PETROGRAPHIC EVALUATION OF CERTAIN FOREIGN COALS*

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ABSTRACT

The present paper discusses the petrographic constitution of some coals from Australia, Canada and Nigeria, and their potentiality for utilization in steel plants has been evaluated. The study reveals that a great variation exists in the type and rank which together determine the quality of these coals. Because of intimate association of the coal types, mineral matter and rank variation found in them, it would be reasonable to presume that the chemical and technological properties vary from sample to sample. The study suggests the necessity of petrological control in preparation of the samples for various uses.

INTRODUCTION

Some coals from Australia (Utah, Clutha and Bellambi), Canada (Balmer) and Nigeria (Engu, Lafia-12 and Lafia-13) have been studied microscopically. These samples are being tested for coking, blending and cleaning etc., by C.F.R.I. As the petrographic studies unfold the nature, origin and constitution of coals, the present study has been made to supplement other studies for critical economic evaluation of these imported coals.

The samples investigated were small coal pieces. Individual samples were crushed (± 18 mesh) and particulate pellets were prepared. The analytical studies were made as per standard procedures (International Committee for Coal Petrology, 1971). The petrographic evaluation has been done on group maceral and microlithotype basis of organic entities. Maximum reflectance values (in oil) of the vitrinitic fractions have also been taken (I.C.C.P., 1971) on Leitz MPV-1 microscope at 548 nm light-band for rank determination. Volatile matter and carbon content (d.a.f.) were obtained directly by plotting the Ro max values of the individual samples on the standard curve (KÖTTER, 1960). Although the samples were few for any generalization of the coals, nevertheless a good approximation of their nature and composition useful for quality assessment could be made.

OBSERVATION

Australian Coals

Vitrinite—Telocollinite and desmocollinite are the chief macerals of the vitrinite group in the Australian coals. Few telinitic constituents showing cellular structures are also discernible. Cell walls of the telinite are either elongated or rectangular generally pressed due to compaction. The vitrinite in the Australian samples are invariably impure either due to intimate association of inertinite pieces or shreds (Utah and Bellambi, Pl. 1, Fig. 2) and/or of mineral matter (Pl. 1, Fig. 1). The associated inertinite pieces are dominantly low reflecting semifusinite. The vitrinite content varies from sample to sample (Table 1). In Utah, the vitrinite forms 27.50 per cent of the total

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petrographic composition whereas in Clutha, an increase to 40.40 per cent was observed. However, the Bellambi sample contains the least vitrinite content (24.40%) of the three Australian coal samples.

Exinite—Most of the exinite fractions recognised in the samples are, generally, of sporinite. Cutinite and other exinite macerals are extremely rare. The sporinite in the Utah sample is occasionally observed in good amount, but only in isolated pockets. It is commonly associated with the inertinite and mineral matter. Quantitatively, the exinite fraction in the Australian coals is rather insignificant. The recorded frequency of the macerals ranges from 3.80 to 6.00 per cent in Clutha and Utah, respectively, while in the Bellambi coal the exinite is totally absent (Pl. 1, Fig. 6 ; Table 1).

Table 1—Maceral and Microlithotype distribution

Macerals	Australian Utah (%)	Australian Clutha (%)	Australian Bellambi (%)	Canadian Balmer (%)	Nigerian Engu (%)	Nigerian Lafia-12 (%)	Nigerian Lafia-13 (%)
Vitrinite	27.50	40.40	24.40	29.00	49.20	49.80	58.20
Exinite (Liptinite) ..	6.00	3.80	..	..	16.00	..	..
Inertinite	59.50	42.40	71.20	57.40	16.40	8.60	13.60
Semifusinite	29.50	16.60	25.80	24.40	6.60	4.00	7.20
Fusinite	23.00	16.00	43.00	23.00	4.80	2.20	2.60
Inertodetrinite ..	7.00	7.80	2.40	10.00	5.00	2.40	3.80
Mineral Matter ..	7.00	13.40	4.40	13.60	18.40	41.60	28.20
Microlithotypes							
Vitrite	5.00	20.60	7.40	14.60	12.80	24.00	48.80
Clarite	2.40	3.20	..	..	35.40	..	..
Inertite	20.80	14.00	30.00	31.20	1.00	0.40	..
Semifusite	12.60	6.60	12.00	16.60	0.40	0.40	..
Fusite	8.20	7.40	18.00	13.60	0.60	..	..
Inertodetrite	..	..	..	1.00	..	..	..
Vitrinertite	20.80	18.00	61.00	46.00	5.40	2.00	12.80
Durite	13.60	4.40	..	..	..	..	..
Trimacerite	33.20	30.40	..	..	31.20	..	..
Duroclarite	11.80	13.60	..	..	22.40	..	..
Clarodurite	21.40	16.80	..	..	8.80	..	..
Carbominerite ..	4.20	9.40	1.60	8.20	14.20	73.60	38.40
Reflectance (Max.) in oil	0.92	0.97	1.02	1.27	0.70	0.99	1.10
Standard Deviation ..	0.04	0.10	0.06	0.09	0.20	0.61	0.06

Inertinite—Mainly semifusinite, fusinite and inertodetrinite constitute the inertinite group in the Australian coal samples. Semifusinite and fusinite occur as broad bands, lenticles or as dispersed fragments (Pl. 1, Figs. 4,5). Generally, it is the semifusinite bands which are more common. Cell walls and tissues of degradofusinite are commonly observed. Pyrofusinite is also a common constituent in Clutha and Bellambi samples. It is highly reflecting, yellowish in colour and shows well preserved cellular structures with cell cavities occasionally filled with mineral matter. Micrinite is also present as disseminations and sometimes as granular infillings in the cell lumens of vitrinite. Inertinite constitutes a range from 42.40 to 71.20 per cent (Table 1) of the total composition. Maximum inertinite content has been recorded in Bellambi sample (71.20%), whereas the Clutha sample shows the minimum inertinite proportion (42.40%). The Utah coal exhibits intermediate value (59.50%) for the inertinite fraction. Semifusinite is the major component among the macerals of the inertinite group. It has a frequency of 29.50 per cent in Utah, 16.60 per cent in Clutha and 25.80 per cent in Bellambi coal samples. Fusinite, next to semifusinite, constitutes 23.00 per cent in Utah, 18.00 per cent in Clutha and 43.00 per cent in Bellambi samples. The maceral inertodetrinite (Pl. 1, Figs. 5, 6), the third maceral in order of dominance constitutes 7.00, 7.80 and 2.40 per cent in Utah, Clutha and Bellambi coals, respectively. In general, inertinite constituents are predominant in petrographic composition of the Australian coals investigated (Table 1).

Mineral matter—It occurs uniformly distributed in all the Australian samples. The percentage distribution of the mineral matter in these coals varies from 4.40 per cent to 13.40 per cent (Table 1). The maximum amount has been found in Clutha whereas the minimum proportion recorded is from Bellambi. Siderite concretions (Pl. 1, Fig. 10) and detrital quartz account for most of the mineral matter present. Pyrite specks have also been recognized alongwith siderite. Shaly matter associated with siderite as well as cavity and crack-filling substance is not uncommon, especially in the Clutha sample (Pl. 1, Fig. 11).

Microlithotype

The various microlithotypes recorded in the Australian coal samples are shown in table 1. Trimacerite is the main microlithotype group in Utah and Clutha samples forming 33.20 and 30.40 per cent, respectively. Conspicuously it is absent in the Bellambi coal. Duroclarite (Pl. 1, Fig. 7) and clarodurite (Pl. 1, Fig. 8) microlithotypes of the trimacerite group have 11.80 and 21.40 per cent in Utah and 13.60 and 16.80 per cent in Clutha, respectively. Inertite group of microlithotype (Pl. 1, Fig. 4) next in dominance to trimacerite along with vitrinertite has a frequency range from 14.00 to 30.00 per cent in Clutha and Bellambi samples respectively, while the Utah sample contains 20.80 per cent of this microlithotype. Semifusite and fusite are the main components of the inertite group. The former varies from 6.60 to 12.60 per cent while the latter from 7.40 to 18.00 per cent. The vitrinertite (Pl. 1, Fig. 5), like inertite, is the next conspicuous group after trimacerite in the Australian coals. It is least in Clutha (18.00%) and highest in Bellambi (61.00%). The Utah sample contains 20.80 per cent of this microlithotype. Durite microlithotype (Pl. 1, Fig. 9) is common in Utah (13.60%) and Clutha (4.40%) while in Bellambi sample it is totally absent. Vitrite (Pl. 1, Fig. 2) and Clarite (Pl. 1, Fig. 6) microlithotypes are not very common in these coal samples. The vitrite and clarite contents in Utah are 5.00 and 2.40 per cent, in Clutha 20.60 and 3.20 per cent, respectively while in Bellambi only vitrite is present (7.40%). The carbominerite formed by the association of various macerals and mineral matters range from 1.60 to 9.40 per cent in Bellambi and Clutha samples, respectively. The Utah sample contains 4.20 per cent of the carbominerite.

In general, trimacerite, vitrinertite and inertite are the main microlithotype groups having a frequency distribution of 62.40 to 91.00 per cent. The other microlithotypes account only for 9.00 to 37.60 per cent. Most of the vitrinitic fraction (27.50 per cent to 40.40 per cent) in the total amount of the microconstituents are distributed in the above three mixed microlithotypes. Because of the inherent mixed nature of the coal entities, all the Australian coal samples are deficient in reactive microlithotype varieties, i.e. vitrite and clarite.

Rank

The reflectance values recorded are shown in the table-1. The coals show reflectance values ranging from 0.92 to 1.02 per cent Ro max. The higher value is recorded for Bellambi coal (1.02%). The minimum of 0.92 per cent has been recorded in Utah. Comparing with the standard curve, it falls in High Volatile Bituminous A Stage, having a volatile matter yield of 32.00 to 34.00 per cent and carbon content 84.00 to 85.00 per cent. The reflectance values indicate that the coals are slightly less matured to be classed under good coking coal (Mackowsky, in Stach *et al.*, 1975). In general, these coals contain relatively less amount of reactive components (vitrinite, vitrite & clarite ; Table 1) and high amount of non-reactives (inertinite, inertite, durite, vitrinertite & trimacerite). Thus, the petrographic constituents also hinder these coals to be of good coking type.

Canadian Coal

Vitrinite—Only one sample (Balmer) of the Canadian coal was available for the study. The vitrinite group comprises chiefly telocollinite and desmocollinite varieties. It is seldom pure due to ubiquitous association of shreds and pieces of inertinite macerals somewhat similar to the vitrinite of the Australian coal samples (Pl. 1, Fig. 3). The vitrinite forms 29.00 per cent of the total composition. It is more like Australian coals than the Nigerian coals studied here.

Exinite—The exinite maceral is repersented only by rarely occurring sporinite which is unaccounted quantitatively.

Inertinite—Semifusinite, fusinite, inertodetrinite, micrinite and macrinite macerals constitute the inertinite group. Bands of semifusinite and fusinite broader than that of vitrinite are quite common. The semifusinite and fusinite are dominantly degradofusinite while well preserved cellular structures of pyrofusinite with partly filled and partly empty cell-lumen are not uncommon. The micrinite is not very common in this sample. Occasional irregular, homogeneous and bright mass of macrinite with oxidation rims has been observed. The inertinite in the Canadian sample forms 57.00 per cent of the total bulk of which 47.40 per cent is represented by semifusinite and fusinite while 10.00 per cent is formed by inertodetrinite (Table 1).

Mineral Matter—The mineral matter in these coals occurs as granular, globular and streak like crack filling inclusions. It constitutes 18.40 per cent of the coal composition (Table-1). It is associated with vitrinite and inertinite macerals. The coal contains more shaly matter than the Australian coal.

Microlithotype

Vitrite, inertite, and vitrinertite form the major part (91.80%) of the total microlithotypes present and have a frequency distribution of 14.60, 31.20 and 46.00 per cent, respectively. The semifusite forms 16.60 per cent while fusite and inertodetrite constitute 13.60 and 1.00 per cent, respectively. Carbominerite in the sample is represented by 8.20 per cent.

Rank

The degree of coalification attained by the sample is fairly high (1.27% Ro max.). Accordingly it has reached Medium Volatile Bituminous coal Stage with 28.00 per cent volatile matter and 87.00 per cent carbon content (d.a.f.). The maturity indicates that the coal is well suited for coking but for its high proportion of non reactive components (inertinite/inertite and vitrinertite) and low amount of reactive components (Vitrinite/Vitrite).

Nigerian coals

Vitrinite—The three Nigerian coal samples have dominant vitrinite contents, and like Australian coal samples, they are impure due to presence of high amount of dispersed mineral matter (Pl. 1, Figs. 12, 13). The vitrinite is collinitic in samples of Lafia-12 and 13 and exhibits typical vitrinitic cracks. The Engu sample surprisingly contains two distinct variety of vitrinite : *a*—like Lafia-12 or 13 having high reflectance in the range of 0.85-1.21 per cent Ro max., the quartz and shaly matter are intimately associated with it, *b*—this type of vitrinite fraction is characteristically of grey colour and shows telinitic and telocollinitic structures. Associated mineral matter is dominantly shaly or clayey matter and rarely of pyrite specks. Its reflectivity is quite low and falls in the range of 0.48-0.65 per cent Ro max. The vitrinite content of the Nigerian coals is the highest among all the coal samples investigated. It constitutes 58.20, 49.80 and 49.20 per cent by volume in Lafia-13, Lafia-12 and Engu samples, respectively (Table-1).

Exinite—Exinites are almost nil in the Nigerian coal samples examined except in Engu. The exinite content in the Engu sample is 16.00 per cent and is associated only with the coal fraction—*b* showing lower reflectivity (Table 1). The high reflecting coal fraction—*a* is devoid of any exinite maceral like Lafia-12 and 13. Mostly, spore exines together with quite commonly occurring resinite and some cutinite form the main component of the Engu exinites which are frequently associated with mineral matter and also with inertinite (Pl. 1, Figs. 15, 16).

Inertinite—Mostly semifusinite, fusinite and inertodetrinite macerals form the inertinite group in these samples. Degraded tissue structures, cells and other organic debris account for the semifusinite and fusinite (Pl. 1, Figs. 15, 16). Their cell lumens are invariably filled with mineral matter. In Engu coal sample, like vitrinite there are two different types of inertinite—(i) chiefly yellowish in colour and fragmented in nature associated with vitrinite fraction—*b*, (ii) dominantly composed of semifusinite associated with vitrinite fraction—*a*. Thus, the coal fraction—*a* partly present in the Engu sample with fraction—*b* appear to be of different coals. The Nigerian coals are characterized by the presence of definite fungal sclerotinite (Pl. 1, Figs. 12, 13, 15). The sclerotinites are smaller in size, mostly circular to subcircular in shape and are like *Sclerotites brandonianus* sp. These sclerotinite bodies appear to be almost identical with the Tertiary fungal sclerotinites. Apart from sclerotinite bodies some uni-to bi-celled fungal teleutospores have also been observed. The Engu coal contains 16.40 per cent of inertinite. Lafia-12 is poor in inertinite (8.60%) consisting mostly of broken pieces of semifusinite. The inertinite of Lafia-13 is almost similar to that of Lafia-12 in character but the former has higher amount (13.60%) of inertinite than that of the latter. The semifusinite content in Engu (6.60%), Lafia-12 (4.00%) and Lafia-13 (7.20%) is higher than the fusinite content (4.80%, 2.20% and 2.60%). The inertodetrinite constitutes 5.00 per cent (Engu), 2.40 per cent (Lafia-12) and 3.80 per cent (Lafia-13 ; Table 1).

Mineral matter—The dispersed mineral matter intimately associated with the organic constituents of the Nigerian coals has rendered most of the vitrinite impure. Chiefly shaly, clayey matter and detrital quartz are the main mineral groups present while siderite and pyrite minerals are less common. However, in Lafia-12 pyrite is quite conspicuous and intimately dispersed in the vitrinite as fine idiomorphic crystals and radiating striated concretions (Pl. 1, Fig. 14). Compared with the Australian coals, the mineral content is relatively more in the Nigerian samples. It has a frequency range from 18.40 to 41.60 per cent in these samples. Lafia-12 has a maximum mineral content (41.60%) while Engu and Lafia-13 have 18.40 and 28.20 per cent, respectively.

Microlithotype

The different microlithotypes recorded in the samples are given in the table 1. In the Engu coal clarite (35.40% ; Pl. 1, Fig. 16) and trimacerite (31.20%) predominate over the other microlithotypes. The above two microlithotypes are recorded from the low reflecting fraction—*b* of the coal. The clarite of the Engu sample is made up of equal amounts of sporinite, clarite and resinoclarite. Most of the trimacerite of the coal is duroclarite (22.40%) while clarodurite is low (8.80%). The proportions of vitrite (12.80%), inertite (1.00%), vitrinertite (5.40%) are quite low while carbominerite constitutes (14.20%) of the total composition. In Lafia-12 the carbominerite is the highest in frequency (73.60%) among all the samples studied here. The vitrite is the next dominant (24.00%) microlithotype while the inertite (0.40%) and vitrinertite (2.00%) are relatively unimportant. The Lafia-13 sample contains by far the highest amount of vitrite (48.80%) recorded in all the present coal samples. Next in order of abundance is the carbominerite fraction (38.40%) while vitrinertite content is only 12.80 per cent.

In general, carbominerite and vitrite are conspicuous microlithotype groups especially in Lafia-12 and Lafia-13 samples. For Engu sample, vitrite, clarite, trimacerite and carbominerite are the dominant microlithotype groups. These associations tend to retard the coking prospect of the coals unless cleaned and separated.

Rank

Reflectance values of the Nigerian coals indicating rank are shown in the table 1. The reflectance data of the Engu sample (0.70%) Ro max. shows a distinct bimodal reflectogram (Fig. 1) and confirm our contention based on petrographic study that the sample is not of a single coal type but appears to be a blend consisting of two separate coal fractions. Thus, the rank indicated by this mixed sample is only High Volatile Bituminous B Stage which is of quite low maturity for coking purpose. The Lafia-12 has attained (0.99% Ro max.) High Volatile Bituminous A Stage while Lafia-13 (1.10% Ro max.) approximates nearly to the Medium Volatile Bituminous Stage. Out of the three Nigerian coal samples, Lafia-13 contains the highest amount of vitrinite/vitrite (58.20/48.80%) and appears to be a good coking coal. However, the influence and

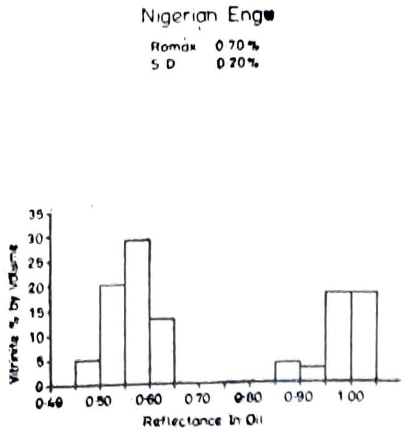

Fig. 1

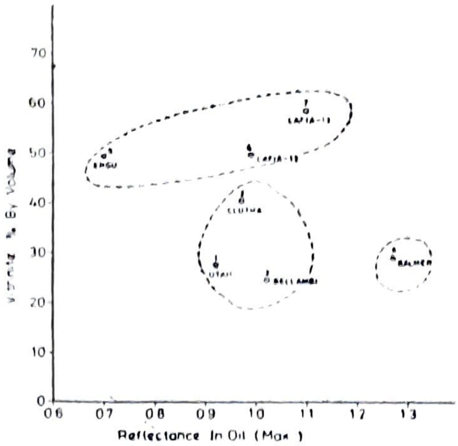

Fig. 2

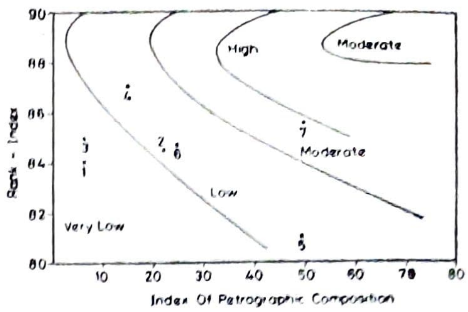

Fig. 3

Fig. 1. Bimodal Reflectogram of Engu coal (Nigerian).

Fig. 2. Comparison of the coal samples based on their vitrinite contents and reflectance values (Ro max. in oil).

Fig. 3. Shows change in the coke strength according to rank (carbon content) and index of petrographic composition (vitrite+clarite)—after Brown, Cook & Taylor, 1964.

behaviour of excessive amount of mineral matter on coking property could only be ascertained by chemical methods.

GENERAL EVALUATION

The coal samples examined were few for a good critical assessment; nevertheless, certain deductions have been made on the basis of micropetrological studies. Before any generalization is attempted, it must be mentioned here that the coking power of a coal is dependent on two basic factors, viz. rank (maturity) and petrographic composition (maceral/microlithotype). Selection of maceral or microlithotype analysis for the assessment of coking potentiality appears to be a matter of choice and suitability. Brown, Taylor and Cook (1964) preferred to use microlithotypes with rank (carbon content obtained from vitrinite reflectance) for such assessments. We have also made our deductions on the similar line (Fig. 3) as it renders rapid results and in many cases provide enough preliminary data, particularly when the investigation is restricted to coal from one seam (Mackowsky, *in* Stach *et al.*, 1975).

In general, (Fig. 2) all the Australian and one Nigerian (Lafia-12) coal samples of the present study have attained High Volatile Bituminous A Stage with 33.50—32.00 per cent volatile matter and 84.00-85.00 per cent carbon content. Their maturity is, accordingly, slightly lower to provide them a good coking ability. The low maturity (rank) is also coupled with low vitrinite+exinite/vitrite+clarite fractions (Table 1) and high proportion of inertinite/inertite, vitrinertite, durite and trimacerite in some samples and exceptionally high mineral matter/carbominerite (41.60%/73.60%) contents especially in Lafia-12 have certainly deprived these coals of good coking property. However, these coals may form cokes of low strength.

The Balmer (1.27% Ro max., Canadian) and the Lafia-13 (1.10% Ro max., Nigerian) coal samples have reached Medium Volatile Bituminous Coal Stage having 28.00-31.00 per cent volatile matter and 87.00-85.50 per cent carbon content, respectively. Their maturity (rank), accordingly, is compatible for a good coking coal. The Canadian sample contains little amount of vitrinite/vitrite (29.00/14.60%) in comparison to high amounts of inertinite/inertite (57.40/31.20%), vitrinertite (46.00%) and mineral matter/carbominerite (13.60/8.20%). The Lafia-13 has high amount of vitrinite/vitrite (58.20/48.80%) as reactive fractions. The only fraction probably, hindering the sample's coking ability is the ubiquitous and high amount of mineral matter/carbominerite (28.20/38.40%) in the dominantly occurring vitrinite/vitrite fraction. The Engu (Nigerian) sample appears to be a blend rather than a single coal type sample. Due to presence of the two distinct coal fractions (a low reflecting and a high reflecting types) the overall rank of the sample has decreased (0.70% Ro max.) and indicates High Volatile Bituminous B Stage with 39.00 per cent volatile matter and 81.00 per cent carbon content. The sample, though contains good amount of reactive components, is rather quite immature to be utilized for coking purpose.

CONCLUSION

The coal samples examined are not of uniform type. Reactive constituents are relatively poor and are of impure variety. The coals show marked variation in rank and most of them contain high amount of mineral matter. All these factors cause variation in technological and chemical properties. Although these coals do not appear to be prime-coking coals, nevertheless, separation of clastics and petrological control by suitable methods may improve the quality for preparation of the coals for utilization.

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REFERENCES

Brown, H. R., Taylor, G. H. & Cook, A. C. (1964). Prediction of coke strength from the rank and petrographic composition of Australian coals. *Fuel, Lond.*, **43**(1) : 43-54.

International Hand Book of Coal Petrography (1963). *Int. Committee for Coal Petrology*, 2nd ed., *Centre National Recherche Scientifique* : Paris.

International Hand Book of Coal Petrography (1971). *Int. Committee for Coal Petrology, Suppl.* 2nd ed., *Centre National Recherche Scientifique* : Paris.

Mackowsky, M. Th. (in Stach *et al.*, 1975). *Stach's Text Book of Coal Petrology, 2nd ed.* Gebruder Borntraeger. Berlin, Stuttgart.

Navale, G. K. B. & Misra, B. K. (1980). Maturation studies of some Indian coals and lignites and their bearing on Oil and Gas prospecting. *IVth Int. Palynol. Conf.*, Lucknow (1976-77), **2** : 551-564.

Kötter, K. (1960). Die mikroskopische Reflexionsmessung mit dem Photomultiplier und ihre Anwendung auf die Kohlenuntersuchung. *Brennst. Chemie*, **41** : 263-272.

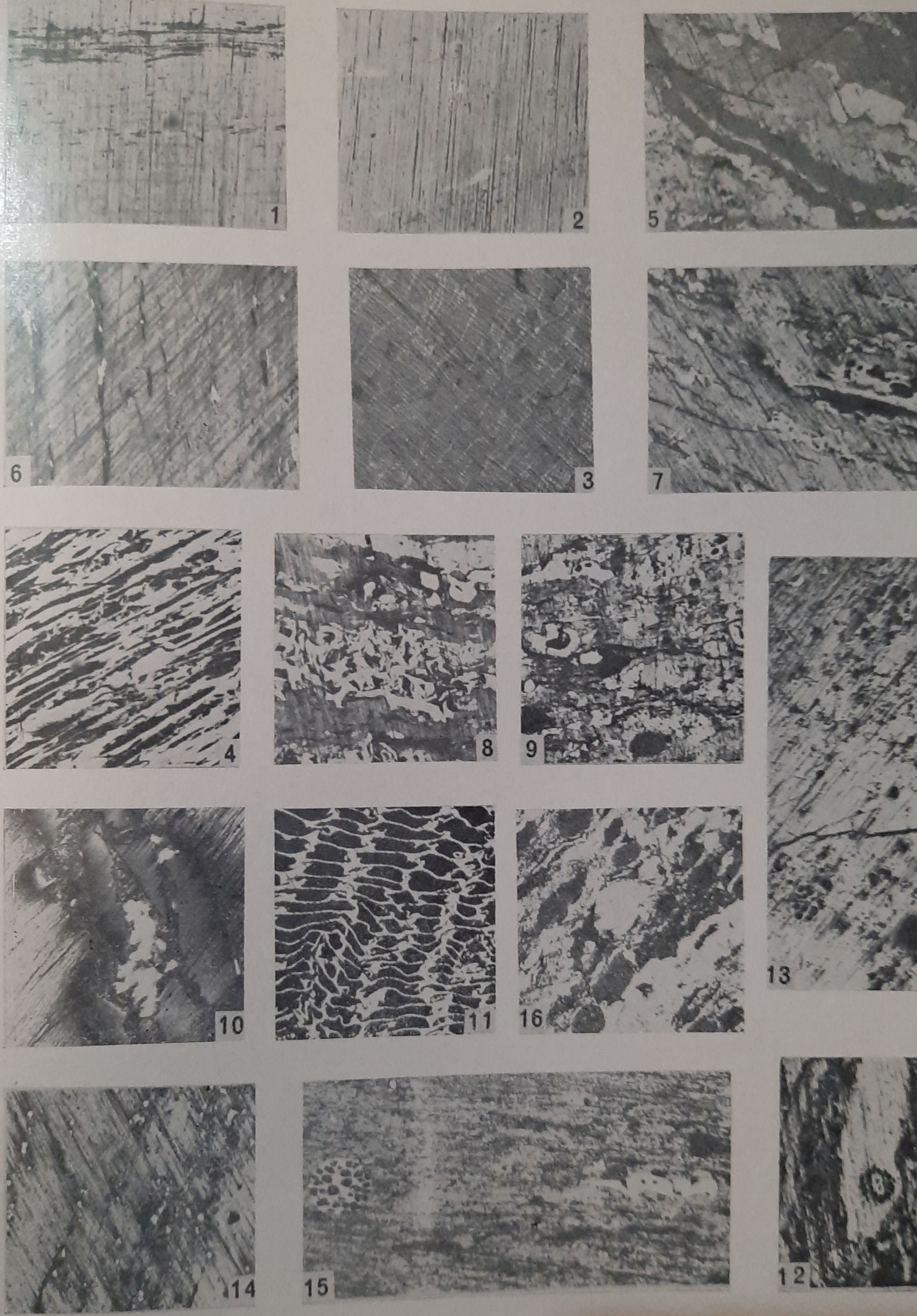
EXPLANATION OF PLATE

(All photomicrographs ×250, reflected light, oil immersion)

PLATE 1

1. Vitrinite (vitrite) with subparallel streaks of mineral matter (shale) forming thin band (Utah coal, Australian).
2. Vitrinite (vitrite) associated with small shreds of inertinite (Balmer coal, Canadian).
3. Structured vitrinite showing semifusinized cell walls (Bellambi coal, Australian).
4. Fusinite (fusite) with well preserved cellular structure (Balmer coal, Canadian).

5. Vitrinertite consisting of broad bands of fusinite and semifusinite alternating with thin bands of dark grey vitrinite. Inertodetrinite and macrinite are present in dispersed state (Balmer coal, Canadian).
6. Sporinite (microsporinite) in desmocollinitic ground mass forming clarite with dispersed inertodetrinite (Clutha coal, Australian).
7. Duroclarite consisting of microsporinite, inertodetrinite and fusinite (Utah coal, Australian).
8. Clarodurite consisting of thick bands of fusinite with dispersed inertodetrinite and alternating thin bands of vitrinite and sporinite (Utah coal, Australian).
9. Durite (Utah coal, Australian).
10. Siderite concretion with secondary pyrite over it in vitrinitic ground mass (Utah coal, Australian).
11. Fine grained (shaly) mineral matter filled in cell lumens of semifusinized cork cells (Clutha coal, Australian).
12. Fungal sclerotinite (*Sclerotites brandonianus*) in vitrinitic ground mass with associated fine grained mineral matter (Lafia-12 coal, Nigerian).
13. Fungal sclerotinite in vitrinitic ground mass with sparsely distributed mineral matter (Lafia-13 coal, Nigerian).
14. Small pyrite concretions and dark shaly matter in vitrinite (Lafia-12 coal, Nigerian).
15. Fungal sclerotinite (*Sclerotites brandonianus*) with fusinite pieces, sporinite and resin bodies (dark grey elliptical bodies) in vitrinite (Engu coal, Nigerian).
16. Resinoclarite consisting of resinite in vitrinitic groundmass (Engu coal, Nigerian).



Navale & Misra—Plate 1