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Characterisation of organic source material from Tatapani and Ramkola coalfields, Chhattisgarh, India

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ABSTRACT

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Detailed study of the coal microconstituents from Tatapani and Ramkola coalfields has revealed preservation of leaf sections, cork cells, microspores, megaspores, algae, resins, seeds and fruiting bodies. The completely intact leaf sections showing various tissues are reported here for the first time from Early Permian coals. Occurrence of such well preserved plant structures indicates that certain part of Indian Lower Gondwana coals could be partially of autochthonous in origin, while the Gondwana coals are known to have been formed by drifted plant matter, as also confirmed by the presence of distorted material. The palaeodepositional environment and nature of coal forming plant community has also been discussed.

Key-words—Macerals, Autochthonous, Liptinite, Palaeodeposition, Tatapani and Ramkola.

भारत के छत्तीसगढ़ प्रान्त के ततापानी तथा रामकोला कोयला क्षेत्रों से प्राप्त कार्बनिक स्रोत पदार्थ का विवेचन

शिंजिनी सरन

सारांश

ततापानी तथा रामकोला कोयला क्षेत्रों से प्राप्त कोयले के कोयला सूक्ष्मसंघटकों के विस्तृत अध्ययन से पर्ण परिच्छेदों, कॉर्क कोशिकाओं, सूक्ष्मबीजाणुओं, गुरुबीजाणुओं, शैवाल, रेज़िन, बीज, फल कायों का सुसंरक्षण प्रदर्शित हुआ है। पहली बार यहाँ के प्रारंभिक परमियन युगीन कोयलों से विभिन्न ऊतकों को प्रदर्शित करने वाले पूर्णतः अक्षुण्ण पर्ण परिच्छेद अंकित किए गए हैं। इस प्रकार की सुसंरक्षित पादप संरचनाओं की उपस्थिति इंगित करती है कि अधो गोण्डवाना कोयलों का कुछ अंश मूलतः स्वस्थानिक हो सकता है, जबकि गोण्डवाना कोयले विस्थापित पादप पदार्थों द्वारा निर्मित हुए जाने जाते हैं; यह भी विकृत पदार्थों की उपस्थिति से अभिपुष्ट हुआ है। इसके अतिरिक्त इस शोध पत्र में पुरानिक्षेपणीय पर्यावरण तथा कोयला निर्मित करने वाले पादप समुदाय की प्रकृति का भी विवेचन किया गया है।

संकेत शब्द—मैसेरल, स्वस्थानिक, लिप्टीनाइट, पुरानिक्षेपण, ततापानी तथा रामकोला.

INTRODUCTION

THE Tatapani and Ramkola coalfields form the eastern- most extension of Son Valley Basin, lying 25 km west of Hutar Coalfield. Rivers Kanhan and Rehar flank the eastern and western sides and drain into Son River. The location map appears in Fig. 1. The coalfields lie between 23°30' & 23°55' latitudes and 83°00' & 83°40' longitudes, the northern strip of coal-bearing rocks forms the Tatapani Coalfield and the southern strip as the Ramkola Coalfield. This area is located between Rampur fault in the north and Tatapani fault or Southern boundary fault in the south. 'Tatapani' owes its name to the famous hot spring emanating at 98·50°C from the Southern boundary fault.

Tatapani-Ramkola is a classical basin in which Gondwana sediments lie unconformably over the Basement metamorphic rocks. Talchir, Barakar, Barren measures, Raniganj, Panchet and Mahadeva formations comprise Gondwana Sequence in the area (Raja Rao, 1983; Fig. 2). Barakar Formation is represented by white fine to medium grained sandstone, micaceous grey shale, carbonaceous shale, shaly coal and coal seams. Thin coal bands occur in Raniganj Formation also. The seams at Tatapani-Ramkola are mostly lying as subsurface deposits represented by numerous coal bands. The thickness

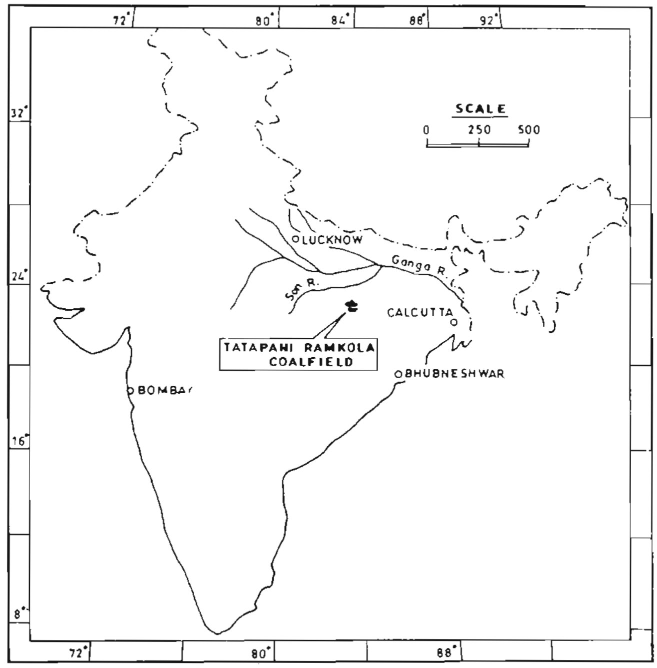
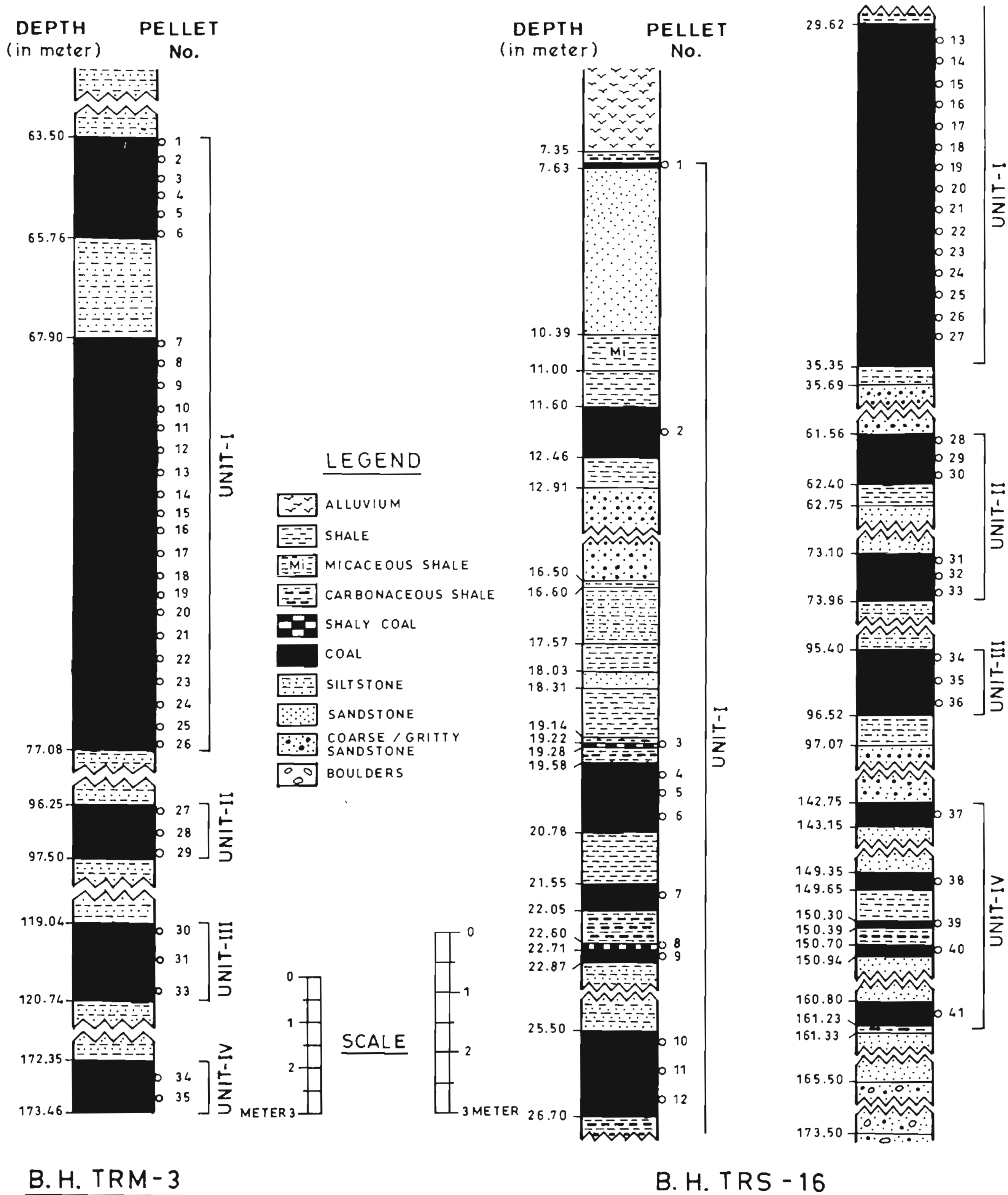


Fig. 1—Map showing the location of Tatapani-Ramkola coalfields in respect to other Gondwana coalfields of India.

AGE	FORMATION	LITHOLOGY
Recent		Alluvium.
Cretaceous?	Basic intrusives	Dolerite dykes.
Upper Triassic	Mahadeva	Thick, cross-bedded, coarse grained ferruginous sandstone.
Lower Triassic	Panchet	Yellowish, fine grained sandstone with alternating red and green siltstones, shales and clays.
Upper Permian	Raniganj	Micaceous fine-grained ripple laminated sandstones, grey and carbonaceous shales and shaly coal bands.
Middle Permian	Barren Measures	Ironstone shales showing box structure, fine grained sandstone, shales and argillaceous sandstone.
Lower Permian	Barakar	Medium to coarse grained pebbly arkosic sandstone, grey and carbonaceous shales and coal seams.
Lower Permian	Talchir	Diamictite, khaki-green needle shales, siltstone fine grained sandstone and varves.
-------------------------------- Unconformity --------------------------------		
Archaean		Granites, gneisses, mica and green schists, phyllites and quartz veins.

Fig. 2—Generalised stratigraphic sequence (after Raja Rao, 1983, modified by the author)

Fig. 3—Lithologs of Bore-Holes TRS-16 and TRM-3 which has been obtained from the GSI.


DEPTH (in meter)
PELLET No.
63.50
65.76
67.90
77.08
96.25
97.50
119.04
120.74
172.35
173.46
UNIT-I
UNIT-II
UNIT-III
UNIT-IV
B.H. TRM-3
LEGEND
ALLUVIUM
SHALE
MICACEOUS SHALE
CARBONACEOUS SHALE
SHALY COAL
COAL
SILTSTONE
SANDSTONE
COARSE / GRITTY SANDSTONE
BOULDERS
SCALE
METER 3
3 METER
Mi
7.35
7.63
10.39
11.00
11.60
12.46
12.91
16.50
16.60
17.57
18.03
18.31
19.14
19.22
19.28
19.58
20.78
21.55
22.05
22.60
22.71
22.87
25.50
26.70
29.62
35.35
35.69
61.56
62.40
62.75
73.10
73.96
95.40
96.52
97.07
142.75
143.15
149.35
149.65
150.30
150.39
150.70
150.94
160.80
161.23
161.33
165.50
173.50
B.H. TRS-16

	No. of spls		Vitrinite	Liptinite (Normal mode)	Liptinite (Fluoresc. Mode)	Inertinite	Min. matter
B.H.TRS-16							
UNIT-I	27	MEAN (%)	14	10	30	27	49
		RANGE (%)	0-52	1-28	12-49	9-48	19-78
UNIT-II	6	MEAN (%)	29	18	34	28	25
		RANGE (%)	12-50	3-34	1-53	15-46	12-41
UNIT-III	3	MEAN (%)	38	21	25	23	18
		RANGE (%)	19-56	16-26	16-32	18-31	10-24
UNIT-IV	5	MEAN (%)	31	15	22	29	25
		RANGE (%)	3-50	1-38	4-51	11-70	16-36
Total	*41*						
B.H.TRM-3							
UNIT-I	26	MEAN (%)	24	13	23	28	35
		RANGE (%)	0-63	3-34	8-46	10-53	21-67
UNIT-II	3	MEAN (%)	29	18	34	28	25
		RANGE (%)	12-50	3-34	14-53	15-46	12-41
UNIT-III	2	MEAN (%)	38	21	25	23	18
		RANGE (%)	19-56	16-26	16-32	18-31	10-24
UNIT-IV	2	MEAN (%)	31	15	22	29	25
		RANGE (%)	3-50	1-38	4-51	11-70	16-36
Total	*34*						
Grand Total	*75*						

Fig. 4—Distribution of macerals in the units.

of coal bands varies between 16 cm to 9 m and the estimated reserve of coal is 1027·76 million tones.

Bose *et al.* (1975), Srivastava and Kar (1997) and Srivastava *et al.* (1997) were the earlier workers who worked on the palaeobotanical and palynological aspects of Tatapani and Ramkola coals. Detailed petrological studies of coals from Tatapani-Ramkola coals have been undertaken for the first time by the author and the results are incorporated in this paper. The present investigation aims to throw light on the characterisation of organic source material based on the papers by Spackman *et al.* (1976), Teichmuller (1974, 1987, 1989), Teichmuller and Teichmuller (1981) and Teichmuller and Wolf (1977) who were the pioneer workers who named and characterised the source material of coal through fluorescence microscopy. In India the detailed fluorescing macerals studies have been done from Singrauli Coalfield (Misra & Singh, 1990, 1993), Rajmahal Basin (Singh & Singh, 1996) and Tertiary coals (Misra, 1992).

The formation of coal starts with the diagenesis of plant polymers (macromolecules) and ends with the formation of macerals. Certain plant polymers maintain themselves throughout the process of diagenesis, while others get degraded and form geopolymers like humic acid, fulvic acid, etc. (Casagrande, 1987). The plant polymers that maintain

PLATE 1 ⟶

(All the photomicrographs are in normal reflected white light)

1. Telinite with higher reflecting cell walls and spaces partially filled with mineral matter (x 150).
2. Telinite showing cell lumen infilled with gelocollinite (x 150).
3. A large grain of fusinite showing annual growth rings, small celled late wood and large celled early wood (Pl. x 150).
4. Secrinite (x 200).
5. Showing cell lumen transform into spheroidal and elliptical bodies (corpocollinite) in formative stages present between layers of cutinite in desmocollinitic groundmass (x 150).
6. Funginite (x 150).
7. A transitional stage between corpocollinite and macrinite showing oxidation rims (x 150).
8. Secrenite (x 100).

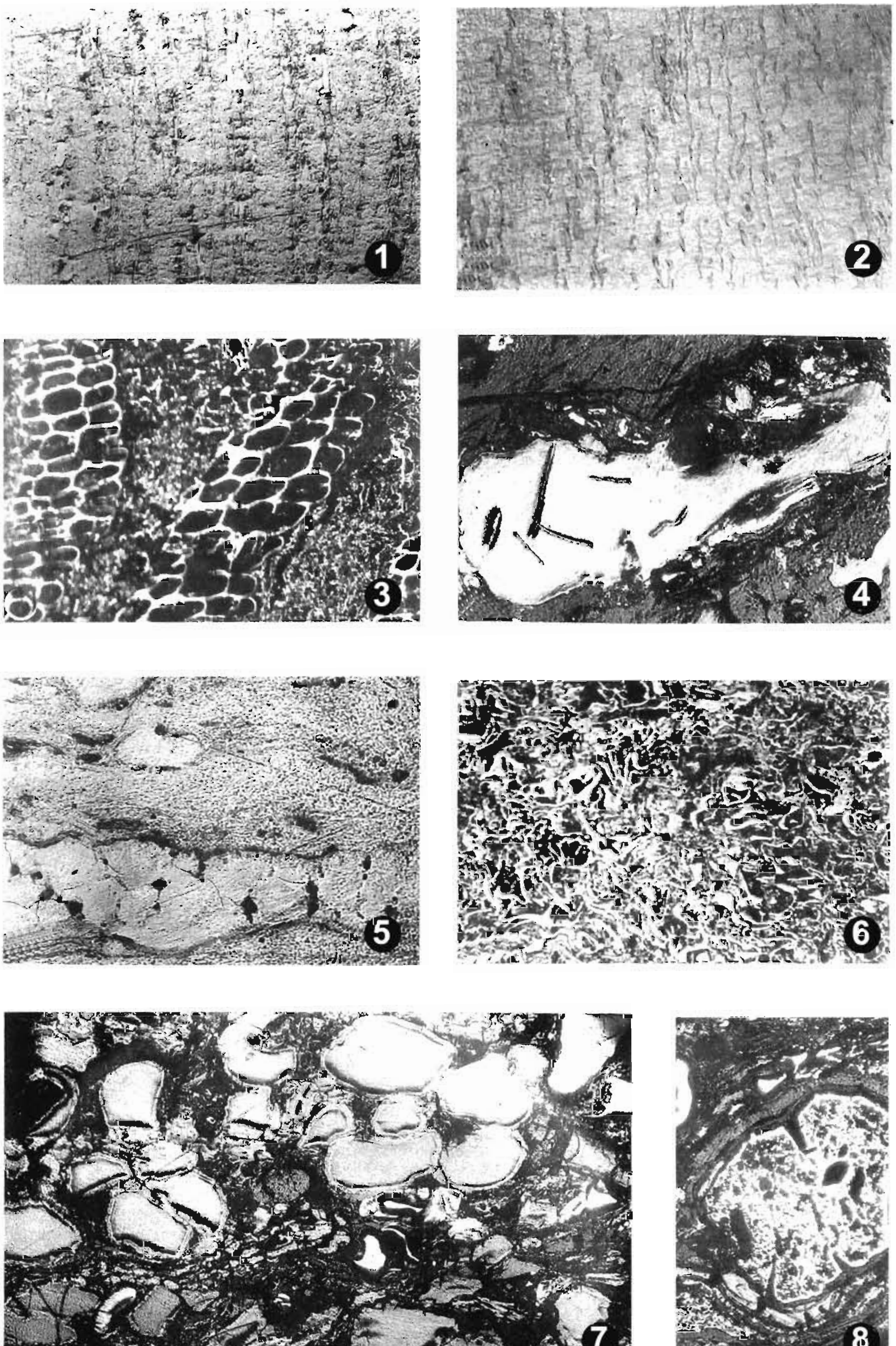


PLATE 1

themselves are manifested as structured liptinite macerals, e.g., cutinite, sporinite, suberinite, alginite and resinite. Those that could not maintain their original form either undergo the process of humification if oxygen is not available or inertinization in the presence of oxygen. The resultant macerals belong to vitrinite or inertinite maceral group, respectively. In addition well preserved cuticles, spores, cork cells, algae, resins and some unidentifiable fruiting bodies have also been reported in the present communication. These well preserved plant bodies indicate the palaeodepositional conditions.

MATERIAL AND METHODS

Seventy five samples of coal and carbonaceous shale from two bore-holes TRS-16 and TRM-3 courtesy GSI have been utilized in the present study. Their litholog appear in Fig. 3. Each sample represents 0·50 m of the bore-core section. A term "Unit" has been given to coal bands separated by inorganic partings of greater than 19 m thickness. Each Unit has one or more major coal bands or one or more minor coal bands or both. The 19 m thickness has been taken as the basis for the separation of Units, as it is the minimum width of the parting present in the bore-holes. These Units represent a particular depositional environment in which the sediments were laid down and were identified in the boreholes, named as Unit I, Unit II, Unit III and Unit IV starting from the top (Fig. 3). However, the number of workable coal seams is only three (Raja Rao, 1983). Therefore, seams form a part of the Unit.

The samples were crushed to ±2·0 mm size, mounted in epoxy resin, ground and polished, according to standard procedures (ICCP, 1971, 1975). The maceral and microlithotype studies were done under normal mode on Leitz Orthoplan Microscope fitted with automatic photographic unit (vario orthomat). Up to 500 counts per sample were taken using automatic point counter (James swift model F) for quantitative assessment of fluorescing and non-fluorescing macerals.

The material from which most of the plant entities have been recovered is collected from a 1·25 m thick coal band at 96.25 m depth in Bore-Hole TRM-3 of Tatapani Coalfield and from certain bore-core samples of Ramkola Coalfield (Fig. 3). The study has been carried out on circular (diameter= 3 cm) coal pellets in fluorescence mode under reflected light.

BOTANICAL ENTITIES IN COAL

On the basis of characteristic morphological features observed during petrological study of coal, the source material has been classified and described under the following subheadings:

1. Dominantly wood derived
2. Dominantly foliage derived
3. Dominantly reproductive entities

Dominantly wood derived

Most of the macerals belonging to vitrinite and inertinite groups are derived from gymnospermous wood except phyllovitrinite. However, suberinite of liptinite maceral group derived from cork cells of bark tissues also belong to this category.

Vitrinite Group

Vitrinite maceral group is represented by telinite, telocollinite, desmocollinite, corpocollinite, vitrodetrinite and gelocollinite macerals. Telinite (Pl. 1·1, 2) and corpocollinite (Pl. 1·5, 7) are the only macerals in which the shape of the plant cell remains preserved. The other macerals of the vitrinite group acquire a more or less homogeneous nature through the processes of compaction, dehydration and gelification.

Telinite is characterised by the presence of incipient cell structure. Telinite occurs in two forms. Commonly the cell walls are more highly reflecting than the cell lumen (Pl. 1·1) and rarely the cell walls are gellified (Pl. 1·2).

Desmocollinite forms the groundmass for most of the bimaceral and trimaceral microlithotype. Due to the large quantity of liptinite macerals associated with desmocollinite often they are found to be fluorescing (Pl. 1·5).

Corpocollinite is often represented as infilled material of cell lumen or secretion of certain cells especially in bark tissue. Corpocollinite occurs as isolated bodies or in cluster. Their origin from cell lumen is quite clearly shown in Pl. 1·5. The upper and lower cuticle of phyllovitrinite (vitrinite formed from leaf tissue) is shown to be absolutely intact (Pl. 1·5). On severe oxidation the reflectance of corpocollinite increases to the level

PLATE 2 ⟶

(All the photomicrographs are in fluorescence mode)

1. A transverse section of leaf showing bright orange-yellow ventral cuticular layer, the yellow upper palisade and spongy parenchyma and feebly fluorescing vascular strand.
2. Yellow resins in fluorescence mode.
3. The transverse section of a complete leaf with dorsal and ventral layers of cuticle and intact cuticular ledges. The ground tissue is of desmocollinite.
4. Resin nodule with sporinite fluorescing bright yellow under fluorescence mode.
5. Suberinite showing rectangular and polygonal cork cells under fluorescence mode. Exsudatinite intruded in a desiccation crack of vitrinite.
6, 7. Alginite-algal colonies of *Botryococcus braunii* showing cups covered by a mucilaginous sheath.
8. A mosaic of smooth walled macrosporinite. Mineral matter and liptodetrinite has replaced the inner body.
9. Unidentified fruiting body.
10. Mosaic of a macrosporinite measuring 1.982 mm.

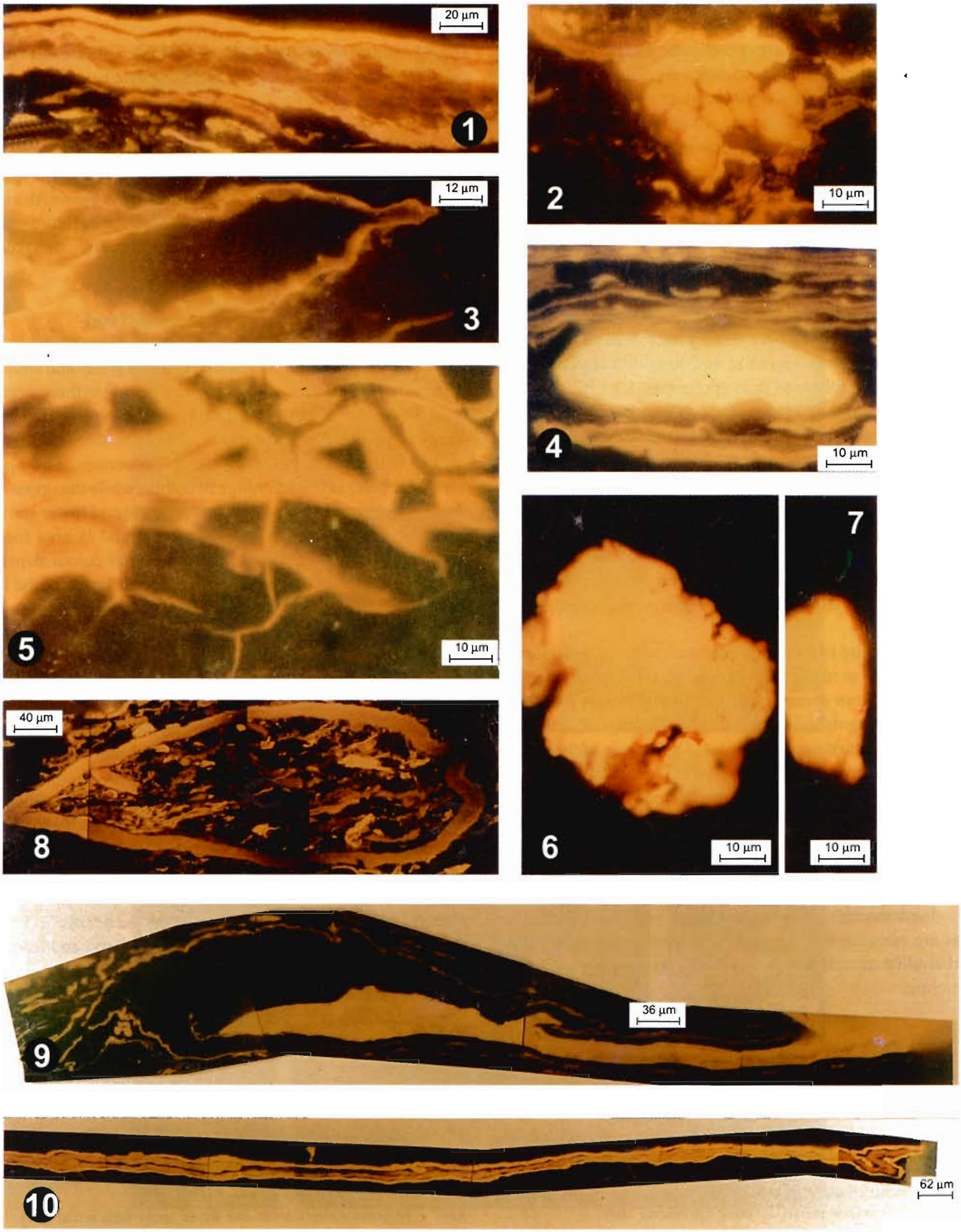

20 µm
1
10 µm
2
12 µm
3
4
10 µm
7
5
10 µm
40 µm
8
6
10 µm
10 µm
36 µm
9
10
62 µm

PLATE 2

of semifusinite and fusinite, sometimes also acquiring similarity to macrinite. Oxidation rims have been developed due to severe oxidation in some of the corpocollinites (Pl. 1·7).

Vitrodetrinite and gelocollinite are not very common in Tatapani-Ramkola coals.·Vitrodetrinite mostly occurs in dull coals in association with durite and carbargillite. Gelocollinite occurs as infillings in cell cavities in association with telinite (Pl. 1.2).

Inertinite Group

Inertinite maceral group comprises fusinite, semifusinite, inertodetrinite, sclerotinite and macrinite (ICCP, 1971, 1975). However, the International Committee for Coal & Organic Petrology (ICCP) replaced the term sclerotinite by the newly recognised macerals secrenite and funginite (Lyons, 2000) which has been followed in the present text.

Fusinite and semifusinite both can be conspicuously recognised on the basis of their higher reflectance and distinct cell structures, the only difference lies in their comparative reflectance. Fusinite is more highly reflecting than semifusinite.

Sclerotinite is the only plant specific maceral of the inertinite group. Sclerotinite has been classified into two categories (Lyons, 2000).

1. Funginite includes macerals with plant structure and is of fungal origin. It encloses fungal spores and mycelium (Pl. 1·6).

2. Secrenite is related to macerals without having plant structures such as macrinite (top right Pl. 1·7). Unlike funginite, it originates from secretory ducts of medullosan seed ferns. They are distinguished by notch and kerfs (curved structures) and resin rodlets or needles (Pl. 1·4, 8). The size of the needle-like bodies in cross section can be used to identify the genera and species of the cycads of Late Palaeozoic and Mesozoic Eras (Lyons, 2000).

In Tatapani-Ramkola Coalfield the percentage of funginite and secrenite is 3%. Pareek recorded them in various Gondwana coals (Pareek, 1966, 1970).

Inertodetrinite represents detrital particles of inertinite that are commonly associated with durite, trimacerite and carbargillite microlithotypes. They may or may not show plant structure.

Liptinite Group

Liptinite group comprises suberinite, cutinite, sporinite, alginite, fluorinite and leptodetrinite of which only suberinite is wood derived.

Cork cells give rise to maceral suberinite. The term is derived from latin word 'suber' meaning cork. In polished sections, it appears as rectangular, brick-like and polygonal four to six sided cellular bodies. Suberinite is brownish black in reflected white light and yellowish orange in fluorescence mode (Pl. 2·5). In Tatapani-Ramkola coals, the overall occurrence of suberinite is rare.

Dominantly foliage derived

Phyllovitrinite of the vitrinite maceral group and cutinite, fluorinite of the liptinite maceral group belong to this category.

Very well preserved leaf section is being reported from Lower Gondwana coals of India. It has been observed that the whole leaf section has fluorescing properties. The upper cuticular layer is bright orange in colour, while the upper and lower epidermis along with upper palisade and lower spongy parenchyma is yellow. The vascular strand is also feebly fluorescing. The fluorescence intensity and colour depends upon the chemical composition of different layers of the leaf section (Pl. 2·1). Since the cuticle is present only on the upper epidermis, the leaf section seems to be a portion of a hydrophytic plant, a plant that grows in water and marshy or swampy habitats. The presence of cuticle only on the upper epidermis prevents excessive transpiration. The surface in contact with water lacks cuticle so that the cells are capable of absorbing water and nutrients throughout their surface directly rather than by roots alone.

The cuticles separated from leaves form a common feature in certain coal bands of Tatapani and Ramkola Coalfields. They are either thin walled tenuicutinite (Pl. 2·3) or thick walled crassicutinite. The "cutine" of cuticles is similar to "sporine" of spores in chemical composition but are less resistant than "sporine" and more resistant than "suberine". These substances are not accepted as food by bacteria and fungi as they are glycerine esters of fatty acids (Teichmuller, 1982). Cutinite is free from cellulose, the secretion of cutine occurs between the cells of the epidermis which forms the characteristic cuticular ledges (Pl. 2·3).

PLATE 3 →

1. Microsporinite showing a bisaccate pollen with saccii attached to the central body.
2. Microsporinite - appears to be a zonate trilete spore.
3. Microsporinite - appears to be a monosaccate pollen showing bright yellow saccus covering the central body.
4. Microsporinite showing a monosaccate pollen with folded saccus.
5. Microsporinite showing a bisaccate pollen with saccii attached to the central body.
6. Microsporinite - appears to be a rounded alete spore.
7. An assemblage of microsporinites.
8. Microsporinite - a circular trilete spore with tetrad mark.
9. Microsporinite - a spore with dull brownish orange fluorescence and slit like mark.
10. Mosaic of a portion of a seed.

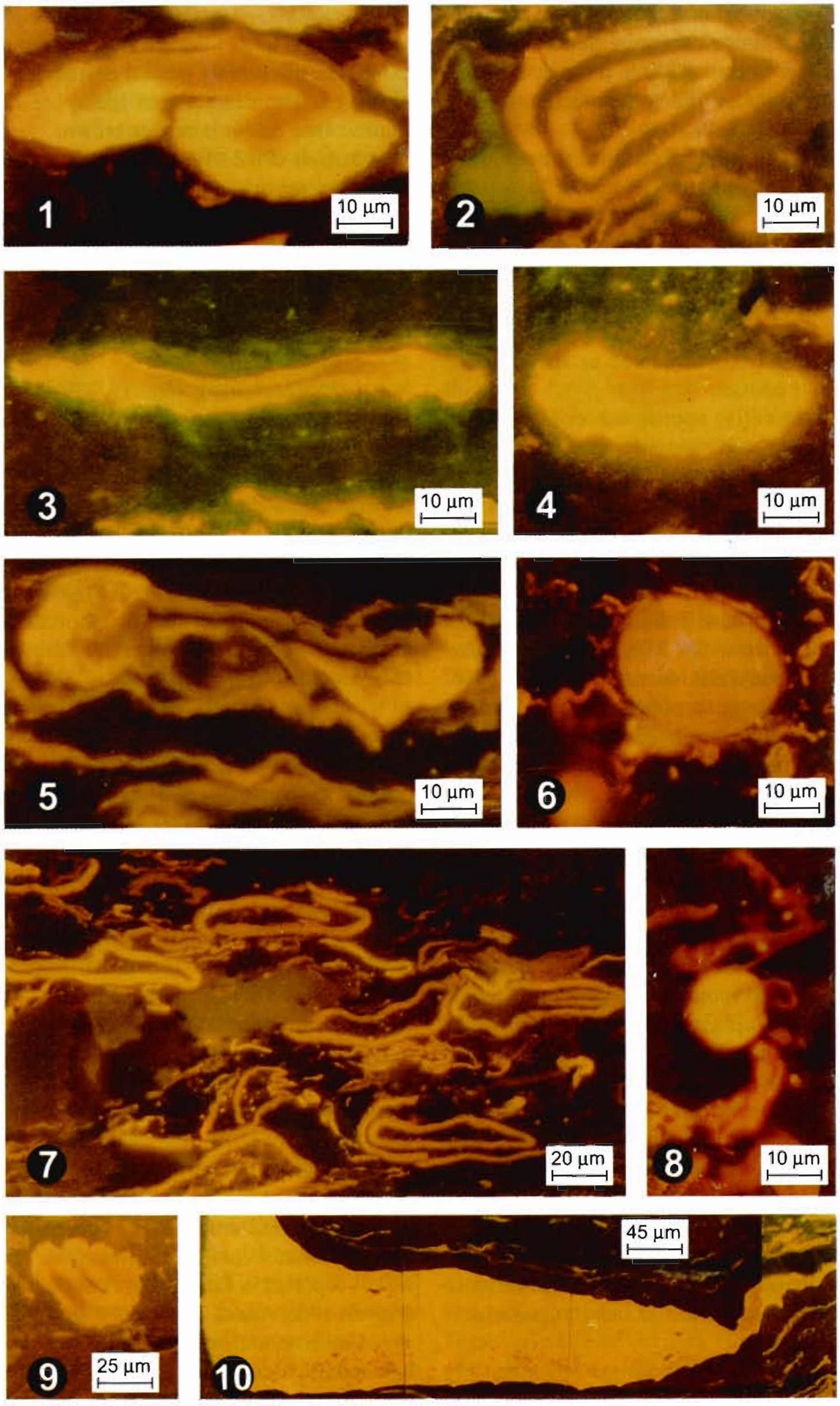

1
10 µm
2
10 µm
3
10 µm
4
10 µm
5
10 µm
6
10 µm
7
20 µm
8
10 µm
9
25 µm
10
45 µm

PLATE 3

Fluorinite has unusually strong yellow to greenish yellow fluorescence in low rank coals (Teichmüller, 1974). Fluorinite shows striking optical properties and a strong affinity to clarite. It typically occurs in association with cutinite. Schneider traced the genesis of fluorinite way back in 1986 through cuticular analysis of leaves of Myricaceae having aromatic essential oils (*in* Spackman & Thompson, 1964).

In Tatapani-Ramkola Coalfield, fluorinite has been found associated with both corpocollinite and cutinite. Taylor and Teichmuller (1993) have already reported similar associations in German coals.

Dominantly reproductive entities

Spores, sporangia and seeds counted as sporinite are dominantly reproductive entities.

Sporinite—Chemically, spores are composed of sporopollenin, which is an oxidative polymer of carotenoid esters present in the exine. Due to the higher degree of cross-linking, it is the most resistant of all liptinite macerals. Since spores and pollen exines are usually compacted in coal, they appear as small flattened lenses (Pl. 3·7).

Maceral sporinite comprises two submacerals namely microsporinite and macrosporinite. The size of microsporinite varies between 10 to 200 microns (Pl. 3·7). The spores greater than 200 microns are grouped under macrosporinite (Pl. 2·10).

Microsporinite—On the basis of palynological studies, a number of classification schemes have been proposed, but petrologically spores cannot be identified with precision as they get cut along various planes during grinding and polishing of pellets. But features like exine, intine, trilete marks, saccii and folds can be broadly distinguished if the preservation is very good and types could be demarcated on the basis of their morphological characters but genus and species could not be identified on the basis of petrology as could be seen in the present investigation.

Spores are single celled reproductive entities of lower plant groups like fungi, bryophyta and pteridophyta, while pollens belong to higher plant group like gymnosperms. Miospore is a term used when distinction between spore and pollen cannot be made. In normal incident light these miospores look like black or brownish black thread like structures, while in fluorescence mode a variation of colour in sporinite has been observed which is from bright yellow to orangish brown (Pl. 3.7).

Three types of spores have been recorded on the basis of their shape and nature of trilete mark from the lowermost coal band of B.H. TRM-3 from Tatapani-Ramkola Coalfield.

1. Circular trilete
2. Zonate trilete
3. Alete

1. *Circular Trilete* (Pl. 3·8) is a small spore having a diameter of 15 microns with trilete mark at the centre and a non-ornamented thin exine, the fluorescence colour being yellow.

2. *Zonate Trilete* (Pl. 3·2) is represented by a transverse section of the spore having a zone and a thin non-ornamented exine. The trilete mark present on one side of the exine can be observed. The diameter of the spore is 50 microns and fluorescence colour is orange brown.

3. *Alete* (Pl. 3·4) spore is characterised by a linear fold. The diameter of the spore is 27 microns and fluorescence colour is brownish-orange.

Two types of pollen grains, on the basis of their morphological characters have been recorded from the third seam of B.H. TRM-3.

1. Monosaccate
2. Bisaccate

1. *Monosaccate pollen* (Pl. 3·3, 4) is characterised by a saccus attached to the central body, which usually appears brown under fluorescence mode. The diameter of the central body is 47 microns. Saccus covers the whole central body and the maximum diameter of the pollen is 79 microns. The fluorescence colour of the central body is brown and that of saccus is bright yellow.

2. *Bisaccate pollen* (Pl. 3·1, 5) has a central body to which two saccii are attached. The photomicrographs show a transverse section of the pollen. The diameter varies between 65 microns to 75 microns.

Macrosporinite—Megaspores (macrospores) included under this category are single celled reproductive bodies of heterosporous pteridophytes. They are not as frequently occurring as microspores. The size range of megaspores varies from 200 microns to 3000 microns or more (Pl. 2·8, 10). The Lower Gondwana megaspores are mostly smaller than 1000 microns (Bharadwaj & Tiwari, 1970). One rare large sized megaspore is being reported here (Pl. 2·10). It is a very well preserved megaspore measuring 1982.00 microns. It has been recorded from B.H. TRS-16 from Ramkola sub-basin. Like most of the megaspores reported from Lower Gondwana sediments this megaspore also has an inner body appearing light brown in fluorescence mode. The exine is fluorescing bright yellow and appears to be without ornamentation. It has a bifurcated trilete mark of dark brown colour. The mark has many thick projections called trilete laesurae noted in Upper Permian coals (Maheshwari & Bajpai, 1984). The inner body and the exine are not clearly distinguishable. The trilete mark appears like a thin brown thread structure. The occurrence of macrosporinite is significant for coal seam correlation. They have been very widely reported in various forms in Gondwana coals of India (Pareek, 1965; Anand-Prakash, 1970)

Under normal reflected light, macrosporinites appear as light reddish brown to dark grey coloured bodies with granular texture. Whereas, under fluorescence mode they show variation of colours. The colour varies from grey exine and bright yellow intine to bright yellow exine and light brown intine. Very well preserved megaspores with sculptured exine have also been observed. Sometimes detrital mineral matter and liptodetrinite replaces the central body of the megaspore (Pl. 2.8)

Algae

Algal remains are represented by the maceral alginite in coals. This term is derived from Latin word "alga" meaning sea grass. It is similar to clay particles and appears as black globular mass, which is darker than the sporinite in normal reflected light and has a positive relief (ICCP, 1971, 1975).

Alginite can be identified on the basis of strong bright yellow fluorescence, showing positive alteration when excited by short wave radiation. The colonies of algal bodies appear as cups, which are connected by a mucilaginous covering and can be observed under different foci. Although many types of alginite, like *Pila* type, *Reinchia* type, *Caldiscothallus* type have been observed in Lower Gondwana coals, the *Botryococcus braunii* is the most common variety that also occurs in Tatapani-Ramkola coals (Pl. 2·6, 7). The size of the colonies varies widely.

Gymnospermous seed

A portion of the gymnospermous seed has been observed from the third coal seam of B.H. TRM-3 (Pl. 3·10). Such seeds have also been reported from Talchir and Rajmahal coalfields (Anand-Prakash *et al.*, 1996). It is a seed or mature ovule cut in longitudinal section showing a micropylar projection and serrated margin of the stony seed coat. It measures 0·194 x 0·575 mm.

Unidentified fruiting bodies

The structure has an oval body with a stalk- like projection at the base (Pl. 2·9). A similar structure has also been observed from Godavari Coalfield (pers. commun. Dr Sarate), but the difference lies in the size. The one reported from Godavari Coalfield is much bigger in size as compared to the present structure. It might be a germinating seed with a radicle or a sporophyll (mega or micro) detached from the cone showing the stalk and a thorn like projection at the base.

Resin

Maceral resinite can be incorporated in any of the above three categories because it occurs either as resin ducts or secretory cells, in sclereids, in leaves, stems, seeds, rinds of fruits or in dispersed form as lumps (Pl. 2·2), nodules (Pl. 2·4) and rodlets. Resins in coal occur as rounded or subrounded fluorescing bodies of pale yellow to orangish yellow colour which appear reddish brown to blackish or greyish under normal reflected light. However, it is for the first time a bright yellow resin nodule has been observed and reported in Indian Lower Gondwana coals (Pl. 2·4).

DISCUSSION

Tatapani-Ramkola coals like most of the Lower Gondwana coals of India are of low rank and grade that are characterised by the dominance of dull bands with occasional bright bands of variable thickness. These dull coals are dominantly composed of the macerals of fusinite and liptinite and subordinate proportions of vitrinite associated with the variable amount of inorganic mineral matter (Fig. 4). This variation in the coal bands reflects upon the nature of source material and depositional conditions. The dull coals rich in inertinite group of macerals generally pass through the process of fusinization, whereas the vitrinite fraction passes through the process of gelification.

However, occasionally the vitrain bands of variable thickness have been encountered in the bore-holes. The petrological investigations of the coals have revealed that some of the bands contain very high amount of liptinite macerals, particularly well preserved microspores, megaspores, leaf sections, cork cells, algal and resin bodies and other liptinite macerals. Such a characteristic dominance of liptinite macerals in a particular coal band raises a question that under what type of depositional conditions so much of liptinitic material has been accumulated? Further, the preservation of liptinitic macerals is of very high quality. Probably, this has been possible either by the plant matter deposited under autochthonous or hypoautochthonous conditions as suggested by Anand-Prakash *et al.* (1996) for Singrauli and Talchir coalfields or due to the quick burial and compaction of the accumulated fossil peat.

If at all the vegetal matter has been transported it was brought to the basin from very short distances. This appears to be the reason for the exceptionally good preservation of fragile and large sized megaspores, algal remains and leaf sections. Here it has also been suggested that the coal bands rich in cuticles and leaf sections seem to have been contributed by the accumulation of leaves in small shallow niches usually present in the flood plains of a fluvial system. Other evidences in support of the short distance transportation of source material, besides non-damaged leaves and megaspores, is the presence of larger grains of fusinite (Pl. 1·1) and of semifusinite (Beeston, 1987, 1991).

The intact plant entities in high frequency indicate that the wetland at that particular span of time had easy access to high spore yielding herbaceous plants, like sedges and reeds and undergrowths mainly comprising lower plant groups such as bryophytes and pteridophytes. It is also suggested that the particular band of coal rich in megaspores might have been developed at the edge of the wetland where a mixed type of vegetation existed comprising both herbaceous and woody plants.

SUMMARY AND CONCLUSION

In the present investigation macerals have been categorised on the basis of source material into three divisions namely (i) dominantly wood derived; (ii) dominantly foliage derived and (iii) dominantly reproductive entities.

The wood derived macerals are dominantly vitrinitic and inertinitic of which phyllovitrinite, corpocollinite, secrenite and funginite are the only ones that could be traced to a specific plant part. Dominantly reproductive entities mainly comprise spores and pollen that can be broadly distinguished into different types on the basis of morphological character if the preservation is very good. It has also been observed that in Lower Gondwana coals of Tatapani and Ramkola coalfields such well preserved plant parts are confined to specific coal band, emphasizing a unique palaeodepositional condition, related to depth of water in the peat swamp which affected the type of vegetation and also mode of preservation of the petrographic entities.

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