Applied Reservoir Engineering Series
Part 2

Geomodeling

PRESENTED BY

THOMAS JEROME
Geomodeling
Generalities

Prepared by
THOMAS JEROME
• WHERE TO GO NEXT?
  • In Alberta  • Bookstore
  • CSPG  • Papers
• GEOMODELING WORKFLOW
• EXAMPLES GEOMODELING APPLICATION
  • Flow simulation
  • Volumes
  • Fracture Stimulation Modeling
• WHY SHOULD YOU CARE?
WHERE TO GO NEXT?
In Alberta

Non-exhaustive

- Professional Associations:
  - CSPG, CSEG, CWLS, SPE
  - CSUR, CHOA
- Conferences:
  - GeoConvention,
  - Gussow Conference (2011 and 2014 on geomodeling)
  - SPE/CSUR Unconventional Resources Conference
- Software vendors:
  - Schlumberger (Petrel), Emerson (RMS), Paradigm (GOCAD & SKUA), Halliburton (DecisionSpace, JewelSuite)
  - Geomodeling (SBED), Geovariance (Isatis), Midland Valley (3D-Move)
  - CMG (Builder), Streamsim (3DSL)
- Science:
  - University of Alberta (CCG)
  - University of Calgary
WHERE TO GO NEXT?
CSPG – Feb ‘16

Monthly Magazine

Clayton Deutsch:
→ Worlwide-expert in geostats
→ CCG group in Edmonton
**Geomodeling Division**

Free, usually-monthly, presentations

**Series on Geomodeling**

Feb 2015 to April 2016
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WHERE TO GO NEXT?

Bookstore

2015, P. Ringrose, former EAGE president

2014, C. Deutsch as co-author
WHERE TO GO NEXT?
Bookstore

2015
Fundamentals of Gas Shale Reservoirs
Edited by Reza Rezaee

2014
Heavy-oil and Oil-sand Petroleum Systems in Alberta and Beyond

2013
Anatomy of a Giant Carbonate Reservoir: Fullerton Clear Fork (Lower Permian) Field, Permian Basin, Texas

Geomodeling - Generalities
WHERE TO GO NEXT?

Papers

Non-exhaustive

• Databases:
  – SPE, AAPG, SEG, EAGE
  – Keywords: geomodel ; reservoir model

• Magazines:
  – AAPG Bulletin
  – SEG/AAPG Interpretation
  – SPE Reservoir Evaluation & Engineering
  – EAGE Petroleum Geoscience

• Research Centers:
  – Stanford School of Earth, Energy & Environmental Sciences
  – Colorado School of Mines
  – Heriot-Watt University (team around Sebastian Geiger)
  – Laboratory RING (France, Nancy)
GEOMODELING WORKFLOW

DATA → SURFACES → GEOLOGICAL 3D GRID

PETROPHYSICS

FACIES

Engineering Tasks
GEOMODELING WORKFLOW
STEP 1 – Gathering the data

- Define Volume of Interest
- Geological Knowledge
- **Well data**: Trajectories, Tops, Facies description, Petrophysical Logs, Core Data
- **Seismic data**:  
  - Seismic Interpretation  
  - Seismic Attributes
GEOMODELING WORKFLOW
STEP 2 – Structural & Stratigraphic Modeling

• Build fault network:
  – Very difficult from well tops alone. Usually based on a seismic interpretation.
  – Ensuring the network is sealed.

• Horizon modeling:
  – Well tops or tops + seismic interpretation for key horizon.
  – Well tops for secondary horizons.

• Challenge for reservoirs with multi-Z surfaces.
GEOMODELING WORKFLOW
STEP 3 – 3D Grid Building

- Define the internal mesh orientation
- Define the vertical cell size based on the logs’ vertical heterogeneity
- Define the horizontal cell size based on the dimension of the lateral changes of facies
- Make sure the total number of cells is manageable (less than 10 Million if possible; avoid more than 100 Million)
- Use the horizons and the faults modeled in the previous step.
- Properties will be cell-centered.
GEOMODELING WORKFLOW
STEP 4 – Facies Modeling

• Translate the geological interpretation of the reservoir into mathematical constraints for the facies interpolation.

• Usually done using geostatistics

• Usually multiple scenarios are built.

• Consider uncertainty in facies proportions and in variogram characteristics
GEOMODELING WORKFLOW
STEP 5 – Petrophysical Modeling

- Usually porosity, SW and permeability. Sometimes VSH too. Others needed in specific reservoirs (GR, TOC, fracture densities…).

- Petrophysics modeled by facies. We also capture the relationships between logs.

- Geostatistics used but also mathematical equations.
  
  Ex: Perm = F(porosity)
TRADITIONAL APPROACH

GEOMODELING APPROACH

Well1 10%
Well2 80%
Well3 90%

HCPV = BRV * NTG * PORO * So

HCPV = BRV * NTG * PORO * So
GEOMODELING APPLICATION FOR ENGINEERS

Volumes

GEOMODELING APPROACH
GEOMODELING APPLICATION FOR ENGINEERS
Production Engineering

Traditional input

Geomodel input

Geomodel
WHY SHOULD YOU CARE?
Carrying uncertainty forward

From Alfhild Lien Eide

GOAL

Discipline/department border

Uncertainty

Value chain

Geophysics Geology Engineering

From Alfhild Lien Eide
WHY SHOULD YOU CARE?
We need you, engineers

Proper presentation of the reservoir

Fit for purpose

We need you, engineers, to:
• Check with us if we can be of assistance on some of your engineering problems.
• Provide us with engineering data.
• Understand how the models are built
• Help us spot any issue in our workflows and our results.

• Take good care of our geomodels while using them in engineering tasks. 😊😊😊
ANY QUESTION AT THIS TIME?
Geomodeling
Answering some of the questions asked by engineers

Prepared by
THOMAS JEROME
Do I need to help defining the well list?

- Build a single well DB for the static and the dynamic model.
- Some wells might be needed for flow simulation, even if not needed for static modeling. Make sure the geomodel includes them.
- DB errors spotted late in the project often lead to redoing a big part of the project.
Do I need to provide any data/information?

- Help building the list of wells needed for the model (previous slide).

- Perforation data if any.

- Check early if you need to include some units above or below the reservoir (for boundary condition).

- Check early if you need to extend the model laterally (for boundary condition).
How do you model horizons?

- By TVDSS interpolation for at least one reference horizon.
- By TVDSS or by isopach for the secondary horizons.
- We choose based on the geology. Isopach if both horizons are related; TVDSS for both, if not.
- TVDSS and isopach can give very different results.
- This is a source of uncertainty sometimes.
Is there uncertainty on horizons?

- Yes!
- Well tops
- Seismic interp
- Time-to-depth conversion
- Velocity modeling
- Choice of modeling by TVDSS or isopach
- Geomodels can take them into account.
Why are you simplifying the fault network? Any workaround?

- Traditional gridding approach: pillar gridding → hard to model complex fault network.
- New techniques: implicit modeling.
Why are you not using a sugar box 3D-grid?
Why are you not using a sugar box 3D-grid?

- Always pick a mesh that follows the directions of the deposition (= follow geology).
- The mesh orientation controls a lot the results of geostats!
Why are you not using a sugarbox 3D-grid?

• When 3D seismic is available, check if you can spot some geological trends expressed as local seismic trends.
• If yes, pick the seismic trends and use them for creating the mesh.
What cell size for the upscaled model?

- Select a cell size that respects the geology while limiting the number of cells.
- Engineers, don’t impose a max number of cells upfront.
- Carry facies to check visually if the upscaling respected the connectivity of the reservoir.
How different are the simulation grid from the geological 3D grid?

Geological 3D grid

Upscaled horizontal mesh

LGR
How different are the simulation grid from the geological 3D grid?

- The 3D geological grid is built to help us model the rock characteristics (= geology = facies).
- The 3D simulation grid is built to help us model fluid properties.
- Physical laws controlling rock distribution and fluid behaviors are different and have different main directions. That is why simulation and geological 3D grids do not have the same mesh.
How are we upscaling the properties?

A: upscale facies and then petrophysics by facies.
B: upscale petrophysics while ignoring facies.

- Upscale so as to respect the characteristics of the reservoir.
- BRV, PV and HCPV of the upscaled grid should be the same as in the geological 3D grid.
- Facies → highest proportions.
- Porosity → arithmetic average
- SW → arithmetic average weighted by porosity.
- Permeability → multiple choices. Discuss it with the engineers.
What about downscaling a 3D geomodel?

- First technique: “block” approach
What about downscaling a 3D geomodel?

- Second technique: interpolate high-resolution details with geostatistics.
What are geostatistics? What is a variogram?

- Variograms capture how the property varies in different orientations.
- Visually, a variogram can be seen as a 3D ellipsoid.
What are geostatistics? What is a variogram?

- Mathematically, variograms are defined by a sill, a shape, and also a range in each main direction.

Too small variogram  
Data-correct variogram  
Too large variogram
What are geostatistics? What is a variogram?

- Kriging technique used with the different variograms.
- The highly anisotropic variogram works better even if it’s not fitting the data as well! But it respects the geological environment better.
Kriging or simulation?

- Both!
- Use kriging to test different variograms.
- For the one or several variogram picked, use simulation to work on the uncertainties on proportions.
- Create multiple realizations from a range of variograms and a range of proportions, using simulation techniques.
There is no geology needed when running geostatistics!

- Wrong!
- It’s about picking the correct geostatistical technique, the correct secondary variables, the correct variogram to capture what we understand about the reservoir (= data + knowledge).
There is no geology needed when running geostatistics!

Pure data-driven model

Data- and geology-driven model

GEOSTAT INPUT

Pure data-driven model

Data- and geology-driven model

Geomodeling – Answering some of the Questions asked by Engineers
Facies proportion map

Pure data-driven map

Data- and geology-driven map
Facies Vertical Proportion Curve (VPC)
Facies Vertical Proportion Curve (VPC)
Seismic attribute as input for creating a cube of facies probability
Why not modeling facies by modeling VSH first?
Why not modeling facies by modeling VSH first?

VSH model then facies 3D model from VSH cut-offs

Facies 3D model then VSH model by facies.
What to take into account when modeling continuous properties?

- Check if the distributions are respected
What to take into account when modeling continuous properties?

- Check vertical trends.
- Check also the correlations between properties.
- Understand / capture the petrophysicist' work carefully.

VSH | PHIE | SW | PERM
---|---|---|---
WELL LOGS

BLOCKED

MODEL3D

PROBLEM?
What to take into account when modeling continuous properties?

- Correct the geostatistical workflows until the correlations between properties and the spatial trends (vertical, horizontal), and the geological hypothesis are respected.
- And keep an eye on the 3D-mesh: don’t like the 3D petrophysical model? Then check if the mesh of the 3D-grid is really appropriate.
ANY QUESTION?

and thank you for your attention