Integrated Shale Gas Evaluation: A Study of QEMSCAN©, SEM and Optical Petrography, XRD and Geochemistry of Selected Potential and Producing North American Gas Shales

Jon Sliwinski*[1], Matt Power[2] & Peta Hughes[2]
SGS Canada Inc, 1)Edmonton, AB 2)Vancouver, BC
jon.sliwinski@sgs.com

and

Jay Harrington
Upper Canada Oil & Gas Ltd., Calgary, AB

Summary

In 2008 shale gas production totaled over 5 Bcf/d and accounted for 8% of the total daily natural gas production in North America. While 70% of this was from the Mississippian Barnett shale of Texas, production in other fields has started to increase. Numerous thermally mature, organic rich shales have been identified and targeted as potential analogues to the Barnett. The evaluation of these shales has proven challenging as many conventional techniques such as well logging, petrophysics and core analysis are inconclusive in the very fine grained sediments that make up these reservoirs.

We present a brief summary of data from a diverse selection of North American shales over a broad geological time frame: Cambrian Conasauga; Ordovician Lorraine and Utica; Devonian Muskwa and Duvernay; Mississippian Barnett and Floyd; Triassic Montney; and Cretaceous Colorado. The emphasis has been placed on correlating QEMSCAN© with other analytical data including XRD, geochemistry, TOC and Rock-Eval.

We illustrate how QEMSCAN© can rapidly characterize bulk mineralogy, texture and identify different depositional facies within a shale section by classifying drill cuttings on the basis of their mineralogy and texture. The QEMSCAN© data is further enhanced when combined with SEM and optical microscopy, XRD and geochemistry. This combined with the bulk mineralogy from the analysis can rapidly identify optimal completion intervals, zones for horizontal development and intervals with a high propensity for fracturing.

Introduction

It has been recognized that mineralogy and texture can be a critical component in the resource potential of shales. Rocks with high silica (quartz) and low clay content typically have high Young's modulus and low Poisson's ratio making them more brittle, more prone to natural fractures and good candidates for fracture stimulation. Many shales exhibit covariance between silica and TOC (total organic carbon) suggesting a biogenic origin for the quartz. This biogenic quartz can also contain trace or rare earth elements typically found in organic materials. Aluminosilicates such as illite can have microporosity suitable for the adsorption of gas while other clay minerals can increase moisture content which reduces the adsorption capacity of a shale.

Theory and/or Method

In this study we utilize QEMSCAN©, a high definition, automated mineralogical analysis tool, to evaluate the mineralogy and micro textures of potential gas shales. QEMSCAN© allows a detailed evaluation far beyond the resolution of conventional thin section petrography and at a speed much faster than conventional SEM analysis.

Several analytical methods were applied to the samples collected, including high definition mineralogical analysis by QEMSCAN©, SEM-EDX/WDX (Scanning Electron Microscopy - Energy and Wavelength Dispersive Spectroscopy), Electron Microprobe and Optical microscopy methods, XRD analysis, and geochemical analysis by XRF, ICP-MS and Leco Carbon analysis. Data was also collated from previous works published by the Energy Resources Conservation Board/Alberta Geological Society, the Quebec Ministry of Natural Resources and Wildlife and various other published reports.

Results

Several important themes emerged from the data:

Total Organic Carbon:

Total organic carbon data was plotted against RockEval and geochemistry/mineralogy data determine the relationship.

Silica: Detrital (Biogenic) Quartz, Feldspars or Clay Minerals:

Various authors have proposed using the geochemical whole rock analysis to try to determine quartz content of various shales.(Ross and Bustin, 2006). Most use an aluminum silica ratio to estimate clay and attribute all excess silica to quartz. Estimates such as these have can give erroneous results due to variability in Al/Si ratios for different clay species, the presence of other silicate minerals such as feldspar. Mineralogy can also be determined by X-ray Diffraction (XRD) but difficulties arise from the poor crystallinity of some clay species and high (2-5%) detection limits. The comparison of QEMSCAN©, XRD and geochemical mineralogy results show variability depending upon the shale and the complexity of the mineralogy.

Importance of Illite:

Illitization of kaolinite and smectite occurs between 80 and 120C) and is indicative of the thermal maturity required for methane production. Illite/Smectite ratios have also been used to give an estimate of thermal maturity and can be used as a geothermometer (Huag et al, 1992 and Pevear 1999). The estimated illite/smectite temperatures are compared to the RockEval data. Additionally the data may give indications of overpressured reservoirs, due to increased pressure form water expulsion during illitization

Smectites and mixed layer illite/smectite (I/S) are also water sensitive and need to be considered in drilling and completions engineering. QEMSCAN© data also add textural information illustrating how these clays are distributed (pore filling, lenses, etc.) in addition to the bulk mineralogy.

All Carbonates are not equal:

Recently carbonaceous gas shale plays have been successfully developed, contrary to the traditional assumption that a high silica content was a requirement. However all carbonates are not equal and various mineral and textures, such as detrital dolomite, seem to be more abundant in producing carbonaceous gas shales.

QEMSCAN and SEM Shale Petrology:

Various authors have developed different proposed depositional facies within shale formations (Hickey & Henk, 2007) (Loucks & Ruppel, 2007) with some facies showing more potential. QEMSCAN© allows rapid classification of different facies based on mineralogy and texture from drill cuttings.

Others have shown through nanoscale analysis that porous and permeable microfabric and silt laminations are very important in both the overall volume of gas in place and the ultimate recovery (Bustin et al 2008). QEMSCAN© and SEM imaging are important tools in identifying these features.

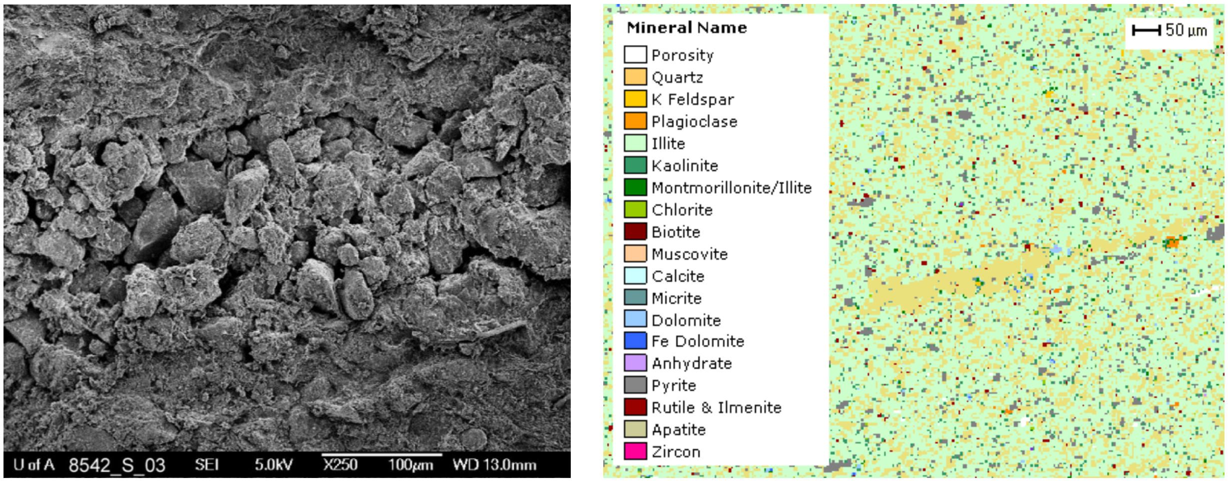

Figure 1. Left: SEM Image of a shale from the Cretaceous Colorado Group (Rokosh et al, 2008) showing a lamination of very fine sand to silt sized quartz grains. Right: QEMSCAN© false colour image showing a similar lamination of quartz grains.

Fractures in cuttings:

QEMSCAN ©cuttings have shown healed fractures which do not contribute to reservoir storage but may enhance effectiveness of hydraulic fracturing by providing planes of weakness.

Conclusions

The complexity of shale gas reservoirs demands new technologies be applied in their evaluation. QEMSCAN analysis is a valuable tool when combined with other advanced techniques.

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