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Influence of Hydrothermal Fluids on the Horn River Shale Sequence

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Summary

The Horn River shale sequence was deposited adjacent to the Slave Point platform carbonates. The Slave Point carbonates were dolomitized by hot fluids that moved upward along faults. These faults extend into the basin. What influence did these hydrothermal fluids have on the deposition and diagenesis of the shale?

Abstract

Samples were collected from a measured section of an outcrop of the Besa River Formation west of Summit Lake British Columbia. Approximately 60 metres of shale overlie the Dunedin Formation limestone at this location. The shale is divided into three intervals which are correlated with the stratigraphic interval from the Evie to middle Otter Park members in the subsurface.

The lower 15 metres contains millimetre-scale fissile lamina interbedded with centimeter-scale platy beds (Figure 1). The platy beds have high TOC values (6.4 to 9%) and the bulk mineralogy is relatively simple, averaging about 91% quartz and 8% illite by XRD. The platy beds have a detrital fabric as observed in polished thin sections using SEM. Thin fissile lamina have somewhat lower quartz and higher illite content. Beds of limestone and dolomite are also present in this interval. A five metre covered interval separates the lower interval from a 10 metre thick succession of cleaved shale (Figure 1). This shale is also composed dominantly of quartz and illite, but has a lower quartz and higher illite content than the interval below it. About 30 metres is exposed above the cleaved shale before the outcrop is covered. This interval contains millimetre-scale fissile lamina and centimeter-scale platy beds similar to those in the lower unit; however, very resistant beds with a concoidal (chert-like) fracture pattern are the most abundant lithology (Figure 1). This interval has highly variable TOC values (2 to 8%). The bulk mineralogy is again relatively simple, averaging about 93% quartz and 6% illite by XRD. The resistant beds have a welded or cemented fabric as observed in polished thin sections using SEM.

Figure 1. Lithologies. The shale is divided into three intervals which are correlated with the Evie to middle Otter Park members in the subsurface. The lower interval (left) contains millimetre-scale fissile lamina interbedded with centimeter-scale platy beds. The middle interval (centre) is more clay-rich and highly cleaved. The upper interval contains very resistant beds with a concoidal (chert-like) fracture pattern.

The mechanical properties of these rocks as evidenced by their fracture patterns in the field are in part controlled by the composition (high clay content of cleaved shale), but more importantly by their fabrics. Two SEM images of polished thin sections of shale are displayed in Figure 2. The major constituents in both samples are quartz, organic material and illite. The sample on the left is from a platy sample and displays a classic detrital texture, with 10 to 20 micron diameter quartz silt grains and 10 to 20 micron long illite grains floating in a finer matrix of micron-scale quartz. The sample on the right is from the resistant beds with a concoidal or cherty fracture and displays a welded texture. Grain boundaries among the quartz silt grains and matrix are difficult to distinguish as a result of the quartz cement that binds the sample together. The petrography of these samples lays the foundation on which understanding of the rocks is built, and defines the questions that need to be addressed through other techniques in order to understand the rock

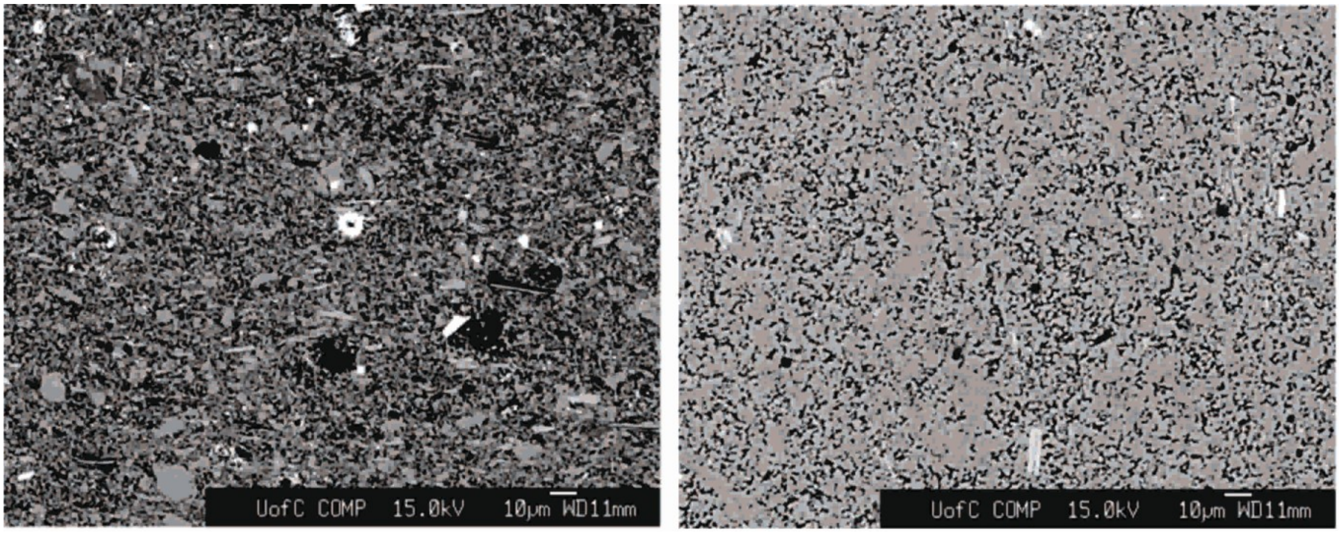

Figure 2. SEM images of siliceous shale. These two rocks have nearly identical mineral compositions as determined by XRD. The image on the left is from a sample that parts in centimeter-scale platy beds and displays a detrital fabric. The image on the right is from a sample of the very resistant beds with a concoidal or chert-like fracture pattern and displays a welded or cemented fabric.

and its properties. For instance, these rocks have fundamentally different mechanical properties. They break or fracture differently in the field; the rock on the left breaks into 1 to 10 cm thick plates a few tens of cm on a side whilst the rock on the right shatters into irregular chunks similar to the pattern observed in chert. Acoustical signals obtained from these rocks during crush tests are also quite different.

The origin of the cements responsible for these fabrics which exert a dominant control on the properties of these rocks is not understood. Petrographic observations indicate that cementation occurred prior to significant burial and compaction. Fossils are not abundant in these rocks; however, in both silica and dolomite cemented beds they tend to retain their original shape. For instance, radiolarian tests are nearly spherical in the silica cemented and dolomite cemented examples in Figure 3 (left and right), but flattened in the uncemented example (Figure 3, centre). Thus we interpret these cements to have formed early in the diagenetic sequence.

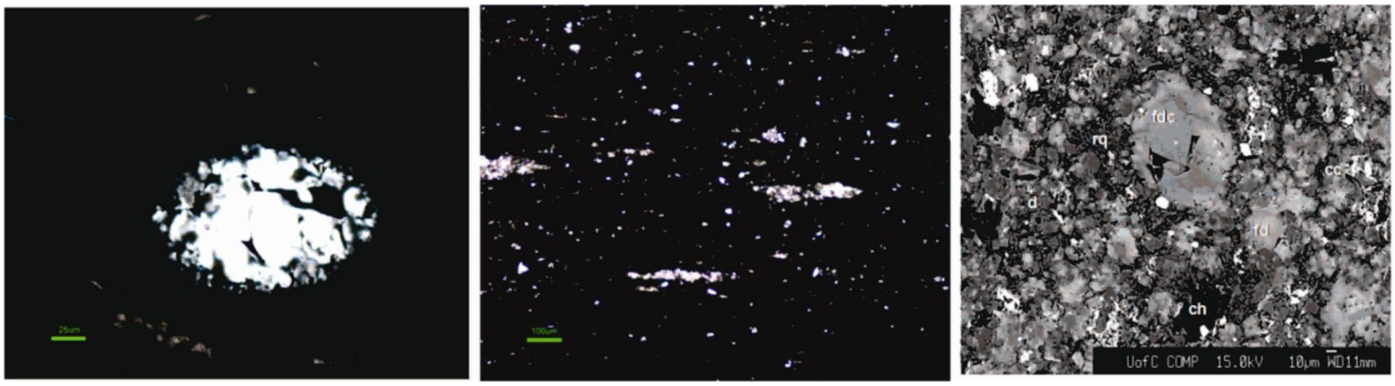

Figure 3. Transmitted light and SEM images of radiolaria. Thin section images in plane polarized light of a slightly flattened radiolarian that is partially in filled with quartz cement from a silica cemented sample (left) and flattened radiolarian from a non-cemented sample (centre). SEM image of a radiolarian filled with dolomite cement from a dolomite bed.

Fluid inclusions within these early diagenetic cements indicate moderately high temperatures of formation. Two phase, liquid-vapour, fluid inclusions are present in quartz, dolomite and albite cements. Figure 4 (upper left) displays fluid inclusions in quartz cement that in-fills a nearly spherical radiolarian. Fluid inclusions are also present in the dolomite cement within a delicate tentaculites fossil in the upper right image on Figure 4. The lower left image on Figure 4 displays fluid inclusions in an albite fill from the centre of a barite lined vug from a sample with a detrital fabric. The lower right image on Figure 4 displays fluid inclusions in quartz cement in a vug from a sample with a detrital fabric.

Accessory minerals, such as the barite and albite cements displayed in Figure 4, also indicate a hydrothermal influence on the shale sequence. Some of the pyrite in these samples exhibit a hexagonal habit; used in the mining industry as an indicator for the proximity to hydrothermal fluids. Also present is the rare earth phosphate mineral monazite. Monazite crystals overgrow and incorporate sediment as displayed in Figure 5. Monazite is rare in sedimentary rocks, but found in metamorphic and hydrothermal systems.

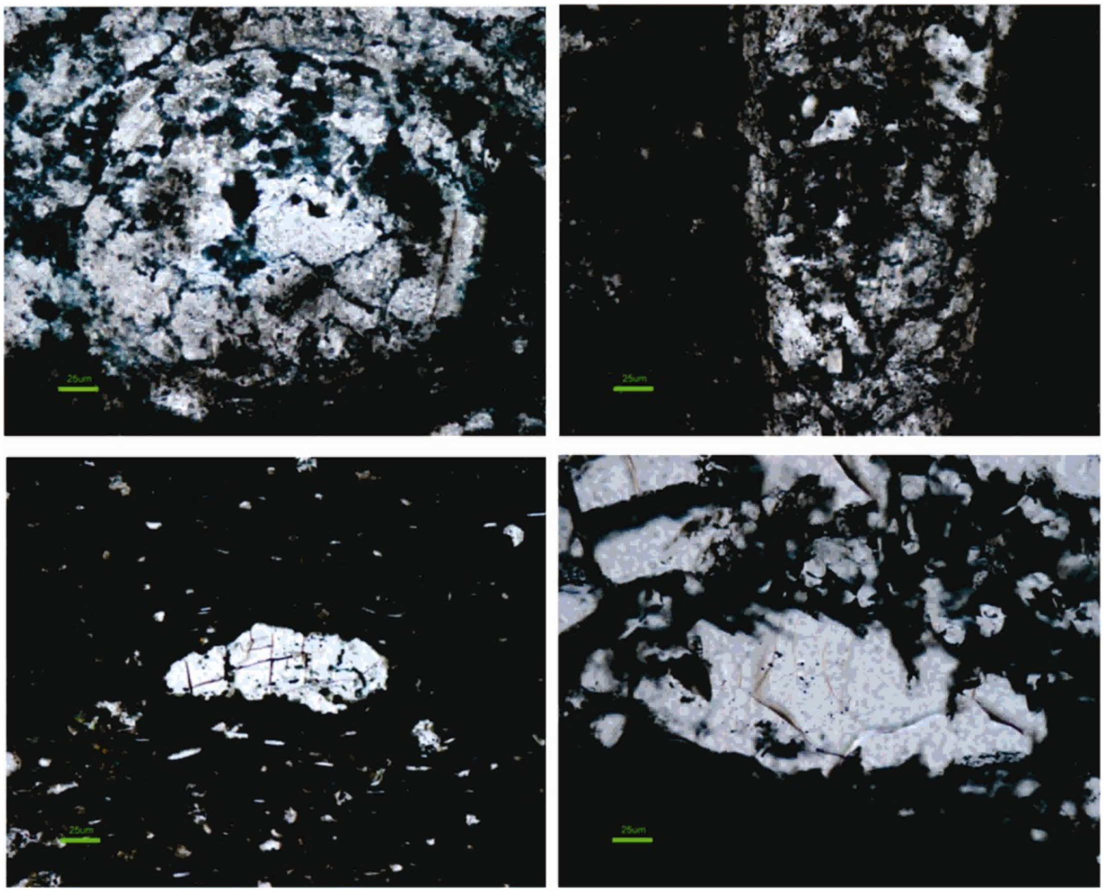

Figure 4. Liquid-vapour fluid inclusions. Thin section images of two phase, liquid-vapour, fluid inclusions in cements. All images in plane polarized light.

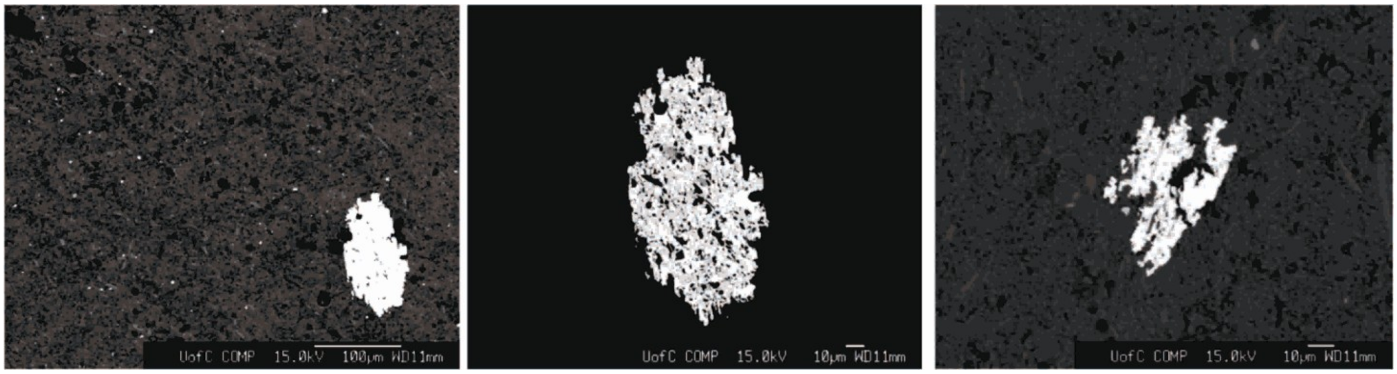

Figure 3. SEM image of Monazite. Monazite is a rare earth phosphate mineral that incorporates thorium, but not lead. Monazite is thought to form in metamorphic and hydrothermal environments.

In summary, there are several lines of evidence that suggest hydrothermal fluids similar to those that dolomitized the Slave Point platform carbonates also influenced the Horn River shale sequence in the basin. Hydrothermal fluids appear to have supplied the silica that cemented siliceous beds early in the diagenetic history of the basin. This cementation occurred prior to significant compaction. We speculate that these fluids circulated during deposition of the shale and may have also impacted the accumulation and preservation of organic matter through intermittent or long-term stratification.