GEOMECHANICS

MITIGATE KEY RISKS FOR CARBON STORAGE

Carbon Guardian supports you in developing strategies to mitigate risks in the key areas of wellbore stability, top seal integrity, and re-activation of pre-existing natural faults, all based on a geomechanical model that is calibrated against operational experience. As models of the subsurface are characterized by inherent uncertainties Carbon Guardian also provides quantitative uncertainties for any geomechanical assessment and prediction.

01

GEOMECHANICAL MODEL

For any geomechanical risk assessment and mitigation the geomechanical model is the fundament. Based on all available field and well data it describes the state of stress, the pore pressure and the mechanical rock properties in the reservoir and the overburden. The geomechanical model is calibrated against field experience and updated over the life of the storage project with new data. If the storage is planned in a previously produced hydrocarbon reservoir changes of pressure and related stress changes need to be considered to derive an accurate geomechanical model.

02

WELLBORE STABILITY

If new wells are drilled for a CO_2 storage project a wellbore stability prediction should be carried out. Based on the geomechanical model and local as well as regional drilling experience, wellbore stability risks and associated drilling risks will be identified. Predictions of mud weights, mud type, and wellbore trajectories will be provided to minimize stability risks and to avoid wellbore failures. This is especially important when drilling shale layers that are regionally known to cause stability issues and for drilling through depleted reservoir sections.

03

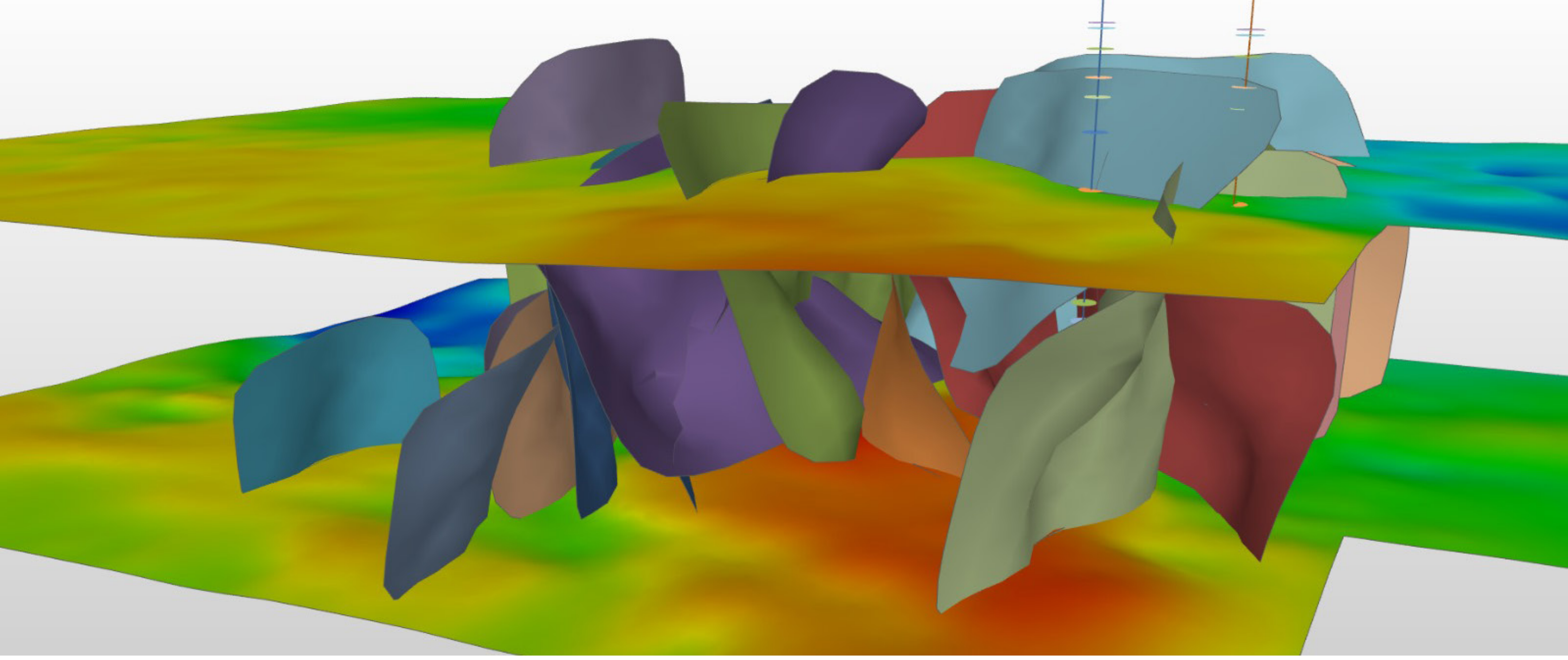
TOP SEAL

Integrity of the reservoir top seal is essential for the long-term safe storage of CO_2. Thus, in addition to the identification of critically stressed faults, the contrasts in mechanical properties and stress magnitudes between the top seal formation and the reservoir layer are determined. Drilling experience as well as pressure tests are used to determine the magnitude of the least principal stress in the sealing formation as this is an important operational constraint.

04

ACTIVATION OF FAULTS

Injection of CO_2 may cause changes in pore pressure and stress state which can lead to the activation of pre-existing faults. Based on the fault orientations mapped in the area and the geomechanical model, critically stressed faults are identified. Changes of pore pressure and stress that could trigger movement or a change of seal capacity of faults are predicted and identified as limits for safe operation of the storage



SERVICE
OFFERINGS

Services

Build and calibrate a geomechanical model

- Quantify geomechanical parameters and related uncertainties as function of depth
- Consider production related stress and pore pressure changes
- Calibrate model against drilling and production experience

Minimize geomechanical risks

- Predict safe drilling parameters such as mud weight and mud type
- Predict safe operating parameters to avoid breach of top seal and reactivation of pre-existing faults
- Limit injection rates, volumes and pressures to avoid triggering of seismic events

Interpretation of unforeseen events

- Interpret unforeseen seismic events and develop mitigation strategies
- Interpret unforeseen movement of CO_2 plume in context of seismic and reservoir simulation data

Value for your project

Cost efficiency

- Avoid drilling problems, related down time and costly side-tracks
- Avoid operational delays or injection shut-downs
- Chose optimal injection parameters while avoiding induced seismicity

Optimize injection

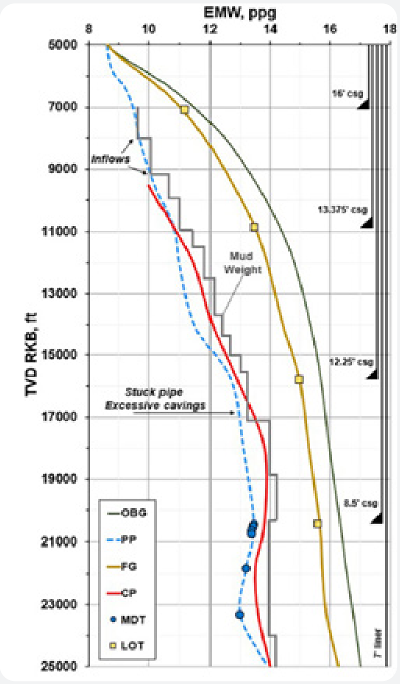
- Select optimal well location and reservoir intersection for injector
- Chose injection pressures and volumes to minimize the risk for triggering induced seismicity or slip on nearby pre-existing faults

Expert support

- Wealth of global geomechanical project experience
- Support in interactions with regulators
- Establish trust with public by geomechanical expertise with a proven track record

GEOMECHANICS

LEARN FROM EXPERIENCE



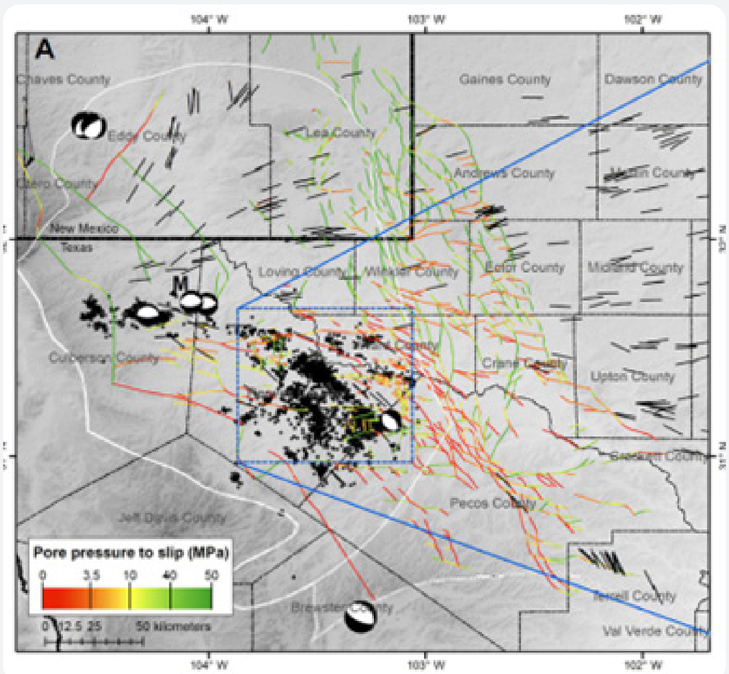
MINIMIZE WELLBORE STABILITY RISKS

Geothermal projects for heat generation rely on the flow between an injector and a producer well through a target horizon that is isolated from shallow aquifers. In October 2023 the second well drilled in a geothermal project in, The Netherlands, (https:// geoexpro.com/a-puncture-in-a-geothermal-seal/) experienced severe wellbore instability problems in the Vlieland Claystone Formation which led to two sidetracks and an abandoned hole that could not be plugged in the sealing formation above the target horizon for heat extraction. The Vlieland Claystone Formation is known for the occurrence of wellbore instabilities from other drilling operations in the area. This case underlines the need for a detailed review of regional drilling experience and appropriate strategies for reduction of wellbore instabilities for any wells to be drilled in geothermal or CO_2 storage projects.

Stress and pore pressure profiles provide the base for safe mud weight prediction.

CHANGES IN STRESS OVER TIME

Determining a reliable geomechanical model and calibration against operational experience in the area is crucial for the quality and predictive value of the model. Evidence from O&G fields but also from analysis of seismicity induced by wastewater injection strongly indicates that production from a geological reservoir is changing its geomechanical behavior. An article in Wall Street Journal from April 29, 2024 provides evidence for the triggering of seismicity by the extensive injection of wastewater from hydrocarbon production. Detailed analysis of the triggered seismicity published by Dvory, N.Z., and Zoback, M.D., 2021 leads these authors to the conclusion "... that pore-pressure and poro-elastic-stress changes associated with prior oil and gas production make induced seismicity less likely". This finding underlines the need for understanding the production history in an area considered for CO_2 storage and the associated changes in the geomechanical behavior.



Pore pressure required for slip on basement faults in the Delaware Basin compared to observed earthquakes and stress directions (Dvory, N.Z., and Zoback, M.D., 2021).

While CO_2 storage is a relatively recent industrial activity, extensive experience gained over decades from geomechanical studies in the oil and gas industry and from geothermal projects, can be transferred to address the challenges faced with long-term, safe, and reliable storage of CO_2. Our geomechanics team has accumulated more than 100 years of experience collected with major oil and gas operators and service companies working on all aspects of geomechanics (WBS, fault activation, underground storage, geothermal). Advanced technologies to constrain the stress state based on work published by Prof. Mark D. Zoback and successfully applied in hundreds of geomechanics projects will ensure a geomechanical model of highest quality and reliable predictions for wellbore stability and operation of the CO_2 storage project.

CO_2 sequestration is a necessary tool to reduce climate gas emissions. We want to derisk CO_2 sequestration and lower its cost in order to maximize stored CO_2 volumes contributing to achieving global net-zero goals and constraining global warming

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Secure Carbon Storage

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