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Reservoir Characterization of the Swan Hills Eastern Platform Trend; a Multi-disciplinary Approach in Building an Applied Model

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Summary

This poster highlights the integrated approach Arcan implemented in developing an applied model that is currently guiding development efforts in the Swan Hills platform, east of the large reefal build-ups (Figure 1). The model was constructed in a systematic approach, simultaneously with development activities, and involved the integration of detailed core descriptions, thin section work, petrophysics, chip sample analysis, geophysics, and reservoir simulation work.

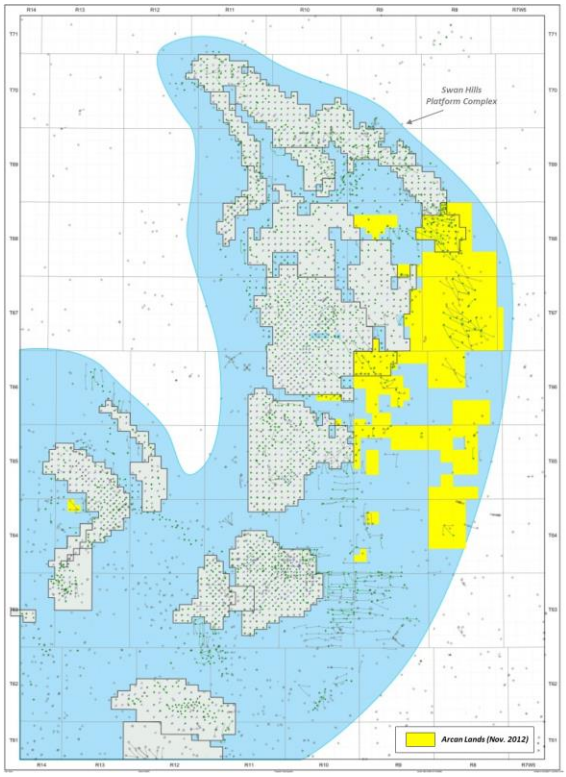

Figure 1: Map highlighting Arcan BHL lands as of November, 2012. The Swan Hills Complex is in blue.

Introduction

The Swan Hills Formation is Givetian in age (~370 million years) and belongs to the Middle to Upper Devonian Beaverhill Lake Group. The Swan Hills Complex, as it is commonly known as, consists of a

broad carbonate platform that is overlain by large reefs (or build-ups), all deposited in an overall transgressive phase of relative sea level rise (Wendte and Uyeno, 2005).

Since the discovery of oil in the large Swan Hills reefal build-ups in the 1950s, there has been a significant amount of industry focus on characterizing these large carbonate structures, and less emphasis on delineating the geomorphology of the Swan Hills platform, particularly eastwards of the main reefal buildups (Hemphill, Smith, and Szabo 1970; and Fischbuch 1968). In the '60s and '70s, it was well known that the platform had large accumulations of oil, however, aside from the unitized blocks of land along the defined "platform edge" (i.e. House Mountain & Deer Mountain Units), it proved difficult to extract oil out of the reservoir at economic rates. Today, with the advent of horizontal drilling and multi-stage fracturing, producing oil at economic rates from the Swan Hills platform has become a reality.

Arcan Resources Ltd., a junior oil company located in Calgary, Alberta, holds a significant acreage position in the Swan Hills, Beaverhill Lake oil play in north-central Alberta. The lands fall entirely within the platform, east of the big buildups, and are estimated to contain approximately 700 million barrels of original oil in place (Figure 1). In order to maximize value and formulate an ongoing development strategy, it was necessary to create a working geologic model that could be used to optimize current and future drilling and waterflood activities. Existing models of the Swan Hills platform attempted to highlight the stratigraphy and composition of this carbonate system, these models lacked the detail that Arcan deemed necessary in order to fully characterize and exploit its land base.

The Arcan model entailed the integration of the following; core descriptions, core analyses, thin section petrography, chip sample descriptions in both horizontal and vertical wells, petrophysics, geophysics, and geomodeling exercises. This applied model was constructed over the course of eight months; however, the model remains dynamic in that it is currently being updated as new data becomes available through ongoing development activities. The model is currently being used by Arcan to control the placement of horizontal wells and to implement waterflood enhanced secondary recovery.

Theory and/or Method

The applied, or working, model of the Swan Hills eastern platform trend was constructed using both existing data, from both vintage vertical and recent horizontal wells, as well as new data that was being collected during this exercise. In addition to employees of Arcan, the process involved a number of consultants, including; carbonate specialists, petrographers, geophysicists, and reservoir engineers.

Various components were used in creating the model, each having representation from each individual of the aforementioned disciplines. The components can be grouped into six categories:

- Core description & interpretation
- Thin section petrography
- Chip sample analysis
- Petrophysics
- Geophysics
- Reservoir simulation

Core Description & Interpretation

Describing and interpreting the rock was the first step in creating the model. Over 70 wells were selected that contained core over the Swan Hills formation, either all or in part. Each core was logged in great detail, with particular focus on; facies, significant surfaces, unit thicknesses, and depositional environments. Particular attention was also given to describing the various stromatoporid morphotypes, as well as other organisms, and their relationship to the shelf-margin-basin environment transition.

This work was the foundation for building a depositional model as well as a refined stratigraphic model. All subsequent work relied on these interpretations to calibrate and re-enforce the observations made. In total, over two kilometers of core were examined, logged, and interpreted.

Thin Section Petrography

From the 70 plus wells that were logged, many of them had samples taken for thin section petrographic work. The thin section work had two main objectives;

1) Characterize the types and origin of the porosity
2) Establish the diagenetic history of the plumbing system

In total, over 50 thin sections were analyzed and interpreted. The information gathered from this exercise was instrumental in not only developing a solid understanding of the porosity, but also its predictability within the various facies identified.

Chip Sample Analysis

Aside from the geological descriptions provided from wellsite geologists, the drill cuttings from dozens of horizontal wells were logged by an independent carbonate specialist. The emphasis of this exercise was on;

1) Establishing the depositional environment and the facies within
2) Identifying transitions from one depositional environment to another
3) Characterize the porosity along the wellbore's path

Understanding the spatial distribution of the various facies along 1200 to 1600m of horizontal wellbores scattered throughout the development area brought another dimension to the data that further enhanced the geologic model. Furthermore, several horizontal wells that crossed depositional edges were later used to calibrate the interpreted 3D seismic data, and establish the extents of various depositional environments, particularly the reef edge.

Petrophysics

With the core descriptions completed, it was then necessary to quantify the porosity across the entire fairway, as well as establish petrophysical parameters in each of the facies identified in core. The data

set consisted of 130 vertical wells that could be used in a log-to-core integration exercise, most of which were 1960s and 1970s vintage. From the 130 wells identified, 107 were used in the computation of porosity within the Swan Hills, and 78 wells contained core data that were used to establish porosity and permeability relationships. The vintage of the data also posed additional challenges with 103 wells requiring core and/or log shifting for proper depth alignment.

With a clean data set, core data was reviewed for statistical understanding and any facies relationships. Porosity and permeability equations were then derived from core data. DTc and NPLS were cross-plotted to core porosity values to establish relationships and develop log correcting equations that were used to determine porosity from logs. A deterministic algorithm was then assembled to perform the petrophysical analysis utilizing shale corrected porosity and water saturation equations. The final petrophysical results integrated both log derived porosity and permeability with the respective core analysis measurements in a "hybrid dataset".

Geophysics

Arcan had acquired two proprietary 3D seismic surveys, one in 2006 over the Deer Mountain Unit #2 lands, and a second in 2010 over the eastern half of the Ethel field. The primary objective for acquiring the surveys was to delineate the reef edge, a significant depositional limit in the play fairway. In 2011, simultaneous with the construction of the geological model, an in depth investigation of various seismic attributes from inversion analysis was carried out by two third parties.

There were three main geologic deliverables that Arcan was looking for;

1) Identify the reef margin, along with any associated foreslope aprons
2) Characterize any structural element (i.e. faults) that may explain the geometry of the platforms geomorphology
3) Attempt to model the porosity within the platform.

Multiple geophysical attributes were studied and interpreted to address these three desired deliverables.

Reservoir Simulation

The building of a geo-cellular model in Petrel was also taking place simultaneously with the aforementioned work. Creating a dynamic reservoir model was important to Arcan so that waterflood recoveries in the Deer Mountain and Ethel fields could be further understood. This was the first iteration of an iterative process, and did not include many of the recent observations and conclusions that Arcan had made upon completion of their geologic model. A second iteration of this process is currently underway that will incorporate all work done to date.

Conclusions

A practical integrated geologic-reservoir model was created that could be used to delineate future drilling locations within the Swan Hills Platform. This was accomplished by using a systematic approach that involved multi-disciplinary efforts working simultaneously with ongoing

development activities. Subsequent drilling and initial waterflood results have confirmed the validity of this model and its significance relative to managing risk and continues to be a critical tool in the development of this asset.

Acknowledgements

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