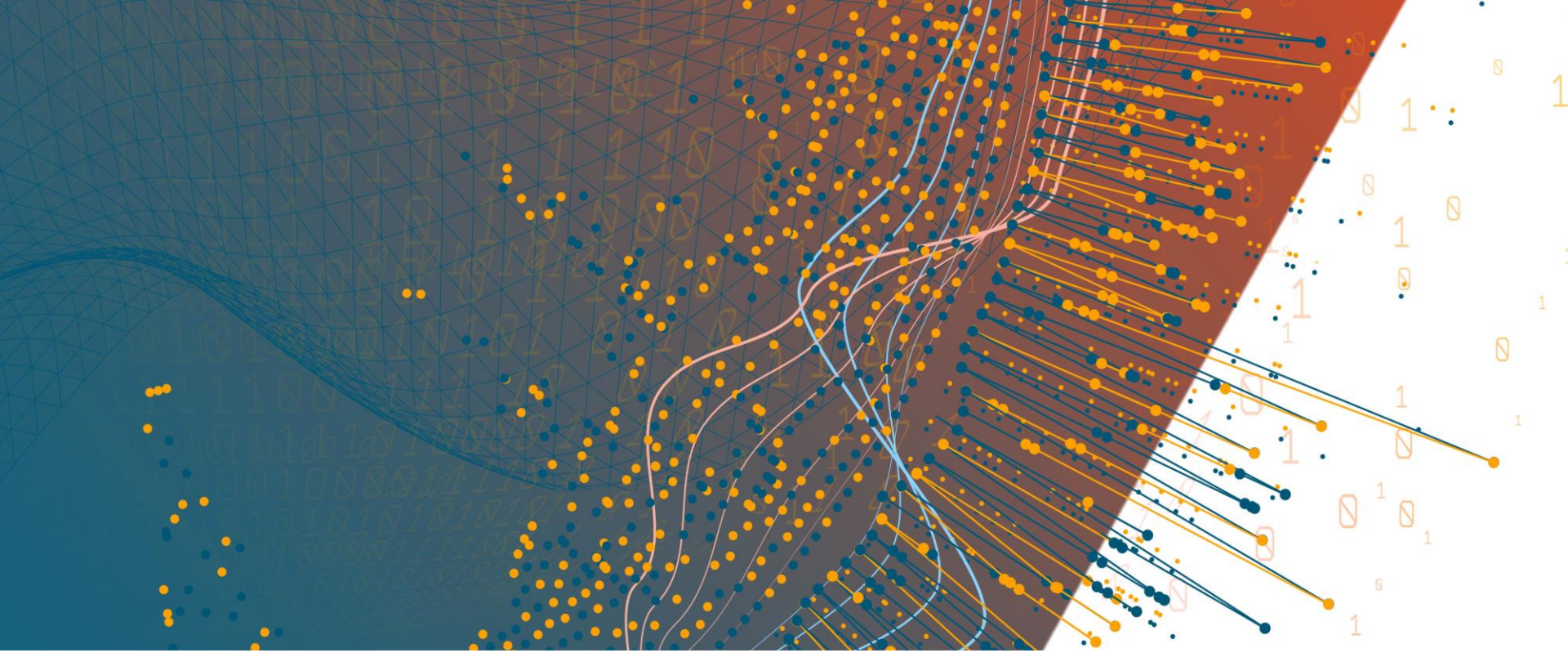

ALTAIR | GEOMECHANICA

IRAZU TOP USE CASES

Altair Partner Alliance

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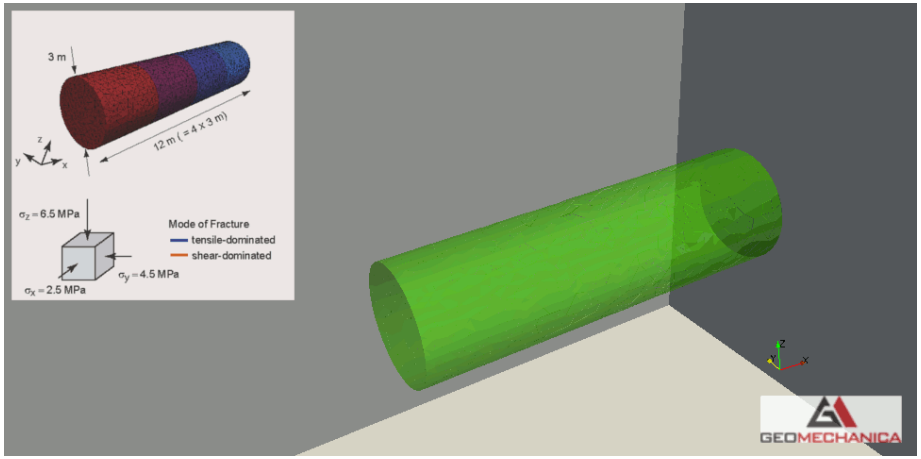
Safety Assessment for Nuclear Waste Repositories

Challenge

- Typical characteristics that make a rock mass suitable for nuclear waste storage include low hydraulic conductivity, low diffusion coefficients, good retention capacity for radionuclides, and potential for self-sealing of fractures.

- A major concern is that the isolation properties of the rock mass could be negatively impacted by rock fracturing during construction of underground structures such as emplacement tunnels and caverns. Therefore, the analysis and prediction of the excavation damaged zone (EDZ) and its evolution with time is a crucial step for the assessment of both short- and long-term safety of a nuclear waste repository.



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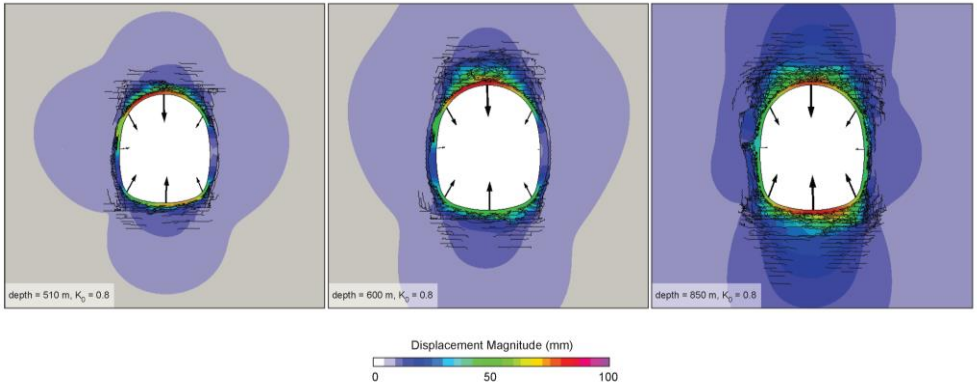
Safety Assessment for Nuclear Waste Repositories

Solutions

- Irazu enables numerical simulation of rock fracturing processes based on non-linear fracture mechanics formulations.
- Staged excavation sequences and rock support (e.g., rock bolts, concrete liners) can be included to achieve a more representative short-term response of the rock mass. Using coupled multiphysics solver capabilities, the long-term behavior of the system can be examined while considering a suite of thermo-hydro-mechanical processes, such as effective stresses, fluid flow through rock fractures, and heat conduction and convection.
- Fracture networks can be used as input for third-party hydraulic flow models. Thanks to state-of-the-art GPU computing all calculations can be carried out with unprecedented speed given the high level of physical complexity.



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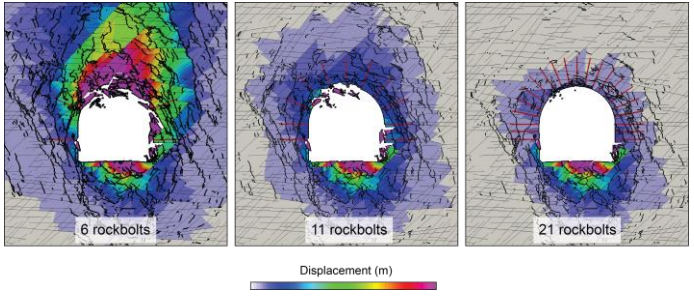
Safety Assessment for Nuclear Waste Repositories

Results

- Successfully back-analyze the rock mass around a test tunnel and provide unique insights into possible EDZ fracture patterns around an emplacement tunnel for nuclear waste at the Mont Terri Underground Rock Laboratory in Switzerland.
- Interpret key mechanisms associated with the swelling of the bentonite backfill, including the long-term reduction of fracture porosity in the EDZ and the formation of highly conductive channels in proximity to the excavation walls due to fracture self-propping.
- Quantify possible variations of EDZ shape and extent as a function of the repository depth, in-situ stress regime, host rock strength and rock support stiffness.
- Supply critical inputs for long-term hydrogeological models: EDZ fracture networks (including fracture aperture, length and inter-connectivity) are used as input for hydraulic models considering long-term, hydro-mechanical effects associated with the pore pressure recovery (e.g., fracture closure, swelling of intact clay matrix).



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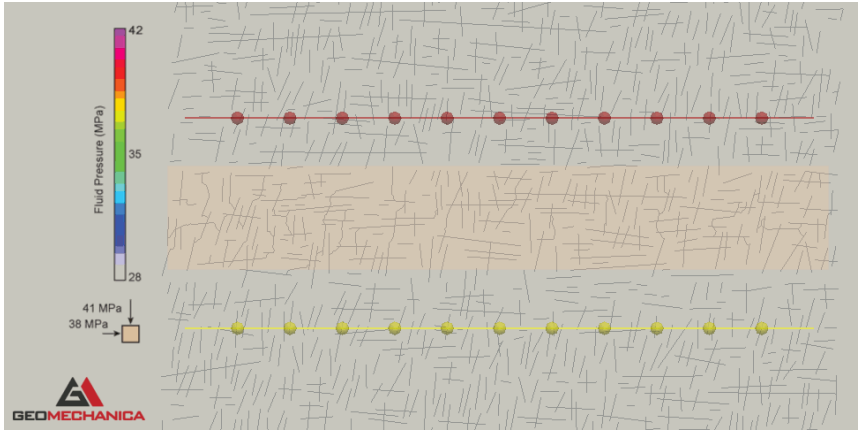
Geomechanical Analysis of Hydraulic Stimulation in Unconventional Reservoirs

Challenge

- Hydraulic fracturing is used to stimulate low permeability reservoirs to economically recover hydrocarbons.
- Similarly, hydraulic stimulation is also employed to enhance the permeability of geothermal systems and to precondition the rock mass in deep mining applications.
- Hydraulic stimulation program design is generally addressed with simplistic models tempered by local experience. These models commonly neglect interactions between injected and existing fluids, in-situ and induced rock mass stresses, newly-created fractures, and natural discontinuities.
- As a result, common design practices fail to predict the reservoir performance in response to changes in geomechanical conditions. These uncertainties may ultimately lead to treatment and recovery inefficiencies, loss of wells, and lower return on investment.



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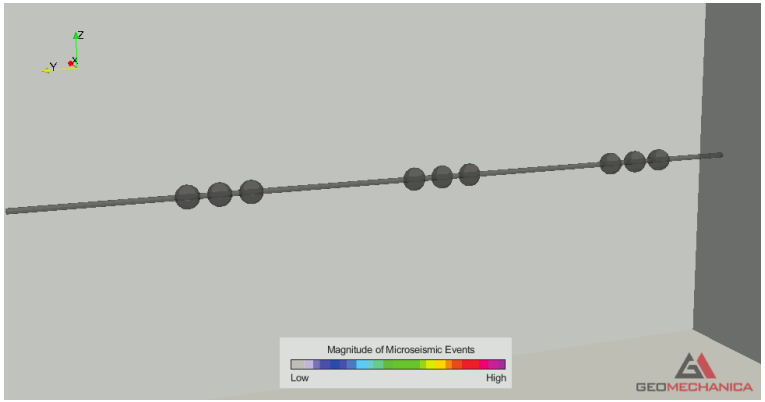
Geomechanical Analysis of Hydraulic Stimulation in Unconventional Reservoirs

Solution

- The Irazu simulation software is equipped with novel modelling capabilities that allow it to provide unique insights into geomechanical processes characterizing the stimulation and production of unconventional reservoirs. These modelling capabilities include:
  - a fully-coupled, hydro-mechanical solver including proppant transport and emplacement processes;
  - the incorporation of an unlimited number of faults, discontinuity surfaces, and heterogeneities; and
  - a fracture model accounting for tensile, shear, and mixed failure modes.
- The software enables accurate computation of stresses, strains, and fracture growth inside the rock at depth without minimal simplifying assumptions regarding fracture shape and growth trajectory.



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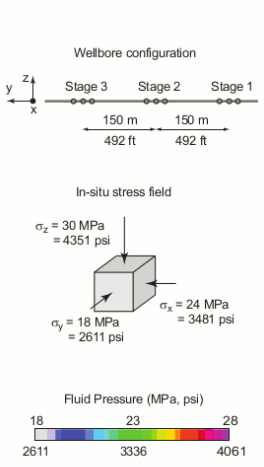
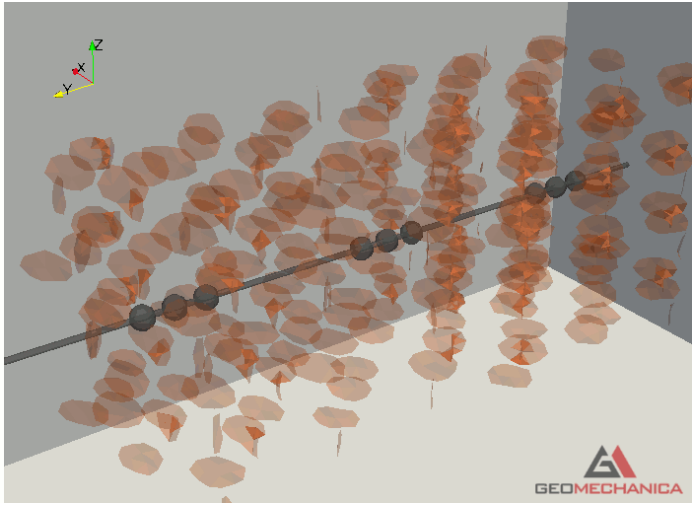
Geomechanical Analysis of Hydraulic Stimulation in Unconventional Reservoirs

Results

- Optimize hydrocarbon extraction operations by numerically experimenting with injection rates, wellbore spacing, and fluid properties.
- Reduce drilling and production costs by predicting and optimizing the stimulation process.
- Evaluate the effectiveness of new stimulation methodologies and techniques, including the analysis of completion strategy, well spacing, and stress shadow effects.
- Better understand the interactions between natural discontinuities, new fractures, and injected fluids. Thanks to novel fracture mechanics, discrete element method, and coupled physics formulations, complex interactions between existing natural discontinuities, new fracture growth, and fluid flow can be simulated without any limiting assumptions.





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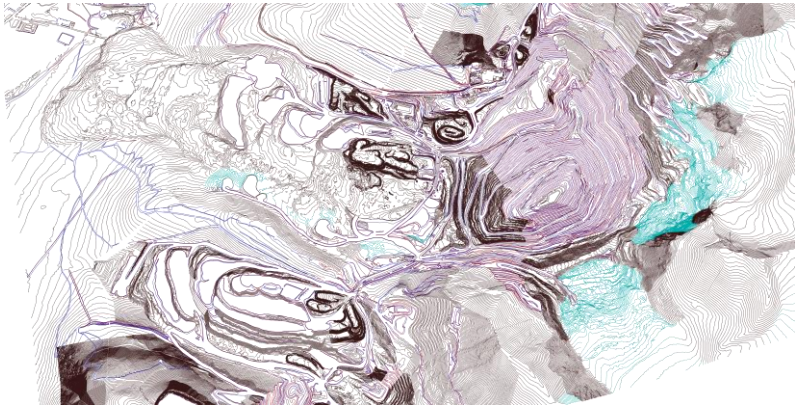
Performance Analysis of Open Pit Mine Walls

Challenge

- A large open pit mine has been undergoing significant wall deformations and instabilities. The rock mass behavior is characterized by an interplay of major discontinuity surfaces (faults and foliation) and groundwater flow.
- Parts of the pit wall have experienced accelerated deformation due to excess pore pressure and ongoing mining operations. A back-analysis of a current cutback is therefore required to (i) to help understand the deformation and failure mechanisms of the open pit and (ii) to calibrate the numerical model for subsequent forward-analyses of future cutbacks.
- Rock slope stability analysis using conventional numerical tools have often failed to correctly capture the main physical processes involved as they require numerous simplifying assumptions regarding the fabric of the rock mass (e.g., continuous, homogeneous, and isotropic) and its mechanical behavior (e.g., linear elastic or elasto-plastic).



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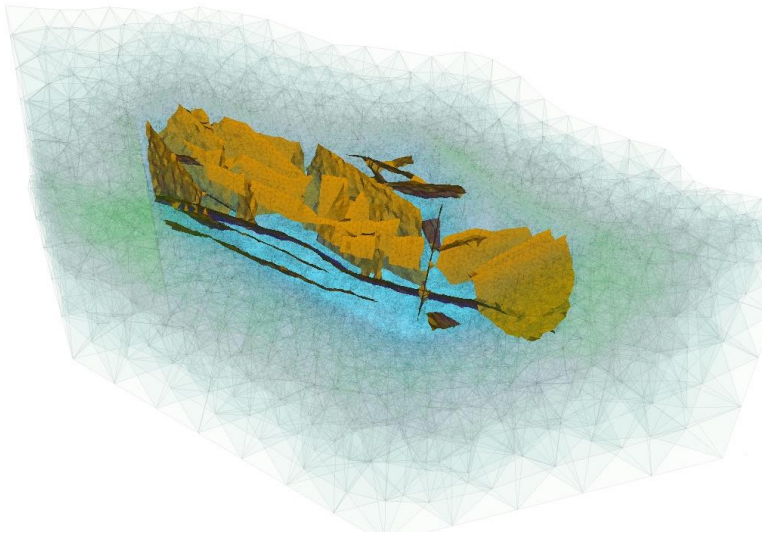
Performance Analysis of Open Pit Mine Walls

Solution

- Irazu can capture a wide spectrum of slope behaviors, including, continuum deformations, fracturing and complex failure kinematics, and large displacements, without the need for complex constitutive models.
- By integrating rock fracture mechanics and discrete fracture network (DFN) capabilities, Irazu can analyze brittle failure processes while accounting for joint persistence and termination effects. Since no assumptions are being made regarding the failure mode, a wide range of behaviors naturally emerge from the simulations from gravity-driven, structurally-controlled failure to stress-driven, brittle fracturing.
- Thanks to the coupled hydro-mechanical solver of Irazu pore pressure effects (e.g., effective stresses) can be considered together with coupled flow of water through rock fractures.



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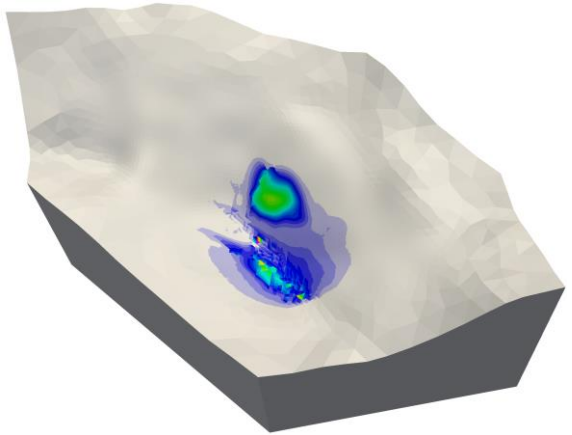
Performance Analysis of Open Pit Mine Walls

Results

- Successfully back-analyze the wall deformations of the current cutback by considering the complex fault network and interaction with groundwater flow, ultimately allowing realistic deformation and acceleration patterns to be numerically reproduced.
- Quantify the effect of pore pressure on wall deformations and slope performance, whereby the models confirm that groundwater flow through the faults could create large deformations on the slope.
- Predict the performance of future cutbacks under different geomechanical scenarios, including excess pore pressure and provide ranges of expected slope wall deformations.
- Capture complex failure and deformation regimes in the slope characterized by gradual slope deformations and multi-block interaction mechanisms (toppling).
- Suggest remediation strategies, such as dewatering campaigns, to further stabilize the slope, thus cutting costs and increasing mine safety.



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