[PS]Strategies for Identifying Organic Matter Types in SEM*

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Abstract

Solid organic matter is easily identified in scanning electron microscope (SEM) images acquired from flat, smoothly polished surfaces (e.g., Ar-ion milled) by its characteristic low secondary electron yield and low backscatter intensity; appearing dark gray in standard grayscale images. However, SEM is poorly suited for interpreting specific organic maceral and kerogen types as described by optical petrographic or geochemical methods.

Lack of consistent and standardized descriptions of organic matter in SEM has led to confusion and controversy in the characterization of organic composition, interpretations of the origins of pores in organic matter, and organic diagenesis.

This paper describes a practical method for the description and classification of organic matter in SEM and various strategies used to help bridge the gap between optical and electron microscopic characterization of organic matter in carbonaceous mudstones.

Reference Cited

Canter, L., S. Zhang, M. Sonnenfeld, C. Bugge, M. Guisinger, and K. Jones, 2016, Primary and Secondary Organic Matter Habit in Unconventional Reservoirs, *in* T. Olson (ed.), Imaging Unconventional Reservoir Pore Systems: American Association of Petroleum Geologists Memoir 112, p. 9-24.

Strategies For Identifying Organic Matter Types in SEM

Wayne K. Camp

Introduction

Solid organic matter is easily identified in scanning electron microscope (SEM) images acquired from flat, smoothly polished surfaces (e.g., Ar-ion milled) by its characteristic low secondary electron yield and low backscatter intensity; appearing dark gray in standard grayscale images. However, SEM is poorly suited for interpreting specific organic maceral and kerogen types as described by optical petrographic or geochemical methods.

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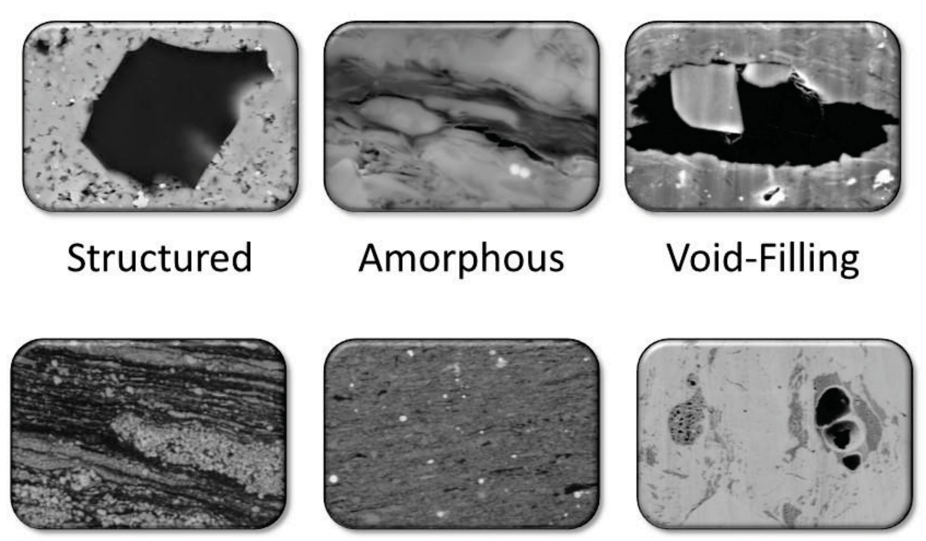
SEM Organic Matter Classification

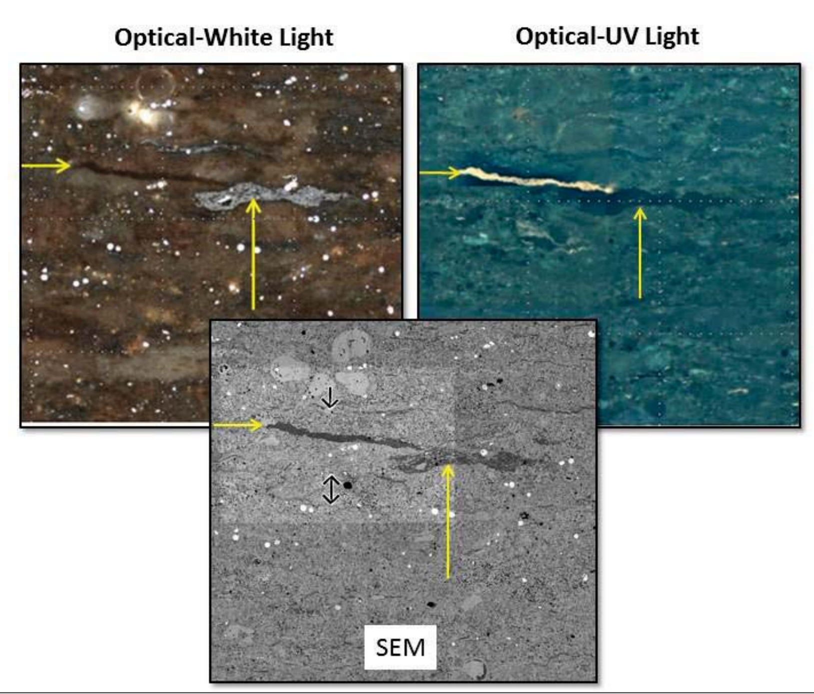


SEM Organic Matter Classification

In the absence of other supporting criteria, it is recommended using common petrographic terms when describing organic matter in SEM images. Terms such as kerogen, vitrinite, type III kerogen, algal mat, bitumen, pyrobitumen, etc. should not be used for organic matter descriptions. These terms are interpretations of the type of organic matter, and should be clearly stated as interpretations, including the supporting evidence.

Organic matter can be classified based on petrographic evidence into three main types: 1) structured, 2) amorphous, and 3) void-filling. The term void-filling should be restricted to where there is clear evidence of a prior void, such as fossil cavities, micro-fractures, and mineral-cement lined pores. Additional descriptive terms such as layered, interlaminated, disseminated, porous, non-porous, etc. can be appended as modifiers.

Direct Optical-SEM Comparison



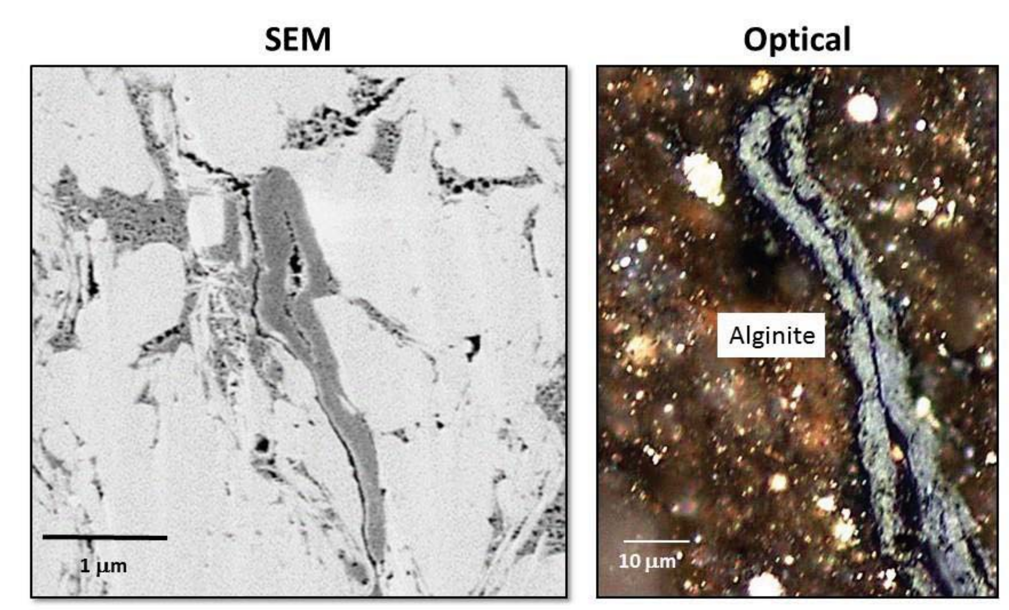
Direct Optical-SEM Comparison

Organic macerals are the microscopically identifiable remains of fossil organic matter. Standardized optical petrographic methodology and nomenclature have been developed initially for coal petrology and later applied to studies of dispersed organic matter in sedimentary rocks. The International Committee for Coal and Organic Petrology (ICCP, 1994) has defined a classification scheme that recognizes four main groups of organic macerals based on optical characteristics observed from polished samples immersed in oil in reflected white and ultraviolet light: 1) liptinite, 2) inertinite, 3) huminite and 4) vitrinite, with over 30 subgroups, macerals and varieties.

The most reliable method for identifying organic maceral types in SEM is by acquiring SEM images of the polished samples used to identify organic macerals in reflected light. Because the optical petrographic specimens are coated in oil, it may be preferable to either remove the oil, or sputter coat the samples with a conductive metal (e.g., iridium, palladium, etc.) to reduce the effect of electron charging. Note that attempting to remove the oil by solvents may alter or remove soluble forms of organic matter (bitumen). Wiping the surface with cloth or paper may contaminate the surface with organic fibers.

Because of the relatively low magnification limits of optical microscopy, this technique is limited to the identification of the larger organic matter particle population observed in SEM.

Comparative Anatomy



Comparative Anatomy

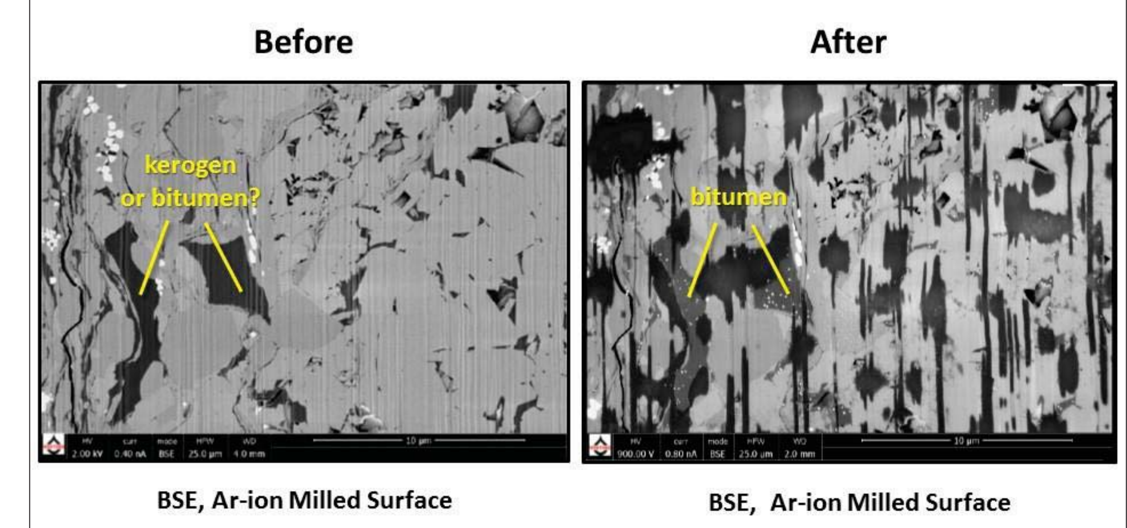
It may be possible to identify certain organic macerals and zooclasts in SEM based on characteristic morphology (comparative anatomy), e.g., *Tasmanities* algal cysts. Best results are produced by comparing identified organic macerals from splits of the same sample in photomicrographs reduced to match the scale of the SEM image.

Images of identified organic macerals are available online that provide a useful resource for comparative anatomy studies, e.g. the U.S. Geological Survey Atlas (http://energy.usgs.gov/Coal/OrganicPetrology/PhotomicrographAtlas.aspx), and the Indiana Geological Survey Atlas (https://igs.indiana.edu/Coal/Macerals.cfm).

Color photomicrographs may be converted to inverse grayscale images with digital image software so that bright, highly reflective organic matter in the optical image is converted to dark gray, to appear more similar to the dark gray tone of organic matter in SEM grayscale images.

Many organic maceral types are classified based on differences in the measured amount of reflected light (a measure of thermal maturity) - a property impossible to measure in SEM. For example, macerals exhibiting preserved botanical cell structures are classified in order of increasing thermal maturity as telohuminite, telovitrinite, semifusinite, or fusinite. Although it may be possible to recognize organic matter with preserved cell structures, it would be impossible to differentiate the maceral type in SEM. A more generic terminology based on physical appearance would be more useful for classifying organic macerals in SEM.

Toluene Immersion Test for Bitumen



Canter et al., 2016: AAPG Memoir 112

Bitumen Solubility Test

Standard geochemical tests for bitumen involve immersing crushed samples in organic solvents, such as toluene, to remove soluble solid bitumen and residual liquid petroleum. The remaining proportion of insoluble organic matter is classified as kerogen.

Comparing SEM images before and after applying organic solvents to broken or polished surfaces may provide a positive test for bitumen. However, these types of test often fail to completely remove all of the bitumen or void-filling organic matter observable in SEM images that may result in ambiguous interpretations.

Geochemical and petrographic evidence for distinguishing kerogen from bitumen are often in conflict. Soluble-resistant forms of post-oil solid bitumen are known to result from advanced thermal alteration and are referred to as pyrobitumen (*sensu stricto*, kerogen!). During the thermal conversion of kerogen to oil, kerogen is first transformed to a soluble bitumen, known as pre-oil bitumen. Interpreting particulate, structured organic matter as kerogen in thermally mature samples is therefore problematic because some of this material is likely composed of pre-oil bitumen.

Acknowledgements

I thank Lyn Canter, Whiting Petroleum (Denver, Colorado) for permission to show her SEM images of the toluene test for bitumen. These results have recently been published as Canter, L., S. Zhang, M. Sonnenfeld, C. Bugge, M. Guisinger, and K. Jones, 2016, Primary and secondary organic matter habit in unconventional reservoirs, *in*, T. Olson, ed., Imaging Unconventional Reservoir Pore Systems: AAPG Memoir 112, p.9-24.

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