Hyperspectral imaging for the determination of bitumen content in oil sands core samples

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Summary

Ore grade is one of the primary variables controlling the economic recovery of bitumen from oil sands reservoirs hence there is a need for the reliable quantification of total bitumen content (TBC) in drill core samples. This is typically achieved through laboratory based Dean-Stark analysis with decimeter scale sub-sampling of the core. Hyperspectral imaging is a remote sensing technique that combines reflectance spectroscopy with high resolution digital imaging. Imagery of a box of core can be acquired in less than a minute with 1 mm per pixel detail, and a reflectance measurement is made in each pixel of the image. Previous studies used point spectrometers for the determination of TBC in oil sands core by collecting reflectance measurements in 1 cm^2 windows on the sample (Shaw & Kratochvil, 1990; Donkor et al., 1995). Hyperspectral imaging is advantageous in that TBC can be estimated for the entire sample and one can examine the spatial distribution of the oil in the core. More recently, Rivard et al. (2010) developed a spectral model for the determination of TBC for homogenized feedstock ore which does not require site-specific calibration. Working with core samples rather than crushed ore, however, presents new challenges. The preservation state of the core sample (fresh, dry or frozen) and the extended range of minerals (e.g. clays, carbonates) will affect the reflectance response. Bitumen-free zones such as shale or mudstone, fractures and man-made materials must be calibrated for.

This study presents examples following the adaptation of Rivard et al.'s (2010) model for use on drill core. A modified version of the model was applied to two suites of drill core from two different locations within the Athabasca oil sands deposit. One suite is dry (i.e. devolatilized through long term exposure to ambient conditions) and the other is fresh (recently drilled). The spectral model calculates TBC on a per pixel scale as shown in the greyscale image in Figure 1. The greyscale is a visual representation of the range of TBC values in the image, where black is void of bitumen and white is the highest grade in weight percent. Sixty-one Dean-Stark samples of fresh core and forty samples of dry core were compared to mean spectral TBC results calculated from pixels corresponding to each Dean-Stark interval. The root mean square errors for the sample populations show that this model predicts TBC within +/- 1.3 wt % for fresh core (R^2 = 0.88) and +/- 2.3 wt % for dry core (R^2 = 0.67). Fine-tuning the model for dry core remains a priority, however even if absolute TBC values cannot be established, relative estimates may still be valuable, particularly in instances where no Dean-Stark analysis was conducted prior to dehydration of the core. Hyperspectral imaging has the distinct benefits of being non-destructive to the core sample and providing results within minutes of measurement while simultaneously creating a detailed digital record of the core.

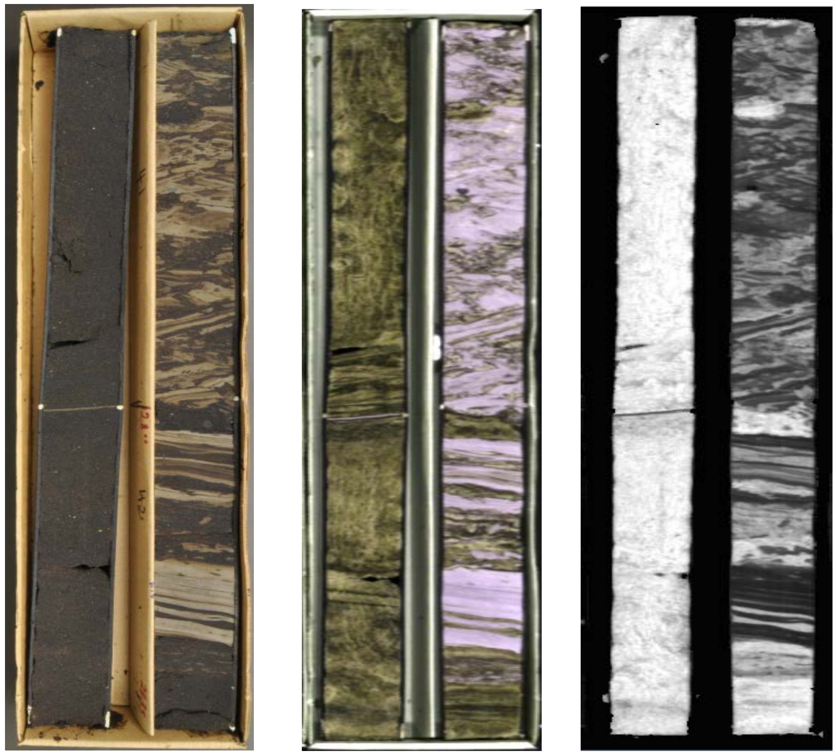

Figure 1: A dry core sample, from left to right: photograph, digital image (shortwave infrared) and greyscale TBC image. Despite the extensive devolatilization of the core, the greyscale image reveals coherent domains of variable bitumen saturation (black represents zones that are void of bitumen and white represents highest grade ore). Note that the mottled appearance of the bitumen saturated sandstone in the infrared image reveals a bioturbate texture otherwise not discernible.

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