Does Grain Size Matter? (what do we know about grain size and reservoir quality of siltstones)

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Summary

Extensive research on clastic rocks has demonstrated a clear connection between composition and grain size of clastic rocks (lithofacies), the diagenetic process that the rock undergoes during burial, and the resultant reservoir quality. These relationships are generally understood for sandstone (for example: Pittman and Larese, 1991; Lander and Walderhaug, 1999; Paxton et al., 2002; Ajdukiewicz and Lander, 2010). Effects of rock composition on mudstone diagenesis and reservoir quality have been studied (for example: Velde, 1996; Milliken et al., 2012; Milliken and Olson, 2017; Dong et al., 2019), but the influence of grain size on the petrophysical properties of mudstones remains ambiguous, mainly because studies of mudstone diagenesis rarely report grain size distribution.

In this study we investigate the influence of grain size on the compositional variability, the diagenetic pathways, and the petrophysical properties of the Lower Triassic Montney Formation siltstone, an example for a silt - rich mudstone.

Theory / Method / Workflow

Detailed sedimentological descriptions were obtained for four cores representing different depositional environments and burial depths that resulted in the identification of three groups of lithofacies. Mineralogy, grain size, mineral size, and apparent grain size (Figure 1) of samples from the four cores, as well as cutting samples from three additional wells were analyzed via QEMSCAN analysis and point count analysis on SEM-CL (Scanning Electron Microscopy with CathodoLuminescence) images. Point count analysis was also used to identify and quantify diagenetic phases in the samples. Mineralogical composition was also confirmed by quantitative XRD analysis.

Apparent grain size includes the detrital grain and cement overgrowths, if present, and thus reflects both the water energy in the environment of deposition and the amount of cement surrounding the detrital grains. To obtain present-day apparent grain size from QEMSCAN analysis, the mineral phase of interest was isolated from the dataset and all grains were measured and grouped into size-bins by the length of their apparent long axis. Results are reported as percent area of the mineral in each size-bin.

Relationships between mineral size and detrital grain size (Figure 1), compositional variations, cements volumes, and He-pycnometery porosity were established for all three lithofacies groups.

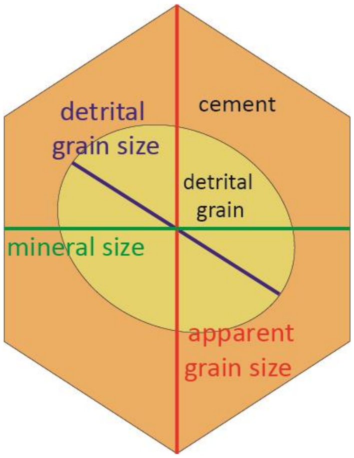

Figure 1: schematic illustration of the measurements taken to establish grain and mineral size distribution. Detrital grain size (blue line) is the apparent long axis of the detrital grain. Mineral size (green line) is the horizontal intercept lengths of mineral crystals within a sample, and present-day apparent grain size (red line) is the apparent long axis of the detrital grain and its surrounding cement.

Results, Observations, Conclusions

Using a combination of the Folk and Ward (1957) and the Macquaker and Adams (2003) classifications, lithofacies were divided into three groups based on their present-day apparent grain size distribution. Group one lithofacies are somewhat coarser than other lithofacies and most samples in this group contain >10% sand size grains. Samples in these lithofacies are poorly to moderately sorted ($0.5 < \sigma1 < 1.5$) with a positively skewed grain size distribution (tail of fine grains); this group has sedimentary features such as current ripples, hummocky cross stratification, and rip-up clasts indicative of higher water energy in the depositional environment.
Group two lithofacies are siltstones with up to 10% sand content, moderately sorted ($0.5 < \sigma1 < 1$), with a nearly symmetrical grain size distribution (skewedness ~ 0). Samples in this group are commonly laminated. Group three lithofacies are all fine grained, with <5% sand size grains, all moderately sorted ($0.5 < \sigma1 < 1$) with a negatively skewed grain size distribution (tail of coarse grains). Samples in group three are usually massive in appearance.
Although the three lithofacies groups have different grain size, we did not identify any significant difference in cement volumes between these groups, nor were there any distinct compositional variations between them in any of the study wells (Figure 2).

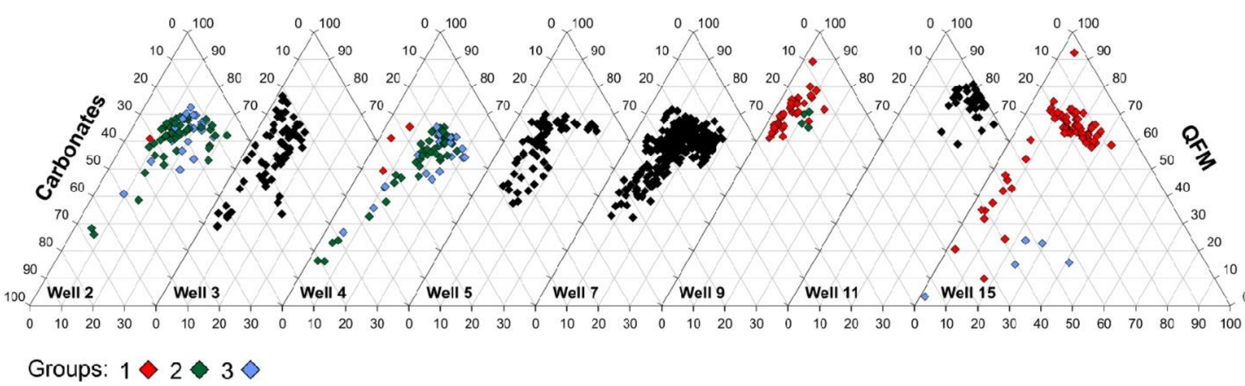

Figure 2: Compositional variations between samples of different lithofacies groups. QEMSCAN analysis results in wt%. QFM is the sum of quartz, K-feldspar, Na-feldspar, and micaceous minerals. Clay minerals include MLIS and kaolinite, and carbonate minerals include calcite, dolomite, and Fe-rich dolomite.

Detrital grain size appears to have little to no relationship to the volumes of individual cement types (quartz, calcite), or total cement (including quartz, feldspar, dolomite, calcite, anhydrite, pyrite, halite, and phosphate), in contrast to previous models (Zonneveld and Moslow, 2018). We suggest that shallow burial diagenesis and homogeneity of the detrital material that composes the siltstone (Vaisblat et al., 2021) rendered the limited variability of grain size insufficient to have a distinct influence on diagenetic processes, cement volumes and thus reservoir quality in the Montney Formation.

Acknowledgements

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