Downhole and surface fiber optic DAS recordings of a 1000 kg TNT-equivalent chemical explosion in alluvium

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Introduction

We present data and analysis from a 1,000 kg TNT-equivalent explosion recorded on a mixed array of downhole and surface fiber optic DAS sensors. The experiment was conducted at the Nevada National Security Site (NNSS) Nevada, USA. The explosion (called Dry Alluvium Geology 1 (DAG-1)) is the first in a series of four planned explosions as part of Phase II of the Source Physics Experiment (SPE). The goal of SPE is to better understand explosion-source phenomenology, especially in regards to shear-wave generation.

DAG-1 was detonated at 385-m depth in June, 2018 and was monitored by an array of over 500 channels of surface and downhole accelerometers, geophones, infrasound sensors, and broadband seismometers. New to the SPE program was the inclusion of multiple sections of fiber optic DAS. A helically-wound section occupied two >385 m borehole sections and a traditional straight cable was trenched on the surface to the recoding station 2 km distant.

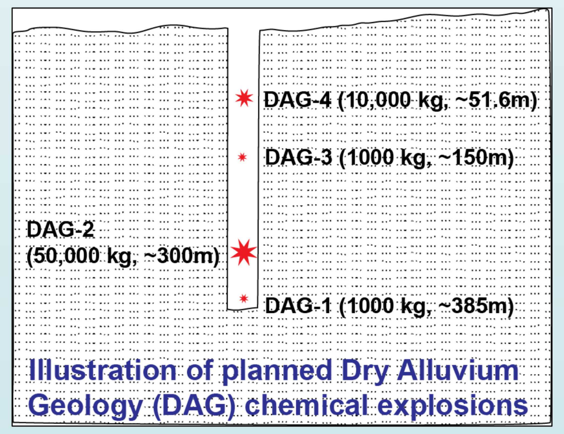
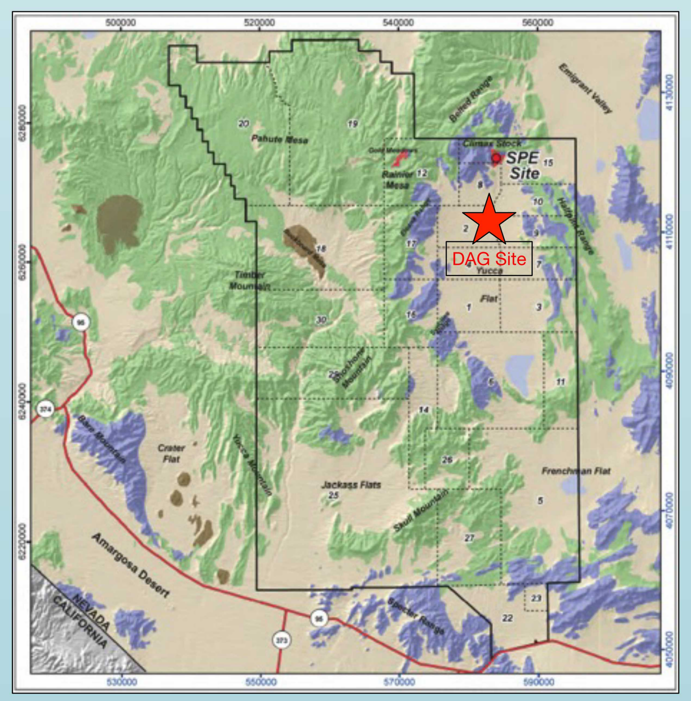
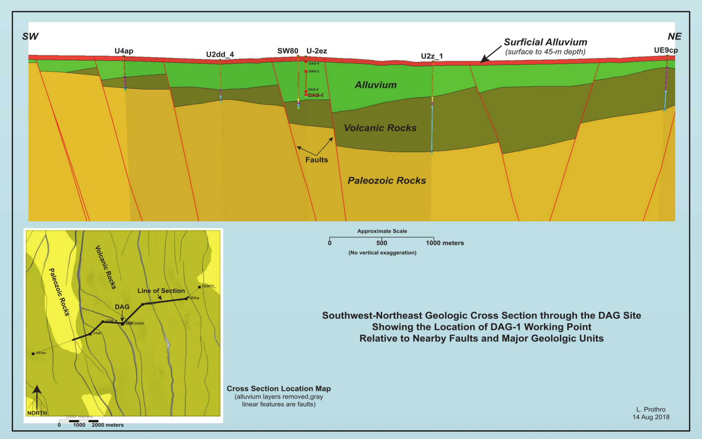


Illustration of planned Dry Alluvium Geology (DAG) chemical explosions

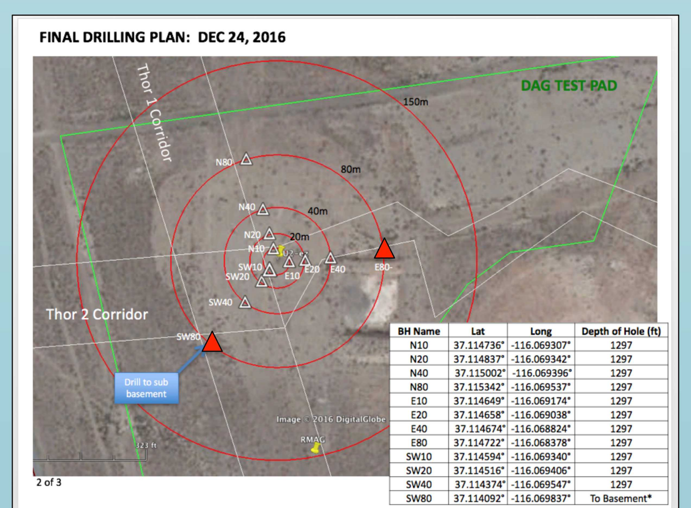
The main goal of the fiber deployment is to supplement traditional 3C acceleration measurements made in boreholes near the explosions.

Field Area



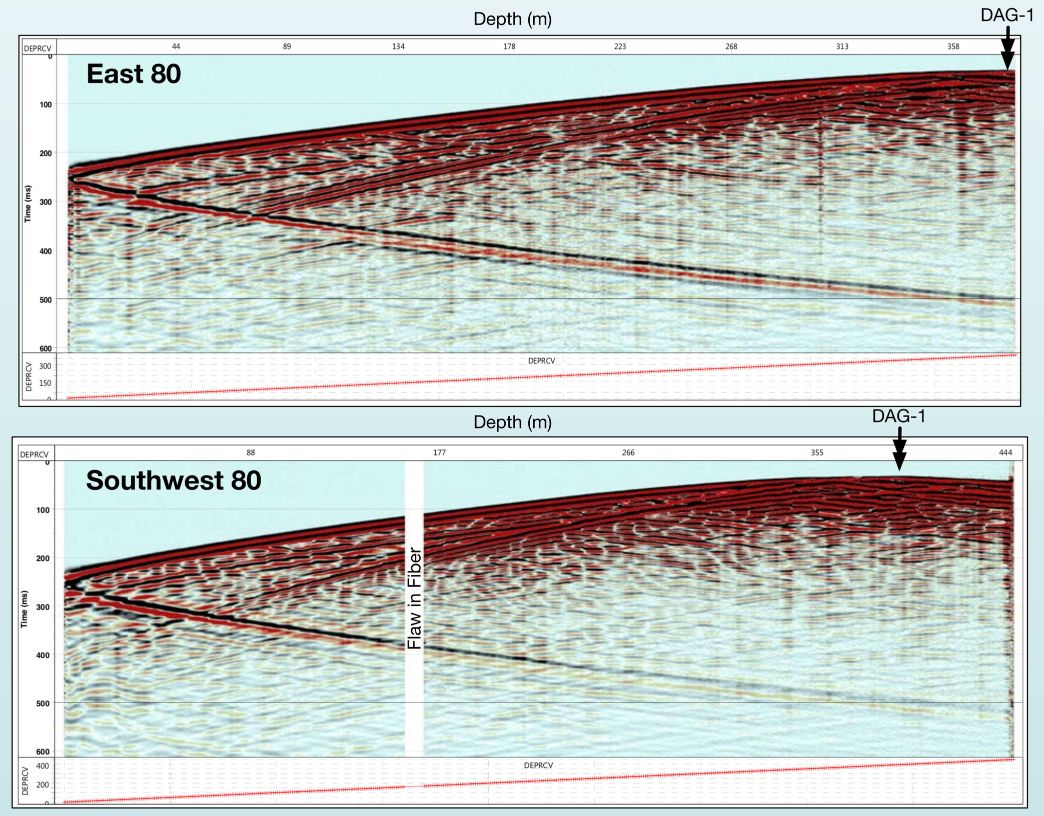


Geology of the site consists of Quaternary alluvium, overlaying Tertiary volcanic rocks and Paleozoic carbonates. The working point of the explosion and the majority of the fiber data are in the alluvium section, which is above the water table.



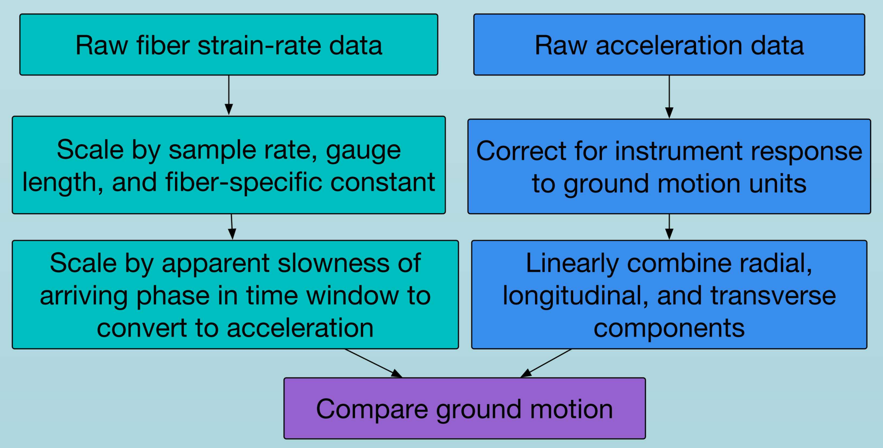
Fiber was installed in boreholes East 80 and Southwest 80 (red triangles). Both boreholes are 80 meters from the explosives borehole. Fiber connecting the two boreholes was surface laid and trenched in (not shown). South of SW 80, traditional straight fiber was trenched to the recording trailer, approximately 2 km distant. The surface fiber data is not part of this presentation. Traditional 3-component accelerometers were installed at DAG-1 depth, and 85 meters above, in both E80 and SW80.

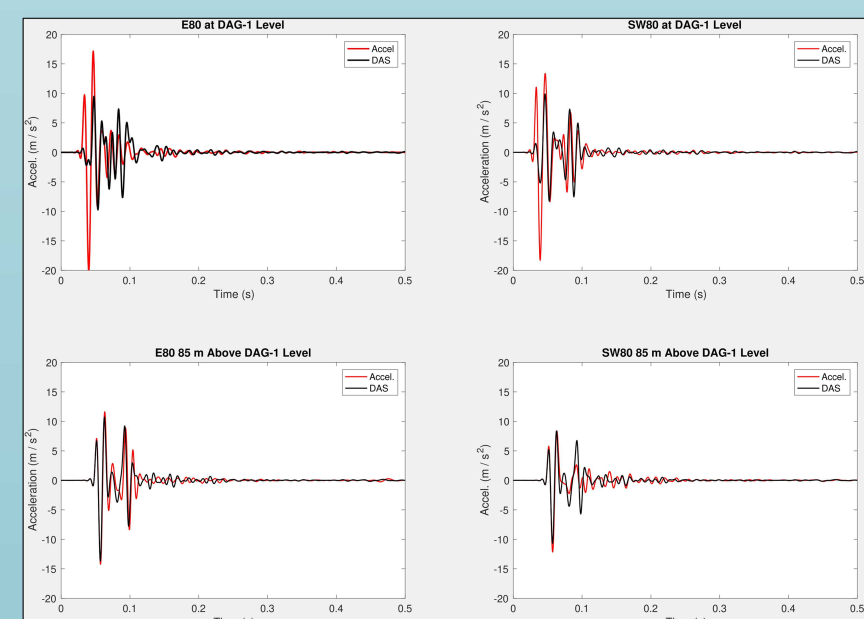
Field Data



Comparison to Accelerometers via Simple Scaling

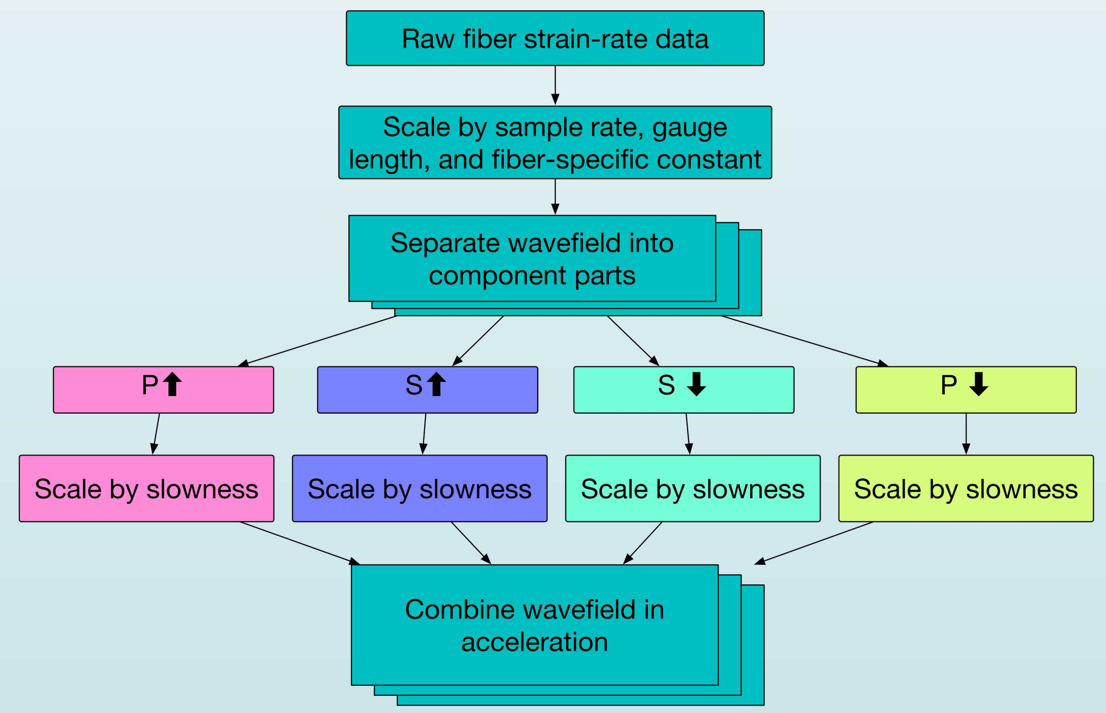
Comparison Workflow



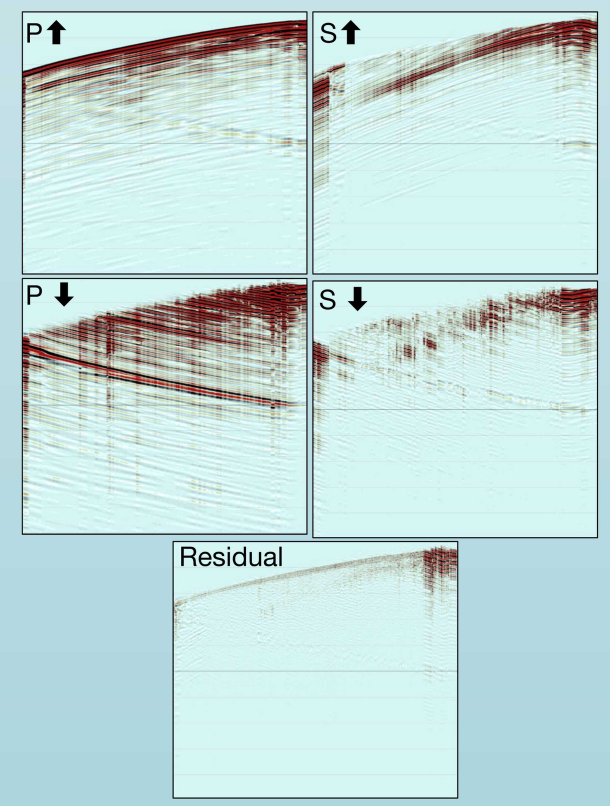


Conversion from fiber strain-rate to acceleration can work well with simple scaling for both P and S windows. Recordings at explosion level have underestimated P-wave motion, perhaps due the difficulty in picking near-zero slowness.

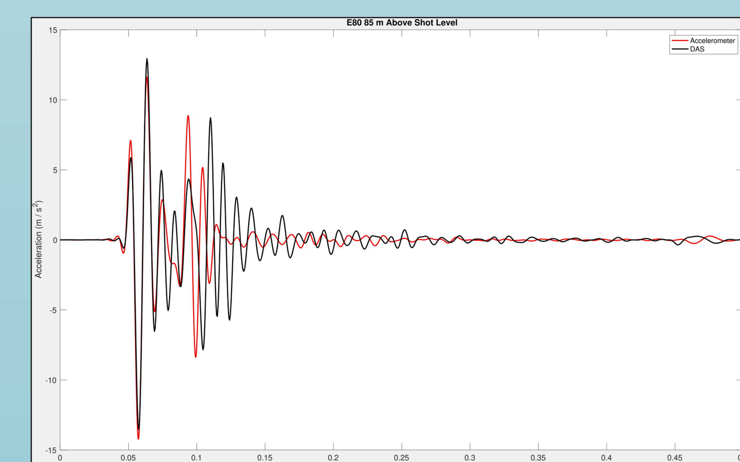
Comparison to Accelerometers via Wavefield Separation



Preliminary Wave Separation



A promising technique to scale the fiber strain-rate data is to separate the data into the dominant wavefields and scale the wavefields appropriately. One such attempt using the technique of Blias (2007) is pictured on the left. Note that artifacts are increased on the edges of the array and that the separation is not without bleed-through of other phases.



Comparison of E80 85 meters above the explosion (the best of the four comparisons to the left), show degradation of results compared to simple scaling. This is most likely due to artifacts added during the deconvolution process. Further work on refining the parameters in the Blias (2007) technique are needed for improved results.

Results

- Helically-wound fiber in VSP configurations record upgoing and downgoing P and S waves
- Fiber strain rate can be accurately converted to acceleration by scaling with the local apparent slowness
- The technique works best in high SNR time windows were phases are well separated
- The acceleration measured by the fiber is omnidirectional, so all three components on co-located accelerometers need to be linearly combine

Lessons Learned for Future DAG Tests

- Consider installing fiber it the explosives hole to aid separation of upgoing and downgoing wavefield in true, zero-offset, VSP
- Install fiber at least 10 meters below the deepest measurement point desired to avoid edge effects in processing
- New analysis techniques are needed for determining explosion-source properties from omnidirectional measurements

Acknowledgements

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