Application of Hyperspectral Core Logging for Coal Mineral Characterisation in CSG Reservoirs

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Abstract

The occurrence of mineral matter in coal matrix and cleat networks can have a deleterious effect on coal seam gas reservoirs through reduction in gas holding capacity, blocking permeability pathways, reactivity with drilling fluids and potentially the generation of fines. Mineral matter in coal is commonly characterised by geochemical analyses, such as XRD, XRF, or petrology and more recently CT scanning, and this requires sampling. Sampling requires time, is not always contiguous, and destructive tests can lose the association with the host coal and strata lithology. Core scanners have become more common, and we trialed the application of Corescan^{TM} hyperspectral core scan technology to characterise Late Permian coals from the Bowen Basin. Hyperspectral loggers can provide information on the mineralogy of coal and interburden using visible and near (VNIR), short wave (SWIR) and thermal (TIR) infrared wavelengths. Corescan^{TM} currently operates in VNIR and SWIR from 450 to 2500nm. Corescan^{TM} can perform profile and 30mm swath scans at 0.5mm intervals to produce high-resolution mineral maps.

Five Late Permian coal cores from the Bowen Basin, Australia were selected for their variability in rank and mineral matter occurrence. Cores ranged in rank from a maximum vitrinite reflectance (Rv_{max}) of 1.2 to 2.2% (Core 1=1.2; Core 2=1.8; Core 3=2.2; Core 4=2.0; Core 5=1.7). The data were processed to the Coreshed^{TM} facility, which provides a virtual warehouse facility to securely store core data. Coreshed^{TM} provided a laser core profile, true and false colour spectral images, core photography, mineral class map, mineral abundance/purity maps for each mineral identified, organic matter abundance/purity map and three organic slope maps for each core. An example of the output is shown in Figure 1, with additional information from manual visual logging of the coal lithotypes.

Corescan^{TM} effectively detected carbonates and clay minerals in coal cores, occurring both as bands or lenses and in the cleat system. It did not detect quartz and feldspar spectra that require TIR (Li et al 2007), nor trace minerals such as rutile, pyrite and apatite with grain size smaller than the 0.5mm map pixel resolution. The mineral content of the cores was confirmed by QEMSCAN, petrography and XRD, and were consistent with a common Bowen Basin suite (Permana et al 2013, Rodrigues et al 2013). In the example in Figure 1, carbonates (in this case siderite and calcite) were common in bands whereas the cleat mineralisation commonly presented as Dickite or Kaolinite. Dickite would suggest some degree of hydrothermal alteration being responsible for cleat infill.

In addition to identifying mineral matter, the Corescan^{TM} produced a spectral organic abundance and organic slope maps using different peaks (1300/600; 2100/600 and 2100/1300). By visual comparison to the photos and logged core, variations were interpreted to reflect the different lithotypes, such as vitrain (bright bands) and durain (dull bands). To test this, an ASD Field Spectrometer of range 350-2500nm and two 70W quartz- tungsten- halogen lamps and were used to measure the spectral reflectance of end member lithotypes from all cores (ASDI 2014). The ASD was optimized, set to a 5mm spot size and calibrated with a spectralon standard. ASD spectral data were processed in Microsoft Excel^{TM}

and imported into Exelis ENVI^{TM} spectral image processing software to create spectral libraries by lithotype means overall and within each core (Exelis 2013).

The spectral organic abundance and organic slope maps partially correlated with coal lithotypes and with thermal maturity. Organic matter displayed a consistent spectral pattern across wavelengths for mean lithotype data with vitrains at higher spectral reflectance than durains in all cores, Figure 2. Although expected, it is nice to have quantitative confirmation from the tool. ASD spectral reflectances were plotted by lithotype to compare spectral slope patterns between cores, Figure 3. Although correspondence was not 100%, the lower ranked cores (Cores 1, 5, 2), had a lower spectral reflectance than the higher ranked cores (Cores 4, 3) for vitrain bands, but the trend was less apparent in the durain bands.

These results suggest that the technology can be improved to provide information to assist in local to regional correlation; identifying zones of deleterious clays that can reduce borehole stability or generate fines, and properties that affect reservoir behaviour of coals and interburden.

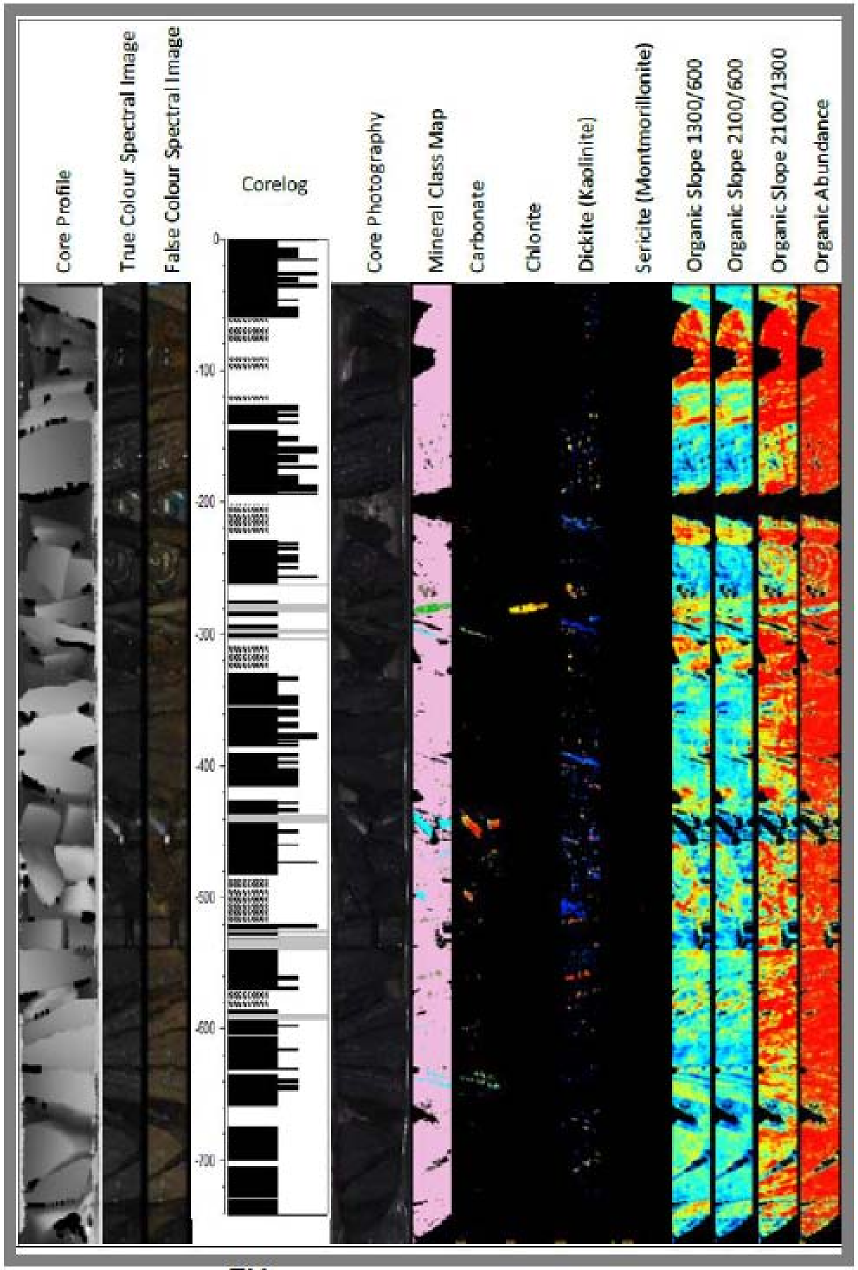

Figure 1. Example of Corescan^{TM} output, with additional visual coal lithotype corelog spliced in.

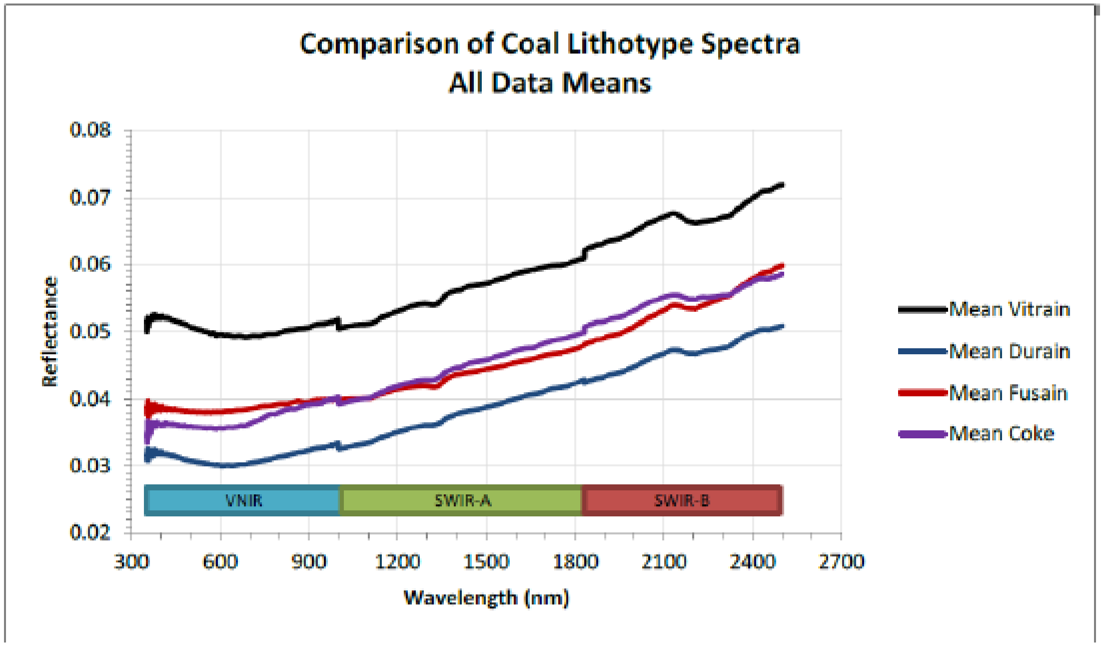

Figure 2. Average spectral reflectance from ASD field spectrometer for different coal lithotypes across all cores.

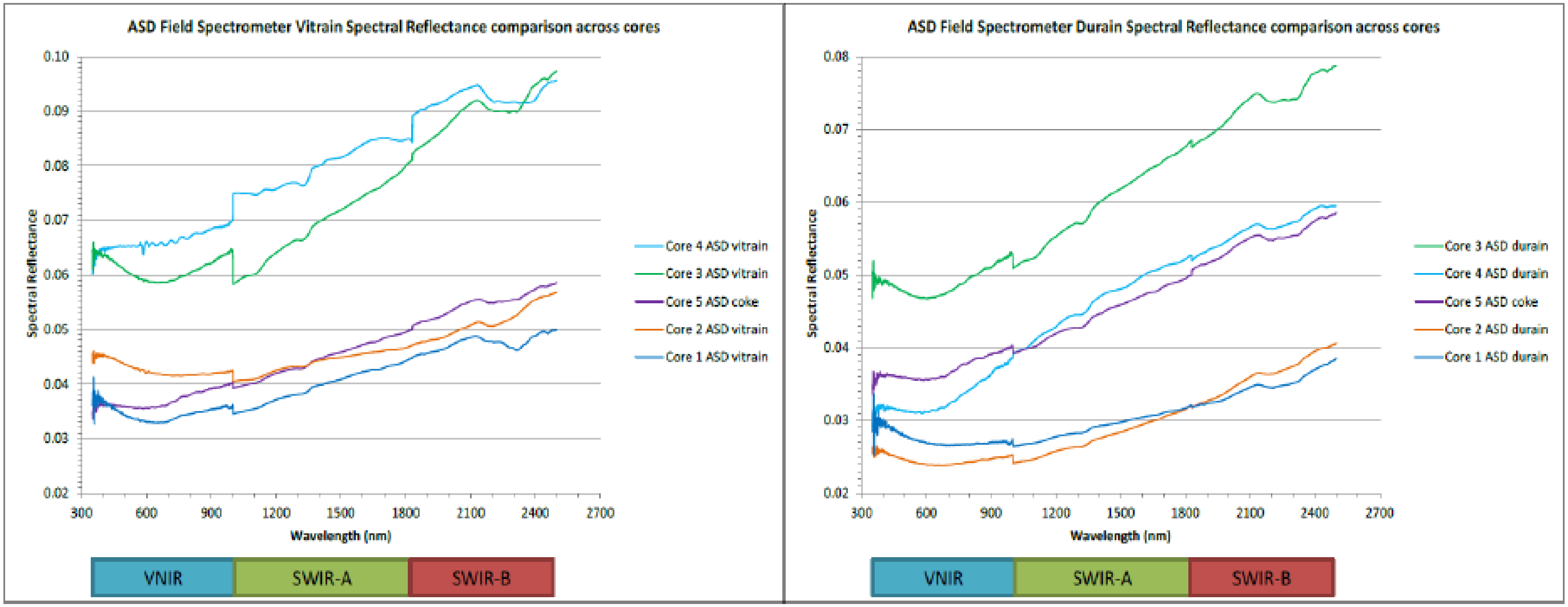

Figure 3. ASD Field Spectrometer spectral reflectances of vitrains (left) and durains (right) in cores. Rank reflectance values of cores are given in the text.