Update of Devonian Hydrostratigraphy in the Athabasca Mineable Oil Sands Area, NE Alberta

John Wozniewicz[1)], Frank A. Stoakes [2)], Michael Davies [3)] Matthijs Verhoef [4)] and Robert Mahood [4)]

[1)] Golder Associates Ltd., [2)] Stoakes Consulting Group Ltd. (SCG), [3)] BGC Engineering Inc. [4)] Shell Canada Energy

Introduction

The Devonian hydrogeology setting underlying the mineable Athabasca Oilsands Area in northeast Alberta is within the thinning edge (<300 m thick) of the Western Canadian Sedimentary Basin. Historically, these Devonian strata have been conceptualized as consisting primarily of lower permeability units (10^{-7} m/s or less) in the upper Devonian units with a regional aquifer within the Keg River Formation. In past years this aquifer was referred to as the Methy Formation, a now obsolete stratigraphic term. Since 2010, there has been a significant increase in the number of Devonian wells drilled by oil sands operators to improve the understanding of the Devonian geology and hydrogeology in the region. The objectives of this presentation are to update the Devonian hydrostratigraphy in the Athabasca Mineable Oil Sands Area in northeast Alberta and discuss the properties and connectivity of a highly transmissive Devonian aquifer.

Results

Based on recent drilling and operational data, a highly transmissive aquifer has been identified within the Prairie Evaporite Formation in an area mapped as *Anhydrite Only* (Grobe 2000). In the area of the Muskeg River Mine (MRM), this Prairie Evaporite Formation averages about 50 m in thickness and has been divided into two informal units: 1) an upper “Collapsed” section of remnant anhydrite and dolomite beds that remain following the dissolution of halite by groundwater flow over geologic time and 2) a lower ‘Intact’ section that consists of interbedded anhydrite and dololaminites. The highly transmissive (10^{-3} to 10^{-0} m^2/s) aquifer has been identified within the ‘Intact’ Prairie Evaporite dololaminites, typically up to 10 to 20 m in thickness, that have undergone various stages of dedolomitization and solution collapse. Losses of circulation drop in drill bits and testing results confirm the presence of the highly transmissive aquifer in localized areas.

The proposed mechanism for dedolomitization is similar to the process described for the Madison aquifer in Montana (Plummer et al. 1990; Plummer et al. 2010): dissolution of the adjacent anyhydrite layers drives calcite precipitation and dissolution of the adjacent dololaminites (dedolomitization) resulting in a vuggy porosity and enhanced permeability. The dedolomitization process likely followed pre-existing preferential pathways such as fractures and faults. In areas where the dedolomitization has not been active, a significantly lower transmissivity (10^{-6} m^2/s or less) has been measured.

Based on the response in a regional borehole monitoring network to an inflow event, the rapid propagation of pressure transients in the ‘Intact’ Prairie Evaporite aquifer is consistent with a high transmissivity aquifer that is confined (storativity of 10^{-4} to 10^{-5}) and well-connected over 10’s of kilometers; at least in a north-south direction in the immediate study area. On a more local scale, typical of fractured rock and karst settings, strong heterogeneity is observed due to the *non-sheet* like

distribution of the dedolomitized laminites within the 'Intact' Prairie Evaporite Formation. Numerous wells in the immediate study area show low permeability throughout the entire Devonian section that suggests the wells are not within the dedelomitized "fairway". Further, the on-lap of the Prairie Evaporite dololaminites onto the sides of Keg River reefs further promotes the local "pathy" hydraulic connection. Monitoring inside one reef showed no hydraulic connection to pressure changes in the 'Intact' Prairie Evaporite aquifer.

In terms of vertical connectivity, measured responses in a subset of Basal McMurray wells to the inflow event suggest that local vertical pathways (i.e. "hydraulic windows") allow various degrees of hydraulic connection with the underlying Devonian aquifer. However, the confined regional response within the 'Intact' Prairie Evaporite aquifer and non-responding Basal McMurray wells together supports a relatively sparse distribution of these "hydraulic windows".

Conclusions

For select operators, the presence of a highly transmissive aquifer in the 'Intact' Prairie Evaporite Formation will need to be considered as part of their risk analysis and, as needed, risk mitigation plans. Risk mitigation will likely include ongoing pressure monitoring in the Devonian, monitoring pit inflows and water quality and continuation of water quality monitoring and pressure monitoring of Basal Aquifer monitoring wells. As the transmissive aquifer in the 'Intact' Prairie Evaporite is regional in scale (greater than the typical lease scale), oil sands operators are collaborating by sharing data and approaches to characterization and sharing approaches to risk mitigation through the Canadian Oil Sands Innovation Alliance.

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References

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