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INTERNATIONAL COMMITTEE
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D.G. Murchison A.H.V. Smith

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This reprint of the *1st Supplement (1971) to the 2nd Edition of the International Handbook of Coal Petrography* has involved substantial editing and correction to the text before reprinting. The British editors (D.G. Murchison and A.H.V. Smith) take full responsibility for the final accuracy and presentation of the text, but they would like to thank the other members (B. Alpern, M-Th. Mackowsky, R. Noel and M. Teichmüller) of the Editorial Committee (Chairman, V. Hevia), who contributed so willingly and usefully to improvement of the text. They are particularly grateful to M. Teichmüller for her contributions.

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SUPPLEMENT	**FOREWORD AND ACKNOWLEDGMENTS OF THE COORDINATING EDITOR OF THE ENGLISH SUPPLEMENT**	

The subject matter for virtually all the terms contained in this Supplement was drafted either in French or in German. As far as possible the English edition represents a faithful translation from the language in which the terms were first prepared. Editing has been kept to the minimum necessary to produce uniformity of presentation throughout the volume, although the English draft of the nomenclature of the Academy of Sciences, Moscow, required considerable modification.

As coordinating editor for the English edition, I would like to thank Dr D. G. Edwards, British Coke Research Association, for translating the drafts of certain of the terms relating to the Analysis Sub-Committee; Mr F. W. Hamilton, Interpreting and Translation Branch, National Coal Board, for assistance in translating the early drafts of the brown-coal nomenclature; Dr A. H. V. Smith, National Coal Board, for the substantial task of sub-editing the Russian nomenclature; and Professor W. Spackman, Pennsylvania State University for preparing the list of synonyms and analogues for the English supplement. The final responsibility for the translation of the entire Supplement and for any errors and misinterpretations which may have occurred, rests with the coordinating editor.

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Duncan Murchison

1971

International Committee for Coal Petrology
Nomenclature Sub-Committee
Analysis Sub-Committee

SUPPLEMENT

INTRODUCTION TO THE SUPPLEMENT TO THE 2nd EDITION

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The two editions of the Handbook of Coal Petrography have been criticized on two grounds:-

(i) the arrangement of terms is alphabetical and not by subject and, because of this, it is difficult for non-specialists to follow. and

(ii) the possibilities of practical applications of coal petrology are not expressed sufficiently clearly. Although the practical importance of numerous individual terms is discussed, a summary, which could arouse the interest of the mining engineer, plant engineers (of power stations, coke ovens etc), petroleum geologists and others, is lacking.

With the publication of many important new terms in the Handbook, the International Committee for Coal Petrology (ICCP) has resolved that there should be:-

a) a re-arrangement of the Handbook terms in eight chapters used in this and subsequent pages according to subject, with an alphabetical index, and

b) an introduction to give a general explanation of the objectives, methods and possibilities of applications of coal petrology.

The form of the terms has not been altered, each consisting of a collection of separate sheets, all contained in a loose-leaf folder. Generally each of the terms contains sections on the origin of the term, a description of the constituent concerned, its properties, its occurrence and practical importance. Retention of this arrangement is justified, because the work is essentially a dictionary, and thus should remain a glossary and not be a dissertation. The sense of a dictionary is to explain the terms used in a particular field of work, in this case coal petrography.

The introductory chapter is followed in chapter II by an explanation of general terms which, besides being used in the general field of geology, also have a particular importance in coal petrography. Thus, for example, it is impossible to discuss the origin of coal without reference to the autochthony or to the allochthony of coal, or to the degree of coalification or rank; or to the definition of the different coal types which occur in nature.

Chapters III, IV and V are devoted purely to petrographic terms. Chapter III is subdivided in the following manner.

As already stated in the introduction to the first two editions of the Handbook, the ICCP, as a result of resolutions passed at the 3rd Congress of Carboniferous Stratigraphy and Geology (Heerlen, 1951), accepted the task of producing a uniform international coal petrographical nomenclature. As the beginning of its work, the Committee found many different terms, based on a variety of methods of investigation, for which there were numerous synonyms, many of which were used locally to an extremely restricted extent. To produce useful work for the proposed international nomenclature, the Committee saw itself forced to retain only a restricted number of terms, which were recognized by a large majority of experienced world specialists. These terms, which were recognized as belonging to international nomenclature, the Stopes-Heerlen nomenclature, are collected in Chapter III. The technical terms used for hard coals are explained in Chapter IIIA and those used for brown coals are explained in Chapter IIIB. An attempt to correlate the macerals of brown coals with those of hard coals forms the conclusion to the chapter.

The supplementary edition contains for the first time data from the Brown-Coal Group of the ICCP (formed in 1963), covering nineteen different macerals, maceral subgroups and maceral groups of soft and dull brown coals. These terms are laid out in a similar manner to the longer-standing terms for hard-coal nomenclature. Sections have been added on the etymology of the terms, the chemical properties of the macerals, their botanical affinities and genesis, as well as on their alteration during the course of coalification. The literature was considered more widely than previously, so as to indicate specialized information to the reader. Since many literature references are the same for different terms, all the references have been collected together in a list at the end of Chapter IIIB. General information about the methods of investigation etc. for brown-coal terms appears in Chapter I.

The results of the Brown-Coal Group still lack complete descriptions for several liptinite and inertinite macerals (suberinite, alginite, bituminite, fusinite, semifusinite and macrinite). A most important problem for the future is the classification and quantitative petrographic definition of microlithotypes and lithotypes, which are of especial interest, particularly for applied brown-coal petrology. A special working group now deals with analytical methods in brown-coal petrology and with their international norms. Another working group is investigating the boundaries between different grades of diagenesis within the brown-coal range and the boundary between brown coals and hard coals on the basis of the reflectance of huminite (or respectively vitrinite), as well as on other optical properties. The results of this future work of the Brown-Coal Group should appear in a later edition or supplement of the Handbook for Coal Petrography.

Chapter IV is devoted to terms or classifications of several special or regional nomenclature systems, upon whose value the Committee does not offer judgement, but whose publication is considered useful to provide comprehensive information for the reader. These different systems have different bases; the "Thiessen-Bureau of Mines System" is based on a special method of study, thin-section microscopy; the "Spackman System" on a particular physical property, reflectance. The "System of the Institute of Geology of the Academy of Sciences of the USSR", which can be used both in investigations in transmitted and in reflected light, sets out from a genetic viewpoint – the structure and type of the progenitors of the macerals, as well as the composition of the plants, which participated in coal formation.

Besides the Stopes-Heerlen international nomenclature and the special nomenclature systems, a number of remaining terms, which are difficult to classify, are grouped together in Chapter V.

With every expansion of a scientific discipline, a large number of new terms necessarily originate, many of which can be synonymous or analogous to other terms. The compilation of an international nomenclature and of a corresponding dictionary would be incomplete if these synonyms and analogues were not listed and this has been done in Chapter VI.

While the first edition of the Handbook was restricted to coal petrographical nomenclature and Part I of the second edition was devoted likewise exclusively to nomenclature, Part II contained analytical methods in coal petrography. What was formerly Part II, can now be found in Chapter VII of this supplementary edition. It has been much expanded and now contains practically all coal petrographical methods of investigation which have been internationally tested and which have been used both in the basic science and in the applied petrography of hard coals.

An alphabetical list of contents of all terms forms the eighth and last chapter of the Handbook.

Finally it should be noted that the following new sheets in this supplement have been exchanged for some of those already published in the 2nd edition, because of improvements or additions – collinite, fusite, maceral, microlithotype, rank (supplement), sporinite (hard coal), telinite and vitrinite.

1971

SUPPLEMENT

International Committee for Coal Petrology
Nomenclature Sub-Committee

COAL PETROLOGY AND ITS PRACTICAL IMPORTANCE

Brown Coal

Hard Coal

Coal occupies a unique position among rocks, due not only to its organic origin and its particular conditions of formation, but also because of its great practical importance. Up to the present, the bulk of the world's hard coals and brown coals are produced for energy requirements. But coal is also the basis for the organic chemical industry and is essential in the form of coke for the steel industry. After some depression, which coal had to endure because of the discovery of new energy sources, its importance today appears again to be increasing. It is therefore not surprising that coal petrography has passed through a considerable development during the last decade. Its task is to analyse this individual rock, coal, to describe its constituents in detail, to determine its essential properties, to investigate the structure of the deposits and, by studying its origin and occurrence, to be able to give an indication of calculable reserves.

A. Hard Coals

Macroscopically two types of hard coals can be distinguished – on the one hand, dull, compact and unstratified coals with an even, granular surface and on the other hand, banded coals, which consist of alternating and more or less fine layers of varying brightness. Exhaustive investigation of the former type, which are described as sapropelic coals, has shown that these are coals of allochthonous origin, formed by the floating together of very small organic constituents of different origin. The mode of formation of the second type is autochthonous or hypauthochthonous. These accumulations of plant remains *in situ* are known as humic coals and the layers that are built up are termed lithotypes.

The lustre of coal depends on two factors; on its composition and on its degree of coalification. Coals of similar composition reflect light more strongly the higher is their rank. Thus, the interbanding of bright and dull layers, which is characteristic of humic coals of low rank, has almost completely disappeared by the anthracite stage. In the low-rank, hard coals the petrographic composition of the individual bands determines the degree of lustre.

The layers or lenses of strongest lustre, which are termed vitrain, are the most homogeneous. They consist generally of more or less large fragments of plant organs and coalified plant tissues. The layers of weak lustre represent a homogeneous mixture of more or less small, bright and dull debris. The identification of these constituents is only possible under the microscope. Since the physical and chemical properties of these various constituents are very different, their proportions in the different coal layers, which can only be decided after an exhaustive microscopical examination, play a large part in the technological character of the coal. Macroscopic study of the seams, which is usually carried out at different times during exploitation of the coal or in borehole cores, should show up variations in seam structure within a specific geographical region. Together with observations on different irregularities in seam formation, for example, faults or wash-outs, such study is useful in helping to formulate working plans for mines etc.

Because of the differing mechanical resistance of the lustrous (brittle) and dull (compact) bands, macropetrographic seam profiles can also help in the selection of the extraction method and the coal-winning machinery, and not least in the prediction of the size distribution of the extracted coal. It is established that dull coal will be enriched in the coarse particle sizes and bright coal in the fine particle sizes.

The proportion of bright to dull coal can vary considerably within a seam and particularly in different seams. The variation depends on the conditions of formation and on the original plant materials. Thus, for example, in Great Britain there are frequent thick, dull-coal layers, while on the European continent, finely banded seams predominate. Such genetic differences can also be seen in the degree of purity of coals. The mineral inclusions in Palaeozoic coals of the southern hemisphere are more finely distributed than in those of the northern hemisphere. Here macroscopic study alone is insufficient to determine the amount of intergrowths in relation to coal-preparation procedures. Similarly, microscopical examination is also recommended for the accurate determination of other technological properties. Microscopical investigations on coal are normally carried out in reflected light using oil-immersion objectives and a total magnification of approximately x300, although today some coal petrographers still use the older technique of thin-section examination. The international nomenclature, laid down by the International Committee for Coal Petrology, which is published in this Handbook, is related exclusively to coal constituents studied in reflected light. The smallest constituents which are recognizable under the microscope are called 'macerals'. Associations of macerals are 'microlithoptypes'. Identification of macerals is based mainly on form (morphography) and reflectance.

Macerals with similar reflectances are collected into maceral groups, because in fresh unoxidized coals, similar reflectance is equated with similar elementary composition and similar technological properties. In hard coals three maceral groups can be distinguished:

Vitrinite group – medium reflectance,

Exinite group – lower reflectance than the associated vitrinite,

Inertinite group – higher reflectance than the associated vitrinite.

The most important maceral group in hard coals of the northern hemisphere is vitrinite to which belong telinite with visible cell structure and structureless collinite. In the Carboniferous coals of north-west Europe, for example, vitrinite amounts to between 60 and 80 per cent. Reflectance and carbon content rise with increasing rank, while the volatile-matter yield falls. On the basis of these data it is possible by measuring the reflectance of vitrinite to determine the rank of a coal precisely.

Macerals of the exinite group in coals with more than 20 per cent volatile-matter yield (in vitrinite) have a lower reflectance than the vitrinite and a distinctly higher content of volatile matter. They are very much more sparsely represented in hard coals than is vitrinite. In the north-west European humic coals, for example, the exinite content generally varies between 5 and 20 per cent, yet exinite in sapropelic coals can be the predominant constituent.

Four macerals are grouped under exinite – sporinite, cutinite, alginite and resinite. The first three have characteristic forms, while resinite occurs mainly as more or less diffuse impregnations of vitrinite or as an infilling of cell cavities or other spaces. Its recognition is important, since resinite-impregnated coals possess particular technological properties. Alginite, which is typical of sapropelic coals, especially boghead coals, shows a characteristic green fluorescence in ultra-violet light. Pollen, spores, and up to a certain rank, leaf epidermis, which forms sporinite or cutinite, can be isolated from coal with chemical solvents and identified. Their large numbers and wide geographical distribution allow statistical studies of their distribution in individual deposits and their use as zone fossils for stratigraphical subdivision of these deposits.

In contrast to the macerals of the exinite group, the macerals of the inertinite group have a higher reflectance than the associated vitrinite. They can be distinguished on their form and their relief. Fusinite always has the highest reflectance, while the other macerals of this group possess a reflectance which lies between those of the corresponding vitrinite and fusinite. All these macerals have similar technological properties and their collection in a group and the name of the group are justified in that they generally behave inertly on coking, low-temperature carbonization and graphitisation.

Because of the differing technological behaviour of these maceral groups, quantitative maceral analyses have been developed. Generally, a quantitative analysis of maceral groups in a polished particulate block is sufficient, because the macerals of each group possess similar technological properties. The maceral-group analysis is, together with the determination of rank by reflectance measurement on vitrinite, the most important analysis in applied coal petrography. The maceral-group analysis is, however, generally insufficient to answer questions on seam identification and correlation. Here every maceral is of importance. In certain cases it may even be advantageous to subdivide a maceral into different submacerals. Thus, for example, the visible cell structure of telinite can be subdivided either on the basis of the type of plant tissue or on the plant type of which it is formed. A concentration of telinite arising from Lepidophytes can, for instance, be characteristic of a seam in a particular geographical region. This would be an example of a maceral variety.

The macerals can also be subdivided on the basis of other criteria, for example, their state of preservation, the particle size of fragments etc. Submacerals are based on such criteria. Maceral varieties and submacerals are primarily used to investigate the origin of seams. In such difficult genetic studies, as much information as possible should be obtained for each constituent. In addition, special methods of examination may be necessary, for example, careful and gradually stronger etching of the polished surface by increasing etching time, fluorescence microscopy, electron microscopy or radioactive etching. With all these methods structures can be seen to appear, which are not apparent in the case of normal microscopy. Such structures are referred to as cryptomacerals.

In problems of seam correlation and coal preparation the microlithotypes (maceral associations) and carbominerite (mineral intergrowths) must be considered as well as the macerals, submacerals, maceral varieties and cryptomacerals. The macroscopically recognizable layers with varying degrees of lustre often correspond to the microlithotypes.

Three types of microlithotypes, mono-, bi- and trimaceral, can be distinguished on the basis of their compositions and depending on whether they contain macerals of one, two or three maceral groups. With the various possibilities for composition and band width of these associations which existed, the ICCP was forced to introduce definitions for the microlithotypes with suitable limiting values. These conventional limits are not random, but have been tested by a working group, and have been determined, not only by agreement through reproducible analytical results, but also on the basis of characteristic technological properties. To allow subdivision of the microlithotypes the ICCP has introduced two specific limitations:-

a) the minimum band width of a microlithotype band must exceed 50 microns, and

b) the monomaceral and bimaceral microlithotypes must not contain more than 5% of macerals from maceral groups which are not characteristic of them by definition; the trimaceral microlithotypes must contain more than 5% of all maceral groups.

To prepare seam profiles for use in seam identification and correlation on a microscopical to macroscopic scale, certain contiguous microlithotypes must be grouped into "Facies" layers of greater thickness. A definition for such collected units is very difficult, because a large number of possibilities exist. The ICCP has still not laid down directives in this sphere. It is, however, known that thick durite bands usually have a wide horizontal distribution, so that these, in the same way as thick rock layers, can be employed for seam correlation. These thick durite bands, whose thicknesses can occasionally amount to several decimetres, become concentrated, when crushed, in the coarse particle fraction, because of their higher mechanical resistance, while on the other hand, the brittle vitrite and the still more friable fusite, are concentrated in the fine particle fraction. Generally it appears that the bimaceral and trimaceral microlithotypes have higher mechanical resistances than the monomaceral microlithotypes. This property is, however, only of importance if the thicknesses of the microlithotype bands in seams exceed at least a few centimetres.

In questions of thermal beneficiation of coals or of the behaviour of coals in power stations, consideration of the microlithotypes is unnecessary; the maceral groups suffice. Thus, for example, it is known that too high a content of fusite reduces the quality of pitch-bound briquettes; and that in power stations firing with powdered fuel carrying too high an amount of fusite causes delay in ignition, producing a reduction in the temperature of the hearth and increased pollution of the heating surfaces.

The microscopical investigation of coal is incomplete if it is only confined to macerals and microlithotypes, because coal contains, in addition, mineral contaminants in varying quantities, which are of great interest because of their practical importance. These mineral contaminants can have different origins: they may form or have been deposited at the same time as the macerals and they are then intimately intergrown with them. Such minerals are described as syngenetic. Other minerals may be deposited later in cracks, fissures or in cell cavities from circulating solutions. Such minerals are described as epigenetic. The syngenetic minerals generally have a wide horizontal distribution, so that they can sometimes be used as marker horizons. Under this heading tonstein bands play a special role, since certain of these are confined to specific stratigraphical horizons and they have been discovered in all European coal deposits. Likewise, some quartz layers can be traced over wide areas. The same is true of fine concretionary pyrite, which is typical of seams with marine roofs.

So useful are the mineral inclusions in coal for geological investigations, it is regrettable that they are so harmful in mechanical and thermal beneficiation of coals. They are particularly troublesome if they occur in fine-grained and finely dispersed forms in coals because they then, quite irrespective of the preparation procedure which is applied, make the preparation of mineral-free coal impossible, the production of which is occasionally necessary for the manufacture of charcoal, electrode coke etc. It is therefore evident that a microscopical examination of mineral content is necessary if the preparation potential of a coal is to be precisely realised or a coal from which to prepare mineral-free coal is sought. The determination of ash content in such a case is inadequate.

Information about a coal with respect to macerals, microlithotypes and mineral constitution is also important in problems of coal genesis, description of deposits and numerous technological processes, but the decisive factor in applied hard-coal petrography is rank, because it is on this property that the possibility of using a coal in an applied field primarily depends. It is therefore not surprising that the precise determination of rank has been given particular attention.

To determine rank the volatile-matter yield of the whole coal or of a density fraction ($< 1.5 g/cm^3$) is insufficient, because, especially in low-rank coals, the yield not only depends upon rank, but also upon maceral constitution, which can vary over wide limits. In contrast, it has been established that the different vitrinites of a single seam profile (vitrinite being the most important and most representative maceral), display very similar reflectances. The arithmetic mean of the reflectances of individual vitrinites shows, moreover, that the scatter of values is very small. The mean reflectance of the vitrinites of a coal seam is consequently a much more useful parameter to denote rank, and one which is independent of maceral constitution. Exhaustive investigations on pure vitrinites isolated from seams of different rank have shown that a close relationship exists between reflectance and volatile-matter yield, as well as with the carbon content of these vitrinites.

'Iso-reflectance maps' can be prepared for all exploitable seams of different coals deposits, and on the basis of these maps an appropriate plan for mine workings can be produced following economic requirements.

Rank determination on the basis of reflectance is today particularly applied to coking-coal blends ('Coal-blend analysis'). Only with such analyses can those responsible for charging coke ovens determine the precise composition of the coking-coal charge and, if necessary, alter it by an appropriate amount. This is all the more useful, since petrographic analyses can be carried out rapidly. Since the composition of a coking coal can be determined from coal-blend analysis and its maceral groups, it is possible nowadays to calculate from the petrographic data its average volatile-matter yield and its coking power. With a knowledge of the coking conditions, moreover, the coke strength, as well as the gas, tar and benzol yields, can be calculated and, if necessary, optimized. Because of the increasingly more complex composition of coking-coal blends, this form of coal petrographic analysis is gaining increasingly in importance.

The possibility of determining rank with the help of reflectance measurements has recently also acquired great importance in petroleum and natural-gas exploration. Bearing in mind the close relationships which exist between rank on the one hand and the formation, chemical constitution and the elimination of petroleum and natural gas from the crust on the other, reflectances are measured on tiny, coaly inclusions in the minerogenic sediments from borehole chippings, because coal seams are seldom penetrated by oil boreholes. Washed samples can be similarly investigated. On the basis of the measured reflectances, conclusions can be drawn on the possibilities of the occurrence of petroleum and natural gas.

Besides these microscopical investigations of coals, which can only be briefly described here, there is still a wide range of possible, but mainly qualitative, investigations to characterize the intermediate and finished products of mechanical and thermal coal beneficiation, e.g. briquetting materials and briquettes, the raw products of conventional and continuous coking, as well as normal cokes and form cokes. Thanks to these studies, the transitional stages between the original materials and the finished products are better known today, while improvements have been introduced to old established techniques and new processes developed. The same is true with regard to increasingly important investigations of mining conditions, especially in relation to the installation of larger continuously advancing machines, the improvement of automatic mine development and to the hydromechanical winning of coal. All these techniques assume a precise knowledge of the strata in the mine workings. In the future, the working petrographer will have to be interested, not only in the coal and its constitution, but also in the properties of the surrounding rocks. These questions do not at present lie, however, within the scope of the work of the ICCP and the Handbook of Coal Petrography.

B. Brown Coals

Brown coals and lignites are, because of their low rank, of quite different composition to sub-bituminous coals and bituminous coals. It should be added that most brown coals are of Cainozoic age and hence are formed from plants other than those forming the bituminous coals (mainly Palaeozoic). The ICCP has therefore created during the last six years an international nomenclature system for the macerals of low-rank brown coals, based on the Stopes-Heerlen hard-coal petrographic nomenclature (also used for sub-bituminous coals), which primarily distinguishes between different subdivisions of the huminite group which is accepted as the precursor of the vitrinite group. The liptinite (exinite) group and the inertinite group in brown coals have similar compositions to those in bituminous coals.

The maceral group huminite in Tertiary brown coals is predominant and is technologically the most important. It is essentially composed of the plant substances cellulose and lignin and it is subdivided on the basis of the morphological state of preservation of these substances into three maceral subgroups: humotelinite (intact cell walls, cell structure), humodetrinite (humic detritus) and humocollinite (humic gel). These three maceral subgroups of brown coals correspond morphographically (not always genetically) to the hard-coal macerals, telinite, vitrodetrinite and collinite. Because of the greater heterogeneity of brown coals, each of these three subgroups comprises different macerals which are distinguished from one another primarily on their state of gelification. The degree of gelification of a huminite maceral is not only genetically important, but it is also an essential factor in determining the technological suitability of a brown coal. Gelification influences the crushing behaviour, the briquetting capacity and with it also the suitability of the coal for the preparation of high-temperature coke. With maceral analyses of huminite, it is also possible to make additional comments on the combustion behaviour of a brown coal and on the crushing behaviour, which is influenced strongly by the amount of humotelinite.

The liptinite fraction of a brown coal is important for bitumen extraction, montan-wax production, tar recovery (in the case of liptinite-rich lignites) and for hydrogenation. Furthermore, it is possible with the liptinite macerals, sporinite and cutinite, to correlate brown-coal seams or seam sections – primarily with the pollen contained in the sporinite – and to carry out stratigraphic-age determinations. Of course, these macerals must be separated and isolated from other macerals by maceration. 'Cuticle analysis' and 'Pollen analysis' have attained great importance for the geologist and the palaeobotanist, not only in problems of age, but also in questions of seam genesis (types of seam-forming plants, depositional conditions etc).

In contrast to the hard coals, inertinite plays a quite secondary role in the brown coals of the great Tertiary deposits. In individual occurrences of brown coals, for example in India and in the Balkans, more inertinite is found. Of the inertinite macerals, sclerotinite has a particular importance, in Tertiary brown coals showing very characteristic forms, which are fundamentally different from those in Palaeozoic and Mesozoic coals and hence have a stratigraphic importance.

In brown-coal microscopy, in contrast to hard-coal microscopy, fluorescence investigations are indispensable, not only for the recognition and differentiation of the liptinite macerals, but also for the macerals of the huminite group. Furthermore, dark-field, reflected-light microscopy and micro-hardness measurements on brown coals are frequently employed, particularly for more satisfactory recognition of gelification differences. Reflectance measurements on huminite (as a precursor of vitrinite), have shown great variation in single coals, depending on humification and the degree of gelification. Such measurements thus (and on other grounds), have not the same importance for rank determination as they do in hard-coal petrography.

The brown-coal lithotypes, namely the macroscopically different strata and bands in a seam, can be subdivided on colour (measurable by remission), fissuring and inclusions (wood, resins, minerals, etc.). The microlithotypes of brown coals should be quantitatively determined on the proportion of different macerals within a microscopical field of prescribed size, in a similar manner to the microlithotypes of hard coals. The proportion of different lithotypes and microlithotypes is of particular interest in applied brown-coal petrography.

In clarifying questions of genesis of the macerals and microlithotypes of hard coals, the petrographic examination of brown coals is indispensible. The existing geological age differences (Carboniferous – Tertiary), and consequently, the differing variety of the plant-source materials, must of course be considered.

To conclude this short introduction to coal petrology and its principal applications in practice, the reader is recommended to consider first of all the terms and analytical methods referred to in this chapter. In this way the detailed study of the complete nomenclature will be made much easier.

1971

SUPPLEMENT

International Committee for Coal Petrology
Nomenclature Sub-Committee

GENERAL NOTES

Brown Coal

1 – For the sheets dealing with brown-coal terms the 'General Notes' and the 'Abbreviations' of the 2nd edition (1963) of the Handbook apply, particularly for the colour of macerals in transmitted light.

2 – Since fluorescence observations have a diagnostic value in brown-coal microscopy, the fluorescence behaviour (usually in blue light) is indicated. The following lamps and filter combinations have principally been used:-

a) Blue light: Phillips high-pressure mercury lamp CS 150W (for Leitz microscopes) or Osram HBO 200 (for Zeiss microscopes) with a Schott exciter filter BG 12/3mm and a Schott barrier filter OG 1/1.5mm (corresponding to the Leitz barrier filter K 530).

b) Ultra-violet: lamps as for blue light: a Schott exciter filter UG 1/2 mm and a Schott barrier filter GG 9/1mm (corresponding to the Leitz barrier filters K 430 and K 460).

3 – Reflectance data relate to measurements at a wavelength of 525nm, if not otherwise stated (the Analysis Sub-Committee has recently decided that in future such measurements should be made at 546 nm). The refractive index of the immersion oil used is n = 1.519 at a wavelength of 525 nm. R_{rand} is the random reflectance (i.e. without polariser); R_{max} is the maximum reflectance in oil (unless otherwise stated) with the polarizer placed in the 45^{o} position.

4 – Remission values relate to measurements at a wavelength of 659 nm with a Zeiss (Jena) "Spekol-Kugel-Reflektometer"[15].

5 – The brown-coal sheets apply to brown coals and to lignites. For sub-bituminous coals the nomenclature for hard coals is used, since sub-bituminous coals are petrographically very similar to hard coals.

CORRELATION OF THE HUMINITE MACERALS OF BROWN COALS WITH THE VITRINITE MACERALS OF HARD COALS

<table>
<tr><th colspan="6">Brown Coal</th><th colspan="3">Hard Coal</th></tr>
<tr><th>Maceral Group</th><th>Maceral Subgroup</th><th>Maceral</th><th colspan="2">Maceral Type</th><th>Maceral Variety</th><th>Maceral Type</th><th>Maceral</th><th>Maceral Group</th></tr>
<tr><td rowspan="11">Huminite</td><td rowspan="3">Humotelinite</td><td>Textinite</td><td colspan="2"></td><td>A (dark)
B (bright)</td><td rowspan="3">Telinite 1
Telinite 2</td><td rowspan="3">Telinite</td><td rowspan="11">Vitrinite</td></tr>
<tr><td rowspan="2">Ulminite</td><td colspan="2">Texto-Ulminite</td><td>A
B</td></tr>
<tr><td colspan="2">Eu-Ulminite</td><td>A
B</td></tr>
<tr><td rowspan="2">Humodetrinite</td><td>Attrinite</td><td colspan="2" rowspan="2"></td><td rowspan="2"></td><td></td><td>Vitrodetrinite</td></tr>
<tr><td>Densinite</td><td rowspan="2">Desmocollinite</td><td rowspan="7">Collinite</td></tr>
<tr><td rowspan="6">Humocollinite</td><td rowspan="4">Gelinite</td><td rowspan="3">Levigelinite</td><td>Detrogelinite</td><td rowspan="3"></td></tr>
<tr><td>Telogelinite</td><td>Telocollinite</td></tr>
<tr><td>Eugelinite</td><td rowspan="2">Gelocollinite</td></tr>
<tr><td colspan="2">Porigelinite</td><td></td></tr>
<tr><td rowspan="2">Corpohuminite</td><td colspan="2">Phlobaphenite</td><td></td><td rowspan="2">Corpocollinite</td></tr>
<tr><td colspan="2">Pseudo-Phlobaphenite</td><td></td></tr>
</table>

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**ALGITE** (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term algite was used by G. H. Cady[1] in 1942. The Nomenclature Sub-Committee resolved in 1964 to use this term to denote a monomaceral microlithotype consisting only of alginite.

II – DESCRIPTION

See alginite.

Algite must contain at least 95% alginite. In quantitative petrographic analysis only layers or fields greater than 50 microns in width are recorded as algite.

Algite can contain occasional small quantities of mineral impurities, which are predominantly clay minerals or pyrites.

III – OCCURRENCE

Algite occurs in sapropelic coals, especially in boghead coals.

IV – PRACTICAL IMPORTANCE

See sapropelic coals.

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1. Cady (G. H.). Modern concepts of the physical constitution of coal. J. Geol., 50, (1942), p.337–356.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**ATTRINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term attrinite was proposed by the Association of Coal Petrographers of the USSR in 1963 for gelified particles in (brown) coals, which are smaller than 50 microns diameter[1]. The International Committee for Coal Petrology has used the word attrinite since 1970 for a maceral of the huminite group (subgroup-humodetrinite), that consists of fine particles, which form the ungelified humic "groundmass" of brown coals.

Etymology: attero (Lat.) – to rub against, to wear away, to disintegrate.
attritus (Lat.) – worn out, disintegrated material.

Synomyms and analogous terms:
ungelified detrinite [83],
translucent humic degradation matter[117],
in part:
detrinite [109, 37],
detritus [126],
humic detritus [113],
detrinitic, attrinitic, herbaceous or humic groundmass [24],
gelinito-posttelinite and gelinito-precollinite [119].

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[1] Reunion of coal petrographers of the USSR (1963), Nov., emend., Babinkova, N. J. and Mussial, S.A. Nomenclature des microconstituants (macéraux) des houilles brunes de l'URSS, Moscow. 1965.

II – DESCRIPTION

a) *Morphography*

Under the term attrinite are classed fine (mostly $<$10 microns) detrital huminite particles of different shape, among them cell-wall fragments (which can also be $>$10 microns), and formless, foamy-porous, huminitic material. These different constituents are mostly intimately mixed with one another and are more or less loosely packed, so that together they display a spongy appearance[83]. Attrinite represents a kind of 'ground-mass' for the other macerals of brown coals, particularly in soft brown coals.

b) *Physical Properties*

Colour: Transmitted light – yellow to light reddish brown.

Reflected light (bright field, oil immersion) – more or less dark gray.

Reflected light (fluorescence) – none or only very weak, dark brown fluorescence[38].

Reflectance: dependent on the original material (see also textinite, ulminite, gelinite).

Anisotropy: isotropic in reflected light; in transmitted light (in peats and low-rank brown coals), in part weakly anisotropic, probably because of cellulose remains[50].

c) *Chemical Constitution and Chemical Properties*

Attrinite consists of humic substances, possibly also of remains of lignin and cellulose. The chemical properties of attrinite vary; they are primarily dependent upon the respective original materials. Since pure attrinite, because of its intimate intergrowth with other macerals, cannot be isolated, analytical data for coals with more than 90 per cent humodetrinite (chiefly attrinite), are reported in the following Table:

Deposit %	Rhenish Brown Coal (German Federal Republic) Miocene	Lower Lausitz Brown Coal (German Democratic Republic) Miocene	
	pale layers[116] (> 90% humodetrinite) (mean of 6 samples)	Burghammer Site	Kleinleipisch Site
		(> 95% humodetrinite)	
Moisture (as mined)	59.1	ca. 60.0	58.8
Ash (moisture-free)	6.6	6.2	5.3
Moisture and ash-free:			
Carbon	68.3	63.8	65.8
Hydrogen	5.6	4.9	4.7
Oxygen	24.5	28.7	28.6
Nitrogen	1.1	0.7	0.8
Sulphur	0.5	1.9	n.d.
Low-temperature tar	12.9		
Bitumen extract[1]	4.1		
Cellulose	1.7		
Methoxyl	1.5		
Free humic acids	16.5		
Ca-humic acids	19.9		
Humic acids (not bound to Ca)	12.7		
Total humic acids[2]		43.0	57.3

n.d. – not determined

[1] Soxhlet – benzene : alcohol = 1:1

[2] after Souci

III – BOTANICAL AFFINITIES AND GENESIS

The detrital part of attrinite originates through strong structural decomposition of plants or plant parts with little resistance. Chief sources for attrinite are herbaceous plants[113] and the wood of angiosperms. Detrital attrinite forms in relatively aerobic facies. The formless, foamy-porous part of attrinite consists of flocculated humic colloids.

IV – ALTERATION DURING COALIFICATION

Through increasing gelification attrinite becomes homogeneous (transition into densinite) and vitrinized. Its reflectance increases and its fluorescence properties disappear almost completely. At the boundary between the dull and bright brown coals, the attrinite, or alternatively the densinite formed from it, passes into desmocollinite. At the same time weak strain anisotropy appears in transmitted light.

V – OCCURRENCE

Attrinite is a principal constituent of nearly all soft brown coals. In hard brown coals it is much reduced. Its contribution to the constitution of soft brown coals is dependent upon facies. It is especially abundant (up to 90 per cent of the whole coal) in coals which form from herbaceous plants (reeds) and from fragments of angiosperm trees[113]. In coals which are derived from conifers (e.g. Taxodiaceae – Cupressaceae), the attrinite content is reduced in favour of the humotelinite macerals[113]. In coals suitable for low-temperature carbonization, the attrinite content is reduced in comparison to the liptinite macerals.

VI – PRACTICAL IMPORTANCE

a) *Crushing Behaviour*

Because of its low mechanical resistance (low hardness, grain shape), attrinite possesses suitable properties for crushing and appears predominantly in the range of particle sizes from 2.0 – 6.3 mm[82].

b) *Briquetting, Low-temperature Carbonization, High-temperature Carbonization (Brown Coals)*

Attrinite is a suitable maceral for a wide range of industrial processes[30, 31, 68, 69, 70, 82, 103, 107]. Its technological properties deteriorate to some extent with increasing rank[34].

The following Table gives a summary:

Technical Process	Moisture Content (as mined)		
	70-55%	ca. 55-45%	<45%
Briquetting (extrusion press)	very good	good to moderate	bad (generally only possible with binder)
Low-temperature carbonization	tar yield generally low		
	coke yield relatively low	coke yield medium	coke yield relatively high
High-temperature carbonization (Bilkenroth-Rammler continuous process)	firm, dense, fissure-free, coke in coarse lumps	coke with less firmness, dense, medium-sized lumps	dense coke in small lumps

c) *Bitumen Extraction*

Relatively poor in extractable bitumen[116].

d) *Oxidizability*

Relatively easily oxidized.

Fig. 1.
Attrinite: mixture of detrital particles and an intermixed porous gel
(note the many pore spaces (black) compared with densinite) in a Miocene soft brown coal
from the Lower Rhine district (German Federal Republic)
reflected light, oil immersion, 250x.

Fig. 2.
Attrinite: porous gel and (secondary) detrital particles in a Miocene soft brown coal
from the Lower Rhine district (German Federal Republic)
reflected light, oil immersion, 250x.

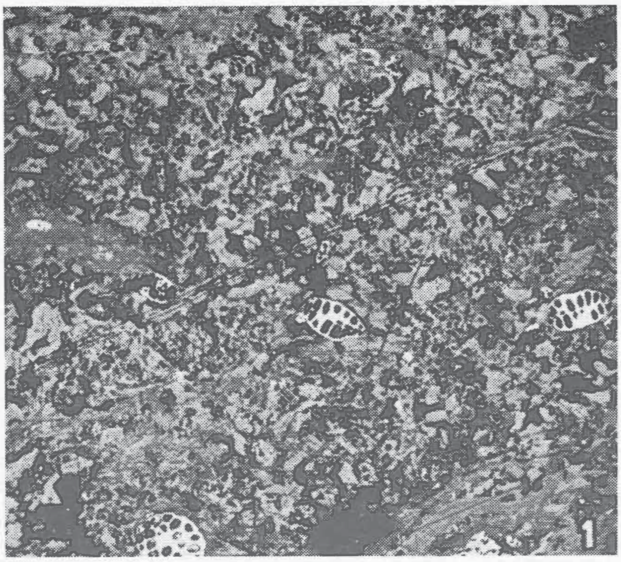
Fig. 3.
Attrinite: predominantly porous gel, besides detrital particles (centre – resinite particle)
in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic)
reflected light, oil immersion, 250x.

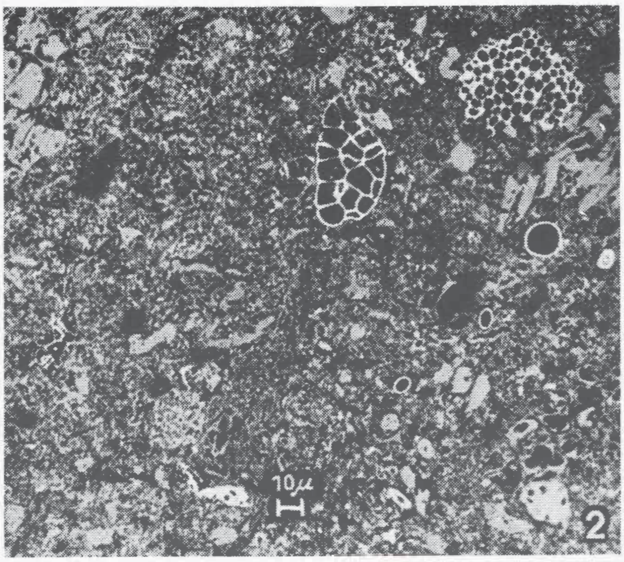
Fig. 4.
Attrinite: a mixture of different sizes of detrital particles and intermixed porous gel
in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic)
reflected light, oil immersion, 610x.

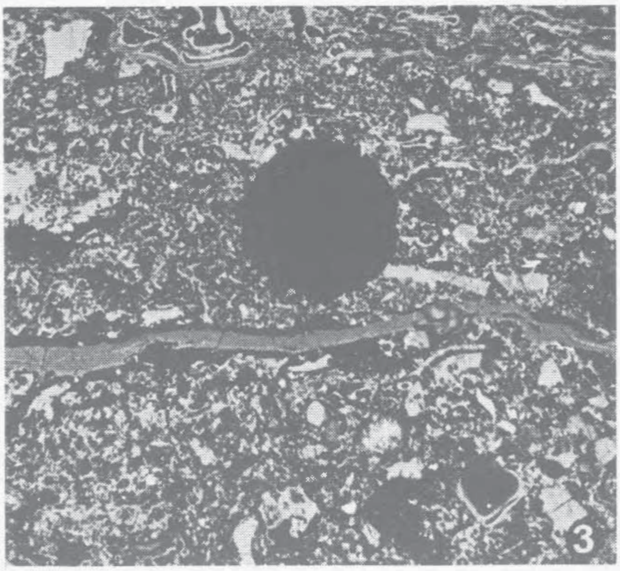
Fig. 5.
Attrinite: mixture of detrital particles ($<$10 microns), cell-wall fragments and porous gel
in a Miocene soft brown coal from East Lausitz (German Democratic Republic);
reflected light, oil immersion, 500x.

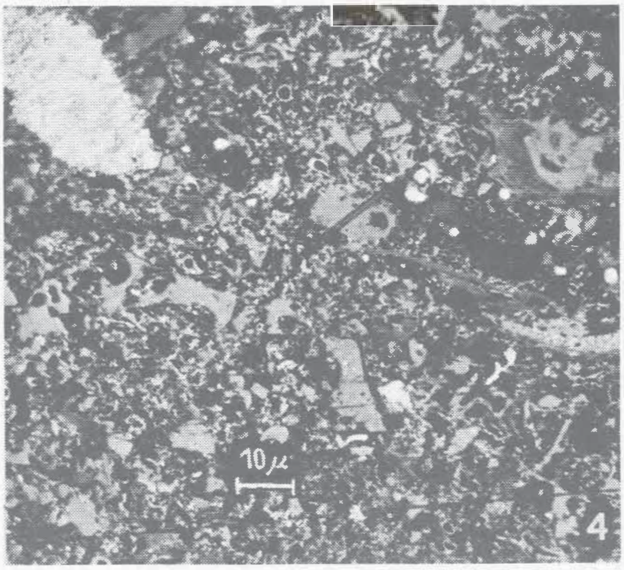
Fig. 6.
Attrinite: mixture of detrital particles ($<$10 microns), cell-wall fragments and porous gel
in a Miocene soft brown coal from East Lausitz (German Democratic Republic);
reflected light, oil immersion, 500x.

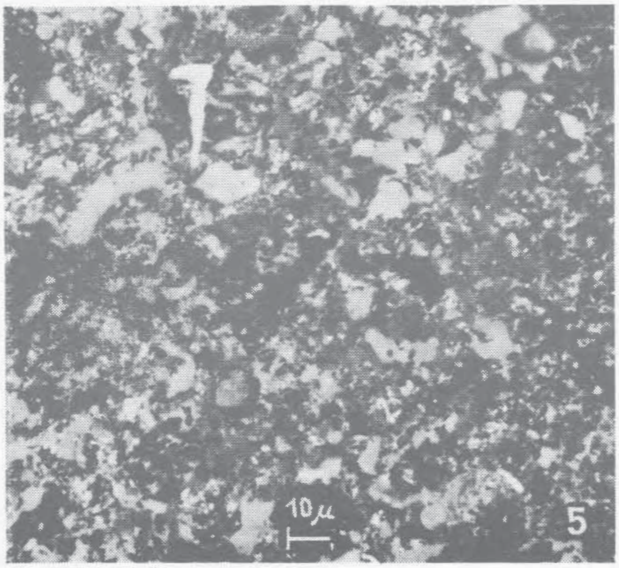
ATTRINITE

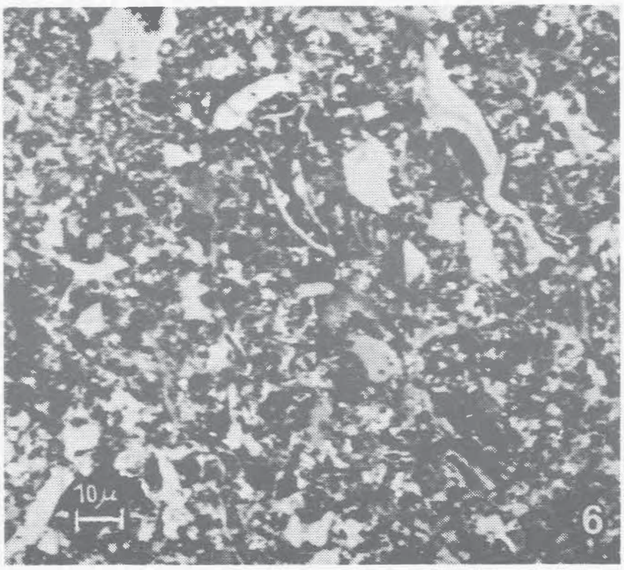












1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee **CARBOMINERITE** (Stopes-Heerlen System)	Hard Coal R. L.

I – ORIGIN OF TERM

The term carbominerite was proposed by M.-Th. Mackowsky in 1963 to designate associations of microlithotypes with different minerals and the term was accepted by the Nomenclature Sub-Committee in 1964. The density of the associations lies between 1.5 and 2.0 g/cm^3 (in the case of anthracites the density is somewhat higher).

II – DESCRIPTION

See carbargilite, carbopyrite, carbankerite, carbosilicite and carbopolyminerite.

Summary of the carbominerites: see the term ‘microlithotype’.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**CARBOPOLYMINERITE** (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term carbopolyminerite was introduced in 1965 by the Nomenclature Sub-Committee for polymineralic coal-mineral intergrowths.

II – DESCRIPTION

Intimate association of each microlithotype with at least two different minerals, which must contain more than 5% by volume and less than 20% by volume of sulphide minerals and less than 20% by volume of clay minerals, carbonate minerals, quartz or other minerals; or less than 5% by volume of sulphide minerals and more than 20% by volume but less than 60% by volume of other minerals.

The largest of the mineral grains or bands must not exceed 30 microns, since otherwise the density of the 50 microns minimum band width of the microlithotype would exceed 2.0 g/cm^3.

Since in polymineralic coal-mineral associations quartz can always be included, it is appropriate to use air or water-immersion objectives before using oil-immersion objectives.

Appearance of the minerals in reflected and transmitted light – see carbargilite, carbankerite, carbopyrite and carbosilicite.

In petrographic analysis only carbopolyminerite layers with a band width greater than 50 microns are recorded separately.

Polymineralic coal-mineral associations with more than 60% by volume of clay minerals, carbonates and quartz, or with more than 20% by volume of sulphide minerals would be classified as ‘rock’, because the density would exceed 2.0 g/cm^3.

The ash content varies, depending on the mineral composition, from between 15 and 20 per cent up to between 50 and 60 per cent.

In the range of bituminous coals the density varies depending on the mineral content and composition from 1.5 to 2.0 g/cm^3. With larger amounts of siderite and sulphide minerals, the density is somewhat higher.

III – OCCURRENCE

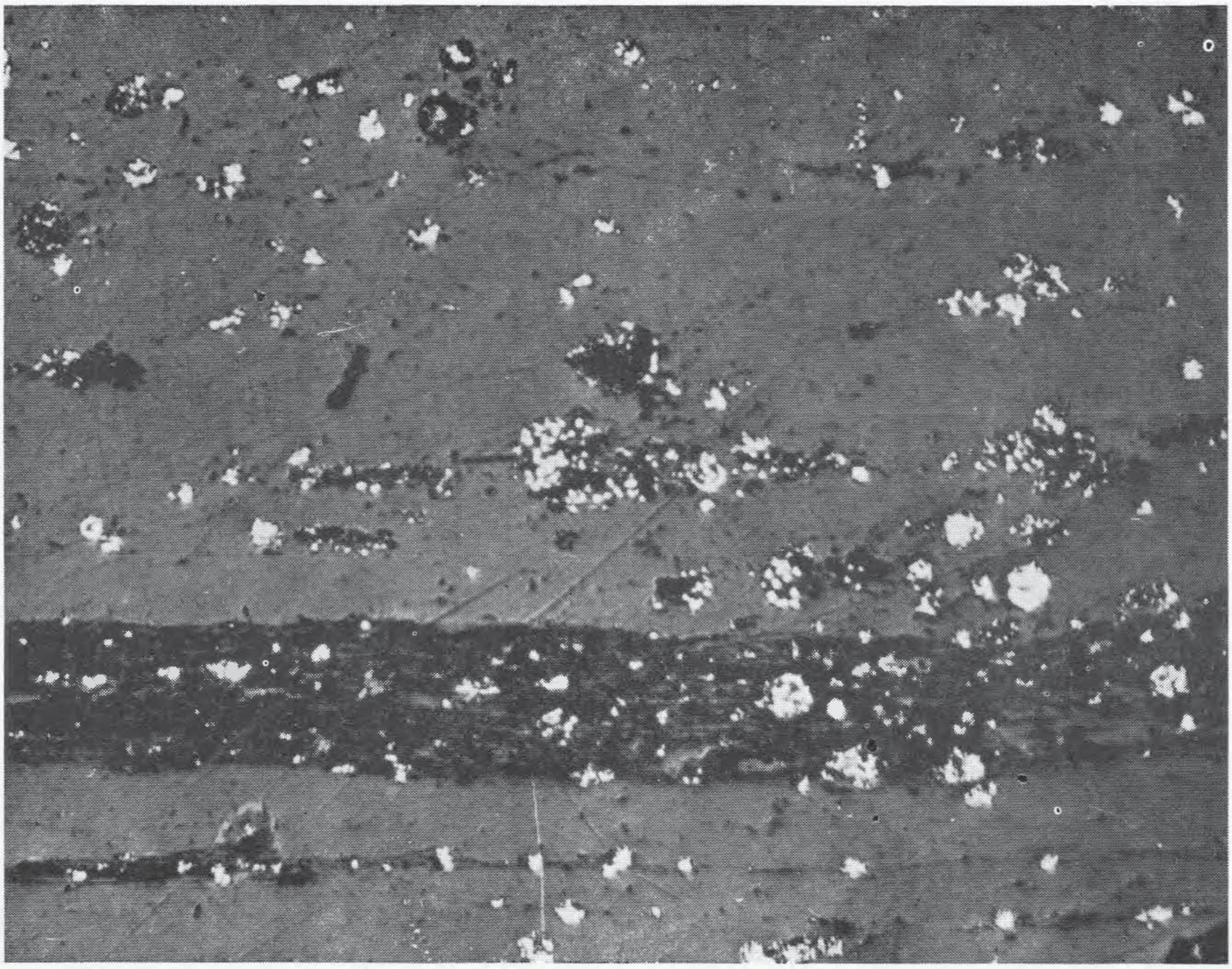
Widespread – apart from carbargilite, carbopolyminerite is the most important coal-mineral association. In matters of seam identification and correlation, carbopolyminerite is generally less useful than the monomineralic coal-mineral intergrowths.

IV – PRACTICAL IMPORTANCE

See carbargilite, carbopyrite, carbankerite and carbosilicite.

Fig. 1.
Carbopolyminerite with pyrite, clay minerals and vitrinite
(pyrite – white; clay minerals – black; vitrinite – gray);
reflected light, oil immersion, 300x.

CARBOPOLYMINERITE



1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**CARBOSILICITE** (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term carbosilicite was introduced in 1964 by the Nomenclature Sub-Committee to designate carbominerite with between 20 and 60% quartz by volume.

II – DESCRIPTION

Intimate association of each microlithotype with 20–60% quartz by volume (including chalcedony), whose grain size must not exceed 30 microns. Larger quartz grains of deposits in cleats and fissures with a width greater than 30 microns are classified as 'rock', since the density of the normal 50 microns minimum band width of the microlithotype would exceed 2.0 g/cm^3.

Quartz appears dark to medium gray in reflected light with a strong relief compared with vitrinite.

Certain identification of quartz is only possible with dry or water-immersion objectives, since with oil-immersion objectives quartz can no longer be identified, because of the similarity in refractive index between immersion oil and quartz.

Quartz appears isotropic in reflected light. In transmitted light it is weakly anisotropic.

In petrographic analysis bands of carbosilicite greater than 50 microns width are recorded separately. Besides quartz, carbosilicite can contain up to 5% by volume of iron pyrites and up to 20% by volume of clay minerals and/or carbonates.

Coal-quartz intergrowths with more than 60% of quartz by volume are assessed as rock, since their density exceeds 2.0 g/cm^3.

The ash content of carbosilicites, which are free of other minerals, varies between 20 and 60%.

Density varies with quartz content from 1.5 to 2.0 g/cm^3.

III – OCCURRENCE

Widespread, although generally in small amounts. Carbosilicite bands can occasionally serve as an aid in seam identification and correlation.

IV – PRACTICAL IMPORTANCE

In coal preparation carbosilicite falls, as do carbankerite, carbopyrite and carbargilite, into the category of 'true intergrowths'. Because the intergrowth of the quartz with the coal is so intimate, it is not possible to free the quartz from the coal by crushing, and it consequently appears in the 'middlings'. It is usually possible to free the quartz from cleats and fissures by crushing.

Because of the high hardness of quartz, carbosilicite causes wear.

When carbosilicite occurs in appreciable quantities in cleaned coal, it acts as an inert material on coking and swelling properties, hydrogenation and gasification, but without giving rise to any particular trouble or difficulty.

Carbosilicite shows no tendency to spontaneous combustion or production of dust.

Larger quantities of carbosilicite may require special attention on the grounds of industrial hygiene.

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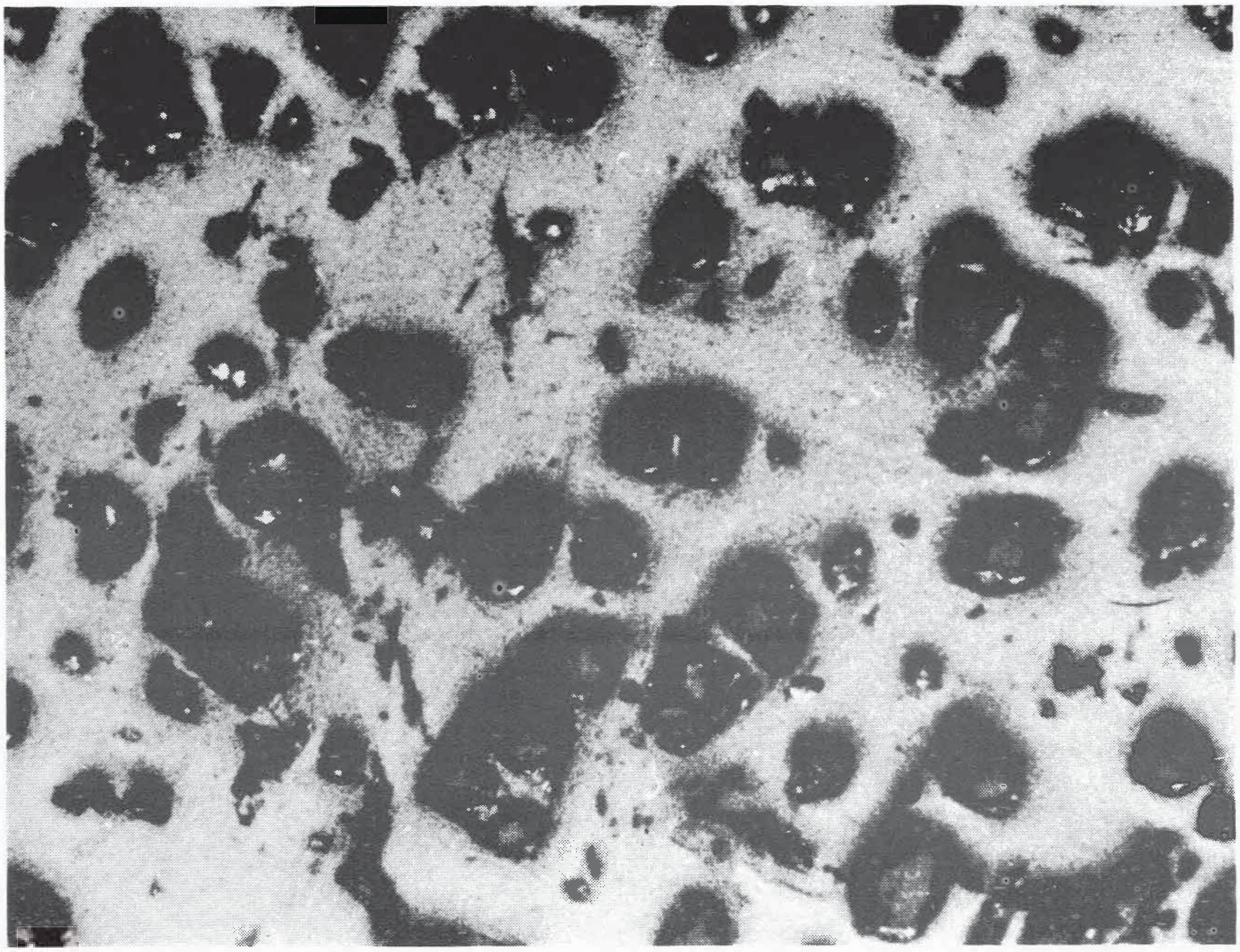
Fig. 1.
Quartz (dark gray with strong relief) associated with vitrinite
in the Kreftenscheer Seam, Ruhr (V.M. -ca. 12% daf);
reflected light, dry objective, 150x.

CARBOSILICITE



1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
	CHLOROPHYLLINITE (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term chlorophyllinite was introduced in 1970 by the Nomenclature Sub-Committee for a maceral of the liptinite group. The term chlorophyllinite has wider implications than the term chlorophyll.

Etymology: chloros (Greek) – green,
phyllon (Greek) – leaf.

II – DESCRIPTION

a) *Morphography*

Chlorophyllinite mainly forms small, round particles of approximately 1-5 microns diameter. In rare cases, for example, algal chlorophyllinite[36], the diameter may reach 100 microns. Red luminescence is characteristic. Chlorophyllinite can be easily identified when it is well-preserved. Recognition is made difficult by imperfect chemical preservation. In doubtful cases such particles would be recorded as liptodetrinite.

b) *Physical Properties*

Colour: Transmitted light – systematic investigations are lacking. Only when heavily concentrated is chlorophyllinite recognizable by its pale green colour[62]. This weak colour can be masked by brown, humic substances.

Reflected light (bright field, oil immersion) – since chlorophyllinite usually consists of small particles and is only weakly reflecting, it cannot be distinguished from liptodetrinite in this type of illumination.

Reflected light (fluorescence) – chlorophyllinite displays strong blood-red fluorescence. Since other macerals do not fluoresce blood-red, the smallest chlorophyllinite particles can be detected and specifically identified [37, 38]. Weak decomposition appears to be sufficient to cause a colour shift from blood-red through rose to creamy-white. Blue-light or ultra-violet radiation will produce this effect within approximately 10-15 minutes; the change is irreversible.

Reflectance: no observations are available; values of a similar order to those of other liptinite macerals can be expected.

c) *Chemical Constitution and Properties*

Since chlorophyllinite displays the same physical properties in fluorescence analysis as recent chlorophyll, it can be inferred that it will also be chemically similar. The following data relate to recent material[8, 19, 80, 99, 127]. Chlorophyll occurs in two varieties with the empirical formulae $C_{55}H_{72}MgN_4O_5$ and $C_{55}H_{70}MgN_4O_6$. Both are waxy di-esters. The Mg atom typical of chlorophyll occupies a central position and is surrounded by four nitrogen atoms, the latter, each with four carbon atoms, forming a pyrole ring. Such compounds are termed porphyrins. Chlorophyllinite will decompose considerably more easily than other liptinite macerals and only remains well-preserved under highly specific facies conditions. Weak acids destroy chlorophyll causing brown colouration and eliminating magnesium. Magnesium can be replaced during fossilization by other elements, e.g. Fe, Ni, V. etc.[12, 25].

Chlorophyll is wholly or partially soluble in ether, alcohol, acetone, benzene and other organic solvents[4, 8, 19]. Consequently, during bitumen extraction it is dissolved. The greenish brown colour and red fluorescence[122] of some peat extracts and of many algal-muds[61] are due to dissolved chlorophyll. With increasing chlorophyll decomposition, extracts of recent sediments (mud deposits) show a change in intrinsic colour from green to yellow to brown, which can be correlated with the pH value of the deposit[23].

Chlorophyllinite can contain the following materials:

i) different pigments belonging to the chlorophyll group,

ii) their decomposition products, and

iii) other residual organic matter as well as inorganic constituents.

III – BOTANICAL AFFINITIES AND GENESIS

Chlorophyllinite originates in chlorophyll pigments (grana) and in hyaloplasmatic-frame material (stroma). Grana and stroma combine to form finely laminated constituents, which are described as chloroplasts. In the higher plants these are mainly lens- or disc-shaped and are found in leaves, young stalks, young fruits etc. Numerous algae also contain chloroplasts whose form is quite different.

The main part of chlorophyll is destroyed before peatification occurs. Only under strongly anaerobic conditions and (in the case of a rather broad facies spectrum) in moderate to cool climates, can chlorophyll be preserved in the form of chlorophyllinite. This chlorophyllinite will not be altered, or only very slightly, by the humification process in the peat and soft brown-coal stages.

IV – ALTERATION DURING COALIFICATION

In sub-fossil stages chlorophyllinite is relatively abundant, but has an irregular distribution. In Tertiary European soft brown coals its amount decreases in relation to the palaeoclimate; thus in coals of the older deposits formed in warm periods, chlorophyllinite is already less abundant. In older soft brown coals its appearance is limited to a few quite specific facies types. In the lignite stage systematic observations are not available and chlorophyllinite has only been identified in algal gyttja at this level of coalification[36]. In the hard coals no investigations are known; this also applies to algal gyttja and bituminous shales.

V – OCCURRENCE

Chlorophyllinite is a sporadic constituent of almost all brown coal, sapropelite and peat deposits. Since fossilization of chlorophyll is only possible under strongly anaerobic conditions, chlorophyllinite is found primarily in strongly gelified soft brown coals, which have not been deposited as gyttjae (e.g. 'leaf coal' of Geiseltal, Germany), as well as in algal gyttjae and other sapropelites. Chlorophyllinite has also been noted in the Moscow brown coal of Lower Carboniferous age[38]. In the younger Tertiary and Pleistocene soft brown coals and peats, chlorophyllinite occurs over a wider facies spectrum. Thus, the normal swamp-forest coals and the young high-moor peats can also both contain chlorophyllinite.

VI – PRACTICAL IMPORTANCE

Since chlorophyllinite only occurs sporadically, it has no direct practical importance. It has an indirect significance as a facies indicator, for example, of the degree of anaerobism and the climate at the time of sedimentation.

International Committee for Coal Petrology
1971 Nomenclature Sub-Committee Hard Coal

SUPPLEMENT **COLLINITE**[+] R. L.
(Stopes-Heerlen System) T. L.

I – ORIGIN OF TERM

The term collinite was proposed by M. C. Stopes[1] to denote ". . . . a reprecipitated gel . . . .", which formed from ". . . . dissolved ulmin . . . . "

Etymology: kolla (Greek) – glue.
Analogous terms: ciment amorphe, pate or gelee,
or substance fondamentale (Duparque and Bertrand),
Collit (Jongmans),
desmite (Ammosov),
anthraxylon (Thiessen) – collinite in layers greater than 14 microns wide,
in part gelinite (Podgajni),
in part gelinitocollinite (IGM),
in part vitrinite A and vitrinite B (Brown, Cook and Taylor),
in part homocollinite and heterocollinite (Alpern).
the Brown Coal term humocollinite corresponds to the Hard Coal term collinite.

II – DESCRIPTION

a) *Morphography*

Collinite comprises a range of constituents, all of which display an absence of cell structure under normal microscopical conditions. Furthermore, the constituents have almost the same reflectance[2].

Morphographically collinite can be differentiated into four submacerals.

[+] see vitrinite

1. *Telocollinite*

Telocollinite appears completely homogeneous and, in contrast to the other submacerals of collinite, occurs in wide layers, whose margins can still be seen (Fig. 1). Its reflectance is slightly higher than that of the other submacerals, lying in the upper part of the reflectance-distribution curve for collinite. Telocollinite was named homocollinite by Alpern[3] and it probably also corresponds at least in part to the vitrinite A of Brown, Cook and Taylor[4]. The properties listed by these authors for these two constituents correspond to a large extent with those of telocollinite.

When coal is crushed, the natural boundaries between individual layers of telocollinite are destroyed and in their place new fracture surfaces are developed. It is therefore difficult to identify telocollinite on polished particulate samples.

After etching a polished surface with oxidizing agents, the greater part of the telocollinite displays a cell structure with either more or less oval cell cavities (Type 1) or compressed closed cell cavities (Type 2). These particular cell structures of telocollinite are known as cryptotelinite after etching (Fig. 2), showing that telocollinite represents the end-stage of gelification of a preserved plant tissue. Telocollinite is therefore synonomous with the term 'ulminite' of M. C. Stopes.

The eu-ulminite of brown coals develops into telocollinite with increasing rank.

2. *Gelocollinite*

Gelocollinite basically corresponds to a pure colloidal gel which has a homogeneous and dense appearance. Before hardening, the gel can impregnate fissures and cell cavities. Unlike telocollinite, gelocollinite has no distinct form and its boundaries are defined by the surfaces of associated macerals. In contrast to gelinite of brown coals (q.v.), gelocollinite rarely occurs pure and in large quantities with its characteristic shrinkage cracks in hard coals. Its reflectance is similar to that of telocollinite and is rather higher than that of desmocollinite. Gelocollinite basically corresponds to the 'true collinite' (eu-collinite) of hard coals. It is abundant, although the part it plays in the petrographic composition of coal is now less than was earlier believed.

After etching with oxidizing solutions, gelocollinite particles of desmocollinite (see desmocollinite) become black. Simultaneously, an unevenness develops on the surface of the polished section due to the removal of cryptogelocollinite by etching.

In other cases rounded bodies, which would not be seen before etching, become visible and are termed cryptocorpocollinite.

3. *Desmocollinite*

Desmocollinite corresponds to completely gelified and compacted humodetrinite of brown coal. When compared to telocollinite, this original heterogeneity of composition of desmocollinite manifests itself in a slightly lower reflectance. In low-rank coals the mean reflectance may lie as much as 0.1% below that of telocollinite.

Desmocollinite was described by the term vitrinite B in 1964 by Brown, Cook and Taylor[4] and by Alpern[3] in the same year as heterocollinite. It had already been established with the electron microscope in 1956 that this type of collinite displayed a granular structure and that it was enriched in syngenetic trace elements (Alpern and Quesson[5]).

When etched with oxidizing agents, the gelocollinitic part of desmocollinite turns black (cryptogelocollinite), while the small fragements of vitrodetrinite (cryptovitrodetrinite) become visible, thus demonstrating the connection with attrinite and densinite of brown coals. Moreover, cryptocorpocollinite also becomes visible occasionally.

It appears that desmocollinite is more abundant than the purer gelocollinite.

4. *Corpocollinite*

The term corpocollinite is used to described homogeneous and massive, round, oval or more or less angular bodies, which are occasionally found in coal. They may be isolated, but they can also occur as cell infillings. Their size corresponds to that of plant-cell cavities (50-100 microns, Type 1) (Fig. 3), but much larger oval and isolated bodies (up to 300 microns) are sometimes found and these occasionally show indications of layering (Type 2) (Fig. 4). Since corpocollinite arises from excretions or cell fillings, its form varies from round to elongate to angular depending on the orientation of the cells or the direction in which the section is cut.

Rounded bodies, whose reflectance differs from that of vitrinite, are not termed corpocollinite.

After etching vacuoles become apparent in some corpocollinite. Cryptocorpocollinite may appear in the three other submacerals of collinite after etching, especially in telocollinite and desmocollinite.

b) *Physical Properties*

Colour: Transmitted light – reddish brown to opaque.

Reflected light – dark gray to white.

Reflectance: $\bar{R}_{max}$ = 0.5 to 8.0% for measurements in oil at a wavelength of 546 nm; between approximately 6 and 17% for air measurements.

The extreme values for n and k, which can be calculated from reflectance values in air and oil, vary at 546nm between:-

Refractive Index: n = 1.73 – 2.60

Absorptive Index: k = 0.02 – 0.60

During the course of coalification the oil reflectance of collinite approaches that of fusinite, until both have reached approximately 5% reflectance. Contrary to the accepted opinion, with further rise of coalification the reflectance of collinite becomes higher than that of all other macerals[6].

Anisotropy: first becomes visible when the reflectance is higher than 0.5%, which corresponds approximately to R_v. The difference $R_{max} - R_{min}$ increases with rise of rank and can reach values as high as 5, or in the peranthracites as much as 6.

Anisotropy can already be observed in transmitted light in the earlier rank stages of hard coals; for the same level of rank the anisotropy is always higher than in reflected light.

Fluorescence (UV): no fluorescence, except in some low-rank hard coals.

Micro-hardness: depending on rank the Vickers microhardness lies between 30 and 100 kg/mm^2. It passes through a minimum at approximately 89% carbon. Since most macerals on polished surfaces have a stronger relief than collinite, statements on the strength of relief are referred to collinite.

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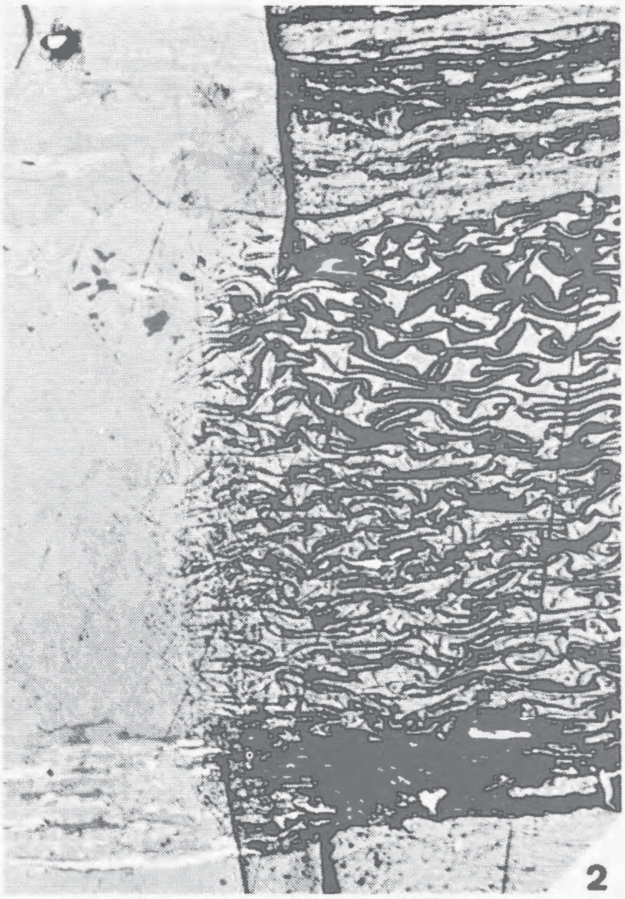
COLLINITE


1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1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
	CORPOHUMINITE (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term corpohuminite was introduced by the Nomenclature Sub-Committee in 1970 for a maceral of the huminite group (humocollinite subgroup), which consists of cell fillings with the reflectance of huminite.

Etymology: corpus (Lat.) – body,
humus (Lat.) – soil, earth.
Synonym: melanoresinite [110].
Analogous terms: phlobaphinite[111].
in part resinite[113].

II – DESCRIPTION

a) *Morphography*

Corpohuminites are *in situ* or isolated phlobaphenic cell excretions (= Phlobaphinite[111]) and secondary huminitic cell infillings, provided that the latter cannot be classified with certainty as gelinite. Essentially as a cell infilling, corpohuminite has an approximately spherical, elliptical, rod- or plate-like form. Its dimensions are similar to those of plant cells[48, 84, 112]. Round forms often have diameters from 10–40 microns; elongate forms may be 20–170 microns in length. The surface of corpohuminite is smooth, porous, cavernous or shows cup-shaped, pitted depressions. The sculpturing of corpohuminites derived from phlobaphene is due to plasmolytic dessication[84].

Two maceral types can be distinguished:

1. phlobaphinite – primary cell excretions which are derived from tannins,
2. pseudo-phlobaphinite – secondary cell infillings which originate in humic colloids.

Allocation of individual corpohuminites to the maceral types is only possible if consideration can also be given to the environment (see III below).

b) *Physical Properties*

Colour: Transmitted light – dark red to brown.

Reflected light (bright field, oil immersion) – medium gray to light gray.

Reflected light (dark field) – cherry red to red brown to black.

Reflected light (fluorescence – blue light) – no fluorescence[29, 84].

Refractive index: $n = 1.64 - ?$[84] (by Becke method).

Reflectance: the same or stronger than strongly reflecting humodetrinite[37, 85]. The following reflectances of corpohuminites from different occurrences of brown coals have been measured:

Locality and Formation	%$\bar{\bar{R}}_{rand}$ (oil)	
Megalopolis (Greece) (Older Pleistocene)	0.38	(525nm)
Ecséd (Hungary) (Pliocene)	0.18	(547 nm)
Lower Rhine (German Federal Republic) (Lower Miocene)	0.37–0.40	(525 nm)
Nordböhmen (Czechoslovakia) (Miocene)	0.41–0.70 ($\bar{x}$=0.54)	(525 nm)
Tatabánya (Hungary) (Lower Eocene)	0.57	(547 nm)

Anisotropy: isotropic.

Density (pyknometer): in water (20°C) – 1.27-?g/cm^3 [84].

Hardness (Vickers): 60-80 kg/mm^2.

c) *Chemical Constitution and Chemical Properties*

Phlobaphenite is derived from polycondensed tannin products (phlobaphenes) and reflects their composition[84].

Analytical data: The elementary analysis[84] of a corpohuminite from Perecesbánya, Hungary is as follows:

		%	Atom %
Carbon	C+H+O = 100	64.8	41.8
Hydrogen		5.6	43.9
Oxygen		29.6	14.3

Ash of moisture-free corpohuminite – 3.1%

Solubility: Corpohuminite is insoluble in the usual polar and non-polar solvents. It is also insoluble in warm alkaline solutions, but becomes darker to opaque.

Melting point: Corpohuminite, when heated to 360°C, does not soften. At approximately 230°C it becomes opaque[84].

III – BOTANICAL AFFINITIES AND GENESIS

Phlobaphinite originates from tannin-rich cell excretions, which have been deposited in cortical cells and in parenchymatous or medullary-ray cells and especially in cork tissues. Tannins are also present in lichens, algae, fungi and ferns. The gymnosperms and angiosperms contain larger quantities of tannins[17, 18, 45]. Phlobaphinite occurs in fossil conifers, for example in *Podocarpoxylon* and in the Taxodiaceae without resin ducts (*Taxodium, Glyptostrobus, Sequoia*), and together with xanthoresinite, occurs also in the conifers with resin ducts (*Pinus, Larix, Picea, Pseudotsuga*)[84, 85]. Remains of Taxodiaceae and Pinaceae, in which the tissues have already been destroyed, are distinguishable from one another[84] because the remains of completely destroyed Taxodiacean tissues yield pure accumulations of phlobaphinite, while the remains of totally destroyed Pinacean tissues produce accumulations of phlobaphinite mixed with resinite. The pseudo-phlobaphinite is derived from colloidal humic solutions.

IV – ALTERATION DURING COALIFICATION

During coalification corpohuminite of Tertiary brown coals retains a relatively high reflectance compared with other huminite macerals. In coals with less than 45 per cent volatile-matter yield, only slight reflectance differences can be observed; these gradually disappear with increasing coalification.

V – OCCURRENCE

Corpohuminite is found in most brown coals and peats. It occurs in larger quantities in xylites from conifers (sometimes more than 10 per cent by volume). It is especially abundant as cell infillings in cork and bark tissues[85, 112, 113]. Very frequently corpohuminite is found isolated in humodetrinitic groundmass, often concentrated where phlobaphene-rich tissue has decomposed to humodetrinite or where resistant cell infillings have concentrated.

VI – PRACTICAL IMPORTANCE

a) *Briquetting*

With increasing concentration of corpohuminite, briquette strength is reduced, although systematic investigations are lacking.

b) *Low-temperature Carbonization*

Apart from shrinkage, no changes are observed up to a temperature of 550°C. Phlobaphinite probably produces pyrocatechin and acid oils during low-temperature carbonization.

c) *Bitumen Extraction*

Corpohuminite yields no extract.

Plate I

Fig. 1.
Typical, tabular-shaped phlobaphinite in cells of a cork bark of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 300x.

Fig. 2.
Phlobaphinite in a coniferous wood tissue of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 3.
Dense and coarsely porous corpohuminite in a cross-section of a root of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 4.
Phlobaphinite in coniferous wood of an Oligocene bright brown coal from Hausham, Upper Bavaria (German Federal Republic); reflected light, oil immersion, 470x.

Fig. 5.
Large and very small (upper left) corpohuminites in a bark tissue of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 470x.

Fig. 6.
Phlobaphinite, in part porous and as thin cell-wall coatings in coniferous wood (textinite A) of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 7.
Isolated corpohuminite (phlobaphinite) of cork tissue in an attrinitic groundmass of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 500x.

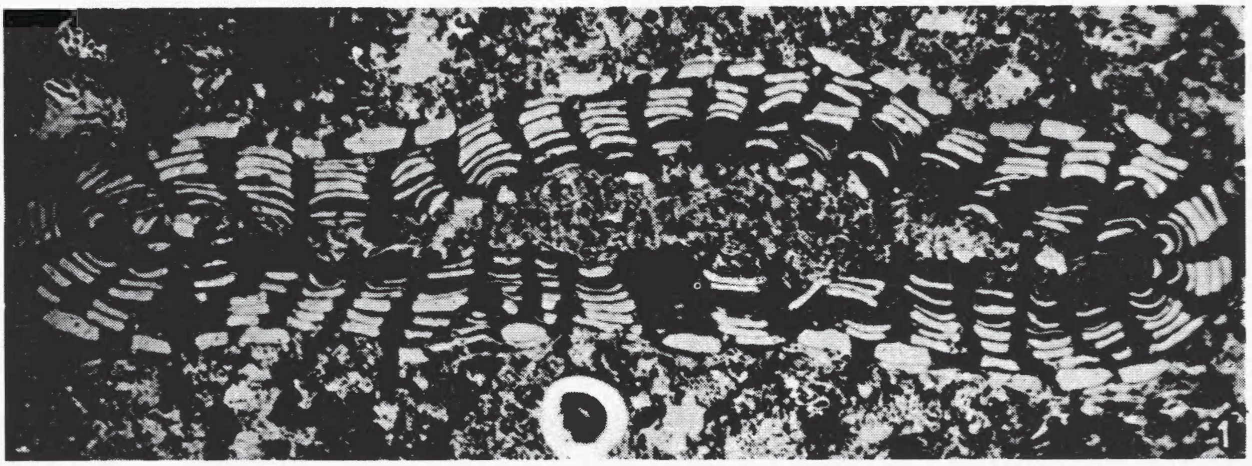
Plate II

Fig. 1.
Corpohuminite in the tissue of a rootlet of a Pliocene bright brown coal from Baccinello, Tuscany (Italy); reflected light, oil immersion, 670x.

Fig. 2.
Accumulation of corphuminite: below–short and rectangular and in part vesicular; above–long and tabular and in part porous, in a Miocene soft brown coal from Bornhausen, Harz (German Federal Republic); reflected light, oil immersion, 500x.

Fig. 3.
Typical tabular-shaped phlobaphinite of a cork tissue: lower right–finely porous, cell walls which are suberinized and very dark in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 500x.

CORPOHUMINITE (I)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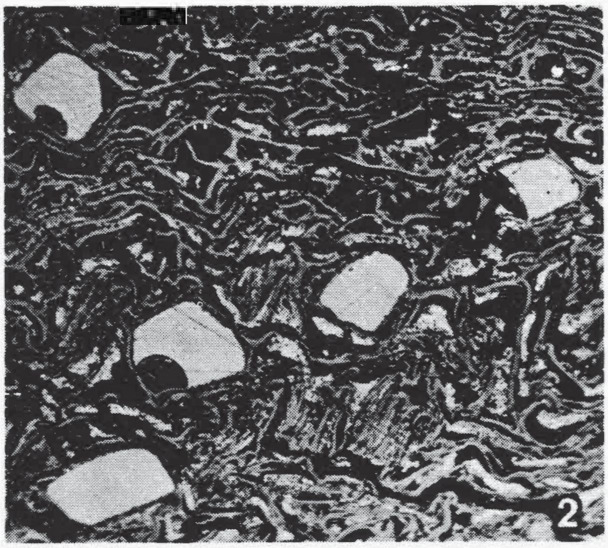
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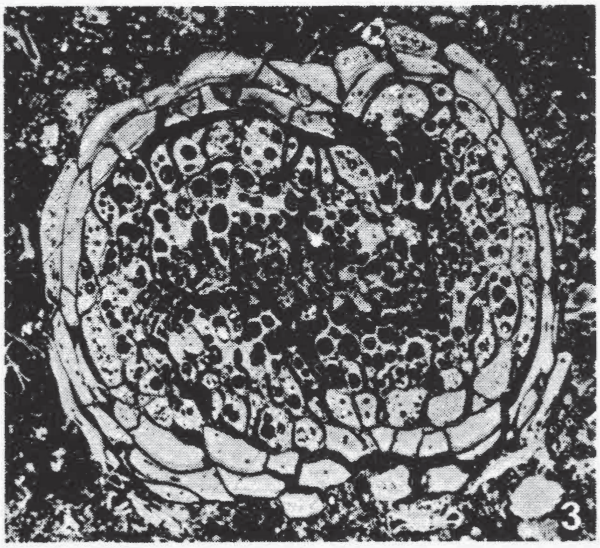
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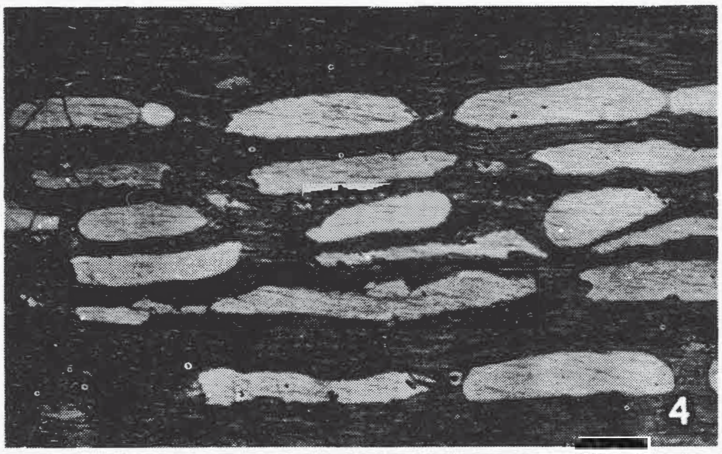
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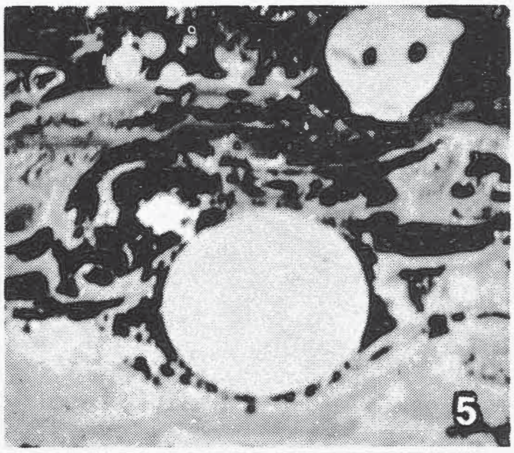
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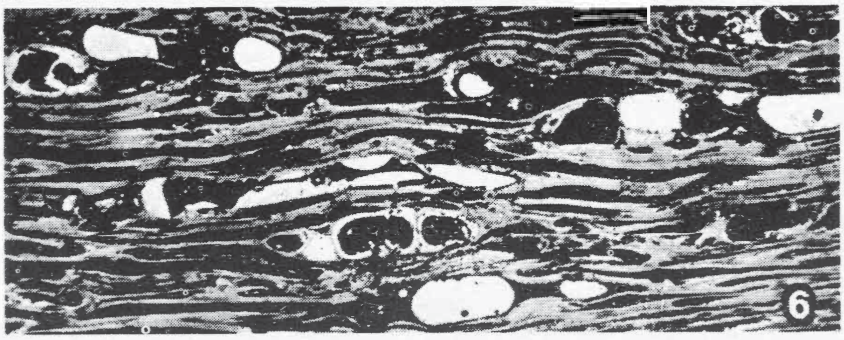
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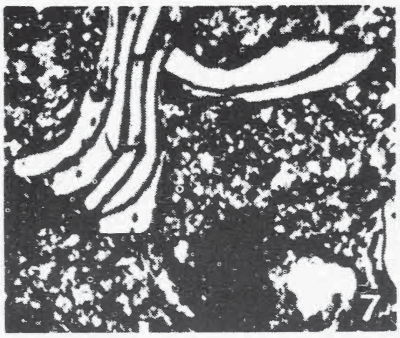
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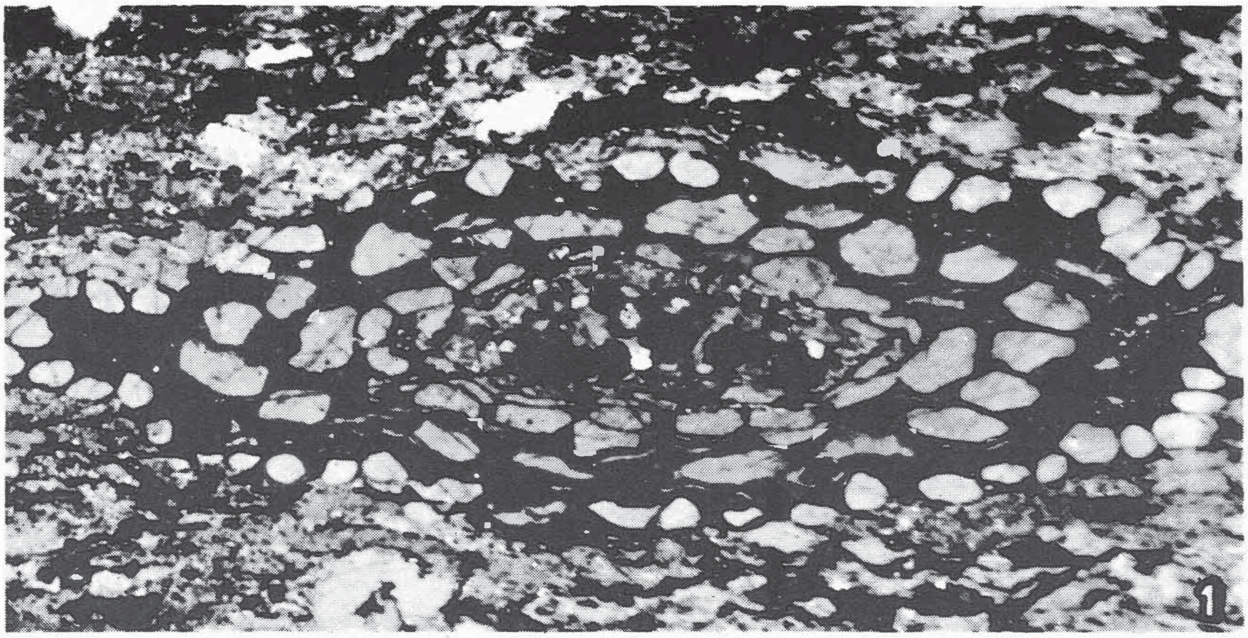
CORPOHUMINITE (II)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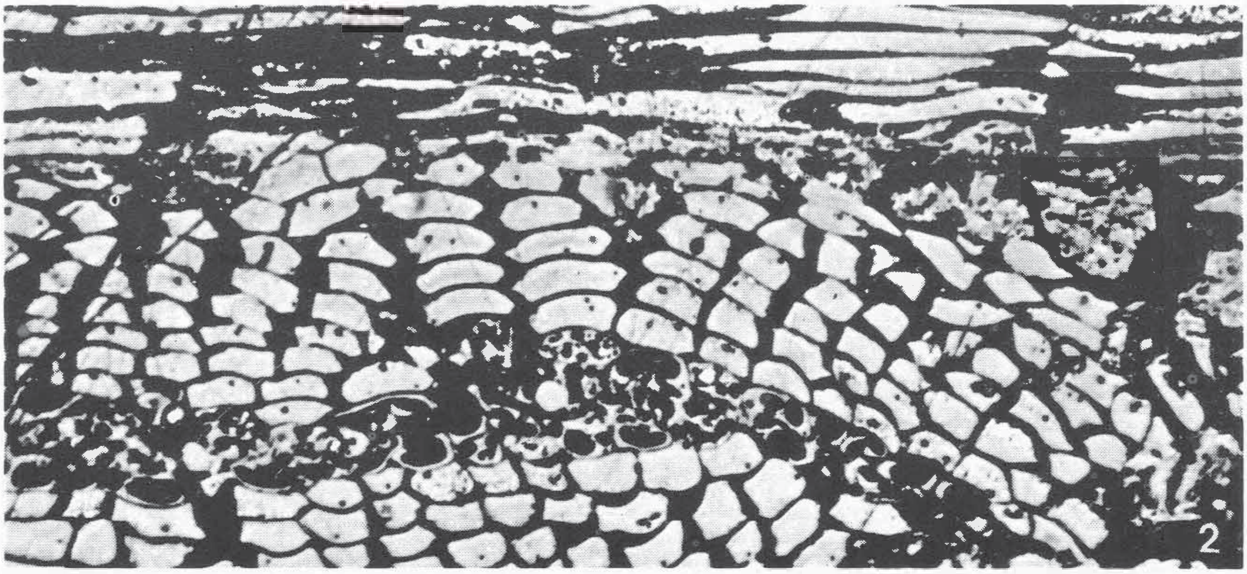
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CORRELATION OF THE HUMINITE MACERALS OF BROWN COALS WITH THE VITRINITE MACERALS OF HARD COALS

Brown Coal					Hard Coal		
Maceral Group	Maceral Subgroup	Maceral	Maceral Type	Maceral Variety	Maceral Type	Maceral	Maceral Group
Huminite	Humotelinite	Textinite		A (dark) B (bright)	Telinite 1 Telinite 2	Telinite	Vitrinite
		Ulminite	Texto-Ulminite	A B			
			Eu-Ulminite	A B			
	Humodetrinite	Attrinite				Vitrodetrinite	
		Densinite			Desmocollinite	Collinite	
	Humocollinite	Gelinite	Levigelinite Detrogelinite				
			Telogelinite		Telocollinite		
			Eugelinite		Gelocollinite		
			Porigelinite				
		Corpohuminite	Phlobaphenite		Corpocollinite		
			Pseudo-Phlobaphenite				

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**CUTINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term cutinite was introduced in 1935 by M. C. Stopes[1]. It is used for a maceral of the liptinite group, which mainly arises from the cuticles of leaves and stalks.

Etymology: kutos (Greek); cutis (Lat.) – skin.

II – DESCRIPTION

a) *Morphography*

Depending upon its origin from cuticles, in sections perpendicular to the bedding cutinite has the form of smooth or one-sided serrated bands of varying thickness. The more obliquely the cuticles are cut, the broader, and in any given instance, the more serrated they appear[13, 90, 112]. In horizontal sections the pattern of the underlying epidermal cells can occasionally still be observed.

b) *Physical Properties*

Colour: Transmitted light – light-yellow to golden-yellow[90, 114].

Reflected light (bright field, oil immersion) – black to dark gray (partly with a reddish cast), sometimes with orange-coloured internal reflections[91].

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[1] Stopes (M. C.). On the petrology of banded bimuminous coal. Fuel, 14, (1935), p.4–13.

Reflected light (dark field) – yellow[91], corresponding to the natural colour of cutinite.

Reflected light (fluorescence) – with U.V. excitation greenish-yellow (sometimes bluish); with blue-light excitation yellow (in soft brown coals) to orange (in lignites). The fluorescence intensity decreases with rising rank.

Reflectance[86]: $\%R_{oil}$ (at 547nm) = 0.17–(0.30?)
$\%R_{air}$ (at 547nm) = 5.60– ?

Refractive Index[86]: (calculated from reflectances measured in air and oil n = 1.60–? (547nm).

Anisotropy (transmitted light): Weak double refraction with whitish gray first-order interference colours; optical character negative. Investigations on small sections by Soos and Kubovics show complete extinction, but extensive cutinite sections exhibit an undulose extinction due to curvature: in places a form of aggregate polarization. Cuticles are pleochroic[90, 112, 114].

Density: Still not measured; graphically determined by van Krevelen[44] from the hydrogen content – <1.10.

c) *Chemical Properties and Constitution*

Recent cuticles consist essentially of cutin, which is secreted externally by the cellulose walls of the epidermis. In many cuticles a quite gradual transition from cellulose into cutin can be observed. The substance of this transitional layer is termed cutocellulose.

Cutinite (fossil cuticles) will probably only differ slightly in its chemical composition from recent material[63]. Besides cutin it can still contain wax in brown coals.

Analytical Data[16, 46, 56]

Elementary Analysis

	%	Atom %
C	70.6–76.4	33.7–39.6
H C+H+O=100)	7.6–11.8	51.3–62.4
O	11.8–21.7	3.9– 9.1
N (daf)	0 – 1.1	
S (daf)	0 – 2.1	

The hydrogen content amounts to >50 atom per cent up to the 'coalification jump'.

Proximate Analysis

	%
Ash	0.6–13.0 (?)
Volatile matter (daf)	*ca.* 80

For the chemical constitution of cutinites, especially their content of long-chain hydroxy-acids, see Hunneman and Eglinton[27].

Solubility: In benzene and alcohol insoluble or only slightly soluble. Chloroform and alcohol extract a little wax from cutinite[46].

Microchemical Behaviour: The microchemical methods of determination of cutin used by botanists show positive results for cutinites of brown coals[63].

III – BOTANICAL AFFINITIES AND GENESIS

Cutinite consists of cuticles, which form protective layers of cormophyte epidermal cells. Cuticles arise from leaves and stalks. Moreover, endodermal matter and embryo sacs of seeds are involved in the initial materials of cutinite.

IV – ALTERATION DURING COALIFICATION

In the high-rank bituminous coals (approximately 87–89% carbon) with increase of rank cutinite pales in reflected light in the same way as resinite and sporinite, matching the vitrinite. In anthracites it can reflect more strongly than vitrinite[114].

V – OCCURRENCE

Cutinite is found sparingly or very sparingly in most brown coals. It occurs in larger quantities in the so-called cuticle coals ('Needle coals', 'Paper coals', 'Leaf coals', 'Porodendron coals'), in which the cutinite content can amount to approximately 20 per cent by weight[46, 91].

VI – PRACTICAL IMPORTANCE

a) *Briquetting*

Systematic investigations are lacking. In small amounts cutinite probably has an insignificant effect.

b) *Low-temperature Carbonization*

Analysis of a cutinite concentrate from Indiana 'Paper coal' gave[56]:

	% daf
Tar	49.8–58.8
Low-temperature coke	22.0–26.5
Gas+ losses (by diff.)	14.7–28.0

Vacuum distillation of cutinite from the Moscow 'Paper coal' liberated 40 per cent of distillate (daf) up to 350°C[46].

c) *High-temperature Carbonization (Bilkenroth-Rammler Continuous Process)*

Since cutinite is hydrogen-rich, it yields only a little residual coke.

d) *Bitumen Extraction*[7]

After exhaustive extraction of the Moscow 'Paper coal', cutinite liberated:

with chloroform	–	1.5% wax extract,
with alcohol	–	2.5% wax extract.

e) *Oxidizability*

Resistant to atmospheric oxidation. Oxidation products after treatment with nitric acid or hydrogen peroxide are suberic acid and a mixture of azelaic acid and sebacic or phellonic acid[16]. Cutinite does not tend towards spontaneous combustion.

f) *Combustion Behaviour*

Determination of the calorific value of cutinite in the Indiana 'Paper coal' gave[56]:

Calorific value (H_o): 6300–7400 cal/g
7700–9300 cal/g (daf)

g) *Seam Correlation: Stratigraphy*

Cuticle analysis in combination with spore analysis may assist in the correlation of coal seams[41, 91]. Moreover, it plays an important role in answering facies and stratigraphic questions and in the reconstruction of plant communities of brown-coal swamps[125].

Fig. 1.
Cutinite in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 200x.

Fig. 2.
As Fig. 1., with blue-light fluorescence.

Fig. 3.
Cutinite in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 200x.

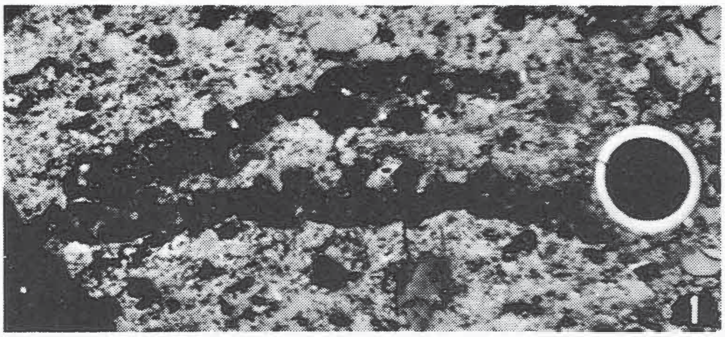
Fig. 4.
As Fig. 3, with blue-light fluorescence.

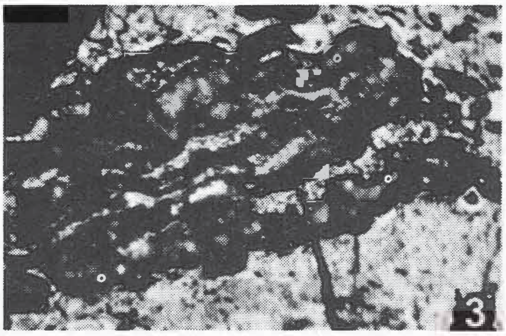
Fig 5.
Cutinite in a transverse section of a leaf in Miocene soft brown coal from Bornhausen/Harz (German Federal Republic); reflected light, oil immersion, 250x.

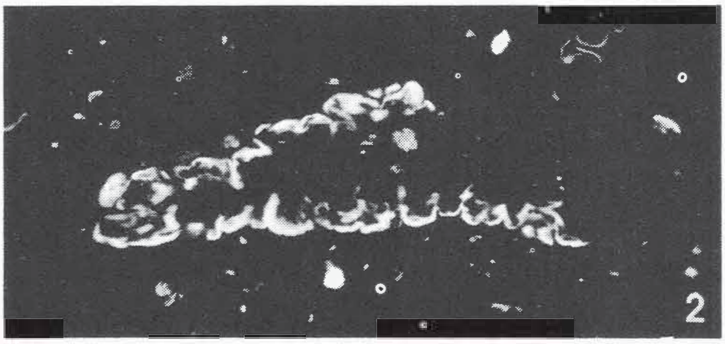
Fig. 6.
Cutinite in a transverse section of a twig in a Miocene soft brown coal from Bornhausen/Harz (German Federal Republic); reflected light, oil immersion, 250x.

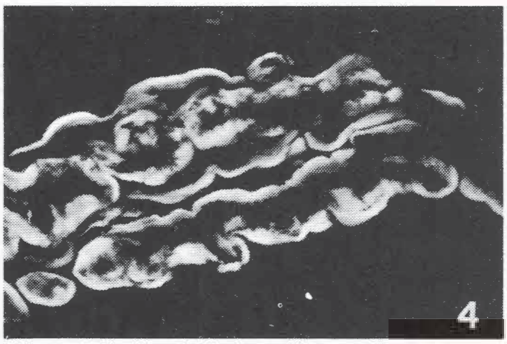
Fig. 7.
Relatively bright cutinite in cuticle clarite of a Pliocene lignite from Baccinello/Tuscany (Italy); reflected light, oil immersion, 270x.

CUTINITE









1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
	DENSINITE (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term densinite was introduced in 1970 by the Nomenclature Sub-Committee to denote a maceral of the huminite group (subgroup – humodetrinite), which comprises the finely detrital and, as a result of gelification, the more or less compressed humic 'Groundmass' of brown coals.

Etymology:	densus (Lat.) – dense.
Synonyms and analogous terms:	translucent humic degradation matter[117], gelified detrinite[83], in part: detrinite[37, 109], detritus[126], humic detritus[113], detrital, attrital, herbaceous or humic groundmass[24], gelinito-posttelinite and gelinito-precollinite[119].

II – DESCRIPTION

a) *Morphography*

Densinite consists of fine (mostly $<$10 microns) detrital huminite particles of varying shape and includes cell-wall debris (which can be $>$10 microns), as well as formless, dense and almost homogeneous huminitic material. These different constituents are mainly densely packed and, as a result of the gelification process, are cemented together over areas at least greater than 15 microns^2. Densinite forms a matrix for the other brown-coal macerals. It is the characteristic humodetrinitic maceral of hard brown coals.

b) *Physical Properties*

Colour: Transmitted light – bright red to red.

Reflected light (bright field, oil immersion) – more or less medium gray.

Reflected light (fluorescence) – none or only a very weak dark brown fluorescence[38].

Reflectance: The mean random reflectance varies over the ranges given below (measured on European brown coals):-

Samples and Localities	$\%R_{rand}$ (Range of Variation)	$\%\bar{R}_{rand}$ (Mean)
Soft brown coals:		
Lower Rhine (German Federal Republic)		
1. Ville block	0.30–0.44	0.37
2. Erft block	0.32–0.48	0.40
Dull brown coals:		
Trimmelkam (Austria)	0.21–0.40	0.33
Handlova (Czechoslovakia)	0.29–0.43	0.36
Kamengrad (Yugoslavia)	0.23–0.53	0.36
Bright brown coals: (desmocollinite)		
Peissenberg (German Federal Republic)	0.21–0.40	0.44
Manosque (France)	0.41–0.60	0.51

Anisotropy: In soft brown coals – isotropic; in hard brown coals – strain anisotropy[50].

c) *Chemical Constitution and Chemical Properties*

Densinite consists of humic materials and possibly also lignin remains. The chemical properties of densinite vary – they are dependent on the respective starting materials and on the degree of gelification. Since pure densinite cannot be isolated, because of its intimate mixing with other macerals, the following analytical data for an Eocene soft brown coal from Central Europe (Ascherleben-Nachterstedt), containing more than 95 per cent of humodetrinite (dominantly densinite), can be taken as representative:

	%
Moisture (as mined)	47.6
Ash (moisture-free)	4.0
Total humic acids (daf)	28.9*
Carbon (daf)	64.8
Hydrogen (daf)	4.9
Oxygen (daf)	28.9
Nitrogen (daf)	1.4

* after Souci daf – dry ash free

III – BOTANICAL AFFINITIES AND GENESIS

Densinite arises from the gelification of attrinite (for further information see 'Attrinite'). The formless material represents flocculated, condensed humic gels.

IV – ALTERATION DURING COALIFICATION

See attrinite – densinite is the preliminary stage of desmocollinite.

V – OCCURRENCE

Densinite is one of the principal constituents of soft brown coals. It appears predominantly in hard brown coals. Its part in the composition of a brown coal is dependent upon facies (see 'Attrinite').

VI – PRACTICAL IMPORTANCE

a) *Crushing Behaviour*

Densinite possesses satisfactory crushing properties. It becomes concentrated in the fine and medium particle sizes ($<$4.0mm)[82].

b) *Briquetting, Low-temperature and High-temperature Carbonisation (Brown Coal (Bilkenroth-Rammler Continuous Process)*

The suitability of densinite for beneficiation processes is due to gelification – rather less good than that of attrinite of the same coal. Its suitability deteriorates still further with increasing rank (cf. 'Attrinite')[30, 31, 34, 68-70, 82, 103, 107].

c) *Bitumen Extraction*

Relatively poor in extractable bitumen[116].

d) *Oxidizability*

Relatively easily oxidized.

Fig. 1.
Densinite: particle to the left - humodetrinite cemented,
± dense with associated attrinite;
particle to the right – humodetrinite, uncompacted and porous:
both particles in a Miocene soft brown coal from the Lower Rhine district
(German Federal Republic);
reflected light, oil immersion, 250x.

Fig. 2.
Spherical densinite patches (coprolites), surrounded by wide
shrinkage cracks in an attrinitic groundmass of a Miocene soft
brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 250x.

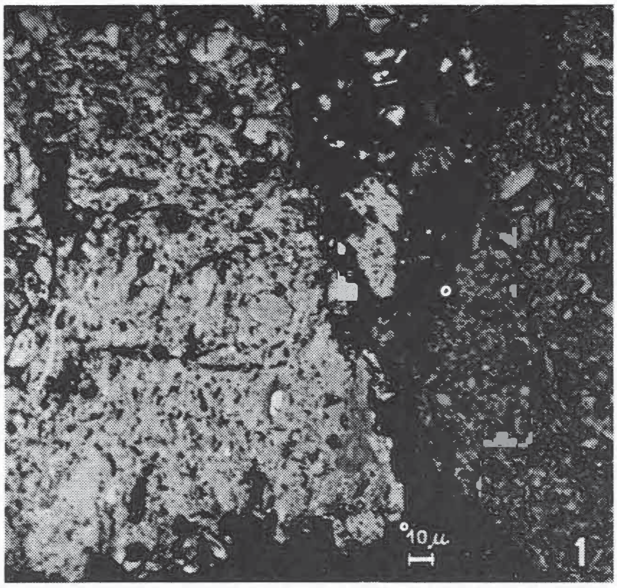
Fig. 3.
Predominantly densinite, in part also attrinite (e.g. centre),
in a Lower Tertiary soft brown coal from Mae Moh (Thailand);
reflected light, oil immersion, 270x.

Fig. 4.
Typical densinite with inclusions of sclerotinite and liptinite
(e.g. below centre – sporinite) in a Miocene soft brown coal from
the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 350x.

Fig. 5.
Densinite and liptinite in a Miocene soft brown coal from
East Lausitz (German Democratic Republic);
reflected light, oil immersion, 500x.

Fig. 6.
Densinite and liptinite in a Miocene soft brown coal from
East Lausitz (German Democratic Republic);
reflected light, oil immersion, 500x.

DENSINITE



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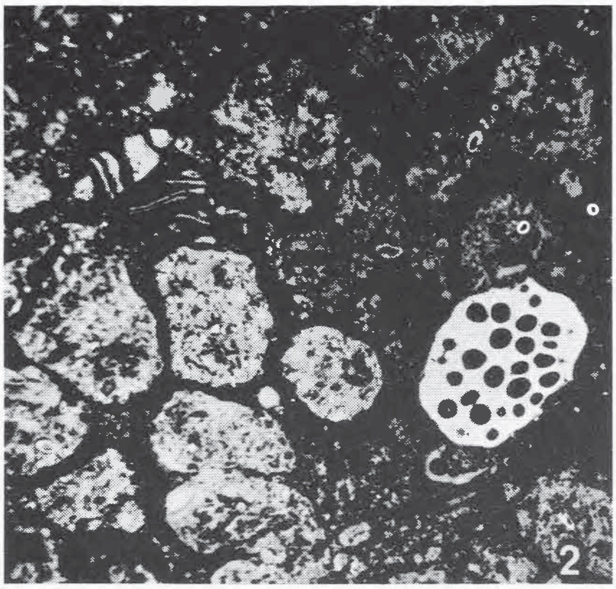

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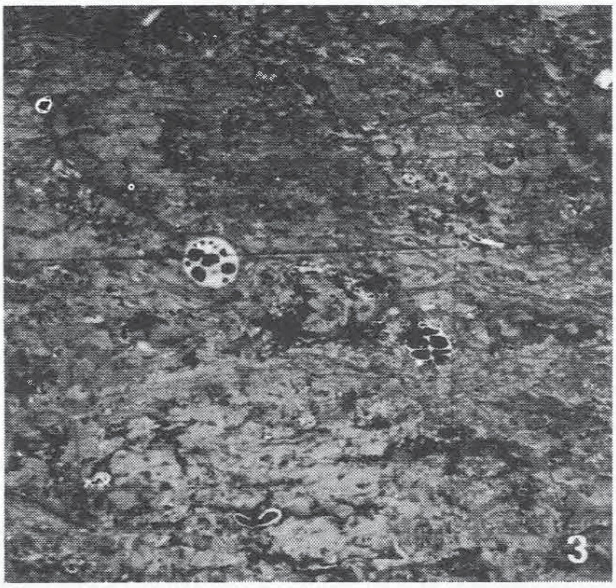

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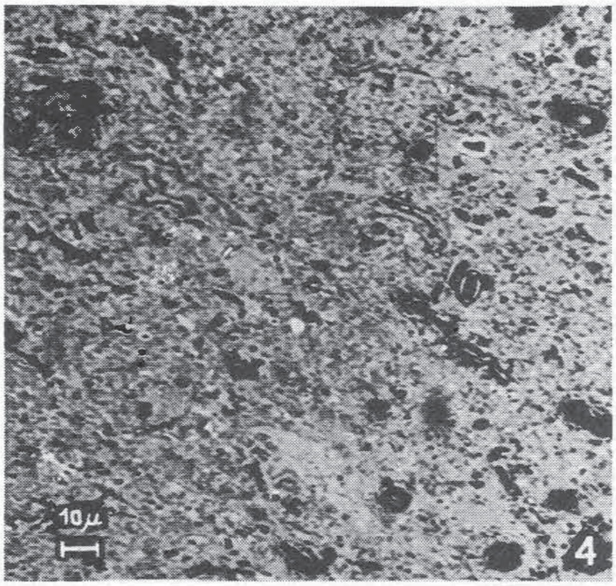

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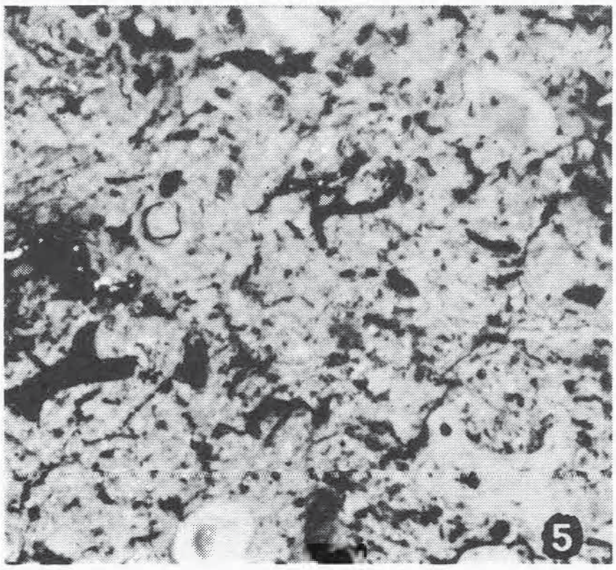

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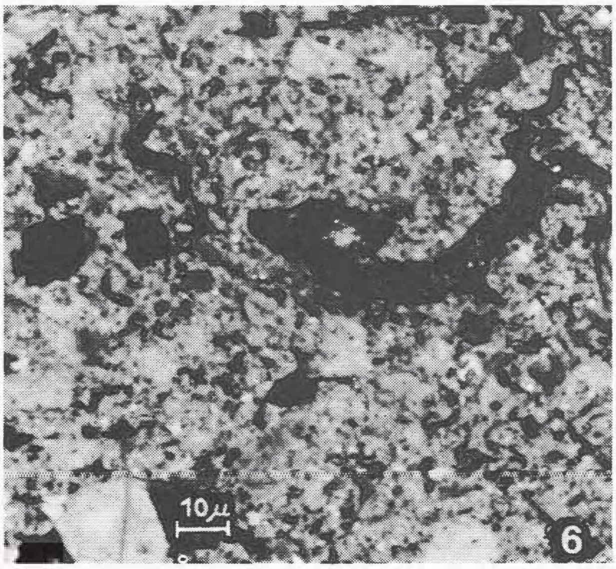

6

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**FUSITE** (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term fusite was used for the first time by R. Potonié[1] in 1924. The Nomenclature Sub-Committee resolved in 1964 to use the term fusite to denote a monomaceral microlithotype consisting of the maceral fusinite.

Analogous term: xylovitrain (Duparque).

II – DESCRIPTION

See fusinite.

Fusite must contain at least 95% of fusinite.

Two varieties of fusite can be distinguished, the friable soft fusite with empty cell lumens and hard fusite in which the cell lumens are impregnated with mineral matter (carbonates, sulphides, quartz, kaolinite and other clay minerals).

In quantitative microscopical analysis only lenses or layers exceeding 50 microns in width are recorded as fusite.

The strength of soft fusite is always lower than that of vitrite. In contrast the strength of hard fusite is clearly higher.

III – OCCURRENCE

Fusite is widely distributed, but apart from a few exceptions, it generally occurs in small amounts. It occurs in thin layers or in more or less thick lenses.

1. Potonié (R.). Einführung in die allgemeine Kohlenpetrographie. Berlin, Verlag, Borntraeger, (1924), p.34.

IV – PRACTICAL IMPORTANCE

See fusinite.

Preparation

Soft fusite is concentrated in the finest particle sizes, because of its ready friability.

Hard fusite is concentrated over a range of particle sizes, depending on the size of lenses or the width of layer.

Hard fusite occurs in the middlings or in the rock, after separation.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**GELINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term gelinite was introduced by Szadeczky-Kardoss[1] in 1948 for precipitated humic gels and was adopted in 1970 by the Nomenclature Sub-Committee to denote a maceral of the huminite group (subgroup–humocollinite), which consists of formless, huminitic gels.

Etymology: gelu, us (Lat.) – frost, stiffening (of bodies due to age).

Synonyms and analogous terms:
gel(s)[76, 77, 113],
brown-coal gel[77],
humus-gel[7, 26],
gel-dopplerite[37],
dopplerinite[37],
gel-dopplerinite[37],
huminite[108],
desminite[52],
gelinito-collinite[120],
peat and gelification-collinite[92],
in part also collinite[2].

II – DESCRIPTION

a) *Morphography*

Gelinites are predominantly precipitated humic gels without any definite form. Under the term gelinite, only huminites, which are homogeneous without etching, are recorded. According to its genesis, gelinite frequently reproduces the shape of spaces and

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[1] Szadeczky-Kardoss (E.). Über Systematik und Umwandlungen der Kohlengemengteile (Hungarian), Mitt. d. Berg – und Hüttenmännischen Abt., Sopron, XVII, (1948–49), p.176–193.

cell lumens filled by it. Gelinitic particles, which are smaller than 10 microns in diameter, are not recorded as gelinite (see humodetrinite). Depending on texture, two submacerals can be differentiated[83]:

(1) porigelinite	–	finely porous to microgranular in appearance,
(2) levigelinite	–	almost structureless and homogeneous, but sometimes with an indistinct, streaky, cloudy appearance.

Secondary fillings of cell lumens (*in situ* or isolated), which cannot be distinguished from phlobaphinite, are grouped together under the term corpohuminite. Levigelinites, which are derived from humotelinite (telogelinite) and humodetrinite (detrogelinite) have the form of their original materials (see under 'Genesis'). The original structure (tissue, detritus) of these levigelinites only becomes clearly visible after etching or in thin section.

Characteristic features of gelinite are a tendency to fissuring (shrinkage cracks due to dessication) as well as sharp-edged, smooth grain boundaries and fissures in fragments.

b) *Physical Properties*

Colour: Transmitted light – yellow to reddish brown.

Reflected light (bright field, oil immersion) – porigelinite is light to medium gray; levigelinite is very light gray to medium gray.

Reflected light (dark field) – black, seldom dark brown with faint reddish cast.

Reflected light (fluorescence) – generally fluorescence-free[38], occasionally weak to very weak fluorescence.

Reflectance: for gelinites of:

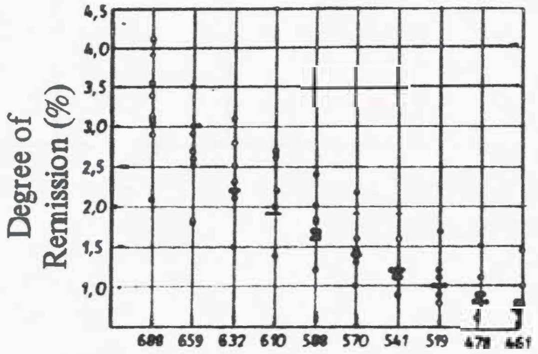
Central European soft brown coals	–	%R_{rand} *ca.* 0.25–0.50 (525nm)
Yugoslavian dull brown coals	–	%R_{rand} *ca.* 0.23–0.53 (x=0.36) (546nm)
Yugoslavian bright brown coals	–	%R_{rand} *ca.* 0.35–0.60 (x=0.50) (546nm)

Anisotropy: None in reflected light; in transmitted light an occasional strain anisotropy.

Density (pyknometer/alcohol): 1.26–1.45g/cm^3 (with 6–12% ash); average – 1.33g/cm^3 referred to air-dried material (*ca.* 14% moisture)[81].

Hardness (Vickers): H_v = 20.2 – 22.7 kg/mm^2[81].

Remission: 1.8–3.5%; average – 2.7% (particles of 0.2mm diameter, air-dried)[81].



Spectral Remission of Gelinites

c) *Chemical Constitution and Properties*

Gelinites consist mainly of humic acids, their precursors and their salts. Their chemistry is influenced by rank as well as by facies and the regional conditions prevailing in the deposits.

Other relevant properties are given by the analyses of pure gelinites from central European brown coals[3, 33, 57, 70, 78, 81, 105].

Deposit %	Coals west of the River Elbe (German Democratic Republic) Eocene	Lausitz (German Democratic Republic) Miocene	Lower Rhine (German Federal Republic) Miocene
Water (as mined)	45	to	70
Ash (d)	$\bar{x}$–3	to	12
Volatile matter (daf)	$\bar{x}$–53.1	$\bar{x}$–49.5	47.8–51.3
Carbon (daf)	66.8–69.6 ($\bar{x}$–67.7)	63.7	65.6–65.8 ($\bar{x}$–65.7)
Hydrogen (daf)	4.2– 5.4 ($\bar{x}$– 4.8)	5.2	4.0– 4.3 ($\bar{x}$– 4.1)
Oxygen (daf)	20.7–25.0 ($\bar{x}$–23.0)	27.1	28.3–28.6 ($\bar{x}$–28.4)
Nitrogen (daf)	0.7– 1.0 ($\bar{x}$– 0.8)	0.6	0.7– 1.0 ($\bar{x}$– 0.8)
Sulphur (daf)	3.0– 6.2 ($\bar{x}$– 3.7)	3.4	0.6– 1.3 ($\bar{x}$– 0.9)
Bitumen (daf)[+]	4.5		3.8
Humic acids[++]	82.2–97.9		61.3–94.2
Humus acids[++]	91.5		n.d.
Humins	1.2		n.d.

d = dry; daf = dry ash free; nd = not determined

[+] Soxhlet, benzene : alcohol = 1:1

[++] method of Souci

III – BOTANICAL AFFINITIES AND GENESIS

Gelinites form both syngenetically and epigenetically. They are flocculation products from pure or colloidal humic solutions[32] (eugelinite), or completely gelified plant residues in which original structure cannot be seen by reflected light under oil immersion (detrogelinite, telogelinite).

IV – ALTERATION DURING COALIFICATION

In the hard brown-coal stage, gelinite, together with humodetrinite and a part of humotelinite, passes into collinite. Its reflectance increases, the weak fluorescence disappears and an increasing amount of strain anisotropy develops.

V – OCCURRENCE

Eugelinite occurs in varying amounts in all brown coals as a filling of shrinkage cracks and root ducts, as well as a cleat filling in associated rocks. Telogelinite and detrogelinite are rare in soft brown coals.

Concentrations of gelinites are facies-dependent. They occur particularly in brown coals deposited under limnotelmatic conditions[74] and in combination with tree stumps[113]. Secondary enrichment is found above argillaceous seam floors or above clay bands in seams. 'Salt coals' ('Salzkohlen' – coals with unusually high contents of sodium chloride) also contain much gelinite. In outcrops that have dried-out enrichment of gelinite through the influence of weathering can occur.

VI – PRACTICAL IMPORTANCE (Soft Brown Coals)

a) *Crushing Behaviour*

Gelinite (especially eugelinite) becomes concentrated during mechanical preparation processes in the fines (0–2mm).

b) *Briquetting*

The properties of gelinite – low pressure-plasticity, high friability, the almost smooth character of its particle surfaces, its typical behaviour on drying and its tendency to internal and external fissuring – cause a weakening of the structural binding of briquettes which leads to breakage into pieces.

c) *Low-temperature and High-temperature Carbonization (Bilkenroth-Rammler Continuous Process)*

Since gelinite shrinks strongly during coking, it causes severe reduction in the mechanical strength of the coke. The pattern of structural damage caused by the gelinite in briquettes is further accentuated in the coke structure (literature for VI a – c: [30, 31, 32, 34, 67–70, 77, 82, 103, 106]).

d) *Behaviour on Weathering*

Because of its tendency to lose moisture, gelinite has little resistance against atmospheric attack. On drying it decomposes very rapidly into a fine debris. Its characteristic macropetrographic characters, such as lustre, brittleness and deep colour (pitch– black) are intensified.

e) *Calorific Value and Combustion Behaviour*

The calorific values of gelinites generally lie below the average for the whole deposit[81]. The following values are typical for Central European soft brown coals.

	Gross Calorific Value (H_o) kcal/kg	Net Calorific Value (H_u) kcal/kg (daf)
Lower Tertiary coals	*ca.* 6250 (average)	*ca.* 5980 (average)
Upper Tertiary coals	*ca.* 5860 (average)	*ca.* 5560 (average)

Fig. 1.
Porigelinite, filling cell lumens, with textinite (cell walls) and corpohuminite (dense cell filling, left) in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 500x.

Fig. 2.
Porigelinite associated with attrinite (above left) in a Miocene soft brown coal from East Lausitz (German Democratic Republic); reflected light, oil immersion, 500x.

Fig. 3.
Porigelinite in cell lumens of fusite in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 4.
Porigelinite (below), levigelinite (eugelinite) (above) with typical dessication cracks and texto-ulminite (above) in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 600x.

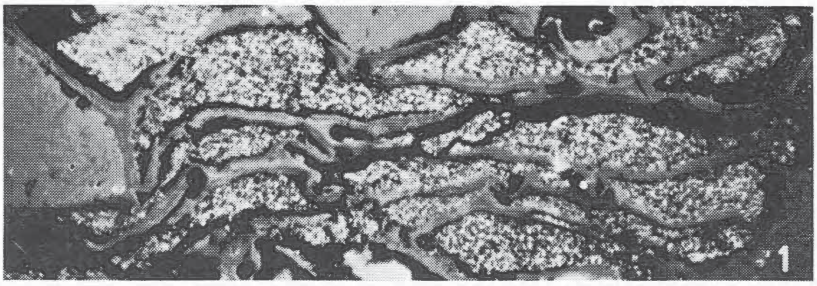
Fig. 5.
Levigelinite with dessication cracks (below right) and inclusions of intertodetrinite in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 6.
Levigelinite with wide dessication cracks between textinite from roots (above and right) in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 7.
Levigelinite (telogelinite) associated with ulminite A with corpohuminites (centre) in an Upper Tertiary coal from Mae Moh (Thailand); reflected light, oil immersion, 270x.

Fig. 8.
Levigelinite with numerous dessication cracks in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

GELINITE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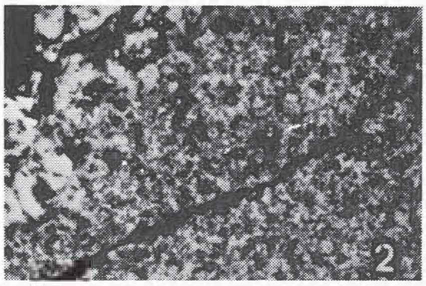
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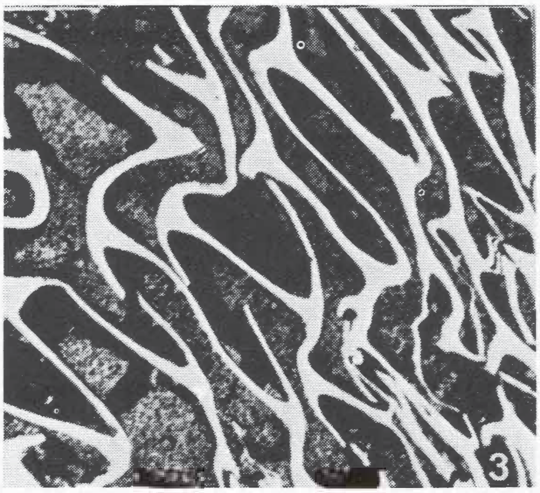
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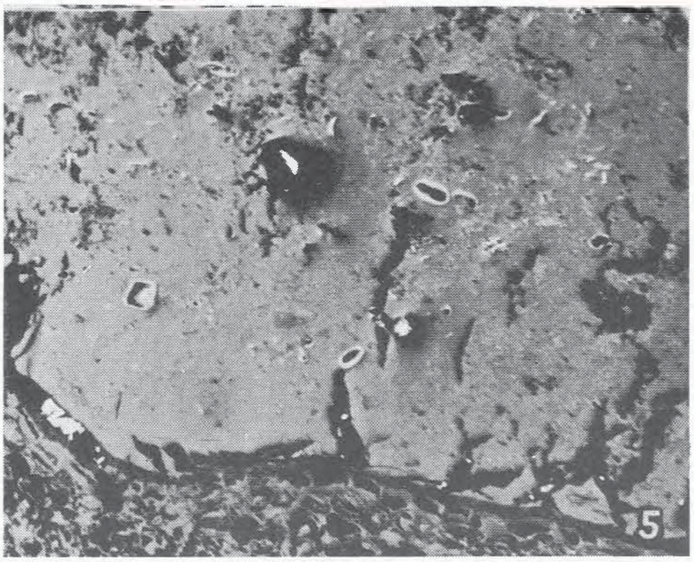
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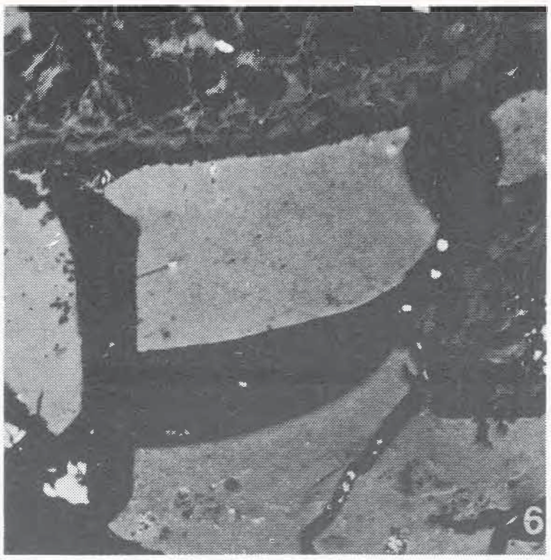
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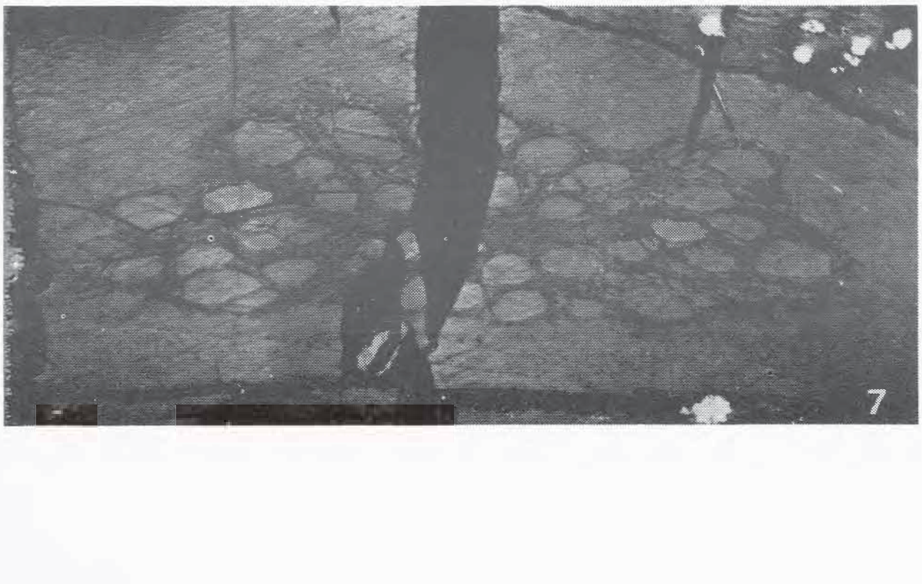
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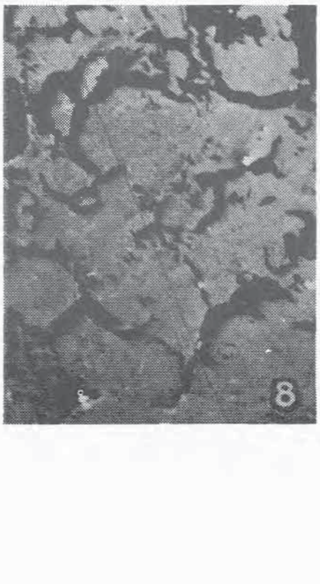
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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**HUMINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term huminite was first used by Szadeczy-Kardoss[1] for a petrographic constituent of brown coals. The Nomenclature Sub-Committee has used the term huminite for a maceral group of brown coals since 1970.

Etymology: humus (Lat.) – soil, earth.

Analogous term: gelinite[118, 120].

II – DEFINITION AND DESCRIPTION

Huminite denotes a maceral group of brown coals which is subdivided into maceral subgroups, depending on the state of preservation of the plant material, and into macerals and submacerals on the basis of degree of gelification or, alternatively, on form and origin.

Huminite consists of humic materials, which essentially arise from lignin and cellulose. Usually only the submaceral phlobaphinite is a catechol-tannin derivative. Huminite (in contrast to the two other maceral groups of brown coals, liptinite and inertinite) is generally distinguished by:– average reflectance in reflected light, a brownish yellow to reddish brown colour in transmitted light, a relatively high oxygen content, a tendency

Maceral Group	Maceral Subgroup	Maceral	Submaceral
Huminite	Humotelinite	Textinite	
		Ulminite	Texto-Ulminite
			Eu-Ulminite
	Humodetrinite	Attrinite	
		Densinite	
	Humocollinite	Gelinite	Porigelinite
			Levigelinite
		Corpohuminite	Phlobaphinite
			Pseudophlobaphinite

to gelification (vitrinization) already in the peat and soft brown-coal stage and a capacity to briquette satisfactorily in an ungelified or non-collinitic condition. For further properties and practical importance – see sheets dealing with the individual huminite macerals.

Huminite is a precursor of the vitrinite of hard coals (*cf.* correlation table: 'Huminite-Vitrinite' accompanying 'General Notes – Brown Coal').

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**HUMOCOLLINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term homocollinite was introduced by the Nomenclature Sub-Committee in 1970 for a subgroup of huminite.

Etymology:	humus (Lat.) – earth, kolla (Greek) – glue.
Synonyms:	gels[77, 113], gelinite[49, 60, 83], dopplerinite group[37].
Analogous terms:	δ-vitrinite[123], gelinito-collinite + semigelinito- collinite[118, 120], in part desminite[53].

II – DEFINITION

Humocollinite is a maceral subgroup of huminite which consists of an amorphous humic gel or of intensely gelified plant tissues and humic detritus. An exception is the submaceral phlobaphinite which represents one of the cell excretions formed by plants. In reflected light under oil immersion humocollinite always appears homogeneous and it often occupies former cavities (slits, pores, cell lumens). Humocollinite is a precursor of collinite, especially of gelocollinite and corpocollinite of hard coals. It is subdivided into the macerals gelinite and corpohuminite (see these terms for further properties); see also the correlation table 'Huminite–Vitrinite', accompanying 'General Notes – Brown Coal'.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**HUMODETRINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term humodetrinite was introduced by the Nomenclature Sub-Committee in 1970 for a subgroup of huminite.

Etymology: humus (Lat.) – soil,
detritus (Lat.) – worn away, disintegrated material.

Synonyms and analogous terms:
herbaceous groundmass[77],
humic detritus[113],
detrinite group[37],
translucent humic degradation matter[117],
attrite + desmite[124],
gelinito-posttelinite + gelinito-precollinite + semigelinito-posttelinite + semigelinito-precollinite[118, 120],
in part desminite + attrinite[53].

II – DEFINITION

Humodetrinite is a maceral subgroup of huminite which consists of the finest humic fragments (mostly <10 microns) intermixed with finely distributed humic gels. Humodetrinite is generally a precursor of desmocollinite and partly also of vitrodetrinite of hard coals. Depending upon its degree of gelification, it is subdivided into the macerals attrinite and densinite (see these terms for further properties); see also the correlation table 'Huminite–Vitrinite', accompanying 'General Notes – Brown Coal'.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**HUMOTELINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term humotelinite was introduced by the Nomenclature Sub-Committee in 1970 for a subgroup of huminite.

Etymology:	humus (Lat.) – soil.
	tela (Lat.) – tissue.
Synonyms and analogous terms:	humic plant tissue[113],
	humophyte[108],
	xylinite[112],
	xylinite group[37, 49],
	textinite[83],
	xylinite + xylinite[123],
	gelinito-telinite + semigelinito - telinite[118, 120],
	in part vitrinite + xylinite[53].

II – DEFINITION

Humotelinite is a maceral subgroup of huminite which consists of intact cell walls of tissue or isolated single cells in a humic state of preservation. Humotelinite is a precursor of telinite and of telecollinite of hard coals. Depending on its degree of gelification, it is subdivided into the macerals textinite and ulminite (see these terms for further properties); see also the correlation table 'Huminite – Vitrinite', accompanying 'General Notes – Brown Coal'.

1971

SUPPLEMENT

International Committee for Coal Petrology
Nomenclature Sub-Committee

INERTITE
(Stopes-Heerlen System)

R. L.

I – ORIGIN OF TERM

The term inertite was introduced in 1955 by V. Hevia Rodriguez[1]. In 1964 the Nomenclature Sub-Committee resolved to use this term to designate a microlithotype group.

II, III, IV – DESCRIPTION, OCCURRENCE AND PRACTICAL IMPORTANCE

See microite, macroite, semifusite, sclerotite, fusite, inertodetrite.

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[1] Hevia Rodriguez (V.). Memoria del XXVIII Congreso Internacional de Quimica Industrial. Madrid, 23-31, Oct. (1955), Vol. I, p.469–472.

1971

SUPPLEMENT

International Committee for Coal Petrology
Nomenclature Sub-Committee

INERTODETRINITE
(Stopes-Heerlen System)

Hard Coal

R. L.

I – ORIGIN OF TERM

The term inertodetrinite was first introduced in 1964 by the Nomenclature Sub-Committee.

Etymology: inertis (Lat.) – inert,
detritus (Lat.) – worn away.
Analogous terms: in part opaque attritus (TBM),
in part fusinite fragments,
in part massive micrinite.

II – DESCRIPTION

a) *Morphography*

All particles in coal, which display a higher reflectance than the corresponding vitrinite and which cannot be classified as micrinite, macrinite, semifusinite or sclerotinite, are grouped under the term inertodetrinite. Inertodetrinite shows no cell structure (one completely preserved cell is accepted as cell structure), but displays a well-defined, multi-sided and angular outline. The size of inertodetrinite particles varies considerably, but extends in general from below 2 to 20 microns.

b) *Physical Properties*

Colour: Transmitted light – predominantly opaque, only showing a dark red to brown in very thin sections.

Reflected light – light gray to white.

Reflectance: always higher than that of the corresponding vitrinite[+].

[+] Inertodetrinite can be differentiated from semi-inertodetrinite on the basis of reflectance.

Density: varies between 1.40 and 1.55 g/cm^3.

Relief: strong, especially if it is associated with vitrinite.

III – OCCURRENCE

Abundant in trimacerite, vitrinertite and durite. Inertodetrinite is especially abundant in Gondwana coals. It is a typical constituent of these coals.

IV – PRACTICAL IMPORTANCE

See inertinite or semifusinite, fusinite, sclerotinite, micrinite and macrinite. A precise statement about the technological behaviour of inertodetrinite cannot be made at present. Observations and investigations up to now indicate the following properties:

a) *Preparation*

Inertodetrinite increases the strength of microlithotypes and reduces fissuring.

b) *Carbonization*

Inertodetrinite acts as an inert material in the range of coking coals.

c) *Hydrogenation*

Because of its low hydrogen content, inertodetrinite does not hydrogenate.

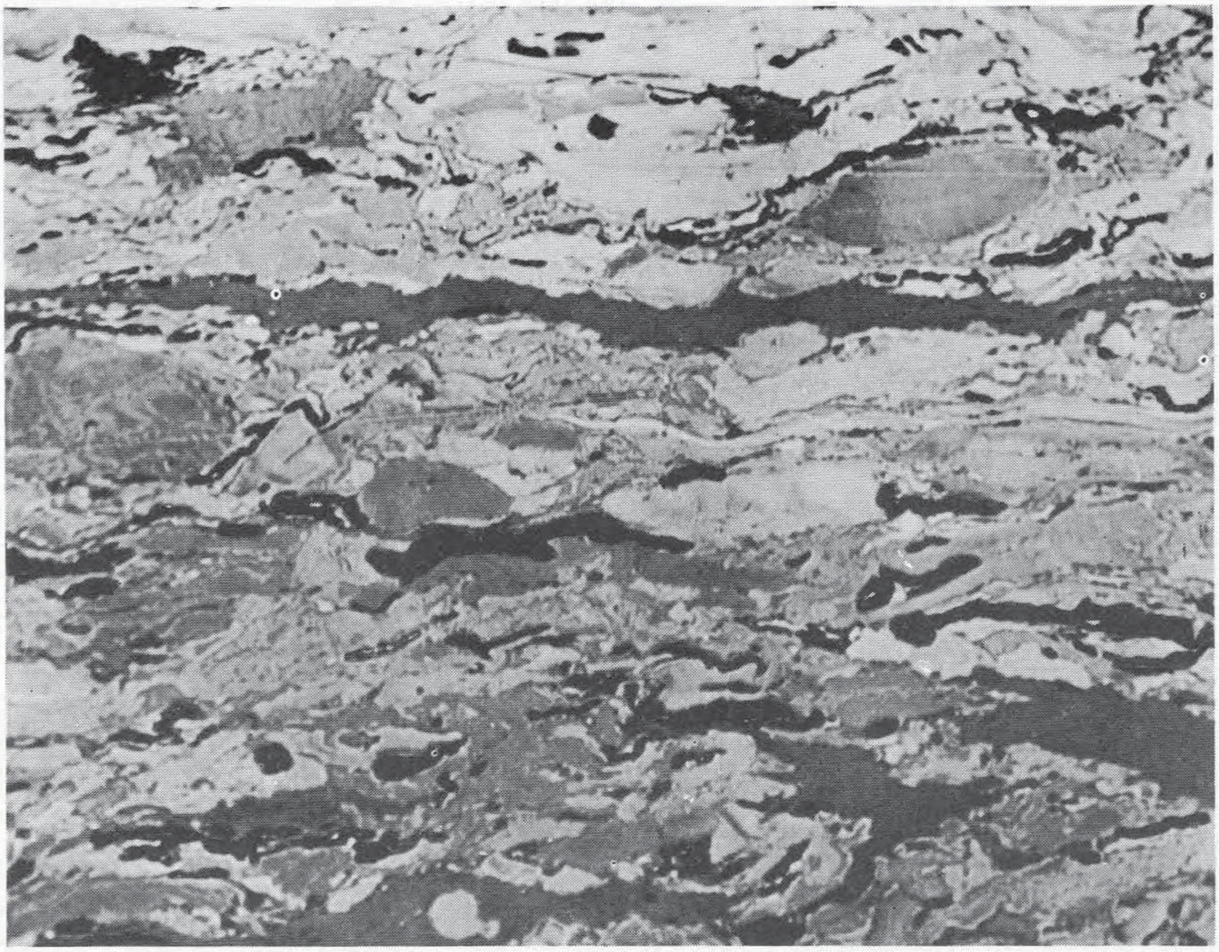
d) *Oxidizability*

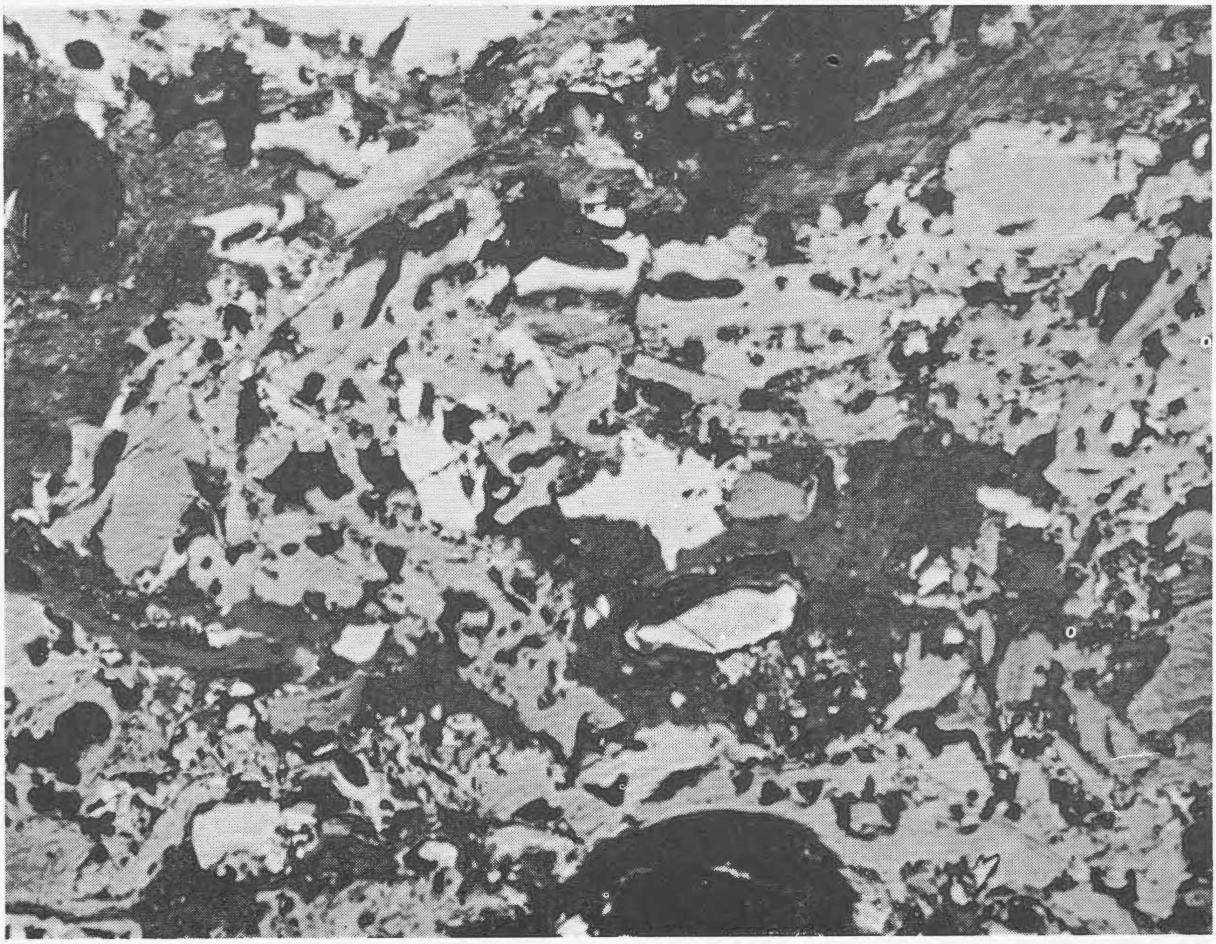
Not readily oxidizable (more difficult than vitrinite).

Fig. 1.
Inertodetrinite in trimacerite from a Carboniferous bituminous coal from the Ruhr;
reflected light, oil, immersion, 350x.

Fig. 2.
Inertodetrinite in a trimacerite from a South African Gondwana coal;
reflected light, oil immersion, 350x.

INERTODETRINITE
(HARD COALS)





1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**INERTODETRINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term inertodetrinite was introduced in the literature in 1966 by E. Stach and B. Alpern[1] and was adopted by analogy with the terms humo-(vitro-)detrinite and liptodetrinite by the Nomenclature Sub-Committee for a finely detrital maceral of the inertinite group.

Etymology: inertis (Lat.) – inert,
detritus (Lat.) – worn away.
Analogous terms: in part massive micrinite,
in part fusinite fragments.

II – DESCRIPTION

a) *Morphography*

Inertodetrinite is a collective term for constituents of the inertinite group, which, on account of their finely detrital condition and/or small particle size, can no longer be assigned with certainty to one or other macerals of the inertinite group (fusinite, semifusinite, sclerotinite, macrinite). Inertodetrinite consists of small fragments and fine particles (approximately 2-20 microns in size) of varying, often splintery or angular form, for example, cell-wall fragments of fusinite, semifusinite and sclerotinite. Intact single cells with the reflectance of inertinite are not recorded as inertodetrinite.

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1. Stach (E.) and Alpern (B.). Inertodetrinite, Macrinite and Micrinite. Fortschr. Geol. Rheinld. u. Westf., 13, 2, (1966), p. 969–980.

b) *Physical Properties*

Colour: Transmitted light – brown to dark brown to black.

Reflected light (bright field, oil immersion) – light gray to white, rarely a yellowish cast.

Reflected light (fluorescence) – no fluorescence.

Reflectance: clearly stronger than the corresponding huminite, but varying like the reflectance of other inertinite macerals; R_{oil} generally $> 0.5\%$.

Polishing hardness: higher than the huminitic constituents.

c) *Chemical Constitution and Chemical Properties*

Compared with macerals of the huminite group, a relatively high carbon content and a low content of hydrogen and volatile matter are characteristic for inertodetrinite. However, the chemical properties vary depending on origin and reflectance.

III – BOTANICAL AFFINITIES AND GENESIS

Inertodetrinite originates from different plant materials by different processes before and during peat accumulation; for example, through charring by the burning of wood or peat, by fungal attack and by strong oxidation[93, 97, 113, 115].

IV – ALTERATION DURING COALIFICATION

Inertodetrinite only alters slightly during coalification; reflectance increases gradually.

V – OCCURRENCE

Compared with Palaeozoic hard coals, inertodetrinite is relatively rare in European and Australian soft brown coals of Tertiary age. Up to a certain level of rank it is found concentrated – predominantly in a splintery form – in sub-aquatic deposits and in pale layers of certain lignites which are suitable for low-temperature carbonization[113].

VI – PRACTICAL IMPORTANCE

Inertodetrinite behaves technologically in a similar manner to other macerals of the intertinite group. Its small particle size and its generally fine distribution may, however, produce certain changes. Thus, for example, during briquetting inertodetrinite does not modify the briquette strength, while coarse fusinite will cause formation of fissures.

Fig. 1.
Inertodetrinite (fusinite fragments) in a clay-coal groundmass
of a Pliocene brown coal from Dettingen/Main (German Federal Republic),
reflected light, oil immersion, 540x.

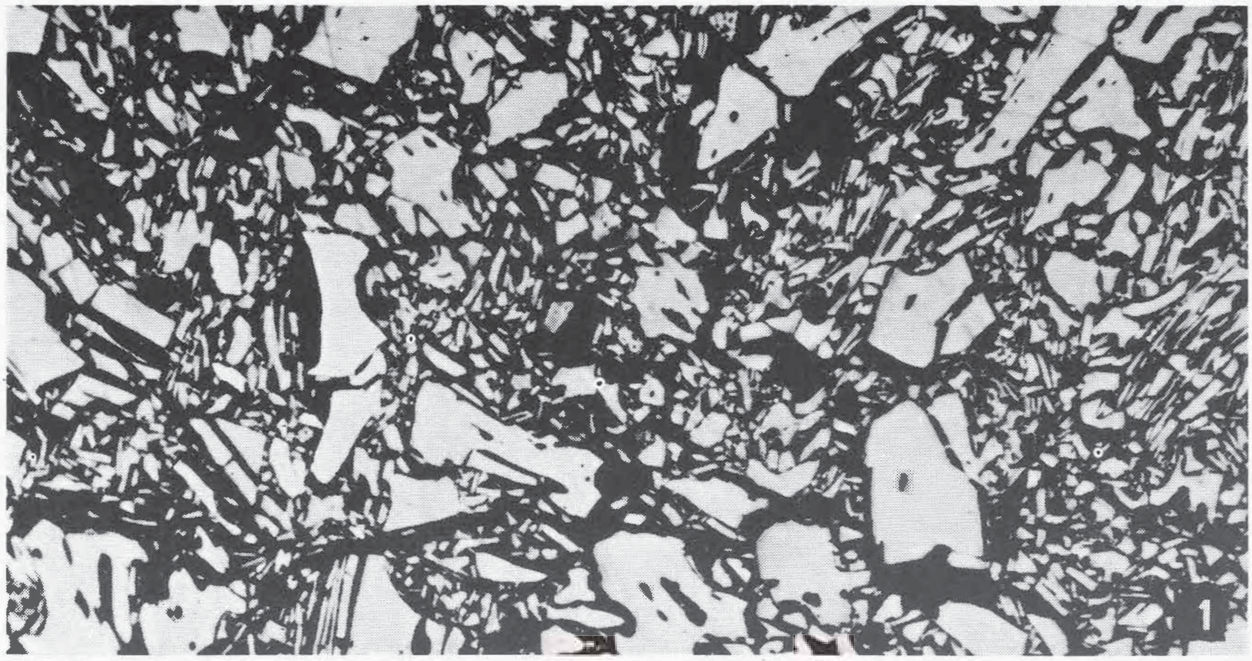
Fig. 2.
Inertodetrinite in trimacerite of an Eocene lignite from
Makarwal (Pakistan),
reflected light, oil immersion, 250x.

Fig. 3.
Inertodetrinite in a Miocene soft brown coal from the Lower
Rhine district (German Federal Republic),
reflected light, oil immersion, 250x.

Fig. 4.
Inertodetrinite in durite of a Jurassic hard coal (gas coal)
from Karmozd-Zirab (Iran),
reflected light, oil immersion, 270x.

Fig. 5.
Inertodetrinite in durite of a Jurassic hard coal (gas coal)
from Karmozd-Zirab (Iran),
reflected light, oil immersion, 270x.

INERTODETRINITE
(BROWN COALS)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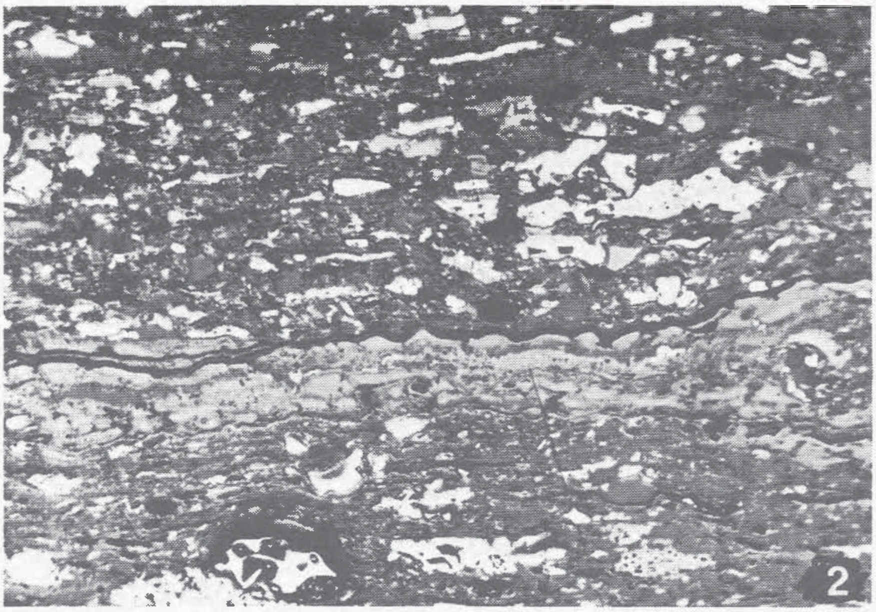
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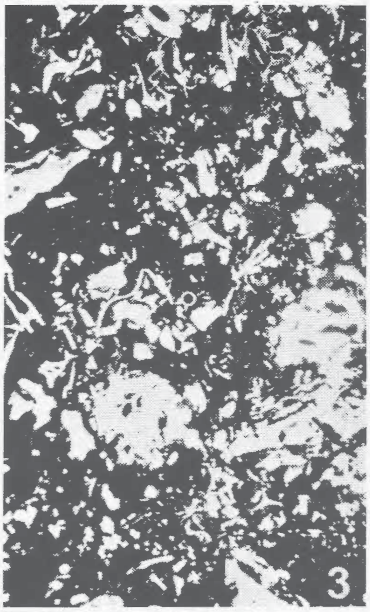
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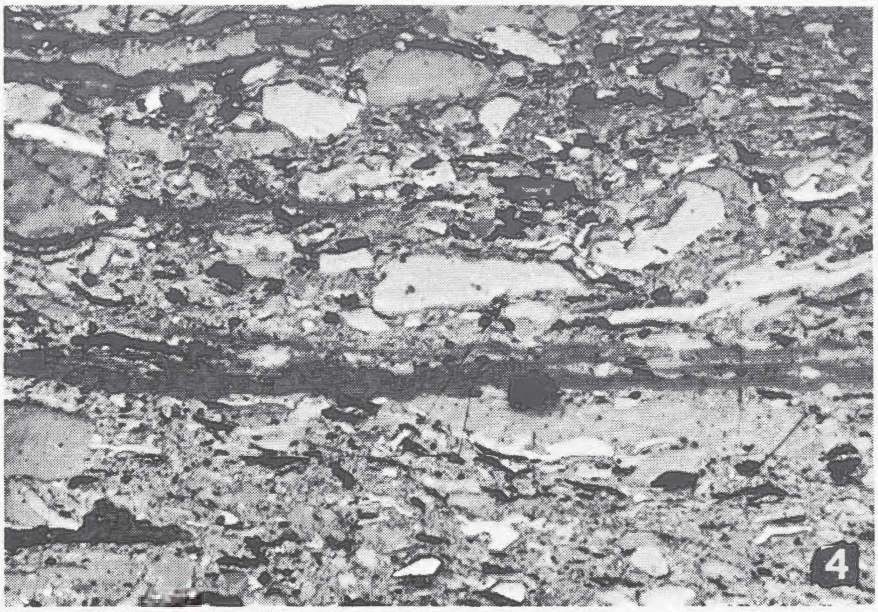
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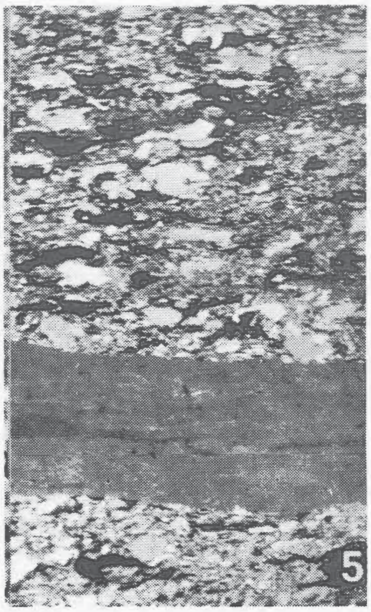
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1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
	INERTODETRITE (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term inertodetrite was introduced by the Nomenclature Sub-Committee in 1966 to designate a microlithotype which consists of inertodetrinite.

II – DESCRIPTION

Inertodetrite must contain at least 95% of inertodetrinite.

In petrographic analysis only inertodetrite layers with a width greater than 50 microns are recorded separately.

The strength of inertodetrite is not accurately known. It must lie in the same range as that of semifusite, fusite, sclerotite and macroite.

Inertodetrite may contain mineral impurities in varying quantities, especially clay minerals.

III – OCCURRENCE

Inertodetrite may occur in all hard coals. It is especially important in Gondwana coals and in certain Permo-Carboniferous coals of the U.S.S.R.

IV – PRACTICAL IMPORTANCE

See semifusite, fusite, sclerotite, macroite.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**LIPTODETRINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term liptodetrinite was introduced by analogy with the terms humo- (vitro-) detrinite and inertodetrinite by the Nomenclature Sub-Committee in 1970 for a maceral of the liptinite group consisting of extremely small particles.

Etymology: leiptos (Greek) – left behind, remaining,
detritus (Lat.) – worn away.
Analogous terms: in part formless bitumen[113].

II – DESCRIPTION

a) *Morphography*

Liptodetrinite is a collective term for constituents of the liptinite group which, because of their finely detrital condition and/or small particle size, can no longer be assigned with certainty to one of the other macerals of the liptinite group. Liptodetrinite may consist of fragments or relicts of sporinite, cutinite, resinite, suberinite or alginite. Moreover, fluorescing constituents of a few microns size, unknown origin and varying form – rodlets, sharp-edged splinters, threadlike and rounded particles, the latter often only of 2-3 microns diameter, belong to liptodetrinite. The size and form of liptodetrinite particles on polished sections of soft brown coals can generally only be distinguished under the luminescence microscope.

b) *Physical Properties*

The optical properties of liptodetrinite vary in a similar way to those of other macerals of the liptinite group. The relatively low reflectance and fluorescence are characteristic. Without high magnification (500x) and particularly without luminescence illumination, liptodetrinite in soft brown coals cannot be distinguished as such (or only rarely), since it hardly differs on polished surfaces under oil immersion from pores of the attrinitic groundmass. It can be more easily recognized in densinite. Particularly in the liptinite-rich yellow and light brown lithotypes of soft brown coals [e.g. 'pale bands' ('helle Bänder') of Eocene coals of central Europe], a distinction between individual liptodetrinite particles in reflected light is impossible without luminescence microscopy.

It should be noted that the light brown, fluorescing and granular-streaky 'groundmass' of very pale, soft brown-coal lithotypes (for which the term 'bituminite' is proposed) is not recorded as liptodetrinite.

Colour: transmitted light – white, yellow, reddish-yellow.

Reflected light (bright field, oil immersion) – black, dark gray or dark brown; in denser layers brown or reddish internal reflections.

Reflected light (fluorescence) – ± strong luminescence with different colours: greenish yellow, citron yellow, yellow, orange and very light brown, depending on the original material, facies, degree of diagenesis and the direction of the section.

Reflectance: mostly lower than huminite, but fluctuating depending on origin (see sporinite, cutinite, resinite, alginite).

Polishing hardness: mostly greater than huminite.

c) *Chemical Constitution and Chemical Properties*

Still not investigated (however, compare sporinite, cutinite, resinite, suberinite, alginite). Characteristically must have a relatively high content of hydrogen and volatile matter.

III – BOTANICAL AFFINITIES AND GENESIS

Part of liptodetrinite consists of spores, pollen, cuticles, resins, waxes, cutinized and suberinized cell wells, and particularly algae, which have been mechanically disintegrated or fractionated through chemical-microbiological decomposition. Thread-like particles may be suberinized cell-wall shreds, which can be related to the fine rodlets of former wax rodlets of fruits or leaves.

IV – ALTERATION DURING COALIFICATION

Liptodetrinite alters relatively little during the brown-coal stage and in low-rank hard coals. Its reflectance first rises more strongly in the medium-rank bituminous coals, until in the high-rank bituminous coals, it reaches the same value as the vitrinite in the same coal. Beyond this level of rank liptodetrinite can no longer be distinguished.

V – OCCURRENCE

Liptodetrinite is usually abundant when other macerals of the liptinite group are strongly represented. In soft-brown coals, which are used for low-temperature carbonization and for bitumen extraction, and particularly in the yellow to light brown lithotypes of Eocene coals of Europe, liptodetrinite is especially strongly concentrated and sometimes forms the dominant constituent.

VI – PRACTICAL IMPORTANCE

The technological properties of pure liptodetrinite have not been investigated and can hardly be determined, because of the difficulties of isolation. It can be inferred from the behaviour of liptodetrinite-rich lithotypes of brown coal that high yields of tar obtained during low-temperature coking are typical of liptodetrinite. In extrusion briquetting presses, liptodetrinitic-rich brown coals tend to shear, but it is not certain whether this is because of their 'bituminite' content or because of their content of liptodetrinite[70]. The possibility of hydrogenating liptodetrinite is probably excellent;

in contrast its sensitivity to oxidation is very low. Coal strength is most probably increased by the presence of liptodetrinite. Furthermore, liptodetrinite should behave technologically in a similar manner to other macerals of the liptinite group (see sporinite, cutinite, resinite, suberinite, alginite).

Fig. 1.
Liptodetrinite (black) in a densinite groundmass of a Miocene soft-brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 200x.

Fig. 2.
As Fig. 1, with blue-light fluorescence.

Fig. 3.
Quite densely packed liptodetrinite particles in clarite of a Jurassic hard coal (flame coal) from Karmozd-Zirab (Iran) – resinite lenses in the centre; reflected light, oil immersion, 270x.

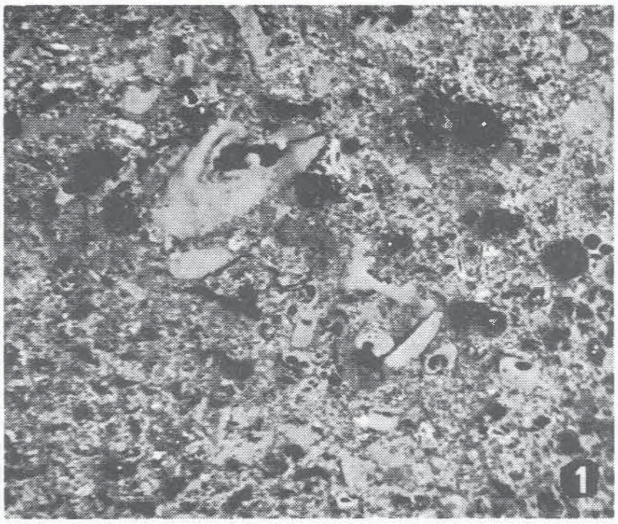
Fig. 4.
Eocene 'Schwelkohle' (lignite suitable for low-temperature carbonization) from Oberröblingen (German Democratic Republic) with numerous internal reflections, but without visible maceral forms; reflected light, oil immersion, 600x.

Fig. 5.
As Fig. 4, with blue-light fluorescence; pollen and numerous liptodetrinite particles visible.

Fig. 6.
Liptodetrinite in clarite of a Jurassic hard coal (gas-flame coal) from Karmozd-Zirab (Iran); reflected light, oil immersion, 270x.

Fig. 7.
Liptodetrinite in clarite of a Jurassic hard coal (flame coal) from Karmozd-Zirab (Iran); reflected light, oil immersion, 540x.

LIPTODETRINITE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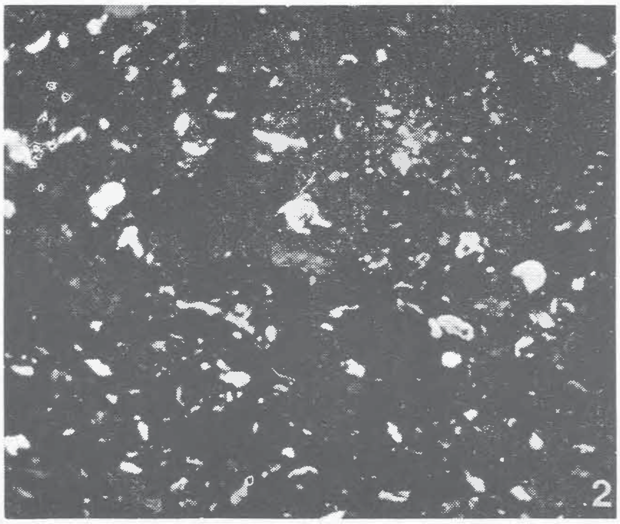
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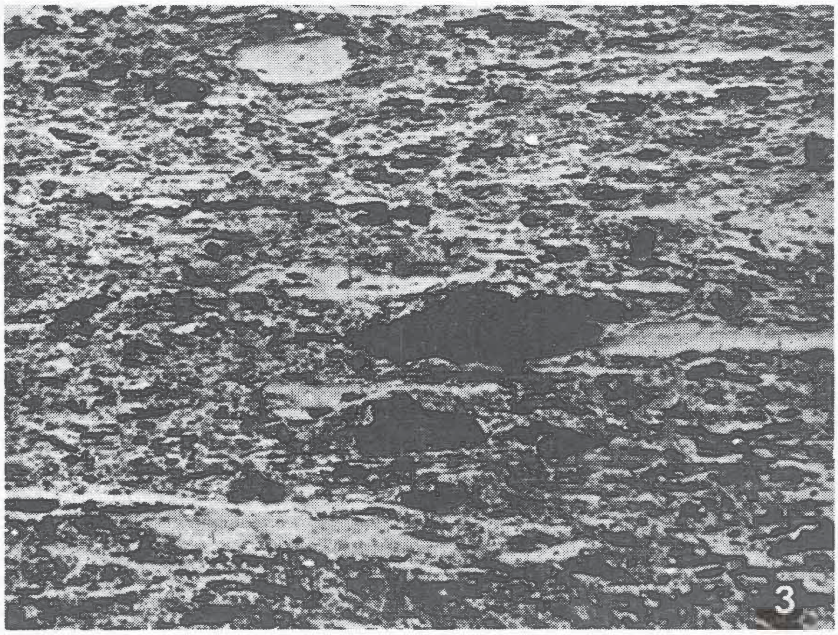
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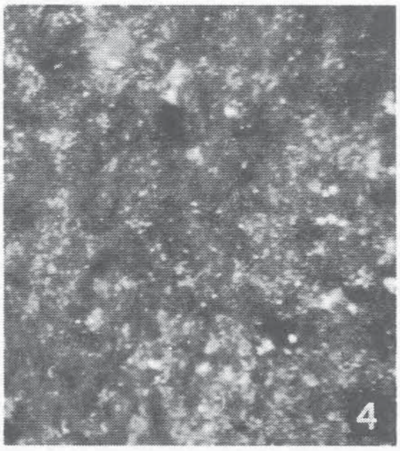
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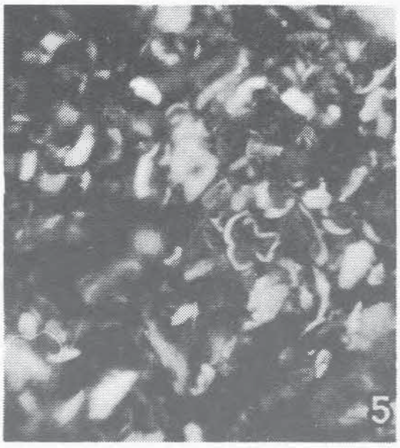
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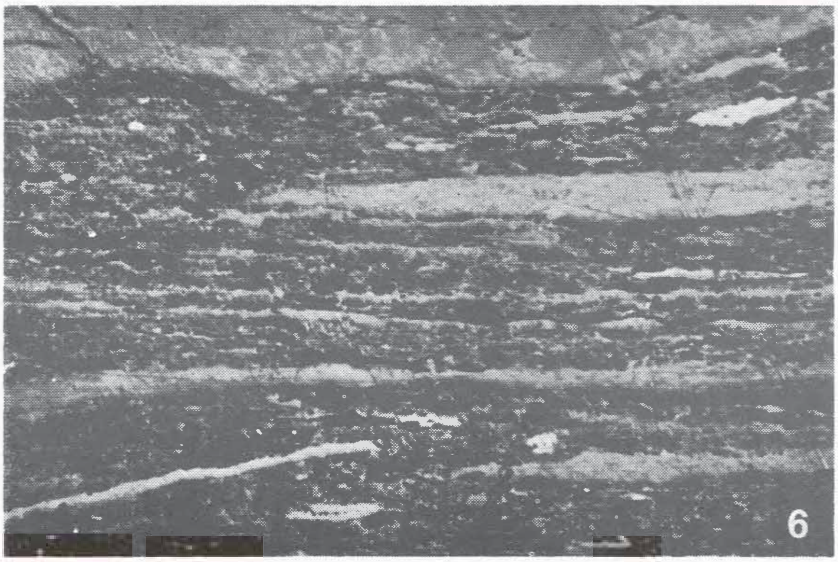
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7

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal Hard Coal
SUPPLEMENT	**MACERAL** (Stopes-Heerlen System)	R. L. T. L.

The term was introduced by M. C. Stopes[1] in 1935.

Etymology:	macerare (Lat.) – to dissolve, soften, digest.
Synonyms and analogous terms:	Gefügebestandteile, Gemengteile. constituent (Thiessen, Parks and O'Donnell), component (Thiessen).

I – DEFINITION

Coal macerals evolve from the different organs or tissues of the initial coal-forming plant materials during the course of the first stage of carbonification (*loc. cit.*). However, because of variable but severe alteration, it is not always possible to recognize the starting materials. Macerals are the microscopically recognizable individual constituents of coal and, depending on their quantitative participation and their associations, they control the chemical, physical and technological properties of a coal of given rank.

In a sense the macerals may be likened to the minerals of rocks.

All macerals have the suffix '-inite'.

Tables 1 and 2 give a summary of the maceral classification that is current for brown coals and hard coals.

---

[1] Stopes (M. C.). On the petrology of banded bituminous coal. Fuel, 14, (1935), p. 4–13.

II – GENERAL CHARACTERISTICS

1. The chemical, physical and technological properties of the macerals vary continuously with increasing rank, but at differing rates.

2. In contrast to minerals, macerals of a given rank are not homogeneous materials, but a mixture of possibly several similar compounds whose exact chemical constitutions are at present unknown.

3. Macerals may also display variability in their physical properties.

4. Macerals do not contain any mineral substances which can be resolved with the light microscope. They do contain, however, inorganic impurities which cannot be detected with the light microscope, either minerals of sub-microscopic size or organometallic complexes (trace elements). The quantity of inorganic impurities in brown-coal macerals may amount to several per cent (e.g. calcium humate), but in the hard-coal macerals, the impurities are generally no more than a few tenths of a per cent.

Minerals, however finely divided, which can be observed with a light microscope, are not constituents of a maceral.

III – SUBDIVISION OF THE MACERALS

The subdivision of macerals is based upon the statements given in the general notes (*loc. cit.*) and on the criteria listed below:-

a) *Reflected light (polished section)*

- Reflectance (R_{oil} 546nm)
- Shape and structure
- Colour
- Anisotropy
- Internal reflections
- Remission measurements (brown coal)
- Luminescence (fluorescence)
- Grinding and polishing hardness (relief)
- Vickers micro-hardness

b) *Transmitted light (thin section)*

- Shape and structure
- Absorption (colour)
- Luminescence (fluorescence)

Reflectance, shape and fragmentation are of considerable importance in distinguishing macerals.

For brown-coal macerals the degree of gelification is important for their subdivision.

Slight, genetically or structurally controlled differences in the microscopical appearance of the macerals are embodied in the term 'submaceral'.

Example: Collinite – Submaceral: Telocollinite

If the form or structure of a maceral can be positively related to a given plant tissue or organ, this is regarded as a 'maceral variety'. Varieties of the brown-coal macerals can be distinguished by reflectance.

Example: Telinite – Variety: Lepidophytotelinite

Examples of different submacerals or varieties can be found in Tables 1 and 2.

Use of supplementary methods, such as

- etching,
- electron microscopy, and
- luminescence measurements (hard coals),

can, in some macerals, reveal structures or details which cannot be observed by normal microscopy. Constituents of this kind are known as 'cryptomacerals' (e.g. cryptotelinite).

It is suggested, when describing cryptomacerals, that reference should be made to the supplementary technique which was employed [e.g. etching – (E): electron microscopy – (EM): luminescence – (L)].

Example: Cryptotelinite (E)
Cryptoexosporinite (L)

A maceral which can be referred to a given plant tissue or organ, as, for example, in the case of sporinite to plant spores or pollens, is also a 'phyteral' (*loc. cit.*). This direct correlation between the initial plant material and the maceral, or between the maceral variety or cryptomaceral, does not imply that the two constituents have identical chemical compositions or chemical constitutions, since in both the first and second stages of carbonification, chemical changes are liable to occur which will not affect either the form or the structure in a manner that can be recognized under the microscope.

The macerals of coal can be arranged in three different groups on the basis of reflectance differences (see Tables 1 and 2). The differences in the reflectances of the three maceral groups are most pronounced in the brown coals and they progressively decrease in the hard-coal range, until in the anthracites, reflectance differences are virtually non-existent. In the anthracites, a coalification phase of the hard coals, both shape and structure are the most important distinguishing characteristics of the macerals.

There is a definite correlation between reflectance and the volatile-matter content or the carbon content of a maceral (see 'Rank'). Consequently the three maceral groups also display different chemical and technological properties. The physical characteristics of macerals within a group, notably resistance to grinding, may be subject to quite marked variation.

The sheets dealing with macerals have the following arrangement:-

I – ORIGIN OF TERM

Name of the author who first used the term.
Etymology of the term.
Synonyms and analogous terms.

II – DESCRIPTION

a) *Optical Properties*
- Morphography
- Colour: in reflected light
  in transmitted light
- Reflectance (R): reflected light
- Remission capacity (reflected light, brown coal)
- Anisotropy: in reflected light
  in transmitted light
- Luminescence (fluorescence): reflected light
  transmitted light
- Internal reflections

b) *Physical Properties*
- Density
- Vickers micro-hardness
- Swelling properties e.g. softening behaviour

c) *Chemical Constitution and Chemical Properties*
- Elementary composition
- Proximate analysis
- Calorific value

III – SUBMACERALS

IV – MACERAL VARIETIES

V – CRYPTOMACERALS

VI – OCCURRENCE

Occurrence – Frequency – Distribution – Associations

VII – BOTANICAL CLASSIFICATION AND GENESIS

VIII – PRACTICAL IMPORTANCE[+]

a) *Preparation*
b) *Briquetting*
c) *Carbonization*
d) *Hydrogenation*
e) *Combustion Behaviour*
f) *Oxidizability, Spontaneous Combustion, Weathering*
g) *Stratigraphy*

IX – REFERENCES

[+] Reference to the practical importance of individual macerals is only made in sheets in which cross reference can be made to investigations on the macerals.

TABLE 1.

SUMMARY OF THE MACERALS OF HARD COALS

Maceral Group	Maceral	Submaceral⁺	Maceral Variety⁺	Cryptomaceral⁺
Vitrinite	Telinite	Telinite 1 Telinite 2	Cordaitotelinite Fungotelinite Xylotelinite Lepidophytotelinite Sigillariotelinite	Cryptotelinite
	Collinite	Telocollinite Gelocollinite Desmocollinite Corpocollinite		Cryptocorpocollinite Cryptogelocollinite
	Vitrodetrinite			Cryptovitrodetrinite
Exinite	Sporinite		Tenuisporinite Crassisporinite Microsporinite Macrosporinite	Cryptoexosporinite Cryptointosporinite
	Cutinite Resinite Alginite Liptodetrinite			
Inertinite	Micrinite Macrinite Semifusinite			
	Fusinite	Pyrofusinite Degradofusinite		
	Sclerotinite		Plectenchyminite Corposclerotinite Pseudocorposclerotinite	
	Inertodetrinite			

⁺ incomplete, can be expanded as required

TABLE 2

SUMMARY OF THE MACERALS OF BROWN COALS

Maceral Group	Maceral Subgroup	Maceral	Submaceral[+]
Huminite	Humotelinite	Textinite	
		Ulminite	Texto-Ulminite Eu-Ulminite
	Humodetrinite	Attrinite	
		Densinite	
	Humocollinite	Gelinite	Porigelinite Levigelinite
		Corpohuminite	Phlobaphinite Pseudophlobaphinite
Liptinite		Sporinite	
		Cutinite	
		Resinite	
		Suberinite[++]	
		Alginite[++]	
		Liptodetrinite	
		Chlorophyllinite	
		Bituminite[++]	
Inertinite		Fusinite[++]	
		Semifusinite[++]	
		Macrinite[++]	
		Sclerotinite	
		Inertodetrinite	

[+] incomplete, can be expanded as desired.

[++] sheets for these macerals not issued until 1975.

1971
SUPPLEMENT

International Committee for Coal Petrology
Nomenclature Sub-Committee

MACROITE
(Stopes-Heerlen System)

Hard Coal
R. L.

I – ORIGIN OF TERM

The term macroite was adopted by the Nomenclature Sub-Committee in 1964 to denote a monomaceral microlithotype consisting of macrinite.

Analogous terms: in part geli-fusinito-collinite coal (IGM),
pulpe végétale (A. Duparque).

II – DESCRIPTION

See macrinite.

Macroite must contain at least 95% macrinite. In petrographic analysis only macroite layers with a width greater than 50 microns are recorded separately.

The strength of macroite has still not been investigated. Macroite may contain mineral impurities in varying quantities, especially clay minerals.

III – OCCURRENCE

Macroite may occur in all bituminous coals. It is especially important in Gondwana coals and in certain Permo-Carboniferous coals of the U.S.S.R.

IV – PRACTICAL IMPORTANCE

See macrinite.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**MICROLITHOTYPE** (Stopes-Heerlen System)	R. L.

ORIGIN AND DEFINITION OF TERM

The term microlithotype was proposed by C. A. Seyler[1] in 1954. In the microscopy of hard coals the term describes typical maceral associations whose minimum band width is fixed at 50 microns. The microlithotypes bear the suffix '–ite'. Their delimitation, although arbitrary and conventional, appears to agree well with their technological behaviour.

All microlithotypes are often contaminated to some degree by mineral matter. If the mineral matter is sufficiently low that a density of 1.5 g/cm^3 in the range of hard coals (see – 'Rank') is not exceeded, then the term is governed solely by the maceral composition.

More strongly mineral-contaminated microlithotypes with a density between 1.5 and 2.0 g/cm^3 (in the range of hard coals) are grouped together under the term carbominerite. In cases of monomineralic coal-mineral associations, the term is governed by the mineral (e.g. carbargilite). Polymineralic coal-mineral associations are described as carbopolyminerite.

There is no clear relationship between the lithotypes and the microlithotypes since, for example, a durain of matt appearance may not only be a spore-rich clarite, a trimacerite and a durite, but also a strongly mineral-contaminated vitrite.

Synonyms: macrotype (G. H. Cady),
in part Streifenart,
in part subtype.
Analogous terms: in part type of coal (TBM),
genetic type of coal for polymaceral microlithotypes (IGM),
type of microcomponent for monomaceral microlithotypes (IGM).

The pattern of the glossary sheets for the microlithotypes is as follows:

---

[1] Seyler C.A. Letter to the Nomenclature Sub-Committee, (1954).

I – ORIGIN OF TERM

Name of author, with the date when the term was first used and the appropriate literature reference.

Synonyms and analogous terms.

II – DESCRIPTION

Maceral composition
Minimum-band width
Density
Strength
Mineral impurities

III – OCCURRENCE

Occurrence – distribution – abundance – associations.

IV – PRACTICAL IMPORTANCE

1. *Preparation*
2. *Carbonisation*
3. *Hydrogenation*
4. *Oxidizability*
5. *Combustion behaviour*
6. *Formation of dust*
7. *Stratigraphy*

See Tables 1 and 2.

TABLE 1
SUMMARY OF THE MICROLITHOTYPES[+]

Maceral Composition (mineral-free)	Microlithotype	Maceral-Group Composition (mineral-free)	Microlithotype Group
Monomaceral			
C > 95%	(Collite)[+]	V > 95%	Vitrite
T > 95%	(Telite)[+]		
VD > 95%			
S > 95%	Sporite	E/L > 95%	Liptite
C > 95%	(Cutite)[+]		
R > 95%	(Resite)[+]		
A > 95%	Algite		
LD > 95%	–		
M > 95%	Macroite	I > 95%	Inertite
Sf > 95%	Semifusite		
F > 95%	Fusite		
Sc > 95%	(Sclerotite)[+]		
ID > 95%	Inertodetrite		
Bimaceral			
V + S > 95%	Sporoclarite	V + E/L > 95%	Clarite V, E/L
V + C > 95%	Cuticloclarite		
V + R > 95%	(Resinoclarite)[+]		
V + A > 95%	(Algoclarite)[+]		
V + LD > 95%	–		
V + M > 95%		V + I > 95%	Vitrinertite V, I
V + Sf > 95%			
V + F > 95%			
V + Sc > 95%			
V + ID > 95%			
I + S > 95%		I + E/L > 95%	Durite I, E/L
I + C > 95%			
I + R > 95%			
I + A > 95%			
I + ID > 95%			
Trimaceral			
V, I, E > 5%	Duroclarite	V > I, E	Trimacerite V, I, E/L
	Vitrinertoliptite	E > I, V	
	Clarodurite	I > V, E/L	

[+] The terms in parentheses are not at present in use.

TABLE 2

SUMMARY OF THE MICROLITHOTYPES

Association of coal with a specific mineral or mineral group	Composition[+]	Collective term for imprecisely designated coal-mineral association
Carbargilite	Coal + 20–60 vol % clay minerals	Carbominerite
Carbopyrite	Coal + 5–20 vol % sulphides	
Carbankerite	Coal + 20–60 vol % carbonates	
Carbosilicite	Coal + 20–60 vol % quartz	
Carbopolyminerite	Coal + 20–60 vol % mineral matter	

[+] The lower limit can be reduced by 5% depending on the content of sulphides.

Note:

Generally it is sufficient in a microlithotype analysis to record microlithotype groups. For special studies (for example genetic studies), it could occasionally be advisable to analyse for individual microlithotypes, in the case of monomaceral, a few bimaceral and trimaceral microlithotypes.

1971

SUPPLEMENT

International Committee for Coal Petrology
Nomenclature Sub-Committee

Supplement to the Term ‘Rank’: Relation between Reflectance and Volatile-Matter Yield

General Term

The relationship between mean random reflectance (R_{rand}) and volatile-matter yield (VM) is the basis for most applications of coal petrography. This very important relationship forms a link between physical and chemical methods. It is evident that since 1963 many measurements of vitrinite reflectance have been made[1, 3, 4, 5, 6] and these have been evaluated for this supplement. The curves of Figs. 1-3 should be placed behind those of Figs. 3 and 4 in the pages referring to ‘Rank’ in the 2nd edition (1963).

Unfortunately, it is impossible to present on one diagram the relationships between reflectance and volatile-matter yield determined in different countries. Accepting that the reflectances were always measured under approximately the same conditions (oil immersion, 25x objective, at 525 or 546 nm), the volatile matter was determined either on vitrinite concentrates (Fig. 1.), or on whole coals (Fig. 2.), at temperatures between 875 and 960°C. In order to compare these different determinations with one another, corrections have been made based on work by Duhameau[2]. The curves of Figs. 1. and 2., prepared by using these corrections, are corrected mean curves.

Fig. 3., based on the curves of Figs. 1. and 2., shows graphically the determined mean curves. These are by no means the ranges of variation for individual measurements. The relationship between reflectance and volatile-matter yield also holds for reflectances higher than 3%, but the relationship is usually for maximum reflectances, which have been measured on oriented polished coal blocks[7].

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7. Alpern, (B,) and Lemos de Sousa, (J.). Sur le pouvoir réflecteur de la vitrinite et de la fusinite des houilles. C. R. Acad. Sc. Paris, 271, Series D, (1971) p. 956–959.

8. The curve of the Bergbau-Forschung, 1970 (Fig. 2.) is based on unpublished work by M-Th. Mackowsky.

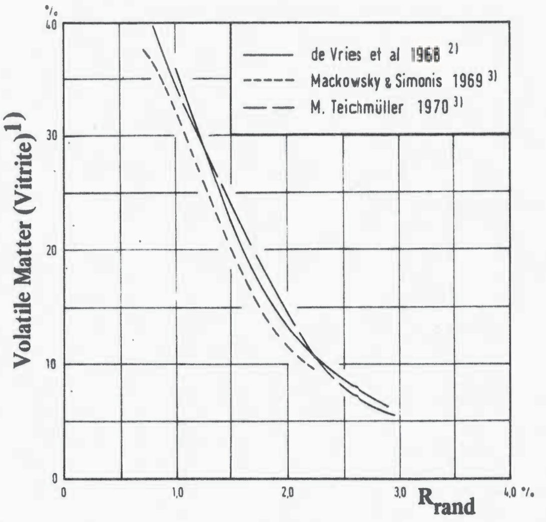


Fig. 1 Relation between %R_{rand} (vitrinite) and %VM (vitrite concentrates)

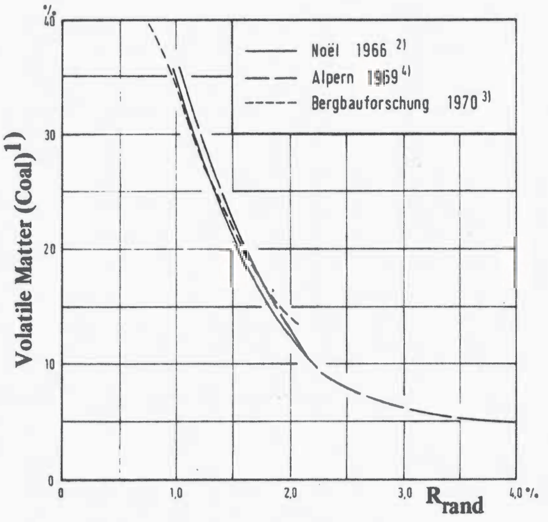


Fig. 2 Relation between %R_{rand} (vitrinite) and %VM of total coal

1) dry ash free
2) VM calculated to German standard (875°C) according to Duhameau 1968[2)]
3) VM determined at 875 or 900°C
4) VM determined at 960°C

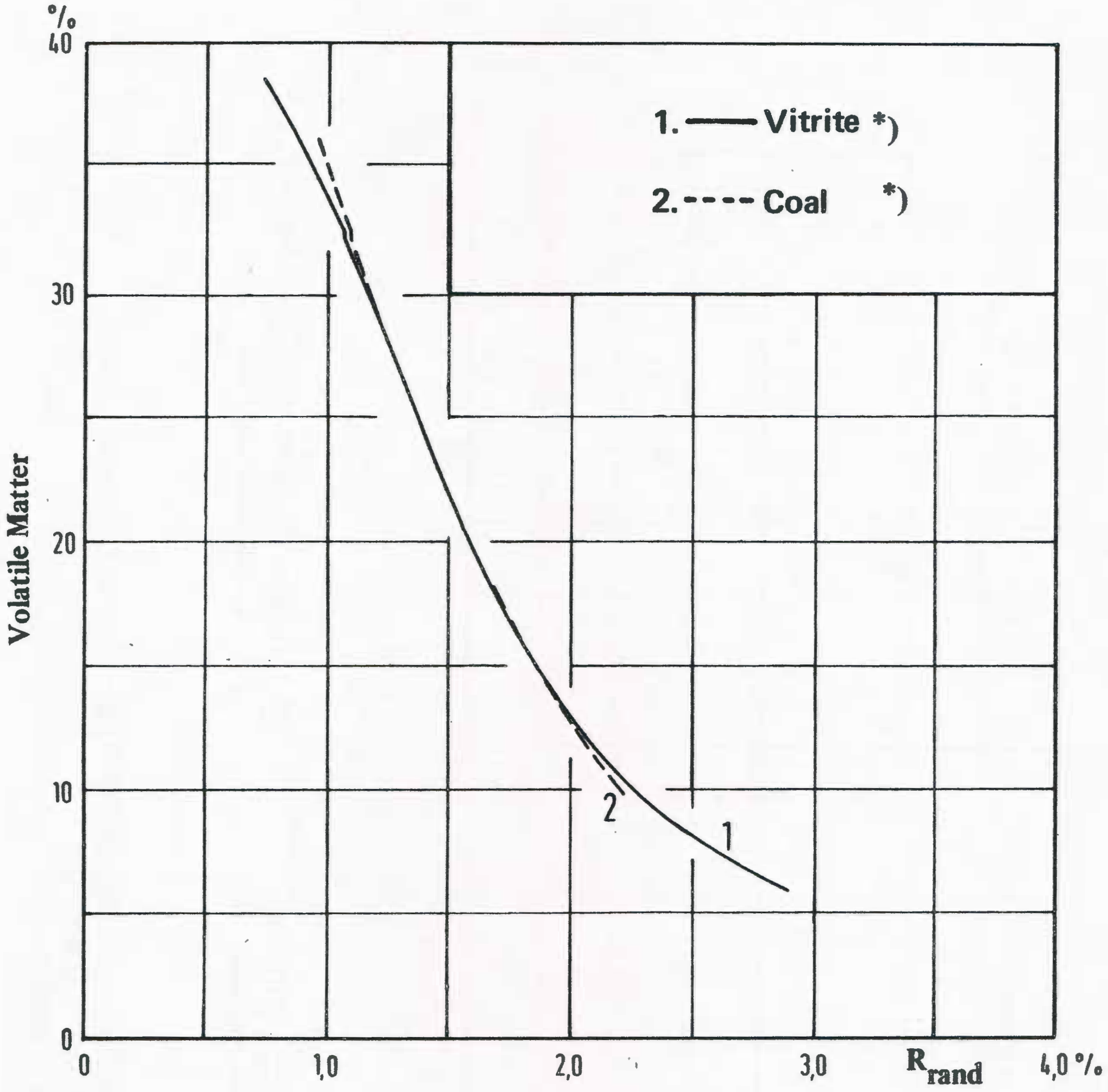


Fig. 3. Relation between %R_{rand} and %VM

*) Mean curves from Figs. 1 and 2.

1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee **RESINITE** (Stopes-Heerlen System)	Brown Coal R. L. T. L.

I – ORIGIN OF TERM

The term resinite was introduced in 1935 by M. C. Stopes[1]. It is used for a maceral of the liptinite group, which mainly arises from resin.

Etymology:	retine (Greek); resina (Lat.) – resin.
Synonyms:	xanthoresinit[110], retinit[29].

II – DESCRIPTION

a) *Morphography*

Since most resinite originates from cell excretions, the maceral is found in coal primarily as cell fillings either *in situ* or as isolated bodies. Its form on polished surfaces is approximately circular, oval or rod-shaped, with a size consistent with the dimensions of plant cells[77, 90, 96, 112, 114]. Resinite also occurs infilling fissures, cleats and pore spaces[55, 91, 112].

Resinite bodies frequently have a zoned structure and internally sometimes contain gas bubbles of varying size[90, 91, 94, 114]. Resin which, because of oxidation processes, has assumed the reflectance of huminite or inertinite, either in or before the peat stage[94, 96], is not recorded as resinite (*cf*. corpohuminite, sclerotinite).

b) *Physical Properties*

Colour: Transmitted light – whitish-yellow, citron-yellow to yellowish-red[114], with numerous resinite bodies displaying dark-coloured external zones.

---

[1] Stopes (M. C.). On the petrology of banded bituminous coal. Fuel, 14, (1935), p. 4–13.

Reflected light (bright field, oil immersion) – black to dark gray often with lighter gray external zones; often displaying yellow, orange-coloured or red internal reflections[91, 114].

Reflected light (dark field) – usually bright yellow or yellow[77, 90], corresponding to the natural colour of resinite.

Reflected light (fluorescence) – in the case of UV excitation, blue to blue green; with blue-light excitation, yellow, orange to light brown. Oxidation rims fluoresce less strongly and display colours at longer wavelengths[35, 37, 77, 88, 91].

Refractive Index: $n=1.53$ (up to 1.60?)[86, 112] – predominantly by Becke method.

Reflectance: R_{oil} (at 547nm) – 0.05–0.20–?%[86],
R_{air} (at 532nm) – 4.50–5.10–?%[55].

Reflectance falls with increasing wavelength[55]. Reflectance and refractive index rise with increasing rank.

Anisotropy: Many brown-coal resinites are isotropic, although some display anisotropy in transmitted light. The degree of anisotropy of different resinites in the same coal can vary. Some resinite bodies display strain anisotropy[114].

Density (pyknometer density): At 20°C – 1.00–1.20 g/cm^3, generally $<$ 1.20 g/cm^3[47, 55, 77, 87].

Hardness: Systematic investigations are still lacking. Average micro-hardness values (with orientation) of amber, succinite, ajkaite and walchowite, determined with a Reichert micro-hardness tester (loading time – 20 sec.), are given below.

	d=10 microns	d=20 microns	d=40 microns
H in kp/mm^2	14.0–28.0	18.0–32.0	20.0–38.0

The polishing hardness of resinites of different origins can vary considerably[113].

c) *Chemical Constitution and Properties*

Analytical Data:

Elementary Analysis[16, 47, 54, 55, 73, 87, 96]:

	%	Atom %
C	77.0–85.0	35.3–42.0
H (C+H+O=100)	8.2–11.0	52.0–61.4
O	2.7–13.0	1.7– 5.0
N(daf)	0– 0.4	
S(daf)	0– 0.4	

The hydrogen content amounts to >50 atom% up to the 'coalification jump'.

Proximate Analysis[16, 55, 73, 90]:

	%
Ash	0–0.8–?
Volatile-matter (daf)	76–100

Solubility: Resinite is only partly soluble in organic solvents[35, 37, 47, 91]. The solubility can be increased by heating[16]. Conversely, the solubility of polymerized brown-coal resinite is reduced or is non-existent.

Fusion Characteristics: Resinite shows a more or less broad fusion range, in which in many cases a chemical decomposition takes place[10]. It softens or fuses with few exceptions at temperatures lower than 400°C[16, 47, 87]. With increase of degree of polymerization, the fusion point shifts to higher temperatures[90, 94].

Microchemical Behaviour: The microchemical methods for the determination of resin used by botanists still show positive results for some brown-coal resinites[64].

III – BOTANICAL AFFINITIES AND GENESIS

Resinite originates in resin and copal, which occur as cell excretions in different parts of plants (bark, wood, leaves, etc), in parenchyma or in medullary-ray cells, as well as in the resin ducts of schizogenous or lysigenous origin in Gymnosperms and Angiosperms[87, 110]. Resin is sometimes concentrated in resin gall and in resinous tissues[96, 110].

IV – ALTERATION DURING COALIFICATION

Resinite alters little during the first stage of coalification[79]. It slowly adjusts its reflectance to that of vitrinite in the high-rank bituminous coals (approximately 87% carbon)[94, 96], so that in the highly coalified hard coals, it can no longer be distinguished from vitrinite.

V – OCCURRENCE

Resinite is found associated with original cells in humotelinite. It occurs isolated together with humodetrinite[114]. Melted, dissolved and rehardened or precipitated resin occurs in fissures and cleats[55, 91, 112]. Resinite is an important constituent of liptobioliths in which it is heavily concentrated.

VI – PRACTICAL IMPORTANCE

a) *Preparation*

During preparation resinite becomes concentrated in the lowest density fraction. Further investigations are lacking.

b) *Low-temperature Carbonization*

Resinite-rich coals give a very large tar yield and little low-temperature coke. An analysis (Gray-King at 600°C) of resinite from the Yallourn brown coal (Victoria)[16] gave:-

		%
Tar	–	85.5
Coke	–	2.0
Liquor	–	2.5
Gas + losses	–	10.0

Fig. 4.
As Fig. 3, with blue-light fluorescence; above left - weakly fluorescing "Palatal" embedding medium.

Fig. 5.
Isolated resinite grains of varying brightness and relief in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); above right – elliptical grain with internal reflections; reflected light, oil immersion, 200x.

Fig. 6.
As for Fig. 5, with blue-light fluorescence of varying intensity.

Fig. 7.
Isolated resinite grains (dark) with particularly strong relief beside sclerotinite (white) in a humodetrinitic groundmass of a Miocene soft brown coal from Bornhausen/Harz (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 8.
Isolated resinite grains of low relief and varying brightness in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); a grain showing zoned structure and an especially bright rim (lower right); reflected light, oil immersion, 250x.

Fig. 9.
A soft, compact and relatively bright resinite grain isolated in a humodetrinitic groundmass of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 10.
A soft, compact and very dark resinite grain, with dark red internal reflections, isolated in a humodetrinitic groundmass of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 11.
An isolated, very bright resinite grain with internal pores and pyrite crystals (white) in a Tertiary Indonesian lignite; reflected light, oil immersion, 660x.

c) *Bitumen Extraction*

Resinite gives a relatively small extract with organic solvents. By increasing the temperature and pressure, the yield can be increased[16]; the yield of extract is clearly higher at 250°C.

d) *Oxidizability*

Containing unsaturated compounds resinite absorbs oxygen[101], which leads initially to a slight, then increasingly stronger, polymerisation. The influence of oxidizing reagents on resinite has been little studied.

e) *Combustion Behaviour*

Resinite has a low ignition point and a relatively high calorific value (H_o–9300cal/g, daf[73]). It will even burn when lit with a match.

f) *Seam Correlation*

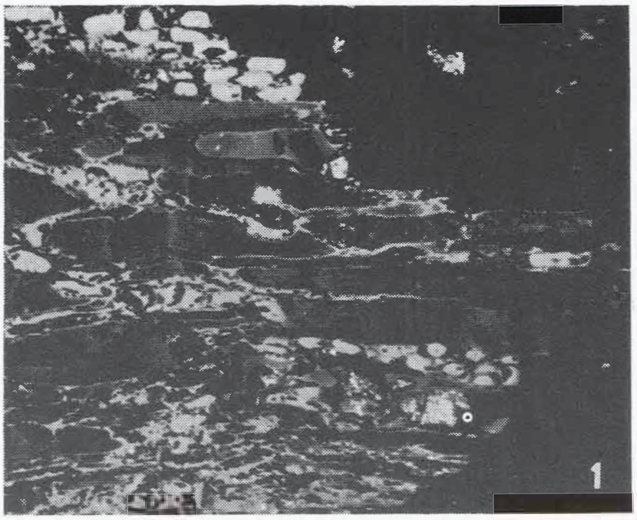
Resinite occasionally occurs strongly concentrated in certain layers of coal seams and may then be useful in seam correlation. In this connection fluorescence tests at the coal face have proved to be useful[88].

Fig. 1.
Autochthonous resinite in a cell tissue of Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 200x.

Fig. 2.
As Fig. 1, with blue-light fluorescence; right – weakly fluorescing "Palatal" embedding medium.

Fig. 3.
Autochthonous resinite (dark) beside phlobaphinite (bright) in a cell tissue of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 200x.

RESINITE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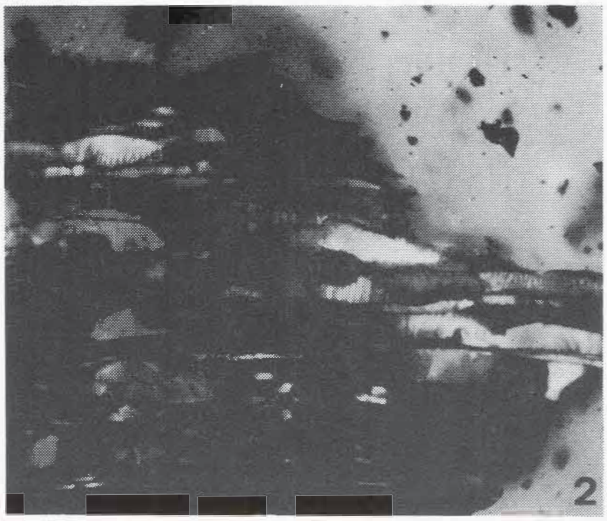
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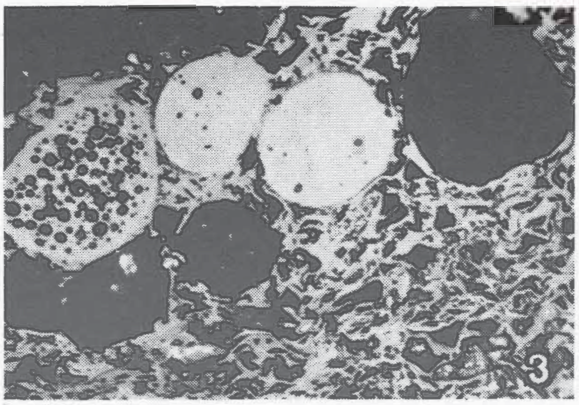
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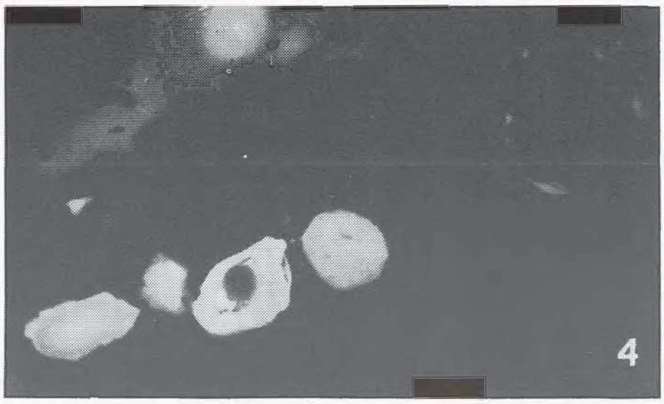
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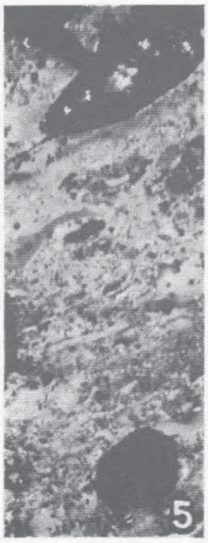
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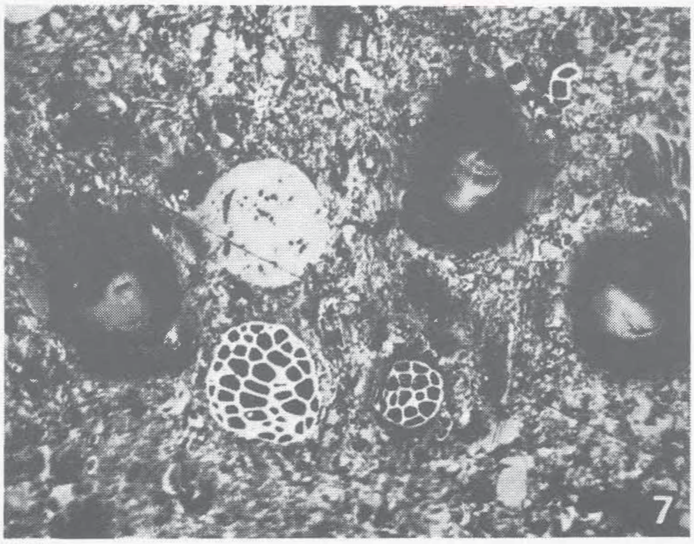
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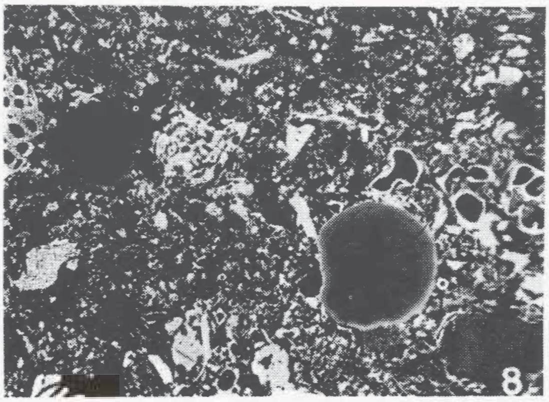
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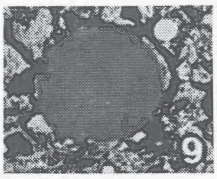
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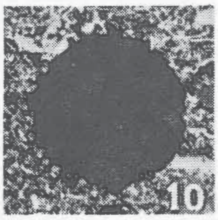
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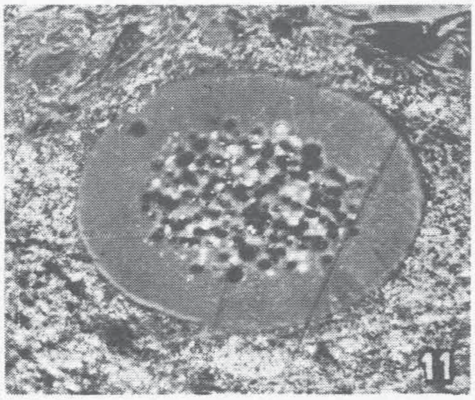
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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**SCLEROTINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The maceral term sclerotinite was introduced in 1952 by E. Stach[1] for all strongly reflecting fungal remains. In Carboniferous and Permian coals (mainly hard coals), hard, mainly oval, secretion bodies of high reflectance are described as sclerotinite, ('secretion sclerotinite') – see the sheet 'Inertinite' for hard coal.

Etymology:	skleros (Greek) – hard, rigid, brittle; the name derives from sclerotium (a persistent fungal body).
Synonyms and analogous terms (predominantly relating to Palaeozoic coals):	sclerotites[89], chitinite[11], sporinites[65], funginite[5], resino-sclerotinite[6], fungo-sclerotinite, corpuscule sclerotiformes[14], sclerotioid[22], fusinized resins, resin rodlets[43], fusiresinite[58].

[1] Stach (E.). Heutiger Stand der genetischen Deutung der Kohlengefügebestandteile. Compte Rendu du 3e Congrès de Stratigraphie et Géologie du Carbonifère, 2, (1952), p. 585–590.

II – DESCRIPTION

a) *Morphography*

Sclerotinite consists mainly of roundish, predominantly oval forms which often display chambers (fungal spores, sclerotia). It also occurs in tubular forms (hyphae), especially as irregularly structured textures of thin tubes (mycelia, plectenchyme). Numerous authors have described the various forms of Tertiary and Carboniferous sclerotinite, differentiating genera and species and arranging them in a morphographic system.

Depending on the number of cells, it is possible to distinguish on polished sections, single-celled forms (spores) and twin-or multi-celled forms (teleutospores and sclerotia). Sclerotia isolated from Tertiary brown coals display smooth to grape-like surfaces under the stereomicroscope.

The size of fungal spores varies from 10 to 20 microns, that of sclerotia and other persistent fungal bodies between approximately 10 and 80 microns (single-celled types) and between 80 and 300 (occasionally greater) microns (multi-celled types). The fungal hyphae (tubes) have varying lengths and breadths; they may be very long. Plectenchyme varies considerably in size. The thickness of cell walls of sclerotia and fungal spores can be less than 1 micron or more than 10 microns; the thickness of walls of the hyphae is approximately 0.2 to 0.4 microns.

Sclerotinite may occasionally be mistaken for vesicular phlobaphinite[84], recent fungal remains or fusinized tissues.

b) *Physical Properties*

Colour: Transmitted light – reddish brown to black, depending on the wall thickness, or in maceration preparations on the temperature, the duration of activity and the concentration of the reagent.

Reflected light (stereomicroscope) – sclerotia isolated from Tertiary soft brown coals are deep black (occasionally brilliant).

Reflected light (bright field, oil immersion) – light gray to white.

Fluorescence – appearance of sclerotinite has not been established so far.

Reflectance: in Tertiary brown coals sclerotinite generally has a higher reflectance than the huminite macerals. Furthermore, the reflectance depends on the initial constitution. (The strong but varying reflectance of the secretion sclerotinite of Palaeozoic coals is dependent on the degree of biochemical coalification).

In soft brown coals reflectance values of R_{rand} = 0.41–1.0% have been measured. Soos[86] obtained values of 0.43–0.67% (547nm) in Hungarian sub-bituminous coals.

Anisotropy: predominantly isotropic.

Density: in soft brown coals – 1.6–2.0g/cm^3.

Hardness: the polishing hardness and with it the relief are low to moderately high in soft brown coals. Both are dependent on type and on the condition of preservation of the sclerotinite.

c) *Chemical Constitution and Properties*

The chemical constitution of sclerotinite is unknown. Treatment with chromo-sulphuric acid dissolved some sclerotinites: in other cases certain layers of exospore are etched out in the sclerotinite.

III – BOTANICAL AFFINITIES AND GENESIS

So far as is known at present, fungal remains represented by the maceral sclerotinite are derived from primary dark-coloured organs (hyphae, spores, sclerotia and plectenchyme) of different fungal species. Particularly in Palaeozoic coals, oxidized secretion bodies (occasionally oxidized resins) are accepted as sclerotinite.

IV – ALTERATION DURING COALIFICATION

The optical properties of sclerotinite only vary a little during coalification; reflectance increases slightly.

V – OCCURRENCE

Sclerotinite generally only occurs in small amounts. It can be associated with all other macerals. Occasionally it is horizontally or locally concentrated. In soft brown coals sclerotinite occurs frequently together with humodetrinite and is often concentrated in light bands[113]. In the dark layers of swamp-forest type, sclerotinite, together with other chemically resistant macerals (fusinite, macrinite, resinite), may appear in the form of 'placer-like' concentrations[113].

It sometimes occurs in autochthonous sites along with telinite.

VI – PRACTICAL IMPORTANCE

Because of the generally very low quantities of sclerotinite in brown coals, no influence of the maceral on preparation behaviour, briquetting and coking properties has been observed.

With the help of sclerotinite, Cainozoic coals can easily be differentiated from Mesozoic and Palaeozoic coals.

Figs. 1. and 2.
Broad, oval, twin-celled teleutospores ('winter spores') in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 800x.

Fig. 3.
Twin-celled teleutospore, slightly crushed, with remains of delicate internal tissues in a hard brown coal from Kukusan (Borneo); reflected light, oil immersion, 1000x.

Figs. 4. to 7.
Elongate, twin-celled teleutospores; the thick central cell wall is cut through in the centre and form 7 is strongly deformed; reflected light, oil immersion, 800x.

Fig. 8.
Six-celled, elongate teleutospore in hard brown coal; reflected light, oil immersion, 1000x.

Fig. 9.
Seven-celled teleutospore in soft brown coal; reflected light, oil immersion, 500x.

Fig. 10.
Sclerotia (Sclerotites brandonianus) *from Lower Miocene hard brown coal; reflected light, oil immersion, 800x.*

Fig. 11.
Sclerotites *sp. from Columbian Tertiary hard brown coal; reflected light, oil immersion, 800x.*

Fig. 12.
Plexus of hyphae from a fungal fruit body in a Miocene brown coal from the Lower Rhine district (German Federal Republic); reflected light, oil immersion, 250x.

Fig. 13.
Sclerotites *sp. from an Indonesian Pliocene hard brown coal; reflected light, oil immersion, 800x.*

SCLEROTINITE


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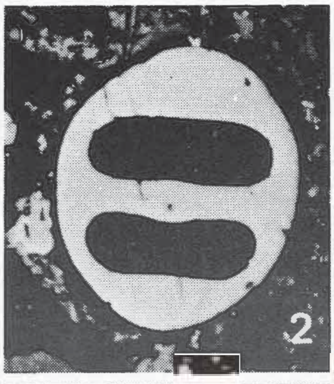
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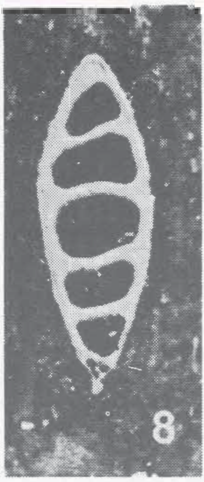
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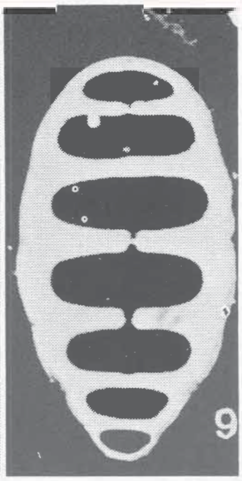
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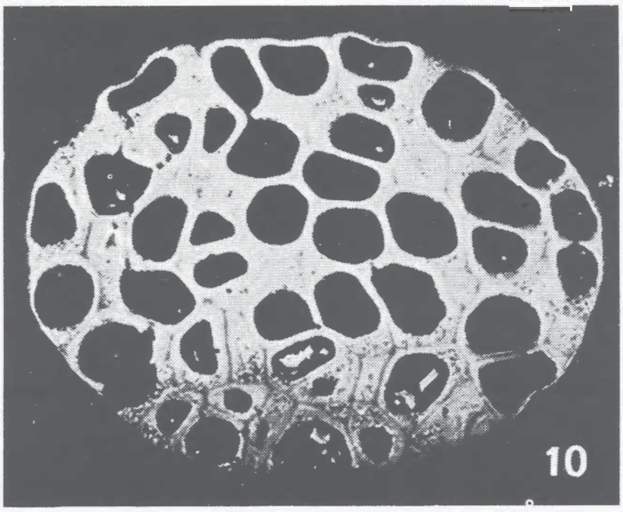
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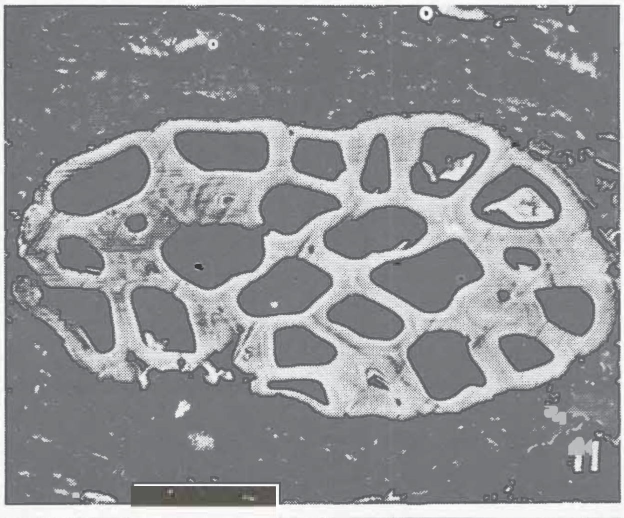
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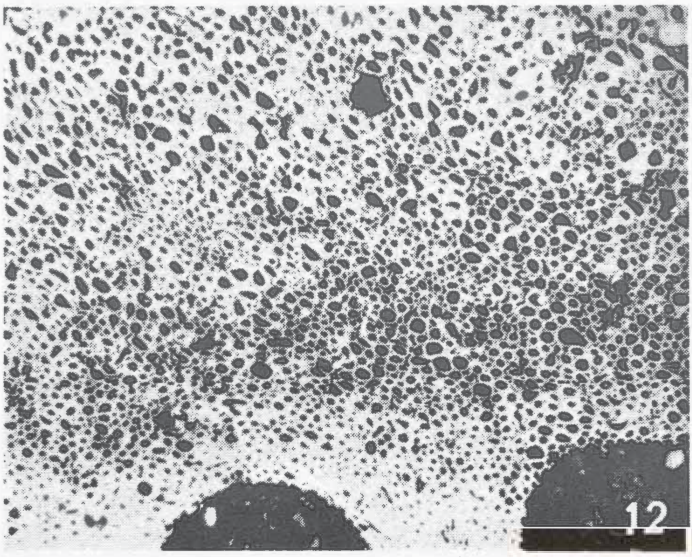
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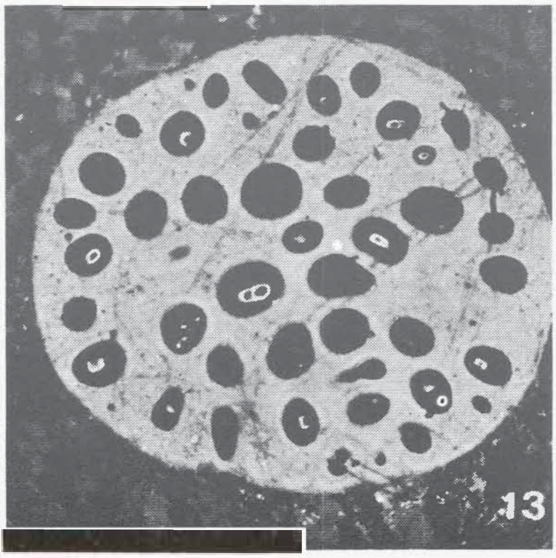
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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**SEMIFUSITE** (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term semifusite was introduced in 1935 by W. J. Jongmans[1] at the Heerlen Congress. In 1964 the Nomenclature Sub-Committee decided to use the term semifusite to denote a monomaceral microlithotype consisting of the maceral semifusinite.

II – DESCRIPTION

See semifusinite.

Semifusite must contain at least 95% semifusinite.

In quantitative petrographic analysis only lenses or layers greater than 50 microns in width are recorded as semifusite.

Semifusite can contain varying proportions of mineral impurities. Most abundant are carbonates and pyrites. Quartz and clay minerals are rare.

III – OCCURRENCE

See semifusinite.

IV – PRACTICAL IMPORTANCE

See semifusinite.

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1. Jongmans (W. J.)., Koopmans (R. G.) and Roos (G.). Nomenclature of coal petrography. Compte Rendu du 2^{e} Congrès de Stratigraphie et Géologie du Carbonifère, III, (1938), p. 1734.

1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
	SPORINITE (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term sporinite was introduced by C. A. Seyler[1] for a maceral of the exinite (liptinite) group, which arises from spores and pollen. The term was published in the International Glossary for Coal Petrography in 1957.

Etymology: spora (Greek) – seed.

II – DESCRIPTION

a) *Morphography*

Sporinite consists of the outer membranes (exines and perines) of spores. The term 'spore' covers spores (*sensu stricto*) and pollen grains.

Since spore coats are generally compressed and aligned with the bedding planes, sporinite displays a more or less lens-shape in sections perpendicular to the bedding. The original cavity is only indicated by a thin line. Occasionally it is possible to distinguish a layering within the cell wall. Convex or vermiform processes sculpture the exines.

The size of sporinite varies from approximately 10 to 2000 microns. In Palaeozoic coals miospores (isospores, microspores and small megaspores) and megaspores can

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[1] Seyler (C. A.). Nomenclature of coal petrography. In Jongmans (W. J.)., Koopmans (R. G.) and Roos (G.). Nomenclature of coal petrography. Compte Rendu du 2^{e} Congrès de Stratigraphie et Géologie du Carbonifère III, (1938), p. 1733–1735.

be distinguished on size. Sporinite of thick-walled megaspores is mostly granular; sporinite of microspores and pollen grains is generally compact and homogeneous. A specific nomenclature[11] has been developed for the description of Carboniferous spore forms on polished surfaces.

b) *Physical Properties*

Colour: Transmitted light – in low-rank hard coals, golden-yellow changing with increasing rank to orange then to red; in coals with less than 20% volatile-matter yield, the same colour as the associated vitrinite.

Reflected light (bright field, oil immersion) – in low-rank hard coals, rusty brown, dark gray, occasionally nearly black; with increasing rank becomes light gray, gradually matching the vitrinite.

Reflected light (bright field, methylene-iodide immersion) – dark brown to dark gray.

Reflected light (fluorescence) – the fluorescence colours of sporinite are dependent on the starting materials, i.e. on the plants from which the spores originate. The colours shift with increasing rank to colours whose maximum intensity always lies at higher wavelengths. Simultaneously, the fluorescence intensity decreases. In coals of approximately 25% volatile-matter yield, the fluorescence disappears.

Ultra-violet radiation – ochre-coloured to brown.

Blue-light radiation – yellow, orange to brown.

Refractive Index: In coals with approximately 36 to 42% volatile-matter yield, $n = 1.710$[14]; in coals with 34.5% volatile-matter yield $n = 1.645$ to 1.655[7]. Systematic investigations are lacking.

Reflectance: R_{rand} (525nm) = 0.10 to 1.50%.

Beyond the 'Coalification Jump' (approximately 29% volatile-matter yield of vitrinite), the reflectances of sporinite and vitrinite converge towards a value of R = 1.50 to 1.60%, after which they follow the same track.

Density: 1.18 – 1.28 g/cm^3(12)
1.20 – 1.35 g/cm^3(6) – for exinite consisting predominantly of sporinite.

Hardness: (Vickers)
$H_V = 12.6 - 24.3$ kg/mm^2(2)

The micro-hardness of sporinite is always lower than that of the vitrinite at the same level of rank[2].

In low-rank hard coals sporinite has a greater resistance to polishing than vitrinite and thus produces a positive relief. When the reflectance is equivalent to that of vitrinite in coals of approximately 20% volatile-matter yield, the relief disappears.

c) *Chemical Constitution and Chemical Properties*

The ash-free substance of sporinite, despite some variation in chemical composition, is termed sporine[8]. Sporine is formed by dehydration and dehydrogenation of recent sporopollenin, which in turn consists of elemental carbon, hydrogen and oxygen. In contrast to the vitrinite macerals, sporines are very rich in hydrogen.

Elementary Analysis: Sporinite

	'Flame Coal'+1 % d.a.f.	'Gas-flame Coal'++5 (36% volatile-matter yield in vitrite) % d.a.f.	'Gas Coal'+5 (32% volatile-matter yield in vitrite) % d.a.f.	'Fat Coal'+5 (23.5% volatile-matter yield in vitrite) % d.a.f.
C	79.2	85.5	87.4	89.3
H	10.6	7.3	6.8	4.9
O	8.5	5.8	4.7	3.6
N	1.5	0.5	0.6	1.5
S	0.6	0.9	0.5	0.6

\+ determined on exinite concentrates and calculated for pure exinite.
++ determined on exinite consisting predominantly of sporinite.

Calorific Value: In exinite, which consists predominantly of sporinite, the calorific value decreases with rising rank[4].

'Gas-flame coal'	–	9000k cal/kg
'Gas coal'	–	9000k cal/kg
'Fat coal'	–	*ca.* 8600k cal/kg

Solubility: Under atmospheric conditions the solubility of sporinite in organic solvents is very low. By raising the temperature and the pressure the solubility can be increased (depolymerisation).

Softening Range: 380–415°C (commencement of softening)[13].

III – BOTANICAL AFFINITIES AND GENESIS

Sporinite is formed from the exines and perines of plant spores. In Palaeozoic coals the outer membranes of spores were produced particularly by the Pteridophytes and the Gymnosperms, in Mesozoic coals especially by the Gymnosperms, and mainly since the end of the Cretaceous in increasing amounts by the Angiosperms. There are only scattered occurrences of Bryophyte spores. The botanical affinities influence the physical and chemical properties of sporinite[3].

IV – VARIATION WITH RANK

Sporinite alters little during the early stages of coalification (up to low-rank bituminous coal). In the biochemical phase of coalification, spores may be altered in isolated instances so that in low-rank coals they display wholly or in part the reflecting power of vitrinite or inertinite[10]. Later, the sporinite gradually becomes similar in its optical properties to vitrinite. The marked increase in brightness of sporinite on polished surfaces indicates the 'Coalification jump'. In 'fat coals' with approximately 22% volatile matter yield, sporinite can usually no longer be distinguished from vitrinite. Using crossed polars, it becomes visible again in strongly metamorphosed anthracites.

V – OCCURRENCE

Sporinite occurs in varying amounts in all hard coals. The sporinite content of a coal is dependent upon facies. It usually lies below 10% of the whole coal, seldom reaching more than 30%. Some Carboniferous coal seams contain spore-rich durites in which the sporinite content can amount to more than 50%, for example, in the Shallow Seam (Cannock Chase Coalfield, England) and the Silkstone and Beeston Seams (North Yorkshire Coalfield, England).

VI – PRACTICAL IMPORTANCE

Pure sporinite has only been investigated up to now in exceptional cases. Generally it has the same technological properties as the other macerals of the exinite group (see exinite).

a) *Low-temperature Carbonisation*

Sporinite is an important tar and gas producer as low-temperature carbonization of pure sporinite has shown[9].

b) *Stratigraphy*

Spores isolated from hard coals are particularly useful for stratigraphic studies and for seam correlation. Moreover, they are important facies indicators.

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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**SPORINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term sporinite was introduced by C. A. Seyler[+] for a maceral of the exinite (liptinite) group, which arises from spores and pollen. The term was published in the International Glossary for Coal Petrography in 1957.

Etymology: spora (Greek) – seed.

II – DESCRIPTION

a) *Morphography*

Sporinite consists of the outer membranes (exines and perines) of spores. The term 'spore' covers spores (*sensu stricto*) and pollen grains. Sporinite in soft brown coals frequently retains the original shape of the spores. In section it displays hollow, more or less round, triangular or spindle-shaped form. In hard brown coals, in sections perpendicular to the bedding, it has a more or less lens-shaped form, because the spore exines are compressed and aligned to the bedding plane. The original cavity is often only indicated by a thin line. Occasionally a layering of the spore wall can be observed. Protruding or worm-like appendages ornament the exines.

The size of sporinite varies between 10 and 2000 microns. Sporinite originating in pollen usually has a size from 10 to 200 microns. In Palaeozoic coals miospores (=isospores + microspores + small megaspores) and megaspores can be differentiated on size.

[+] Seyler (C. A.). Nomenclature of coal petrography. In Jongmans (W. J.), Koopmans (R. G.) and Roos (G.). Nomenclature of coal petrography. Compte Rendu du 2^{e} Congrès de Stratigraphie et Géologie due Carbonifère, III, (1938), p. 1733–1735.

Sporinite of thick-walled megaspores is mostly granular. Sporinite of microspores and pollen grains generally appears dense and homogeneous.

b) *Physical Properties*

Colour: Transmitted light – bright yellow (in parts almost white) to yellowish orange.

Reflected light (bright field, oil immersion) – dark bluish gray.

Reflected light (bright field, methylene-iodide immersion) – dark brown.

Reflected light (fluorescence) – the fluorescence colour of sporinite depends on the starting material, i.e. on the plants from which the spores originate. With increasing diagenesis the fluorescence changes to colours whose maximum intensity shifts to higher wavelengths.

Ultra-violet radiation – bluish white, yellowish white, yellow to orange.

Blue-light radiation – citron yellow to orange.

Refractive Index: systematic investigations lacking – $n = 1.615 - 1.618$[128].

Reflectance: systematic investigations lacking – $R_{rand} = 0.05 - 0.10\%$.

Hardness: the microhardness of brown-coal sporinite has still not been determined. Sporinite has a high resistance to polishing and correspondingly a positive relief against huminite.

c) *Chemical Constitution and Chemical Properties*

Despite a certain variation in chemical constitution, the ash-free substance of sporinite is termed sporine. Sporine forms through the dehydration and dehydrogenation of recent sporopollenin which consists only of the elements carbon, hydrogen and oxygen. In contrast to the huminite macerals, sporines are very hydrogen-rich. Brown-coal sporines contain much sulphur.

Elementary Analysis: Sporinite

(% daf)	Soft brown coal[129] Geiseltal (Eocene)	Hard brown coal[20] Moscow Basin (Lower Carboniferous)
Carbon	61.6	79.9
Hydrogen	7.4	6.0
Oxygen	17.8	6.3
Nitrogen	0.6	0.5
Sulphur	12.5	7.2

daf – dry ash free

Calorific Value: Sporinite from the hard brown coal of the Moscow Basin – 7641 kcal/kg.[20].

Solubility: Under atmospheric conditions solubility in organic solvents is very low. By increasing temperature and pressure the solubility can be raised (depolymerization).

III – BOTANICAL AFFINITIES AND GENESIS

Sporinite originates from exines and perines of plant spores. The outer skins of spores in Palaeozoic coals were produced especially by the Pteridophytes and Gymnosperms, in Mesozoic coals particularly by the Gymnosperms, and mainly since the end of the Cretaceous in increasing amounts by the Angiosperms. Only scattered spores of Bryophytes are found. The botanical origin influences the physical and chemical properties of sporinite[28].

IV – ALTERATION DURING COALIFICATION

In the first stages of coalification – up to the transition into hard coal – sporinite alters little. In the biochemical phase of coalification spores can exceptionally be altered in such a way that in low-rank coals they possess wholly or partly the reflectance of vitrinite or inertinite[96]. Later, sporinite becomes similar in its optical properties to vitrinite. Its increased brightness on polished surfaces is denoted the ‘coalification jump’. In fat coals with vitrites containing approximately 22% volatile matter, it is usually indistinguishable from vitrinite. In strongly metamorphosed anthracites it becomes visible again between crossed polars.

V – OCCURRENCE

Sporinite occurs in varying amounts in all brown coals. Sporinite content is dependent on coal facies. In Tertiary soft brown coals, it is especially high in the pale layers[113, 116], lying, however, almost always below 10% of the whole coal[66]. The highest sporinite contents in seam sections have been recorded in the Lower Carboniferous Moscow brown coal which contains 35%.

VI – PRACTICAL IMPORTANCE

a) *Briquetting*

Because of its small amounts in briquetting coals, sporinite has no importance in briquetting practice. Since sporinite is a facies indicator, and the briquetting potential depends in a large part upon the facies, sporinite (after maceration and palynological investigation), may serve as an indirect indication of the suitability of a brown coal for briquetting[21, 106].

b) *Low-temperature Carbonization*

Because of its richness in hydrogen, sporinite possesses a high gas content and an extraordinarily high tar yield.

c) *Bitumen Extraction*

Since no relationship exists between sporinite content and extract yield, sporinite is not an important source of bitumen extract[29, 116].

d) *Seam Correlation*

Isolated pollen and spores from brown coals are particularly suitable for stratigraphic investigations and for seam correlation. Moreover, they are important as facies indicators.

Fig. 1.
Fluorescing spore exines in Lower Carboniferous brown coal (USSR) with two layers of differing fluorescing colour and light intensity;
reflected light, dry objective, blue-light excitation, 1000x.

Fig. 2.
Fern spore in Pliocene bright brown coal from Baccinello, Tuscany (Italy);
transmitted light, oil immersion, 1000x.

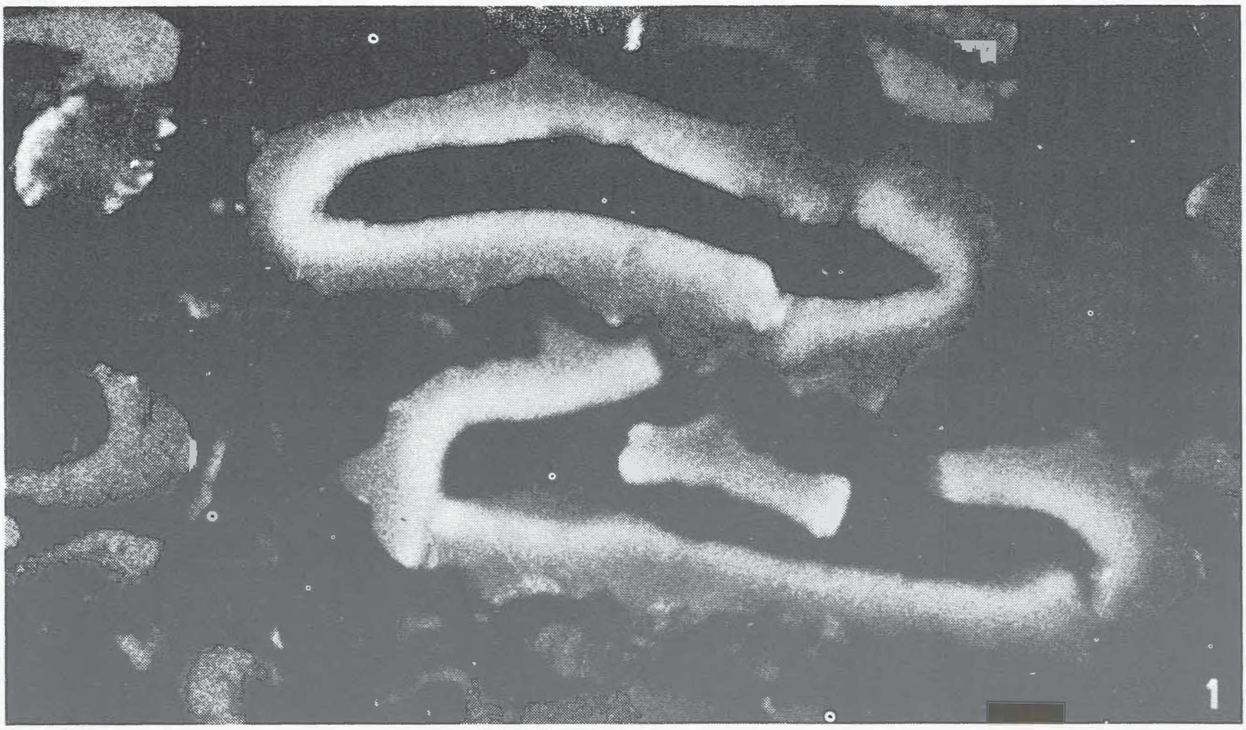
Fig. 3.
Sporinite (dark grey) in Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 500x.

Fig. 4.
As Fig. 3. *with blue-light excitation, fluorescing.*

Fig. 5.
Single spore in Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 1000x.

Fig. 6.
As Fig. 5, *with blue-light excitation, fluorescing.*

SPORINITE
(BROWN COALS)



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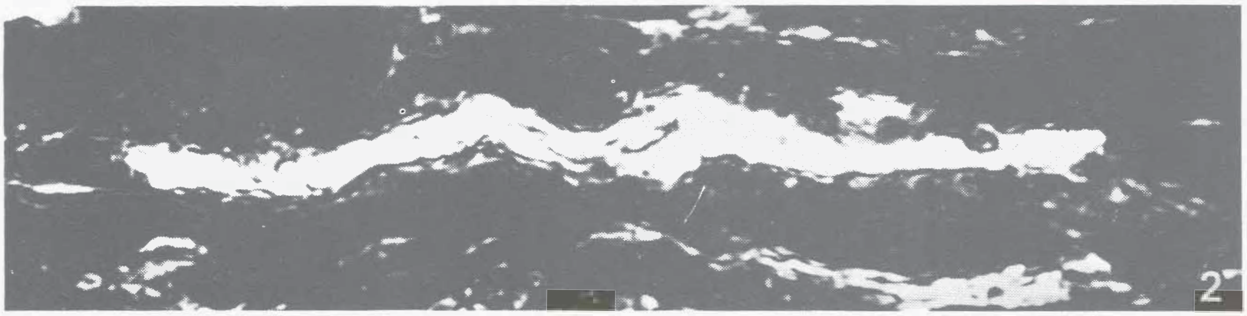

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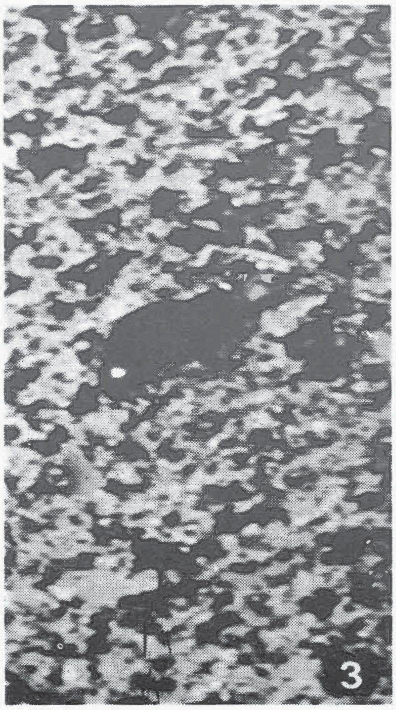

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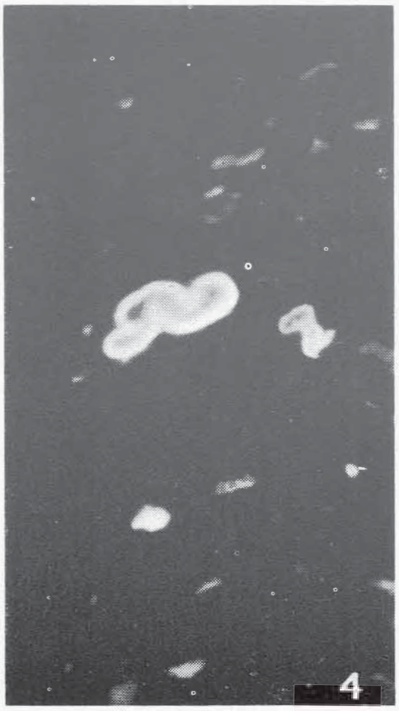

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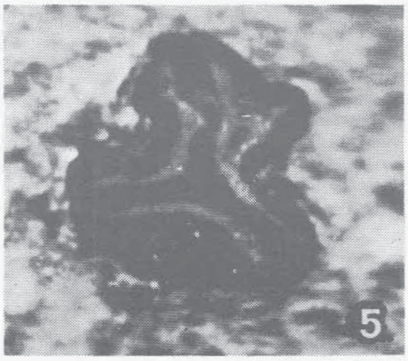

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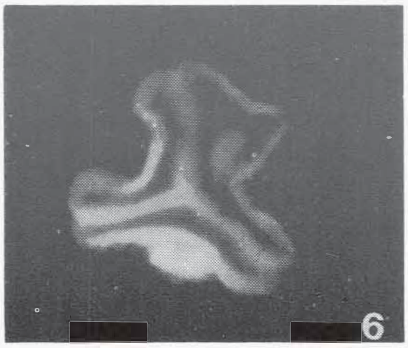

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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**TELINITE**[+] (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term telinite was used by W. J. Jongmans and R. G. Koopmans[1] in 1933 and was adopted in 1935 by the Heerlen Congress[2] to denote a vitrinite with cell structure. The Nomenclature Sub-Committee decided in 1957 to use the term telinite solely for the cell walls of recognizable plant tissues in vitrite. Only in this way is it possible to classify telinite as a maceral.

Etymology: tela (Lat.) – tissue,
Analogous terms: provitrite (Potonie),
xylovitrain (Duparque),
anthraxylon (Thiessen) – telinite in layers greater than 14 microns in width,
gelinito-telinite (IGM),
gelinito-posttelinite (IGM).

II – DESCRIPTION

a) *Morphography*

Telinite is a maceral of the vitrinite group, which shows more or less distinct, although often deformed, cell structure of the initial plant materials (wood, periderm, etc). The cell walls are always gelified and because of this they generally have no internal structure (lamellae, pores etc). The cell cavities are either round or oval (Type 1) or completely compressed to lines (Type 2). They are occasionally empty; mostly, however, they are filled with other substances (Type 1), which can be collinite (corpocollinite),

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[+] See vitrinite

resinite, micrinite, clay minerals, etc. The more strongly the reflectance of the cell fillings differs from that of the cell walls, the more distinct is the cell structure. Cell structure is more easily observed in transmitted light than by reflected light. After etching with oxidizing agents, Type 1 becomes more distinct, especially on polished surfaces and particularly if the cell cavities are filled with collinite. At the highest levels of coalification it is difficult to distinguish telinite from semifusinite.

If the plant tissues are so far decomposed that the cell structure can no longer be distinguished, the telinitic fragments ($<$ 10 microns) are classified as vitrodetrinite.

b) *Physical Properties*

Colour: depending on rank, the colour varies from approximately dark gray to white in reflected light and from a reddish brown to black in transmitted light.

Reflected light (fluorescence): no fluorescence, except in some low-rank coals.

Reflectance: the reflectances of telinite and collinite are very similar. Within the macerals of the vitrinite group, telinite usually has the highest reflectance. There are, however, rare exceptions in which the collinitic cell infillings are more strongly reflecting than the telinitic cell walls[3].

Density and Microhardness: these properties are probably similar to those of collinite.

c) *Chemical Constitution and Chemical Properties*

The chemical properties of telinite have still not been investigated. It is fairly certain that the starting materials consist of lignin and cellulose. The elementary composition (C,H,O,N,S) is probably the same as that of vitrinite.

III – VARIETIES

Depending upon the botanical origin of the tissues, different varieties of telinite can be distinguished; Lepidophytotelinite, Cordaitotelinite, Sigillariotelinite, etc. In some cases the type of plant tissue can be determined; parenchyma, sclerenchyma, wood, bark, etc. A further variety can be distinguished in the 'pseudotissues' (plectenchyma) that are derived from fungal hyphae and which have the same reflectance as the vitrinite of the same coal. It should, however, be noted that the fungal hyphae, with their higher reflectance than telinite, are not a variety of semifusinite or fusinite, but are grouped under sclerotinite.

Cryptotelinite, which becomes visible after etching, is not classed under telinite, but is a submaceral of collinite (telocollinite).

IV – OCCURRENCE

Telinite forms layers of different width in humic coals. It is abundant in vitrites. Occasionally it is also found in vitrinertite.

V – PRACTICAL IMPORTANCE

The properties of telinite are largely similar to those of collinite; nevertheless there are some differences, viz.,

1. the 'primary-ash' content of telinite is somewhat lower,
2. swelling power and plasticity are lower, and
3. volatile-matter yield is lower.

These differences cannot always be established and the reverse may even hold.

References.

1. Jongmans (W. J.) and Koopmans (R. G.). Kohlenpetrographische Nomenklatur. Jaarsverslag over 1933/Geol. Bur. Nederl. Mijngebiet Heerlen, (1934), p. 49–64.

2. Jongmans (W. J.), Koopmans (R. G.) and Roos (G.). Nomenclature of coal petrology. Compte Rendu du 2^{e} Congrès de Stratigraphie et Géologie du Carbonifère III, (1938), p. 1734–1735

3. Stach (E.). Die Bedeutung der Zellulose für die Kohlenentstehung. Fortschr. Geol. Rheinld. u. Westf. 17, (1970), p. 439–460.

4. Hacquebard (P. A.). The value of a quantitative separation of the maceral vitrinite into its constituents telinite and collinite for the petrography of coking coals. Proceedings of the International Committee for Coal Petrology, 3, (1960), p. 131–139.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**TEXTINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term textinite was proposed in 1963 by the Nomenclature Sub-Committee for all huminitic cell-wall material in brown coals. The word was introduced into the literature with the same sense in 1965[1]. Since 1970 the International Committee for Coal Petrology has limited the term textinite to a maceral of the huminite group (subgroup-humotelinite), which consists of ungelified cell-wall material.

Etymology:	textum (Lat.) – tissue, network, structure.
Synonyms and analogous terms:	ungelified textinite[84], plant tissue[113], xylinite + phyllinite[109], xylinite[37, 51, 112], gelinito-telinite[118, 120].

II – DESCRIPTION

a) *Morphography*

Textinite consists of plant-cell walls, both isolated occurrences of intact individual cells and also cell tissues, which are ungelified. Size and form of the cells may vary and the cell lumens are mainly open. In tissues the cell walls may be deformed or torn; as long

1. Sontag (E.), Tzschoppe (E.) and Christoph (H. J.). Beitrag zur mikropetrographischen Nomenklatur und Analyse der Weichbraunkohle. Z. angew. Geologie, 11, (1965), p.647–658.

as the cell form is still recognizable, the cell walls are termed textinite. If this is not so, they are considered to be attrinite. Individual cells are thus only referred to textinite, when the cell wall contains not more than one fissure whose breadth does not exceed the thickness of the cell walls. Separated cell-wall layers inside an intact cell are recorded with textinite. In contrast to ulminite (gelified cell walls), the primary structures of cell walls (layers, pits, intercellular spaces etc.) are still ± clearly visible in textinite. Shrinkage cracks are very rare. The reflectance is often weaker than for ulminite and can vary in the same coal, and even within a single cell wall.

It is possible to distinguish two varieties of textinite on the basis of reflectance.

Compared with the associated humodetrinite (as possible densinite)+:

variety A – more weakly reflecting, and

variety B – similar to or more strongly reflecting.

b) *Physical Properties*

Colour: Transmitted light – yellow to yellowish brown to light reddish brown.

Reflected light (bright field, oil immersion) – more or less dark gray, partly with a brownish tinge or with reddish brown or brownish red internal reflections.

Reflected light (fluorescence) – only a part of textinite, primarily variety A, fluoresces in different brown tones. The fluorescence intensity varies. It is usually weak and lower than for macerals of the liptinite group. Very dark and cellulose-bearing textinite fluoresces most strongly.

+ If this subjective comparison is replaced by reflectance measurement, it remains to be seen whether further varieties will be distinguished.

Reflectance: the reflectance of textinite varies strongly and is dependent on the botanical origin of the tissues. The values given below for average reflectance were measured on textinite varieties A and B in the same sections of the following coals[+].

Locality	$\%R_{rand}$ Textinite A	$\%R_{rand}$ Textinite B
Cologne	0.05–0.23	0.23–0.35
Niederlausitz	0.03–0.08?	0.24–0.37
Bafi (Attica)	0.18–0.25	0.25–0.35
Upper Rhine graben (Pliocene)	0.21–0.25	0.28–0.36

Anisotropy: isotropic in reflected light – in transmitted light textinite A often shows + strong anisotropy, which is due to cellulose inclusions[42].

Remission: remission measurements (at 659nm) on equivalent types of xylite gave the following values[102]:

'mummified wood' (Oberlausitz)	–	21.1%
cellulose-rich xylite (Niederlausitz)	–	15.8%

c) *Chemical Constitution and Chemical Properties*

Textinite consists of humic substances as well as the remains of lignin and cellulose of cell walls. while small amounts of resin, wax, cutin, suberin and tannins are also concerned in the constitution of textinite. Analytical data for isolated textinites are unknown. Suss[102] gives chemical data for different xylite types of the Lausitz soft brown coals, of which (a) – 'mummified wood' and (b) – cellulose-bearing xylite, correspond microscopically to textinite. According to Suss the ash contents are low

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[+] These reflectance values are not a measure of rank.

(0.2–0.5%), the tar content, due to high cellulose contents, high (22–26%, moisture free). The cellulose content varies between approximately 25–45%, while the content of humic substances (dry, ash-free) ranges between 4 and 20%.

III – BOTANICAL AFFINITIES AND GENESIS

Textinite is the cell walls of very chemically and microbiologically resistant plant tissues (predominantly coniferous wood), or plant organs (roots), which are very well protected from oxidation. The chemical resistance of cell walls can be conditioned by resinification, cutinization, suberinization or impregnation by tannins (e.g. in the case of *Sequoia* wood). With the high lignin content of sclerenchymatous tissues (e.g. of seed coats or bast fibres), the resistance of lignin and the thickness of the cell walls are obviously decisive for good preservation. A great part of textinite has formed from root tissues, because these are better protected from the influence of oxidation in the peat, and therefore from microbiological decomposition, than the tissues of aerial plant parts. With textinites which have originated from wood, the cell structure can often still be distinguished, whether gymnosperm or angiosperm wood. Only rarely can an accurate botanical origin be determined for a textinite; in every case comparative anatomical studies using precisely identified fossil and/or recent plant remains are necessary. In this way it is possible to recognize today, for example, tissues of *Marcoduria inopinata* and of Dracenaceae ('Palm wood') in polished sections.

IV – ALTERATION DURING COALIFICATION

During the course of coalification textinite alters first into ulminite in the dull brown-coal stage and ultimately into telinite in the bright brown coals and hard coals. It becomes telocollinite in the gas- and fat-coal stages. Its reflectance increases with rank, first slowly, then more rapidly. Fluorescence has already disappeared by the dull brown-coal stage. The visibility of the cell walls on polished surfaces gradually becomes less throughout the vitrinizing process whereas in transmitted light form and structure remain clearly visible up to a mature hard-coal stage. In the hard brown-coal stage, due to the increasing formation of humic colloids, a strain anisotropy appears oriented to the bedding.

V – OCCURRENCE

Textinite occurs in ± large quantities in almost all brown coals. It is particularly abundant in xylite-rich brown coals or in brown-coal layers of coniferous forest-swamp type. The cellulose-rich, weakly reflecting and relatively strongly fluorescing textinite (= variety A) is found primarily in the long-fibred xylites. In subaquatically deposited brown coals – particularly in the pale-coloured "Schwelkohle" (brown coals yielding much tar) layers – textinite is found only sporadically in the form of root tissues.

VI – PRACTICAL IMPORTANCE

Depending upon the frequency of its occurrence, textinite only has a practical importance in xylite-rich brown coals. Investigations on isolated textinites are still lacking. The behaviour of xylite-rich soft brown coals and isolated xylites can, however, be related to the specific properties of textinite below[31, 34, 82, 104].

a) *Preparation*

Because of its elasticity textinite does not easily crush. Many textinite-rich coals are also difficult to sieve, since during crushing textinite disintegrates into fibrous particles. Textinite concentrates therefore in the coarser particle fractions, especially in the elongated particle ('fibre') fraction.

b) *Briquetting*

Since textinite indents easily, its briquetting potential is better than that of the associated attrinite[40] and, of course, better than that of gelified huminite (ulminite, densinite, gelinite). Textinite-rich coals, therefore yield briquettes of the highest strength.

As with all huminitic brown-coal macerals, the briquetting capacity falls with increasing diagenesis. It is greatest in brown coals with 70–55 per cent moisture.

c) *Low-temperature Carbonization*

Because of its frequent high cellulose content and/or resin content, textinite generally produces a high tar yield (approximately 15–20% moisture-free) and much gas. The tar contains many acid oils. The coke yield is variable and rises with degree of gelification and rank.

d) *High-temperature Coking (Bilkenroth-Rammler Continuous Process)*

Textinite in brown coals with 70–55% water behaves very unsatisfactorily in high-temperature coking, because it shrinks strongly and thus raises the amount of fine coke particles.

e) *Extraction Behaviour*

Textinite is poor in extractable bitumen.

f) *Behaviour on Weathering*

Textinite is relatively stable to weathering and oxidation. With severe weathering black gels (gelinite) develop from the humic-rich, cellulose-poor varieties, which on drying-out, disintegrate into fine, angular debris.

g) *Stratigraphical Importance*

In certain circumstances textinite from tissues of known botanical origin can indicate the age of the brown coal. For example, in brown coals from Central Europe bast fibres of palms no longer appear from the Upper Miocene.

Fig. 1.
Textinite B in a root tissue of a Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 180x.

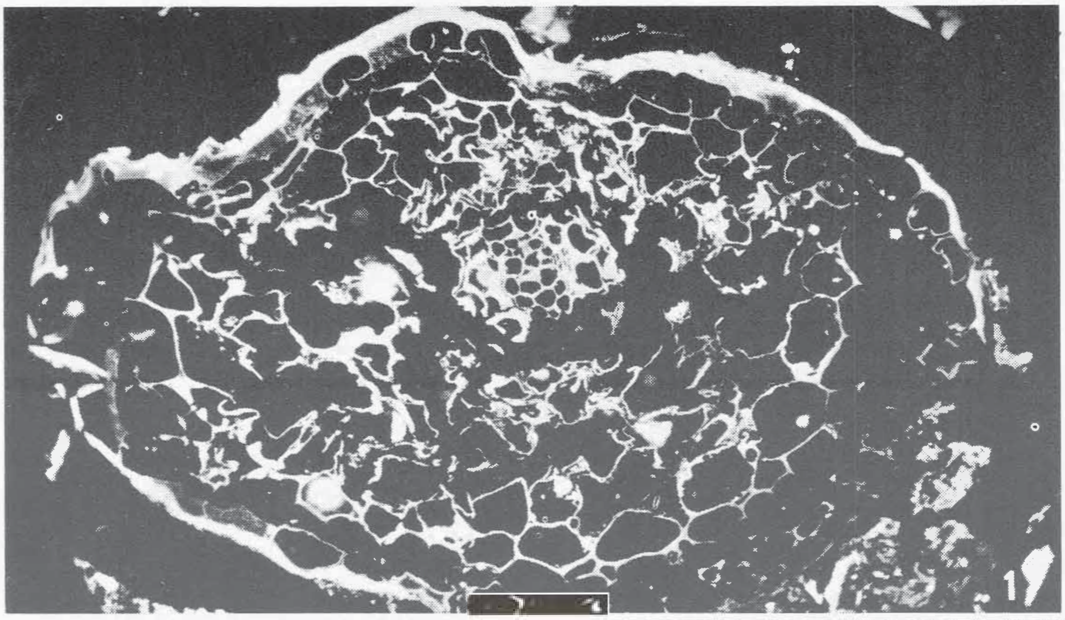
Fig. 2.
Textinite B in an oblique section of an Helobian leaf in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 250x.

Fig. 3.
Textinite B in a Pliocene soft brown coal from Mercure, Calabria (Italy);
reflected light, oil immersion, 250x.

Fig. 4.
Textinite A in a tangenitial section of coniferous wood (centre – with phlobaphinitic cell infillings), in a Pliocene soft brown coal from Dettingen on Main (German Federal Republic);
reflected light, oil immersion, 270x.

Fig. 5.
Textinite A, finely layered in tissue with Marcoduria, *in a Miocene soft brown coal from the Lower Rhine district (German Federal) Republic);*
reflected light, oil immersion, 610x.

TEXTINITE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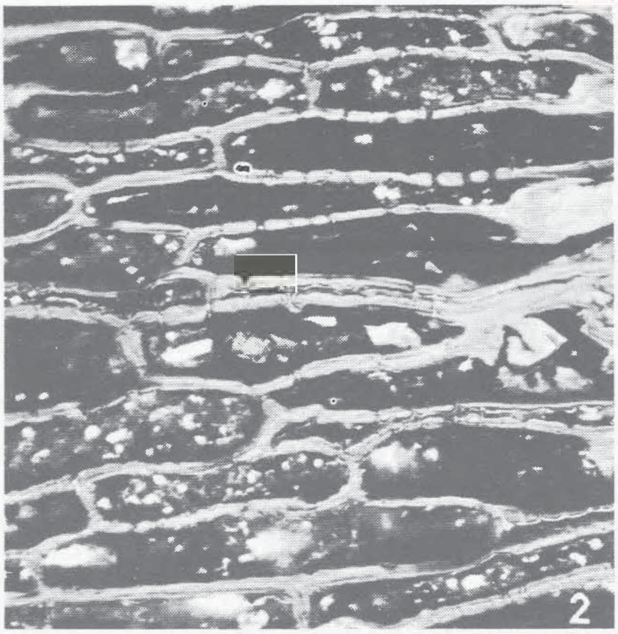
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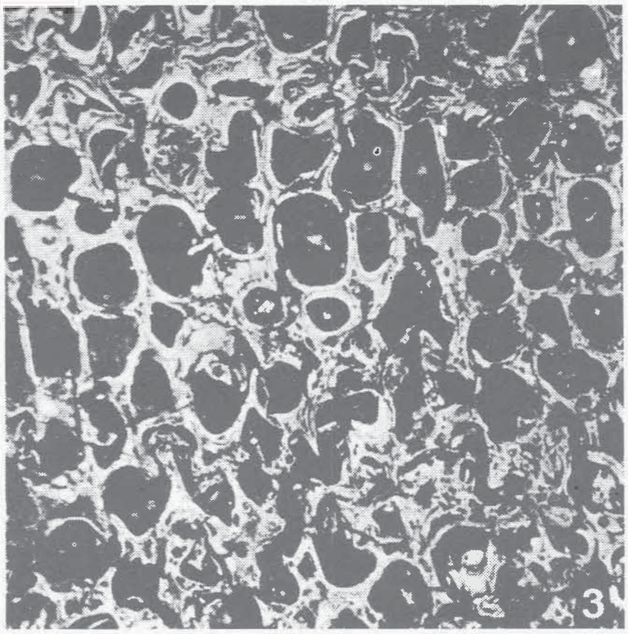
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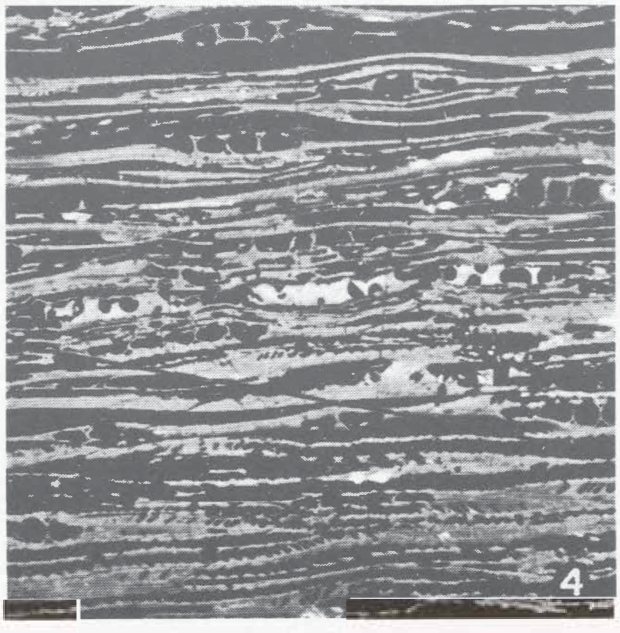
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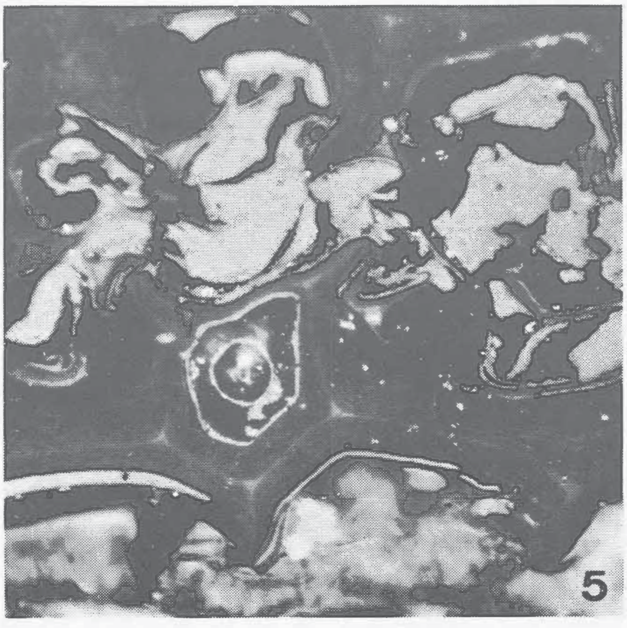
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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal
SUPPLEMENT	**TRIMACERITE** (Stopes-Heerlen System)	R. L.

I – ORIGIN OF TERM

The term trimacerite was proposed in 1956 by M. -Th. Mackowsky[1] to denote a general microlithotype group to which all three maceral groups contribute.

The term trimacerite was adopted by the Nomenclature Sub-Committee in 1964.

Analogous term: in part Zwischenstufen.

II – DESCRIPTION

See duroclarite, vitrinertoliptite, clarodurite.

Trimacerite consists of an association of all three maceral groups in which the proportion of each individual maceral group must exceed 5%.

Trimacerite can be subdivided into trimacerite$_V$ (duroclarite), trimacerite$_E$ (vitrinertoliptite) and trimacerite$_I$ (clarodurite), if one of the maceral groups is present in larger proportions than the other two groups.

In quantitative petrographic analysis, only layers or lenses greater than 50 microns in width are recorded separately.

III – OCCURRENCE

See duroclarite, vitrinertoliptite, clarodurite. Trimacerite is the microlithotype next in importance to vitrite in all humic coals.

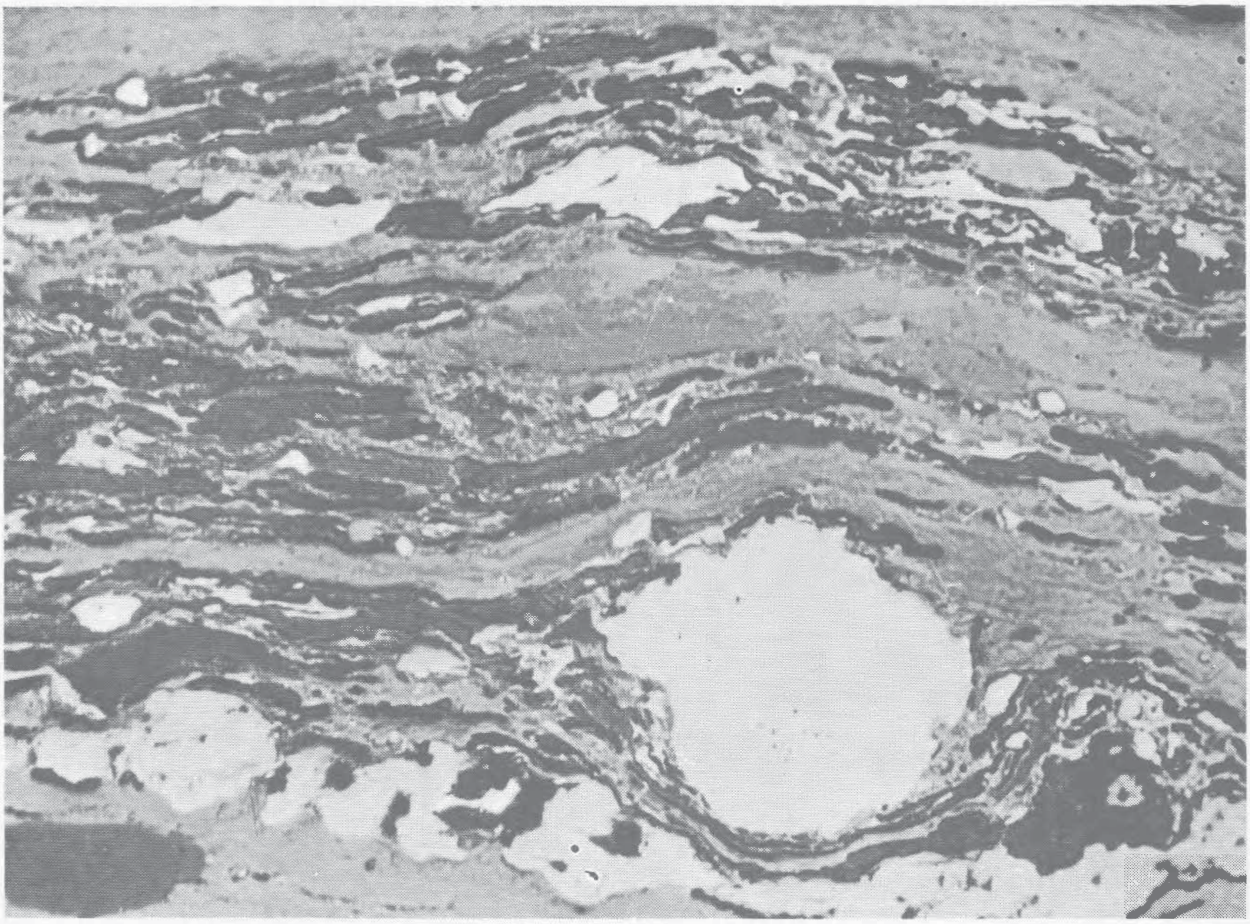
IV – PRACTICAL IMPORTANCE

See duroclarite, vitrinertoliptite, clarodurite.

Fig. 1.
Trimacerite in a low-rank bituminous coal – vitrinite, gray: exinite, dark gray: inertinite, white.
reflected light, oil immersion, 350x.

[1] Mackowsky, (M. -Th.). Letter to the Nomenclature Sub-Committee (1956).

TRIMACERITE



1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Brown Coal
SUPPLEMENT	**ULMINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term ulminite was first used by M. C. Stopes[1] for 'completely gelified plant material' in coals. Following a resolution by the International Committee for Coal Petrology, the term ulminite has been limited since 1970 to a maceral of the huminite group (subgroup – humotelinite), which consists of ± gelified plant tissues in which cell structure can still be seen in reflected light.

Etymology:	ulmus (Lat.) – elm (ulmin – decomposition product of diseased elms[2]).
Synonyms and analogous terms:	textinite, partly gelified + gelified textinite[83], xylovitrinite + vitrinite[51], gelinito-telinite + gelinito-posttelinite[118, 120], xylovitrain + structure - vitrain[128], xylo-dopplerinite[37].

II – DESCRIPTION

a) *Morphography*

Ulminite denotes the partly or totally gelified plant-cell walls in isolated occurrences of individual cells and cell tissues. Size and shape of the cells can vary. The cell lumens are

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1. Stopes, (M. C.) On the petrology of banded bituminous coal. Fuel, Lond., 14, (1935), p. 4–13.
2. Vauquelin, Annales Chimiques, 21, (1797), 99.

partly or wholly closed. In tissues the cell walls are often packed together, so that individual cells in sections perpendicular to the bedding appear elongated. The thickness of the cell walls is, due to swelling, generally larger than in the case of textinite of the same cell type. Shrinkage fissures ('gel fissures') are typical. Due to homogenizing, the original structures of the cell walls (layering, pits, intercellular spaces etc.), are indistinct or not preserved. The reflectance is often higher than that of corresponding varieties of textinite in the same coal. Two submacerals can be differentiated on the basis of degree of gelification:

1. *Texto-ulminite* – cell lumens partly closed, cell-wall structure weakly visible, cell structure in tissues still easily recognizable.

   Synonyms and analogous terms:
   textinite, partly gelified[83],
   plant tissues[113],
   xylotelinite[109],
   xylinite[37, 112],
   gelinito-telinite[118, 120],
   gelinito-posttelinite[118, 120],
   xylinite + xylovitrinite[51].

2. *Eu-ulminite* – cell lumens completely closed, structure of the cell walls no longer visible, cell structure in tissues only weakly visible, appearance like telinite of hard coals.

   Synonyms and analogous terms:
   textinite, completely gelified[113],
   vitrinite[51],
   gelinito-posttelinite[118, 200],
   structure - vitrain[128],
   xylo-dopplerinite[37].

Just as with textinite, the submacerals can be subdivided into two varieties on the basis of reflectance compared with densinite of the same coal:

variety A – more weakly reflecting, and

variety B – similar or more strongly reflecting.

b) *Physical Properties*

Colour: Transmitted light – yellow brown to reddish brown.

Reflected light (bright field, oil immersion) – dark to medium gray, rarely with a brownish cast.

Reflected light (fluorescence) – none or generally a very weak, dark brown fluorescence.

Reflectance: generally rather stronger than the corresponding textinite varieties of the same coal (see textinite). The values below were measured on ulminites (predominantly variety B):

Locality	$\%R_{rand}$ (range)	$\%R_{rand}$
Soft brown coals		
Lower Rhine (German Federal Republic)	0.33–0.55	0.48
Mae Moh (Thailand)	0.44–0.64	0.50
Dull brown coals		
Bohemia (Czechoslovakia)	0.31–0.43	0.37
Handlova-Novaky (Czechoslovakia)	0.25–0.59	0.42
Irrsee (Upper Bavaria)	0.35–0.49	0.42
Trimmelkam (Austria)	0.22–0.49	0.40
Karachi (Pakistan)	0.28–0.50	0.40
Bright brown coals (telinite, telocollinite)		
Upper Bavaria (German Federal Republic)	0.41–0.68	0.50
Handlova Ost (Czechoslovakia)	0.42–0.56	0.50
Zenica (Yugoslavia)	0.46–0.60	0.52

Anisotropy: isotropic in reflected light; in transmitted light, in the case of eu-ulminites, strain anisotropy oriented to the bedding.

Remission: measurements on the equivalent xylite types ('Dark structured xylite' with approximately 60% texto-ulminite) gave remission values of R=5–8% and in the case of gelified ('doppleritic') xylite (100% eu-ulminite) of R=5.4%[102].

c) *Chemical Constitution and Chemical Properties*

Ulminite consists of humic-acid progenitors, humic acids, humates and traces of lignin and cellulose[102].

Constitution of Equivalent Lithotypes (after Süss[102])

	Ash+ %	Tar+ %	Cellulose++ %	Humic Substances++ %
Structured xylite (ca. 60% texto-ulminite)	4–6	ca.12	8	55
'Doppleritic' xylite (100% eu-ulminite)	3	12	4	33

\+ moisture-free ++ dry ash-free

Elementary Analysis : Ulminite from a Clay Band in Brown Coal (Cologne)[113]

	%
Ash	12.7
Moisture (air dried coal)	13.7
dry ash free:	
Carbon	65.8
Nitrogen	2.2
Sulphur	2.6
Oxygen	24.8

Ulminite, especially eu-ulminite, swells strongly, since it consists of hydrogels. On drying it shrinks correspondingly strongly and forms ‘gel-fissures’.

III – BOTANICAL AFFINITIES AND GENESIS

Ulminite originates during peatification and brown-coal diagenesis from plant tissues through humification of lignin and cellulose and through associated peptization and precipitation of humic colloids as finely dispersed hydrogels. The botanical origin of specific plant genera or families is not usually determinable. Types of tissue (parenchyma, sclerenchyma, collenchyma, wood, bark, bast) can still occasionally be distinguished from one another. Parenchymatous tissues incline especially to ulminite formation, while lignin-rich tissues (wood, bark, sclerenchyma), especially if the cell walls are protected by resin, cutin, suberin or tannins, resist early gelification and with it, ulminite formation because of greater resistance (cf. textinite genesis). Subaquatic facies, especially clay- and calcium-rich environments favour ulminite formation. Secondary formation of ulminite occurs readily in water-saturated clay layers in and under seams.

IV – ALTERATION DURING COALIFICATION

Ulminite of soft brown coals alters with increasing rank, in part into telogelinite; in the hard-coal stage it partly forms telinite, partly telocollinite. Reflectance increases and the clarity of structure lessens.

V – OCCURRENCE

Ulminite, already present in peats, is more abundant in all soft brown coals. It occurs particularly in subaquatic deposits and as coaly inclusions in clays and marls. Xylite-rich coal layers at the base of seams, as well as calcium- and NaCl-rich soft brown coals, carry relatively large amounts of ulminite. Because of the gelification caused by geochemical coalification, dull brown coals, and especially pale brown coals, are very much richer in ulminite than are soft brown coals.

VI – PRACTICAL IMPORTANCE

The technological properties of ulminite are fundamentally determined by its state of gelification[31, 34, 82, 104]. With increasing gelification both shrinkage capacity and fissure formation (and with it disintegration into fine particles), increase; briquetting capacity, as well as tar and bitumen yields, decrease. These characteristics are more pronounced with increasing diagenesis of brown coal. Ulminite is not suitable for high-temperature coking.

a) *Preparation*

In comparison to textinite, ulminite crushes more easily and becomes concentrated in the fine particle fractions.

b) *Briquetting*

Ulminite, especially eu-ulminite, yields relatively poor briquettes. Larger amounts cause disintegration of the briquettes because of increased fissure formation.

c) *Low-temperature Carbonization*

In comparison to textinite, ulminite yields relatively little tar and gas. The coke yield is correspondingly higher than in the case of textinite.

d) *Extraction Behaviour*

Ulminite generally yields little extracted bitumen.

e) *Behaviour on Weathering*

On weathering ulminite-rich lithotypes form a fine, very dusty slack.

Fig. 1.
Texto-ulminite (B) in Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 610x.

Fig. 2.
Texto-ulminite with phlobaphinite (centre) in coniferous wood of a Miocene soft brown coal from Bornhausen/Harz (German Federal Republic);
reflected light, oil immersion, 250x.

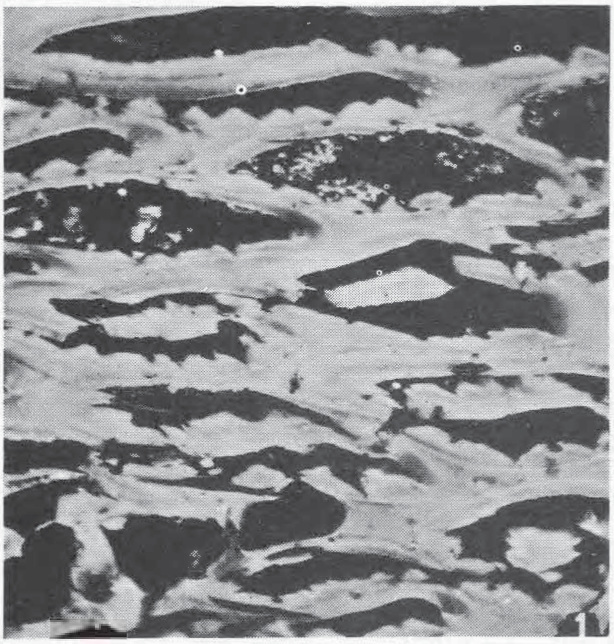
Fig. 3.
Texto-ulminite (A) with phlobaphinite (left centre) in a tangentically cut section of coniferous wood in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 250x.

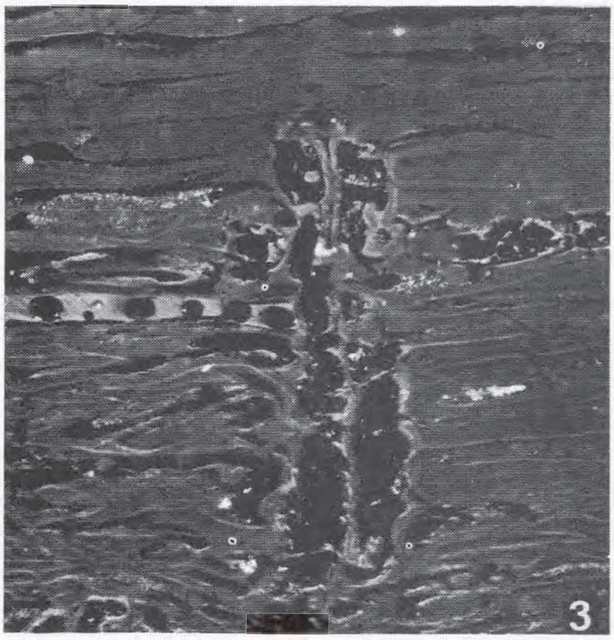
Fig. 4.
Eu-ulminite with phlobaphinite in a Miocene dull brown coal from Trimelkam (Austria);
reflected light, oil immersion, 250x.

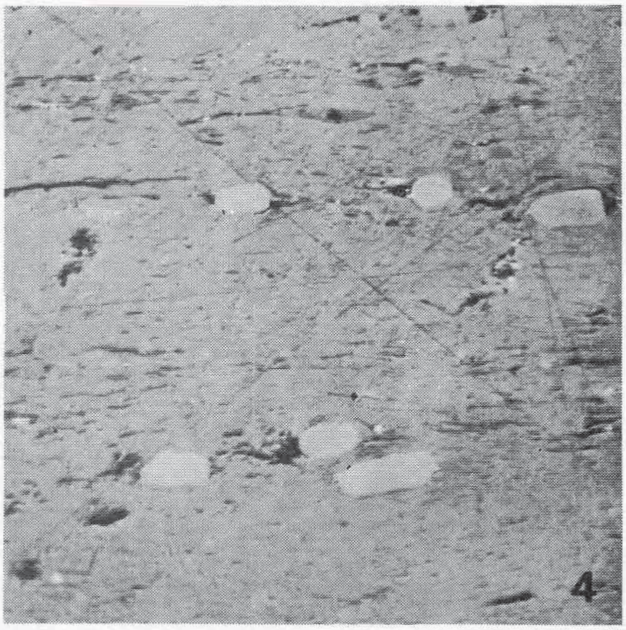
Fig. 5.
Eu-ulminite (B) in coniferous wood in a coaly inclusion from Oligocene salt from Buggingen/Baden (German Federal Republic);
reflected light, oil immersion, 270x.

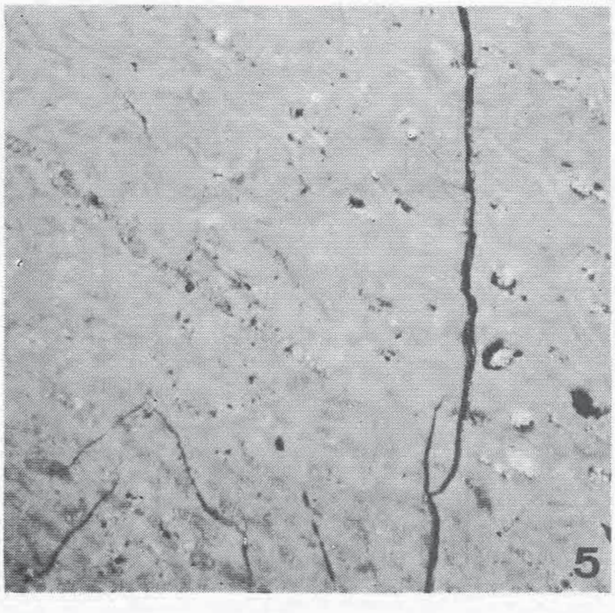
Fig. 6.
Texto-ulminite (B) (left and below) with transitions into eu-ulminite (above right and centre) in a Miocene soft brown coal from the Lower Rhine district (German Federal Republic);
reflected light, oil immersion, 270x.

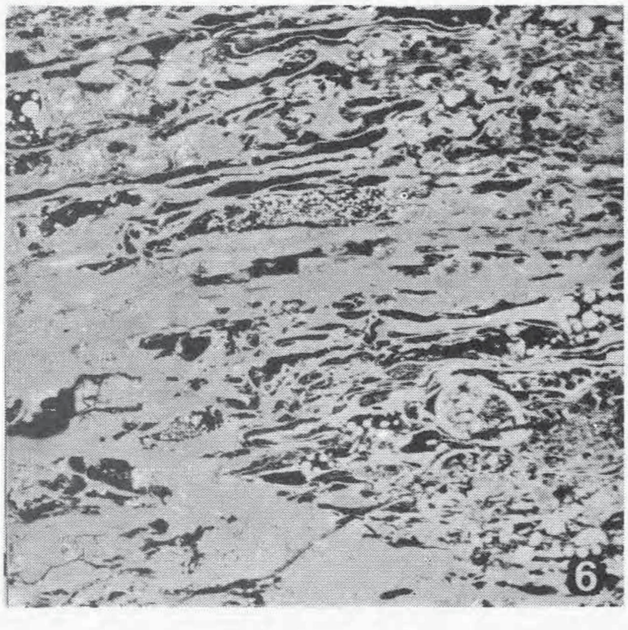
ULMINITE











1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal Brown Coal
SUPPLEMENT	**VITRINERTOLIPTITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term vitrinertoliptite was introduced in 1964 by the Nomenclature Sub-Committee to denote a trimaceral microlithotype in which liptinite (exinite) contributes to a greater extent than vitrinite and inertinite.

II – DESCRIPTION

Vitrinertoliptite contains:

$>$ 5% vitrinite,
$>$ 5% liptinite,
$>$ 5% inertinite,
more liptinite than vitrinite and inertinite.

Vitrinertoliptite can also be described as trimacerite$_E$ (see trimacerite).

In petrographic analysis only vitrinertoliptite layers with a width greater than 50 microns are recorded.

The density varies depending upon rank between 1.20. . .1.25 and 1.70 g/cm^3. For a coal of given rank the density rises with increasing inertinite content. It lies generally between that of duroclarite and clarodurite.

The strength varies between 30 and 80 kg/mm^2. It is similar to that of duroclarite and clarodurite.

Vitrinertoliptite may be contaminated by different minerals (clay minerals, pyrites, carbonates and rarely quartz).

III – OCCURRENCE

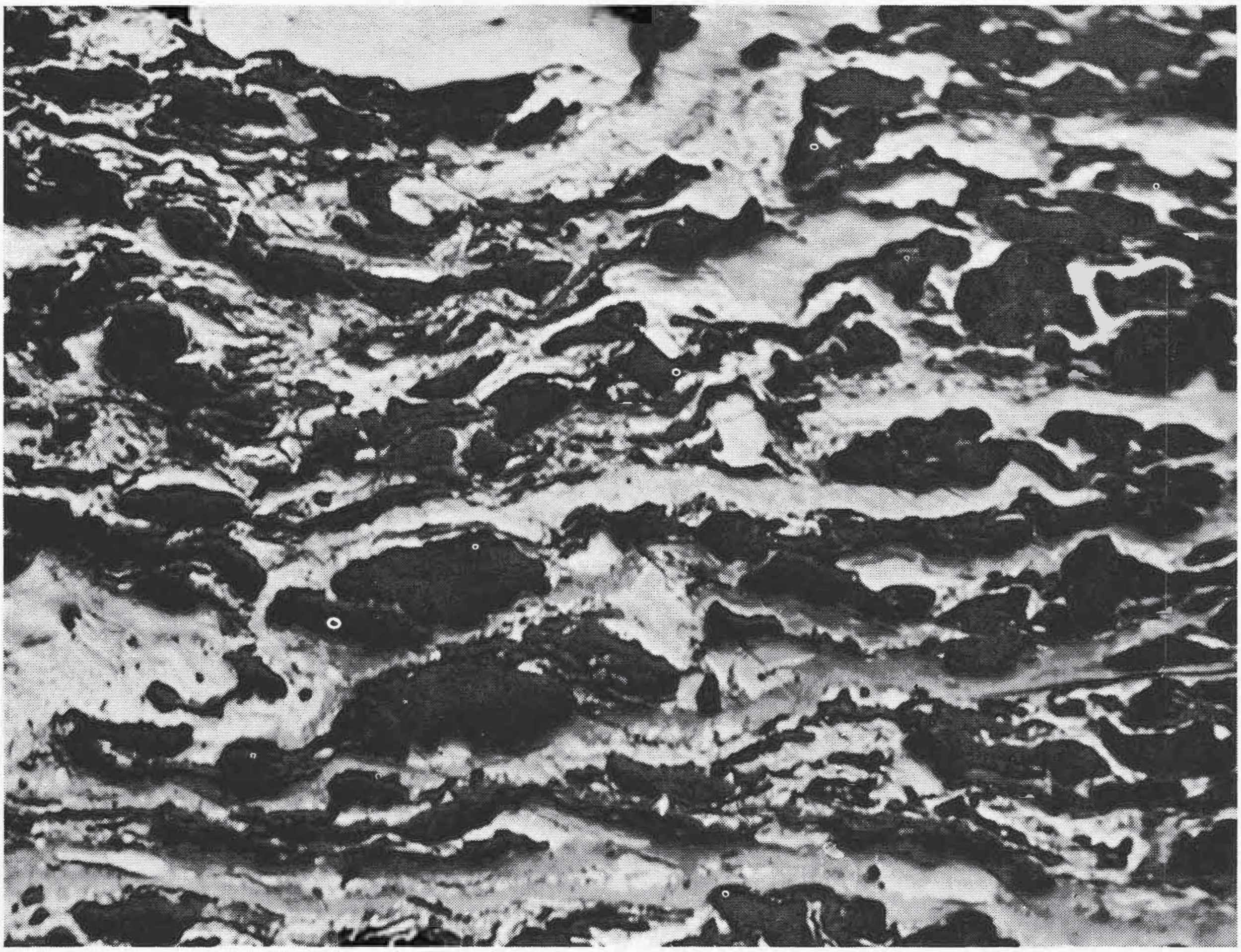
Vitrinertoliptite occurs in more or less broad layers and lenses in all humic coals. It is widely distributed, but is less common than duroclarite and clarodurite.

IV – PRACTICAL IMPORTANCE

The technological properties of vitrinertoliptite have still not been investigated in detail. They must resemble the properties of clarodurite. During carbonization the tar yield is higher than in the case of duroclarite and clarodurite because of the high liptinite content.

Fig. 1.
Vitrinertoliptite in a gas-flame coal from the Ruhr (exinite-dark gray; vitrinite-gray; inertinite-white);
reflected light, oil immersion, 350x.

VITRINERTOLIPTITE



1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee **VITRINITE** (Stopes-Heerlen System)	Hard Coal R. L.

I – ORIGIN OF TERM

The term vitrinite was used for the first time by M. C. Stopes[1] to denote a microscopically recognizable constituent of coal which corresponds to macroscopically bright coal (vitrain).

Etymology: vitrum (Lat.) – glass.
Analogous terms: anthraxylon – vitrinite in layers greater than 14 microns wide,
huminite – in brown coals corresponding to vitrinite of hard coals,
gelinite – (IGM).

II – DESCRIPTION

a) *Morphography*

In hard coals the term vitrinite embraces a maceral group containing the macerals and submacerals shown in Table 1. Those macerals, whose structure can only be observed by using supplementary methods, for example etching with potassium permanganate in sulphuric-acid solution, are known as cryptomacerals. The list of these cryptomacerals is not complete; only the most important are shown. The varieties of vitrinite describe the nature of the plant tissues from which they were formed. This list is also incomplete.

The reflectance of vitrinite varies less than that of the other maceral groups, but as with other macerals the reflectance increases continuously with rising rank, although at a different rate. Because of this the reflectance of vitrinite can be used to establish the degree of coalification of hard coals and, as far as possible, to determine the level of diagenesis of coal-bearing sediments.

Typical for the macerals of the vitrinite group are their gray-white colour and reflectance ($\overline{R}_{max}$), both of which, except for the peranthracites, lie between those of the exinite group and the inertinite group of the same coal. The macerals of the vitrinite group are distinguished on the basis that when using normal light microscopy, telinite exhibits plant-cell structure, which is absent from the two other vitrinite macerals. The more less homogeneous vitrodetrinite can be differentiated from collinite, which it resembles, by its high mechanically and/or biochemically controlled degree of comminution (particle size <10 microns).

Subdivision of the vitrinite group depends on criteria other than those used in the subdivision of the huminite group in brown coals (see Table: Correlation of Vitrinite – Huminite).

At present, the classification adopted is a compromise, which aims, as far as possible, at maintaining the existing extensive bibliography intact and avoiding any fundamental alterations to earlier nomenclature.

b) *Physical Properties*

Density: The density varies depending upon the rank between 1.2 and 1.8 g/cm^3 (pyknometer density). True density (for example, helium density), passes through a minimum at approximately 89% carbon. It is possible that this minimum is due to an inaccessibility of the pores and is related to a minimum of porosity.

Structure (X-ray): In X-ray investigations[2] the diffraction maximum corresponding to the 002 interference band of graphite is already present in low-rank vitrinites. During the course of coalification this maximum becomes much larger and sharper. It can therefore be used as a measure of the degree of coalification of high-rank coals.

c) *Chemical Properties and Constitution*

Carbon: The carbon content lies between approximately 77 and 96%; in the anthracites it can reach 98% (Newport, U.S.A.: Leoben, Austria.)

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Hydrogen: The hydrogen content lies between approximately 6 and 1% and can fall to 0.2% in the peranthracites. The hydrogen content of highly coalified vitrinites is a very good indicator of their degree of coalification.

Oxygen: The oxygen content lies between approximately 16 and 1%.

Volatile-Matter Yield: The volatile-matter yield lies in general between 45 to below 2% in the peranthracites. Exceptionally, in post-Palaezoic hard coals, values up to 55% for volatile-matter yield are encountered.

In recent years many scientific papers on the chemical properties of vitrinite have been published. These deal predominantly with the content of aromatic and aliphatic carbon and the different types of functional groups. A specific structural formula for vitrinite has been developed by Given[3]. Further details may be found in fundamental texts on coal chemistry, particularly in the book by van Krevelen[4] and the recent publications by Oehlert and Hemmer[5] (relating to physical methods of investigation), and by Kolling and Hausigk[6] (on chemical methods of study).

III – PRACTICAL IMPORTANCE

See vitrite.

Note: For technological purposes some American petrographers[7] subdivide vitrinite into two populations on the basis of reflectance. These two populations are referred to as 'Normal Vitrinite' and 'Pseudovitrinite'. Pseudovitrinite is slightly higher in reflectance than normal vitrinite and sometimes exhibits cellular structure or 'comma slits' which aid in identification. During coking pseudovitrinite reacts as a semi-inert constituent.

TABLE 1

Maceral Group	Maceral	Submaceral[+]	Maceral Variety[+]	Cryptomaceral[+]
Vitrinite	Telinite	Telinite 1 Telinite 2	Lepidophytotelinite Cordaitotelinite Sigillariotelinite Fungotelinite	
	Collinite	Telocollinite Corpocollinite Gelocollinite Desmocollinite		Cryptotelinite Cryptocorpocollinite Cryptogelocollinite Cryptovitrodetrinite
	Vitrodetrinite			

[+] incomplete, can be expanded as required.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Hard Coal Brown Coal
SUPPLEMENT	**VITRODETRINITE** (Stopes-Heerlen System)	R. L. T. L.

I – ORIGIN OF TERM

The term vitrodetrinite was adopted in 1970 by the Nomenclature Sub-Committee to describe a maceral of the vitrinite group.

Etymology: vitrum (Lat.) – glass,
detritus (Lat.) – worn away.
Analogous terms: in part gelinito-posttelinite,
gelinito-precollinite (IGM).
in part humodetrinite.

II – DESCRIPTION

Vitrodetrinite consists of small fragments with more or less angular and variable outlines. These fragments originate by extensive comminution of gelified tissues (telinite and telocollinite), rarely from hardened gels (gelocollinite). The same relationship generally exists between vitrodetrinite and telinite as exists between inertodetrinite and semifusinite or fusinite. The essential characteristic of this maceral is its degree of comminution. The size of the particles is generally less than 10 microns. The definition of vitrodetrinite is rather different to that of humodetrinite of brown coals, which consists of a more or less porous mixture of detrital particles with a humic gel. In hard coals vitrodetrinite is comprised only of detrital particles with no gel. In desmocollinite, which forms by intensive compression and gelification of humodetrinite, the former gel and detrital particles can no longer be distinguished, and thus special methods of investigation are used. After etching with oxidizing solvents, the gel becomes black, so that only the detrital particles are visible, which are then described as cryptovitrodetrinite (see collinite).

The detrital fragments can only be recognized without etching if the surrounding material differs in reflectance from that of the vitrinite (exinite, inertinite, clay minerals). The colour, the reflectance and all other optical properties correspond with those of collinite and telinite. Because of the small size of the particles, it is not possible to isolate them to investigate their physical and chemical properties. Nevertheless, because of the great similarity of the reflectances, it is assumed that the other properties are also comparable, particularly with those of telinite (cell walls) and telocollinite.

III – OCCURRENCE

Vitrodetrinite particles occur in sediments associated with coals, in carbargilites, in durites and some trimacerites. Cryptovitrodetrinite is higher in collinite (desmocollinite). Without etching vitrodetrinite cannot be recognized, or only with very great difficulty.

Just as in the case of inertodetrinite, vitrodetrinite shows evidence of disintegration and transport. Since vitrodetrinite is a gelified material, however, these effects are observed more rarely than with fusinized materials.

IV – PRACTICAL IMPORTANCE

See vitrite.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Peat Brown Coal Hard Coal
SUPPLEMENT	**The Structural Principles of the Genetic Classification of Humic Coals and their Microcomponents**[+] (System of the Institute of Geology of the Academy of Sciences of the USSR, Moscow (IGM)	T. L.

Complex and detailed lithological-facies studies and an analysis of the formation of coal-bearing deposits have revealed new data about the structure of coal substance which determine its properties. The facies of peat accumulation have also been established, as well as the relationship between genetic coal types and particular environments of deposition. These data allowed P. P. Timofeev and L. I. Bogolyubova[+] to postulate the fundamental principles of a new genetic classification of humic coals. They were also able to propose a nomenclature of coal types and microcomponents based on new concepts about the genesis and composition of their materials. The genetic classification of humic coals was developed at the Institute of Geology of the Academy of Sciences of the USSR, Moscow and the classification is designated as a system of this Institute (abbreviated IGM).

This text briefly discusses the concepts and the nomenclature of the main taxonomic units in the classification of microcomponents and in the genetic classification of humic coals. The paper also defines the process of primary transformation of the original plant material and it also establishes the characteristics of the various structures present in the coal substance which arise mainly from lignin-cellulose tissues.

[+] References will be found at the end of the section on ‘General Terms’ (IGM).

The work is based on experimental data from the majority of coal basins and coal deposits in the Soviet Union. The deposits vary in shape and include recent peats; they are associated with different structural zones of the crust and are characterized by various combinations of palaeogeographical conditions of sedimentation.

In the microcomponent classification (Table 1), classes and subclasses are characterized by differences in the substance of the microcomponents; type and species are distinguished by the degree of structural preservation and by the amount of degradation of the plant material during its transformation; and variety is defined on the basis of the parts and tissues of plants present in the original material. The nomenclature of the microcomponents belonging to a particular taxonomic unit is determined by the features on which the unit is distinguished. Thus, for example, the nomenclature of the microcomponent class reflects its basic substance – gelinites, gelifusinites, etc.; and the nomenclature of type and species reflects the basic substance and its structure – gelinite-telinite, gelinite-collinite, gelifusinite-posttelinite, etc. Using this microcomponent classification it is possible to characterize the coals petrographically with any degree of detail; this depends on the purpose of the research and the nature of the material under investigation.

The genetic classification of humic coals (Table 2), just as in the microcomponent classification, contains both a generalized and a more detailed subdivision of coals into taxonomic units, which show a corresponding degree of complexity. For example, in certain cases to characterize the coal, it is sufficient to know the class or genetic subgroup to which it belongs. In other instances, when an exhaustive evaluation of the material composition of the coal is required, the genetic type of coal under investigation must be determined. In this Handbook only a generalized Table is given listing the genetic types of coals which occur within each genetic subgroup.

In the genetic classification of humic coals, classes (horizontal rows) are distinguished by the type of substance forming the coal-forming microcomponents and they are independent of any structure in the substance; for example, gelinitic coals, gelifusinitic coals, etc. Each class includes coals which originate in a peat bog characterized by a regime which involves a particular degree of flooding and water movement, which act against a background of either an unstable or stable environment.

The genetic groups of coal in the classification (vertical columns) are established on the basis of the structure of the substance of the coal-forming microcomponents and are independent of type. A total of five genetic groups of coal are distinguished; telinitic, posttelinitic, precollinitic, collinitic and leiptinitic. Proceeding down each column each subsequent genetic group is characterized by a progressively greater degree of decomposition and degradation (both biochemical and mechanical) of the lignin-cellulose tissues occurring during the processes of gelification, gelifusainization and fusainization, until there is an almost complete disappearance of the tissues and an accumulation of stable entities.

The formation of genetic coal groups results from a differing degree of stability within the area of peat accumulation caused by varying amounts of flooding and water movement. The macrofacies of various types of peat deposit arise from this complex of conditions. Thus, telinitic coals are derived from a macrofacies of peat swamps in an unstable environment, while collinitic coals develop in a macrofacies of peat deposits in a stable environment etc.

Genetic groups of coal are divided into genetic subgroups on the basis of the type of coal-forming microcomponents. For example, the telinitic and posttelinitic groups each comprise six genetic subgroups of coal; the precollinitic, collinitic and leiptinitic groups contain five subgroups, etc. A certain facies of peat accumulation corresponds to each genetic subgroup of coal. Thus, the gelinite-telinitic subgroup corresponds to a facies of unstable, extremely wet and stagnant peat swamp; the semigelinite-fusinite-posttelinitic subgroup develops in a facies of fairly unstable and wet, forest-peat bog which is subject to short periods of drying out; a subgroup of the quasi-gelifusinite-collinitic coals arises in a facies of a stable but wet peat swamp with water movement.

The genetic subgroups of coal are further subdivided into genetic types on the basis of the ratio of coal-forming and secondary microcomponents, allowing for the nature of the original material, where this can be determined. For example, the gelinite-telinitic subgroup consists of seven genetic types of coal (gelifusinite-gelinite-telinitic, gelinite-telinite-parenchymatous, etc.); the gelinite-collinitic subgroup consists of fifteen genetic types of coal (gelinite-collinitic with gelifusinite, gelinite-collinitic with cortical tissues, gelifusinite-gelinite-collinitic, etc.).

Summarising the data on all the available genetic types of coal, it is possible to conclude that each type is determined by the following combination of characters:-

a) the precise type of substance and its structure,

b) a definite proportion of the dominant and subsidiary coal-forming microcomponents, and

c) certain kinds of plant material.

These characters develop from a particular facies of peat accumulation and sedimentary environment, i.e. they reflect coal genesis and thus the coal types distinguished on this basis must be genetic.

The regularity with which the genetic types of coal occur both vertically and laterally, as well as their relationship to the conditions of sedimentation, make it possible to establish the paragenesis of the genetic types of coal. It also allows definition of the boundaries between types with respect to each other and, as a consequence, the compilation of a genetic classification of coals, which encompasses in one comprehensive system the wide variety of fossil coals found in nature. The value of such a genetic classification is not only theoretical. On this topic Y. A. Zhemchuzhnikov (1960) wrote: 'A scientific classification is the only firm basis for any industrial classification of caustobioliths, because it is based on the nature of the geological situation from which commercial coal is being won, i.e. on the nature of a coal seam and not on accidental features' (op. cit. p.100).

In the genetic classification of humic coals, the nomenclature of classes, groups, subgroups and genetic types of coals relates to the features that formed the basis for their differentiation. Thus, the nomenclature of coal classes is based on the type of substance forming the coal microcomponents.

Example:

class – gelinitic coal, gelifusinitic coal, etc.

The nomenclature of the groups is determined by the structure of the substance of the coal-forming microcomponents.

Example:

group – telinitic coals, collinitic coals, etc.

The nomenclature of subgroups refers to the substance of the coal-forming microcomponents and its structure.

Example:

subgroup – gelinite-telinitic subgroup, gelifusinite-precollinitic subgroup, etc.

The nomenclature of genetic coals types is associated with a complex of features embodied in points a), b), and c), above. Thus, when coal-forming microcomponents amount to more than 95 per cent of the coal type, its nomenclature is governed by the type names of these microcomponents. For example, a coal in which the coal-forming microcomponents are of the gelinite-telinitic type, is called 'gelinite-telinitic coal'. The presence of secondary microcomponents in amounts less than 25 per cent is indicated in the coal-type nomenclature by the addition of a term denoting these microcomponents accompanied by the preposition 'with'; for example, 'gelinite-precollinite coal with gelifusinite', or 'gelinite-precollinitic coal with spores and pollen'. If the coal contains between 25 and 50 per cent of a secondary microcomponent, its name is then combined with the name of the coal-forming microcomponent and it occupies the first place in the sequence of nomenclatural terms; for example, 'gelinite-gelifusinite-telinitic coal', etc. If necessary, the term applied may also include a reference to the plant material from which the coal was formed; for example, 'gelinite-telinite-parenchymatous coal', etc.

The suggested glossary only lists the characteristics of the main genetic types of coal involved in the composition of coal seams.

The classification of microcomponents and the genetic classification of humic coals apply to the entire range of coal rank from peat, the first stage of coalification, up to anthracite. It has long been known that secondary features, which reflect changes in the organic matter after burial of the peat swamp, do not affect the genetic pattern of the microcomponents and types of coal formed during the peat stage. These secondary features impose their imprint on the original different types of coal, modifying their physico-chemical and technological properties, which are additionally reflected in the petrographic characters of the coal.

At the present state of advancement of coal science, when the efficient use of coal acquires an ever-increasing importance, it is particularly vital to establish the properties and characteristics of coal which are determined by genesis and the process of coalification. By so doing, first, the idea of separate classifications for brown coals (soft and hard), hard coals and anthracites will be eliminated, since these fuels represent one continuous series in the formation of coal matter, and second, the creation of a single industrial classification of coals will be brought closer.

1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee	Peat Brown Coal Hard Coal
SUPPLEMENT	**GENERAL TERMS** (System of the Institute of Geology of the Academy of Sciences of the USSR, Moscow (IGM))	T. L.

Transformation of vegetable matter into a peat stage is related to its biochemical decomposition and degradation during the processes of gelification, gelifusainization and fusainization.

1. *Gelification* (Zhemchuzhnikov, Y. A. 1934).

Gelification is a biochemical process by which vegetable matter is transformed by intensive softening and dispersion due to swelling under water saturation. It proceeds through the action of bacteria and fungi in a reducing medium with an insignificant access of oxygen (essentially an anaerobic environment). The process is characteristic of very wet stagnant swamps with a high level of ground water.

2. *Gelifusainization* (Timofeev, P. P. and Bogolyubova, L. I. 1964_1, 1965_2)

Gelifusainization refers to a two-stage biochemical transformation process of vegetable matter during the period of accumulation produced by a combination of gelification and subsequent fusainization. Gelifusainization is characteristic of flood-peat bogs with moving ground water and of stagnant flooded peat bogs with a reasonably periodic drainage (anaerobic/aerobic environment).

3. *Fusainization* (Luber, A. A. 1934)

This term refers to a biochemical process of transformation of vegetable matter during the period of peat accumulation under 'dry' swamp conditions with a low level of ground water. The process proceeds in an oxidizing environment under aerobic conditions. Various plant remains can be subjected to fusainization. In coals, however, fusainized tissues arise mainly from the coarse tissues of trees.

In the processes of gelification, gelifusainization and fusainization, three main types of coal substance can occur, gelified, gelifusainized and fusainized, each with appropriate structure.

4. *Type of Coal Substance*

Type of coal substance, in any rank of coal, has definite petrographic characters and possesses certain physical, chemical and technological properties. In some cases the type of substance is the result of a definite process of decomposition of the original plant material (gelified matter, etc.); in other cases it is determined by the character of the original plant material (leiptinitic matter, etc.). The types of coal substance may be of a definite structure depending on the duration of the process of biochemical decomposition and degradation of the plant material.

5. *Structure of Coal Substance*

The structure of the coal substance refers to the size, shape, degree of preservation of plant remains and their quantitative proportions. The following structures are distinguished:-

a) Telinitic structure (Timofeev, P. P. 1961), which is characterized by the cellular structure of the plant tissue preserved in a distinct or concealed form, as well as by the obvious outlines of the tissue fragments. The telinitic structure of the coal substance generally is determined by the predominance of a combination of microcomponents with telinitic structure.

b) Posttelinitic structure (Timofeev, P. P. 1961) of the microcomponent substance represents the stage following telinitic structure in the degree of biochemical decomposition and degradation of the lignin-cellulose tissues during their transformation. The microcomponent substance with a posttelinitic structure exhibits an indistinct cellular structure or is structureless. The posttelinitic structure of the coal substance generally is determined by the predominance of microcomponents with posttelinitic structure.

c) Precollinitic structure (Timofeev, P. P. 1961) of the microcomponents of coal substance expresses the degree of biochemical decomposition and degradation of the lignin-cellulose tissues which follow the posttelinitic structure. The precollinitic structure of the microcomponents is expressed in an indistinct lumpy or spongy structure of the substance.

d) Collinitic structure (Timofeev, P. P. 1961) of the microcomponents or the entire coal substance emphasizes its amorphous appearance caused by a severe decomposition of the plant material during gelification or gelifusainization or by coagulation of humic acids.

e) Leiptinitic structure (Timofeev, P. P. and Bogolyubova, L. I. 1964_1, 1965_1) of the coal substance is determined by a combination of certain microcomponents of the leiptinite class cemented together by varying amounts of any type of substance with collinitic structure.

6. *Coal Microcomponents and their Classification*

Using the basis of the system outlined in Table 1, all the microcomponents found in coals are subdivided into classes, subclasses, species and varieties.

a) Classes and subclasses of microcomponents represent a complex of microcomponents consisting of a definite type of substance which is independent of its structure.

b) A type of microcomponent either corresponds to one, or unites several, species of microcomponents which are characterized by a definite type of substance and a similar structure (gelinite-telinite, gelinite-posttelinite, etc.).

c) Species of microcomponents are the individual coal components which originate in lignin-cellulose tissues (xylain, structural vitrain, etc.).

d) Variety of microcomponents refers to coal components originating from a definite source and characterized by a certain type and structure (coarsely-xyloid xylain, lumpy parenchymatous xylovitrain, etc.).

7. *Genetic Subdivision of Coals*

Coals are subdivided into genetic groups, subgroups, types and classes (Table 2).

a) Genetic groups of coals (Timofeev, P. P. 1956, 1960) are characterized by a uniformity of structure in the substance of the coal-forming microcomponents independent of its type. The groups are distinguished by the degree of biochemical decomposition and degradation of the original lignin-cellulose tissues during the processes of gelification, gelifusainization and fusainization. On this basis five genetic groups of coal can be established:

i) coals with a low degree of decomposition of the lignin-cellulose tissues – telinitic;

ii) coals with a relatively low degree of decomposition of the lignin-cellulose tissues – posttelinitic:

iii) coals with a relatively high degree of decomposition of the lignin-cellulose tissues – precollinitic:

iv) coals with a high degree of decomposition of the lignin-cellulose tissues – collinitic;

v) coals with an almost complete decomposition of lignin-cellulose tissues – leiptinitic.

The genetic groups of coal are represented in the classification by three vertical rows. Each row is characterized by the paragenesis of genetic subgroups and types of coals which originate under comparable conditions of sedimentation in a particular tectonic regime. Each genetic group of coals corresponds to a definite macrofacies of peat accumulation. A macrofacies is a complex of facies originating from a particular tectonic regime in the area of peat accumulation, regardless of the character of the swamps in which the formation of peat takes place (macrofacies of deposits of stable peat bogs, etc.).

b) A genetic subgroup of coal refers to a complex of coals which are characterized by a particular type of coal-forming microcomponent with a specific structure (gelinite-telinitic coals, gelifusinite-collinitic coals, etc.). The origin of the coals of each subgroup within a genetic group is related to changes in the amount of flooding and the amount of water movement in a peat swamp against a background of a general tectonic regime in the area of peat accumulation, which is characteristic for the formation of coals of a given group as a whole. Each genetic subgroup corresponds to a definite facies of peat accumulation, that is a complex of physico-geological conditions under which the peat was formed and which is characterized by a definite type and structure of its substance (facies of unstable, heavily flooded, stagnant peat swamp, etc.). The main factors determining the complex of physico-geological conditions or a facies include the geotectonic regime of the area of peat accumulation and the amount of flooding and water movement in the peat swamp. These factors determine the rate of submergence and the time interval required for burial of the peat-forming layer, as well as the direction followed by the biochemical decomposition of the plant material. When combined with the specific characteristics of the original plant material, these factors determine the entire variety of genetic types of humic coals.

c) A genetic type of coal is characterized by a complex of features reflecting the general conditions of accumulation and the environment of primary transformation of the original plant material. The features of a genetic coal type include:-

i) the type of substance of the coal-forming microcomponents and its structure,

ii) the proportions of coal-forming and secondary microcomponents, and

iii) the original material if this can be established.

d) Genetic classes of coals are complexes of genetic types of coal in which microcomponents of the same class form the coal. The recognition of a class of coal is made on the basis of a substance type of coal-forming microcomponent, independent of its structure (gelinitic coal, gelifusinitic coal, etc.).

In the genetic classification, classes of coal are represented by horizontal rows. These combine the genetic types of coals, the origin of which has been determined by a definite degree of flooding, water movement and stagnation in areas of peat accumulation with any tectonic regime. For example, gelinitic coals are formed both in unstable and stable environments of peat accumulation, but always under conditions of very wet, stagnant peat swamps. By the character of the structure of the substance of the coal-forming microcomponents, each class of coals can be divided into subclasses, which actually correspond to a genetic subgroup of coal.

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TABLE 1

CLASSIFICATION AND NOMENCLATURE OF COAL MICROCOMPONENTS IN THE MAIN COAL BASINS OF THE USSR

by P.P. Timofeew and L.I. Bogoliubova

By material composition		By the degree of preservation and fragmentation (biochemical and mechanical) of the vegetable material				By the original matter of plant parts and tissues
Class	Subclass	Type	Species			Variety
			By the degree of structure preservation		By the degree of fragmentation	
Gelinites (red)	Gelinites	GELINITE-TELINITE	Xylain, xylovitrain with semi-swelled cell walls, structure and structureless vitrain		fragmentary	coarse-and fine-xyloid. perenchymous
		GELINITE-POSTTELINITE	Lumpy xylovitrain. structureless vitrain „B"		coarse-attritic, attritic	
		GELINITE-PRECOLLINITE	Consists of small structureless granulated particles with indistinct outlines. Generally the matter is of a spongy or indistinctly lumpy structure		indistinctly fine-attritic	in practice nondeterminable
		GELINITE-COLLINITE	Transparent (red) matrix		colloidal	nondeterminable
Semigelinites (reddish-brown)	Semigelinites	SEMIGELINITE-TELINITE	Semixylain, semixylovitrain with semiswelled and swelled cell walls. structure and structureless semivitrain		fragmentary	coarse-and fine-xyloid, perenchymous
		SEMIGELINITE-POSTTELINITE	Lumpy semixylovitrain, structureless semivitrain, semivtrain „B"		coarse-attritic and attritic	
		SEMIGELINITE-PRECOLLINITE	Consists of small structureless granulated reddish-brown particles with indistinct outlines. Generally the matter is of a spongy or indistinctly lumpy structure		indistinctly fine-attritic	in practice nondeterminable
		SEMIGELINITE-COLLINITE	Transparent (reddish-brown) matrix		colloidal	nondeterminable
Semigelifusinites (brown)	Semigelifusinites	SEMIGELIFUSINITE-TELINITE	Semixylo-fusain, semixylovitraino-fusain, semivitraino-fusain		fragmentary	coarse-xyloid
		SEMIGELIFUSINITE-POSTTELINITE	Semixylovitraino-fusain, semivitraino-fusain		coarse-attritic and attritic	
		SEMIGELIFUSINITE-PRECOLLINITE	Consists of small structureless granulated brown particles with indistinct outlines. Generally the matter is of an indistinct lumpy structure		indistinctly fine-attritic	in practice nondeterminable
		SEMIGELIFUSINITE-COLLINITE	Semitransparent (brown) matrix		colloidal	nondeterminable
Gelifusinites (black-reddish-brown)	Gelifusinites	GELIFUSINITE-TELINITE	Xylofusain, xylovitraino-fusain, vitraino-fusain		fragmentary	coarse-xyloid
		GELIFUSINITE-POSTTELINITE	Xylovitraino- fusain, vitraino-fusain		coarse-attritic and attritic	
		GELIFUSINITE-PRECOLLINITE	Consists of small structureless granulated brownish-black particles with indistinct outlines. Generally the matter is of an indistinct lumpy structure		indistinctly fine-attritic	in practice nondeterminable
		GELIFUSINITE-COLLINITE	Opaque matrix		colloidal	nondeterminable
Quasi-gelifusinites (brown, black-reddish-brown)	Quasi-semigelifusinites	QUASI-SEMIGELIFUSINITE-TELINITE	Semixylo-fusain, semixylovitraino-fusain, semivitraino-fusain	is accompanied by a terrigenous mineral admixture	fragmentary	coarse-xyloid
		QUASI-SEMIGELIFUSINITE-POSTTELINITE	Semixylovitraino-fusain, semivitraino-fusain		coarse-attritic and attritic	
		QUASI-SEMIGELIFUSINITE-PRECOLLINITE	Consists of small structureless brown granulated particles with indistinct outlines Generally the matter is of an indistinct lumpy structure		indistinctly fine-attritic	in practice nondeterminable
		QUASI-SEMIGELIFUSINITE-COLLINITE	Semitransparent (brown) matrix		colloidal	nondeterminable
	Quasi-gelifusinites	QUASI-GELIFUSINITE-TELINITE	Xylofusain, xylovitraino-fusain, vitraino-fusain		fragmentary	coarse-xyloid
		QUASI-GELIFUSINITE-POSTTELINITE	Xylovitraino-fusain, vitraino-fusain		coarse-attritic and attritic	
		QUASI-GELIFUSINITE-PRECOLLINITE	Consists of small structureless granulated brownish-black particles with indistinct outlines. Generally the matter is of an indistinct lumpy structure		indistinctly fine-attritic	in practice nondeterminable
		QUASI-GELIFUSINITE-COLLINITE	Opaque matrix		colloidal	nondeterminable
Fusinites (black)	Fusinites	FUSINITE-TELINITE	Fusain		fragmentary	coarse-xyloid
		FUSINITE-POSTTELINITE	Fusain		coarse-attritic and attritic	
Suberinites (red, brownish-red, yellow)	Suberinites	SUBERINITE-TELINITE	Suberino-xylain, suberino-xylovitrain, suberino-vitrain		fragmentary	—
		SUBERINITE-POSTTELINITE	Suberino-xylovitrain, suberino-vitrain		coarse-attritic and attritic	—
		SUBERINITE-PRECOLLINITE	Consists of small structureless granulated particles with indistinct outlines. Generally the matter is of a spongy structure		indistinctly fine-attritic	—
		SUBERINITE-COLLINITE	Suberinilic transparent matrix		colloidal	—
Leiptinites (yellow)	Cutinites	CUTINITE	—		fragmentary	—
		CUTINITE-COLLINITE	—		colloidal	—
	Resinites	—	—		—	—
	Sporinites	—	—		—	—
Sporanginites (yellow orange, red)	Sporanginites	—	—		fragmentary	—
Sclerotinites (red, reddish-brown, black-reddish-brown)	Gelinite-sclerotinites	—	—		fragmentary	—
	Fusinite-sclerotinites	—	—			
Alginites (yellow)	Alginites	ALGINITE-TALLOMITE	—		fragmentary	—
		ALGINITE-COLLINITE	—		colloidal	—

TABLE 2

GENETIC CLASSIFICATION OF HUMIC COALS
(System of the Geological Institute of the Academy of Sciences of the USSR, Moscow - GIM) (generalized)

Class of coals by the type of coal-forming microcomponents	The nature of the process of transformation of the vegetable matter	Types of coal-forming microcomponents (>50%)	Chemism of the medium of the bog	The degree of flooding of the bog	Degree of mobility of the aqueous medium of the bog	Genetic groups of coals by decomposition degree of lignin-cellulose tissues														
						First genetic group (I)			Second genetic group (II)			Third genetic group (III)			Fourth genetic group (IV)			Fifth genetic group (V)		
						Coals with slight decomposition of the lignin-cellulose tissues Telinitic coals			Coals with relatively weak decomposition of the lignin-cellulose tissues Posttelinitic coals			Coals with relatively heavy decomposition of the lignin-cellulose tissues Precollinitic coals			Coals with heavy decomposition of the lignin cellulose tissues Collinitic coals			Coals with nearly complete decomposition of the lignin-cellulose tissues Leiptinitic coals		
						Genetic subgroup of coals	Facies	Macrofacies	Genetic subgroup of coals	Facies	Macro-facies	Genetic subgroup of coals	Facies	Macro-facies	Genetic subgroup of coals	Facies	Macro-facies	Genetic subgroup of coals	Facies	Macro-facies
Gelinitic (1)	Gelefication	Gelefied	Anaerobic	Heavily flooded	Stagnant	Celinite-telinitic (I-1)	Mobile, heavily flooded stagnant peat bog	Deposits of mobile peat bogs	Gelinite-posttelinitic (II-1)	Relatively mobile, heavily flooded stagnant peat bog	Deposits of relatively mobile peat bogs	Gelinite-precollinitic (III-1)	Relatively stable, heavily flooded stagnant peat bog	Deposits of relatively stable peat bogs	Gelinite-collinitic (IV-1)	Stable, heavily flooded stagnant peat bog	Deposits of stable peat bogs	Leiptinitic coals with gelinite-collinite (V-1)	Rather stable heavily flooded stagnant peat bog	Deposits of rather stable peat bogs
Semigelinitic (2)		Semigelefied	Aerobic-anaerobic	Flooded		Semigelinite-telinitic (I-2)	Mobile flooded stagnant peat bog		Semigelinite-posttelinitic (II-2)	Relatively mobile, flooded stagnant peat bog		Semigelinite-precollinitic (III-2)	Relatively stable, flooded stagnant peat bog		Semigelinite-collinitic (IV-2)	Stable, flooded stagnant peat bog		Leiptinitic coals with semigelinite-collinite (V-2)	Rather stable, flooded, stagnant peat bog	
Semigelifusinitic (3)	Gelefusainization	Semigelefusainized	Anaerobic - aerobic	Flooded Periodical drying for short periods		Semigelifusinite-telinitic (I-3)	Mobile flooded, periodically dried for short periods stagnant forest peat bog		Semigelifusinite-posttelinitic (II-3)	Relatively mobile flooded, periodically dried for short periods, stagnant forest peat bog		Semigelifusinite-precollinitic (III-3)	Relatively stable, flooded, periodically dried for short periods, stagnant peat bog		Semigelifusinite-collinitic (IV-3)	Stable, flooded, periodically dried for short periods, stagnant peat bog		Leiptinitic coals with semigelifusinite-collinite (V-3)	Rather stable, flooded, dried for short periods stagnant peat bog	
Gelifusinitic (4)		Gelefusainized		Periodical drying for long periods		Gelifusinite-telinitic (I-4)	Mobile, flooded, periodically dried for long periods stagnant forest peat bog		Gelifusinite-posttelinitic (II-4)	Relatively mobile, flooded, periodically dried for long periods, stagnant forest peat bog		Gelifusinite-precollinitic (III-4)	Relatively stable, flooded, periodically dried for long periods, stagnant peat bog		Gelifusinite-collinitic (IV-4)	Stable, flooded, periodically dried for long periods stagnant peat bog		Leiptinitic coals with gelifusinite-collinite (V-4)	Rather stable, flooded, periodically dried for long periods stagnant peat bog	
Quasi-gelifusinitic (5)		Quasi-gelefusainized	Anaerobic	Flooded	Running-water	Quasigelifusinite-telinitic (I-5)	Mobile, flooded running-water peat bog		Quasi-gelifusinite-posttelinitic (II-5)	Relatively mobile, flooded running-water forest peat bog		Quasi-gelifusinite-precollinitic (III-5)	Relatively stable flooded running-water peat bog		Quasi-gelifusinite-collinitic (IV-5)	Stable, flooded running-water peat bog		Leiptinitic coals with quasigelifusinite-collinite (V-5)	Rather stable flloded running-water peat bog	
Fusinitic (6)	Fusainization	Fusainized	Aerobic	„Dry"	Stagnant	Fusinite-telinitic (I-6)	Mobile „dry" stagnant forest peat bog		Fusinite-posttelinitic (II-6)	Relatively mobile „dry" stagnant forest peat bog		—	—		—	—		—	—	
Geotectonic conditions (degree of mobility or stability of the area of peat accumulation)						Mobile area of peat accumulation			Relatively mobile area of peat accumulation			Relatively stable area of peat accumulation			Stable area of peat accumulation			Rather stable area of peat accumulation		
Sedimentation conditions						Alluvial - lacustrine - boggy, alluvial-littoral - bassin, alluvial-littoral-marine, basin-proper, marine-proper						Lacustrine - boggy, littoral - basin, littoral - marine								
Change of sedimentation conditions before and after peat accumulation						Abrupt						Not abrupt (relatively stable conditions)								
Rate of submergence of the area of peat accumulation (rate of burial of the peat-forming layer)						High			Relatively high			Relatively low			Low			Rather low		
Duration of biochemical decomposition of the vegetable matter						Small (weak decomposition)			Relatively small (Relatively weak decomposition)			Relatively great (relatively heavy decomposition)			Great (heavy decomposition)			Rather great (very heavy decomposition)		

1971	**International Committee for Coal Petrology** Analysis Sub-Committee	Hard Coal
SUPPLEMENT	**Combined Maceral and Microlithotype Analysis** **(Combination Analysis)** (after M-Th. Mackowsky and V. Hevia)	R. L.

I – GENERAL

In maceral analysis the percentage proportions of the macerals or maceral groups in a coal sample are determined quantitatively, irrespective of their association with other macerals. The quantitative determination of maceral associations (microlithotypes) is given by the microlithotype analysis, which, however, does not yield any quantitative data on the proportion of the macerals or maceral groups in the individual microlithotypes. The aim of the 'Combination Analysis' is to determine the macerals or maceral groups in relation to their associations, thus making it possible to obtain the following three types of information from one analytical procedure:

i) the composition of the coal in terms of macerals or maceral groups,

ii) the composition of the coal in terms of microlithotypes, and

iii) the composition of the microlithotypes in terms of macerals or maceral groups.

The combination analysis can be carried out on seam-profile columns, which are cut at right angles to the bedding, and on particulate sections. The sections are prepared in the same way as for maceral or microlithotype analysis (see 'Recommendations for the Preparation of Particulate and Lump Sections').

II – ANALYTICAL PROCEDURE

Basically the combination analysis is made by point-counting. An automatic point-counter is recommended for the operation. In contrast to maceral analysis, in combination analysis the '20-point graticule' (after Kötter), which is also used in microlithotype analysis, is inserted into one ocular of a reflected-light microscope. The measuring point for determination of the individual macerals is as shown in Fig. 1(a and b). Before recording a measuring point, at least 10 intersections of the measuring field of the graticule must lie within a coal particle.

To obtain the same results in the combination analysis as in separate maceral and microlithotype analyses, the following special situations must also be considered.

i) If more than 10 intersections lie above a coal particle, but not the measuring point, the region would be recorded in the microlithotype analysis, but not in the maceral analysis. In the combination analysis such a point would be recorded as an 'observed microlithotype' (Fig. 1b).

ii) If the measuring point lies within a maceral (Fig. 1c), without 10 intersections lying within the coal particle, then this measuring point would be counted in the maceral analysis, but not in the microlithotype analysis. In the combination analysis this point would be recorded as a 'maceral at the particle edge'.

iii) With particles ⩽30 microns the measuring point can lie above a maceral without 10 intersections lying within the coal particle (Fig 2e). Such a measuring point would be counted in the maceral analysis, but not in the microlithotype analysis. In combination analysis the point would be recorded as an 'isolated maceral'.

The categories of intergrowths for the individual maceral groups are shown for vitrinite in Fig. 2a–d.

Fig. 2a – vitrinite in vitrite,
Fig. 2b – vitrinite in clarite,
Fig. 2c – vitrinite in vitrinertite,
Fig. 2d – vitrinite in trimacerite.

Table 1 shows the categories of intergrowth which must be determined in the simplest form of combination analysis. In this simple form of the analysis, only the maceral groups in association with other maceral groups and carbominerites are determined. Obviously the same type of analysis can be carried out for individual macerals, but with a considerable increase in the number of intergrowth categories. The carbominerites can likewise be subdivided.

It is necessary to record at least 1000 measuring points for the analysis. To be certain of achieving this number of measuring points, a point and line interval of approximately 0.4–0.5mm is required for a section with an area of 4 cm^2. Care must be taken that the whole area of the section is examined. Conversion of the recorded points into volume percentages is made in the usual way, the values being expressed as whole numbers.

To evaluate the analysis the use of diagrams is recommended from which the results of the maceral or maceral-group analysis, the microlithotype analysis and the composition of the individual microlithotypes can rapidly be determined. Fig. 3a shows the simplest form, in which only the maceral groups, the microlithotypes and the carbominerites are considered.

When determining the maceral-group composition, category '5' ('observed microlithotype') is ignored: and in calculating the composition of the coal in terms of microlithotypes, categories 'a' and 'b' ('isolated macerals' and 'macerals at particle edges') are ignored, since here the measuring point does not lie within a maceral. From the data given in Fig. 3a the composition of the sample in terms of maceral groups and microlithotypes and the composition of the microlithotypes in terms of maceral groups can be obtained (see Table 2). Fig. 3b shows a diagram for evaluating the case in which subdivision of the carbominerites is required. Both diagrams (Fig. 3a and 3b) can be combined. Moreover Fig. 3a, alone or in combination with Fig. 3b, can be expanded by subdividing the maceral groups into single macerals. For such a detailed analysis the number of keys on the normal automatic point-counter would be far too few and in this situation the point-counter should merely be used as a transport device and the various intergrowth categories recorded with a mechanical counter (e.g. the 'Statitest' made by Ferrari, Berlin or Clay-Adams, New York), or if this is not available, by simple marking with a pencil.

III – ACCURACY OF ANALYSIS

The accuracy of analysis for 1000 measuring points is approximately + 2 per cent, irrespective of whether macerals, maceral groups, microlithotypes or the composition of the microlithotypes are determined.

IV – RANGE OF APPLICATION OF THE ANALYSIS

Combination analysis is used instead of maceral analysis or microlithotype analysis when the composition of the microlithotypes or the carbominerites has to be determined quantitatively in addition to the percentage proportions of the macerals or microlithotypes. The decision whether to determine individual macerals or maceral groups, with or without subdivison of the carbominerites, is governed by the aims of the particular analysis. To assist in technical preparation problems or coking problems, it is sufficient in each case if maceral groups are distinguished, but subdivision of the carbominerites may occasionally be important. In problems of seam identification or coal genesis, analysis in terms of single macerals is recommended.

TABLE 1. – LIST OF INTERGROWTH CATEGORIES FOR THE SIMPLEST FORM OF COMBINATION ANALYSIS

No.	Composition of intergrowth categories
1	Vitrinite (Fig. 2a)
2	Vitrinite at particle edge (Fig. 1c)
3	Isolated vitrinite 30 microns (Fig. 2e)
4	Vitrinite in clarite (Fig. 2b)
5	Vitrinite in trimacerite (Fig. 2d)
6	Vitrinite in vitrinertite (Fig. 2c)
7	Exinite
8	Exinite at particle edge
9	Isolated exinite
10	Exinite in clarite
11	Exinite in trimacerite
12	Exinite in durite
13	Inertinite
14	Inertinite at particle edge
15	Isolated inertinite
16	Inertinite in vitrinertite
17	Inertinite in trimacerite
18	Inertinite in durite
19	Minerals and rock (sterile) (isolated and at grain margin)
20	V,E,I + minerals (carbominerite)
21	Minerals + V,E,I (carbominerite)
22	Observed microlithotype (observed carbominerite) (Fig. 1b)

TABLE 2 – RESULTS OF COMBINATION ANALYSIS (Fig. 3a)

Group Macerals	Vol %	Microlithotypes	Vol %	V	E	I	M
		Vitrite	34	100			–
Vitrinite	66	Liptite	1		100		–
		Inertite	7			100	
Exinite	9	Clarite	14	85	15	–	–
		Durite	16		29	71	–
Inertinite	24	Vitrinertite	4	64	–	36	1
Minerals	1	Trimacerite	24	50	22	28	–
		Carbominerite and rock	1		20		80
	100		100				

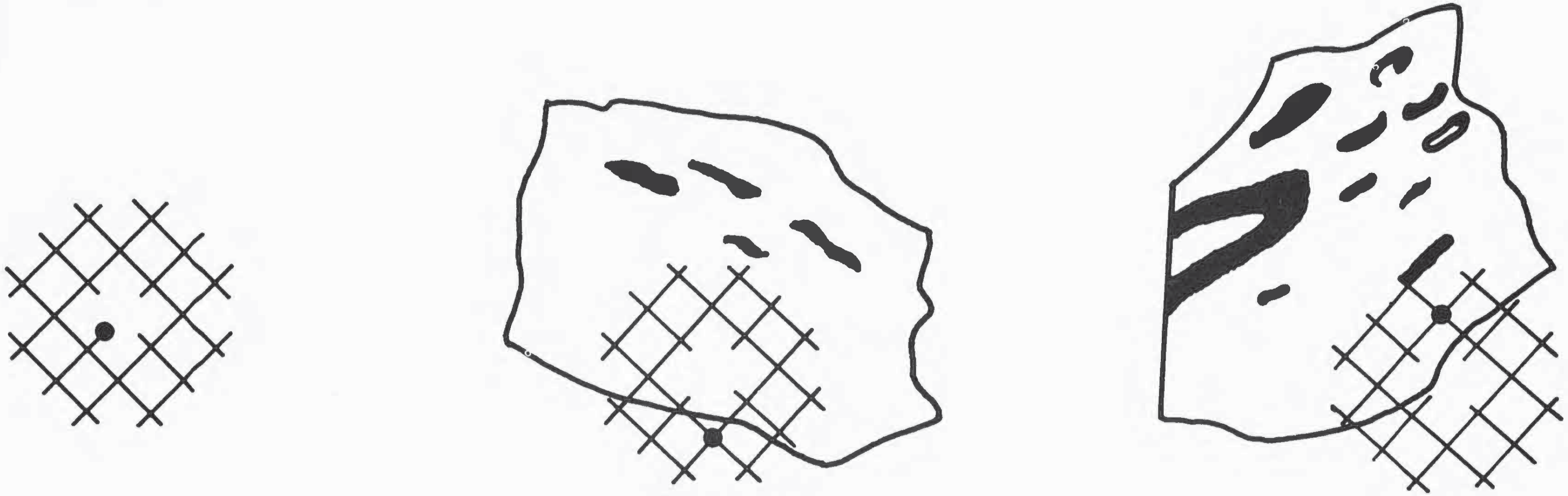

Fig.1 a b c

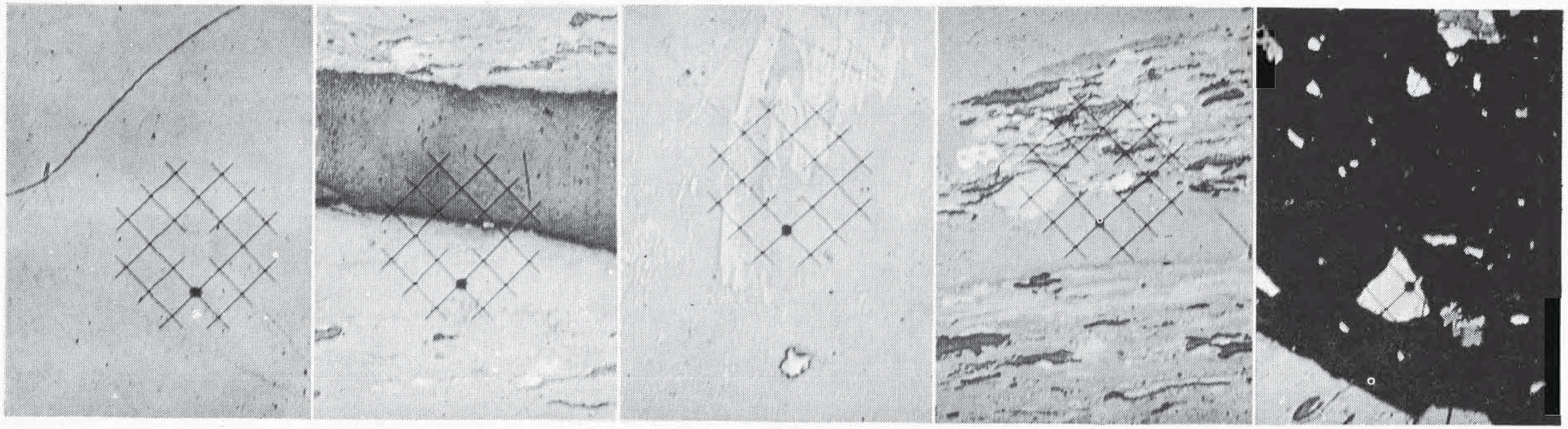

Fig. 2 a b c d e

The measuring point lies in:

The measuring field lies in:

		1 VITRINITE	2 EXINITE	3 INERTINITE	4 MINERALS	5 OBSERVED	6 TOTAL
ISOLATED	a	41	1	24	5	☒	71
VITRITE	b	246	☒	☒	0	30	276
LIPTITE	c	☒	2	☒	0	0	2
INERTITE	d	☒	☒	53	0	7	60
CLARITE	e	84	18	☒	0	14	116
DURITE	f	☒	10	22	0	2	34
VITRINERTITE	g	74	☒	45	1	6	126
TRIMACERITE	h	85	42	54	1	12	194
CARBOMINERITE + ROCK	i	1	0	1	3	0	5
ON GRAIN MARGIN	j	80	11	24	1	☒	116
TOTAL	k	611	84	223	11	71	1000

Fig. 3a

			VITRINITE 1	EXINITE 2	INERTINITE 3	QUARTZ 4	CLAY MINERALS 5	CARBONATES 6	PYRITE 7	OTHER MINERALS 8	OBSERVED 9	TOTAL 10
	ISOLATED	a									☒	
	COAL	b										
CARBOMINERITE	C.quartzite	c					☒	☒	☒			
	C.argilite	d				☒		☒	☒			
	C.ankerite	e				☒	☒		☒			
	C.pyrite	f				☒	☒	☒				
	C.polyminerite	g										
	ROCK	h										
	ON GRAIN MARGIN	i									☒	
	TOTAL	j										

Fig. 3b.

1971 SUPPLEMENT	**International Committee for Coal Petrology** Analysis Sub-Committee **ANALYSIS OF BLENDS OF COALS OF DIFFERENT RANK**	Hard Coal

I – GENERAL

When blending seams or coal types from different seams with one another, rank determination by reflectance measurement on vitrinite begins the so-called 'Coal-blend analysis', with whose help the percentage composition of the different coals can be determined. Reflectance measurement of vitrinite is the basis of coal-blend analysis and it pre-supposes a strict relationship between rank and reflectance of vitrinite. This supposition has been demonstrated (see Figs. 3 and 4 of the term 'Rank').

The determination of the percentage composition of the seams or coal types contained in a coal blend, without a knowledge of the reflectance distributions of the individual components contained in the blend, causes difficulties, because with seams whose ranks lie close to one another (Fig. 1), the individual reflectance distributions overlap. A further difficulty is that the composition of the seam in terms of microlithotypes, even in coals of a single deposit, can vary between relatively wide limits. To remove this difficulty, in coal-blend analysis the reflectance of all the vitrinite (including that in clarite, vitrinertite and trimacerite), is measured. Consequently, for coal-blend analysis only equipment suitable for measurement on small fields (<10 microns) can be used. Only the vitrinite-free microlithotypes (durite, fusite, semifusite and sclerotite[+]), if these occur as isolated particles and are not associated with other vitrinite-containing microlithotypes,

---

[+] Occasionally the vitrinite layers contained in some particles are also so thin that it is not possible to measure them.

remain to be considered. The proportion of vitrinite-free microlithotypes, occurring as isolated particles on a polished block, depends on the banding or on the bedding of the seam. With very finely banded layers of microlithotypes, the proportion is lower than when the seam is coarsely banded. To assign the microlithotypes semifusite, fusite and sclerotite to a specific rank range, when these occur isolated, is not possible. For durites a relatively coarse subdivision into specific coalification ranges can be made on the basis of increasing reflectance of exinite.

Coal-blend analyses are carried out basically on polished particulate blocks (for sample preparation, see 'Recommendations for the preparation of polished surfaces of particulate and lump samples of coal'). So as to ensure separation and at the same time observing correct sampling procedure to obtain a suitable quantity of coal on the section surface, it is necessary to cast a block approximately 2 x 2 x 2 cm., then to halve it and to polish a side-face of each half.

For a coal-blend analysis at least 500 (better 1000), vitrinite reflectances must be measured (250–500 on each surface). A mechanical stage (not an automatic point counter) is used for the work. The point and traverse intervals should be approximately 0.5mm. The 500–1000 individual measurements are recorded as a reflectance distribution (Fig. 3). Fig. 2 illustrates several reflectance distributions for coal blends with approximately the same volatile-matter yields, but markedly different coking potentials. The Figure shows a particularly important field of application of coal-blend analysis, namely, analysis of coking coals.

A mean reflectance value can be calculated from the 500–1000 individual measurements. An approximately true mean volatile-matter yield for the vitrinite (determined on isolated vitrinite – see the term 'Rank'), can then be derived from a standard curve. With the help of the results of maceral-group analysis, the mean volatile-matter yield (VM_{RM}) of the whole coal can be calculated using either R_{rand} or alternatively R_{max}, thus making possible a comparison between the volatile-matter yield (dry, ash-free), determined by proximate analysis, with that estimated from the measurements[7].

The standard deviation (σ) serves as a measure of the range in which approximately 95% of the values of the measured vitrinite reflectance lie. It is calculated as follows:

$$\sigma = \sqrt{\frac{n}{100(n-1)} \cdot \left[\sum(\bar{R}_1^2 \cdot x_1) - 100\bar{R}^2\right]}$$

where n = number of individual values,

$\bar{R}_1$ = mean value of the random or maximum reflectance of V–stages in %,
x_1 = relative frequency of measured values in V–stages in %,
$\bar{R}$ = mean value of the random or maximum reflectance of the measured points in %.

In coal blends in which V–stages or V–stage groups are shown (see Table 1), or gaps are present in the blends (Fig. 2), it is recommended, in addition to the mean values $\bar{R}_{rand}$ or $\bar{R}_{max}$, that the limits of the individual V–stage groups with their quantities in volume per cent are quoted with an accompanying statement of the most frequently occurring ½V–stages or V–stages. All ½V–stages or V–stages lying between two minima are allocated to a specific V–stage group.

An example is shown in Table 2 in which the following V–stage groups are defined.

Component	Most Frequent Class Mid-Point	Limits of the Range in ½V–Stages	Proportion %
1	9.25	7.50–10.50	33
2	11.25	10.50–14.00	47
3	16.25/16.75	14.00–18.50	20

If a minimum extends over an uneven number of ½V–stages, the boundary must be placed so that the larger fraction of ½V–stages is grouped along with the more important V–stage group.

With the help of analytical values from the coal-blend analysis and from maceral-group analysis, the coke strength can be calculated. For this the ½V–stages are grouped together in V–stages, for example, 0.80–0.89%:$R=V_8$. The calculation of coke strength according to the 'Tumbler test' requires the determination of the 'Strength Index' and the 'Inert Index' ('Composition-balance Index')[1, 3, 10, 11]. Similarly the volatile-matter yield (VM_{RM}) and coking power (G_{RM}) can be calculated from the reflectance and maceral-group analysis.

Using these data it is possible to calculate the Micum Index of the coke. In both instances the calculated values of coke strength apply to a given particle-size distribution and coking conditions[7].

II – APPARATUS EMPLOYED

The reflectance measurements on vitrinite necessary for coal-blend analyses can in principle be carried out by using subjective[1, 2] or objective methods of measurement[5, 6, 7, 8, 12, 13, 14]. Since, however, for subjective measurements no apparatus with a field of measurement $<$ 10 microns is available and, moreover, the time required for such measurements is so great, only the objective method, using a single-beam apparatus with a photocell or photomultiplier, is recommended for this analysis (for further details see – 'Determination of rank by reflectance measurement on vitrinite').

III – ANALYSIS PROCEDURE

[See Section III(a–f) in – 'Determination of rank by reflectance measurement on vitrinite'].

To ensure constancy of the instrument over the time interval necessary for at least 500 measurements, it is recommended after each group of 20–25 measurements that a measurement on the standard and a check on the zero point are made. If the measured value for the standard or the zero point is displaced, the 20–25 vitrinite reflectances measured between the two standard values are rejected, the zero point and standard value are standardized correctly and the vitrinite reflectances are re-measured.

[Evaluation of measurements – see 'Determination of rank by reflectance measurement on vitrinite'.]

To obtain an approximately correct classification of particles without vitrinite, a grouping of the determined reflectance ranges (V–stages or V–stage groups) is recommended. Table 1 shows an example of the evaluation of results measured on a coking-coal blend and the way in which the vitrinite-free particles can be classified. Under 'A' is noted the number of points measured on isolated fusite, semifusite and sclerotite: under 'B', depending on their rank which is predominantly based on the reflectance of exinite, are placed the subjectively-determined durite, vitrinite-poor trimacerite and vitrinertite[+]. In column 7 the subjectively-graded particles (B) are added to the number of points measured in the different rank stages and these are then recalculated to 100% (column 8).

IV – ACCURACY OF THE ANALYSIS AND MEAN ERROR OF THE DETERMINED FRACTIONS

The accuracy of individual measurements is the same as that quoted in 'The determination of rank by reflectance measurement on vitrinite'.

With analyses of coal blends, it is important to state how large the mean error is for the fraction determined in ½V–stages, V–stages or V–stage groups. This mean error depends on the absolute value of the particular fractions (see Table). The calculation of errors follows a binomial distribution[4].

[+] The limits for the coal types are based on the standard 'DIN 21900'. This classification can be adapted to coal classifications of different type.

Fractions in ½V–Stages, V–Stages or V–Stage Groups in Vol %	Mean Error in Vol %
> 25	< 2.5
< 25	< 2.0
< 4	< 1.0

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National Norms:

GOST 12113 – 66 (USSR)
ASTM Designation D 2798 – 69 T (USA)
BB 22020, Sheet 6, 1970 (GFR);

Table 1
Reflectance Data for Coal-Blend Analysis
Analysis Procedure

J.–Nr.: 136-69/MP28 Sample Ref: No. 11	V–Stage	Vitrinite Reflectance	Mid-Point of Class	Section 1 P	Section 2 P	Totals	Totals + subj.	Amounts in Vol. %
	1	2	3	4	5	6	7	8
	4	< 0.50	4.75					
Date	5	0.50–0.55	5.25					
		0.55–0.60	5.75					
	6	0.60–0.65	6.25					
		0.65–0.70	6.75					
Observer:	7	0.70–0.75	7.25					
		0.75–0.80	7.75	3	1	4	4	1
	8	0.80–0.85	8.25	6	6	12	12	2
		0.85–0.90	8.75	27	12	39	39	8
Particulate Section	9	0.90–0.95	9.25	23	33	56	58	11
		0.95–1.00	9.75	16	22	38	38	7
	10	1.00–1.05	10.25	7	15	22	22	4
		1.05–1.10	10.75	16	9	25	25	5
Briquette Section	11	1.10–1.15	11.25	41	22	63	63	12
		1.15–1.20	11.75	31	24	55	55	11
	12	1.20–1.25	12.25	17	31	48	48	9
		1.25–1.30	12.75	18	12	30	30	6
A Unmeasurable Points	13	1.30–1.35	13.25	11	6	17	18	3
		1.35–1.40	13.75	3	3	6	6	1
	14	1.40–1.45	14.25	4	2	6	6	1
		1.45–1.50	14.75	6	3	9	10	2
Inertite	15	1.50–1.55	15.25	6	6	12	12	2
		1.55–1.60	15.75	7	8	15	15	3
	16	1.60–1.65	16.25	13	8	21	21	4
		1.65–1.70	16.75	12	11	23	23	4
B Subj.Point	17	1.70–1.75	17.25	8	10	18	18	2
		1.75–1.80	17.75	3	3	6	6	1
Brown Coal	18	1.80–1.85	18.25	1	1	2	2	1
		1.85–1.90	18.75	1	2	3	3	–
Hard Coal	19	1.90–1.95	19.25	1		1	1	
		1.95–2.00	19.75					
HBC,C: HBC,B: //	20	2.00–2.05	20.25					
		2.05–2.10	20.75					
HBC,A:	21	2.10–2.15	21.25					
MBC: //		2.15–2.20	21.75					
LBC,B:	22	2.20–2.25	22.25					
		2.25–2.30	22.75					
LBC,A:	23	2.30–2.35	23.25					
		2.35–2.40	23.75					
AC:	24	2.40–2.45	24.25					
		2.45–2.50	24.75					
$\bar{R}_{rand}$ = 1.19%	25	2.50–2.55	25.25					
		2.55–2.60	25.75					
VM_{RM} = 27.0%	26	2.60–2.65	26.25					
		2.65–2.70	26.75					
	27	2.70–2.75	27.25					
		2.75–2.80	27.75					
G_{RM}–Value = 1.018	28	2.80–2.85	28.25					
		2.85–2.90	28.75					
Totals				281	250	531	535	100

Table 2
Coal Blend Analysis
Reflectance Data for Mean Reflectance at 546 nm

Mine/Company

Plant

No: 136–69/MP 28

Location No:
Horizon No:
Sample No: 11

V-Stage	Vitrinite Reflectance %	Mid-Point of Class	Totals Vol.–%	Combined Totals Vol.–%
4	0.50	4.75		
5	0.50–0.55	5.25		
	0.55–0.60	5.75		
6	0.60–0.65	6.25		
	0.65–0.70	6.75		
7	0.70–0.75	7.25		
	0.75–0.80	7.75	1	
8	0.80–0.85	8.25	2	
	0.85–0.90	8.75	8	
9	0.90–0.95	9.25	11	33
	0.95–1.00	9.75	7	
10	1.00–1.05	10.25	4	
	1.05–1.10	10.75	5	
11	1.10–1.15	11.25	12	
	1.15–1.20	11.75	11	
12	1.20–1.25	12.25	9	
	1.25–1.30	12.75	6	47
13	1.30–1.35	13.25	3	
	1.35–1.40	13.75	1	
14	1.40–1.45	14.25	1	
	1.45–1.50	14.75	2	
15	1.50–1.55	15.25	2	
	1.55–1.60	15.75	3	
16	1.60–1.65	16.25	4	20
	1.65–1.70	16.75	4	
17	1.70–1.75	17.25	2	
	1.75–1.80	17.75	1	
18	1.80–1.85	18.25	1	
	1.85–1.90	18.75		
19	1.90–1.95	19.25		
	1.95–2.00	19.75		
20	2.00–2.05	20.25		
	2.05–2.10	20.75		
21	2.10–2.15	21.25		
	2.15–2.20	21.75		

$\bar{R}_{rand}$: 1.19%

VM_{RM} : 27.0%

G_{RM}–Value : 1.018

Coal-Blend Analysis

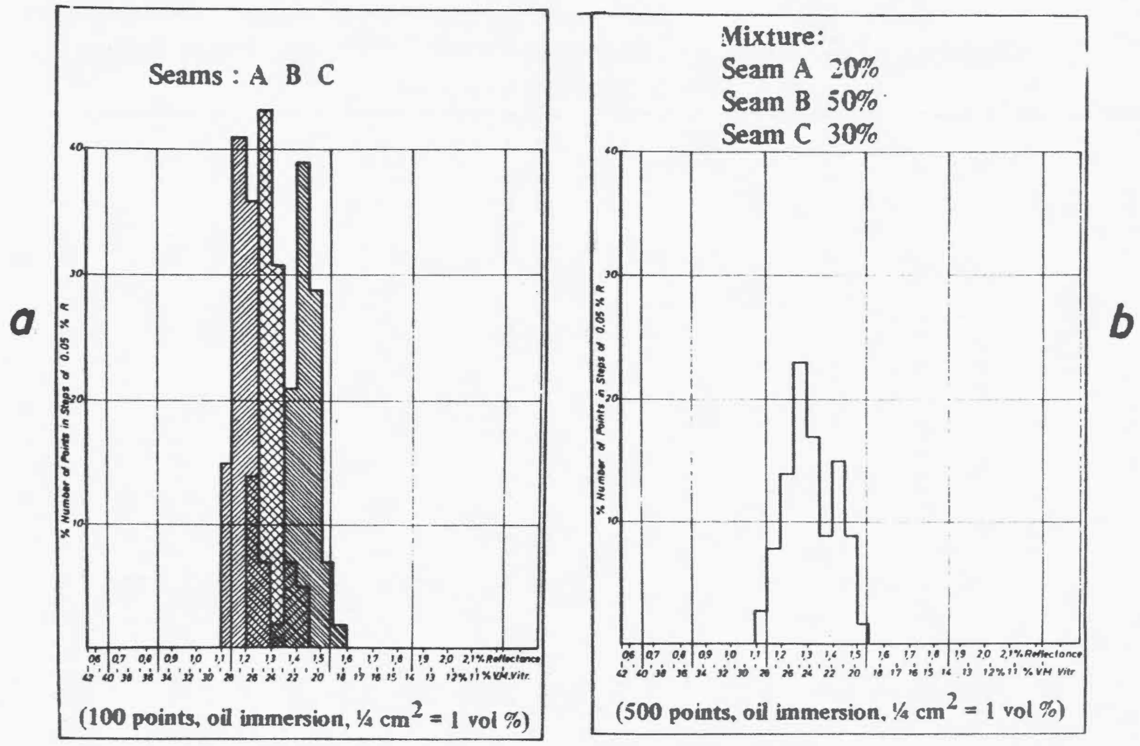


Fig. 1
Reflectogram of 3 Individual Seams (1a) and Their Blend (1b)

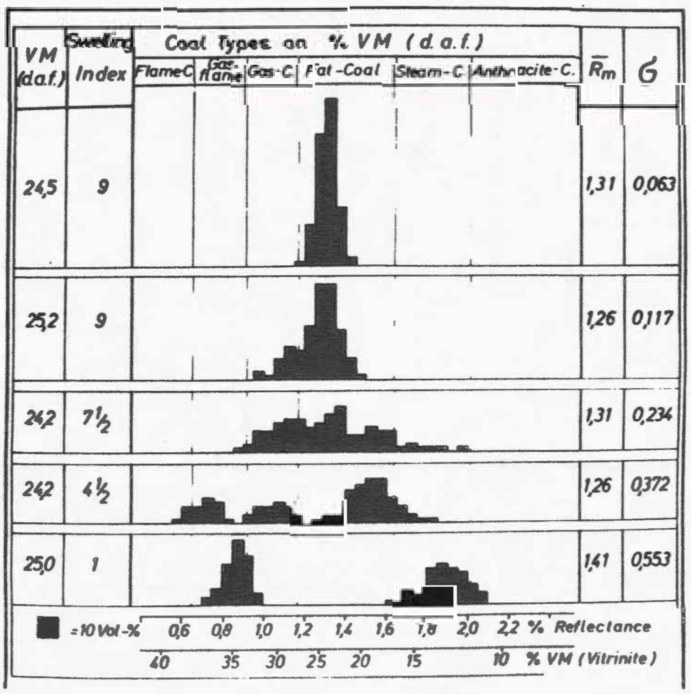


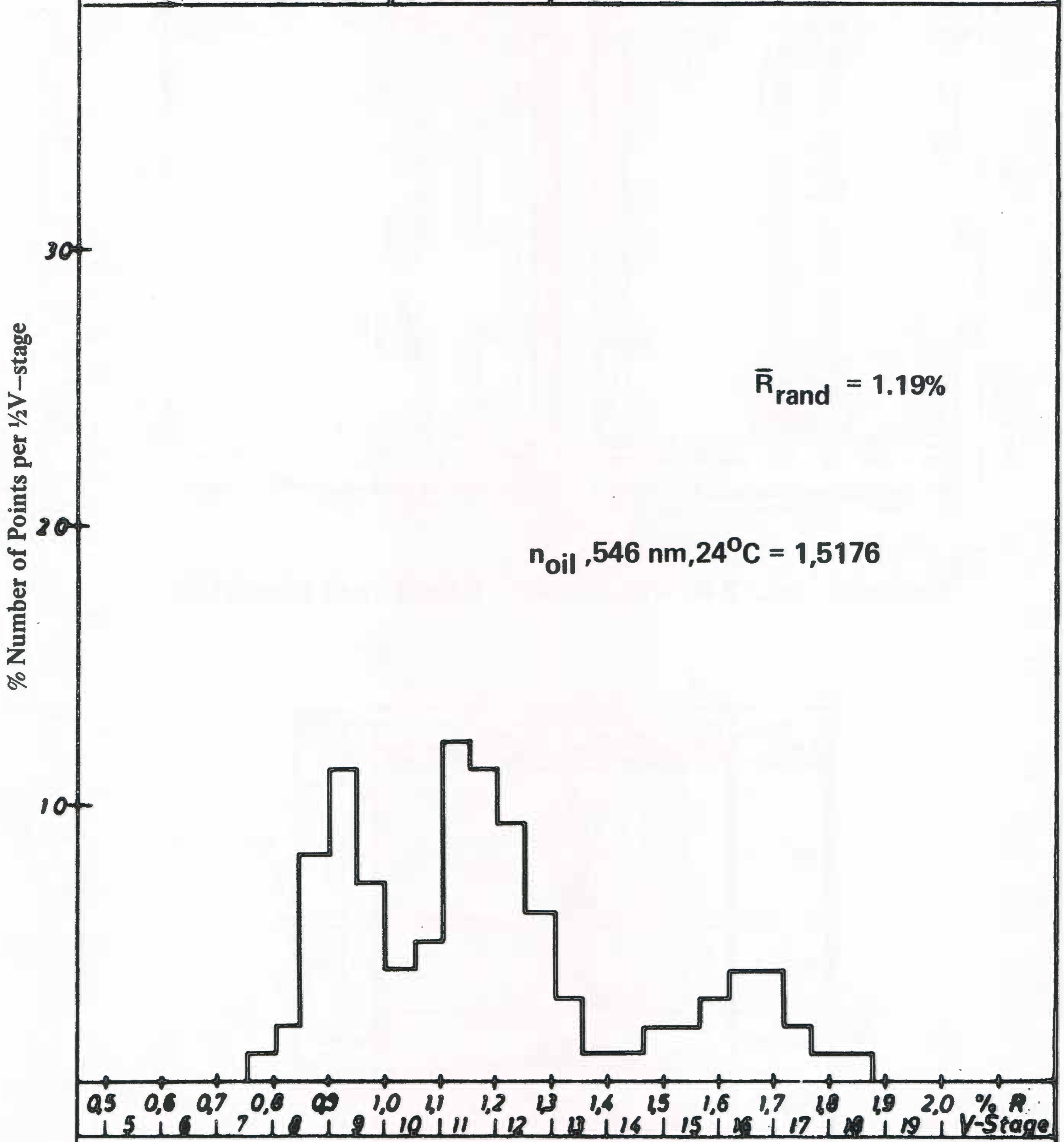
Fig. 2
Reflectogram : Mean Reflectance, Scatter and Swelling Index of 5 Coking-Coal Blends

$R_m = R_{rand}$

No.: . . . . Sample . . . .

R_{rand} = ... % , 2s = ... , G_{RM} = ...

Coal-Blend Analysis by Measurement of Random Reflectance (546 nm) of Vitrinite



535 points of measurement, oil immersion: 1/4cm^2 = 1Vol-%. V-stage=%R.10

The Range of Mean Reflectance of:

<0.65% corresponding to ca.>40% V.M. (d.a.f.) from Proximate Analysis (ash-dry 8%)
0.65–0.90% " " 40–35% " " " " " "
0.90–1.15% " " 35–28% " " " " " "
1.60–1.90% " " 19–14% " " " " " "
>1.90% " " <14% " " " " " "

Fig. 3.

1971	**International Committee for Coal Petrology** Analysis Sub-Committee	Hard Coal
SUPPLEMENT	**MINERAL DISTRIBUTION ANALYSIS** (after M-Th. Mackowsky)	R. L.

I – GENERAL

In evaluating the behaviour of samples from individual coal seams or of coal blends in preparation plants, particularly the ‘fines’ (<5mm) that result from crushing, the mineral distribution analysis is frequently as important as the maceral or microlithotype analysis or the determination of rank by measurement of vitrinite reflectance.

The object of preparation procedures is to produce marketable products, i.e. products whose ash contents match the purpose for which the coal is used.

Normally the preparation behaviour of a particular coal is tested by ‘float-and-sink’ methods. The ash contents of the individual density grades and their percentages generally provide sufficient information about the level of the separation cut or cuts and the yields of cleaned product, ‘middlings’ and waste. However, they do not give information on the possibility of eliminating or concentrating a particular mineral, or indicate whether the yield of low-ash coal for sale can be improved by further size reduction. Mineral-distribution analysis has provided a means of answering this question. The analysis of the mineral distribution of whole-seam samples, crushed <1mm, gives a rough indication of the probable yields of ultra-clean coal (ash content <0.5 per cent), high-grade coal (ash content <1 per cent) or normal marketable coal, ‘middlings’ and waste.

II – ANALYTICAL PROCEDURES

In contrast to maceral and microlithotype analyses, in mineral-distribution analysis the coal particles lying on the surface of the section are not subdivided into individual constituents (macerals or microlithotypes), but are regarded as a whole, since they pass through the various grading processes as units. This means that mineral-distribution analyses can be carried out only on fine particle sizes (maximum 6–10mm: better <5mm), since with coarser fractions the size and number of sections for the study of representative average samples would be so great that the time and cost involved would be out of all proportion to the value of the possible data.

It is convenient to carry out mineral-distribution analyses on restricted size grades. Table 1 shows the dimensions, particle sizes and minimum number of sections required for the investigation of individual size fractions.

TABLE 1

Size Grade (mm)	Dimensions of Section (cm)	Number of Sections	Objective[+]
5–3	5x5	4–6	x 6– 8
3–1	3x3	2–3	x12–15
1–0.5	2x2	1–2	x15
0.5–0.1	2x2	1	x25
0.1–0.06	2x2	1	x25
<0.06	2x2	1	x25

[+] A wide-field eyepiece with x8–10 magnification is always used, together with a reflected-light microscope with binocular tubes.

With the >1mm size grades, the section is moved with a mechanical stage; for counting the particles a mechanical counter is used (e.g. the 'Statitest' made by Ferrari, Berlin or Clay-Adams, New York). In this way account can be taken of all particles contained in the section.

For the analysis of <1 mm size grades, both the movement of the section and the recording are carried out with an automatic point counter. At least 500 particles should be counted and each particle should be counted only once. The point and traverse separation are determined by the maximum particle size of the sample under investigation; both should correspond to approximately half the diameter of the largest particle.

Sections are prepared in the manner recommended (q.v.). To avoid segregation with <1mm size grades, it is convenient to cast a cube of 2 cm side and to polish a side surface (not the base). With >1mm size grades, segregation is prevented by avoiding the casting of too thick a section and ensuring that the mould is filled with fluid resin after the embedding medium has hardened, allowing the section to be handled more easily.

Mineral-distribution analyses can be carried out from three points of view:

i) total mineral-distribution analysis,
ii) individual mineral-distribution analysis, and
iii) mineral-distribution analysis depending upon the type of 'Intergrowth'.

i) *Total mineral-distribution analysis*

In this form of the analysis the proportion of mineral matter in the individual coal particles is determined. The 'categories' which have to be separately evaluated, are arranged as in Table 2.

TABLE 2

POSSIBILITIES FOR TOTAL MINERAL-DISTRIBUTION ANALYSIS

<table>
<tr><th rowspan="2">Method of Analysis</th><th rowspan="2">Pure Coal</th><th colspan="5">Mineral Matter : % by volume</th></tr>
<tr><th>0–5</th><th>5–10</th><th>10–20</th><th>20–60</th><th>60</th></tr>
<tr><td>(A) Ultra-clean coal</td><td>+</td><td>+</td><td>+</td><td colspan="3">+</td></tr>
<tr><td>(B) High-grade coal</td><td>+</td><td colspan="2">+</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>(C) Normal grading</td><td>+</td><td colspan="3">+</td><td>+</td><td>+</td></tr>
</table>

If ultra-clean coals with less than 0.5 per cent ash are produced, the categories indicated in '(A) – Ultra-clean coal' are investigated. Row (B) contains the corresponding categories when 'High-grade coal' with less than 1 per cent ash is supplied and finally, row (C) shows the categories with which, for example, the selectivity of a machine under test or the reason for faulty products can be assessed under 'Normal grading'. The categories, '0–5 per cent mineral matter' (A), '0–10 per cent mineral matter' (B) and '0–20 per cent mineral matter' (C), are of critical significance for the evaluation of the coal in this system.

If in case A more than 5 per cent by volume of coal-mineral intergrowths is contained in the category '0–5 per cent mineral matter', it is virtually impossible to produce 'Ultra-clean coal'; this is because such mineral-poor particles neither alter the density nor the surface properties of the coal sufficiently to allow their separation from the mineral-free coal. In case B, 10 per cent by volume of mineral intergrowths (with less than 10 per cent mineral matter), can still be tolerated without the ash content of the 'High-grade coal' rising above 1 per cent. In case C the normal commercial ash content is still not exceeded if 30–50 per cent by volume of mineral intergrowths (with less than 20 per cent mineral matter), remains in the coal. When determining the sharpness of separation attainable with preparation equipment, it must be borne in mind that 20 per cent by volume of mineral matter corresponds approximately to a density of 1.5 g/cm^3 and that 60 per cent by volume corresponds to a density of approximately 2.0 g/cm^3. These values tally with the separation cuts that are frequently used between 'washed clean coal', 'middlings' and 'reject'. By considering all six categories shown in Table 2, examination, for example, of the raw fines should establish whether the coal should be suitable for the production of 'Ultra-clean' coal or 'High-grade coal'.

Various cross-hair micrometers, which are analogous to the 20-point ocular (see 'Microlithotype analysis'), can be used for delimiting the individual categories, if estimation of the proportion of mineral matter presents too much difficulty.

ii) *Individual mineral-distribution analysis*

In contrast to the form of analysis described above, only the distribution of an individual mineral, e.g. pyrite, is considered in the individual mineral-distribution analysis. The categories shown, for example, in Fig. 1 (a–d) are differentiated:

a) free pyrite (>80 per cent by volume),
b) intergrowths with 50–80 per cent by volume of pyrite,
c) intergrowths with <50 per cent by volume of pyrite,
d) pyrite-free coal and mineral intergrowths, and
e) mineral-free coal.

Because of their high specific gravity, categories (a) and (b) are separable almost without regard to the grading method. Categories (d) and (e) are unimportant – they are used only for conversion of the analytical values recorded in per cent by volume into per cent by weight. Category (c) (Fig. 1c) is the most critical. If, for example, all the pyrite present is held in the coal, the preparation engineer is faced with great difficulty, when recourse cannot be made to completely new processes, e.g. crushing of the sample to a particle size of approximately 20–30 microns. Obviously category (c) can be subdivided still further, e.g. into categories with less than 5 per cent by volume, 5–20 per cent by volume and 20–50 per cent by volume of pyrite.

The individual mineral-distribution analysis can be carried out on the raw material, on the intermediate product and on the final product, as well as on individual size or density grades. The same type of analysis can be used if, for example, the distribution of quartz or some other mineral intergrown with the coal is required.

iii) *Mineral-distribution analysis depending on the type of intergrowth*

With the help of this third type of mineral-distribution analysis, it should be possible to decide whether the yield of mineral-free coal or coal low in mineral matter can be increased by further size reduction. Only two categories are differentiated in this form of analysis:

a) particles in which the mineral matter is uniformly (evenly) distributed (Fig. 1e),

and

b) particles in which the mineral matter is non-uniformly (unevenly) distributed (Fig. 1f).

If the mineral matter intergrown with the coal is uniformly distributed throughout each particle, it is almost impossible to reduce the ash content by size reduction and repeated grading. Greater success can be expected, however, with a non-uniform distribution.

In all three types of mineral-distribution analysis, an accuracy of ±2–3 per cent by volume can be achieved. The conversion of the results of mineral-distribution analysis, expressed in volume per cent, into weight per cent, which is frequently desired by the preparation engineer, is difficult and as a rule the conversion is liable to error. If, however, the conversion to weight per cent must be made, the density of one or more sections of the sample under investigation should be determined and then the accuracy of the mean densities used for the individual categories should be controlled by calculating average densities.

The following are approximate values for the densities of the minerals most frequently intergrown with coal:

TABLE 3

Mineral or Group	Density g/cm^3
Ferrous sulphides (pyrite, marcasite, melnikovite pyrite)	5
Siderite	3.8
Ankerite	3.5–3.8
Calcite	2.7
Dolomite	2.9
Quartz	2.65
Clay minerals	2.3–2.6

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Fig. 1.

a) Free pyrite (> 80 per cent pyrite by volume).

b) Intergrowths with 50–80 per cent pyrite by volume.

c) Intergrowths with < 50 per cent pyrite by volume.

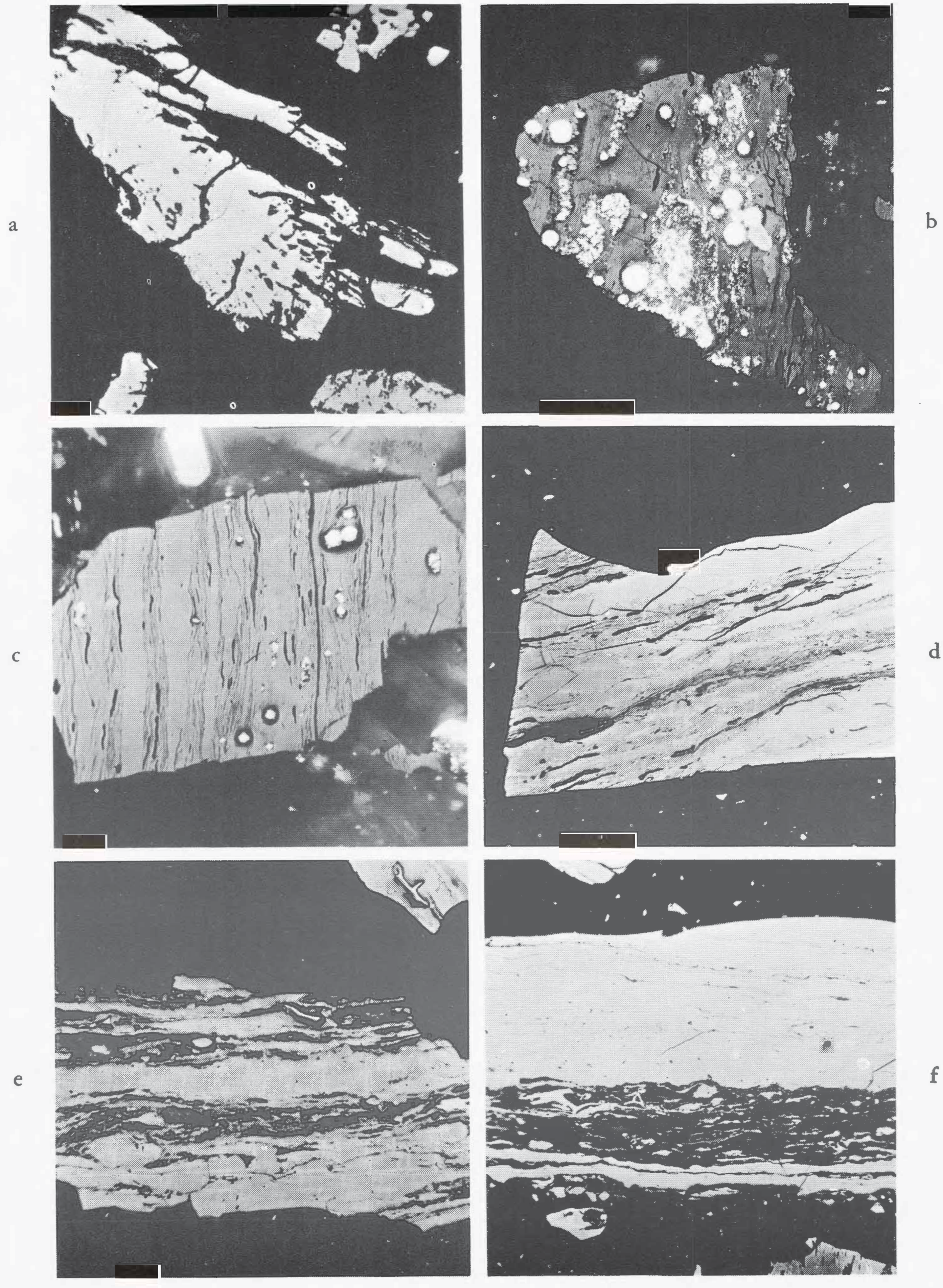
d) Pyrite-free coal and mineral intergrowths.

e) Coal particle with uniformly distributed mineral matter.

f) Coal with unevenly distributed mineral matter.

All photographs: reflected light, oil immersion, 100x.

MINERAL DISTRIBUTION ANALYSIS



1971 SUPPLEMENT	**International Committee for Coal Petrology** Analysis Sub-Committee	Hard Coal
	Determination of Rank by Reflectance Measurement of Vitrinite	

I – GENERAL

The rank of a coal seam can be determined by measuring the reflectance of vitrinite. The reflectance of a substance cannot generally be measured directly, since accurate determination of the intensity of the light incident on the object is necessary for this, which is very difficult. The reflectance of an unknown substance is therefore determined by comparison with a substance of known reflectance (a standard).

The reflectance of vitrinite can be determined both on polished blocks and also on representative average samples of particulate material. Similarly, the reflectance of finely-dispersed, solid organic substances ('coaly material') in inorganic sediments, for example shales, can be measured. Since the rank of a coal is independent of the degree to which it is crushed, no range need be specified for the particle size on the polished section for analysis. It is convenient, however, to choose a range of particle size that will allow micro-lithotype and maceral analyses on the same polished section (see data on preparation of sections – crushing to a particle size <50 microns should be avoided as far as possible).

If the size range of particles for reflectance determination is <10 microns, or the volatile-matter yield (dry ash-free) is <10 per cent, the measurements should be carried out on preparations which are low in relief. Reflectances are measured in monochromatic light (usually 546 nm), so that they are independent of the spectral composition of the microscope lamp. Monochromatic filters may be placed between the light source and the objective, but also in the path of the reflected-light beam.

Possible measurements are the random reflectance and, in the case of plane-polarized light, the bireflectance ($R_{max} - R_{min}$), by determining the maximum and minimum reflectances, to give a measure of the anisotropy. In the case of isotropic materials the random, maximum and minimum reflectances should be of similar value.

Over the entire coalification range vitrinite displays a bireflectance. This bireflectance is, of course, so low in some low-rank coals that it cannot be measured or is only measurable with difficulty. To denote degree of coalification, the maximum reflectance should always be determined. Moreover, the microscope stage must be rotated through 360°, since only in this way can the maximum reflectance value be precisely detected. Determination of the minimum reflectance is only meaningful on oriented polished blocks, since the minimum reflectance is dependent on the orientation of the section due to the optically negative character of vitrinite, which is not defined on polished particulate blocks.

Reflectance can be measured with dry objectives, water- and oil-immersion objectives. Various measured values will then be obtained if the incident light falls as a parallel beam on to the surface of the polished section at right angles. This condition will be fulfilled if the refractive index of the glass of the front lens of the objective is the same as the refractive index of the immersion oil. An immersion oil is used with:-

$$n_{Na}D = 1.515–1.525, \text{ and}$$

$$n_{546nm} = 1.516–1.528.$$

In stating measured values of reflectance, the refractive index of the oil, its temperature and the wavelength of light used should be quoted. Generally, oil-immersion objectives with x25 or x40–60 magnification are used for reflectance measurements (eyepieces x8 or x10).

For the determination of rank at least 100 reflectances must be measured. In the case of these measurements, it should be emphasised that the reflectances of the submacerals of collinite can be slightly different. Normally the reflectance of telocollinite is measured. Reflectance measurements on desmocollinite may be rather lower, especially in low-rank coals. It is particularly important that the vitrinite in the field of measurement has no polishing defects, cracks and mineral inclusions.

In investigations on polished pillar sections, the points for measurement should be distributed throughout the whole seam thickness. For measurements on polished particulate blocks (particle size $<$ 0.75 mm), a mechanical stage and not an automatic point counter, should be used. The traverse distance on a polished surface of 4 cm^2 should be approximately 0.5mm, thus ensuring that the reflectance measurements are statistically distributed over the whole of the polished surface.

To construct a reflectogram, the 100 individual reflectance values are collected together in groups of 0.05% reflectance, that is, for example, all values between 0.80 and 0.84 or 0.85 and 0.89. These groups are designated 'half V–stages'. The 'V–stages' summarize individual values in groups of 0.1% reflectance. 'V–stage 8 (V_8)' denotes all reflectance values between 0.80 and 0.89 and results from the multiplication by 10 of the lowest reflectance value in the particular group[10] (Fig. 1).

The arithmetic mean ($\bar{\bar{R}}_{max}$), calculated from 100 measurements, is of use for standard curves giving approximately exact data for volatile-matter yield, or alternatively, for the carbon content of vitrinite (see the term 'Rank'). To obtain a comparison between the volatile-matter yield of the whole coal, determined by proximate analysis, the varying maceral composition of the coal must be considered. VM_{RM} can be calculated from the results of maceral-group analyses and the reflectance measurements[8].

Besides the mean reflectance value, it is also appropriate to calculate the degree of scatter of the reflectance. The standard deviation is a measure of the homogeneity of the vitrinite reflectance of a seam coal. It is calculated as follows:

$$\sigma = \sqrt{\frac{n}{100(n-1)} \cdot \left[\sum (R_1^2 \cdot x_1) - 100\bar{R}^2_{max} \right]}$$

where, σ = single standard deviation,
n = number of individual values (usually 100),
R_1 = mean reflectance of '½ V stage',
x_1 = % fraction vitrinite in '½ V stage', and
$\bar{R}_{max}$ = mean value of maximum reflectance.

In making comparisons of relationships between $\bar{R}_{max}$ and volatile-matter yield (dry, ash-free) established in different countries, it must be remembered that methods of determining volatile-matter yield (temperature, crucible shape and type of heating) vary. Furthermore, it is also possible that the relationship, $\bar{R}_{max}$/volatile-matter yield, even when the same methods of determination are used, has to be corrected for coals which are not of Carboniferous age or are of other origins.

II – APPARATUS EMPLOYED

The reflectance of vitrinite can be measured by subjective or objective methods.

Subjective measurements are made by the 'two-ray method' by comparing the intensity of light reflected from the coal surface with a comparison beam of specific brightness (e.g. Berek photometer). A reflected-light microscope with a monocular tube and a Berek photometer is used. Stabilization of the light source is not necessary in such investigations[1, 6].

For objective measurements a photocell or a photomultiplier in the path of a single beam is employed. A reflected-light microscope with a binocular tube is used. Focusing on the vitrinite for measurement is made with the binocular. The measuring equipment employed is mounted on the short vertical connecting tube. A completely stabilized current supply is absolutely essential to both the microscope lamp and to the measuring apparatus. An electrical stability with variation on the output current of $\pm 1.10^{-4}$A is recommended. To measure the reflected intensity, a galvanometer (minimum sensitivity approximately 10^{-10} a/mm), an automatically registering potentiometric recorder, a cathode-ray oscillosope or other recording system may be used.

All parts of the apparatus should be carefully earthed to avoid 'noise'.

III – ANALYSIS PROCEDURE

a) *Selection of Standards*

The substance used as a standard must have the following properties:-

i) good grinding and polishing characteristics,
ii) low cleavability,
iii) stability of reflectance over the longest possible time,
iv) optical isotropy, at least on the surface of the polished section, and
v) reflectance in the range of that of coals (not < 0.3 and not $> 8\%$ for measurements in oil).

It is convenient to use a series of standards, which differ from one another in their reflectance, so that the linearity of readings can be checked.

Transparent standards are prepared so that light which penetrates does not return again to the objective (cf. Fig. 2). Such standards must be embedded in a highly absorbing substance (e.g. black artificial resin). To avoid reflections at the resin/standard interface, the aim should be that both, if possible, possess the same refractive indices.

At present the following standards are used:-

	n_{546nm}	$\%R_{546nm}(oil)$
Leucosapphire	1.772	0.598 (calculated)
Standard glasses	1.6945	0.303
	1.7572	0.535
	1.8564	1.008
	1.9255	1.403
	1.9908	1.819
Diamond	–	5.305
Carborundum	–	ca.7.0–7.3

b) *Determination of the Refractive Index of the Immersion Medium*

For precise determination of the reflectances of the standard and the vitrinite, the immersion medium used should display a constant refractive index. Variation of more than ± 0.001 shows clearly in the measured reflectances. Because of this, the refractive index of the immersion oil should be checked from time to time (at least every 4 weeks), with the help of a refractometer. If the variation lies outside the stated tolerance, the correct value of the deviating oil can be attained by admixture of an oil of opposite trend. After mixing (also after vigorous stirring), the oil must stand for at least 24 hours, so that air bubbles resulting from the mixing or the stirring can escape, since the smallest air bubbles enclosed in the oil will influence the level of the measured reflectance. Short-term temperature variations of $> \pm 2.5^{\circ}C$ alter the refractive index of the oil by approximately 0.001–0.002. Thus as much work as possible at constant temperature is recommended.

c) *Examination of the Stability and Linearity of the Apparatus*
(only necessary when using single-beam apparatus)

The reflectances of vitrinite in a seam-pillar sample or in a polished particulate block prepared from a channel sample, lie scattered more or less closely around a mean value, so that to determine the mean reflectance, at least 100 measurements must be undertaken on different vitrinite bands, or alternatively, on different particles. Thus, it follows that the instrument reading (e.g. zero point) must remain constant for a long period (several hours). It is recommended in checking the stability of the detector, when using a galvanometer, that the measured value of a standard or a test sample is read and recorded every 15 minutes over a time interval of 4–5 hours. When using a pen recorder, the measured value should be recorded over the same time interval. If the variation is $>0.025\%R$, the apparatus must be checked, giving particular attention to any influence from stray and external light. In such long-term control, the temperature of the working area should also be checked every 15 minutes. With temperature variations $> \pm\ 2.5^{\circ}C$, the measurements must be rejected (see section IIIb). Care should also be taken to ensure constancy of focus.

The oil reflectance of vitrinite rises with increasing rank from approximately 0.5 to 8% and so a strict linearity must be ensured between the intensity of the reflected light and the measured photocurrent. Checking of this linearity can be achieved either by measuring the reflectances of at least three (better more) standards of clearly differing reflectance, or by using neutral-density filters which alter the intensity of the reflected light in a known manner.

d) *Determination of Parasitic Reflections and Correction of Zero Point Background*

In spite of improvements, the objectives used for reflectance measurements display parasitic reflections to some degree, so that the measurements are in error. For accurate investigations it is thus necessary to determine the intensity of the parasitic reflections for every objective used by measuring the photocurrent and then to correct the zero point correspondingly. Determination of parasitic reflections must be undertaken in a darkened working area.

The intensity of the photocurrent is measured with the standard pressed carefully plane-parallel to the microscope slide, using increased high voltage or increased sensitivity of the recording instrument which is adjusted to 100 scale divisions. The reading of 100 scale divisions is the sum of the intensity of light reflected by the standard (I_s) and the intensity produced by the parasitic reflections (I_p).

$$I_s + I_p = 100$$

After removing the standard, a completely absorbing substance or a light-reflecting device is placed under the objective and the minimum deflection of the recording instrument is measured in scale divisions. As completely absorbing substances, the following can be used:-

i) a hole drilled in the middle of the surface of a polished block of powdered coal (diameter and depth of hole approximately 2 mm; particles of coal < 0.06mm), or

ii) an internally blacked, spherical vessel, or

iii) a dark-coloured artificial resin embedded in a black glass prism.

The hole drilled in the powdered coal block or the cavity of the vessel is filled with immersion oil. As a light-deflecting device, a microscope slide in the 45^{o} position with immersion oil can be held under the objective (Fig. 3).

The intensity of the photocurrent produced by the parasitic reflections is then related to the intensity of the photocurrent of the standard. By applying the following formula, the reflectance value of the parasitic reflections is determined so that the zero point of the instrument must be corrected:-

$$R_p = \frac{I_p}{100 - I_p} \cdot R_s$$

where R_p = reflectance value of the parasitic reflections in %R,
R_s = reflectance value of the standard in %R,
I_p = intensity of parasitic reflections in scale divisions.

The correction to the zero point of the instrument is R_p.

If a value $> 0.03\%R$ is measured for the parasitic reflections, an influence of the aperture angle of the aperture and field diaphragms on the measurements becomes noticeable. In this case the aperture angle must be held absolutely constant.

e) *Preparation of Sections*

The reflectance of low-rank vitrinite ($R < 0.7\%$) falls due to the presence of a thin film of moisture on the section surface[13]. In order to avoid such a film, the section for analysis must be stored in a dessicator for at least 15 hours before measurement. By storage in a dessicator, contamination of the section is also avoided at the same time. It is therefore recommended that sections for analysis, and particularly standards, are stored in dessicators.

If the reflectance of the standards employed falls, despite constancy of measuring conditions within the equipment, this is usually traceable to contamination (a fine film of immersion oil, or something similar). In such cases the standards must be carefully reground and repolished. The sections are mounted plane-parallel to the microscope slide, since even a low angle of inclination will lower and falsify the reflectance.

f) *Measuring Procedure (Single-Beam Apparatus)*

i) *Switching on the apparatus*

Before beginning measurements, stability of the detector must be attained. Depending on the type of stabilization, a few minutes up to 1 or 2 hours may be necessary.

ii) *Adjusting the corrected zero point*

Measure the standard, adjust the zero value on the galvanometer scale, pen recorder or other recording system.

iii) *Position of the field of measurement*

Since a high amplification of photocurrent can be obtained when using a photomultiplier, the field of measurement can be much reduced, in contrast to the Berek photometer. When using objectives of approximately x25 magnification (total magnification approximately x250), the field of measurement, which is defined by inserting a diaphragm in the reflected-beam path, has a diameter of 5–10 microns. If more strongly magnifying objectives are employed, the field is correspondly smaller. Since not all equipment is fitted with a device which accurately locates the field of measurement in the field of view, when measuring vitrinite reflectances, the position of the field of measurement must be established. This can be satisfactorily accomplished with the help of a distinct and more strongly-reflecting inclusion in the coal, e.g. a pyrite concretion of approximately 5 microns diameter. To locate the measuring point, a micrometer with cross-wires or a micrometer grid is inserted in one eyepiece of the binocular tube. By moving the mechanical stage, it is possible to determine when the highly-reflecting pyrite is registering on the galvanometer, the pen recorder or the oscilloscope. The position of the pyrite grain in relation to the intersection of the cross-wire or to the micrometer grid corresponds to the position of the field of measurement and due allowance is made in subsequent measurements.

iv) *Measurement of the maximum reflectance of vitrinite (collinite) with the polariser in the* 45^{o} *position* $\overset{\leftarrow}{\diamond}$ 90^{o}

By rotating the microscope stage, the highest value can be determined by reading the galvanometer or observing the curve on the pen recorder.

v) *Zero-point control and measurements on the standards*

If the zero point or the measured value for the standard deviates by more than one scale division, all the measurements are rejected. If the stability of the detector over the period necessary for 100 measurements is doubtful, the standard should be measured at intervals (after 20–25 measurements). Should the measurements still deviate, the vitrinite reflectances measured between the readings on the two standards are rejected. The zero point and the standard values are checked before beginning to re-measure the vitrinite reflectances.

vi) *Calculation of the measurements*

The reflectance values are calculated using the formula:-

$$R_v = R_s \cdot \frac{A_v}{A_s}$$

where R_v = reflectance of the vitrinite (collinite),
R_s = reflectance of the standard,
A_v = the deflection of the galvanometer or the pen recorder for the vitrinite,
A_s = the deflection of the galvanometer or the pen recorder for the standard.

To avoid calculating 100 individual vitrinite reflectances, the galvanometer or the chart of the pen recorder can be so scaled that reflectance values can be read off directly. The scale used must be subdivided linearly and with respect to a value which corresponds to the highest expected level of reflectance. Two different scales should be used (e.g. 0–2% and 0–10% reflectance), so that with low-rank coals, a sufficient accuracy of reading can be obtained.

IV – ACCURACY OF MEASUREMENT

σ_p – standard deviation of the measuring equipment for a single measurement amounts to $\sim$ 0.005%R.
$2\sigma_p$ – confidence limit (95%) ± 0.01%R.
σ_T – standard deviation of the results of measurements on a seam sample $\sim$ 0.1%R.
$\sigma_{\bar{R}}$ – standard deviation of mean value in the case of n measurements on a seam sample = $\sigma_T / \sqrt{n}$,
where n = 100 0.01%R,
confidence limits of mean value ± 0.02%R.

Increasing the number of individual measurements beyond approximately 100 is unrealistic, because the accuracy only increases in proportion to n and therefore, for example, to increase the accuracy ten-fold, 10,000 individual measurements would be neçessary.

V – DETERMINATION OF BIREFLECTANCE AS A MEASURE OF ANISOTROPY

By measuring maximum and minimum reflectances on polished blocks cut perpendicular to the stratification, the bireflectance can be calculated by the difference $\bar{R}_{max} - \bar{R}_{min}$. The degree of anisotropy generally rises with increasing rank, but no strict relationship exists between rank and the degree of anisotropy.

VI – DETERMINATION OF THE DISPERSION OF REFLECTANCE

By using a monochromator or several filters for specific wavelengths, which are placed between the light source and the objective or, alternatively, in the reflected-beam path, the dispersion of reflectance between 300 and 800 nm can be determined. The dispersion of reflectance is independent of rank and is relatively small. In low-rank hard coals it amounts to approximately 0.3%R and in high-rank hard coals to approximately 0.75%R.

VII – DETERMINATION OF REFLECTANCE OF OTHER MACERALS

Using a single-beam apparatus with a photomultiplier and a measuring field, possibly $<$ 5 microns, the reflectances of macerals of the exinite and inertinite groups can also be determined by the same technique. Because of the small size of these macerals and their greater polishing hardness than vitrinite, measurements of this kind must always be carried out on relief-free surfaces.

The determination of the reflectances of individual macerals of the exinite or inertinite groups with a two-beam instrument cannot be recommended, because of the large field of measurement (area approximately x500–1000 larger than in the case of a single-beam apparatus). Because of the varying brightness of the reflected-light beams from different constituents in the associated half-field of view of the Ramsden ocular, brightness or colour comparisons with the comparison beam become very difficult, which can lead to inaccurate results.

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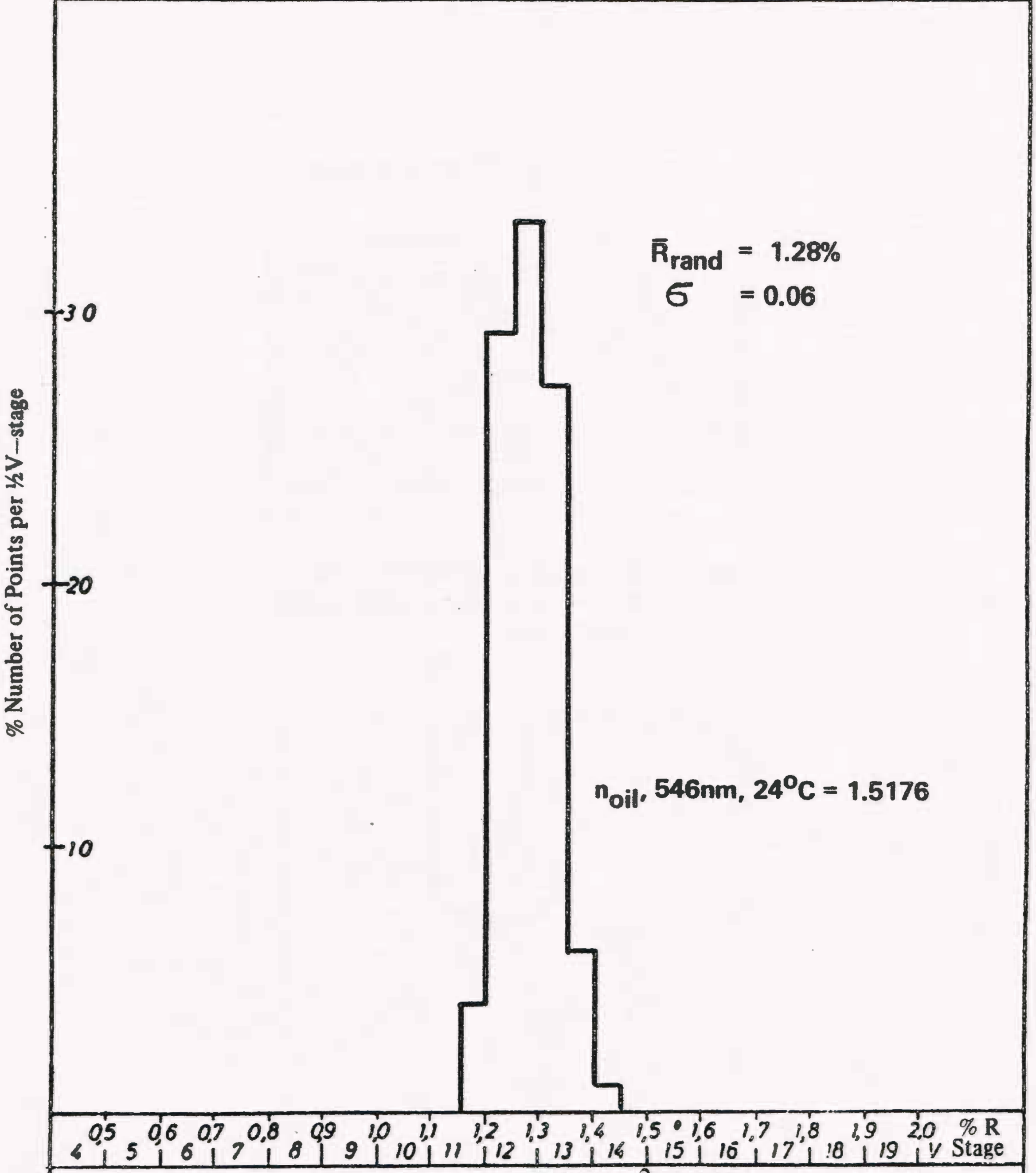
National Norms:

GOST – 12113–66 (USSR)
ASTM – Designation D2798–69T (USA)
BB 22020 Sheet 5, 1970 (GFR)

Fig. 1. Determination of Rank from the Reflectance of Vitrinite



100 points of measurement, oil immersion 1/4cm^2 = 1Vol-%, V-stage=%R.10

Range of average of maximum reflectance

<0.65%	corresponding	to	>40%	V.M.	(d.a.f.)	from	Proximate	Analysis	(ash-dry <8%)
0.65–0.90%	“	“	40–35%	“	“	“	“	“	“
0.90–1.20%	“	“	35–28%	“	“	“	“	“	“
1.15–1.65%	“	“	28–15%	“	“	“	“	“	“
1.60–2.00%	“	“	19–14%	“	“	“	“	“	“
1.90–2.45%	“	“	14–10%	“	“	“	“	“	“

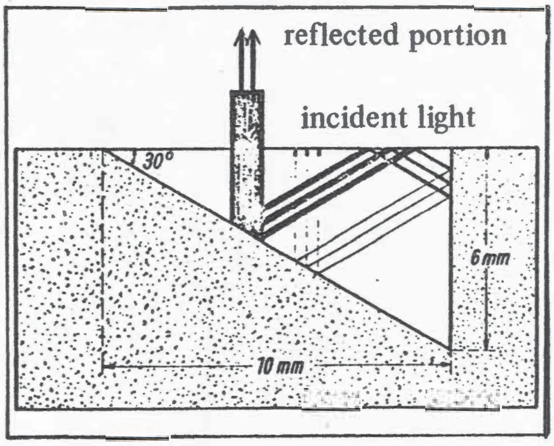


Fig. 2 Ray path in a standard used in photoelectric measurements of reflectance.

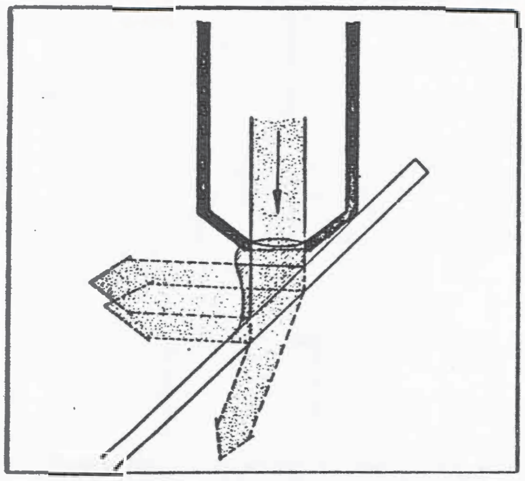


Fig. 3 Ray path when determining internal reflections of an oil-immersion objective.

1971 SUPPLEMENT	**International Committee for Coal Petrology** Nomenclature Sub-Committee **SYNONYMS AND ANALOGUES**	Hard Coal

	see page on	Synonym	Analogue
Algal coal	Boghead coal		X
Algal remains	Alginite		X
Algite (Cady)	Alginite		X
Anthraxylon	Vitrite		X
Anthraxylon (Thiessen) (>14 microns wide)	Vitrinite		X
Anthraxylon (Thiessen) (>14 microns wide)	Collinite		X
(in part)	Telinite		X
Banded constituent	Lithotype	X	
Banded ingredient	Lithotype	X	
Bâtonnets de résine	Resin rodlets		X
Black fundamental matrix	Opaque attritus		X
Black fundamental matter	Opaque attritus		X
Boghead-cannel (Renault)	Boghead coal		X
Braunkohlen-Gele	Dopplerite		X
Brown cell-wall degradation matter	Brown matter	X	
Brown matter (Thiessen)	Semifusinite		X
Cell-wall degradation matter	Translucent humic degradation matter	X	
Charbon brillant	Vitrain (SH)	X	

(SH) = Stopes-Heerlen System
(TBM) = Thiessen-Bureau of Mines System
(IGM) = Geological Institute (Academy of Sciences, Moscow) System

	see page on	Synonym	Analogue
Charbon fibreux	Fusain (SH)	X	
Charbon mat	Durain (SH)	X	
Charbon semi-brillant	Clarain (SH)	X	
Chitinite	Sclerotinite	X	
Ciment amorphe	Collinite		X
Clarite	Hydrite		X
Clayat	Coal ball		X
Coalification	Carbonification	X	
Collit (Jongmans)	Collinite		X
Component (TBM)	Maceral		X
Constituent (TBM) (in part)	Maceral		X
Corps résineux	Resin rodlets		X
Corpuscule sclerotiformes	Sclerotinite		X
Cortical tissues	Suberinite	X	
Cuticles	Cutinite		X
Cuticular substance	Cutinite		X
Cutinized elements	Liptinite	X	
Degré de houillification	Rank	X	
Degree of coalification	Rank	X	
Desmit (Ammosov)	Collinite		X
Dull coal	Durain		X
Durain	Splint coal		X
Exinite	Liptinite	X	
Exinite group	Liptinite	X	
Faserkohle	Fusain (SH)	X	
Faulschlamm-Kohle	Sapropelic coal	X	
Finely divided anthaxylous matter	Translucent humic degradation matter	X	
Funginite	Sclerotinite	X	
Fusinito-collinite (Timofeev)	Microite		X
Fusinite fragments (in part)	Intertodetrinite		X
Fusinized resins	Sclerotinite		X
Fusi-resinite	Sclerotinite		X
Fusovitrit (Jongmans)	Semifusinite	X	

	see page on	Synonym	Analogue
Gayet	Cannel coal	X	
Gefugebestandteil	Maceral	X	
Gelée fondamentale (Duparque and Bertrand)	Collinite	X	
Gelifusinite-collinite (IGM) (in part)	Macroite		X
Gelinite (Podgajni) (in part)	Collinite		X
Gelinite (IGM)	Vitrinite		X
Gelinito-collinite (IGM) (in part)	Collinite		X
Gelinito-posttelinite (IGM)	Telinite		X
(in part)	Vitrodetrinite		X
Gelinito-precollinite (IGM) (in part)	Vitrodetrinite		X
Gelinito-telinite (IGM) (in part)	Telinite		X
Gemengteil	Maceral	X	
Genetic Coal Type (IGM) (in part)	Microlithotype		X
Glanzkohle	Vitrain	X	
Grobmicrinite (in part)	Inertodetrinite		X
Halbglanzkohle	Clarain	X	
Harzkörper	Resin rodlets		X
Heterocollinite (Alpern) (in part)	Collinite		X
Homocollinite (Alpern)	Collinite		X
Houillification	Coalification (Carbonification)	X	
Huminite (brown coal)	Vitrinite		X
Humocollinite (brown coal)	Collinite		X
Humodetrinite (brown coal)	Vitrodetrinite		X
Humotelinite (brown coal)	Telinite		X
Inertit (Snyman)	Microite	X	
Ingredient	Lithotype	X	
Inkohlung	Carbonification (Coalification)	X	
Inkohlungsgrad	Rank	X	
Intermediates (Seyler)	Semifusinite	X	

	see page on	Synonym	Analogue
Kohlentonstein	Kaolin-coal tonstein	X	
Kohlentyp	Lithotype	X	
Liptinite	Exinite	X	
Liptite	Sporite	X	
Maceral	Phyteral		X
Macrotype (Cady)	Microlithotype	X	
Massive micrinite (in part)	Inertodetrinite		X
Mattkohle	Durain	X	
Microvitrain (Cady)	Vitrite		X
Mineral charcoal	Fusain (SH)		X
	Fusain (TBM)	X	
Mother of coal	Fusain (SH)		X
Nodule calcaire	Coal ball (Torfdolomit)	X	
Nodule dolomitique	Coal ball (Torfdolomit)	X	
Opaque attritus (TBM) (in part)	Intertodetrinite		X
Opaque attritus (TBM) (in part)	Macrinite		X
	Micrinite		X
Opaque matter (Thiessen) (in part)	Macrinite		X
	Micrinite		X
Opaque matter	Opaque attritus	X	
Parrot coal	Boghead coal		X
	Cannel coal		X
Pâte fondamentale (Duparque and Bertrand)	Collinite		X
Phyteral (Cady) (in part)	Maceral	X	
Plant bullion	Coal ball (Torfdolomit)		X
Provitrit (Potonié)	Telinite		X
Pulpe végétale (Duparque) (in part)	Macroite		X
	Microite		X
Rank	Rang	X	
Residuum (Kellet)	Micrinite		X
Resin canal casts	Resin rodlets (resin bodies)	X	

	see page on	Synonym	Analogue
Resin casts	Resin rodlets (resin bodies)	X	
Resin fibrils	Resin rodlets (resin bodies)	X	
Resin needles	Resin rodlets (resin bodies)	X	
Resin rodlets (in part)	Resinite		X
Resin rods	Resin rodlets (resin bodies)	X	
Resinous bodies	Resin rodlets (resin bodies)		X
Resinous components	Resin rodlets (resin bodies)		X
Resinous constituents	Resin rodlets (resin bodies)		X
Resinous substance	Resinite		X
Rock type	Lithotype	X	
Russkohle	Fusain (SH)		X
Sapanthracit (Potonié) (Sapropel-Anthrazit)	Sapropelic coal		X
Sapanthrakon (Potonié) Sapropel-Steinkohle)	Sapropelic coal		X
Sclerotia (Kosanke)	Resin rodlets		X
Seam nodule	Coal ball (Torfdolomit)		X
Semifusain (in part)	Semifusinite		X
Semi-opaque matter	Brown matter	X	
Semi-translucent matter	Brown matter	X	
Splint coal	Durain		X
Spore and pollen remains	Sporinite		X
Spore-coat material	Sporinite		X
Sporite	Liptite	X	
Stabilprotobitumina (Potonié)	Exinite-liptinite	X	
Streifenart (in part)	Microlithotype	X	
Substance fondamentale (Duparque and Bertrand)	Collinite	X	
Subtype (in part)	Microlithotype	X	

	see page on	Synonym	Analogue
Tonstein	Kaolin-coal tonstein	X	
Torbanite	Boghead coal	X	
Torfdolomit	Coal ball	X	
Torf-Gele	Dopplerite		X
Translucent humic degradation matter (Thiessen) (in part)	Degradinite		X
Translucent humic matter	Translucent humic degradation matter	X	
Type of coal (TBM)	Microlithotype		X
Type of microcomponent (IGM) (in part)	Microlithotype		X
Übergangsstufen (Kuhlwein)	Semifusinite	X	
Ugolnaja potschka	Coal ball (Torfdolomit)		X
Vitrinite A (Brown, Cook and Taylor (in part)	Collinite		X
Vitrinite B (Brown, Cook and Taylor (in part)	Collinite		X
Vitrofusit (Stach)	Semifusinite	X	
Xylain (Duparque)	Semifusinite	X	
Xylovitrain (Duparque)	Fusite		X
	Telinite		X
Zone type	Lithotype	X	
Zwischenstufen	Trimacerite		X

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	see page on	Synonym	Analogue
Attrinite (Minčev)	Humodetrinite		X
Attritus (Waltz)	Humodetrinite		X
Bitumen, formless (Teichmüller)	Liptodetrinite		X (in part)
Braunkohlengel (Schochardt)	Gelinite	X	
Brown-coal gel (Berger)	Dopplerite		X
Chitnit (Draht)	Sclerotinite		X
Collinite (Babinkova and Moussial)	Gelinite		X (in part)
Corpuscules sclerotiformes (Duparque)	Sclerotinite		X
Desminite (Minčev)	Gelinite		X
	Humocollinite		X (in part)
	Humodetrinite		X (in part)
Desminite (Waltz)	Humodetrinite		X
Detrinite (Svoboda, Jacob)	Attrinite		X (in part)
(Svoboda, Jacob)	Densinite		X (in part)
(Svoboda, Malan, Sontag *et al*)	Humodetrinite	X	
Detrinite, gelified (Sontag *et al*)	Densinite	X	
Detrinite group	Humodetrinite	X	
Detrinite, ungelified (Sontag *et al*)	Attrinite	X	
Detritus (Wiesner)	Attrinite		X (in part)
	Densinite		X (in part)
Detritus, humic (Teichmüller)	Attrinite		X (in part)
	Densinite		X (in part)
	Humodetrinite	X	
Dopplerinite (Jacob)	Gelinite	X	
Dopplerinite group (Jacob)	Humocollinite	X	
Funginite (Benes)	Sclerotinite	X	
Fungo-sclerotinite (Duparque)	Sclerotinite	X	
Fusinite fragments (ICCP, 1963)	Inertodetrinite		X (in part)
Fusinized resins (Kosanke)	Sclerotinite	X	
Fusiresinite (Pareek)	Sclerotinite	X	

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	see page on	Synonym	Analogue
Gelinite (Malan, Podgajni, Sontag et al., Timofeev and Bogoliubova)	Huminite		X
	Humocollinite	X	
Gelinito-collinite (Timofeev and Bogoliubova)	Gelinite		X
	Humocollinite		X
Gelinito-posttelinite (Timofeev and Bogoliubova)	Attrinite		X (in part)
	Densinite		X (in part)
Gelinito-posttelinite (Timofeev and Bogoliubova)	Humodetrinite		X
	Attrinite		X
	Ulminite		X
Gelinito-precollinite (Timofeev and Bogoliubova)	Attrinite		X (in part)
	Densinite		X (in part)
	Humocollinite		X
	Humodetrinite		X
Gelinito-telinite (Timofeev and Bogoliubova)	Humotelinite		X
	Textinite		X
	Ulminite		X
Grobmikrinit (ICCP, 1963)	Inertodetrinite		X (in part)
Groundmass-attrital (Hock)	Attrinite		X (in part)
	Densinite		X (in part)
Groundmass-detrital (Hock)	Attrinite		X (in part)
	Densinite		X (in part)
Groundmass-herbaceous (Schochardt, Hock)	Attrinite		X (in part)
	Densinite		X (in part)
	Humodetrinite	X	
Groundmass-humic (Hock)	Attrinite		X (in part)
	Densinite		X (in part)
Humified plant tissues (Teichmüller)	Humotelinite	X	
	Textinite		X
Huminite (Svoboda)	Gelinite		X
Humophyte (Svoboda)	Humotelinite	X	
Humus gel (Hummel, Berger)	Gelinite	X	
Massive micrinite (ICCP, 1963)	Inertodetrinite		X (in part)
Melanoresinite	Corpohuminite	X	
Peat gel	Dopplerite		X
Peat and gelification collinite (Stach)	Gelinite		X
Plant tissue (Teichmuller)	Textinite		X
Phlobaphenite (Szádeczky-Kardoss)	Corpohuminite		X
Phyllinite (Svoboda)	Textinite	X	

	see page on	Synonym	Analogue
Resinite (Teichmuller)	Corpohuminite		X (in part)
Resin rodlets (Kosanke)	Sclerotinite		X
Resino sclerotinite (Benes)	Sclerotinite		X
Retinite Jacob)	Resinite	X	
Sclerotioid (Haquobard)	Sclerotinite		X
Sclerotites (Stach)	Sclerotinite	X	
Semigelinito-collinite (Timofeev and Bogoliubova)	Humocollinite		X
Semigelinito-posttelinite (Timofeev and Bogoliubova)	Humodetrinite		X
Semigelinito-precollinite (Timofeev and Bogoliubova)	Humodetrinite		X
Semigelinito-telinite (Timofeev and Bogoliubova)	Humotelinite		X
Sporinites (Potonie Kremp)	Sclerotinite		X
Structurevitrain (Žemčužnikov and Ginsburg)	Humotelinite Ulminite		X X
Textinite (Sontag, Tschoppe and Christoph)	Humotelinite Ulminite	X X	
Textinite, ungelified (Sontag, Tschoppe and Christoph)	Textinite	X	
Textinite, partly gelified (Sontag, Tschoppe and Christoph)	Ulminite (Texto-ulminite)	 (X)	X
Textinite, gelified (Sontag, Tschoppe and Christoph)	Ulminite (Eu-ulminite)	(X) (X)	
Torf-Collinit (Stach)	Gelinite		X
Torf-Dopplerit	Dopplerite	X	
Translucent humic degradation matter (Thiessen)	Attrinite Densinite Humodetrinite		X (in part) X (in part) X
Vergelungs-Collinit (Stach)	Gelinite		X
Vitrinite δ (Waltz)	Humocollinite		X
Vitrinite (Minčev)	Humotelinite Eu-Ulminite		X X
Weichbraunkohlen-Dopplerit	Dopplerite		X

	see page on	Synonym	Analogue
Xanthoresinit (Szadeczky-Kardoss)	Resinite	X	
Xylinite (Szadeczky-Kardoss,	Humotelinite	X	
Svoboda, Jacob)	Textinite		X
Xylinite (Mincev)	Humotelinite		X (in part)
	(Texto-ulminite)		(X)
Xylinite and (Waltz)	Humotelinite		X
Xylinite group (Jacob, Malan)	Humotelinite	X	
Xylo-dopplerinite (Jacob)	Ulminite		X
Xylotelinite (Svoboda)	Texto-Ulminite		X
Xylovitrain (Zemcuznikov and Ginsburg)	Ulminite		X
Xylovitrinite (Mincev)	Ulminite		X

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International Committee for Coal Petrology
Nomenclature Sub-Committee

REFERENCES FOR BROWN-COAL NOMENCLATURE
(Stopes-Heerlen System)

Brown Coal

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1971	**International Committee for Coal Petrology** Nomenclature Sub-Committee Analysis Sub-Committee	Brown Coal
SUPPLEMENT	**ALPHABETICAL INDEX**	Hard Coal

(IGM) = Geological Institute (Academy of Sciences, USSR) System
(SH) = Stopes-Heerlen System
(TBM) = Thiessen-Bureau of Mines System
(USA) = Spackman System

[+] sheets for these macerals not issued until 1975

Vitrain
Vitrinertite
Vitrinertoliptite
Vitrinite
Vitrite
Vitrodetrinite