Fracture Decoupling Experiment Phase I

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INTRODUCTION

The Former Soviet Union (FSU) practiced detonating multiple nuclear tests in the same or similar tunnel location. It has been observed that the seismic amplitudes of the “repeat nuclear test” are significantly decreased, when compared to a “first nuclear test” of the same yield (e.g. Sokolova, 2008). In addition, several calibration chemical explosions conducted at the Semipalatinsk Test Site (STS) confirm that fracture decoupling reduces the amplitudes of the secondary shots (e.g. Knowles, 2006). The decreased seismic amplitudes reduce the detection/identification thresholds and seismically estimated yield of a “repeat nuclear explosion” and could act as a “decoupling” mechanism.

The objective of the proposed research is to conduct a seismic field experiment to:

a) Define the physics responsible for causing seismic amplitude reductions and
b) Quantify the phenomena in terms of a “decoupling factor” as a function of frequency.

In order to quantify the degree of the amplitude reduction and to evaluate possibilities of concealing nuclear tests, Weston Geophysical Corp. (WGC) in cooperation with Columbia University’s Lamont Doherty Earth Observatory (LDEO) conducted a multi-phase field experiment near Groton, NH. The objective of this project is to conduct a series of co-located explosion pairs ranging from 500 to 2000 lbs in extensively fractured granitic emplacement media in order to achieve the project’s scientific goals. The original experiment plan was:

The experimental part of the Phase I of the experiment was completed in October 2011; however, there were differences between the planned and the final scenarios due to a containment failure by the first 500 lbs explosion. We completed the experiment with smaller yield (100 lbs) explosions, and *the observed results support our initial hypothesis*. The lessons learned during the Phase I will be used to plan and execute Phase II of the experiment. In the coming sections of this QuickLook Report, we discuss the geological setting of the experiment, discuss the explosions, detail changes to the original blast plan, present preliminary data analyses, and provide lessons learned for Phase II.

EXPERIMENT LOCATION OVERVIEW

To conduct the proposed series of fracture-decoupled explosions, we chose a site on private land near Groton, New Hampshire. The major rock type at the site is Kinsman Granodiorite created during late stages of the Acadian orogeny (400 – 390 ma) (Allen, 2003). Gravity studies (e.g.

Smith, 2009) indicate that the Kinsman Granodiorite is a 2 to 3 kilometer-thick sill, rather than a batholith with deep roots. There is some debate about whether the Kinsman rocks originated solely as a result of melting of the enclosing metasediments**,** or whether they received input from a mantle source (Lyons, 1988; Rodgers, 1970). Later more volatile and less viscous portions of the melt were forced into the surrounding rock to slowly cool and form Newfound Lake area pegmatites, characterized by the very large mineral size. Large crystals of mica and feldspar deposits found in pegmatites were extensively mined in the area and supported the local economy from the early 1800s to the middle 1900s (e.g. Cameron et al., 1954).

Several outcrops have been found on or near the main road, which in this area appears to have very thin sediment layer. The topsoil layer at the site is approximately 0.5 m thick on the ridges, and becomes 1-2 m around the stream valleys. The drilling has shown that it varied between 0 and 2 m at the test site.

EXPLOSIONS

The original plan was to detonate two 500 lbs (227.3 kg) explosions: the first (FD1) in the virgin rock with the second in the rock fractured/damaged by FD1. In addition we detonated 1 lb calibration shots approximately 1.5 m from the initial explosion. The calibration shot was conducted at the same depth as the 511 lbs explosion, but before the first larger explosion, to record (calibrate) the medium response to an approximate point source.

To conduct the blasts, two 15” boreholes (FD1 and FD2) were drilled to approximately 45 ft. or 12.8 m in depth. FD2 was located approximately 20 ft away from FD1 and was later filled with cuttings to prevent it from collapsing during FD1 explosion. Due to excessive rain in the months before the experiment, the ground was saturated with water. The FD1 blasthole was making water at about 18 ft, and eventually became filled with water. All attempts to drain FD1 borehole prior to blasting failed. It is highly undesirable to have water in the test borehole, because it may dilute the explosive mixture. The blaster had two choices: a) use Heavy ANFO in plastic containers and drop it to the bottom, or b) pump 80% emulsion:20% ANFO slurry directly to the bottom of the shot borehole. The blaster chose pumping the emulsion due to concern that the Heavy ANFO would not sink to the bottom consistently, would have large water filled voids in the explosives column, and would not detonate efficiently. In addition, pumping emulsion from the truck could lead to significant error in the mass of the explosives in the borehole. After loading the borehole, the hole was stemmed with ¾" stemming (small rock pieces used to fill up the loaded borehole). Later a pile of dirt and stemming was placed on top of the stemming to reduce the chance of ejecting the stemming from the borehole.

Due to significant damage to the test bed created by FD1 we decided that it would be unwise to detonate another 500 lbs explosion close to the rubble zone. It would result in an even larger crater and would not provide the desired reproducibility in the design of the explosions. Instead of abandoning that test, we decided to use the fracture zone it produced as our test area, and to conduct smaller (100 lbs) rubble shot (FD3). In addition we detonated another shot (FD2) in virgin rock approximately 34 m away as the control shot. The hole for FD2 was drilled in very competent rock with very few fractures and produced the smallest amount of water. Both the 8" FD2 and FD3 holes were drilled to 49' depth and filled with 5' (98 lbs) of Heavy ANFO and 4 lbs of COMP-B boosters. As a result, FD2 shot produced no surface expression, with stemming remaining in the shot borehole. FD3 shot ejected some of the stemming and created a small crater (approximately 8' in diameter and 3.6 ft in depth. Table 1 shows the shot times and locations of the all shots while Table 2 provides information on the explosives.

Table 1. Explosion locations and origin times.

Shot	Date	Origin time	Latitude	Longitude	Elevation	Yield (lbs)	Notes
FD1	10/19/2011	18:35:16.628	43.68699	-71.85261	393	511	Virgin rock, wet
FD2	10/26/2011	20:53:35.221	43.68718	-71.85131	391	102	Virgin rock, dry
FD3	10/26/2011	21:13:44.656	43.68735	-71.85162	393	102	Fractured rock, wet

Table 2. Explosion characteristics

Shot	BH depth, m	Depth after loading, m	BH diameter, cm	Explosive density, g/cm^3	Explosive column, m	Total emulsion, lbs/kg	Heavy ANFO, lbs/kg	Z-boost boosters, Comp B	Total yield, lbs/kg
FD1	12.80	11.19	38.1	1.2	1.61	507.6/230.2	-	4	511.1/231.8
FD2	14.94	13.66	20.32	1.2	1.28	-	98/44.5	4	102/46.3
FD3	14.94	13.5	20.32	1.2	1.44	-	99/44.9	4	103/46.8

SEISMIC INSTRUMENTATION

WGC deployed short-period seismometers at local distances around the test site.

Spruce Ridge Network

The network stations were located at distances between 0.6 – 1.2 km (Figure 1). These stations were equipped with Sercel L22 2 Hz 3C sensors. The data were recorded with RT130 data loggers. The data at these stations were recorded at 500 samples per second.

The network consisted of 16 instruments at a range of distances between 600 m and 1200 m, with 200 m intervals at various azimuths. This was done to investigate both distance and azimuthal effects of the explosion source on seismic amplitudes. We installed five profiles along the existing roads or trails extending in approximately north (N profile), northeast (NE profile), east (E profile), south (S profile) and west (W profile) directions. Each profile consisted of 2-4 sensors.

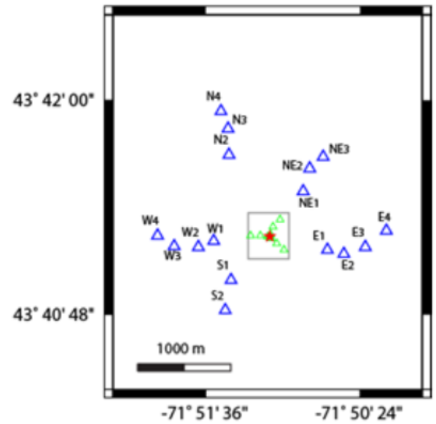

Figure 1. Blue triangles show the Spruce Ridge seismometer network.

CONCLUSIONS

The original plan was to conduct two approximately 500 lbs explosions and two 1 lb calibration shots before each of these explosions. Due to a containment failure resulting from the first explosion, mostly related to rocks being saturated with water, we modified the experiment. We detonated a 100 lbs shot in the fracture zone produced by a 511 lbs explosion. An additional 100 lbs explosion was detonated approximately 34 m away in virgin rock that had not been damaged by previous explosions. As we had hypothesized, the seismic wave amplitudes produced by the explosion in undamaged rock exceeded the amplitudes produced by a fractured rock blast by a factor of 2-3. The amplitude differences are frequency dependent, with the explosion in the undamaged rock having a higher corner frequency than the explosion in the damaged zone. Higher corner frequencies are indicative of a stronger medium or smaller explosion; however, the blasters were very careful with Shots FD2 and FD3 to load the same amount of explosives. Therefore we conclude that the amplitude differences were solely caused by the differences in the emplacement media properties.

Table 3. List of the seismic stations

Station	Latitude	Longitude	Elev, m	Distance, km	DAS	DAS Serial	Clock	Sensor	Serial
NE1	43.69151	-71.84738	399	0.6	RT130	9791	6217	L22	112
NE2	43.69365	-71.84653	398	0.8	RT130	9256	1942	L22	125
NE3	43.69474	-71.84479	397	1	RT130	985D	6260	L22	?
N2	43.69493	-71.85699	378	1	RT130	9793	6524	L22	108
N3	43.69736	-71.85712	366	1.2	RT130	990B	6324	L22	127
N4	43.699	-71.85803	348	1.4	RT130	9875	6334	L22	110
W1	43.68688	-71.85897	435	0.6	RT130	92AD	1749	L22	111
W2	43.68631	-71.86095	427	0.8	RT130	980E	6376	L22	105
W3	43.68639	-71.86408	451	1	RT130	981B	6234	L22	102
W4	43.68739	-71.86623	430	1.2	RT130	953C	6309	L22	104
S1	43.68323	-71.85673	445	0.6	RT130	9578	6436	L22	121
S2	43.68041	-71.85748	492	0.8	RT130	91E7	6317	L22	100
E1	43.68605	-71.84425	348	0.6	RT130	9772	6357	L22	123
E2	43.68566	-71.84212	334	0.8	RT130	9240	6499	L22	120
E3	43.68631	-71.83933	361	1	RT130	944A	6496	L22	237
E4	43.68784	-71.83661	356	1.2	RT130	92C0	6304	L22	122

ACKNOWLEDGEMENTS

This research was sponsored by DTRA grant HDTRA1-11-1-0029. We would like to thank our field crew including Aaron Ferris, Jill Franks, Sam Huffstetler, and Won-Young Kim. Our special thanks go to property owners for allowing us to do the experiment on their property. We thank Noel Barstow and IRIS PASSCAL for providing sensors and systems for this project.

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