Unlocking probabilistic 3D geomechanics with DELFI – Next-generation operational guidance for the Hokchi field, Gulf of Mexico

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Agenda

1. Introduction
2. Hokchi field resume
3. Project evolution
4. Model integration
5. Wrap up

Introduction

- The **Hokchi field** in the Southeastern Tertiary Basin in the **Gulf of Mexico** represents an **unconsolidated turbiditic** reservoir from the middle Miocene.

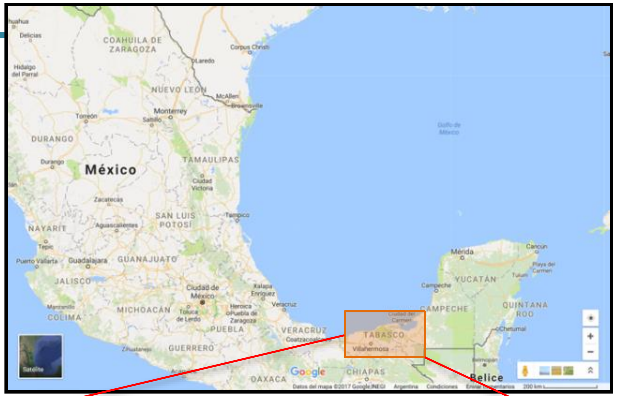
- To guide field development, a **3D Earth Mechanical Model (MEM)** was built based on data from 2 exploration wells and 5 delineation wells.

- The 3D MEM provides in-situ stress field information, which was directly applied for **wellbore stability analyses**, successfully guiding the initial selection of crucial drilling parameters and optimizing the sand control strategy to prevent the production of solids.

- In the next stage of field development, additional producers and injection wells are planned to help reach plateau production under varying pressure conditions.

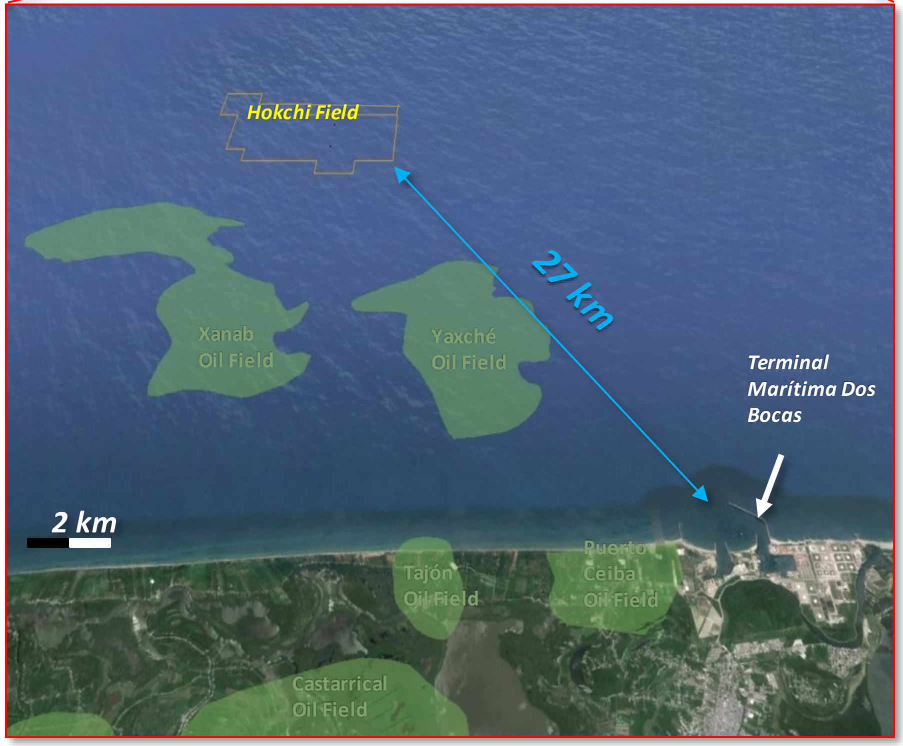
- This is achieved by generating **sets of 3D geomechanical simulations** that sample the corresponding parameter distributions and capture input uncertainty and different scenarios in a **consistent** manner, taking into account local stratigraphy, petrophysical and mechanical rock properties, as well as a depletion strategy with water injection and implementation of ESP.

Hokchi Field resume



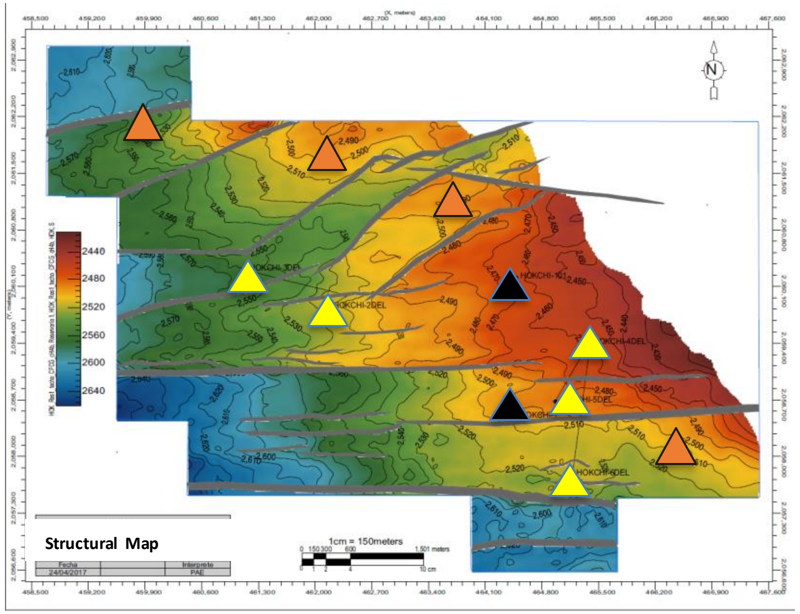
Location:

- Hokchi Field is located in the prolific Cuencas del Sureste Tertiary Basin, close to producing fields and recent offshore discoveries.
- In close proximity to Dos Bocas onshore Treatment Facilities.
- Block surface: 40 km^{2}.
- Water depth: 88 ft (27 m).



Existing wells:

- 2 Wells drilled by PEMEX (2009 & 2011).
- 5 Wells drilled by Hokchi (2016-2017) during delineation campaign
- 4 wells drilled by Hokchi (2021-2022) during development campaign



<u>Field operator</u>: PAE (Hokchi Energy)

Project evolution

HOKCHI energy

2022

Depleted field scenarios.
Model integration: New analisis and possibilities

2021

Field development continuos under original pressure scenarios

2020

Fields first oil

First Dynamic response adjustment

2018-2019

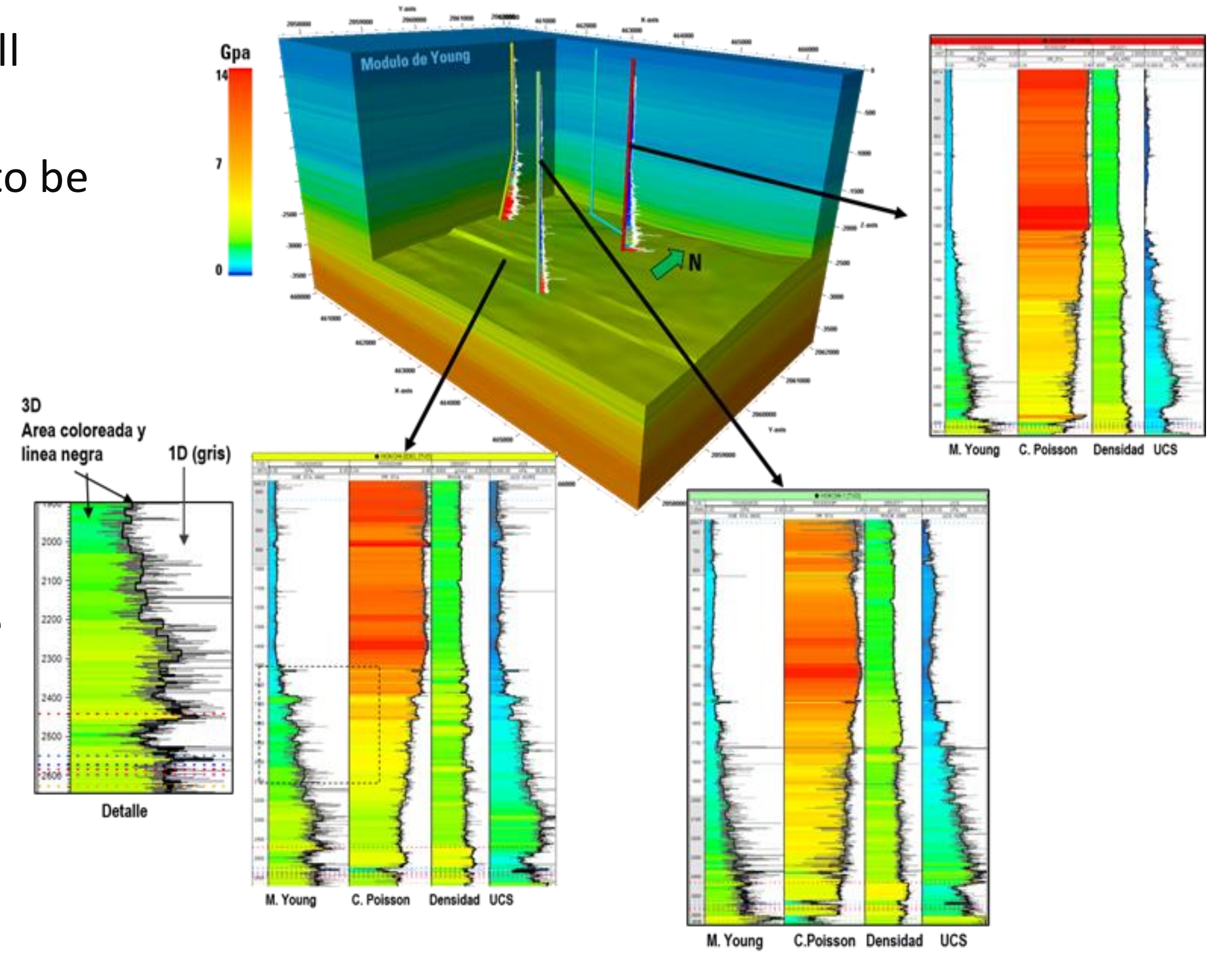
Single Dynamic model + single geomechanical model

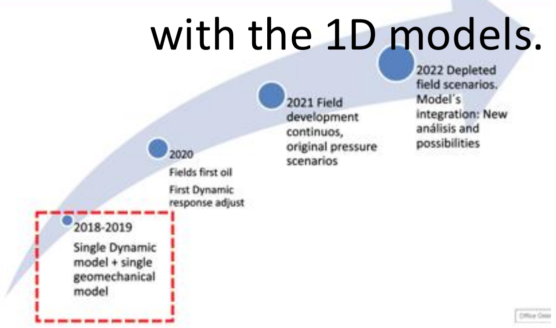
Project evolution

2018-2019 Single Dynamic model + single geomechanical model

- 1D model objectives:
  - ➢ Build a subsurface geomechanical model (MEM) using all the information from the 7 wells
  - ➢ Construction of the stability windows for the locations to be drilled in the development campaign

- Build a 3D geomechanical model starting from the results presented above in the 1D models.
  - ➢ Re-evaluate the stability windows for the locations to be drilled in the next campaign and compare the results with the 1D models.

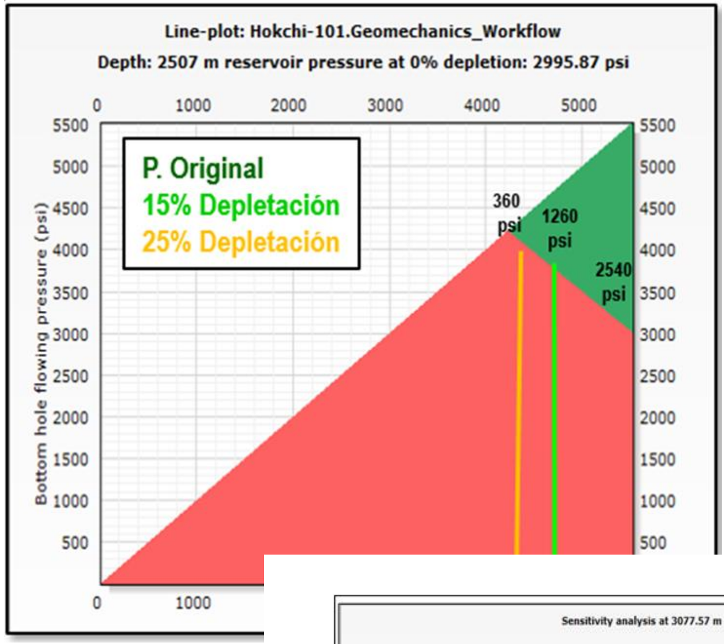


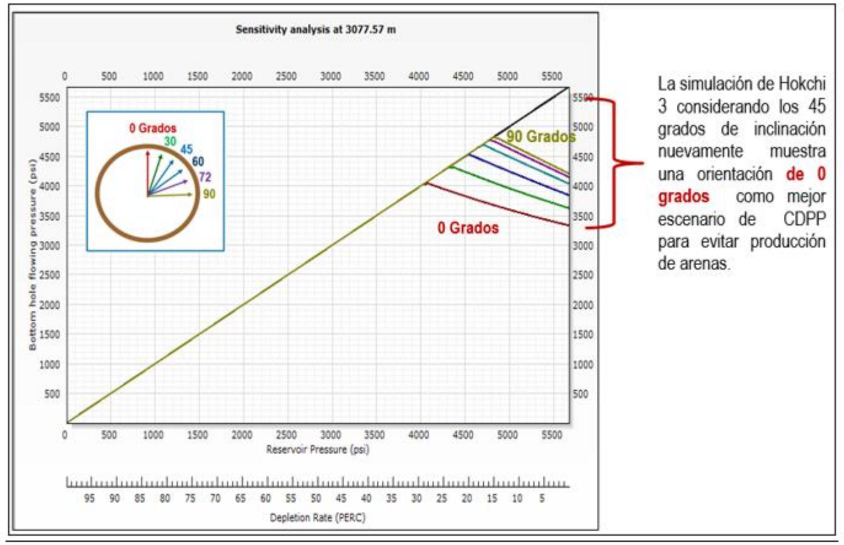


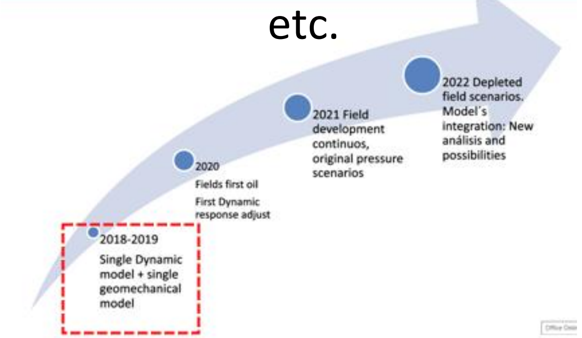
Project evolution

2018-2019 Single Dynamic model + single geomechanical model

- Sand prediction model objective:
  - This study shows the conditions under which the Hokchi field could begin to have sand production
  - This helped to predict the behavior of the Critical Draw down Pressure (CDDP) in each of the wells
  - Different scenarios were analyzed based on depletion, type of completion, granulometry, rock hardness, selective shots etc.



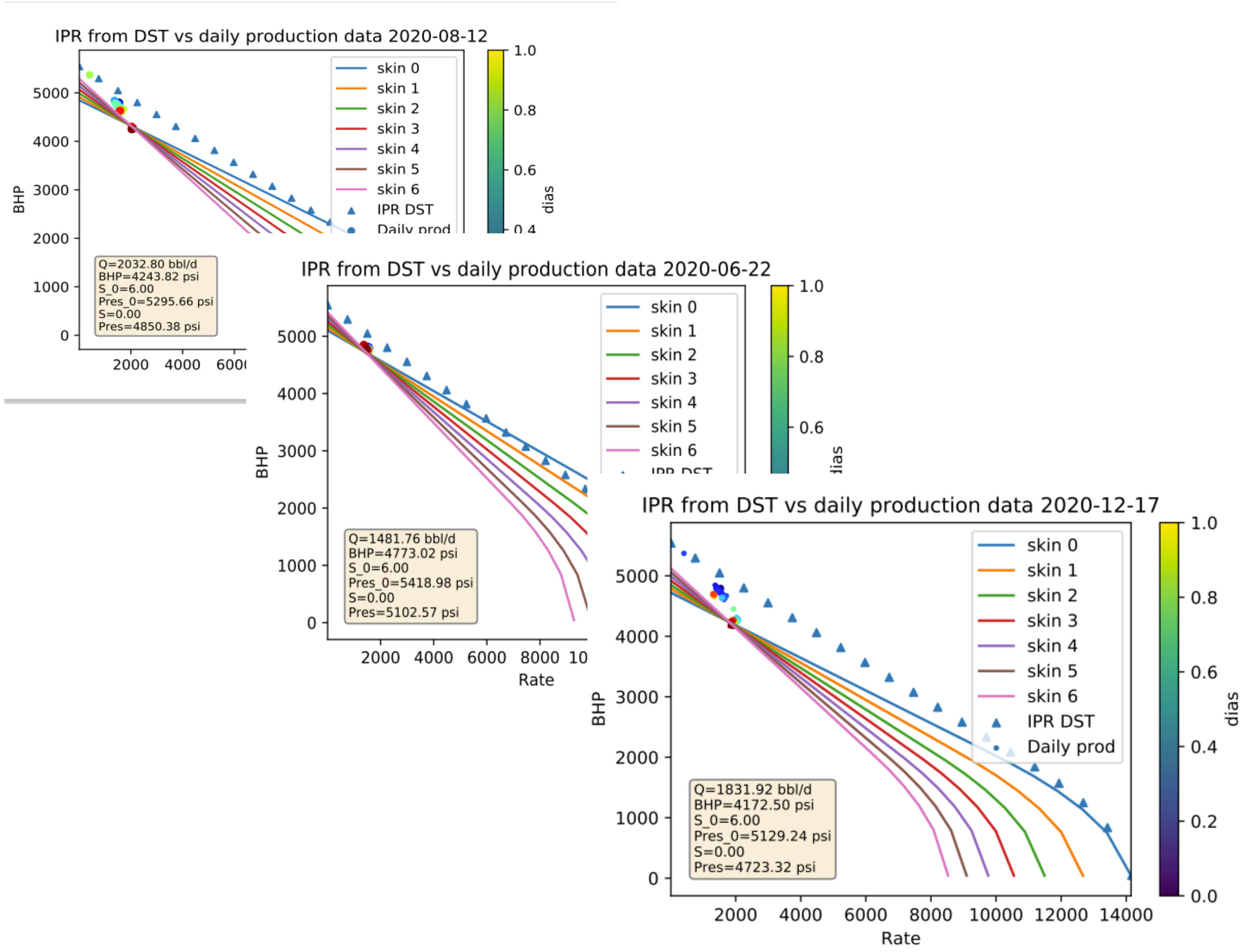


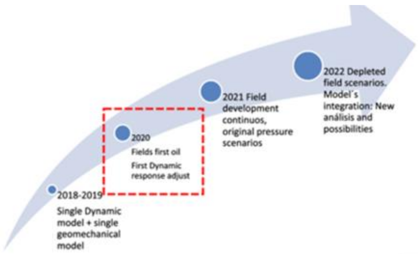


Project evolution

2020 Fields first oil & First Dynamic response adjustment

- Because of Covid-19 crisis it was not possible to perform the frack pack recommended.
- The management decision was to complete the well without sand control but managing the choke in order to avoid sand production
- The CDDP was used to monitor the flowing constrains in order to avoid sand production
- No evidence of sand was detected until the re-entry in 2021 to perform the frack pack

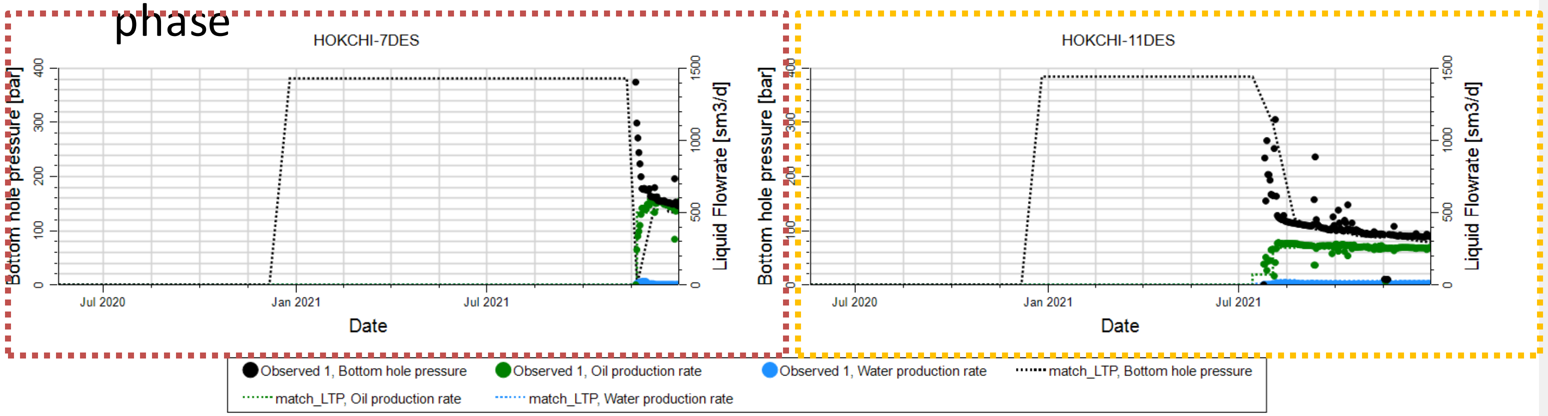


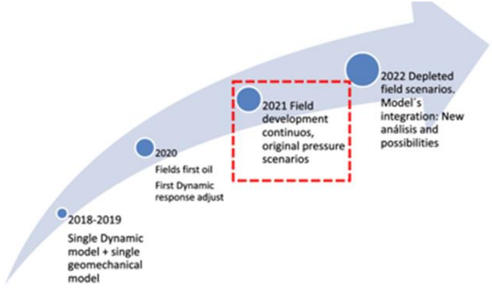


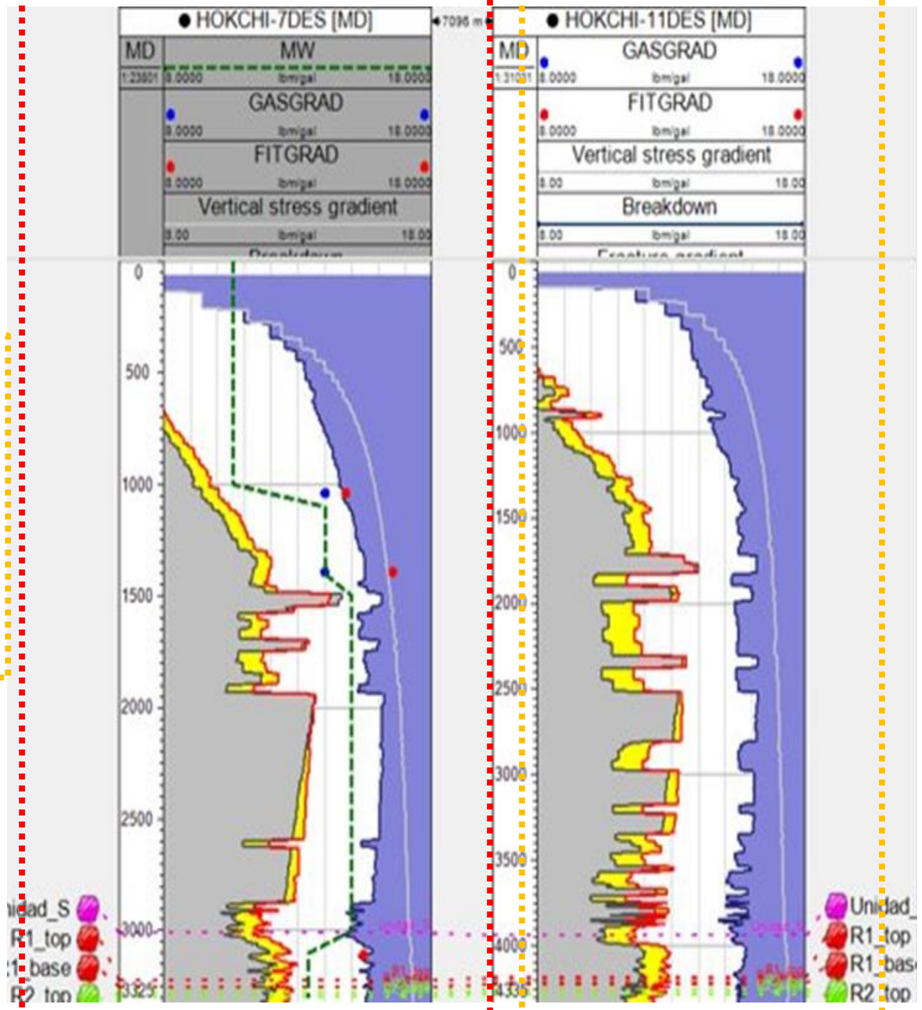
Project evolution

2021 Field development continues @ original pressure scenarios

- After COVID-19 crisis the development plan continuous:
- One re-entry and two additional wells drilled during 2021 under original pressure conditions successfully supported by the original geomechanical model.
- Pressure response continues to be updated during the development phase







Project evolution

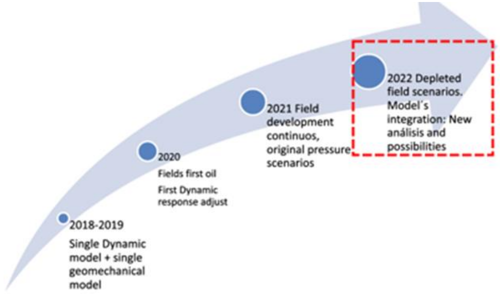
2022 Depleted field scenarios. Model´s integration: New analysis and possibilities

- Under different pressure scenarios and drilling schedules a new approach was required in order to optimize and ensure the project goals.

- The geomechanics ensemble results include probabilistic insights for wellbore stability and safe mud weight pr edictions during well planning, as well as operational pressure constraints to avoid fault reactivation that could jeopardize reservoir integrity

- 3 aplications for two ensambles

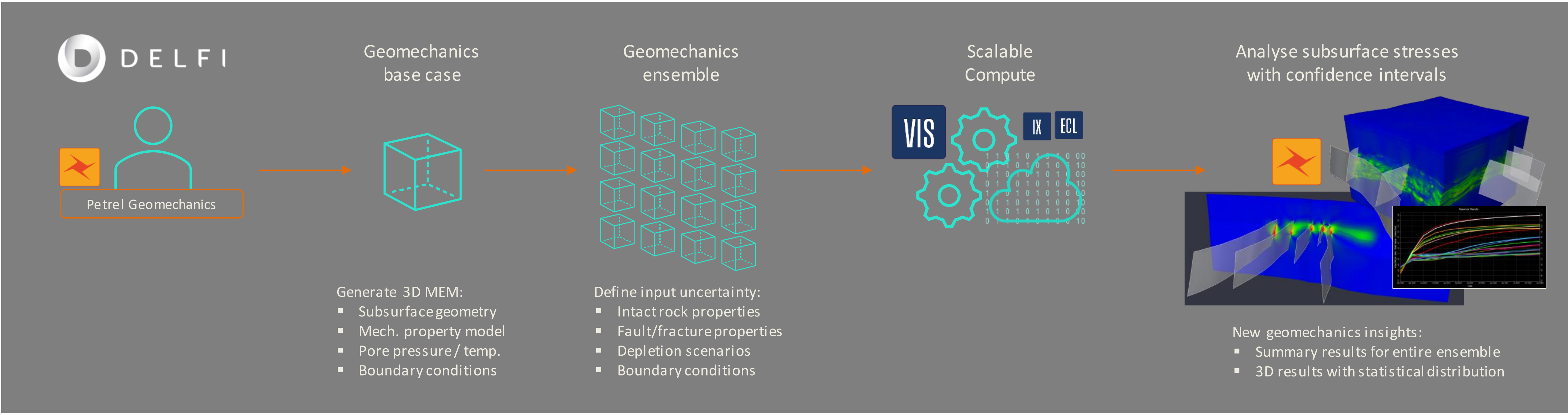
  - **Aplication #1: Capturing Uncertainty in Fault Compliance**
  - **Aplication #2: Confidence Quantification for Wellbore Stability Analyses**
  - **Aplication #3: Fault Stability During Field Development**

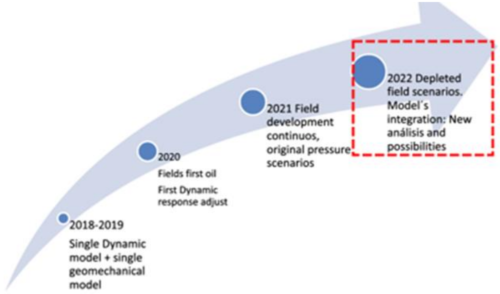


Model integration: new possibilities and analysis

Uncertainty Quantification for 3D Geomechanics

- The ensembles were created in Petrel in the Petrotechnical Suite in DELFI and the multiple realizations of simulations were solved simultaneously utilizing the elastic compute power of the DELFI environment.



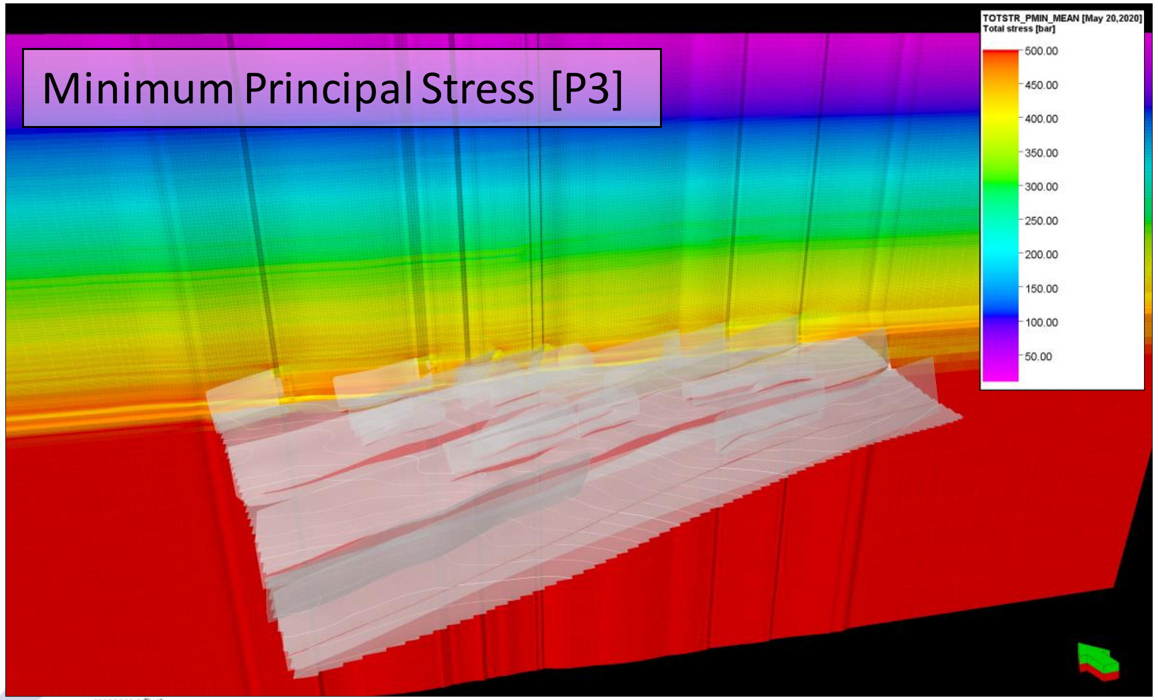


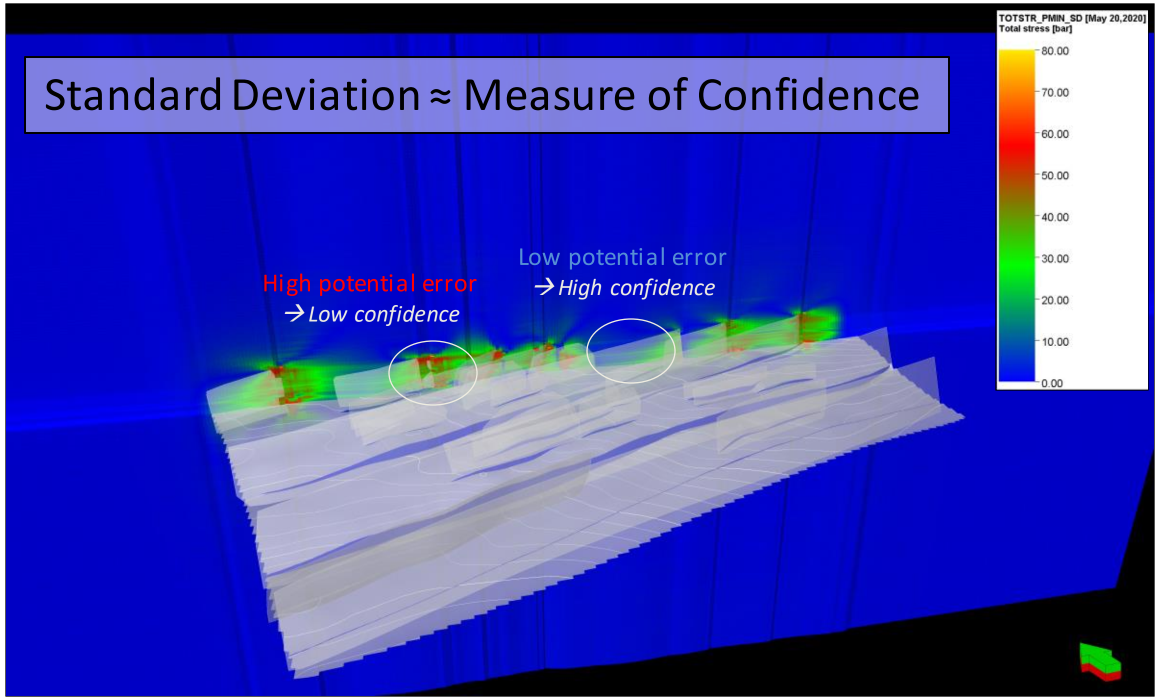
Model integration: new possibilities and analysis

Capturing Uncertainty in Fault Compliance

Compliance of faults is hardly measured and highly uncertain – but significantly impacts in-situ stresses

- ➢ Uncertainty of fault compliance is captured in an ensemble of VISAGE simulations
- ➢ Impact on the confidence of computed 3D stress results becomes quantifiable



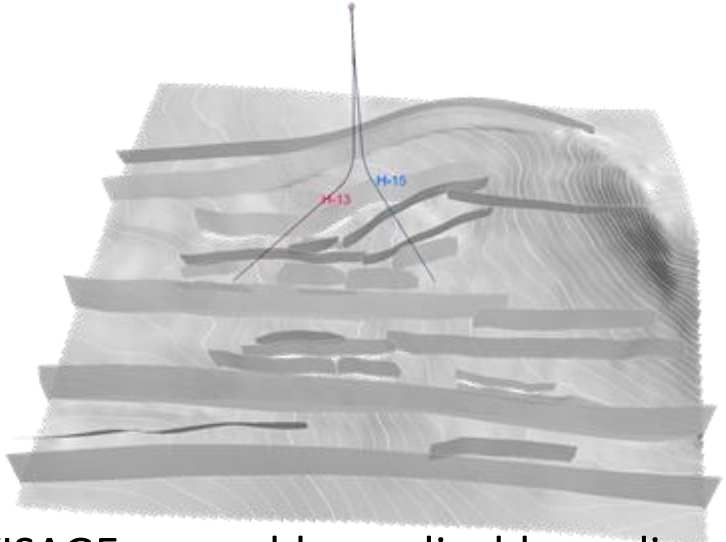


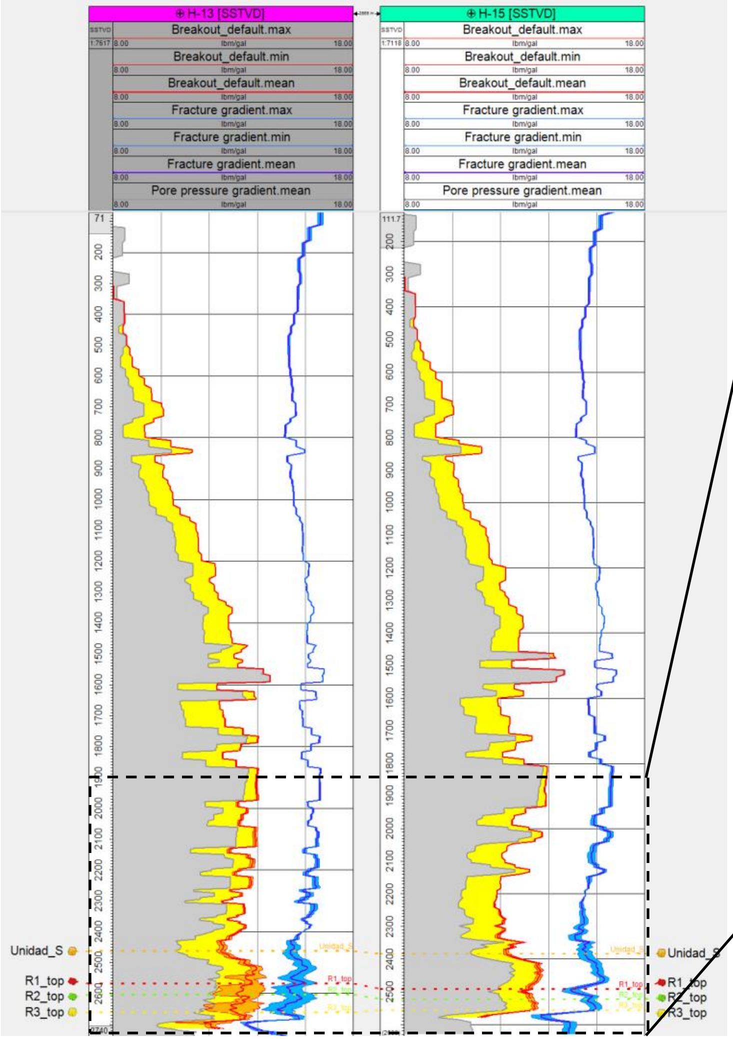
response adjust

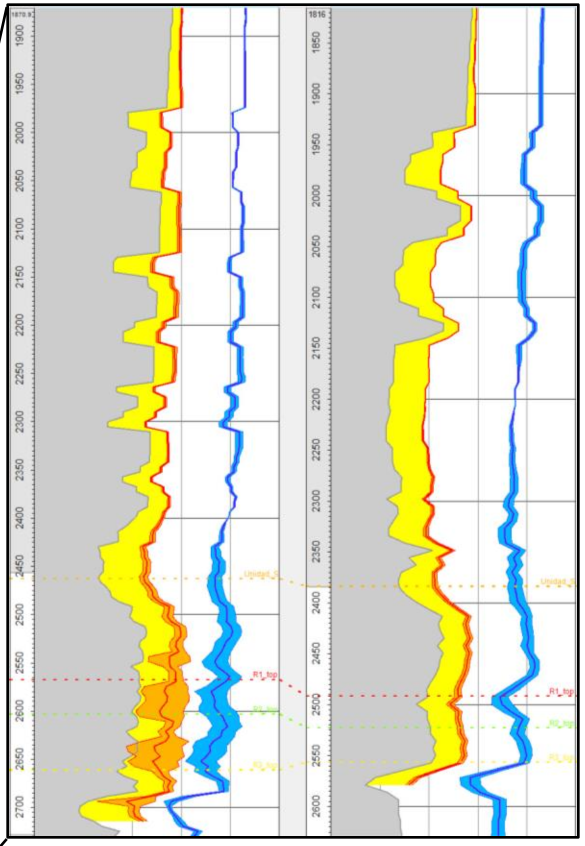
2018-2019
Single Dynamic model + single geomechanical model

Model integration: new possibilities and analysis

Confidence Quantification for Wellbore Stability Analyses



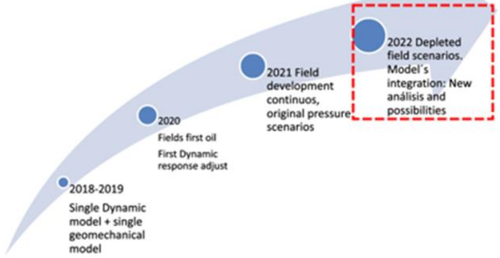




VISAGE ensemble applicable as direct input for wellbore stability analysis

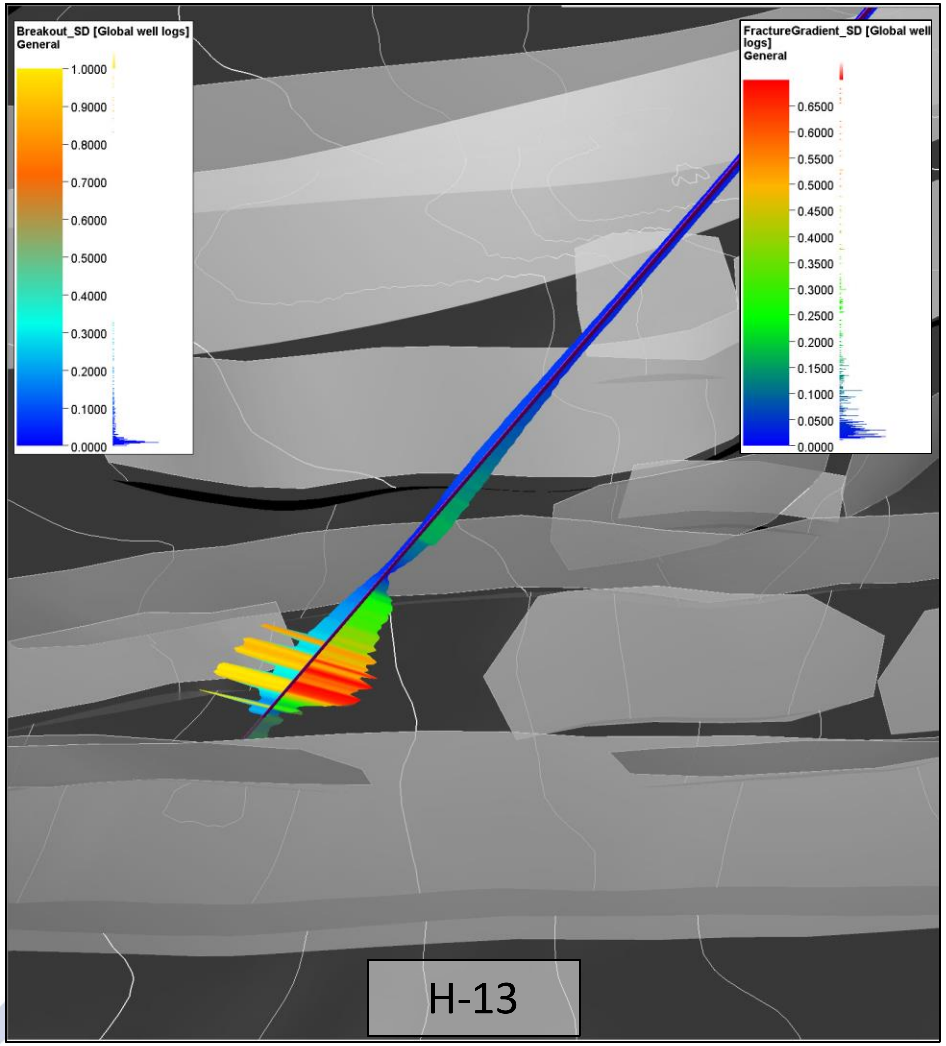
- Confidence calculated for breakout and fracture gradient calculation
- Significantly lower confidence for BO & FG for H-13 in reservoir section

None of the two wells crosses any fault – yet there is a difference in confidence



Model integration: new possibilities and analysis

Confidence Quantification for Wellbore Stability Analyses

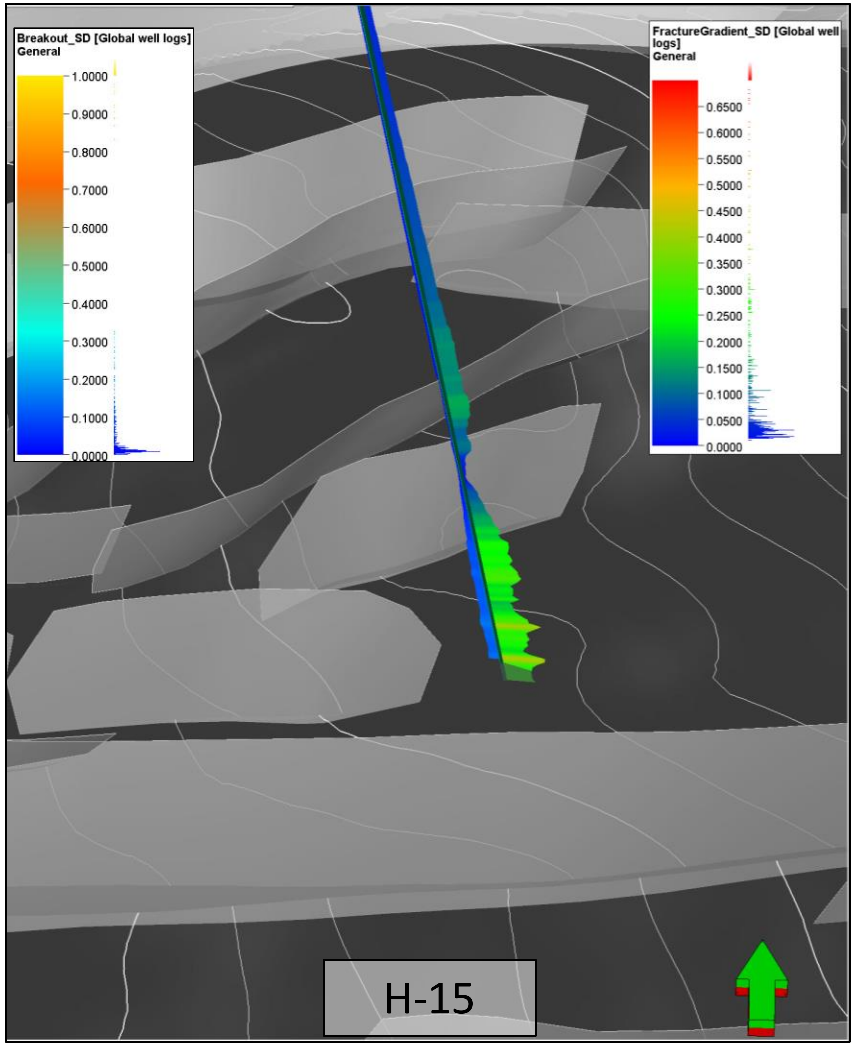


Standard deviation [SD] as measure of confidence

Low SD = High confidence

SD of BO & FG shows significant difference between both wells

Higher confidence in WBS result for H-15



2018-2019
Single Dynamic model + single geomechanical model

Model integration: new possibilities and analysis

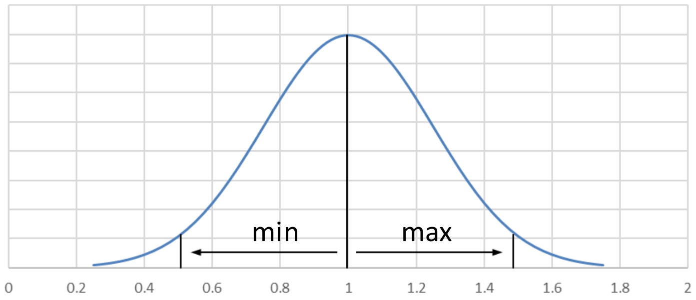
Fault Stability During Field Development

Optimize field development to minimize risk for fault reactivation

- ➢ Informed constraints on production and injection procedures required

Ensemble created for time-lapse 3D geomechanics simulation

- ➢ Base case considers 3 characteristic depletion time steps
- ➢ Uncertainty described using a multiplier on the pressure change

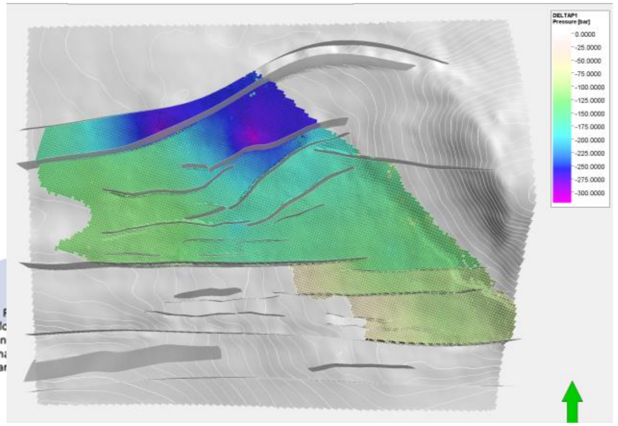


Delta Pressure Multiplier

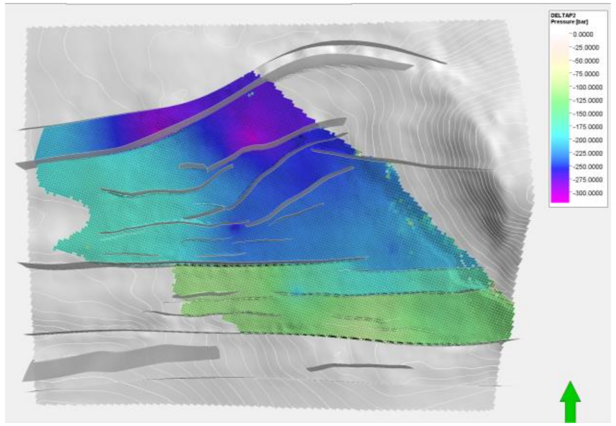
Mean = 1 | SD = 0.25

Delta Pressure

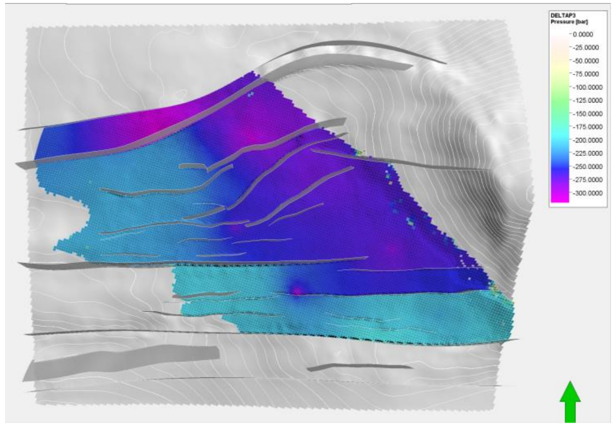
Time step 1

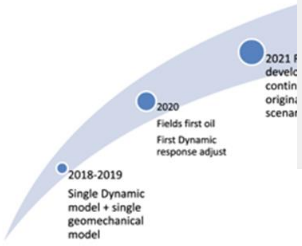


Time step 2



Time step 3

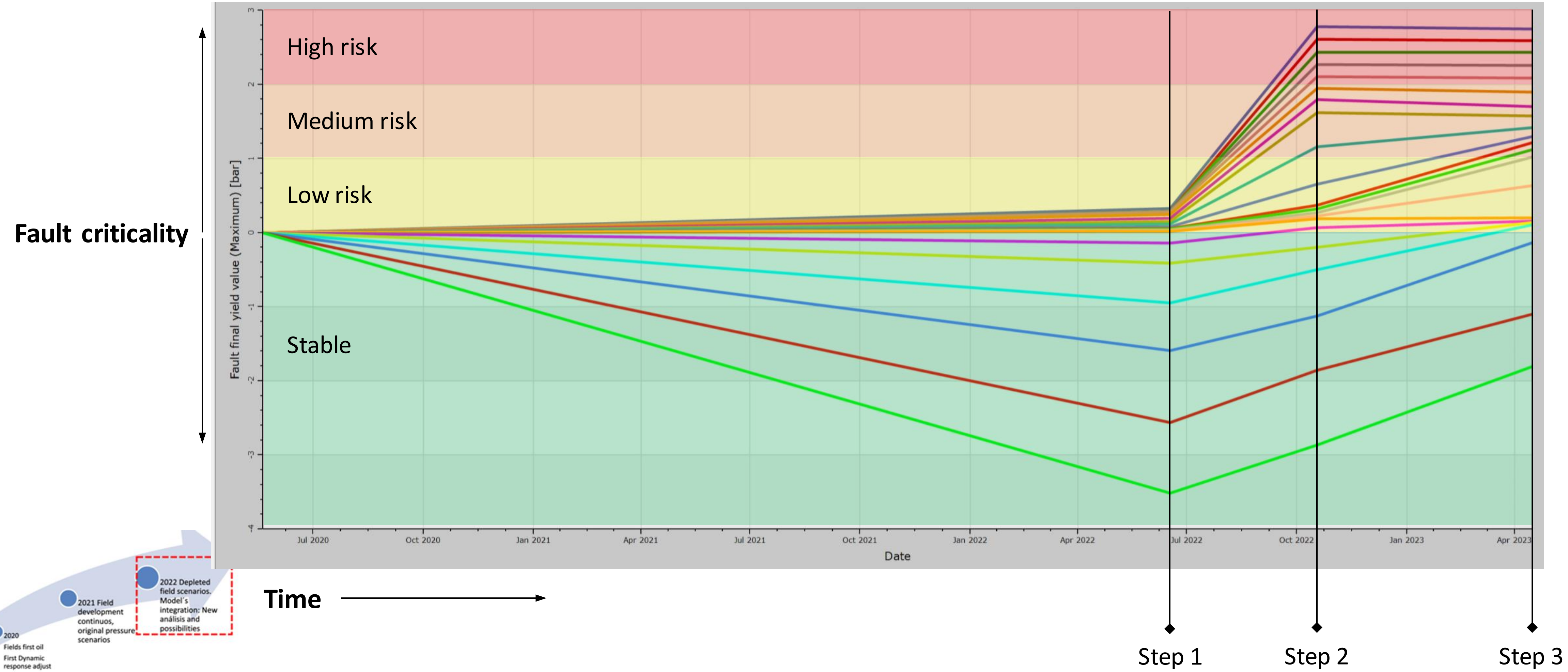


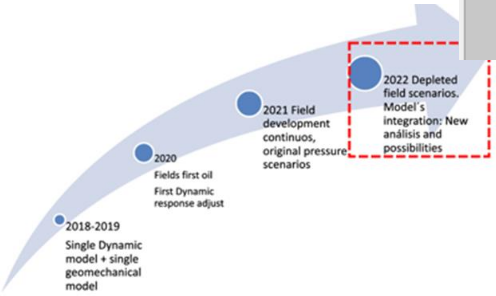


Model integration: new possibilities and analysis

Fault Stability During Field Development

Screening scenarios and identifying key realizations across the geomechanics ensemble





Model integration: new possibilities and analysis

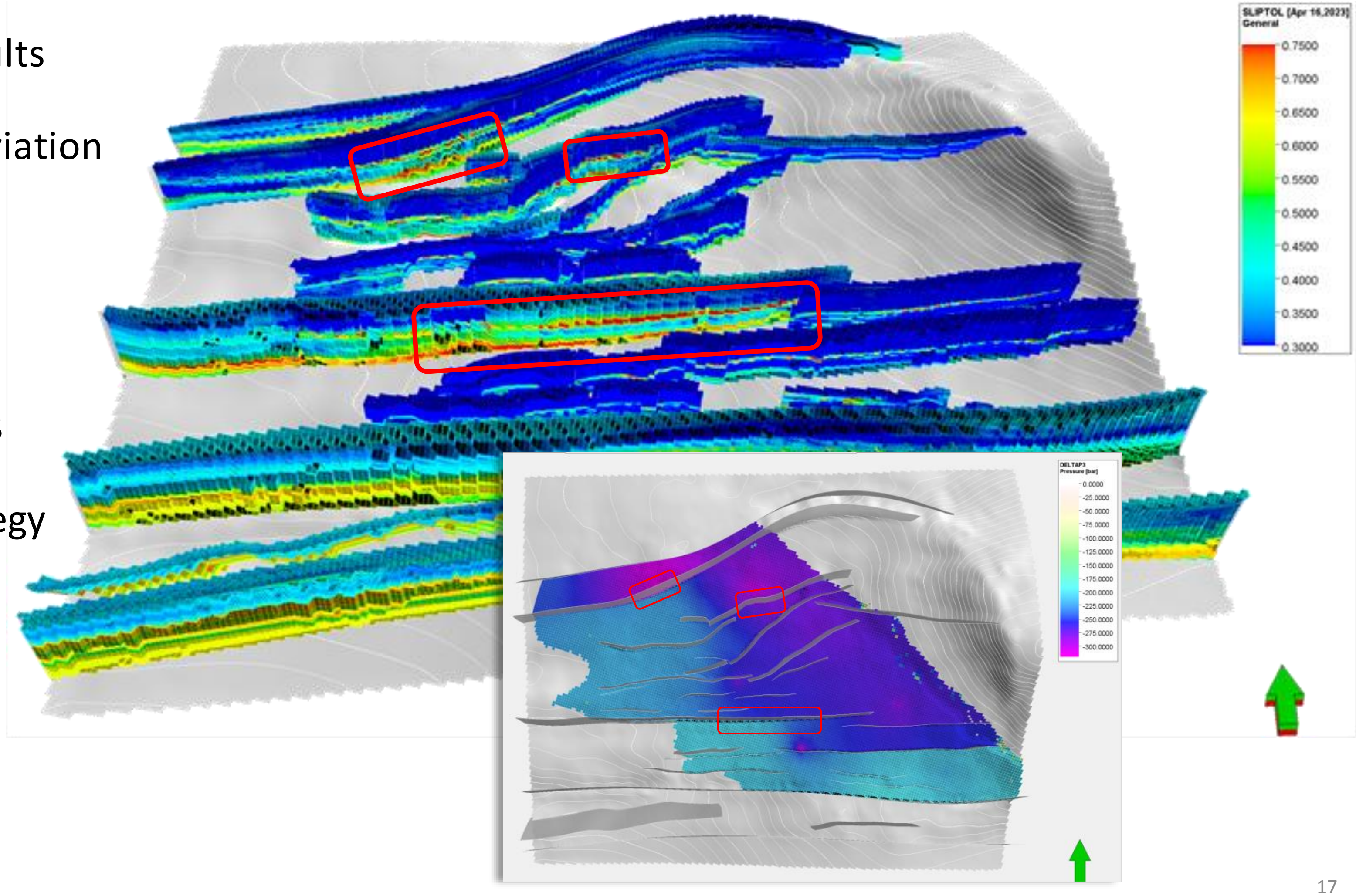
Fault Stability During Field Development

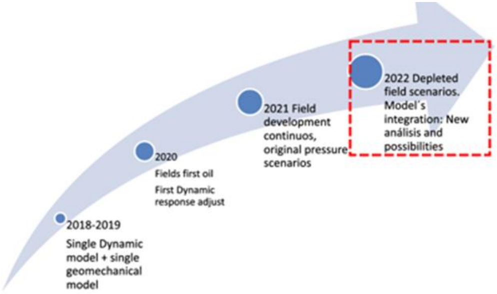
Compute probabilistic 3D geomechanics results

- Normal and shear stress on all faults
- Compute Mean and Standard Deviation across all ensemble case results
- Identify critical fault segments

Apply insights for mitigation plans

- Optimize field development strategy to account for critical segments





Wrap up

- Providing robust operational guidance for this drilling campaign and field development strategy requires the consideration of uncertainty for several subsurface parameters including rock mechanical properties and strength and compliance of pre-existing faults, as well as the impact of different production and injection designs.

- This approach harnesses the power of the cloud to provide probabilistic 3D geomechanics results with quantified confidence to provide drilling and field development with more robust guidance than ever before.

- The geomechanics ensemble results include probabilistic insights for wellbore stability and safe mud weight predictions during well planning, as well as operational pressure constraints to avoid fault reactivation that could jeopardize reservoir integrity.

- Adopting digital workflows allows Pan American Energy to introduce a step change in the turnaround time of geomechanics modeling workflows and in the fidelity of uncertain quantification, clearly improving the impact and benefit for operations