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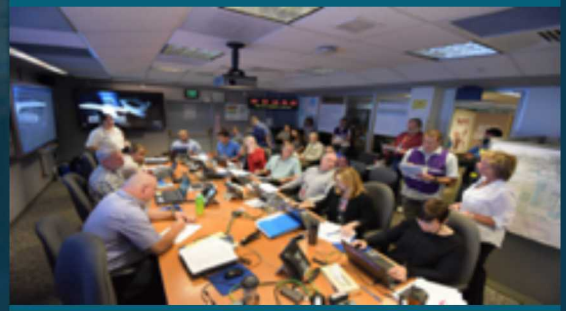
SAND2019-14706C

Explosion Phenomenology Revealed by Fiber Optic Distributed Acoustic Sensing Measurements at the Source Physics Experiments Phase II (Dry Alluvium Geology) Chemical Explosion Series



PRESENTED BY
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U.S. DEPARTMENT OF ENERGY | NNSA

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The Source Physics Experiments

- SPE systematically examines the phenomena in the source region of explosions
  - The causes of shear-wave creation is of particular interest
- Conduct a well-instrumented series of explosions at the Nevada National Security Site (formerly NTS)
- Use seismic and other recordings as groundtruth for more physics-based models (as opposed to current empirical models)

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NEVADA NATIONAL NNSS SECURITY SITE

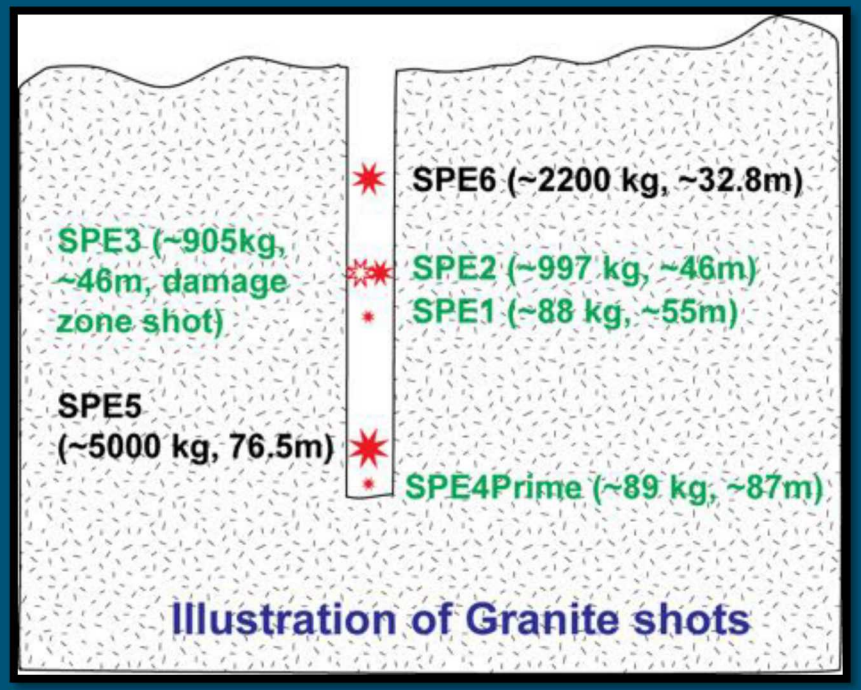
University of Nevada, Reno

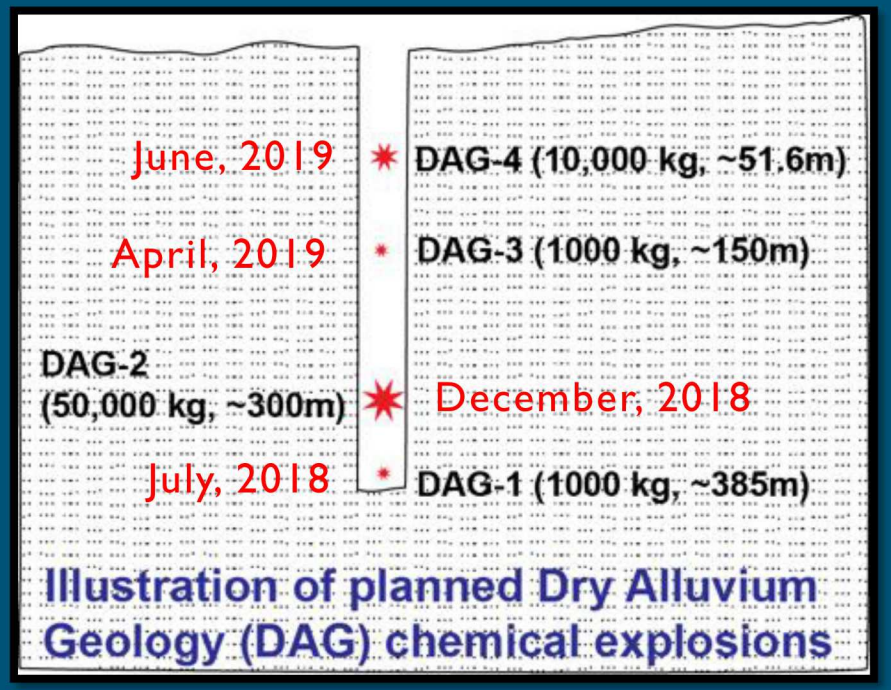
Lawrence Livermore National Laboratory

Los Alamos NATIONAL LABORATORY EST. 1943

NNSA

SPE Chemical Explosions





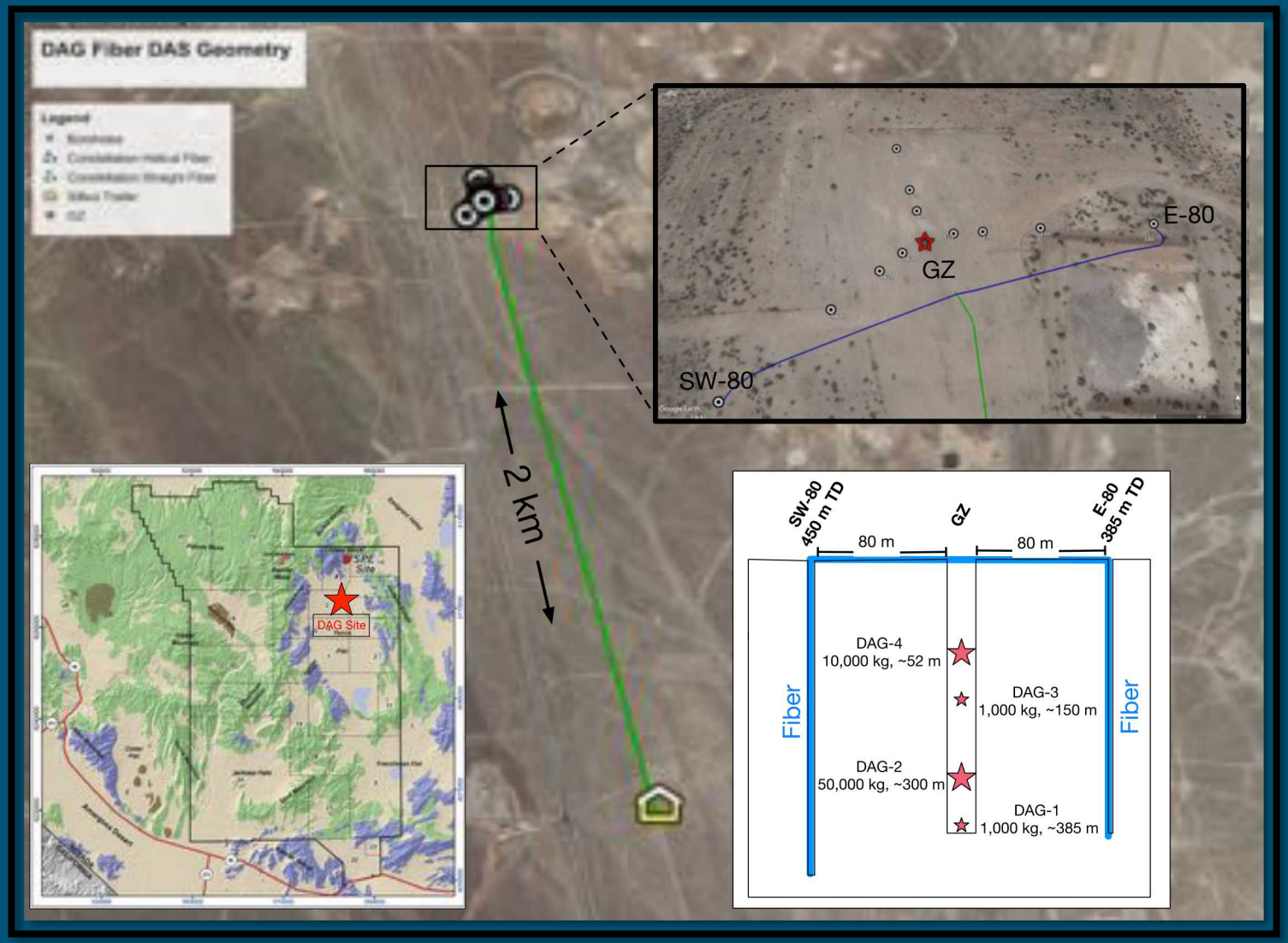
Phase I (granite) is complete

- Seismo-acoustic data is available for download at IRIS
- No DAS data acquired

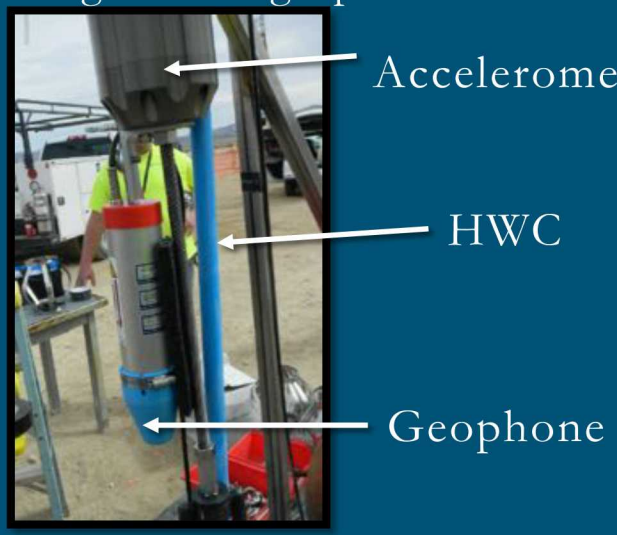
All DAG data includes DAS

DAG-2 Canister
50,000 kg TNT-equivalent

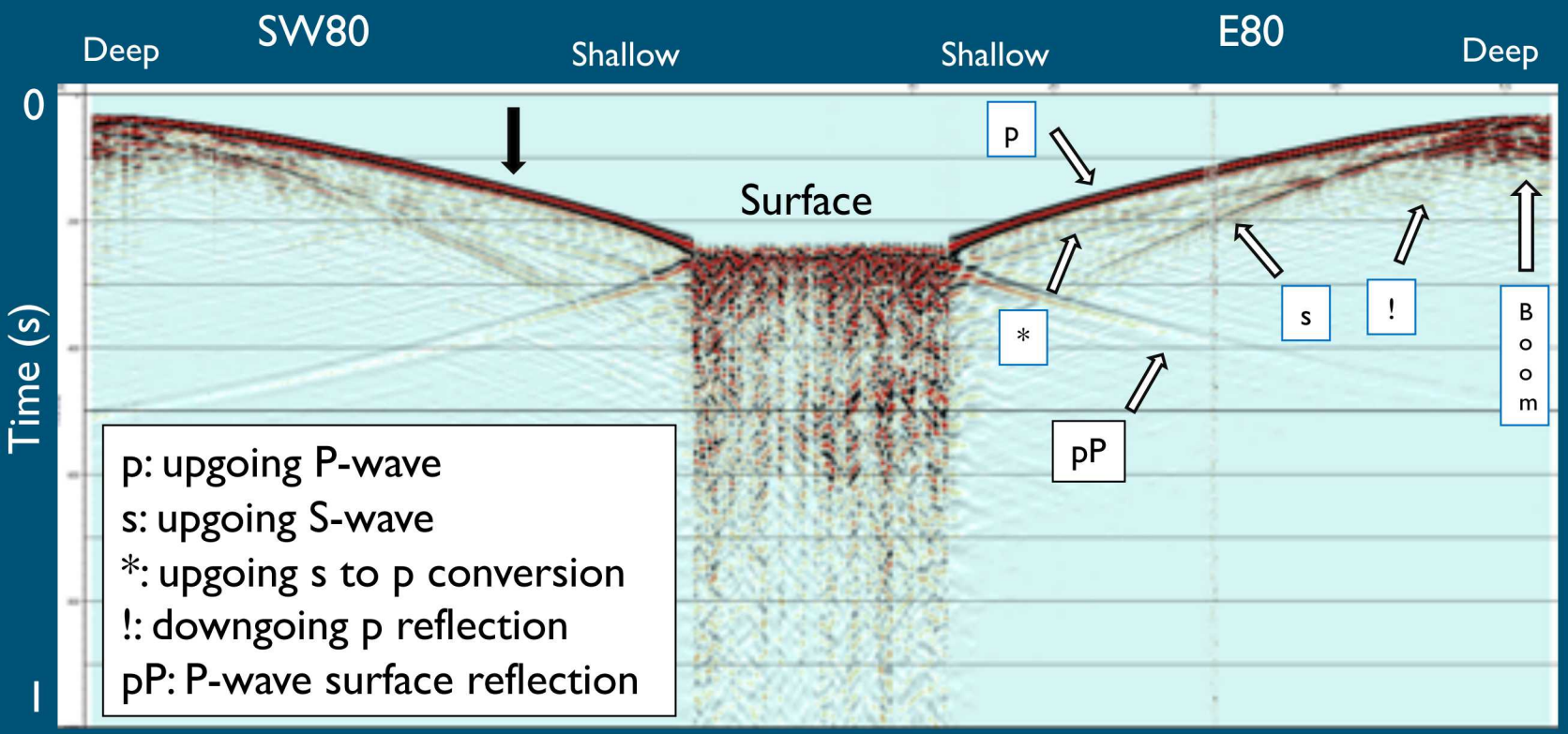
DAG Fiber DAS Acquisition and Geometry

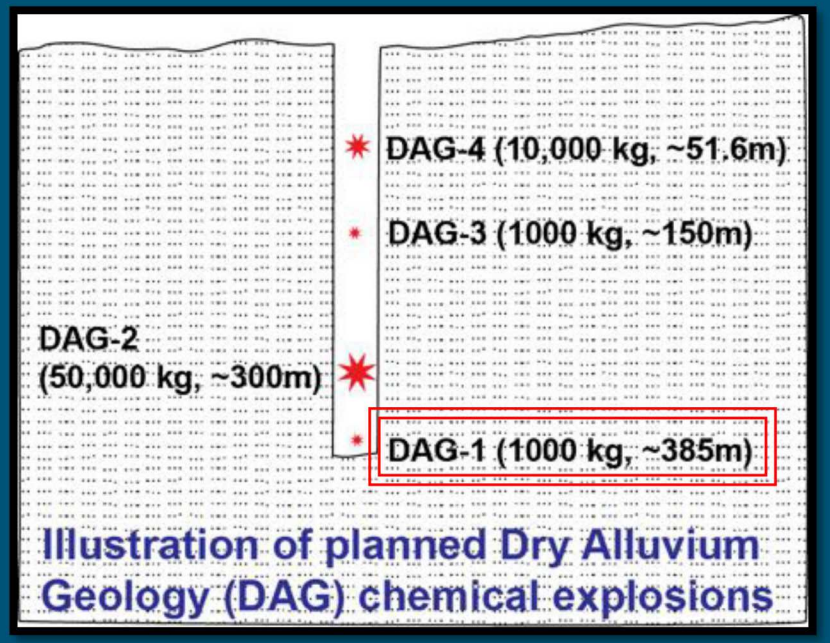


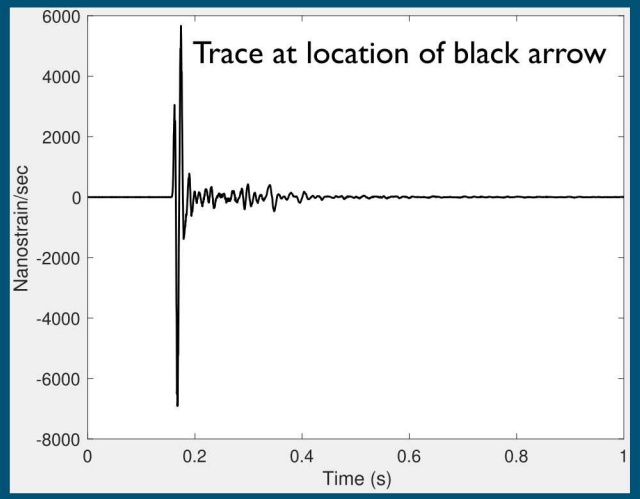
- 1 km of helically wound cable (HWC)
  - HWC cable grouted in two boreholes 80 m from GZ
  - HWC surface-trenched cable between the two boreholes
- 2 km of straight Constellation cable
  - Straight cable run in trench to recording trailer ~ 2 km from GZ
- Triaxial accelerometers at level of each explosion in 12 surrounding boreholes
- Single triaxial geophone



DAG-1

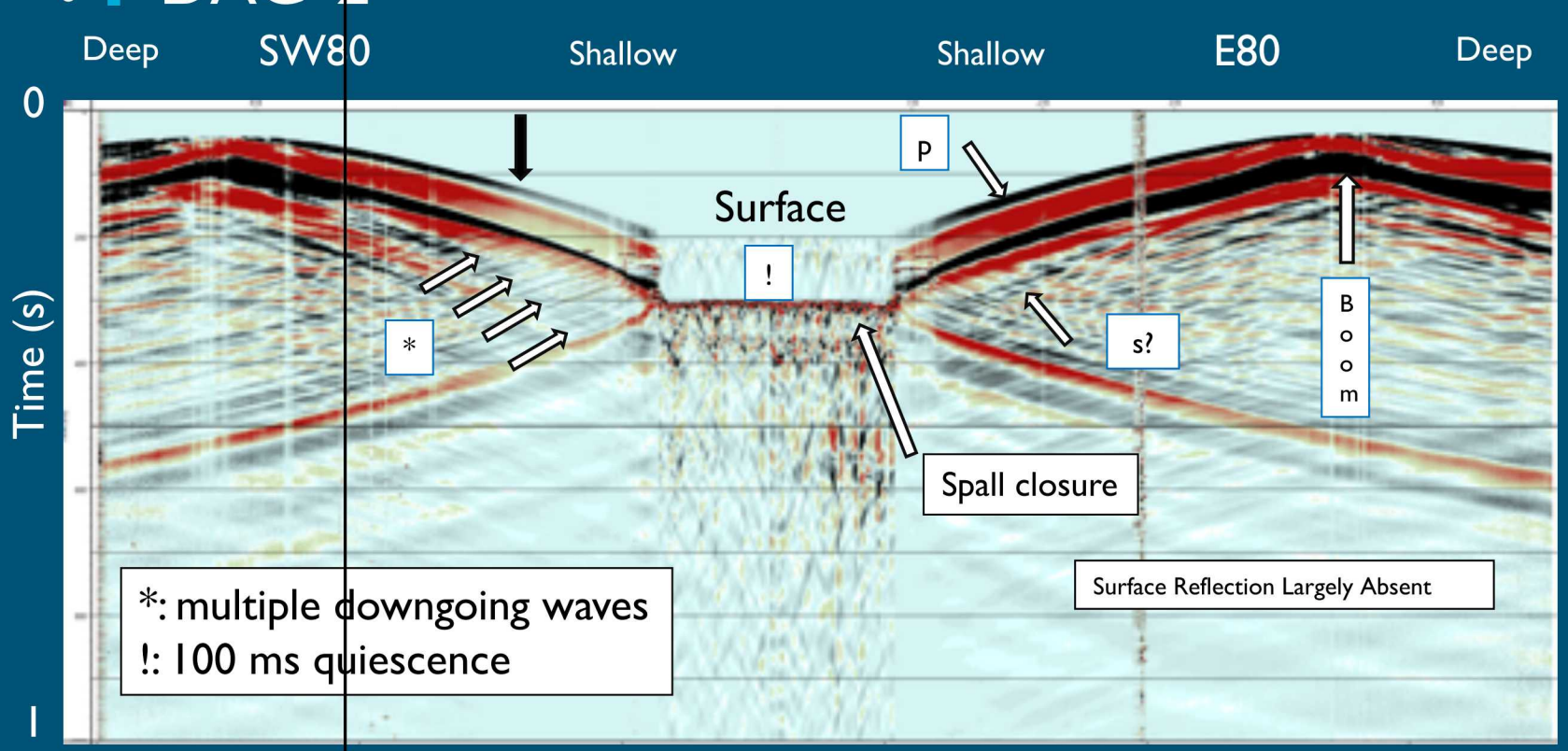


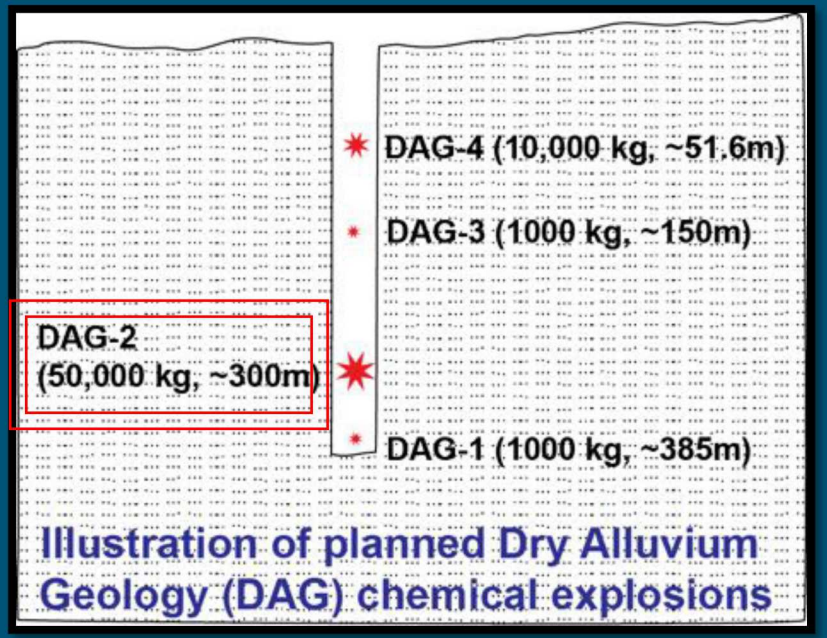


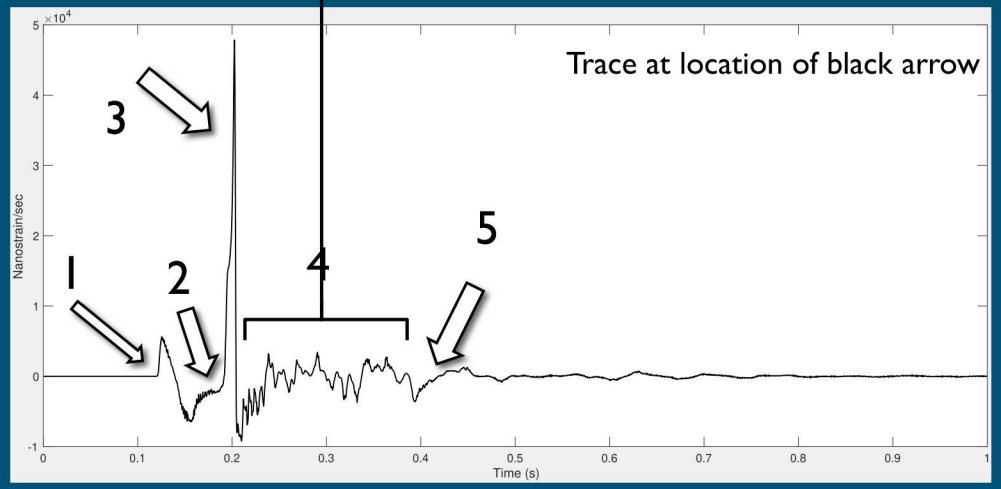


- Over 900 stations of downhole data at 80 meters from SGZ.
- Compared to 9 stations of traditional acceleromters

DAG-2

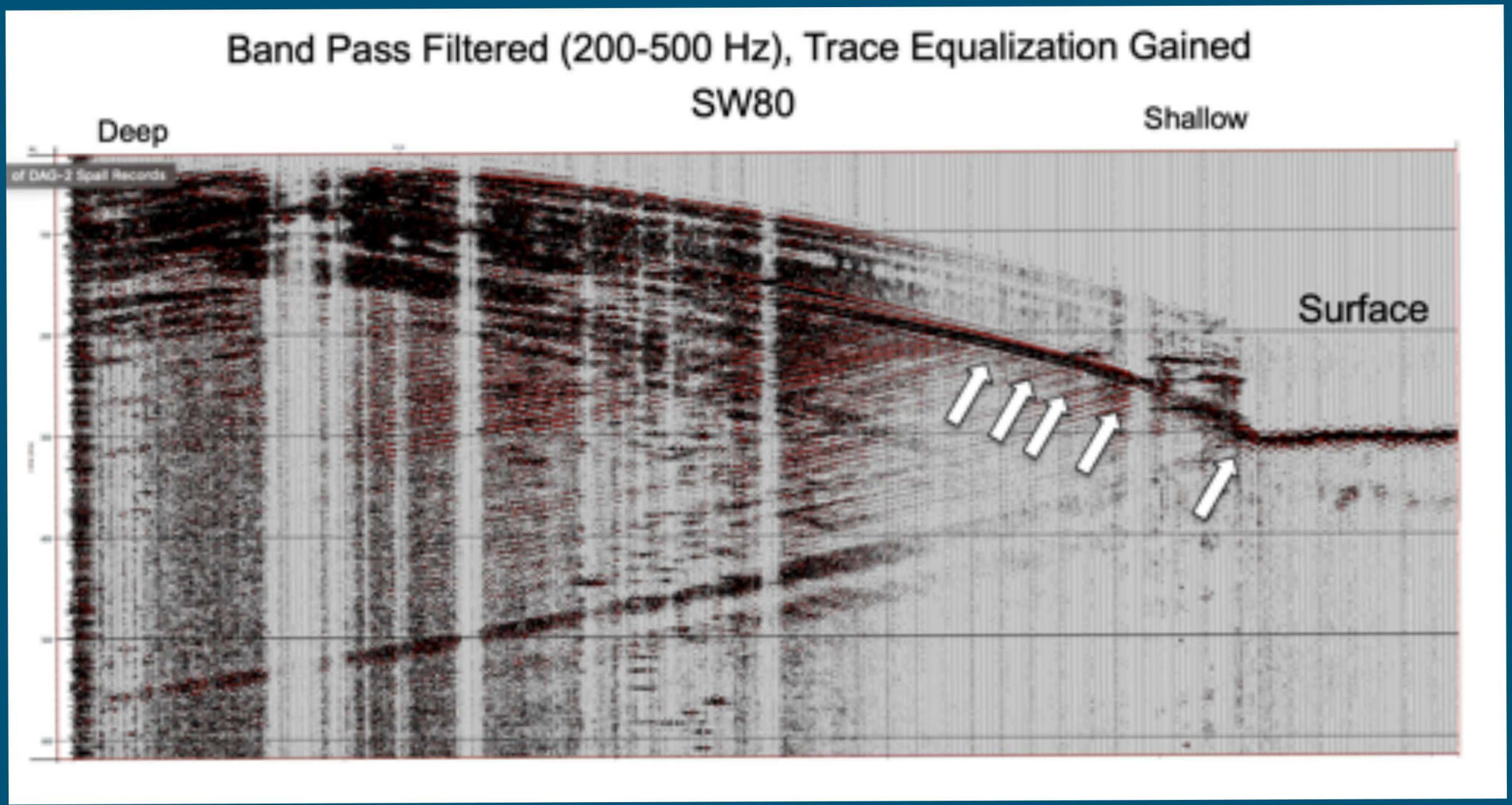




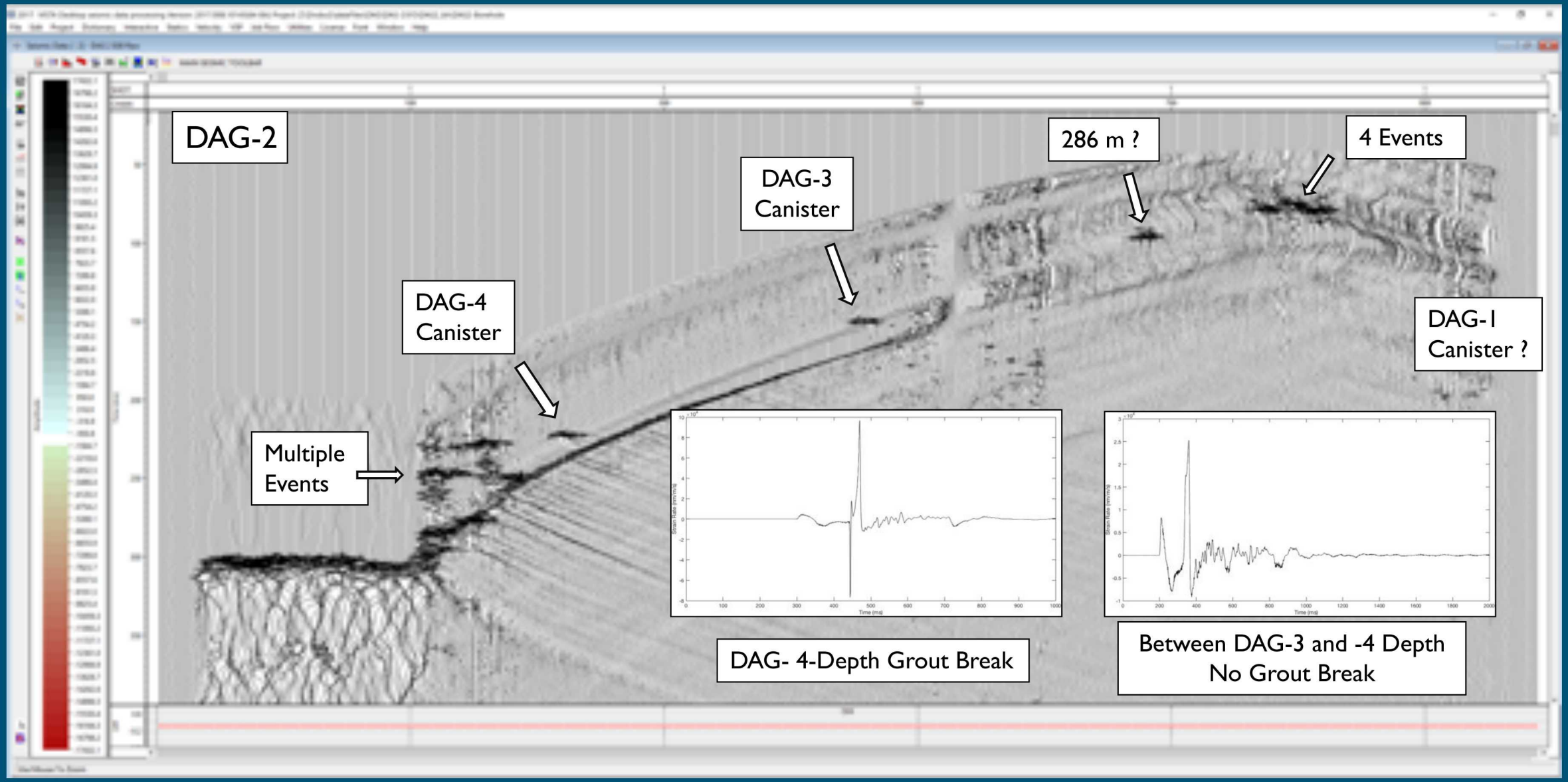


1. First arrival 1/10th amplitude of later arrival
2. Flat ramp
3. Impulsive spall closure arrival (flat ramp to closure 40 ms at all depths)
4. Down-going spall closures from shallower depths.
5. Surface reflection or spall closure

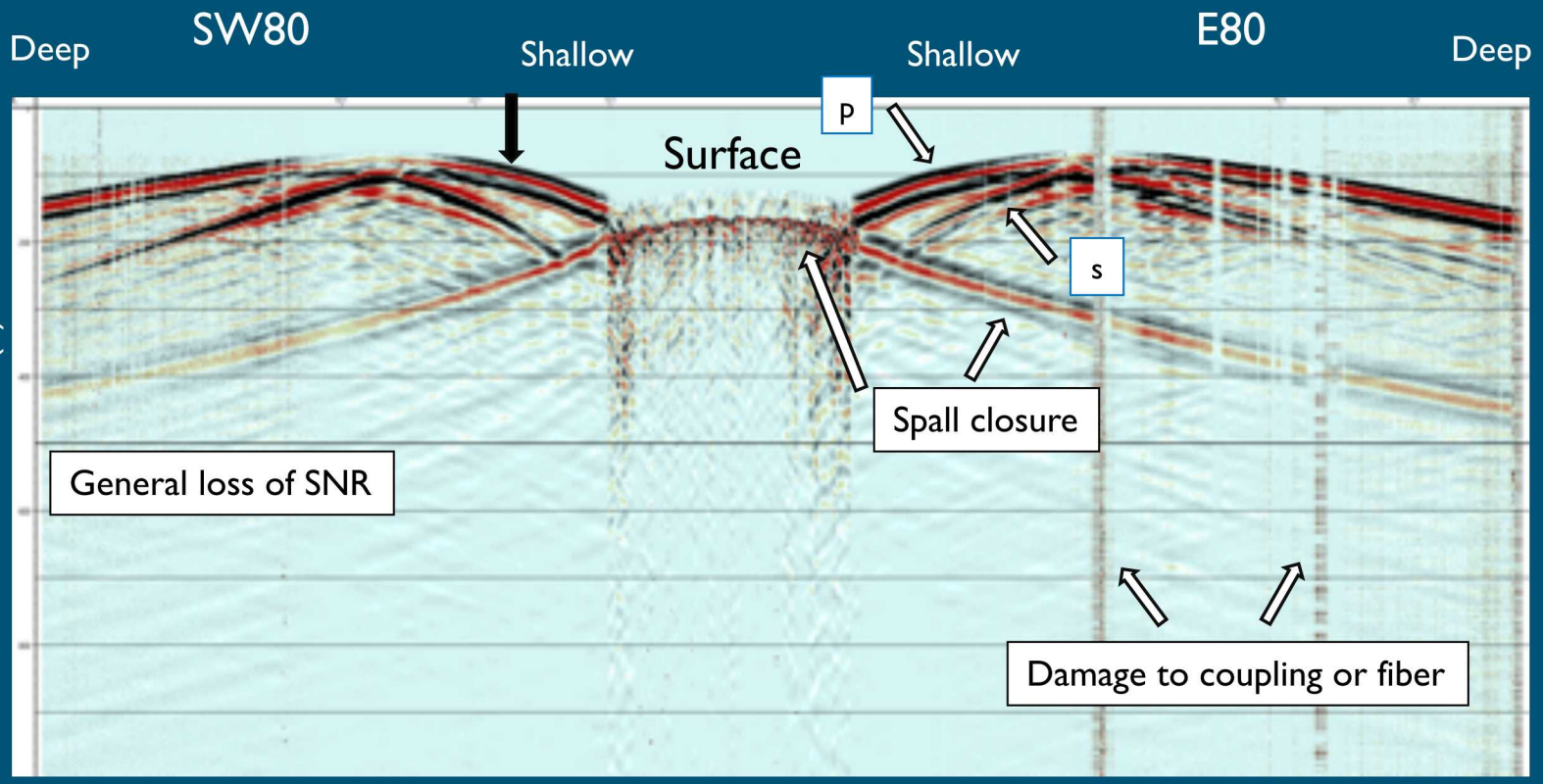
DAG-2 Subsurface Spall

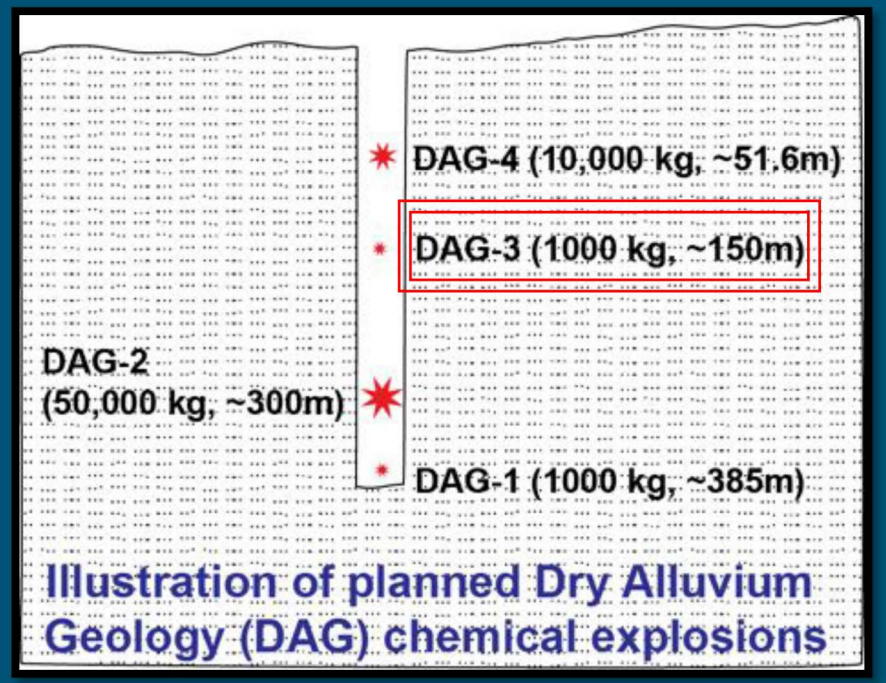


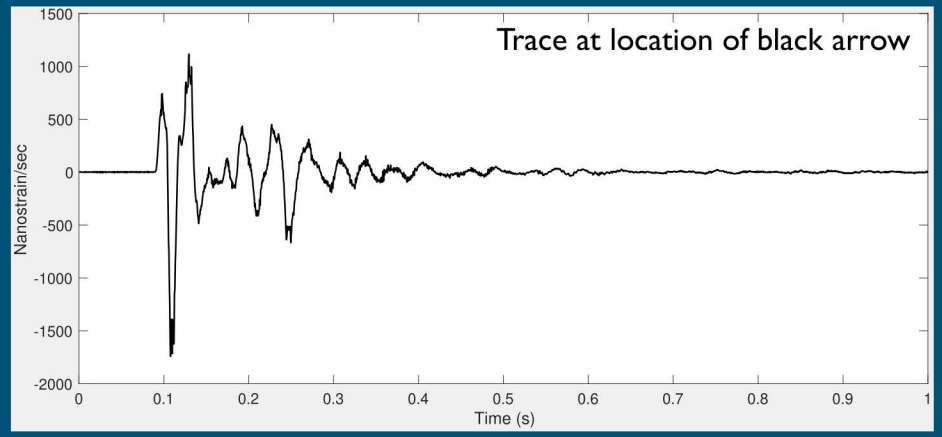
DAG-2 Damage


DAG-2
DAG-3 Canister
286 m ?
4 Events
DAG-4 Canister
DAG-1 Canister ?
Multiple Events
DAG- 4-Depth Grout Break
Between DAG-3 and -4 Depth No Grout Break

DAG-3

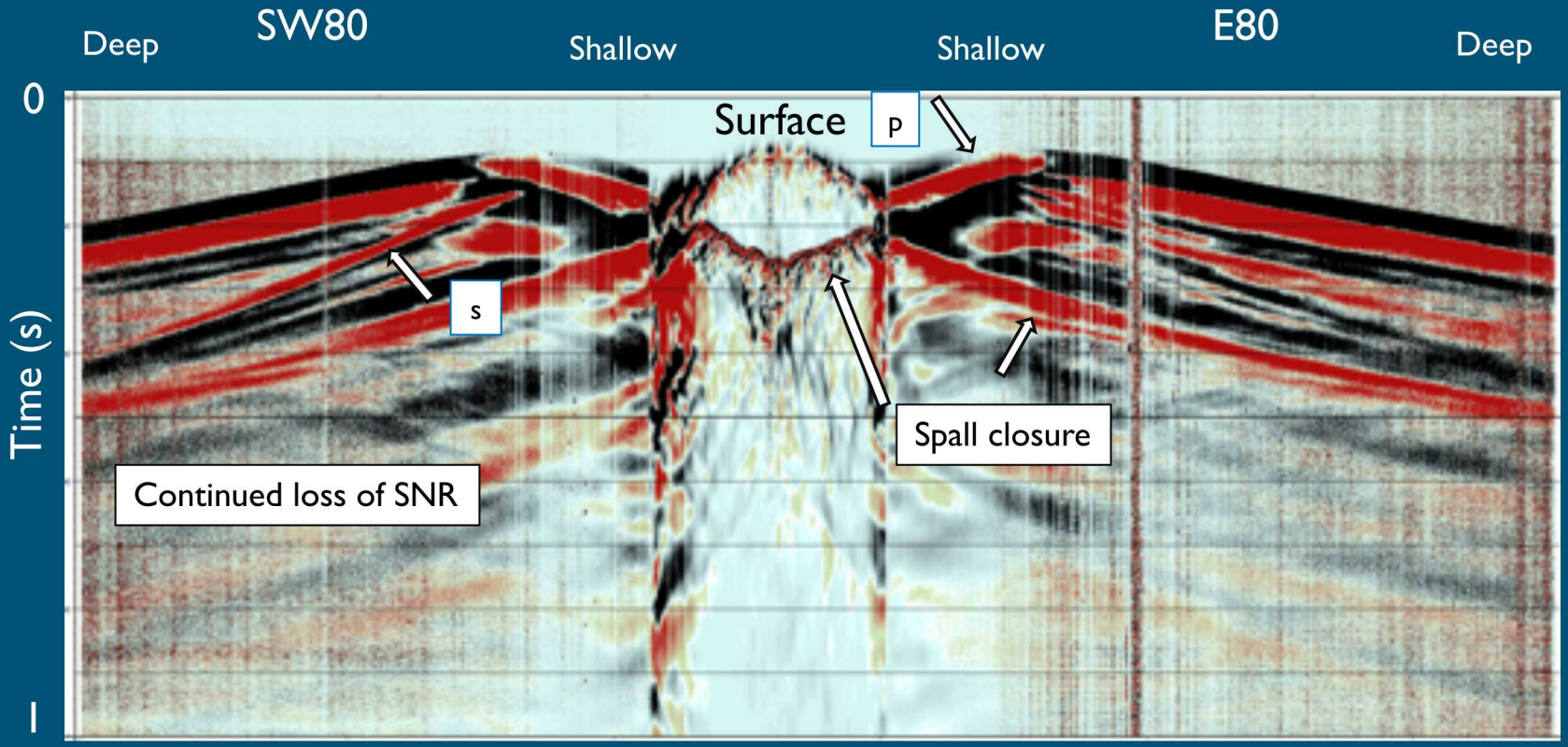


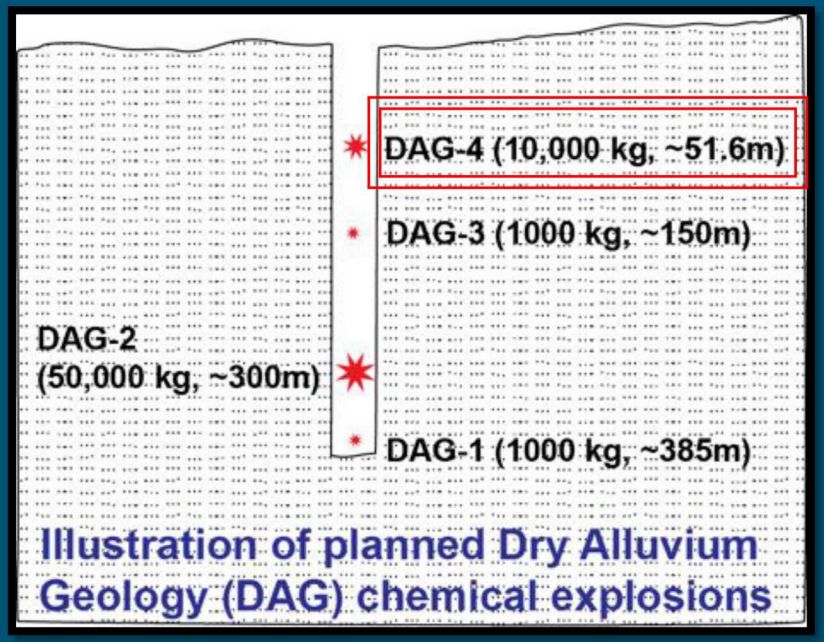


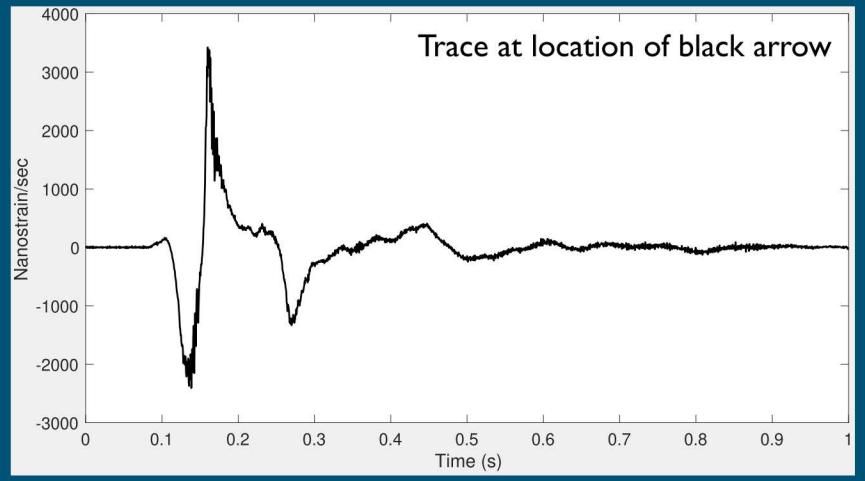


1. Little evidence of ramp
2. 1st arrival reasonable percentage of subsequent phases
3. Surface spall evident, but not deeper spall
4. Larger s-wave relative to DAG-2

DAG-4

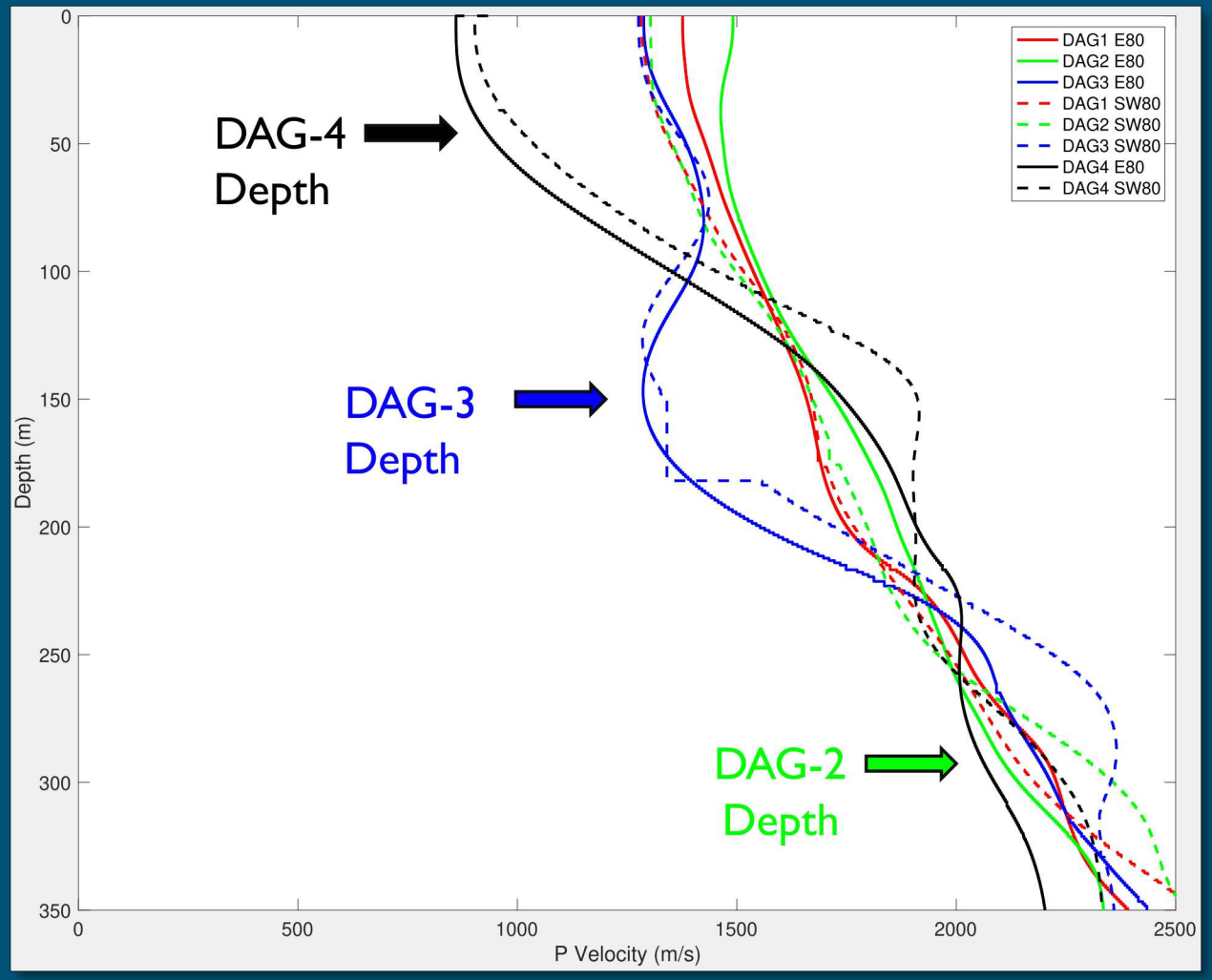






1. Some evidence of ramp
2. Large surface slapdown phase
3. Damage and phases intermingling make analysis challenging

Another Manifestation of Damage



- Another benefit of having hundreds of downhole sensors is the ability to invert for velocity profiles with only one source
  - Conjugate Gradient method
- Post DAG-3 and DAG-4 velocity is reduce by ~30% at shot level only
- Dynamic effect that "heals" itself?

Post DAG-2 Microseismicity (Monday Poster Advertisement)

- After DAG-2, thousands of microseismic events were detected on the surface array, extending to weeks after the event
  - Mechanism and precise locations of the events were unknown
- The first 48 hours were recorded by the DAS, as well
  - Relative to surface-only location of the event:
    - -50% RMS travel-time error
    - 3x tighter depth distribution
    - 6x smaller error ellipsoids

Summary

Unqualified success in recording seismic wavefield

- Two orders of magnitude more data relative to traditional geophones/accelerometers
- Recorded complete seismic wavefield instead of a few waveforms
- Helical cable performed well in recording relevant phases
- Greatly aids in interpreting primary diagnostics

Evidence for two types of spall

- ”Traditional” spall (originating from the interaction of upgoing and downgoing tensile P-waves) observed on DAG-3 and DAG-4
- Spall originating at depth solely along the tensile portion of the upgoing P-wave on DAG-2.

Silixa, LLC recorded the dataset under subcontract to SNL

The authors wish to express their gratitude to the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (DNN R&D), and the SPE working group, a multi-institutional and interdisciplinary group of scientists and engineers.