Defining Vertical Permeability Distribution to Support SAGD Operations: An Integrated Multi-Scale Approach to Modelling a Bitumen Reservoir

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The natural bitumen deposits in Alberta, Canada, comprise about 1,700 billion bbls of bitumen in place with an estimated 174 billion bbls recoverable. They are deemed critical to the future security of North American energy supplies. The primary extraction method for these deposits will be steam assisted gravity drainage (SAGD), a method dependent on vertical reservoir permeability. The Lower Cretaceous McMurray Formation, the dominant reservoir, is an estuarine channel and tidal bar system with significant lateral and vertical heterogeneity. Although tidal bar and channel sands exhibit great permeabilities in the order of darcies, this reservoir exhibits relatively low permeability and porosity associated with abandoned channel fill and tidal flat lithofacies. The objective of this study was to define potential barriers to steam migration by modelling vertical permeability distribution in the reservoir.

To represent large-scale reservoir permeability accurately, we implemented a modelling and upscaling approach that incorporates small-scale heterogeneities impacting fluid flow. To identify metre-scale to decimetre-scale heterogeneity, we applied a number of techniques to the seismic dataset, including spectral decomposition, attribute cross-plotting, and opacity filtering. The output was then incorporated into a reservoir scale modelling tool, which employs grid geometries that reflect the depositional architecture and the lithofacies distribution in the reservoir. To incorporate the effects of centimetre- to decimetre-scale flow barriers, we generated near-well-bore models that simulate the bedding structures and lithological components observed in core and inferred from well logs. We then applied flow-based upscaling to the near-well-bore models to derive facies-dependent effective properties, including vertical and horizontal permeability. These upscaled values were then used to populate the geo-cellular grid model to derive overall effective directional permeability distribution within the reservoir.

The results honour core analysis, well log data, and seismic interpretation, and provide a useful input to reservoir simulation tools, such as STARS and Eclipse. This multi-scale approach can be applied to other unconventional reservoirs to improve estimates of critical reservoir properties.

References

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