Scale Consistent Modelling for Reservoir Characterization

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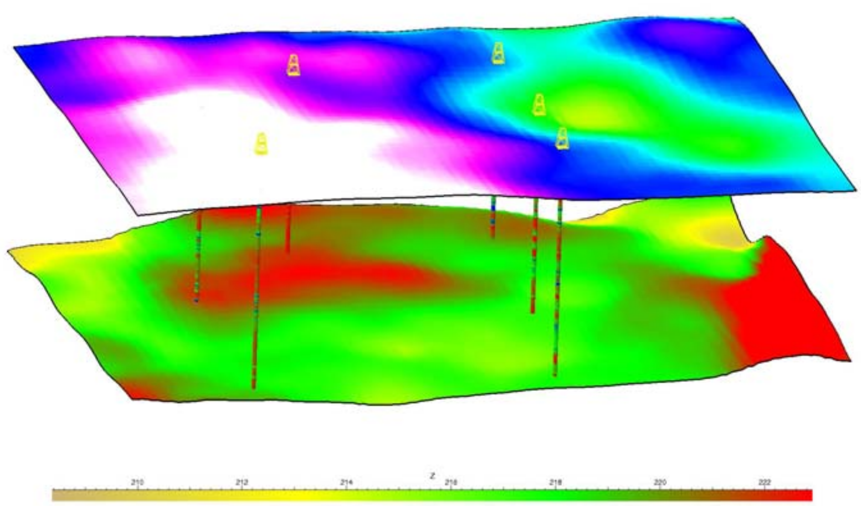
It is common that a variety of data are available for reservoir modelling. These data include core and log data, seismic attributes, and conceptual geological models. Data scale, reliability, coverage and availability must be taken into account in integrating these data into numerical reservoir models. It is also common that numerical models of a reservoir are constructed at different scales for different purposes. Different modelling techniques and different usage of the data usually cause inconsistency between the models at different scales. The scale consistent reservoir modelling scenario is proposed to build reservoir models that are scale consistent and honour the data at different scales. The basic idea is to construct a large model by integrating all available data, and then downscale for different modelling purposes. The downscaling must exactly honour the large scale model to ensure models consistency.

This short note summarizes key results in the Ph.D. thesis of Weishan Ren available on the CCG server. Interested readers are encouraged to get the thesis and review.

Scale Consistent Reservoir Modeling

The scale consistent reservoir modeling scenario consists of three main steps: (1) construct a large scale model over the entire lease by integrating multivariate information; Gaussian-based Bayesian Updating technique can be used; local uncertainty assessment is provided, (2) perform petroleum resource estimation with global uncertainty assessment from the large scale model; a spatial/multivariate simulation approach can be used to account for the spatial and multivariate correlations among the local uncertainties, the global uncertainty is consistent with the local uncertainties (3) construct fine scale 3-D models of heterogeneity that are consistent with the large scale model and well data using the exact downscaling techniques.

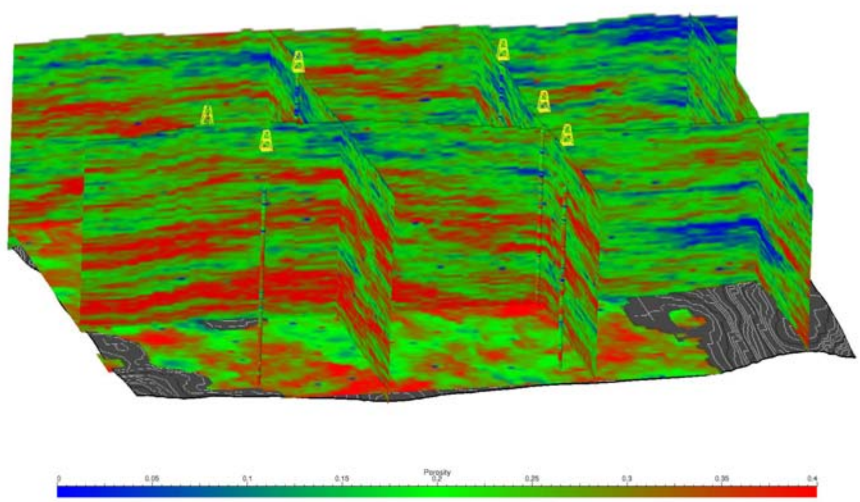
Large-scale 2-D modelling may be achieved with Bayesian Updating. Fine scale 3-D models are required for well placement and flow simulations. Consider a half-pad area for 3-D modeling. The model area is 1,400m by 1,000m, and there are six wells in the area.



The structure of the model is bounded by two stratigraphic surfaces (see above). The top is a maximum flooding surface and the bottom is an unconformity surface. The vertical stratigraphic coordinates of the model are set to be “parallel to top”. The maximum distance between the two surfaces are 91m. The 2-D averages of wells are calculated at the maximum distance. The Bayesian updating technique is used to generate 2-D porosity and water saturation at scale of 50m by 50m. Multiple simulated realizations are generated by using Bayesian updating with P-field simulation. Realizations may be ranked to pick the p10/p50/p90. For simplification in this example, one realization is used for exact downscaling to construct 3-D fine scale models.

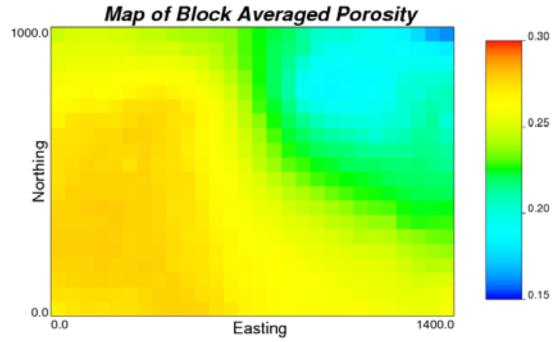
The target grid resolution of the 3-D model is 10 x 10 x 1m. We can directly downscale the 2-D porosity data, but it will time consuming. Instead, the 2-D porosity is first downscaled aerially to 10m by 10m, and then the downscaled 2-D results are downscaled vertically to construct the 3-D model. The simulated results are converted back to the regular coordinates and clipped with the two structural surfaces.

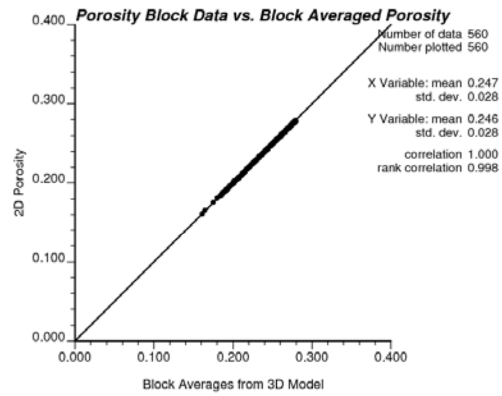
The final model of 3-D porosity realization is shown below. The model has a grid resolution of 10 x 10m areally and 1m vertically. The field spans 1,400m, 1,000m and 91m in the Easting, Northing and Elevation directions, respectively. The vertical direction is exaggerated by 5 times. The fine scale model is converted back into 2D model (column average) and compare with the input 2D model, they are identical.

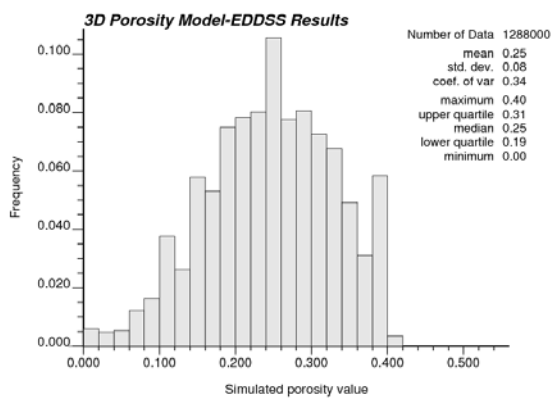


Conclusion

In Canadian heavy oil reservoirs where dense wells and multiple secondary data are available, the large scale models of structural and petrophysical variables can be reliably constructed to reproduce all available data. When small scale models are required for recovery predications and evaluation of flow processes, it is appropriate to construct small scale models that consistent with previous large scale models. Overall, the scale consistent modeling scenario can improve the accuracy of reservoir description by considering multiscale data integration and consistency of models at different scales. The application in a Canadian oil sands reservoir shows a great applicability for reservoir characterization.







References

Alabert, F. G.: "The practice of fast conditional simulations through the LU decomposition of the covariance matrix," Mathematical Geology, 19(5), p. 369-386. 1987.

Deutsch, C.V.: "*Geostatistical Reservoir Modelling*," Oxford University Press, New York, 2002.

Deutsch, C.V., Tran, T.T., and Xie, Y-L.: "An Approach to Ensure Histogram Reproduction in Direct Sequential Simulation," Centre for Computational Geostatistics 3rd Annual Report, University of Alberta, 2001.

Deutsch, C. V. and Zanon, S.: "Direct Prediction of Reservoir Performance with Bayesian Updating Under a Multivariate Gaussian Model," Paper presented at the Petroleum Society's 5th Canadian International Petroleum Conference (55th Annual Technical Meeting), Calgary, Alberta, 2004.

Doyen, P.M., Den Boer, L.D., and Pilley, W.R.: "Seismic porosity mapping in the Ekofisk field using a new form of collocated cokriging," Society of Petroleum Engineers, SPE 36498. 1996.

Kelkar, M. and Perez, G.: "*Applied Geostatistics for Reservoir Characterization*," Society of Petroleum Engineers Inc., Richardson, Texas, USA, 2002.

Journel, A.G. and Huijbregts, Ch.J.: "*Mining Geostatistics*," Academic Press, 1978.

Lasseter, T. J., Waggoner, J.R. and Lake, L.W.: "Reservoir Heterogeneities and Their Influence on Ultimate Recovery," pp. 545-560. In: Lake, L.W. and Carroll, H.B. (eds.), *Reservoir Characterization*, Academic Press, 1986.

Ren, W., Leuangthong, O., and Deutsch, C.V.: "Geostatistical Reservoir Characterization of McMurray Formation by 2-D Modeling," Centre for Computational Geostatistics Report Six, Edmonton, Alberta, 2004.

Ren, W., Leuangthong, O., and Deutsch, C. V.: "Global Resource Uncertainty Using a Spatial/Multivariate Decomposition Approach," Paper presented at the Petroleum Society's 6th Canadian International Petroleum Conference (56th Annual Technical Meeting), Calgary, Alberta, 2005.

Ren, W., McLennan, J., Cunha, L.B., and Deutsch, C.V.: "An Exact Downscaling Methodology in Presence of Heterogeneity: Application to The Athabasca Oilsands," paper presented in *SPE ITOHOS 2005*, Calgary, November 2005.

Ren, W., and Deutsch, C.V.: "Exact Downscaling in Geostatistical Modeling," Centre for Computational Geostatistics Report Seven, Edmonton, Alberta, 2005.

Ren, W., McLennan, J., Leuangthong, O., and Deutsch, C.V.: "Reservoir Characterization of McMurray Formation by 2-D Geostatistical Modeling," *Natural Resources Research*, 2006a.

Ren, W., and Deutsch, C.V.: "Bayesian Updating with Local Varying Correlation," Centre for Computational Geostatistics Report Eight, Edmonton, Alberta, 2006b.

Ren, W., Deutsch, C.V., Garner, D., Wheeler, T.J., Richy, J.F., and Mus, E.: "Quantifying Resources for the Surmont Lease with 2D Mapping and Multivariate Statistics," SPE 102094 presented at the SPE Annual Technical Conference and Exhibition, October 2006c.

Ren, W: "*Scale consistent geostatistical modeling for reservoir characterization*," PhD Thesis, University of Alberta, Edmonton, Canada, 2007.

Srivastava, R. M.: "Reservoir characterization with probability field simulation," SPE Formation Evaluation, 7(4), p. 927–937, 1992.

Weber, K.J.: "How Heterogeneity Affects Oil Recovery", pp 487-544. In: Lake, L.W. and Carroll, H.B. (eds.), *Reservoir Characterization*, Academic Press, Inc. 1986.

Wen, X.H., Deutsch, C.V., Cullick, A.S. and Reza, Z.A., "*Integration of Production Data in Generating Reservoir Models*," Centre for Computational Geostatistics, University of Alberta, Edmonton, Canada, 2005.