Characterization of tight shales from hyperspectral imagery of drill core

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Shale reservoirs are major resources of natural gas and oil. The development of carbonate mudrock and shale reservoirs worldwide has highlighted small-scale mineralogical and stratigraphic complexity in fine-grained rocks that were once thought to be fairly uniform. Resolution of these complexities can be aided through geochemical analyses and hyperspectral imagery. Geochemical variations represent changes to the paleophysiochemical conditions during deposition and changes in the mineralogy due to input from different sources. Hyperspectral imagery enables the detection of infrared active mineralogy (e.g. quartz, clays, carbonates, and hydrocarbons). In this study, models were derived to convert spectral imagery into a series of geochemical and mineral indicators at the per pixel scale.

Of these, the total organic carbon (TOC) content and the quartz/clay ratio are critical elements of shale reservoir characterization. TOC influences the volumes of hydrocarbon generated and the fraction of porosity. The quartz/clay ratio influences the mechanical properties of shales and therefore whether they are prone to develop natural or hydraulically induced fractures. Quantitative measurements of these properties are based on either direct chemical analyses of rock samples or interpretations of well logs. Chemical measurements are a subsample of the entire formation and offer an incomplete or blurry record of the rock properties that vary significantly at smaller scales. Well logs provide a continuous record but average properties at scales up to one meter. Hyperspectral imaging can provide continuous, high-resolution (mm-scale) measurements of these important properties.

From the collection of shortwave infrared (1-2.4 μm) and longwave infrared (8-12 μm) spectral imagery at a spatial resolution greater than 1 mm/pixel, we report on the predicted distribution of TOC, several minerals (quartz, biogenic silica, clays, carbonates) and geochemical indices (wt% SiO_2, % Al_2O_3, % K_2O, % CaO) for two shale formations, the Horn River in BC and the Duvernay in AB (Kaybob and Willesden Green fields). Predictive models were constrained by approximately 200 analyses of TOC and 100 analyses of whole rock geochemistry for the Horn River shales and then applied to both sample suites. The spectral imagery and its derived information products are used for both formations to: 1) highlight sedimentological features not perceived visually, 2) define formational and intra-formational boundaries, and 3) examine geochemical and mineralogical changes and patterns across stratigraphic sections. Hyperspectral imaging of drill core in high resolution reveals the distribution of minerals and organic matter in shale sections that otherwise appeared largely monotonous to the unaided eye.