Insights from Microseismic Monitoring of Enhanced Geothermal Systems: Case Study from Cape Modern, Utah, USA

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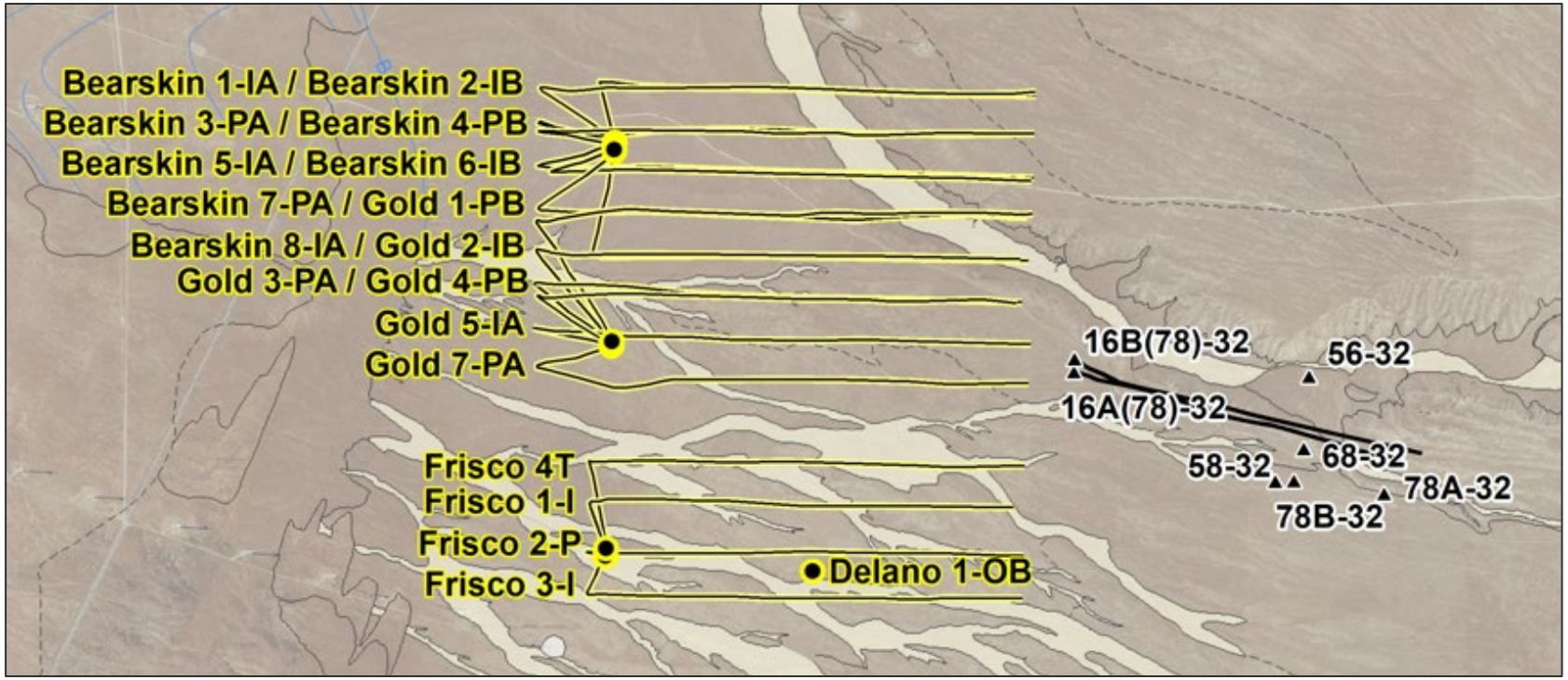
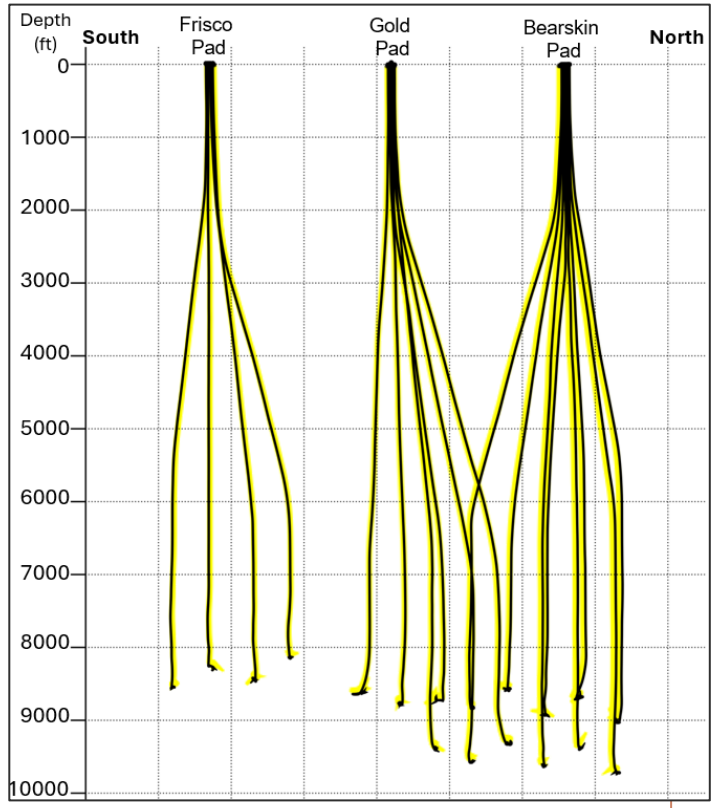
Project Cape Updates

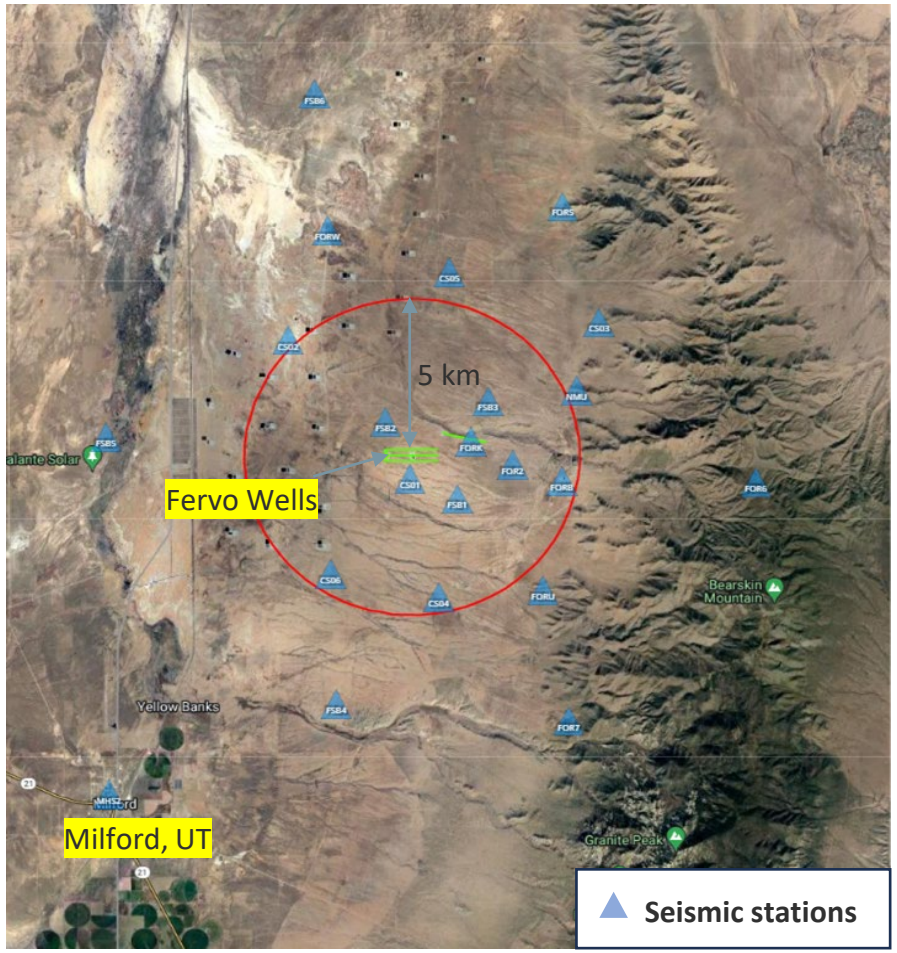
- Over 20 horizontal wells have been drilled at the site, targeting 3 pads. Drilled out two reservoir benches at different temperature horizons
- Drilled and stimulated at reservoir temperatures of >435 °F. Two pads stimulated and one pad flow tested. Approx. 200 stages stimulated. Stimulation done in a phased manner for example four wells stimulated at a time.
- The Frisco pad was drilled first, with its wells being stimulated concurrently with the drilling of Bearskin wells. Gold wells are currently being drilled while Bearskin wells undergo stimulation.



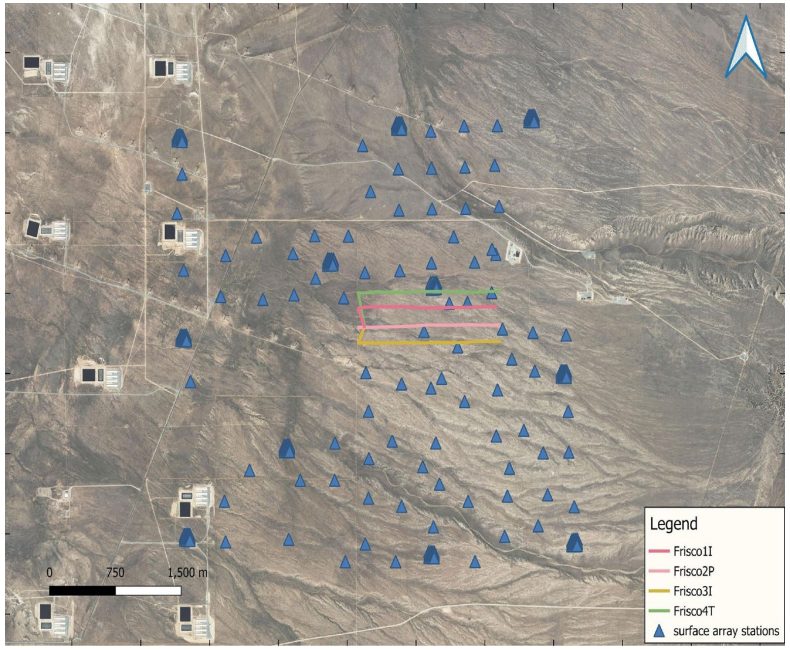


Seismic monitoring network

- Backbone seismic network for 24/7 real time alerts. UU, Fervo and LBNL sensors.

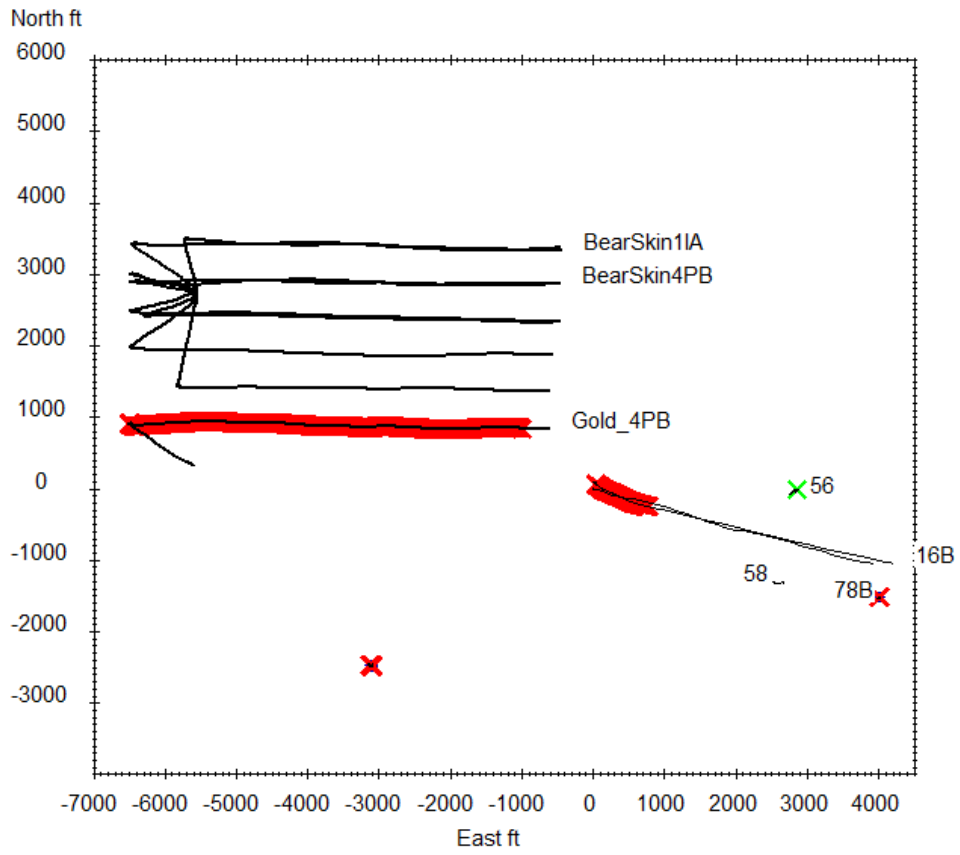


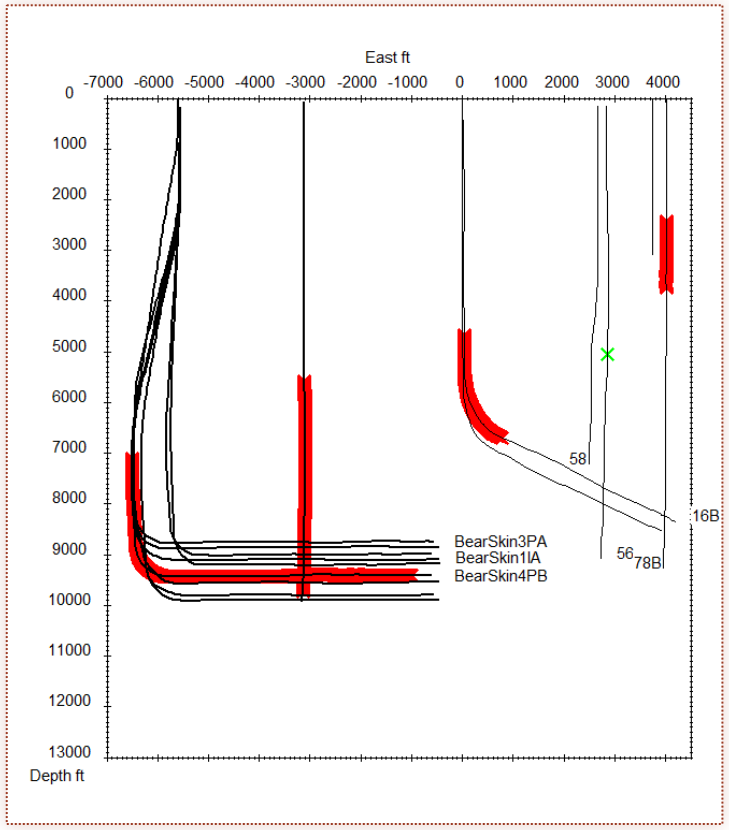
- Dense nodal array for focal mechanism, stress inversion, ambient tomography deployed by LBNL (Nori et al., 2024)
- Deployed since February 2024 and recording continuously.



Fiber optic data acquisition

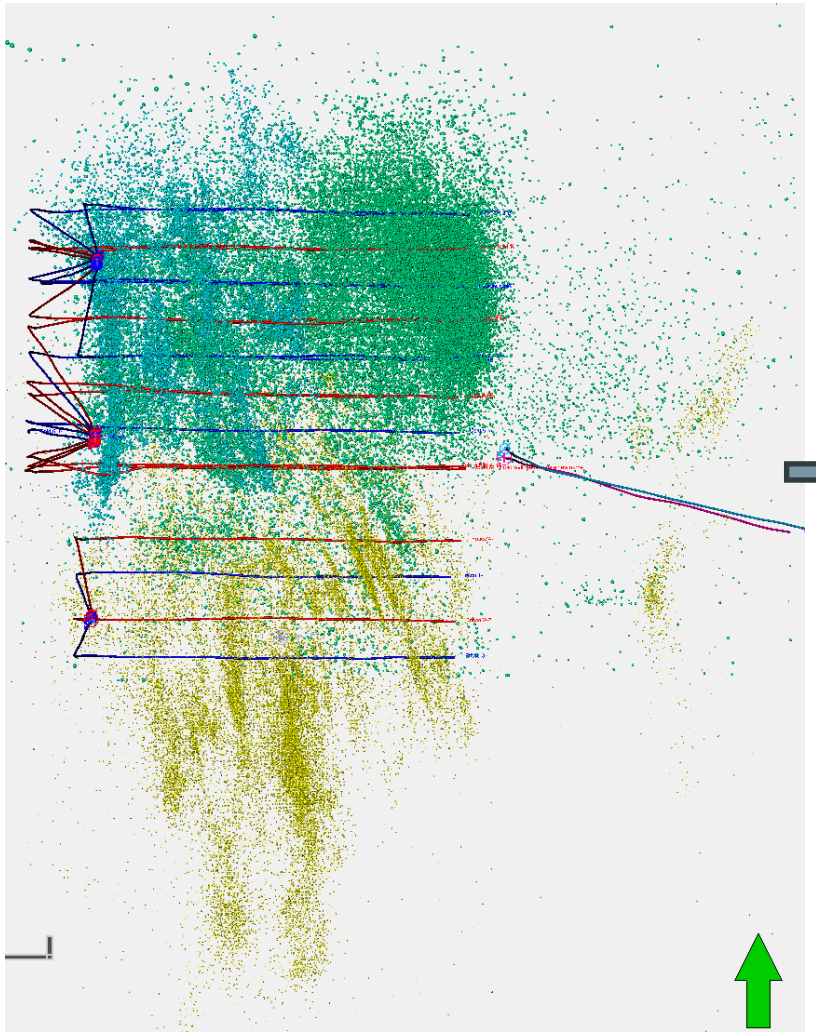
- Fiber optics sensors behind casing on the Delano and Gold 4 wells.
- Temporary fiber optic cable deployment, FORGE 16A fiber behind casing and 3-C sensor in 56-32 during Frisco stimulation.
- Downhole pressure gauge at the reservoir level in Delano and well head pressure sensors on all offset wells during stimulation



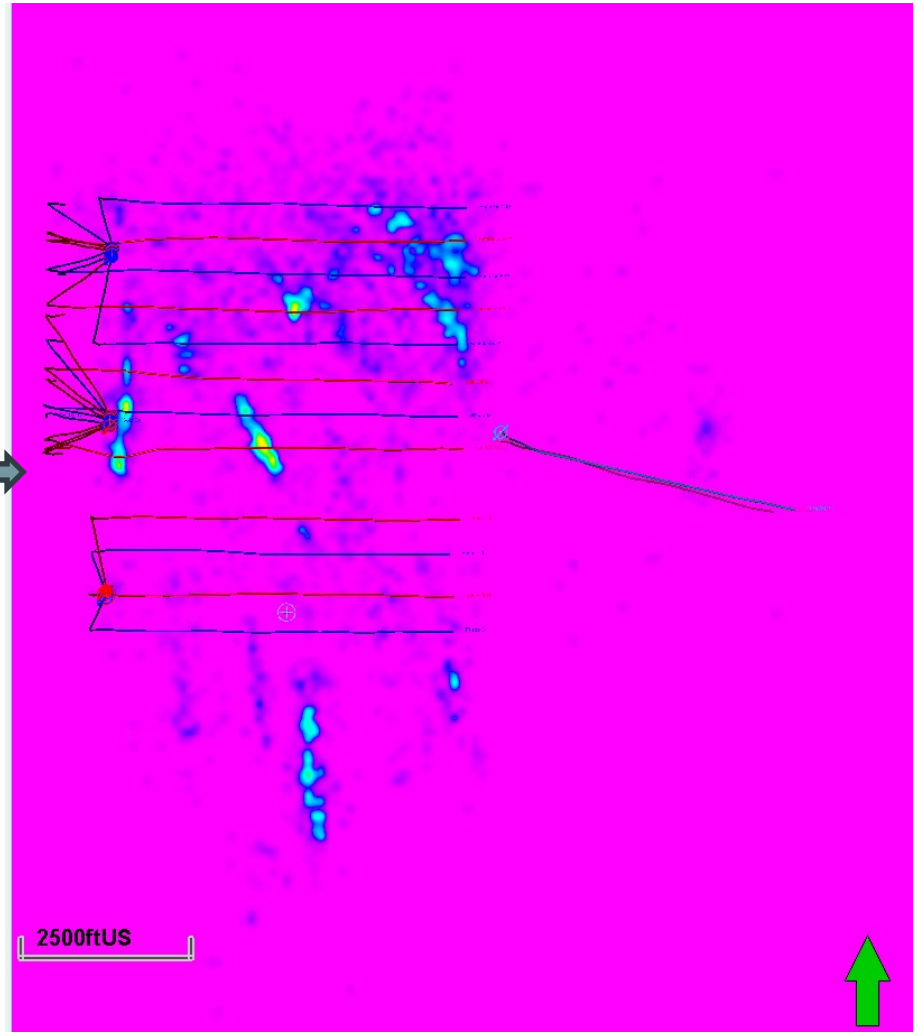


Frisco and Bearskin Pad microseismic Map View

Microseismic locations



Microseismic density cube depth cross section



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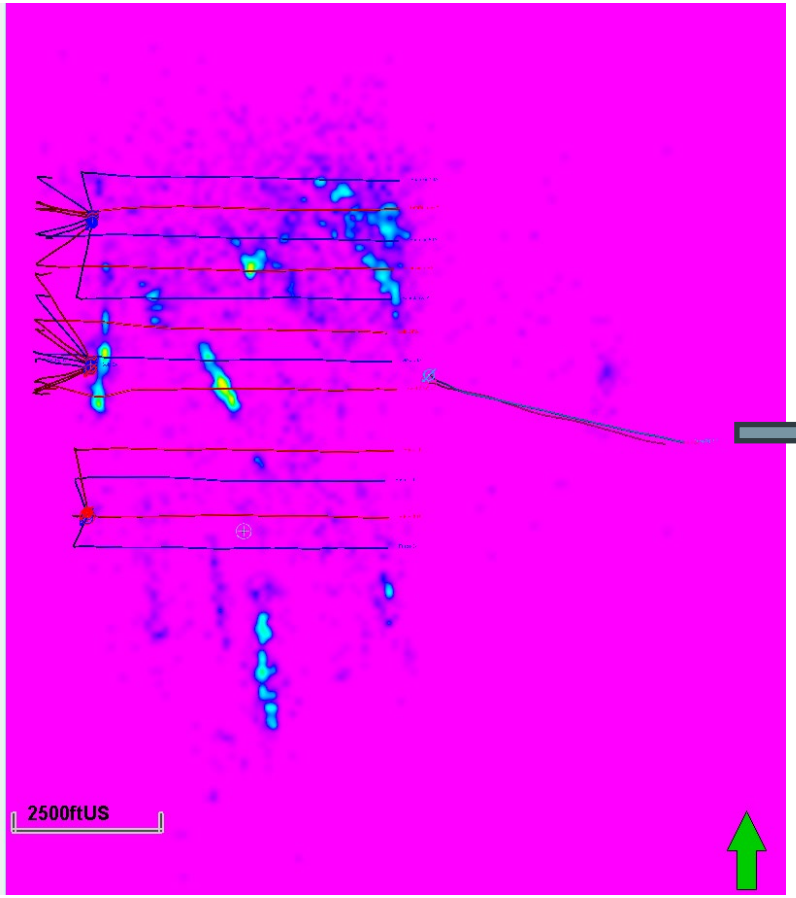
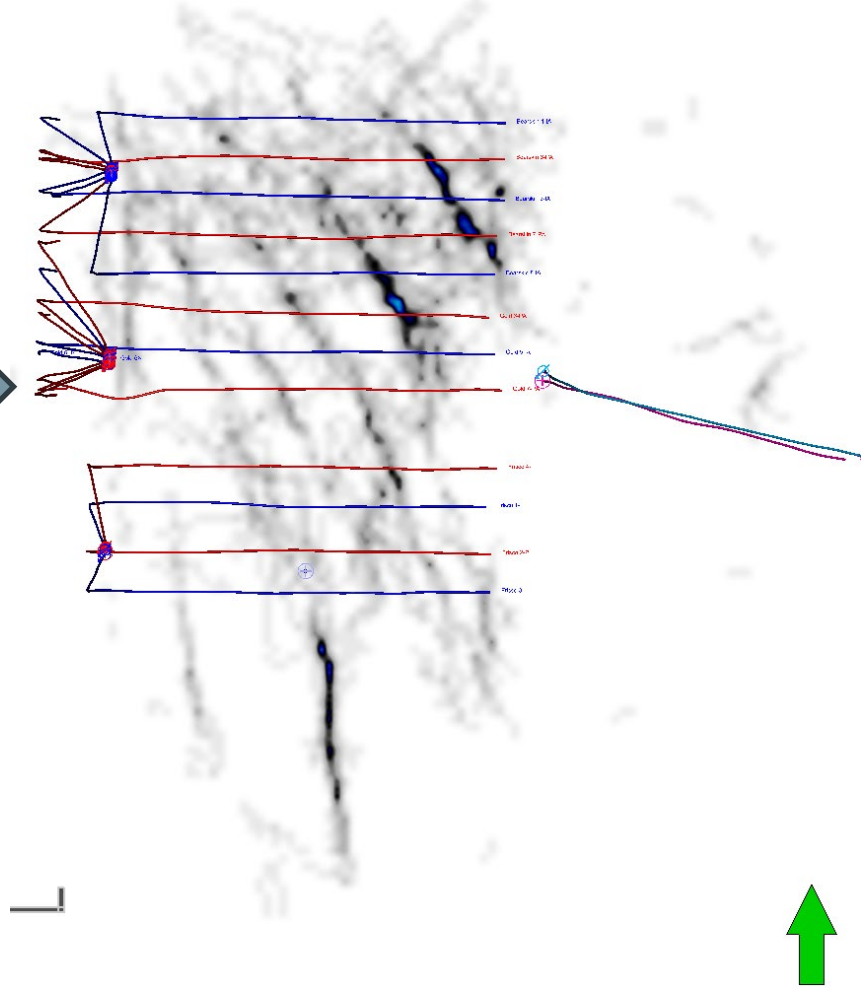
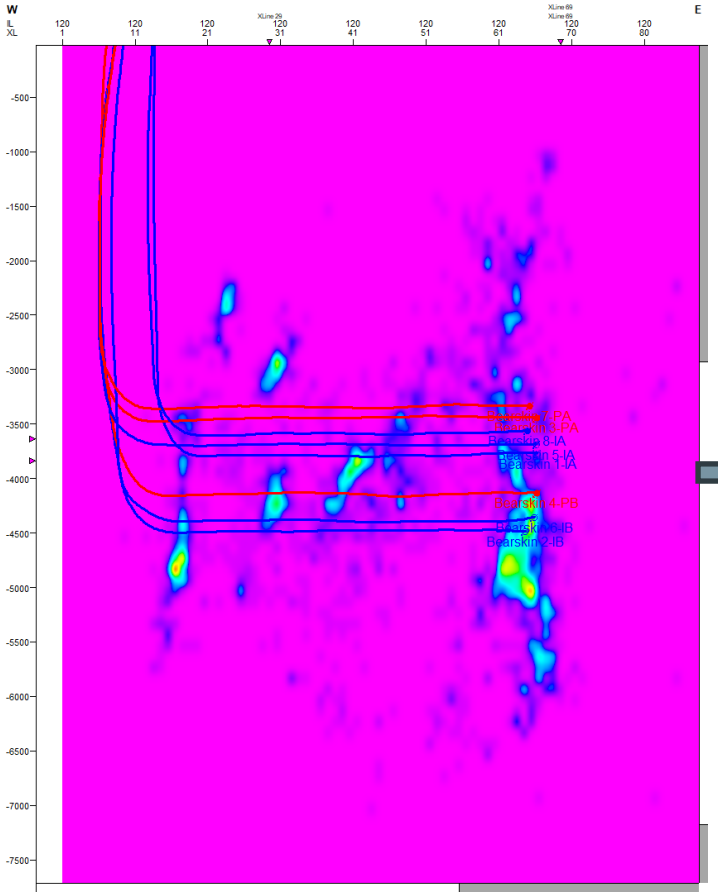


Mild Ant Tracking on microseismic density at depth cross section at reservoir level



Bearskin Pad microseismic cross section view

Microseismic density cube cross section



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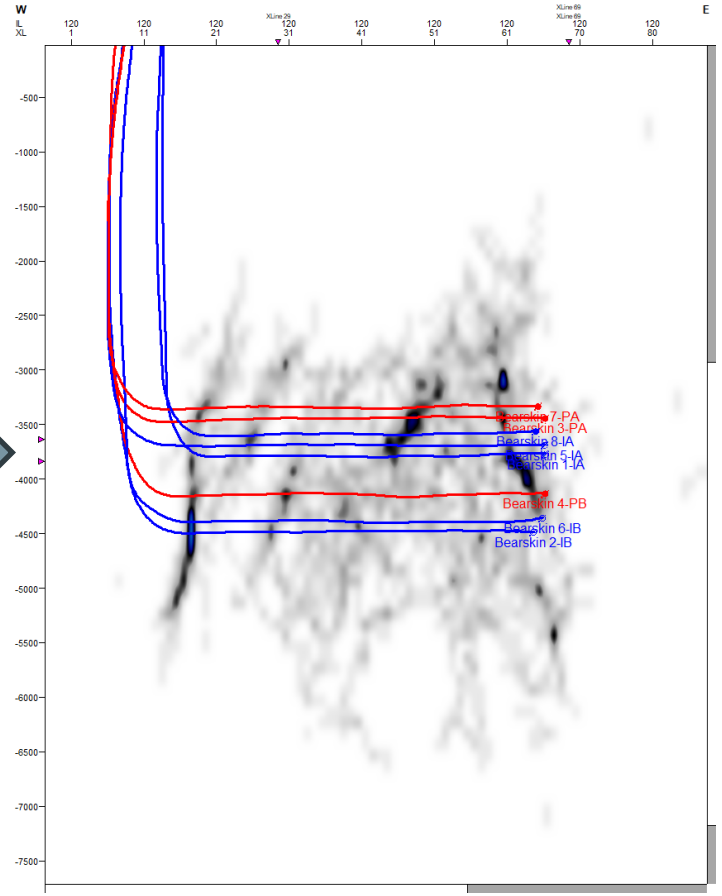
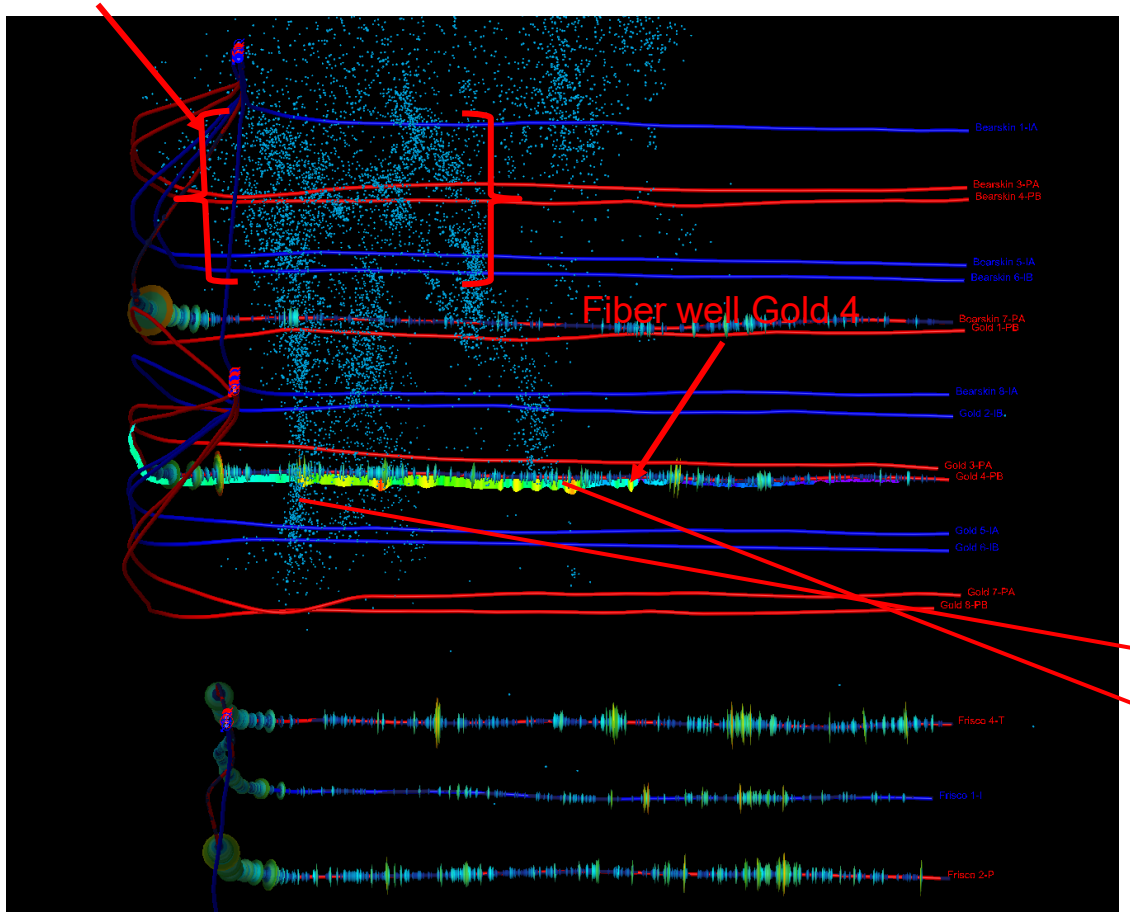


Fault activation and Fluid flow in faults

Stimulated stages

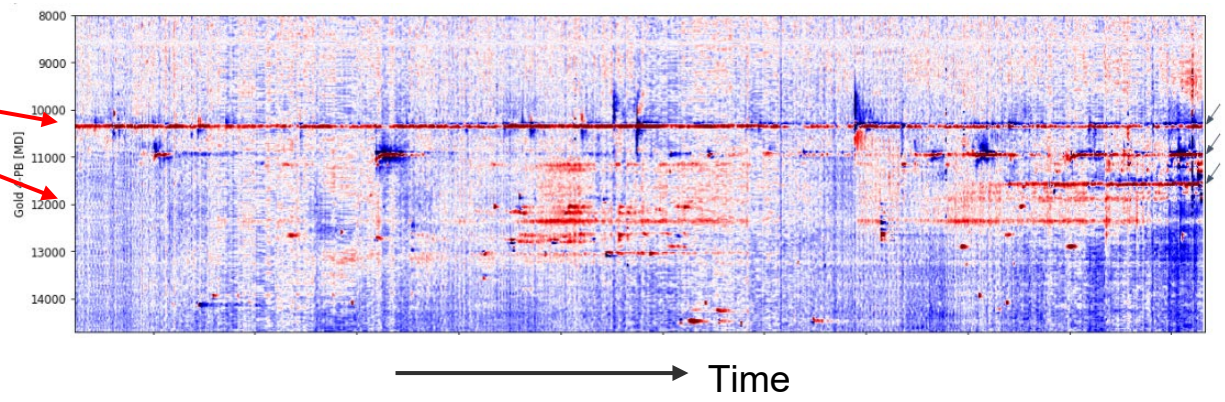


•Integrating drilling-based data on losses, gas emissions, and mineral changes with image logs, fiber optics, and microseismic data enables real-time assessment of induced seismicity risks.

•Stage-by-stage monitoring allows for detailed evaluation of seismic hazards at each phase of stimulation, capturing localized variations in stress and fracture behavior.

•By identifying potential induced seismicity, stimulation designs can be dynamically adjusted to mitigate risks and improve operational safety.

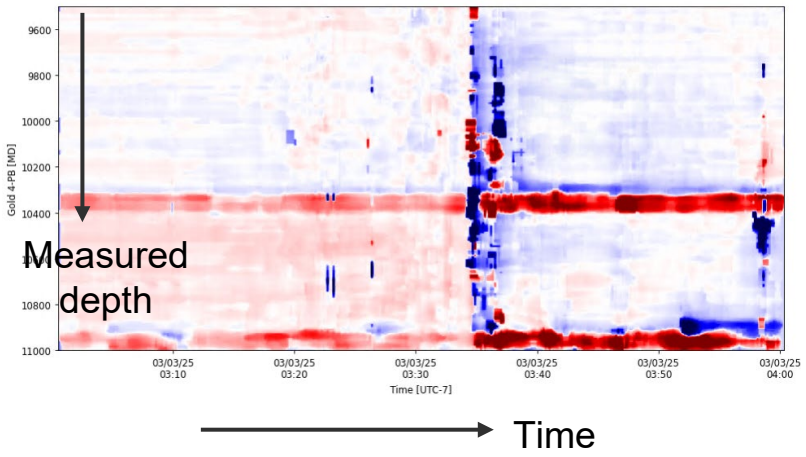
Low frequency strain data



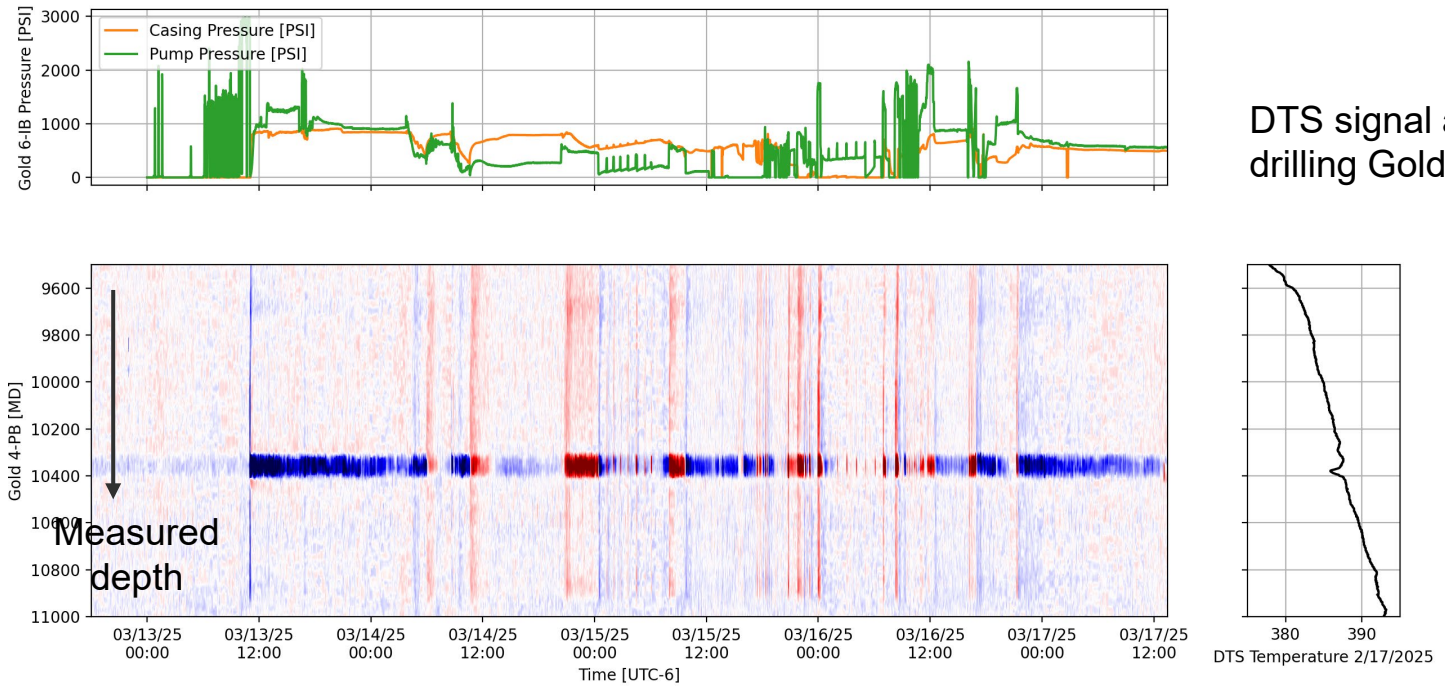
Investigation of fault activation using fiber optic sensing

- Post-drilling temperature profile in Gold 4 fiber providing insights into fluid movement.
- Visualization of strain variations before, during, and after a **M2.97 seismic event** in March 2025. Demonstrating the impact of fault activation on fluid migration and stress redistribution.
- Changes in strain detected during drilling indicate variations in **fault aperture**. Correlation between casing pressure, pump pressure, and fiber optic strain response during offset well drilling losses.

LFDAS signal before, during and after M2.97 event in March 2025



Response on the fiber optic strain during drilling of an offset well

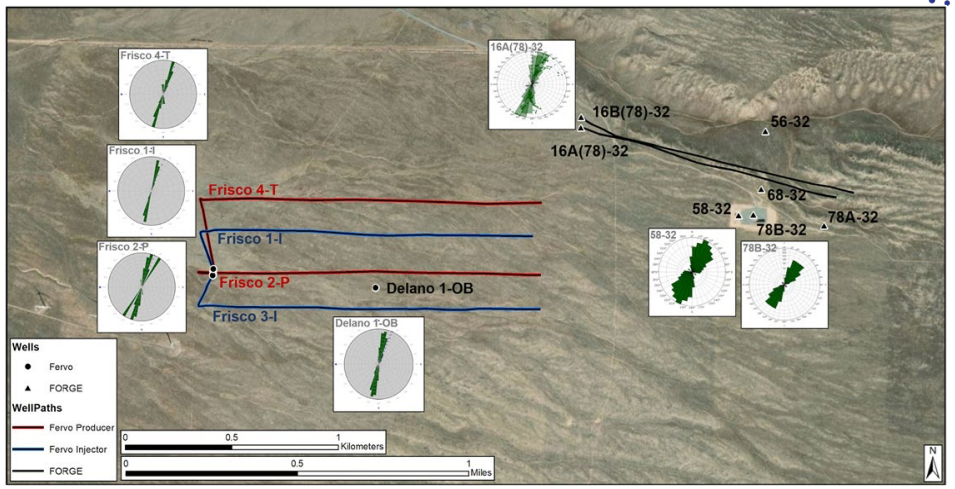


DTS signal after drilling Gold 4

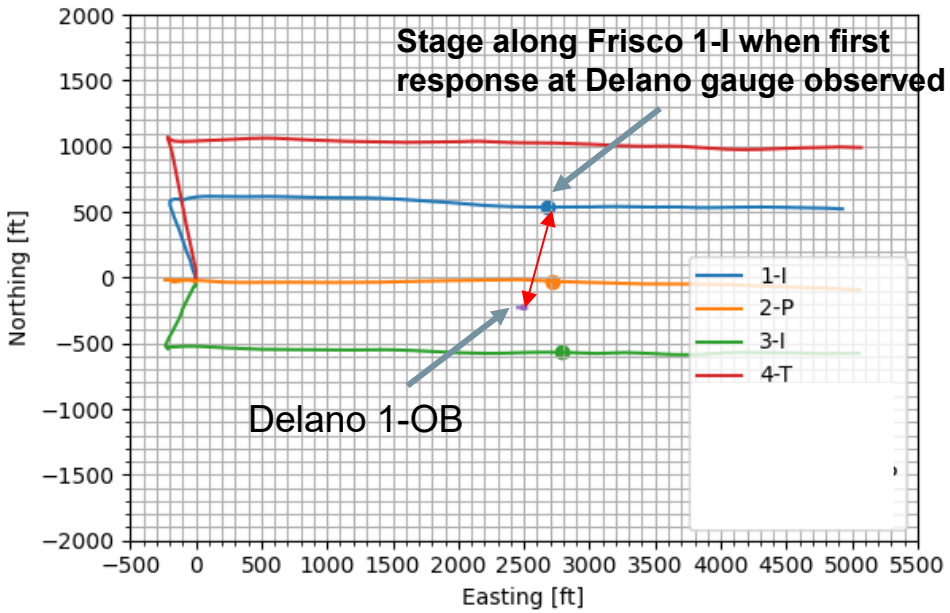
Evidence for planar hydraulic fractures

- Local principal stress orientations are very well characterized through image log analysis (Drilling-induced fractures and borehole breakouts).
- In Delano 1-OB, DIFs were found to be well developed and tightly aligned to a 10° SHmax orientation.
- First frac hit from the Frisco 1-I stimulation response on Delano 1-OB pressure gauge aligns with the Shmax orientation from image logs providing possible evidence of hydraulic fracture extension.

Local State of Stress

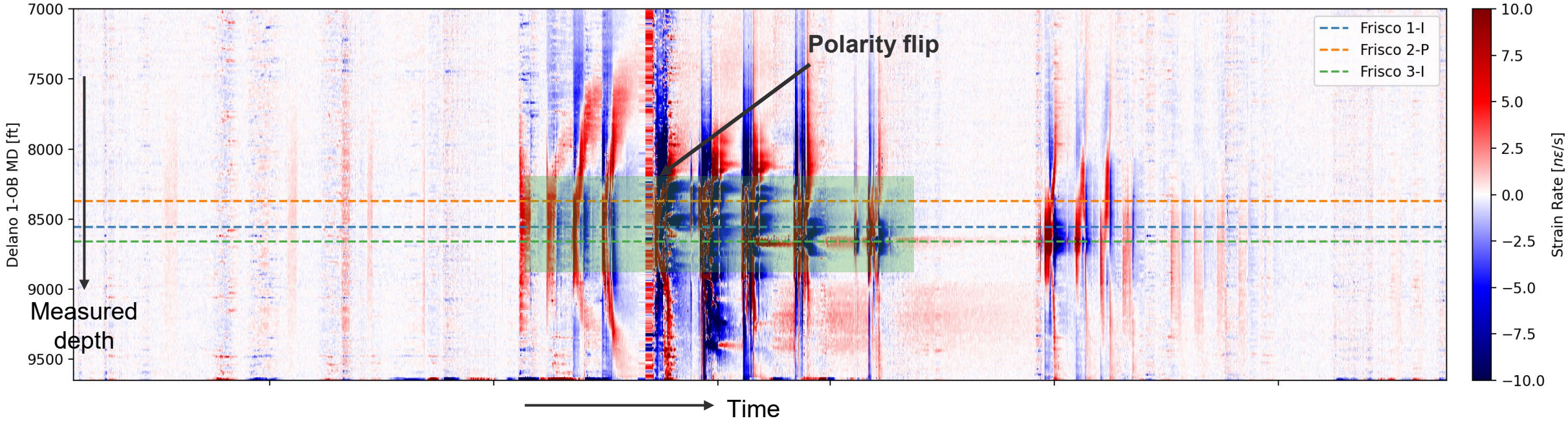


Stages with first observed frac hit signal in OBS



Evidence for planar hydraulic fractures

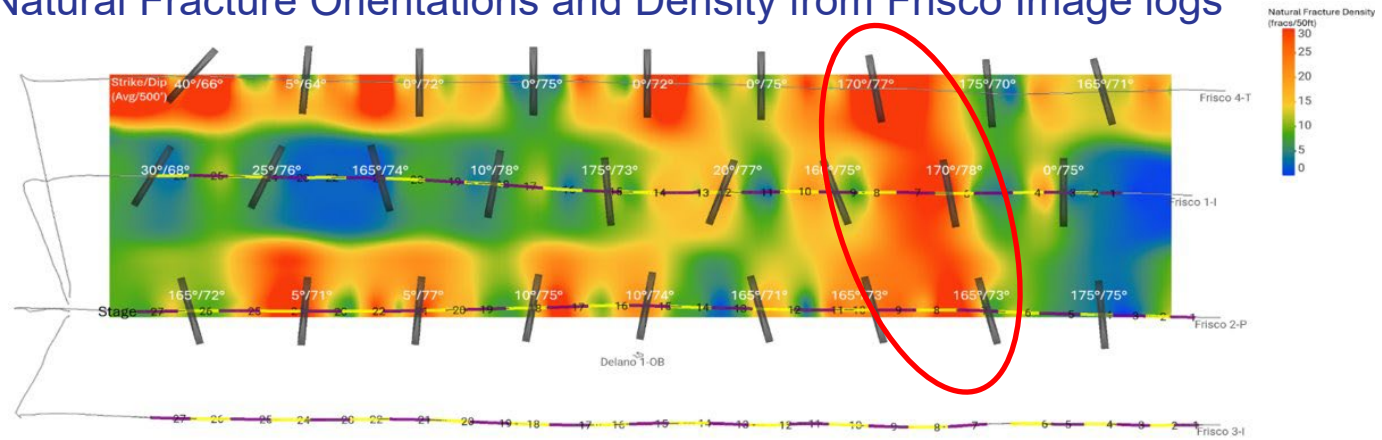
- Low-frequency DAS signal exhibits a polarity flip with height and time after stage shutdown, a pattern consistent with planar hydraulic fractures observed in unconventional oil and gas reservoirs.
- First fracture hits detected from low-frequency DAS provide direct evidence of fracture growth and height estimation.
- Fracture height for 3-I is estimated at 700 ft, with a 400 ft upper half-height and a 300 ft lower half-height significantly lower than microseismic extension deeper and shallower.



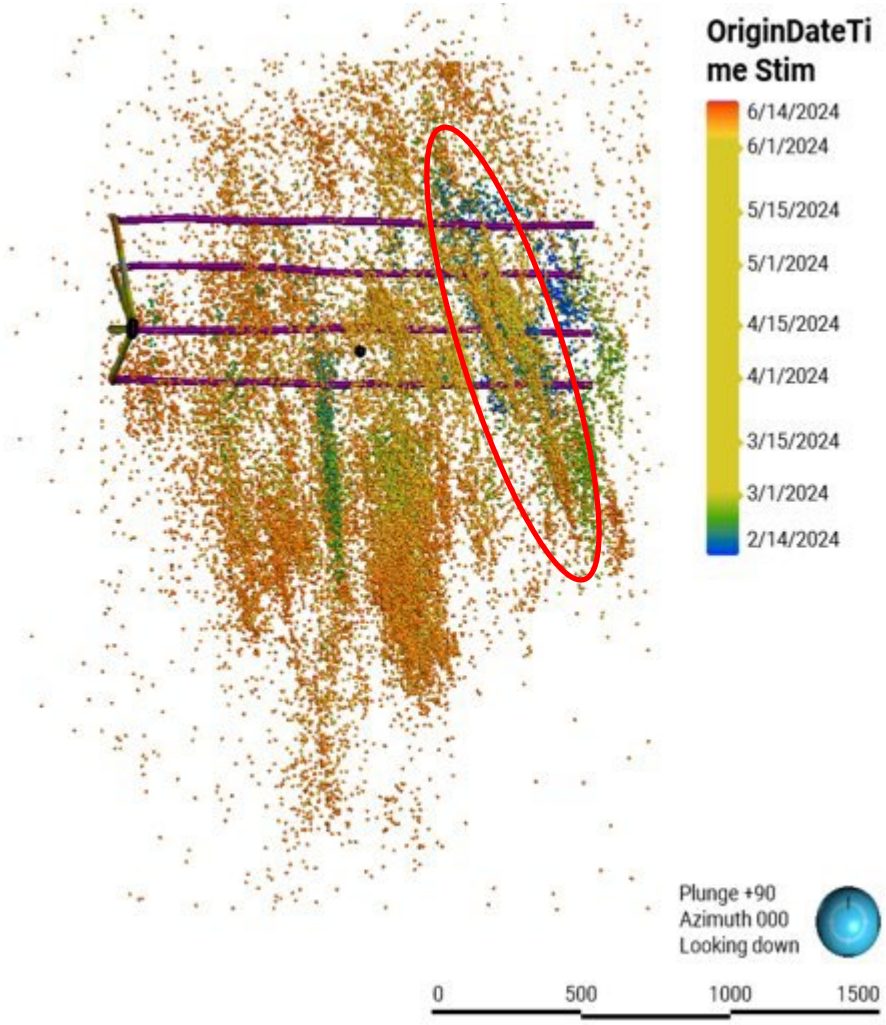
Natural fracture reactivation

- Micro fractures observed in image logs for Delano 1-OB and Frisco wells are dominantly N-S striking, and have high angle (60°- 80°) dips
- Fracture density shown gridded across the Frisco laterals
- A high fracture density zone correlates with high microseismic density, multiple Mag > 2 events and higher stress drop values along this zone.

Natural Fracture Orientations and Density from Frisco Image logs



Frisco pad microseismic



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Thank you.