Fall 11-11-2015

Probing micro- and nano-scale elastic modulus variation in organic-rich shale—A naturally occurring composite

Corinne Packard
Colorado School MInes, cpackard@mines.edu

Taylor Wilkinson
Colorado School MInes

Saeed Zargari
Colorado School of Mines

Manika Prasard
Colorado School MInes

PROBING MICRO- AND NANO-SCALE ELASTIC MODULUS VARIATION IN ORGANIC-RICH SHALE—A NATURALLY OCCURRING COMPOSITE

Corinne E. Packard, Colorado School of Mines
cpackard@mines.edu
Taylor M. Wilkinson, Colorado School of Mines
Saeed Zargari, Colorado School of Mines
Manika Prasad, Colorado School of Mines

Key Words: nano-dynamic mechanical analysis, indentation, elastic modulus, property mapping, shale

Organic-rich shales are heterogeneous, naturally occurring composites that act as source rocks for oil and gas, which can be extracted through the process of hydraulic fracturing. Shales are composed of clays, minerals, and evolving organic matter and developed through long periods of sedimentation and compression. An elastic modulus mapping technique based on spatially continuous dynamic nanoindentation is applied to map microscale variations in a fine-grained, organic-rich shale consisting of inorganic minerals with an inter-penetrating network of microscale pores filled with organic matter. A sample of Bakken shale from the Williston Basin was chosen for analysis, in which the organic matter is predominantly kerogen. Figure 1 illustrates the degree of spatial variation in microstructure, with thin lathes of clay in gray, kerogen in black, and minerals including calcite and pyrite shown as larger grains in various light shades of gray. Procedures for sample preparation, scanning, and data analysis were optimized through experimentation and analysis using Hertzian contact mechanics. The magnitude of influence from surface roughness and spatially varying stiffness on property extraction were assessed and mitigated through implementing data filtering routines. As a result, spatial variation in elastic modulus was mapped at higher resolution than had previously been reported. This improvement in data extraction provides a better understanding of intergranular properties in shales and is applicable to other natural and manufactured composites containing stiff and compliant materials. The data presented here for organic-rich shales are the first of their kind and have the potential to inform procedures for upscaling to representative volume elements and developing physics-based models for assessing deformation and fracture potential.

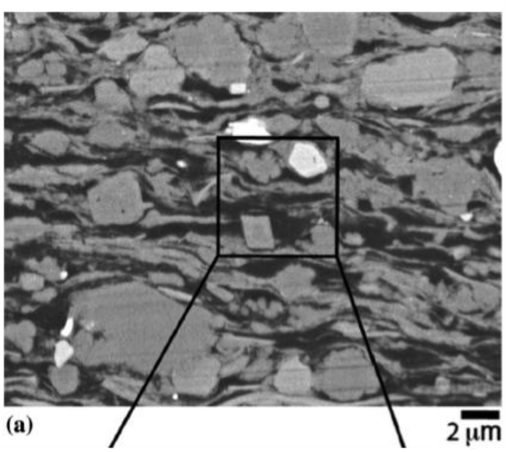

Figure 1 – Scanning electron micrograph of an organic-rich shale. The highlighted section contains materials with elastic moduli spanning 5-200+ GPa over an area of only 25 μm².