

# Coal petrographic characteristics and depositional conditions of the subsurface Barakar Formation (Early Permian) in Belampalli Coalfield, Godavari Valley, Telangana

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## ABSTRACT

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The coal analytical studies have been taken up, to ascertain the rank on the basis of maceral composition and depositional environment of different seams namely Index, Index below top, Index below bottom, IA, I and the lowermost II (top section) intersected in Bore-hole No. SBS-182, from Sravanapalli area.

The random vitrinite reflectance ( $R_o$ , mean %) study of coal from Index and Index below bottom seams ranges between 0.61% and 0.63%, whereas IA and Seam I have shown lower reflectance which ranges between 0.52% and 0.54%. Thus, all these seams have attained high volatile bituminous C stage of rank. However, III (top section) seam has shown low reflectance (0.45%–0.46%), which indicates attainment of Sub-bituminous B stage. The coal maceral study has revealed that the Index, Index below Top, Index below Bottom seams contain vitric type of coal, whereas IA seam has vitric, fusic and mixed type of coal constitution. The lowermost III top and I seam, however, are represented by both vitric and fusic coal types. The facies study suggests that the vegetal resource of the Index, Index below top and Index below bottom seam has been accumulated during wet moor with intermittent moderate to high flooding. The resource for IA and III Top seam has been deposited during the prevalence of alternate oxic and anoxic moor conditions, which in due course of time changed to wet moor with intermittent moderate to high flooding whereas, I seam has witnessed wet moor with intermittent moderate to high flooding with shift to oxic (dry) moor with sudden high flooding. It has also been noticed that coal quality of III seam has shown deterioration towards the south-western direction of the Belampalli Township.

**Key-words**—Coal petrography, Maceral, Reflectance, Coal seams, Depositional environment, Sravanapalli, Belampalli Coalfield, Godavari Valley, Telangana, India.

तेलंगाना की गोदावरी घाटी के बेलमपल्लि कोयला क्षेत्र में उपपृष्ठीय बराकार शैलसमूह (प्रारंभिक पर्मियन) की कोयला सजातीय शैल अभिलक्षणन एवं निक्षेपणीय स्थितियाँ

ओमप्रकाश एस. सराटे

## सारांश

श्रावनपल्लि क्षेत्र से प्राप्त वेध छिद्र संख्या एस.बी.एस.—182 में प्रतिच्छेदित तमाम सीमों नामतः सूचक, शीर्ष के अधो सूचक, धरातल के नीचे सूचक, I ए, I और निम्नतम II (शीर्ष खंड) के मैसेरल संघटन व निक्षेपणीय पर्यावरण के आधार पर कोटि अभिनिर्धारित करने हेतु कोयला तात्विक अध्ययनों का जिम्मा लिया गया है।

सूचक और धरातल के नीचे सूचक कोयला सीमों की यादृच्छिक विट्रीनाईट ( $R_o$  माध्य %) परावर्तकता 0.61% व 0.63% के बीच है, जबकि I ए और I सीमों ने अत्यन्त परावर्तकता दर्शायी है जो कि 0.52% और 0.54% के मध्य है। इस प्रकार, इन समस्त सीमों ने उच्च वोल्टीय

बिटुमेनी सी कोटि की अवस्था प्राप्त की है। फिर भी, III (शीर्ष खंड) सीम ने अल्प परावर्तकता (0.45% से 0.46%) दर्शायी है, जो उप-बिटुमेनी बी अवस्था की प्राप्ति दर्शाती है। कोयला मैसेरल अध्ययन ने खुलासा किया है कि सूचक, शीर्ष के नीचे सूचक, धरातल के नीचे सीमों में विट्रिक प्रकार का कोयला सन्निहित है, जबकि I ए सीम में विट्रिक, फ्यूजिक और मिश्रित प्रकार का कोयला संघटन है। निम्नतम III शीर्ष व I ए सीम, फिर भी, विट्रिक व फ्यूजिक दोनों प्रकार के कोयले से निरूपित हैं। संलक्षणी अध्ययन सुझाता है कि सूचक, शीर्ष के नीचे सूचक और धरातल के नीचे सूचक सीम का वनस्पति स्रोत आंतरायिक मध्यम से उच्च बाढ़ के साथ आर्द्र मूर के दरम्यान संचित हो गए हैं। I ए व III शीर्ष सीम हेतु स्रोत एकांतरण ऑक्सी व अनॉक्सी मूर स्थितियों में निक्षेपित हुए हैं, जो आंतरायिक मध्यम से भयंकर बाढ़ के साथ यथोचित समय पर आर्द्र मूर में परिवर्तित हो गया जबकि, यकायक प्रचंड बाढ़ में ऑक्सी (शुष्क) मूर को विस्थापित के साथ आंतरायिक मध्यम से प्रचंड बाढ़ सहित I सीम ने दर्शाया है। यह भी देखा गया है कि III सीम की कोयला गुणवत्ता में बेलमपल्लि बस्ती की दक्षिण-पश्चिम दिशा की ओर ह्रास दर्शाया है।

**सूचक शब्द**—कोयला शैलवर्णन, मैसेरल, परावर्तकता, कोयला सीम, निक्षेपणीय पर्यावरण, श्रावनपल्लि, बेलमपल्लि कोयला क्षेत्र, गोदावरी घाटी, तेलंगाना, भारत।

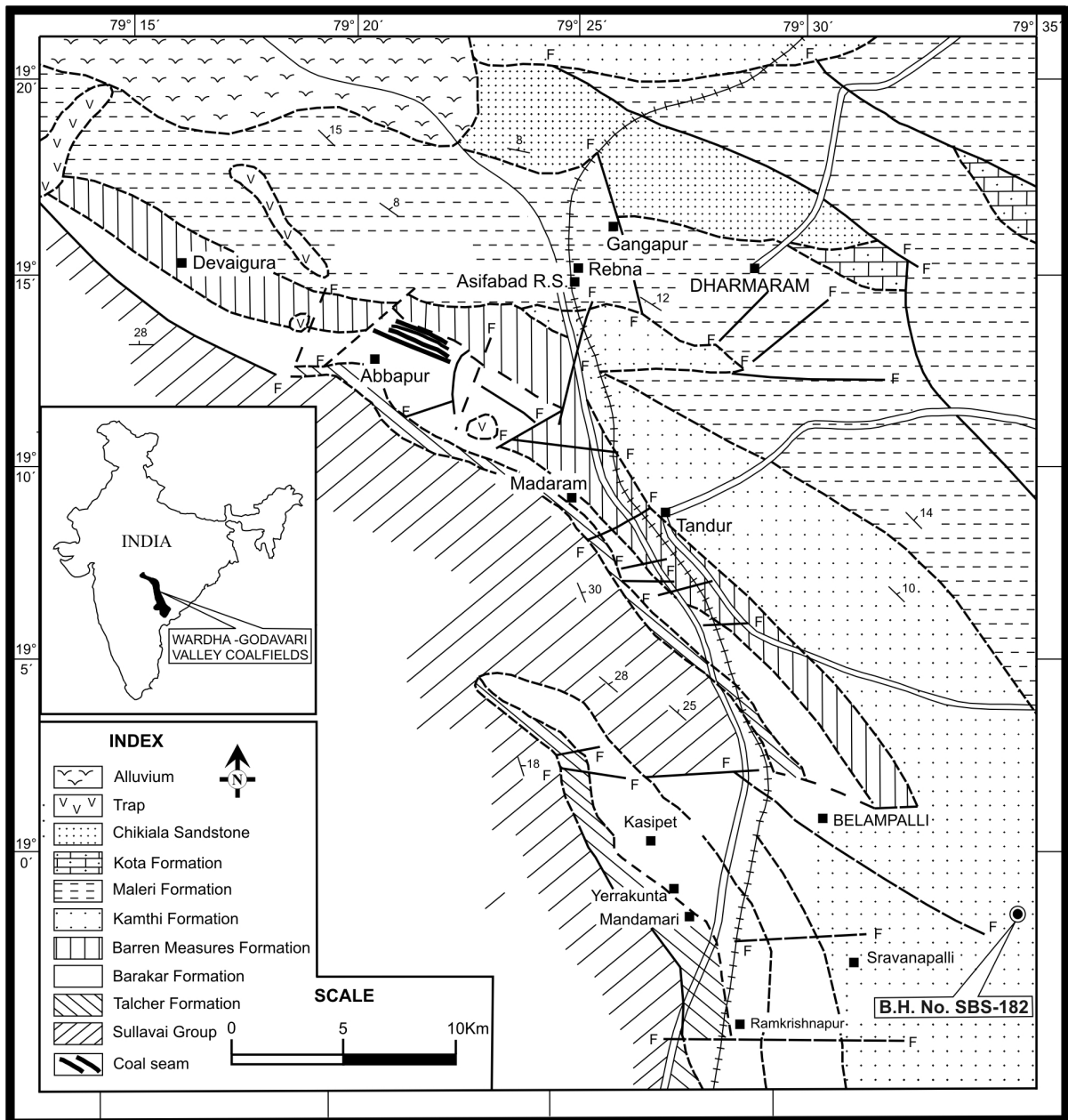


Fig. 1—Geological map showing location of bore-hole No. SBS-182, Sravanapalli area, Belampalli Coalfield, Godavari Valley, Telangana.

## INTRODUCTION

**S**RAVANAPALLI area is situated in the south-eastern extremity of Belampalli Coalfield located in Telangana State. There exists skimpy information regarding the petrographic characteristics of the sub-surface coal seams of the Belampalli Coalfield, except for the petrographic contributions provided by Ramana Rao (1962), Pareek *et al.* (1964), Moiz and Ramana Rao (1976), Navale *et al.* (1983) and Sarate (2001). Significant petrographic research work has been carried out on the coal deposits of different Indian Gondwana Basins, e.g. Singh and Shukla (2004) and Bharadwaj *et al.* (1974), from Pench Kanhan and Tawa Valley, Madhya Pradesh, Singh and Singh (1996), Rajmahal Basin, Bihar, Naik *et al.* (2016) from Mand–Raigarh coals, and Singh (2016) from Talcher Coalfield, Mahanadi Basin, Chhattisgarh, and Singh *et al.* (2016) from Umaria, Korba & IB–Valley Coalfields and Sarate (2004) on the coals of Wardha Valley Coalfield, Maharashtra.

The present coal petrographic study from Sravanapalli area has been undertaken which is a new locality known from Belampalli Coalfield, to understand the coal constitution and vitrinite reflectance variation in sub-surface coal seams, to evaluate their quality and rank, besides, the depositional environment and economic potentials. Similarly, based on the coal petrographic information available from various parts of the coalfield, an attempt has also been made to find the trends in maturity and coal quality in different areas of the Belampalli Coalfield.

## GENERAL GEOLOGY

Godavari Valley displays the existence of monotonous sequence of undulating sediments spread over 17400 km<sup>2</sup> area in Adilabad, Karimnagar, Warangal and Khammam districts of Telangana. The Gondwana sediments occupy the area with an average width of about 47 km, exposed all along the course of the rivers Pranhita and Godavari, however, a small

Age	Group	Formation	Maximum Thickness (Metres)	Lithology
Late Permian to Early Triassic	L O W E R	Kamthi	600	Middle Member: Alternating sequence of medium grained white to greenish grey white sandstones and buff to greenish grey clays.
Late Permian		Barren Measures	500	Lower Member: Medium to coarse grained, greyish white calcareous sandstones with a few coal seams.
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	A	Talchir	350	Fine-grained sandstones, splintery green clays/shales, chocolate coloured clays, pebble beds and tillite.
? Late Proterozoic		Sullavai	545	Medium to coarse grained, white to brick red sandstones, at places quartzitic and mottled shales.
Early Proterozoic		Pakhal	3335	Greyish white to buff quartzites, grey shales, phyllites and marble.
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, Telangana and Andhra Pradesh, India (after Raja Rao, 1982).

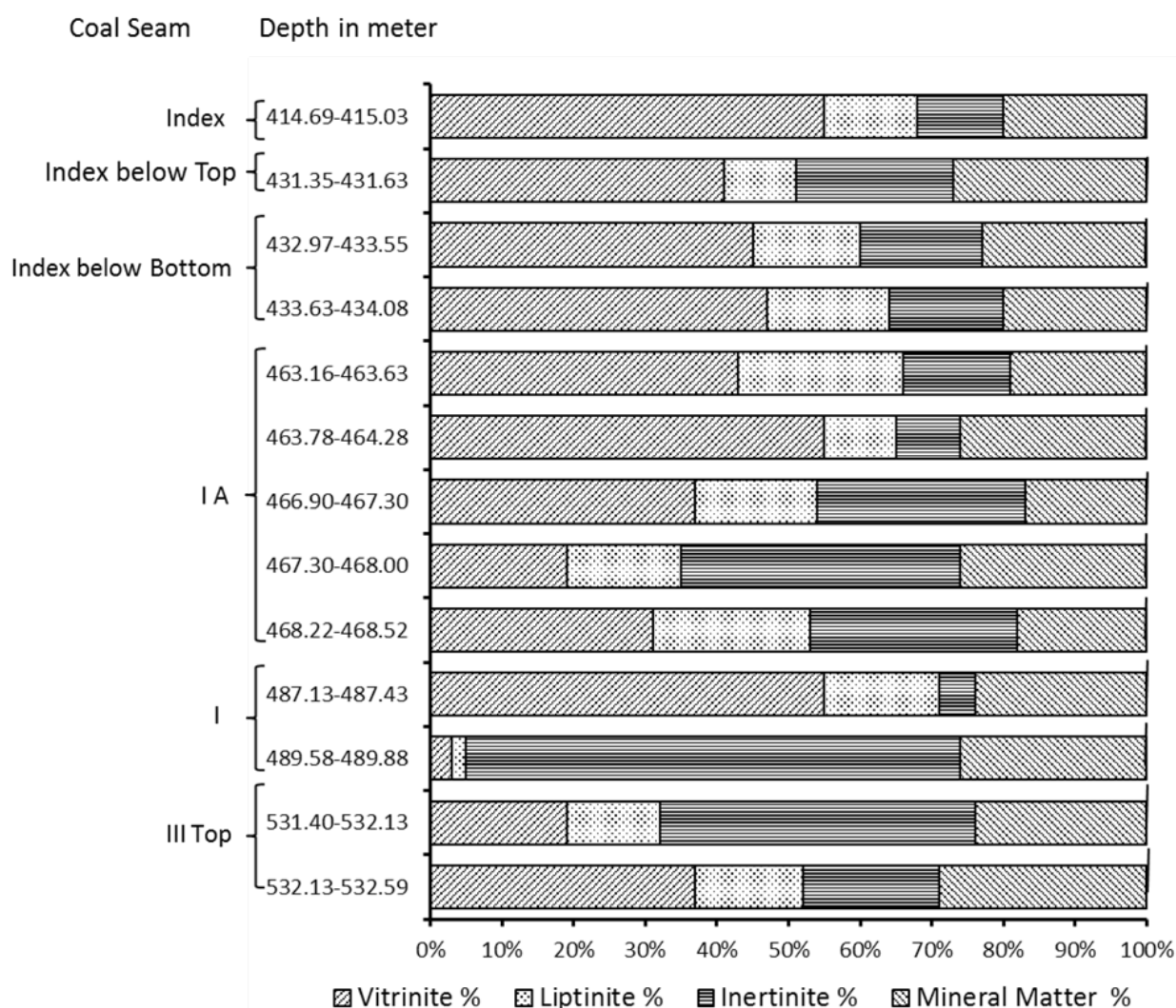


Fig. 2—Maceral constitution of the coal seams intersected in bore-hole No. SBS-182, Sravanapalli area, Belampalli Coalfield, Godavari Valley, Telangana.

constriction of the Gondwana succession with merely 6 km in width has also been observed in Palauncha–Koyagudem area. The Godavari Valley Coalfield is delineated between latitudes 16°38' and 19°32' north and longitudes 79°12' and 81°39' east. The geomorphic studies have revealed it to be a large graben that displays NNW–SSE trend and is flanked on either side by the Precambrian uplands. Qureshi *et al.* (1968) and Bhaskar Rao *et al.* (1970) studied the gravity anomalies in the Coalfield and termed it as a rift valley; structurally Godavari Valley has been divided into four sub-basins, e.g. (1) Godavari, (2)

Kothagudem, (3) Chintalapudi and (4) Krishna–Godavari coastal sub-basin, whereas the study area represents a part of the Godavari sub-basin.

Godavari Valley Coalfield is unique in the entire Peninsular India and has conserved almost uninterrupted litho–succession from Permian to the Lower Cretaceous age, along with the floral and faunal evidences, well marked palaeosoles, biozones, as well as signatures for the tectonic events.

## PLATE 1

1. Collotelinite band
2. Collotelinite with dispersed pyrite grains
- 3, 6. Collotelinite with microspores
- 4, 7, 10, 13. Collotelinite in normal mode
- 5, 8, 11, 14. same collotelinite in fluorescent mode, showing expulsion of

9. exudatinite.
- Dispersed cuticles
12. Fusinite with highly compressed cells
15. Secretinite





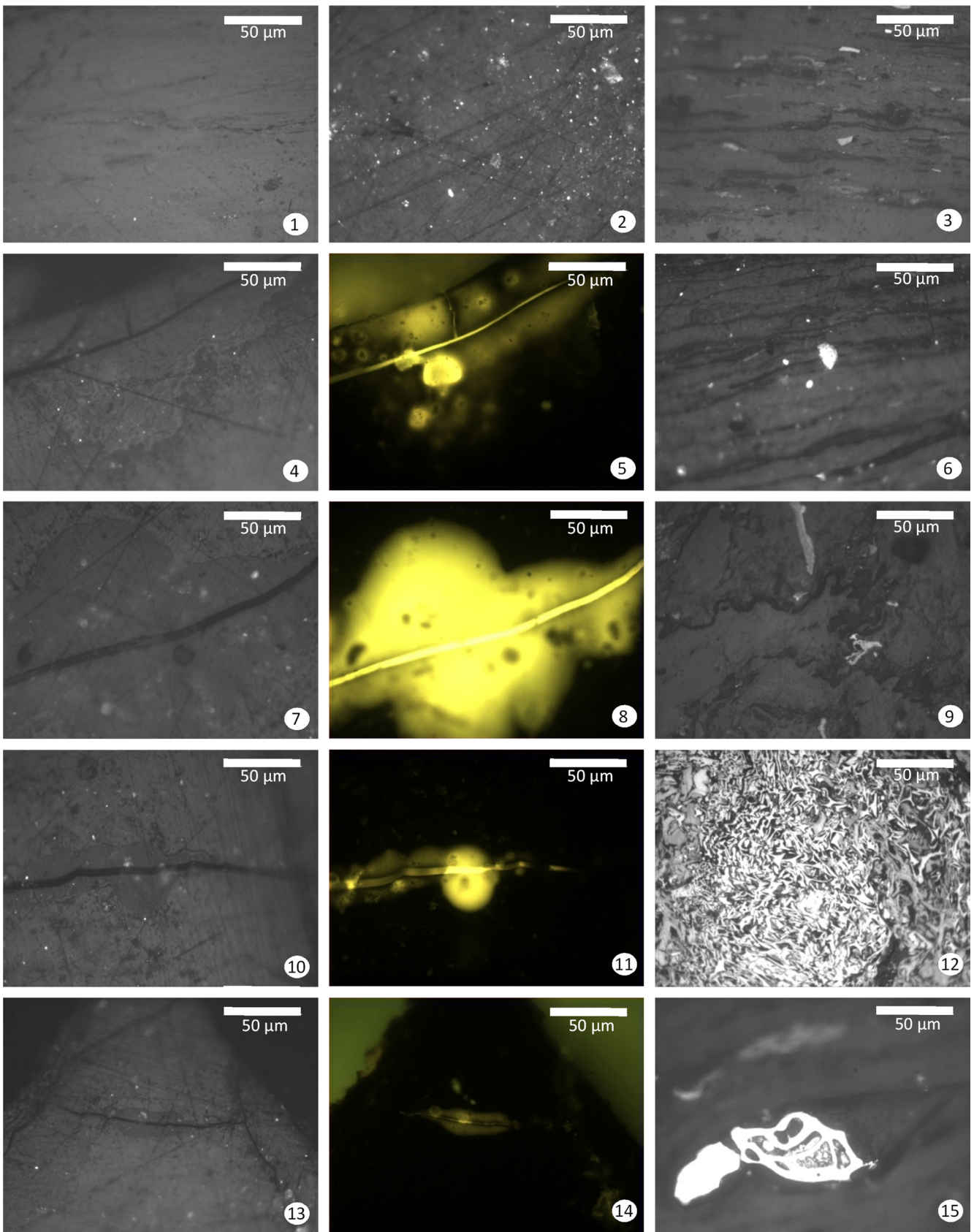


PLATE 1

### Geology of Belampalli Coalfield

Sravanapalli area represents a part of Belampalli Coalfield, Godavari sub-basin. The study area is described under Golet–Belampalli belt (Raja Rao, 1982) which extends over strike length of 45 km; the coalfield also shows the development of four persistent seams which are confined to the Barakar Formation. The area is traversed by a major boundary fault and two minor faults. However, the II, III Top and II Bottom seams have also attained workable thickness, but it is confined only to some parts and the other seams serve only as marker beds (Table 1).

### MATERIAL AND METHODOLOGY

The collection site represents a part of Sravanapalli Block II area which marks the south–eastern continuity of Shanti Khani Block, covering nearly 12 km area spread over a strike length of 7 km. The Lower Gondwana deposits mainly include the sediments of Talchir, Barakar and Barren Measures but the deposits in this area are confined only to the Barakar Formation. Total nine recognizable coal seams have been encountered out of which only four, viz. IA, I, III top and III Bottom seam have attained workable thickness. The thickness of Seam IB is less and it also contains interventions of the clay bands at the roof and floor. Similarly, seams II, IB and IV are not persistent and their thickness is too less to be considered suitable for mining purpose.

Collection site—Bore-hole No. SBS–182 is drilled in the extreme southern edge of the Belampalli Coalfield, in Mandamari Mandal of Adilabad District, Telangana and is located at the distance of nearly 8 km north–east of Sravanapalli and about 10 km south–east of Belampalli Township. The Sravanapalli Block is delineated between 18°31'54" and 19°02'00" north latitudes and 79°31'54" and 79°34'50" east longitudes (Fig. 1, Table 2).

The coal seam samples were gently and cautiously crushed using agate pestle and mortar to obtain  $\pm 18$  (1 mm) mesh particles. Adequate ( $>3/4$  capacity) amount of crushed samples was decanted in the plastic moulds, pre-coated with releasing agent. A mixture of hardener and resin in proportion of 1: 5 was then poured in plastic moulds containing samples and mixed thoroughly and immediately labelled. The moulds were allowed to harden for nearly 24 hours, at room temperature. The hardened pellets were removed from the moulds after a day and are subjected to grinding and polishing, following the recommendations of ICCP (1971, 1975, 1998, 2001), Stach *et al.* (1982) and Taylor *et al.* (1998). The micro-constitutional observations (maceral composition) were carried out using Leica DM 4500P, version 2.35 of petroglite. Random vitrinite reflectance ( $R_o$  mean %) measurements were taken using Microscope Photometry System (PMT III). Similarly, selective photomicrography is carried out with the help of software tool Leica Application Suit (LAS).

Sr. No.	Pellet No.	Coal Seam	Depth (meter)	Vitrinite %	Liptinite %	Inertinite %	Mineral Matter %	Reflectance ( $R_o$ mean %)
1.	SBS–182/1	Index	414.69–415.03	55 (69)	13 (16)	12 (15)	20	0.61
2.	SBS–182/2	Index below Top	431.35–431.63	41 (56)	10 (14)	22 (30)	27	0.56
3.	SBS–182/3	Index below Bottom	432.97–433.55	45 (58)	15 (20)	17 (22)	23	0.60
4.	SBS–182/4	Index below Bottom	433.63–434.08	47 (59)	17 (21)	16 (20)	20	0.63
5.	SBS–182/5	IA	463.16–463.63	43 (53)	23 (28)	15 (19)	19	0.53
6.	SBS–182/6	IA	463.78–464.28	55 (74)	10 (14)	09 (12)	26	0.54
7.	SBS–182/7	IA	466.90–467.30	37 (45)	17 (20)	29 (35)	17	0.52
8.	SBS–182/8	IA	467.30–468.00	19 (26)	16 (21)	39 (53)	26	0.52
9.	SBS–182/9	IA	468.22–468.52	31 (38)	22 (27)	29 (35)	18	0.54
10.	SBS–182/10	I	487.13–487.43	55 (72)	16 (21)	05 (07)	24	0.52
11.	SBS–182/11	I	489.58–489.88	03 (04)	02 (03)	69 (93)	26	–
12.	SBS–182/12	III Top	531.40–532.13	19 (25)	13 (17)	44 (58)	24	0.45
13.	SBS–182/13	III Top	532.13–532.59	37 (52)	15 (21)	19 (27)	29	0.46

Table 2—Maceral constitution (vol. %) and Reflectance ( $R_o$  mean %) analysis of the coal seams intersected in bore-hole No. SBS–182, Sravanapalli area, Belampalli Coalfield, Godavari Valley, Telangana.

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

## DESCRIPTION OF COAL MACERALS

Most of the coal seams in Sravanapalli area contain vitrinite as the dominant group of macerals, barring a few intervening inertinite rich coal bands present in some of the coal seams. Liptinite Group of macerals is consistently found associated with other macerals; however its representation is comparatively low.

**Vitrinite**—This maceral group includes thin and very thick bands of light to dark grey colouration, caused due to the spreading of an extra thin film of hydrocarbon coating over the normal vitrinite, which at times makes it fluorescent (fluorescing vitrinite). Telinite bands are occasionally noticed with distinct cellular structures, their intercellular spaces (lumens) are generally occupied either by collinite, gelinite or mineral matter. Collinite is most frequently noticed as homogeneous mass of the thick as well as thin bands, which contain desiccation cracks and fissures, filled mostly with argillaceous or at times occupied by calcareous mineral matter or pyrite grains. Exudatinite (Pl. 1.5, 8, 11, 14) and fluorinates have also been occasionally noticed. Oval or round bodies of corpogelinite with dark grey shade have also been randomly recorded. Dark grey coloured collodetrinite exists as ground mass of either clarite or trimacerite and displays lower reflectance than the collotelinite (Pl. 1.1, 4, 7, 10, 13), at times collotelinite has also displayed the existence of dispersed pyrite grains (Pl. 1.2). The transitional stages of collinite and pseudovitrinite were also witnessed during the study.

**Liptinite**—Sporinite is the most frequently noticed structured maceral, which is either thread like, spindle/disc shaped or elongated displaying grey or dark grey coloration. Thin walled microsporinites (tenuisporites) are commonly noticed in linearly arranged rows, however, at times, they are also seen in randomly distributed fashion, interspersed with different maceral groups, mostly with the collotelinite (Pl. 1.3, 6). However, thick walled crassispores are occasionally observed. Similarly, megaspores with thin (tenui) and thick (crassi) walls and dark grey colouration, showing wide variation in size as well as ornamentation pattern are also noticed, but their frequency is quite low. Dark grey thick and thin walled cutinites (Pl. 1.9) are seen randomly distributed and associated with other macerals and at times are noticed in groups as well as in linear rows (thin walled variety) whereas, the thick walled cutinites are rarely observed and generally display serrated margins with dark grey colouration. Oval or elongated resin bodies are occasionally noticed. Leptodetrinite mainly includes broken fractions of structured liptinite which are commonly found in dispersed condition in the vitrinitic ground mass, as well in cracks, fissures and cavities of other macerals.

**Inertinite**—Sub-surface coal deposits of Sravanapalli area contain inertinite as sub-dominant group of macerals. However, some of the coal seams contain a few intervening bands which are exceedingly rich in inertinite contents

and mostly include thick and thin bands of fusinite and semifusinite, besides deformed inertodetrinite fractions. The fusinites can easily be segregated from semifusinite as the former has well defined, intact and well preserved cells, along with higher reflectivity, whereas the later displays lower reflectivity and ill preserved cell structures. The cell lumens of both these forms are generally occupied by mineral matter. Fusinites also show highly compressed cellular structures (Pl. 1.12). Micrinites and macrinites both are found in dispersed condition and display white colour and high reflectivity; however, macrinites mostly display oval shape and white colour. The micrinites exhibit fine granular structure, lenticular shape and high reflectivity. Bulk of the inertinite is found dispersed in the form of broken fractions, derived from the fusinite and semifusinite, besides some particles of uncertain identity termed as inertodetrinite. Secretinites (Pl. 1.15) and funginite are also occasionally noticed in these coals.

**Mineral Matter**—Most common mineral matter found associated with other maceral groups in the different coal seams has been the argillaceous clay, which exists in the form of ground mass as well as occupying the spaces available in the cracks, fissures and cleats. Highly reflecting pyrite in the form of discrete grains as well as framboids are also found dispersed in inertinite, inertodetrinite as well as in vitrinite bands in some of the coal samples. Carbonate and sulphides minerals also exist in low amounts in the ground mass occupying the empty spaces in the fissures.

## MACERAL CONSTITUTION

In the Index and its underlying Index below top and Index below bottom seams vitrinite group of macerals are predominant by volume (41–55 vol. %) along with liptinite (10–17 vol. %), inertinite (12–22 vol. %) and mineral matter (20–27 vol. %) respectively. The upper coal horizon of Seam IA has also shown the predominance of vitrinite group of macerals by volume (37–55 vol. %) with maximum representation in the middle portion. Liptinite (10–23 vol. %) is highest at the top with considerable drop in frequency distribution in the middle region (10 vol. %). Mineral matter association is recorded between 17 vol. % and 26 vol. %, with maximum in the middle part. The underlying small coal band is fusic in nature and contains inertinite dominance by volume (39 vol. %), followed by vitrinite (19 vol. %), liptinite (16 vol. %) and mineral matter 26 vol. % respectively. The coal at the bottom of the seam is vitric in nature and contains vitrinite dominance (31 vol. %) with intimate association of inertinite (29 vol. %), besides liptinite (22 vol. %) and significantly low amount of mineral matter (18 vol. %). The coal of Seam I is distinctly divisible into two parts having dominance of vitrinite by volume (55 vol. %) group of macerals at the top along with liptinite (16 vol. %) and fair representation of inertinite (5 vol. %). The basal part of the seam, however, contains fusic coal having inertinite with predominance by

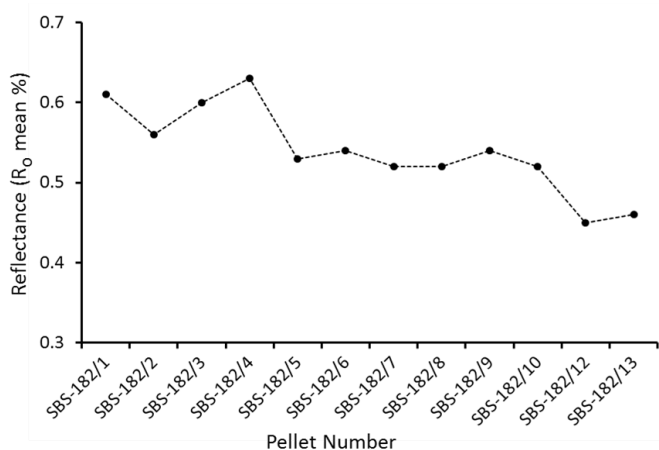


Fig. 3—Random Reflectance (R<sub>o</sub> mean %) analysis of the coal seams intersected in bore-hole No. SBS-182, Sravanapalli area, Belampalli Coalfield, Godavari Valley, Telangana.

inertinite (44 vol. %), vitrinite (19 vol. %), liptinite (13 vol. %) and mineral matter 24%, whereas the coal at the bottom contains vitrinite (37 vol. %) as the dominant group of macerals by volume, along with inertinite (19 vol. %) and liptinite 15 vol. %. Mineral matter association is recorded to be 29 vol. % (Table 2, Fig. 2).

**REFLECTANCE ANALYSIS**

The mean random (R<sub>o</sub> mean %) vitrinite reflectance recorded from the coals of the Index seam is 0.61%. Index below top seam has shown reflectance 0.56%. However, Index below bottom coal seam has depicted higher vitrinite reflectance which ranges between 0.60% and 0.63%. Similarly, the older seams, viz. IA and I have indicated lower vitrinite reflectance with variation from 0.52% to 0.54%. Thus, Index, Index below top, Index below bottom, IA and I seams have attained high volatile bituminous C (sub-bituminous A) stage of rank, whereas the lowermost III top seam with low vitrinite reflectance of 0.45%–0.46% indicates the attainment of sub-bituminous B stage (Table 2, Fig. 3).

volume (69 vol. %) along with scanty distribution of vitrinite and liptinite macerals (2–3 vol. %). Mineral matter in this seam is recorded between 24 and 26 vol. %. The lowermost III top seam also contains fusic coal at the top with dominating

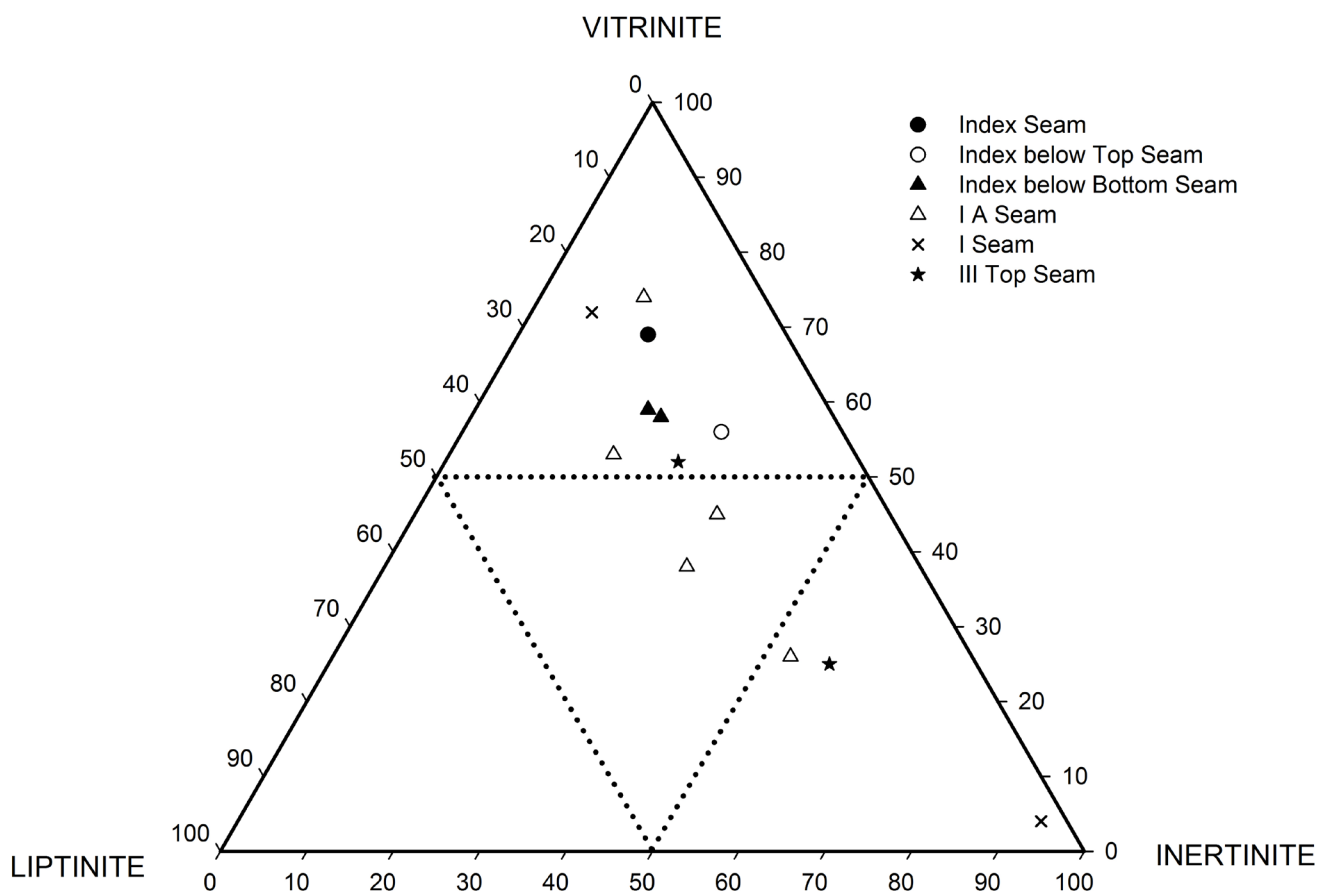


Fig. 4—Ternary diagram showing Maceral composition of the coal seams intersected in bore-hole No. SBS-182, Sravanapalli area, Belampalli Coalfield, Godavari Valley, Telangana.



The ternary mineral matter free (m.m.f.) maceral plotting has shown that the Index, Index below top and Index below bottom seams contain vitric type of coal, whereas IA seam has displayed wide range of variation in its maceral constitution as reflected by the presence of vitric, fusic as well as mixed coal types. The lowermost III top seam and I seams are characterized by vitric and fusic type of coal configuration (Fig. 4).

The facies diagram as suggested by Singh and Singh (1996) has been plotted to interpret the depositional environment during the deposition of source material responsible for the formation of sub-surface coal deposits in Sravanapalli area has indicated that the Index, Index below top and Index below bottom seams have witnessed wet moor with intermittent moderate to high flooding. IA and III Top seams have been deposited initially during alternate oxic and anoxic moor conditions which shifted to wet moor with intermittent moderate to high flooding. Similarly, the climate fluctuated from oxic (dry) moor with sudden high flooding to wet moor with intermittent moderate to high flooding during the deposition of vegetal resource of the I seam (Fig. 5).

## DISCUSSION AND CONCLUSIONS

Early Permian de-glaciations initiated shifting and breaking of the huge ice-burys and ultimately exposed the underlying basements rocks to the surface, which served as the platform for Gondwana deposition. Talchir Formation represents the basalmost Gondwana member to be deposited. Similarly, the plant life started invading the crevices created on the basement by de-glaciations as indicated by the existence of scanty stunted and stunted floral evidences of *Gangamopteris* and *Noeggerathiopsis* recorded from the Late Talchir sequence, which proliferated during the Karharbari Formation with the dominance of deciduous plants of the group Glossopteridae, along with Lycophytes, Pteridosperms, Filicales, Equisetales and Cycadales (Joshi *et al.*, 2014), besides the aquatic plants belonging to the family Calamariaceae flourished in the stagnant swampy and marshy habitat Chandra and Chandra (1988), Plumstead (1961). King (1958) opined that initially cold temperate conditions prevailed, which during later stages became warm temperate (King, 1961; Kräusel, 1961). Similarly, the slowly sinking nature of the Gondwana basin resulted into deposition of

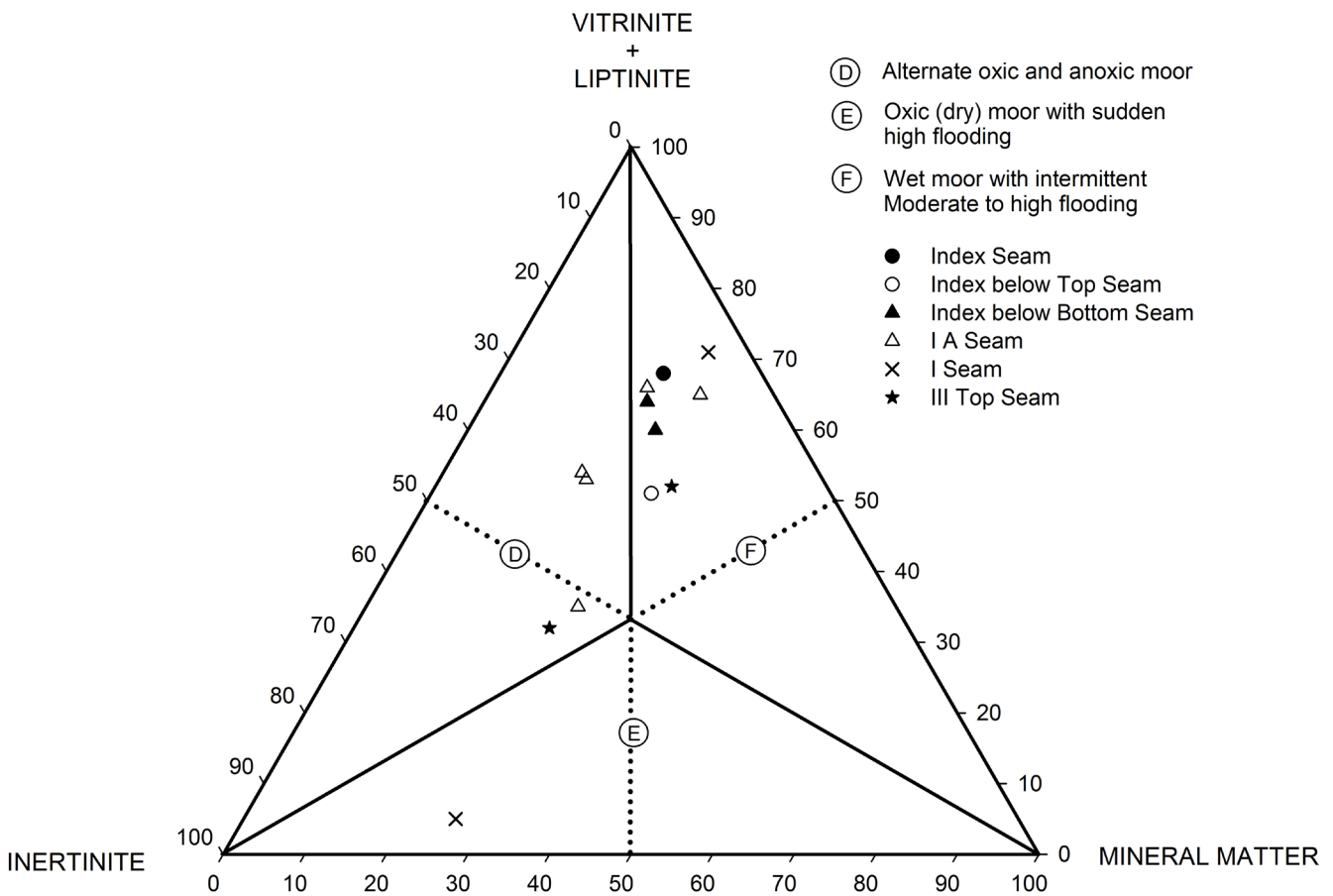


Fig. 5—Facies diagram showing the depositional environment of the coal seams intersected in bore-hole No. SBS-182, Sravanapalli area, Belampalli Coalfield, Godavari Valley, Telangana.

uninterrupted vegetal resource which formed the Gondwana coal deposits.

The present study also provides a supporting evidence for the existence of seasonal changes (cold humid and dry oxidizing) prevailed during the deposition of the lowermost III Top (Salarjung) and its overlying I and IA seams as the coal deposited contain alternate bands of vitric and fusic coal constituents.

Similarly, vitric coal recorded from the uppermost Index, Index below top and Index below bottom seams indicate the prevalence of cold climatic conditions.

The coal maceral constitutional study and the reflectance data from different parts of Belampalli Coalfield suggests that the coal quality of III seam deteriorate as we move towards south-western part of the coalfield. However, in view of the low mineral matter association and vitrinite rich constitution recorded in several sub-surface coal seams of the study area these coal deposits can selectively be judged for their economic utility.

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