Organic Matter Chemical Composition & Mechanical Properties Measured at Nanoscale

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Solid organic matter (OM) plays an essential role in the generation, migration, storage, and production of hydrocarbons from economically important mudrock formations (commonly termed shale). This OM is heterogeneous at even submicron length scales, as evidenced by scanning electron microscopy images showing wide variations in pore shape and abundance among OM particles separated by microns. In addition to porosity, properties of OM such as chemical composition and mechanical stiffness are also of interest because they are integral to petroleum product composition, hydrocarbon storage/transport, and properties relevant to hydraulic fracturing in mudstones. These properties, particularly chemical composition, have been shown to vary widely among shales from different locations or with different maturities but exist at length scales too fine to be imaged by conventional techniques, obscuring understanding of heterogeneity at small length scales.

Here were describe a novel method for simultaneous characterization of the chemical composition and mechanical properties of OM grains at nanoscale. The measurements are performed using a technique that combines atomic force microscopy with infrared spectroscopy (AFM-IR). In this measurement, the infrared spectra of organic matter particles are recorded by a detector based on AFM, which enables chemical imaging at length scales finer than the classical diffraction limit that constrains traditional methods of IR imaging. This technique is used to measure, at a spatial resolution of ~100 nm, the spectra of individual OM particles in a maturity sequence of New Albany Shales prepared by hydrous pyrolysis. The results document how the chemical composition (abundances of aliphatic, aromatic, and oxygenated carbon) and mechanical properties (stiffness) of OM evolve at the maceral level during petroleum generation. By providing maceral-specific chemical data using a general method that can access even the smallest relevant length scales, this work is intended to connect petrographic and geochemical tools and to help provide a microscopic picture of the heterogeneous process of petroleum generation.