3D Modeling and Reservoir Uncertainties: A Case Study

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Introduction

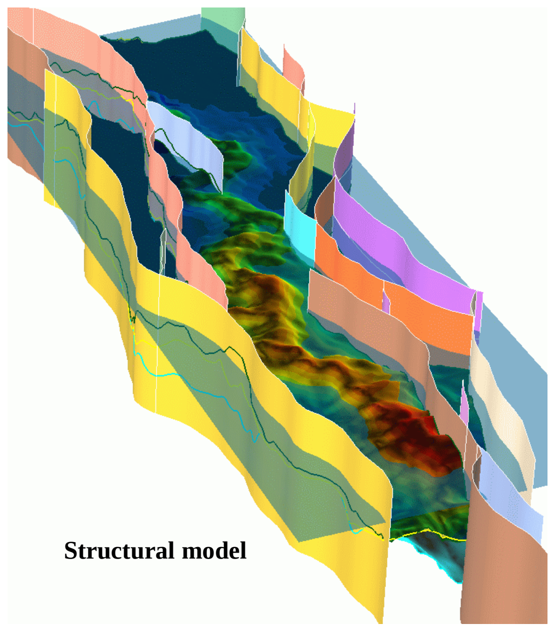
The present paper illustrates, through a case study, the objective, methodology, tools and benefit of a 3D integrated study with uncertainties.
This presentation covers only the static part of the modeling and uncertainty integrated workflow of a global study.
The reservoir is a deep-water channel system within which 5 individual turbidite channels are identified from wells, from average amplitude maps and from seismic lines.

Workflow

Structural Modeling

The structural modeling step is done with GOCAD.
It consists in completing the seismic interpretation in the depth domain. The resulting structural model is the framework for the following steps.
The seismic interpretation provides data for the structural model. This data includes:

- A Set of Points for each of the three horizons (depth converted).
- Fault Polygons per horizon.



Structural model

Fault Network Modeling

First a Z location is given to each fault polygon.
Next a fault surface is built through the 3 fault polygons of each fault.
The building of a fault network includes both:

- The fault construction.
- The fault to fault hierarchy and contacts.

Horizons Modeling

Once the fault network is built the horizons are constructed based on the depth-converted set of points, the well markers and the fault network.
The intermediate horizon being erosive, the lower horizon once built independently is cut by the intermediate horizon.

Model simplification

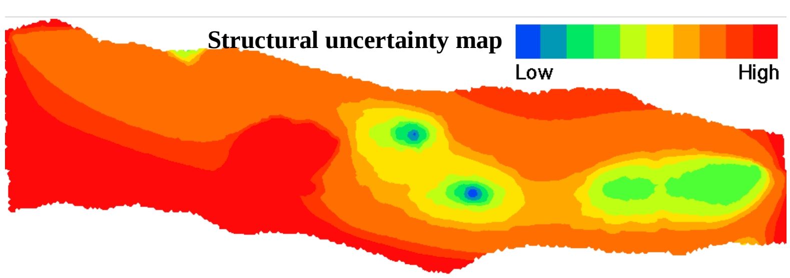
After a detailed analysis of the diping of the faults compared to the reservoir thickness, it has been decided to verticalize the faults. This was done in order to simplify the geometry for the downstream part of the study (static and dynamic reservoir).

Structural Uncertainties

The structural uncertainties processing is performed by ALEA. ALEA is a GOCAD based in house product.

Uncertainty map estimation

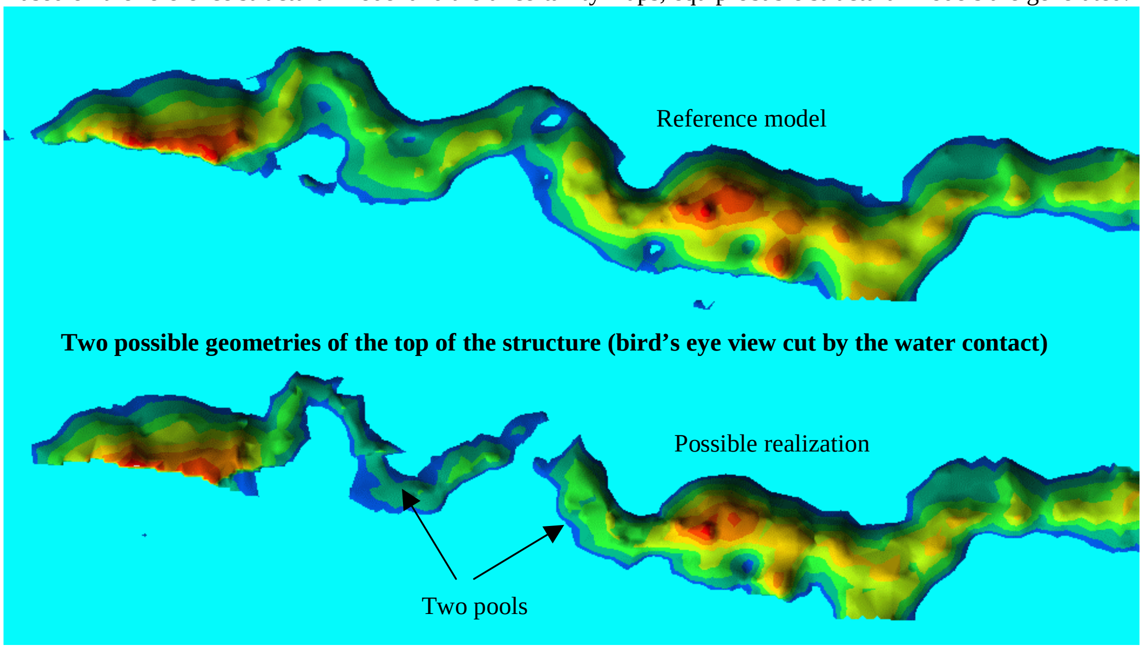
The depth maps resulting from the seismic interpretation are affected by uncertainties.



An uncertainty map is generated for each horizon. It combines the picking uncertainties with the uncertainties related to the time to depth conversion.

Equiprobable simulated models

Based on the reference structural model and the uncertainty maps, equiprobable structural models are generated.



Two possible geometries of the top of the structure (bird's eye view cut by the water contact)

300 realizations of the geometry have been performed.

Volumetric and Geometric analysis

This high number of simulated equiprobable structural model allows to statistically analyze the impact of the structural uncertainties on the gross rock volume.

Successively reviewing in a GOCAD camera all the possible geometries is important to understand the local geometrical impact of the structural uncertainties.

In this specific study, the simulated horizons demonstrate that the channel system can be geometrically divided into two disconnected pools of oil drastically affecting the development plan.

Geological Model

It consists in incorporating internal horizons defining 5 channels. They are used to build the reservoir grid geometry. Well information, amplitude maps are combined with geological insight to define Architectural Elements.

Channel geometry

The individual channels cannot be easily picked on the seismic due to the their complex geometry, their thickness and the fluid effects.

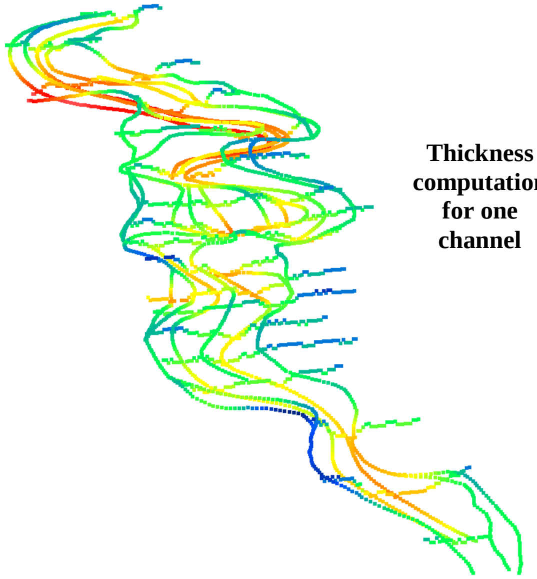
They have been modeled based on two complementary information:

- The interpreted average amplitude maps (which usually integrate several channels)
- A few picked seismic lines (about 20) over the area of interest.

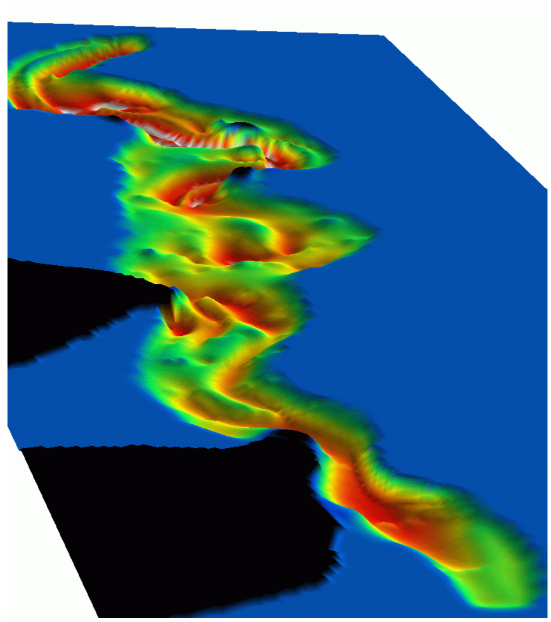
The average map allows an interpretation of the bird's eye shape of the channels while the picking describes the depth location and the thickness of the channels.

Curves following the meandering of the maps and linking the high and low thickness points from the picking are added, to allow to compute the channel thickness maps.

After generating the five thickness maps the channels are located in depth within the structural model. A special care is given to their connection.



Thickness computation for one channel

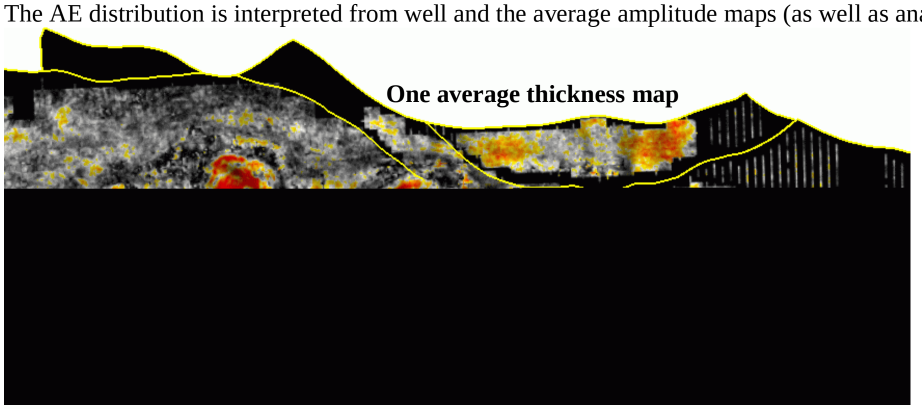


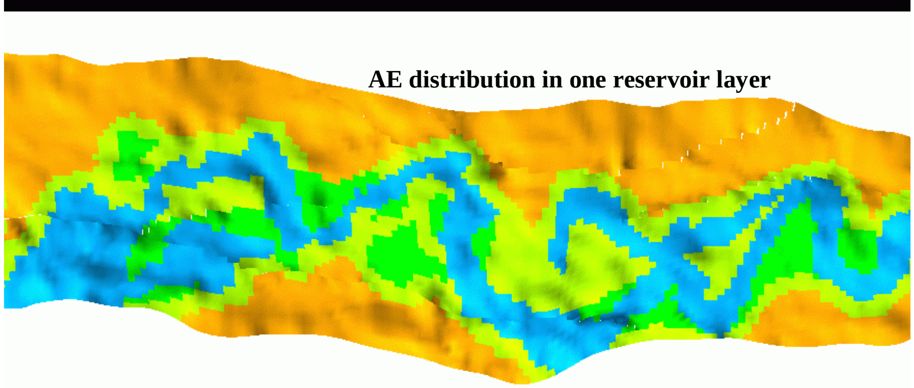
Gridding

A Reservoir grid is created. It includes all the faults. The macro-layering is defined by the structural horizons and the 5 channels. Within each channel the layering follows depositional information identified at the wells (proportional or parallel to the top, cell thickness allowing to reproduce the main heterogeneity).

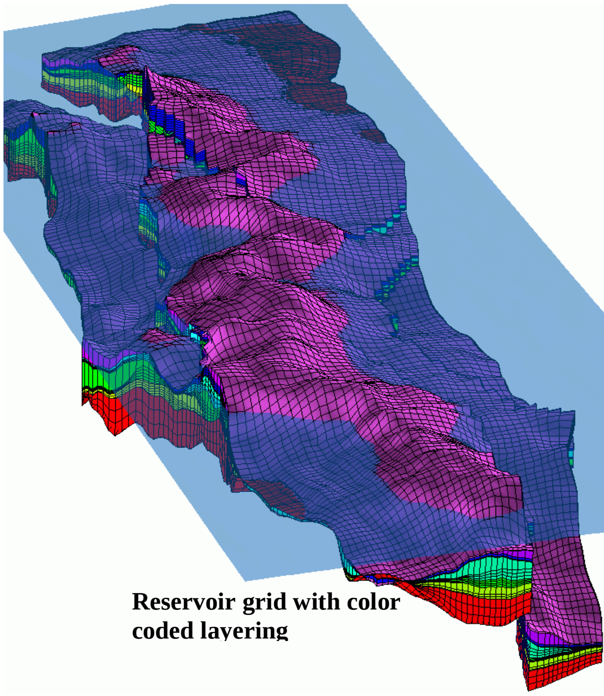
Filling with Architectural Elements

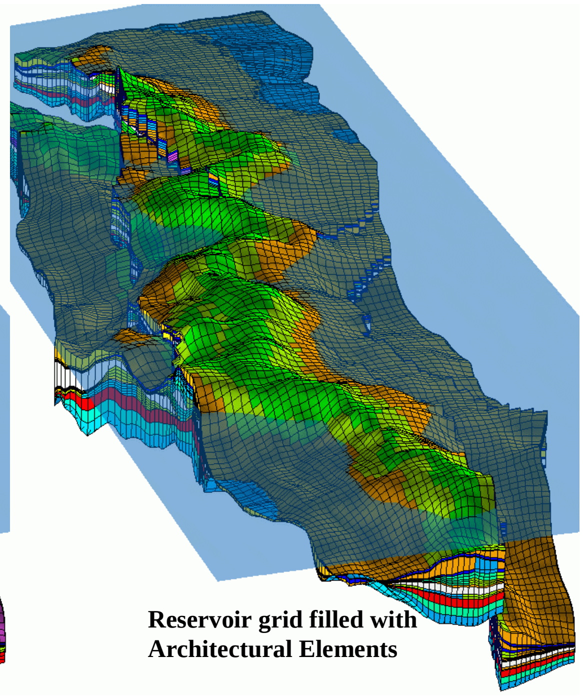
Each channel was then filled with Architectural Elements (AE).
The AE distribution is interpreted from well and the average amplitude maps (as well as analogs).





A channel sequence starts from some erosive debris flows, and evolve towards a sand body before being abandoned and covered by shale. A channel can be erosive and therefore allows connection between reservoir units.





Geological Uncertainties

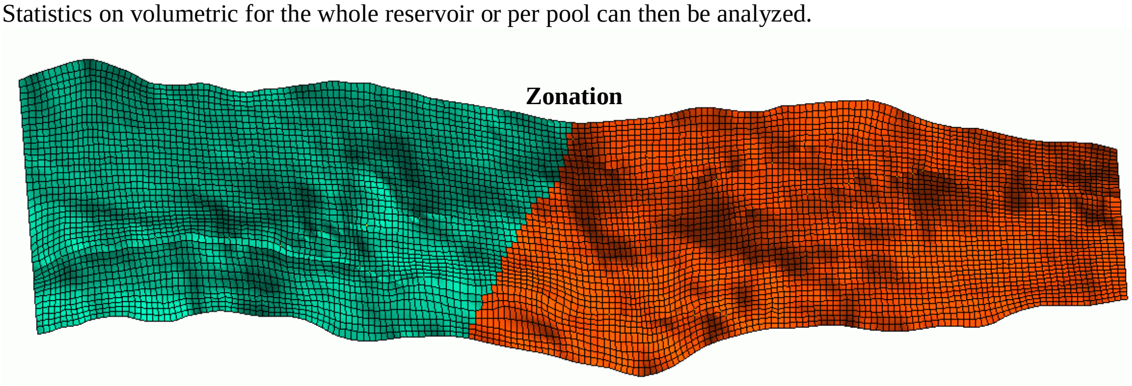
This part of the study is based on JACTA. A GOCAD based product developed by T-Surf for Elf. JACTA is now a commercial product from T-Surf.

Description of the methodology

In this example no uncertainty is applied to the AE distribution.
An Architectural Element (there are seven of them) is filled by a combination of Architectural Facies (there are 8 of them). The proportion, and distribution of each AF depends on the considered AE.
Each AF is characterized by a distribution of Porosity, Permeability, Net to Gross and Water Saturation.
For the static reservoir uncertainty analysis, three scenarios are done (a low case, a medium case, an upper case). Each case has its own proportion of AF per AE.
The AF are simulated using Sequential Indicator Simulation. Within each AF, the petrophysical parameters are simulated using Sequential Gaussian Simulation.
The AF and petrophysical uncertainties are combined with the geometrical realization given by Alea.

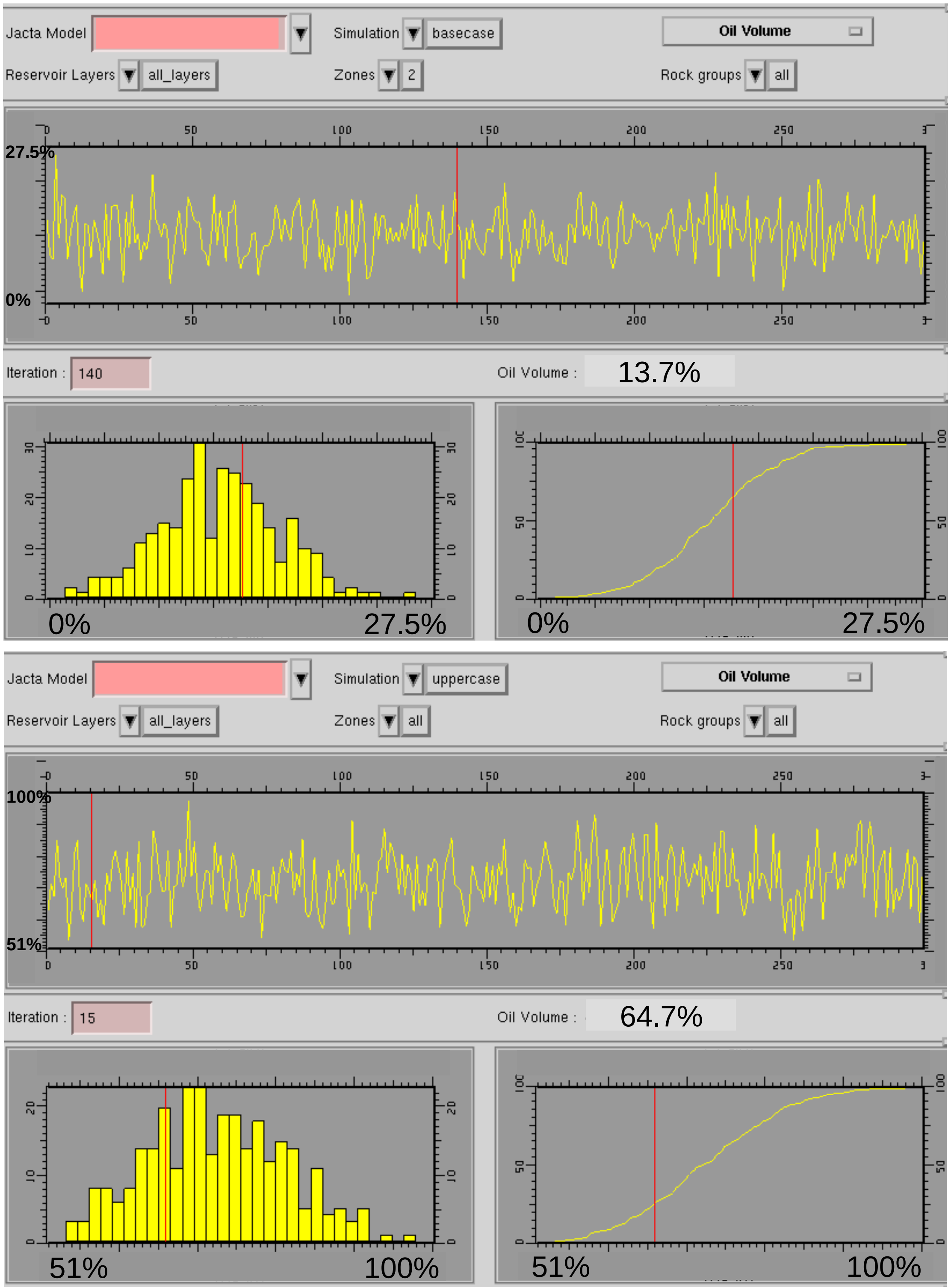
Spatial zonation

The ability of Jacta to define a spatial zonation is used. The zonation limits the possible two pools shown by Alea.
Statistics on volumetric for the whole reservoir or per pool can then be analyzed.



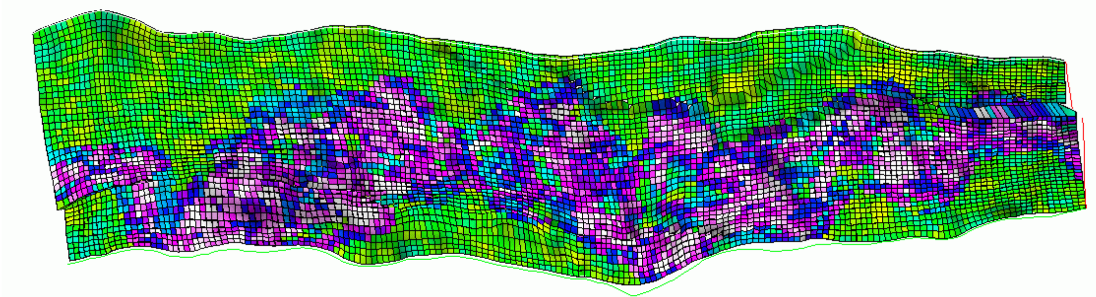
Simulation

300 simulations are performed for each of the three scenarios.

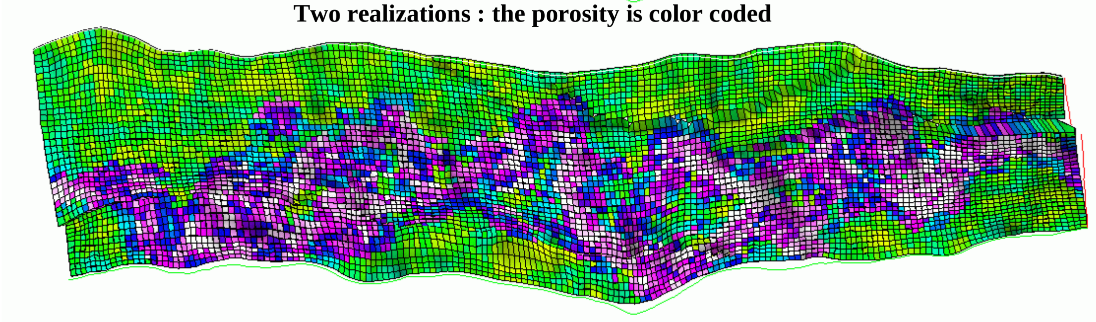


Remark: For confidentiality reason, in the simulation panel the volume is expressed here in percentage (0% for the lower realization of the base case and 100% for the higher realization of the upper case.

Each of these simulation can be accessed and analyzed in detail for the geometry, for the AF, and for the petrophysical parameters.

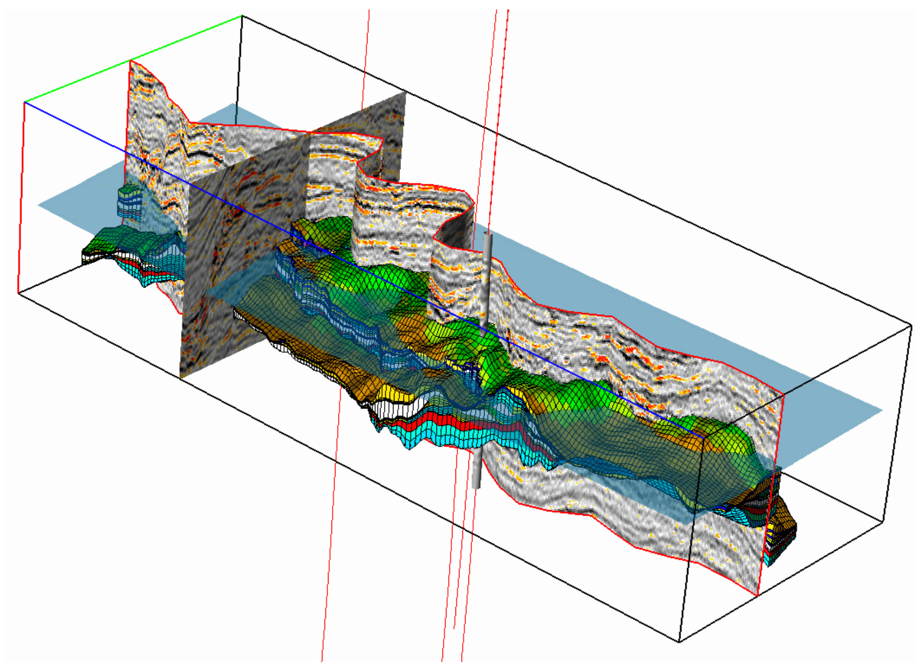


Two realizations : the porosity is color coded



Data integration

The reservoir grid has been converted back in time to compare the reservoir model with the seismic.



Conclusion

If 3D Modeling is now well established as a central piece of an integrated study, the systematic quantification of 3D Uncertainties is quite new in our industry. Elf Exploration Production has developed a unique set of tools "Alea Jacta Est" for assessing and combining uncertainties. "Alea" is an in-house product dedicated to structural uncertainties, this tool which uses GOCAD libraries, may soon be industrialized by T-Surf. "Jacta", now a commercial product from T-Surf, was initially developed for Elf; it combines the geometrical and static reservoir uncertainties. "Est", not covered in this paper, is an in-house product adding the dynamic part to the uncertainties; following suggestion from Elf, T-Surf has incorporated dynamic capabilities into "Jacta" by connecting "Jacta" to 3DSL. Such a workflow allows to assess risk both for economic decision and for development plan.