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Shale Fabric, Mineralogy and Effective Porosity of the Upper Colorado Group

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Summary

Permeable shale microfabrics and silt laminae may play a vital role in shale gas production (Davies et al. 2002; Gingras et al. 2004, Bustin et al. 2008). We have begun a study of shale microfabric and will contrast low to non permeable shale with overlapping stacked clay sheets that may be a relatively good seal with more permeable shale that has a relatively open microfabric. Porous silt laminae less than 200 microns thick are interbedded with shale in some cases and are adequate conduits for fluid flow. The permeable shale and silt features seen here are too thin to be detected on well logs and may easily be overlooked as a candidate for perforating and induced fracturing.

Introduction

Studying the development and preservation of effective primary and secondary porosity are fundamental aspects of understanding fluid flow in shale reservoirs (Davies et al. 1991; Javadpour et al. 2007; Bustin et al. 2008). Shale however is anisotropic so porosity and permeability must be evaluated with respect to sedimentary features that influence vertical and lateral fluid flow. Anisotropy in shale arises principally from the geometry of clay minerals and because the sedimentation process of clay mineral deposition normally results in a fabric of successive relatively parallel layers of flat-lying sheets. Hence, fluid flow in unfractured shale may be more conducive laterally than vertically, resulting in shale often being a seal to vertical fluid flow. However, factors such as bioturbation, re-sedimentation (e.g. gravity flows), natural fracturing and the deposition of permeable silt or sand laminae may enhance both vertical and lateral fluid flow by altering the microfabric of shale (Davies et al. 1991, 2002; Gingras et al. 2004). Diffusive flow of natural gas from shale to a horizontal or vertical the well bore may be more economic in the presence of these factors (Bustin et al. 2008). Here we examine Scanning Electron Microscope (SEM) images of shale fabric and mineralogy from the Colorado Group, and the Banff and Exshaw Formations in the Western Canada Sedimentary Basin (WCSB). Our purpose is to study the development of effective porosity as reflected in the fabric or microfabric of potential gas shale reservoirs to reveal the potential for enhanced vertical and lateral fluid flow in shale.

Geological Setting and Sample Collection

Shale samples from core and outcrop were collected in the WCSB for a project involving the evaluation of shale gas resources in the Province of Alberta (Rokosh et al. 2008a, 2008b, 2008c). Some of the samples were viewed and imaged using the JEOL 6301F Field Emission Scanning Electron Microscope (SEM) housed in the Earth Sciences Building at the University of Alberta. In our evaluation the SEM was used to characterise the microfabric of the samples and the morphology, size and distribution of the pores. A semi-qualitative elemental analysis is available via a PGT X-ray analysis system (Energy Dispersive X-ray, EDAX) as well as backscattering images on selected samples. The JEOL 6301F SEM is has magnification ranging from 20x to 250,000x. The resolution of mineralogical analysis is 1 micron. All samples were coated with gold prior to analysis.

SEM Images

Over 75 images of Colorado and Banff sediment were taken using the SEM. There are too many to be discussed in this abstract, but we select a few images that will show a variety of microfabrics of Upper Colorado Group shale.

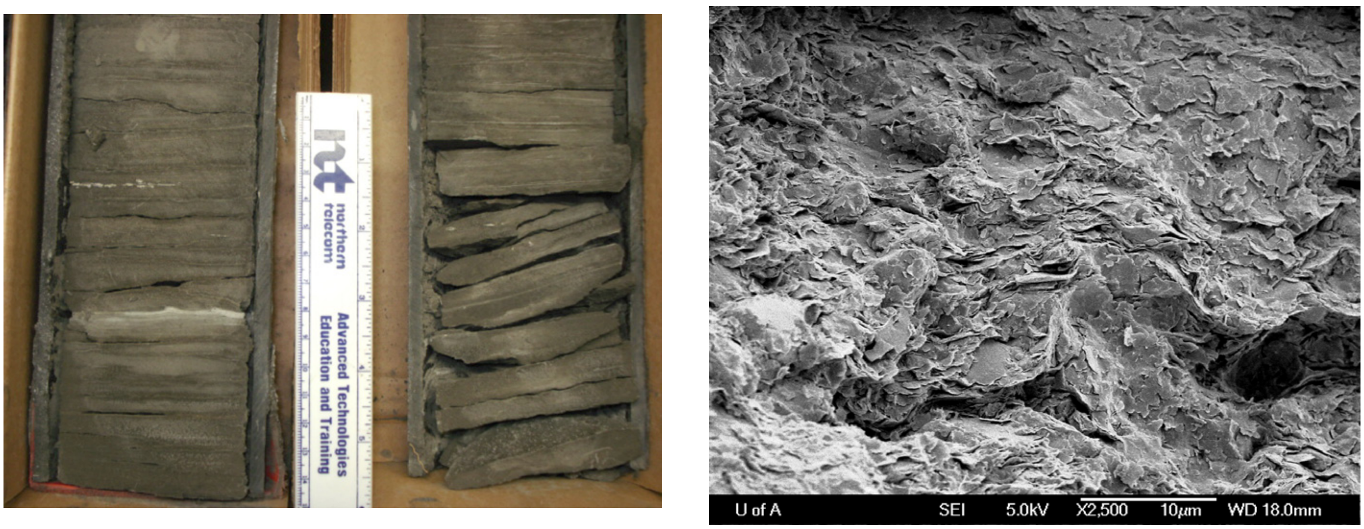

Figure 1: a) Core Photo of sample #8518, 102/03-14-018-11W4; b) Scanning Electron Microscope image of sample #8518_S_05

Sample # 8518 was taken at a depth of 407.5 m in the First White Speckled Shale from 102/03-14-018-11W4. Figure 1b is an image of shale at 2500X magnification that may be a better example of a hydrocarbon seal than a shale reservoir. The clay sheets are stacked and overlapping with few openings on top of the surface to allow for vertical fluid migration. Some degree of lateral migration is likely due to porosity at the edges of the clay sheets, provided this is not an artifact of sampling. The plucked site of a silt grain is evident in the lower right of the image. Thus the undulating nature of the surface of the sample may be due to silt grains floating in the clay matrix. EDX mineralogical analysis indicates that smectite is the dominant clay mineral in the sheets, and that the silt-sized grains are mostly quartz with some potassium feldspar and aluminum silicate (muscovite?). Organics, fossil bones (calcium phosphate), shell fragments, dolomite crystals and framboidal pyrite were also identified in the sample.

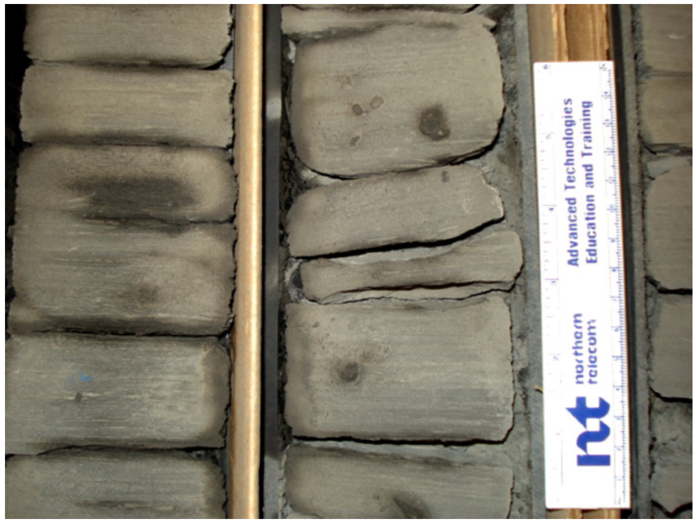

Figure 2: Core Photo of sample 8542_S_03, 100/06-36-49-05W4/00

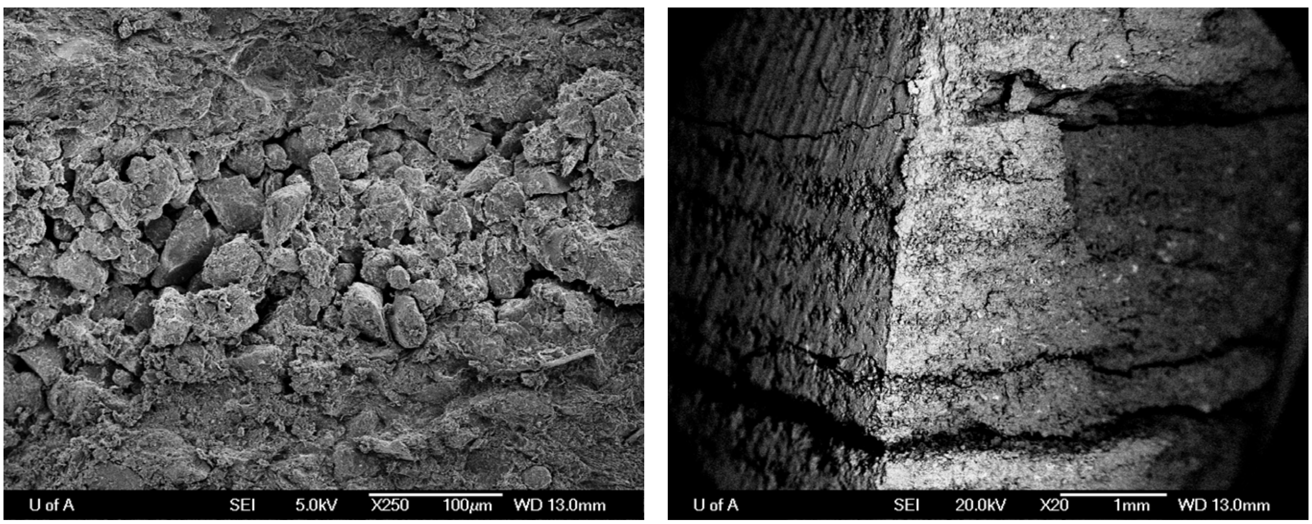

Figure 3: a) Scanning Electron Microscope Image 8542_S_03. b) Scanning Electron Microscope Backscattering Image 8542_S_20

Sample # 8542 is a 250X magnification image that was taken at a depth of 410 m from 100/06-36-49-05W4/00 and lies within the Upper Colorado or First White Speckled Shale. Figure 3a identifies a layer of poorly cemented silt grains that is approximately 150-200 microns thick (0.15 to 0.2 mm), or approximately the same diameter of a single grain of medium grained sand. These laminae are often difficult to find or view with the naked eye in core. The long axis of some of the silt grains are up to 50-60 microns which corresponds to coarse silt. The grains appear to be coated with secondary cement (quartz overgrowth and clay). The grains are moderately well sorted and subangular to subround with poor sphericity. EDX mineralogical analysis indicates that the clay mineralogy above and below the silt layer is a mixture of detrital smectite/illite and a small amount of authigenic kaolinite. The silt grains are primarily composed of quartz with some sodium feldspar. There is also secondary mineralization in the form of pyrite framboids (ball-shaped clusters of crystals) in the clay that can be seen in backscattering image Figure 3b as white spots or specks on the center right of the image.

Figure 3b is a lower magnification image of the same sample. The laminae are part of a two mm thick zone containing five laminae, all of which appear to be porous and poorly cemented. The laminae are encased in shale and are too thin to be located on well logs, yet the presence of multiple laminations in shale will contribute a small amount of free gas storage and production. More importantly the laminae will act as a conduit for gas diffusion from shale through the laminations to the well bore, provided the zone is perforated and the laminations are linked to the well bore by induced fracturing.

Porosity is viewed as dark areas between the grains. A visual estimate of porosity may be as high as 15-20% with pore throats as wide as a few 10s of microns. At this scale of magnification, the shale on either side of the silt laminae exhibits very low effective porosity. However, Figure 4 is an image of the shale at 10,000X magnification and shows the microfabric to be relatively open and more loosely packed than is seen in Figure 1b. Some of the pore throats in this image are more than one micron in width. The relatively chaotic nature of the clay sheets, the curvature of some of the sheet edges (see the middle and lower left of the image) and the multi-directional trend of many of the sheets suggest that the shale has been disturbed, although by an unknown process (bioturbation?).

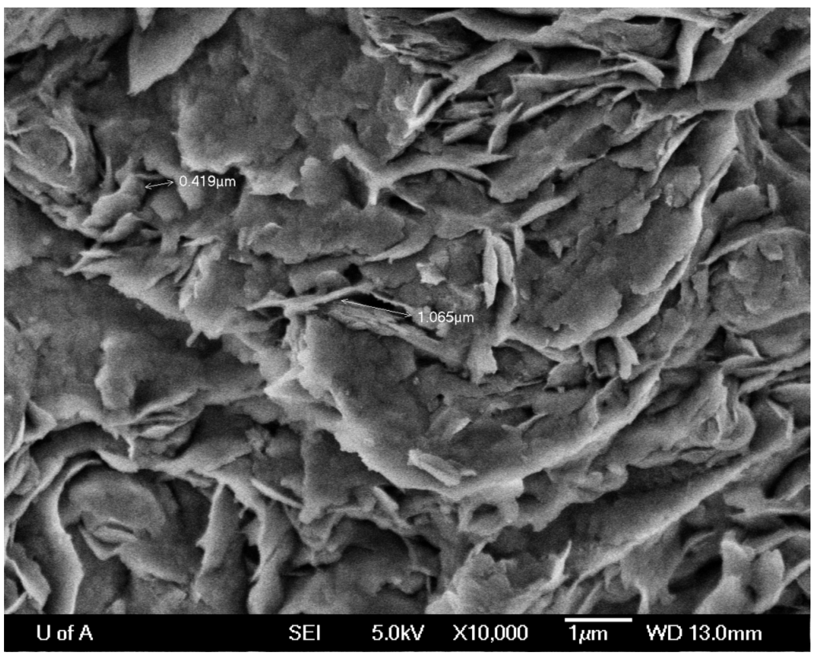

Figure 4: a) Scanning Electron Microscope Image 8542_S_XX

Conclusions

There is much to learn about shale fabrics and their role in enhancing shale gas production in the WCSB. The classical image of shale in Figure 1b with relatively parallel clay sheets is contrasted with Figure 4 that reveals a more open, chaotic microfabric. The silt laminae along with porous shale lamina are too thin to be detected on well logs but may play a vital role in shale gas production. These features cannot be located on well logs using standard log analysis techniques and hence a determination of the lateral extent of many of the features seen here awaits further study.

Acknowledgements

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