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

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Summary

The Elk Point Group of Alberta includes a number of thick evaporite successions of economic importance. These 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). Within Alberta, halite beds within the Lotsberg and Prairie Evaporite formations have been utilized as solution-mined caverns for storage and waste disposal. Given the increased interest in thick halite beds as vessels for disposal, and new possibilities including compressed-air energy storage, this paper presents new province-wide stratigraphic mapping of the Elk Point Group lithostratigraphy (Figure 1), down to the resolution of marker beds within evaporite-bearing formations (Figure 2). Within this framework, the province-wide halite potential is assessed through net-evaporite mapping using modern log suites within the Lotsberg, Cold Lake, and Prairie Evaporite formations. These data provide an up-to-date picture of halite deposits within these formations, and provides: 1) cumulative halite thicknesses, 2) thicknesses of individual halite beds parsed by discontinuities comprising anhydrite, shale, red beds, and dolomite, and 3) areas where there is evidence of both regional- and local-scale dissolution of evaporite minerals (e.g., Prairie Evaporite halite dissolution scarp and eastern flank of the Peace River Arch, respectively).

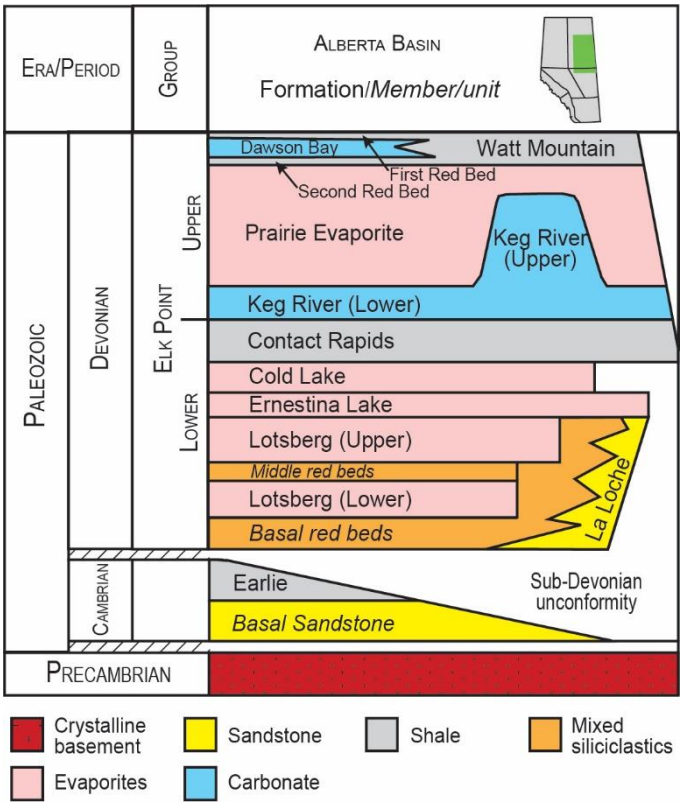
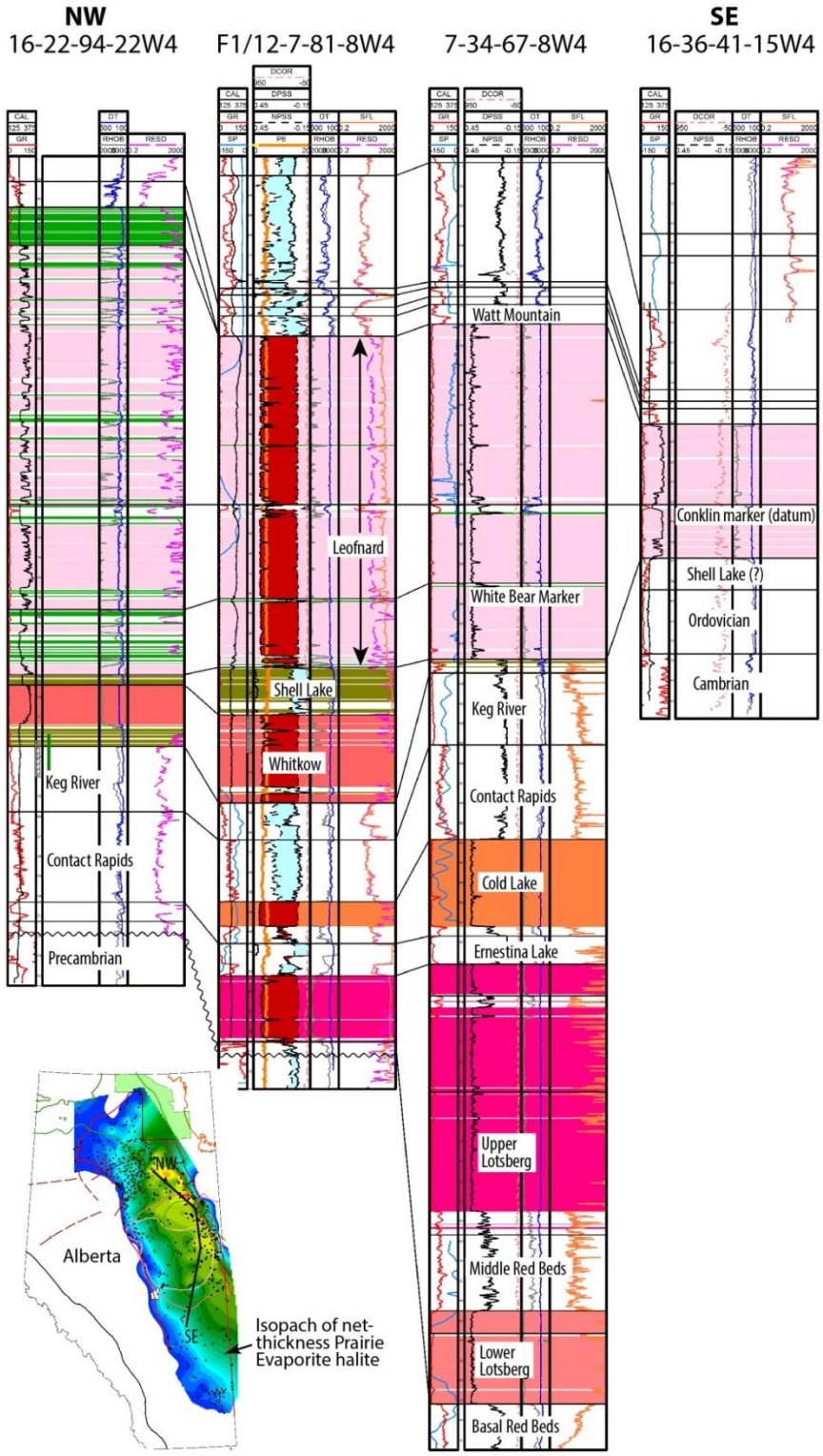


Figure 1. Lithostratigraphy of mapped Elk Point Group strata resting on the sub-Devonian unconformity in northeastern Alberta. This location in the basin represents the most complete assemblage of Elk Point Group stratigraphic units.

Methods

Lithostratigraphic mapping and net-pay mapping of evaporites of the Elk Point Group expands on previous work undertaken in the Lower Athabasca Regional Plan area of northeastern Alberta (Hauck et al., 2017a, 2017b). Correlations of group- to member-level stratigraphy, and marker beds within evaporite successions, have been extended to the area of the province



within roughly 4300 wells. A modern log suite, comprising neutron and density curves from wells drilled after 1980, was used to determine the thickness of evaporite intervals (halite, anhydrite, gypsum) in each well (Figure 2) (see Hauck et al., 2017a). These data were supplemented by older wells analyzed by Hamilton (1971). Halite data was collected from 166 wells within the Lotsberg Formation, 261 wells within the Cold Lake Formation, and 549 wells within the Prairie Evaporite Formation. In addition, 494 wells in the Prairie Evaporite were used to assess anhydrite and/or gypsum. In total, approximately 18 300 individual pay intervals describing beds of halite, anhydrite, or gypsum were mapped within the Elk Point Group.

Figure 2 Stratigraphic cross-section from northwest to southeast (inset map). Intervals of halite in the Prairie Evaporite and Lotsberg (upper and lower) are coloured shades of pink. Anhydrite in the Prairie Evaporite in shades of green. Halite in the Cold Lake is coloured orange. Datum = Conklin marker within the Prairie Evaporite Formation.

Results, Observations, Conclusions

Strata of the Lower–Middle Devonian Elk Point Group rest unconformably on the sub-Devonian unconformity across much of the Alberta Basin. The Elk Point Group is subdivided into lower and upper subgroups. Depositional patterns in the Lower Elk Point subgroup are largely controlled by regional-scale topography on the sub-Devonian unconformity. This topography includes the central and the northern Alberta sub-basins, which were two major depocentres, separated by the Peace River–Athabasca Arch (Moore, 1993). Halite deposits of the Lotsberg Formation are confined to the central Alberta sub-basin, whereas halite of the Cold Lake Formation accumulated in both depocentres. Maximum cumulative halite thickness for the Cold Lake Formation is just 81 m, with a maximum individual halite bed at 58 m.

Maximum net-thickness of the lower Lotsberg halite in the central Alberta sub-basin is 66.5 m, and 170.0 m for the upper Lotsberg halite. The thickest individual halite bed mapped within a well is 40 m for the lower Lotsberg, and 106 m for the upper Lotsberg, making the latter the preferred cavern target. No zones of dissolution were encountered in any of the Lotsberg wells.

The Prairie Evaporite Formation is more regionally extensive as part of the Upper Elk Point subgroup, and can be subdivided into a number of members, including the Whitkow, Shell Lake, and Leofnard. The Whitkow and Leofnard members are the halite-bearing intervals (Figure 2). The Leofnard can be further subdivided by regionally extensive marker beds, especially the Conklin (Hauck et al., 2017a), which is equivalent to the ‘Muskeg 40’ marker of Klingspor (1969). This marker in particular is of importance because it can be correlated within the Leofnard Member over most of its distribution, and as Klingspor (1969) has shown, continues to be an important marker horizon within the anhydrite-dominated Muskeg Formation (equivalent to the Prairie Evaporite Formation) to the northwest.

The maximum net-thickness of halite within the entire Prairie Evaporite Formation is 222 m. Over much of the province, the Whitkow and Leofnard halites are clearly separated by the Shell Lake Member, allowing for assessing the individual thicknesses of these two halite-bearing members. Based on correlation, this subdivision breaks down toward the northwest of the province, where halite of the Telegraph Beds (Klingspor, 1969), are likely equivalent to both the Whitkow Member halite, and the lower part of the Leofnard Member halite (Rogers, 2017). However, where these halite beds appeared mostly continuous (i.e., no clear stratigraphic break such as the Shell Lake Member), they were mapped together as the Whitkow Member. Maximum net-thickness of the Whitkow halite is 78 m, with a maximum individual halite bed thickness of 68.4 m. Maximum net-thickness of the Leofnard halite is 174.5 m, with a maximum individual halite bed thickness of 93 m.

Unlike the Lotsberg and Cold Lake formation, evaporites of the Prairie Evaporite Formation have experienced dissolution, which presents a hazard to consider when proposing a potential cavern location. This occurs in the northeast of the province along the well-known halite dissolution scarp (Hauck et al., 2017), but also occurs in more localized areas associated with the eastern flank of the Peace River Arch. In the latter location, halite beds are interbedded to a high degree with anhydrites, as the Prairie Evaporite formation transitions to the Muskeg Formation. However, due to the heterogeneous nature of the evaporites, these localized dissolution occurrences do not fall within the optimal locations for cavern placement.

Data collected from the net-pay mapping of evaporite minerals allows for a regional view of the optimal locations for cavern placement within the Elk Point Group of Alberta. In addition, the regional correlation of lithostratigraphic units, including the Keg River Formation, provides a comprehensive, up-to-date picture of the distribution of Elk Point strata across the province.

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