Geocellular Modeling*

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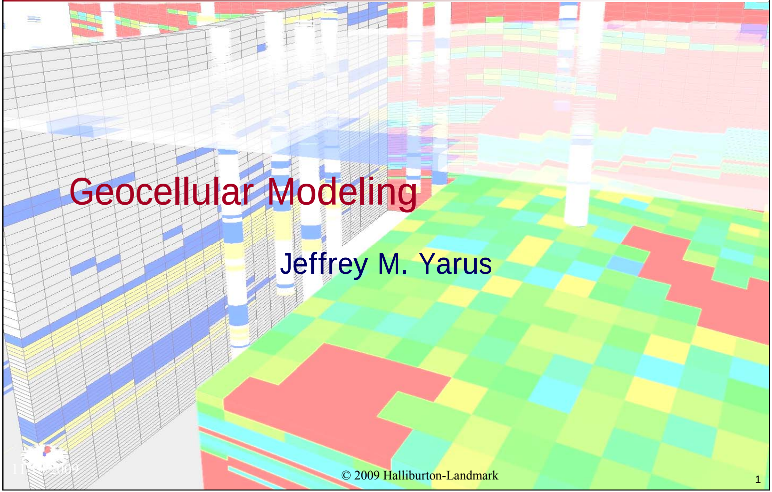
Abstract

High-resolution geological models are built upon 3D mathematical meshes that provide the numerical architecture for building the structural stratigraphic framework. Models are generally constructed and parameterized through software products that allow professional geoscientists to approximate the static state of reservoir by interpolating or simulating geologic facies and their petrophysical properties within a 3D volume. This process, however, is not done "willy-nilly," but is "model driven" from a scenario comprising a conceptual geological model. The interpolation and simulation algorithms used to fill the inter-well space are performed using workflows based on these conceptual models and attempt to bind results to logical rules derived from underlying geologic principles. While the workflows can vary based on individual interpretation of the data, the results are generally obligated to honor the observed data. Within a given scenario, it is the interpolation algorithm that is responsible for providing the best estimate at every grid location and the simulation algorithm that is responsible for capturing the inherent variability, providing the basis for uncertainty analysis.

However, there are less obvious aspects of uncertainty that go beyond the conceptual geological model, interpolation, and simulation. Many aspects of geocellular modeling involve technology that is not well understood by modelers: Grid design and volume support, stochastic principles including spatial modeling and algorithm selection, appropriate methods for capturing the space of uncertainty, how to integrate the "human" factor in the model. All of these issues can significantly effect dynamic modeling and risk assessment, thus impact reserve estimation. The presentations in this session highlight many of these issues and provide insights into appropriate geocellular-modeling principles that can provide better input into the subsequent crucial steps that lead to reserve reporting.

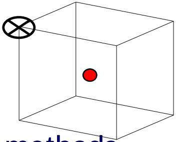


Geocellular Modeling

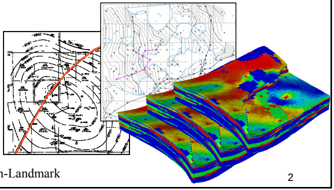
Jeffrey M. Yarus

Geocelluar Modeling – What is it?

- A way to mathematically describe the subsurface in 3D space constrained by a structural and stratigraphic framework
- Provides values at:
  - Grid (Mesh) nodes
  - Centers of Gravity (3D - Voxels)



- Uses deterministic and/or stochastic methods
  - Manual interpretation
  - Computer interpolation
  - Stochastic simulation



Deterministic Modeling

Single Solution

- Synthesize state-of-the-art knowledge about something we don't understand
  - a common language
  - Facilitate progress
  - Help discover gaps
  - Dependent on current state of knowledge
- They are not crystal balls which can be used to find an answer
  - Varying Subjectivity
  - Often misused
  - Offer one possibility
  - More like "Polite Fictions" – we hope they behave well

Dominique Bachelet, Oregon State University

Presenter's Notes: Provide interdisciplinary teams with a common language

Help researchers make progress

They are misused by everybody who wants an answer and cannot find it any other way.

Multiple Solutions

- Synthesize state-of-the-art knowledge about something we don't understand
  - Same input as deterministic model
  - Provides multiple realizations from the same set of data
  - ✶Are not scenarios, but addresses "SOU"
- More like crystal balls which can be used to narrow the range of solutions
  - Allows for subjectivity
  - Requires some knowledge of spatial statistics
  - Does not prevent misuse/misunderstand-ing

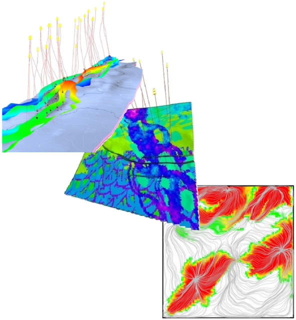
The space of uncertainty

- Theoretically
  - All possible “outcomes” or the distribution of all possible “values” resulting from stochastic modeling.
- Pragmatically
  - Unlikely that we will capture reservoir complexity
  - Subject what we know to a probabilistic framework.
  - Construct a set of scenarios matching our observations
  - And a set of equi-probable realizations by scenario
  - Stochastic (geostatistical) methods are generally used

Gooverts, 1997 ,Chambers and Yarus, 2007

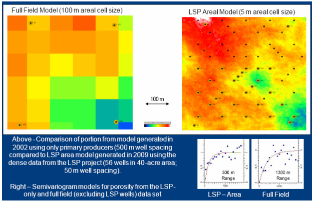
“Uncertainty is everywhere!”

- Data acquisition and processing



- Data interpretation
- Conceptual geological model
- Structural model
- Petrophysical model
- Flow model

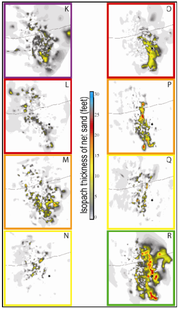
Scott Meddaugh - Chevron

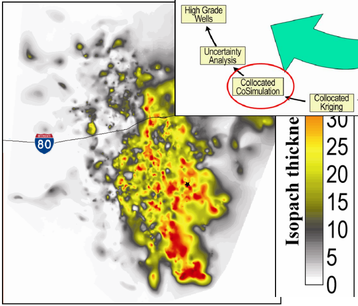


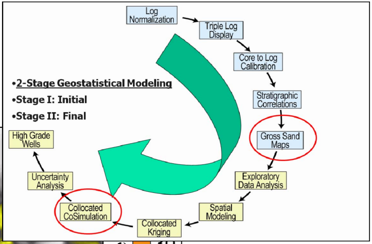
- Impact on Recovery:
  - Variogram Range
  - Grain size
  - Cell Size
- Impact on Fluid Flow
  - Vertical-Scale up
  - Aerial Scale-up
- Design of Experiments
- Thoughts on Uncertainty

•Total Unit 2 Average Net Sand Map

- Case Study
- Wamsutter Field, SW Wy.



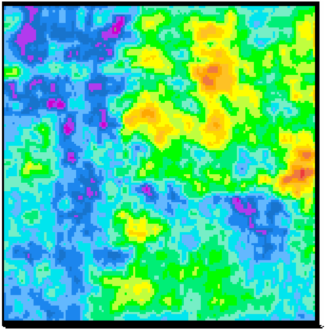




Summary

- Geocellular Models:
  - Mathematical representation of the subsurface
  - Can be deterministic or Stochastic
  - Deterministic models can provide “best” estimates – P50
  - Stochastic Models provides uncertainty assessment (probable and possible reserves)
  - There are pitfalls!
  - Provide input into Risk Assessment
  - Great visualization tools

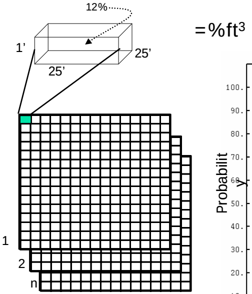
Dynamic Display

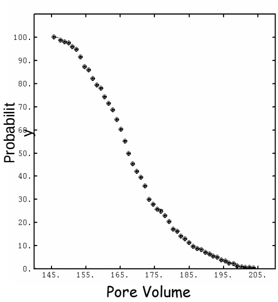


Agenda for Session

- Jeffrey M. Yarus – Introduction to Geocellular Modeling
- Emmanuel Gringarten -Uncertainty Assessment Using 3D Modeling
- Scott Meddaugh – Perspectives on Uncertainty in Reservoir Models
- Natasha Rigg - *Regional Mapping of Genetic Intervals in the Almond Formation, Greater Wamsutter Field, Southwest Wyoming*
  - *An Iterative Geostatistical Approach to High-Grading Well Locations and Implications for Reserves Bookings*
- Discussion

Calculating Total Volume

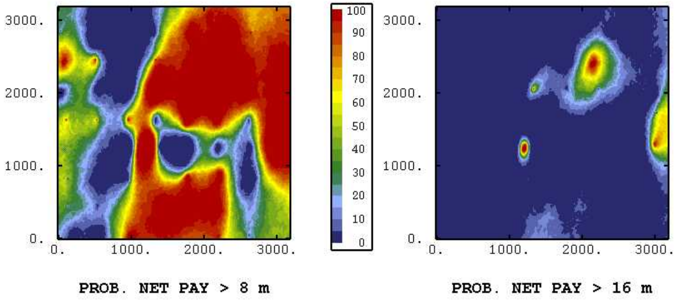




For example, the total summed volume from each realization is ranked and now represents a single point on the CPDF. In this case, the attribute was pore volume. However, it could be complex formula to derive OOIP. Further, the calculation can be restricted to a polygon or selected portion of the model.

Additionally, from such a CPDF, one could identify the realizations that correspond to the same volume (K and Ø) found for each of the p10, p50, and p90. These realizations could then be upscaled and presented to the simulator.

Risk Maps

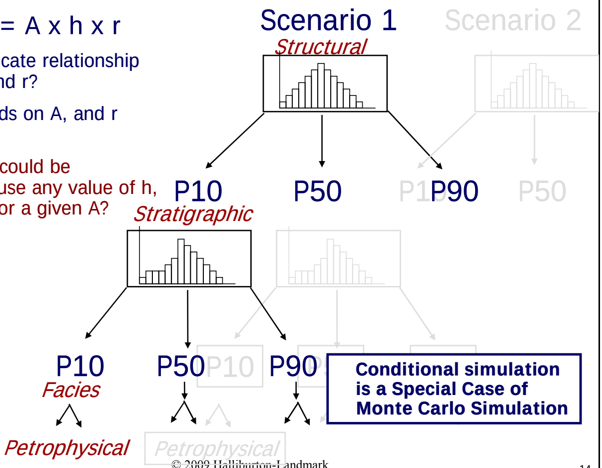


3000.
2000.
1000.
0.
0.
1000.
2000.
3000.
100
90
80
70
60
50
40
30
20
10
0
PROB. NET PAY > 8 m
PROB. NET PAY > 16 m

Thoughts about Ranking and Risk

If Reserves = A x h x r

- There is an implicate relationship between A, h, and r?
- That is, h depends on A, and r depends on h
  - Therefore, it could be dangerous to use any value of h, for example, for a given A?

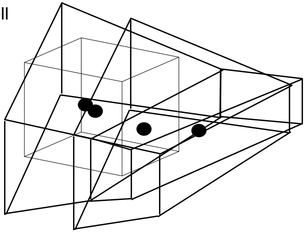


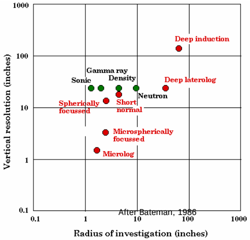
Conditional simulation is a Special Case of Monte Carlo Simulation

Support and Scale

- Modeling begins with a “mini” upscaling
  - What is the effect of inconsistent volume support?
  - What is the appropriate cell size?
  - What is the appropriate cell shape?
  - What is the method for selecting a representative value?

HRGM Cell





...and now?
Now What?