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Beyond Mineralogy: Utilizing Geochemical Spectroscopy for Improved Petrophysical Evaluation in McMurray Oilsands

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Summary

The Lower Cretaceous McMurray formation hosts one of the largest reserves of oil in North America. Located in the Western Canadian Sedimentary Basin in Northern Alberta, the formation contains significant amounts of bitumen within fluvial-estuarine channel deposits. A pulsed neutron geochemical spectroscopy logging tool, designed and developed for the precise determination of formation chemistry, is used with traditional petrophysical methods to not only determine mineralogy, but to provide inputs for advanced calculations such as effective porosity, oil saturation, and weight percentage of bitumen within the McMurray formation.

Theory / Method / Workflow

The Geochemical Spectroscopy Instrument (GSI), along with a Spectral Gamma Ray tool (SGR) is used to measure a suite of elements in the inelastic, capture, and natural spectra (Pemper et al. 2018) (Table 1). Formation mineralogy is established using a deterministic mineral model. X-ray fluorescence (XRF) and X-ray diffraction (XRD) measurements on core samples are used to validate elements from the GSI and the resulting mineral model, respectively. In addition to other elements, the measurement of Aluminum in the inelastic and Potassium in the natural spectra are used to work out low amounts of feldspars as well as Kaolinite, Illite, and other clay minerals present within the quartz-rich formation. By quantifying these minerals, the model provides a more accurate grain and clay density to use with and improve upon traditional petrophysical methods.

Grain density derived from the mineral model, along with a bulk density measurement from a traditional photo density tool, is used to produce a matrix independent porosity. Instead of relying on assumed values of matrix density, as in traditional logging techniques, the determined grain density allows for a more accurate porosity measurement. A shale corrected effective porosity can then be calculated employing clay volume and density from the modeled minerology.

Carbon, measured in the inelastic spectrum, is separated into inorganic, present as part of the formation mineralogy (i.e., calcite, dolomite, etc.), and organic, present in the formation as oil or kerogen. From the organic Carbon, oil saturation is calculated (Craddock et al. 2013). This method provides a saturation measurement uncompromised by common limitations in standard approaches, such as formation water salinity and the conductivity of clay minerals present.

With an accurate measurement of saturation, clay and grain density, and known values of hydrocarbon fluid density, the weight percentage of bitumen can be determined (AEUB 2003). The result is a quantifiable measurement of formation richness and potential reservoir productivity. Figure 1 shows the final petrophysical model including mineralogy, effective porosity, fluid saturations and weight percentage bitumen.

Results, Observations, Conclusions

The measurement of formation chemistry through elemental spectroscopy has allowed for the precise determination of mineralogy. This mineralogy, useful on its own to provide an accurate understanding of the geological characteristics of the formation, can be further used to improve upon traditional petrophysical workflows resulting in a more robust measurements of formation attributes and a better quantification of formation potential. By eliminating assumptions about matrix and clay density, clay conductivity, and removing the need for formation salinity the use of geochemical spectroscopy enhances evaluation methods, providing benefit well beyond minerology.

Novel/Additive Information

This paper presents a new approach and improved workflow for analysis of bitumen content in the McMurray Formation through the incorporation of geochemical spectroscopy data. Utilizing this approach reduces uncertainty present with traditional approaches by eliminating assumptions about matrix density and utilizing clay grain density and volume to calculate effective porosity. Uncertainty is further reduced using a direct measurement of carbon for saturation along with the incorporation of clay and grain density in the calculation of weight percentage bitumen.

Element	Symbol	Capture spectrum	Inelastic Spectrum	Natural Spectrum
Aluminum	Al	x	x	
Calcium	Ca	x	x	
Carbon	C		x	
Chlorine	Cl	x		
Gadolinium	Gd	x		
Hydrogen	H	x		
Iron	Fe	x	x	
Magnesium	Mg	x	x	
Oxygen	O		x	
Potassium	K	x		x
Silicon	Si	x	x	
Sulfur	S	x	x	
Thorium	Th			x
Titanium	Ti	x	x	
Uranium	U			x

Table 1: Elements measured in inelastic, capture, and natural spectra.

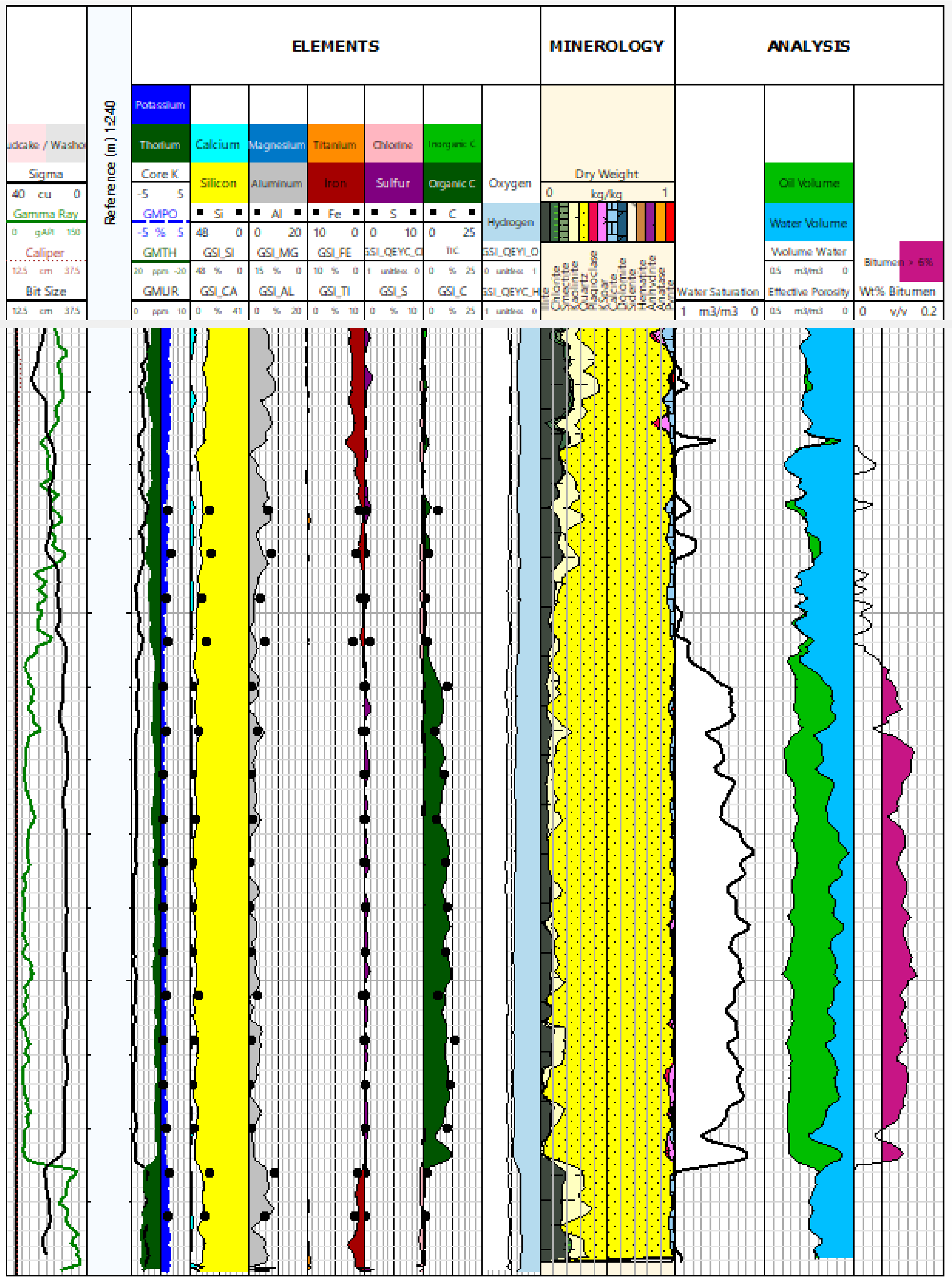

Figure 1: Log plot showing measured elements, formation mineralogy, effective porosity, water saturation, fluid volumes, and weight% bitumen.

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