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Shoreface and Fluvial Reservoirs in the Lower Grand Rapids Formation, Taiga Project, Cold Lake Oil Sands

Garrett M. Quinn and Tammy M. Willmer
Osum Oil Sands Corp.

Introduction

The Lower Grand Rapids (LGR) in the Cold Lake Oil Sands area is a highly prospective thermal recovery reservoir with over 10 billion barrels of initial bitumen in place (ERCB, 2012). This zone has been producing bitumen commercially at CNRL's Wolf Lake beginning in 1997 and is being tested at Husky's Tucker Lake Project, both using the steam-assisted gravity drainage (SAGD) process (see adjacent core presentation Hayes and Quinn (2014) for a discussion of the geology of these two areas). Osum Oil Sands Corp. is planning to develop the LGR for the first phases of its Taiga Project. High definition 3D seismic and high cored well density have allowed for a detailed stratigraphic framework at Taiga to be constructed (Figure 1). The primary reservoir is interpreted to be a shoreface deposit whereas other prospective reservoirs included channelized sands.

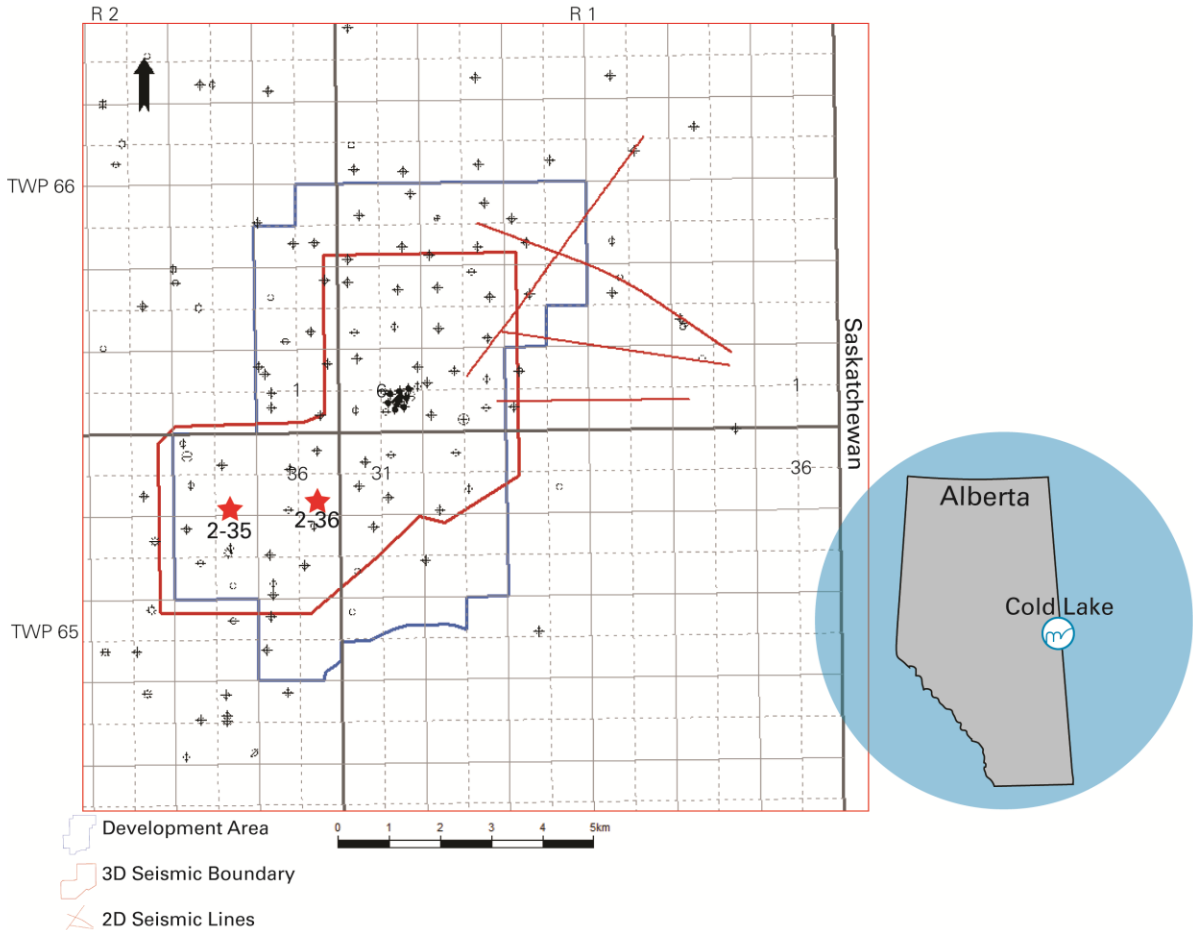

Figure 1 Map of Taiga lease. The locations of two presented cores are marked with red stars. 3D seismic area and 2D seismic lines are also shown on map.

Shoreface Reservoir

The reservoir sandstone in 1AA/02-35-065-02W4 (2-35) (Figure 2) coarsens upward from lower-fine to upper-fine-grained. The basal water-saturated portion of the core is dominated by horizontal-planar lamination with some low-angle-parallel laminations. High bitumen saturations largely obscure structures in the rest of the core; however, faint parallel and low-angle laminations are still present. Towards the middle to upper portion of this unit there are millimeter-scale carbonaceous laminations and some larger carbonaceous debris. The unit is capped by a lightly saturated, carbonaceous unit that is 15 cm thick which is overlain by a 15 cm low-quality coal interpreted to represent a paleosol. The coal is overlain sharply by 20 cm of bioturbated sandstones and mudstones. This unit is overlain by an approximately 1 m thick medium gray, slightly fissile and lightly bioturbated mudstone. The coarsening-up, exceptionally clean sandstone in this core is interpreted as a shoreface deposit with preserved backshore deposits at the top. The mudstone at the top is a regionally mappable flooding surface (Hayes and Quinn, adjacent presentation). The reservoir unit is present in the southwest part of the Taiga lease where not eroded and replaced by younger deposits.

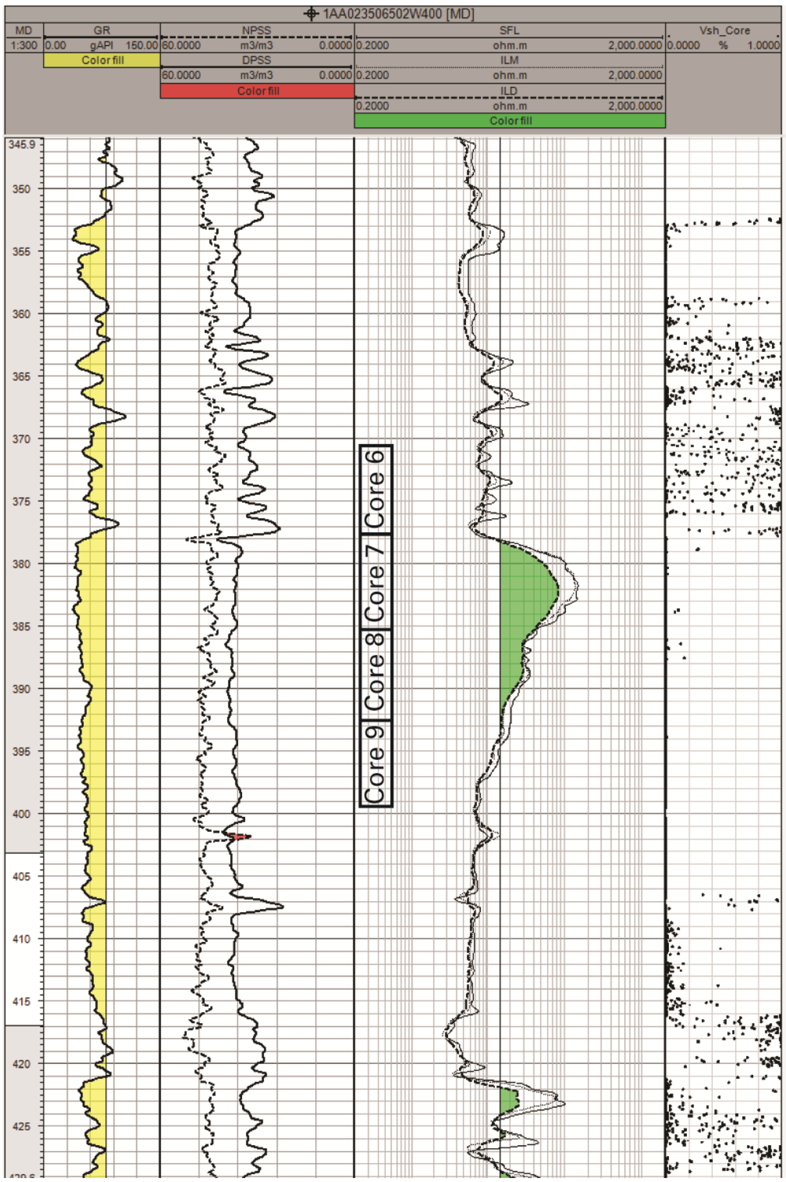

Figure 2 Log suite from well 1AA/02-35-065-02W4 showing intervals of core for this presentation.

Fluvial Reservoir

Well 1AA/02-36-065-02W4 (2-36) (Figure3) is 1.7 km to the east of 2-35 and has a comparably thick pay column. At the base of the core there is medium-grained, cross-bedded sandstone that fines upward to lower-fine-grained sandstone at the top of the reservoir interval. Cross bed sets are common and are up to 50 cm thick. There is an overall thinning of the cross-bed sets toward the top of the core. Horizontal-laminated sandstone is also common in the succession. Mudstone clasts and current ripples are present toward the middle and top of the succession. Whereas there are no visible burrows in the lower part of the succession, toward the top there are diminutive (1 mm), simple horizontal and vertical burrows associated with mudstone beds. The reservoir interval is capped by a 75 cm dark gray, lightly bioturbated and slightly fissile mudstone. Above the reservoir unit are interbedded sandstones and mudstones that define thin background parasequences that are mappable over the project area where not eroded and replaced by younger beds. The reservoir unit at 2-36 is interpreted as being fluvial in origin.

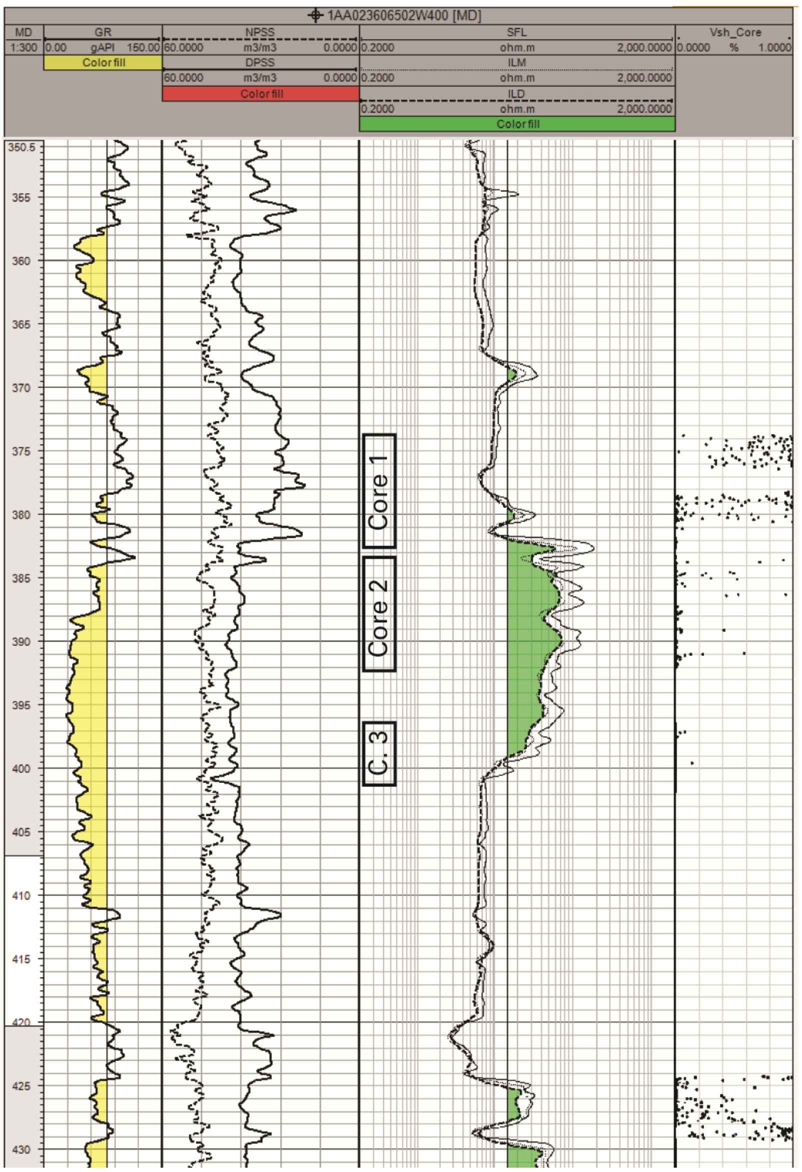

Figure 3 Log suite from well 1AA/02-36-065-02W4 showing intervals of core for this presentation.

Core Data Comparison

The two cores have different reservoir properties. The permeability of 2-35 ranges from 1,479 mD at the base to 10,000 mD just below the paleosol (Figure 4). The paleosol has low bitumen content (36%) interpreted to be due to authigenic kaolinite growth in the pore network. The 2-36 core has a permeability range from 5123 mD at the base to 1976 mD toward the top of the continuous reservoir interval (Figure 4). Like the permeability data, the calculated porosity and bitumen weight fraction data show upward trends interpreted to be consistent with lithologies and textures found in shoreface and fluvial successions.

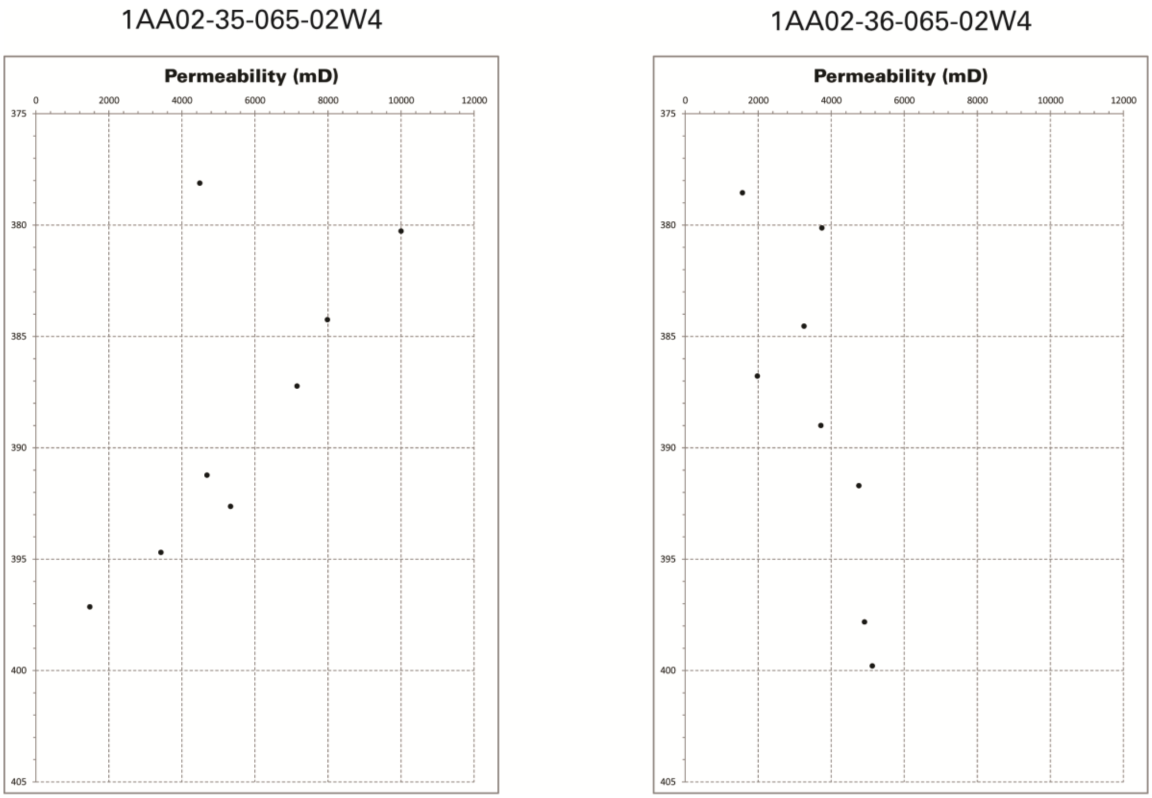

Figure 4 Comparison of measured permeability from core.

Stratigraphy

Detailed geophysical work has led to an interpretation of the spatial relationship between the shoreface (2-35) and fluvial (2-36) sandstones. Five flooding surfaces (FS0-FS4) were mapped on logs and seismic through the lease to constrain the timing of incision events. The fluvial unit at 2-36 was deposited after the shoreface and after erosion and deposition of a large complex incised valley fill (Figure 5). A density inversion shows the lateral extent of the shoreface and fluvial sands. The shoreface sand is a blanket sand where not eroded (Figure 6). A smaller channel fill in the top of the shoreface is recognized as a low density feature, with a northeast trend, that replaces the upper 8 m of the shoreface succession (Figure 6). This channel fill is hung as the larger valley fill (FS2) and is interpreted as a tributary fill to this valley fill. The fluvial sandstone body is an east-west elongate lens (Figure 7). Maynard et al (2010) and Hayes and Quinn (2014, adjacent table) show the complex stratigraphy found at the Taiga lease is not unique to the LGR of the Cold Lake area.

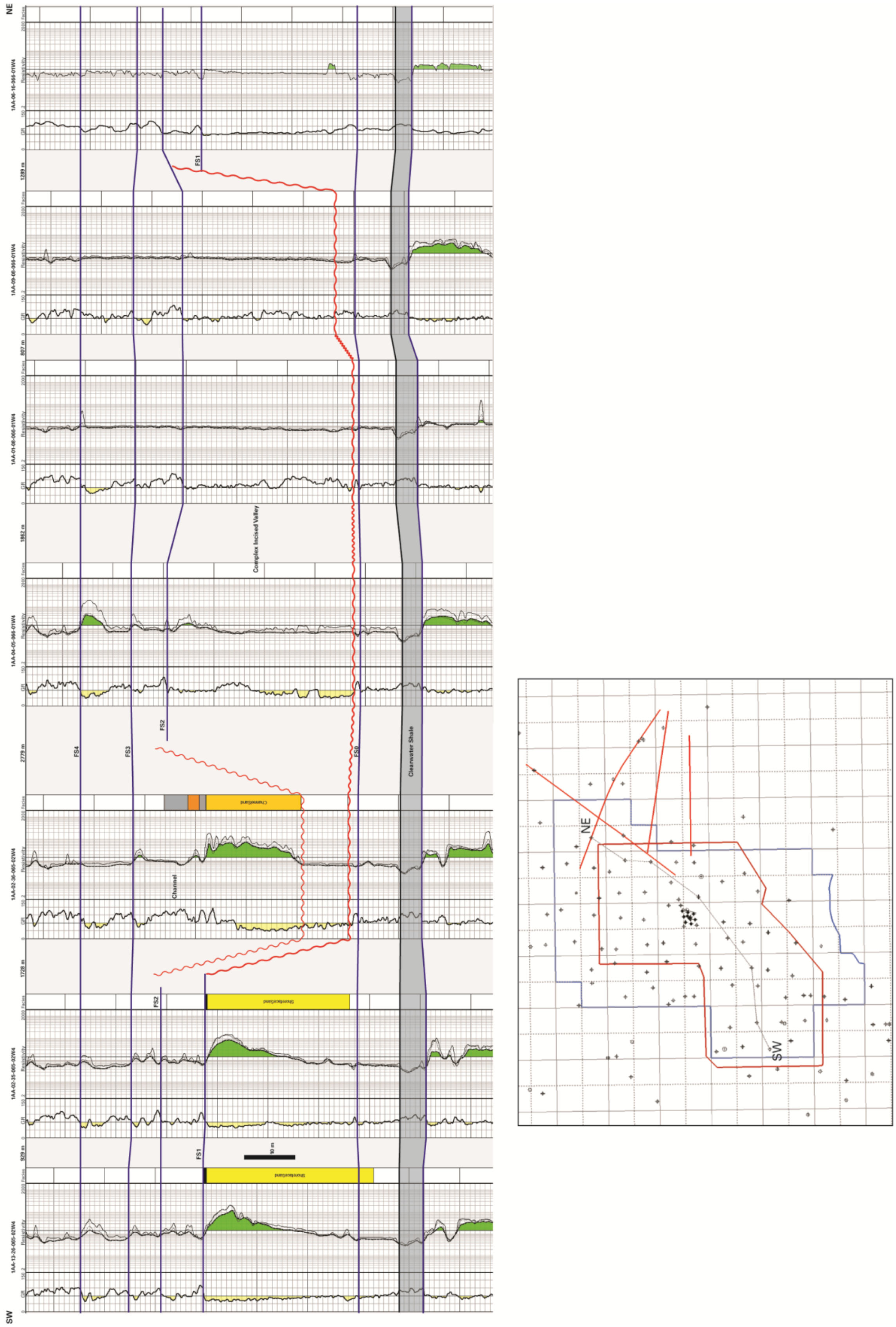

Figure 5 Stratigraphic cross section hung on FS4. The section illustrates the stratigraphic picks for FSO-FS4 and erosional surfaces.

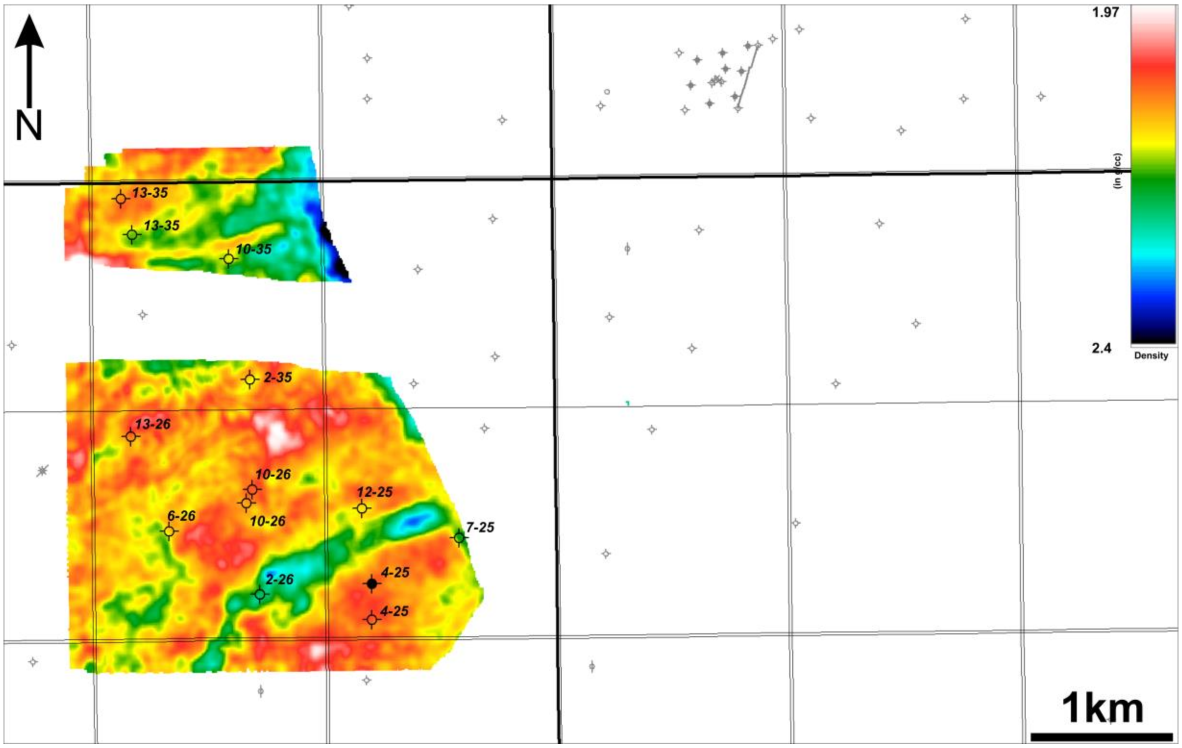

Figure 6 Average amplitude extraction from a calculated depth-converted density volume taken over the interpreted shoreface succession. The extraction window is 8m in size and referenced from the FS4. The window is positioned deeper than FS4 to 28m to highlight the high porosity of the top of the shoreface reservoir. A small 8 m thick channel fill nestled in the shoreface succession is the higher density feature trending northeast that was penetrated with the 2-26 well.

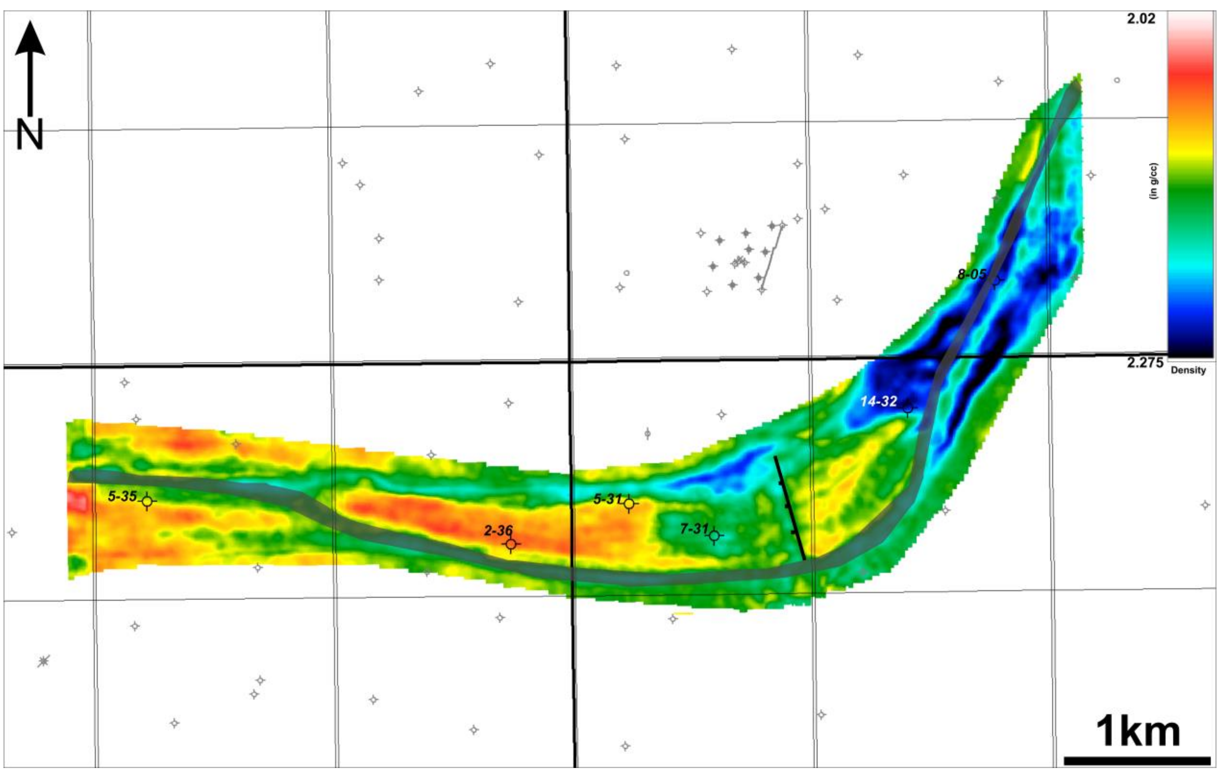

Figure 7 Average amplitude extraction from a calculated depth-converted density volume taken over the interpreted channel fill. The extraction window of the channel fill is 22m in size and was referenced from the base of the channel as interpreted by seismic to 22 m above that horizon. An interpreted muddy channel fill is highlighted in the grey outline.

Conclusion

The LGR on the Taiga lease has reservoir quality strata in both shoreface and fluvial sandstones. Both reservoir types have measured rock properties that are amenable to SAGD. Detailed geophysics and stratigraphic work shows that the shoreface reservoir is superior in terms of lateral extent. The complex stratigraphy on the lease is found elsewhere within the LGR in Cold Lake Area. Future attempts to recover a portion of the estimated 10 billion barrels in the LGR with thermal recovery methods will precede with less risk provided high quality geoscience data sets, like those employed at the Taiga Project, are used to interpret environment of deposition, reservoir quality, stratigraphic framework and sandstone body geometry.

References

Energy Resources and Conservation Board 2012. ST98-2012: Alberta's Energy Reserves 2011 and Supply/Demand outlook 2012-2011.

Hayes, B. J. and Quinn, G.M. 2014. Lower Grand Rapids Bitumen Pools at Cold Lake, Alberta – Variations in Stratigraphic Setting and Depositional Environments. Geoconvention 2014 Core Conference.

Maynard, J., Feldman, H.R. and Always, R 2010. From Bars to valleys: the sedimentology and seismic geomorphology of fluvial to estuarine incised-valley fills of the Grand Rapids Formation (Lower Cretaceous) Iron River Field, Alberta, Canada. Journal of Sedimentary Research, **80**, 611-638.