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Born This Way — Inherited Heterogeneity and Microporosity Modalities in "Hybrid" Reservoirs of the Upper Cretaceous Colorado Group, Western Canada Foreland Basin

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Summary

Microfabric characteristics of Upper Cretaceous (Cenomanian – Turonian) Colorado Group carbonaceous mudstones provide insights into the large-scale depositional and shallow burial processes in the foredeep and back-bulge segments of the Western Canada Foreland Basin (WCFB). Specifically, textural relationships between disseminated kerogen and clay floccule aggregates were largely determined at the time of deposition, forming a record of the complex interaction between organic and inorganic constituents in a surprisingly dynamic setting. The physicochemical processes that determine these inherited textures reflect the large-scale dynamic evolution of the WCFB.

Diverse modes of microporosity are associated with distinct classes of depositional microfabric in carbonaceous mudstones of the Second White Specks and Belle Fourche Formations (and correlative units). The distinctions result from both time-variant and paleogeographically-constrained differences in climatic, tectonic and eustatic controls across the span of the WCFB. The depositional fabrics are commonly modified by subsequent compaction, early diagenesis and later catagenetic processes, but the inherited depositional texture determines the pathway and outcome. Laterally correlative strata spanning a foreland basin system offer the opportunity to evaluate how microfabric characteristics preserve evidence of distinct depositional and burial processes of different foreland basin segments. The understanding resulting from this investigation can be used to refine prediction of mudstone reservoir characteristics based on knowledge of the large-scale basinal processes.

Method

The study is based on secondary electron and backscatter electron microscopy of 319 ion-milled cross-sectional surfaces from 43 core samples. These samples are a representative suite of Second White Specks, Belle Fourche and Fish Scale Formation carbonaceous mudstones from thirteen cored wells spanning the WCFB in Alberta and Saskatchewan. The sedimentological and stratigraphic features of the cores were logged in detail, and subsequently tied to well log responses in order to incorporate the wells into our developing allostratigraphic framework based on Tyagi, et al. (2007).

Approximately 2600 SEM photomicrographs were acquired and evaluated in order to construct a comprehensive atlas of micropore and nanopore types. The imaging work was conducted using the Leo (Zeiss) 1540XB Cross Beam Focused Ion Beam Scanning Electron Microscope (FIB/SEM) workstation in the Western University Nanofabrication Facility. Porosity classification followed the scheme proposed by Loucks and co-authors (2012), using the broad categories of intercrystalline, intraparticle, organic matter and dissolution pores.

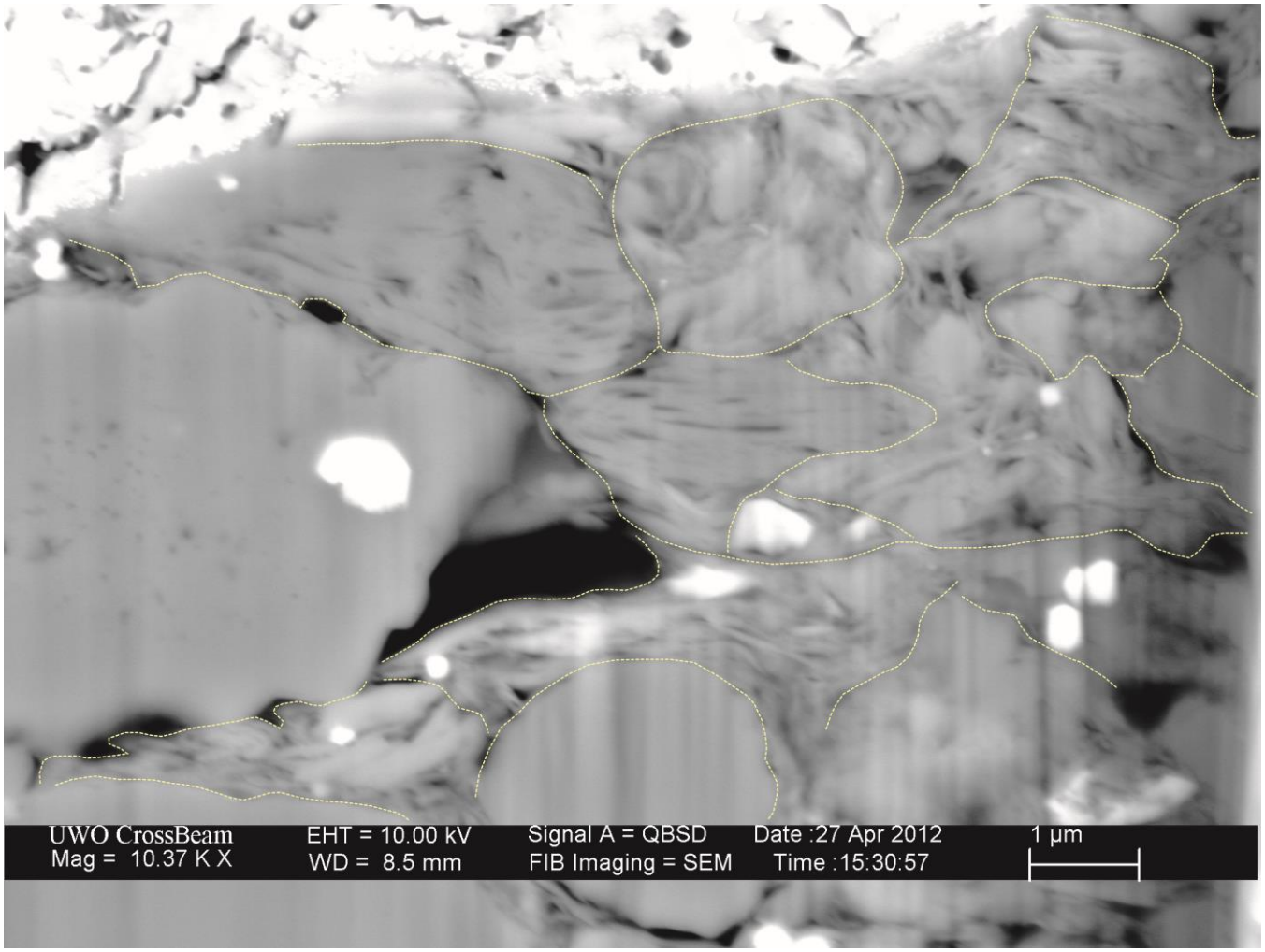

Figure 1: Yellow dotted lines indicate interpreted outlines of clay floccule domains within an aggregate grain. Note that several of the individual domains have retained an approximately equant form despite subsequent compaction. Backscatter-mode SEM photomicrograph of an ion-milled surface, Sunkay Member, Blackstone Formation, 100/07-19-045-06W5 [1866.0 m MD].

Examples

Figure 1 shows an example of one of the most abundant depositional microfabrics in the sample suite. Clay floccule aggregates, which are transported by intermittent combined flows (e.g.: Plint, et al (2012)), can be identified on the basis of localized domains of oriented clay platelets with both sharp and diffuse boundaries between adjacent domains. Individual domains are typically scaled between 1 and 10 microns in diameter, and these are aggregated into compound grains approximately one order of magnitude larger. Dispersed organic matter is commonly intimately intercalated with the clay platelets or between domains in larger aggregate grains. Intraparticle micro- and nanoporosity is preserved between sub-parallel clay platelets and in triangular voids formed by edge-to-face packing of clay platelets.

Despite significant post-depositional compaction, which is indicated by reduction of intergranular volume, clay domains and aggregates commonly retain roughly equant forms. This suggests that the material and its associated microtexture were substantially consolidated at the time of deposition or during early diagenesis prior to burial compaction. Consequently, the intraparticle porosity is “fixed” within the inherited depositional microtexture.

Conclusions

Primary textural variability is the principal determinant of porosity heterogeneity in “hybrid” mudstone-dominated reservoirs such as the Second White Specks Formation. The dominant mode of the porosity (i.e.: intraparticle versus interparticle), however, appears to conform to the local dynamics of sediment dispersal and deposition. To the extent that the morphometric characteristics of each matrix-related porosity type determines the effectiveness of pore network connections (Loucks, et al., 2012), it follows that depositional microfabric is a critical consideration for prediction of mudstone reservoir quality. In this regard, therefore, play and prospect development of “unconventional” carbonaceous mudstone petroleum systems must not eschew the proven methods of sedimentary geology in favour of the brute force of engineered extraction.

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