GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

Geologic Considerations of Shallow SAGD Caprock; Seal Capacity, Seal Geometry and Seal Integrity, Athabasca Oilsands, Alberta Canada

Gordon T. Stabb, P.Geol.

Suncor Energy Inc., Durando Resources Corp., Calgary Alberta

The rapid growth of insitu bitumen thermal extraction technologies, in particular SAGD, since the mid-1990s has necessitated close investigation of the geologic nature of caprock to maintain reservoir containment under conditions of high temperature and pressure. Here, caprock is discussed from the geologic perspective of three defining criteria: Caprock Seal Capacity, Caprock Seal Geometry and Caprock Seal Integrity and the identification of potential intersecting transmission pathways of pressure and fluid.

Introduction

The geologic nature of caprock and reservoir containment is of importance to efficient SAGD operations. Caprock reliability is of particular importance in the Shallow Thermal Area (defined as base caprock <150 m, AER 2014) and in the vicinity of high consequence socio-economic facilities such as dams, airports, communities, and areas of natural importance such as lakes, rivers and valleys. The vertical and lateral geologic characteristics of caprock are strong indicators of the risk and reliability that can be expected of caprock performance in reservoir containment.

Theory and/or Method

A caprock in a SAGD operation can demonstrate effective performance when the three criteria of seal potential are met: Seal capacity, seal geometry and seal integrity (after Kaldi and Atkinson, 1993). Seal capacity can be defined by permeability resistance to buoyancy of underlying fluid and gas, and to pressure transmission. Seal geometry can be defined by the lateral and vertical extent of the caprock (stratigraphy and erosion). Seal integrity is defined by the absence or presence of mechanical discontinuities such as faults fractures or joints,capable of transmitting pressure or fluids. Assessment of caprock potential for reservoir containment in a SAGD operation can include investigation of geologic occurances that could risk compromise of any of the three criteria of caprock seal potential; capacity, geometry and integrity.

Vertical lithologic variation and laterally continuous porous beds in the caprock interval can affect seal capacity by altering expected capillary and fluid properties and providing horizontal pathways of fluid and pressure transmission. Seal geometry can be compromised by changes in caprock thickness due to erosion and replacement by younger, non sealing deposits. Seal integrity can be compromised by strain induced by underlying geological stress and manifested as faults and fractures capable of transmiting fluids and pressure through the caprock. Well log based assessment of risk to SAGD caprock seal potential is augmented by field investigation of pitwall exposures in the Suncor Millennium Mine and of regional geologic studies.

Examples

This work investigates the caprock geology of the Clearwater Formation in the vicinity of the Suncor South Tailings pond (STP) and the adjacent Suncor Millennium Mine. Investigation of well log, drill core, mine pitwall exposures and regional studies presents an interesting overview of potential intersecting vertical and horizontal pathways of pressure and fluid transmission.

Regional studies show the north-south trend of the Prairie Evaporite salt dissolution zone in the Athabasca area. East of the zone, salts and anhydrites are predominantly absent and are interpreted as completely dissolved. West of the zone, salts and anhydrite are predominantly present and salts are only partially dissolved. The scarp is about 15 miles wide. Within the dissolution zone the salts have been removed and anhydrite is subjected to active dissolution (after Schneider and Grobe, 2013). The Prairie Evaporite salt dissolution zone is interpreted to be a zone where stress induced by differential salt dissolution has caused strain in the overlying rocks.

The map by Cowie et al 2014, shows the Prairie Evaporite salt dissolution zone and McMurray salinity on a regional scale. Greater than 15,000 TDS indicates McMurray water mixing with Devonian water (orange and red indicator circles). Note that the predominance of McMurray water samples with greater than 15,000 TDS are coincident with the Prairie Evaporite salt dissolution zone.

The Beaverhill Lake (BHL) carbonates below the McMurray are dominated by very low permeability lime mudstone. Regardless, Devonian fluids have been transmitted into the McMurray Formation at the BHL Pre-Cretaceous unconformity via faults, fractures, karst and collapse breccias.

The implication is that the current position of the Prairie Evaporite dissolution zone defines a trend of active stress in the BHL group introduced by differential salt dissolution and has resulted in a predictable strain-response trend of faults, fractures, karst and collapse breccias in the BHL carbonates capable of long distance fluid and pressure transmission.

The photos of the graben fault in the Clearwater shale above a Devonian karsted low and of the fractured and jointed Clearwater formation, both from the Suncor Millennium mine, show the manifestation of strain induced by active dissolution of the Prairie Evaporite after Cretaceous deposition in the Clearwater caprock. The faults and fractures demonstrate a risk to seal integrity of the Clearwater caprock along faulted and fractured planes of weakness.

Potential intersecting vertical and horizontal pathways of fluid and pressure transmission can be investigated when assessing caprock seal criterion for SAGD operations.

Potential vertical transmission pathways (Figure 1) to be considered include:

- Faults and fractures in the Devonian Beaverhill Lake Group, the McMurray and Clearwater Formations can occur as a strain response to stress originating from normal, thrust and strike slip faults in the Precambrian, from differential rates of evaporite dissolution in the Devonian Elk Point Group and from collapse and karst of overlying Beaverhill Lake carbonates. Faults and fractures in the McMurray and the Clearwater Formations can also occur as a strain response to stress originating from glacial compression, glacial motion and glacial rebound.
- Glacial rafts of dislodged Clearwater shales can occur as a strain response to stress originating from glacial motion and glacial compression. Glacial rafts are commonly observed in the Millennium and North Steepbank mines and can include deposits of Quaternary gravels and cobbles along the base of imbricated rafts (Photo by MacPherson, Millennium Mine).
- Post Cretaceous incised valleys and tributaries that are filled with Quaternary channel sands and gravels can cut down into the Wabiskaw Member or the McMurray Formation. The sand and gravel filled incised valleys have created vertical pathways of pressure transmission that will

intersect with and provide sand on sand contact to the horizontal pathways of communication in the progradational sands of the coarsening up parasequences in the Clearwater shale interval and to the fining up transgressive sands of the Wabiskaw C and the Wabiskaw A.

- Old well bores that have not been abandoned to thermal standards can be present in the proximity of SAGD project areas. Old wells have the potential to create vertical pathways of pressure transmission that will intersect with the horizontal pathways of communication in the laterally continuous progradational sands of the coarsening up parasequences of the Clearwater shale interval and with the fining up transgressive sands of the Wabiskaw C and the Wabiskaw A units.

Potential horizontal transmission pathways (Figure 2) to be considered include:

- Devonian: Where the BHL is faulted, fractured or brecciated it has the potential to transmit pore pressure and Devonian fluids horizontally through the Devonian and vertically into the overlying McMurray Formation.
- McMurray Formation; through the Basal McMurray Aquifer (BMA), through mobile fluids within the bitumen pay, and through bitumen lean deposits saturated with gas and water in the upper part of the McMurray Formation.
- Wabiskaw Member: through the laterally continuous Wabiskaw C sand and the laterally continuous Wabiskaw A sand.
- Clearwater Formation: along silty sands and sands in the coarsening up parasequences above the T31, T51 and T61 transgressive surfaces of erosion.

Conclusions

Geologic assessment of SAGD caprock seal capacity, seal geometry and seal integrity is warranted for efficient thermal operations in general and is warranted in particular in the Shallow Thermal Area and in the vicinity of high consequence socio-economic facilities and areas of natural importance.

Acknowledgements

Suncor Energy Inc., Bob King, Bruce James, Michael Webb, Stan Stancliffe.

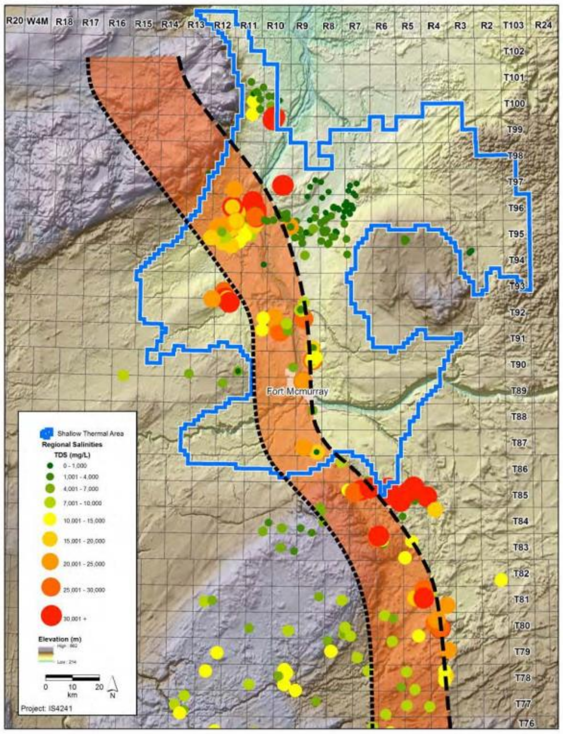
References

Alberta Energy Regulator, 2014, Summary of Conclusions from the Reservoir Containment Project for Steam-Assisted Gravity Drainage Schemes in the Shallow Thermal Area (June 2014).

Cowie, B.R., James, B., and Mayer, B. 2014. Distribution of total dissolved solids in McMurray Formation water in the Athabasca Oil Sands Region, Alberta, Canada: implications for regional hydrogeology and resource development. American Association of Petroleum Geologists Bulletin, (in press; preliminary version published online Ahead of Print 15 September 2014), doi: 10.1306/07081413202.

Kaldi, J.D., and Atkinson, C.D., 1993. Seal Potential of the Talang Akar Formation, BZZ Area, Offshore NW Java, Indonesia. Proceedings Indonesian Petroleum Association, 22nd Annual Convention, Oct 1993. Page 373. IPA93-1.1-005.

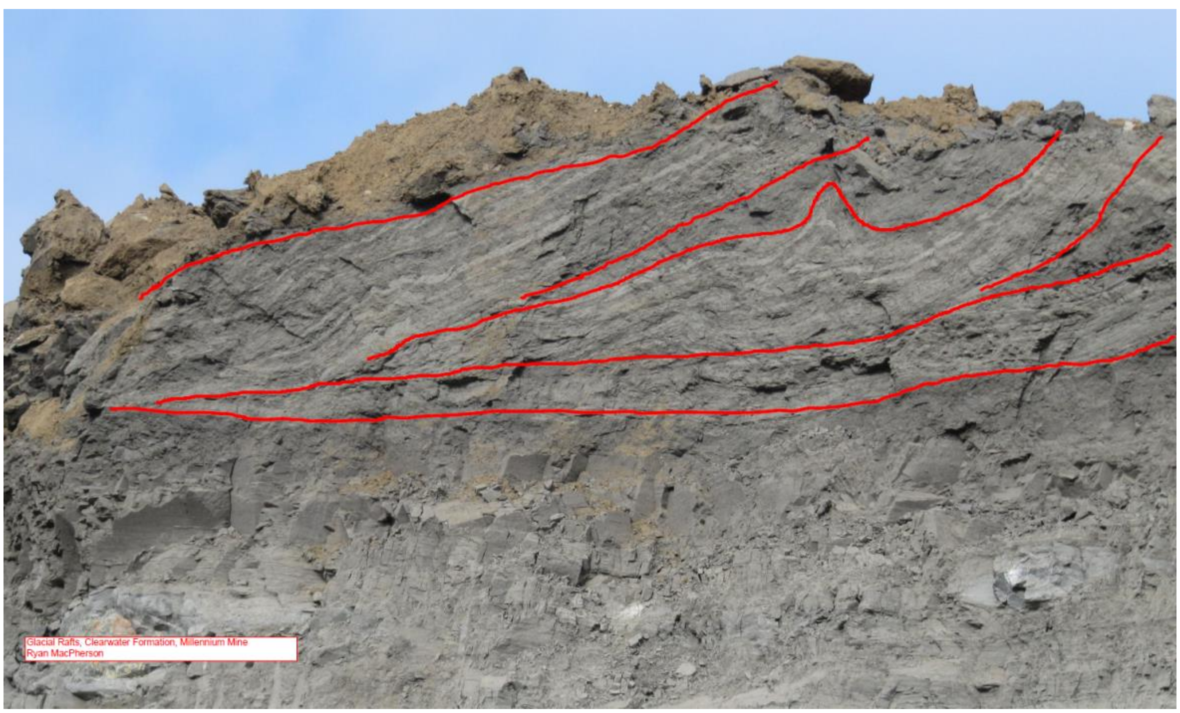
Schneider, C.L., and Grobe, M. 2013. Regional Cross-Sections of Devonian Stratigraphy in Northeastern Alberta (NTS 74D, E). Alberta Energy Regulator / Alberta Geological Survey Open File Report 2013-05.



After Cowie et al, 2014

Graben Fault in Clearwater Formation Above Karst Trend.
Millennium Mine. Macneil, 2012-07-26

Fractured and Jointed Clearwater Formation, Millennium Mine.
Stabb, 2012-09-26



Imbricated Glacial Rafts in Clearwater Formation, Millennium Mine, R. MacPherson

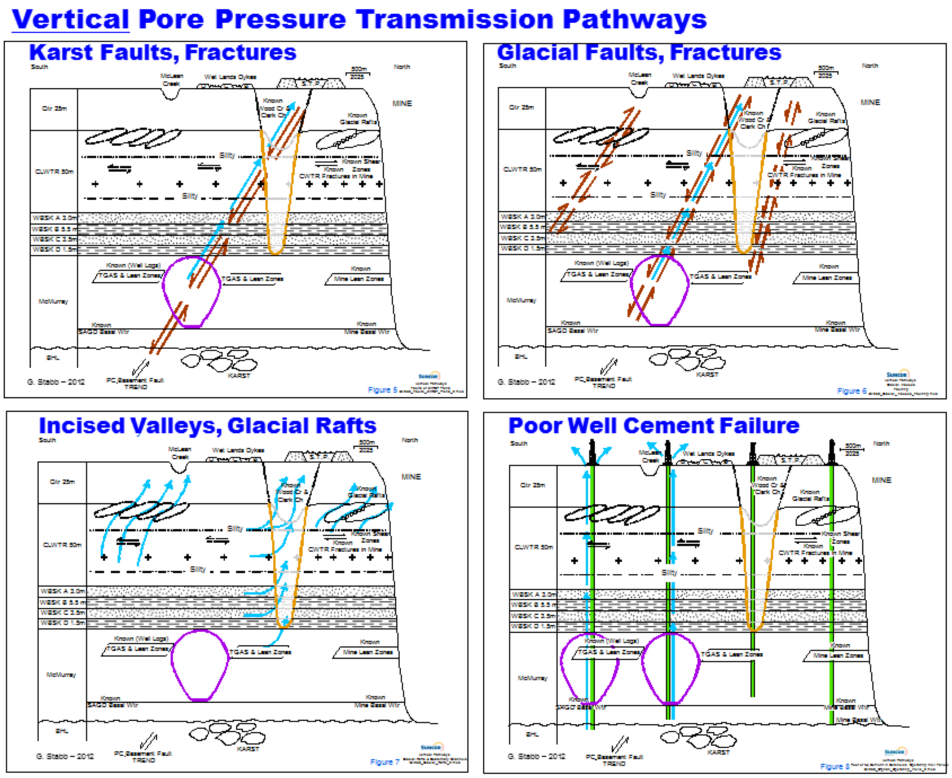


Figure 1, Stabb

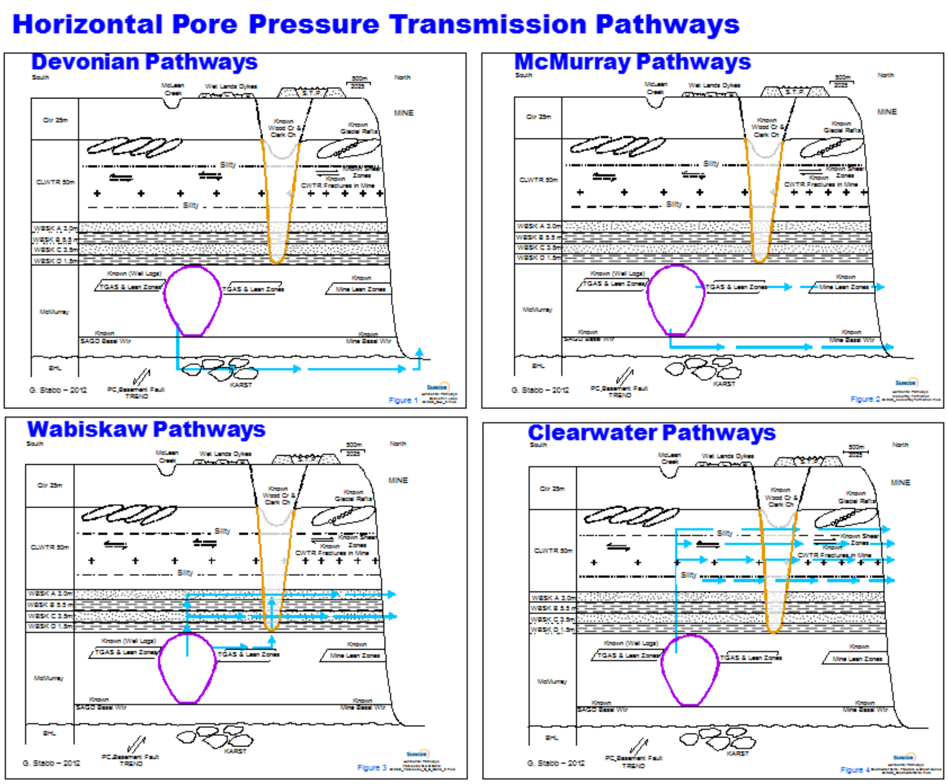


Figure 2, Stabb