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Post-Test Evaluation of HTEPW II A Hard Rock Weapon Penetrator Test (U)

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Classified by K. D. Nokes, Supervisor, Phase 1 and Phase 2 Division 5161, July 22, 1988.

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Post-Test Evaluation of HTEPW II A Hard Rock Weapon Penetrator Test (U)

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Abstract (U)

A weapon penetration test was conducted into exposed, solid granite, at high velocity, utilizing a large, recoilless gun. The geology of the test site and the terradynamic performance of the penetrator are described. This test models an extreme condition of target hardness, regarding penetrability of a geologic medium.

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Summary

The second of a series of granite bedrock penetration tests of the Sandia Hard Target Earth Penetrating Weapon (HTEPW) was conducted by Sandia National Laboratories, Albuquerque, at China Lake, California on 23 September 1987. The target of choice was a bare bedrock surface of competent, widely jointed leucogranite with unaxial compressive strength within the range of 14 kpsi to 22 kpsi.

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Post-Test Evaluation of HTEPW II A Hard Rock Weapon Penetrator Test

Introduction

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[redacted] This test was conducted at the Naval Weapons Center (NWC), China Lake, California.

DOE b(3)

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[redacted] These results indicated that the HTEPW could penetrate bedrock locations where the bedrock was weathered at the surface and could be expected to achieve more than sufficient depths of penetration (a minimum of one body length being sufficient) under such conditions.

Based on these results, the next test environment was chosen to represent an extreme condition: clean hard bedrock surface entry. Such a target would test the ability of the HTEPW to penetrate a hard surface where no low-strength material existed to act as a weapons penetration guide. Previous tests of various experimental ordnance devices, fired directly into exposed competent rock, indicate that incoming projectiles either ricochet off of the surface or rebound if the projectile case survives the impact. A successful penetration for the HTEPW would leave the projectile embedded in the bedrock by at least a body length. This test environment would also determine the capability of the penetrator body and the internal components to survive the complex, multidimensional (lateral and longitudinal loading) and rapid deceleration. The survival of the penetrator case alone would not guarantee the survival of the weapon.

The results of this latest test are discussed below.

Upper Wilson Canyon Test Site

The Naval Weapons Center is in the Mojave desert of Southern California. Within the NWC test range are numerous types of igneous and sedimentary bedrock. Several areas were studied prior to the selection of upper Wilson Canyon. The first NWC test of the HTEPW was conducted in the lower Wilson Canyon area, but more competent bedrock was sought in other localities. The Pumice Mine Gate and Sugarloaf Gate sites were originally chosen for test No. 2, but detailed examination of the rocks at these sites revealed that they were not sufficiently strong nor was the jointing sufficiently wide for our purposes. The joint spacing needed to be large in order for the penetrator to sample a more homogeneous half-space and to minimize the joint/fracture induced trajectory deviations which are known to occur in such tests.

The upper Wilson Canyon site was chosen based on ease of access, limited site preparation requirements, lack of overburden, and general quality of the leucogranite bedrock. The site was prepared first by removing a thin overburden and subsequently blowing the surface clean with high pressure air. Thirteen core test holes were drilled to characterize the geology of the site (Figures 1 and 2 and the Appendix). The final designated ground zero (GZ) was located within a triangle described about holes 6, 7, and 11 (Figures 3 and 4). The joint patterns in the vicinity of GZ are plotted on Figure 4.

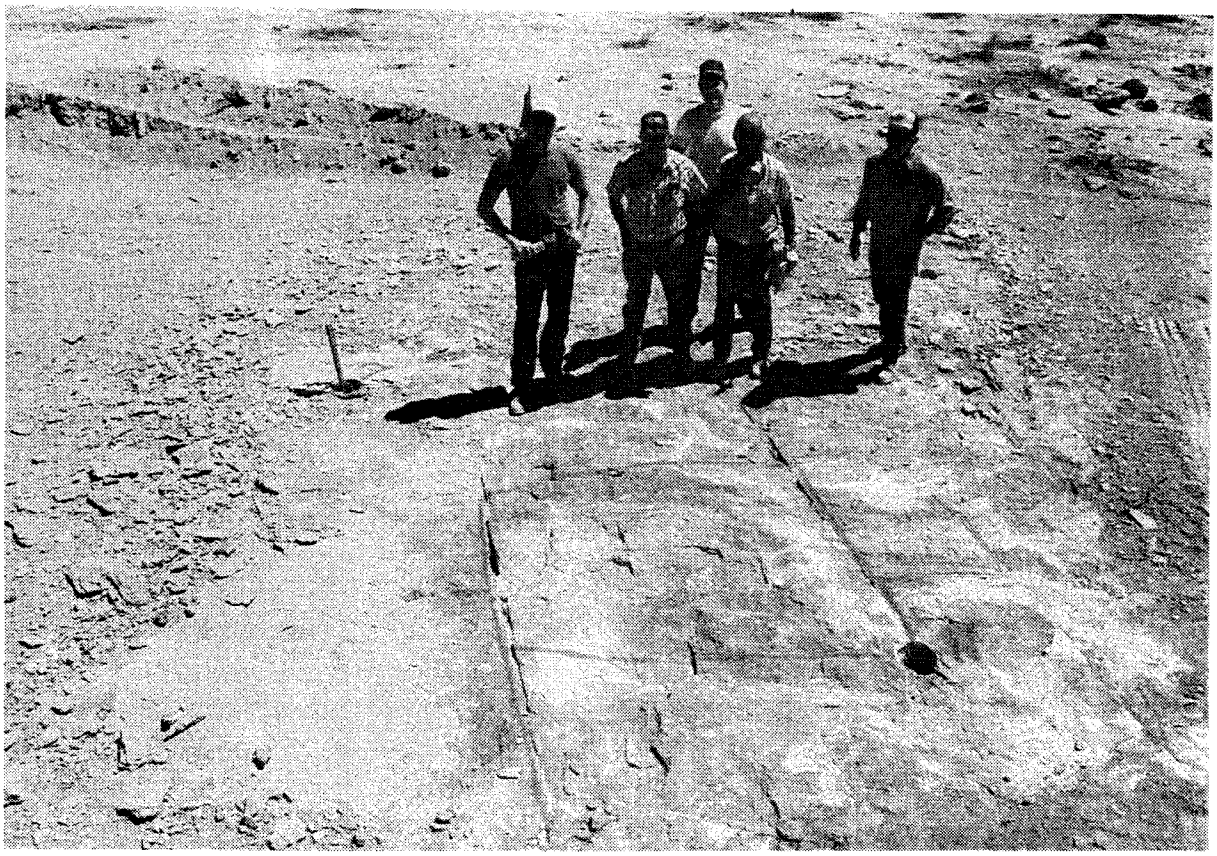

Figure 3. Target

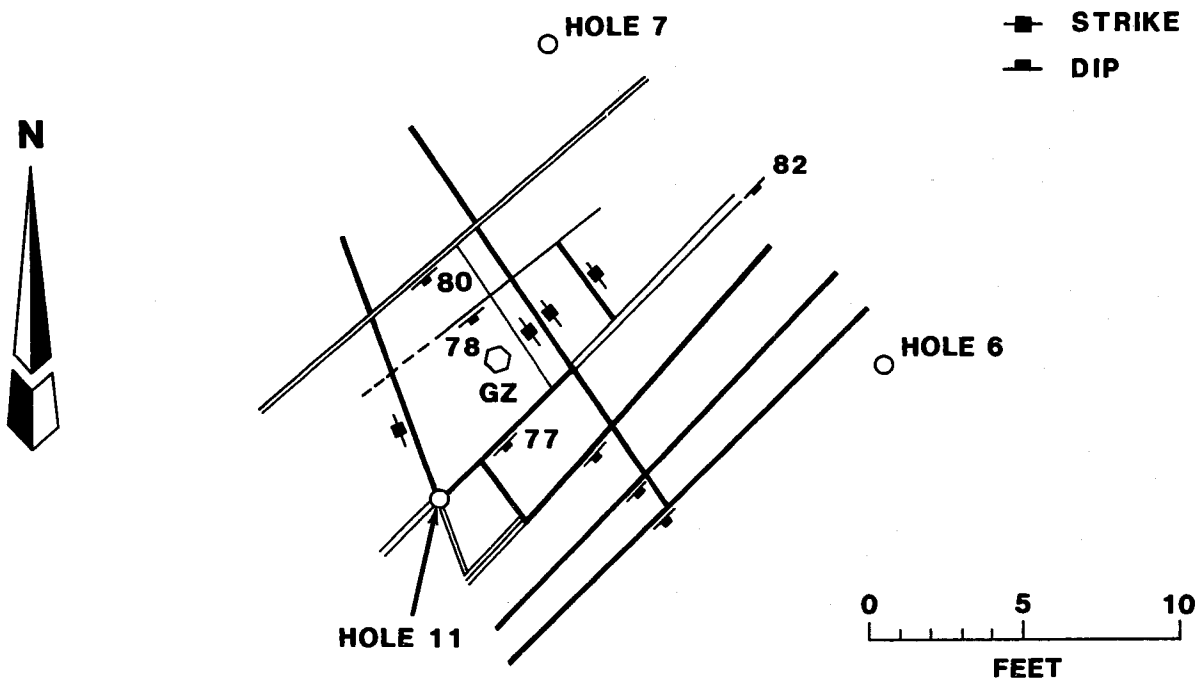

Figure 4. Plot of Granite Joint Patterns

Figure 6. Projectile Before Excavation With Davis Gun in Firing Location

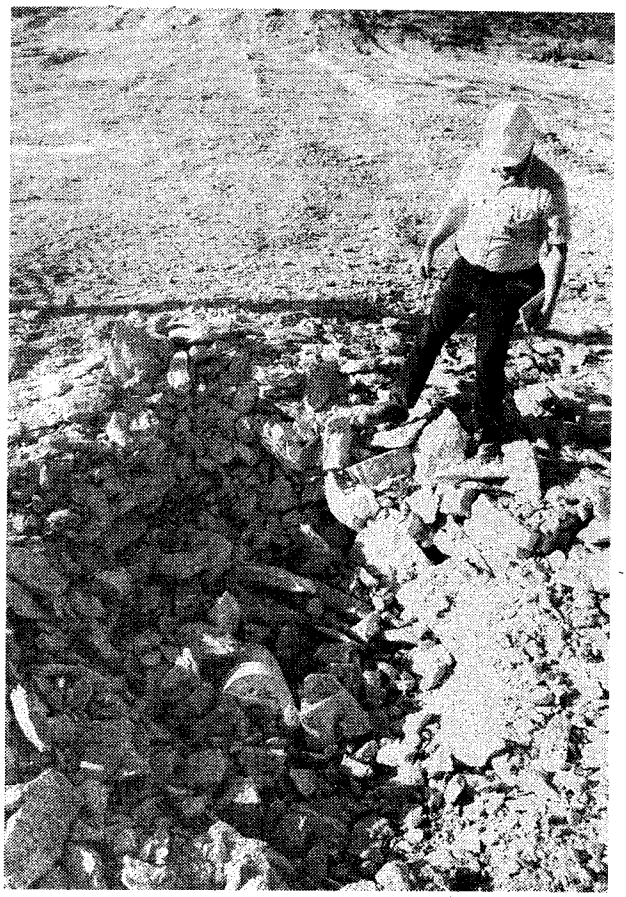

Figure 7. Projectile Viewed From Firing Position

Figure 10. Removal of Intact Projectile

Conclusions

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References

[1] Eastler, Thomas E., "Pre-Penetration Site Evaluation for Test #2 Sandia Hard Target Earth Penetrating Weapon (HTEPW)"; unpublished research note; Sandia National Laboratories, Div. 5161, July 1985.

[2] Durbin, Bill, "Drilling Logs of Upper Wilson Canyon Test Site"; unpublished field notes; Naval Weapons Center, China Lake, CA, 1988.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 1
Date: 3 June 1987

Interval	Description
0–1′	6-inch Tricone drilling.
	Pilot hole drilled directly into leucogranite outcrop, no alluvial overburden cover.
1–2′	Core drilling — 2.75″ diameter core.
	Leucogranite —1–2 mm grain size, light gray, 10–15% quartz, 80–90% feldspar, predominantly plagioclase with a few scattered potassium feldspar phenocrysts, 5% biotite and other dark minerals; quartz and feldspars fractured and sericitized; rock iron-stained; rock is non-jointed; core interval recovered from 1′ to 1′9½″ — bottom 2½″ of core left in hole. Two diamond bits were destroyed in drilling this hole as a result of drilling dry. Variations in air pressure and column pressure did not alleviate bit overheating problem.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 2
Date: 3 June 1987

Interval	Description
0–13′9″	6-inch Tricone drilling.
	Hole collared on leucogranite outcrop; rock chips fresh and hard.
13′9″–14′ 1½″	Core drilling — 2.75″ diameter core.
	Drilled 4½″ and burned bit. No core recovery.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 3
Date: 3 June 1987

Interval	Description
0–1′3″	6-inch Tricone drilling.
	0–1′1½″ Alluvial overburden.
	1′1½″–1′3″ Leucogranite — altered, gray-white.

NOTE: This hole drilled to determine depth of overburden.

APPENDIX

Drilling Logs

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 4
Date: 3 June 1987

Interval	Description
0–2′	6-inch Tricone drilling.
	0–1′8″ Alluvial overburden.
	1′8″–2′ 0″ Leucogranite — altered, gray-white.

NOTE: This hole drilled to determine depth of overburden.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 5
Date: 8 July 1987

Interval	Description
0–4′	6-inch Tricone drilling.
	0–2′ Alluvial overburden.
	2–4′ Weathered leucogranite — chips soft and clay-rich.
4–12′	Core drilling — 2.25″ diameter core.
	Leucogranite — Pale whitish-gray, punky, soft, abundant intergranular pore space, many mineral grains fractured, 10 – 15% quartz, 7 – 10% mafic minerals (mostly biotite), feldspar mainly plagioclase group, feldspars partially altered to clay, sericite alteration common along grain boundaries and within fractured grains.
	Core disked from 4 to 4½ feet, ½-foot core loss.
	Hole terminated at 12′0″.
	NOTE: Insufficient solid core for compressive strength testing.
	Jointing.
	Thin joint from 5′9″–6′2″; 36-degree angle to core axis.
	Joint from 6′2″–6′5½″; nearly parallel to core axis, at edge of core.
	Joint from 6′7″–7′2″; 18-degree angle to core axis.
	Joint from 9′½″–9′1½″; 65-degree angle to core axis.
	Joint at 9′3″; thin, clay-filled, perpendicular to core axis.
	Joint from 9′4″–9′8½″; thin, clay-filled, manganese oxide staining on joint surface, 26-degree angle to core axis.
	Joint from 9′10″–10′1″; thin, clay-filled, manganese oxide staining on joint surface, 36-degree angle to core axis.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 6
Date: 9 July 1987

Interval	Description
0–1′8″	6-inch Tricone drilling.
	0–8″ Alluvial overburden
	8″–1′8″ Leucogranite — Chips fresh, light gray.
1′8″–3′0″	3-inch Tricone drilling.
	Leucogranite — Chips fresh, light gray.
3′0″–19′0″	Core drilling — 2.25″ diameter core.
	Leucogranite — 1 to 3 mm grain size, light gray, 15–20% quartz, feldspars of plagioclase group, approx. 5% mafic minerals, mainly biotite, core has yellowish iron-staining, slight clay alteration of feldspars, sericite alteration at grain boundaries and within fractured grains.
	Severely altered zone from 15′10½″–16′8″; mineral grains broken and clay altered, cut by clay-filled joints.
	Hole terminated at 19′0″.
	Jointing.
	Joint from 3′8″–4′4½″; 26-degree angle to core axis.
	Joint from 4′0″–4′8″; closed, 16-degree angle to core axis.
	Joint from 4′4″–5′2″; closed, 14-degree angle to core axis.
	Joint from 4′9″–5′4½″; 17-degree angle to core axis.
	Joint from 6′1½″–6′7″; ⅛″ wide with clay filling, 22-degree angle to core axis.
	Joint from 6′1″–6′4″; clay-filled, terminates at above joint, 36-degree angle to core axis.
	Joint from 11′0″–11′1½″; clay filling and manganese oxide staining, 55-degree angle to core axis.
	Joint from 12′5½″–12′10″; tan clay filling, tight, 26-degree angle to core axis.
	Thin hairline fracture from 12′10″ to 13′4½″, tight, parallel to core axis, cut off by joints above and below.
	Joint from 13′4½″–13′7″; tight, 42-degree angle to core axis.
	Joint from 13′10½″–14′1″; 42-degree angle to core axis.
	Joint from 13′10½″–15′6″; irregular joint, nearly parallel to core axis.
	Joint from 15′10″–16′0″; clay-filled, 55-degree angle to core axis.
	Joint at 16′8″; perpendicular to core axis.
	Joint from 17′3″–17′5″; thin, tight fracture, 48-degree angle to core axis.
	Joint from 17′4″–19′0″; irregular fracture nearly parallel to core axis, terminated at upper end by above joint.
	Joint from 17′6–18′0″; cross-cuts above joint, 21-degree angle to core axis.

Sandia Davis Gun Test
Upper Wilson Canyon Test Site, NWC
Compressive Strength Tests of Drill Core Samples—Hole No. 6

Interval (feet)	Compressive Strength (psi)
3.08–3.41	13,610
6.78–7.12	22,110
7.82–8.16	16,670
9.00–9.34	16,240
12.95–13.29	22,880*

*Hairline fracture parallel to core axis the full length of sample.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 7
Date: 10 July 1987

Interval	Description
0–2′	6-inch Tricone drilling.
	0–1′10″ Alluvial overburden.
	1′10″–2′ Leucogranite — chips light gray and fresh.
2–3′	3-inch Tricone drilling.
	Leucogranite — chips light gray and fresh.
3′–13′8″	Core drilling — 2.25″ core diameter.
	Leucogranite — 1 to 2 mm average grain size with scattered grains up to 4 mm, light gray, 10–15% quartz, feldspar mainly of plagioclase group, 3–5% mafic minerals, predominantly biotite, core generally fresh and shows little alteration in hand specimen.
	Hole terminated at 13′8″.
	Jointing.
	Joint from 5′½″–5′2″; 55-degree angle to core axis — intersected by a joint from 5′2″–5′3″, 65-degree angle to core axis.
	Joint from 7′9″–7′11″; 48-degree angle to core axis.
	Joint with clay filling at 8′11″; perpendicular to core axis.
	Joint from 9′1″–9′2″; 65-degree angle to core axis.
	Joint from 11′7″–11′8″; closed hairline fracture, 65-degree angle to core axis.
	Joint from 11′8″–11′11″; 36-degree angle to core axis.
	Joint from 12′2″–12′11″; open fracture with clay filling and manganese oxide staining, 15-degree angle to core axis.
	Remarks.
	The interval from 12′11″–13′4″ was fresh, non-jointed rock that was ground and spiral fractured as a result of wedging of a section of rock broken from the above joint plane.

Sandia Davis Gun Test
Upper Wilson Canyon Test Site
Compressive Strength Tests of Drill Core Samples—Hole No. 7

Interval (feet)	Compressive Strength (psi)
3.10–3.45	21,880
6.28–6.64	17,730
9.59–10.00	18,300
10.35–10.72	17,870
11.18–11.54	17,870

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 8
Date: 10-11 July 1987

Interval	Description
0–2′2″	6-inch Tricone drilling.
	0–2′0″ Alluvial overburden.
	2′0″–2′2″ Leucogranite — chips weathered, clay-rich.
2′0″–4′4″	3-inch Tricone drilling.
	Leucogranite — chips weathered, clay-rich.
4′4″–20′6″	Core drilling — 2.25″ diameter core.
	4′4″–8′2″ Leucogranite — 1 to 3 mm average grain size, gray, mineral grains weathered and fractured, rock fractured along grain boundaries, 10–15% quartz, feldspars predominantly plagioclase group, 5–10% mafic minerals–mainly biotite.
	Core fractured and broken from 4′5″–5′2″, 2-inch core loss.
	8′2″–8′9″ Leucogranite — 1 to 2 mm grain size, pale gray, rock hard and fresh, 3–5% mafic minerals.
	8′9″–20′6″ Leucogranite — Slightly coarser texture than above intervals — 2–3 mm grain size, gray, 5–10% mafic minerals.
	Hole terminated at 20′6″.
	Jointing.
	Joint from 4′6″–5′9″; open fracture with clay filling and manganese oxide staining. 9-degree angle to core axis.
	Joint from 5′9″–6′6″; thin, clay-filled, 15-degree angle to core axis.
	Joint from 8′11″–9′4″; 24-degree angle to core axis.
	Joint from 12′½″–12′3″; sealed, 42-degree angle to core axis.
	Joint from 12′4″–13′2″; hairline fracture, nearly parallel to core axis.
	Joint from 13′0″–13′2″; 48-degree angle to core axis.
	Joint from 17′8″–17′11″; 36-degree angle to core axis.
	Joint from 17′10″–17′11″; 65-degree angle to core axis, tight fracture, manganese oxide stained, truncates joint above.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 9
Date: 11 July 1987

Interval	Description
0–1′11″	6-inch Tricone drilling.
	Alluvial overburden.
1′11″–3′9″	3-inch Tricone drilling.
	1′11″–2′3″ Alluvial overburden.
	2′3″–3′9″ Leucogranite — Chips fresh, light gray.
3′9″–20′8″	Core drilling — 2.25″ diameter core.
	3′9″–20′8″ Leucogranite — 2 to 3 mm average grain size, light gray, approx. 10% quartz, 5–7% mafic minerals — predominantly biotite, low to moderate clay and sericite alteration, feldspars mainly of plagioclase group, fracturing of mineral grains and breakage along grain boundaries has resulted in a series of fractures at 4′4″, 4′5″, 4′9″, 5′1″, and 6′3″ — all nearly perpendicular to core axis, rock strongly decomposed from 7′0″–7′6″, and from 12′7″– 12′10″.
	Rock has decreased mafic mineral content (3–5%) from 12′10″ to end of hole, rock is very light gray color.
	Hole terminated at 20′8″.
	Jointing.
	Joint from 7′0″–7′7″; 3/16″ wide, filled with white clay, 18-degree angle to core axis.
	Joint from 8′4″–9′2″; thin, 14-degree angle to core axis.
	Joint from 10′2″–10′4″; thin, clay-filled and manganese oxide stained, 48-degree angle to core axis.
	Joint from 10′9½″–11′1″; clay-filled and manganese oxide stained, 33-degree angle to core axis.
	Joint from 11′8″–12′1″; clay-filled and manganese oxide stained, 36-degree angle to core axis.
	Joint from 12′2″– 12′7″; thin, irregular.
	Joint from 13′7″–13′7½″; thin, trace manganese oxide stain, 78-degree angle to core axis.
	Joint from 15′3″–15′4″; thin, 65-degree angle to core axis.
	Joint from 15′8″–16′2″; tight, 21-degree angle to core axis.

Sandia Davis Gun Test
Upper Wilson Canyon Test Site
Compressive Strength Tests of Drill Core Samples—Hole No. 9

Interval (feet)	Compressive Strength (psi)
5.78–6.12	3,550*
9.17–9.51	9,690*
10.42–10.77	12,500
13.09–13.44	14,000*
16.62–16.97	12,150
19.25–19.63	7,150
19.83–20.17	7,410*

*The samples tested had a length over Diameter (L/D) of less than 2, therefore the compressive strength was computed using the following equation.

$$C = Co / [0.88 + (0.24\ b/h)]$$

where

C = computed compressive strength of an equivalent L/D = 2 sample.

Co = measured compressive strength of the sample tested

b = measured core sample diameter

h = measured core sample length

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 10
Date: 11-12 July 1987

Interval	Description
0–1′7″	6-inch Tricone drilling.
	Alluvial overburden.
1′7″–3′1″	3-inch Tricone drilling.
	1′7″–1′10″ Alluvial overburden.
	1′10″–3′1″ Leucogranite — Rock chips weathered, pale gray, soft.
3′1″– 21′7½″	Core drilling — 2.25″ diameter core.
	Granite/Leucogranite — 1–3 mm grain size, gray, slightly weathered, scattered hairline cracks along mineral grain boundaries and through mineral grains, sericitized, approx. 5% mafic minerals — mainly biotite, 10–15% quartz, scattered feldspar phenocrysts, clay-rich severely decomposed zone from 6′9½″ to 7′½″ approximately perpendicular to core axis.
	Core pale gray and more competent from 10′ to 12′3″, quartz and feldspar iron-stained from 10′6″ to 12′3″.
	Core gray and extremely hard and solid from 12′3″ to 18′10″, severely decomposed zone from 18′10″ to 19′ filled with tan clay, nearly perpendicular to core axis.
	Hole terminated at 21′7½″.
	Jointing.
	Joint from 7′4″–4′½″; clay-filled, 78-degree angle to core axis.
	Joint from 8′11½″–10′11″; nearly perpendicular to core axis.
	Joint from 10′2″–15′1″; nearly perpendicular to core axis.
	The 2 joints immediately above intersect each other at nearly right angles.

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Sandia Davis Gun Test
Upper Wilson Canyon Test Site
Compressive Strength Tests of Drill Core Samples—Hole No. 10

Interval (feet)	Compressive Strength (psi)
3.15–3.49	5,300*†
3.75–4.12	7,290
6.00–6.35	6,060
7.45–7.84	6,720
16.83–17.17	11,630*
18.42–18.80	11,580
19.59–19.93	10,560*

*The samples tested had a Length over Diameter (L/D) of less than 2, therefore the compressive strength was computed using the following equation:

$$C = Co / [0.88 + (0.24\ b/h)]$$

where

C = computed compressive strength of an equivalent L/D = 2 sample.

Co = measured compressive strength of the sample tested

b = measured core sample diameter

h = measured core sample length

†Sample ends unpolished and slightly off parallel

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Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 11
Date: 11 August 1987

Interval	Description
0–1′8″	6-inch Tricone drilling.
	0–6″ Alluvial overburden.
	6″–1′8″ Leucogranite — chips fresh, unweathered
1′8″–8′0″	3-inch Tricone drilling.
	1′8″–3′0″ Leucogranite — chips fresh, unweathered.
3′0″–20′10″	Core drilling — 2.25″ diameter core.
	Leucogranite — 1–3 mm grain size, light gray, slight sericitic alteration, core generally unweathered and competent, 5% mafic minerals, predominantly biotite, 10–15% quartz, local clay and sericite alteration around fracture at 7 feet.
	Solid core retrieved from core barrel for each interval from 5′3″ to 20′2″.
	Hole terminated at 20′10″.
	Jointing.
	Highly irregular joint from 3′0″–5′3″, minor clay alteration along joint surfaces.
	Joint from 7′0″–7′2″, tight fracture, clay and sericite alteration.
	Joint from 20′2″–20′7″, approximate 50-degree angle to core axis, joint surfaces manganese-stained.

Sandia Davis Gun Test
Upper Wilson Canyon Test Site
Compressive Strength Tests of Drill Core Samples—Hole No. 11

Interval (feet)	Compressive Strength (psi)
5.42–5.75	14,580
6.00–6.35 (approx.)	15,700*
7.54–7.89	10,300
9.79–10.14	11,380
12.59–12.94	15,160
13.00–13.35	13,870
15.75–16.10	12,580
16.20–16.35	7,580†
19.00–19.35	10,700
19.63–19.98	2,430†

*Sample tested at Sandia National Labs
†The machinery used to test these samples experienced hydraulic failure during testing, therefore, the results listed should not be considered reliable.

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 12
Date: 12 August 1987

Interval	Description
0–1′5″	6-inch Tricone drilling
	0–7″ Alluvial overburden.
	7″– 1′5″ Leucogranite — chips light gray, slightly altered.
1′5″–3′0″	3-inch Tricone drilling.
	Leucogranite — chips light gray, slightly altered.
3′0″–19′7½″	Core drilling — 2.25″ diameter core.
	Leucogranite — 1 to 3 mm grain size, light gray, 10–15% quartz, 5–7% biotite, sericite alteration, yellowish iron staining throughout core length, slight clay alteration of feldspars.
	Hole terminated at 19′7½″.
	Jointing.
	Long, irregular joint from 9′10″–13′8″, nearly parallel to core axis.
	Joint from 11′2″–11′8″, terminated by long joint above.
	Joint from 16′4″–17′2″, clay-filled, 16-degree angle to core axis.
	Joint from 18′6″–19′4″, clay-filled, 14-degree angle to core axis.

Sandia Davis Gun Test
Upper Wilson Canyon Test Site
Compressive Strength Tests of Drill Core Samples —Hole No. 12

Interval (feet)	Compressive Strength (psi)
3.00–3.35	7,890
4.50–4.85	8,690
6.64–6.99	9,320
8.64–8.99	9,840
9.43–9.78	9,780
14.92–15.27	14,180
18.00–18.35	7,350

Upper Wilson Canyon Test Site, NWC
Drilling Log: Hole No. 13
Date: 12 August 1987

Interval	Description
0–1′5″	6-inch Tricone drilling.
	0–7″ Alluvial overburden.
	7″–1′5″ Leucogranite — chips fresh, unaltered, light gray.
1′5″–3′0″	3-inch Tricone drilling.
	Leucogranite — chips fresh, light gray.
3′0″–5′0″	Core drilling — 2.25″ diameter core.
	Leucogranite — 2-3 mm grain size, light gray, 10–15% quartz, 3–5% biotite, core fresh and unfractured.
	Core appears to have been broken during drilling operations resulting in wedged and ground core.
	Hole terminated at 5′0″.

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