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Classification of huminite—ICCP System 1994

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Abstract

In the new classification (ICCP System 1994), the maceral group huminite has been revised from the previous classification (ICCP, 1971. Int. Handbook Coal Petr., suppl. to 2nd ed.) to accommodate the nomenclature to changes in the other maceral groups, especially the changes in the vitrinite classification (ICCP, 1998. The new vitrinite classification (ICCP System 1994). Fuel 77, 349–358.). The vitrinite and huminite systems have been correlated so that down to the level of sub-maceral groups, the two systems can be used in parallel. At the level of macerals and for finer classifications, the analyst now has, according to the nature of the coal and the purpose of the analysis, a choice of using either of the two classification systems for huminite and vitrinite. This is in accordance with the new ISO Coal Classification that covers low rank coals as well and allows for the simultaneous use of the huminite and vitrinite nomenclature for low rank coals.
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1. Introduction

The International Committee for Coal and Organic Petrology (ICCP) is continuously revising ICCP's classification systems for macerals. A new vitrinite classification system was published in 1998 (Fuel 77, 349–358, ICCP, 1998), and in 2001, the new inertinite classification system was published (Fuel 80, 459–471, ICCP, 2001). These systems are collectively referred to as the "ICCP System 1994". They are the result of the work of two editorial groups combined with extensive discussions and revisions of prepared drafts during several annual ICCP meetings attended by numerous international experts.

This document presents the ICCP huminite classification and is also a part of the "ICCP System 1994". The definitions of the huminite macerals have been

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presented, discussed and approved at annual ICCP meetings.

2. Huminite

2.1. Origin of term

Term introduced by Szádecky-Kardoss (1949) for a structural constituent of brown coals (now commonly termed lignites). The ICCP has used this term for a maceral group of lignites (brown coals) since 1970. Derivation: *humus* (L)–soil.

2.2. Related terms

Vitrinite (low, medium and high rank coals; ICCP, 1998).
Gelinite (Babinkova and Moussial, 1965; Belau et al., 1967).

2.3. Definition

Huminite designates a group of medium grey macerals having reflectances generally between those of the associated darker liptinites and the lighter inertinites.

2.3.1. Comment

The huminite group is subdivided into three maceral subgroups and six macerals; partly, the latter are subdivided in maceral types, submacerals and maceral varieties (see Table 1). The maceral subgroups are divided by structure (degree of preservation of the plant residues) and the macerals by gelification (gelohuminite excluded). Maceral varieties show differences in reflectance. The A varieties are generally lower in reflectance than the corresponding B varieties.

Table 1
The new Huminite system, huminite terminology bold, the corresponding vitrinite in normal font

Maceral group	Maceral subgroup
Huminite/vitrinite	Telohuminite/Telovitrinite
	Detrohuminite/Detrovitrinite
	Gelohuminite/Gelovitrinite

2.3.2. Note

Huminite and its macerals are defined only for lignites/soft brown coals. For subbituminous coal, the coal of the highest rank within the low rank coal, the vitrinite nomenclature, is used.

2.4. Physical properties

2.4.1. Colour and reflectance

Both depend on rank, gelification degree, botanical origin and chemical composition of the huminite macerals (Cameron, 1991; Taylor et al., 1998). The colour is dark to medium grey. Random reflectance measured in oil ranges between ~0.2 and 0.4% R_r. The upper reflectance limit has been taken as the reflectance value separating low rank coal and medium rank coal in the ECE classification (1988). In general, huminite is isotropic. Anisotropy (bireflectance) occurs if remnants of cellulose are present. This phenomenon, more easily visible in transmitted light, is used for the identification of cellulose.

2.4.2. Note

Huminite reflectance in peat may vary between 0.1% and 0.26% R_r depending on the type of the submacerals (Cohen et al., 1987) (Table 2).

2.4.3. Fluorescence

Fluorescence colour and intensity are dependent on the rank, the degree of degradation, humification and bituminization of the huminite. The colour ranges from yellow-brown to red-brown and is most marked in textinite A and ulminite A (Taylor et al., 1998).

2.4.4. Polishing hardness

Huminite is soft and shows no relief in relation to the accompanying liptinite and inertinite macerals (except corpohuminite).

2.5. Chemical properties

Huminite is characterized by relatively high oxygen and low carbon contents compared with the macerals of the other two groups (Cronauer et al., 1992; Stankiewicz et al., 1996). The elemental composition is rank dependent, carbon increases and oxygen decreases during the coalification process

Table 2
Subdivision of the maceral group huminite

Maceral group	Maceral subgroup	Maceral	Maceral type	Maceral variety
HUMINTE	TELOHUMINITE	Textinite		A (dark)
				B (light)
		Ulminite		A (dark)
				B (light)
	DETROHUMINITE	Attrinite		
		Densinite		
	GELOHUMINITE	Corpohuminite	Phlobaphinite	
			Pseudophlobaphinite	
		Gelinite	Levigelinite	
			Porigelinite	

(van Krevelen, 1993; Taylor et al., 1998) and ranges as follows:

Carbon	60–77%
Hydrogen	4–6%
Oxygen	18–28%

The primary organic components of the humic matter cellulose, lignin and tannin, alter during humification and peatification and disappear in the course of the ortholignite stage. The newly formed humic acids condense step by step to larger molecules, losing their acid character and forming alkali-insoluble "humins" (Given and Dyrkacz, 1988; Teichmüller, 1989; Diessel, 1992; Taylor et al., 1998). The atomic ratios H/C and O/C and the amount of methoxyl groups decrease as a result of biochemical processes, while aromaticity and the content of carboxyl groups increase (Hatcher et al., 1981; Liu et al., 1982; Russel and Barron, 1984; Chafee et al., 1984). Also, highly phenolic signatures of the lignin-derived material within the huminite with only minor content of aliphatic groups are typical for huminite (Chafee et al., 1984; Mastalerz and Bustin, 1993a, b; Stankiewicz et al., 1996).

2.5.1. Note

From NMR and Py-GC-MS data, it is evident that amongst the chemical structures in lignitic wood and huminite, the catechol-like rings are dominant whereas the major components in vitrinite may be phenol-like structures (Hatcher and Clifford, 1997).

2.6. Derivation

Huminite is derived from parenchymatous and woody tissues and the cellular contents of roots, stems, barks and leaves composed of cellulose, lignin and tannin. Depending on the process of decomposition, the degree of humification and gelification and the rank, cell structures are preserved and visible to varying extents. The macerals of the huminite group are defined by the different structures resulting from different sources and pathways of transformation within the mires. The source of the dark A varieties of the huminite macerals is conifer wood or may be related to hydrogen-rich conditions in the peat (Sykes et al., 1994; Taylor et al., 1998). For further information, see corresponding macerals.

Huminite is the precursor of vitrinite.

2.7. Occurrence

Huminite occurs in coal seams formed as a result of anaerobic preservation of lignocelluloses material in mires. It also occurs in peat, soils (horizon A) and sediments. In humic clays, it is preserved if the organic and mineral matter is deposited rapidly.

In most Tertiary coals, huminite is the main component. It may exceed 90%.

2.8. Practical importance

The degree of humification and especially gelification of huminite in coal affects most industrial processes such as briquetting, carbonization, liquefaction, gasification and combustion (for further information, see corresponding macerals).

The reflectance of the B-varieties of the telohuminite macerals is a reliable rank parameter. If these maceral varieties are not present (which may be possible in sediments other than coal), densinite and corpohuminite may be used with restriction (Taylor et al., 1998).

3. Telohuminite

3.1. Origin of term

Term introduced by the ICCP 1970 to denote huminite with cell structure. This structure is visible to variable extent in reflected white light. Derivation: *humus* (L)–soil, *tela* (L)–tissue.

3.2. Related terms

Humoses Pflanzengewebe (Teichmüller, 1950)
Humophyt (Svoboda, 1956)
Xylinit (Szádecky-Kardoss, 1949; Waltz, 1956)
Xylinit-Gruppe (Jacob, 1961)
Textinit (Sontag et al., 1965)
Telovitrinit (Jacob, 1970)
Humotelinite (ICCP, 1971)

3.3. Definition

Telohuminite is a subgroup of the maceral group huminite comprising macerals with preserved intact botanical cell structures visible to various extents and isolated cells showing reflectance between the darker liptinite and the lighter inertinite macerals.

3.3.1. Comment
The subgroup comprises the macerals textinite and ulminite distinguishable by their different degree of gelification. Textinite shows separate cell walls, ulminite consists of clearly recognizable but compressed and gelified cell walls.

3.3.2. Note
Huminite that shows cellular structures only after etching is called telogelinite.

3.4. Physical properties

See Textinite and Ulminite.

3.5. Chemical properties

See Huminite, Textinite and Ulminite.

3.6. Derivation

The macerals of this subgroup derive from the parenchymatous and woody tissues of roots, stems, barks and leaves chemically composed of cellulose and lignin, originating from herbaceous and arborescent plants. Large amounts of telohuminite indicate a high degree of cell tissue preservation under wet, possibly low pH conditions within forested peatlands or forested wet raised bogs (Diessel, 1992). Most of the telohuminite in Tertiary lignites originate from coniferous wood, whereas angiospermous wood and the non-lignified tissues of herbaceous plants are structurally more or less decomposed (Diessel, 1992). Telohuminite is the precursor of telovitrinite in medium rank and high rank coals.

3.7. Occurrence

See Textinite and Ulminite.

3.8. Practical importance

See Textinite and Ulminite.

4. Textinite

4.1. Origin of term

Term proposed to the ICCP in 1963 to describe huminitic cell wall material in lignites (brown coals). In the same sense used by Sontag et al. (1965). In 1970 the ICCP restricted the term to a maceral consisting of ungelified cell wall material. Derivation: *textum* (L)–tissue.

4.2. Related terms

Textinit, nicht vergelt (Sontag et al., 1965)
Pflanzengewebe (Teichmüller, 1950)
Xylinite and Phyllinite (Svoboda and Beneš, 1955)

Xylinite (Szádecky-Kardoss, 1949; Jacob, 1961; Minčev, 1962)

Gelinito-Telinit (Timofeev et al., 1962; Timofeev and Bogoliubova, 1965)

4.3. Definition

Textinite is a maceral of the maceral group huminite, subgroup telohuminite, consisting of ungelified cell walls either of isolated but intact individual cells or within tissues (see (Figs. 1, 2, 4 and 10).

4.3.1. Comment

Size and form of the cells may vary; they greatly resemble the original cell structures. The cell lumens are mainly open, or filled with other macerals or with minerals. Most common fillings are resinite, corpo-huminite, porigelinite, micrinite, clay minerals and carbonates. In tissues, the cell walls may be deformed or torn. As long as the tissue is recognizable, its ungelified cell walls are called textinite. Isolated cells have to be more or less intact. Single fissures, whose width does not exceed the thickness of the cell wall, are included. Primary internal cell wall structures may be preserved (e.g., lamination, intracellular spaces).
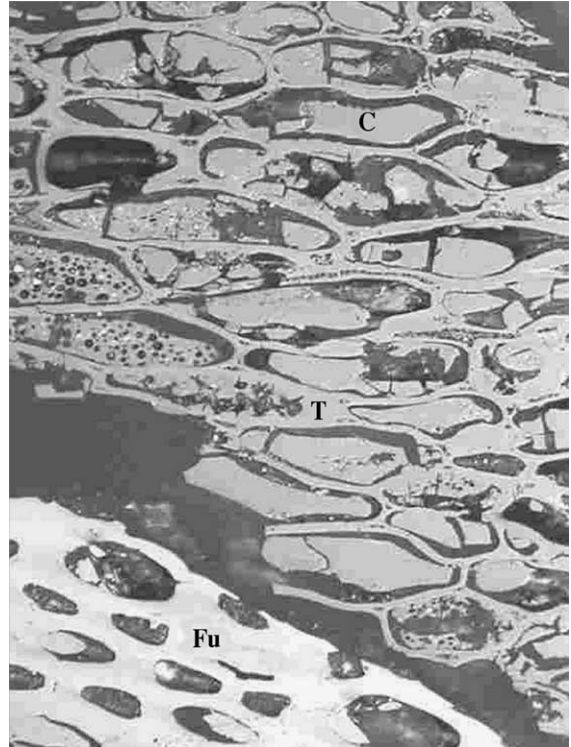

Fig. 2. Textinite (T) and corpohuminite (C) in lignite, together with fusinite. Kuhfeldschichten (Lower Cretaceous, Valendis), Germany. Reflected white light mode, field width: 0.17 mm.
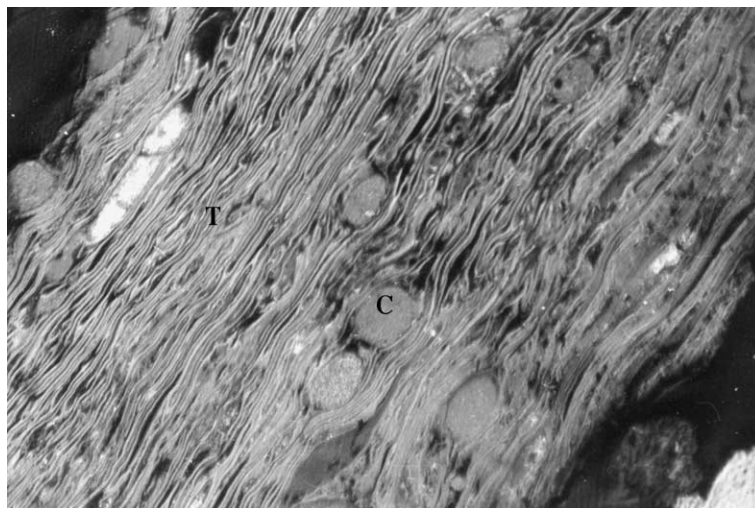

Fig. 1. Textinite (T) with corpohuminite (C) in Miocene lignite coal, Basic seam, Central part of the North Bohemian Basin, Czech Republic. Reflected white light, field width: 0.24 mm.

Two varieties of textinite exist: textinite A has a lower reflectance than textinite B.

4.3.2. Note

Ungelified huminitic cell wall relics that do not match the textinite definition belong to attrinite. Cell wall material of fungal tissues does not belong to textinite, irrespective of its reflectance. Also, the inner low reflecting waxy layer of root tissues and cork is not part of textinite (see Suberinite).

4.4. Physical properties

4.4.1. Colour and reflectance

Textinite A is dark grey, commonly with a brownish tinge and abundantly with orange to red-brown internal reflections. Textinite B is grey and does not show internal reflections. The reflectance of textinite A is very low and close to the reflectance of the accompanying liptinite macerals. Textinite B shows rank dependent reflectances of ~ 0.2 to $\sim 0.4\%$ R_r. In reflected light, textinite is isotropic. In transmitted light, textinite A shows strong anisotropy, produced by remnants of cellulose.

4.4.2. Fluorescence

In general, the fluorescence varies from dirty yellow to brown. In textinite A, the fluorescence intensity is higher than in textinite B, but is lower than that of the accompanying liptinite macerals.

4.4.3. Polishing hardness

Textinite is soft. In polished blocks, it does not show any relief.

4.5. Chemical properties

Textinite consists of humic substances as well as of the remains of cellulose and lignin. Significant differences exist between the chemical composition of textinite A and textinite B. Whereas textinite B in general is composed only of humins and remains of lignin, textinite A may contain remarkable portions of cellulose, resins, waxes and tannin. Süss (1959) published chemical data for xylites of different humification stages of

which the so-called "mummified wood" and the cellulose containing xylite corresponds microscopically to textinite:

Humic substances	4–20% (dry, ash-free)
Cellulose	25–45% (dry, ash-free)
Tar	22–26% (moisture-free)
Ash	0.2–0.5%

4.6. Derivation

Textinite derives from the cell walls of parenchymatous and woody tissues of roots, stems and barks, rarely also from leaves, composed of cellulose and lignin. It originates from both herbaceous and arborescent plants. Textinite A in most cases is formed from gymnosperm wood (Taxodiaceae, Cupressaceae) or from special roots (e.g. *Marcoduria inopinata*). Textinite B results from angiosperm wood and herbaceous plants. Textinite is the precursor of telinite in medium rank coals.

4.7. Occurrence

The amount of textinite in lignite depends largely on the degree of gelification and rank. Textinite occurs more or less in all lignites to various extents. Large amounts of textinite indicate a high degree of cell–tissue preservation under relatively dry, possibly low pH conditions within forested peatlands or forested raised bogs (Diessel, 1992). The chemical composition of a tissue affects its preservation. Textinite A, impregnated with resins, tannin, etc. is chemically more resistant than textinite B. Therefore, in Tertiary lignites textinite A is generally more common than textinite B.

4.8. Practical importance

Textinite influences the technical properties of lignites markedly only where present in large amounts. Following Jacob (1956, 1959), Süss (1959), Sontag and Süss (1969a,b), the main properties are:

Preparation   With regard to its elasticity, textinite rich coal is difficult to grind. Unge-

lified wood composed of textinite, breaks to fibrous pieces making sieving difficult. Therefore, textinite is concentrated in the coarse size fractions.

Briquetting　Textinite increases the briquetting properties of low rank lignites with moisture contents of 7055%. In general, briquettes produced from low rank lignites containing textinite are of high strength.

Carbonization　Due to its high content of cellulose and/or resin, textinite produces high yields of tar (1520%) and gas. The char yield is rank-dependent (Süss et al., 1968).

Extraction　Textinite produces low yields of bitumen.

Liquefaction　Texinite's reactivity is lower than that of gelified huminite macerals (Shibaoka, 1982).

Combustion　Textinite-rich low-rank lignites with poor milling properties can create problems. Dependent on the amount of elongated fibrous grains (see Preparation) nozzles may be blocked. The combustion of such big grains is incomplete (Allardice and Newell, 1991).

Weathering　Textinite is relatively resistant against weathering. By oxidation, humic compounds are formed, that result in gelinite with low contents or without cellulose.

Stratigraphy　The texture of textinite can be used for the identification of certain plants and therefore for stratigraphic correlations. For example, in Central Europe, the typical bast tissues of palms do not occur earlier than Late Miocene.

Schneider (1984) gave an excellent survey of various textinites in Tertiary lignites (brown coals) of Lusatia (Germany) according to their origin from roots, wood, bark, and leaves. Kuan et al. (1996) show textinite textures from Chinese Tertiary coals.

5. Ulminite

5.1. Origin of term

Term used at first by Stopes (1935) for "completely gelified plant material" in coals. In 1970 introduced by the ICCP to denote more or less gelified plant tissues in which cell structures still can be seen. Derivation: *ulmus* (L)—elm; ulmin is a decomposition product of diseased elms (Vauquellin, 1797).

5.2. Related terms

Textinit, halb vergelt;Textinit, vergelt (Sontag et al., 1965)
Xylovitrinit, Vitrinit (Minčev, 1964)
Gelinito-Telinit, Gelinito-Posttelinit (Timofeev et al., 1962)
Xylovitrain, Strukturvitrain (Žemčužnikov and Ginsburg, 1960)
Xylo-Dopplerinit (Jacob, 1961)

5.3. Definition

Ulminite is a maceral of the maceral group huminite, subgroup telohuminite that denotes the cell walls of more or less gelified tissues (see Figs. 3 and 7).

5.3.1. Comment
Size and shape of the cell walls can vary. Due to homogenisation, structures within the cell walls are not visible. The cell lumens are closed. As a result of the gelification process, the cell walls are markedly swollen and therefore thicker than those of textinite of the same plant origin. In tissues, the cell walls are packed together. Shrinkage fissures may occur.

Two varieties of ulminite can be distinguished on the basis of reflectance. Ulminite A is dark, ulminite B is light (further details see below).

5.3.2. Note
The optical appearance of ulminite B is similar to that of telinite in medium rank coals. The above-mentioned shrinkage fissures should not be confused with fissures that result from weathering.
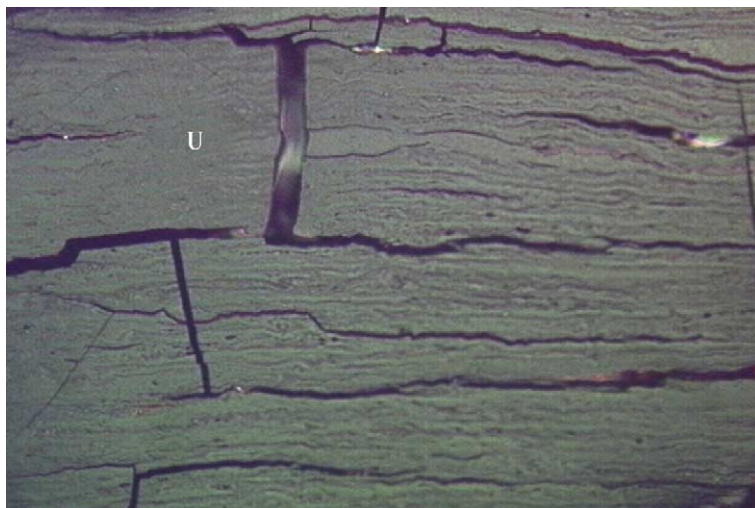
Fig. 3. Ulminite (U). Kuhfeldschichten (Lower Cretaceous, Valendis), Germany. Reflected white light mode, field width: 0.22 mm.

5.4. Physical properties

5.4.1. Colour and reflectance

Ulminite A is dark gray, ulminite B gray, rarely with a brownish cast. Ulminite A may show weak orange internal reflections. The reflectance of ulminite B is rank dependent, it varies between ~0.2 and ~0.4% R_r, ulminite A of the same coal shows a significant lower reflectance.

5.4.2. Fluorescence

Dirty-yellow, brown to dark brown. Ulminite A shows higher fluorescence intensity than ulminite B. Fluorescence intensity decreases within increasing gelification and the rank.

5.4.3. Polishing hardness

Ulminite is soft. It shows no relief against other macerals.

5.5. Chemical properties

Ulminite consists of humic acids, humates and traces of lignin and cellulose (Süss, 1959). According to Taylor et al. (1998), gelified cell walls are free of cellulose. Therefore, the relatively low reflectance of ulminite A must be related to resin or wax impregnations in the cell walls. Also decomposition products of cellulose may be present.

The elemental composition is rank dependent (see Huminite).

5.6. Derivation

Ulminite derives from the parenchymatous and woody tissues of roots, stems, barks and leaves, composed of cellulose and lignin, of herbaceous and arborescent plants. Large amounts of ulminite indicate a high degree of cell–tissue preservation under wet, possibly low pH conditions within forested peatlands or forested wet raised bogs (Diessel, 1992). According to Taylor et al. (1998), the biochemical gelification process is accelerated in waterlogged environments by the supply of specific ions (e.g. Na, Ca). Woods in which the cell walls are impregnated with resin, wax, tannin, etc. are very resistant against chemical and structural decomposition. Therefore, ulminite A derived from gymnosperms is more abundant in Tertiary lignites than ulminite B derived from various angiosperms. The relation between ulminite A and B does not mirror the primary vegetation of a mire. Ulminite is the precursor of collotelinite in medium and high rank coals.

5.7. Occurrence

Ulminite is formed primarily in peat and soil under wet conditions and in limnic sediments (see Deriva-

tion) but also by rank. Therefore, enrichment in ulminite reflects both, palaeoenvironmental conditions and advanced coalification. Lignites derived from wet forested peatlands show higher amounts of ulminite than those derived under dry conditions with a high rate of decay. The amount of ulminite increases also at the cost of textinite with increasing rank.

5.8. Practical importance

The technological properties of ulminite depend on its degree of gelification (Jacob, 1959; Sontag and Süss, 1969a,b; Cameron et al., 1984).

5.8.1. Preparation
Since gelification increases the hardness of huminite macerals and drying promotes the formation of fissures, ulminite has a better grindability than textinite. It is enriched in the finer size fractions.

5.8.2. Briquetting
High contents of ulminite prevent the development of links between coal grains during binderless briquetting. The briquettes have a low strength.

5.8.3. Carbonization
Ulminite produces lower yields of tar and gas and higher amounts of char than textinite.

5.8.4. Hydrogenation
Ulminite reacts at lower temperatures compared with textinite (Kurtz, 1981).

5.8.5. Rank determination
The reflectance of ulminite B is a reliable rank parameter. It correlates well with other rank-sensitive parameters such as the calorific value or the carbon content.

6. Detrohuminite

6.1. Origin of term

Term introduced by the ICCP in 1970 to denote a subgroup of huminite. Derivation: *humus* (L)–soil; *detritus* (L)–a product of disintegration.

6.2. Related terms

Transmitted light microscopy: Translucent humic degradation matter (Thiessen, 1930)

Reflected light microscopy	Detrinit-Gruppe (Jacob, 1961)
	Detrinit (Malán, 1965; Sontag et al., 1965; Svoboda, 1956)
	Attrite and desmite (Waltz, 1960)
	Attrinite (Minčev, 1964)
	Desminite (Minčev, 1964), in part
	Humodetrinite (ICCP, 1971)
	Detrohuminite (Kalkreuth et al., 1991), in part

6.3. Definition

Detrohuminite is a subgroup of the maceral group huminite consisting of fine humic fragments (<10 μm) of a reflectance between those of liptinite and inertinite macerals, that may be cemented by amorphous humic matter.

6.3.1. Comment
Detrohuminite consists in coals of loosely packed cell fragments or other humic plant debris. Depending on its gelification, detrohuminite is subdivided into the macerals attrinite (not gelified) and densinite (gelified). Differences in the texture of both macerals may be determined in more detail by transmission electron microscopy (Taylor et al., 1982, 1983; Rascher et al., 1983). In sediments, all humic fragments that cannot be grouped with certainty to other huminite macerals are called detrohuminite even when their size is>10 μm.

6.4. Physical properties

See Attrinite and Densinite.

6.5. Chemical properties

The chemical composition of detrohuminite is more or less independent on its degree of gelification (Gaines et al., 1981).

Detrohuminite at early stage of coalification is derived from demethylated dehydrated lignin monomers intermixed with lipids such as polymethylene

long chain acids, esters and triterpenoids of both higher plant and microbial origin (Taylor et al., 1982).

Infrared spectra are characterized by absorption due to aliphatic and aromatic structures, hydroxyl and carboxyl groups. Densinite may contain a larger proportion of chemical structures that are more or less identical with those in the original plant material (e.g. phenyl propane) (Gaines et al., 1981). The degraded lignin structure is closer to that derived from present day gymnosperms than that from angiosperms as confirmed by the presence of guaiacyl structural units (Taylor et al., 1982). Some chemical features of three low rank lignites composed mainly of detrohuminite are shown in Table 3.

6.6. Derivation

The macerals of this group derive from herbaceous and arborescent plants through the strong decay of parenchymatous and woody tissues of stems and leaves. Herbaceous plants and angiosperm woods disintegrate more readily than lignified cell walls (Teichmüller, 1989; Diessel, 1992; Taylor et al., 1998) but also conifers contribute to detrohuminite (von der Brelie and Wolf, 1981). Detrohuminite is the precursor of detrovitrinite in medium and high rank coals.

6.7. Occurrence

Detrohuminite is the main constituent of Tertiary lignites. In general, its content is >50% (von der Brelie and Wolf, 1981). In pale coals it may exceed 90%.

6.8. Practical importance

Dependent on the gelification degree, detrohuminite-rich coal is suitable for a range of industrial processes, e.g. briquetting, coke production, production of organic fluids and gases by low temperature carbonization (Kurtz, 1981; Durie, 1991). (for details see Attrinite and Densinite).

7. Attrinite

7.1. Origin of term

Term suggested by Babinkova and Moussial (1965) following a proposal of the Association of Coal Petrographers of the USSR in 1963. Originally, the term denoted gelified particles in lignites. The ICCP has used the term since 1970 for a maceral of the huminite group that consists of fine humic particles that form the non-gelified "groundmass" of (brown) coals. Derivation: attritus (L)–matter pulverized by attrition.

7.2. Related terms

Detritus (Wiesner, 1892)
Unvergelter Detrinit (Sontag et al., 1965)
Humoser Detritus (Teichmüller, 1950)
Detrinitische, attrinitische, krautige oder humose Grundmasse (Hock, 1932)
Gelinito-Posttelinit, Gelinito-Praecollinit (Timofeev and Bogoliubova, 1964)

7.3. Definition

Attrinite is a maceral of the maceral group huminite, subgroup detrohuminite, consisting of a mixture of fine huminitic particles (<10 μm) of different shape and spongy to porous, ungelified amorphous huminitic substances (Figs. 4 and 5).
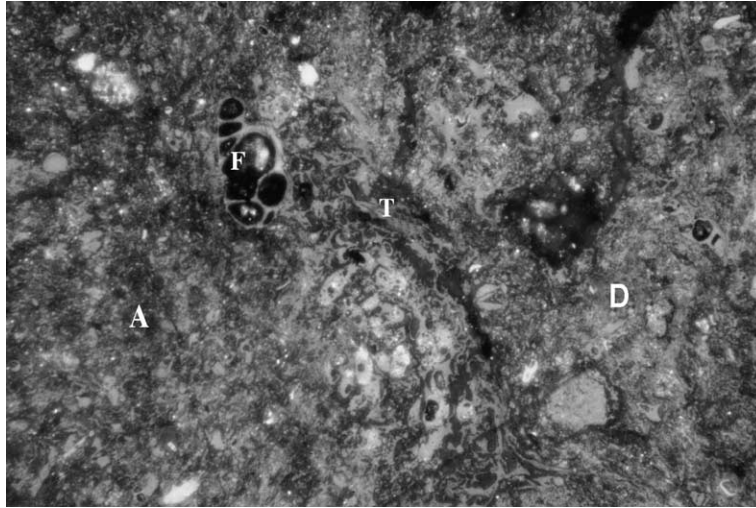
Table 3
Chemical composition of detrohuminite in lignites

	Rhine valley	Lusatia		Nachterstedt
	>90% Detrohuminite	>95% Detrohuminite		
	(Attrinite)	(Attrinite)		(Densinite)
Moisture (as mined, %)	59.1	ca. 60	58.8	47.6
Ash (% mf)	6.6	63.8	65.8	64.8
H (% maf)	5.6	4.9	4.7	4.9
O (% maf)	24.5	28.7	28.6	28.9
N (% maf)	1.1	0.7	0.8	1.4
S (% maf)	0.5	1.9	n.d.	
Tar (% maf)	12.9			
Bitumen (% maf)	4.1			
Cellulose (% maf)	1.7			
Humic acids (% maf)	49.1	43.0	57.3	28.9

Fig. 4. Attrinite (A) and densinite (D). Note also textinite fragment (T) and funginite (F). Reflected white light mode, field width: 0.25 mm.

7.3.1. Comment

The various detrital constituents of attrinite are intimately mixed but only loosely packed and therefore well differentiated from each other. The formless flocculated humic colloids act as a kind of cement. By the very small size of the attrinitic components it is difficult to differentiate between the detrital and the amorphous matter. The spongy texture of attrinite is the reason that attrinite appears darker in reflected light microscopy than other huminite macerals.

7.3.2. Note

Elongated cell wall fragments that may exceed 10 μm in length belong also to attrinite if they are less than <10 μm wide.
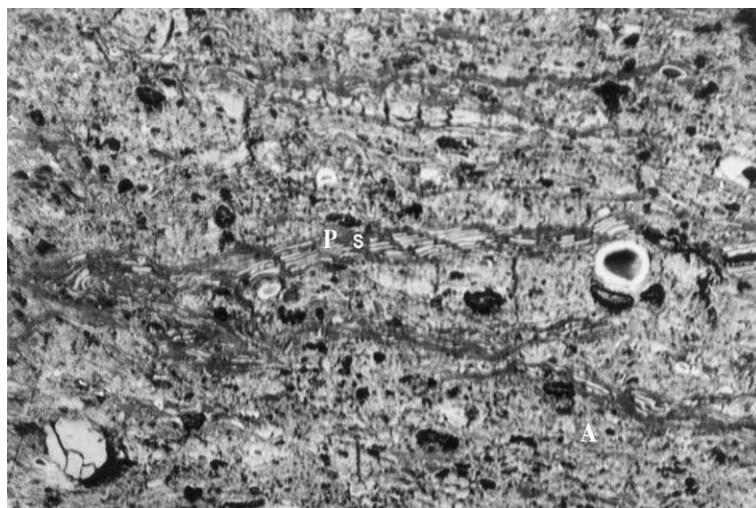

Fig. 5. Attrinite (A) with suberinite (S) and phlobaphinite (P). Miocene lignite from the Anežka seam, Sokolov Basin. Czech Republic. Reflected white light mode, field width: 0.24 mm.

7.4. Physical properties

7.4.1. Colour and reflectance

Colour dark grey, dependent on pore density. True reflectance may not be measurable if the single particles are too small in order to cover the whole measuring field.

7.4.2. Fluorescence

In general, dependent on the composition of attrinite, it is weak brown. The intensity may increase where the attrinite is derived from the litter of gymnosperm tissues.

7.4.3. Polishing Hardness

Attrinite is soft, it does not show any relief.

7.5. Chemical properties

Attrinite consists of humic substances and remains of cellulose and lignin. The chemical properties vary depending upon the plant sources (for further information, see Detrohuminite).

7.6. Derivation

The detrital part of attrinite is the result of strong structural decomposition of parenchymatous and woody tissues of stems and leaves of herbaceous and arborescent plants, originally composed mainly of cellulose and, to a lesser extent, lignin. It forms under aerobic conditions. The shapeless, porous part of attrinite consists of flocculated humic colloids.

In the course of coalification, attrinite passes into densinite by gelification and collodetrinite by vitrinitization, although densinite also occurs along with attrinite in the same seam depending on the depositional conditions (see Occurrence).

7.7. Occurrence

Attrinite is a major component of soft brown coals (Ortho-Lignite) and may be present at levels exceeding 90%. In hard brown coals (Meta-Lignite) it is much less abundant. High amounts of attrinite indicate relatively dry conditions at the mire surface followed by aerobic decomposition of the humic parts of plants (von der Brelie and Wolf, 1981). Attrinite occurs also in subaquatically deposited plant litter (Schneider, 1986).

7.8. Practical importance

Attrinite-rich lignites are a suitable for a whole range of industrial processes. The following statements result from papers of Jacob (1956), Teichmüller and Thomson (1958), Rammler et al. (1967), Sontag and Süss (1969a,b) and Durie (1991).

7.8.1. Preparation

Attrinite is very well grindable and appears predominantly in particle sizes of 2.0–6.3 mm.

7.8.2. Briquetting

Attrinite has very good briquetting properties if it is not mixed with too much liptinite.

7.8.3. Carbonization

Low-temperature carbonization results in relatively low contents of tar and coke. High-temperature carbonization results in firm, dense and fissure-free coke of high quality. The coke occurs in coarse lumps.

7.8.4. Bitumen extraction

Relatively poor in extractable bitumen.

7.8.5. Combustion

Attrinite ignites at relatively low temperatures during combustion.

7.8.6. Weathering

Attrinite oxidizes relatively easily.

8. Densinite

8.1. Origin of term

Term introduced by the ICCP in 1970 to denote a maceral of the huminite group that consists of gelified small particles cemented by amorphous humic matter. Derivation: *densus* (L)–dense, compact.

8.2. Related terms

Transmitted light:	Translucent humic degradation matter (Thiessen, 1930)
Reflected light:	Vergelter Detrinit (Sontag et al., 1965)
	Detrinit (Svoboda and Beneš, 1955; Jacob, 1961;), in part.
	Detritus (Wiesner, 1892)
	Humoser Detritus (Teichmüller, 1950)
	Gelinito-Posttelinit, Gelinito-Praecollinit (Timofeev and Bogoliubova, 1964)

8.3. Definition

Densinite is a maceral of the maceral group huminite (subgroup detrohuminite) that consists of fine huminitic particles (<10 μm) of various shape cemented by amorphous dense huminitic substances so that in polished blocks this maceral shows a more or less homogenous and, more rarely, a mottled surface.

8.3.1. Comment

Densinite is a gelified, more or less homogenous huminitic groundmass binding other coal components. The area that shows the dense surface should be >15 μm².

8.3.2. Note

The surface of densinite may be irregular as a result of slight differences in the polishing hardness between the discrete huminitic particles and the binding amorphous huminitic matter.

8.4. Physical properties

8.4.1. Colour and reflectance

The colour is grey. The reflectance is rank dependent and varies between ~0.2 and ~0.4% R_r. If ulminite B is not present, densinite can be used for rank determination (Figs. 6–8).

8.4.2. Fluorescence

None or only very weak dark brown fluorescence.

8.4.3. Polishing hardness

Densinite is soft and does not show strong relief in polished blocks.

8.5. Chemical properties

Densinite consists of humic substances and possibly also lignin remains (see also Detrohuminite).

8.6. Derivation

Densinite is formed by two different processes: (1) extensive decay of parenchymatous and woody tissues of stems and leaves composed of cellulose and lignin followed by biochemical gelification under wet con-
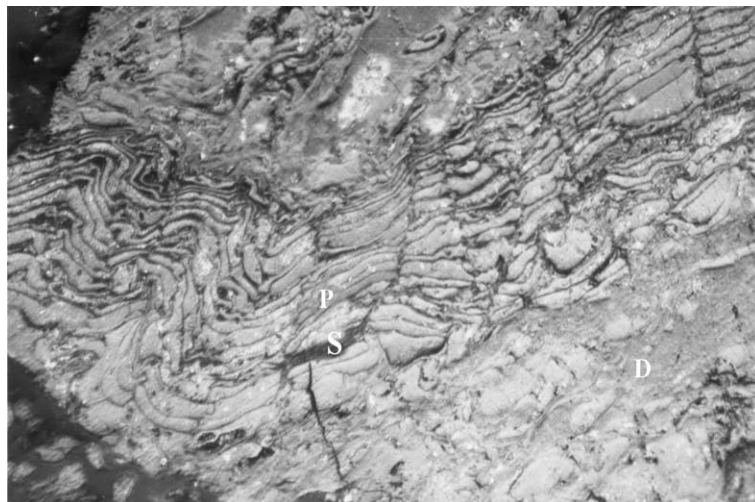

Fig. 6. Densinite (D), phlobaphinite (P) and suberinite (S). Miocene lignite, Basic seam, central part of the Bohemian Basin. Reflected white light mode, field width: 0.24 mm.
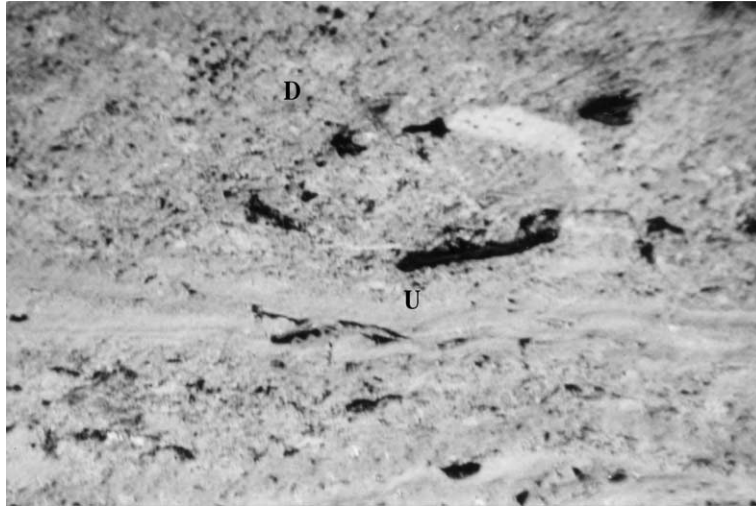
Fig. 7. Densinite (D) and ulminite (U) in Miocene lignite. Basic seam, central part of the North Bohemian Basin, Czech Republic. Reflected white light mode, field width: 0.16 mm.

ditions during the peat stage. (2) Geochemical gelification of former attrinite during increasing coalification.

8.7. Occurrence

Densinite occurs in high amounts in Tertiary low rank lignites originated from peats that accumulated under wet conditions. In lignites of higher rank, densinite is a major constituent and forms the "groundmass" in which other macerals (e.g., liptinite) are embedded.

8.8. Practical importance

8.8.1. Preparation
Densinite has a good grindability. It is enriched in the fine and intermediate size fraction (<4 mm) (Sontag and Süss, 1969a,b).
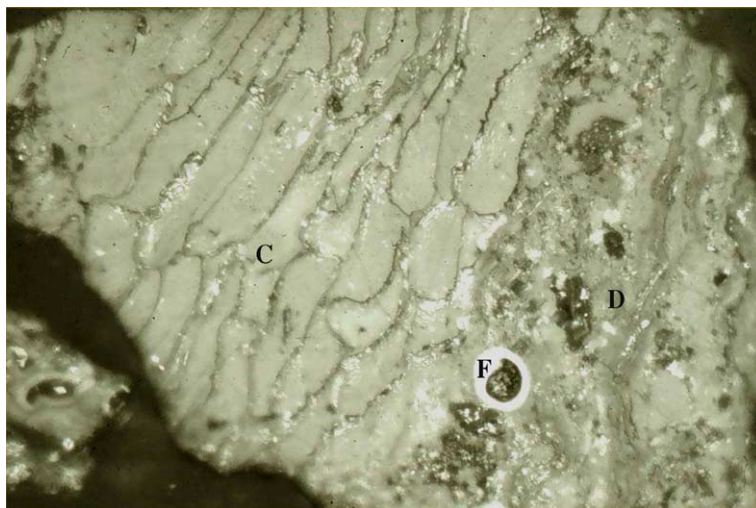

Fig. 8. Corpohuminite (C, phlobaphinite), densinite (D) and funginite, reflected white light. Rheinische Braunkohle, Main seam (Hauptfloez), Miocene. Reflected white light mode, field width: 0.20 mm.

8.8.2. Briquetting

Densinite has poor briquetting properties because it is inelastic and does not interact with other coal grains during binderless briquetting.

8.8.3. Carbonization

Densinite has no coking properties (Sontag and Süss, 1969a,b).

8.8.4. Extraction and liquefaction

Densinite is relatively poor in bitumen extracts but it reacts relatively easily with oxygen (Shibaoka, 1982). It improves the conversion of coal and can even become plastic.

9. Gelohuminite

9.1. Origin of term

Term introduced by the ICCP to denote a maceral subgroup comprising macerals originating from amorphous humic matter. Derivation: *gelu, us* (L)–frost, stiffening *humus* (L)–soil.

9.2. Related terms

Gel (Schochardt, 1943; Teichmüller, 1952)
Gelinit (Malán, 1965; Podgajni, 1957; Sontag et al., 1965)
Dopplerinit-Gruppe (Jacob, 1964)
Humocollinite (ICCP, 1971)

9.3. Definition

Gelohuminte denotes a maceral subgroup within the maceral group huminite that comprises grey coloured structureless, homogenous substances of huminite reflectance.

9.3.1. Comment

Gelohuminte consists of the macerals corpohuminite and gelinite. The former describes discrete bodies representing mainly the primary phlobaphenitic infillings of cell lumens occurring in situ or isolated; the latter describes secondary homogenous infillings of formerly empty spaces.

9.4. Physical properties

See Corpohuminite and Gelinite.

9.5. Chemical properties

See Corpohuminite and Gelinite.

9.6. Derivation

Humocollinite has more than one origin. It may derive from intensely gelified plant tissues and humic detritus, the structure of which is not recognizable in reflected light. It may also derive from precipitated humic colloids. A third derivation is from primary phlobaphenic cell fillings formed by the plants themselves (mainly in gymnosperm wood).

9.7. Occurrence

See Corpohuminite and Gelinite.

9.8. Practical importance

See Corpohuminite and Gelinite.

10. Corpohuminite

10.1. Origin of term

Term introduced by the ICCP in 1970 for a maceral of the huminite group that consists of structureless bodies of humic cell fillings. Derivation: *corpus* (L)–body; *humus* (L)–soil.

10.2. Related terms

Melanoresinit (Szádecky-Kardoss, 1946)
Phlobaphinit (Szádecky-Kardoss, 1949)
Corpogelinit (Teichmüller, 1950)

10.3. Definition

Corpohuminite is a maceral of the maceral group huminite, subgroup gelohuminite, consisting of homogenous, discrete bodies of former humic cell

fillings occurring in situ together with textinite or ulminite or isolated within attrinite, densinite or clay.

10.3.1. Comment

Depending on the shape of the cells that were filled with the excretions and on the orientation of the grains at the polished surface of a block the shape of corpohuminite bodies may be spherical, oval or elongated. Also the size of the bodies depends on the original cell size (Mader, 1958; Soós, 1963; Szádecky-Kardoss, 1952). In Tertiary coals, the size of spherical bodies ranges from about 10 to 40 μm and this of elongated bodies from 20 to 170 μm. Most of the corpohuminite bodies are compact but they may be also cavernous.

Two submacerals can be distinguished: Phlobaphenite describes the coalification product of primary cell excretions and Pseudo-Phlobaphenite the secondary cell fillings that originate from humic colloids. Both are only distinguishable within tissues of textinite or ulminite. If the grain does not have contact with the enclosing cell walls (the grain lies isolated within the cell) the submaceral phlobaphinite is present. In cases where the cell lumen is completely filled with amorphous humic substances and the boundary between the cell wall and the infilling is vague pseudo-phlobaphinite is present.

10.3.2. Note

Secondary humic cell fillings may also be grouped to gelinite. Isolated humic bodies that do not show their former position within a tissue should be called corpohuminite in general because their definite derivation is not now recognizable.

10.4. Physical properties

10.4.1. Colour and reflectance

Grey to light grey. The reflectance of corpohuminite embedded in textinite A or ulminite A (originated from Taxodiaceae or Cupressaceae) may be lower than that of the ulminite B or in densinite from the same coal. Apart from this exception, the reflectance of corpohuminite is slightly higher than that of the corresponding ulminite B or densinite (for reflectance data, see Ulminite and Densinite). The differences in reflectance between corpohuminite of different origins on the one hand and corpohuminite and other huminite macerals on the other hand decrease with increasing rank. This is an important factor to note where the reflectance of corpohuminite is used for rank determination. Corpohuminite is illustrated in (Figs. 1, 2 and 8).

10.4.2. Fluorescence

Corpohuminite does not fluoresce.

10.4.3. Polishing hardness

Variable depending on the origin of the corpohuminite. In general, soft without relief in polished blocks. Corpohuminite is found within an attrinitic or densinitic groundmass or is embedded in sediments shows positive relief.

10.4.4. Vickers hardness

60–80 kp/mm^2 (Taylor et al., 1998).

10.5. Chemical composition

Corpohuminite originating from primary cell excretions, tannins, consists of mixtures of aromatic compounds that vary in composition (e.g., gallic acid, tannin acid, ellagic acid) and possesses phenolic properties (Taylor et al., 1998). The tannins convert to phlobaphenes, i.e., oxidation or condensation products insoluble in water (catechol, phlobatannin), that have high molecular weights. Corpohuminite is insoluble in polar, and non-polar solvents and in hot hydroxide. Corpohuminite is chemically and structurally very resistant.

Analysis of corpohuminite from the lignite of Perecesbánya, Hungary (Soós, 1963):

Ash (moisture-free)	3.1%
Carbon (daf)	64.8%
Hydrogen (daf)	5.6%
Oxygen (daf)	29.6%

Corpohuminite (pseudo-phlobaphinite) formed by the precipitation of humic colloids consists of humins.

10.6. Derivation

Phlobaphinite originates from tannin-rich cell excretions, deposited in cortical cells, in parenchymatous or medullary-ray cells and especially in cork tissues. Phlobaphinite occurs in Taxodiaceae. In

conifers with resin ducts it is less common (Soós, 1963, 1964). Pseudo-phlobaphinite derives from colloidal humic solutions.

10.7. Occurrence

Corpohuminite is a regular but not very abundant compound of lignites and peats. It is especially abundant as cell fillings in cork and bark tissues (Soós, 1964). It occurs also in larger quantities in textinite or ulminite of former conifers (abundantly >10% by vol.). Together with detrohuminite, corpohuminite is found isolated, and is enriched in some layers indicating its resistance to decay (Figs. 5, 6 and 8).

10.8. Practical importance

10.8.1. Briquetting
With increasing amounts of corpohuminite the briquette strength is reduced. Systematic investigations are lacking.

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

10.8.3. Bitumen extraction
Corpohuminite yields no extract.

10.8.4. Facies analysis
In cases where plant tissues are destroyed but the corpohuminite remains, corpohuminite may allow the identification of the former tissues. Completely destroyed tissues of Taxodiaceae yield pure accumulations of phlobaphinite. The remains of totally destroyed Pinaceae tissues are recognizable by the accumulations of phlobaphinite mixed with resinite.

11. Gelinite

11.1. Origin of term

Term introduced by Szádecky-Kardoss (1949) for precipitated humic gels and adopted by the ICCP to denote a maceral of the huminite group consisting of formless huminitic gels. Derivation: *gelu, us* (L)– frost, stiffening.

11.2. Related terms

Gel(e) (Schochardt, 1940, 1943; Teichmüller, 1950)
Humusgel (Berger, 1958; Hummel, 1930)
Dopplerinit (Jacob, 1961)
Huminit (Svoboda, 1956)
Desminit (Minčev, 1964)
Gelinito-Collinit (Timofeev and Bogoliubova, 1965)

11.3. Definition

Gelinite is a maceral of the maceral group huminite (subgroup gelohuminite) that appears under reflected light as homogenous structureless or porous substance of huminitic reflectance.

11.3.1. Comment
Gelinite is subdivided in two submacerals. Levigelinite is completely structureless, compact and homogenous. It may show shrinkage cracks due to dessication. After etching three different cryptomacerals can be observed. Telogelinite shows cellular structures, detrogelinite has an attrinitic occurrence and eugelinite shows no structure. Eugelinite fills spaces such as cell lumens, cracks and other voids (Fig. 9). Porigelinite has a spongy, porous or microgranular occurrence (Fig. 10). Similar to eugelinite it occurs in a range of locations within lignites (brown coals).

11.3.2. Note
Porigelinite may be present also in attrinite, where it is mixed intimately with the detrital humic matter. There it is—by the reason of that intimate mixture— part of attrinite. Gelinite particles of a size <10 μm are grouped with attrinite.

11.4. Physical properties

11.4.1. Colour and reflectance
The colour is medium to light grey. Porigelinite may show discrete internal orange reflections
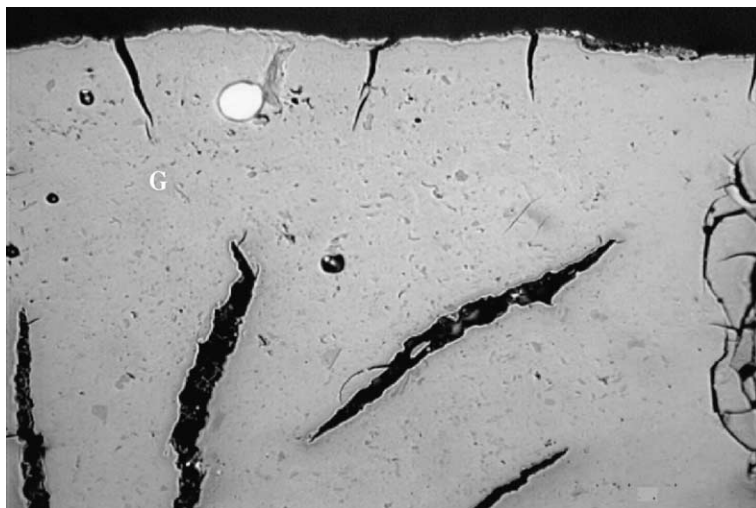
Fig. 9. Gelinite (G). Kuhfeldschichten (Lower Cretaceous, Valendis), Germany. Reflected white light mode, field width: 0.3 mm.

([Mukhopadhyay and Hatcher, 1993](#)). The reflectance of levigelinite is rank dependent and increases from ~0.25 to ~0.40% R_r. In general, its reflectance is slightly higher than that of ulminite B or densinite of the same coal. If used for rank determination, the measurements should specify that gelinite was used. Due to the pores, porigelinite appears abundantly slightly darker than levigelinite of the same coal.

11.4.2. Fluorescence

Gelinite does not fluoresce.

11.4.3. Polishing hardness

Gelinite is smooth and does not show polishing relief.

11.4.4. Vickers hardness

20.12–22.7 kg/mm^2.

11.5. Chemical properties

Gelinite consists of humic acids and their salts (especially Ca and Na salts) (see Table 4). The
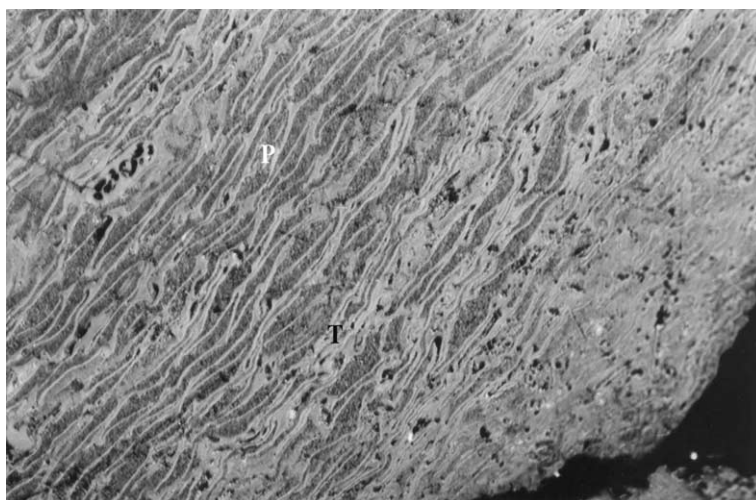

Fig. 10. Porigelinite (P) and textinite (T) in Miocene lignite. Basic seam, central part of the North Bohemian Basin, Czech Republic. Reflected white light mode, field width: 0.24 mm.

Table 4

Chemical composition of gelinite in lignites of Germany (Jacob, 1958; Schröder and Teichmüller, 1958; Rammler et al., 1964; Belau et al., 1967; Sontag, 1967) and Czech Republic (Sykorova et al., 1996)

Parameters	District of Leipzig (Eocene)	Lusatia (Miocene)	Lower Rhine Valley (Miocene)	North Bohemian Basin (Miocene)
Bed moisture (%)	45	to	70	42.0
Ash (%)	12	to	3	3.7
Volatile matter (%)	Ø 53.1	Ø 49.5	47.8–51.3	45.2
C (%daf)	66.8–69.6	63.7	65.6–65.8	71.4
H (%daf)	4.2–5.4	5.2	4.0–4.3	3.6
O (%daf)	20.7–25.0	27.1	28.3–28.6	21.5
N (%daf)	0.7–1.0	0.6	0.7–1.0	1.6
S (%daf)	3.0–6.2	3.4	0.6–1.3	1.8
Bitumen (%)	4.5	–	3.8	–
Humic acids (%)	82.2–97.9	–	61.3–94.2	–

chemical composition is influenced by rank, facies and regional conditions.

11.6. Derivation

Gelinite occurs both syngenetically and epigenetically. Syngenetic eugelinite and porigelinite may form as a humic amorphous substance excreted from cell walls directly during wet periods at the peat stage and filling former cell cavities. In the most cases, eugelinite and porigelinite are the precipitation products from colloidal humic solutions and fill secondary spaces. Whether the dense eugelinite or the spongy porigelinite occurs seems to depend on the concentration of humic substances in the colloidal solution.

Telogelinite and detrogelinite are of syngenetic or epigenetic origin. They may represent strongly gelified tissues or humic litter in peat that is deposited where they occur together with eugelinite (Taylor et al., 1998), or may form by gelification during increasing coalification.

Eugelinite and porigelinite are the precursors of gelinite in medium and high rank coals. Telogelinite is a precursor of collotelinite and detrogelinite turns into collodetrinite.

11.7. Occurrence

Gelinite is a common but not very abundant compound of low rank lignites. Telogelinite and detrogelinite are rare in low rank lignites their amounts increase during the transition from ortho to meta lignite. In peats and lignites eugelinite and porigelinite fill shrinkage cracks, cleats and voids formerly occupied by now decomposed plant organs such as roots (Taylor et al., 1998) or they fill cell cavities. Eugelinite occurs also in cracks of sediments associated to coal seams (Berger, 1958). Generally, the gelinite content depends on facies conditions. Gelinite is enriched in limno-telmatic deposited peats (Roselt, 1969) and in peats originating from wet grasslands (Glumiflorae facies of Schneider, 1986) or if the concentration of Ca ions in the water within the peat is high (e.g., when limestone surrounds the mire). Gelinite may be also enriched in lignites originated from palaeomires in the neighbourhood of salt deposits that caused increasing Na concentration in the peat water (Taylor et al., 1998).

In lignite open pits, where the working face dries out, humic solutions migrate from inner parts of the seam towards its surface. There they precipitate forming a black and lustrous cover that consists of pure humic gels, eugelinite under the microscope.

11.8. Practical importance

11.8.1. Preparation
Gelinite is easy to grind. The fines (0–2mm) are enriched in gelinite.

11.8.2. Briquetting
Gelinite has very bad briquetting properties. The smooth surface of the grains prevents grain adherence during binderless briquetting. Together with the tendency to internal and external fissuring, these properties cause low briquette strength (Jacob, 1959).

11.8.3. Carbonization

Gelinite shrinks strongly during coking and causes a severe reduction of coke strength (Jacob, 1959).

11.8.4. Combustion

The calorific value of gelinite is generally below the average of the whole deposit.

11.8.5. Weathering

During drying, it degrades rapidly into fine debris.

Acknowledgements

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