Re-Fracturing and Water Flooding Western Canada Tight Oil Reservoir Horizontal Wells

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Summary

Horizontal multistage fracturing technology has been used with multiple tight oil formations in the Western Canadian sedimentary basin. The paper presents and answers the following questions: How does performance vary between geological areas? How does the geological/depositional environment affect the performance? What options are available to improve ultimate recovery?

The study includes the analysis of production data from fractured and re-fractured horizontal oil producers from three typical tight oil formations: Bakken, Cardium and Viking. Re-fracturing wells increased oil production significantly, with the incremental oil production ranging from 3,000 Bbl in Viking to 30,000 Bbl in Bakken.

The study also includes geomodeling and water flooding simulations of three typical tight oil reservoirs: Viewfield Bakken, Pembina Cardium and Kindersley Viking. Layer constrained geostatistical modeling is employed instead of box models to accurately model the heterogeneities that exist in tight oil reservoirs. The simulation results show that with horizontal water flooding, the ultimate recovery factor for tight oil reservoirs can be significantly improved with ultimate recovery factors up to 25 to 30% compared to 10 to 15% under primary production with hydraulic fractures.

Introduction

More attention is being paid to tight oil reservoirs in Western Canada. The Bakken, Cardium and Viking formations are the major tight oil-bearing formations. The sedimentary environment of the tight reservoirs is typically a low-energy environment such as Delta-front, Prodelta, Tidal Flat, or Transition Zone between Shore and Offshore facies. As a result, the permeability of the reservoirs can be very low, ranging from 0.1 mD to 10 mD. The permeability is much lower than conventional oil reservoirs and can only be effectively developed with horizontal multi-fracture technology. In the study, the performance of the tight oil formations is evaluated with emphasis on how the geological environment plays a role in production performance. For the purposes of this study, the Pembina Cardium formation is classified into two types of reservoirs: one with the high permeable conglomerate zone at the top of the reservoir and the other without.

The study also reviews two optimization techniques for improving the productivity and ultimate recovery factor of the fields: re-fracturing and horizontal water flooding technology.

Horizontal Well Re-Fracture

Around 8,000 horizontal wells have been drilled and fractured in the Bakken, Cardium and Viking tight oil formations in Western Canada with approximately 50 wells being re-fractured. The production data shows that re-fracturing horizontal wells significantly increased the oil production rate and decreased the water cut in most wells. Figure 1 shows the oil production improvement in the Viking formation from re-fracturing.

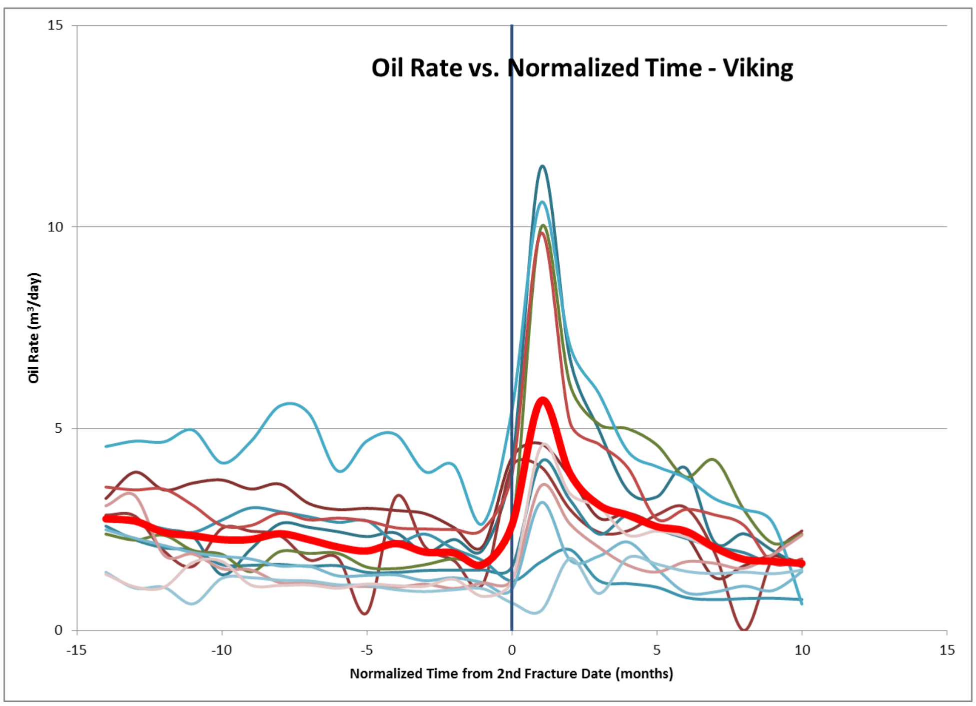

Figure 1. Example of Oil Rate Increment after Re-Fracture

A screen was performed on the 8,000 fractured horizontal wells to determine which wells should be re-fractured. Approximately 2,000 wells can benefit from re-fracturing. The cumulative incremental oil production from the wells could reach more than 40 Million Bbl.

Reservoir Flow Units Geomodeling

Box models have been used for many previous studies of tight oil reservoirs in the oil industry. However, the box models cannot capture the heterogeneity that exists in the tight oil reservoirs, with inter-layers vertically and inner-layers horizontally.

Layer-constrained geostatistical modeling was conducted for four types of reservoirs, which included one geomodel for Viewfiel Bakken, two types of geomodels for Pembina Cardium sandstone reservoir, and one for Kindersley Viking. The four geomodels were used for water flood simulation. Figure 2 shows an example of the heterogeneous model.

The flow unit-derived geomodel provides a better characterization of the tight reservoir, and makes the simulation of inner-layer and cross-layer flow simulation more reasonable and practical.

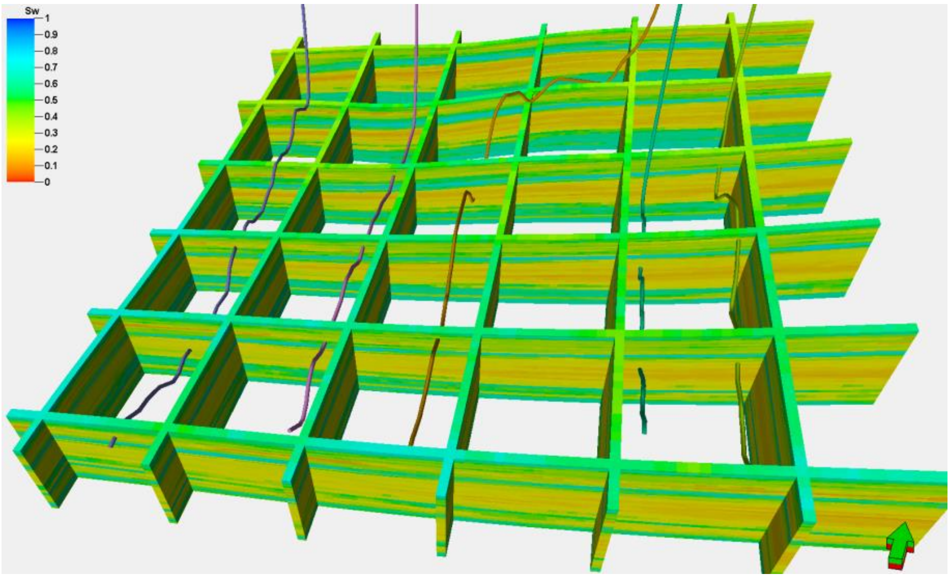

Figure 2. Example of a Heterogonous Flow Unit Geomodel

Reservoir Horizontal Water Flooding Simulation

Horizontal water flooding simulation was performed on four types of reservoirs. Various flooding plans were created and forecasted. Various fracture methods such as line fracture and zip fracture were applied in the studies.

Compared with the base no water flooding case, the horizontal water flooding significantly improved the tight oil reservoir recovery, usually doubled the primary recovery as seen in Figure 3 and Figure 4.

The study also included other flooding methods such as vertical water injectors and CO_2 flooding. Compared with these methods, horizontal water flooding was recommended for the tight oil reservoir as the best recovery method.

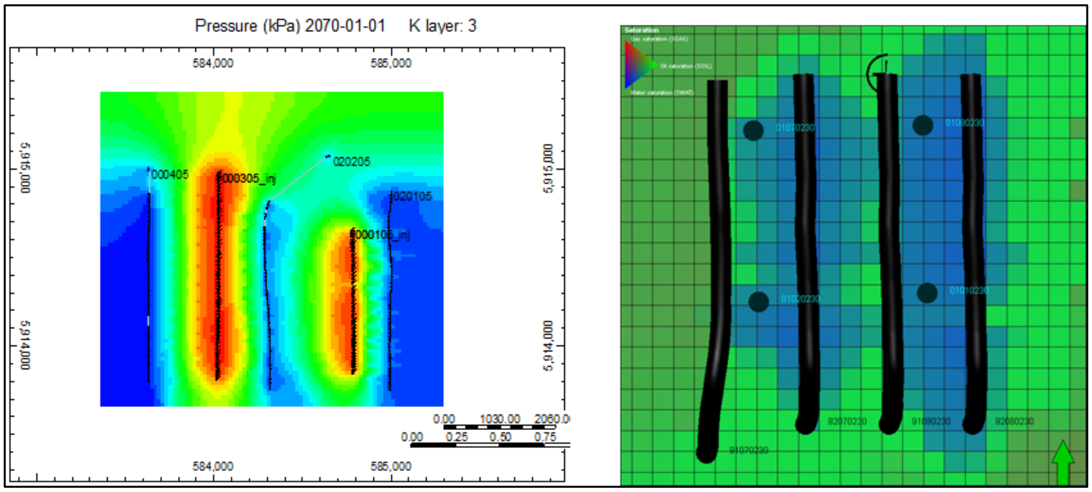

Figure 3. Example of Reservoir Parameter Changes after Water Flooding

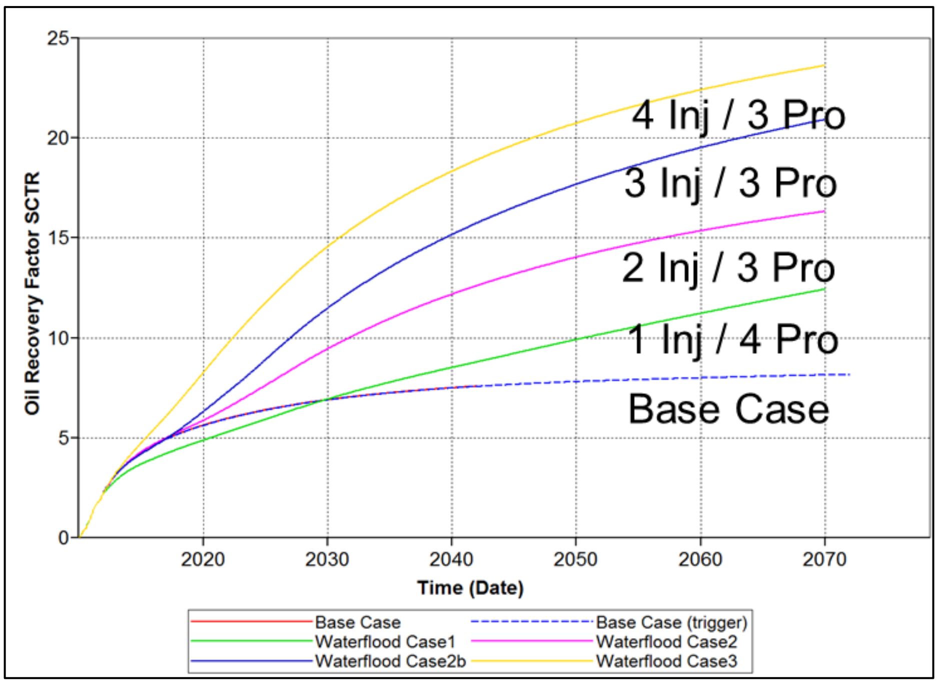

Figure 4. Example of Reservoir RF Comparison with Different Plans

Conclusions

After the analytical and simulation study, horizontally fractured and re-fractured wells combined with water flooding proved to be an effective way to improve the well performance and to enhance recovery for Western Canada tight oil reservoirs. However, not all reservoirs responded the same way to each technology; therefore, it is important to understand the system's geology before determining an appropriate enhanced recovery technique.

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