ADVANCED CHARACTERIZATION OF UNCONVENTIONAL OIL AND GAS RESERVOIRS TO ENHANCE CO_2 STORAGE RESOURCE ESTIMATES – ORGANIC STRUCTURE AND POROSITY OF ORGANIC-RICH SHALES

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ABSTRACT

Advanced analytical and image analysis techniques have been employed to examine the detailed structure of organic matter (OM) in the shales of the Bakken Formation. Samples from three different locations in the Bakken Formation with varying levels of thermal maturity (immature, marginally mature, and mature) were selected for analysis. A high-resolution field emission scanning electron microscope (FESEM) was used to observe detailed morphological features and nanoporosity of ion-milled specimens. Subsequent advanced image analysis and segmentation approaches applied to the FESEM images yielded estimates of porosity associated with OM and the shale matrix. Preliminary results indicate varying degrees of porosity within the OM, ranging from highly porous to little-to-no apparent porosity. Porosity estimates based on image analysis of the porous organics range from 5%–8%, with average pore diameters of about 20–40 nm. These types of data, including matrix porosity and organic porosity, are critical to better estimate the CO_2 storage potential in organic-rich shales and to elucidate CO_2 migration pathways and potential sorption mechanisms. This project is being conducted by the Energy & Environmental Research Center (EERC) in collaboration with the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) and Hitachi High Technologies. The goal of this project is to use advanced FESEM, image analysis, and computed tomography (CT) visualization techniques to identify and quantify key features that could affect CO_2 storage in unconventional formations.

PROJECT GOALS AND OBJECTIVES

Goal

Development of advanced characterization methods and procedures for studying the properties of organic-rich, tight rock formations, with the aim to improve assessment methods for estimating the CO_2 storage potential.

Specific Objectives

- Develop advanced FESEM and image analysis methods to better characterize sample composition in terms of clays, kerogen or organic content, and major minerals.
- Develop improved methods to better estimate porosity and pore-size distributions.
- Develop enhanced methods to improve the characterization of fracture networks.
- Collaborate with Hitachi's research and development division to develop and/or improve data processing and image analysis protocols for enhanced quantification of desired features and their proportions.
- Collaborate with NETL's CT scanning Lab in Morgantown to investigate the effects of CO_2 exposure on petrophysical properties of organic-rich shales at the core scale.
- Utilize the acquired data to develop improved volumetric estimates of CO_2 storage potential in collaboration with NETL.

METHODS DEVELOPMENT

Sample Specimen Preparation

- Sample prepprepared by mechanical polishing to 1-µm finish
- Final cross-section area finished by Ar ion mill polisher
- Thin carbon coat layer applied to reduce charging effects during image acquisition

IM4000 Plus Ion Mill Polisher

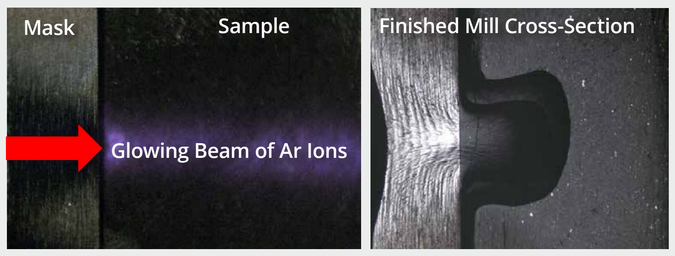
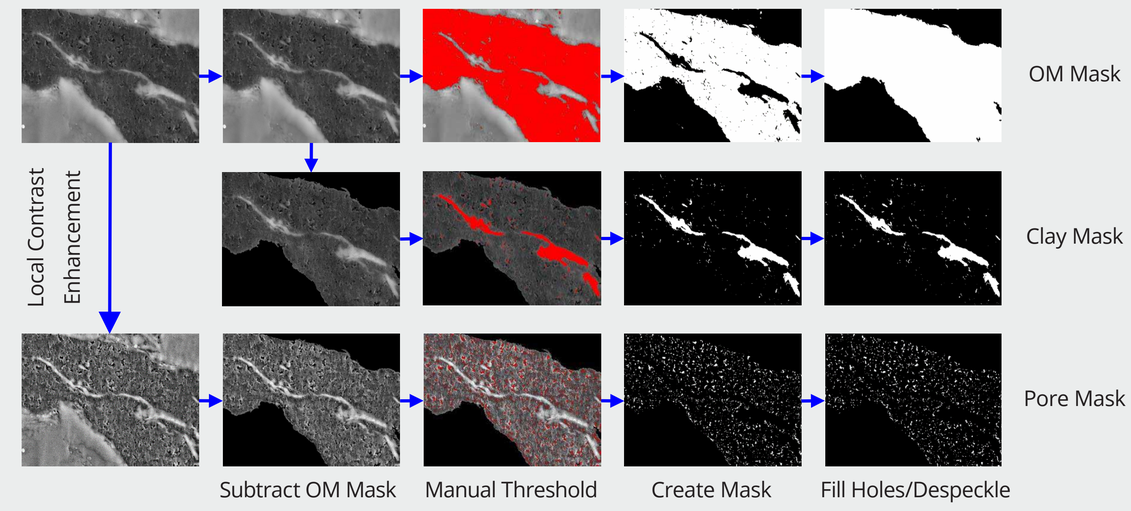


Image Acquisition and Analysis

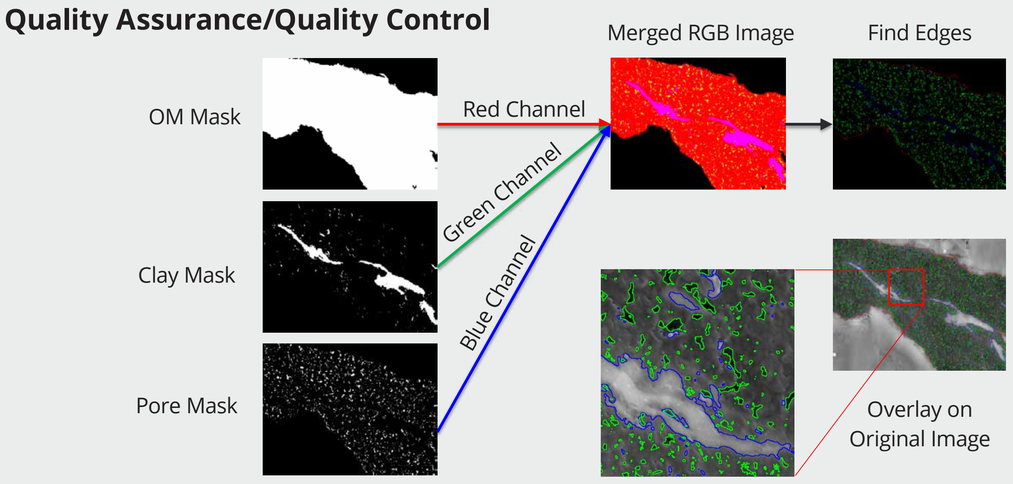
- **FESEM Imaging Modes:**
  - Low-vacuum mode for reduced charging effects (back-scattered electron [BSE] and ultravariable pressure detector [UVD] signal detection)
  - High-vacuum mode for BSE and secondary electron signal detection
  - UVD detector for enhanced observation of quartz overgrowths
- **Image Quality Enhancements:**
  - Low kV imaging
  - Small spot size
  - Beam deceleration or charge suppression mode to reduce charging effects at high magnification

Image Segmentation Workflow

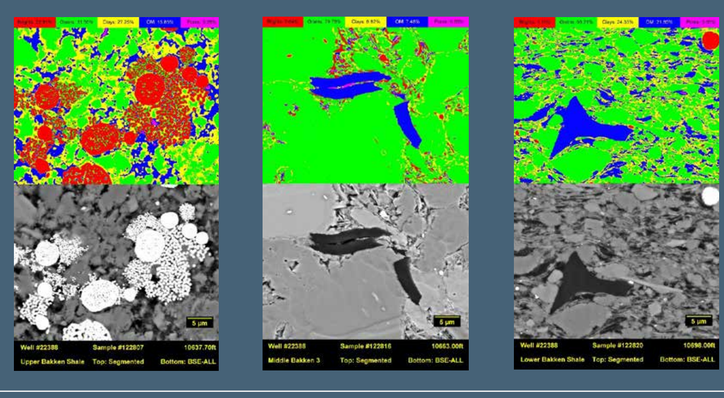
Organic Porosity Segmentation Workflow



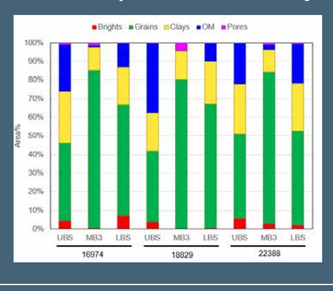
Quality Assurance/Quality Control



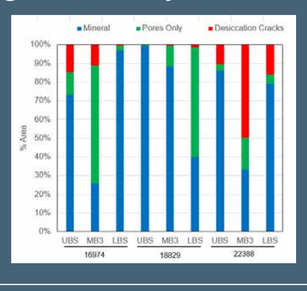
PRELIMINARY RESULTS OF ORGANIC STRUCTURE AND POROSITY



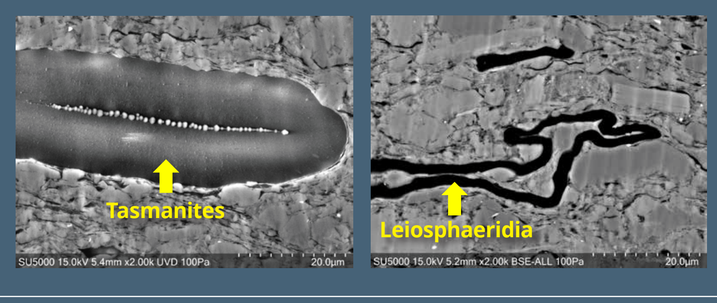
Overall Compositional Analysis



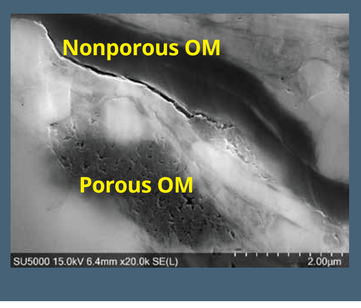
Organic Porosity Estimates



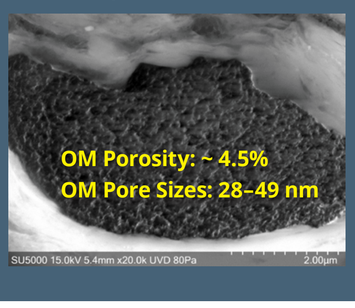
Lower Bakken Shale OM Origin – Marine Algae



OM Types – Porous and Nonporous



Organic Nanopores in Immature Shale



PROJECT EXPECTATIONS AND IMPACTS

- Development of better methods and/or protocols to identify and quantify the geochemical factors that affect CO_2 transport, migration, and sorption in tight rock, organic-rich reservoirs
- Better understanding of how CO_2 migration and sorption are affected by kerogen type and thermal maturity, as well as clay type and occurrence
- Implications for both CO_2-based EOR and CO_2 storage in unconventional reservoirs
- Development of improved volumetric equations for estimating the CO_2 storage potential for organic-rich and tight rock formations

ACKNOWLEDGMENT

DOE Disclaimer

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