Advanced Algorithms for Quantification of Mineralogical Composition from Elemental Composition (XRF) Data: Examples from the Montney, Duvernay and Bakken Formations (Canada)

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Summary

Low-permeability tight oil reservoirs are composed of a variety of minerals and exhibit rock compositional variations vertically and horizontally in the reservoir. Quantification of mineralogical composition is important for understanding controls on fluid transport, rock mechanical properties, and fluid-rock interactions in these unconventional reservoirs which, in turn, can be used to better predict hydrocarbon production and the effectiveness of the hydraulic fracture treatment.

This work presents results from an ongoing laboratory study, comparing advanced predictive algorithms for quantification of mineralogical compositions from elemental composition data obtained from the portable energy dispersive X-ray fluorescence (XRF) technique. Focusing on selected tight oil reservoirs in Western Canada (Montney, Duvernay, Bakken), the primary objectives are to 1) establish rigorous workflows for calibrating XRF data based on the ICP-MS data, customized to different formations and 2) develop predictive algorithms for quantification of mineralogical compositions from XRF data.

Theory / Method / Workflow

Calibrated based on the ICP-MS data, a portable XRF apparatus is employed in this study for measuring elemental composition of core samples obtained from target reservoir intervals within the Montney, Duvernay and Bakken formations (Western Canada). Understanding the merits and limitations of a previously-developed algorithm – that is based on the application of ICP-MS data as input (Wang et al., 2016) – an improved algorithm is developed for quantification of mineralogical composition from XRF data. For the analyzed reservoir samples, ten minerals can be quantified by the algorithm using elemental contribution equations and a trace element (Rubidium). The minerals include apatite, anhydrite, pyrite, anatase/rutile, calcite, dolomite, quartz, K-feldspar, plagioclase, illite, and muscovite. The X-ray diffraction (XRD) technique, performed on the same sample suite, is employed to validate the results of the predictive algorithms. An additional mineralogical composition analysis – that is based on scanning electron microscopy (SEM) observations combined with Energy-dispersive X-ray spectroscopy (EDS) maps (Vocke et al., 2018) – is further conducted on the same sample suite for comparison purposes.

Results, Observations, Conclusions

Integrating a variety of laboratory techniques including ICP-MS, XRF, XRD and SEM/EDS, a comprehensive laboratory workflow is established for developing predictive algorithms for quantification of mineralogical composition from elemental composition data, customized to the target formations. The proposed laboratory workflow is comprised of three stages: 1) (bulk) elemental composition measurement and calibration, 2) mineral phase identification and 3) mineralogical composition calculation. The experimental observations demonstrate that the calculated mineralogical compositions for selected reservoir samples correspond closely with the compositions obtained from the XRD technique, particularly for major minerals (e.g. quartz, carbonate). Detailed discussions are provided for observed discrepancies, if any, and possible sources of uncertainty are clarified.

Novel/Additive Information

It is well-understood that the relative proportions of elements/minerals (e.g. silica, carbonates and clays) partly govern the petrophysical and geomechanical properties of tight oil reservoirs. Compared to direct mineralogical composition analysis (i.e. XRD technique), elemental composition analysis (i.e. XRF technique) is inexpensive, fast, non-destructive, and more importantly, can be applied to drill cutting samples – that are commonly the only reservoir samples obtained from the multi-fractured horizontal wells (MFHWs) – with a fast laboratory turnaround. Currently, there are multiple commercial methodologies/tools available for quantification of mineralogical composition from elemental composition (i.e. XRF data). However, the details of these commercial algorithms are not fully disclosed in the literature. The advanced predictive algorithm presented herein elaborates on details of such calculations, and are beneficial to the tight oil operators in Western Canada by enabling them to acquire high-resolution high-precision mineralogical composition logs along the length of MFHWs by performing inexpensive, fast, non-destructive XRF analysis under laboratory and field conditions.

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