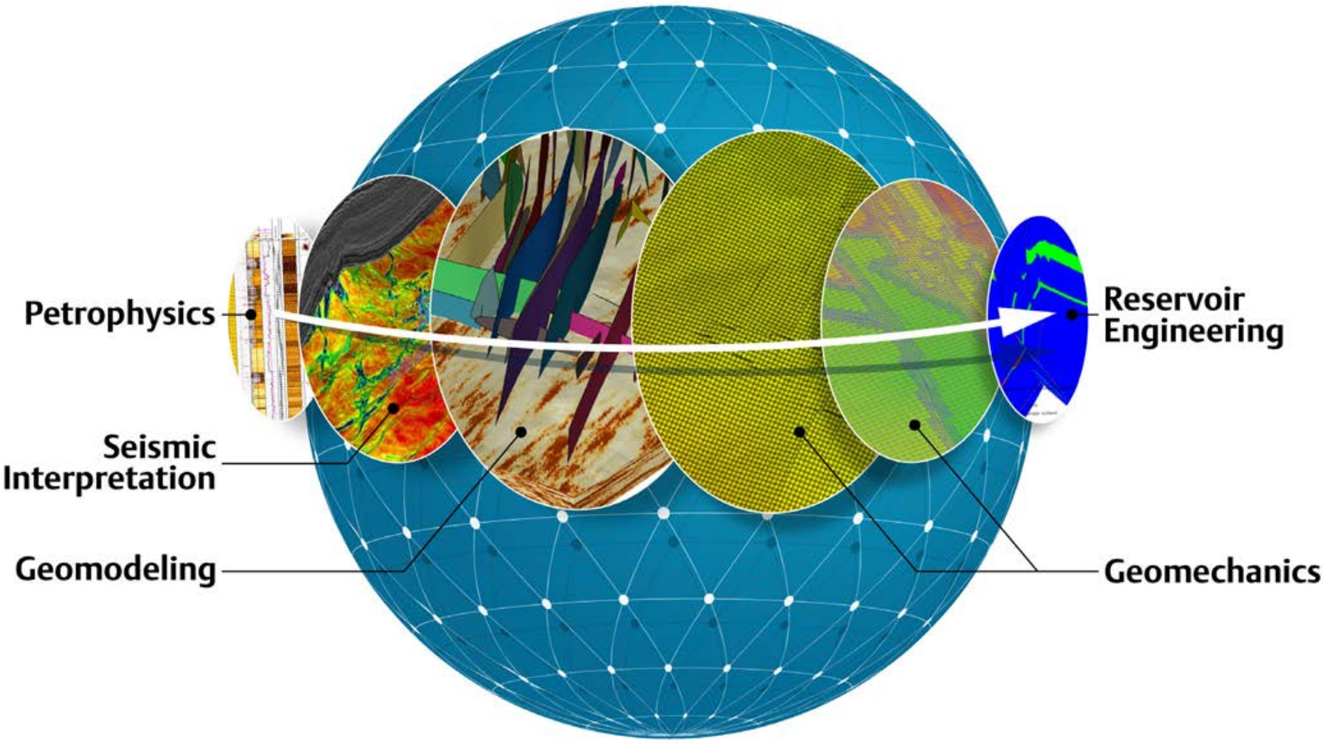
White Paper
October 2018

Managing Production Risks with Accurate 3D Geomechanical Models

Integrate Geology and Geomechanics with SKUA-GOCAD™ 18



Emerson E&P Software

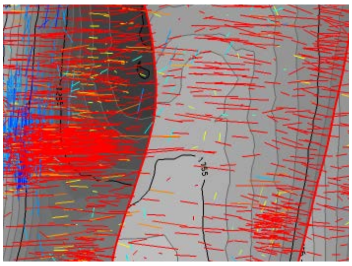
www.Emerson.com/Paradigm

The Challenges

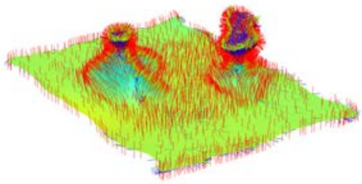
Sustainable field management cannot be performed without a thorough knowledge of reservoir mechanics and how it changes throughout the life of the field. These changes can affect infrastructure, well stability, life expectancy, reservoir productivity, and consequently investment and revenues.

Reservoir mechanics requires advanced Finite Element Models which preserve all of key complexities.

Structural complexities, rock properties and depletion strongly impact the 3D stress field, i.e. reservoir geomechanics, eaning that they affect all field management decisions.



Sh,max after 25 years of production is displayed in SKUA-GOCAD. Stresses are locally reoriented in the fault neighborhood.



Orientation of the principal stresses are locally changed along weaker salt diapirs.

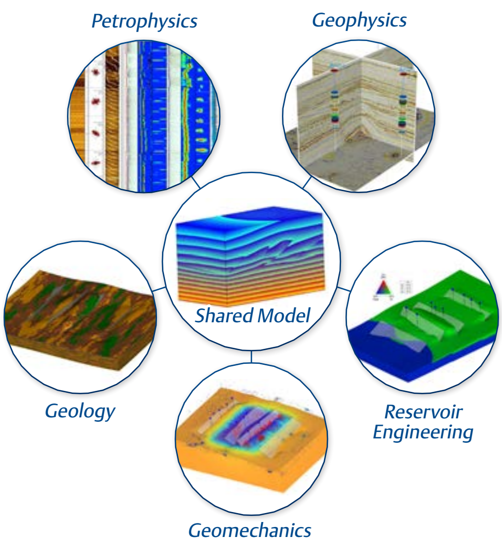
The Emerson Solution

Automated geology to geomechanics workflow

Advanced 3D gridding technology

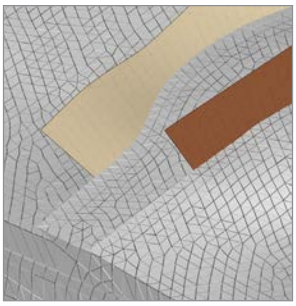
We propose an innovative workflow that enables the integration of all information from different sources into a common framework - the SKUA model. We then propagate the information back across domains so that all models are consistent with one another and integrate all the key information, with no unwarranted simplification.

This solution also benefits from the cross-domain, open SKUA-GOCAD platform, enabling reconciliation between Geoogy and Geomechanics, for more accurate geomechanical models.

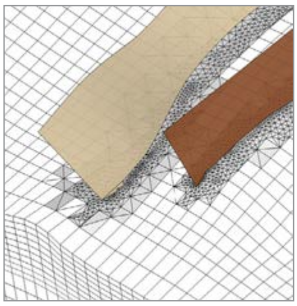


Emerson E&P Software offers a superior 3D gridding technology to ensure the generation of optimal Finite Element Meshes that fully capture current and future reservoir geomechanical behavior. They are optimized for any FE geomechanical simulator.

Through a partnership with Dassault Systèmes, accurate subsurface models are transferred seamlessly to Abaqus for geomechanical simulations. An efficient link delivers all the information needed to set up and run advanced geomechanical simulations, and obtain valuable results, such as stress field, subsidence, fault reactivation, etc.



SKUA-GOCAD tetrahedral grid

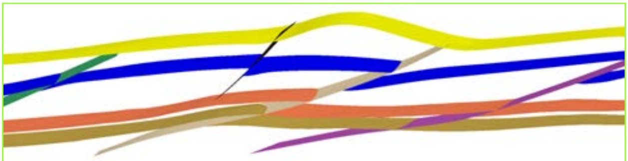


SKUA-GOCAD hybrid grid

- Accurate and reliable reservoir mechanical model
- Better stress estimation in reservoirs
- Optimally manage reservoirs and control production

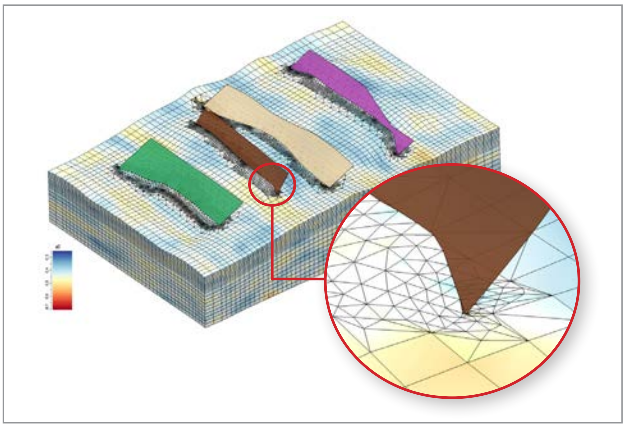
Reverse-Faulting Case Study

The model was generated for a field located in highly distorted foothills. The aim of the study was to evaluate the impact of depletion in one of the reservoirs located along a faulted anticline. An initial high-resolution geologic model integrating all information related to rocks, faults and fluid properties was generated. A stair-step flow simulation model integrating all reverse faults was derived from the geological framework. Then, 25 years of oil and water production were simulated in a standard finite difference flow simulator. The dynamic simulation results were brought back to the geomodeling platform so that both the geological and flow models fed the geomechanical model.



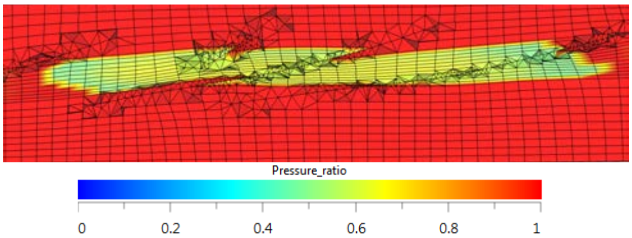
Geological framework displayed in cross-section in SKUA-GOCAD. The compressive context generated faulted folds.

The geomechanical model was generated from the common framework which was used to build the geological and flow model. It took the form of a hybrid mesh composed of two types of elements: Most of the grid was composed of regular hexahedral cells. In some areas, they were replaced by tetrahedra for better capturing structural complexities such as faults. This resulted in a 450.000 cell geomechanical model that was built from scratch in 2 hours.



The 3D mechanical model generated using SKUA-GOCAD includes various element types, so that it perfectly captures all subsurface complexities that may impact reservoir geomechanics. Here the Void property is painted on the grid.

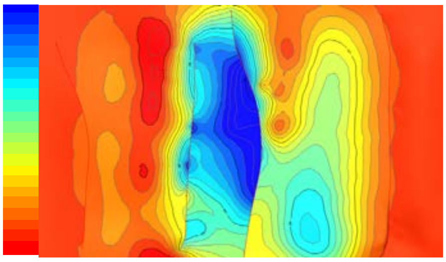
The grid was populated with the rock and fluid properties from the geologic and flow models that are required for geomechanical simulations.



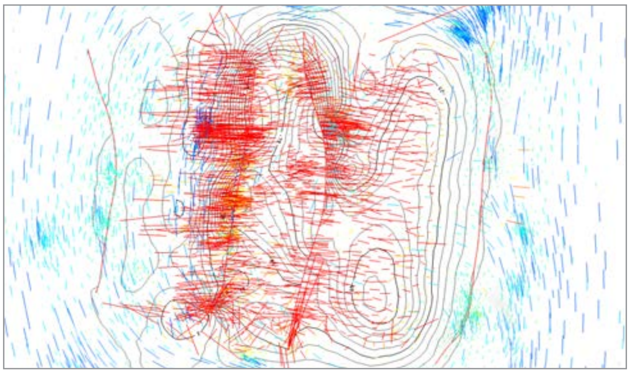
Flow simulation grid section displayed in SKUA-GOCAD. In the reservoir, pressure had decreased by 40% after 25 years of production.

Results

Simulations ran for the 25 years of production, during which the reservoir pressure has decreased by 40%. Results showed that it largely impacted reservoir subsidence. We can measure a maximum of 10m subsidence. Faults also have a major impact on the stress distribution, causing rotation of the main stress orientation before and during production.



Subsidence map of top of reservoir after 25 years of production



A map of the distribution of Sh,max principal stress component created in SKUA-GOCAD. As indicated by the blue to red lines, Sh,max is dramatically re-oriented n the promixity of the fault.

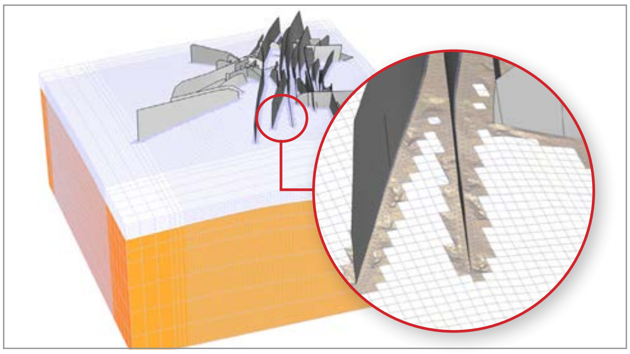
Thanks to the automated and integrated SKUA-GOCAD workflow, the overall process took less than two days. It made accurate geomechanical risk assessment easily achievable in record time.

Geologic Modeling

Extensive and Highly Faulted Case Study

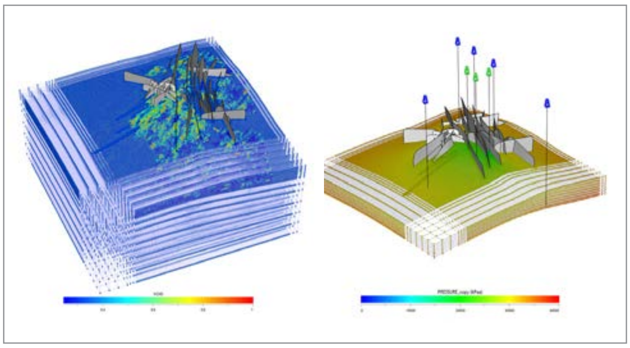
The 3D geomechanical model was generated for a field in the North Sea. It includes a dense fault network cutting through silicoclastic layers where the reservoir lies, and a shallower robust limestone layer. This complex 3D configuration needed to be geomechanically analyzed before continuing field development and production.

The geomechanical model was generated from the common framework which was used to build the geological and flow model. It takes the form of a hybrid mesh comprising two types of elements: Most of the grid comprises regular hexahedral cells. In some areas, they are replaced by tetrahedra for better capturing structural complexities such as faults. This resulted in the construction of a 3-million cell geomechanical model in 5 days.



The 3D mechanical model created in SKUA-GOCAD includes different types of elements so that it perfectly captures all subsurface complexities that may impact reservoir geomechanics.

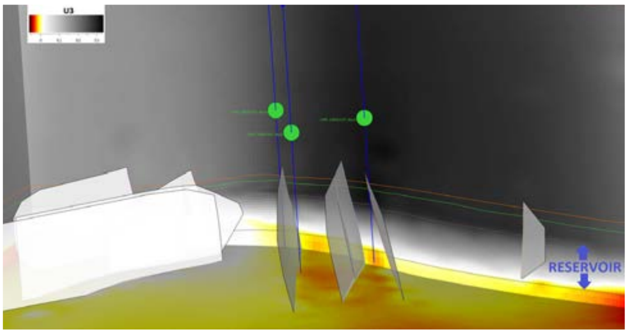
The rock and fluid properties were generated in a geological and flow simulation model. Because these models are linked by the common shared framework, the properties required for geomechanical simulation were transferred to the hybrid grid, while preserving geological consistency. This is key, especially in this case where faults and stratigraphy make rock properties vary rapidly in both areal and vertical directions, resulting in highly heterogeneous models at all scales. For capturing rock mechanic variations with depth and between silicoclastic and carbonated facies, a layer-based model of materials was also defined.



The void (left) and pressures (right) were consistently painted into the geomechanical model.

Initial boundary conditions were set up so that the bottom and side of the model were fixed. It then submitted to gravity, fluid pressure and stresses. However, the subsurface system was under-constrained and multiple uncertainties remained. Computing an acceptable initial stress state was challenging, especially in this highly faulted environment, as slip might occur. At the end of three days of model calibration, 40 years of production were simulated in one day using a 20-CPU cluster.

Results showed that few subsidence has occured and the faults are stable. After two weeks of analysis, it was possible to validate the production plan that might impact field production for decades.



The vertical displacement resulting from production can be forecast in the reservoir. Here, depletion makes the overburden move downward when the underburden rebounds upward, resulting in reservoir compaction.

Thanks to the SKUA-GOCAD integrated and automated solution, accurately assessing geomechanical risks in a reduced time frame has become a reality!

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