CALIFORNIA STATE UNIVERSITY
LONG BEACH

Geomechanical Strain Measured by DAS

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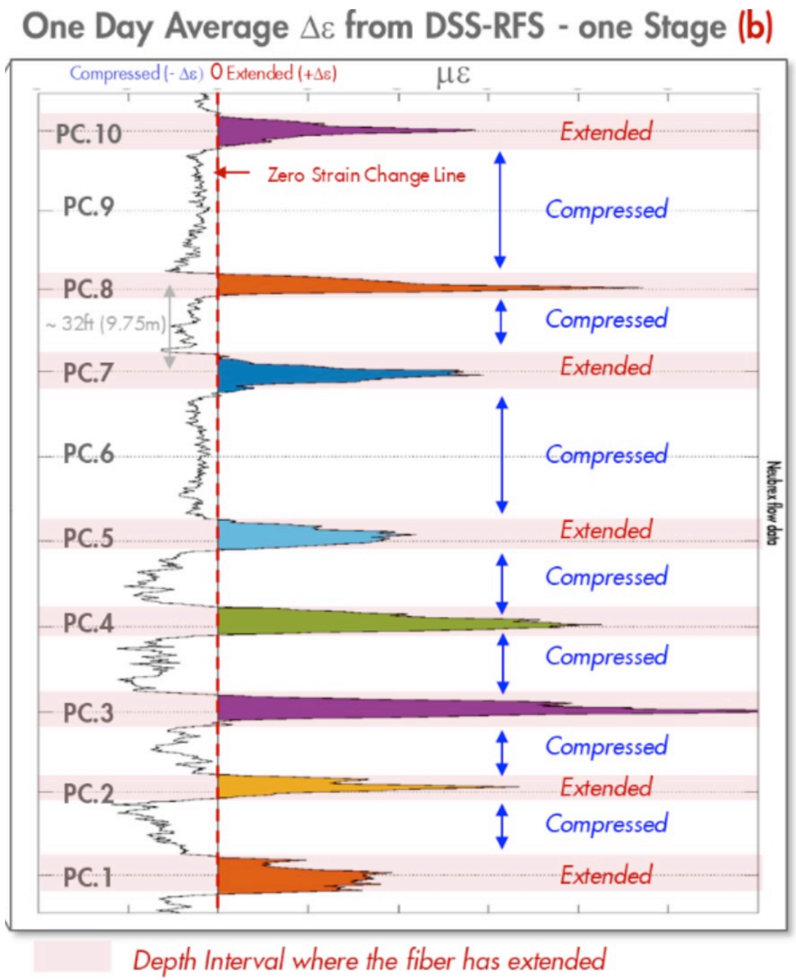
DAS as a Strain meter

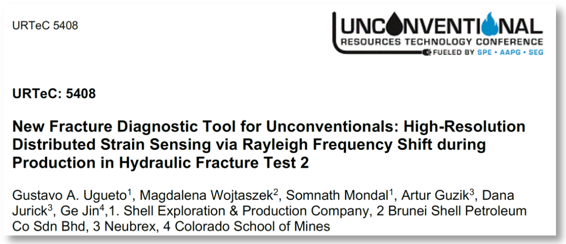
- DAS has excellent resolution for dynamic strain (strain rate)
- Installation in boreholes or trenches allows for distributed dynamic strain measurement in response to hydraulic or geomechnical forcing
- Installations to date:
  - Shallow bedrock
  - Deep mountain boreholes
  - Alluvial aquifers

DAS Installation San Gabriel Mountains

DAS vs DSS

- Why not use Distributed Strain Sensing?
- DSS has superior spatial resolution but inferior strain resolution
  - DSS: <1 m and >1 $\mu\varepsilon$
  - DAS: <10 m and <1 $n\varepsilon$
- However, DAS may already be monitoring for microseismic or induced seismicity so low-frequency strain becomes value added
- DAS and DSS are complimentary





URTeC 5408

UNCONVENTIONAL RESOURCES TECHNOLOGY CONFERENCE FUELED BY SPE • AAPG • SEG

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New Fracture Diagnostic Tool for Unconventionals: High-Resolution Distributed Strain Sensing via Rayleigh Frequency Shift during Production in Hydraulic Fracture Test 2

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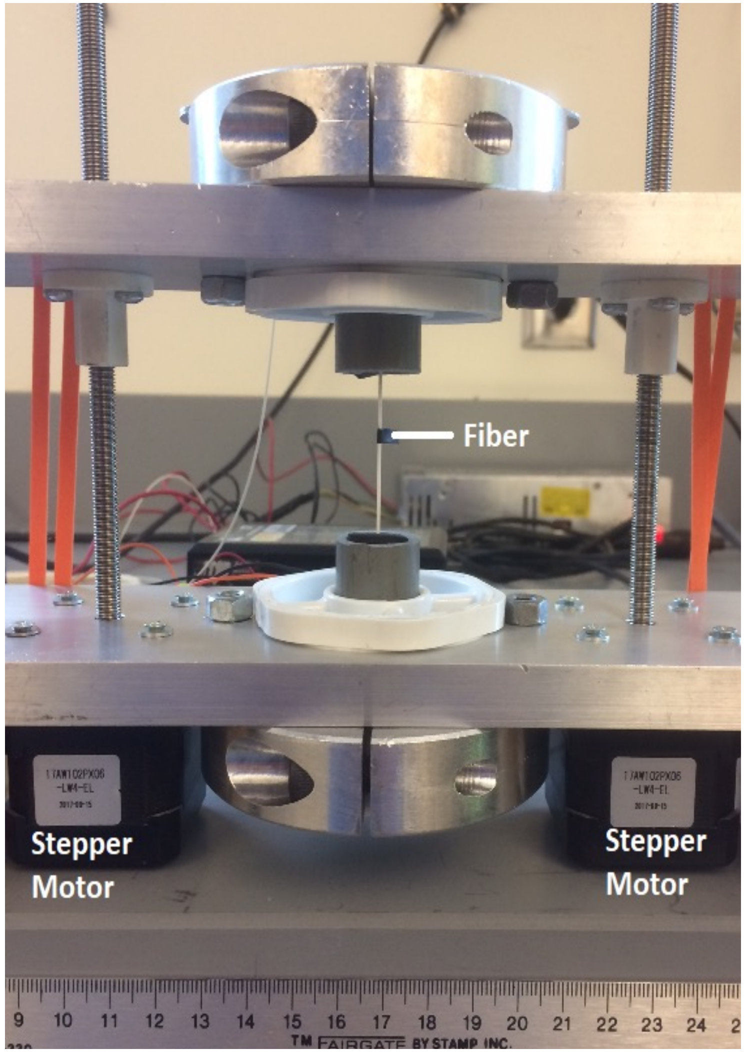
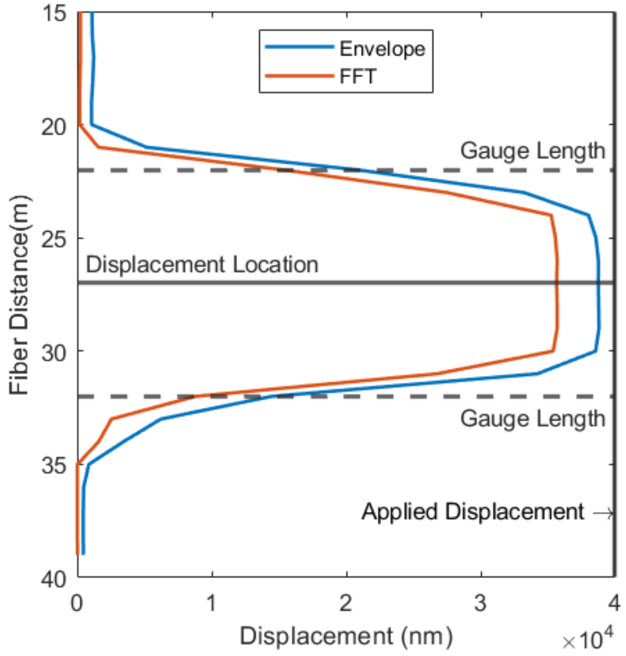
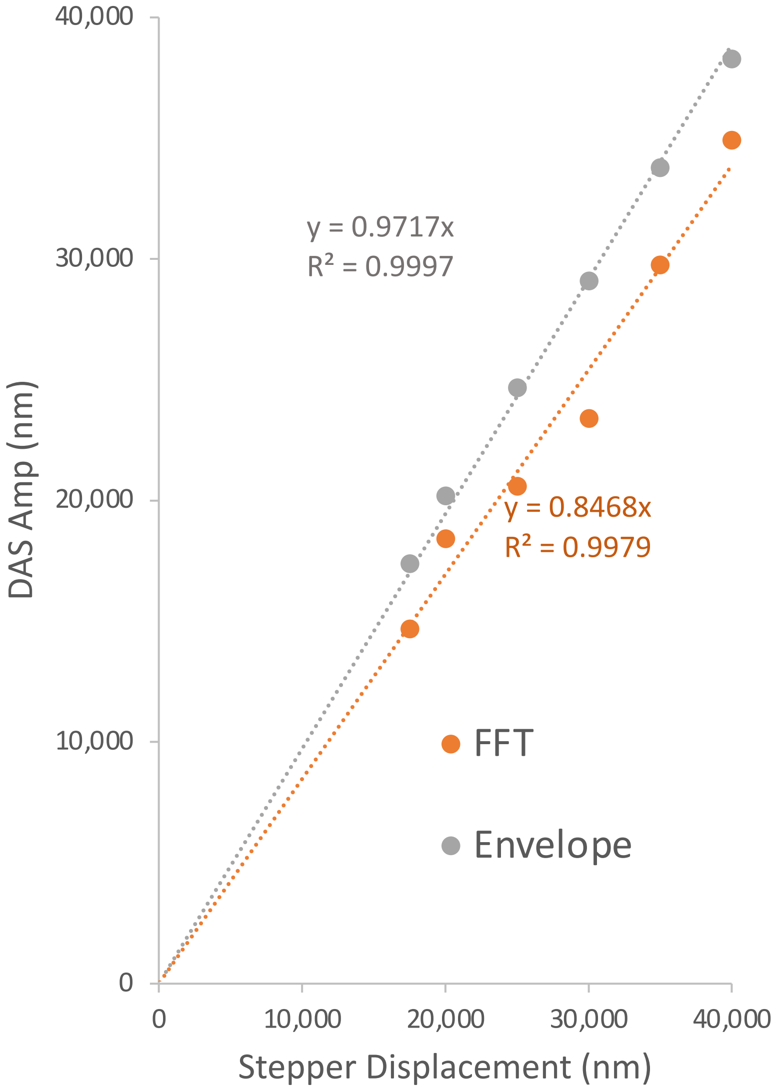
Laboratory Validation



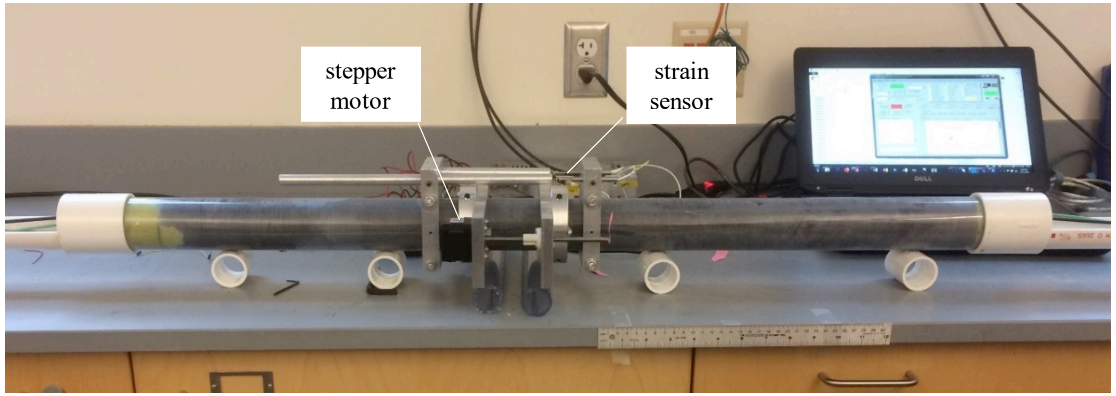


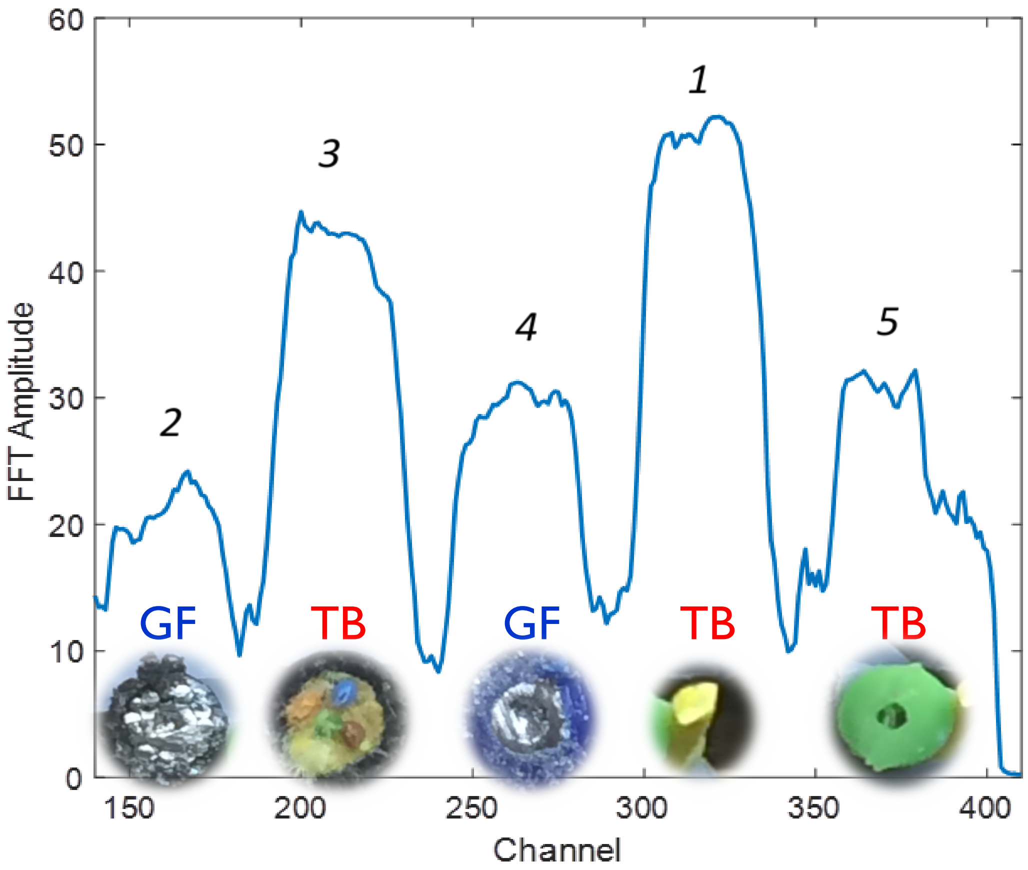


Becker, M. W., T. I. Coleman, and C. C. Ciervo (2020), Distributed Acoustic Sensing as a Distributed Hydraulic Sensor in Fractured Bedrock, Water Resources Research, 56(9), e2020WR028140.

Fiber-Cable Coupling

- Tight buffered designs preferred for strain measurements but leave fiber vulnerable to installation damage
- Not all tight buffered designs are superior to gel-filled designs
- Good mechanical coupling at high frequency (seismic) does not necessary mean good mechanical coupling at low frequency (strain)

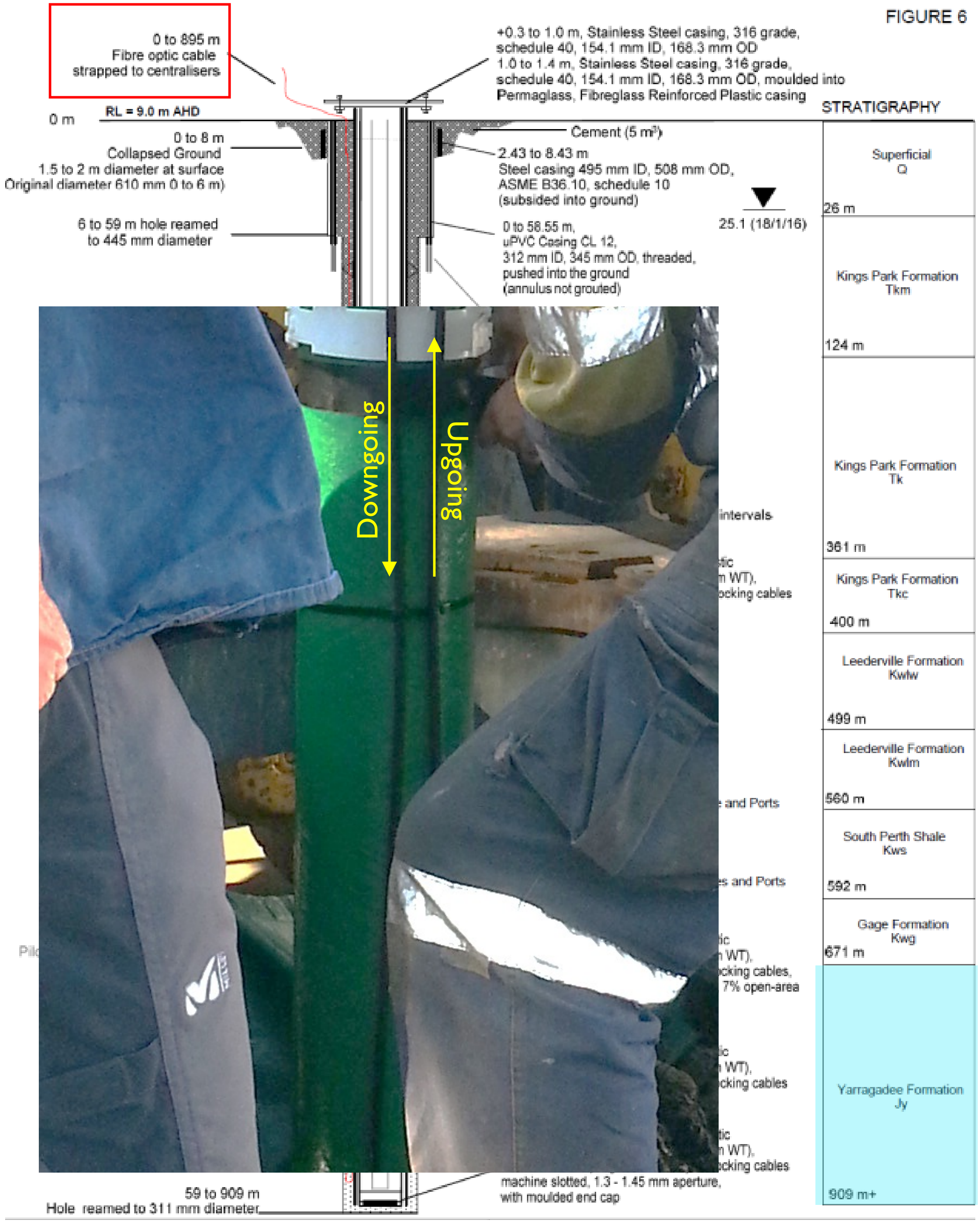




Becker, M. W., C. Ciervo, and T. I. Coleman (2018), Laboratory testing of low-frequency strain measured by distributed acoustic sensing (DAS), in *SEG Technical Program Expanded Abstracts 2018*, edited, pp. 4963-4966, Society of Exploration Geophysicists.

Experiments in the Curtin U. Borehole

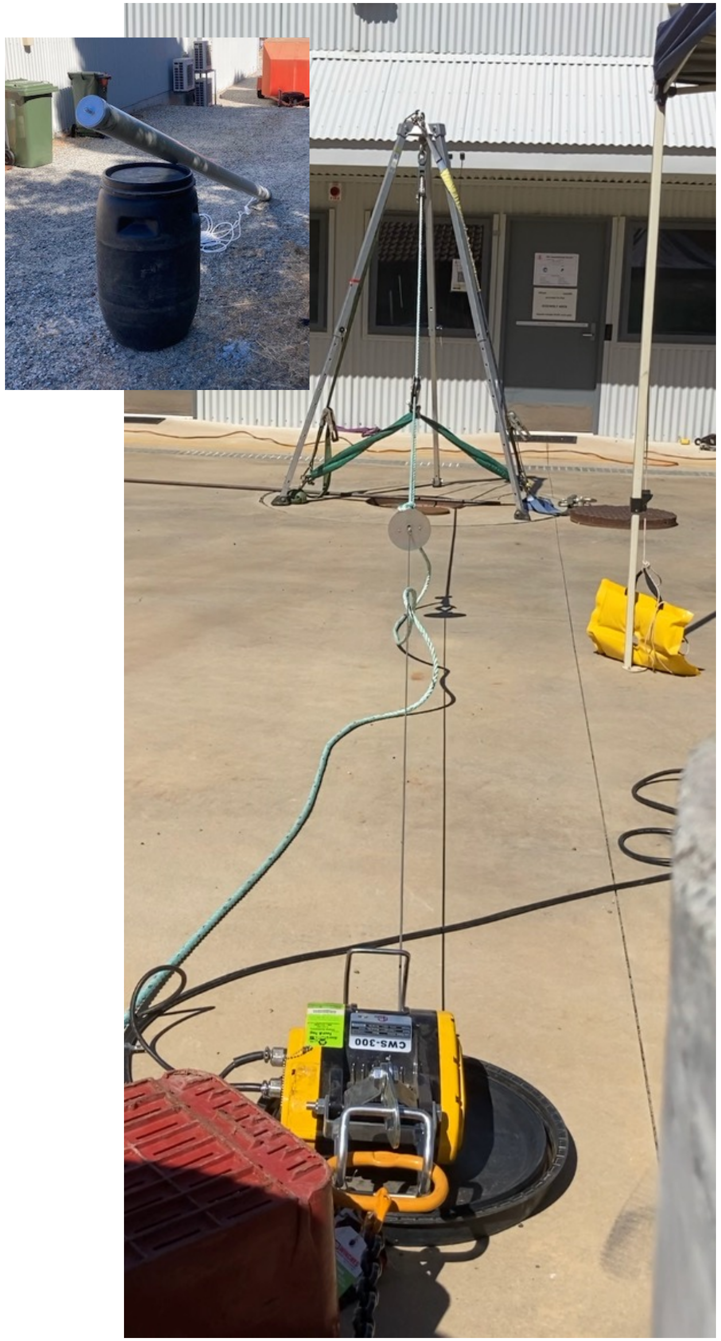
- The 900 m deep borehole is screened in the local important Yarragadee Aquifer
- The Yarragadee is fine- to medium-grained poorly cemented sandstone interbedded with finer-grained units
- The fiber optic cable used for DAS was strapped outside the fiberglass casing while lowered, then surrounded by gravel pack and sand



Becker, M. W., B. Harris, and R. Pevzner (2023), Characterization of Aquifer Poroelastic Response to Impulse and Oscillatory Well Pressure Using Distributed Acoustic Sensing, *Geophysical Research Letters*, 50(1), e2022GL100904.

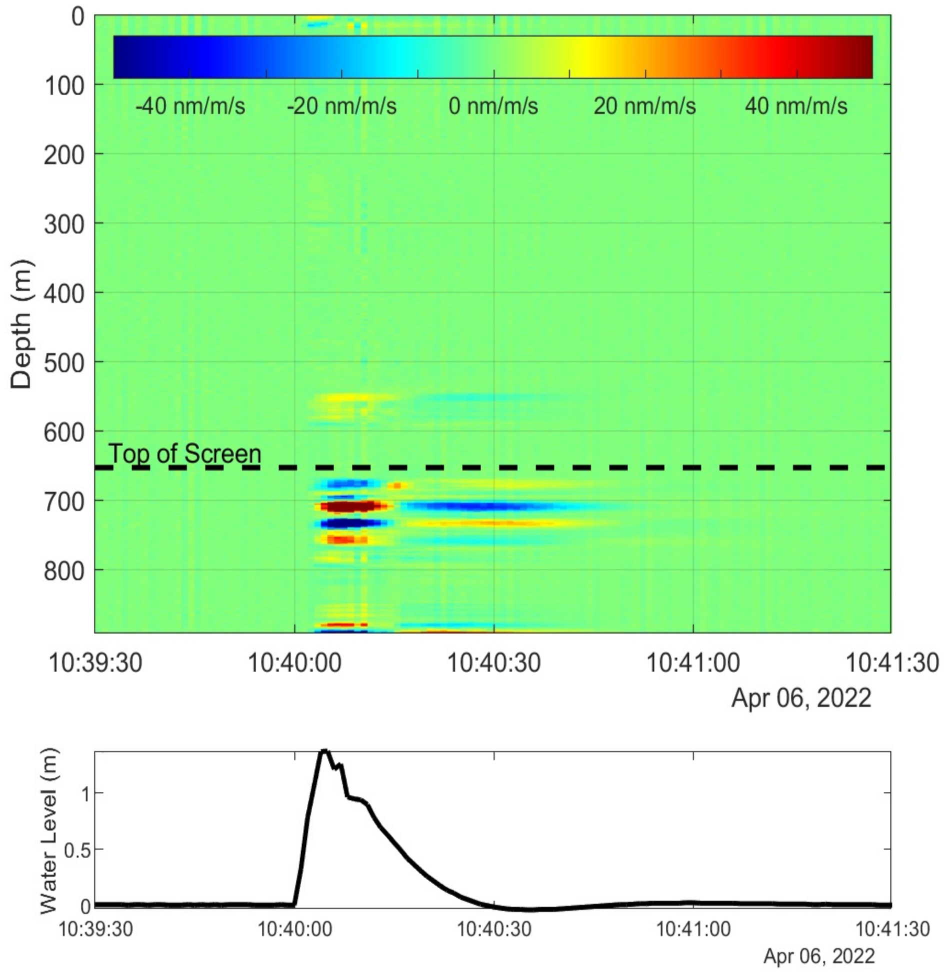
Slug Test

- Slug was constructed from 3 m long 0.1 m diameter PVC which displaced ~11 L of water
- Slug was lowered and raised with an electric hoist
- Hoist speed was varied using 1,2,3 pulley blocks to reduce the slug velocity by a factor of 0.5 and 0.33 from the full cable speed



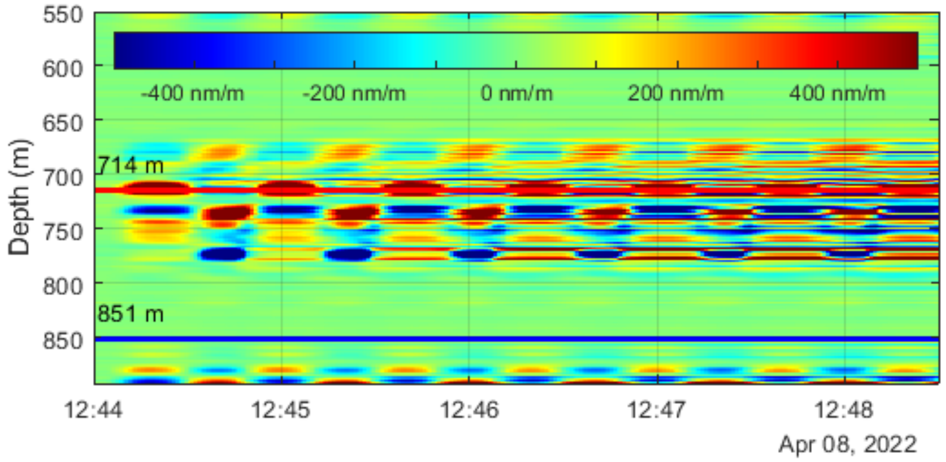
Distributed Displacement from Slug Test

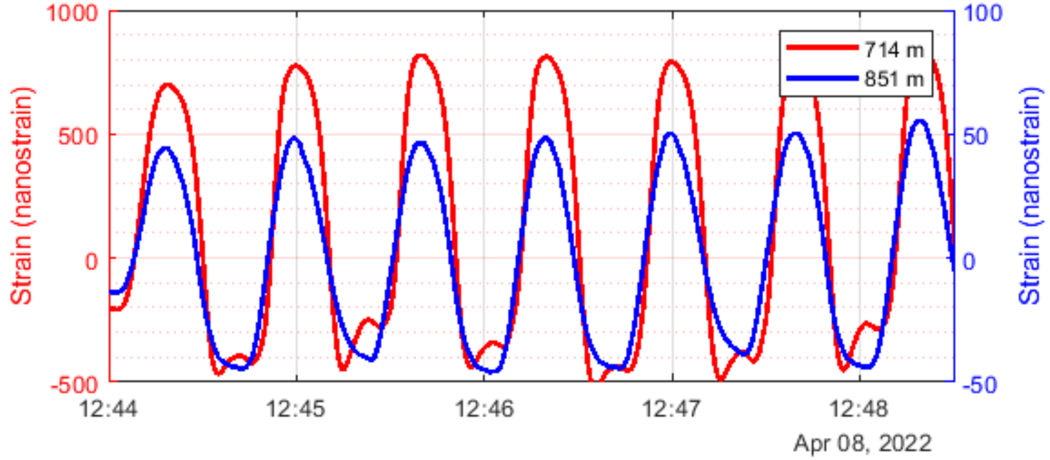
- The DAS fiber elongates in response to the poroelastic strain
- Strata that accept fluid are presumably displaced more
- Displacement rate is anticorrelated with water level at some depths
- There is displacement above the screened interval (~550 m depth) that coincides with grouting ports



Strain Magnitude

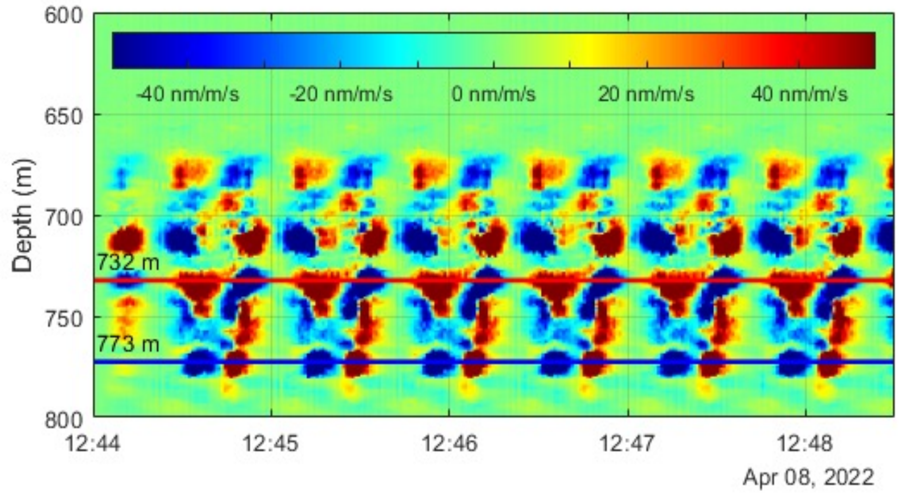
- The strain response to head oscillation in the well varies by at least two orders-of-magnitude
- Sensitivity is in the picostrain range
- Note that because the gauge length of the DAS measurement is 10 m, we cannot see fine high or low compliant strata

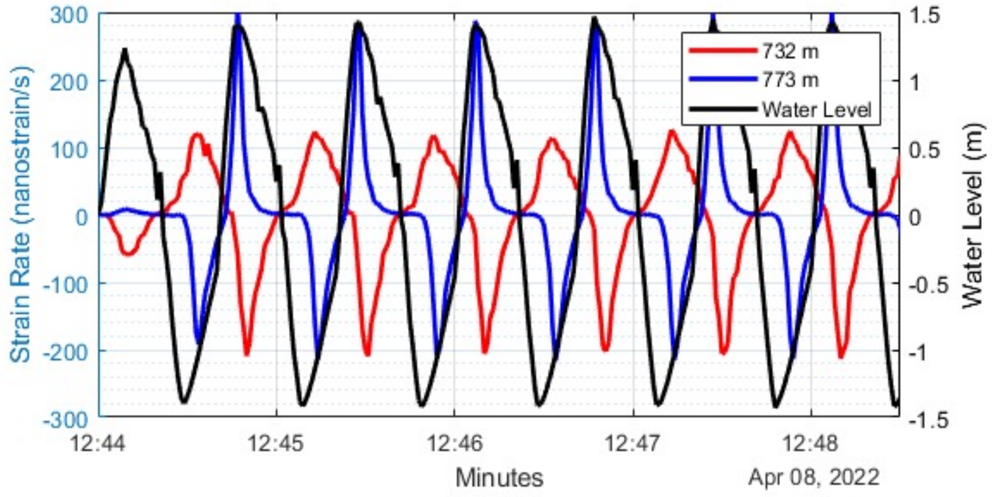




Strain Rate Behavior

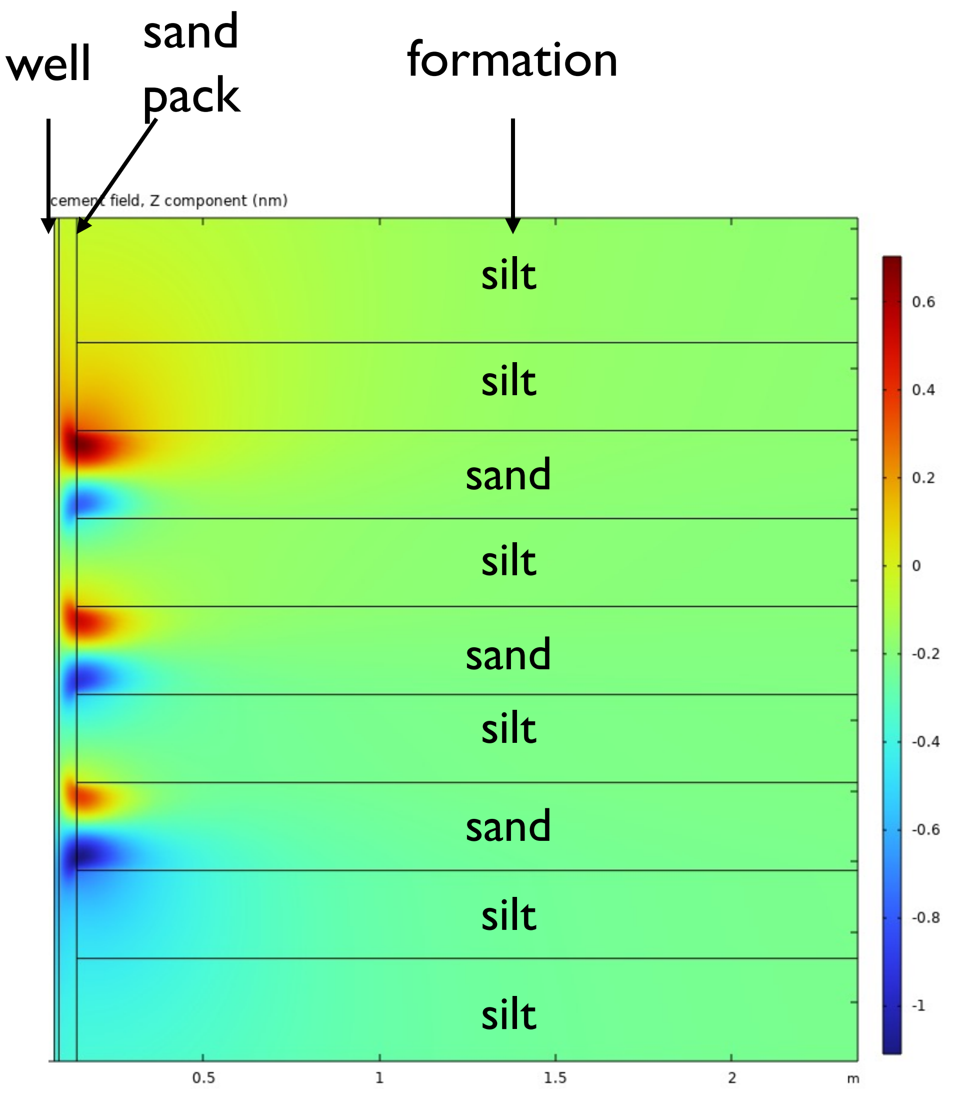
- Strain rate is correlated or anticorrelated with injection pressure in some zones
- Strain rate is asymmetric with regard to expansion and contraction of the formation
- Complex strain response may indicate inter-layer hydraulic exchange (leakoff)





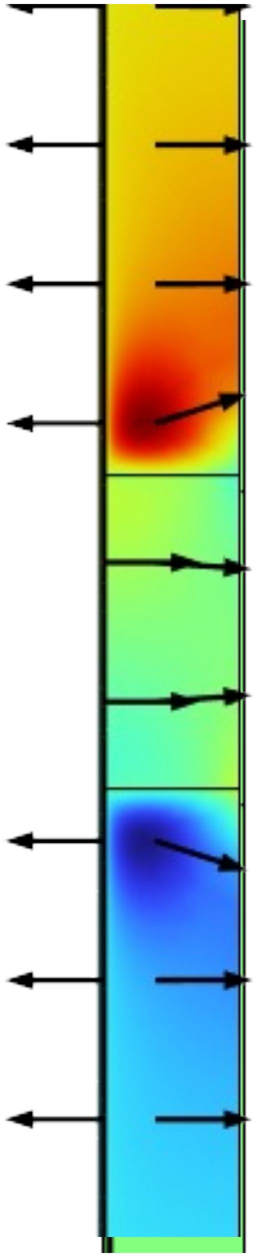
Poroelastic Modeling

- A radial symmetric simulation with COMSOL shows that the displacement contrast occurs at the top and bottom of transmissive units.



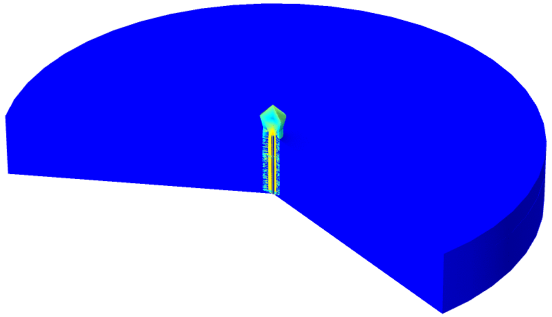
Noordbergum Effect

- The differential propagation rate of mechanical strain and fluid flow can lead to brief flow to the well during the injection phase
- This is sometimes referred to as the Noordbergum Effect
- This simulation shows Darcy vectors superimposed on the strain signal
- Noordbergum behavior is predicted to occur with these strain signatures



Conclusions

- The excellent dynamic strain (strain rate) sensitivity of DAS makes it suitable for observing previously unobserved geomechanical behavior
- More work is needed to understand mechanical coupling for ultra-low-frequency measurements, e.g. cable construction, anchoring to wells, cements and grouts…



Acknowledgements

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