

High Resolution Quantitative Characterization of Organic Rich Mudstones using Laser Confocal Microscopy and Micro-FTIR Imaging

T. D. Jobe¹, D. Jacobi¹, S. Csutak¹, S. Eichmann², and W. Li¹

¹ Aramco Research Center- Houston, Houston, TX, USA

² Aramco Research Center- Boston, Cambridge, MA, USA

ABSTRACT

Evaluation of hydrocarbon potential in mudstone reservoirs relies heavily on an understanding of the kerogen type, maturity and nature of the host sediments. Arrangement of the mineralogical and organic microstructures and how they interact during hydrocarbon generation are a first order control on reservoir quality. Quantitative analysis of both the inorganic and the organic components is fundamental to understanding the bulk rock properties needed for larger-scale reservoir evaluation and prediction.

Current standard methods for imaging mudstone microtextures include transmitted light microscopy and electron beam microscopy. These methods, however, either limit the resolution of investigation or they limit the areal scope of investigation. Electron beam microscopes are capable of providing high resolution large area images, but these are costly both in terms of time and equipment. Furthermore, standard methods for obtaining quantitative information on kerogen type and maturity, involve destructive bulk rock measurements on homogenized crushed samples. These types of analyses determine chemical composition either by pyrolysis or by acid/solvent digestion. While these reactions can quantify the components of the samples they are costly, time consuming, and the results obtained are difficult to correlate to the original rock fabric or mudstone microtextures.

We present two methods for spectral characterization of mineralogy and geochemistry based on non-destructive measurements: Laser Scanning Confocal Microscopy (LSCM) and Micro-Fourier Infrared (FTIR) Imaging. These spectroscopic techniques have specific molecular responses from which physical and chemical properties such as kerogen type and maturity can be inferred. Although widely used in other sciences, these imaging techniques are still emerging technologies in the geosciences.

LSCM is a fluorescence imaging method that relies on the light response associated with electronic transitions from UV to Visible light excitation. Laser scanning microscopes are superior to traditional UV light microscopes in that they utilize point illumination and a pin-hole placed in front of a detector. This greatly increases signal-to-noise ratio and supports quantitative measurements at a much higher spatial resolution (250 nm). Motorized stages enable large area high resolution scans to be automated and acquired quickly. These large area scans provide the resolution necessary for quantitative analysis and the spatial context for interpretation of rock fabrics.

FTIR spectroscopy measures the infrared absorption spectra which correspond to the vibrational stretching and bending modes of molecular bonds. These vibrational modes are characteristic of specific chemical functional groups. Micro-FTIR Imaging uses a focal plane array and a traditional FTIR spectrometer for simultaneous acquisition of multiple spectra in a single measurement.

The resulting spectral maps provide the relevant spatial distribution of chemical information at a high resolution. Simultaneous multispectral acquisition supports advanced spectral analysis and, thus, significantly improves the signal-to-noise ratio. In addition to mineral quantification in the rock matrix, Micro-FTIR Imaging can be used to distinguish specific compositional structures within kerogen, such as aliphatic and aromatic compounds. This joint geochemical and spatial characterization enables improved classification of mudrocks according to kerogen type and maturity. Using Micro-FTIR imaging, genetic relationships can be documented between organic content and the surrounding microtextures and mineralogy. These relationships are not readily apparent using traditional bulk rock FTIR analysis. Furthermore, high resolution chemical maps can be related to fluorescence responses.

This allows the chemical information to be up-scaled and mapped over a larger area using LSCM.

Mudstone rock fabric is an important control on flow in source rock reservoirs. Documenting the relationship between organic content, surrounding micro textures and relating to larger-scale rock fabrics is a necessary first step in predicting potential hydrocarbon mobility. Coupling Micro-FTIR Imaging and LSCM supports quantitative, non-destructive, evaluation of the chemical and spatial heterogeneity within mudstone fabrics.