T2.3–P3

Combined Experiment and Numerical Modeling to Understand Response Near Chemical Explosions

David Steedman[1], Emily Schultz-Fellenz[1], Souheil Ezzedine[2], Oleg Vorobiev[2]
[1]Los Alamos National Laboratory, [2]Lawrence Livermore National Laboratory

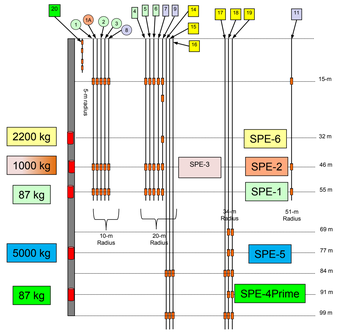
LA-UR-17-23790

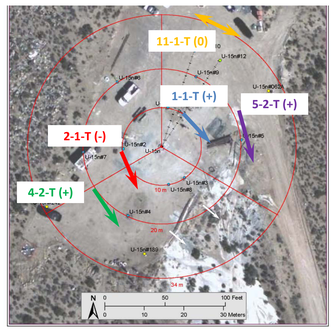
CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

Source Physics Experiment (SPE) Near Field

- Six chemical explosive tests of varying yield-scaled depth-of-burial (SDOB).
  1) Produced shock should have insignificant non-radial component.
- Dense array of triaxial accelerometers at varying yield-scaled range (SR) provides the following observations:
  1) Large tangential motion at small to moderate SDOB and SR.
  2) Tangential response is delayed until after radial peak.
  3) Delayed response has a consistent southeast bias.
  4) This response is not evident at larger SDOB and/or SR.

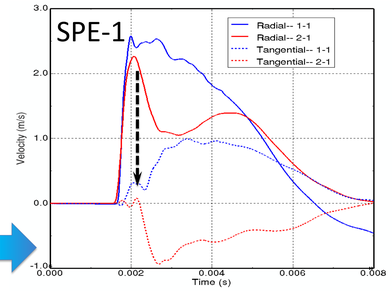
Schematic of SPE Testbed

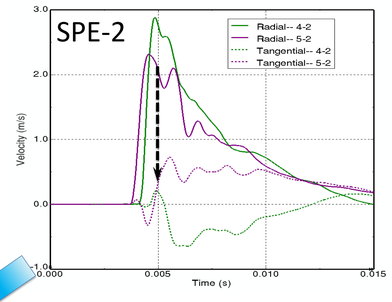




Typical records at Small to Moderate SDOB/SR

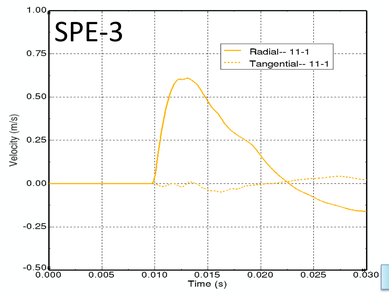
- Tangential response at R_{peak} (----➤)

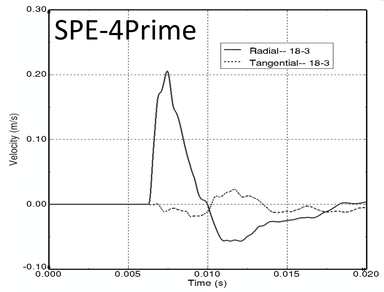




Typical records at Large SDOB/SR

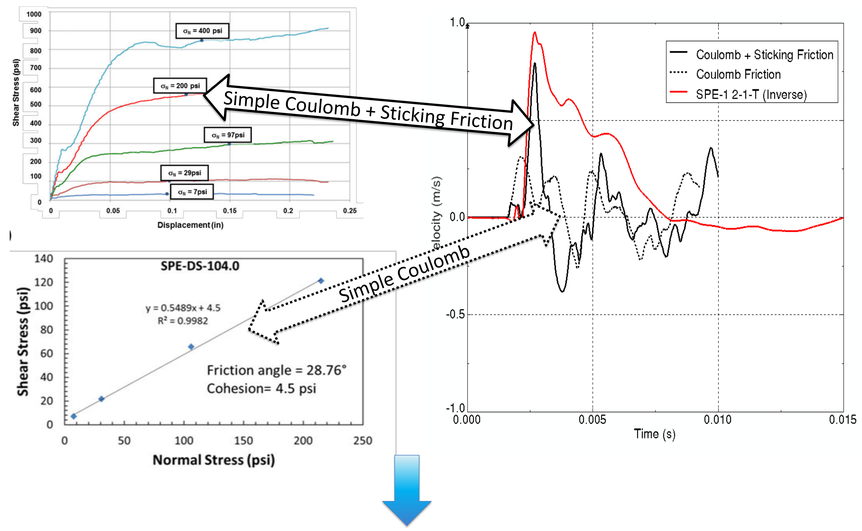
- No significant tangential Response





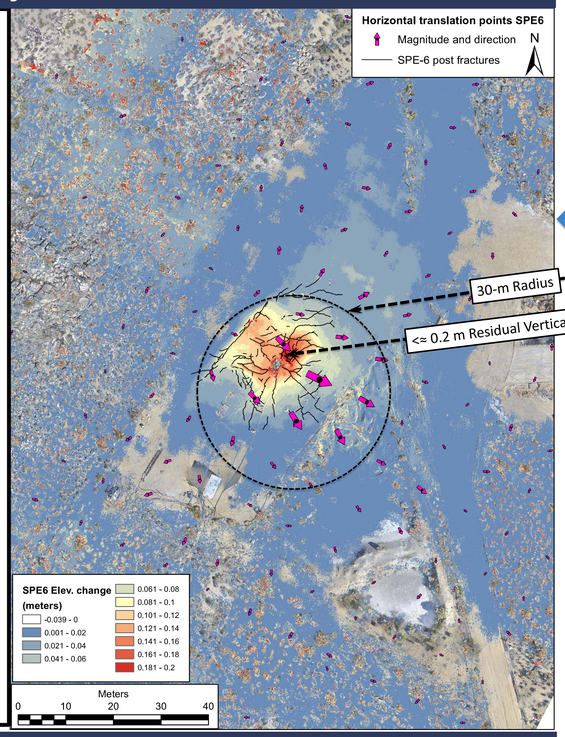
Finite Element Model Study: Explicitly Joint Models

- Finite element calculations Including explicit representation of joint sets
  1) Confirm that a sticking friction model can achieve delayed, amplified tangential response (horizontal symmetry plane causes rapid return to zero)
  2) We relate this to sudden release of stored shear strain energy



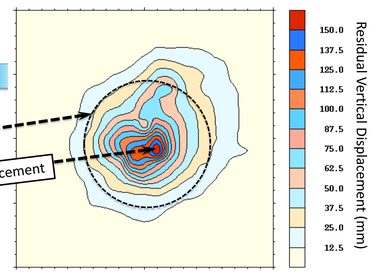
Photogrammetry with Horizontal and Vertical Offsets

- Spherical shock wave surface expression should present radial cracking and circular uplift
- Post-test observations indicate a NE-SW component to these patterns
  - This suggests tensile cracking caused by mass movement to the southeast direction consistent with tangential slippage indicated by active velocity records
- Horizontal offsets measured for SPE-6 indicate this same direction of movement



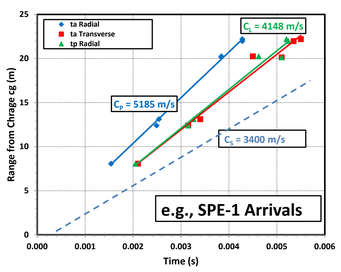
Surface Displacement

- Continuum simulation from source to ground surface includes topography.
- Provides reasonable match to photogrammetry vertical offset data.

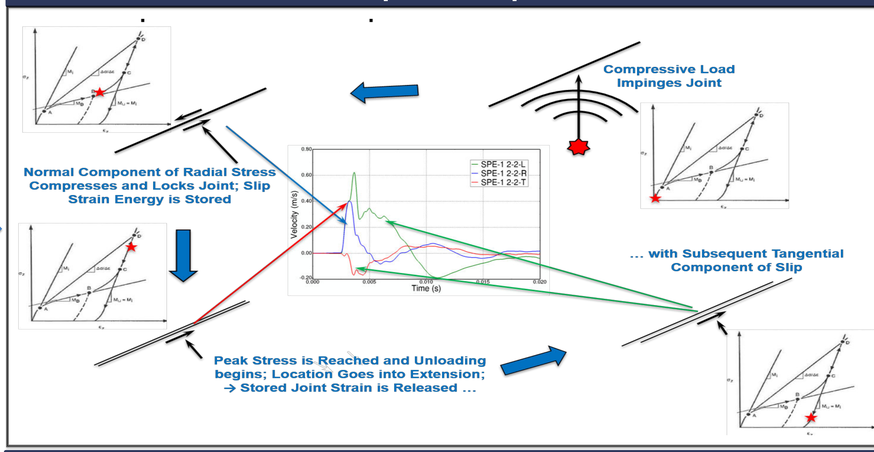


Arrival Times

- T-motion consistently follows R_{peak}
- Too slow to be a shear wave from the source
- Not an arrival but a new source at eac pre-existing fracture



Conceptual Response



Discussion

- Spherical shock should have insignificant non-radial component.
- We observe significant post-arrival tangential motions on most triaxial measurement sets
  - This deviation from theoretical consistently occurs near the peak loading.
  - Tangential response is delayed until after radial peak.
  - Shock-induced load must be of magnitude to generate sufficient shear energy to overcome *in situ* loads.
  - This phenomenon acts on existing fractures within a radius defined by combined range-to-effect and scaled depth-of-burial, possibly creating a "virtual source" containing significant shear content
- The motions are biased by site conditions which may be confirmed by other measurement techniques (*e.g.*, photogrammetry).

References

Steedman, et al. (2015), "Phenomenology and Modeling of Explosion Generated Shear Energy for the Source Physics Experiments," BSSA-D-15-00011R2.

Schultz-Fellenz et al. (2017), "Detecting surface changes from an underground explosion in granite using unmanned aerial system photogrammetry," accepted for publication in *Pure and Applied Geophysics*.

Ezzedine and Vorobiev (2017), "Application of HPC and Non-Linear Hydrocodes to Uncertainty Quantification in Subsurface Explosion Source Physics, Accepted Rock Mechanics & Rock Engn.

Vorobiev, Ezzedine, et al. (2015), "On the generation of tangential ground motion by underground explosions in jointed rocks", Geophys. J.Int., 200, 1651-1661

The Source Physics Experiment (SPE) would not have been possible without the support of many people from several organizations. 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. This work was done by Los Alamos National Laboratory under award number DE-AC52-06NA25946.