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Moving beyond 'salt thickness': a detailed assessment of lithological heterogeneity within salt-bearing evaporite successions in the Elk Point Group of Alberta

Introduction

• The Elk Point Group in Alberta includes a number of thick, bedded evaporite successions of economic importance, including the Lotsberg and Prairie Evaporite formations, and to a lesser extent the Cold Lake Formation.

• The evaporites have been the focus of regional-scale studies in the past as part of assessments of halite and potash potential (Crockford, 1949; Hamilton, 1971; Meijer Drees, 1986; Grobe, 2000).

• Salt beds in the Lotsberg and Prairie Evaporite formations have been utilized as solution-mined caverns for storage and waste disposal (Fig. 1), and new possibilities include compressed-air energy storage (CAES).

• New province-wide stratigraphic mapping of the Elk Point Group incorporates group-level to member-level stratigraphy, within which net-evaporite mapping of salt, anhydrite, and gypsum is conducted using modern log suites.

• Mapping of individual beds of salt and anhydrite in **796** wells allows not only for an assessment of net-thickness of salt deposits, but importantly the degree of interbeddedness both vertically and laterally.

• An assessment of the degree of interbeddedness between readily soluble halite and less soluble lithologies (e.g., anhydrite, carbonates, shale, and red beds) is a critical component of a thorough characterization of a potential cavern, especially for CAES where higher pressures are needed to generate power.

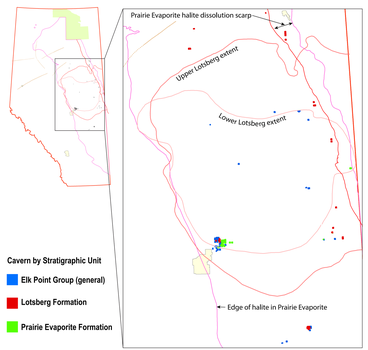


Figure 1. Locations of current caverns in the Elk Point Group of Alberta (Alberta Department of Energy, Coal and Mineral Development).

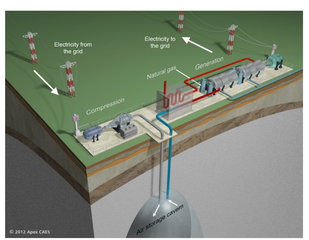


Figure 2. Schematic of a CAES facility (from APEX CAES, 2012)

What is Compressed Air Energy Storage (CAES)?

• CAES is a mechanical form of energy storage, where air is pumped and compressed into a storage vessel, such as a salt cavern in the subsurface, for later release to drive a turbine generator to produce electricity (Fig. 2).

• Wind and solar power generation is intermittent, but when combined with a CAES scheme, they can become more reliable (Duhan, 2018), and therefore CAES is considered a promising technology for 'greening' the power grid.

• In addition to salt thickness and depth, critical data needed to assess salt deposits for suitability for CAES include salt interbeds (anhydrite, carbonates, and shales) and their geomechanical properties (Duhan, 2018).

Stratigraphy and Evaporites of the Elk Point Group

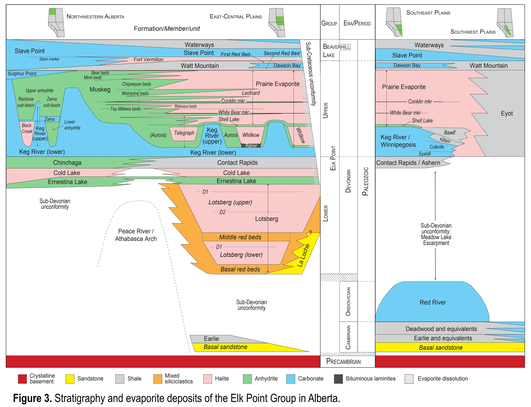


Figure 3. Stratigraphy and evaporite deposits of the Elk Point Group in Alberta.

• Three semi-regional marker beds comprising carbonates and shale were mapped within the Lotsberg Formation: D1 and D2 within the upper Lotsberg, and D1 within the lower Lotsberg (Fig. 3). Correlation of these markers is somewhat tentative given the poor well control.

• A large number of members and marker beds were correlated within the Prairie Evaporite-Muskeg (Fig. 3) (Muskeg: Klingspor, 1969; Prairie Evaporite: Meijer Drees, 1994; Rogers, 2017; Hauck et al., 2017).

• The more limited distribution of the Lotsberg and Cold Lake formations reflects significant paleotopography on the sub-Devonian unconformity, which is reflected in the isopach of the Elk Point Group (Fig. 4).

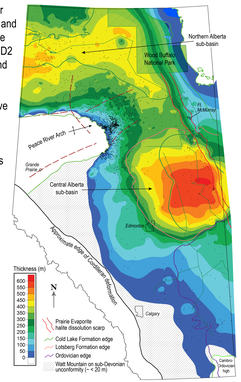


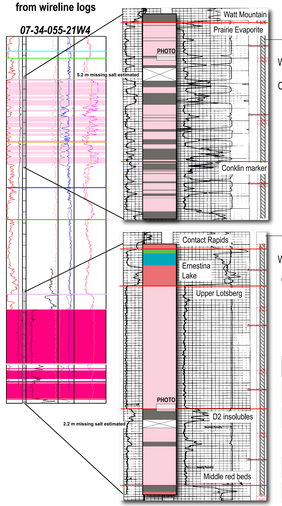
Figure 4. Isopach of the Elk Point Group in Alberta.

Methods: Net-Pay Evaporite Mapping

(1) Net-pay mapping from wireline logs

(2) Core assessment (ground truth)

(3) Comparison of measured salt thicknesses



Prairie Evaporite

Wireline log = 47.0 metres; 15 salt beds

Core = 52.3 metres; 24 salt beds

Upper Lotsberg

Wireline log = 72.2 metres; 5 salt beds

Core = 70.35 metres; 3 salt beds

Missing core

Anhydrite

Carbonate: lime mudstone, dolomudstone

Halite: clear and 'dirty'; some potash salts

Insolubles: shale and carbonate

Red beds

• The distinct log signatures of the evaporite minerals halite, anhydrite, and gypsum on logs allowed for the differentiation of these minerals in 796 wells across the province. Manual net-evaporite mapping on raster logs was employed (1).

• Net-evaporite mapping from wireline logs was ground-truthed in a limited number of cores through the evaporite successions (2).

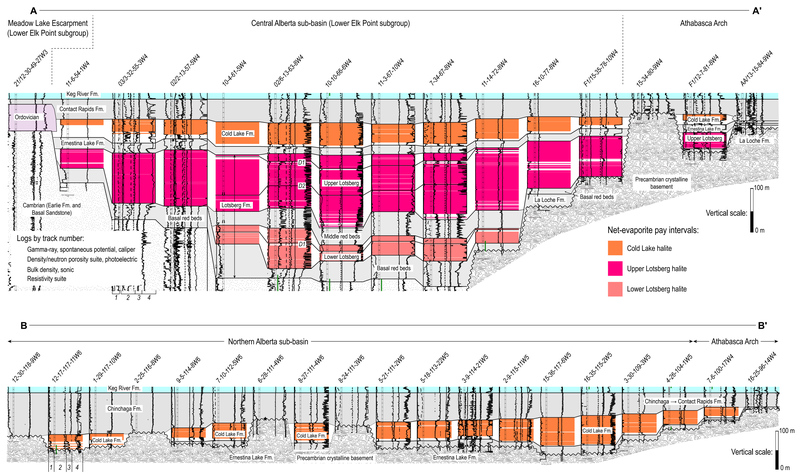
• A core through a highly interbedded Prairie Evaporite interval, which also cored the upper Lotsberg Formation, highlights the comparison (7-34-55-21W4).

• Within the Prairie Evaporite, wireline log evaluations slightly underestimate the cumulative halite and underestimate the degree of salt interbeds (3). This is likely due to the resolution of the wireline logging tools, as interbeds in this particular core can be < 20 cm thick (core photo).

• Wireline log evaluations in the Lotsberg Formation slightly overestimate both cumulative salt and salt interbeds (3). This slight overestimation is due to the resolution of the wireline logging tools, but may also be related to the fact that the Lotsberg salt interbeds are often admixtures of both salt and carbonate/shale with convoluted bedding textures (core photo). Exceptions to this are major correlatable interbeds such as the D2 marker bed (2).

• Overall, the wireline-log net-evaporite mapping method is a good estimation of evaporite thickness within the Elk Point Group.

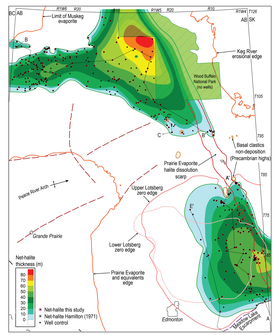
Halite in the Lotsberg and Cold Lake Formations



• The Lotsberg Formation is restricted to the Central Alberta sub-basin, where it can be divided into informal lower and upper members separated by the middle red beds (A-A'). No anhydrite was recognized in the Lotsberg Formation. Non-salt interbeds comprise shale and lesser carbonate, and appear discontinuous, with the possible exception of markers D1 and D2 of the upper Lotsberg, and D1 of the lower Lotsberg.

• The Cold Lake Formation is present in both the Central and Northern Alberta sub-basins. A lower red bed has been mapped as part of the Cold Lake. Like the Lotsberg Formation, non-salt interbeds are intermittent and un-correlatable (A-A' and B-B'). In the Northern Alberta sub-basin, the Cold Lake Formation is thin and discontinuous in the far northwest where it is missing over a number of local Precambrian basement paleo-highs (B-B').

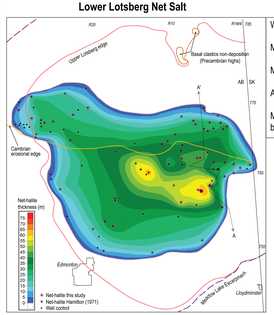
Cold Lake Net Salt



• Maximum net salt thickness in the Cold Lake Formation is 81.6 m in the Northern Alberta sub-basin. Maximum thickness in the Central Alberta Sub-basin is under 60 m. The maximum thickness of an individual salt bed is 58.4 m, and the average number of salt beds is 2.5 (maximum 11, minimum 1).

• Given the correlation of the eastern edge of the Cold Lake and overlying Prairie Evaporite halite dissolution scarp, it is likely that the eastern edge of the Cold Lake represents a salt dissolution front similar to the Prairie Evaporite Formation.

Lower Lotsberg Net Salt



Well control = 80

Maximum = 74.5 m

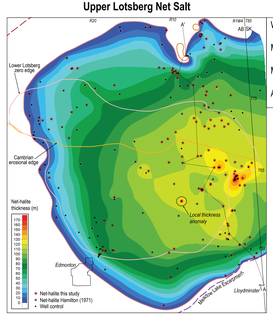
Minimum = 1.4 m

Average = 30.5 m

Max halite bed thickness = 40.1 m

• The lower Lotsberg is restricted to the central part of the Central Alberta sub-basin. Its northwestern edge coincides with the erosional limit of the underlying Cambrian Basal Sandstone unit, suggesting a minor Cambrian erosional escarpment in this area. Cumulative salt thickness is greatest in the centre of the sub-basin.

Upper Lotsberg Net Salt



Well control = 163

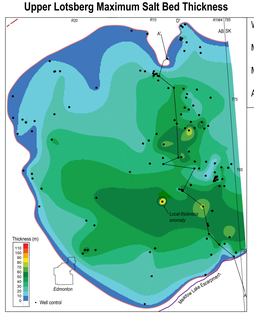
Maximum = 165.6 m

Minimum = 1.6 m

Average = 82.8 m

• The northern and southern limits of the upper Lotsberg are constrained by the Athabasca Arch and the Meadow Lake Escarpment (Ordovician), respectively. Cumulative thickness is greatest in the east-central part of the sub-basin beyond the limit of the lower Lotsberg; however, this may reflect the difficulty of differentiating lower and upper Lotsberg members due to salt beds in the middle red beds (i.e., the upper Lotsberg includes lower Lotsberg deposits).

Upper Lotsberg Maximum Salt Bed Thickness



Well control = 133

Maximum = 106.1 m

Minimum = 1.6 m

Average = 34.2 m

• Given the significant thickness of the upper Lotsberg salt, maximum salt bed thickness was mapped separately to highlight areas with thick, potentially continuous, individual salt beds lacking non-salt interbeds. An anomalous 106.1 m salt bed occurs in one well (local thickness anomaly). The majority of salt beds are 40 to 60 m thick.