Dolomitization and Burial Diagenesis of Devonian Slave Point and Keg River Formations in the Cordova Embayment Region of Northeast British Columbia, Canada

David.W. Morrow* and Lavern D. Stasiuk
Geological Survey of Canada, 3303-33rd Street N.W.,Calgary, Alberta T2L 2A7

Mengwei Zhao
HC Geoconsulting Co., 128 Hampstead Rise NW, Calgary AB T3A 6B4

ABSTRACT

White dolospar of the Presqu'ile Dolomite forms the reservoir for many gas fields of northeastern British Columbia. Several of these occur in the Presqu'ile Dolomite within the Keg River, Sulphur Point and Slave Point formations along the shelf margin bordering the Cordova Embayment (Figures 1,2). The Cordova Embayment was a narrow, north-facing Middle Devonian paleogeographic depression located along the Presqu'ile Barrier Reef in the extreme northeast corner of British Columbia. The Helmet and Peggo gas fields in the Slave Point Formation and the July Lake gas pool in the Keg River Platform immediately north of the Helmet gas field border the shelf-to-basin transition along the southern edge of the embayment (Figures1,2).

The depositional fabric formed a hydrostratigraphic "template" that strongly influenced dolomitization. The embayment fill succession of the organic-rich Klua and Otter Park shales, and the basinal argillaceous marlstones equivalent to the Sulphur Point and Slave Point formations, are aquicludes that blocked the upward and lateral flow of dolomitizing brines (Figure 2). Presqu'ile dolomitization along the Slave Point shelf edge is also interrupted in places where the basinal Klua Shale extends underneath the Slave Point Formation and prevented upward fluid circulation. The east side of the Cordova Embayment has a Klua Shale tongue extending underneath the Slave Point along the shelf edge. Consequently, Slave Point limestones have not been "Presqu'ilized" along the east side of the embayment. The Watt Mountain shale was also a regional aquiclude that prevented upward circulation of dolomitizing fluids in areas behind the Slave Point shelf edge.

Microthermometric data were obtained from fluid inclusions in 15 samples of coarsely crystalline sparry carbonates and cements from Presqu'ile Dolomite. These cements are from both Keg River Platform and Slave Point (Figure 2). Carbonate cement samples were classified initially according to their macroscopic style of cementation as vein-fill cements, vug-fill cements, vug-fill/replacement cements, or simply as massive replacement white dolospars.

Two-phase hypersaline aqueous inclusions were observed in all samples. Homogenization temperatures (Th) for two-phase inclusions ranged from 108° to 192°C for all samples with modal temperatures of between 130° and 150°C.

Their eutectic (Te) temperatures range from -57° to -34°C and their final melting temperatures (Tm) range from –30.9° to –9.0°C.

Based upon cementation style, mineralogy, and fluid inclusion characteristics, fluid inclusion samples were divided into three categories, Dolomite 1, Dolomite 2 and Calcite. Dolomite 1 is vug-filling and replacement white dolospar that has two-phase inclusions with low Tm measurements (-30.9° to -11°C), indicating a salinity of 14.97 to >23.18 wt.% NaCl eq., and low Te measurements (-57° to -53°C, indicating a dominant brine composition of NaCl-$CaCl_2$-$MgCl_2$-H_2O. Dolomite 2 is vein, or fracture-filling cement that has two-phase inclusions with melting temperatures of –11.8° to –9.0°C indicating a salinity of 12.85 to 15.76 wt.% NaCl eq., and Te measurements ranging from -36° to -34°C, indicating a dominant brine composition of NaCl-$MgCl_2$-H_2O. Calcite cements are characterized by two-phase fluid inclusions with Tm measurements of -12° to -9.5°C, indicating a salinity of 13.40 to 15.76 wt.% NaCl eq., and Te measurements of -36° to -34°C, indicating a dominant brine composition of NaCl-$MgCl_2$-H_2O. The eutectic and melting temperature of Dolomite 2 more closely resemble those of the calcite cements than those of the Dolomite 1 replacement white dolospars.

These cement types do not display a clear segregation according to Th values. Dolomite 1 cements have a pronounced modal Th between 130° and 150°C with relatively few Th measurements falling outside this range. In contrast, Dolomite 2 cements display a much more subdued histogram of Th values with a significantly greater part of the distribution extending beyond 180°C although the modal Th is about the same as for Dolomite 1 cements. The histogram of Th values for calcite cements is similar to that for Dolomite 2 cements but has a slightly higher modal value. The average Th value for Dolomite 1 cements (142.4°C) is slighty lower than that of Dolomite 2 cements (148.9°C) or for calcite cements (148.8°C)

Dolomite 1 two-phase fluid inclusions display a linear relationship between Tm and Th such that Tm values (i.e. salinities) remain constant over a broad range of Th values for individual samples. This indicates that some irreversible thermal expansion, or stretching, of inclusions occurred after cementation but that the inclusion remained sealed to external fluids, and that the lowest homogenization temperature recorded, on average about 130°C, may be close to the original temperature of precipitation. A positive correlation between inclusion size and Th values provides corroboration for post-precipitational stretching and an initial precipitational temperature of 130°C. Dolomite 2 fluid inclusions exhibit the same relationships between Tm and Th and between inclusion size and Th as Dolomite 1 inclusions with a similar estimate of 130°C for a precipitational temperature. Fluid inclusions in calcite cements display a weak, correlation between Th and inclusion size.

In addition to the two-phase inclusions observed in all samples, five samples of the Dolomite 1 cement type also contain abundant, small (<2µm to 5µm), single-phase, liquid-filled inclusions with no vapor phase bubble. Abundant methane-filled and both one- and two-phase hydrocarbon-filled inclusions were observed in calcite cements. Slightly darkened single-phase dark liquid oil- or condensate-filled inclusions along with two-phase vapor and liquid oil-filled inclusions and abundant large, dark, methane-filled inclusions (Th of -87°C) occur along with aqueous two-phase fluid inclusions. The oil-filled inclusions display white-yellow fluorescence under ultraviolet incident light and have fluorescent light spectra with maximum wavelengths at between 480 and 500 nanometers indicating a mature oil of about 35 to 40 °API. No fluorescent, hydrocarbon-bearing inclusions were observed in any dolomite cements.

The presence of abundant all-liquid aqueous inclusions in dolomite type 1 cements indicates that flow of dolomitizing $NaCl-CaCl_2-MgCl_2-H_2O$ brine solutions began in the shallow subsurface and precipitated dolomite cements initially at temperatures less than 50°C. This may have begun even during Slave Point deposition, as a northwestward-directed, shallow subsurface brine reflux from the evaporitic Elk Point Basin began. This was followed by upward-directed subsurface convective flow of $NaCl-CaCl_2-MgCl_2-H_2O$ and $NaCl-MgCl_2-H_2O$ brines and precipitation of dolomite cements (cement types 1 and 2) at temperatures of up to 130°C during Late Devonian to Carboniferous time before the generation of liquid hydrocarbons. Lower salinity brines that precipitated calcite cements and some dolomite (cement type 2) may have interacted with connate fluids of marine origin, or, less likely, with meteoric fluids.

Post-dolomitization calcite cements may have precipitated in latest Paleozoic to Mesozoic time during generation and migration of hydrocarbons. Reflectance values (%Ro 2.17%) for vitrinite macerals in the organic-rich Muskwa Formation shale overlying the Slave Point Formation are consistent with maturation of liquid hydrocarbons in Permian time and the onset of dry gas generation during deep burial in mid-Mesozoic time. High temperatures of close to 200°C experienced by Slave Point strata during deep Triassic burial probably caused caused stretching, but no leakage or refilling, of fluid inclusions in all previously-precipitated dolomite cements.

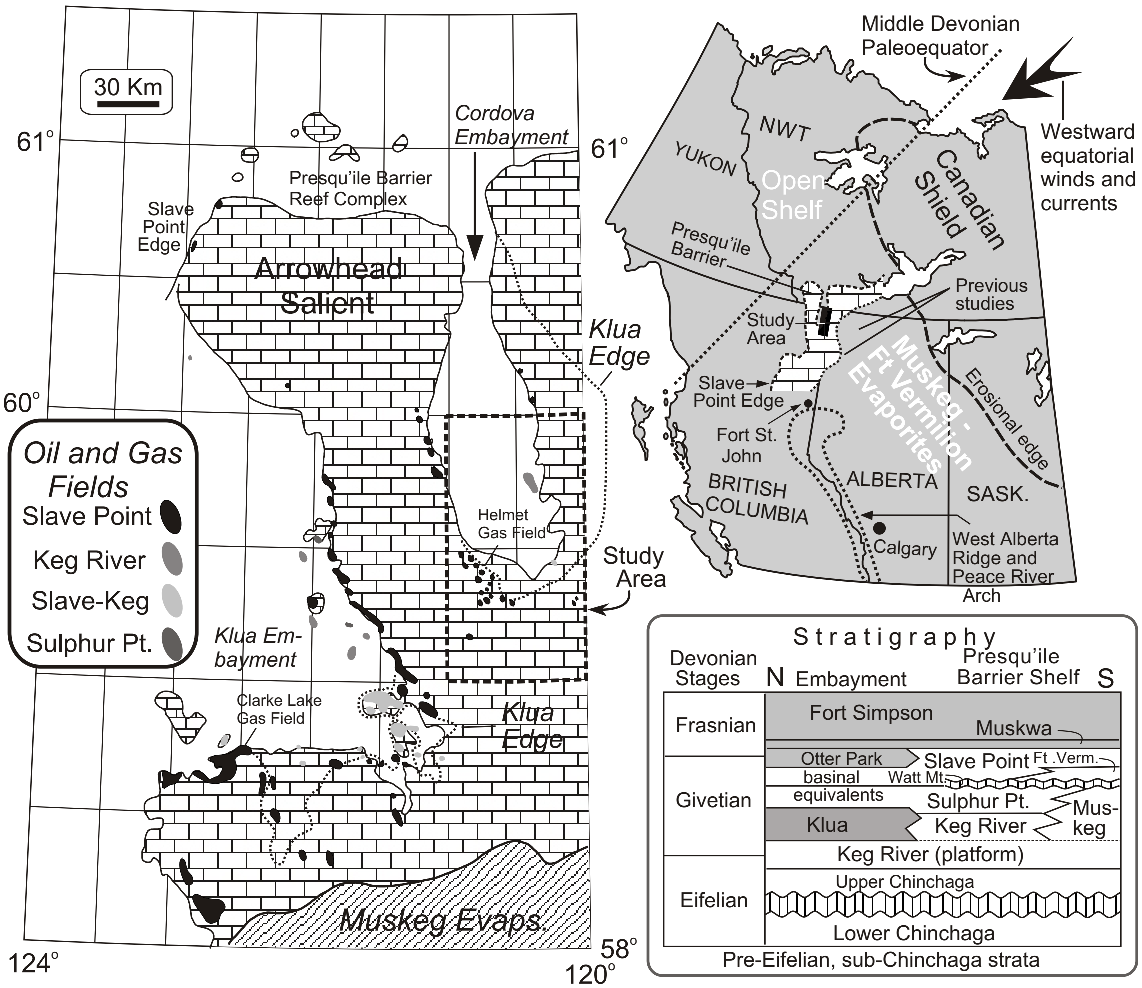

Figure 1. Index map of study area at south end of Cordova Embayment within the Presqu'ile Barrier Reef Complex. A stratigraphic chart shows the distribution of formal straigraphic units within the embayment and the adjacent Devonian shelf carbonates of the Presqu'ile Barrier.

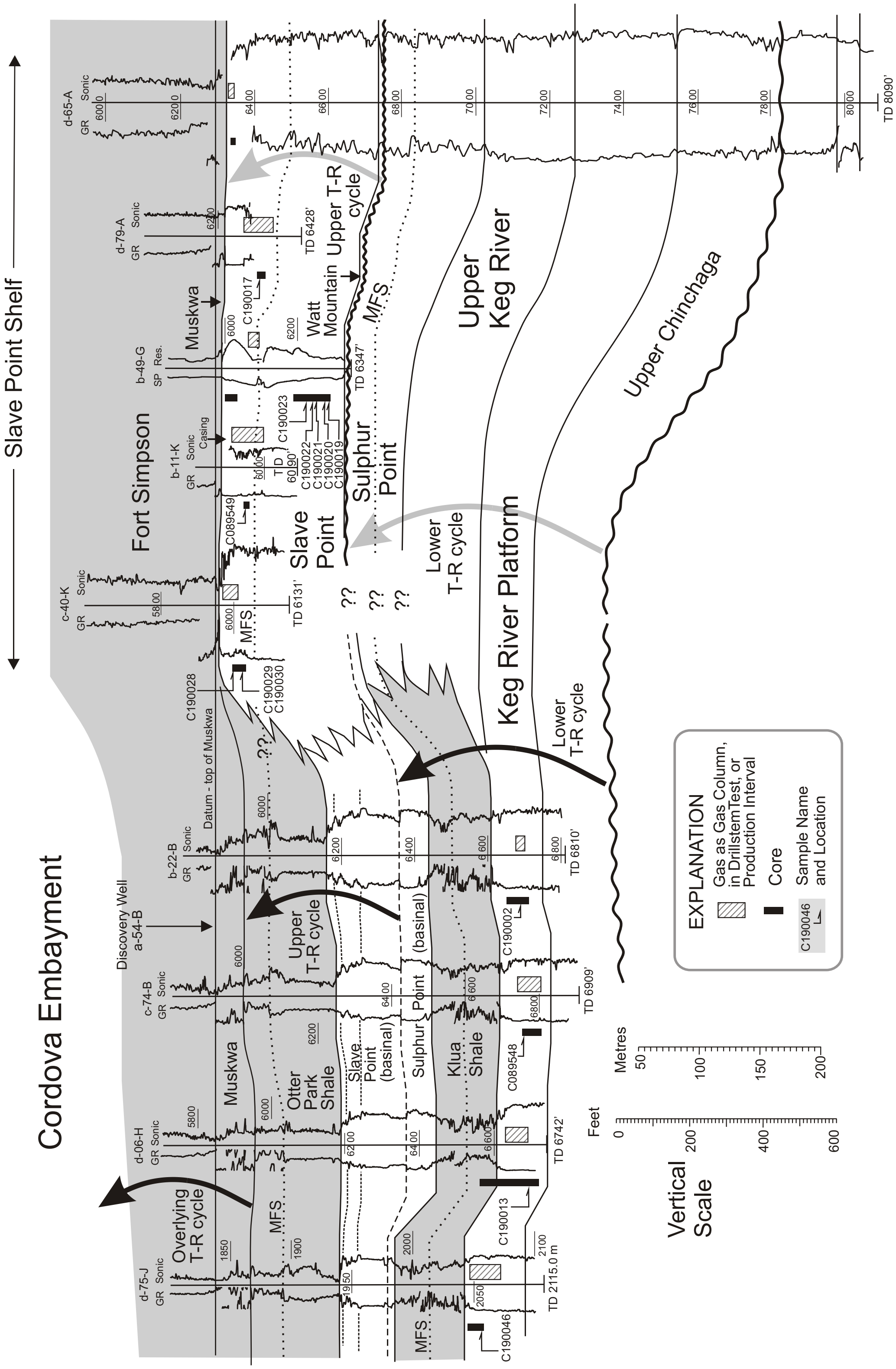

Figure 2. A stratigraphic cross-section of subsurface lithologies across the shelf-to-basin transition at the south end of the Cordova Embayment. Also shown here are the locations of fluid inclusion samples.