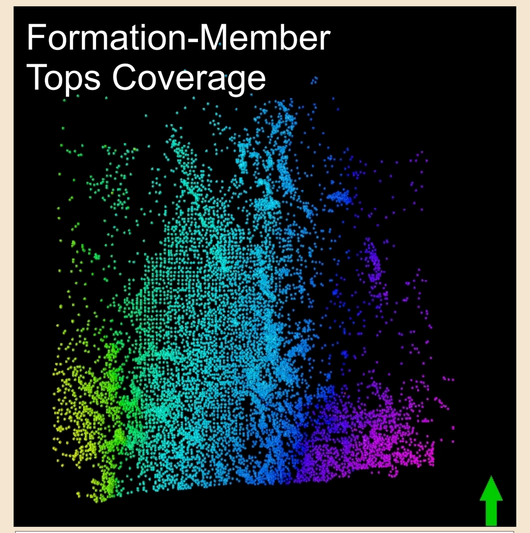
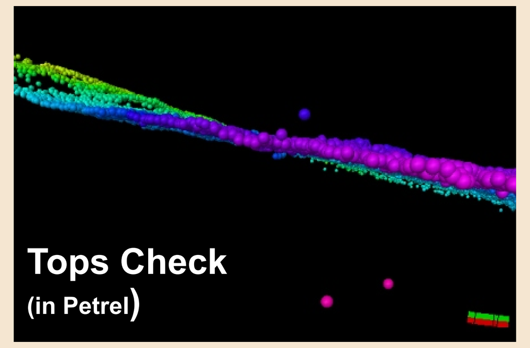
Panoma (Council Grove) Geomodel

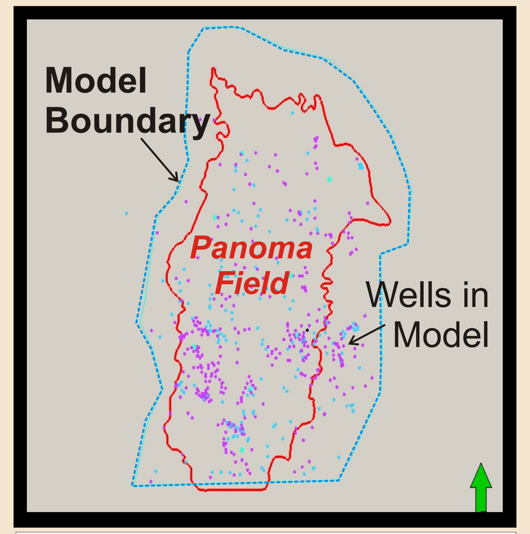
Data



Initial data set included 11,367 wells with detailed formation-member level tops picked by Hugoton consortium funded KGS geologists



Initial quality check of tops showing obvious data busts; rotated view looking north. Tops were corrected for wells with proper log suite for facies/ petrophysical modeling. Other tops were deleted.



Distribution of approximately 500 wells with proper log suite used for facies and petrophysical modeling

Data Management:

Tops data set

24,879 Total wells in initial PETRA project, including regions outside of model
12,097 Wells having at least Council Grove top pick by KGS geologist
11,367 Wells in initial structure model.
10,836 After screening for tops busts. Further screening reduced the well count to10,700.

Digital well log data set

1,103 Sufficient Council Grove penetration
536 After removing wells with bad curves, data gaps or other problems
469 Final count after further screening

Model Architecture

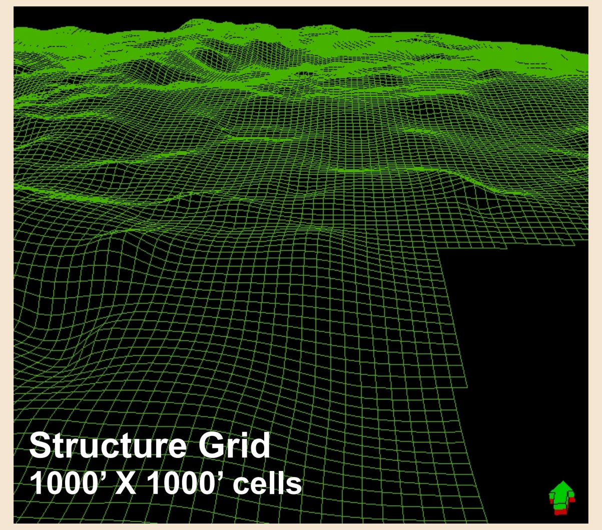
To keep model size manageable, yet accurately reflect the fine scale vertical and horizontal heterogeneity over the entire Panoma Field in Kansas, the Council Grove was subdivided during the lithofacies, porosity and permeability modeling phase. The Panoma was divided horizontally into seven genetically related stratigraphic units, A1 (Funston) through C (Neva). Each is a cycle that has a non-marine interval underlain by a marine interval (e.g.: A1SH and A1LM). The seven permeability models will be joined and uspcaled in the later reservoir simulation phase.

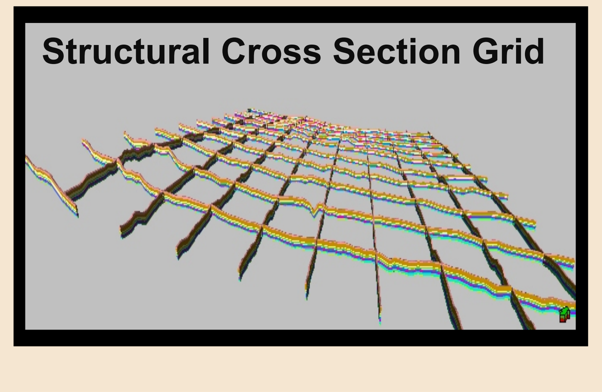
Proportional layering method results in layers proportional to mean thickness of the interval being layered. Number of non-marine interval layers equals the number of feet in the thickness mean. Number of marine interval layers equals mean thickness in feet plus one standard deviation. Marine and non-marine intervals were carried through each model resulting in 12 “dummy” layers in each.

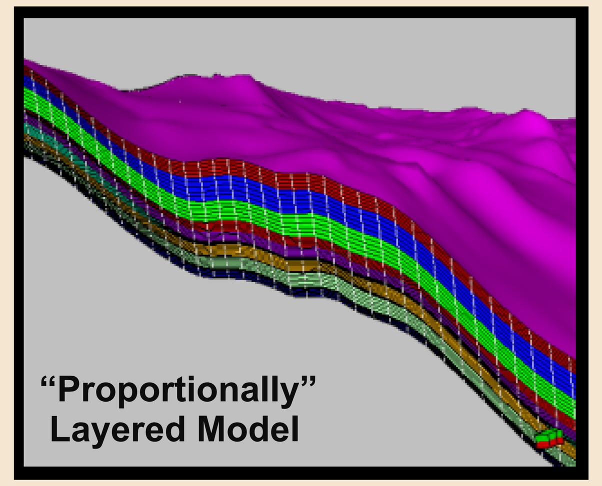
Layers per Model

	SH	LM	"Dummy"	Total
A1	23	41	12	76
B1	19	16	12	47
B2	12	15	12	39
B3	20	15	12	47
B4	17	18	12	47
B5	8	34	12	54
C	28	61	12	101

Cell size for the modeling is 1000 X 1000 feet, resulting in an average of 8.6 million cells per 5,200 square mile model. The largest model has15 million, the C cycle, and the smallest has 5.7 million, the B2 cycle. Approximately 11 million cells are in the model highlighted in this poster, the A1 cycle.







Defining the Structural Framework for Panoma

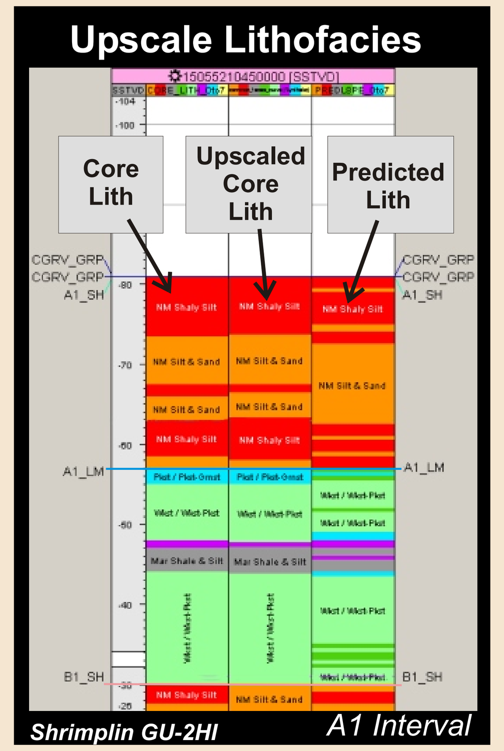
(1) Create a "skeleton grid" defining the cell size for the model. For Panoma a grid cell size of 1,000' x 1,000' was used to maximize the number of wells for the model to honor exactly. Populating a cell with more than one well results in an "averaging" of those two (or more) data points.

(2) Construct a top horizon using the Council Grove Group top (A1_SH). Then create isochores for each of the subjacent zones and hang those isochores from the top horizon.

(3) Fill the newly created horizons with layers thus defining the cell thickness. The Panoma model used "proportional" layering keeping the same number of layers through a given interval regardless of thickness variations. For non-marine shale intervals layer thickness was defined by the average thickness in the zones, and for limestones layer thickness was defined by the average zone thickness PLUS one standard deviation.

(4) Create general intersection cross-sections to QC structural framework.

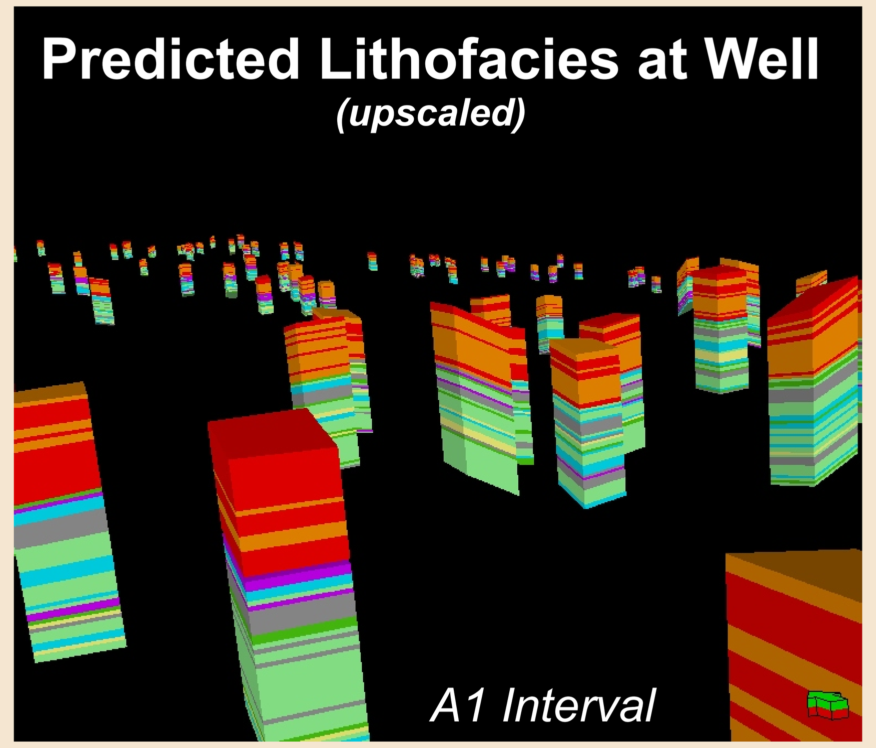
Lithofacies Model

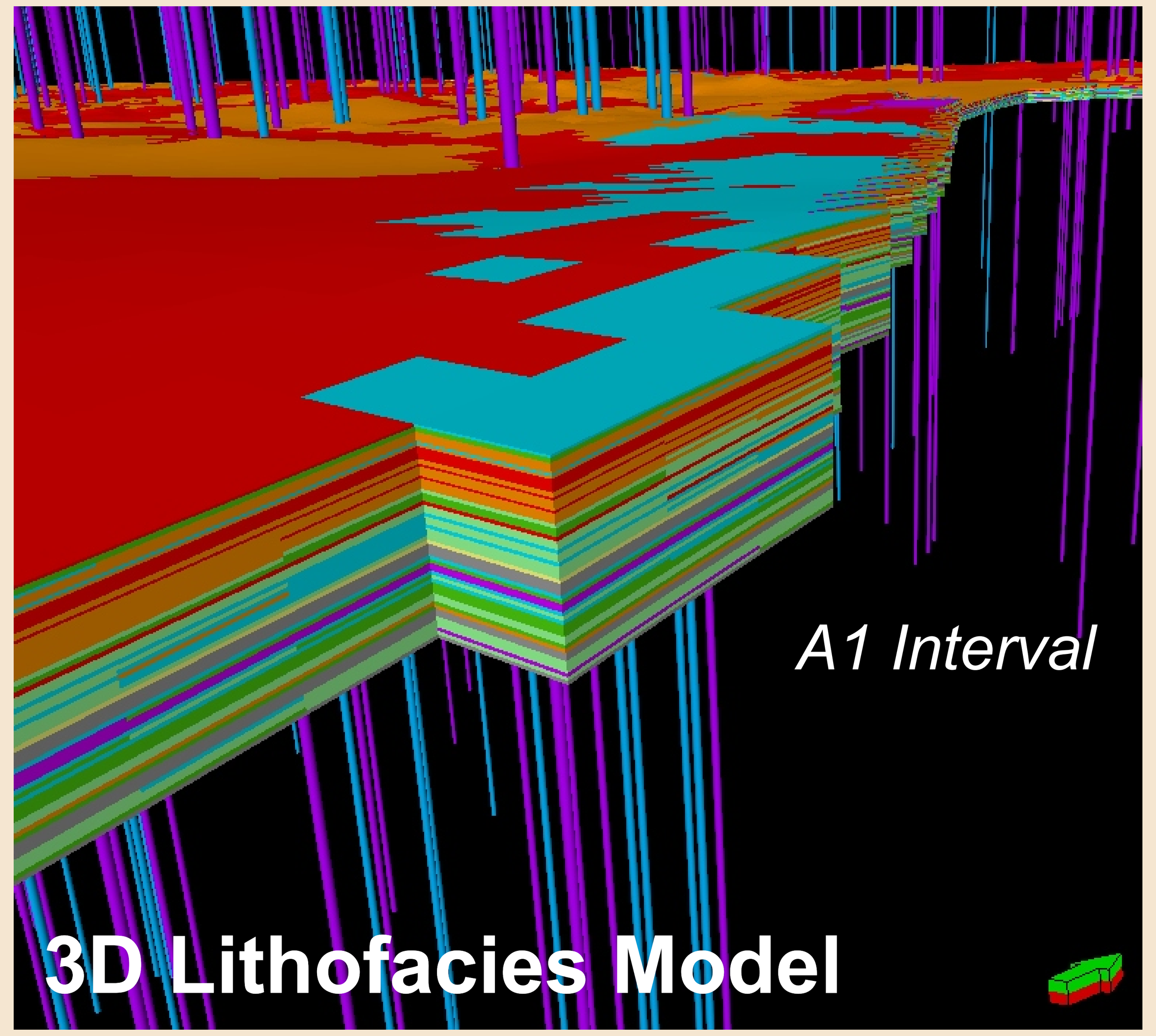


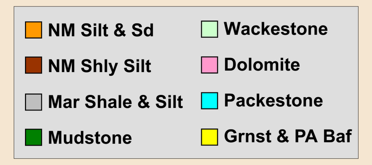
(1) "Upscale" the "lith-code" curves for each of wells having logs used in facies predictions.

(2) Populate cells at the wells with upscaled lithofacies.

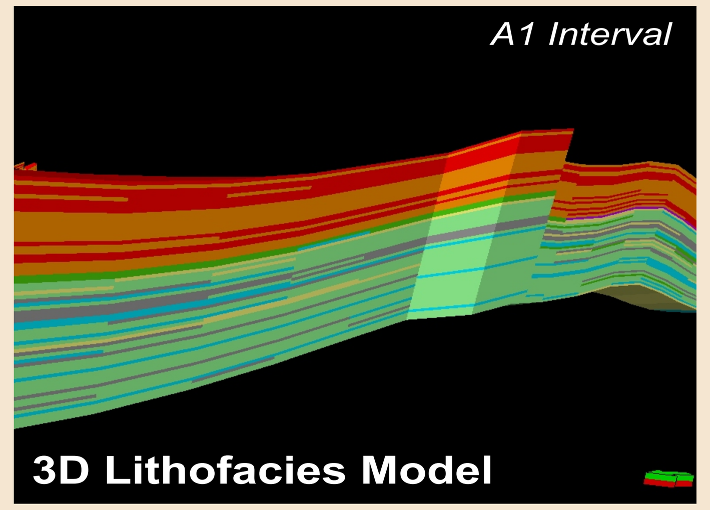
(3) Model cells between wells for lithofacies (Sequential Gaussian). A constant average curve was fitted creating a constant distribution (from "lith-code" curves) equal to the average probability of that facies.





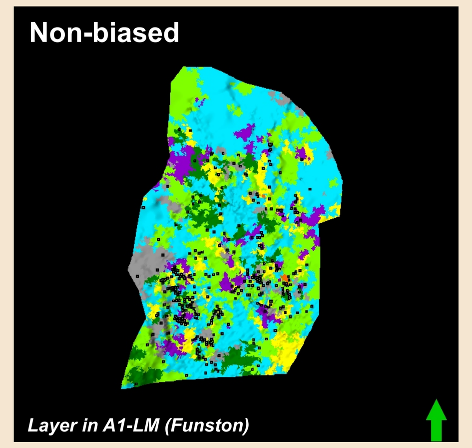


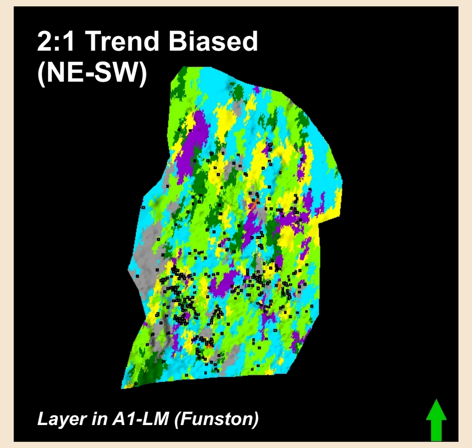
QC facies modeling by comparing values that are assigned for the cells at the well to what is being modeled beyond the well bore.

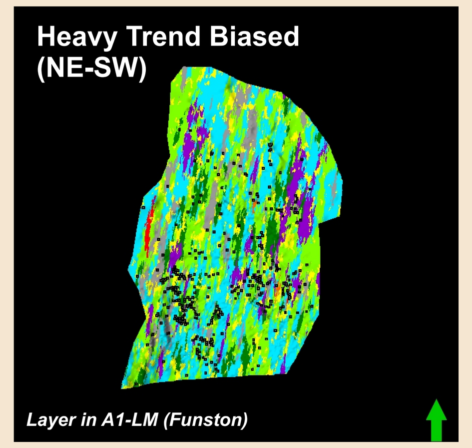


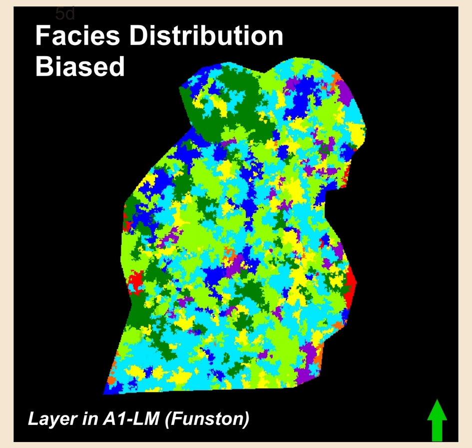
Biasing Lithofacies Geometry

Model facies using different biasing parameters based on geologic understanding of field. Examples include “non-biased” using a spherical range of 100,000' x 100,000', slightly biased (2:1 ratio to NE-SW), heavily biased to NE-SW, and bias based on mapped regional facies distribution patterns.

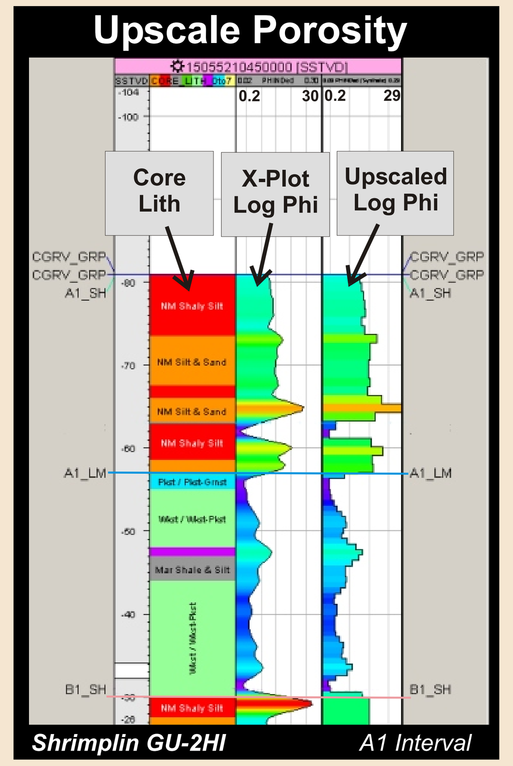






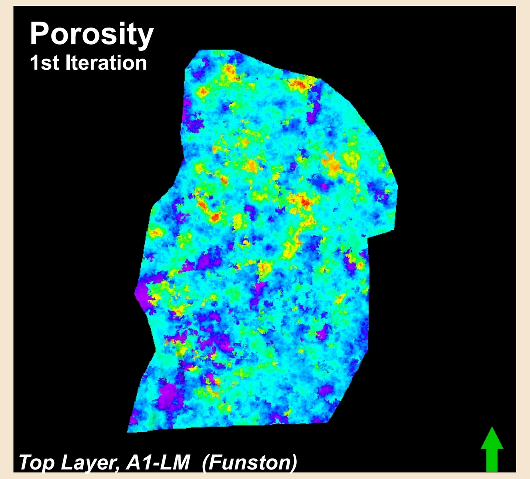


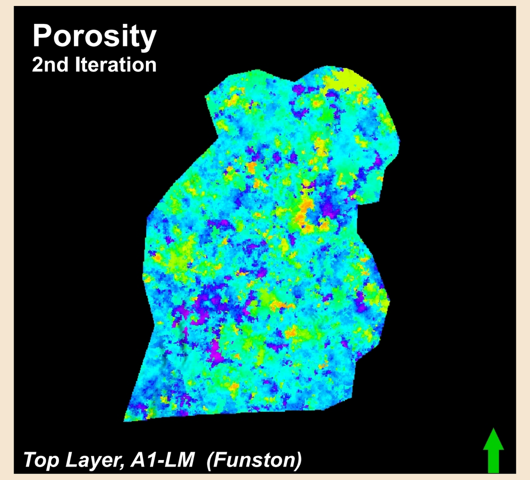
Petrophysical Model

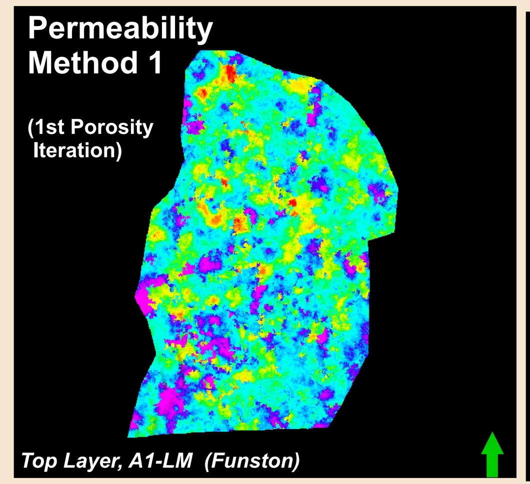


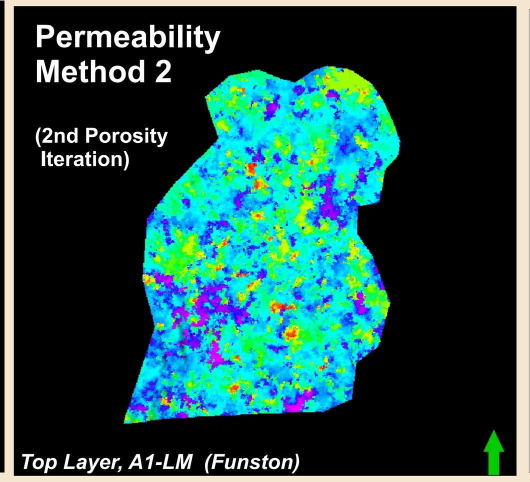
Raw log data was quality checked and aliased*. During the processing a cross-plot porosity curve was generated using the Neutron and Density Porosity curves. No shale correction was made in the first models. Similar to facies modeling, porosity curves were "upscaled" at the wells for modeling porosity in cells between the wells (Sequential Gaussian).

Map view of porosity models for the top layer of the A1-LM. First iteration at modeling porosity used maximum 30% porosity cut-off for all lithofacies. Second iteration at modeling porosity used facies specific porosity cut-offs inside new modeling boundary that eliminated a few outlier wells.

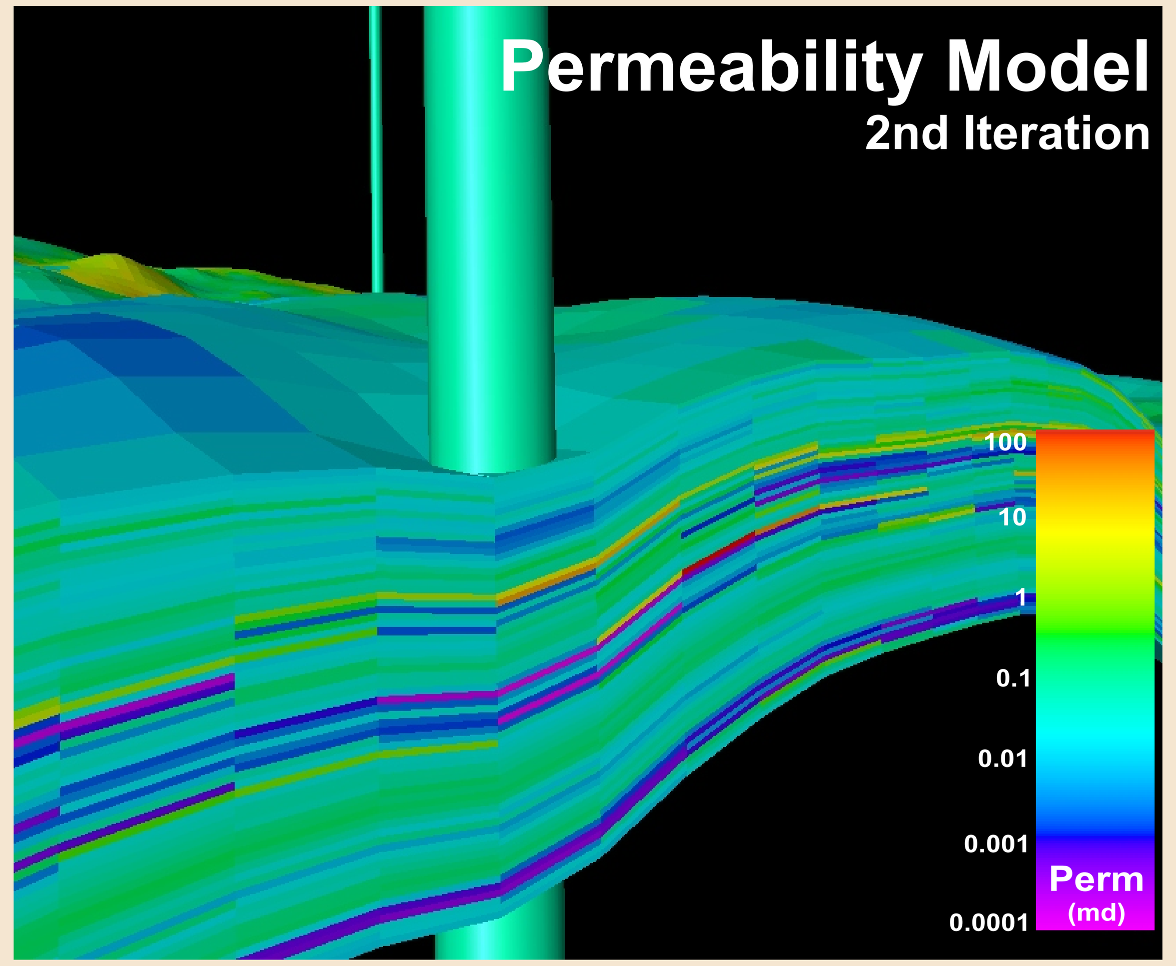




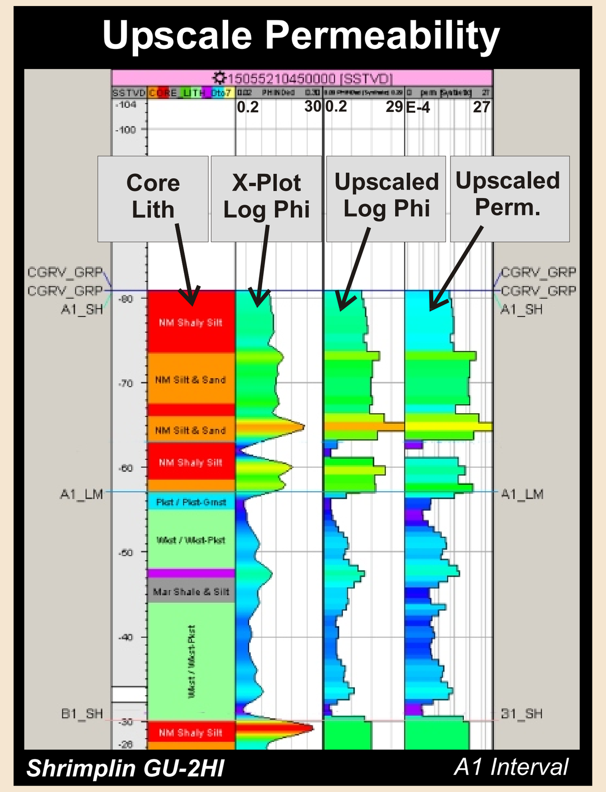


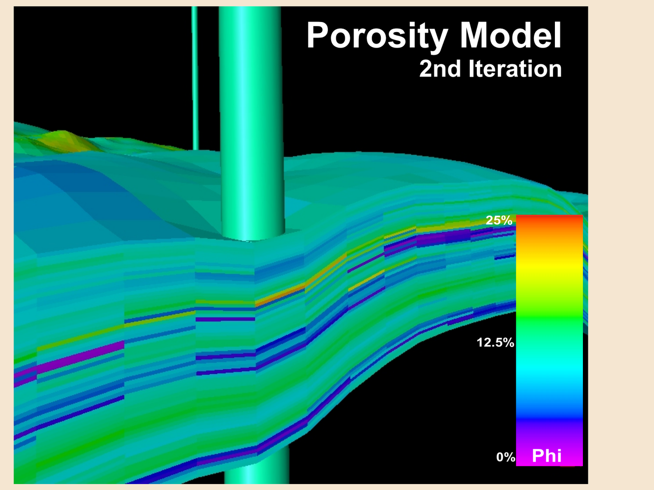


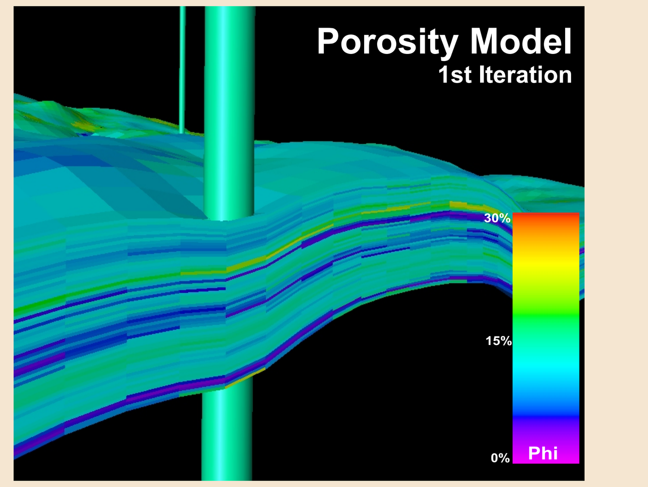
Map view of permeability models for the top layer of the A1-LM. Permeability Model 1 used facies probabilities predicted by neural net in field-wide extrapolation using Sequential Gaussian Simulation. Permeability Model 2 used values of the facies and porosity defined in a particular cell and facies dependent porosity-permeability transforms.

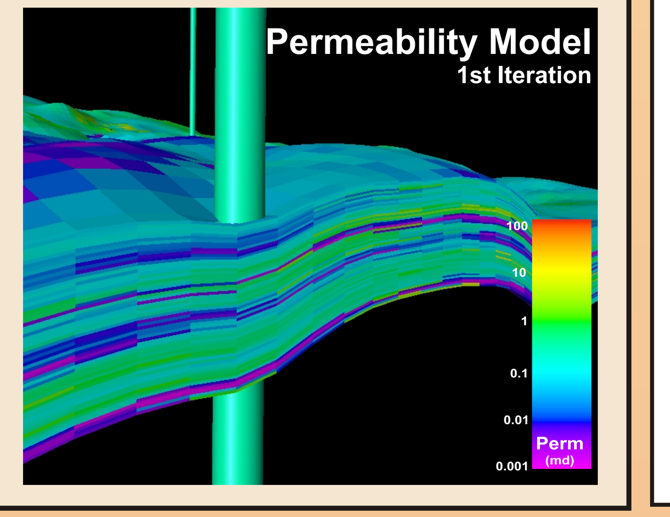


Upscaled absolute permeability curves were calculated using porosity-permeability transorm equations developed by Byrnes.









Summary

This paper is a snap-shot of an ongoing effort with the ultimate goal of the creation of a robust three-dimensional geomodel suitable for accurate reserve analysis and reservoir simulation. The work to date demonstrates:

1. There are significant differences in petrophysical properties between lithofacies
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2. Error in estimation of original gas in place (OGIP) and distribution are likely if lithofacies are not taken into account.
3. Lithofacies can be predicted in non-cored wells with sufficient accuracy by using a neural net model trained on lithofacies defined from a relatively small set of cores associated well logs and other defined curves (Marine-Nonmarine).
4. A vast tops data set, availability of digital well logs, and the automation of the prediction process allows the development of a model to accurately represent the heterogeneous Panoma reservoir.

Work presented here represents the first iteration of a multiple iteration process. The model has not been taken to the reservoir simulation stage due to the need to step back and rebuild the porosity model using shale corrected porosity (left out in this stage) followed by regeneration of the permeability model.

Further Work

Additional effort will be in several broad areas; 1) “ground truthing” lithofacies prediction and extrapolation, 2) increasing coverage, 3) improving the neural net model and Petrel models, and 4) moving to reservoir simulation phase. These will be accomplished in the following steps:

1. Test the neural net lithofacies prediction models by comparing additional core lithofacies (from undescribed available core) with those lithofacies predicted.
2. Test Petrel's stochastic lithofacies modeling procedure by comparing its results to neural net predictions at wells that were not used in conditioning the Petrel model.
3. Increase well coverage by “recovering” data from the set that was removed for a variety of data quality and standardization reasons including interval skips and log curves requiring normalization (especially the gamma ray and neutron porosity).
4. Improve porosity model by correcting porosity log curves for shale.
5. Explore other possible lumping and splitting schemes for the training set using the digital lithologic data.
6. Consider other predictor variables such as vertical transition probability biasing and relative position within an interval.
7. Expand efforts in lithofacies geometry biasing in the area of inter-well extrapolation by incorporating predicted lithofacies probabilities and other statistical methods.
8. Further optimization of input parameters in all aspects of model development.
9. Develop a detailed, field-wide free water level map
10. Calculate original gas in place and compare with production history.
11. Move into reservoir modeling phase and compare with production history.

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