Practical Implementation of Stratigraphic Compartmentalization in Turbidite Lobe Reservoirs*

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Search and Discovery Article #41207 (2013)**
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Abstract

In sheet-sand reservoirs, the presence of shale draping the lobes tends to compartmentalize the reservoir sand into multiple flow units. This stratigraphic compartmentalization has dramatic implications in terms of field development and hydrocarbons recovery and has to be characterized as early as possible in the field life. Geochemistry and fluid pressure analyses along the well path are common tools to identify the different flow units (a flow unit corresponding typically to a lobe), but they provide an incomplete description of the full 3-D reservoir compartmentalization. A traditional approach to achieve a complete reservoir description from sparse data is to use geostatistical algorithms. However, geostatistics are ill-equipped to integrate compartmentalization information and to generate the corresponding shale drape geometry.

In this study, we propose a 2-point geostatistical workflow that overcomes this limitation. First, the geometry of each lobe (i.e., compartment) observed in the wells is propagated in the geocellular grid by Sequential Indicator Simulation. The lobe shapes are controlled by the algorithm input parameters. A probability map of shale occurrence is then computed. High probabilities are assigned to the surface of the previously simulated lobes, where the shale drapes are found. Using this probability map, a 2-point geostatistical facies modeling step is performed. The simulated shale, which is, therefore, located at the lobes surfaces, forms drapes and compartmentalizes the reservoir as observed in the well data.

This workflow is stochastic in nature and generates models in seconds. For that reason, it can be easily used to assess reservoir compartmentalization uncertainty. The method is successfully applied to a real turbidite reservoir in offshore Gulf of Mexico composed of 6 wells and 8 identified lobes. The geological consistency of the resulting models is compared to an outcrop, considered an analog of the reservoir and located in Frazier Park, California.

Selected References

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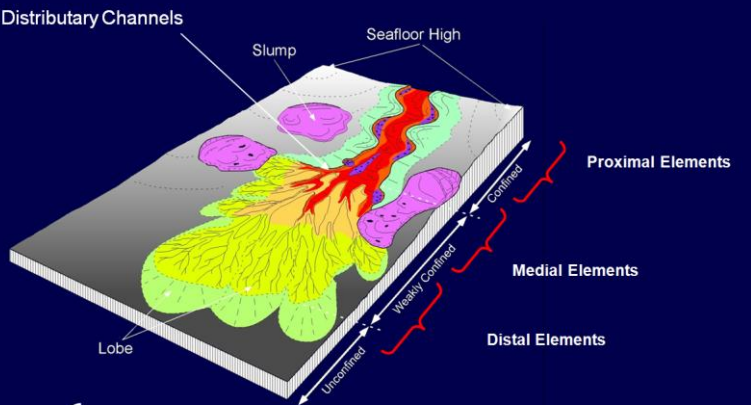
Introduction

- Lobe and lobe complex can be surrounded by shale
- The presence of shale compartmentalizes the reservoir, having tremendous implication in term of development and oil recovery (no flow between compartments)
- Pressure data may help identifying such reservoir compartments

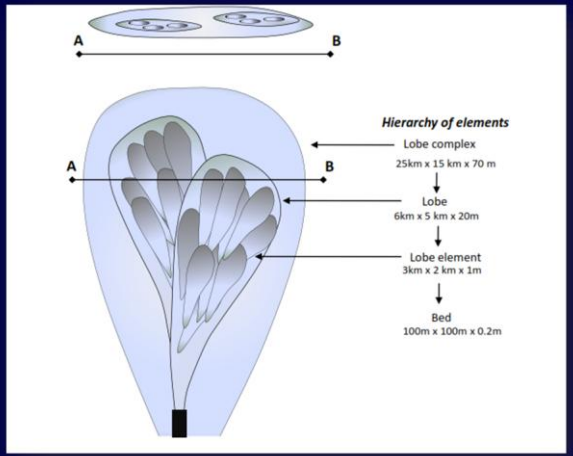
HOW TO INTEGRATE PRESSURE DATA IN A TRADITIONAL RESERVOIR MODELING WORKFLOW ?

Environment of Deposition



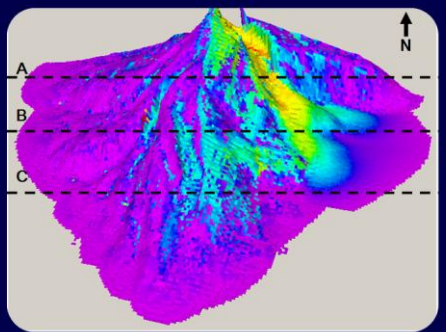
*Courtesy of Robert Handford: AAPG 2011

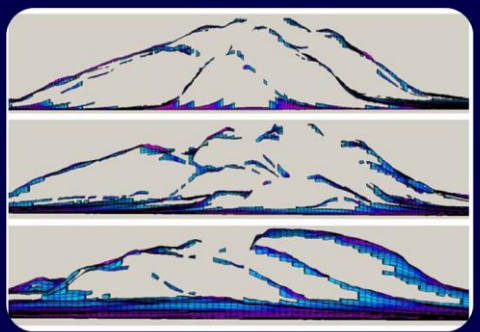
Environment of Deposition



Hierarchical structures in lobe deposits

Environment of deposition

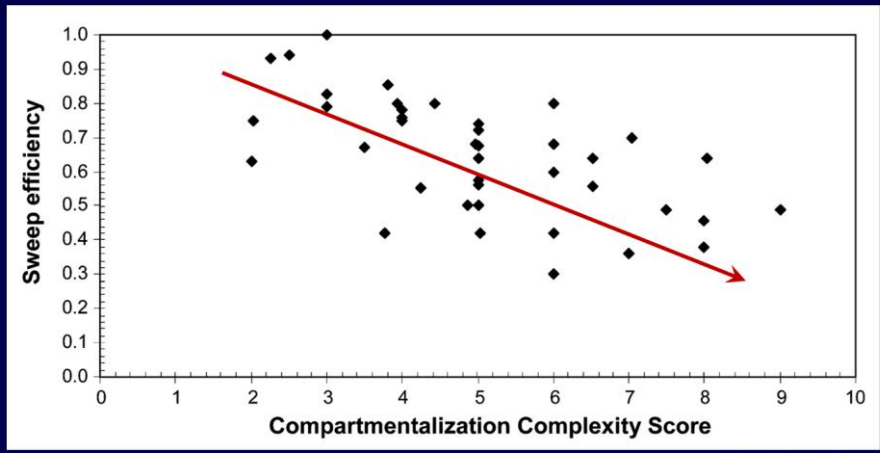




Process-based models predict the existence of thin shale barriers continuously distributed along lobe top surfaces, except where erosion is present. Those geological features impact flow behavior and need to be included in reservoir models.

Li et al. 200950164
Search and Discovery Article # (2009)

Impact on Production

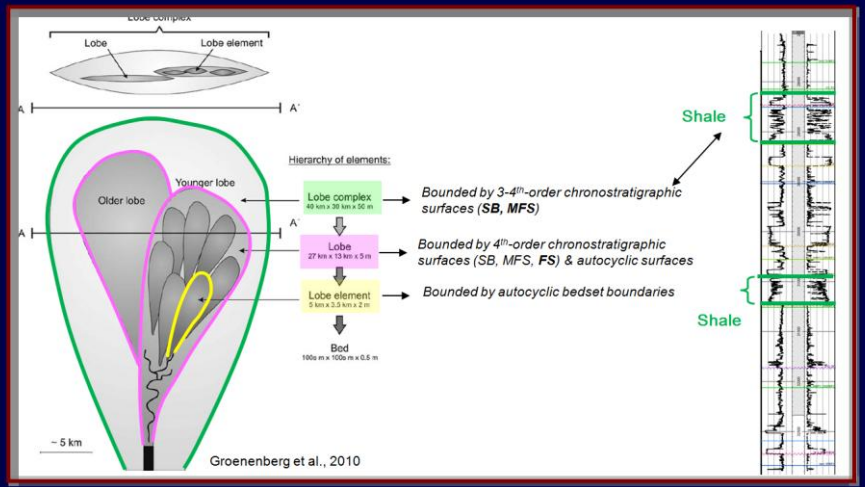


Smalley et al., 2010

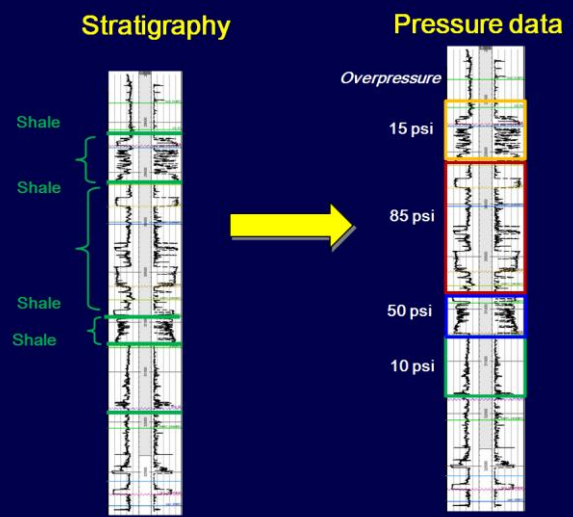
Sweep efficiency vs. Compartmentalization

Log Data

The reservoir compartments correspond to stratigraphic elements (lobe and lobe complex)



Pressure Data



Modeling challenges

- Require to define the 3D geometry of the pressure cells and shale barriers

- Seismic data are too coarse to be informative

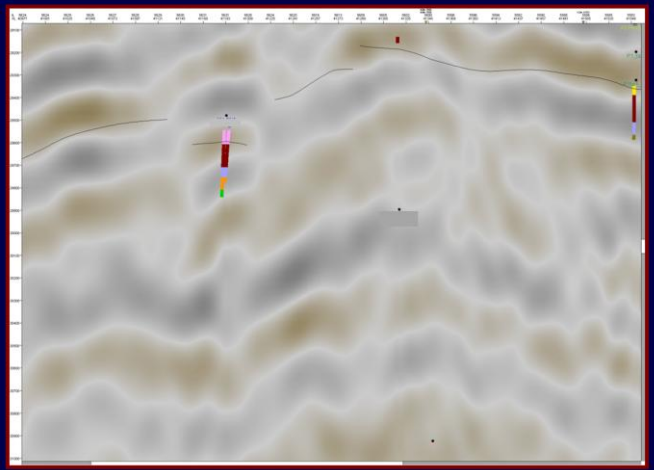
- Well data are sparse

Deterministic/manual approach may be strenuous

Forward modeling of lobe deposition possible but CPU intensive

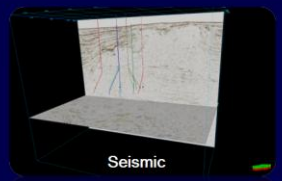
Stochastic approach is more suitable

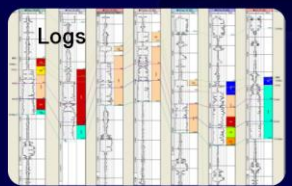
Seismic Data

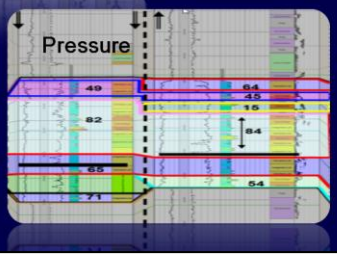


Seismic data are too coarse to provide information on the reservoir compartments

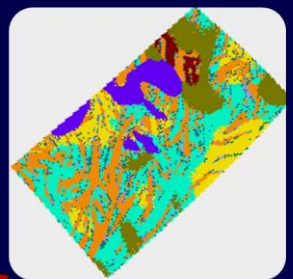
Reservoir data







Reservoir Model



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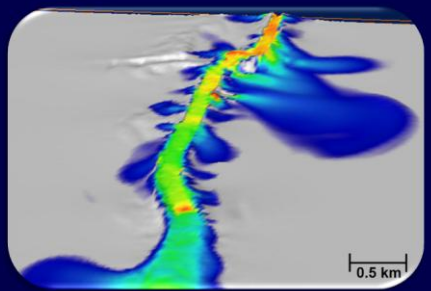
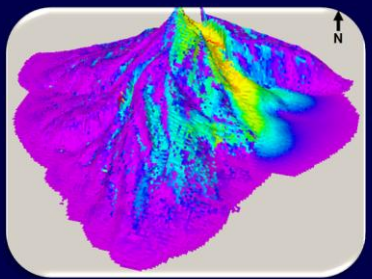
Existing Modeling Approaches

Process-based models



Channels and crevasse splay



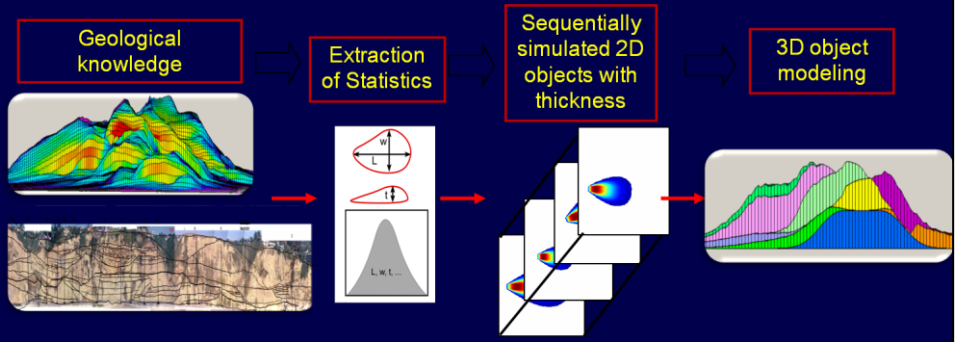
Lobes

Limitations due to CPU cost and data conditioning

Miller et al., 2008

Existing Modeling Approaches

Surface-based models



Pyrcz (2004) Miller et al. (2008) Michael et al. (2010) Bertoncello et al. (2013)

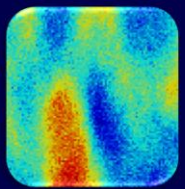
Limitations due to data-conditioning

Presenter's notes: Forward model.

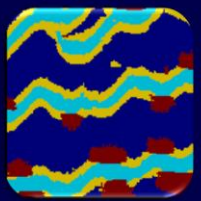
Existing Modeling Approaches

Geostatistics

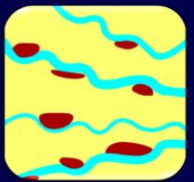
Two-point geostatistics



Multiple-point geostatistics



Object-based geostatistics



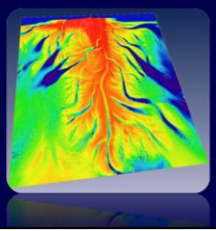
Limitations due to lack of information and complexity of the geological structures

Existing Modeling Approaches

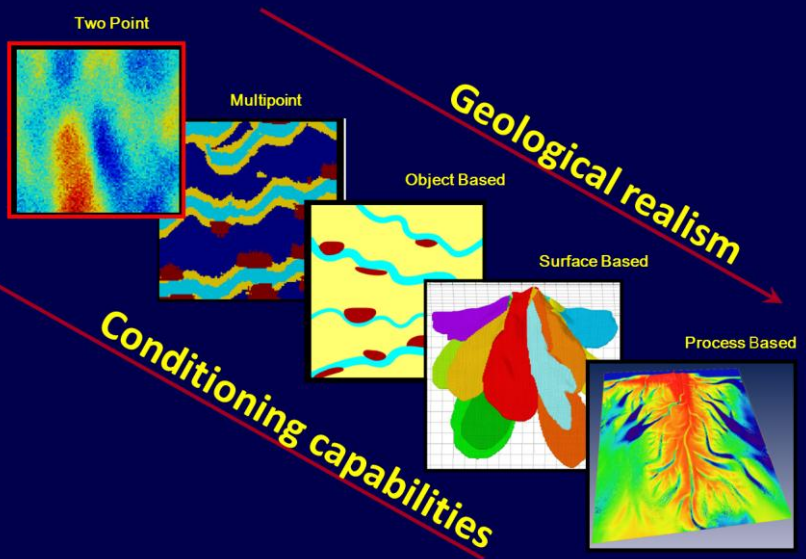
- Rules-based or physic-based algorithms are able to build realistic lobe models.
- However, these research algorithms are CPU costly and the data conditioning remains an issue.
- The aim of the presented models is to propose a alternate approach that is efficient and easy to implement. The method is based on two-points geostatistics.

Surface-Based Models

Physic-Based Models



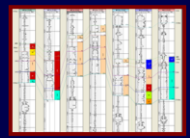
Existing Modeling Approaches



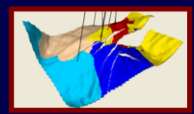
Devised workflow for stochastic approach

HESS

Creation of synthetic logs using the pressure information



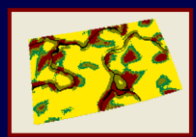
Creation of 3D pressure compartments in the grid *(SIS)*



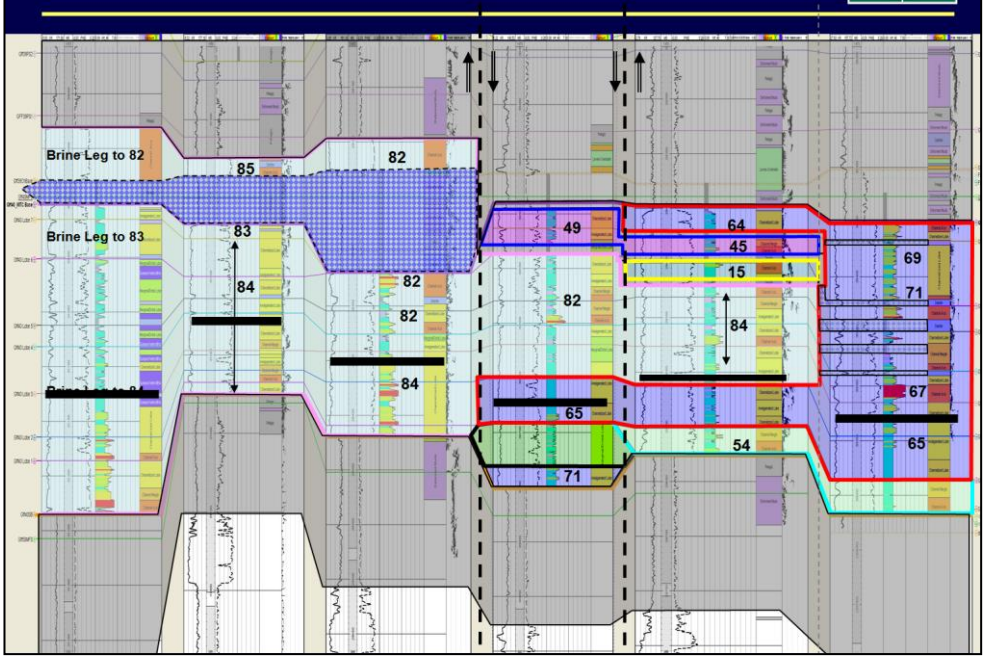
Definition of a shale layer between pressure compartments

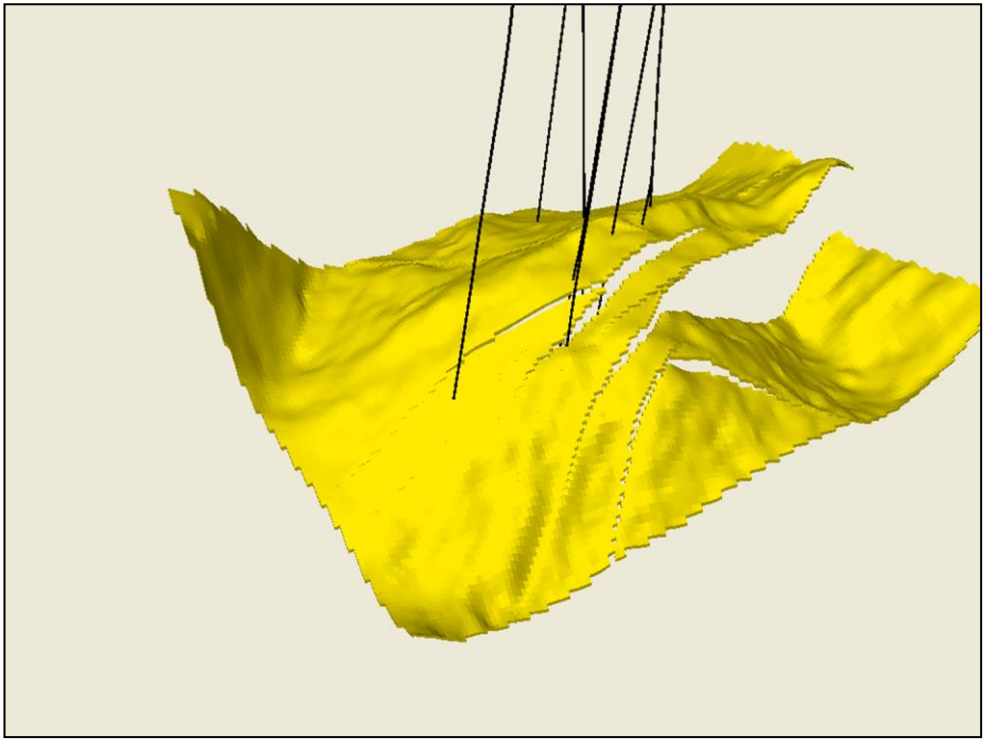
Definition of a shale probability map inside the reservoir

Filling each pressure cell with Truncated Gaussian Simulations

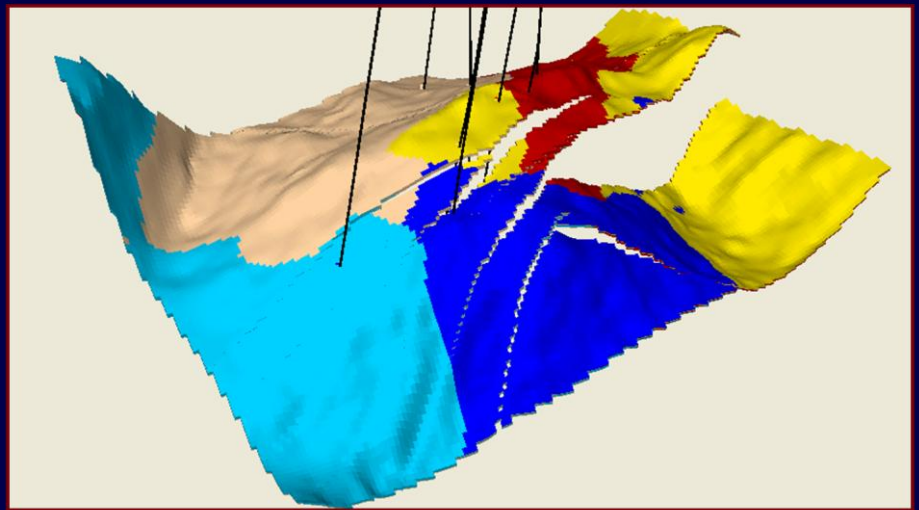


Reservoir compartments



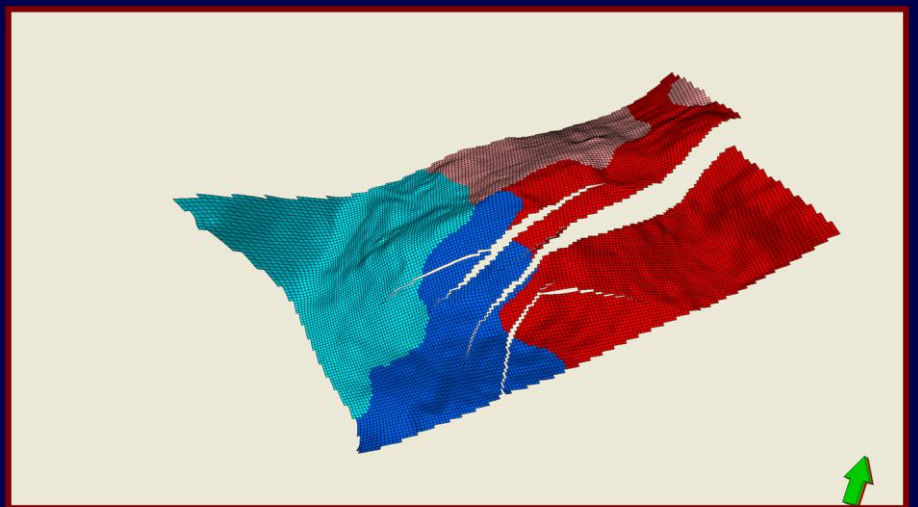


Reservoir compartments definition



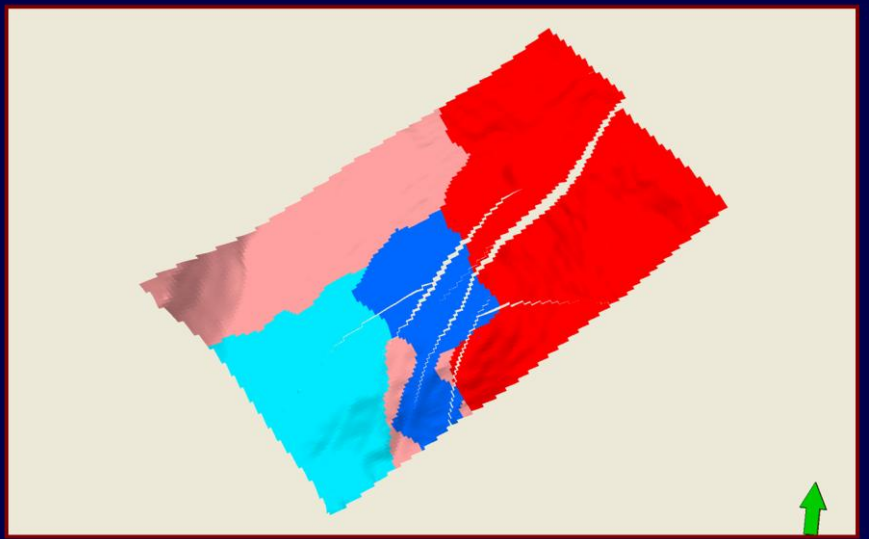
Sequential indicator simulation

Reservoir compartments definition

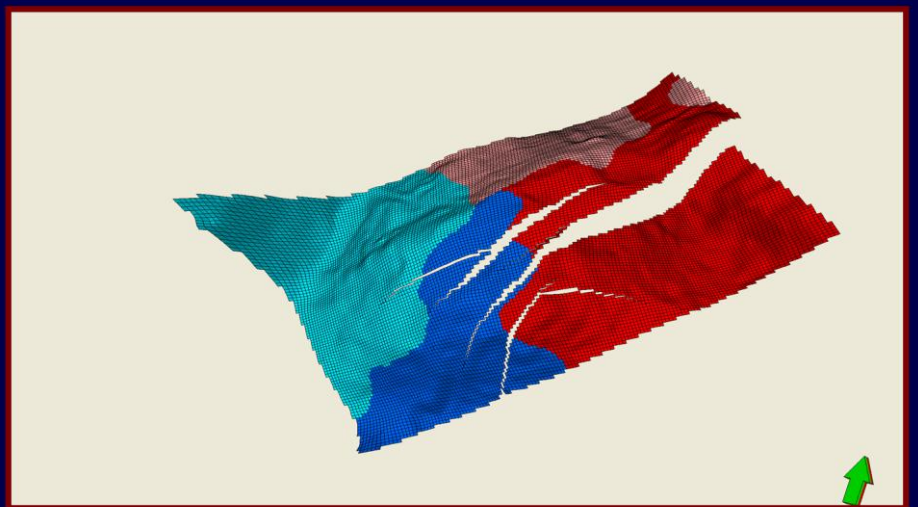


Sequential indicator simulation

Generation of multiple models

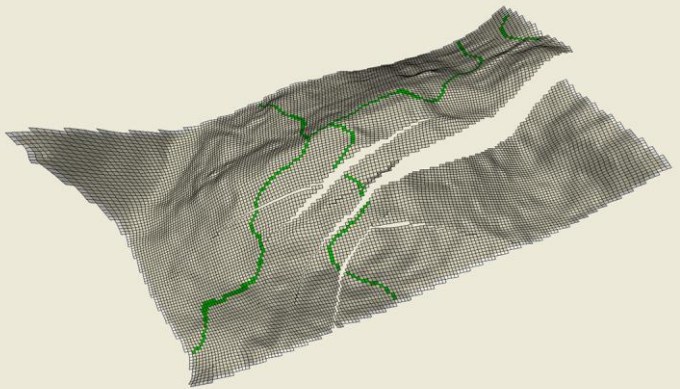


Reservoir compartments definition



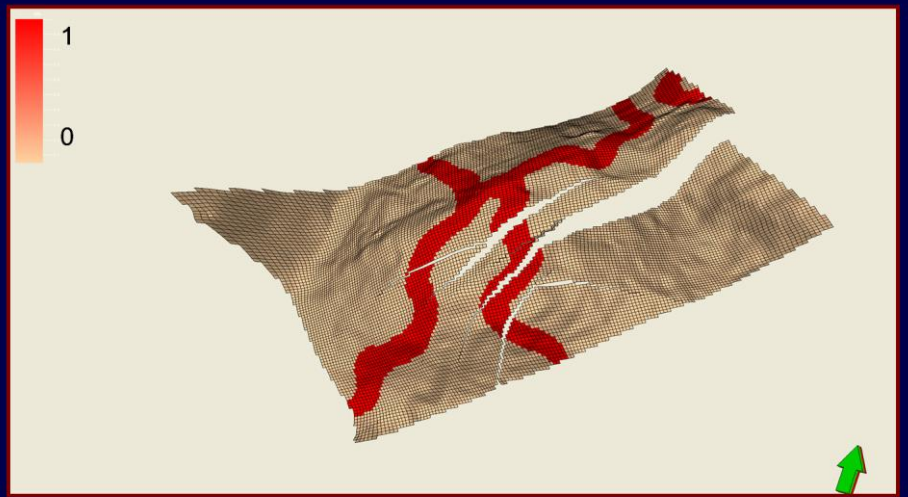
Sequential Indicator Simulation

Shale barriers definition



Adjacent cell workflow implemented

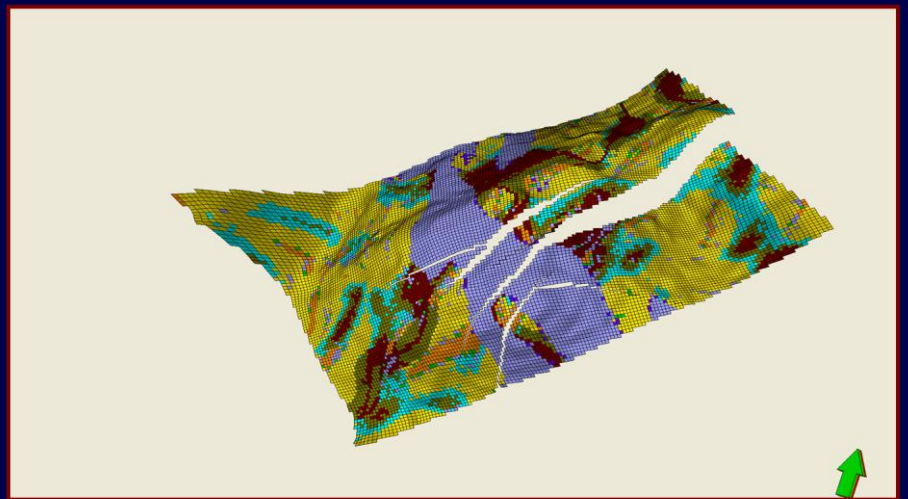
Shale barriers definition



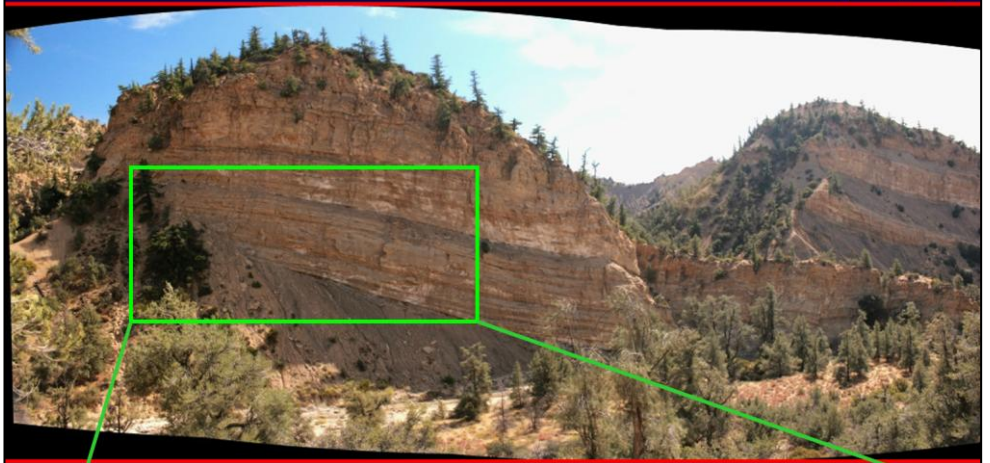
Shale probability map

Presenter's notes: Lobes have distal shales.

Property modeling



Analog from Frazier Park, Ca



Advantages

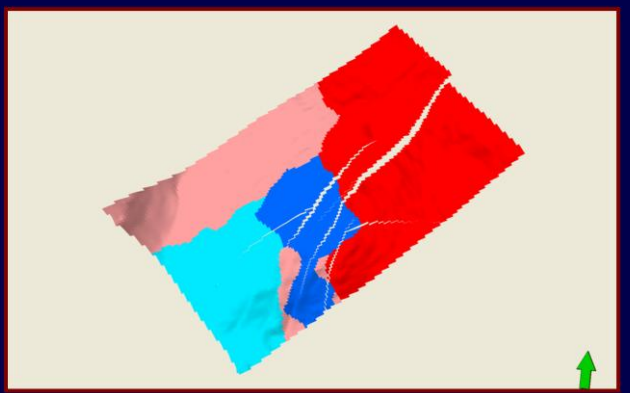
- One single grid is used

- Multiple models can be generated

- Honors wells, pressure and seismic data (if available)

Disadvantages

Challenging to control the geometry of the compartments



Conclusion

- Definition of pressure cells in the reservoir using 2-point geostatistics
- The pressure compartments are separated by layers of shale (stratigraphic compartmentalization)
- Multiple realizations can be generated
- The approach is straightforward to implement in a workflow