SUBSURFACE ALLIANCE

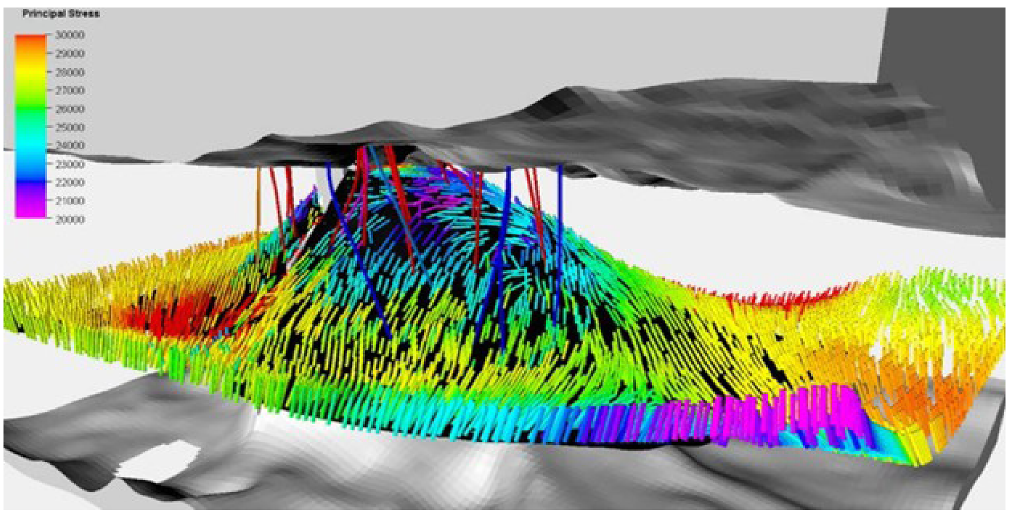
DATA DRIVEN | SCIENCE BASED | FIT-FOR-PURPOSE

If you check the box, you need a 3D:

- ☑ Seal/Casing Integrity
- ☑ Induced Seismicity
- ☑ Mature field
- ☑ *Compaction/Subsidence*

We are multi-discipline subsurface specialists using a team-of-teams approach to efficiently solve problems that have a direct business impact in today's fast-paced and evolving energy industry.

We provide high quality subsurface solutions by bridging the gap between geoscience and engineering.



Complex problems often require advanced models. We offer 3D geomechanical models for those more challenging situations where our clients require advanced numerical solutions. Starting from a 1D geomechanical model, it is possible to generate three-dimensional models with the adequate detail and resolution to address any problem at hand. As opposed to the general thinking, not all 3D models are the same. **Our models are customized to our clients needs.** For instance, the degree of resolution and accuracy needed for wellbore stability studies is not the same that what a compaction study might require. Investing in a 3D model ensures long-term benefits during field development and production. These models when appropriately maintained are long-lived and can be regularly updated providing the user a one-stop-shop for most of their geomechanics needs.

STATIC GEOMECHANICAL MODELS

They are the simplest kind of geomechanical models and provide a three-dimensional representation of the subsurface in situ stresses and rock mechanical properties for a given pore pressure scenario (Figure 1). These models are adequate for two types of situations:

1. when there is a large number of offset wells, and there is a drilling campaign ahead. This 3D model can integrate all well data and provide a volume where the user can plug-and-play infinite new trajectories to **optimize their drilling trajectories**.
2. when assessing the risk of **fault reactivation at a screening level** in areas with seismically resolvable faults, the static 3D model allows to map normal and shear stresses on the fault planes to estimate critical injection pressures.

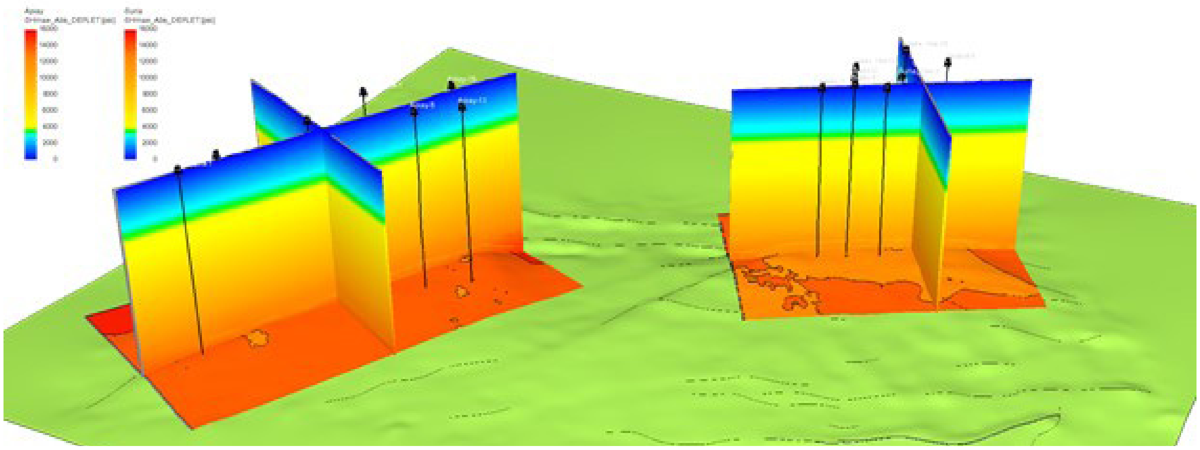


Figure 1. Example of a static 3D model built for two nearby fields with close to 100 wells available. The figure displays the magnitude of the overburden stress on each field and the location of some key wells. Figure from Fernandez-Ibanez et al. (2010), SPE 138869.

COUPLED GEOMECHANICAL MODELS

One-way or two-way **coupled models** use Finite Elements Method (FEM) to generate a grid describing the reservoir (in great detail) and the overburden to the seafloor or ground levels. Models also include underburden and sideburden as well as any more complex geological structures like salt or shale diapirs. Seismic interval velocities are a key input to populate the grid with both in situ stresses and rock mechanical properties. Once a stress model is initialized, these models can be used to incorporate multiple scenarios of pore pressure evolution in the reservoir as a function of injection or depletion operations.

For each pore pressure scenario, a FEM simulation can be conducted to determine the stresses/strains induced by the pore pressure changes. As a result, **compaction/dilation** and correspondent **subsidence/heave** levels can be computed up to the ground level or seabed. In our latest developments we can integrate ground level displacement measurements coming from **InSAR** into the modeling workflow to calibrate the model results. This is particularly relevant to **CCS** and **waste water injection** projects where plume monitoring becomes a critical path to the success of a project.

Injection and production operations induce strains which can compromise **casing integrity** over the production lifetime of a field. In this analysis, a well-centered mesh is built around a selected well (Figure 2). Mechanical properties, stresses and displacements are captured in the well-centered model. Proper mechanical properties are used for the casing and cement. The well-centered mesh is run for each timestep (i.e. change in reservoir pore pressure) so that the induced strains in the casing are calculated. Strains are then compared to steel critical strains to assess whether the well casing is at risk at any point during production operations.

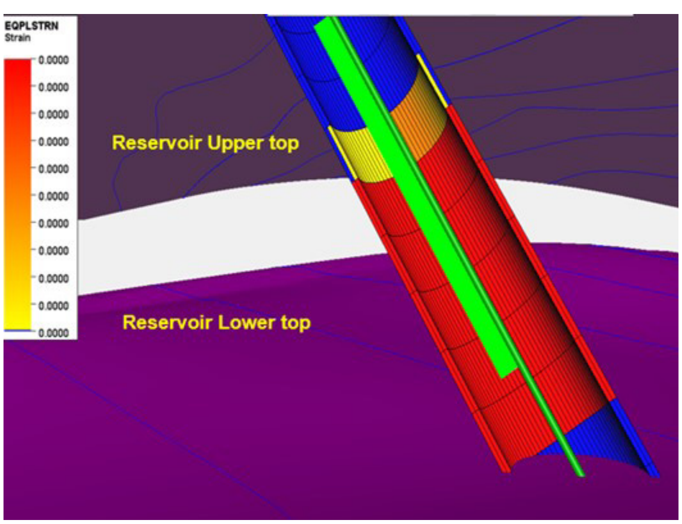


Figure 2. Example of a wellbore centered FEM mesh employed for casing integrity assesment. Araujo et al. (2019) American Association of Rock Mechanics.

Simulation results can be used to more accurately assess the **risk of fault reactivation** by mapping plastic strains along fault surfaces. This becomes a powerful tool to assess faults that pose a high risk of failing or might have undergone aseismic slip.

Similarly to the fault stability case, changes in reservoir pressure (usually related to injection operations) can result in a negative effective stress scenario in the **caprock**, which effectively will fracture the reservoir seal. In our 3D models we run scenarios of increased pore pressure in the reservoir near the wellbores to mimic injection operations. For each scenario, a 3D transient model is run to determine the magnitude of least stress in the cap rock, thus providing the maximum injection pressure allowed to prevent failure.