

Microns to Millimeters: Multi-range Hyperspectral Imaging of Organic and Inorganic Reservoir Rock Samples

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Reservoir quality assessment in conventional and unconventional petroleum systems relies heavily on understanding the mineralogy and arrangement of host sediments and their relationship to organic components such as kerogen and other residual hydrocarbons. At the microscale, reflectance spectroscopy has been extensively used to gather non-destructive chemical and compositional information from geologic samples, using techniques such as confocal fluorescence microscopy, scanning electron microscopy, Raman spectroscopy, and micro-Fourier transform infrared spectroscopy imaging [1-4]. These techniques provide semi-quantitative information about mineral distribution and organic thermal maturity while preserving spatial heterogeneities within in the reservoir rock fabrics [5].

The microscale information while robust and reliable is, however, insufficient for understanding the larger-scale bulk rock properties which can affect the productivity of a reservoir. Here we demonstrate the application of a custom-built multi-range hyperspectral imaging system that bridges the gap between micro-spectral analysis and core (mm-cm) scale reflectance spectroscopy. The system includes spectrometers that cover the ultra-violet (UV), visible to near infrared (VNIR), shortwave infrared (SWIR) to mid-wave infrared (MWIR) regions for comprehensive characterization of both organic and inorganic components in core and cuttings from a variety of rock types. The spectral image maps generated provide a means for rapid assessment of mineralogy and relative thermal maturity. The VNIR (400-1000nm) and SWIR (1000-2500nm) regions are particularly sensitive to mineral content while the MWIR (2000-6000) and UV (400-100nm) are useful for detecting organic components and hydrocarbons.

Hyperspectral imaging combines digital imagery for spatial information and reflectance spectroscopy for chemical information [6]. Digital images (~1mm/pixel) are acquired in conjunction with reflectance measurements that correspond to each pixel of the image. The imaging system used in this study includes four hyperspectral camera stations, each with a pushbroom imaging spectral sensor and independent illumination. The system transports samples via an automated conveyor belt to each of the four camera stations where full spectral data is simultaneously collected with spatial line scanning. A hypercube of data is generated where each pixel in the image contains the full spectral information for each spatial point in the sample. Integration over a specific spectral band generates a spectral map where pixel color represents the relative intensity of that spectral band across the sample. Each spectral sensor has a different optical detection limit and therefore must be calibrated and scaled relative to the visible light digital images. The system automatically scales the images from each camera and outputs the spectral results for comparative evaluation.

The multispectral data generated can then be used, with proper calibration, to infer physical and chemical properties related to mineralogy and organic content. The system is designed to accommodate whole rock, slabbed drill-core, as well as drill cuttings creating a unique ability to acquire multiscale-multispectral data for geologic interpretation.

Here we present examples of spectral maps generated for several rock types and their representative spectral responses demonstrating the utility of the technique to discriminate bulk mineralogy. In addition, we examine samples from source rock reservoirs of varying maturity to assess relative differences in spectral responses [7].

References:

[1] Y Chen et al., *International Journal of Molecular Sciences* **16** (2015), p. 30223.

[2] P Hackley and J. Krus, *Fuel* **143** (2015), p. 343.

[3] S Reed in “*Electron Microprobe Analysis and Scanning Electron Microscopy in Geology*”, ed. S Reed, (Cambridge University Press, Cambridge) p. 201.

[4] SL Eichmann et al., *Journal of Petroleum Geology* **41** (2018), p. 421.

[5] TD Jobe et al., *SEPM-AAPG Hedberg Research Conference (2016) AAPG #90283*.

[6] M Speta et al., *American Association of Petroleum Geology Bulletin* **99** (2015), p. 1245.

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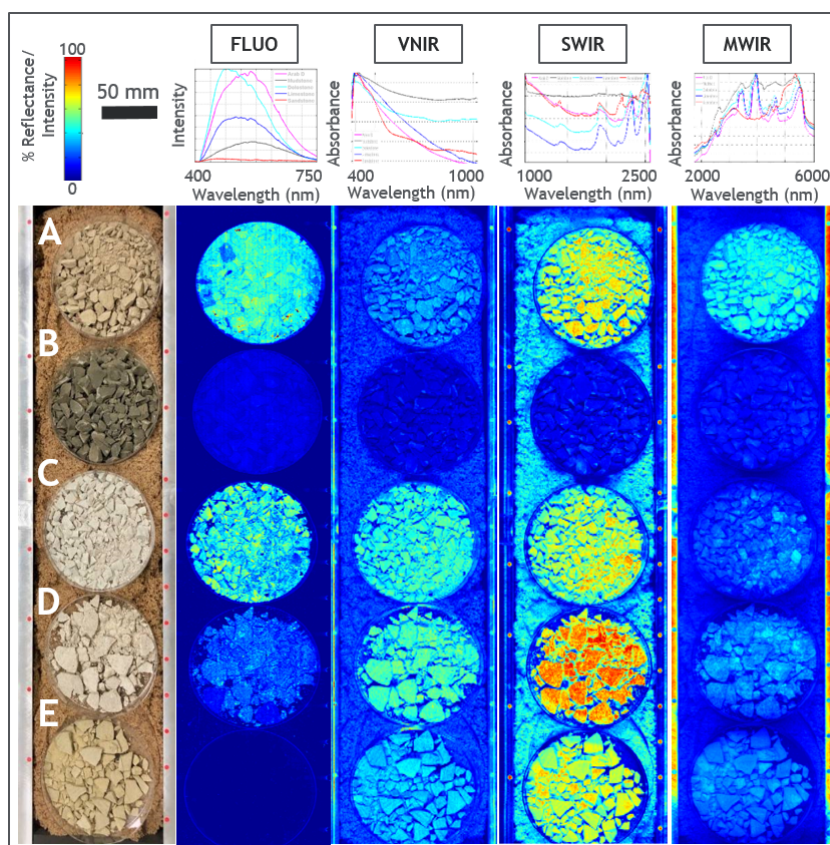


Figure 1. Representative spectral maps for several reservoir rock types including A) oil saturated sandstone, B) mudstone, C) dolostone, D) limestone and E) a clean sandstone. The colored intensity maps represent the mean % reflectance (average intensity of the spectrum at each pixel) while the spectral plots at top represent the average spectra for each of the rock samples (average of all pixels). Note, these are plotted in absorbance units. The spectra clearly show not only differences in absorbance but also characteristic absorption features (peaks) related to the different rock types. Finally, one should note the contrast between the oil saturated sandstone (A) and the clean sandstone (E) which is highlighted in both the MWIR and FLUO intensity maps.