Defining a Geo-model of the South Swan Hills Reef Complex for Geothermal Use, Swan Hills, Alberta.

Christopher Noyahr[1], John A. Weissenberger[2], Nicholas B. Harris[1], Jonathan C. Banks[1]

[1] University of Alberta. [2] ATW Associates.

Summary

South Swan Hills is a Devonian reef complex and a prolific oil-pool located near Swan Hills, Alberta. The reef also serves as a reservoir of hot water in which average temperatures across the aquifer are above 100 degrees Celsius. The hot water is currently recycled because it lacks use. The water, however, has geothermal potential that can be converted to electrical energy to operate a field independent of an electrical grid. This research aims to build a geologically-based 3-D cellular model in order to characterize the permeable zones within the reef build-up and model the behavior of hot water as it flows through these permeable bodies. As highly productive, favourable targets are revealed in the model, a suitable injection/production system can be planned for installation to maximize production and by extension electrical output.

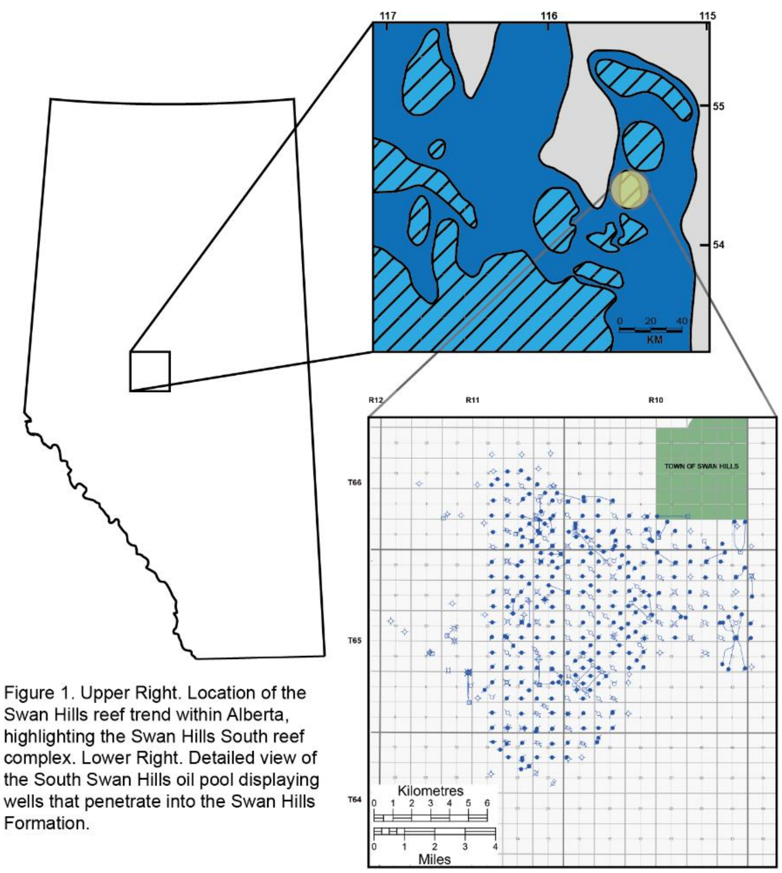

Figure 1. Upper Right. Location of the Swan Hills reef trend within Alberta, highlighting the Swan Hills South reef complex. Lower Right. Detailed view of the South Swan Hills oil pool displaying wells that penetrate into the Swan Hills Formation.

Development of a 3-D geo-model is common within the oil and gas industry but geothermal applications have not been considered. This research attempts to build a geo-model that focuses on characterizing water flow through a reservoir. While the use case for the reservoir characterization is non-traditional, many of the techniques used are the same. The final product seeks to unify lithological and petrophysical data to describe the geometry of the reef with accuracy and in the context of the regional sequence stratigraphic framework.

Workflow

Developing a geo-model is a stepwise process that begins with core observations. By logging core, distinct lithofacies can be distinguished, observations about the lateral and vertical distributions of the lithofacies can be made and distinct surfaces can be noted. Lithofacies can then be linked to a depositional model in order to understand the lateral variability in the context of paleo-environment. For core observations to be effective, cores are employed from locations forming representative N-S and E-W sections across the reef. The majority of these cores extend from the base of the platform to the top of the reef -- allowing for the formation of detailed descriptions of the entire reef history.

With an understanding that the reef has grown analogously to the rim-bounded facies model, it is possible to observe how the paleo-environment changed based on vertical stacking. Recognizing that eustasy is a primary control on sedimentation, it is practical to integrate data about cyclicity and exposure surfaces into a sequence stratigraphic framework and track the surfaces across the entire reef. Based on previous work, (Collins 2017, Potma et al. 2001, Wendte and Uyeno 2005), the exposure surfaces correspond to third-order sequence boundaries, whilst megacycles operate at a higher order within these sequences and are controlled by continuous floods.

The final integration of lithological data and petrophysical data is done in Petrel. In this model, sequence stratigraphic boundaries can be correlated throughout the entire reef and a three-dimensional model of the reef can be visualized. The model will display the positions at which the permeable facies deposited and how they moved with respect to changes in sea level within and across the three sequences.

Results

Two important patterns arise when observing core. Cyclicity, especially in the reef interior, is evident. Commonly, lagoonal sediments will grade into tidal flats and repeat. The second pattern that is evident are the significant backsteps in reef sedimentation, demarcated by erosional surfaces composed of breccias, paleo-karst and waxy green clays.

The reef is characterized by three sequence packages. The first package is bounded below by the top of the platform and above by the first sequence boundary (designated as the BHL2 surface). It is the most laterally extensive atoll stage with rim-bounded character. After the BHL2 exposure, flooding occurs causing the significant backstep in the second sequence package. This sequence is also a rim-bounded reef capped by a sequence boundary. There is a significant time gap between the second sequence boundary (BHL3) and the following transgression. The major transgression effectively drowns the reef. The depositional style of the third (and most areally limited) sequence package changes to a high-energy ramp flat before completely drowning.

The main control on porosity is the depositional fabric. Cementation and leeching affect primary porosity, most prominently in the reef interior. The position of the paleo-water table caused occlusion and augmentation of porosity within megacycles. At the base of cycles, phreatic cements occlude porosity, whilst at the top, vadose cements have the same effect. Near the paleo-water table, porosity is enhanced due to leeching by unsaturated water. Although porosity can be enhanced, the process is not consistent or extensive enough to be build a viable reservoir, the effects are important to note and are integrated into the geo-model.

There are two potential reservoir targets. The final sediment package deposited as the reef drowns, is dominated by mixed stromatoporoid grainstones deposited in a high-energy ramp flat; however, the package is thin. The second target comprises a range of environments found on the margin of the reef including lower foreslope talus grainstones grading into middle foreslope sand that form porous repeating megacycles. Aggradational reef flat deposits where cyclicity is not evident can also form near the margin and also develop into extensive columns of porous rock.

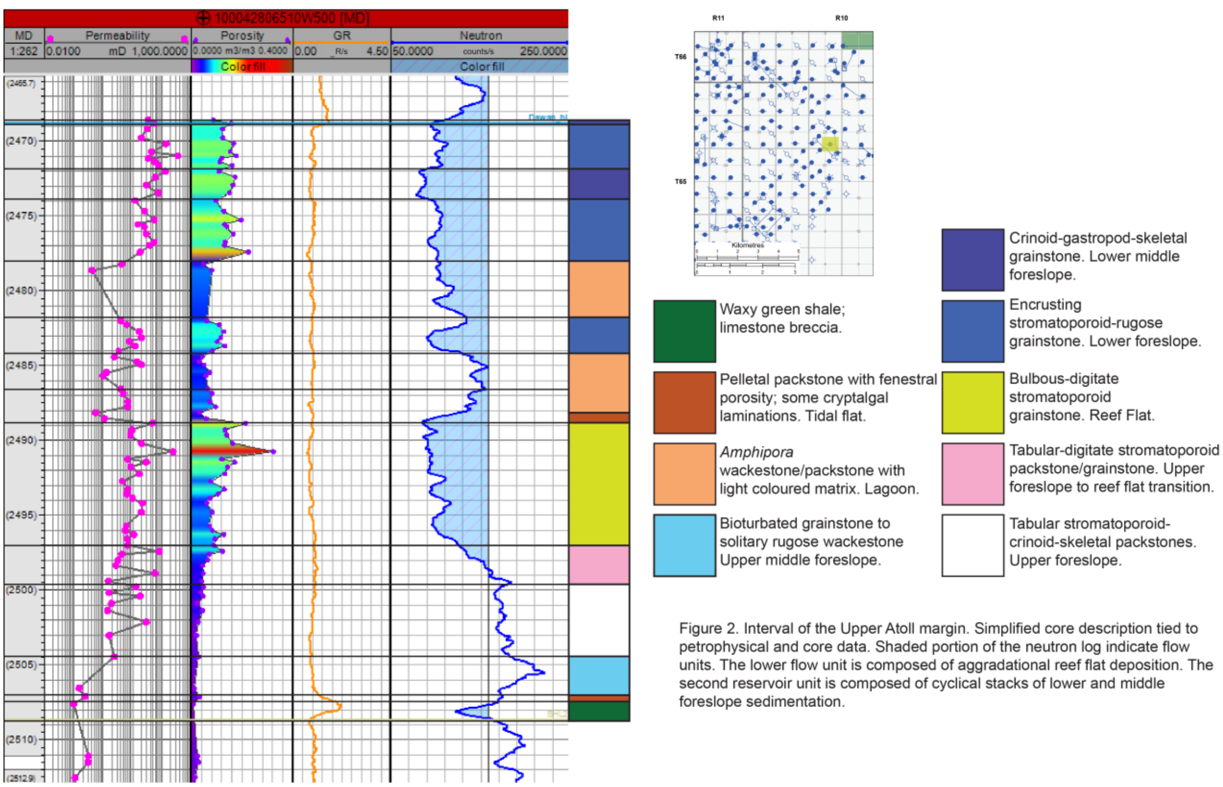

Figure 2. Interval of the Upper Atoll margin. Simplified core description tied to petrophysical and core data. Shaded portion of the neutron log indicate flow units. The lower flow unit is composed of aggradational reef flat deposition. The second reservoir unit is composed of cyclical stacks of lower and middle foreslope sedimentation.

Acknowledgements

As a part of the University of Alberta's Future Energy Systems research initiative, this research was made possible in part thanks to funding from the Canada First Research Excellence Fund.

References

Collins J. F., 2017. PALEOTOPOGRAPHY ON THE INTRA-SWAN HILLS FORMATION UNCONFORMITY IN AN ISOLATED PLATFORM, CARSON CREEK NORTH FIELD (UPPER DEVONIAN, FRASNIAN), AND IMPLICATIONS FOR REGIONAL STRATIGRAPHIC CORRELATION IN THE BEAVERHILL LAKE GROUP, SOUTHERN ALBERTA, CANADA: THE CASE OF THE MISSING REGRESSION", NEW ADVANCE IN DEVONIAN CARBONATES: OUTCROP ANALOGS, RESERVOIRS AND CHRONOSTRATIGRAPHY, Ted E. Playton, Charles Kerans, John A.W. Weissenberger

Potma K., Weissenberger J. A. W., Wong P. K., Gilhooly M. G., 2001. Toward a sequence stratigraphic framework for the Frasnian of the Western Canada Basin. Bulletin of Canadian Petroleum Geology 49:37–85.

Wendte J, Uyeno T. 2005. Sequence stratigraphy and evolution of Middle to Upper Devonian Beaverhill Lake strata, south-central Alberta. Bulletin of Canadian Petroleum Geology 53:250–354.