McMurray Formation Bedding Scale Heterogeneity Model Templates and Directional Permeability Distributions

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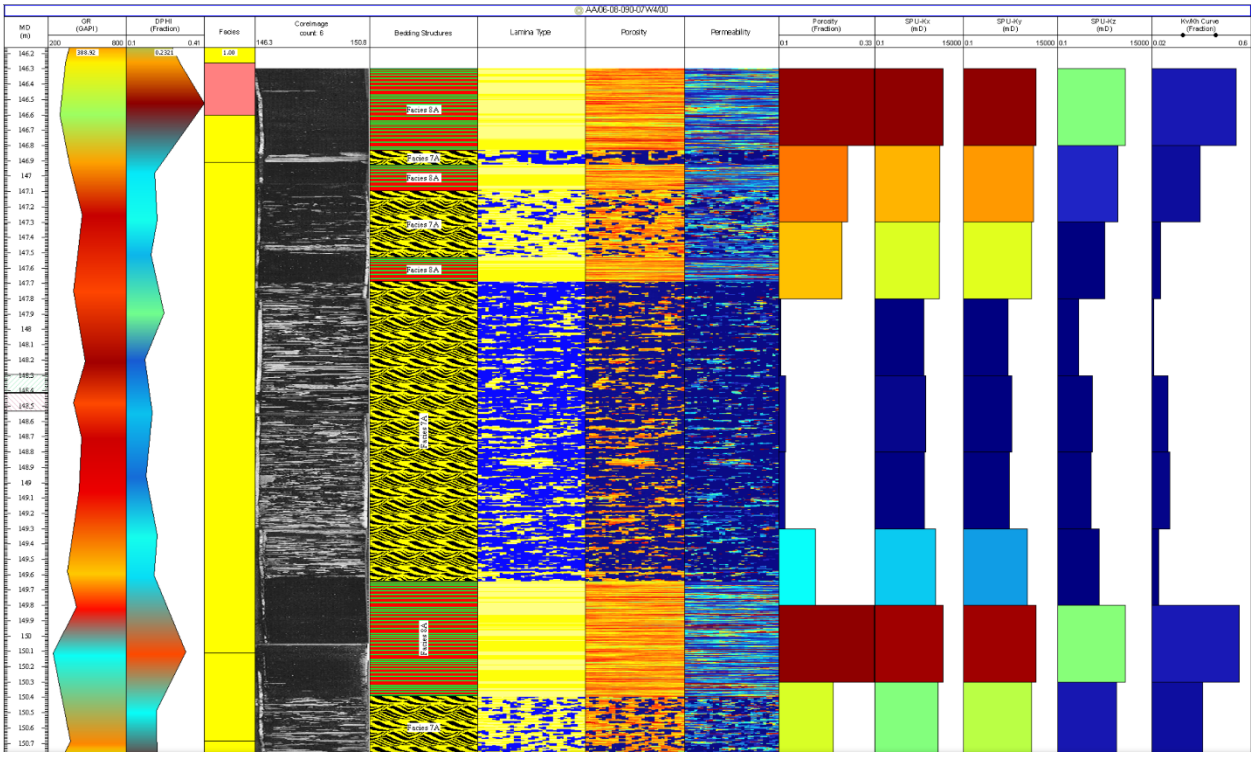
Summary

We have built templates of bedding scale heterogeneity models for the 28 lithofacies classified by Hein et al (2000) in McMurray formation, Athabasca Oil Sands Deposit. The model templates, generated by SBED^{TM}, are able to capture major sedimentary features that impact fluid flows, such as 3-D geometry of sand and mud laminae of various bedding and biogenetic structures in McMurray formation. These model templates can be used for deriving directional permeability of the McMurray formation at larger scale reservoir models by applying the following workflow:

1) Make a lithofacies log by classifying lithofacies of each well according to the Atlas of lithofacies in McMurray formation established by Hein et al (2000). Well logs and core photos can be used to derive lithofacies log.
2) Define the 3-D near-well bore models by assigning a model template to each lithofacies along the facies log.
3) Generate realizations of near-well bore models with varying geometry of sand and mud laminae.
4) Simulate realizations of permeability grids for each realization of near-well bore models. Statistics of permeability from core measurements are the input data for the property simulation
5) Upscale permeability grid at intervals defined model cells in larger scale model along the well bore.
6) Data analysis of upscaled Kx, Ky, Kz from the near well bore models. The data analysis results are the input for permeability modeling in the larger scale reservoir models.

Unlike the conventional workflow which assumes the permeability is isotropic inside cells of a static reservoir model, the workflow above generates directional permeability grids (Kx, Ky, Kz) which capture the impact of facies internal heterogeneity to the full field model. The results have a 15-25% improvement to the reserve estimation and history match in the full field model.



Theory / Method / Workflow

The data for building generic SBED models for the McMurray facies comes from Hein et al (2000). The report describes the properties of a unified lithofacies classification which contains 18 different lithofacies and 9 sub-facies for the McMurray Formation in the Athabasca Oil Sand deposits. The interpretation of the depositional environment, representative outcrop and core photographs, and the corresponding well logs for each facies are studied in the report. Based on the detailed text description, schematic sketch and representative photos, the bedding structure and biogenic structure models for the McMurray facies are made. The property models are generated by populating the synthetic petrophysical data (permeability and porosity) to each facies. In this study, single-phase upscaling is used to obtain the upscaled results which are further used to plot the directional permeability distribution (Kx, Ky, Kz) for each facies in Excel. A process-oriented modeling tool (SBED) is used to make all the models and upscaling process. To capture the variability and reduce the uncertainties, 10 bedding realizations, and 50 property realizations under each bedding realization are generated within each model. The 500 upscaled results can be used to plot the directional permeability distribution within each model.

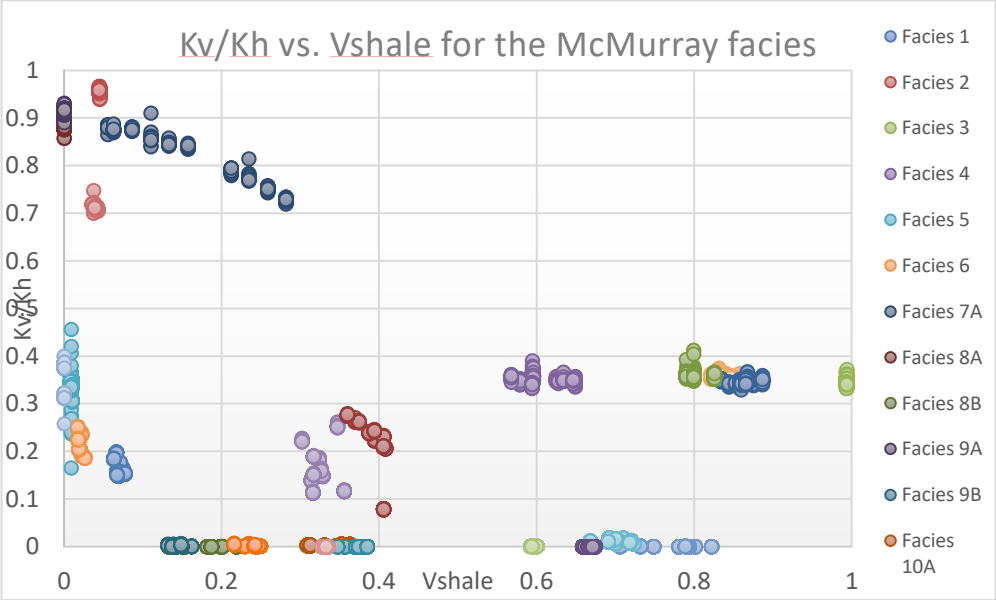
Results, Observations, Conclusions

Templates of bedding scale heterogeneity models for the 27 lithofacies classified by Hein et al (2000) in McMurray formation, Athabasca Oil Sands Deposit has been built. The upscaling results from each template show the upscaling directional permeabilities have a large difference from the permeability at the lamina scale, as this upscaled permeability captures the bedding scale heterogeneity that impacts fluid flows. Instead of assuming the permeability is isotropic inside cells of a static reservoir model, these model templates can be used for deriving directional permeability of the McMurray formation at larger scale reservoir models. The 27 facies model templates built in this study can be used for quickly building near-well bore 3-D bedding scale models in wells that have a facies log. Porosity and permeability grids

for the near-well models are then generated using statistics from core data. A flow-based upscaling algorithm (SBED user guide) is used to derive Kx, Ky, Kz at interval that is equivalent to cells along the well bore in a static reservoir grid. The upscaled Kx, Ky, Kz at cells along the well bores are used as input data for the permeability modeling in the larger scale static model. By capturing the major sedimentary features that impact fluid flows, those derived directional permeabilities (Kx, Ky, Kz) would help to give reservoir engineers more accurate estimation when doing the full field simulation and lower the uncertainties of the prediction.

Novel/Additive Information

Kv/Kh ratio calculated from the flow-based upscaling results in each realization are plotted. There is a systematic reduction trend of Kv/Kh as shale content increases. Functional relationships have been tried to other similar works (Ringrose et al 2005). Note that such a relationship is distinctively different for some facies.



Acknowledgements

Core photos and the summary text of McMurray formation facies characteristics are from Hein et al (2000).
SBED™ software from Geomodeling Technology Corp is used to simulate multiple realizations of bedding models, porosity & permeability grids. SBED is also used to do a flow-based upscaling to derive distribution of Kx, Ky, and Kz for each lithofacies in this study.

References

1. Gotawala, D. R., & Gates, I. D. (2010). On the impact of permeability heterogeneity on SAGD steam chamber growth. *Natural Resources Research*, *19*(2), 151-164.
2. Hein, F.J., Cotterill, D.K. (2006). The Athabasca Oil Sands-A Regional Geological Perspective, Fort McMurray Area, Alberta, Canada. *Natural Resources Research, 15*, 85-102. 10.1007/s11053-006-9015-4.
3. Hein, F.J., Cotterill, D.K. and Berhane, H. (2000): An atlas of lithofacies of the McMurray Formation, Athabasca Oil Sands deposit, northeastern Alberta: surface and subsurface; Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2000-07, 217 p.

4. Hein, F.J., Langenberg, C.W., Kidston, C., Berhane, H. and Berezniuk, T. (2001): A comprehensive field guide for facies characterization of the Athabasca Oil Sands, northeast Alberta; Alberta Energy and Utilities Board, EUB/AGS Special Report 13, 422 p.
5. Nordahl, K., Ringrose, P.S. and Wen, R., 2005, Petrophysical characterization of a heterolithic tidal reservoir interval using a process-based modeling tool, *Petroleum Geoscience*, Vol. 11, pp. 71-28.
6. Nordahl, K., Messina, C., Berland, H. Rustad A. B., and Rimstad, E., 2014, Impact of multiscale modelling on predicted porosity and permeability distributions in the fluvial deposits of the Upper Lunde Member (Snorre Field, Norwegian Continental Shelf). *In* Sediment-Body Geometry and Heterogeneity: Analogue Studies for Modelling the Subsurface edited by A.W. Martinius, J.A. Howell , T.R. Good. Geological Society, London, Special Publications, February 2014; doi 10.1144/SP387. Pages 85-100.
7. Ringrose P. S, Nordahl K., and R. Wen, 2005, Vertical Permeability estimation in tidal deltaic reservoir systems, *Petroleum Geoscience*, Vol. 11, pp. 29-36
8. SBED 4.3 User Guide, . Geomodeling Technology Corp.
9. Wen, R., 2005, 3D geologic modelling of channellized reservoirs: applications in seismic attribute facies classification, First Break, Vol. 23, p. 71 – 78.
10. Wen, R., A Naess, P. Ringrose, and A. W. Martinius, 1998, Three-dimensional simulation of small-scale heterogeneity in tidal deposits – a processbased stochastic simulation method. In: Buccianti, A., Nardi, G. & Potenza, R. (eds) Proceedings of the 4th Annual Conference of the International Association of Mathematical Geology (IAMG). De Frede Editore, Naples, 129–134.
11. Wightman, D.W., Attalla, M.N., Wynne, D.A., Strobl, R.S., Berhane, H., Cotterill, D.K., and Berezniuk, T., 1995, “Resource Characterization of the McMurray/Wabiskaw Deposit in the Athabasca Oil Sands Area: A Synthesis,” AOSTRA (Alberta Oil Sands and Technology Research Authority) Technical Publication Series 10.