Project Summary: New England Damage Experiment, Phase II

Mark Leidig and Jessie Bonner
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1. INTRODUCTION

Weston Geophysical Corp. conducted the experimental field phase of the follow-up New England Damage Experiment (NEDE2) during June 2013. The experiment was conducted in the same granite quarry near Barre, VT as the original NEDE. The goals of this experiment were to address questions created by the first experiment in July 2008 and to test new theories that were proposed from the original dataset. A primary objective remained to identify possible source(s) of shear wave generation resulting from rock damage during explosions.

The velocity of explosive detonation (VOD) and resulting borehole pressures have been shown to influence the amount of damage from an explosion. A faster VOD generates higher pressures that crush the rock into a powder, which inhibits the explosive gasses from driving fractures during the crack forming processes. We detonated various types of explosives with significantly different VOD so we could alter the quantity of damage from each source. During the first experiment, we detonated equal weights of the different types of explosives. Since the explosives have differing energy densities and burn rates, the explosions released different amounts of energy. In the follow-up experiment, we controlled the amount of each explosive so that the explosive charges represented similar TNT equivalent yields.

2. DATA RECORDING

The NEDE2 explosions were recorded on a ring of 12 seismometers installed at a radius of 6 km from the test site with 30° azimuthal spacing and on a linear array of seven seismometers (an eighth site was also part of the ring) deployed to a distance of 24 km with an interstation spacing of 3 km. We attempted to utilize the same sites occupied during the 2008 experiment to remove site effect variations; however, this was not always possible due to property permissions. Figure

1 shows the locations and Table 1 lists the station details. Stations R01-R12 and SE01-SE04 utilized 2 Hz L-22 seismometers with a sensitivity of 88 V/m/s. Stations SE05-SE08 used 1 Hz L-4C 3D seismometers with a sensitivity of -280 V/m/s.

The sensors were placed in a shallow hole, oriented to truth north, leveled, and loosely covered with soil. The soil was generally an organic rich dense soil, but sometimes had large amounts of decaying plant matter that left the site somewhat "spongy". No solid bedrock was found at the sites within a foot of the surface. Therefore, it is expected that site responses will have some variation.

Table 1. Sensor Information.

Station	Latitude (°; WGS84)	Longitude (°; WGS84)	Elev (m)	Depth (m)	DAS	DAS Serial	Sensor
SE01	44.13357	-72.46658	521	0.5	RT130	92F3	L-22 222L
SE03	44.08342	-72.42962	467	0.5	RT130	983D	L-22 238L
SE04	44.05868	-72.39523	597	0.5	RT130	943F	L-22 953L
SE05	44.03678	-72.39517	544	0.5	RT130	9E4F	L-4C 3D 65
SE06	44.01757	-72.37782	507	0.5	RT130	9D63	L-4C 3D 69
SE07	43.99570	-72.36603	513	0.5	RT130	9E17	L-4C 3D 64
SE08	43.96445	-72.33678	462	0.5	RT130	9DAA	L-4C 3D 68
R01	44.21172	-72.47897	337	0.5	RT130	9805	L-22 1488
R02	44.20173	-72.42900	502	0.5	RT130	947C	L-22 975L
R03	44.16988	-72.41126	438	0.5	RT130	92E8	L-22 725L
R04	44.15655	-72.40298	490	0.5	RT130	9804	L-22 506L
R05	44.13411	-72.40986	417	0.5	RT130	929A	L-22 ???
R06/SE02	44.10950	-72.44365	477	0.5	RT130	9442	L-22 1503L
R07	44.09792	-72.48762	553	0.5	RT130	984D	L-22 740L
R08	44.10972	-72.52071	383	0.5	RT130	92C3	L-22 954L
R09	44.14112	-72.54592	327	0.5	RT130	92A6	L-22 462L
R10	44.15577	-72.55312	387	0.5	RT130	9245	L-22 ???
R11	44.19044	-72.54471	357	0.5	RT130	984E	L-22 963L
R12	44.20353	-72.51665	220	0.5	RT130	9144	L-22 ???

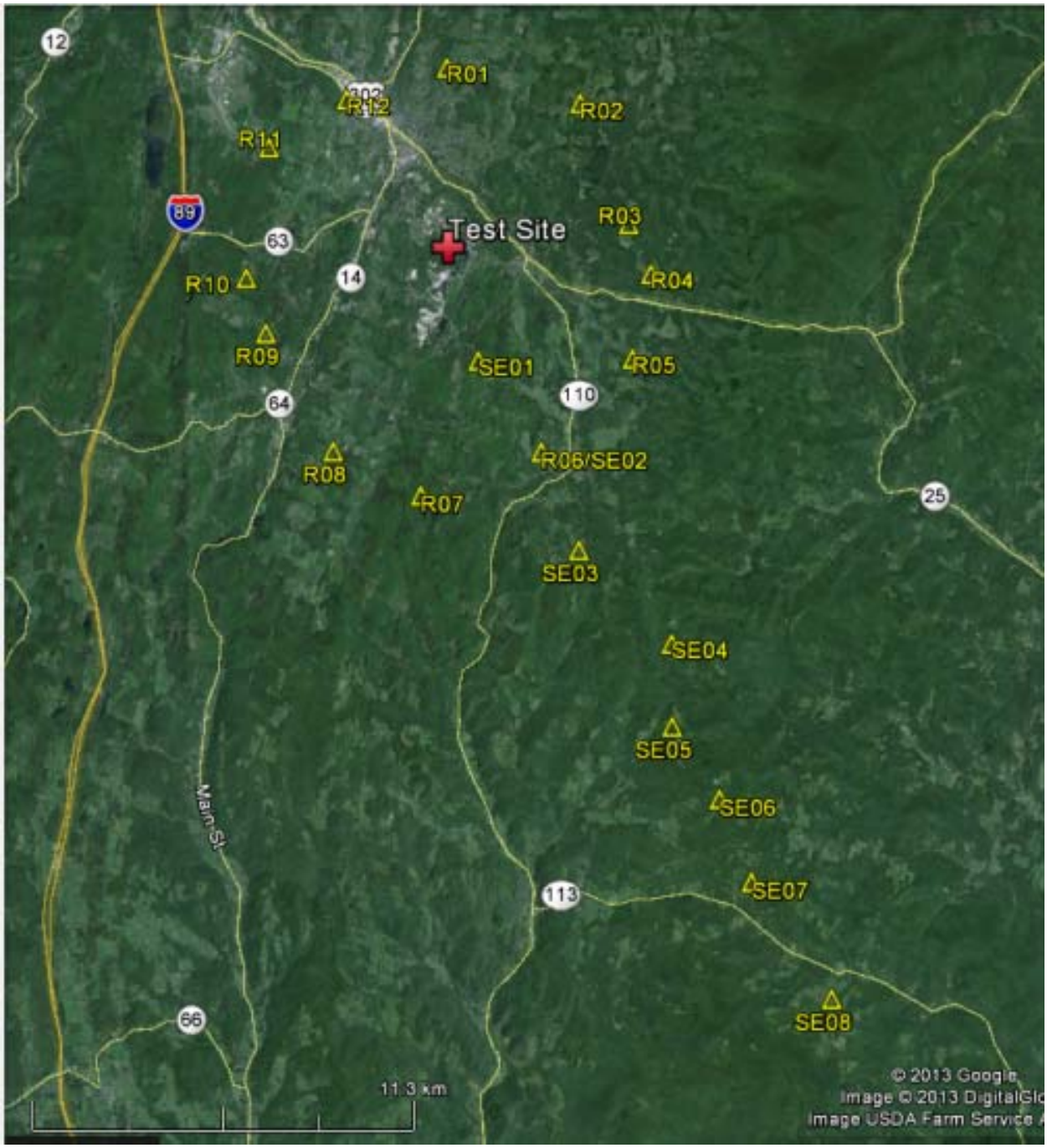

Figure 1. Short period array stations (yellow triangles). (Google Earth Background)

3. EXPLOSIONS

Shot Characteristics

Nine explosions, including 3 calibration shots, were detonated at the test site on 21-22 June 2013 (Table 2 and Figure 2) and their charge characteristics are provided in Table 3.

The primary goal of this experiment was to examine how damage affects shear wave generation. One way to vary damage is to use explosives with dramatically different velocity of detonation (VOD). As done with the 2008 experiment, this experiment used black powder (BP), ANFO/Emulsion (Heavy ANFO; HANFO), and Composition B (Comp B).

For shots 5 and 6, we drilled into the damage zones of two shots conducted in 2008 and detonated charges to examine the effects of fracture decoupling. We have termed these as "reshoots".

For this experiment, a ~150 lb (68 kg) TNT equivalent amount of each explosive was used. The weight of the 14 oz boosters, primarily composed of Comp B, were included in the charge weight calculations.

Table 2. Origin Characteristics for NEDE2 Shots.

Shot #	Latitude (°;WGS84)	Longitude (°;WGS84)	Elev (m)	Date (UTC)	Julian Date (UTC)	Time (UTC)	Description
1	44.15794	-72.47843	507	6/21/2013	172	20:22:10.701	Black powder virgin rock
2	44.15797	-72.47791	509	6/22/2013	173	17:29:09.320	Heavy ANFO virgin rock
3	44.15776	-72.47816	508	6/22/2013	173	18:15:33.492	Comp B (boosters) virgin rock
4	44.15770	-72.47795	511	6/22/2013	173	14:46:42.734	Heavy ANFO Deep shot
5	44.15751	-72.47803	507	6/21/2013	172	21:42:36.444	Reshoot of previous Heavy ANFO
6	44.15753	-72.47765	511	6/21/2013	172	20:51:33.925	Reshoot of previous Comp B
7	44.15754	-72.47806	514	6/21/2013	172	21:26:22.428	Comp B booster calibration
8	44.15742	-72.47809	513	6/21/2013	172	21:13:54.476	Comp B booster calibration
9	44.15800	-72.47823	508	6/22/2013	173	18:41:36.135	Comp B booster calibration

Table 3. Explosive Characteristics for NEDE2 Shots.

Shot	Explosive 1	Explosive 2	Weight of explosive 1 (lbs)	Weight of explosive 2 (lbs)	TNT Equivalent Yield (lbs)	Charge bottom (m)	Charge center (m)
1	Black powder	N/A	250.0	0.0	150.0	14.20	12.89
2	Heavy ANFO	Booster	184.5	1.8	150.0	14.25	13.50
3	Comp B	Emulsion	100.7	31.6	161.2	13.36	12.32
4	Heavy ANFO	Booster	184.5	2.6	151.1	29.79	29.03
5	Heavy ANFO	Booster	184.5	1.8	150.0	14.02	13.31
6	Heavy ANFO	Booster	184.5	1.8	150.0	13.51	12.80
7	Booster	N/A	1.8	N/A	2.4	14.02	13.94
8	Booster	N/A	1.8	N/A	2.4	10.67	10.59
9	Booster	N/A	1.8	N/A	2.4	14.02	13.94

Figure 2. Location of the shot points on the test site.

4. SEISMIC DATA EXAMPLES

In this section, we present a few examples of the waveforms collected during the experiment.

Waveform Examples

In Figure 3 through Figure 5, we present examples of the waveforms for the 6 large shots recorded on the radial network. Figure 6 provides a record section of the Shot 2 data recorded on the linear array.

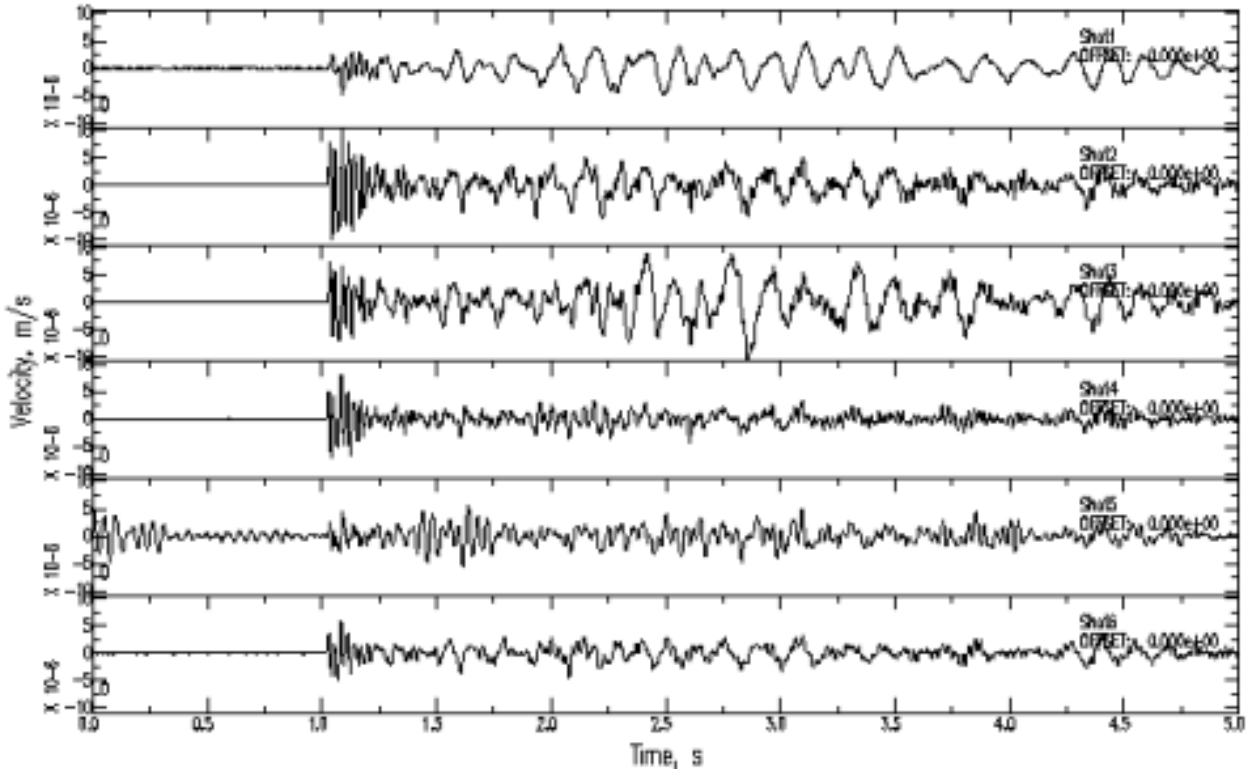

Figure 3. Shot 1 to Shot 6 vertical components at R03 (~6 km).

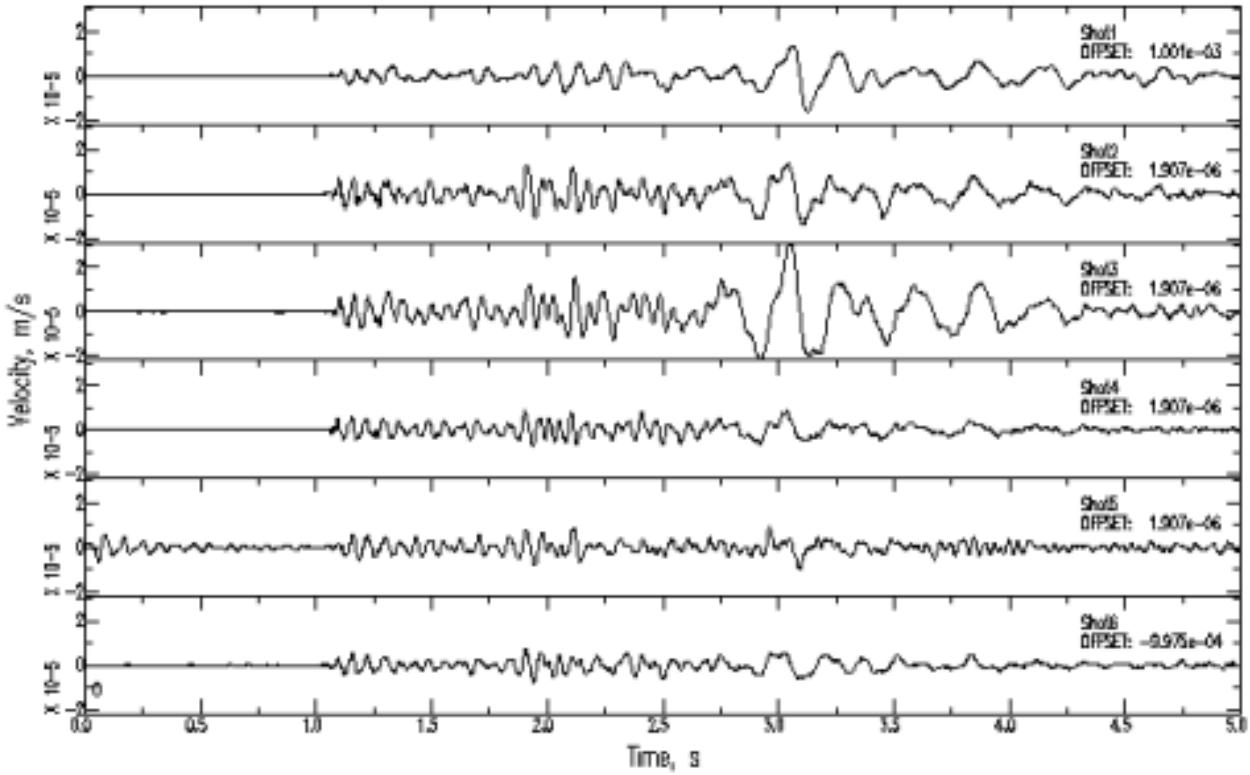

Figure 4. Shot 1 to Shot 6 radial components at R03 (~6 km).

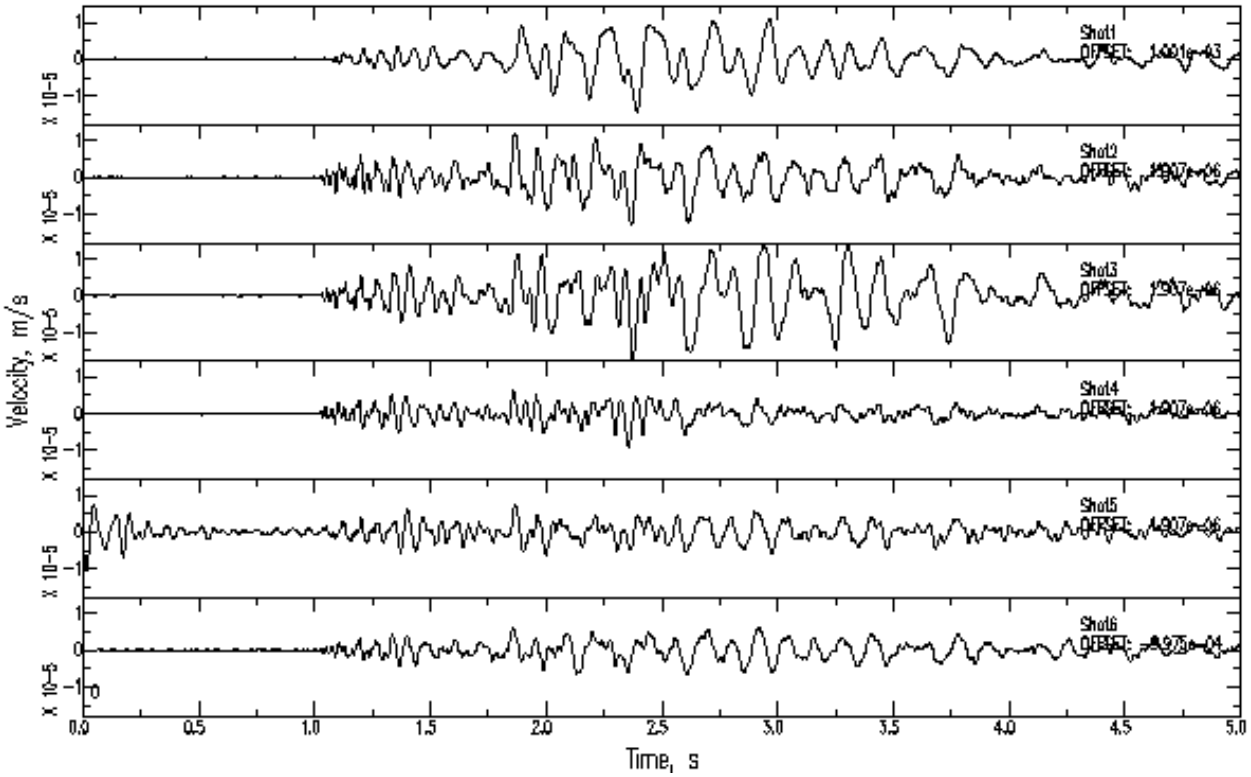

Figure 5. Shot 1 to Shot 6 transverse components at R03 (~6 km).

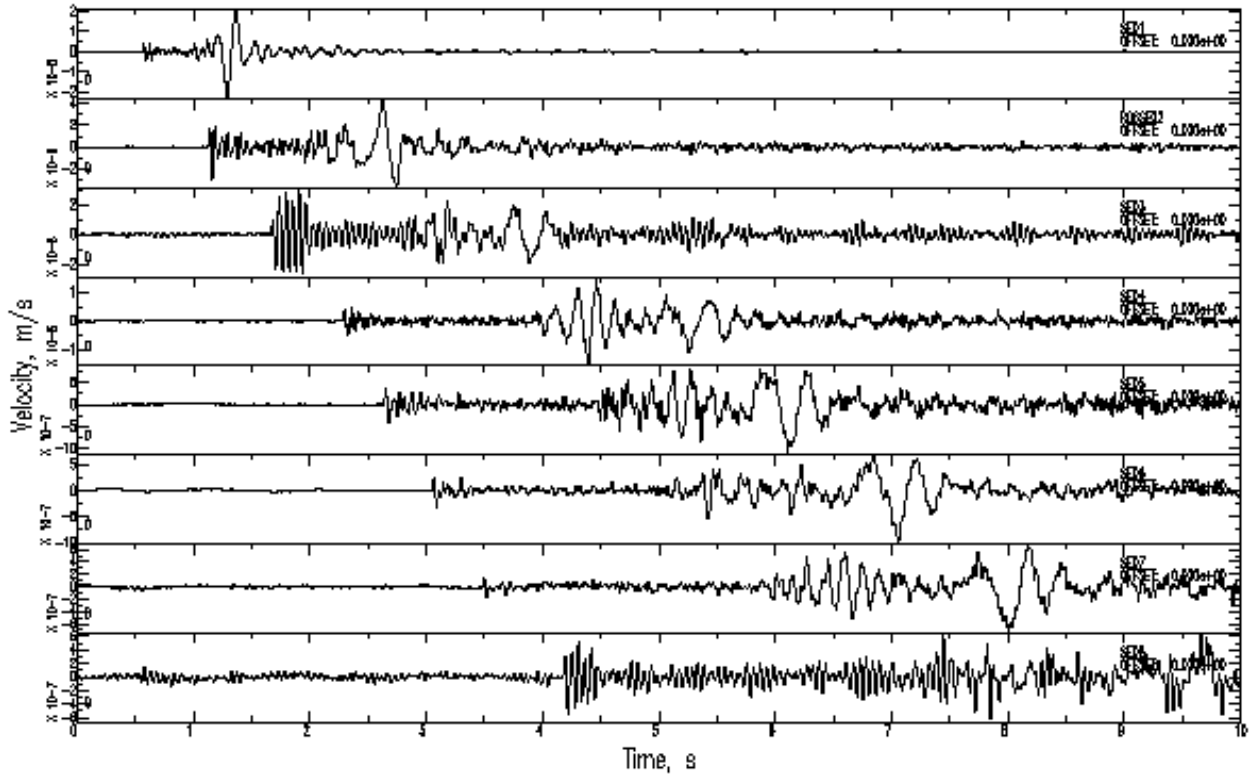

Figure 6. Shot 2 vertical components along the SE array (3-24 km).

5. ACKNOWLEDGMENTS

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