 (34)	20 (24)	35 (42)	17	0.60
12.	KYG 353-12	165.12-165.54	Queen Seam	52 (60)	9 (10)	26 (30)	13	0.63
13.	KYG 353-13	166.00-166.75	Queen Seam	59 (78)	10 (13)	7 (9)	24	0.49
14.	KYG 353-14	179.93-180.46	Queen Seam	40 (48)	23 (27)	21 (25)	16	0.54
15.	KYG 353-15	185.15-185.50	Queen Seam	40 (49)	15 (18)	27 (33)	18	0.48

Note: The values mentioned in the bracket indicate the mineral matter free (m.m.f.) %.

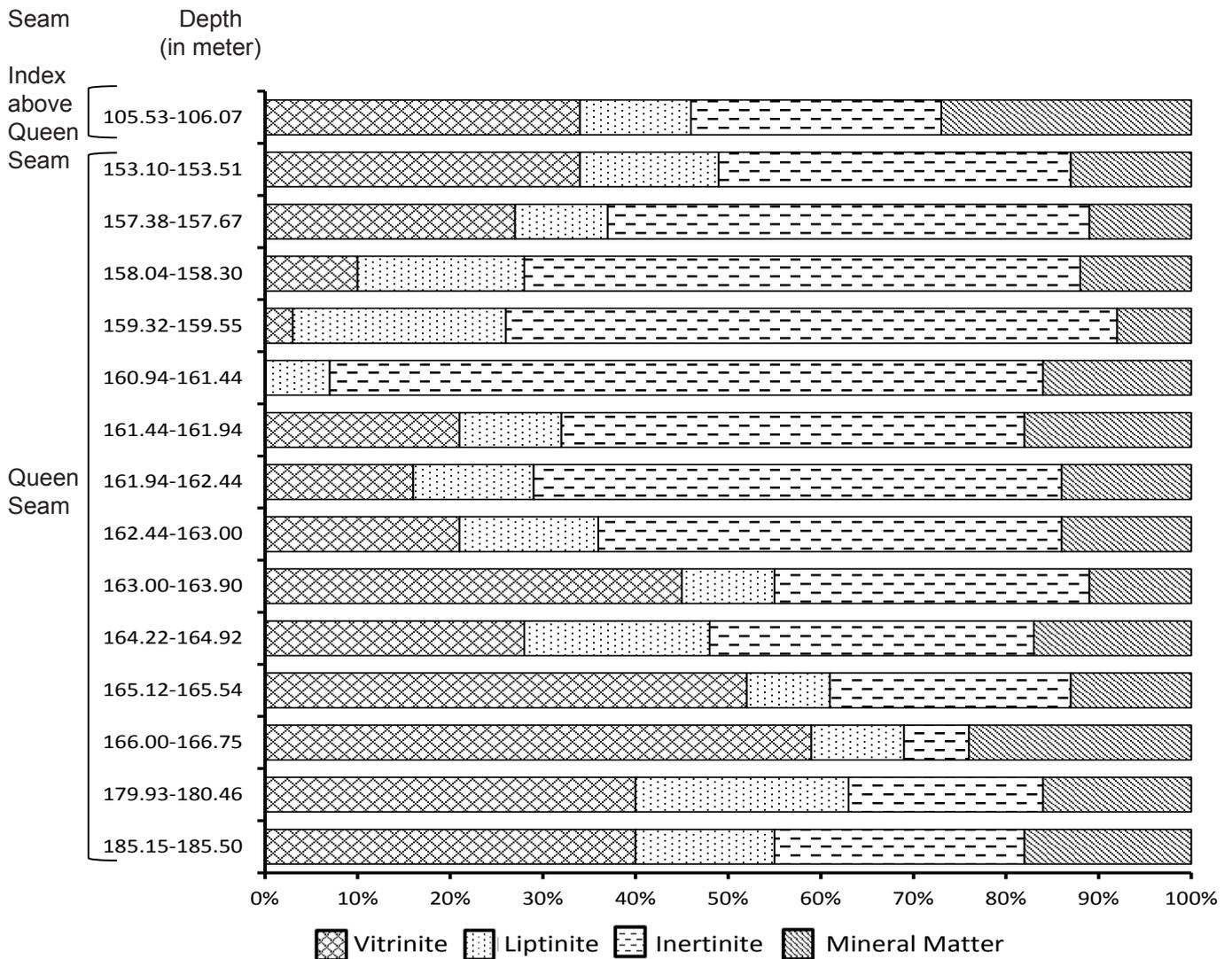


Fig. 2—Maceral constitution of the coal seams intersected in Bore-hole No. KYG-353.

forms, fungal mycelia as well as hyphae. Fungo-sclerotinites are also found associated with fusinite and inertodetrinite fractions. Similarly, randomly distributed secretinite (Pl. 1.15) is observed in the form of more or less ovoid, spherical or elongated bodies, considered to be the oxidized resinous material and show wide range of variation in their shape and size.

*Mineral Matter*—It is commonly recognized by grey colouration and granular appearance and found associated with vitrinite and inertinite group of macerals. The most commonly noticed minerals in these coals are clay, carbonate and sulphide. Mostly they are found embedded in the cracks, fissures of vitrinite and cell lumens and intercellular spaces of the inertinite group of macerals. Pyrite has generally been found as highly reflecting and randomly distributed spherical entities as well as in the form of framboids.

## MACERAL CONSTITUTION

*Index above Queen Seam*—This seam is characterized by the predominant association vitrinite (34 vol. %) group of macerals. Telovitrinite subgroup has been most frequently noticed, as compared to the detrovitrinite or gelovitrinite, thus displaying vitric nature of the coal. The sub-dominance is occupied by inertinite (27 vol. %) macerals with almost equal frequency distribution of the pyro and the degrado types, besides, comparatively meagre representation of simifusinite. Similarly, the transitional stages from vitrinite to semifusinite were also observed during the study. Liptinite (12 vol. per cent) macerals chiefly includes linearly arranged as well as randomly distributed thin walled microsporinites in abundance with occasional presence thick walled spores. Cutinites with smooth and serrated margins, megaspores, sporangial remains

and resins are also seen. The coal of this seam contains quite high mineral matter (27 vol. %) association.

*Queen Seam*—This seam has been encountered between 153.10 m and 185.50 m depth range. The top and the middle sections of the seam contain inertinite group macerals in abundance (38 to 77 vol. %), which in general has shown an increasing trend of frequency distribution with the increased depth. Vitrinite has occupied sub-dominance with percentage variation between 16 to 34 vol. per cent. However, considerable drop in the vitrinite (10 to 3 vol. %) association is observed in the coal band lying just below the top part of this seam. Mineral matter association in this seam has been recorded between 8 vol. % and 18 vol. per cent.

The part of the seam marked between 163.00 m and 185.50 m depth range has shown distinctly different constitution than the overlying coal succession, as it contains vitrinite as the dominant maceral group (40–59 vol. %), with an intimate association of inertinite (21–35 vol. %) and liptinite (9 vol. % and 23 vol. %). Mineral matter association in this region ranges from 11 to 24 vol. per cent. The continuity of vitrinite rich coal sequence in the interim (i.e. between 164.22 m and 184.92 m depth range) is seen interrupted by the intervention of a coal band which has shown inertinite

(35 vol. %) group of macerals in abundance followed by vitrinite (28 vol. %) and liptinite 20 vol. percent. Mineral matter association in this coal band is recorded to be 17 vol. per cent (Table 3, Fig. 2).

### REFLECTANCE ANALYSIS

*Index above Queen Seam*—The random vitrinite reflectance ( $R_o$  mean %) in this seam has been recorded to be 0.62 %, which indicates the attainment of high volatile bituminous C stage of rank (Fig. 4).

*Queen Seam*—A quite high degree of variation in the vitrinite reflectance has been recorded in this seam. In general, the vitrinite reflectance ( $R_o$  mean %) value ranges between 0.48% and 0.64%, this shows that this coal seam has reached high volatile bituminous C rank, as recorded in the overlying Index above Queen Seam except for the coal sequence laid down between the depth range of 158.04 m to 158.30 m and 161.44 to 162.44 m respectively, which has shown comparatively higher vitrinite reflectance ( $R_o$  mean %) of 0.72%, this suggests that the coal in these regions has reached high volatile bituminous B stage (Fig. 4).

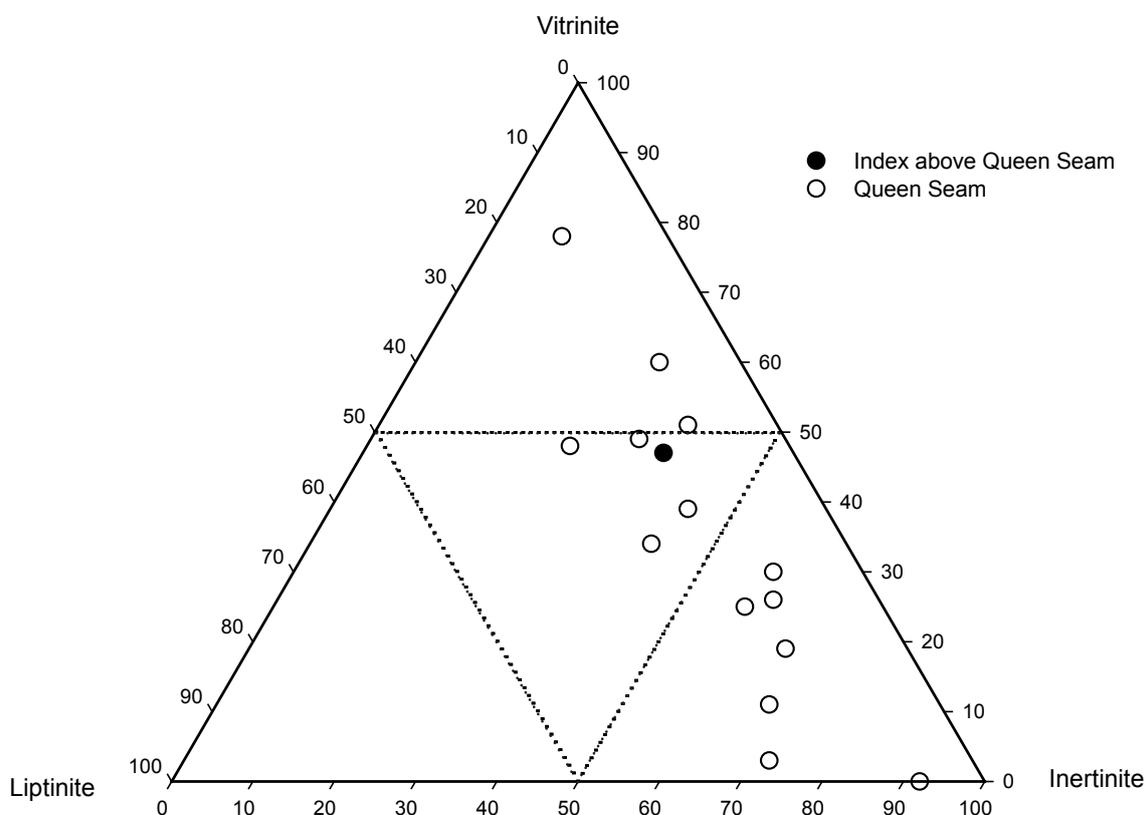


Fig. 3— Ternary diagram showing mineral matter free (m.m.f.) maceral constitution of the coal seams intersected in Bore-hole No. KYG-353.

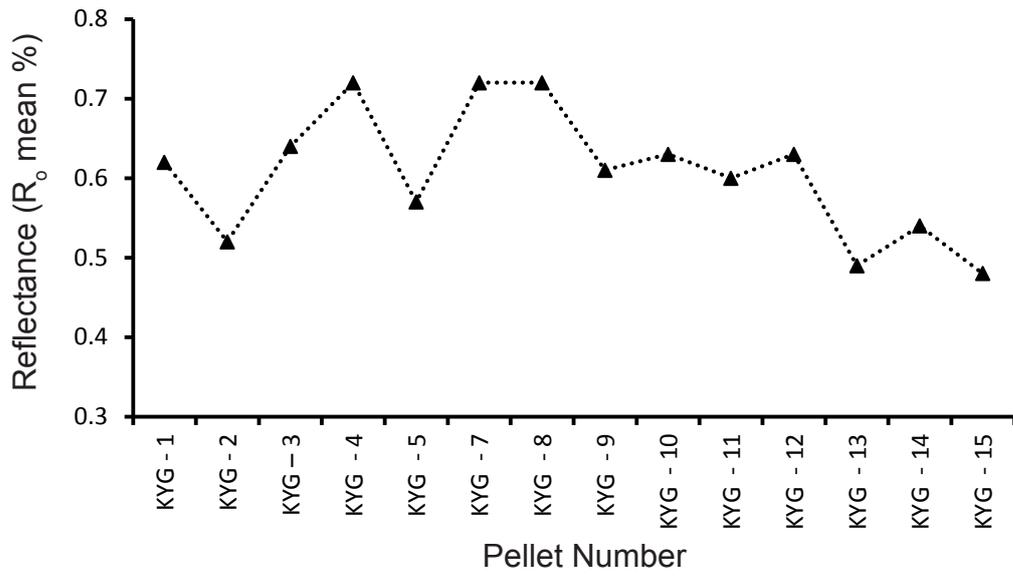


Fig. 4—Reflectance (R<sub>0</sub> mean %) analysis of the coal seams intersected in Bore-hole No. KYG-353.

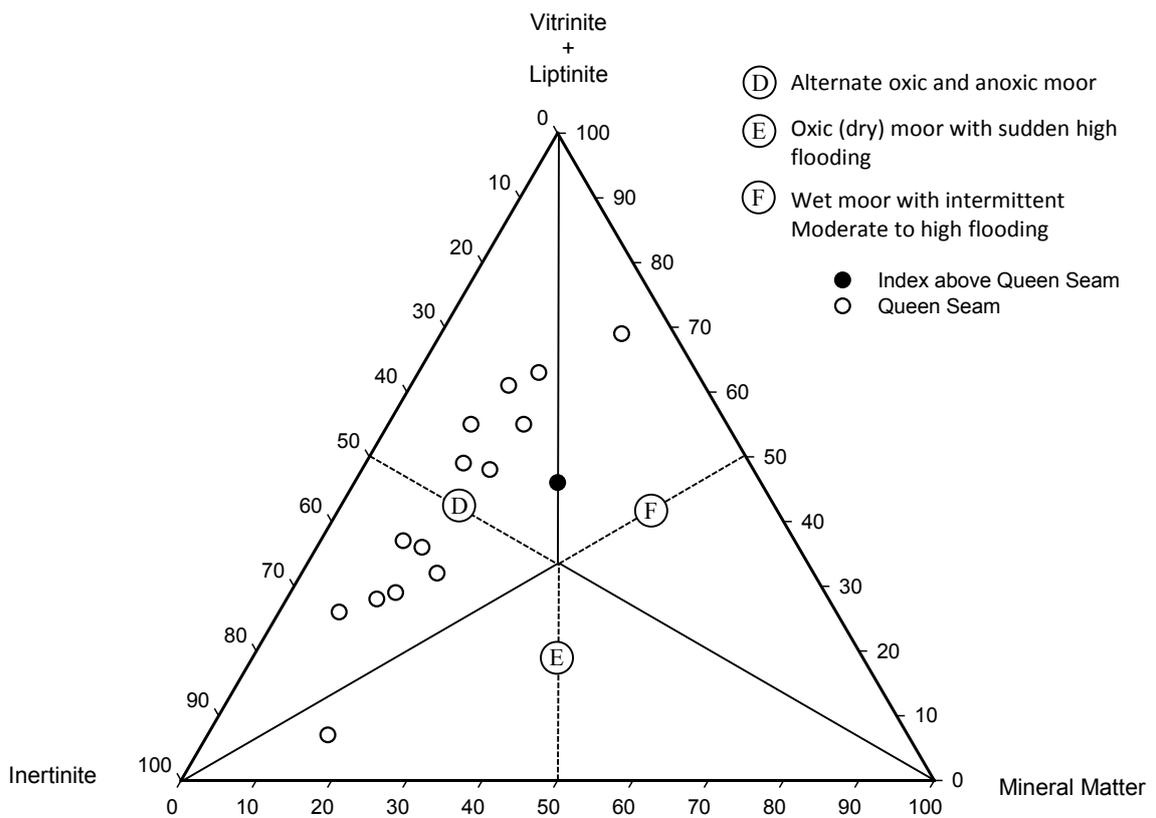


Fig. 5—Facies model showing depositional conditions of the coal seams intersected in Bore-hole No. KYG-353 (after Singh & Singh, 1996).

The mineral matter free (m.m.f.) ternary maceral plotting (Fig. 3) has indicated that the coals of Index above Queen Seam can be classified under mixed coal type whereas, the coal of the Queen Seam is characterized by the presence of vitric (vitrinite rich), fusic (inertinite rich) as well as the mixed coal types.

The facies diagram (Fig. 5) based upon the maceral and mineral matter contents, Singh and Singh (1996) has been plotted to ascertain the depositional scenario of the Index above Queen and Queen Seams, suggests that both these seams have experienced oxic and anoxic condition as the dominant phase. However, Queen Seam experienced change in the depositional conditions to oxic (dry) moor with sudden high flooding and wet moor with intermittent moderate to high flooding for a very short period.

## DISCUSSION AND CONCLUSIONS

The existence of vitrinite rich constitution recorded from the basal part of the Queen Seam of the study area evoke that the coal forming woody material has reached the basin of deposition during prevalence of cold and humid climatic conditions. However, when the Middle and the Lower parts of the Queen Seam were being deposited, the climate became warm and oxidizing conditions were predominant, as indicated by the existence of inertinite rich constitution of these coal deposits. Again the climate changed to cold and humid conditions during the depositional stage of the uppermost Index above Queen Seam in the study area.

Sarate (1998) studied the coals of Index above Queen and the Queen seams from north-eastern side where the coal seams are encountered at much shallower depths than those intersected in the study area and also contain the coal having reached C, B and Medium volatile bituminous stage of rank the and therefore have comparatively more economical feasibility.

During the Gondwana regime there existed two seasons, Krausel (1961), Plumstead (1961). Cold climate, King (1958) prevailed initially which gradually changed to warm temperate conditions, King (1961).

The palaeogeographic location of the Gondwanaland during the Permian Period was near by the subarctic regions, Stach *et al.* (1982) and there also exists similarity in the morphological characteristics displayed by the flora that prevailed during the Gondwana regime (Glossopteris flora) Chandra and Chandra (1986) and the flora that presently prospers in the sub arctic regions, the present petrographic study also supports climatic inferences drawn by the earlier researchers.

It is also inferred that the Index above Queen seam has been deposited during which the cold climatic conditions prevailed as indicated by the predominance of vitrinite group of macerals in the coal seam. Whereas, the climatic fluctuations from cold to dry and oxidizing phases, have

induced the genesis of vitric, fusic and the mixed coal types during the deposition of the Queen seam.

The coal from both the Queen and Index above Queen Seam has quite high economical potentials because of its vitrinite and inertinite rich constitution, significant maturity and having low mineral matter association.

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