

The Swan Hills Formation at Kaybob South Field, Alberta : An Example of Remaining Reserves Potential within Mature Fields

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Summary

The “rediscovery” of reserves within mature fields can occur when new technologies are applied and integrated. Fundamental building blocks are the integration of geological, geophysical, and petrophysical concepts to guide the renewed development plan. The Devonian Swan Hills Formation at Kaybob South is a case study for this opportunity.

Introduction

In 1961 approximately $104,772 \times 10^6 \text{m}^3$ (3.7 trillion ft^3) of in-place sour gas reserves were discovered within the Late Devonian Swan Hills Formation (Beaverhill Lake A pool) at the Kaybob South field of west-central Alberta. Production at Kaybob South occurs within three operating Units (Gas Units #1, #2 and #3). Production commenced in 1968 at Gas Unit #1 with a sweet gas cycling scheme that continued until 1983. After this date, gas was harvested through gas depletion with a sweet gas lift system to help move fluids.

Cumulative gas production to date at Gas Unit #1 suggests that 47-56% of the in-place gas reserves will ultimately be captured by the remaining productive wells. This recovery is low when compared to analogue Swan Hills pools. Challenges to increasing the recovery include current well bore spacing, water production due to near-well bore coning, well bore mechanical restrictions resulting from highly corrosive formation fluids, and tubing constrictions caused by mineral precipitant deposits.

Comparison of Gas Unit #1 with analogous Swan Hills gas pools within the region suggests that the drilling of infill development wells may capture between $1,183 \times 10^6 \text{m}^3$ ($42 \times 10^9 \text{ft}^3$) and $5,192 \times 10^6 \text{m}^3$ ($183 \times 10^9 \text{ft}^3$) of gas reserves. These reserve additions, combined with the $651 \times 10^6 \text{m}^3$ ($23 \times 10^9 \text{ft}^3$) reserves that are anticipated to be recovered by the current producing wells, would

increase the ultimate recovery at Gas Unit # 1 to 63-77% of OGIP. This is aligned to analogous Swan Hills pool recoveries.

Study Method

The geologic study is based upon a dataset of 66 wells correlated within a grid of stratigraphic cross sections that extend across both Gas Unit #1 and the northernmost portion of Gas Unit #2. All available cores from the Swan Hills Formation (1494 m of core from 60 of the 66 total wells) were described. Petrophysical logs were digitized, integrated with core, and interpreted. Facies models were built into a sequence stratigraphic interpretation for the study area. Facies, fracture, and structural maps were generated for each depositional sequence correlated within the gas-saturated portion of the Swan Hills reservoir interval. Pore volume, composite facies, and fracture density maps were produced for the entire Swan Hills interval.

Geologically based structural mapping was integrated with a depth converted time structure map developed from 3D seismic coverage over the northernmost portion of Gas Unit #1. The seismic was used to optimize the locations of prospective infill wells.

The constrained rock volumes were used to refine the range of in-place and recoverable gas volumetrics for the pool, and expected recoverable gas for prospective infill well locations.

Conclusions of Study

The Beaverhill Lake A pool (Swan Hills Formation) within the Kaybob South study area accumulated as a complex of 12 platform margin to interior depositional environments that were periodically subjected to subaerial exposure. The relationship between facies and reservoir quality is homogenized by diagenetic overprint that is dominated by dolomitization. Trends in porosity, permeability, fracture density, and well performance predictably coincide with facies groupings into related facies associations. Porosity, permeability, fracture density, and rates of maximum daily gas production are highest within the forereef margin (facies 4, 5 and 8) and stromatoporoid shoal (facies 6 and 7) associations.

The stratigraphic interval is regionally equivalent with the upper portion of the “third-order” Beaverhill Lake 2 (BHL-2) and most, if not all, of the Beaverhill Lake 3 (BHL-3) sequences of Potma et al. (2001). The BHL-2 and -3 are partitioned into 5 high-frequency sequences (HFS-2 through HFS-6) that are characterized by an aggradational to slightly retrogradational stacking pattern within HFS-2 through -4, and a retrogradational stacking pattern within HFS-5 and -6. Due to southwestward structural dip, gas is trapped against the eastern platform margin at Kaybob South, and the gas-saturated reservoir at Gas Unit #1 largely coincides with the forereef margin and stromatoporoid shoal facies associations of HFS-2 through -5. Because the study interval is highly fractured and gas-charged, high-frequency sequence boundaries and intrasequence facies distributions do not likely compartmentalize the reservoir into flow units.

The expected-case original in-place gas (OGIP) reserves at Gas Unit #1 are $28,600 \times 10^6 \text{m}^3$ (1.01 trillion ft^3). Cumulative production to date from all wells, and anticipated recoverable reserves from the remaining 13 productive wells (including shut-in wells) are anticipated to collectively capture between 48-59% of the OGIP.

Although Kaybob South was discovered as a sour gas reservoir in 1961, the fifteen year practice from 1968-1983 of cycling sweet gas into the reservoir has lowered the H_2S from its original value of 17.7% to as low as 4% in some areas. This reservoir management strategy, along with the limited recovery from some historical wells and spacing reviewed within analogue pools, indicates that recovery at Gas Unit #1 may be enhanced through additional development drilling. At least 17 infill

wells could be drilled at Gas Unit #1, and are predicted to have recoverable reserves that range from $1,183 \times 10^6 \text{m}^3$ ($42 \times 10^9 \text{ft}^3$) to $5,192 \times 10^6 \text{m}^3$ ($183 \times 10^9 \text{ft}^3$). Combining these reserve additions with the $651 \times 10^6 \text{m}^3$ ($23 \times 10^9 \text{ft}^3$) that are anticipated to be recovered by the 13 current producers, increases recovery to approximately 63-77% of OGIP, a value that is better aligned with analogue pools.

The average position of the original gas-water contact at Gas Unit #1 was -2359 m (7739'). The current base of the gas-water transition zone is predicted to occur between -2342 m (7684') and -2346 m (7697').

The relative performance potential of infill development wells were ranked through a semi-quantitative assessment that takes into account structural position (confirmed with 3D time-depth structure), proximity to current producers, thickness of the gas-saturated pore volume, dominant facies, Kmax permeability, and total fracture density.

Examples: Evaluation by Drilling

As of this writing, three of the prospective wells have been drilled and serve as a test of the proposed strategy for infill development: 102/16-31-061-19W5/0 (4th quarter of 2006), 100-16-30-061-19W5 (3rd quarter of 2007), and 102-04-13-062-20W5 (4th quarter of 2007). Results from the three wells are consistent with the pre-drilling predictions of structural position, reservoir geology, position of the gas-water transition zone, and ultimate recoverable reserves as projected from well performance to date. Other production challenges have been addressed through application of new technologies in the areas of chemical corrosion inhibition programs, using polyglass lined tubing to inhibit brine precipitation, and using polymer to restrict water production.

Conclusion

The “rediscovery” of reserves within mature fields can occur when newer technologies are applied and integrated. The application of integrated geoscience concepts was key to a renewed development plan that is expected to see 63-77% of OGIP recovered, a significant increase over current expected recovery. The Devonian Swan Hills Formation at Kaybob South is a case study for this opportunity, and illustrates the remaining potential that may exist within other mature fields across the Western Canada Sedimentary Basin.

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