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GEOLOGIC ASSESSMENT OF THE DAMAGE ZONE FROM THE SECOND TEST AT SOURCE PHYSICS EXPERIMENT - NEVADA (SPE-N)

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ABSTRACT

The National Center for Nuclear Security, established by the U.S. Department of Energy, National Nuclear Security Administration (NNSA), is conducting a series of explosive tests at the Nevada National Security Site that are designed to increase the understanding of certain basic physical phenomena associated with underground explosions. These tests will aid in developing technologies that might be used to detect underground nuclear explosions in support of verification activities for the Comprehensive Nuclear-Test-Ban Treaty. The initial project is a series of explosive tests, known collectively as the Source Physics Experiment-Nevada (SPE-N), being conducted in granitic rocks. The SPE-N test series is 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.

The first SPE N (SPE-N-1) test was conducted in May 2011, using 100 kg of explosives at the depth of 54.9 m in the U 15n source hole. SPE-N-2 was conducted in October 2011, using 1,000 kg of explosives at the depth of 45.7 m in the same source hole. The SPE-N-3 test was conducted in the same source hole in July 2012, using the same amount and type of explosive as for SPE-N-2, and at the same depth as SPE-N-2, within the damage zone created by the SPE-N-2 explosion to investigate damage effects on seismic wave propagation.

Following the SPE-N-2 shot and prior to the SPE-N-3 shot, the core hole U-15n#10 was drilled at an angle from the surface to intercept the SPE-N-2 shot point location to obtain information necessary to characterize the damage zone. The objective was to determine the position of the damage zone near the shot point, at least on the northeast, where the core hole penetrated it, and obtain information on the properties of the damaged medium.

Geologic characterization of the post-SPE-N-2 core hole included geophysical logging, a directional survey, and geologic description of the core to document visual evidence of damage. Selected core samples were provided to Sandia National Laboratories (SNL) for measurement of physical and mechanical properties. A video was also run in the source hole after it was cleaned out.

A significant natural fault zone was encountered in the angle core hole between 5.7 and 7.5 m from the shot point. However, several of the fractures observed in the core hole are interpreted as having been caused by the explosion. The fractures are characterized by a "fresh," mechanically broken look, with uncoated and very irregular surfaces. They tend to terminate against natural fractures and have orientations that differ from the previously defined natural fracture sets; they are common starting at about 5.4 m from the shot point. Within about 3.3 m of the shot point to the end of the recovered core at 1.6 m from the shot point, some of the core samples are softer and lighter in color, but do not appear to be weathered. It is thought this could be indicative of the presence of distributed microfracturing.

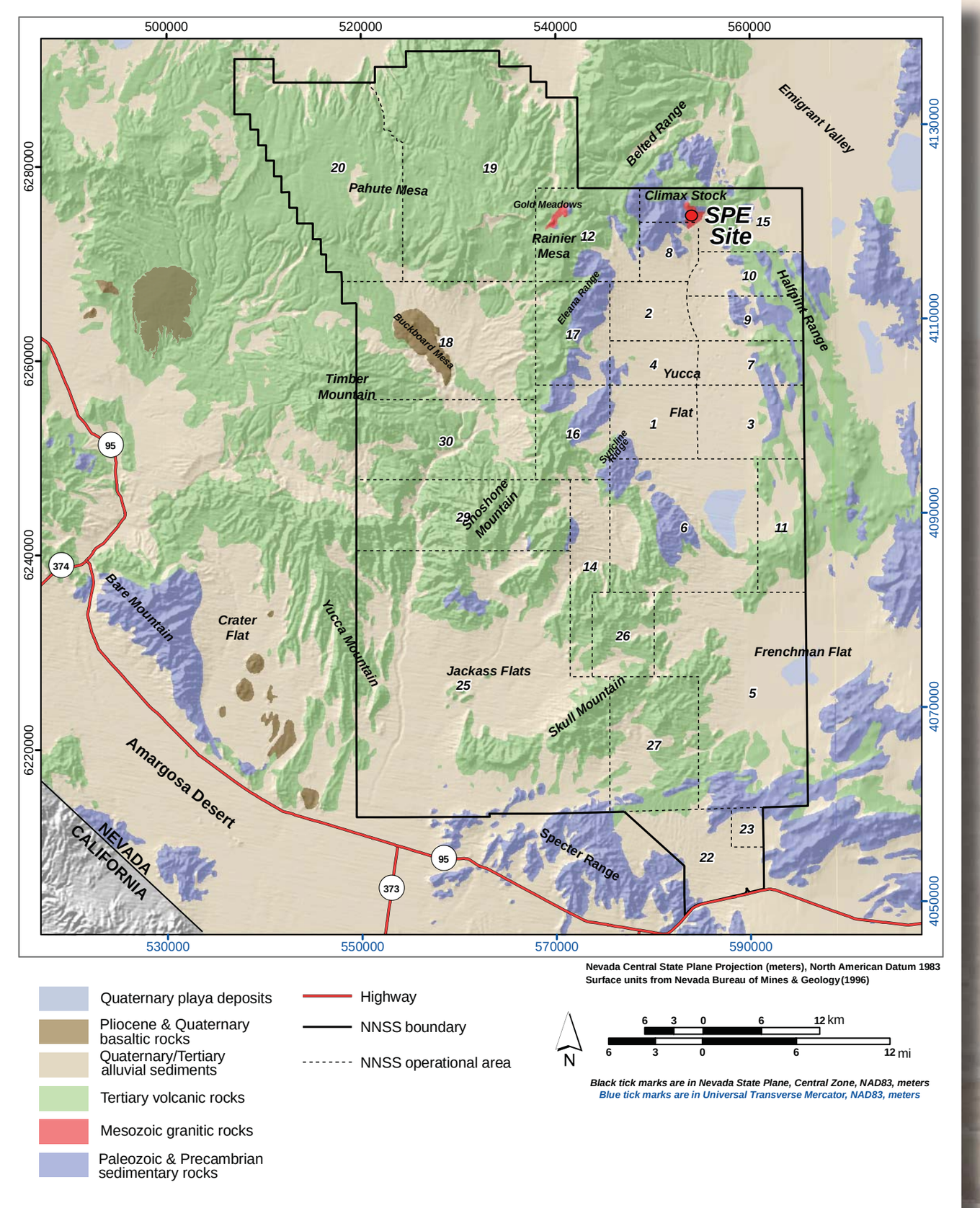
Properties Measured on Core from the U-15n Source Hole Location

SAMPLE DEPTH (m [ft])	DENSITY (g/cc)	UNCONFINED COMPRESSIVE STRENGTH (MPa)	COMPRESSIONAL VELOCITY (m/s)	SHEAR VELOCITY (m/s)
32.9 [108]	2.64	210.2	5,802	3,525
40.2 [132]	2.63	205.4	5,820	3,500
46.9 [154]	2.64	195.8	5,928	3,449
53.9 [177]	2.64	227.8	5,888	3,367
58.5 [192]	2.65	165.8	5,908	3,574
Average	2.64	200.4	5,869	3,483

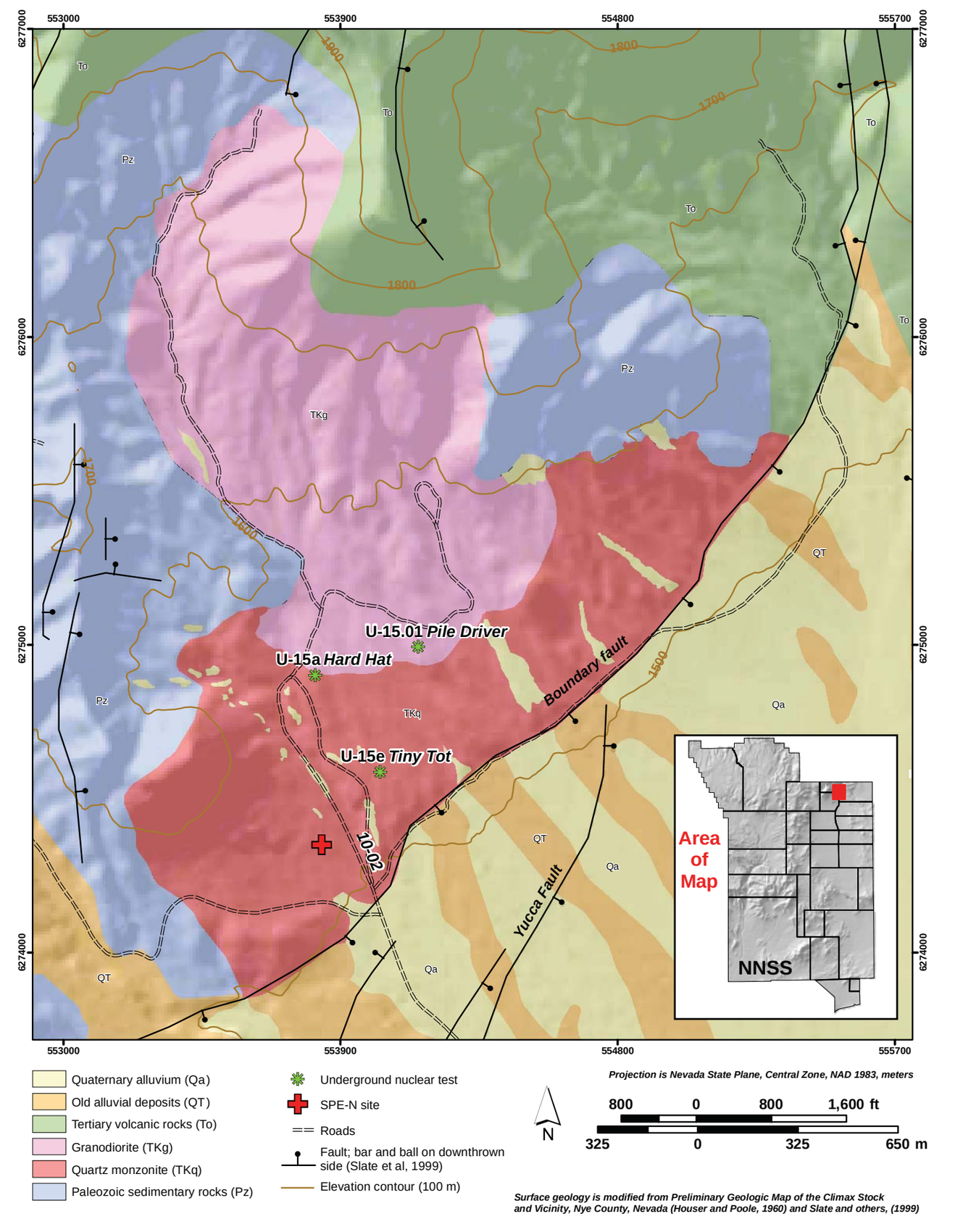
Notes: g/cc = grams per cubic centimeter; MPa = megapascals; m/s = meters per second
Measurements by SNL Geomechanics Department (Broome and Pfeifle, 2011)

View of 0.91-m-diameter source hole prior to SPE-N-2, showing SPE-N-2 shot point location at a depth of 45.7 m. Note smooth borehole walls.

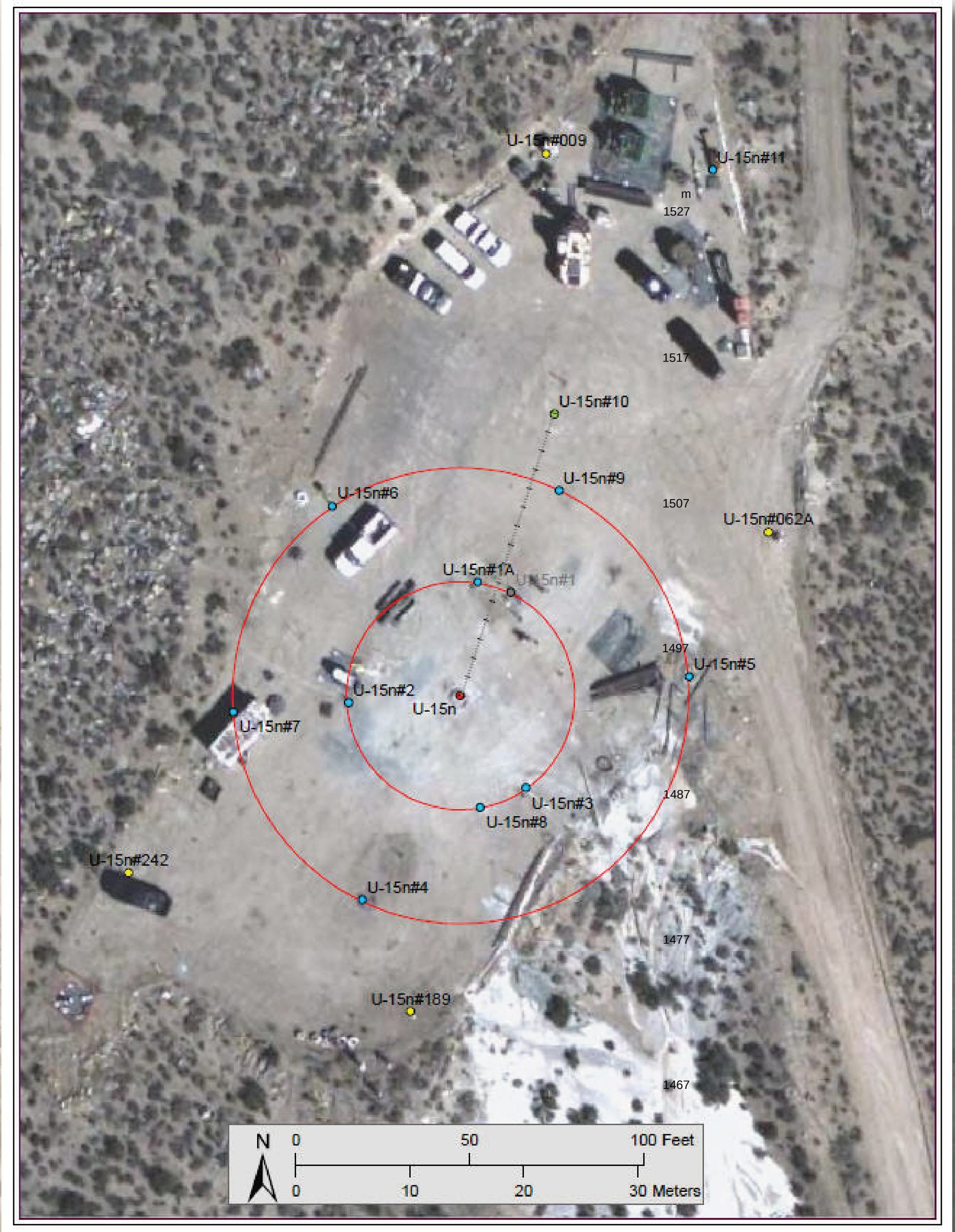
View of SPE-N source hole showing shot point location after the SPE-N-2 shot. Note slight enlargement of hole, blackened borehole walls, and stemming material resting on ledges within borehole walls.



Generalized geologic map of the Nevada National Security Site and vicinity



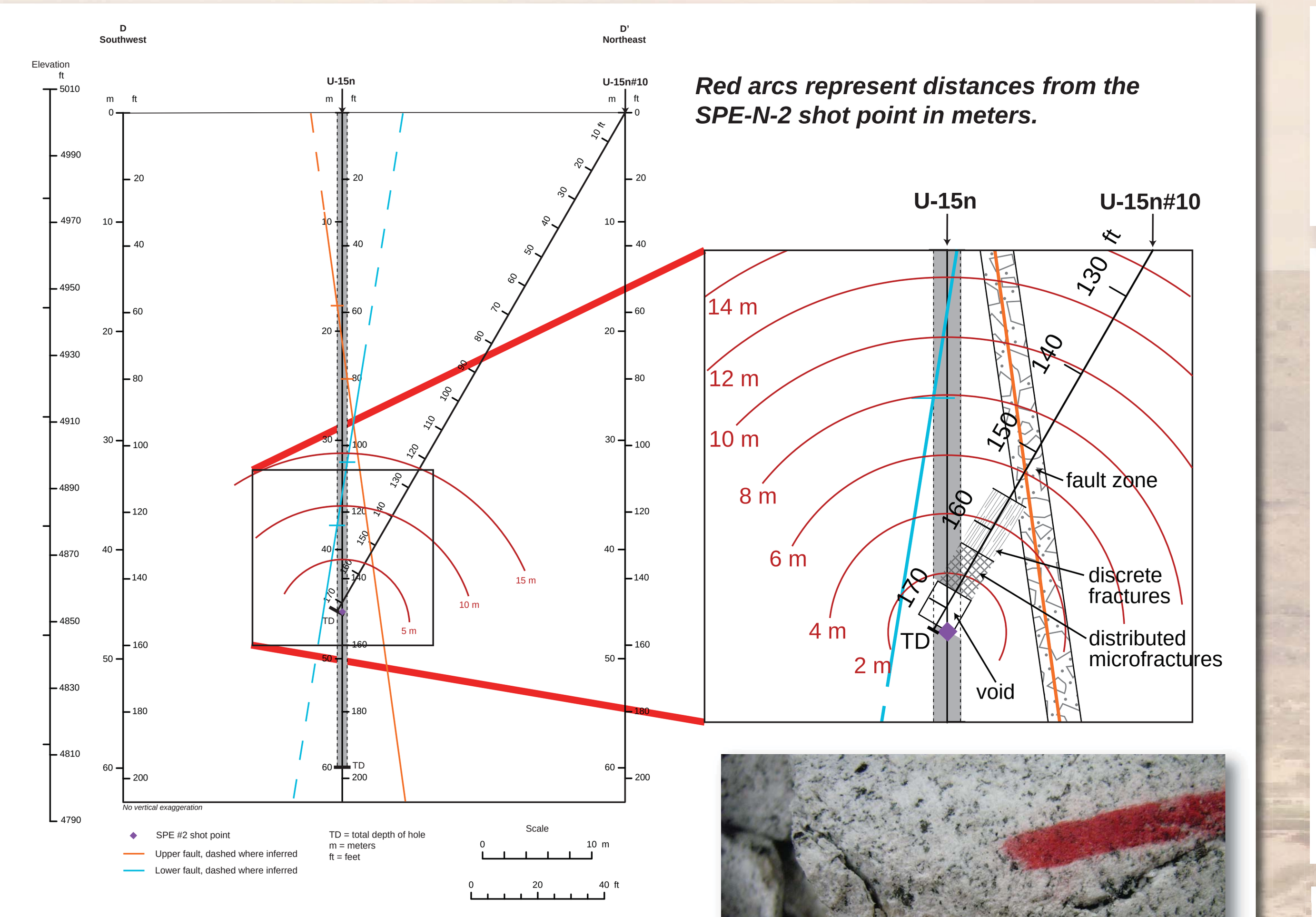
Surficial geologic map of the Climax Stock area showing location of the SPE-N site. Also note locations of three nearby underground nuclear tests.



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

Photo of core recovered from angle-hole U-15n#10 near drilled depth of 149 ft. Note altered appearance of granite and coated fracture surfaces, indicating a natural fault. SPE-N-2 source is approximately 7.6 m to the right. Yellow block is approximately 8 cm long.

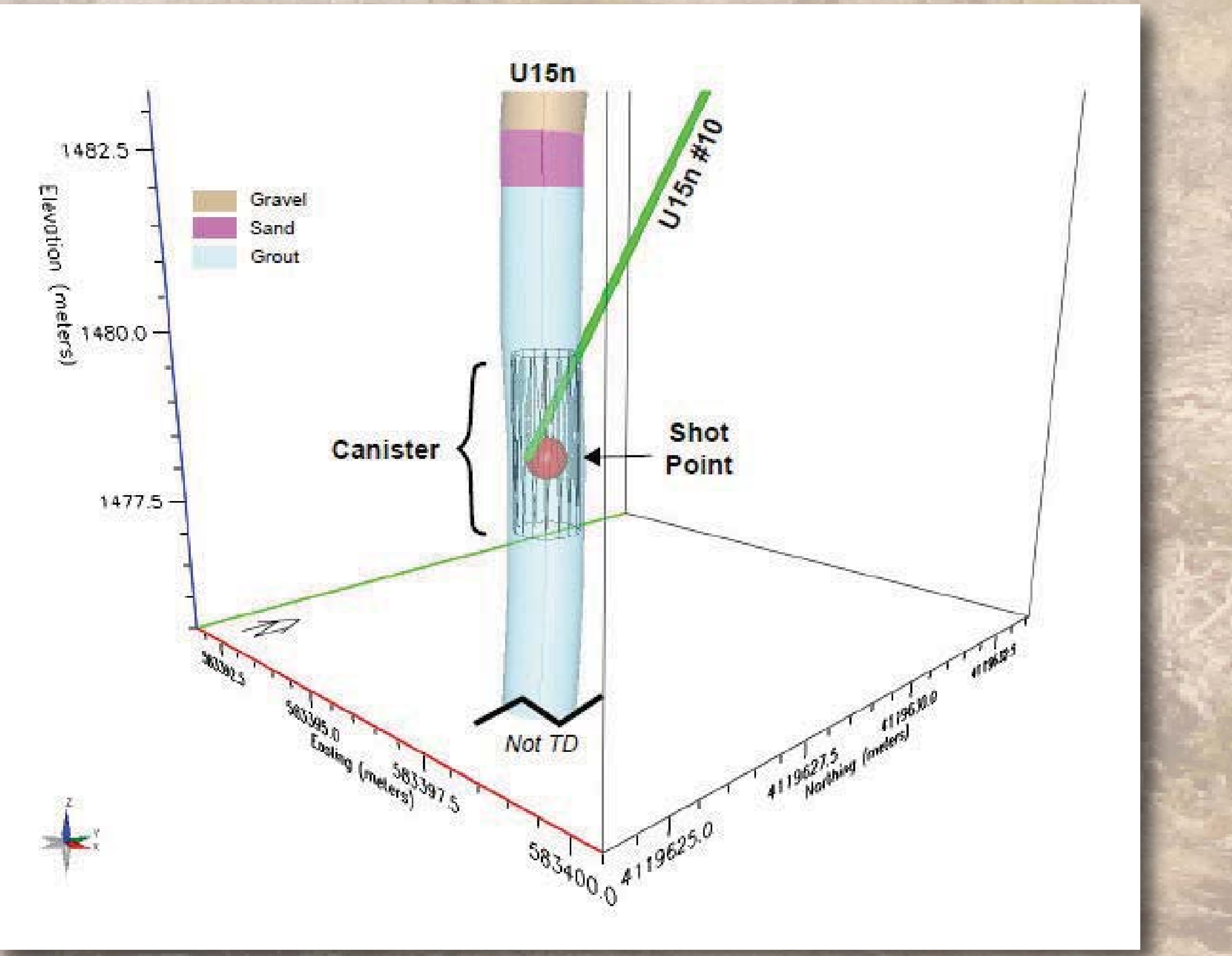
Photo of core recovered from angle-hole U-15n#10 near drilled depth of 159 ft. Fresh-looking fractures closest to yellow block are interpreted to be explosion-induced. SPE-N-2 source is approximately 4.5 m to the right. Yellow block is approximately 8 cm long.



Section view of the SPE site showing the relative positions of the U-15n source hole, SPE-N-2 shot point, and path of angle core hole U-15n#10. Note locations of two natural faults encountered in the source hole, with projected extents shown by orange and blue lines.

Fractured feldspar crystal retrieved from drilled depth of 168 ft in hole U-15n#10, approximately 1.8 m from the SPE-N-2 shot point. Red line is approximately 2.5 cm long.

Drilling of angle core hole U-15n#10.



3-D view of the path of the U-15n#10 angle core hole showing penetration through the pre-shot position of the SPE-N-2 shot point region

Fault Zone:

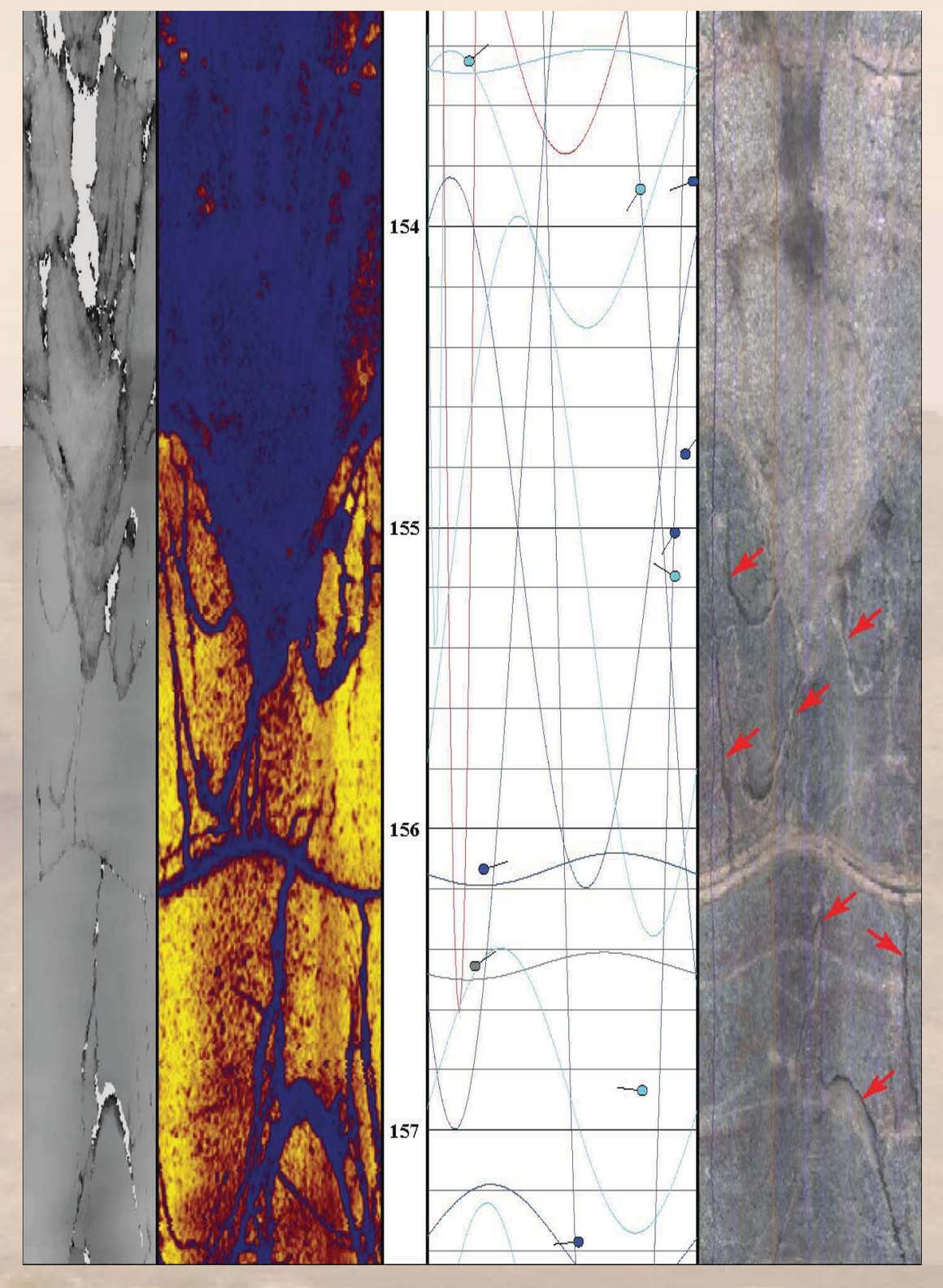
- Significant natural fault zone characterized by an interval of highly altered rock, including breccia, gouge, and slickesided surface
- Logged between the drilled depths of 149.0 to 155.0 ft

Discrete fracture interval:

- Intepreted to have been caused by the SPE-N-2 explosion
- Distinctive in both the recovered core and in the televiewer logs
- Appear fresh, with no associated secondary staining or alteration
- Have rougher fracture surfaces and more irregular shapes than the clearly natural fractures observed in the hole
- Tend to terminate against the natural fractures
- Most fractures observed in the borehole televiewer logs have orientations different than those in the established fracture sets, which suggests that the explosion-induced fractures formed in a stress field that is different than that associated with the majority of natural fractures
- Observed only below the drilled depth of 141 ft (approximately 10 m from the shot point), and are most prevalent 3.3 to 5.4 m from the shot point

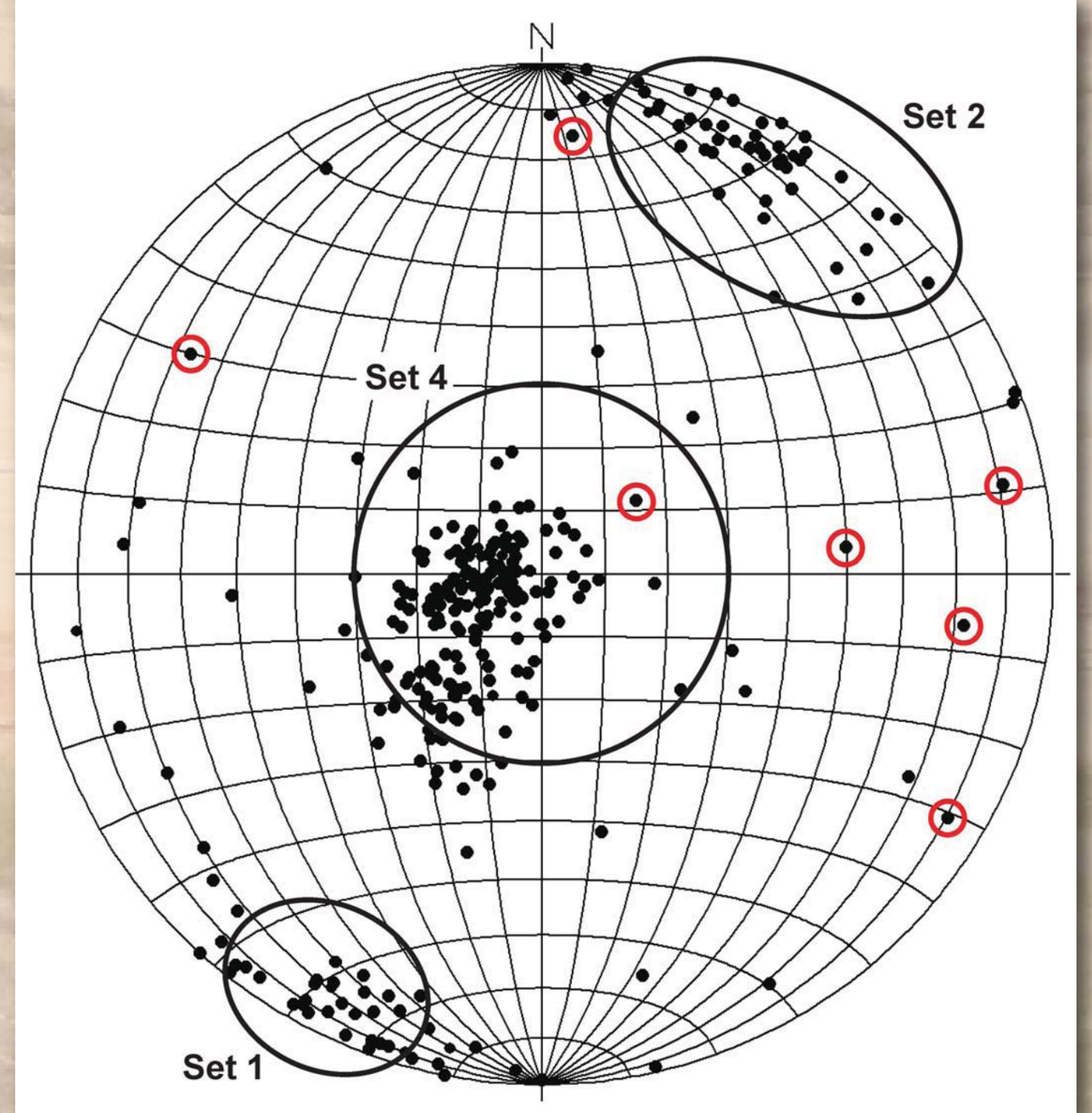
Distributed microfacture interval:

- Many pieces of the recovered core have a white, chalky, damaged look
- Naturally occuring feldspar crystals are highly fractured
- Observed from the depth of 163 ft to the end of the recovered core at the depth of 168.4 ft, approximately 1.6 to 3.3 m from the shot point). SNL and Los Alamos National Laboratory studies currently in progress may provide more definitive data for this region



A portion of the U-15n#10 borehole image log showing explosion-induced fractures (red arrows)

Fractures are plotted on a lower-hemisphere Schmidt net. Natural fractures grouped as Sets 1, 2, and 4 are circled in black. Explosion -induced fractures are circled in red.



Stereonet diagram of all fractures identified in the U-15n#10 televiewer logs, showing the orientations of explosion-induced fractures

CONCLUSIONS

- One core hole has been drilled into the northeast side of the SPE-N-2 shot point region.
- Fracturing that is distinct in character from abundant natural discontinuities in the SPE-N-2 test bed is the primary indicator of damage to the granite medium evaluated to date.
- The most distant fracture that could be interpreted as having been caused by the explosion was seen at approximately 10 m from the shot point.
- The presence of a large altered zone associated with a natural fault encountered in the core hole between 5.7 and 7.5 m from the shot point likely influenced the creation of new fractures in the vicinity; no explosion-induced fractures are recognized in the altered interval.
- Starting at approximately 5.4 m from the shot point, explosion-induced fractures are abundant.
- At approximately 3.3 m from the shot point to the end of the recovered core at 1.6 m from the shot point, some of the core samples have a damaged appearance, which may indicate a zone of distributed microfractures.
- Measurement of mechanical properties and microscopy studies of samples from the shot zone are currently underway and will likely provide more quantitative data on the damage zone.

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Broome, S. T., and T. Pfeifle, 2011. Written communication prepared for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. Subject: "Phase 1 Mechanical Testing Results on Core from Borehole U-15n, Nevada National Security Site, in Support of NCNS Source Physics Experiment." Sandia National Laboratories Report dated June 8, 2011.