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# Mixing of halite brines with meteoric water in the Clarke Lake gas field, Canada

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**Abstract**

Formation water samples from the Middle Devonian Slave Point Formation in the subsurface of northeastern British Columbia, Canada, were collected from producing gas wells in the Clarke Lake field. Stable and Sr-isotope data, ionic compositions, and circumstantial evidence show that (i) a "halite brine" end member originated during the Late Devonian and was retained in the Slave Point Formation; (ii) meteoric water recharged from the Rocky Mountains after the Laramide Orogeny in the southwest, flowed through the Devonian aquifer system northeastward, and mixed with the halite brine in the Clarke Lake region. Trapping of hydrocarbons was controlled mainly by the configuration of the Slave Point platform margin relative to the structural tilt, which provided closure in many locations. The regional flow pattern of the meteoric water did not change the trap locations, as it was directed structurally updip, but it probably modified trap capacity in several pools.


*Keywords:* Fluid origin and evolution; Isotopes; Hydrochemistry; Fluid mixing

## 1. Introduction

Formation water samples from the Middle Devonian Slave Point Formation in the subsurface of northeastern British Columbia, Canada, were collected from producing gas wells in the Clarke Lake field (Fig. 1). In this area, the top of the Slave Point Formation is currently at depths of around 2000 m, and dips gently to the southwest towards the Rocky Mountain disturbed belt (Fig. 1).

The primary objectives of this study are to identify the origin and/or evolution of the present-day formation waters in the Slave Point Formation, and how they relate to past hydrothermal alteration in the Clarke Lake field (Lonnee, 2005). This has implications regarding gas trapping as well as field development.

## 2. Hydrostratigraphy

The crystalline basement constitutes a basin-wide aquiclude, except where fault zones have acted as conduits for fluid flow. The earliest Phanerozoic sediments are Cambrian quartzose sandstones, which form an aquitard. They are overlain by Devonian strata that are dominated by a thick succession of platform carbonates. These carbonates show a lateral facies transition at the platform margin to basinal shales of the Horn River Shale Basin (Fig. 1). These shales form aquitards, whereas the carbonates, which include the

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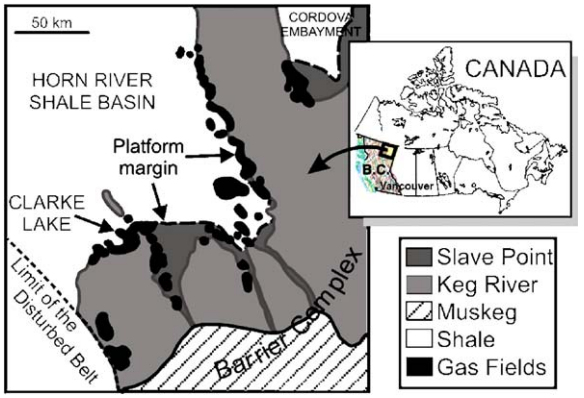


Fig. 1. Location map of the Clarke Lake study area in relation to the distribution of Middle Devonian units in the northern part of the Western Canada Sedimentary Basin.

Slave Point Formation, form regional aquifers that are dolomitized and in places hydrothermally altered. Over much of the area this entire package is overlain by a thick aquitard system.

## 3. Regional hydrogeology

Bachu (1997) found that formation waters in the Beaverhill Lake aquifer regionally flow from southwest to northeast. Formation water salinity values range from less than 50 g/L in the northeast and southwest to more than 150 g/L in the central part of the Beaverhill Lake aquifer system. Locally, low-salinity values of 30 g/L within the Clarke Lake field suggest dilution by meteoric fluids recharging from the fold and thrust belt of the Rocky Mountains (Underschultz and Bachu, 1997).

## 4. Methods

Formation water samples from the wellheads of fourteen producing Slave Point Formation gas wells were analyzed for their stable and radiogenic isotope compositions, and ionic hydrochemistry. Sampling and analytical procedures are described in Lonnee (2005).

## 5. Results and discussion

The $\delta^{18}O$ values of the present-day formation waters in the Slave Point Formation range from −2.40‰ to +10.51‰ SMOW, whereas $\delta D$ values vary between −131.2‰ and −50.7‰ SMOW. These values fall well to the right of the meteoric water line and along a trajectory (E) similar to those proposed by other authors from the Alberta Basin, albeit displaced to lower $\delta D$ values (Fig. 2: HFC).

The $^{87}Sr/^{86}Sr$ ratios of the formation waters in the Slave Point Formation range from approximately 0.713 to 0.750 (Fig. 3). Most of these values are significantly enriched in $^{87}Sr$ compared to the host limestones and dolostones (which range from 0.708 to 0.718), and are

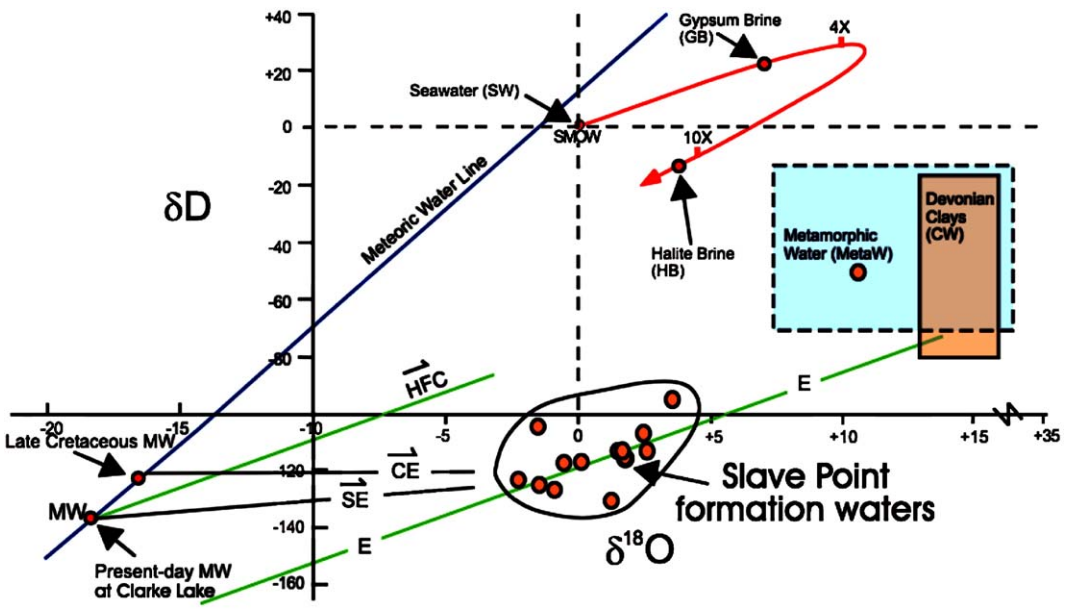


Fig. 2. Stable isotope composition of formation waters. The majority of the data plot near the seawater $\delta^{18}O$ but have highly depleted $\delta D$ values. Abbreviations are explained in the text, where necessary.