PS Who Should Make the Optimum Upscaling Decisions, A Geologist or An Engineer?*

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Abstract

Upscaling is the process of changing a fine grid to a coarse grid while preserving the original geology and its properties (Schlumberger, 2014). Many petroleum fields produce oil and gas from large volume reservoirs. A modeling technique is commonly applied to many of these fields to understand internal architecture of the reservoir and the fluid flow behavior of the reservoir simulation. High heterogeneity reservoirs require high resolution geological model s which are usually constructed on a fine scale with an immense number of cells.

The necessity of upscaling is due to the limitations of computing hardware, computing speed and the time required to process the reservoir simulation. Therefore, in order to test the fluid flow behavior of the reservoir, model upscaling is required to convert the fine scale model to a coarser scale. Reducing the number of cells while preserving the fundamental integrity of the model allows for the delivery of simulation results within a reasonable run time.

However, the upscaling process presents several challenges. The main challenge is to avoid upscale elimination of the potentially favorable vertical and lateral reservoir heterogeneity, which will avoid false results of reservoir simulation. Optimal upscaling approaches must: 1) honor reservoir heterogeneity, 2) retain thin beds of reservoir, and 3) predict the possible reservoir heterogeneity in areas where no data is available.

To conduct optimum upscaling, project engineers need to understand the realities of reservoir heterogeneities that originate from the nature of depositional environments. In order to test the fluid flow behavior of the reservoir on such a fine scale model, both geologists and engineers are confronted with long computational times leading to the point of impracticality. Frameworks for reservoir projects have a relatively brief time period; thus, they should collaborate closely to conduct optimum upscaling to deliver correct fluid flow behavior through simulation.

The Hunton Group of Oklahoma provides the data for this study. Integration among geology, petrophysics, geophysics, geomechanics, and fluid dynamics is truly essential for addressing upscaling. Petrel Software will be used for this study to develop 3D geological models for the Hunton reservoir with sufficient detail to represent vertical and lateral reservoir heterogeneities. This study will integrate natural fractures from core, borehole image logs

and outcrop(s) to examine their impacts on the flow simulation before and after upscaling. In addition, geostatistical analyses will be utilized to predict all possibilities of the reservoir heterogeneities, such as permeability and porosity, in sparse areas. Specific workflows are presented to examine the optimum upscaling characterized in this study

References Cited

Fritz, R.D., and P.L. Medlock, 1994, Sequence stratigraphy of the Hunton Group as defined by core, outcrop, and log data: in Johnson, K.S., ed., Hunton Group core workshop and field trip: Oklahoma Geological Society Special Publication 93, p. 161–180.

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Who should make the optimum upscaling decisions, a geologist or an engineer?

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ABSTRACT

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GEOLOGICAL SETTING

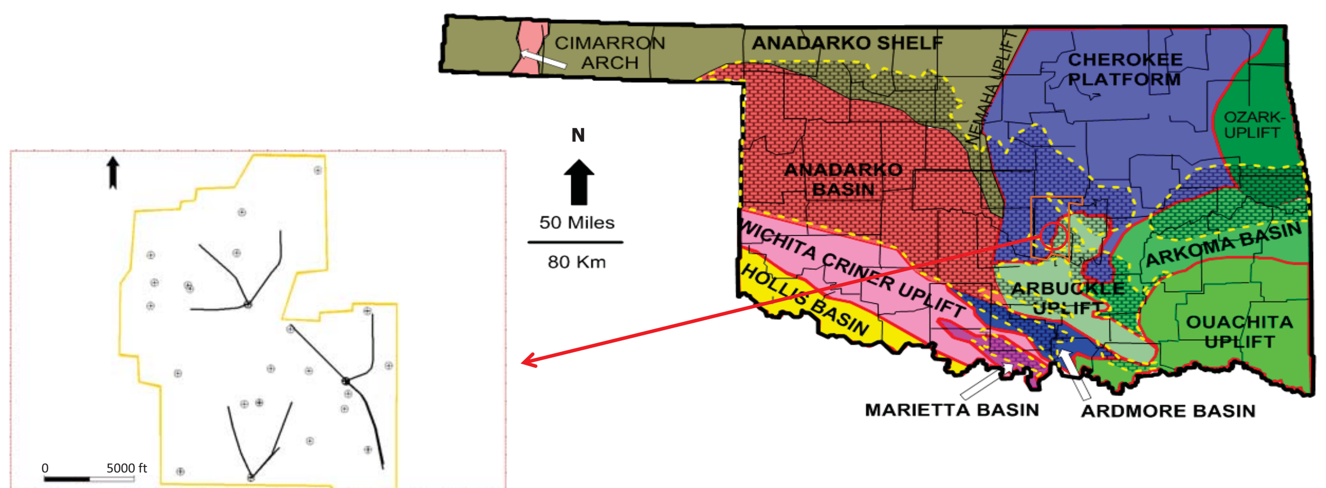


Figure 1. Map of Oklahoma showing geologic provinces and the Hunton Group distribution (Modified from Northcutt and Campbell, 1996; Jordan, 1964; Northcutt, 2000). Yellow dash lines show the boundaries of the Hunton Group. Yellow polygon to the left shows the location of seismic volume and well data in Pottawatomie County (study area).

***Figure 2.** Depositional model for Chimneyhill subgroub through Bois d'Arc Formation strata of the Hunton Group (modified from Fritz and Medlock, 1994).*

- ✓ Shallow-water carbonate ramp sequence <1/5⁰
- ✓ Hunton strata deposited at several places
- ✓ Between the Ordovician Sylvan Shale and late Devonian Woodford Shale.
- ✓ Three major subdivisions, the Ordovician-Silurian Chimneyhill subgroup, the Silurian Henryhouse and Haragan Formations, and the lower Devonian Frisco and Misener formations
- ✓ Mainly limestone and dolomite.
- ✓ The Hunton is typically up to **400** ft. thick

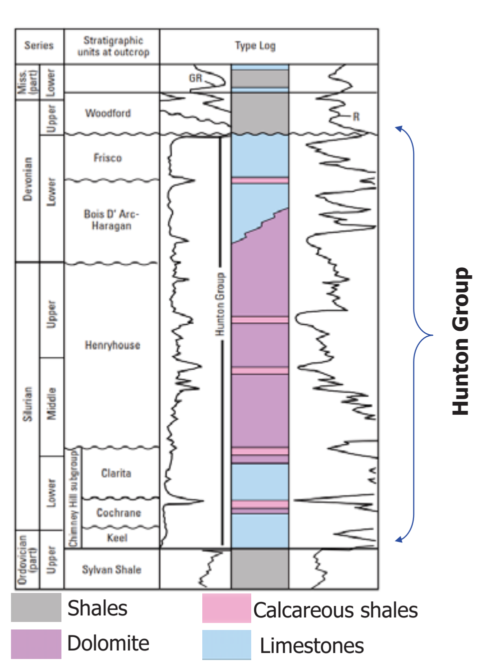


***Figure 3.** Type log of the Hunton Group in central Oklahoma (modified from Fritz and Medlock, 1994).*

WHAT IS UPSCALING?

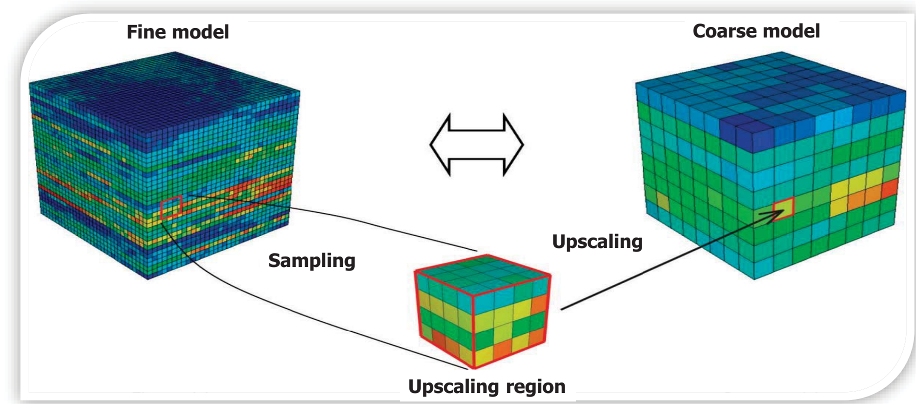


***Figure 4.** A conceptual illustration of the upscaling process. http://petrowiki.org/Upscaling_of_grid_properties_in_reservoir_simulation*

RESEARCH QUESTIONS

1) What are the effects of the vertical permeabilities in the thin beds on the flow simulation and how can the small scale thin beds be considered in the upscaling processes?

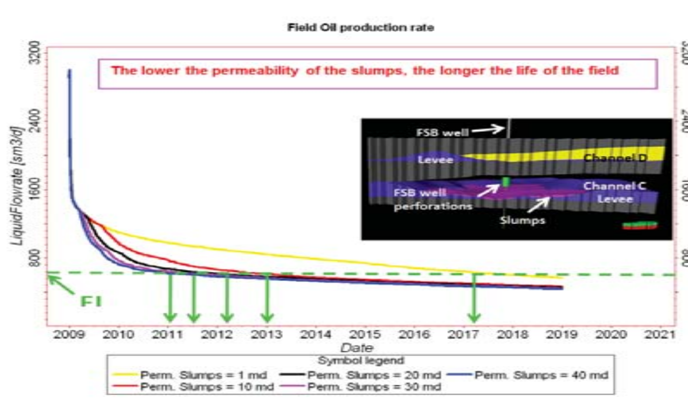


***Figure 5.** The impact of thin beds on flow simulation (Santacruz, 2009).*

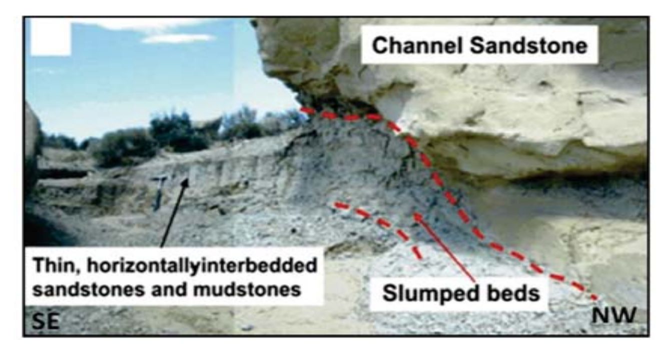


***Figure 6.** Mudstone Slumped beds beneath a SS Channel–Outcrop (Santacruz, 2009). (Modified from Correa, 2007).*

2) What is an optimum upscaling that can give true indications of fluid flow?

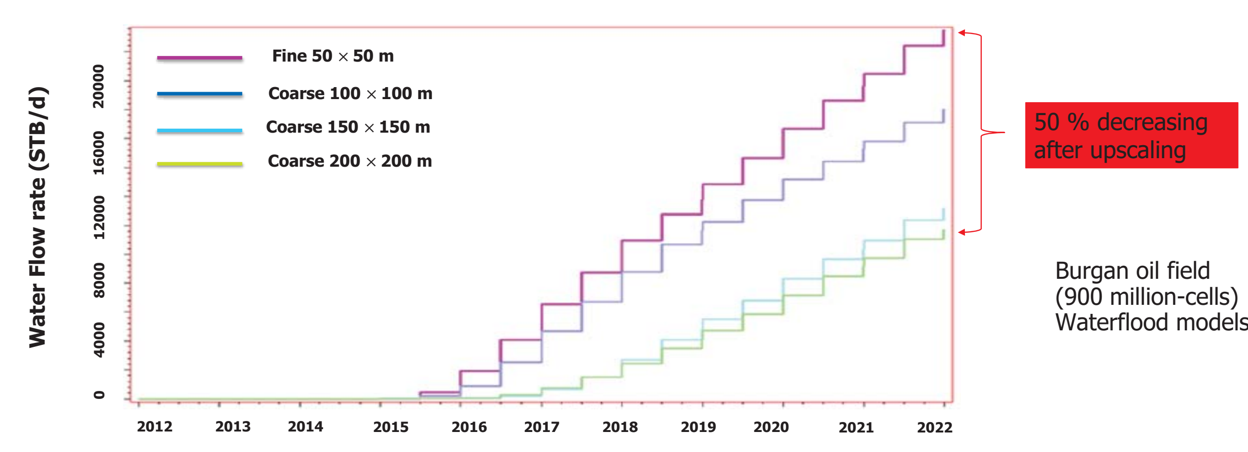
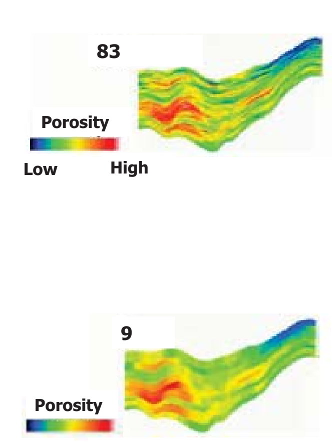


***Figure 7.** Comparison of water production rate between fine and coarse scales of different areal grid size. As areal upscaling increases, reservoir water flow rate significantly decreases compared to fine scale models. (Ma et al., 2013)*

3) How many realizations of 3D models could be built in order to minimize the uncertainties, predict the reservoir heterogeneities between the wells and their effects on fluid flow?

***Figure 8.** The results of vertical upscaling to series of porosity models with 9 and 83 vertical layers. The porosity heterogeneity was preserved better for the porosity model with 83 vertical layers compared to the porosity model with 9 vertical layers. The more vertical layers, the less vertical cell size.*
(Meddaugh, 2006)



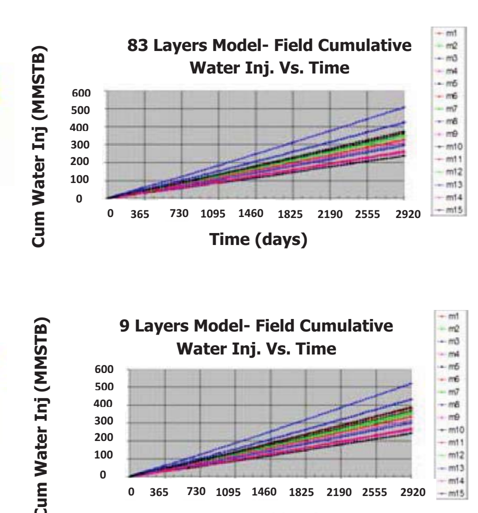


***Figure 9.** Cumulative water injection vs time for the 9 and 83 vertical layer porosity model. Note, m1, m2, etc. indicating the number of fifteen realizations of the porosity model. i.e. m1 is the realization number one; m9 is the realization number nine, etc. The number of realizations impacted the cumulative water injection more than the level of vertical upscaling.*
(Meddaugh, 2006)

METHODOLOGY

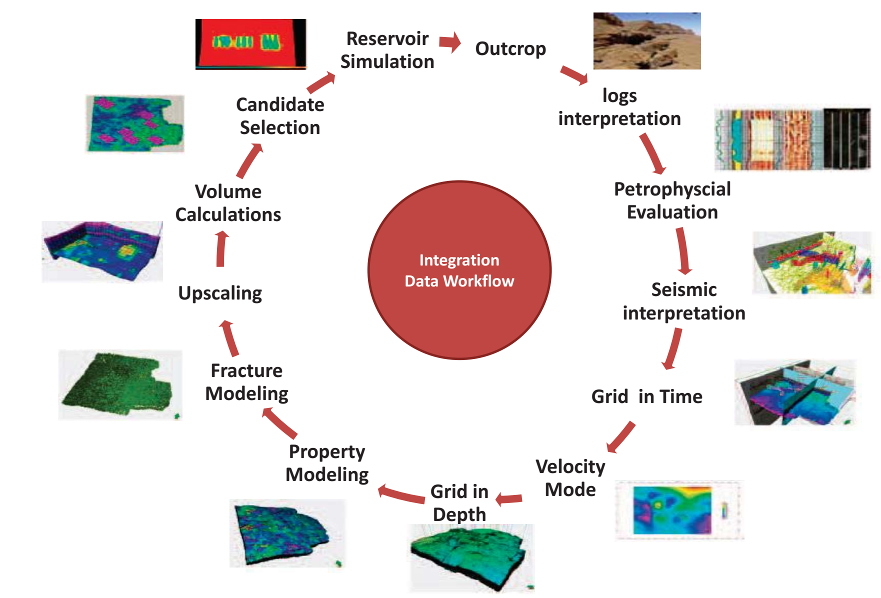


***Figure 10**. An integrated outcrop- to- simulation approach to build a detailed static model. (Modified after Schlumberger and The American Oil & Gas Reporter, 2012).*

FINE AND COARSE SCALE MODEL WORKFLOWS

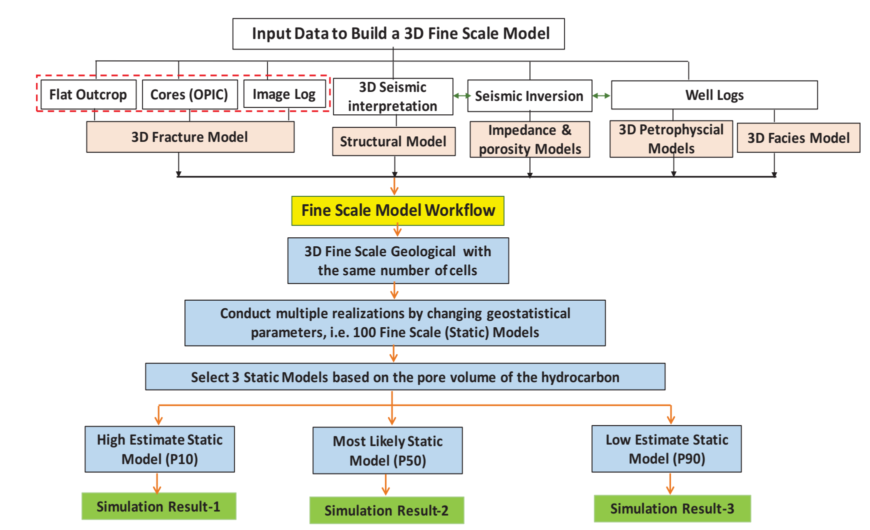


***Figure 11**. The workflow illustrating the steps of building fine scale models. The simulation result 1, 2, and 3 will be processed without upscaling and will be considered as a reference for the next simulation results from the upscaled models.*

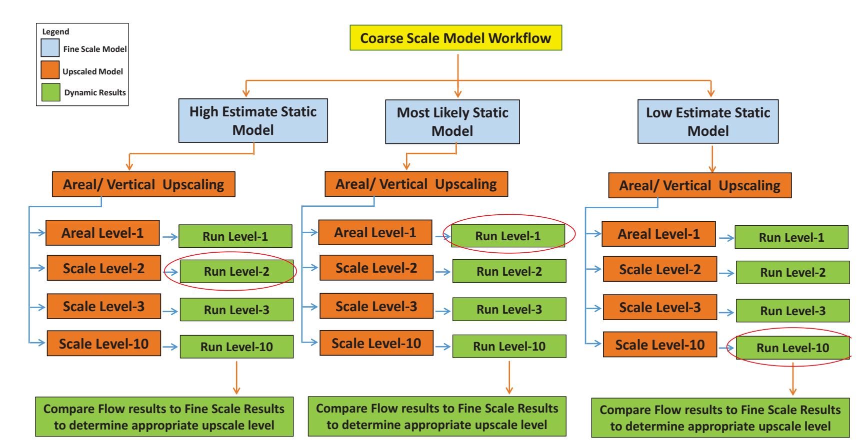


***Figure 12**. Workflow illustrating the steps of building coarse scale models. Light blue boxes represent the fine scale models, the orange boxes represent the upscaled models and the green boxes represent the simulation results. The selected three fine scale models are the input for this workflow (High estimate, Most likely and Low estimate models), which were carried from the previous workflow (Fig. 11). Different areal and vertical scenarios of upscaling will be conducted resulting into multiple levels of upscaled static models. Each level of upscaled model will be simulated and its results will be compared with the correspondence simulation results from Fig. 11. For example, the simulation results from the high estimate static model will be compared with the simulation result from the high estimate static model of Fig. 11, which is considered as a reference simulation result before upscaling. The comparisons of simulation results before and after upscaling will lead determining if the reservoir heterogeneities were preserved or not. The thin beds of reservoir will not be upscaled to preserve their heterogeneities.*

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