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GEOLOGIC ASSESSMENT OF THE DAMAGE ZONE FROM TWO EXPLOSIONS AT THE SOURCE PHYSICS EXPERIMENT

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ABSTRACT

Explosive tests are being conducted in fractured granite in Nevada to increase the understanding of certain basic physical phenomena associated with underground explosions. These tests, collectively known as the Source Physics Experiment (SPE), are designed to study the generation and propagation of seismic waves. The results will help advance the seismic monitoring capability of the United States by improving the predictive capability of physics-based modeling of explosive phenomena (Snelson et al., 2012). Three of seven planned tests have been conducted to date. All the tests have been conducted in the same source hole. The geology of the SPE-N site is described in Townsend et al. (2012).

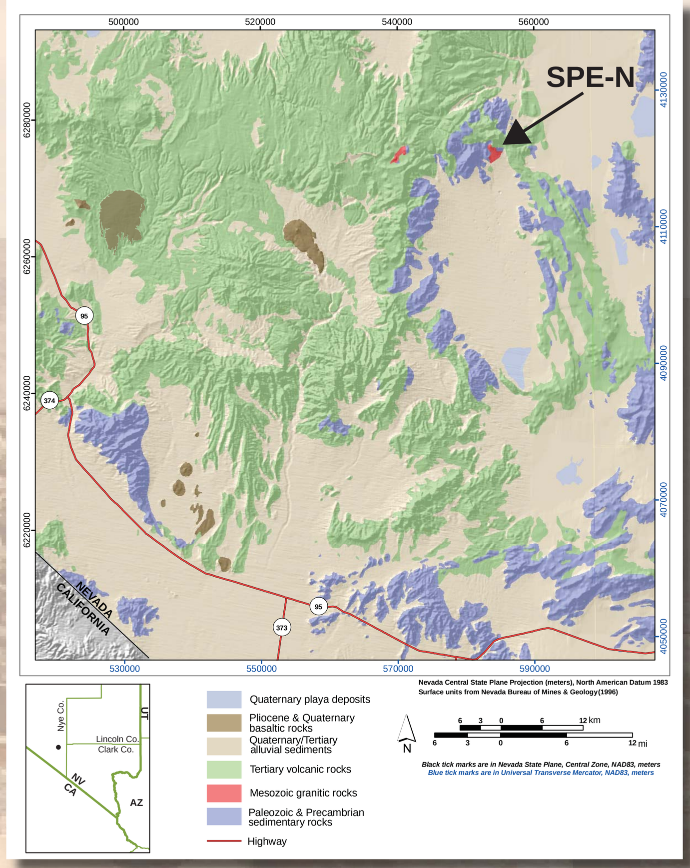
The first SPE shot (SPE-N-1) was a Green's function test conducted at the depth of 54.9 m, with an explosive yield of 88 kg (TNT equivalent). This study addresses the second and third shots (SPE-N-2 and SPE-N-3), which were conducted at the same depth, shallower than SPE-N-1 and with a larger explosive yield, to explore the influence of explosion-induced damage on seismic wave propagation.

SPE-N-2 was conducted at the depth of 45.7 m in October 2011, with a yield of 997 kg, after which an angled core hole (U-15n#10) was drilled from the surface to the shot point to characterize the damage zone. After the source hole was cleaned out, SPE-N-3 was conducted at 45.8 m in July 2012, with a yield of 905 kg. Following SPE-N-3, a second angled core hole (U-15n#12) was drilled sub-parallel to U-15n#10 to provide a comparison of explosion-induced damage between the two shots. Geophysical logs were run in both holes, core samples were provided to Sandia National Laboratories for measurement of physical and mechanical properties, and down-hole videos were made in the source hole following both tests.

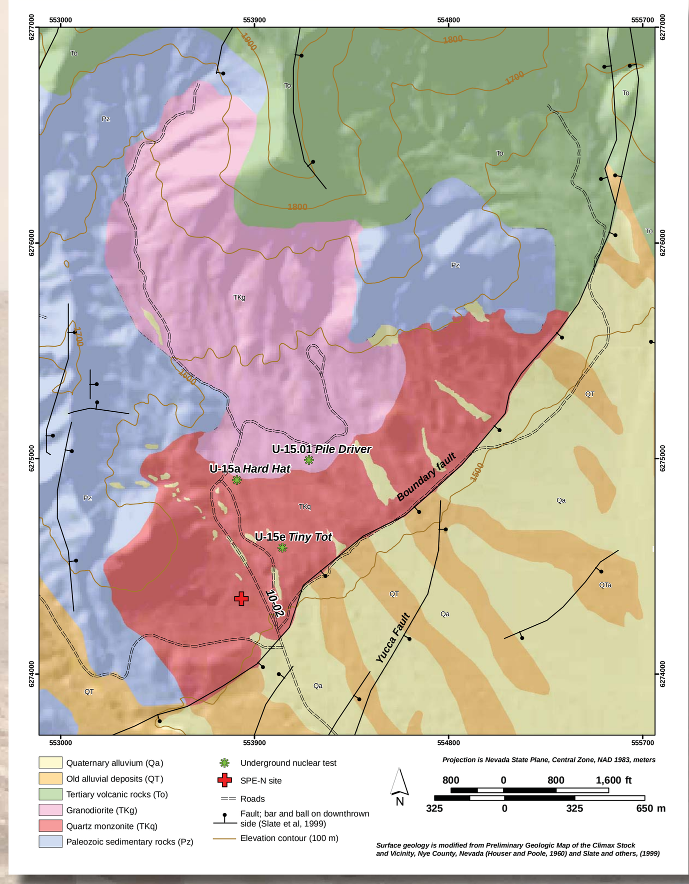
The presence of natural faulting near the shot point complicates the comparison of the damage from the SPE-N-2 and SPE-N-3 shots, using only information from the two similarly positioned angled core holes. Characteristics of natural fractures allow them to be distinguished from shock-induced breaks; however, closed natural fractures may have been broken open by the explosions, causing an apparent increase in fracturing. Also, it is not possible to distinguish fracturing from the SPE-N-3 test from that associated with the SPE-N-2 test.

Interpreted explosion-induced fractures are common in the U-15n#10 angle hole starting at about 5.4 m from the SPE-N-2 shot point. In the U-15n#12 hole, the presence of explosion-induced fractures is more difficult to recognize, but the most distant possibly explosion-induced fracture was seen at the distance of approximately 5.8 m from the SPE-N-3 shot point. Thus, explosion-induced damage from both SPE-N-2 and SPE-N-3 was observed at similar distances from the shot point. However, damage appears to be more intense in U-15n#12 than in U-15n#10, possibly indicating that the rock was weakened by the earlier SPE-N-2 explosion.

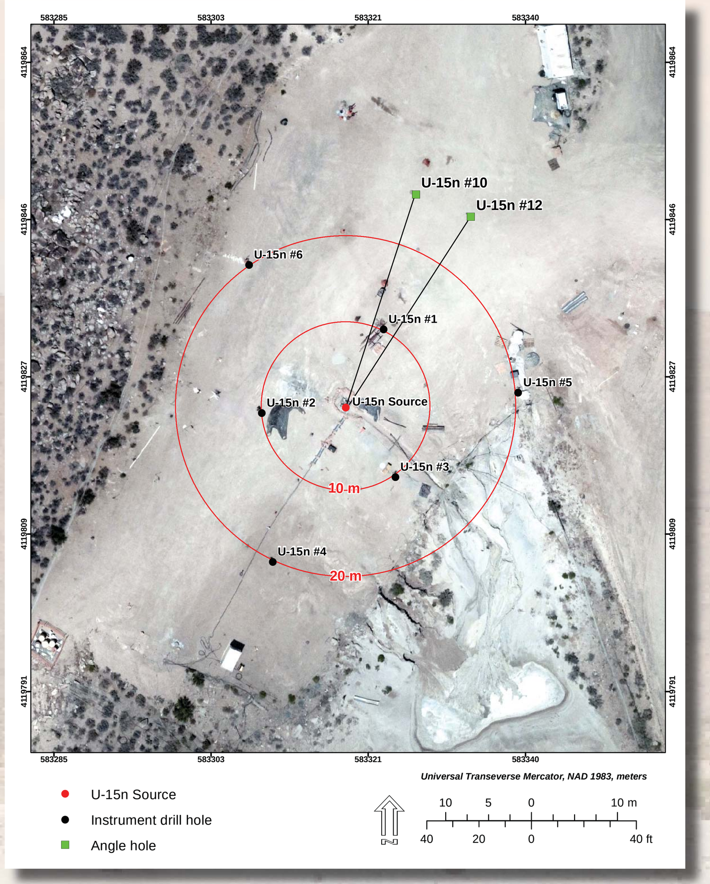
Results from this characterization effort will be integrated with other research at the SPE-N site as scientists continue to build physics-based predictive capability for seismic monitoring.



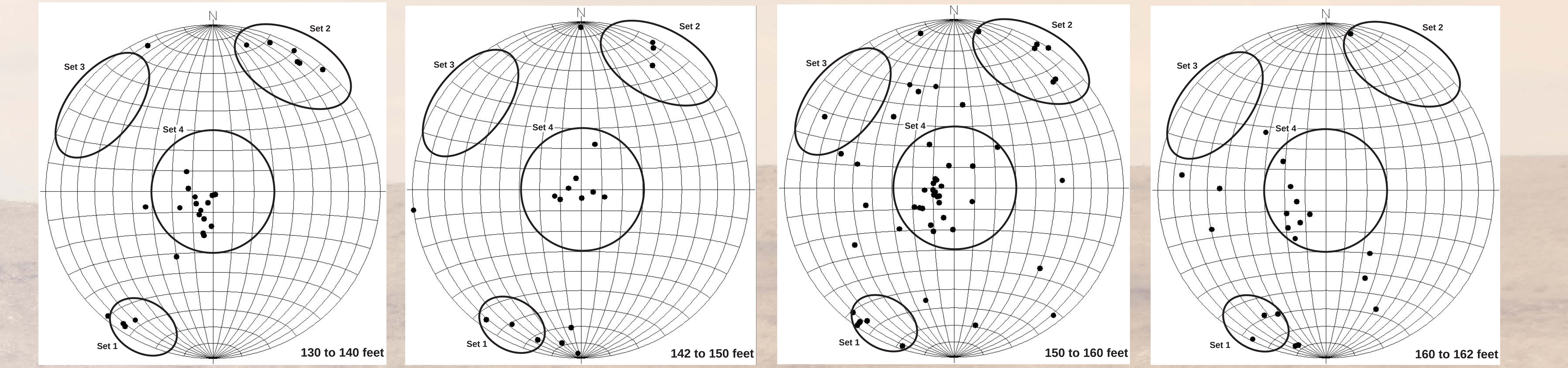
Generalized geologic map of a portion of southern Nye County, Nevada



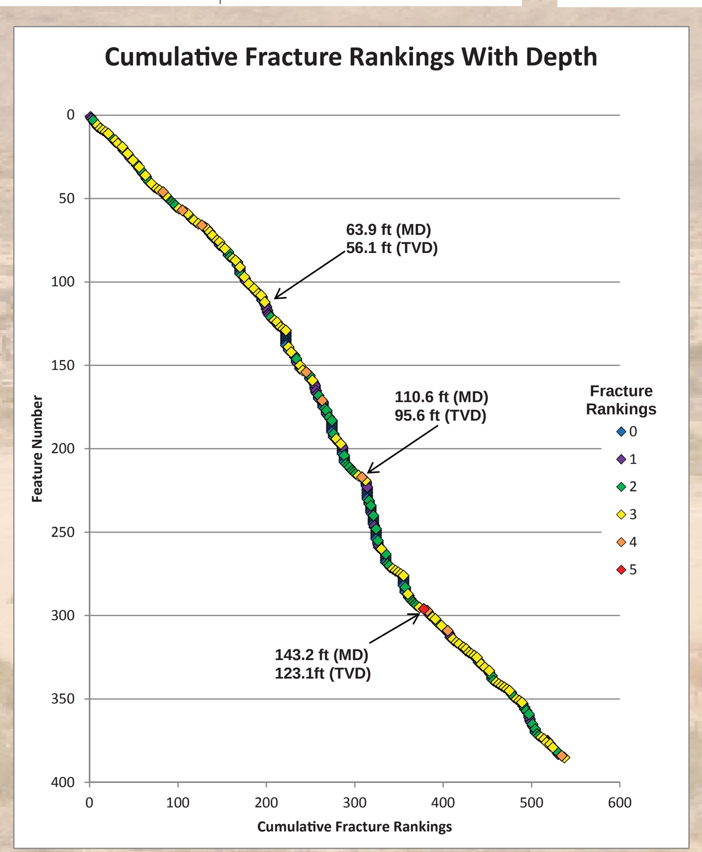
Surficial geologic map of the area around the SPE-N site.



Aerial view of SPE-N showing locations of the source hole (U-15n), angled core holes (U-15n#10 and U-15n#12), instrument holes, and monitoring holes.



Lower hemisphere, equal area Schmidt nets illustrating orientations of fractures encountered in angled hole U-15n#12. Positions of four natural fracture sets are indicated by the circles. Each plot shows fractures encountered within the indicated depth interval. Increasing drilled depth corresponds to decreasing distance from shot point.
Note the increase of fractures whose orientations fall outside those of the natural fracture sets as the hole approaches the shot point.



Plot of cummulative fractures logged in U-15n#12. Colors indicate rank (severity) of fracture, with 1 being the least severe (i.e., closed or discontinuous fracture) and 5 being the most severe (i.e., large opening or washout).

Note increase in fracture frequency and increase in higher-ranked fractures starting at depth of 143.2 ft, which corresponds to upper position of the natural fault zone.

This fault may have accommodated the explosion-induced strain, functioning as a structural bounding feature that limited the extent of the damage zone.

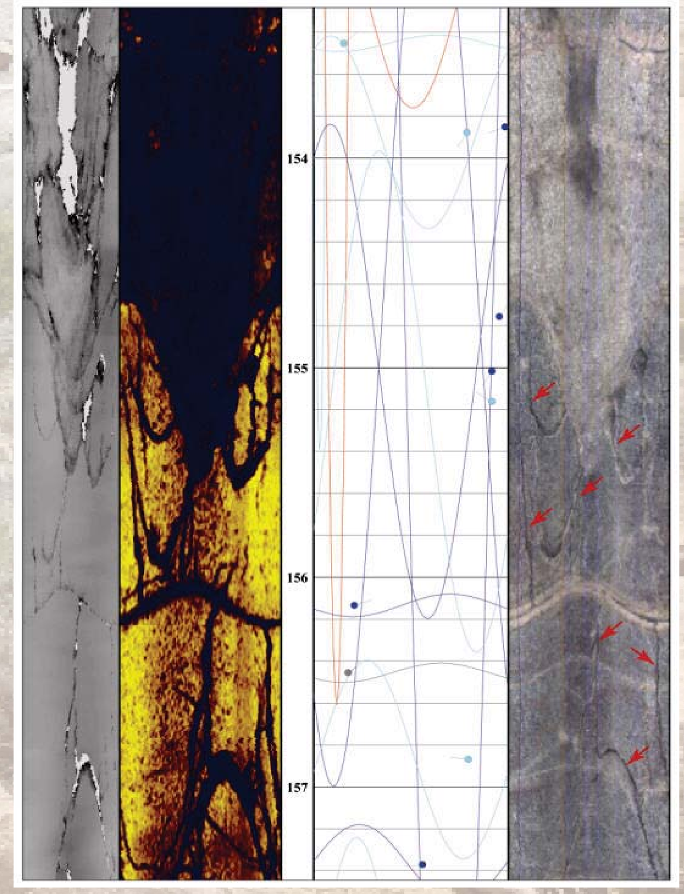
MD = measured depth
TVD = total vertical depth

Photo courtesy of U.S. Geological Survey.

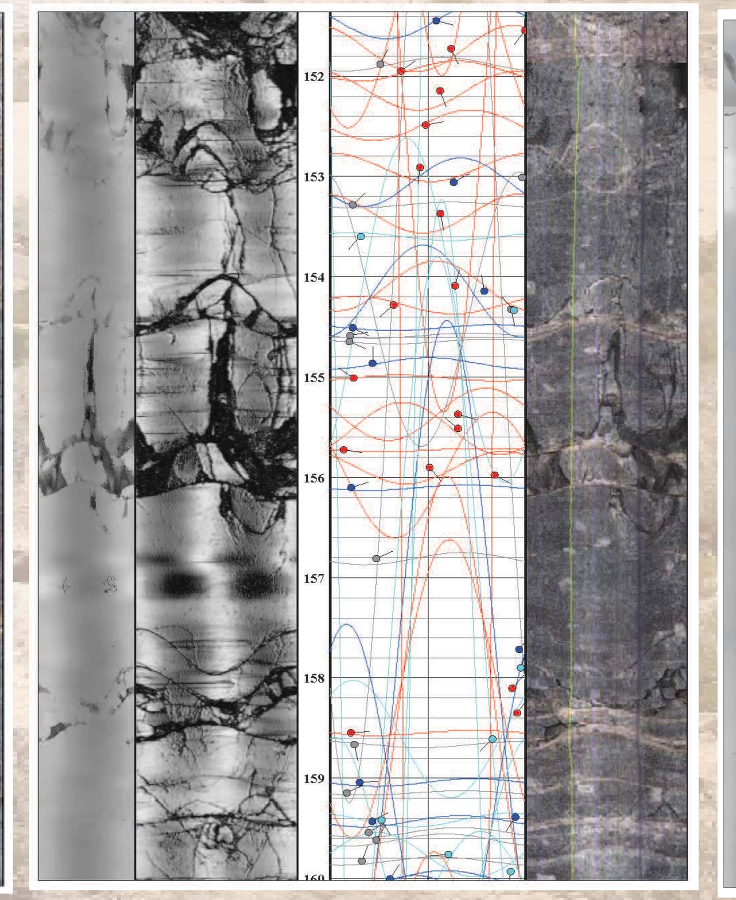
Photo of core recovered from angle hole U-15n#10 near drilled depth of 159 ft. Fresh-looking fractures closest to yellow block are interpreted to be explosion-induced.
SPE-N-2 source is approximately 4.5 m to the right. Yellow block is approximately 8 cm long.

Photo courtesy of U.S. Geological Survey.

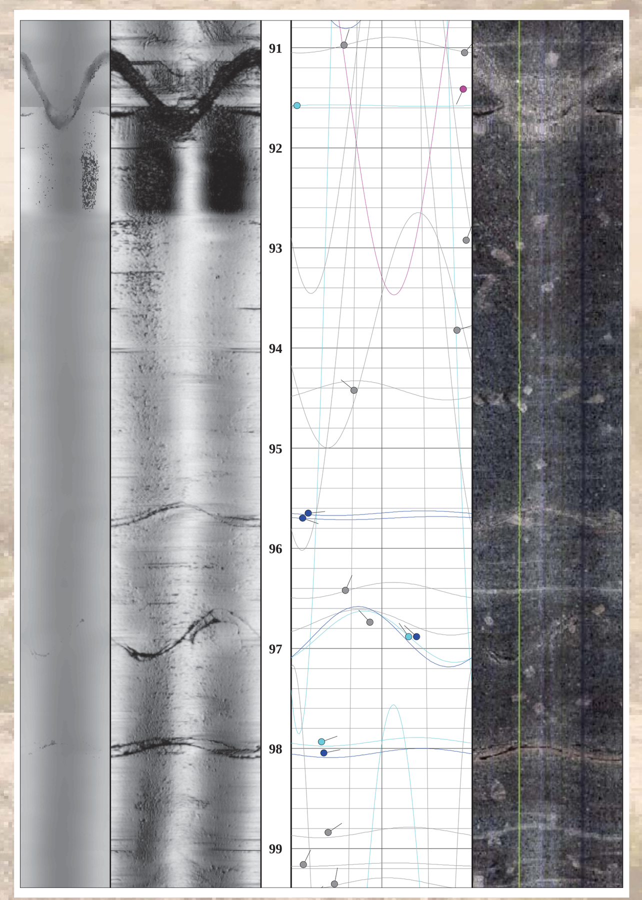
Photo of core recovered from angle hole U-15n#12, drilled depths of 159.2 to 166.5 ft. Note lack of well-defined fresh-looking fractures, and more rubblized appearance compared to similar interval in U-15n#10. Distance to SPE-N-3 source at the depth of 159 ft is approximately 4.9 m.



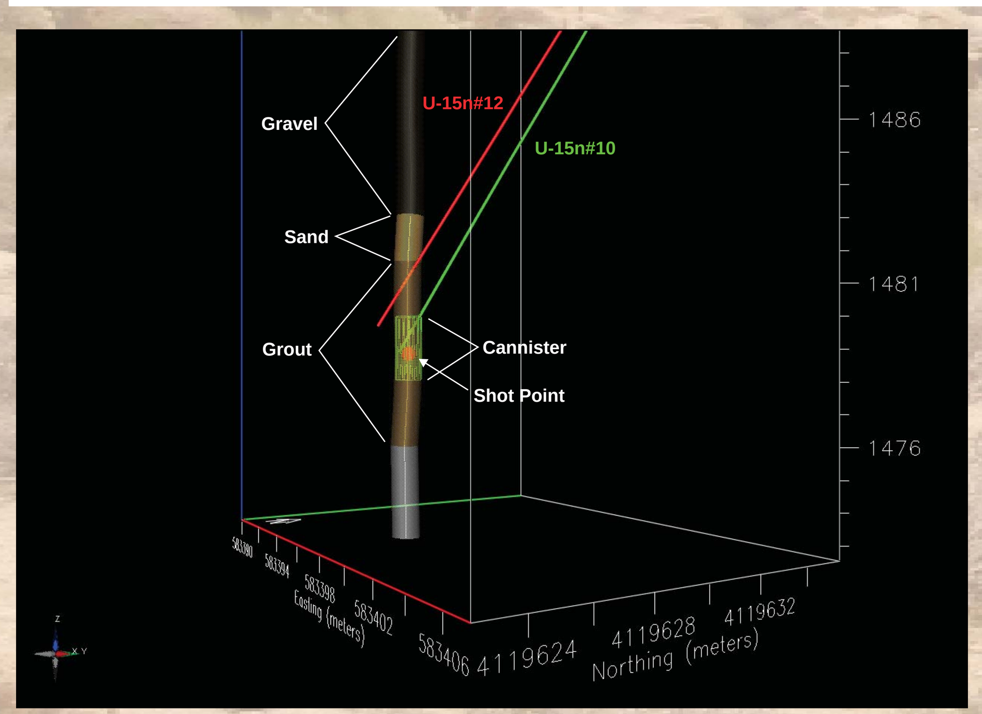
Portion of the U-15n#10 borehole image log showing explosion-induced fractures (red arrows) following SPE-N-2. Drilled depth in feet.



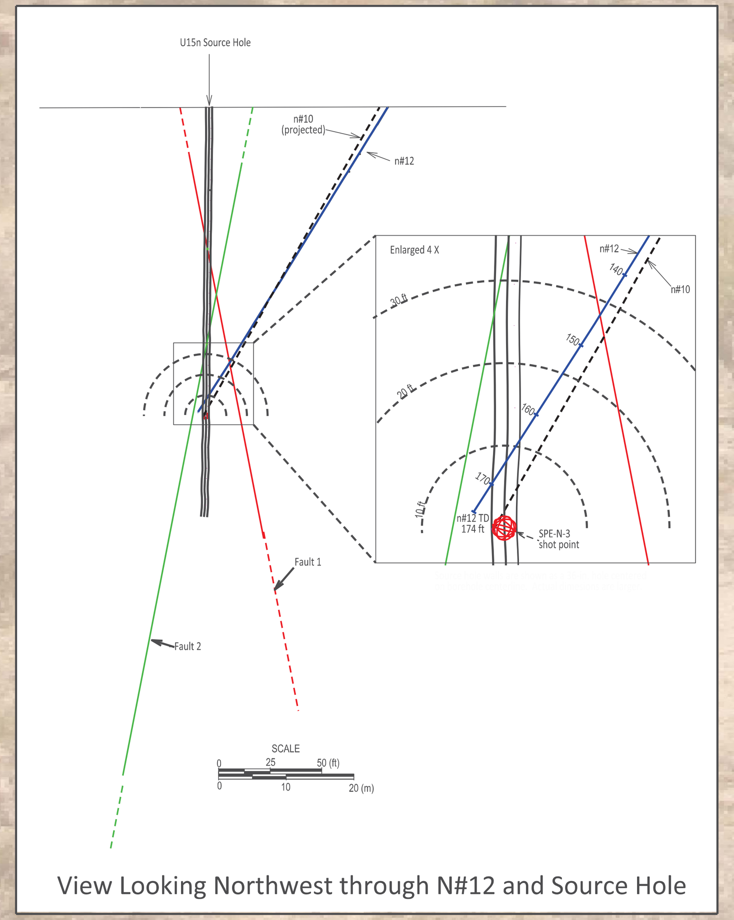
Portion of the U-15n#12 borehole image log showing more rubblized appearance of area adjacent to shot zone, following SPE-N-3. Drilled depth in feet.



Portion of the U-15n#12 image log above damage zone showing only natural fractures. Drilled depth in feet.



3-D view of the SPE-N source hole showing penetration through the position of the SPE-N-2/3 shot point region by the U-15n#10 and U-15n#12 angled core holes. The #10 core hole passed within 1 ft of the shot point. The #12 core hole passed approximately 8 ft above the shot point.



Cross section through the U-15n#12 angled core hole showing position of hole relative to natural faults. A natural fault (red line) and associated altered rock were encountered between the drilled depths of approximately 144 and 153 ft, and may have acted as a structural boundary that limited the extent of the damage zone.

View of 0.91-m-diameter source hole prior to SPE-N-2, showing location of SPE-N-2 and SPE-N-3 shot points at a depth of 45.7 m (150 ft). Note smooth borehole walls.

View of SPE-N source hole showing shot point location after the SPE-N-2 shot. Note slight enlargement of hole, blackened borehole walls, and stemming material resting on ledges within borehole walls. Light area is top of water.

View of SPE-N source hole showing shot point location after the SPE-N-3 shot. Note greater enlargement of hole and more fractured appearance of borehole walls.

Drilling of angled core hole U-15n#12.

SUMMARY AND CONCLUSIONS

- Two shots of approximately equal size were conducted at the same depth in the same 0.91-m diameter source hole. The purpose of the second shot was to obtain data from a shot in a region already damaged by an explosion.
  - SPE-N-2 was conducted in October 2011
  - SPE-N-3 was conducted in July 2012
- After SPE-N-2, an angled core hole (U-15n#10) was drilled into the northeast side of the shot point region to characterize damage from the first explosion.
- After SPE-N-3, another angled core hole (U-15n#12) was drilled at about the same distance and orientation as the first into the shot point region to characterize damage from the second explosion.
- The presence of natural faulting near the shot point complicates the comparison of the damage from both shots, using only information from the two similarly positioned angled core holes. No explosion-induced fractures were recognized within the altered rock material of the fault zone in either hole.
  - In the #10 hole, the fault zone was penetrated 5.7 to 7.5 m from the SPE-N-2 shot point.
  - In the #12 hole, the fault zone was encountered 6.8 to 9.7 m from the shot point.
- After the SPE-N-2 shot, fracturing that was distinct in character from abundant natural discontinuities was observed in the U-15n#10 angled core hole. Starting at approximately 5.4 m from the shot point, explosion-induced fractures are abundant.
- In the U-15n#12 hole, explosion-induced fractures are more difficult to recognize, but the most distant possibly explosion-induced fracture was seen at the distance of approximately 6.8 m from the SPE-N-3 shot point, just below the altered zone associated with the pre-existing natural fault.
- Explosion-induced damage from SPE-N-3 appears to extend to a greater distance from the shot point than observed for the SPE-N-2 shot.
- Damage appears to be more intense in U-15n#12 than in U-15n#10, possibly indicating that the rock was weakened by the earlier SPE-N-2 explosion.
- Larger pre-existing discontinuities such as faults may absorb and accommodate explosion-induced strain and thus limit the extent of the damage zone.
- Measurement of mechanical properties and microscopy studies of samples from the shot zone following both shots are currently underway and will likely provide more quantitative data on the damage zone.

REFERENCES

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