Raman Spectroscopy in Shale Reservoirs: Organic Material Type, Maturity, and Dynamic Modulus

Research Themes

Vitrinite reflectance and Rock-Eval pyrolysis (Tmax) are the two standard techniques used to determine source rock maturity. However, it is frequently difficult to apply these techniques to small volumes of organic material (OM), high maturity samples with heterogeneity and increased bireflectance, and where vitrinite is rare to absent (e.g. pre-Silurian rocks which do not have vitrinite macerals). This is important because the mechanical properties of shale samples change with thermal maturity.

In SEM (scanning electron microscopy) imaging, different OM types in shale samples are identified by their morphology and gray level contrast. However, this information is often not enough to determine the OM types. There is a need to link the distribution and morphology of the organic matter types with other information. Raman spectroscopy, based on molecular vibration, provides information regarding chemical bonds present in individual organic components. A relationship is demonstrated between Raman spectra and thermal maturity of coal and kerogen samples. We intend to develop similar relationships for the various OM types in unconventional reservoirs. We simultaneously use a high resolution (50 micron) acoustic microscope to directly measure velocities associated with varying organic matter content in highly laminated samples.

Compared to vitrinite reflectance and Rock-Eval pyrolysis, Raman spectroscopy has several advantages:

1. The laser focal volume is around 3 μm3 under the Raman microscope, enabling the analysis of small volumes of dispersed OM.

2. The technique detects the Raman spectrum of target samples based on their chemical composition instead of their optical reflectance. The Raman spectrum is not influenced by optical bireflectance and heterogeneity.

3. Raman techniques can also be applied to samples with no vitrinite macerals.

Recent Accomplishments

We have performed Raman spectroscopic analysis and SEM imaging on shale kerogen at different thermal maturity levels. Shale kerogens with low thermal maturity typically exhibit a strong fluorescence background that can overwhelm or mask the Raman spectrum. We have successfully measured the Raman spectrum of low maturity (0.5% Ro) OM by selection of the appropriate Raman excitation laser. The Raman spectrum of shale kerogen shows a D band around 1350 cm-1 and a G band around 1590 cm-1. Several associated bands are also revealed by deconvolution. We are able to pinpoint different OM types in the field of view by simultaneously viewing the sample in reflected light and obtaining a Raman spectrum. Different OM types are shown to have different Raman spectra. Thermal maturity of the shale samples are correlated with the Raman spectrum for both marine and terrestrial sedimentary OM, as well as bitumen. Our results are shown together with SEM imaging of OM of various types (e.g. bitumen, marine Type II kerogen, and terrestrial OM) so that an integrated understanding of the Raman spectra, OM type, and maturity is achieved.

Issues

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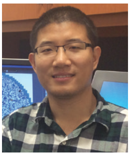

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