Biopetrological study of Koyagudem coals, Godavari Basin, Andhra Pradesh, India

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The present study is aimed to record a detailed petrological information on the organic constitution of the Queen Seam from Koyagudem Sector of Godavari Basin. The coals are characterized by vitric and mixed (fuso-vitric & vitro-fusic) coal types. Clarite, duroclarite, inertite and durite are the main microlithotypes in the seam. An abrupt increase in the rank of the coals in the bottom part of the seam is probably due to the series of faults and subsequent tectonic events which occurred in the area. It is inferred that the coal forming vegetal matter flourished under relatively cold climatic conditions and witnessed two climatic regimes. The first having plenty of water available in the basin with enhanced vitrinization (Vitrinite-rich) and the second characterized by drier spells causing partial surface oxidation (Inertinite-rich) of the peat.

Key-words— Biopetrology, Coal, Koyagudem, Permian.

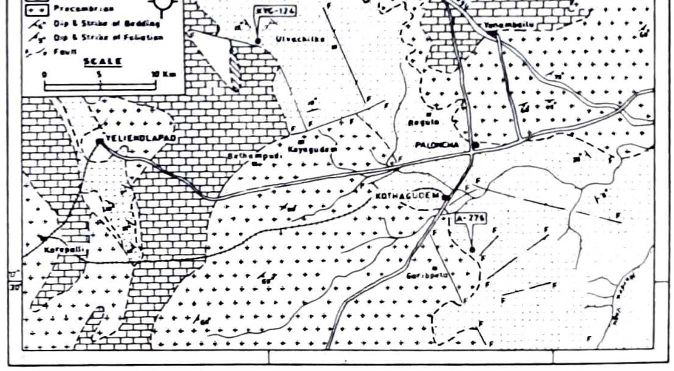
INTRODUCTION

GODAVARI VALLEY serves as the only source of coal supply for the entire South Indian Peninsula. The rapid stride for coal exploration undertaken by various agencies has led to the discovery of some virgin tracts of coal deposits having very high economic potential. However, large areas still need systematic study. The Godavari Valley has attracted geological pursuits as it houses an almost uninterrupted Permo-Triassic sedimentary sequence.

The Lower Gondwana sediments have been laid down on the Precambrian platform which presently occupies marginal position in the coal belt. The Upper Gondwana sediments are mostly confined to the central part of the basin, except for the extreme northeastern part where they are laid down in juxtaposition to the boundary fault. The southeastern boundary particularly the Chintalpudi area contains the exposures of Kamthi Formation. However, in the southern region the coastal Upper Gondwana sediments are sub-parallel and occur all along the coast line (Raja Rao, 1982).

Geological Setting (Map 1)

The geological details of Koyagudem Sector are based upon the surface and subsurface information provided by Sarolkar *et al.* (1990) and Bhattacharjee and Sabale (1990). The sector represents a part of the Mulug coal belt of the Godavari Valley. About 1100 m thick Lower Gondwana Sequence rests upon Archean Gneissic Complex and/ or Proterozoic Pakhal rocks in the area. The basal part of Lower Gondwana sediments represented by Talchir Formation consists of a thick sequence of shale and intermittent thin limestone bands. The overlying Barakar Formation has the dominance of sandstone alongwith the intervening bands of shale and siltstone. The coal in the area is confined to the Barakar Formation. A thick and persistent coal seam, locally known as "Queen seam", is encountered at a much shallower depth between 34.45 m and 45.05 m. The sediments in the Koyagudem Sector, are traversed by a number of faults which have displaced the Queen Seam at a shallower



Map 1. Location map of the collection sight (Bore-hole No. KYG-124) showing geological details (after Raja Rao., 1982).

A general geological succession of the Gondwana Sequence in Godavari Valley coalfields is given below after Ramanmurthy, 1985.

Age	Group	Formation	General Lithology	Maximum Thickness(m)
Late Early to Middle Triassic	UPPER GONDWANA / MALERI	Upper	Mainly vermilion clays with subordinate sandstones and lime pellet rocks	200
		Middle	Dominantly argillaceous sandstones with variegated clasts (forming low hillocks)	200
		Lower	Dominantly brown sandy clays	200
?Late Permian to Early Triassic	KAMTHI	Upper	Ferruginous sandstone with subordinate clays (forming prominent hill ranges)	400
			..............................Unconformity..............................	
	LOWER	Middle	Sandstone and shales	1000
		Lower	Sandstones with subordinate shale and coal seams	200
		Barren Measures	Coarse to pebbly felspathic sandstone with subordinate clays	450 ± 50
Permian	GONDWANA	Barakar	Dominantly sandstones with seven regionally persistent coal seams and subordinate shales	300
		Talchir	Greenish sandstones, clays/shales conglomerates and boulders	200
			..............................Disconformity..............................	
		Suallavai & Pakhal	White to brown sandstones, shales, phyllites and Dolomites	
			..............................Non-conformity..............................	
		Archean	Granite with dolerite, quartz and pegmatite intrusives	

depth as well as have induced the formation of silicified and extremely bracciated sediments at some places. It is because of this reason the sector has been assigned a high economic status. The sediments of the Barakar Formation have gradational contact with those of the Barren Measures and Kamthi formations.

Sampling and analytical technique (Map 1, Text-fig. 1, Table 1)

The representative samples were collected from drill-core (KYG-124) located at about 10 km NW of Koyagudem Village on way to Yelienldpad from Paloncha in Khammam District, Andhra Pradesh. The "Queen Seam" has been intersected between the depths of 97.90 m and 109.20 m. The seam is divided into top 97.90 m to 103.62 m (5.72 m) and the bottom 103.62 m to 109.20 m (5.58 m) parts. Out of the collected 21 coal samples, sample nos. 1-3 represent 3 coal bands lying above the Queen Seam, sample nos. 4-11 belong to the top and nos. 13-21 to the bottom parts of the Queen Seam.

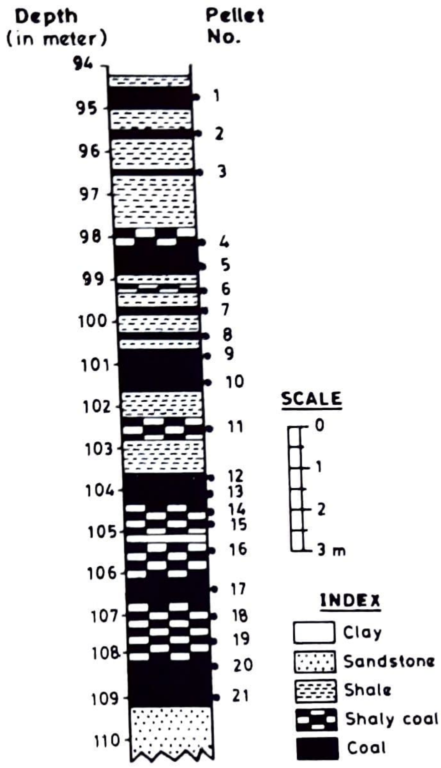
Table 1 : Showing details of samples from Borehole No. 124, Koyagudem area, Godavari Basin, Andhra Pradesh.

Sample No.	Depth (in Meters)	Lithology	Coal Seam	Pellet No.
1	94.74 - 94.26	Grey clay		
2	94.26 - 94.51	Dark grey shale		
3	94.51 - 95.04	Coal		KYG 1
4	95.04 - 95.50	Carbonaceous shale		
5	95.50 - 95.79	Coal		KYG 2
6	95.79 - 96.42	Carbonaceous shale		
7	96.42 - 96.55	Coal		KYG 3
8	96.55 - 97.90	Carbonaceous shale		
9	97.90 - 98.22	Shaly Coal	Queen (Top)	KYG 4
10	98.22 - 98.84	Coal	—do—	KYG 5
11	98.84 - 99.11	Shale (grey)	—do—	
12	99.11 - 99.31	Shaly coal	—do—	KYG 6
13	99.31 - 99.65	Carbonaceous shale	—do—	
14	99.65 - 99.81	Coal	—do—	KYG 7
15	99.81 - 100.28	Carbonaceous shale	—do—	
16	100.28 - 100.40	Coal	—do—	KYG 8
17	100.40 - 100.66	Carbonaceous shale	—do—	
18	100.66 - 101.16	Coal	—do—	KYG 9
19	101.16 - 101.67	Coal	—do—	KYG 10
20	101.67 - 102.28	Carbonaceous shale	—do—	
21	102.28 - 102.80	Shaly coal	—do—	KYG 11
22	102.80 - 103.62	Carbonaceous shale	—do—	
23	103.62 - 104.00	Coal with vitrinite bands	Queen (Bottom)	KYG 12
24	104.00 - 104.35	Coal with vitrinite bands	—do—	KYG 13
25	104.35 - 104.70	Shaly coal	—do—	KYG 14
26	104.70 - 105.09	Shaly coal	—do—	KYG 15
27	105.09 - 105.26	Clay	—do—	
28	105.26 - 106.13	Shaly coal	—do—	KYG 16
29	106.13 - 106.70	Coal with vitrinite bands	—do—	KYG 17
30	106.70 - 107.40	Shaly coal	—do—	KYG 18
31	107.40 - 108.10	Shaly coal	—do—	KYG 19
32	108.10 - 108.90	Coal (dull)	—do—	KYG 20
33	108.90 - 109.20	Coal with vitrinite bands	—do—	KYG 21

The coal samples were crushed to ± 18 mesh size particles and embedded in a mixture of epoxy resin and hardener in the ratio of 5:1 at room temperature. The coal pellets were ground and polished following international standards. The qualitative and quantitative (pellet-wise) studies of macerals, microlithotypes and reflectance have been done using Leitz Orthoplan MPV 1 microscope fitted with mechanical stage, swift automatic point counter and photomultiplier. The recommendations of ICCP (1963, 1971 & 1975) and Stach *et al.* (1982) are followed for collecting the data regarding reflectance and other organic constituents.

Macerals

The petrographic study of Koyagudem coals has revealed that they are primarily constituted by the macerals of vitrinite, exinite (liptinite) and inertinite groups interspersed with varied proportions of mineral matter.



Text-figure 1. Lithological details of bore-hole No. KYG-124.

Vitrinite group – This group of maceral is mostly recognized in the bright coal bands. It mainly includes the microbands of telocollinite (Pl. 1, figs. 3, 4 and 5) and desmocollinite (Pl. 1, fig., 2). Vitrodetrinite mostly contain irregular borders. Bark tissues (Pl. 1, fig. 6) with semifusinized cell walls contain corpocollinitic infillings.

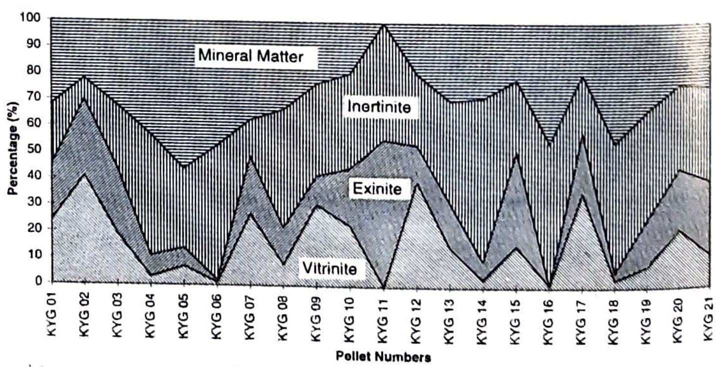
Exinite (Liptinite) group – The components assigned to this group are found dispersed in the vitrinitic groundmass forming flat layers which run parallel to the stratification. Megasporinites, thick and thin walled cutinites (Pl. 1, fig. 8) and resinites have random distribution. Dull coal bands contain significantly high frequency of the exinite group of macerals particularly the sporinites.

Inertinite group – It consists of semifusinite, fusinite, inertodetrinite and sclerotinites. The semifusinite and fusinite are the most dominating macerals. Often their cell walls are deformed and deteriorated (Pl. 1, fig. 7) possibly during the process of coalification. A transition from vitrinite to semifusinite and semifusinite to fusinite (Pl. 1, fig. 1) in the same coal band indicates the exposure of the vegetal matter to the aerobic oxidation during early diagenetic stages. Micrinites and macrinites are also present, though their frequency is very low.

Mineral matter – Mineral matter has intimate association with all the maceral groups. The most common minerals recognized in Koyagudem coals are the pyrite, siderites, calcite and black argillaceous matter. The latter also occurs as fillings in cells, crack and fissures of vitrinite, semifusinite and fusinite, besides occurring predominantly in bi- and trimaceral microlithotypes.

Maceral composition (Table 2, Text-fig. 2)

Coal above Queen seam – Out of the three coal bands which occur above Queen seam, the first (pellet 1) and the third (pellet 3) band is characterized by the dominant association of mineral matter content (32%) alongwith vitrinite (19% to 24%), exinite (21% to 25%) and inertinite (23% to 24%). However, the second (pellet 2) coal band has the dominance of vitrinite (41%), exinite (29%) and inertinite (8%) besides, mineral matter 22%.



Text-figure 2. Showing maceral composition of Koyagudem coals.

PLATE 1 ⟶

(All magnifications x 250)

Figs. 1 & 2 Collinite band. 3, 4, & 5. Telocollinite. 6. Bark tissue. 7. Inertinite showing cellular compression and degradation. Fig. 8. Cutinite in vitrodetrinitic ground mass.

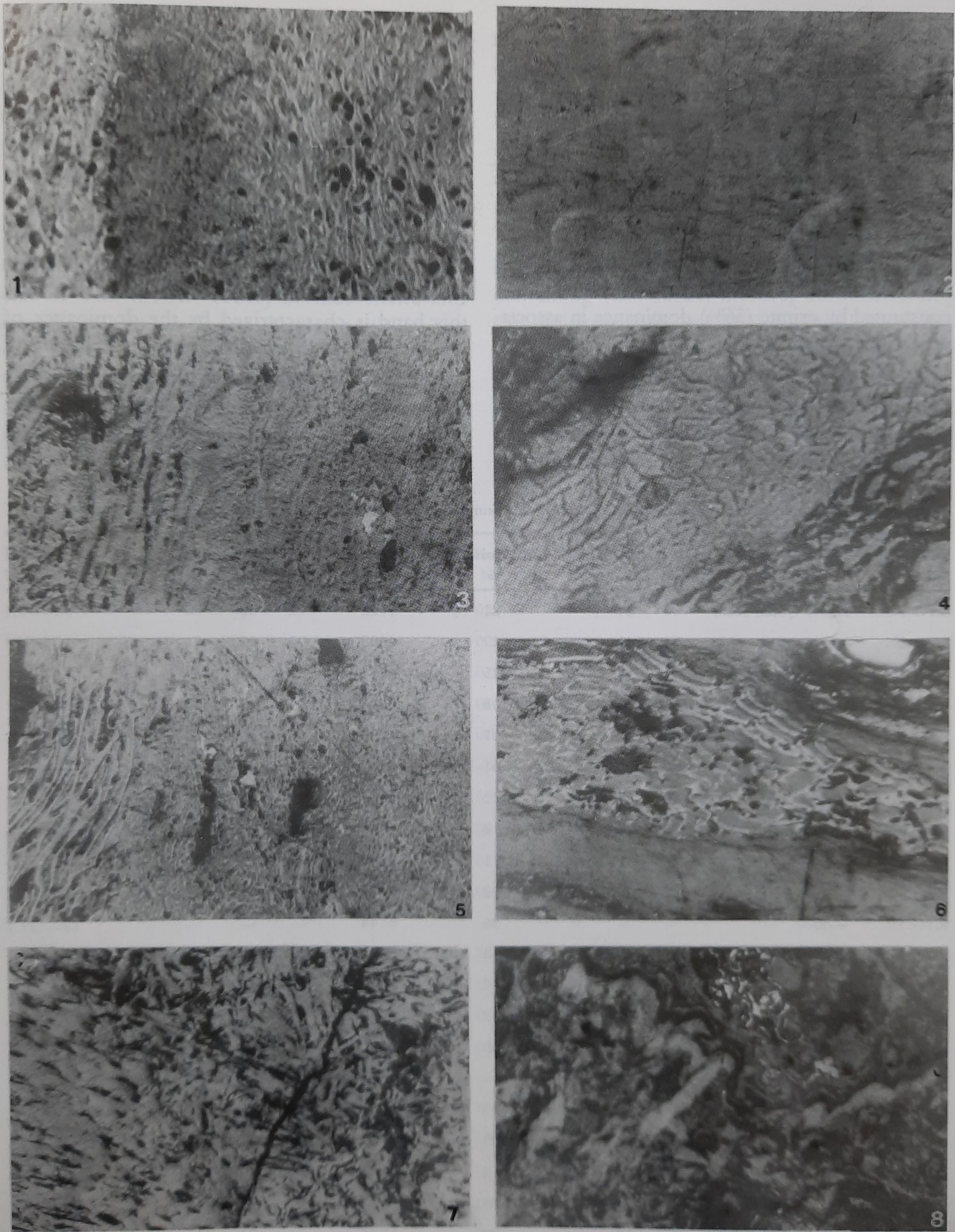


PLATE 1

Queen seam (Top part) – The coal representing the upper part (pellet 4 to 8) contains higher frequency of mineral matter (33% to 56%) alongwith inertinite (30% to 45%), exinite (7% to 14%) and vitrinite (7% to 8%). The underlying coal (pellet 9 & 10) is characterized by the dominance of inertinite (35% to 36%) in association with vitrinite (23% to 31%) and exinite (11% to 22%). Mineral matter association is recorded between (19% to 23%). The coal at the basal part of this section is constituted by exinite (56%) dominance in association with inertinite (44%).

Queen Seam (Bottom part) – Vitrinite (40%) rich coal marks the top (pellet no. 12) of this section with an intimate association of inertinite (27%). Exinite is recorded to be 14% and mineral matter 19%. The underlying coal sequence is inertinite (39%) rich having mineral matter (29%), vitrinite and exinite (15% to 17%). This is followed by the coal (pellet 14) showing inertinite (62%) dominance in association with mineral matter (28%) however, exinite (7%) and vitrinite (3%) have low frequency distribution. Exinite (36%) rich coal follow this sequence with an intimate association of inertinite (27%), vitrinite (16%) and mineral matter (21%). The coal below this band is characterized by the dominance of vitrinite (36%) in association with exinite and inertinite (22% to 23%) besides mineral matter (19%). The underlying coal contains inertinite (49%) alongwith high association of mineral matter (45%). This is followed by coal having

Table 2 : Showing maceral composition and rank of coals from Koyagudem area, Godavari Basin, Andhra Pradesh

Pellet No.	Name of seam	Vitrinite %	Exinite %	Inertinite %	Mineral matter %	R_0 max. %
KYG 1	Above Queen Seam	24	21	23	32	0.59
KYG 2	—do—	41	29	08	22	0.70
KYG 3	—do—	19	25	24	32	0.62
KYG 4	Queen Seam (Top part)	03	08	46	43	——
KYG 5	—do—	07	07	30	56	0.65
KYG 6	—do—	01	01	51	47	——
KYG 7	—do—	27	22	14	37	0.63
KYG 8	—do—	08	14	45	33	0.66
KYG 9	—do—	31	11	35	23	0.59
KYG 10	—do—	23	22	36	19	0.71
KYG 11	—do—	—	56	44	—	——
KYG 12	Queen Seam (Bottom part)	40	14	27	19	1.30
KYG 13	—do—	15	17	39	29	1.00
KYG 14	—do—	03	07	62	28	——
KYG 15	—do—	16	36	27	21	——
KYG 16	—do—	01	—	54	45	——
KYG 17	—do—	36	23	22	19	0.96
KYG 18	—do—	03	03	49	45	——
KYG 19	—do—	08	18	41	33	——
KYG 20	—do—	22	23	32	23	0.57
KYG 21	—do—	12	28	36	24	0.86

inertinite (32% to 41%) dominance intimately associated with mineral matter (23% to 33%), exinite (18% to 28%) and vitrinite (8% to 22%) except for pellet nos. 16 and 18 where very high mineral matter association is recorded.

Microlithotype composition (Table 3)

Coal above Queen Seam – The topmost coal band lying above Queen seam has the dominance of duroclarite (28%) and clarite (23%) in association with inertite (16%) besides vitrite and clarodurite (5%) each and vitrinertite (2%). The underlying coal band (pellet 2) contains the dominance of clarite (50%) in association with vitrite (17%), carbominerite, duroclarite and inertite (8% to 12%). Vitrinertite and clarodurite (1%) each have scanty distribution. The coal band just above the Queen Seam (pellet 3) is constituted by the dominance of inertite (60%) intimately associated with duroclarite (14%) and carbominerite (11%). Durite and clarodurite are recorded between 4% to 5%. However, clarite, vitrinertite and vitrite (1% to 2%) have low frequency distribution.

Queen Seam (Top part) – The coal representing top part of the Queen Seam has been found containing clarodurite, inertite, duroclarite and carbominerite (16% to 20%) followed by clarite and durite (12% each). Vitrinertite and vitrite (2% to 1%) have scanty distribution. The underlying coal (pellet 5) is carbominerite (39%) rich containing inertite (27%), durite (21%) and clarite (7%) besides the rare occurrence of duroclarite,

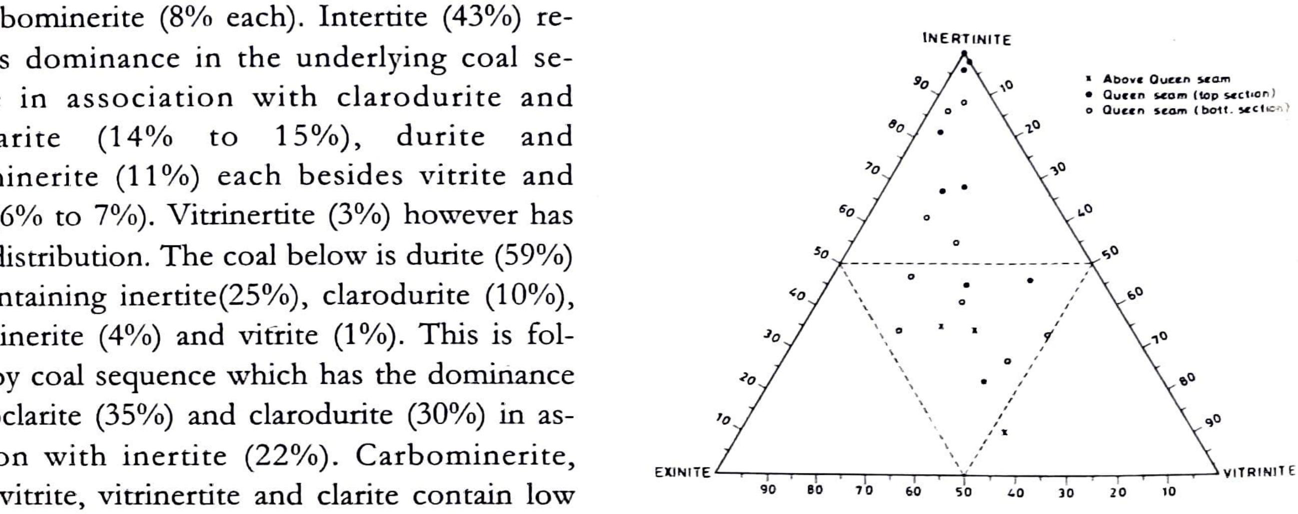
Table 3 : Showing microlithotype composition of Koyagudem coals Godavari Basin, Andhra Pradesh.

Pellet No.	Vitrite %	Clarite %	Inertite %	Vitrinertite %	Durite %	Duroclarite %	Clarodurite %	Carbominerite %
KYG 1	05	23	16	02	—	28	05	19
KYG 2	17	50	08	02	—	10	01	12
KYG 3	01	02	60	02	06	14	04	11
KYG 4	02	12	19	01	12	18	20	16
KYG 5	02	07	27	01	21	02	01	39
KYG 6	—	01	39	—	33	—	01	26
KYG 7	06	13	22	03	09	24	13	10
KYG 8	01	13	49	03	14	08	04	08
KYG 9	02	19	17	02	12	30	11	08
KYG 10	08	08	28	04	03	32	14	15
KYG 11	—	—	38	—	36	—	—	26
KYG 12	27	09	25	03	09	11	08	08
KYG 13	06	07	43	03	11	15	14	11
KYG 14	01	—	25	01	59	—	10	04
KYG 15	02	01	22	03	02	35	30	05
KYG 16	—	—	31	—	57	—	02	10
KYG 17	03	31	10	02	02	41	07	04
KYG 18	—	05	54	—	28	02	03	08
KYG 19	02	04	19	—	60	06	06	03
KYG 20	04	15	22	04	08	29	06	12
KYG 21	02	08	24	02	03	28	26	07

clarodurite, vitrinertite and vitrite (1% to 2%). The coal lying below is characterized by the dominance of inertite (39%), durite (33%) and carbominerite (26%). However, clarodurite and clarite (1%) each occur rarely. Duroclarite (24%) and inertite (22%) occupies dominance in the underlying coal (pellet 7). Clarite and clarodurite are recorded to be 13% each, carbominerite and durite (9% to 10%), vitrite (6%) and vitrinertite (3%). The coal lying below has inertite (49%) dominance in association with clarite and durite (13% to 14%), duroclarite and carbominerite (8% each), clarodurite (4%) and vitrite (1%). Duroclarite (30%) occupies dominance in the underlying coal in association with inertite and clarite (17% to 19%), clarodurite and durite (11% to 12%) and carbominerite (8%). However, vitrinertite and vitrite (2%) each have scanty distribution. The bottom part is marked by inertite and durite (36% to 38%) dominance alongwith carbominerite (26%).

Queen Seam (Bottom part) – The coal in the upper part is mostly constituted by inertite and vitrite (25% to 27%) dominance besides, duroclarite (11%), clarite and durite (9% each) and clarodurite and carbominerite (8% each). Intertite (43%) retains its dominance in the underlying coal sequence in association with clarodurite and duroclarite (14% to 15%), durite and carbominerite (11%) each besides vitrite and clarite (6% to 7%). Vitrinertite (3%) however has scanty distribution. The coal below is durite (59%) rich containing inertite(25%), clarodurite (10%), carbominerite (4%) and vitrite (1%). This is followed by coal sequence which has the dominance of duroclarite (35%) and clarodurite (30%) in association with inertite (22%). Carbominerite, durite, vitrite, vitrinertite and clarite contain low (1% to 5%) frequency distribution. The underlying coal is constituted by durite (57%), inertite (31%) and carbominerite (10%) besides clarodurite (1%). Duroclarite (41%) rich coal (pellet 17) follows the sequence in association with clarite (31%), inertite (10%) and clarodurite (7%). Carbominerite (4%), vitrinertite and durite (2%) occur rarely. The coal lying below is characterized by the dominance of inertite (54%) in association with durite (28%) and carbominerite (8%). However clarite (5%), clarodurite and duroclarite (2% to 3%) have scanty distribution. The underlying coal is durite (60%) and inertite (19%) rich containing duroclarite and clarodurite (6%) each, clarite and carbominerite (3% to 4%) and vitrite (2%). The coal below this sequence has the dominance of duroclarite (29%) and inertite (22%). Clarite (15%), carbominerite (12%) and durite (8%) follow the order of dominance alongwith clarodurite (6%) and vitrite and vitrinertite (4%) each. The coal representing bottom part of this section is characterized by duroclarite and clarodurite (26% to 28%) dominance intimately associated with clarite and carbominerite (7% to 8%). However, durite, vitrinertite and vitrite have frequency range of 2% to 3%.

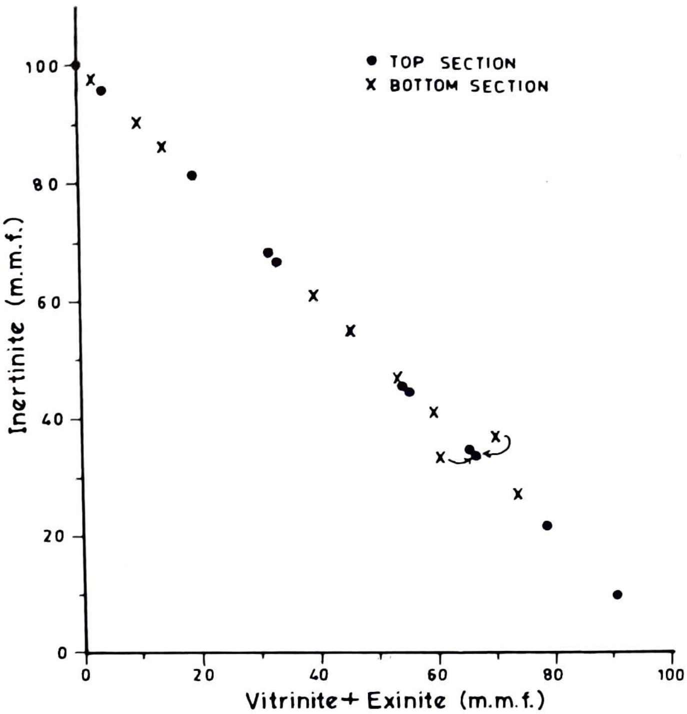
Triangular (Text-fig. 3) and biaxial (Text-fig. 4) m.m.f. maceral plottings have revealed that the Queen Seam is mainly characterized by the fusic (inertinite rich) and mixed (fuso-vitric and vitrofusic) coal types.



Text-figure 3. Triangular diagram showing maceral (m.m.f.) distribution.

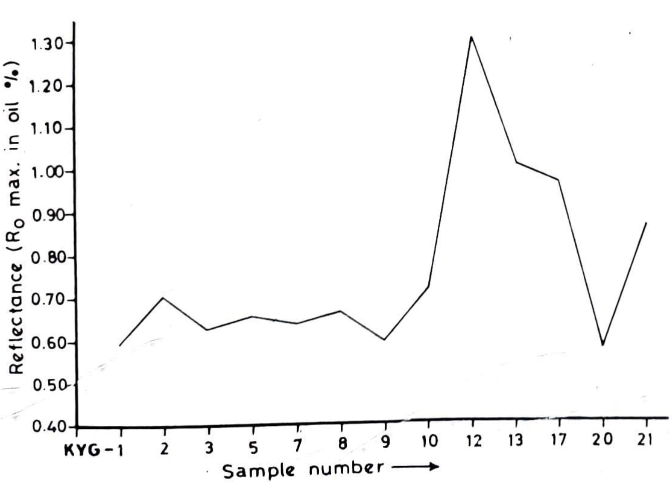
Rank variation (Table 2, Text-fig. 5).

The coal bands having the thickness range of 0.14-0.49 cm, occurring above the Queen Seam, attain the mean value of reflectance range from



Text-figure 4. Biaxial (m.m.f.) data plotting.

0.62% to 0.70% (R_o max.) indicating a coalification stage of high-volatile bituminous C to high volatile-bituminous B rank. The coals from the top section of Queen Seam are within the range of R_o max. 0.59% to 0.73% indicating sub-bituminous C to B stage. The bottom part of the seam has recorded an abrupt increase in reflectance values 0.86%-1.30% (R_o max.). The most convincing reason for this appears to be the existence of a number of faults and the subsequent tectonic events at the sight of collection.



Text-figure 5. Reflectogram (showing R_o max. values).

DISCUSSION

The dominance of any maceral group in the coal, its association with the other maceral groups and mineral matter content indicates the environment of deposition. Venkatachala and Tiwari (1987) visualized the existence of Marine pathways during Lower Gondwana sedimentation in Godavari valley. The sight of deposition (Koyagudem) represents near shore area as evidenced by its present geological position. The transgression phase of the sea has been the major source providing ample water to the sight of deposition. The vegetal matter that coalified in due course of time has mostly been contributed by the then existing deciduous forests besides, the bryophytic and the pteridophytic plants growing in the adjoining marshy habitat and the algal flora growing at the sight of deposition. Shah (1976) considered faunal, whereas Chandra and Chandra (1987) considered megafloral evidences for interpretation of climate during the Lower Gondwana deposition. The vegetal matter remained submerged in the water enhancing the process of vitrinization due to arrested oxidation. However, the mixed coal type indicates the regression phase of the sea causing lowering in the level of water table and the onset of drier regime in the basin. Thus, the peat remained exposed to the surface perhaps for shorter span causing its partial oxidation.

Environment of Deposition

Teichmuller (1989) opined about the phenomenon of coal fire associated with the dry period. The inertinite dominance however, suggests that the climate was mostly cold Taylor *et al.* (1989). The luxuriantly growing vegetation in the high latitudes at present experiences the environment with mild and moist summer and dry winters providing an ideal condition for the vitrinization in summers and fuisnization in winters. The coal seam contains a number of shaly coal and/or shale bands which represents the enrichment of mineral matter to the basin of deposition most probably this would have been the period of heavy rains and floods which have carried high proportion of mineral matter to the sight of deposition. A similar environment of deposition is also depicted for the Koyagudem area.

The Pathakhera Coalfield of Satpura Basin (Anand-Prakash & Sarate 1993) experienced more intense oxidizing conditions at the sight of deposition than those prevailed in Koyagudem area. However, a similar climatic conditions prevailed in Mulug Coal Belt (Sarate, 1996) and Ramagundam Coalfield of the Godavari Valley (Sarate 1996a; Navale *et al.* 1993).

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