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# A hyperspectral analysis of sandstones, siltstones, shales, and mudstones from the Duvernay and Montney Formations: relating quartz, amorphous silica, clay, and carbonates identified on the micrometer scale to TOC and porosity

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## Introduction

Hyperspectral imaging techniques based on micro-Fourier-transform infrared (micro-FTIR) reflectance spectroscopy can be used for the *in-situ* identification and quantification (modal abundances) of minerals on the micrometer scale in a rapid and non-destructive manner. These techniques, which require very little sample preparation, are well-suited for the analysis of fine-grained sedimentary rocks, including those with high organic carbon contents. Unlike traditional analytical techniques (*e.g.*, whole rock geochemical analysis or electron microscopy), micro-FTIR-based imaging techniques are capable of distinguishing different mineral polymorphs (*e.g.*, quartz vs. amorphous silica), which is crucial for the correct interpretation of fine-grained sedimentary rocks. The compositional and textural information provided by micro-FTIR hyperspectral imaging can also be used to obtain information about the total organic carbon (TOC) content and the porosity in these rocks.

## Methods

To evaluate the ability of micro-FTIR imaging systems to obtain compositional information from fine-grained sedimentary rocks from unconventional oil and gas deposits, hyperspectral imagery was collected using a Bruker Vertex 70 micro-FTIR spectrometer. Operating with a pixel size of 2.7 x 2.7 µm, more than 100,000 reflectance spectra were collected from each sample between 6 and 11 µm. Altogether, hyperspectral imagery was collected from ten samples of sandstones, siltstones, shales, and mudstones from the Devonian Duvernay Formation and the Early-Triassic Montney Formation of Alberta (Canada). The resulting hyperspectral images were subsequently analyzed to identify the presence of quartz, amorphous silica, clay, and carbonates, and to determine the relative abundances and characteristic textures of these minerals.

## Results - Compositional Maps

The results of the hyperspectral imagery analysis are compositional maps for each of the ten samples from the Duvernay and Montney formations that show the distribution of spectrally distinct pixels on the sample surface. Each colour represents either a specific mineral (pure pixel) or a spectrally uniform assemblage of two or more minerals (mixed pixel). By classifying pure and mixed pixels, it is not only possible to analyze the composition of larger clasts (*e.g.*, detrital quartz grains) in these rocks, it is also possible to determine the mineralogical composition of the matrix and the cement, which usually has grain sizes below the resolution of the instrument. Considering that quartz, amorphous silica, clay, and carbonate generally fulfill different rolls in these sedimentary rocks (*e.g.*, quartz is often found as a clast, whereas amorphous silica is typically found in the matrix and cement), it is conceivable that TOC and porosity are directly or indirectly governed by the presence, abundance, and physical arrangement of these different minerals in these sedimentary rocks.

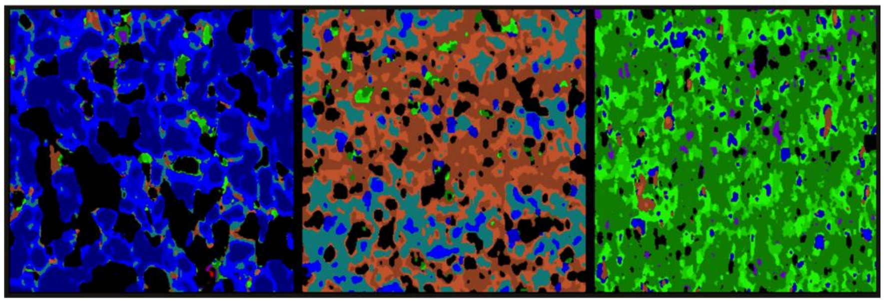


Figure 1. Compositional maps of three samples from the Montney and Duvernay formations. Each map contains more than 100,000 spectra, and each pixel was assigned a colour based on its composition, with similar compositions having a similar colour. Black pixels represent lithic fragments (e.g., feldspar) that have compositions other than quartz, amorphous silica, clay, and carbonate analysis. The field of view for each compositional map is < 1 x 1 mm.

## Conclusions

Preliminary research conducted on sedimentary rocks from the Duvernay and Montney formations using micro-FTIR spectroscopic imaging techniques shows that important compositional information can be collected from sandstones, siltstones, shales, and mudstones that may relate to TOC and porosity, as it not only captures the mineral content but also the *in-situ* arrangement of the minerals. The compositional maps produced using this technique show the presence, abundance, and spatial distribution of quartz, amorphous silica, clay, and carbonate, allowing for a direct compositional comparison between different samples. Given the high costs associated with drilling and producing from unconventional reservoirs, a better understanding of the distribution of the mineral components in these rocks may provide a easy way to reduce some of these costs. Unlike current destructive whole rock analytical techniques, micro-FTIR hyperspectral imaging is capable of identifying minerals and determining their *in-situ* distribution at the micron scale, providing unparalleled understanding of the textures in fine-grained reservoir rocks.

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