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Fluorescence microscopic investigations of the main lignite seam from the Neyveli Lignitefield, Tamil Nadu, India*

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ABSTRACT

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The organic (maceral) composition of the main lignite seam encountered in bore-holes NLE-27, 35 and 36 from mine III of Neyveli Lignitefield has been investigated under fluorescence mode (blue light excitation). The lignites are of sub-bituminous C stage (R_o max. 0.39% ASTM classification) and predominate in the huminite group of macerals followed by those of the liptinite and inertinite groups. Liptinite macerals, viz., liptodetrinite, bituminite, chlorophyllinite and various forms of resinite and perhydrous huminite, usually indistinct under normal mode, are recognized and more information about their characters and mode of occurrences has been presented. The data generated have led to a more detailed understanding of the source material, swamp type, and genesis of Neyveli main lignite seam.

Key-words—Petrology, Fluorescence, Neyveli lignite, Tertiary.

सारांश

भारत के तमिलनाडु प्रान्त के नयवेली लगुडांगार (लिग्नाइट) क्षेत्र से प्राप्त मुख्य लगुडांगार सीम का प्रतिदीप्ति सूक्ष्मदर्शी की सहायता से अन्वेषण

अल्पना सिंह एवं बसन्त कुमार मिश्र

नयवेली लगुडांगार क्षेत्र की खदान सं. 3 के वेध छिद्र सं. एन.एल.ई.- 27, 35 एवं 36 में समागमित प्रमुख लगुडांगार सीम के कार्बनिक (मैसेरल) संघटन का प्रतिदीप्तीय अवस्था (नीले प्रकाश उत्तेजन) के अन्तर्गत अन्वेषण किया गया। यह लगुडांगार उप बिटुमेनी 'सी' अवस्था (R_o अधिकतम 0.39% ए.एस.टी.एम. वर्गीकरण) का है तथा इसमें मैसेरलों के ह्यूमीनाइट वर्ग की प्रधानता है, तत्पश्चात क्रमशः लिप्टीनाइट तथा इनर्टीनाइट वर्ग आते हैं। लिप्टीनाइट मैसेरल, जैसे - लिप्टोडेट्रीनाइट, बिटुमिनाइट, क्लोरोफ़िल्लीनाइट तथा रेज़िनाइट एवं परहाइड्रस ह्यूमीनाइट के विभिन्न रूप प्रायः सामान्य अवस्था में अस्पष्ट स्थिति में पहचाने गए हैं तथा उनके अभिलक्षणों एवं प्राप्ति की अवस्था के विषय में अधिक जानकारी प्रस्तुत की गई है। उपलब्ध आंकड़े स्रोत पदार्थ, अनूप प्ररूप तथा मुख्य लगुडांगार सीम की उत्पत्ति से सम्बन्धित अधिक विस्तृत सूचनाएँ प्रदान करते हैं।

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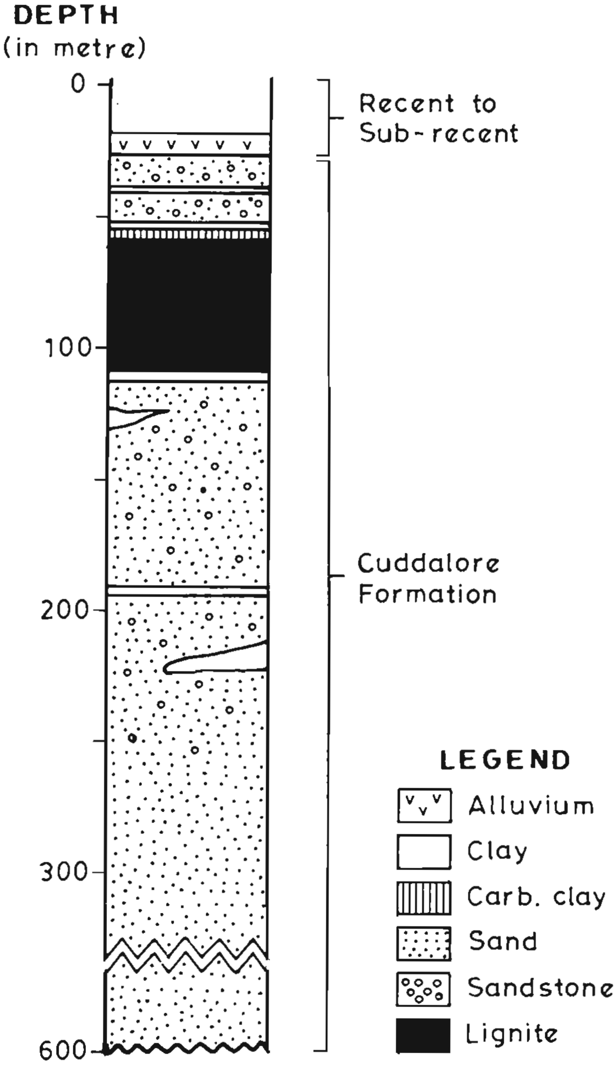
INTRODUCTION

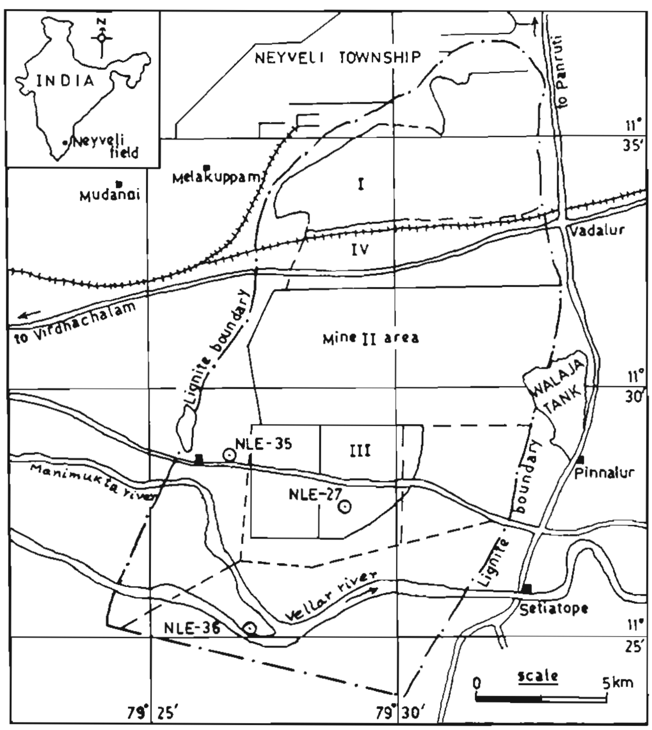
NEYVELI Lignitefield, extending in an area of about 480 sq. km between the latitudes 11°15' : 11°40'N and longitudes 79°25' : 79°40'E in the State of Tamil Nadu, is the largest mining lignitefield of India with an estimated reserve of about 3,300 million tonnes. The lignite occurs in and around village Neyveli in South Arcot Basin or Ariyalur-Pondicherry sub-basin of the Cauvery main Basin.

In the area, the Precambrian metamorphic rocks (schists and gneisses) form the basement over which lies a sedimentary sequence of Ariyalur Group (Late Cretaceous). The Cretaceous rocks (fossiliferous limestones, calcareous sandstones and marlstones) are unconformably overlain by the Tertiary sediments. The Cuddalore Formation (Mio-Pliocene), containing the lignite deposit, tops the sequence and is in turn covered completely by recent alluvium (Text-figure 1; for details refer Gowrisankaran *et al.*, 1987; Singh *et al.*, 1992).

The Cuddalore Formation comprises alternating beds of sandstone, clayey sandstone, sandy clay, carbonaceous clay, besides a thick lignite seam— the main seam in its upper part. The seam is encountered at a depth of about 40 to 150 m below ground level. Its thickness varies between 6 to 27 m and it tends to split into two or three (sometimes more) seams towards southern and western periphery of the area. There are few local and uneconomic seams overlying the main seam.



Text-figure 1—A generalized lithological succession of the Neyveli Lignitefield, Tamil Nadu (not to scale).



Text-figure 2—A Map showing mining blocks in Neyveli Lignitefield and location of investigated bore-holes NLE-27, 35 and 36.

PLATE 1 ⟶

(All photomicrographs were taken on polished surface under incident blue light excitation using oil immersion)

1. Fluorescing (perhydrous) huminite associated with liptodetrinite, ca x 400.
2. Suberinite (suberinized cell walls), ca x 400.
3. Cutinite showing epidermal cells and stomata. Note elongated cuticular ledges in oblique section at the bottom, ca x 400.
4. Resinite filled in cell lumina, ca x 600.
5. Resinite- single elongated body fluorescing with yellowish-brown colour, ca x 400.
6. Sporinite- a trilete and a monolete spores, ca x 600.
7. Alginite (*Botryococcus*), ca x 700.
8. Chlorophyllinite fluorescing with red colour inside the leaf tissue, ca x 800.

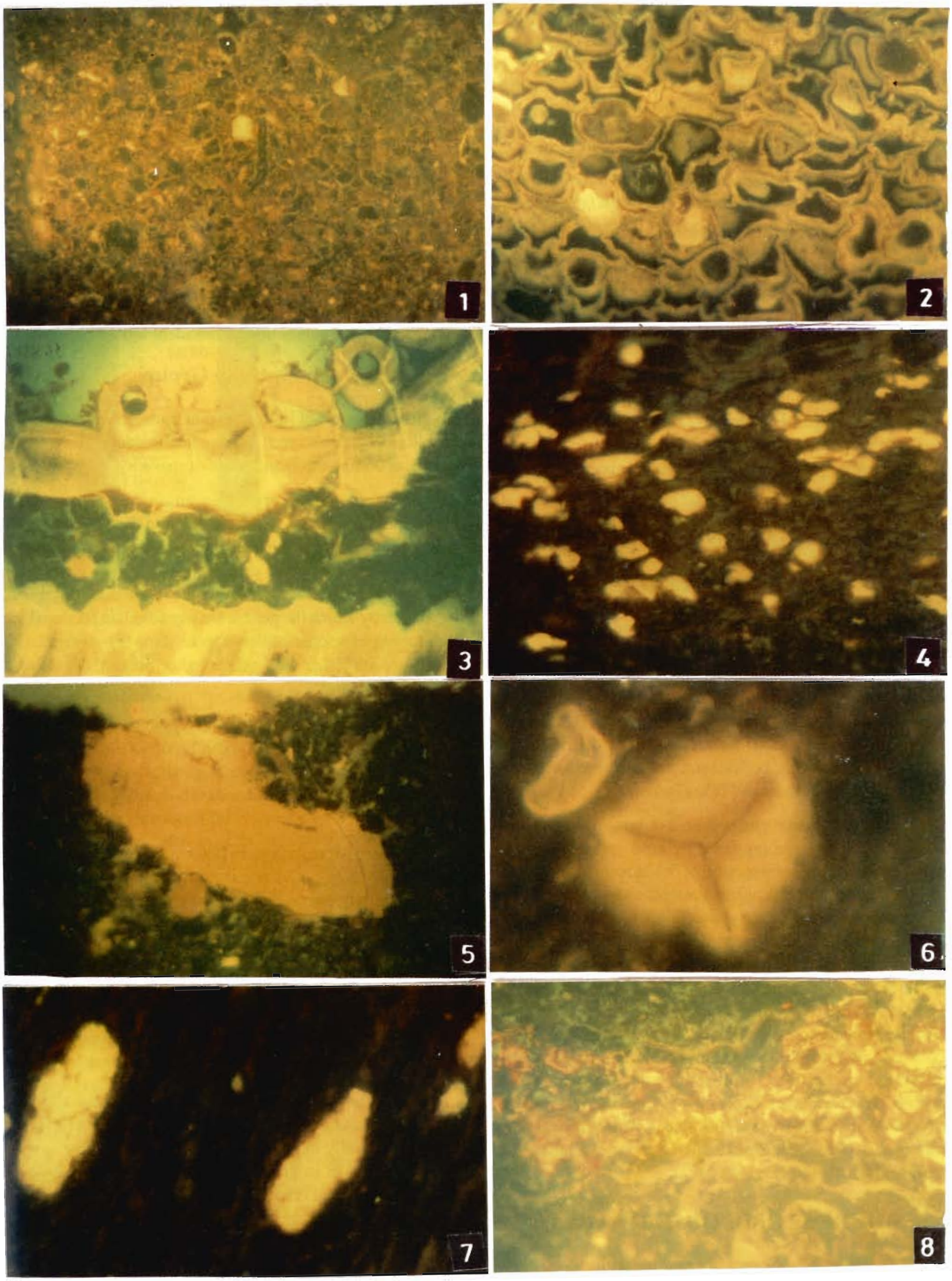


PLATE 1

Stupendous information on palaeobotanical constituents of the Neyveli lignite has been gathered since latter part of the 1950 (for detail references see Singh *et al.*, 1992) . The data accumulated have been potentially used to interpret palaeofloristics and palaeoclimate of the deposit. However, the studies on petrological constituents of lignites, much useful to understand the process of coalification and the genesis of the organic deposit, started during the late sixties (Navale, 1968). The available information on petrology of Neyveli lignite is mainly based on incident white light microscopy (Navale, 1971; Navale & Misra, 1980; Singh *et al.*, 1992; Singh & Singh, 1993).

A considerable advancement in the microscopic techniques during recent years necessitates the assessment of lignite deposit by newer techniques. The fluorescence microscopy, a better and more reliable method to evaluate and to assess the hydrogen-rich macerals (liptinites and perhydrous or fluorescing huminite) in particular, has been used presently and the information gathered on liptinite macerals has been utilized for a critical evaluation of the lignites.

MATERIAL AND METHOD

Thirty-nine core samples (37 lignite and 2 lignitic clay) from three bore-holes NLE-27 (25.0 m lignite), NLE-35 (5.85 m lignite) and NLE-36 (7.50 m lignite and 6.20 m lignitic clay) from mine III of Neyveli Lignitefield (Text-figure 2), obtained through the courtesy of the Geological Survey of India, have been used for the present study. The samples collected vertically (approximately metre by metre) represent the main lignite seam in different sections. The distribution of lignite and lignitic clay beds encountered in the three bore-holes are shown in lithologs (Text-figure 3).

The samples were crushed (± 1-2 mm grain size) and particulate pellets were prepared by cold embedding using epoxy resin and hardner in a ratio of 5:1 at room temperature. The fluorescence microscopic investigations were carried out under violet-blue light excitation (Filter block H3: 420-490 nm) on Leitz MPV-3 unit using 150 Watt ultra high pressure Xenon lamp as a source of illumination, 25x NPL Fluotar oil objectives with 0.75 numerical aperture and fluorescence free immersion oil following the recommendations of ICCP (1971, 1975). By using automatic point counter (James-Swift Model F), 500 counts per sample have been counted for quantitative assessment of various fluorescing and non-fluorescing macerals. The results are expressed as volume per cent (vol. %) on mineral matter-free (m.m.f.) basis. The descriptive terminology for fluorescing macerals is given by Stach *et al.* (1982) and Misra and Navale (1992).

MICROSCOPIC OBSERVATION

Of the three main maceral groups of lignite— huminite, liptinite and inertinite (ICCP, 1971, 1975), the fluorescence is shown mainly by relatively hydrogen-rich liptinite macerals. A fraction of huminite designated as fluorescing or perhydrous huminite (=fluorescing or perhydrous vitrinite in bituminous coals) fluoresces with low intensity. On the contrary, the macerals of inertinite group do not fluoresce at all.

Huminite Group

The huminite maceral fluoresces with yellowish-brown to dark brown colours when it is associated with very small fluorescing particles of liptinite group (Pl. 1, fig. 1). The perhydrous huminite generally forms the groundmass for other macerals. Fluorescing huminite appears low reflecting and spongy in nature under normal incident light.

Liptinite Group

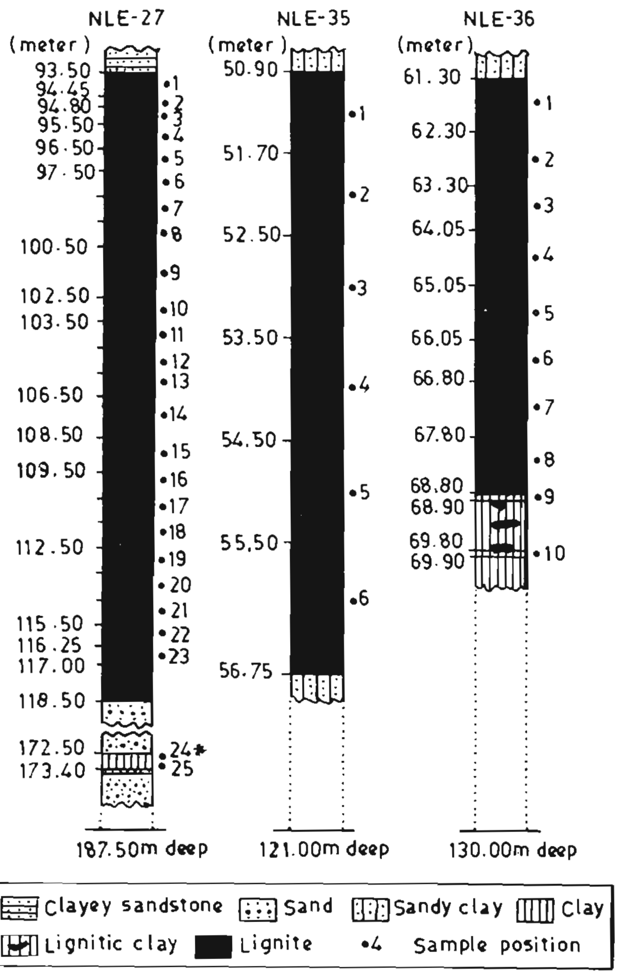
The macerals of liptinite group fluoresce with wide range of colours (green to red) and intensities depending on their chemical composition and stage of maturity.

Sporinite—It incorporates angiospermic pollen and pteridophytic spores. It exhibits dull and dark yellow, brownish-yellow, yellowish-brown and reddish-brown fluorescence colours. The outer wall of pollen and spores is invariably brighter than the inner wall. The outer wall also contain ornamentation by which the genera are identified. In sectional view, the lumina of spores-pollen appear dark (Pl. 1, fig. 6). The sporinites are either well-preserved or broken, degraded and in granular forms.

Suberinite—The maceral fluorescing with brownish-yellow to yellowish-brown colours incorporates periderm and covering of fruits and roots. It generally occurs as tabular multicellular thick or thin bands (Pl. 1, fig. 2) but sometimes it is represented by a few-celled fragments or shreds.

Cutinite—It incorporates outer covering of leaves, shoots and thin stems, etc. Cutinite is easily recognized by cuticular ledges (cutin between the walls of the epidermis). In surface view it exhibits underlying polygonal epidermal cells. Both tenui- (thin) and crassicutinites (thick) have been recorded. Generally the first type fluoresces with brown to reddish-brown colours, whereas the second type fluoresces with brownish-yellow colour with relatively higher intensity. Cutinite with well-preserved cuticular ledges and stomatal structures have also been observed (Pl. 1, fig. 3).

Alginite—It is mostly represented by the algae *Botryococcus* which is formed by numerous unicellular algae arranged radially in groups. Its colonies have been found either discretely or in groups (Pl. 1, fig. 7). In most cases it is well-preserved and is recognized by the cup-shaped openings. Degraded and broken, but still identifiable specimens have also been observed. Alginite emits bright yellow and orangish-yellow fluorescence colours with higher intensities in comparison to other liptinite macerals.



Text-figure 3—Core logs showing lignite seam and associated sediments along with position of samples in bore-holes NLE-27, 35 and 36.

Resinite—It occurs as circular, sub-circular, elongated and irregular bodies either discretely (Pl. 1, fig. 5) or in rows or groups. The latter are mostly cell-filling resinite aquiring the shapes of cell lumina (Pl. 1, fig. 4). The resinite exhibits widest range of fluorescence colours, viz., yellowish-green, greenish-yellow, pale, deep and orangish-yellow, yellowish-brown, reddish-brown, and greyish-brown. The fluorescence intensity generally varies between low to moderately high.

Chlorophyllinite—It fluoresces with red colour and is occasionally observed inside the leaf tissues (Pl. 1, fig. 8) and also as disperse small particles. The blood-red colour of the chlorophyllinite easily distinguishes it from the other liptinite macerals.

Liptodetrinite—All the detrital and unidentifiable liptinite macerals consisting the fragments or relics of sporinite, cutinite, resinite, suberinite, alginite, etc. constitute liptodetrinite which fluoresces with different colours and intensities. The fluorescence colour and intensity of liptodetrinite depend upon original material, chemical or biological decomposition and degree of diagenesis.

Bituminite—A secondary maceral fluorescing with dull yellow colour. Mostly it is found as groundmass for other macerals in Neyveli lignite and rarely as small spongy granules inside the cells lumina emitting light of very low intensity. 'Mineral bituminite', that is the fluorescing groundmass formed by close association of mineral and bituminite is quite significant in lignitic clay bed.

Besides the preceding liptinite macerals, multicellular spindle shape fluorescing bodies in association with cutinite have also been recorded. These bodies, occurring discretely or in a chain, fluoresce with yellow, orangish-yellow and brownish-yellow colours with moderately high to low intensities. Source of origin of these fluorescing bodies is yet to be confirmed (Singh & Misra, 1998).

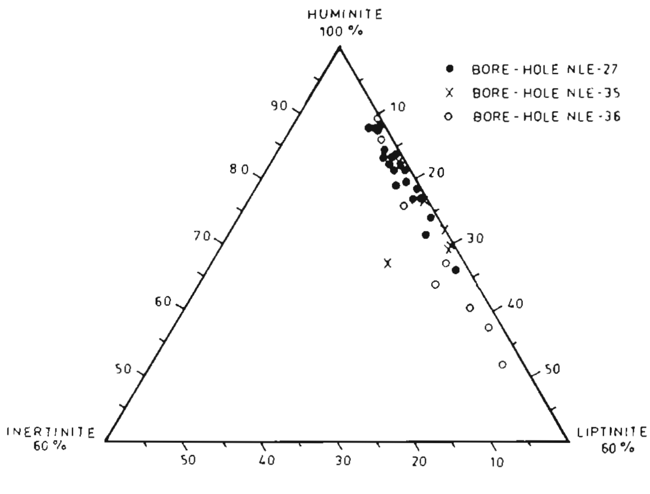
MACERAL COMPOSITION

(Table 1, Text-figure 4)

Bore-hole NLE-27—The lignite seam encountered in this bore-hole is dominated by the huminite (65.8-88.2%) followed by liptinite (10-33%) and inertinite (0.2-2.8%). The huminite includes a high proportion of non-fluorescing

Table 1—Maceral composition (mean and range, under fluorescence mode) in the main lignite seam sections of Neyveli Lignitefield.

Bore-hole	NLE-27	NLE-35	NLE-36
No. of samples	23	6	8
Macerals :			
Fluorescing huminite	6.5 0.0-21.2	9.0 2.8-25.8	4.4 1.0-13.8
Non-fluorescing huminite	74.4 59.0-87.0	63.9 43.6-78.6	64.6 49.8-83.4
Total huminite	80.9 65.8-88.2	73.0 66.8-83.4	69.0 52.6-88.8
Sporinite	0.1 0.0-0.6	0.1 0.0-0.6	0.1 0.0-0.4
Cutinite + Suberinite	1.0 0.0-5.6	1.3 0.0-6.4	1.3 0.0-8.2
Resinite	8.1 1.4-20.4	7.5 4.4-11.0	5.1 1.2-16.2
Liptodetrinite	6.4 2.0-18.0	13.6 4.6-21.6	20.6 10.4-31.2
Unidentified fluorescing bodies	0.8 0.2-6.8	0.8 0.8-2.0	0.1 0.0-0.6
Total Liptinite	18.0 10.0-33.0	25.0 16.4-30.2	28.6 10.6-44.8
Total Inertinite	1.1 0.2-2.8	2.0 0.2-1.0 10.0 in one sample	2.3 0.6-5.0



Text-figure 4—Ternary diagram showing composition of three main maceral groups in lignite of bore-holes NLE-27, 35 and 36.

huminite (59.0-87.0%) and a subordinate amount of fluorescing huminite (0.2-21.2%).

Among the liptinite macerals, the resinite has the highest frequency (1.4-20.4%, av. 8.1%) followed by the liptodetrinite (2.0-18.0%, av. 6.4%), suberinite (0.2-5.4%, av. 1.3%), cutinite (0.4-5.6%, av. 0.8%) and sporinite (up to 0.6%). The chlorophyllinite and alginite (*Botryococcus*) have been also observed, but they are quantitatively insignificant. The unidentified fluorescing bodies are recorded in relatively higher proportion (0.2-6.8%, av. 0.8%) than the seams encountered in other two bore-holes.

Bore-hole NLE-35—The lignite encountered in this bore-hole is dominated by huminite (66.8-83.4%) fraction followed by liptinite (16.4-30.2%) and inertinite (0.2-10.0%) fractions. The huminite fraction as a whole does not show any particular trend in distribution, however the fluorescing huminite (2.8-25.8%) indicates a decreasing trend towards the bottom of the seam. The amount of inertinite macerals sharply increases in the middle part of the seam (10% in one sample) which otherwise is almost uniform throughout (0.2-1.0%).

Among the liptinite macerals, the liptodetrinite is dominant (4.6-21.6%, av. 13.6%) followed by resinite (4.4-11.0%, av. 7.5%), cutinite (0-6.4%, av. 2.2%), suberinite (0.2-1.0%, av. 0.5%), sporinite (up to 0.6%) and alginite (up to 0.2%). The latter three macerals, though distributed throughout the seam, are non-recordable in few samples. The unidentified fluorescing bodies are present throughout the seam and range from 0.8 to 2.0 per cent (av. 0.8%).

Bore-hole NLE-36— The lignites of the main seam encountered in this bore-hole shows dominance of huminite macerals (52.6-88.8%; non-fluorescing: 49.8-83.4%, fluorescing: 1.0-13.8%). The concentration of inertinite macerals is relatively higher (0.6-5.0%) than the seam sections encountered in other two bore-holes.

The macerals of the liptinite group (10.6-44.8%, av. 28.6%), in decreasing order of abundance are represented by the liptodetrinite (10.4-31.2%, av. 20.6%), resinite (1.2-16.2%, av. 5.1%), suberinite (0.6-8.2%), cutinite (up to 0.8%) and sporinite (up to 0.4%). The unidentifiable fluorescing bodies are recorded in low proportion (up to 0.6%). No specific trend in the distribution of macerals is discernible in this seam section.

The lignitic clay bed, associated with bottom part of the seam, also has a high huminite content (63-79%, av. 71.2%). The liptinite maceral content is relatively lower (12.0-15.5%, av. 13.7%) than those in lignite sections. 'Mineral bituminite' is recorded in appreciable amount (9-21%, av. 15%). The inertinite macerals have been found to be quantitatively insignificant. The required 500 counts could not be made on lignitic clay samples because of the scarcity of clean particles.

A comparative data of lignite seam encountered in three bore-holes, on the basis of frequency distribution of fluorescing and non-fluorescing macerals, are provided in Table 2 and Text-figure 5. The data indicate that the lignite in bore-hole NLE-27 has relatively higher proportion of non-fluorescing macerals than in the lignite seams in other two bore-holes. The content of fluorescing macerals have been found to be higher in the lignite seam of bore-hole NLE-35 than in the seams of bore-holes NLE-27 and 36.

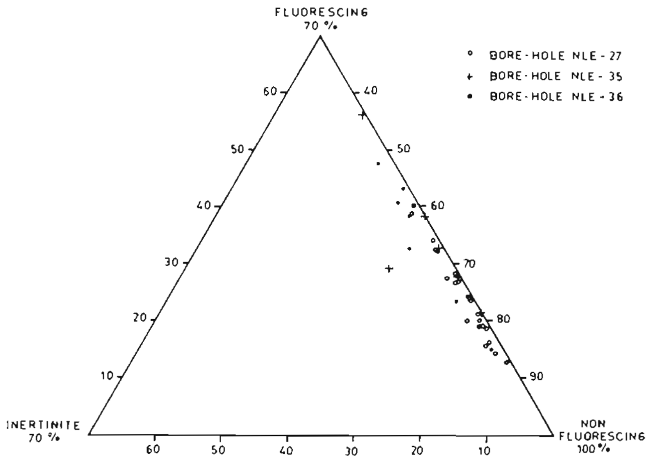
Table 2— Frequency of fluorescing and non-fluorescing macerals in lignites of bore-holes NLE-27, 35 and 36 from Neyveli Lignitefield.

Bore-hole	NLE-27	NLE-35	NLE-36
No. of samples	**23**	**6**	**8**
Macerals			
Fluorescing	24.4 12.6-38.8	34.0 21.2-56.0	33.0 15.2-47.6
Non- fluorescing huminite	74.4 59.0-87.0	63.9 43.6-78.6	64.6 56.6-83.4
Inertinite	1.1 0.2-2.8	2.0 0.4-10.0	2.3 0.6-5.0

Note: Fluorescing macerals incorporate all the liptinites, fluorescing huminite and unidentifiable fluorescing bodies.

DISCUSSION AND INFERENCE

Each organic constituent (maceral) provides important information about an organic deposit because its origin is dependent on climate, peat-forming plant communities, ecological conditions (pH, Eh of water) and degree of carbonification (Stach *et al.*, 1982; Teichmüller, 1989). Proper recognition of organic constituents is, therefore, important to obtain information about these aspects. A better distinction of liptinite



Text-figure 5—Ternary diagram showing composition of fluorescing and non-fluorescing macerals in the lignite seams of bore-holes NLE-27, 35 and 36.

macerals, under fluorescence mode, has made it possible to generate useful data and to establish a generalized picture of the depositional conditions. The inferences drawn from the earlier studies and also from the present investigations under fluorescence mode, are as follow:

Earlier evidences gathered from mega- and microfloral investigations carried out on the main lignite seam (mine I, II, and III) indicated the predominance of angiospermic vegetation which served as source material in the formation of lignite seam (Refer to Singh *et al.*, 1992). Besides, deciduous forest vegetation of tropical climate with high rainfall together with coastal elements were responsible for lignite formation.

The petrographic data from the lignites of mine I (normal reflected mode) and mine III (reflected and fluorescence modes) also corroborate the existence of wood dominated forest vegetation as evidenced by higher proportion of huminite macerals (Misra, 1992; Singh *et al.*, 1992). Appreciable amount of resinite in the absence of gymnospermous flora suggests the existence of resin producing angiospermic plants. Thick bands of suberinite also indicate the dominance of angiosperms (Kantsler, 1980). Variation in resinite morphology, nature of occurrence and fluorescing colours suggest it's origin from different sources (oil, fat, wax, latex, etc.). The presence of alginite (*Botryococcus*) throughout the entire thickness of the seam indicate marine influenced fresh water (brackish water) conditions for the formation of lignite (Misra *et al.*, 1997). The petrological and palynological studies on Neyveli lignites also indicate its origin in lagoons or back swamps having more fresh water influence than brackish (Pareek, 1984; Ramanujam *et al.*, 1984; Singh *et al.*, 1992). Fluctuations in frequency and size of algal colonies indicate the seasonal changes and also the changes in the pH of swamp water.

In view of the predominance of humodetrinite over humotelinite and humocollinite, high degree of vegetal degradation in the middle part of the main seam was suggested by Misra (1992). However, degradation effects were found to be pronounced in different portions of the seam encountered in three bore-holes of mine III area. Well-preserved leaf sections and epidermal tissues with stomata, which are normally easily decomposed, indicate low energy reducing environment. Preservation of chlorophyllinite, which most easily decomposes among all the liptinite macerals, also suggests a non-oxidizing environment. This suggests a rapid burial of vegetal matter growing at or very near to the site of peat formation (autochthonous or hypautochthonous deposition). The presence of perhydrous huminite, liptodetrinite and bituminite which are generally formed during the later stages of diagenesis reflect an undisturbed swampy condition. Relatively higher proportion of inertinite in the lignite seam of bore-hole NLE-36 (Table 1) indicate that the ancient peat which formed the lignite was exposed to oxidative conditions periodically in the particular area. High amount of inertinite (10%) in the middle part of the seam of bore-hole NLE-35 appears to suggest such periodic dryness.

From the earlier palaeobotanical and petrological information, besides that of the present investigation, it has been inferred that predominantly woody angiospermous forest vegetation including beach, back-mangrove and mangrove plants, besides associated pteridophytes were responsible for the formation of Neyveli lignite. The identification of newly recorded multicellular fluorescing bodies (Singh & Misra, 1998) will further add to our knowledge about palaeoflora and palaeoclimate of the lignite-bearing region.

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