Effects of Prairie Formation Salt Dissolution on the overlying Waterways Formation in Northeastern Alberta

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Summary

In northeastern Alberta, dissolution of Prairie Formation halite in the subsurface impacted overlying Devonian strata in terms of structural deformation and fracturing. These features are easily recognized in outcropping and subsurface Waterways Formation limestone. Although the effects of Prairie halite dissolution on Waterways strata have long been observed, this new study seeks to quantify the collapse, deformation, and other effects on Waterways Formation strata. Preliminary results are reported herein.

Introduction

Throughout most of Alberta, the Prairie Formation halite is buried beneath a thick succession of Devonian and younger rock, and remains largely unaltered. However, in northeastern Alberta, Devonian strata, including the Prairie halite, subcrop along the Devonian erosional edge very near the surface. Here, salt dissolution is pervasive and has impacted overlying strata, particularly evident in the structural deformation of the Waterways Formation.

Since the early days of exploration, travelers noticed the folded and faulted limestone beds of the Waterways Formation along the banks of the Athabasca and tributary rivers. Later stratigraphic work indicated a subsurface dissolutional, rather than tectonic, cause of limestone deformation: the gradual, present-day eastward loss of Prairie Formation halite and the slow collapse of overlying strata. Recent investigations have recognized the effects of salt dissolution on Devonian strata, including a zone or “scarp” of rapid decrease in halite thickness roughly paralleling the Athabasca River north of Fort McMurray (e.g., Bachu et al., 1993; Hein et al., 2000), a reversal in regional dip of overlying Devonian strata (e.g., McPhee and Wightman, 1993; Bachu et al., 1993), and a regional pattern of jointing, possibly related to slow collapse (Nikols, 1996).

Dissolution of the Prairie halite and its effects on overlying strata have the potential to significantly impact northeastern Alberta industrial activities. With the decrease, fracturing, and/or loss of the thick Prairie Formation aquitard, underlying saline aquifers and overlying fresher aquifers are contiguous, as reconstructed in regional models (Bachu et al., 1993, 1996) and evident in the abundant salt springs throughout the halite dissolution zone. Fractures in collapsed Waterways Formation limestone can become conduits for fluid movement and prime environments for karst processes.

This new investigation into the effects of Prairie halite dissolution on overlying Waterways strata aims to reconstruct the impact of halite dissolution at multiple scales. The largest scale consists of mapping the regional stratigraphy in subsurface, with the goals of reconstructing the three-dimensional relationship of the Prairie halite dissolution zone with overlying strata and modeling the Devonian subcrop surface in order to understand the effects of halite dissolution on the topography of the pre-Cretaceous unconformity. The median scale includes measuring the effects of halite loss on Waterways Formation deformation in terms of fold geometry and distribution, and fault magnitude and frequency. At the finest scales, data is being collected from core and outcrop, such as fracturing, faulting, and karstification. Herein, I present the preliminary data of this investigation.

Methods and Results

The investigation into the Prairie halite dissolution effects on Waterways Formation strata has three components: well log interpretation and regional stratigraphic reconstruction, core description and fieldwork. Current work includes the collection of core and outcrop data, stratigraphic correlation and subsurface mapping; future work with AGS colleagues will expand the investigation into three-dimensional modeling and structural analysis.

At the finest scale of core and outcrop work, the Waterways Formation is pervasively fractured. Some fracturing, particularly near the Devonian subcrop surface, is related to processes that occurred during subaerial exposure before lower Cretaceous sedimentation. Fractures near this surface tend to be short (<10cm), open, bitumen-stained and follow bedding or limestone nodule boundaries. Deeper fractures are often longer (20cm or more), calcite-filled, occasionally contain pyrite and cross-cut bedding or fabric. Fractures tend to be more common in limestone-rich units. Shale-bearing units such as the Christina Member, and particularly the Firebag Member, occasionally contain slickensides in shale beds.

At the outcrop scale, Waterways Formation strata are gently folded and often contain small faults (usually <50cm offset; Figures 1, 2). Low amplitude folds rarely have limb dips greater than 12 degrees. Comparison of folded strata on the Athabasca and Clearwater rivers supports the dome-and-valley structure of the Waterways limestone suggested originally by Hume (1947), rather than cylindrical folds. Smaller folds often occur on large-scale (500+m) fold limbs.

Figure 1: Folded Moberly Member, Waterways Formation limestone along the Athabasca River north of Fort McMurray.

Figure 2: A small fault in the Moberly Member, Waterways Formation, along the Beaver River, northeastern Alberta.

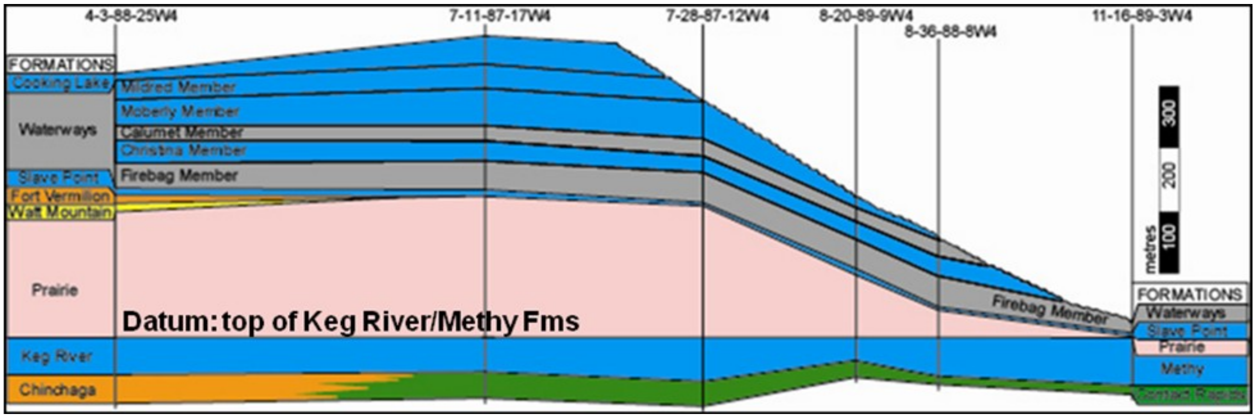

Figure 3: Reversal of regional dip in post-Prairie Formation Devonian strata, from west to east along the Athabasca and Clearwater rivers. Salt dissolution occurred between wells 7-28-87-12W4 and 11-16-89-3W4. The horizontal datum is restored to the top of the Keg River formation in order to emphasize the reversal in dip. Stratigraphic data are taken from core.

Regionally, the Waterways Formation has a "reverse dip" in the Prairie halite dissolution zone. In northeastern Alberta, west of the halite dissolution zone, Devonian strata dip gently to the west or southwest. Within, and east of, the Prairie halite dissolution zone, Waterways strata instead are nearly horizontal because of the loss of underlying halite and the subsequent collapse of overlying formations. This "reverse dip" is very apparent in regional stratigraphic cross sections, in which the Keg River Formation is reconstructed as the datum (Figure 3).

Conclusions

The Waterways Formation bears evidence, at multiple scales, of collapse during and following Prairie Formation halite dissolution in northeastern Alberta. Folds and faults are apparent in outcrops, as are fractures and evidence of localized faulting in core. At the regional scale, outcrops are folded into three-dimensional dome-and-saddle structures, which have been truncated by post-Devonian, pre-Cretaceous erosion.

Halite dissolution and deformation in the Waterways Formation may have effects outside of the obvious features of faults, salt springs, and fluid movement along fractures. Further work may uncover other potential effects, such as the influence of deformation on subcrop patterns and the topography of the sub-Cretaceous unconformity, the configuration of regional jointing and potential brine upwelling, and the distribution of karst in Waterways limestones.

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References

Bachu, S., Underschultz, J.R., Hitchon, B. and Cotterill, D., 1993, Regional-scale subsurface hydrogeology in northeast Alberta: Alberta Research Council, Alberta Geological Survey, Bulletin **61**, 44 p.

Bachu, S., Underschultz, J.R. and Hitchon, B., 1996, Regional subsurface hydrogeology in northeast Alberta: Alberta Research Council, Alberta Geological Survey, Open File Report **1996-14**, 149 p.

Hein, F.J., Cotterill, D.K., and Berhane, H., 2000, An atlas of lithofacies of the McMurray Formation Athabasca oil sands deposit, northeastern Alberta: surface and subsurface: Alberta Geological Survey Earth Sciences Report **2000-07**, 217 p.

Hume, G.S., 1947, Results and significance of drilling operations in the Athabasca bituminous sands: Transactions of the Canadian Institute of Mining and Metallurgical Engineers, **50**, 298-333.

McPhee, D.A. and Wightman, D.M., 2003, Timing and dissolution of Middle Devonian Elk Point Group evaporites: townships 47 to 103 and ranges 15W3M to 20W4M: Bulletin of Canadian Petroleum Geology, **39**, 218-219.

Nikols, D.J., 1996, Assessment Report, Fort MacKay Property, 1996: Alberta Energy, Mineral Assessment Report **19960008**, 34 p.