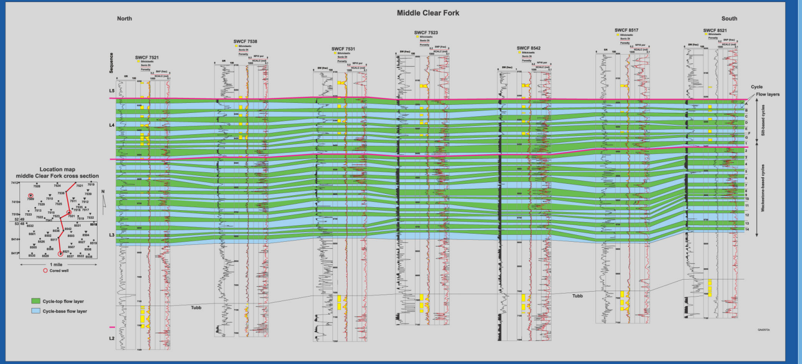
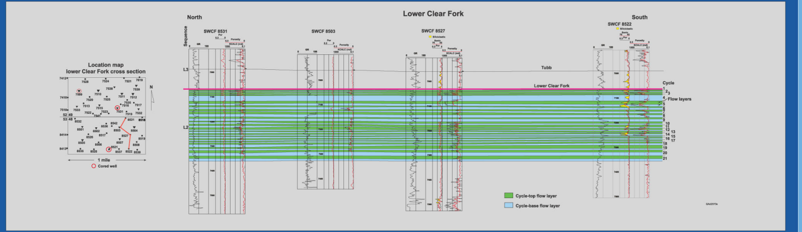
RESERVOIR MODEL CONSTRUCTION

CORRELATION OF HIGH-FREQUENCY CYCLES AND ROCK-FABRIC FLOW UNITS

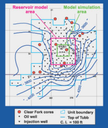
84 FLOW LAYERS ARE DEFINED, 42 IN THE MIDDLE CLEAR FORK AND 42 IN THE LOWER CLEAR FORK





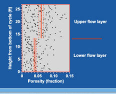
SIMULATION MODEL CONSTRUCTION

STUDY AREAS



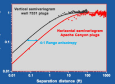
SMALL-SCALE POROSITY VARIABILITY FROM CORE AND OUTCROP DATA

STATISTICAL DISTRIBUTION OF POROSITY WITHIN FLOW LAYERS Core data



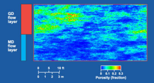
Average core-analysis porosity for a normalized high-frequency cycle from well 7531 shows that higher porosity values tend to be concentrated in the upper flow layer.

POROSITY VARIOGRAMS



The variograms shown here are used to construct a porosity model (below). The horizontal variogram is taken from outcrop data, and the vertical variogram is based on core data.

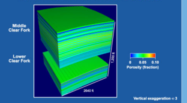
POROSITY SIMULATION FOR TYPICAL CYCLE



This stochastic model illustrates the most likely distribution of porosity at the one-foot scale. Note that
(1) porosity is concentrated in the grain-dominated (GD) flow layer,
(2) lateral variability in the grain-dominated flow layer is such that low porosity can occur 30 feet from high porosity, and
(3) the high porosity is distributed as elongated bull's-eyes rather than layers.

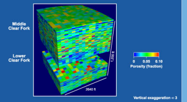
SCALEUP OF ONE-DIMENSIONAL PETROPHYSICAL PROFILES INTO A 3-D SIMULATION MODEL

SIMULATION FLOW LAYERS SHOWING MOVING AVERAGE POROSITY VALUES



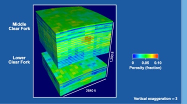
Moving average porosity of each flow layer is presented here to show distinct porosity values between adjacent flow layers. Small-scale lateral variability has been mostly removed.

WELL-LOG-SUPPORT STOCHASTIC SIMULATION



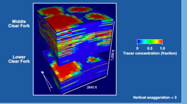
Conditional stochastic simulation of porosity using well data averaged within flow layers. The variance is too large because only a single porosity value is used to characterize each simulation block. The data need to be increased from log scale to block scale. Block is 150 ft square.

BLOCK-SUPPORT STOCHASTIC SIMULATION



Conditional stochastic simulation of porosity at the grid-block scale. Most small-scale variability is removed, but large-scale variability is retained.

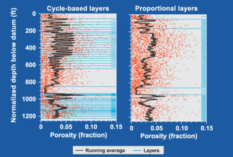
TRACER SIMULATION USING SCALEUP HIGH-FREQUENCY-LAYER MODEL



An important test of a flow simulation is the appearance of geologic layering known to be present in the reservoir on the basis of outcrop studies. In this model, high-frequency cycles and rock-fabric flow layers are clearly visible in the simulated reservoir performance.

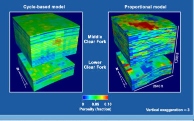
IMPROVEMENTS IN FLOW MODEL USING CYCLE-BASED LAYERS INSTEAD OF PROPORTIONAL LAYERING

EFFECT OF LAYERING METHOD ON PROPERTY DISTRIBUTION



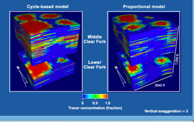
A more traditional method of defining flow layers is to divide intervals proportionally between correlated surfaces. A comparison of the proportional and high-frequency methods presented here shows that
1. the cycle-based model reflects geologic variability in porosity observed in cores and outcrop, and
2. there is very little difference in petrophysical properties between proportional layers because geologic variability is not accounted for.

COMPARISON OF SIMULATION MODELS



Geologic layering is retained in the cycle-based model but is smoothed over in the proportional model because
1. proportional layers do not honor geologic variability, and
2. traditional geostatistical methods often are not scaled up to simulation block size. Therefore, the variance in the proportional model is unrealistically high.

COMPARISON OF TRACER SIMULATIONS



Major improvements over the proportional model include
1. better imaging of sweep for locating remaining oil saturation,
2. reducing the adjustment in kv/kh multiplier from 0.0002 to 0.02 to obtain a history match, and
3. reducing the adjustment in permeability from 2X to 1X. No modification in log-calculated permeability was necessary using the cycle-based model and this scaleup method.

CONCLUSIONS

- Reservoir-analogous outcrops provide a fundamental geological and petrophysical data set for improved reservoir characterization and modeling.
- Sequence boundaries can create effective top seals in carbonate reservoirs.
- Depositional facies, rock fabrics, and porosity are closely related even in dolomitized reservoirs such as the Clear Fork.
- Porosity profiles can be used to define cycle-based, rock-fabric flow layers.
- Permeability is characterized by a single porosity-permeability transform in this reservoir because of the presence of poikilotopic anhydrite.
- Porosity and permeability horizontal variograms from outcrop data show a high degree of small-scale variability with very poor spatial correlation.
- A cycle-based reservoir framework using 84 rock-fabric flow layers provide a realistic permeability model that can be scaled up from core data to simulation block size.
- Cycle-based, flow-layer modeling is a major improvement over proportional layer modeling because (1) reservoir sweep is controlled by cycle geometry, (2) the adjustment to kv/kh is significantly reduced, and (3) the permeability adjustment is minimized.

ACKNOWLEDGMENTS

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