Raman Spectroscopy of Organic Material in Shales: Relationship to Thermal Maturity, Mechanical Properties, and Organic Matter Type Interpreted from SEM Images

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ABSTRACT

Vitrinite reflectance and Rock-Eva! 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, heterogeneity and bireflectance in high maturity samples, and where vitrinite is rare to absent (e.g. pre-Silurian rocks which do not have vitrinite macerals).

Raman spectroscopy, based on molecular vibration, can provide chemical composition information of samples. In addition, a relationship has been demonstrated between Raman spectra and thermal maturity of coal and kerogen samples. Compared to vitrinite reflectance and Rock-Eva! pyrolysis (Tmax), Raman spectroscopy has several advantages. First, the laser focal volume is around 3 J..Lm3 under the Raman microscope. This enables analysis of small volumes of dispersed organic material. Second, as this technique detects the Raman spectrum of target samples based on their chemical composition instead of their optical reflectance, it does not suffer from optical bireflectance and heterogeneity. Third, this technique can also be applied to samples with no vitrinite macerals.

We have performed Raman spectroscopy analysis, acoustic microscopy, and SEM imaging on shale kerogen and coal samples at different thermal maturity levels. Shale kerogens with low thermal maturity typically exhibit a strong fluorescence background that can overwhelm or cover the Raman spectrum for analysis. Using instrumentation developed at the University of Houston, we have successfully measured the Raman spectrum of low maturity (0.5% Ro) organic material. The Raman spectrum of shale kerogen shows a D band around 1350 cm·1 and a G band around 1590 cm·t, consistent with the Raman spectrum obtained from coals. Recent studies have illustrated a relationship between thermal maturity of coal samples and the details of the Raman spectra. From the Raman spectra of coal samples measured for this study, we obtained results consistent with previous research performed by other groups. Acoustic properties of shale kerogen samples were also measured to correlate with their thermal maturity. Our results will be shown together with SEM imaging of organic material of various types (e.g. bitumen, marine Type II kerogen, and terrestrial OM) so that an integrated understanding of the Raman spectra, mechanical (acoustic) properties, organic matter type, and maturity can be achieved. This study has proved the feasibility of Raman spectroscopy as a thermal maturity indicator for shale kerogen.