

The new vitrinite classification (ICCP System 1994)

International Committee for Coal and Organic Petrology (ICCP)

Within the new vitrinite classification (ICCP System 1994) the maceral group vitrinite is divided into three subgroups, telovitrinite, detrovitrinite and gelovitrinite, which are each further sub-divided into two macerals. The dominant parameter for these newly ordered and in part newly defined sub-groups is the degree of destruction (degradation), whereas the macerals can be further distinguished by their morphological characteristics and their degree of gelification. The new system is furthermore related more closely to the huminite classification system still in use and a future one to be published by the ICCP. © 1998 Elsevier Science Ltd. All rights reserved

(Keywords: maceral; vitrinite; telovitrinite; detrovitrinite; gelovitrinite; telinite; collotelinite; vitrodetrinite; collodetrinite; corpogelinite; gelinite)

INTRODUCTION

The Stopes Heerlen definitions of bituminous coal macerals are more than 30 years old. As used until now, they were included in the 1963 edition of the *International Handbook of Coal Petrology*. Since then, experience in the use of these definitions and descriptions has accumulated, and new applications, for example in studies of dispersed organic matter, have been developed. In time, it became apparent that the needs of petrologists were not being met by the original set of definitions, and in 1991 the General Assembly of the ICCP decided that a small editorial group should commence the preparation of new definition sheets for the macerals of bituminous coals as seen in reflected light. The drafts prepared by this group have been discussed and revised several times.

During the 46th meeting of the ICCP in Oviedo (Spain) in 1994 the final set of drafts of definitions of the vitrinite maceral group, its subgroups and macerals were accepted. Because it will be some time before the new edition of the Handbook is compiled and printed, it was decided to print these sheets for the vitrinite macerals separately. Everyone will then have available for immediate use these new definitions for the most important maceral group.

The new system of subdivision of the vitrinite maceral group differs substantially from the Stopes Heerlen System. Subgroups have been introduced which were not used before, based upon the following criteria:

maceral group:	defined by level of reflectance
maceral subgroup:	defined by degree of destruction
maceral:	defined by morphology and/or degree of gelification

In addition, the terms have been changed partly in order to make the nomenclature easier to follow and to show by the term itself to which level within the classification of vitrinite the term used belongs: within the subgroups the prefix of vitrinite shows the degree of destruction. Within the macerals, single terms indicate a relatively pure material, and prefixes indicate that gelification has modified the substances or that a specific morphology occurs.

The new system is called ICCP System 1994 in order to make clear that it differs from the old classification and definitions of vitrinite within the Stopes Heerlen System. The name ICCP System 1994 should be stated whenever reference is made to the new terms.

The structure of the new sheets also differs from that used in earlier editions of the Handbook. In keeping with the ISO format, the definition of a term is given in one sentence. Descriptions are added under 'Comments'. Users are therefore urged to read all of these details. Additional remarks (e.g., relationship to other terms) are grouped under 'Notes'. The editorial group hopes that this arrangement of the sheets will lead to a better understanding and more uniform usage.

Some rarely used data (e.g., refractive index) have been eliminated from the new edition, while other information, notably chemistry, has been expanded. The description of fluorescence properties is based in general on blue light excitation, variations are especially indicated. Overall, the new definitions and descriptions do not replace the old ones in each and every detail, so that the old Handbooks have not been rendered superfluous by the new set of sheets.

Following the new ECE Coal Classification, in place of the terms lignite, bituminous coal, anthracite etc. the terms low rank coal, medium rank coal and high rank coal are used. The limit between low and medium rank coal is defined at 0.5% random vitrinite reflectance for which the abbreviation R_r is used. This means that vitrinite as such does not occur before a reflectance of 0.5% R_r is reached. Lower rank humic material is grouped within the maceral group huminite, its subgroups and macerals (not included in the new set of sheets).

It is now apparent, as was the intention of the editorial group, that the subdivisions of the huminite group correspond with those of the new vitrinite group. This makes it easier to draw comparisons between the two systems. Misunderstandings may be avoided by this correspondence.

This revision of the vitrinite maceral group definitions will be published anonymously. However, it should be

mentioned that besides a small editorial group numerous colleagues from all continents have contributed to the definitions and descriptions, sentence by sentence. Therefore the new sheets are, as it was in the past, the result of international compromises and, finally, of international agreement. It is hoped that the new vitrinite classification will be accepted and soon achieve world-wide usage.

VITRINITE

Origin of term

Term introduced by Stopes¹ to denote a microscopically recognizable constituent of medium rank coal which is the chief constituent of bright coal (vitrain). Derivation: *vitrum* (L)—glass.

Related terms

Huminite (brown coal).

Definition

Vitrinite designates a group of macerals whose colour is grey and whose reflectance is generally between that of the associated darker liptinites and lighter inertinites over the rank range in which the three respective maceral groups can be readily recognized.

Comment. The term vitrinite embraces 3 subgroups and 6 macerals derived from humic matter (Table 1). Vitrinite occurs in coal as:

- (1) relatively pure layers or lenses ranging in thickness from several micrometres to several centimetres;
- (2) the continuous phase of the coal's groundmass binding other coal components; or
- (3) amorphous fillings of cells, pores and fissures.

In sedimentary rocks vitrinite occurs either in the form of isolated layers and lenticular bodies or as angular or rounded grains.

Table 1 Subdivision of the maceral group vitrinite according to the new ICCP system 1994

Subgroup	Maceral
Telovitrinite	Telinite Collotelinite ^a
Detrovitrinite	Vitrodetrinite Collodetrinite ^b
Gelovitrinite	Corpogelinite ^c Gelinite ^d

According to ICCP 6: ^aTelocollinite; ^bdesmocollinite; ^ccorpogelinite; ^dgelocollinite.

Note. 'Dark vitrinite' is a type of vitrinite characterized by its significantly lower reflectance and stronger fluorescence when compared with other vitrinite macerals in the same coal. It is the main vitrinite component of sapropelic coal (cannels and bogheads) as well as certain hydrogen-rich humic coals^{2,3}. It has, therefore, a broader connotation than 'saprovitrinite'⁴. In form it generally resembles vitrodetrinite or collodetrinite. The distinction from colloresinite is morphological (cell fillings and lamellae). Colloresinite also fluoresces more strongly than 'dark vitrinite'⁵. The lower reflectance of 'dark vitrinite' is the result of impregnation by bituminous substances derived from associated lipid

components. The degradinite of tertiary coals⁶ belongs to 'dark vitrinite'.

Physical properties

Colour and reflectance. Both change progressively with rank. The colour is dark grey in low rank coal and thermally immature sediments but light grey to white in medium and high rank coal and sedimentary rocks of corresponding rank. Random reflectance measured in oil over this colour range is approximately 0.5 to >7.0%. The lower reflectance limit has been taken as the reflectance value separating medium rank coal (bituminous coal) and low rank coal (brown coal) in the ECE classification⁷. Bireflectance also increases with rank, except in some cases where coalification is caused by contact metamorphism. For this reason measurements of maximum reflectance are recommended above 1.3% Rr. Vitrinite reflectance values from a single seam or sediment can vary in response to differences in the origin of the vitrinite macerals, changes in diagenesis or secondary thermal influences. The distribution of the reflectance measurements becomes then non-Gaussian with a bias towards lower or higher values⁸. This is particularly noticeable in low rank coals and their corresponding sediments. In high rank coals and corresponding sedimentary rocks variations in vitrinite reflectance may result also from the change from uniaxial to biaxial symmetry⁹.

Note. In the upper range of medium rank, vitrinite reflectance is surpassed by liptinite reflectance (where liptinite is recognizable) whilst at very high rank (Rr > 4.0%) the reflectance of both, liptinite and vitrinite may exceed that of inertinite¹⁰.

Fluorescence. Fluorescence colour and intensity vary within the macerals of this group. They are also dependent on the rank and the degree of bituminization (absorbed petroleum-like substances). Vitrinite fluorescence begins at approximately 0.5% random vitrinite reflectance and attains a maximum intensity between 1.0 and 1.2% Rr, thereafter declining rapidly. Fluorescence colours range from red-orange to red-brown and are most marked in the attrital component of vitrinite (collodetrinite)¹¹.

Polishing hardness. Vitrinite is soft and shows no relief in relation to the accompanying liptinite and inertinite macerals (except corpogelinite). Vitrinite surfaces in sediments are smooth. The macerals of this group may show relief against the embedding resin and the polishing technique may exaggerate this feature.

Chemical properties

Vitrinite is characterized by a relatively high oxygen content compared with the macerals of the other groups. Elemental composition is rank dependent^{12,13} and ranges as follows:

Carbon:	77–96%; rarely 98%
Hydrogen:	6–1%; in peranthracites 0.2%
Oxygen:	16–1%

Carbon increases and oxygen decreases steadily during coalification whereas the highest hydrogen content is observed in vitrinite of about 85% C¹⁴, corresponding to a random reflectance of 1.0–1.1%.

Vitrinite is rich in aromatic structures^{15,16}. The aromaticity increases with rank from about 70% C in aromatic bonding in subbituminous coal to over 90% in anthracite¹⁷. The lower the atomic H/C and O/C ratios the higher the aromaticity¹³. The heteroatom (O, N, S) concentration decreases with increasing rank. Oxygen functional groups are -COOH, -OH, >C=O, -C-O-C-; N occurs mainly as amines, and S as thiols and sulfides in heterocyclic rings¹⁷.

Vitrinite also contains various aliphatic compounds¹⁸. It seems to act (especially in 'dark vitrinite') as an absorbent for aliphatics¹⁹.

Derivation

Vitrinite is derived from parenchymatous and woody tissues of roots, stems, barks and leaves composed of cellulose and lignin. Depending on the process of decomposition, the degree of gelification and rank, cell structures are preserved and visible to varying extents. The macerals of the vitrinite group are defined by the different structures resulting from different sources and pathways of transformation within the mires.

Occurrence

Vitrinite occurs in coal seams formed as a result of anaerobic preservation of ligno-cellulosic material in swamps. It also occurs in coaly shales where organic and mineral matter were deposited rapidly.

Vitrinite is the main component of bright coal comprising the microlithotypes vitrite, vitrinertite and clarite. It is more frequent in Carboniferous seams of the Northern Hemisphere (60–80 vol.%) than in Gondwana coal (sometimes <20 vol.%;²⁰) or in Cretaceous seams of North America. Tertiary coals in general are rich in vitrinite. In sediments vitrinite is the main component of kerogen Type III.

Practical importance

Being a major component of most coals, the properties of vitrinite affect most industrial processes in which coal is utilized. In medium rank coals it readily fuses during carbonization^{21,22}, and this property also influences both the course and products of hydrogenation and combustion²³. Oxidation during storage results in deterioration of the quality of vitrinite including thermoplasticity in the case of bituminous coal. Vitrinite is a major source of natural gas of primary origin.

TELOVITRINITE

Origin of term

Term introduced by the ICCP 1994 to denote vitrinite with cell structure. This structure may or may not be apparent in reflected white light. Derivation: *tela* (L)—tissue; *vitrum* (L)—glass.

Related terms

Transmitted light microscopy: anthraxylon^{24,25}; humotelinite (brown coal).

Definition

Telovitrinite is a subgroup of the maceral group vitrinite, comprising vitrinites with preserved botanical cell structures which may or may not be visible.

Comment. The subgroup comprises the macerals telinite and collotelinite which are distinguishable by their different degree of geochemical gelification (vitrinitization). The former consists of clearly recognizable cell walls; the latter is of more or less structureless form which, in sections more or less parallel to the bedding may be of considerable areal extent and without linear margins. When viewed perpendicular to the bedding collotelinite appears as layers of varying thickness.

Physical properties

See 'Vitrinite', 'Telinite', 'Collotelinite'.

Chemical properties

See 'Vitrinite', 'Telinite' and 'Collotelinite'.

Derivation

The macerals of this subgroup are derived from the parenchymatous and woody tissues of roots, stems, barks and leaves composed of cellulose and lignin and originating from herbaceous and arborescent plants. Large amounts of telovitrinite indicate a high degree of cell-tissue preservation under wet, possibly low-pH conditions within forested peatlands or forested wet raised bogs²⁶. The precursor of telovitrinite in low rank coals is humotelinite.

Note. The so-called pseudovitrinite is derived from similar plant material. Its reflectance is somewhat higher than that of telinite and collotelinite in the same coal²⁷. It may show some cell structure and typically has small slits ('comma-slits') and serrate fragment margins.

Occurrence

See 'Telinite' and 'Collotelinite'.

Practical importance

In combustion, telovitrinite tends to form cenospheres, whereas in carbonization telovitrinite of medium rank coal is fusible. For additional properties see 'Telinite' and 'Collotelinite'. Higher amounts of pseudovitrinite may diminish the thermoplastic properties of the coal. For further information see 'Vitrinite'.

TELINITE

Origin of term

Term introduced in 1933 by Jongmans and Koopmans²⁸ and adopted in 1935 by the Heerlen Congress to describe layers of vitrinite with distinct cell structure. In 1957 the ICCP decided to restrict the term telinite to the coalified cell walls of recognizable plant tissues. Derivation: *tela* (L)—tissue.

Related terms

Xylain²⁹; textinite (brown coal); ulminite (brown coal).

Definition

Telinite is a maceral of the vitrinite group, subgroup telovitrinite, consisting of clearly recognizable cell walls of more-or-less intact plant tissue.

Comment. The size, shape and openness of cell lumens are variable depending on the original plant material and orientation of the section. The shape of the cells may be subspherical or oval, although often deformed. The cell

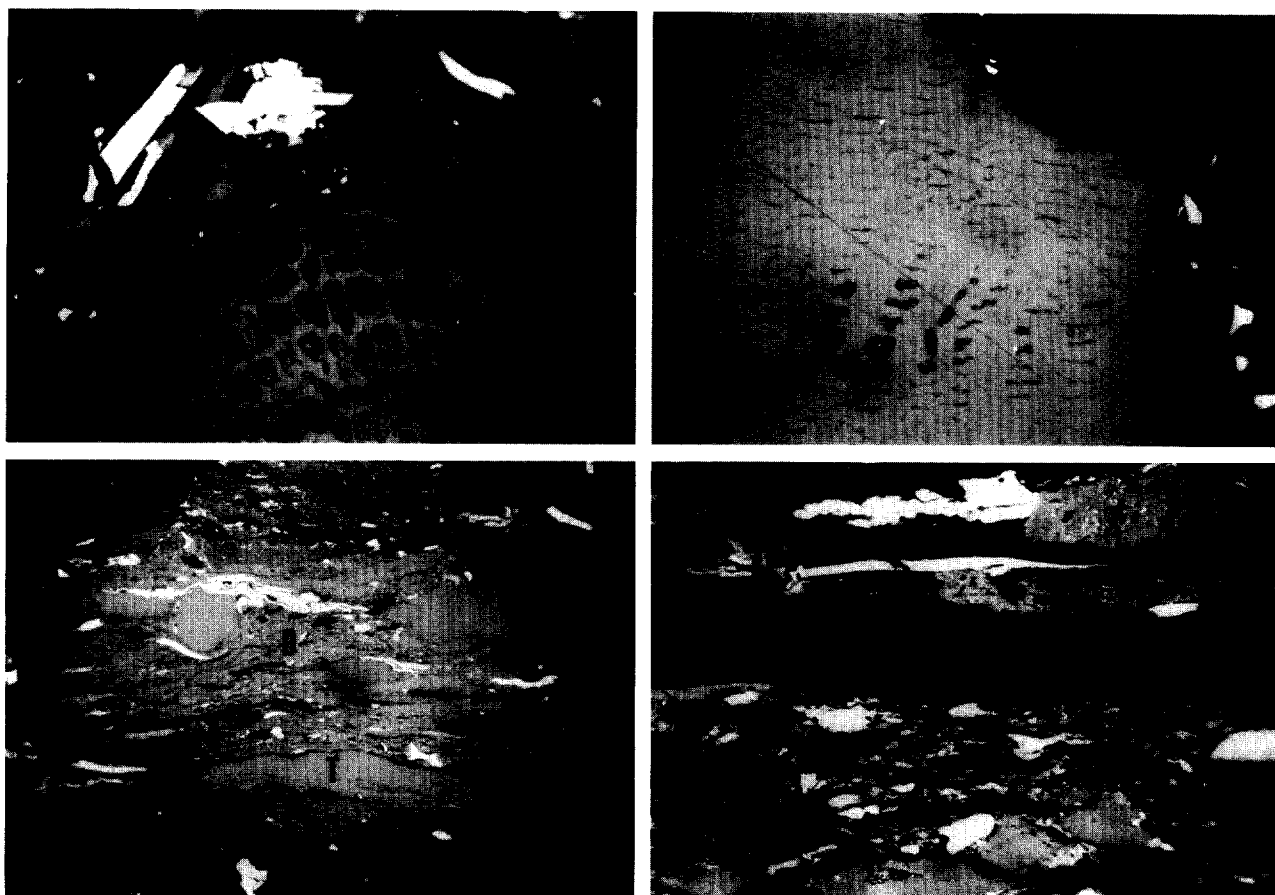


Figure 1 (a) Telinite (T). (b) telinite (open cell lumina filled with resinite); (c) collotelinite (T) indicating former woody cell structure and collodetrinite (D) forming the groundmass for lipto (dark) and inertodetrinite (bright); (d) collotelinite, structureless (T), collodetrinite (D) and corpogelinite (G). Figures clockwise from upper leftside, vertical size corresponds to 0.2 mm

walls are always gelified, and because of this rarely show internal structure as can be seen in the precursor macerals textinite and ulminite of low rank coals. The cell lumens are occasionally empty, but usually they are closed by swollen cell walls. They may be filled with other macerals or minerals. The most common inclusions are corpogelinite, resinite and micrinite, clay minerals and carbonates. The more the reflectance of the cell fillings differs from that of the cell walls, the more distinct is the cell structure (*Figure 1, (a) and (b)*).

As rank increases, telinite becomes more difficult to distinguish from other vitrinite macerals because of the convergence of their optical properties. Telinite revealed by etching is referred to as crypto-telinite.

Note. Cell wall material of fungal tissues does not belong to telinite, irrespective of its reflectance.

Physical properties

Colour and reflectance. See 'Vitrinite'. The reflectance of telinite often differs from that of the cell fillings. Fillings of gelovitrinite usually have a higher reflectance than that of associated telinite. Fillings of lower reflectance belong to resinite (liptinite group), see also 'Colloresinite'⁵

Fluorescence. In general, similar or weaker than that of the accompanying collotelinite.

Polishing hardness. Telinite is relatively soft. In polished blocks it does not show relief but may be harder than the associated corpogelinite.

Chemical properties

The elemental composition and the aromaticity are rank-dependent. There is little information available on the chemical composition of pure telinite. See also 'Collotelinite'.

Derivation

Telinite is derived from the cell walls of parenchymatous and woody tissues of roots and stems composed of cellulose and lignin and it originates from both herbaceous and arborescent plants. Geochemical gelification (vitrinitization) has mainly affected the cell walls themselves. The precursors of telinite in low rank coals are textinite and ulminite.

Occurrence

Telinite occurs in high volatile bituminous coals. It is less abundant than collotelinite. In high rank coals telinite is apparent only where the cell lumens have been infilled by mineral matter. For the same reason telinite is present in sediments at all ranks. Telinite is part of kerogen Type III.

Practical importance

See 'Collotelinite'.

COLLOTELINITE

Origin of term

Term introduced by ICCP 1994 to denote more-or-less homogenized vitrinite layers which may exhibit poorly defined structure. Cell structure may be revealed or

Table 2 Chemical properties of collotelinite

Rank	Collotelinite vol. %	C	H	% (dmmf)			VM% (dmmf)	Reference
				N	O	S		
0.55% Rr	82.7 (+ Tel.)	67.0	5.0	0.7	16.0	0.2	36	Cameron ⁶⁷
0.68% Rr	72.7	77.2	5.4	0.9	16.3	0.2	35	
hvB	97.1	81.5	5.1	2.0	10.8	0.6	35.1	Given et al. ⁶⁸
hvA	88.7	88.8	5.3	1.7	3.6	0.6	29.8	
1.49% Rr	ca. 90	88.8	4.9		5.2	1.1	25.1	Teichmüller ⁶⁹
1.61% Rr	ca. 90	88.9	4.9		4.8	1.4	21.4	
2.08% Rr	ca. 90	90.5	4.3		4.2	1.0	14.0	
3.73% Rr	87.0	94.8	2.1	1.0	1.6	0.5	6.4	Cameron ⁶⁷

accentuated by the use of etching procedures. Derivation: *colla* (GR)—glue, *tela* (L)—tissue.

Related terms

Xylovitrain²⁹; vitrinite A³⁰; homocollinite³¹; pseudo-vitrinite²⁷; telocollinite³²; ulminite (brown coal).

Definition

Collotelinite is a maceral of the vitrinite group, subgroup telovitrinite, with a homogeneous, more-or-less structureless appearance.

Comment. In low rank coals it may show a mottled texture or remnant cell structure. Etching may enhance details of cellular structure; the visible cell walls are then called crypto-telinite (*Figure 1, (c) and (d)*).

Note. Collotelinite is discernible from collodetrinite by its homogeneity.

Physical properties

Colour and reflectance. See 'Vitrinite'. The reflectance value of collotelinite is widely used to determine the rank of coal and organic matter in sediments. Its reflectance is commonly higher than that of collodetrinite by approximately 0.05–0.10%³³.

Fluorescence. Improvements in the fluorescence microscopy of vitrinite macerals^{34–39} have shown that collotelinite fluoresces over a wide rank range (high volatile bituminous–semi-anthracite). Teichmüller⁴⁰ and Teichmüller and Durand⁴¹ demonstrated that the fluorescence intensity of vitrinite macerals passes through a minimum at about 0.5% Rr and reaches a maximum at a vitrinite reflectance of 1.0–1.1% Rr depending on the wavelength of excitation and measurement. With a further increase in rank the fluorescence intensity decreases. Spectral fluorescence measurements showed that with increasing rank lambda max and the Red/Green Ratio (Q) shift towards longer wavelengths^{40,42}. Hagemann *et al.*³⁵ and Kalkreuth *et al.*³⁹ recorded lambda max and Q-values obtained from collotelinite macerals over a wide coalification range.

The lambda max values were found to range from 590 nm (high vol. bit. coal) to 725 nm (med./low vol. bit. coal) using 365 nm irradiation. The Q-values were found to range from 1.15 (high vol. bit. coal) to 3.60 (med./low vol. bit. coal) using 365 nm irradiation (Hagemann *et al.*³⁵).

Teichmüller⁴⁰ explains the fluorescence of vitrinite as a result of the generation of petroleum-like substances in coal. Lin *et al.*^{36,37} and Lin and Davis⁴³ refer to the development of a mobile phase within the molecular structure of vitrinite, which is responsible for the fluorescence of vitrinite in medium rank coals. The mobile phase is thought to

consist of relatively small molecules (fluorophores) with a high proton mobility. The condensed and cross-linked aromatic structures within the vitrinite are believed to be non-fluorescent⁴³.

Polishing hardness. Collotelinite shows no relief against other vitrinite macerals.

Chemical properties

The elemental composition and the aromaticity are rank-dependent. Increasing aromaticity causes increasing reflectance. No information is available on the chemical composition of pure collotelinite (*Table 2*).

For further information see refs^{30,44,45}. Davis *et al.*⁴⁶ reported on the composition of extractable matter from collotelinite (telocollinite) concentrates. Alkyl-naphthalenes and alkylphenols were found to be the dominant aromatic compounds.

Derivation

Collotelinite is derived from the parenchymatous and woody tissues of roots, stems and leaves, composed of cellulose and lignin and originating from herbaceous and arborescent plants. By geochemical gelification (vitrinitization) the primary structures disappear. The precursor of collotelinite in low rank coals is ulminite. At higher rank levels collotelinite is also formed from telinite and its vitrinitic cell fillings.

Occurrence

Collotelinite is most abundant in the bright lithotypes vitrain and to a lesser extent in clarain. In sediments collotelinite is the main vitrinite maceral. It is very common in coaly shales. Collotelinite is part of kerogen Type III.

Practical importance

The reflectance of collotelinite is used widely as an index of the rank of coal and also of the organic matter in sediments. In geology, knowledge of coal rank derived from reflectance measurements made on collotelinite provides the basis for estimating palaeotemperatures, the amount of eroded overburden and the time of deformation with regard to coalification processes.

Collotelinite as part of the vitrinite group forms the principal reactive maceral in technological processes such as carbonization and liquefaction. However, the reactivity of vitrinite in carbonization is restricted to a narrow reflectance (rank) range from approximately 0.8–1.6% Rr, and rarely to 2.0% Rr^{47–49}. In liquefaction, optimum rates of conversion to liquid and gaseous products are obtained from high volatile medium rank coals⁵⁰. Experimental studies on coal gasification⁵¹ and combustion reactivities of coals showed that ignition temperatures

in gasification and burnout rates in combustion can be directly related to the reflectance levels of the maceral collotelinite⁵²⁻⁵⁵.

The technological properties of collotelinite can also be related to its fluorescence^{11,22,34,35,40,54,56-59}.

Note. In coal and sediments rich in alginite and its degradation products the reflectance of collotelinite may be lower than in coals not so enriched⁶⁰. In those cases the fluorescence properties may indicate the correct rank³⁵.

DETROVITRINITE

Origin of term

Term introduced by the ICCP 1994 to denote particulate vitrinitic substances. Derivation: *detritus* (L)—abrasion, *vitrum* (L)—glass.

Related terms

Transmitted light microscopy: translucent humic degradation matter²⁴; humodetrinite (brown coal).

Definition

Detrovitrinite is a subgroup of the maceral group vitrinite consisting of finely fragmented vitrinitized plant remains occurring either isolated or cemented by amorphous vitrinitic matter.

Comment. To this subgroup belong the macerals vitrodetrinite and collodetrinite. The former describes the clearly visible and separate particles of vitrinite, occurring isolated or cemented by amorphous vitrinitic matter or minerals; the latter describes aggregates or a groundmass of vitrinite in which boundaries of individual particles can no longer be distinguished without etching because of gelification. Where the outline of individual particles of detrovitrinite is discernible, particle size is less than 10 μm in the maximum dimension for rounded grains. Elongate remains representing fragments of cell walls should have a minimum dimension of less than 10 μm ⁶¹.

Physical properties

See 'Vitrinite', 'Vitrodetrinite' and 'Collodetrinite'.

Chemical properties

See 'Vitrinite' and 'Collodetrinite'.

Derivation

The macerals of this subgroup are derived through the strong decay of parenchymatous and woody tissues of roots, stems and leaves originating from herbaceous and arborescent plants, originally composed of cellulose and lignin. By chemical decay and/or mechanical attrition the former structures have been broken down. Large amounts of detrovitrinite indicate a high degree of cell-tissue destruction, especially of cellulose-rich herbaceous plant material. Where neutral or weakly alkaline and oxidizing conditions prevailed during the peat stage, detrovitrinite is typically the dominant vitrinite maceral subgroup^{62,63}. The precursor in low rank coals is humodetrinite.

Occurrence

See 'Collodetrinite' and 'Vitrodetrinite'.

Practical importance

In combustion, detrovitrinite of medium rank coals tends to

form cenospheres, whereas in carbonization it is fusible. For additional properties see 'Vitrodetrinite' and 'Collodetrinite'.

VITRODETRINITE

Origin of term

Term adopted in 1970 by ICCP to describe a maceral of the vitrinite group which occurs as small particles. Derivation: *vitrum* (L)—glass; *detritus* (L)—abrasion.

Related terms

Transmitted light microscopy: humic degradation matter²⁵ in part.

Definition

Vitrodetrinite is a maceral of the maceral subgroup detrovitrinite within the maceral group vitrinite, occurring as discrete small vitrinitic fragments of varying shape that become discernible when surrounded by non-vitrinitic material.

Comment. The particle size is less than 10 μm in the maximum dimension for rounded grains and 10 μm in the minimum direction for thread-shaped fragments. The discrete nature of a particle of vitrodetrinite is an important criterion in its recognition and is enhanced by etching (*Figure (c)*).

Note. Corpogelinite less than 10 μm maximum dimension occurring in structured vitrinite is excluded.

Physical properties

Colour and reflectance. See 'Vitrinite'. In coals within the range of 0.5% to about 1.4% Rr the transitions to associated inertodetrinite are gradual. As rank increases it becomes more difficult to distinguish vitrodetrinite from other macerals of the vitrinite group unless outlined by inertodetrinite. In sedimentary rocks, especially shales, the reflectance may be slightly lower than in coals of corresponding rank^{60,64}.

Fluorescence. In coal the fluorescence of vitrodetrinite corresponds to that of the telovitrinite macerals if it is surrounded by inertodetrinite. In sediments it may be more intense in cases where the sediment is rich in alginite (e.g., oil shales)^{60,64}.

Polishing hardness. Vitrodetrinite is relatively soft. In polished blocks it shows no or weak positive relief against other macerals and minerals. This allows a quick differentiation from inertodetrinite and liptodetrinite which both have a distinct relief. In cases where vitrodetrinite is used for reflectance measurements this distinction is important.

Chemical properties

'See Vitrinite'.

Derivation

Vitrodetrinite is derived by extensive comminution from parenchymatous and woody tissues of roots, stems and leaves composed of cellulose and lignin. It was gelified prior to transportation and deposition or after sedimentation.

Occurrence

Vitrodetrinite is a constituent of the microlithotypes

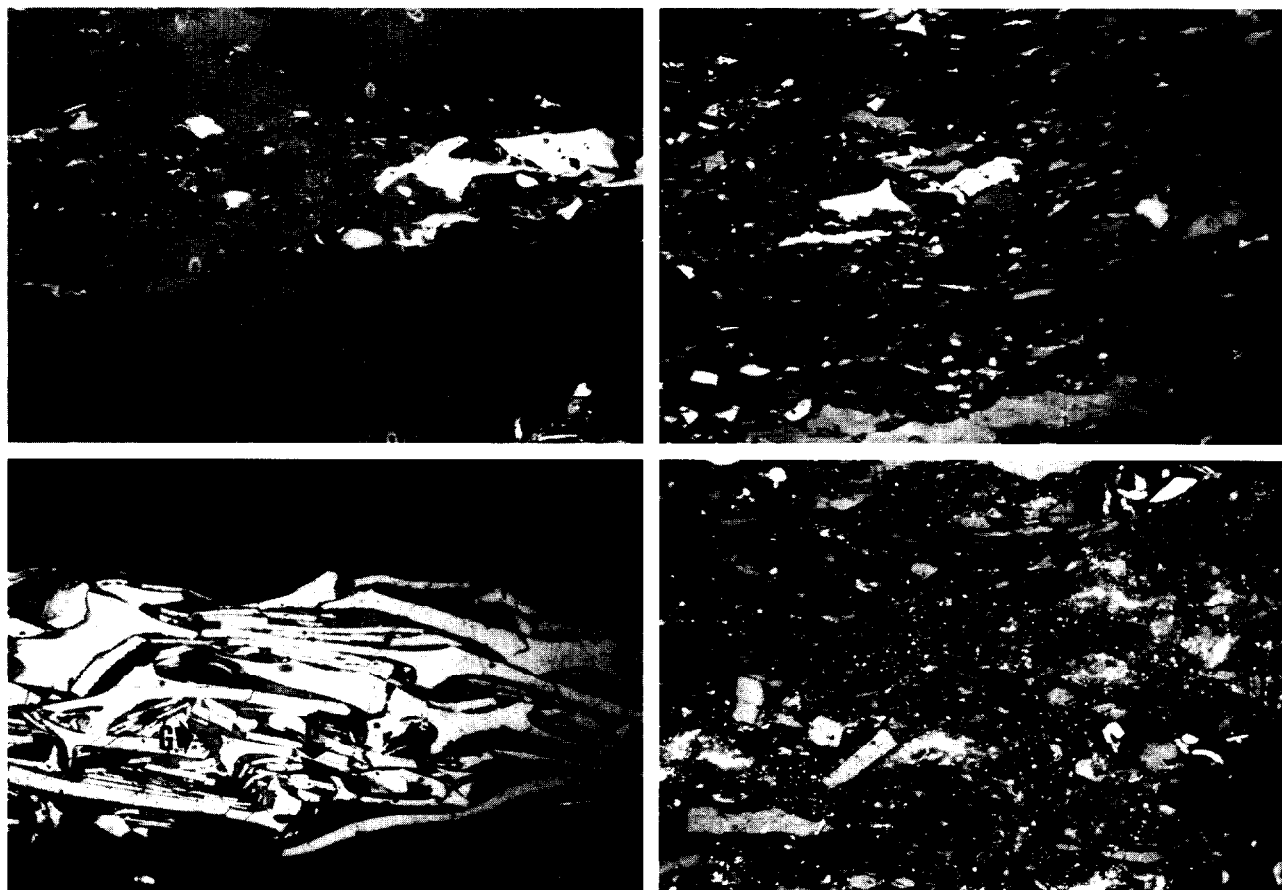


Figure 2 (a) Corpogelinite (G) and collodetrinite (D); (b) collodetrinite (D); (c) vitrodetrinite (medium grey) and inertodetrinite (bright grey) dispersed in shaly sediment; (d) gelinite (G) within fusinite. Figures clockwise from upper leftside, vertical size corresponds to 0.2 mm

vitroinertite, trimacerite and, rarely, durite. Its abundance in coal can be associated with the more poorly banded dull coals. In sediments, vitrodetrinite along with collotelinite is a principal constituent of kerogen Type III.

Practical importance

In sedimentary rocks vitrodetrinite is a major source for the generation of natural gas. Its behaviour in coal corresponds to the other vitrinite macerals (see 'Vitrinite'). In cases where the reflectance of vitrodetrinite is depressed by bituminization, its reactivity increases.

COLLODETRINITE

Origin of term

Term introduced by ICCP 1994 to denote the compact vitrinitic groundmass of the microlithotypes clarite, trimacerite and vitroinertite. Derivation: *kolla* (Gr)—glue; *detritus* (L)—abrasion.

Related terms

Vitrinite B³⁰; heterocollinite³¹; desmocollinite³²; attrinite (brown coal); densinite (brown coal).

Definition

Collodetrinite is a maceral of the maceral subgroup detrovitrinite within the maceral group vitrinite occurring as a mottled vitrinitic groundmass binding other coal components.

Comment. Compared to collotelinite, collodetrinite

lacks textural continuity and is less markedly layered perpendicular to the bedding. It is a mixture of vitrinite particles less than 10 μm in size and amorphous vitrinitic matter. Collodetrinite contains more submicroscopic inorganic substances than other vitrinite macerals⁶⁵. However, unlike vitrodetrinite, the component particles are not clearly visible in the light microscope due to a higher degree of homogenization; instead, it has a mottled surface especially in subbituminous and high volatile bituminous coals. Polished sections, cut perpendicular to the bedding plane, show the collodetrinite in layers of varying thickness. Parallel to the bedding, collodetrinite appears as irregular patches. At low rank it may have a slightly porous surface and internal reflections. As rank increases it becomes more difficult to separate collodetrinite from collotelinite. In anthracite the original presence of collodetrinite may be inferred when vitrinite having the required morphology is intermixed with inertodetrinite. After etching only the attrital part of collodetrinite is visible and then is called crypto-vitrodetrinite (Figure 1 (c) and (d), Figure 2 (a) and (b)).

Physical properties

Colour and reflectance. See 'Vitrinite'. In coals within the range of 0.5% to about 1.4% Rr the reflectance of collodetrinite is about 0.05–0.10% Rr lower than that of the corresponding collotelinite. The transitions are gradual. With increasing rank the differences disappear. The anisotropy of collodetrinite differs from that of the macerals of the liptinite group. Thus, by viewing anthracite through crossed polars the original presence of these macerals can be

detected. In sediments, especially shales, the reflectance may be slightly lower than in coals of corresponding rank^{60,64}.

Note. Transitions to the darker grey and lower reflecting 'dark vitrinite' (see 'Vitrinite'), resinite and colloresinite⁵ also occur.

Fluorescence. Fluorescence colour and intensity vary depending on rank and the degree of bituminization (adsorbed petroleum-like substances). Depending on the wavelengths used for excitation and measurement, collodetrinite fluorescence begins at approximately 0.6% Rr and attains a maximum intensity between 1.0 and 1.2% Rr, thereafter declining rapidly³⁵. Fluorescence colours range from yellow-brown to red-orange and red-brown. The fluorescence intensity of collodetrinite is stronger than that of the corresponding collotelinite. It is influenced also by associated liptinite macerals. In the presence of alginite and cutinite the fluorescence intensity of collodetrinite is higher than when associated with sporinite. In sediments, especially shales, the fluorescence may be more intense than in accompanying coals⁶⁴.

Note. The distinction from colloresinite is given by slightly higher intensity of the latter and also by different internal structures⁵. 'Dark vitrinite' also shows more intense fluorescence than collodetrinite.

Polishing hardness. Collodetrinite is soft. In polished blocks it shows no relief.

Chemical properties

The elemental composition and the aromaticity are rank-dependent (see 'Vitrinite'). The optical properties of the collodetrinite indicate that this maceral may have a higher hydrogen content than the corresponding collotelinite due to its lower aromaticity.

Derivation

Collodetrinite is derived from parenchymatous and woody tissues of roots, stems and leaves, composed of cellulose and lignin. The original plant tissues are destroyed by the strong decomposition at the beginning of the peat stage. The small particles are cemented by humic colloids within the peat and subsequently homogenized by geochemical gelification (vitritization)⁶⁶. Cellulose-derived substances may be more commonly the source of collodetrinite than lignin-rich wood⁶⁶. Precursors of collodetrinite in low rank coals are attrinite and densinite.

Occurrence

In many coals collodetrinite is the most abundant vitrinite maceral. It occurs in all hard coals, and is the main constituent of clarite, less common in vitrinertite and trimacerite, and rare in durite. Vitrinite composed of collodetrinite is rare in Palaeozoic coals. In sediments, the organic detritus is usually finely dispersed and collodetrinite is not common (see 'Vitrodetrinite'). Collodetrinite is part of kerogen Type III.

Practical importance

Collodetrinite is the vitrinite maceral with the highest content of volatile matter which degasses first during

carbonization. Its bitumen content markedly influences the caking and coking properties of a coal. During hydrogenation collodetrinite contributes substantially to the liquefaction products. Collodetrinite also reacts early during combustion. It degasses and forms pores earlier than the associated liptinite²³. In the case of low burnout, collodetrinite forms carbospheres.

GELOVITRINITE

Origin of term

Term introduced by the ICCP in 1994 to classify a subgroup of macerals originated from the jelling of humic solutions and not corresponding to specific plant tissues. Derivation: *gelu, us* (L)—frost, stiffening (of bodies due to age), *vitrum* (L)—glass.

Related terms

Humocollinite (brown coal).

Definition

Gelovitrinite is a maceral subgroup of the maceral group vitrinite consisting of colloidal infillings of vitrinitic material in former voids.

Comment. The subgroup consists of the macerals corpogelinite and gelinite. The former describes discrete bodies representing mainly the primary phlobaphenic infillings of cell lumens occurring *in situ* or isolated within the coaly or mineral matrix; the latter describes secondary homogeneous infillings of microfissures, cleats or other formerly empty spaces. The size is variable.

Note. Dispersed organic bodies or infillings within telinite with a lower reflectance than that of the surrounding collodetrinite or enclosing telinite component are excluded from gelovitrinite.

Physical properties

See 'Vitrinite', 'Corpogelinite' and 'Gelinite'.

Chemical properties

See 'Vitrinite', 'Corpogelinite' and 'Gelinite'.

Derivation

Gelovitrinite probably has more than one origin, but in general it is assumed to be derived from the contents of plant cells or from humic fluids formed from plant tissues during decay and diagenesis and subsequently precipitated as colloidal gels within voids or cavities within the source material.

Occurrence

See 'Corpogelinite' and 'Gelinite'.

Practical importance

See 'Corpogelinite' and 'Gelinite'.

CORPOGELINITE

Origin of term

Term adopted in 1994 by ICCP to classify a maceral of the vitrinite group comprising structureless bodies of humic cell fillings, *in situ* or isolated. Derivation: *corpus* (L)—body; *gelu, us* (L)—frost, stiffening (of bodies due to age).

Related terms

Corpocollinite³²; phlobaphinite (brown coal).

Definition

Corpogelinite is a maceral of the maceral subgroup gelovitrinite within the maceral group vitrinite, consisting of homogeneous and discrete bodies representing cell infillings.

Comment. Corpogelinite bodies may be found incorporated within telovitrinite at their original sites of deposition; alternatively, they may occur isolated within an attrital matrix as a result of degradation of the enclosing plant tissue. Therefore, corpogelinite bodies may occur grouped together or as single bodies. Depending upon orientation, the shape of occurrences can be spherical, oval or elongate. The size varies. Corpogelinite in Carboniferous coals (e.g., from *Alethopteris*) may reach a length of 1–10 mm. Outlines are generally smooth, but may be angular. Exceptionally, corpogelinite contains vacuoles of various sizes. Typically, corpogelinite has a higher level of reflectance than other associated vitrinite macerals. Etching may reveal or enhance the appearance of corpogelinite incorporated within collotelinite or collodetrinite (*Figure 1 (d), Figure 2 (a)*).

Physical properties

Colour and Reflectance. See 'Vitrinite'. Generally the colour is paler and has higher reflectance than the associated collotelinite and collodetrinite. Occasionally corpogelinite shows rims of lower reflectance.

Fluorescence. In general the fluorescence intensity is weaker than that of the associated collotelinite and collodetrinite macerals or fluorescence may be absent.

Polishing hardness. Corpogelinite may show relief when associated with other macerals of the vitrinite group.

Chemical properties

No information is available due to the difficulty of obtaining enough material for analysis; however, it probably should be classed among the less reactive and lower volatile vitrinite macerals at a given rank level.

Derivation

Corpogelinite may be of primary origin corresponding to cell contents, derivable from tannin in part; it also may have been derived from secretions of the cell walls. Alternatively, it may consist of the secondary infillings of tissue cavities by humic solutions which subsequently precipitate as gels during peatification and the early stages of coalification. Botanical affinity can sometimes be recognized, for example when found between cuticular layers of leaf tissue and as infillings of vascular tissue.

Note. The corpogelinite contained in Late Mesozoic and Cainozoic coals and sediments has commonly been derived from corpohuminite (phlobaphinite). Due to floral differences, this is not necessarily the case in older deposits.

Occurrence

Corpogelinite occurs in all Palaeozoic coals in minor amounts, generally in those microlithotypes containing appreciable quantities of vitrinite. In coals of the Mesozoic,

especially those of Cretaceous period, and in the Cainozoic, corpogelinite is more common. The larger bodies are less common in geologically younger coals. Owing to its chemical and physical resistance corpogelinite is often enriched in sedimentary rocks. Corpogelinite is part of kerogen Type III.

Practical importance

See 'Vitrinite'.

GELINITE

Origin of term

Term adopted in 1971 by ICCP³² to classify a component of the huminite group consisting of a pure colloidal gel. It corresponds to the original concept of a 'reprecipitated gel' for which Stopes¹ proposed the name collinite. Derivation: *gelu, us* (L)—frost, stiffening (of bodies due to age).

Related terms

Collinite¹; gelocollinite³²; gelinite (brown coal).

Definition

Gelinite is a maceral of the maceral subgroup gelovitrinite within the maceral group vitrinite, consisting of homogeneous and structureless infillings of cracks and other voids.

Comment. Gelinite is of secondary origin. It may occur as a matrix embedding mylonitized coal particles in micro-faults within coal seams, or it may impregnate the cell cavities of sclerotinite, semifusinite and fusinite. Size and shape are variable depending upon the configuration of the infilled void. Massive infillings may exhibit desiccation cracks (*Figure 2 (d)*).

Physical properties

Colour and reflectance. The reflectance is often slightly higher than that of other vitrinite macerals which are associated. Structureless material infilling voids may comprise discrete bands of differing reflectance.

Fluorescence. In general the fluorescence intensity is weaker than that of the associated collodetrinite and collotelinite macerals. Fluorescence may be absent.

Polishing hardness. Gelinite commonly shows the lowest relief against the other macerals of the vitrinite group.

Chemical properties

See 'Vitrinite'.

Derivation

The maceral is formed by humic colloids originating during the early diagenesis of plant material and secondarily impregnating source material followed by precipitation as colloidal gel. Some occurrences suggest that infilling took place during late-stage coalification after the deposit had achieved a degree of rigidity. Gelinite in low rank coals may be the precursor of gelinite of medium and high rank coals.

Occurrence

Gelinite is the least common maceral of the vitrinite group. It is likely to be found in coals subjected to tectonic disturbance during early stages of coalification. In voids it

may occur in association with colloresinite⁵. It is not recognizable in sedimentary rocks when isolated from other macerals. Gelinite is part of kerogen Type III.

Practical importance

See 'Vitrinite'.

REFERENCES

1 Stopes, M. C., *Fuel*, 1935, **14**, 4.
 2 Newman, J. and Newman, N. A., *New Zealand J. Geol. Geophys.*, 1982, **25**, 232.
 3 Wolf, M. and Wolff-Fischer, E., *Glückauf-Forschungshefte*, 1984, **45**(5), 243.
 4 Drath, A., *Brown Coal of the 'Zygmunt' Mine in Poreba Near Zawiercie*. Warsaw.
 5 ICCP, *Int. Handbook Coal Petr.*, 3rd suppl. to 2nd edn, 1993.
 6 ICCP, *Int. Handbook Coal Petr.*, 2nd edn, 1963.
 7 ECE, *International Codification System for Medium and High Rank Coals*. Geneva, 1988.
 8 Buiskool Toxopeus, J. M. A., in *Petroleum Geochemistry and Exploration of Europe*, ed. J. Brooks, Vol. 12, Geol. Soc. Spec. Publ. Blackwell, Oxford, 1983, p. 295.
 9 Murchison, D. G., *Fuel*, 1976, **55**, 79.
 10 Alpern, B. and Lemos de Sousa, M., *C. R. Acad. Sc. Paris*, 1970, **271**, 956.
 11 Ottenjann, K., Wolf, M. and Wolff-Fischer, E., *Glückauf-Forschungshefte*, 1982, **43**, 173.
 12 Patteisky, K., Teichmüller, M. and Teichmüller, R., *Brennstoff-Chemie*, 1960, **41**, 79, 97, 133.
 13 van Krevelen, D., *Coal*. Elsevier, Amsterdam, 1993.
 14 van Krevelen, D. W. and Schuyer, J., *Coal Science*. Elsevier, Amsterdam, 1957.
 15 Given, P. H., *Fuel*, 1960, **39**, 147.
 16 Given, P. H., *Fuel*, 1961, **40**, 427.
 17 Tissot, B. P. and Welte, D. H., *Petroleum Formation and Occurrence*. Springer, Berlin, 1984.
 18 Schenck, P. A., de Leeuw, J. W., Viets, T. C. and Haverkamp, J., in *Petroleum Geochemistry and Exploration of Europe*, ed. J. Brooks, Vol. 12, Geol. Soc. Spec. Publ. Blackwell, Oxford, 1983, p. 267.
 19 Winans, R. E., Dyrkacz, G. R., McBeth, R. L., Scott, R. G. and Hayatsu, R., *Proc. Int. Conf. Coal*, Düsseldorf, 1981, p. 22.
 20 Stavrakis, N. and Smyth, M., *Int. J. Coal Geol.*, 1991, **18**, 1.
 21 Mackowsky, M.Th., *J. Microsc.*, 1977, **109**, 119.
 22 Diessel, C. F. K. and McHugh, E. A., *Glückauf-Forschungshefte*, 1986, **47**, 60.
 23 Bengtsson, M., *Comun. Serv. Geol. Portugal*, 1984, **70**(2), 277.
 24 Thiessen, R., *Bur. Mines Bull*, Vol. 117.
 25 Thiessen, R., *J. Geol.*, 1920, **28**, 185.
 26 Diessel, C. F. K., *Coal-Bearing Depositional Systems*. Springer, Berlin, 1992.
 27 Benedict, L. G., Thompson, R. R., Shigo, J. J. and Aikman, P. R., *Fuel*, 1968, **47**, 125.
 28 Jongmans, W. J. and Koopmans, R. G. Kohlenpetrographische Nomenklatur. Jaarsverslag over 1933, *Geol. Bur. Nederl. Mijnged. Heerlen*, 1934, **49**.
 29 Duparque, A., *Proc. Int. Comm. Coal Petr.*, 1956, **2**, 18.
 30 Brown, H. R., Cook, A. C. and Taylor, G. H., *Fuel*, 1964, **43**, 111.
 31 Alpern, B., *Advances in Organic Geochemistry 1964*. Pergamon Press, Oxford, 1966, p. 129.
 32 ICCP, *Int. Handbook Coal Petr.*, suppl. to 2nd edn, 1971.
 33 Goodarzi, F., Geol. survey of Canada. Paper 86-IB, 1986, p. 671.
 34 Diessel, C. F. K., *Advances in the Study of the Sydney Basin. Proceedings of the 20th Symp.*, University of Newcastle, 1986, p. 71.

35 Hagemann, H. W., Ottenjann, K., Püttmann, W., Wolf, M. and Wolff-Fischer, E., *Erdöl und Kohle, Erdgas, Petrochemie*, 1989, **42**, 99.
 36 Lin, R., Davis, A., Bensley, D. F. and Derbyshire, F. J., *Int. J. Coal Geol.*, 1986, **6**, 215.
 37 Lin, R., Davis, A., Bensley, D. F. and Derbyshire, F. J., *Organic Geochemistry*, 1987, **11**, 393.
 38 Steller, M. and Kalkreuth, W., *Erdöl und Kohle*, 1990, **43**(10), 387.
 39 Kalkreuth, W., Steller, M., Wieschenkämper, I. and Ganz, S., *Fuel*, 1991, **70**, 683.
 40 Teichmüller, M., Fluoreszenzmikroskopische Änderungen von Liptiniten und Vitriniten mit zunehmendem Inkohlungsgrad und ihre Beziehungen zu Bitumenbildung und Verkokungsverhalten. Geologisches Landesamt NRW, 119 S, 1982. (In English, *Soc. Org. Petrol., Spec. Publ.*, Vol. 1, 1984.
 41 Teichmüller, M. and Durand, B., *Int. J. Coal. Geol.*, 1983, **2**, 197.
 42 Ottenjann, K., *Zeiss-Inform., Oberkochen*, 1982, **26**(93), 40.
 43 Lin, R. and Davis, A., *Organic Geochemistry*, 1988, **12**(4), 363.
 44 Jones, J. M., Davis, A. and Cook, A. C., *Int. J. Coal Geol.*, 1984, **3**, 315.
 45 McCartney, J. T. and Teichmüller, M., *Fuel*, 1972, **51**, 64.
 46 Davis, M., Abbott, J. and Gaines, A., *Fuel*, 1985, **64**, 1362.
 47 Cudmore, J. F., in *Coal Geology and Coal Technology*, C. R. Edward. Blackwell, Oxford, 1984, p. 113.
 48 Marshall, R. J., *Fuel*, 1976, **55**, 346.
 49 Schapiro, N. and Gray, R. J., *J. Inst. Fuel*, 1964, **37**, 234.
 50 Whitehurst, D., Mitchell, T. and Farcasiu, M., *Coal Liquefaction*. Academic Press, New York, 1980.
 51 Furimsky, E., Palmer, W., Kalkreuth, W., Cameron, A. and Kovacic, G., *Fuel Processing Technology*, 1990, **25**, 135.
 52 Bailey, J. G., Tate, A. G., Diessel, C. F. K. and Wall, T. F., *Fuel*, 1990, **69**, 225.
 53 Crelling, J. C., Skorupska, N. M. and Marsh, H., *Fuel*, 1988, **67**, 781.
 54 Steller, M., Kalkreuth, W. and Wieschenkämper, I., *Intern. Conf. on Coal Science Proc.*, 16–20 September 1991, University of Newcastle-upon-Tyne, UK, 1991, p. 90.
 55 Vleeskens, J. M., *Int. Conf. on Carbon, Proc.*, 1983, p. 509.
 56 McHugh, E. A., *Advances in the Study of the Sydney Basin. Proceedings of the 20th Symp.*, University of Newcastle, 1986, p. 66.
 57 Kalkreuth, W., Brouillard, D. and Roy, C., *Biomass*, 1986, **10**, 27.
 58 Diessel, C. F. K. and Wolff-Fischer, E., *Int. J. Coal Geol.*, 1987, **9**, 87.
 59 Sasaki, M., Takahashi, R. and Mochida, I., *Fuel*, 1990, **69**, 529.
 60 Hutton, A. and Cook, A., *Fuel*, 1980, **59**, 711.
 61 Moore, T. A. and Ferm, J. C., *Int. J. Coal Geol.*, 1992, **21**, 1.
 62 Benner, R., Moran, M. A. and Hodson, R. E., *Limnol. Oceanogr.*, 1985, **30**, 489.
 63 Pickel, W. and Wolf, M., *Erdöl und Kohle, Erdgas, Petrochemie*, 1989, **42**, 481.
 64 Kalkreuth, W. and Macauley, G., *Bull. Canad. Petroleum Geology*, 1984, **32**(1), 38.
 65 Alpern, B. and Quesson, A., *Bull. Soc. franç. Minér. Crist.*, 1956, **79**, 449.
 66 Stach, E., Mackowsky, M.-Th., Teichmüller, M., Taylor, G. H., Chandra, D. and Teichmüller, R., *Stach's Textbook of Coal Petrology*, 3rd edn. Gebrüder Borntraeger, Berlin, 1982.
 67 Cameron, A., *Geological Society of America Annual Meeting, San Diego, California, 1991. Abstracts with Program*, 1991, **23**, 56.
 68 Given, P. H., Spackman, W., Davis, A., Zoeller, J., Jenkins, R. G. and Khan, R., *Fuel*, 1984, **63**, 1655.
 69 Teichmüller, M., *Geol. Mitteilungen*, 1971, **11**, 181.