# Geothermal resource characterization of the Middle Devonian Slave Point Formation at Clarke Lake Field, Fort Nelson, B.C., Canada

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## Summary

Clarke Lake field in northeastern British Columbia displays anomalously high reservoir temperature and a strong water drive, making it suitable to investigate the potential of repurposing the field as a source of geothermal electrical power. An initial estimate of the total field-wide potential for electricity generation was found to be 34 MW (Walsh, 2013). The field occurs in carbonate sediments of the Slave Point Formation, which were deposited within a rimmed carbonate platform environment flanking the Horn River Basin during Givetian time. The development of porous and permeable reservoir resulted from hydrothermal alteration of parent limestone to dolomite due to the movement of halite- and gypsum-saturated brines through aquifers toward the reef margin. Hydrothermal alteration is common throughout the Keg River, Sulphur Point and Slave Point formations, which constitute the Presqu'ile Barrier, a Devonian carbonate barrier reef extending from northeastern B.C. to Pine Point, NWT.

## Workflow

The workflow for this study involves description of cores taken from the Slave Point Formation using Dunham's (1962) carbonate classification to identify depositional and diagenetic facies, correlating these facies to well log signatures and mapping facies distribution throughout the field using well logs. By comparing petrophysical measurements with facies, we can constrain reservoir continuity and produce a static geomodel of the reservoir. Seismic data will serve to further constrain the geometry of the reservoir. Initial flow simulations based on representative petrophysical properties will be completed to assess the ability for reservoir rock to produce formation water. More robust simulations will be produced that incorporate stochastic realizations representative of the spatial distribution of porosity and permeability at Clarke Lake field.

## Results

Nine depositional facies and two diagenetic facies were described. Deposition of these facies occurred within lagoonal, back-reef, reef margin, foreslope and open platform settings associated with a rimmed carbonate platform. Observed bioclasts are predominantly stomatoporoids, but also include crinoids, corals, brachiopods, gastropods and ostracods. Packstones and grainstones of Facies 1A and 1B represent high energy back-reef and lagoonal deposits, which are dominantly composed of nodular stromatoporoid, *Amphipora*, *Stachyodes* and *Thamnopora* bioclasts. Packstones, grainstones and boundstones of Facies 2A and 2B represent high energy reef margin deposits, which are dominantly composed of massive, hemispherical stromatoporoid and *Stachyodes* bioclasts. Dolomitized units of back-reef and reef margin facies show enhanced porosity and permeability at the top of shoaling upward cycles where stromatoporoid bioclasts have been dissolved, leaving mouldic and vuggy porosity (Figure 1). Average porosity and permeability in back-reef facies are 6.4 % and 124 md. Diagenetic facies show high permeability but reduced porosity from increased precipitation of dolomite, fluorite, and sulphide minerals that occlude mouldic, vuggy and fracture porosity (Figure 2). Average porosity and permeability for these facies are 5.1 % and 183 md. High quality reservoir zones exist at the reef margin due to hydrothermal alteration that preferentially occurred in more porous and permeable sediments that are stratigraphically trapped between shales of the Horn River Formation and unaltered, tight limestone within the reef interior. Faults may have provided primary conduits for hydrothermal fluids to move from deeper aquifers upward to the Slave Point reef margin. High quality reservoir zones also extend into the back-reef within porous and permeable carrier beds of back-reef facies. Internal flooding surfaces within the reef interior provided baffles to hydrothermal fluid flow, which affect the continuity of the dolomite reservoir.

Clarke Lake field has shown water production rates upward of 2800 $m^3$/day in two wells, with an average reservoir temperature from DST measurements of 98.2 °C. Applying these values of temperature and water rates and an appropriate range of porosity and permeability values, we use simple flow simulations to assess the viability of hot water production over a 25 year time span. Initial simulations show the rock properties inherent to the reservoir at Clarke Lake field are capable of sustaining 25 years of hot water production. Estimates of geothermal power potential are 300 kW using a doublet well model and 2400 kW using a four injector and eight producer well model.

## Additive Information

Petro-Canada Oil & Gas investigated the viability of liberating trapped gas within Clarke Lake field. To accomplish this, they attempted to depressure the reservoir by producing formation water at high rates (between 2100 and 2800 $m^3$/day) between January 1st, 2007 and December 29th, 2008 water (Petro-Canada Oil & Gas, 2009). An unintended result of this experiment was the observation of a strong water drive. Two wells were designated as water producers and two wells as water disposal wells. Six remaining wells were designated as gas lift wells. Water-gas ratio plots showed no gas had been liberated as a result of dewatering. Water rates at one water producer well peaked at 1800 $m^3$/day while the gas-to-water ratio remained stable at 3 $m^3$ gas / $m^3$. In order to access the trapped gas they speculated that they would need at least a 1 MPa drop in reservoir pressure. At the end of the experiment they found that reservoir pressure dropped by 100 KPa. This unexpectedly low pressure drop was a result of a high water drive.

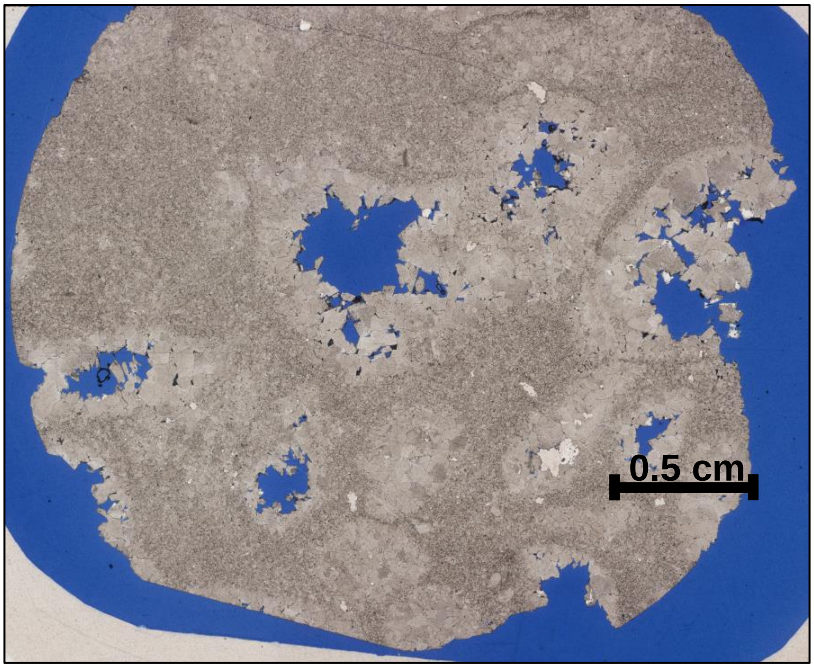


Figure 1

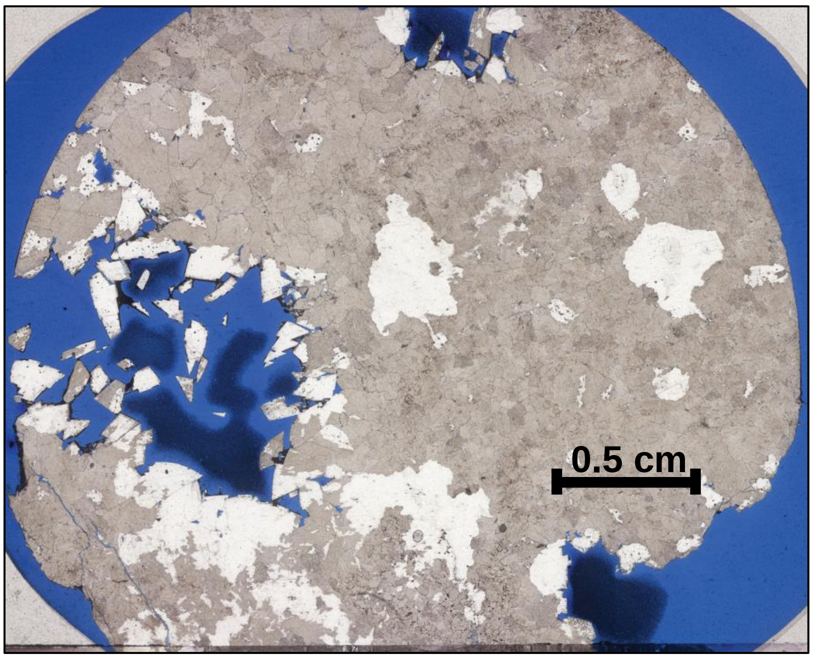


Figure 2

## Acknowledgements

Geoscience BC, BC Hydro, BC Oil and Gas Commission, Canlin Energy, Husky Energy, SURGe research group at the University of Alberta.

As a part of the University of Alberta's Future Energy Systems research initiative, this research was also made possible in part thanks to funding from the Canada First Research Excellence Fund.

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