High-Resolution X-Ray Fluorescence and Mechanical Hardness: Building a Mineralogical Model, an example from the Montney Formation

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Introduction

X-Ray Fluorescence (XRF) is a technique used to determine the bulk elemental composition of a material. It is non-destructive, low cost and allows for fast data acquisition. Elemental data acquired from the core/cuttings is accurate and precise. Data is calibrated to XRD (X-Ray Diffraction) data in order to produce a high-resolution mineralogical model. Mechanical hardness, measured in Leeb hardness units, is converted to Unconfined Compressive Strength (UCS) using an exponential fit model built on data from a number of public sources, including Verwaal and Mulder (1993). Leeb hardness can also be calibrated using rock mechanics data to output high-resolution geomechanical models for Young's Modulus and Poisson's Ratio. Hardness data is acquired quickly, non-destructive and low cost.

Data Acquisition/Procedure

SRM's (Standard Reference Materials) of known values are shot with XRF at the beginning and end of each day to ensure the equipment is working properly and known values are compared in order to calibrate the data. Data is acquired at 10 cm intervals along the length of a core with each sample point being exposed to X-rays for 90 seconds per beam (2 beams - 40 kV & 10 kV). For cuttings, they are placed into sample cups and a benchtop station is used to analyze the samples.

Element suite:

***Beam 1 40 kV**	**Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Y, Zr, Nb, Mo, Ag, Cd, Sn, Sb, W, Hg, Pb, Bi, Th, U, LE (Light Elements)**
Beam 2 10 kV	**Mg, Al, Si, P, S, K, Ca, Ti, Mn**

*All elements are calibrated with the exception of Co & Sn

Hardness data is acquired at 10 cm intervals, with 10 measurements at each sample point. Min, max, mean and standard deviations are calculated from this data. This data can only be acquired on intact core samples.

Discussion

A synthetic core gamma ray curve can be calculated using a simple equation, based on the Potassium (K), Uranium (U) and Thorium (Th) measured. This is compared directly with the core gamma measured in tubes when the core arrives.

Total Organic Carbon (TOC) is modelled using XRF data to identify zones with high or low organic content. Redox sensitive trace elements (Mo, V, U, Sr, Ni, etc.) can be linked indirectly to the TOC. In the

Montney Formation TOC modelled from XRF data matches quite well with the lab measured TOC (Figure 1).

A high-resolution mineralogical model is built by calibrating XRF data to the available XRD data. The elemental data is then converted to their respective oxides. Quartz, Feldspars (Plagioclase & K-Feldspar), Clays, Dolomite, Pyrite and occasionally Calcite and Anhydrite are modelled in the Montney (Figure 2). Modelled data corresponds quite well with the XRD measured lab data.

Unconfined Compressive Strength (UCS) is acquired using the mechanical hardness data. This helps identify stronger/more brittle rock and helps quantify the mineralogical model. In the Montney, high UCS correlates really well with beds that are highly dolomite cemented and corroborates the XRF generated mineralogical model (Figure 2).

Clay typing and abundance is also important in various formations as certain types of clays can be detrimental to well completions. The intricacy of individual clay structures and ability for incorporation and substitution of various trace metals only adds to the complexity. Core Laboratories is currently working on modeling for individual clays types within the Montney Formation, specifically illite and mica. Total clays in the Montney are typically overestimated as the mica fraction is commonly observed in thin section as a detrital framework grain and not a clay.

Conclusion

XRF and mechanical hardness is a great cost effective way to gather high resolution data quickly with very little sample preparation. XRF and mechanical hardness is portable, non-destructive and can be used to analyze slabs and cuttings (XRF only). Chemical stratigraphy can be determined from the elemental data acquired from XRF analyses which is used to create high-resolution mineralogical models and with geomechanical profiles that can aid in completion and production strategies.

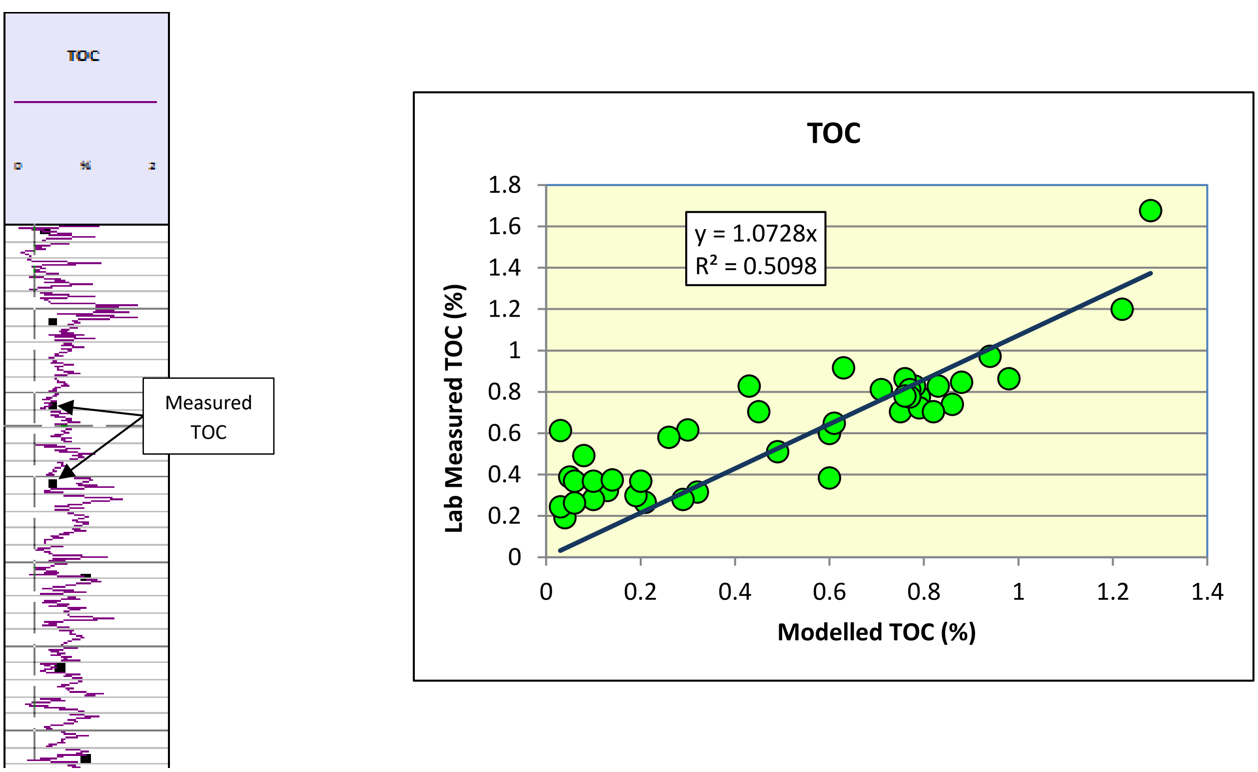

Figure 1. Modelled TOC with lab measured data points shown to the left. Modelled TOC vs lab measured TOC data shown to the right.

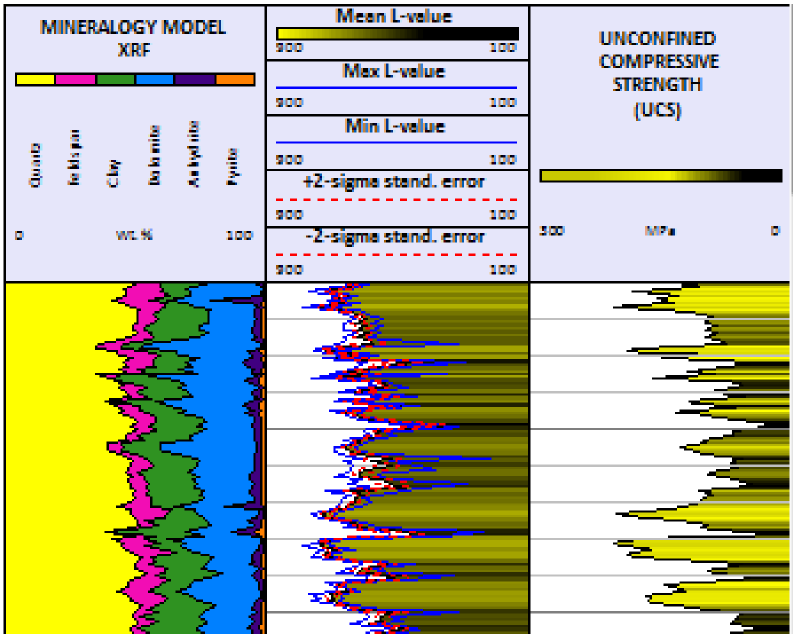

Figure 2. High UCS observed in zones of increased dolomite content and lower UCS in clay-rich zones.