Field Results from New Tensor Borehole Optical Fiber Strainmeter Installations in Oklahoma and Utah

The time evolving strain field contains a wealth of information that can be used to interpret subsurface behavior. For example, injecting or removing fluids from reservoirs or aquifers causes deformation that can be used as a diagnostic signal in some cases, while it can interfere with geodetic interpretations in other cases. We've previously demonstrated the feasibility of measuring the strain tensor at a depth of 30m caused by injection into a reservoir at 530m. The observed strain signals were interpreted using four independent analytic and numerical methods that resulted in estimates of the poroelastic properties and geometry of the reservoir that was consistent with data from well logs. However, studies like these are only possible if these deformations can be reliably measured.

Years of lab and field work has culminated in the development of a novel borehole strainmeter capable of resolving multiple components of strain using embedded optical fibers configured as Michelson interferometers. It features four horizontal gauges separated by 45° to resolve the horizontal strain tensor as well as a vertical strain gauge and a sixth null component for state-of-health monitoring. The downhole sensing package also includes an open pipe through its center for grout circulation during single-trip deployments and a fully welded stainless steel exterior for robustness and longevity. These instruments have a resolution of $2x10^{-13}$ strain that can easily measure the solid earth tides.

Preliminary data are available from four strainmeters in shale at our Oklahoma site and four in compacted sand and gravel in Utah. These are deployed from 40-60m, except one of the strainmeters in Oklahoma is deployed at 500m. The data include strains from the initial grout curing, comparisons to predicted earth tide models and in-situ calibration results, barometric pressure admittances and spectral analyses as well as signals from underground injections and surface waves from teleseismic events. Preliminary analyses indicate behavior consistent with other strainmeter deployments, and comparison to data from a Gladwin strainmeter at the Oklahoma site validate the performance of the new design. Analyses from a suite of six well tests at the Oklahoma site show for the first time how the strain tensor field varies with location during well testing.