



Standard Test Method for Microscopical Determination of the Reflectance of Vitrinite Dispersed in Sedimentary Rocks¹

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1. Scope

1.1 This test method covers the microscopical determination of the reflectance measured in oil of polished surfaces of vitrinite dispersed in sedimentary rocks. This test method can also be used to determine the reflectance of macerals other than vitrinite dispersed in sedimentary rocks.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

[D121 Terminology of Coal and Coke](#)

[D388 Classification of Coals by Rank](#)

[D2797 Practice for Preparing Coal Samples for Microscopical Analysis by Reflected Light](#)

[D2798 Test Method for Microscopical Determination of the Vitrinite Reflectance of Coal](#)

[E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods](#)

[E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)

3. Terminology

3.1 *Definitions*—For definitions of terms, refer to Terminology [D121](#).

3.2 *Abbreviations:*

¹ This test method is under the jurisdiction of ASTM Committee [D05](#) on Coal and Coke and is the direct responsibility of Subcommittee [D05.28](#) on Petrographic Analysis of Coal and Coke.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.1 *R_{o,ran}*—mean random reflectance measured in oil. Other organizations may use other abbreviations for mean random reflectance.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *alginite, n*—a liptinite maceral occurring in structured morphologies, telalginite, and unstructured morphologies, lamalginite.

3.3.2 *bituminite, n*—an amorphous primary liptinite maceral with low reflectance, occasionally characterized by colored internal reflections and weak orange-brown fluorescence, derived from bacterial biomass and the bacterial decomposition of algal material and faunal plankton. Bituminite is equivalent to the amorphous organic matter recognized in strew slides of concentrated kerogen **(1)**.³

3.3.2.1 *Discussion*—Bituminite may be distinguished from vitrinite by lower reflectance, as well as higher fluorescence intensity if fluorescence is present in vitrinite. Bituminite has poorly-defined wispy boundaries and may be speckled or unevenly colored whereas vitrinite has distinct boundaries and is blockier and evenly colored. The occurrence of bituminite in association with lamalginite and micrinite is common. Rock type, thermal maturity, and geologic occurrence can be used to interpret the potential presence of bituminite; for example, bituminite may be expected to occur in lacustrine or marine settings. It is less commonly present in fluvial or similar proximal depositional environments, where vitrinite may be expected to occur in greater abundance.

3.3.3 *chitinozoan, n*—a group of flask-shaped, sometimes ornamented marine microfossils of presumed metazoan origin which are composed of 'pseudochitin' proteinic material and which occur individually or in chains. Chitinozoan cell walls are thin, opaque to translucent, and range from dark gray to white in reflected white light similar to vitrinite. Chitinozoans are common in Ordovician to Devonian marine shales.

3.3.4 *conodont, n*—the phosphatic, tooth-like remains of marine vertebrate worm-like animals present from the Cambrian through Triassic, composed predominantly of apatite with subordinate amounts of organic matter. Conodont morphology is variable, but often well-defined denticles and blades

³ The boldface numbers in parentheses refer to a list of references at the end of this standard.

are preserved. In reflected white light examination conodonts range from pale yellow to light brown to dark brown and to black.

3.3.5 *fusinite*, *n*—an inertinite maceral distinguished principally by the preservation of some feature(s) of the plant cell wall structure, high relief, and reflectance substantially higher than first cycle vitrinite in the same sample. When less than 50- μm in size this maceral is assigned to inertodetrinite. Other organizations may define macerals using different technical specifications.

3.3.6 *graptolite*, *n*—colonial, chitinous animal which occurs as thin, elongate bodies sometimes showing complex skeletal morphology and with reflective dark gray to white color in reflected white light similar to vitrinite (2). Graptolites occur from the Cambrian through Carboniferous.

3.3.7 *huminite*, *n*—maceral group present in lignite and immature sedimentary rocks with reflectances intermediate to those of associated darker liptinites and brighter inertinites (3). Huminite is equivalent to the vitrinite maceral group that occurs in subbituminous and higher rank coals with measured reflectance values greater than 0.5% (4).

3.3.8 *inertinite*, *n*—maceral group with macerals that exhibit higher reflectance than other organic components in the same sample; for example, semifusinite, fusinite, and inertodetrinite. Inertinite macerals generally lack fluorescence and usually retain preserved plant cell wall structure(5).

3.3.9 *inertodetrinite*, *n*—an inertinite maceral occurring as individual, angular, clastic fragments incorporated within the matrix of other macerals (commonly vitrinite) or minerals, and in the size range from 2- to 50- μm . Other organizations may define macerals using different technical specifications.

3.3.9.1 *Discussion*—Inertodetrinite is derived through the disintegration of other inertinite macerals, that is, fusinite and semifusinite, by mechanical abrasion during transport.

3.3.10 *kerogen*, *n*—dispersed or concentrated organic matter, or both, occurring in sediments and sedimentary rocks that is insoluble in organic solvents.

3.3.11 *lamalginitite*, *n*—an unstructured liptinite maceral with low reflectance distinguished primarily by the presence of bright fluorescence and lamellar character.

3.3.12 *liptinite*, *n*—maceral group with macerals that exhibit lower reflectance than other organic components in the same sample of sedimentary rocks and coal, appearing black to dark gray in reflected white light and that fluoresce under blue to ultraviolet light in coals ranked medium volatile bituminous and lower. Liptinite maceral fluorescence can be used as a qualitative thermal maturity indicator as fluorescence changes from green to yellow to orange before becoming extinguished at advanced maturity.

3.3.12.1 *Discussion*—Liptinite macerals are observed only in coals of maturity up to approximately the high volatile bituminous to medium volatile bituminous transition, and in sedimentary rocks of equivalent thermal maturity. Liptinite macerals undergo chemical changes during maturation which render their optical distinction from vitrinite and inertinite macerals difficult at maturities higher than medium volatile bituminous.

3.3.13 *maceral*, *n*—an organic component occurring in sedimentary rocks and coal that is distinguished on the basis of its optical microscopic properties, primarily reflectance and morphology.

3.3.14 *maceral classification*, *n*—the systematic division of the organic components (macerals) in sedimentary rocks and coal based on their appearance in the optical microscope under incident white and fluorescent light.

3.3.15 *micrinite*, *n*—an inertinite maceral, generally nonangular, exhibiting no relict plant cell wall structure, smaller than 10 μm and most commonly occurring as granular particles around 1- to 5- μm diameter. Other organizations may define macerals using different technical specifications.

3.3.15.1 *Discussion*—Micrinite is a secondary maceral formed from liptinite macerals during maturation.

3.3.16 *mineral matter*, *n*—in sedimentary rocks and coal, the non-organic fraction composed of physically discrete particles of minerals such as clays, pyrite, quartz, carbonates, etc., and all elements other than carbon, hydrogen, oxygen, nitrogen and sulfur in the organic fraction.

3.3.17 *recycled vitrinite*, *n*—vitrinite that has undergone at least one additional cycle of burial, exhumation, and erosion in contrast to first cycle vitrinite which has undergone only one burial cycle. The additional cycle may result in exposure to thermal maturation, chemical or thermal oxidative processes, or both, and mechanical abrasion (sometimes resulting in increased particle rounding) that is not experienced by first cycle vitrinite contained in the same sample.

3.3.17.1 *Discussion*—Recycled vitrinite has higher reflectance than co-occurring first cycle vitrinite, and sometimes is less angular, due to the rounding of grain boundaries experienced during transportation. Recycled vitrinite may have bright or dark halos, representing thermal oxidation and weathering processes, respectively, which are not present in the co-occurring first cycle vitrinite. Recycled vitrinite has a higher variance of reflectance values, representative of the many possible sources and processes occurring during transportation, and may show greater relief than first cycle vitrinite in the same sample. Recycling of vitrinite may be inferred from the geologic context; for example, a higher proportion of recycled vitrinite may be observed in a catchment collecting sediments derived from a growing orogenic belt.

3.3.18 *scolecodont*, *n*—the chitinous, variably mineralized fossil remains of the jaw elements of polychaete annelid worms, which occur as lamellar to tooth-like structures with spongy, laminated, or granular texture, and with reflective dark gray to white color similar to vitrinite. Scolecodonts occur from the Ordovician to recent.

3.3.19 *semifusinite*, *n*—an inertinite maceral with morphology like fusinite sometimes with less distinct evidence of cellular structure, and with reflectance ranging from slightly greater than that of the associated vitrinite to that of the least reflective fusinite. Semifusinite may show irregular mosaic texture or satin anisotropy when viewed under polarized reflected white light.

3.3.19.1 *Discussion*—Low-reflecting semifusinite may be distinguished from vitrinite by higher reflectance and relief,

and the presence of more arcuate boundaries. The most reliable distinguishing feature of low-reflecting semifusinite is the frequent presence of well-preserved cellular structure or open cell lumens, or both. However, it is not unusual for cell lumens to also remain open in vitrinite when deposited in clay-rich sediments. Semifusinite usually has more distinct particle boundaries, which distinguishes it from vitrinite which has a more porous and textured surface. Geologic context is important; a greater proportion of semifusinite can be expected in sediments or coals associated with more arid locations, climates, and time periods.

3.3.20 *solid bitumen, n*—a secondary maceral associated with hydrocarbon generation from kerogen distinguished primarily by its conformation to pores, voids and fractures in the rock matrix, embayment by authigenic mineral grains, and the absence of features such as cellular structure indicating derivation from precursor plant material. Solid bitumens may show homogenous or granular textures; irregular anisotropic mosaic textures also are common, particularly at advanced stages of thermal maturity (6). Solid bitumens may exhibit fluorescence at low thermal maturity.

3.3.20.1 *Discussion*—For the purpose of reflectance measurement it is important to distinguish solid bitumen from vitrinite since both macerals appear gray under reflected white light and the reflectance of both advances with increasing maturity. Several populations of solid bitumen with distinct reflectance ranges can be present in a single whole-rock sample. Solid bitumens are characterized by their pore-filling or anastomosing forms. Boundaries of solid bitumen can be well-defined by textural embayment by authigenic minerals such as calcite and dolomite that commonly form contemporaneously with solid bitumen deposition. However, vitrinite can be replaced by authigenic minerals and therefore textures indicative of embayment or mineral inclusion are not always diagnostic of solid bitumen. Solid bitumen exhibits mosaic anisotropic domains at higher thermal maturity whereas vitrinite does not. Use of cross-polarized light by insertion of a post-sample analyzer into the light path may help to distinguish mosaic bitumens. Solid bitumens may be deposited in voids and fractures with orientations normal to sedimentary bedding. Solid bitumens may occur as droplets and may be translucent (recognized by reflections from pyrite inclusions) and contain pyrite crystals at edges. Rock type, thermal maturity, and geologic occurrence can be used to interpret the potential presence of solid bitumens; for example, bitumens may be present if the sample is or occurs in proximity to a mature hydrocarbon source rock or if the sample is from an exhumed oil reservoir. Solid bitumens can be physically associated with bituminite or other liptinite macerals from which they are derived. Some solid bitumens are soluble in organic solvents and may be distinguished from vitrinite in low maturity source rocks by low magnification observation of fluorescence streaming after pipetted solvation of the examination surface.

3.3.21 *telalginite, n*—a liptinite maceral characterized by strong fluorescence and structured morphologies. Common botanical varieties include *Botryococcus*, a freshwater indicator, and *Tasmanites*, a marine indicator. Fluorescence

intensity diminishes and fluorescence color shifts toward red wavelengths with increasing thermal maturity.

3.3.22 *thermal maturity, n*—the degree of thermal alteration of the dispersed organic matter contained in sedimentary rocks, synonymous with coal rank. Thermal maturity of sedimentary rocks commonly is defined by vitrinite reflectance, spectral fluorescence, X-ray diffraction crystallography, or by organic geochemical parameters.

3.3.23 *vitrinite, n*—vitrinite dispersed in Upper Silurian and younger age sedimentary rocks is the remains of coalified material from vascular land plants. Vitrinite dispersed in sedimentary rocks may be representative of a large variety of precursor plant materials with differing original chemistries and structures. Vitrinite typically occurs as finely comminuted dark gray to white particles (in reflected white light) of sizes less than 100 μm dispersed throughout the mineral matrix although particles of larger size can also be present. Vitrinite dispersed in sedimentary rocks may occur as fragments of coal which include other macerals, including inertinite and liptinite.

3.3.23.1 *Discussion*—The identification of the primary vitrinite (first cycle vitrinite) population is essential for determining the peak thermal maturity experienced by a sedimentary rock. This can be complicated by: the chemical and structural heterogeneity of dispersed vitrinite reflecting multiple sources; the presence of similar organic components resembling vitrinite, including solid bitumen, bituminite, recycled vitrinite, low-reflecting semifusinite, and zooclasts; vitrinite reflectance retardation or suppression, or both; alteration by oxidation or weathering from sample handling or by exposure to the atmosphere at outcrop; and the potential for contamination such as cavings and drilling mud additives in the case of drill cuttings. The term vitrinite is currently used as both a maceral and maceral group.

3.3.24 *vitrinite reflectance retardation, n*—a reduction in vitrinite reflectance values below thermal maturity levels determined by geochemical or other petrographic parameters. Vitrinite reflectance retardation occurs due to decreased reaction rate and inhibition of the rearrangement of vitrinite molecular structure principally as a result of overpressure.

3.3.24.1 *Discussion*—The presence of vitrinite reflectance retardation can only be assessed if other thermal maturity parameters are available for the same sample or if vitrinite reflectance data from different depths or locations in an area are available for comparison. Vitrinite reflectance retardation cannot be assessed from the reflectance result of a single sample or the appearance of a single vitrinite particle.

3.3.25 *vitrinite reflectance suppression, n*—a reduction in vitrinite reflectance values below thermal maturity levels determined by geochemical or other petrographic parameters arising as a result of atypical hydrogen-rich vitrinite chemistry inherited from the precursor plant material or introduced into the vitrinite by the chemical microenvironments of deposition, diagenesis, and catagenesis.

3.3.25.1 *Discussion*—The presence of vitrinite reflectance suppression can only be assessed if other thermal maturity parameters are available for the same sample or if vitrinite reflectance data from different depths or locations in an area are