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Quantitative analysis of smectite and associated clay minerals in drill cutting samples by XRD with Rietveld and relative intensity ratio methods

Mashrur Zaman, Graham Spray, Philip Haig, Raphael A. J. Wust, Brent Nassichuk
Geology Division, AGAT Laboratories Ltd.

Abstract

Clay minerals such as smectite, kaolinite, illite, or chlorite are ubiquitous in the geosphere and encountered during drilling and completion operations. Because of their size and ability to exchange cations and anions and thus change structural habits, smectite group clay minerals are the nightmare of any reservoir and drilling engineer. However, these clay minerals are also difficult to quantify properly (due to chemical variability and different structure patterns) and thus proper remediation or solution applications are challenging to develop in the laboratory. Here we focus on X-ray diffraction (XRD) techniques for the identification, characterizations and (semi-) quantification of these minerals, including Rietveld peak pattern modeling, relative intensity ratio analysis (RIR), etc. This approach is selected to identify crystal structures and therefore cation dominance (e.g. Ca^{2+}, Mg^{+}, Fe^{2+}, etc) as well as complex crystal structures (i.e. mixed-layer clay minerals). Over 100 drill cuttings samples that contain some smectite minerals are utilized for the comprehensive clay mineral study to investigate (1) the controls of sample preparation strategies and particle size, (2) the crystal-chemical and quantitative analyses of these minerals with XRD coupled with RIR and Rietveld methods, and (3) the implications in oil and gas exploration and production.

Beside the common clay minerals of illite, chlorite and kaolinite, the smectite minerals appear elevated in the smaller size fractions with the nano-size clay minerals showing significant flocculation effects (i.e. large particle behaviour) at pH = 8 that increases under lower pH conditions. These findings illustrate that nano size clay mineral stability in oil and gas reservoir environments may be controlled by pH (H^{+} and OH^{-}) and pH_0 (pH at PZNC) and these conditions may play a critical role in terms of fines dispersion and potential migration. In addition, the lateral continuous sample analysis illustrates the variability in clay composition which is rarely considered during completion strategies. This paper emphasizes the challenges of proper clay mineral speciations when multiple complex clay mineral phases are present and also discusses the use of such data in completion and stimulation applications.