Seismic Calibration Shots Conducted in 2009 in the Imperial Valley, Southern California, for the Salton Seismic Imaging Project (SSIP)

By Janice Murphy, Mark Goldman, Gary Fuis, Michael Rymer, Robert Sickler, Summer Miller, Lesley Butcher, Jason Ricketts, Coyn Criley, Joann Stock, John Hole, and Greg Chavez

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Seismic Calibration Shots Conducted in 2009 in the Imperial Valley, Southern California, for the Salton Seismic Imaging Project (SSIP)

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Abstract

The Salton Seismic Imaging Project (SSIP) is a large-scale collaborative project with the goal of developing a detailed 3-D structural image of the Salton Trough (including both the Coachella and Imperial Valleys). The image will be used for earthquake hazard analysis, geothermal studies, and studies of plate-boundary transition from an ocean-ocean to a continent-continent plate-boundary.

As part of SSIP, a series of calibration shots were detonated in June 2009 in the southern Imperial Valley for four specific reasons: (1) to measure peak particle velocity and acceleration at various distances from the shots, (2) to calibrate the propagation of energy through sediments of the Imperial Valley, (3) to test the effects of seismic energy on buried clay drainage pipes, which are abundant throughout the irrigated parts of the Salton Trough, and (4) to test the ODEX drilling technique, which uses a downhole casing hammer for a tight casing fit.

Currently, we are using information obtained from the calibration shots to plan the data collection phase of the SSIP project. We have validated the use of ground-motion tables developed with Los Angeles Region Seismic Experiment (LARSE) data for use in the Imperial Valley and we have demonstrated that seismic energy from shots will not damage the drainage pipes used throughout the Salton Trough for irrigation.

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Introduction

Rupture of the southern section of the San Andreas Fault, from the Coachella Valley to the Mojave Desert, is believed to be the greatest natural hazard facing California in the near future. With an estimated magnitude between 7.2 and 8.1, such an event would result in violent shaking, loss of life, and disruption of lifelines (freeways, aqueducts, power, petroleum, and communication lines) that would bring much of southern California to a standstill. As part of the Nation's efforts to prevent a catastrophe of this magnitude, a number of projects are underway to increase our knowledge of Earth processes in the area and to mitigate the effects of such an event.

One such project is the Salton Seismic Imaging Project (SSIP), which is a collaborative venture between the United States Geological Survey (USGS), California Institute of Technology (Caltech), and Virginia Polytechnic Institute and State University (Virginia Tech). This project will generate and record seismic waves that travel through the crust and upper mantle of the Salton Trough. With these data, we will construct seismic images of the subsurface, both reflection and tomographic images. These images will contribute to the earthquake-hazard assessment in southern California by helping to constrain fault locations, sedimentary basin thickness and geometry, and sedimentary seismic velocity distributions. Data acquisition is currently scheduled for winter and spring of 2011.

The design and goals of SSIP resemble those of the Los Angeles Region Seismic Experiment (LARSE) of the 1990's (Murphy and others, 1996; Henyey and others, 1999; Fuis and others, 2001a,b; Murphy and others, 2002; Fuis and others, 2003). LARSE focused on examining the San Andreas Fault system and associated thrust-fault systems of the Transverse Ranges. LARSE was successful in constraining the geometry of the San Andreas Fault at depth and in relating this geometry to mid-crustal, flower-structure-like decollements in the Transverse Ranges that splay upward into the network of hazardous thrust faults that caused the 1971 M 6.7 San Fernando and 1987 M 5.9 Whittier Narrows earthquakes. The project also succeeded in determining the depths and seismic-velocity distributions of several sedimentary basins, including the Los Angeles Basin, San Fernando Valley, and Antelope Valley. These results advanced our ability to understand and assess earthquake hazards in the Los Angeles region.

In order to facilitate permitting and planning for the data collection phase of SSIP, in June of 2009 we set off calibration shots and recorded the seismic data with a variety of instruments at varying distances (fig. 1). We also exposed sections of buried clay drainage pipe near the shot points to determine the effect of seismic energy on the pipes. Clay drainage pipes are used by the irrigation districts in both the Coachella and Imperial Valleys to prevent ponding and remove salts and irrigation water. This report chronicles the calibration project. We present new near-source velocity data that are used to test the regression curves that were determined for the LARSE project. These curves are used to create setback tables (Fuis and others, 2001a) to determine explosive charge size and for placement of shot points. We also found that our shots did not damage the irrigation pipes and that the ODEX drilling system did well in the clay rich soils of the Imperial Valley.

Geologic Setting

The Salton Trough is a tectonically complex basin that is affected by three geologic systems: the Colorado River depositional region, the San Andreas transform fault system, and the Gulf of California extensional province (fig. 1). Compressional tectonics associated with a major bend in the San Andreas Fault in the north end of the Salton Trough competes with extensional tectonics farther south. For more detail on the geologic setting, see appendix 1.

Prior Work

Early seismic work in the Salton Trough by Biehler and others (1964) consisted of short (10 to 30 km) seismic-refraction lines. A more extensive seismic-refraction study in 1979 (Fuis and others, 1982, 1984; Fuis and Kohler, 1984) consisted of longer (30 to 90 km) profiles, 1-km-spaced seismic receivers, and seven shot points that were fired repeatedly. In 1991, additional shot points and profiles augmented this survey, as described in Parsons and McCarthy (1996). These two later surveys chiefly addressed structures—faults and sedimentary-basin depths and shapes—of the Imperial Valley.

The SSIP will extend the prior studies geographically into the Coachella Valley and to upper-mantle depths throughout the Salton Trough. The project will also provide higher resolution tomographic and reflection images because it includes a significant increase in the number of shot points (170) and a significant decrease in seismic receiver spacing (100 to 200 m).

Goals of Calibration Shots

In June 2009, before the data collection phase of SSIP, several test shots were fired and recorded with four different types of instrumentation. The information gained from these test shots is needed to design several important aspects of the final project. First, these test shots measured peak particle velocity and acceleration at various distances from the shot points. During the LARSE project, we developed tables of particle motion versus shot size and distance that enable us to determine ground shaking from our shots at nearby buildings and engineered structures (Fuis and others, 2001a). With the calibration data, we will update the tables for expected ground motion in the Imperial Valley. Second, the shot data are used to calibrate the propagation of energy through sediments of the Imperial Valley. With these data, we can make adjustments to the SSIP plan that will allow us to maximize our imaging results. Third, the shots were used to test the effect of seismic energy on buried clay drainage pipes. Understanding this effect is essential to the permitting process because drainage pipes are present throughout the Salton Trough. Finally, we tested the ODEX drilling technique, which uses a downhole casing hammer for installation of casing during drilling and for a tight casing fit. It is necessary to find a suitable drilling technique because the lake clays of the Salton Trough are mobile and can quickly close a drilled hole.

Project Planning and Design

Permitting

The three shots points were located in a fallow field on land owned by the California Department of Public Transportation (CalTrans). All of the 6-channel receivers, the Geometrics cabled array, two Texans, and some of the 3-channel receivers were deployed in this field. All other instruments were deployed along roads in the Caltrans right-of-way. See appendix 2 for our proposal to Caltrans and the Caltrans Encroachment Permit.

Shot-Point Drilling and Shots

Three buried explosive charges (shots) were used as sources of seismic energy. The three shot points were located near the southeast corner of Highway 7 and Heber Road (table 1a, fig. 2), ~18 km southeast of El Centro, Calif. fig. 1). They were arranged linearly in an approximately north-south array, with an average spacing of 16 m (fig. 2). Each hole was drilled to a depth between 20 and 27 m and filled with an ammonium nitrate-based blasting agent, embedded boosters, and a detonating cord (fig. 3). The northernmost shot point (SP1) was drilled to a depth of 20.7 m and filled with 27 kg (60 lbs) of explosive (tables 1b and 1c). The second shot point (SP2) was drilled to a depth of 23.5 m and filled with 68 kg (150 lbs) of explosive. The third and southernmost shot point (SP3) was drilled to a depth of 27 m and filled with 123 kg (270 lbs) of explosive.

We used the ODEX drilling system, which employs an air-hammer drill and a downhole casing hammer. It was necessary to lubricate the air-hammer drill with water to control the adherence of clay to the drill stem. Drilling of the third and deepest shot hole caused an initial rise of a sand and water slurry to a depth of ~15 m in the cased hole. This slurry was washed out with water, and a water column was left in the hole to prevent further slurry rise. Each hole was plugged with bentonite pellets before and after loading the explosives (plugs were placed at the bottom of the hole and at the top of the explosive column; see fig. 3). After loading the hole, the top of each explosive column was approximately of 18 m (60 ft) below the surface. Washed gravel was shoveled on top of the upper bentonite seal to a depth of 1.5 m below the ground surface. Minutes before the shot time, a detonating cap was attached to the detonating cord in each hole. To reduce possible airwaves, the cord and cap were lowered into the borehole and covered with gravel. Detonation of all three holes ejected a mixture of water and gravel to heights of ~ 6 to 9 m (20 to 30 ft). After detonation the holes at SP1 and SP3 retained some gravel; SP2 ejected all the gravel and was open to the bottom after detonation.

Seismic Receivers

We deployed a diverse group of seismic receivers to record the shots (table 2; fig. 2). These instruments included six 6-channel REF TEK RT130's, seven 3-channel REF TEK RT130's, thirty-five 1-channel REF TEK RT125's ("Texans"), and a 60-channel Geometrics StrataView cabled array. The 6-channel instruments recorded velocity from an external 3-component 2-Hz Mark Products L22 velocity sensor (tables 3a and 3b) and recorded acceleration from an internal 3-component 1500-Hz Colibrys SF 1500 accelerometer (FBA; force-feedback)(J. Evans, Oral commun., 2010). The accelerometer has a sensitivity of 1.2 V/g (differential), and the response is essentially flat with 1 pole and no zeros (F. Klein, Oral commun., 2010). The 3-channel instruments recorded velocity from an external 3-component 4.5-Hz Mark Products L28 velocity sensor (tables 3a and 3b). The Texans recorded velocity from external single-component 4.5-Hz OYO Geospace GS11 velocity sensors (tables 3a and 3b). The StrataView recorded velocity from 60 cabled vertical-component 40-Hz L40A velocity sensors.

The 6-channel instruments were deployed at distances of 3 m to 130 m southwestward from the shot points and recorded strong motion on-scale with the accelerometers. To extend the region of 3-component recording, the 3-channel instruments were deployed at distances of 0.27 km to 3.4 km farther southwestward from the shots (fig. 2). Station 106 is a collocation site for a 6-channel receiver and a 3-channel receiver. To obtain data in the transition range from the near field to the far field, 24 Texans were deployed in a north-south line extending to 40 km north of the blast site (fig. 4). To sample far-field wave propagation, eight Texans were deployed at scattered locations east, north, and west of the shot points, at distances ranging from 35 km to 90 km (fig. 5). Two of the remaining three Texans (201 and 252) were collocated with the end-point sensors (1001 and 1060) of the cabled array and within close proximity to the blast site. The cabled array was deployed in a 300-m-long line extending from the center of the blast area northwestward (fig. 2).

The REF TEK seismic receivers were placed in pits ~60 cm deep in firm sandy ground. The accelerometers are attached to the base of the 6-channel receivers. Therefore, to attain good coupling, the 6-channel receivers were bolted to a paver stone that was set in mortar and carefully leveled. For the sites nearest the shots (101, 102, and 103; see fig. 2), rebar was driven ~1 m into the sand, and the paver stones were wired to the rebar to prevent potential uncoupling during shooting of the nearby shots. Sensors at all multicomponent sites were oriented with a Brunton compass to magnetic north.

For the north-south array, the single-channel Texan receivers were deployed in shallow holes along a northward trending line at intervals of 0.5 to 1 km within the first 2 kilometers of the shot point area. At distances greater than 2 kilometers, Texans were spaced 2 km apart. The single-component geophones of the cabled array were deployed at 5-m intervals along a northwest trending line (fig. 2).

Engineered Structures

In addition to recording seismic energy from the blasts, another major goal of the calibration shots was to directly observe the effect of seismic waves on buried clay drainage pipes. These pipes are used for irrigation purposes throughout the Imperial Valley and are abundant in our study area. The drainage pipes are buried at depths of 1 to 3 m and are used to carry away water and salts from irrigated areas. To obtain permits for detonating shots in the Salton Trough, it was first necessary to demonstrate to landowners that our shots would not damage these pipes. Toward that end, we exposed a drain near the shot points with a backhoe (fig. 6). The exposed pipe was located at distances of 7 m, 13 m, and 15 m from SP1, SP2, and SP3, respectively (distances are perpendicular from the trench to each shot point).

Data Processing

Shot Times

Normally, shot times are determined from the USGS blaster's box. During our test shots, the timing equipment (USGS master clock) failed and the shots were fired manually. The 6-component receiver nearest to the shot point was used to determine the time of each shot. Shot times were calculated by subtracting the travel time between the receiver station and the shot point from the arrival time at the receiver. A near-surface velocity of 600 m/s was used to calculate the travel time. This velocity is based on results of a high-resolution seismic project in the Imperial Valley 23 km northeast of our study area (Gary Fuis, Oral commun. 2010; Michael Rymer, Oral commun., 2010; Rymer and others, 2008). Shot information is listed in table 1a.

Seismic Data

After retrieving the seismic receivers and downloading the data, the 6-component, 3-component, and Texan data were post-processed with PASSCAL programs that associated GMT time to the traces and converted the data to standard SEG-Y format (Barry and others, 1975).

Normally, a USGS master clock is used to provide timing for the Geometrics StrataView. However, because the master clock failed in the field, the StrataView was operated manually. Therefore, timing for traces of the cabled array was relative to the end-point traces (1001 and 1060) and the Geometrics data were written to SEG-Y format without absolute time (GMT). The SEG-Y data were read into the seismic processing package, ProMAX*. For each shot, the collocated Texan receiver traces (stations 201 and 252) were cross-correlated with the two cabled-array end-point traces (station 1001 to 252 and station 1060 to 201) to get absolute time for the cabled array.

All seismograms were processed in ProMAX* to remove DC bias and convert counts to volts/m/sec for the velocity traces and volts/g for the acceleration traces. Maximum peak-to-peak amplitudes (table 4) were determined from the vertical-component seismogram.

Results

Seismograms

The 6-component REF TEKs recorded seismograms from the near-source area. Acceleration and velocity plots are shown in appendix 3 (acceleration in appendix 3a, velocity in appendix 3b). Receiver gathers from the StrataView cabled array are shown in appendix 4. The transition from the near field to the far field is shown in appendix 5. These plots contain traces from the Texans and the vertical-components of the 3-component REF TEKs.

Discussion of Amplitudes

An empirical model of maximum vertical ground motion from explosive sources was developed in the late 1980s (Kohler and Fuis, 1989) and the early 1990s (Kohler and Fuis, 1992). These studies found that ground velocities are proportional to the amount of explosive and they show a strong dependence on site conditions. The models were used to create tables of shot size versus distance for a number of site conditions (setback tables). The setback tables are used to determine how much explosive can be put in a borehole and how far a shot point must be from buildings and other manmade structures. During the LARSE project, before the second LARSE transect, the model was updated with data from the first transect and a new set of setback tables were developed (Fuis, 2001a). These setback tables were used in the planning phase of LARSE II. In figure 7, we plot amplitude data from the calibration shots (shots 1 & 2) and overlay the regression curves from the LARSE model. Amplitudes from shots 1 and 2 were picked within 3 seconds of the shot time. Because of drilling complications, shot 3 failed to produce the expected energy from a 250-lb shot, and so the data are not plotted. We find the no distance-weighted regression curve fits the Imperial Valley data best at distances less than 200 meters. These data validate the use of our setback tables (Fuis, 2001a) in the Imperial and Coachella valleys.

Effects on Clay Drainage Pipes

After each shot, the exposed section of pipe closest to the shot point was examined visually (figs. 6 and 8). We found no damage to any parts of the pipe. Inspection of the exposed pipe by an engineer from the Imperial Irrigation District (IID) the following morning also found that our shots did not damage the pipe.

Clean Up

After our tests, the drillhole casing for each shot point was cut off ~1 m below the ground surface and a cap was welded to the top of the casing. Rebar and pavers were removed from the 6-component receiver holes. All holes and trenches were filled in and returned to their approximate original state. One year after the project, the area looked undisturbed (Michael Rymer, Oral commun., 2010).

During excavation of the drainage pipes, a section of pipe in the northern trench (near SP1) was damaged by the backhoe. The broken section of pipe was replaced with PVC pipe during the clean-up phase.

Conclusions

Our tests demonstrated that the planned SSIP work will not damage the irrigation pipes used throughout the Imperial and Coachella Valleys. We find that the ODEX drilling system is a useful drilling technique for boreholes drilled in clay-rich soils. Finally, we find that setback tables determined from other projects are valid in the Imperial Valley. This information is important because the tables are used to determine the size of the explosive charge and the location of shot points relative to buildings and other structures.

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We thank Caltrans (State of California) for allowing us to operate on their land and put seismic recorders in their road right-of-way. We are grateful to the staff at the IRIS-PASSCAL Instrument Center for their help with the instrumentation and software. We especially thank Caltech students Steven Skinner, Yunung Nina Lin, and Wang Yu for their help in the field. They worked tirelessly in temperatures well over 100 degrees and late into the night to the early hours of the morning.

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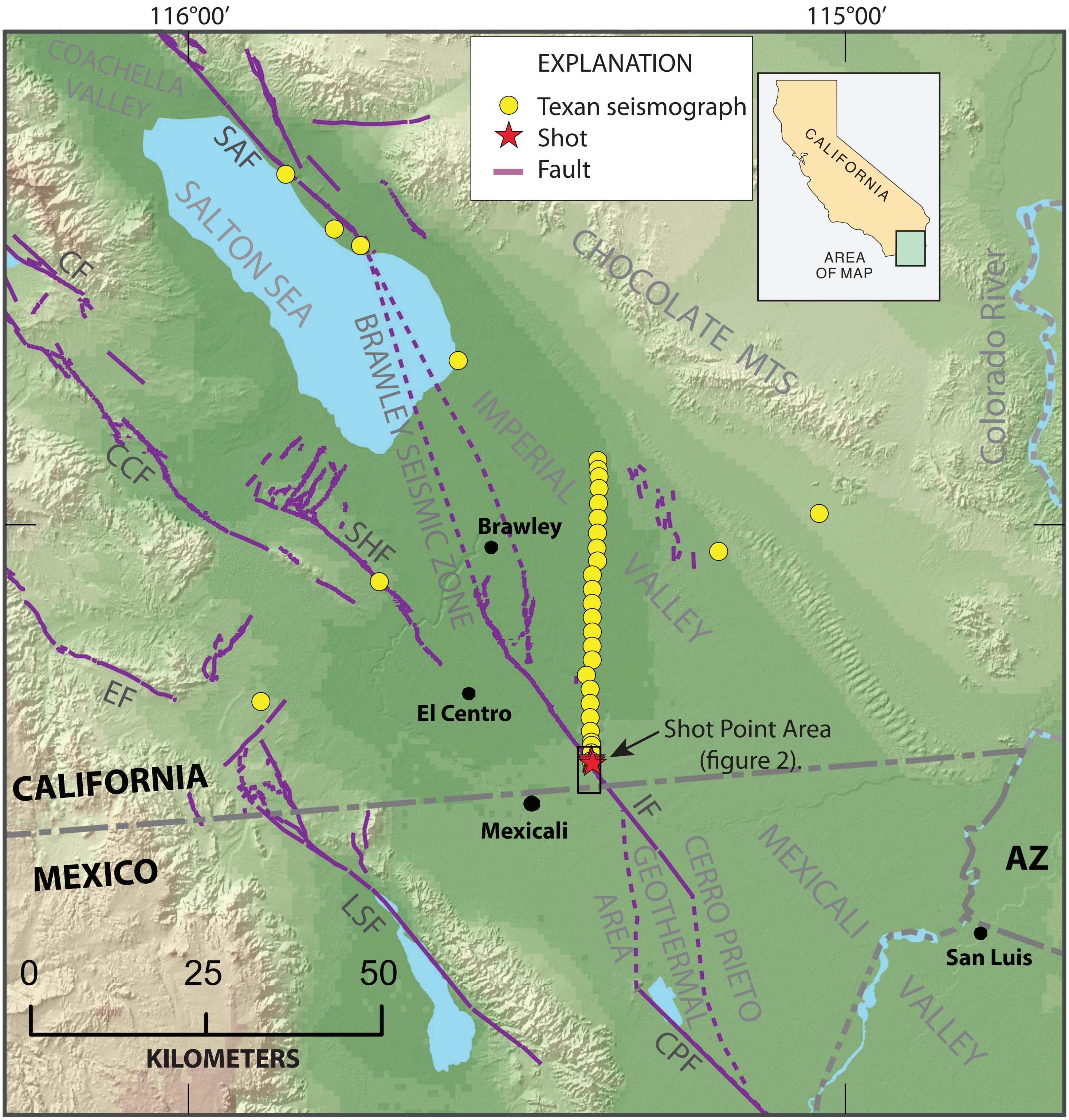


Figure 1. Map of Salton Trough. The locations of the shots, in the southern Imperial Valley, are shown with red stars. Locations of the Texan receivers are shown with yellow circles. The box outlines the shot point area map shown in figure 2. CPF, Cerro Prieto Fault; CF, Clark Fault; CCF, Coyote Creek Fault; EF, Elsinore Fault; IF, Imperial Fault; LSF, Laguna Salada Fault; SAF, San Andreas Fault; SHF, Supersition Hills Fault.

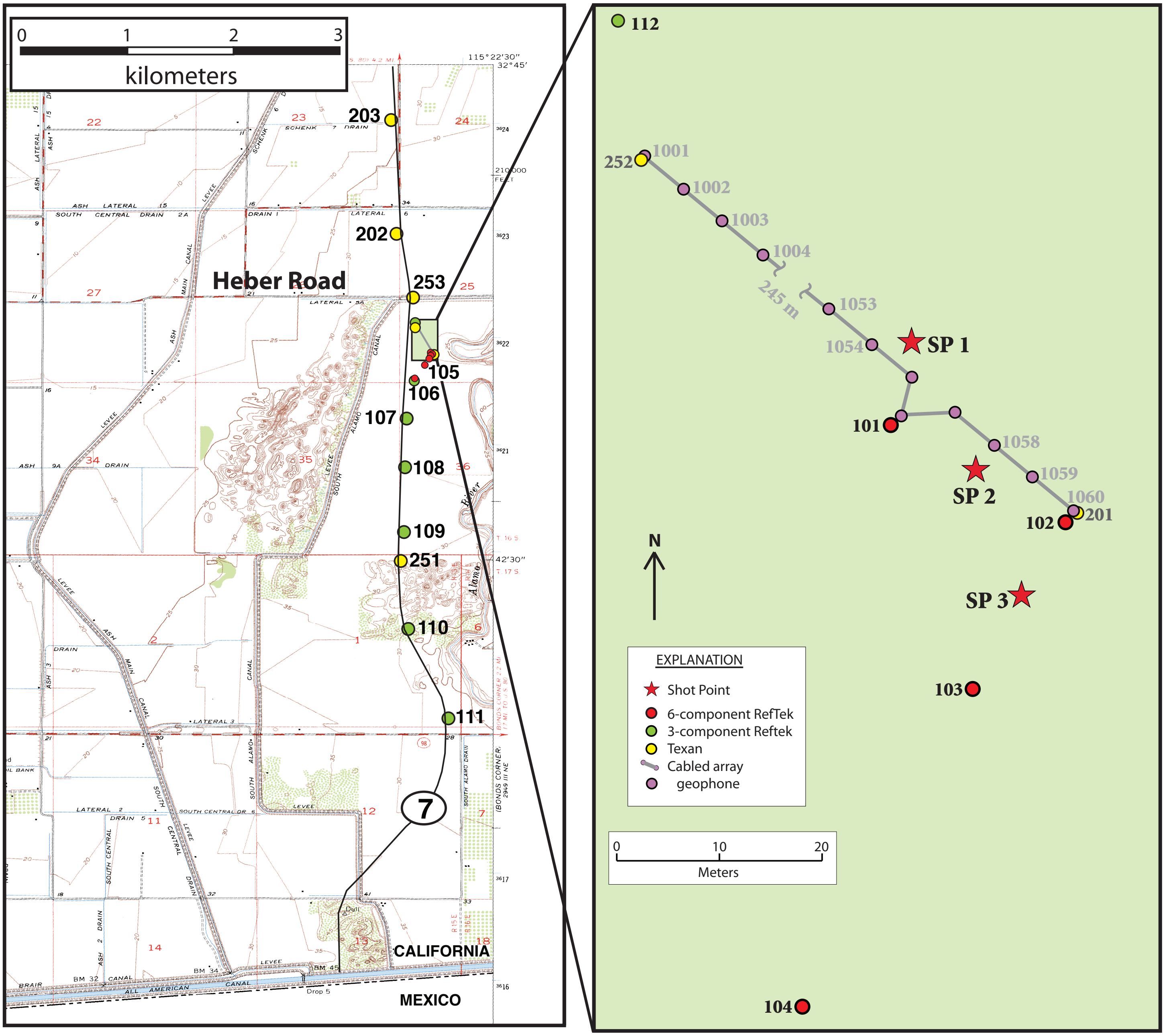


Figure 2. Map of Imperial Valley in the vicinity of the shot points. The Immediate shot point area is shown in the diagram on the right. Shot points and receivers are shown as described in explanation.

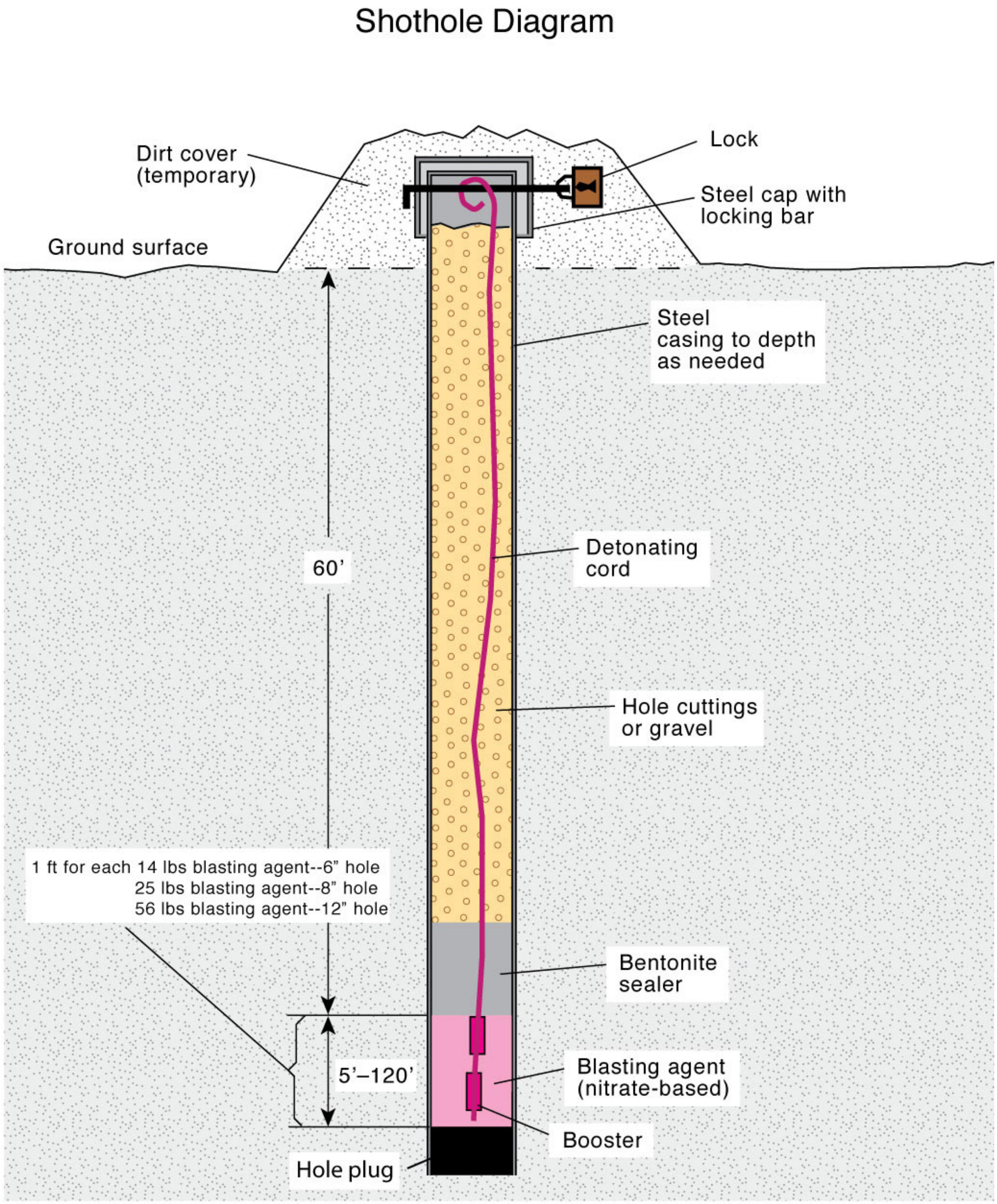


Figure 3. Diagram of loaded shothole.

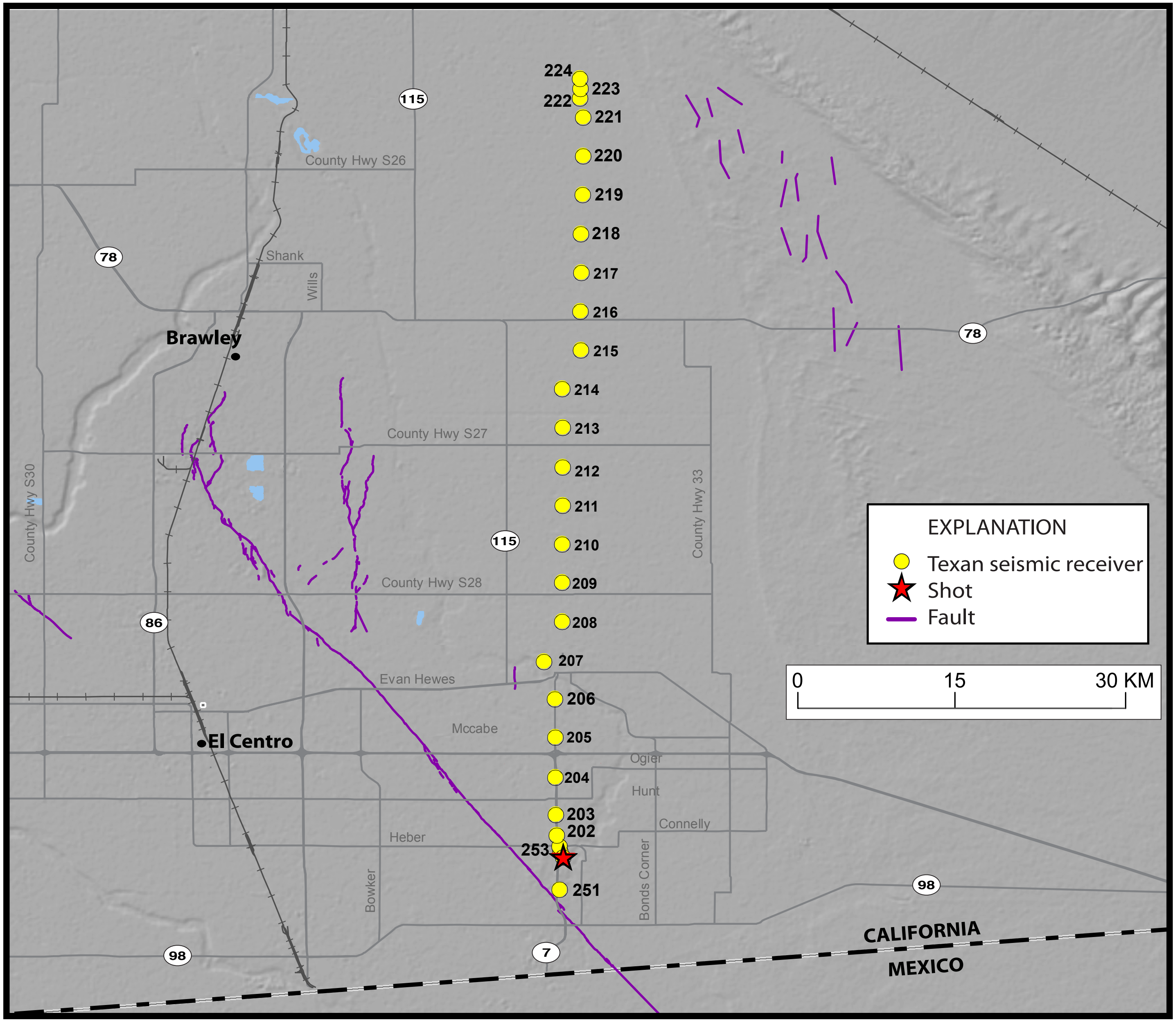


Figure 4. Map showing the north-south profile. Shot points and Texan seismic receivers are described in expanation.

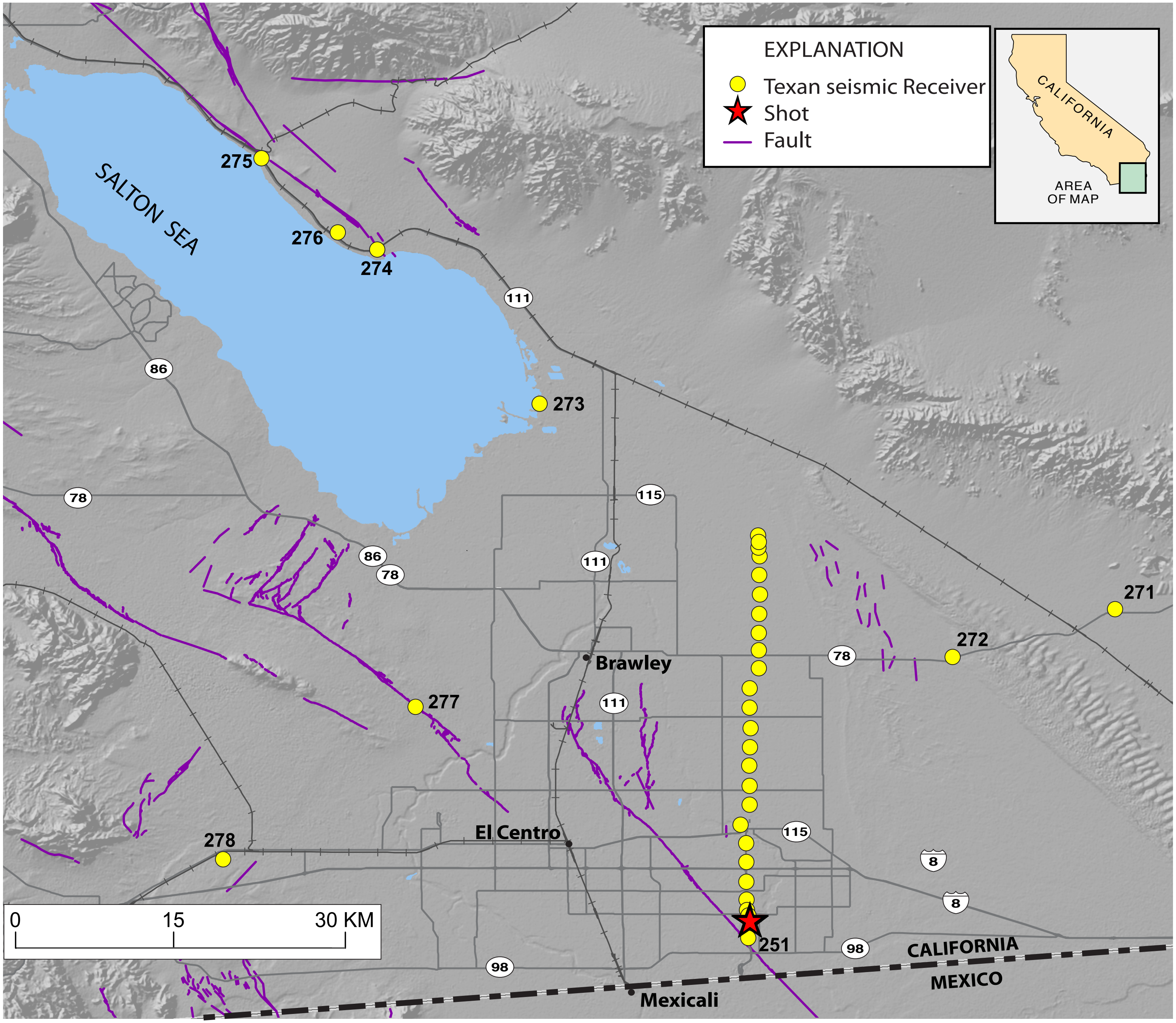


Figure 5. Map showing the far-field scatter array.

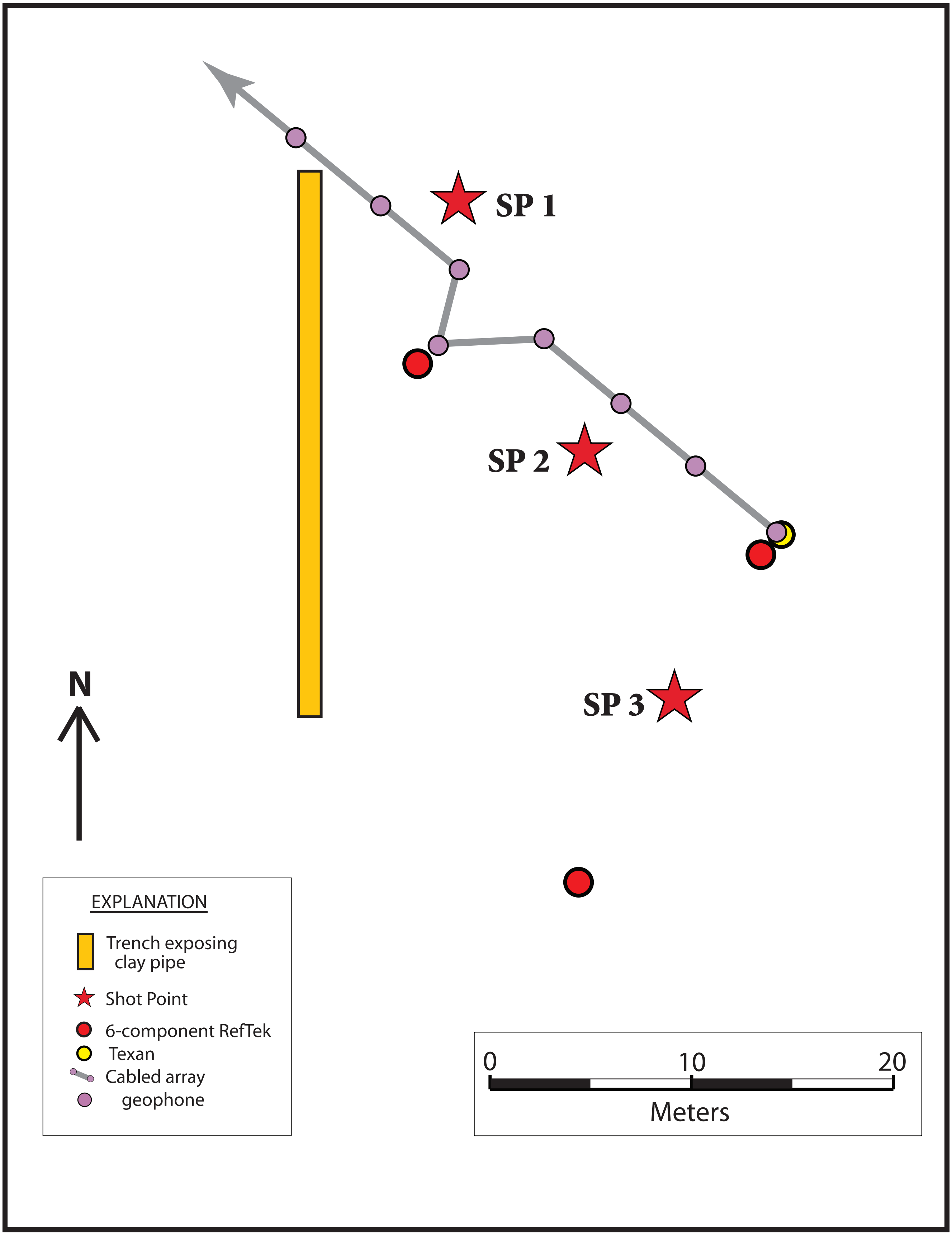
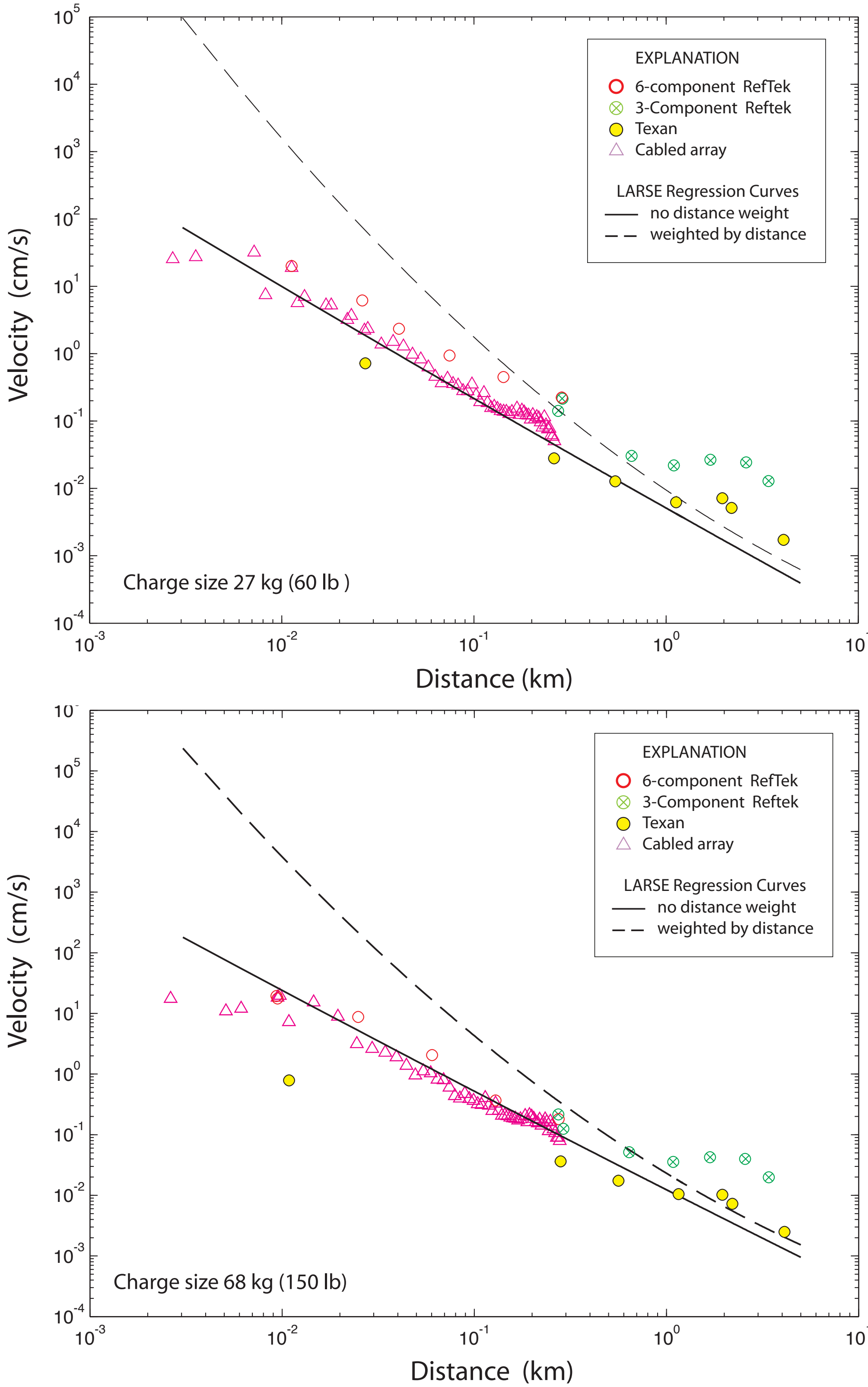


Figure 6. Map of the shot point area with the location of the trench where clay drainage pipes were exposed (orange bar). Shot points and receivers are shown as described in explanation.

A



B

Figure 7. Seismic amplitudes of vertical ground velocity versus distance for seismic receivers within 5 km of shot points. Curves are determined from the LARSE data as described in the explanation. A, shot 1, charge size 27 kg (60 lb); and B, shot 2, charge size 68 kg (150 lb).

Figure 8. Photographs of the partially exposed clay drainage pipe located west of shot point 2. Left, pipe before shot; right, pipe after shot. Dark spots in right photograph are water stains from spray while the shot geysered. Pipe in photos is approximately 75 cm long (3.5 ft). The diameter of the pipe is 13.5 cm (5.5 in).

Appendixes

Appendix 1. Details of Geologic Setting

The Salton Trough is a tectonically complex basin that is affected by three geologic systems: the Colorado River depositional region, the San Andreas transform fault system, and the Gulf of California extensional province. Compressional tectonics associated with a major bend in the San Andreas Fault at the north end of the Salton Trough competes with extensional tectonics farther south (see for example, Dair and Cooke, 2009).

Initial dextral displacement and extension in the Gulf of California began as early as 12 Ma (Stock and Hodges, 1989; Weldon and others, 1993; Lee and others, 1996; Helenes and Carreño, 1999; Oskin and others, 2001) and subsequent trans-tensional faulting opened the Gulf of California and moved Baja California north relative to the stable North American Plate. The deep basins of the southern Gulf are underlain by oceanic lithosphere due to continued extension (Nava-Sanchez and others, 2001), whereas transitional crust, consisting of Colorado River sediments and intrusive magmatic rock, is thought to underlie the Salton Trough (Fuis and others, 1984).

The opening of the Gulf of California created a marine incursion on the North American continent in the late Neogene, and marine sedimentary rocks can be found at various outcrops throughout the Salton Trough today. The Colorado River's prograding delta has created a divide between the Salton Trough and the Gulf of California and has filled the Salton Trough with Pliocene and Pleistocene fluvial and lacustrine deposits (Merriam and Bandy, 1965; Muffler and Doe, 1968; Van de Camp, 1973; Winker, 1987).

Sedimentary units derived from different sources are present in the Imperial Valley, which forms part of the Salton Trough and lies south of the Salton Sea, east of the Peninsular Ranges, and north of the Mexican border (fig. 1). Late Cenozoic sedimentary deposits within the Imperial Valley originated in continental lacustrine and marine environments from nearby and distant sources (Sharp, 1982). Mountainous areas surrounding the valley contribute a large proportion of coarser grained detritus along the flanks of the Salton Trough. Sediment within the central part of the Trough derives mostly from the Colorado River (Merriam and Bandy, 1965; Muffler and Doe, 1968).

Scientific drilling within the Imperial Valley reveals that the thick sedimentary cover increases in metamorphic grade with depth (Elders and Sass, 1988). Seismic velocities of "basement" in the Imperial Valley are low (5.6-5.8 km/s), in contrast to basement velocities outside of the Imperial Valley (5.9-6.1 km/s), and there is no velocity discontinuity between this "basement" and the sedimentary rocks above. Fuis and others (1984) therefore interpret the valley "basement" to be greenschist-facies-metamorphosed Colorado River sedimentary rocks. Below 10- to 16-km depth, this interpreted metamorphic sedimentary basement is underlain by a mid-crustal subbasement composed of mafic intrusions that resembles oceanic crust. This subbasement is largely confined to the central axis of the Valley (Fuis and others, 1984; Parsons and McCarthy, 1996). The 1979 seismic refraction survey of the Imperial Valley by Fuis and others (1982, 1984) suggests that the total thickness of both unmetamorphosed and metamorphosed sedimentary rocks ranges from 10 km at the northern end of the Imperial Valley to 16 km at the Mexican border.

Two series of northwest-striking dextral faults associated with the San Andreas and related fault zones also characterize the Imperial Valley. Along the western flank, the Elsinore

Fault zone and the Superstition Hills and Superstition Mountain segments of the San Jacinto Fault zone originate in the Salton Trough and continue northwest to, or nearly to, the Transverse Ranges of southern California. The southernmost segment of the San Andreas Fault originates along the eastern shore of the Salton Sea in the northeast margin of the Valley. Additionally, the Imperial Fault lies along the central axis of the Valley. These faults make up a diffuse plate boundary in southern California (Lomnitz and others,1970; Elders and others,1972) that is highly active seismically (Lin and others, 2007).

Extensional tectonics occurring in the stepover regions between northwest-striking dextral faults in the Imperial Valley constitute the northernmost rifting associated with the Gulf of California extensional province. For example, the right steps between the San Andreas and Imperial Faults and between the Imperial and Cerro Prieto Faults are occupied by geothermal systems (including volcanoes) and local depressions (see, for example, Fuis and Kohler, 1984). One important puzzle is that these stepover regions are characterized chiefly by strike-slip earthquake focal mechanisms, which do not produce subsidence. For example, the Brawley Seismic Zone (BSZ), in the stepover region between the San Andreas and Imperial Faults, consists of a "ladder"-shaped pattern of strike-slip faults (Johnson and Hadley, 1976; Magistrale, 2002; Lin and others, 2007). Just west of this zone, however, normal faulting has been imaged using marine seismic-reflection techniques (Brothers and others, 2009). Most normal faulting may be aseismic.

The Salton Trough has and will continue to produce devastating earthquakes, yet the complex tectonic structure is not known well enough, particularly in the Coachella Valley, to accurately assess earthquake hazards. SSIP will improve our knowledge of tectonics, including subsurface shapes and interconnections of faults, sedimentary basin thicknesses and shapes, and seismic velocities in the sedimentary basins, and therefore help us understand the potential effects of a large earthquake.

Appendix 2a. USGS Proposal to Caltrans

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
EARTHQUAKE HAZARDS TEAM

June 3, 2009

Bill Owen
Geophysics and Geology Branch
California Department of Transportation
Sacramento, CA
916.227.0227
bill.owen@dot.ca.gov

Dear Bill:

Thanks for your input to our original proposal to detonate 3 buried explosions within the footprint of the Brawley Bypass Project, in southern California. I hope this revised proposal addresses your concerns adequately.

The U.S. Geological Survey (USGS) Earthquake Hazards team is planning a major seismic-imaging survey of the Salton Trough (Coachella and Imperial Valleys) in the Winter/Spring of 2010. I have attached an "Info Sheet" describing the goals of this large project. This survey would utilize buried shots as sources of vibrations to produce images of the subsurface.

To initiate the permitting process for buried explosions in the Imperial Valley, which is underlain almost everywhere with buried clay and plastic drain tiles, we propose to detonate 3 test shots within short distances (50-100) ft of these tiles. The Caltrans' Brawley Bypass Project would present a unique opportunity to detonate test shots near some of the abandoned, or soon to be abandoned, drain tiles that occur within the footprint of this project. After consulting with the Bypass Project engineers, we propose to conduct our test shots in a former irrigated field southwest of the junction of Shank and Groshen roads (~630 ft south of Shank Rd and ~970 ft west of Groshen Rd).

The objectives of this project are the following:
1) To observe how the buried drain tiles fare during nearby shots of varying size. We plan to expose a length of these pipes and examine them before and after each shot. Proposed shotpoint sizes are 60 lbs, 150 lbs, and 270 lbs. We would also invite engineers from the Imperial Irrigation District to examine these pipes.
2) To test drilling techniques in the sediments of the Imperial Valley. We plan to use a downhole casing hammer (Odex system) in as many locations as feasible during the main survey in 2010, in order to obtain tight fits of casing to drill hole and to prevent borehole collapse. Thus, we propose to test this drilling technique for the test shots, and would switch to standard rotary drilling if unsuccessful.
3) To calibrate our "setback" curves for the Imperial Valley, which we use to ensure that we do not exceed thresholds of peak particle velocities for various structures and for

human complaints. (Our current curves are in the attached Preliminary Environmental Assessment. More detail on our drilling, loading, and shooting can be found at http://geopubs.wr.usgs.gov/open-file/of01-408/)
4) To examine logistics required for drilling, loading, instrument deployment, shooting, and cleanup in the Imperial Valley.

We propose to begin drilling during the week of June 15, and anticipate no more than 2-3 days of drilling. The footprint of the drilling would be approximately 50 x 50 ft. The proposed holes would be 70, 80, and 90 ft in depth and would be arranged in a triangle or line about 40 ft. apart. They would be cased to the bottom with 6-inch steel casing, plugged with bentonite, and pumped dry using an air compressor (the water would be disposed of by evaporation in fine spray).

The explosives would arrive in our own (placarded) rental truck early in the week of June 22 from Alpha Explosives, in Mojave, CA. We would load sensitized blasting agent (Titan 100 SD, a product of Alpha Explosives) into each of the drill holes. The blasting agent would be packaged in 5 x 30-inch plastic "sausages" or "chubs" (30 lbs each) and would be strung (taped) together in 3 strings (for the 3 holes) with single strands of detonating cord that are inserted into or through boosters arranged along each string. We would use a non-ferrous, non-sparking tool for cutting the detonating cord. All explosive would be loaded below 60 ft depth beneath the ground surface. Above the explosive, we would load bentonite followed by gravel, filled to the top of the drillhole. We would lock steel caps on the tops of the loaded drill holes and would cover each with a pile of dirt, as shown in the attached Info Sheet and the Preliminary Environmental Assessment, in order to reduce visibility of the shotholes. No explosives would be stored onsite except during the loading period.

The Blasting Officer will be Coyn Criley. Blasting assistants may include Robert Sickler, Michael Rymer, Janice Murphy, Rufus Catchings, and myself. All of these personnel are USGS employees who have had regular explosives training courses and who have had years to decades of experience in handling explosives. Coyn Criley has had 10.5 years experience as a supervisory blaster.

Personal Protective Equipment would include hardhats, safety glasses, earplugs, and appropriate clothing.

For emergencies, we would retain onsite at least one appropriate fire extinguisher (in our truck) and a first-aid kit.

Licenses are not required for USGS explosives handlers, as stated in Cal/OSHA Explosives Orders Title 8, Group 18, Article 113, Part 5236, Item b: 5A, 5B, and 5C, which states that specified standards "shall not apply to operations governed by the provisions of Group 18 under contract with federal government agencies requiring compliance with DOD Contractors Safety Manual." (The Manual can be found at http://www.ddesb.pentagon.mil/2008-03-13%20-%20DoD%204145.26-M.pdf). In actual practice, we follow the more detailed Cal/OSHA regulations (Title 8) and, in particular, the explosives training manual put out by Alpha Explosives. Our explosives handlers take explosives training courses every couple of years or so. Further requirements (in 5B and 5C, above) for DOD surveillance and inspections are met in that we commonly perform explosives handling on military bases.

We would obtain all necessary permits from the Imperial Irrigation District, with whom we are cooperating on this project, and any other local agencies with concerns. We would notify the sheriff and local police and fire departments of our activity. We would activate Underground Services Alert prior to our drilling.

While loading the drillholes, we would deploy approximately 6 seismographs capable of recording on-scale strong ground motion within a 1-km radius of the test holes, and 5-10 other seismographs at greater distances. We may deploy an additional 45 seismographs ("Texans"—see Info Sheet) along one or more lines extending to ranges of as much as 10-20 km from the shots to test signal propagation, if these instruments are available. (Their availability is uncertain at the moment.)

We plan to detonate the shots at night, when wind and cultural noise is at its lowest level near our seismographs. (Ground-noise conditions in the Imperial Valley during the daytime are too high for us to see our signals at distances of 10-20 km, our most distant proposed seismograph sites.)

Our standard shooting procedure, which follows Cal/OSHA Explosive Orders, Title 8, Group 18, Article 116, Part 5291, includes the following

1) Check the weather to ensure that no thunderstorms are approaching or within 25 miles (see Cal/OSHA Explosive Orders, Title 8, Group 18, Article 116, Part 5278). Storms within 50 miles would be monitored.
2) Limit access to the loaded shotholes about 1 hour prior to shot time with persons standing guard at the entrances to the field in which the shots would be detonated.
3) Turn off all radios and cell phones.
4) Reel out ~500 ft of shooting wire, which is shunted at our shooting box. (No powerlines are close enough to the testing site to be of concern.)
5) Test for stray currents, following Cal/OSHA Explosive Orders, Title 8, Group 18, Article 116, Part 5299.
6) Five minutes prior to shot time, attach the electrical blasting cap to the detonation cord and cover cap and cord with sandbags. Attach cap wire to shooting wire, insulating the connection from the ground.
7) Test the cap and shooting wire for continuity.
8) Check the area for presence of persons and use the signaling system recommended in Cal/OSHA Explosive Orders, Title 8, Group 18, Article 116, Part 5291.
9) Fire the shots using our specially designed shooting boxes, which receive Universal Greenwich Mean Time via a GPS receiver. When the shooting button is depressed, the box fires the shot on the upcoming minute mark. (We need to shoot on absolute time in order to calculate traveltimes of signals from our shotpoints to our seismographs.)
10) For a period of 5 minutes after the shot, no personnel would be allowed at the blast site until it is inspected and cleared by the Blast Officer.

11) A misfire would be handled according to Cal/OSHA Explosive Orders, Title 8, Group 18, Article 116, Part 5293.

We would repeat this procedure for all three shotholes.

Our cleanup procedure would include one or more of the following:
1) We would expose the casing 2 ft below ground surface, cut it off with a welding torch, and cap the hole.
2) Prior to the shot, we would remove a "stub" of casing a few feet long, that is not welded to the string of casing below it. This eliminates the need for excavation required in 1).
3) In all cases, we would return the site to as near its original condition as possible. In ~90% of our shots, there is no disturbance of the surface. In the other ~10%, the casing may be pushed up (1-10 ft) and/or there may be a small slump crater in the immediate vicinity of the shothole. We would fill in any such disturbances with off-site material.

Our Preliminary Environmental Assessment has additional details, including FAQ's.

To expose the drain tiles near our test holes for observation purposes, we propose to dig one or more trenches near our test shotholes, using a combination of backhoe and hand shoveling. We would use proper shoring of trenches more than 5 ft in depth (Cal OSHA Construction Safety Orders, Section 1541.1). We would rope off the trenching area. We would examine and photograph the drain tiles after each test shot. Finally, we would restore the trenched area to as near its original condition as possible.

We appreciate your taking time from your schedule to consider this proposal. We have always enjoyed and benefited from working with Caltrans.

Yours truly,

Gary Fuis, Geophysicist
U.S. Geological Survey
345 Middlefield Rd.
Menlo Park, CA 94025
Ph. 650-329-4758
Fax 650-329-5163
fuis@usgs.gov

Appendix 2b. CalTrans Encroachment Permit

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

ENCROACHMENT PERMIT

TR-0120

Permit No.	0409-NSV0340
Dist/Co/Rte/PM	All Districts-VAR-VAR-VAR VAR
Date	March 11, 2009
Fee Paid $	Deposit $
Performance Bond Amount (1)	Payment Bond Amount (2)
Bond Company	
Bond Number (1)	Bond Number (2)

In compliance with (*Check one*):

☒ Your application of March 10, 2009

☐ Utility Notice No. ________ of ________

☐ Agreement No. ________ of ________

☐ R/W Contract No. ________ of ________

TO: United States Geological Survey
345 Middlefield Road
Menlo Park, CA 94075

Attn: W. Karl Gross
Phone: (650) 329-4133

, **PERMITTEE**

and subject to the following, **PERMISSION IS HEREBY GRANTED** to:

Conduct geological, hydrological and biological investigations; and perform rock deformation surveys, and other scientific research investigations on various State Highways at various Post Mile locations with the State of California.

A minimum of one week prior to the start of work under this permit, notice shall be given to, and approval of construction details, operations, public safety, and traffic control shall be obtained from the State Representative listed on page 2 of this permit.

All permitted work requires the permittee to apply for and obtain a work authorization number prior to the start of work. See the attached "Encroachment Permit Project Work Scheduling Procedures" and the attached "Permit Project Work Scheduling Request Form". Additional time beyond the minimum seven days advanced notice required in the above paragraph may be required for obtaining approval for the traffic control.

The following attachments are also included as part of this permit (*Check applicable*):

☒ Yes	☐ No	General Provisions
☐ Yes	☒ No	Utility Maintenance Provisions
☐ Yes	☒ No	Storm Water Special Provisions
☐ Yes	☒ No	A Cal-OSHA permit required prior to beginning work: #

In addition to fee, the permittee will be billed actual costs for:

☐ Yes	☒ No	Review
☒ Yes	☐ No	Inspection
☐ Yes	---------	Field Work

(If any Caltrans effort expended)

☐ Yes ☒ No The information in the environmental documentation has been reviewed and considered prior to approval of this permit.

This permit is void unless the work is completed before March 31, 2013

This permit is to be strictly construed and no other work other than specifically mentioned is hereby authorized.
No project work shall be commenced until all other necessary permits and environmental clearances have been obtained.

BCW

DTM/P.Chan, TMC/J.Richardson,

CC Dist.1/Royal McCarthy, Dist.2/Stacy Barnes, Dist.3/Bruce Capaul, Dist.4/Massoud Movassat, Dist.5/Steve Senet, Dist.6/Benjamin Camarena, Dist.7/Zo Yu, Dist.8/Marlin Feenstra/Jesus Galvan, Dist.9/Jerry Gabriel, Dist.10/Frank Weishaar, Dist.11/John Markey, Dist.11/Mort Mohtashami

APPROVED:

BIJAN SARTIPI, District Director

BY:

for Bahman Zareeh

M.D. CONDIE, District Permit Engineer

District 1	Eureka	Royal McCarthy	(707)445-6389
District 2	Redding	Stacy Barnes	(530)225-3314
District 3	Marysville	Bruce Capaul	(530)741-4403
District 4	Oakland	Masssoud Movasat	(510)286-3152
District 5	San Luis Obispo	Steve Senet	(805)549-3152
District 6	Fresno	Benjamin Camarena	(659)445-6578
District 7	Los Angeles	Zo Yu	(213)897-8498
District 8	San Bernardino	Martin Feenstra	(909)383-4626
		Jesus Galvan	(909)383-4017
District 9	Bishop	Jerry Gabriel	(760)872-0650
District 10	Stockton	Frank Wishaar	(209)948-3819
District 11	San Diego	John Markey	(619)688-6158
District 12	Orange County	Mory Mohtadhami	(949)724-2525

When approved, traffic control performed under this permit shall be in accordance with the appropriate State Standard Plans T-10 through T-14. Where required by the plan, the use of a flashing arrow-board is MANDATORY.

Traffic control is restricted to closure of shoulder between 9 AM and 3 PM, Monday through Friday, holidays excepted. See attached Standard Plan T-10.

When survey operations are being conducted, the permittee shall furnish, place and maintain required signs, safety equipment in accordance with the latest edition of the "Manual of Traffic Controls for Construction and Maintenance Work Zones."

Permittee's personnel shall wear hard hats and lime green vests, shirts, or jackets with retro-reflective material and safety glasses and shall carry appropriate U.S. Department of Interior identification card.

The site of the work shall be enclosed by suitable barricades, signs and lights, as approved by State's representative, to warn and protect traffic effectively.

Any damage to existing facilities, landscaping or irrigation within the State's Right of Way shall be replaced in kind by the Permittee at Permittee's expense.

Any collected survey data requested by Caltrans shall be furnished to Caltrans free of charge.

Any painted markings shall be made with water-soluble paint.

Survey information and assistance maybe obtained upon request to: Survey Section, Department of Transportation, P.O. Box 23660, Oakland, CA 94623-0660.

SURVEY WORK IS PROHIBITED ON FREEWAYS.

1. **AUTHORITY:** The Department's authority to issue encroachment permits is provided under, Div. 1, Chpt. 3, Art. 1, Sect. 660 to 734 of the Streets and Highways Code.

2. **REVOCATION:** Encroachment permits are revocable on five days notice unless otherwise stated on the permit and except as provided by law for public corporations, franchise holders, and utilities. These General Provisions and the Encroachment Permit Utility Provisions are subject to modification or abrogation at any time. Permittees' joint use agreements, franchise rights, reserved rights or any other agreements for operating purposes in State highway right of way are exceptions to this revocation.

3. **DENIAL FOR NONPAYMENT OF FEES:** Failure to pay permit fees when due can result in rejection of future applications and denial of permits.

4. **ASSIGNMENT:** No party other than the permittee or permittee's authorized agent is allowed to work under this permit.

5. **ACCEPTANCE OF PROVISIONS:** Permittee understands and agrees to accept these General Provisions and all attachments to this permit, for any work to be performed under this permit.

6. **BEGINNING OF WORK:** When traffic is not impacted (see Number 35), the permittee shall notify the Department's representative, two (2) days before the intent to start permitted work. Permittee shall notify the Department's Representative if the work is to be interrupted for a period of five (5) days or more, unless otherwise agreed upon. All work shall be performed on weekdays during regular work hours, excluding holidays, unless otherwise specified in this permit.

7. **STANDARDS OF CONSTRUCTION:** All work performed within highway right of way shall conform to recognized construction standards and current Department Standard Specifications, Department Standard Plans High and Low Risk Facility Specifications, and Utility Special Provisions. Where reference is made to "Contractor and Engineer," these are amended to be read as "Permittee and Department representative."

8. **PLAN CHANGES:** Changes to plans, specifications, and permit provisions are not allowed without prior approval from the State representative.

9. **INSPECTION AND APPROVAL:** All work is subject to monitoring and inspection. Upon completion of work, permittee shall request a final inspection for acceptance and approval by the Department. The local agency permittee shall not give final construction approval to its contractor until final acceptance and approval by the Department is obtained.

10. **PERMIT AT WORKSITE:** Permittee shall keep the permit package or a copy thereof, at the work site and show it upon request to any Department representative or law enforcement officer. If the permit package is not kept and made available at the work site, the work shall be suspended.

11. **CONFLICTING ENCROACHMENTS:** Permittee shall yield start of work to ongoing, prior authorized, work adjacent to or within the limits of the project site. When existing encroachments conflict with new work, the permittee shall bear all cost for rearrangements, (e.g., relocation, alteration, removal, etc.).

12. **PERMITS FROM OTHER AGENCIES:** This permit is invalidated if the permittee has not obtained all permits necessary and required by law, from the Public Utilities Commission of the State of California (PUC), California Occupational Safety and Health Administration (Cal-OSHA), or any other public agency having jurisdiction.

13. **PEDESTRIAN AND BICYCLIST SAFETY:** A safe minimum passageway of 4' shall be maintained through the work area at existing pedestrian or bicycle facilities. At no time shall pedestrians be diverted onto a portion of the street used for vehicular traffic. At locations where safe alternate passageways cannot be provided, appropriate signs and barricades shall be installed at the limits of construction and in advance of the limits of construction at the nearest crosswalk or intersection to detour pedestrians to facilities across the street. Attention is directed to Section 7-1.09 Public Safety of the Department Standard Specifications.

14. **PUBLIC TRAFFIC CONTROL:** As required by law, the permittee shall provide traffic control protection warning signs, lights, safety devices, etc., and take all other measures necessary for traveling public's safety. While providing traffic control, the needs and control of all road users [motorists, bicyclists and pedestrians, including persons with disabilities in accordance with the Americans with Disabilities Act of 1990 (ADA)] shall be an essential part of the work activity.

    Day and night time lane closures shall comply with the California Manual on Uniform Traffic Control Devices (Part 6, Temporary Traffic Control), Standard Plans, and Standard Specifications for traffic control systems. These General Provisions are not intended to impose upon the permittee, by third parties, any duty or standard of care, greater than or different from, as required by law.

15. **MINIMUM INTERFERENCE WITH TRAFFIC:** Permittee shall plan and conduct work so as to create the least possible inconvenience to the traveling public; traffic shall not be unreasonably delayed. On conventional highways, permittee shall place properly attired flagger(s) to stop or warn the traveling public in compliance with the California Manual on Uniform Traffic Control Devices (Chapter 6E, Flagger Control).

16. **STORAGE OF EQUIPMENT AND MATERIALS:** The storage of equipment or materials **is not** allowed within State highway right-of-way, **unless specified** within the Special Provisions of this specific encroachment permit. If Encroachment Permit Special Provisions allow for the storage of equipment or materials within the State right of way, the equipment and material storage shall comply with Standard Specifications, Standard Plans, Special Provisions, and the Highway Design Manual. The clear recovery zone widths must be followed and are the minimum desirable for the type of facility indicated below: freeways and expressways - 30', conventional highways (no curbs) - 20', conventional highways (with curbs) – 1.5'. If a fixed object cannot be eliminated, moved outside the clear recovery zone, or modified to be made yielding, it should be shielded by a guardrail or a crash cushion.

17. **CARE OF DRAINAGE:** Permittee shall provide alternate drainage for any work interfering with an existing drainage facility in compliance with the Standard Specifications, Standard Plans and/or as directed by the Department's representative.

18. **RESTORATION AND REPAIRS IN RIGHT OF WAY:** Permittee is responsible for restoration and repair of State highway right of way resulting from permitted work (State Streets and Highways Code, Sections 670 et. seq.).

19. RIGHT OF WAY CLEAN UP: Upon completion of work, permittee shall remove and dispose of all scraps, brush, timber, materials, etc. off the right of way. The aesthetics of the highway shall be as it was before work started.

20. COST OF WORK: Unless stated in the permit, or a separate written agreement, the permittee shall bear all costs incurred for work within the State right of way and waives all claims for indemnification or contribution from the State.

21. ACTUAL COST BILLING: When specified in the permit, the Department will bill the permittee actual costs at the currently set hourly rate for encroachment permits.

22. AS-BUILT PLANS: When required, permittee shall submit one (1) set of folded as-built plans within thirty (30) days after completion and approval of work in compliance with requirements listed as follows:

1. Upon completion of the work provided herein, the permittee shall send one vellum or paper set of As-Built plans, to the State representative. Mylar or paper sepia plans are not acceptable.
2. All changes in the work will be shown on the plans, as issued with the permit, including changes approved by Encroachment Permit Rider.
3. The plans are to be stamped or otherwise noted AS-BUILT by the permittee's representative who was responsible for overseeing the work. Any original plan that was approved with a State stamp, or Caltrans representative signature, shall be used for producing the As-Built plans.
4. If As-Built plans include signing or striping, the dates of signing or striping removal, relocation, or installation shall be shown on the plans when required as a condition of the permit. When the construction plans show signing and striping for staged construction on separate sheets, the sheet for each stage shall show the removal, relocation or installation dates of the appropriate staged striping and signing.
5. As-Built plans shall contain the Permit Number, County, Route, and Post Mile on each sheet.
6. Disclaimer statement of any kind that differ from the obligations and protections provided by Sections 6735 through 6735.6 of the California Business and Professions Code, shall not be included on the As-Built plans. Such statements constitute non-compliance with Encroachment Permit requirements, and may result in the Department of Transportation retaining Performance Bonds or deposits until proper plans are submitted. Failure to comply may also result in denial of future permits, or a provision requiring a public agency to supply additional bonding.

23. PERMITS FOR RECORD PURPOSES ONLY: When work in the right of way is within an area under a Joint Use Agreement (JUA) or a Consent to Common Use Agreement (CCUA), a fee exempt permit is issued to the permittee for the purpose of providing a notice and record of work. The Permittee's prior rights shall be preserved without the intention of creating new or different rights or obligations. "Notice and Record Purposes Only" shall be stamped across the face of the permit.

24. BONDING: The permittee shall file bond(s), in advance, in the amount set by the Department. Failure to maintain bond(s) in full force and effect will result in the Department stopping of all work and revoking permit(s). Bonds are not required of public corporations or privately owned utilities, unless permittee failed to comply with the provision and conditions under a prior permit. The surety company is responsible for any latent defects as provided in California Code of Civil Procedures, Section 337.15. Local agency permittee shall comply with requirements established as follows: In recognition that project construction work done on State property will not be directly funded and paid by State, for the purpose of protecting stop notice claimants and the interests of State relative to successful project completion, the local agency permittee agrees to require the construction contractor furnish both a payment and performance bond in the local agency's name with both bonds complying with the requirements set forth in Section 3-1.02 of State's current Standard Specifications before performing any project construction work. The local agency permittee shall defend, indemnify, and hold harmless the State, its officers and employees from all project construction related claims by contractors and all stop notice or mechanic's lien claimants. The local agency also agrees to remedy, in a timely manner and to State's satisfaction, any latent defects occurring as a result of the project construction work.

25. FUTURE MOVING OF INSTALLATIONS: Permittee understands and agrees to relocate a permitted installation upon notice by the Department. Unless under prior property right or agreement, the permittee shall comply with said notice at his sole expense.

26. ARCHAEOLOGICAL/HISTORICAL: If any archaeological or historical resources are revealed in the work vicinity, the permittee shall immediately stop work, notify the Department's representative, retain a qualified archaeologist who shall evaluate the site, and make recommendations to the Department representative regarding the continuance of work.

27. PREVAILING WAGES: Work performed by or under a permit may require permittee's contractors and subcontractors to pay appropriate prevailing wages as set by the Department of Industrial Relations. Inquiries or requests for interpretations relative to enforcement of prevailing wage requirements are directed to State of California Department of Industrial Relations, 525 Golden Gate Avenue, San Francisco, California 94102.

28. RESPONSIBILITY FOR DAMAGE: The State of California and all officers and employees thereof, including but not limited to the Director of Transportation and the Deputy Director, shall not be answerable or accountable in any manner for injury to or death of any person, including but not limited to the permittee, persons employed by the permittee, persons acting in behalf of the permittee, or for damage to property from any cause. The permittee shall be responsible for any liability imposed by law and for injuries to or death of any person, including but not limited to the permittee, persons employed by the permittee, persons acting in behalf of the permittee, or for damage to property arising out of work, or other activity permitted and done by the permittee under a permit, or arising out of the failure on the permittee's part to perform his obligations under any permit in respect to maintenance or any other obligations, or resulting from defects or obstructions, or from any cause whatsoever during the progress of the work, or other activity or at any subsequent time, work or other activity is being performed under the obligations provided by and contemplated by the permit.

The permittee shall indemnify and save harmless the State of California, all officers, employees, and State's contractors, thereof, including but not limited to the Director of Transportation and the Deputy Director, from all claims, suits or actions of every name, kind and description brought for or on account of injuries to or death of any person, including but not limited to the permittee, persons employed by the permittee, persons acting in behalf of the permittee and the public, or damage to property resulting from the performance of work or other activity under the permit, or arising out of the failure on the permittee's part to perform his obligations under any permit in respect to maintenance or any other obligations, or resulting from defects or obstructions, or from any cause whatsoever during the progress of the work, or other activity or at any subsequent time, work or other activity is being performed under the obligations provided by and contemplated by the permit, except as otherwise provided by statute.

The duty of the permittee to indemnify and save harmless includes the duties to defend as set forth in Section 2778 of the Civil Code. The permittee waives any and all rights to any type of expressed or implied indemnity against the State, its officers, employees, and State contractors. It is the intent of the parties that the permittee will indemnify and hold harmless the State, its officers, employees, and State's contractors, from any and all claims, suits or actions as set forth above regardless of the existence or degree of fault or negligence, whether active or passive, primary or secondary, on the part of the State, the permittee, persons employed by the permittee, or acting on behalf of the permittee.

For the purpose of this section, "State's contractors" shall include contractors and their subcontractors under contract to the State of California performing work within the limits of this permit.

29. **NO PRECEDENT ESTABLISHED:** This permit is issued with the understanding that it does not establish a precedent.

30. **FEDERAL CIVIL RIGHTS REQUIREMENTS FOR PUBLIC ACCOMMODATION:**
A. The permittee, for himself, his personal representative, successors in interest, and assigns as part of the consideration hereof, does hereby covenant and agree that:
1. No person on the grounds of race, color, or national origin shall be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination in the use of said facilities.
2. That in connection with the construction of any improvements on said lands and the furnishings of services thereon, no discrimination shall be practiced in the selection and retention of first-tier subcontractors in the selection of second-tier subcontractors.
3. That such discrimination shall not be practiced against the public in their access to and use of the facilities and services provided for public accommodations (such as eating, sleeping, rest, recreation), and operation on, over, or under the space of the right of way.
4. That the permittee shall use the premises in compliance with all other requirements imposed pursuant to Title 15, Code of Federal Regulations, Commerce and Foreign Trade, Subtitle A. Office of the Secretary of Commerce, Part 8 (15 C.F.R. Part 8) and as said Regulations may be amended.
5. That in the event of breach of any of the above nondiscrimination covenants, the State shall have the right to terminate the permit and to re-enter and repossess said land and the land and the facilities thereon, and hold the same as if said permit had never been made or issued.

31. **MAINTENANCE OF HIGHWAYS:** The permittee agrees, by acceptance of a permit, to properly maintain any encroachment. This assurance requires the permittee to provide inspection and repair any damage, at permittee's expense, to State facilities resulting from the encroachment.

32. **SPECIAL EVENTS:** In accordance with subdivision (a) of Streets and Highways Code Section 682.5, the Department of Transportation shall not be responsible for the conduct or operation of the permitted activity, and the applicant agrees to defend, indemnify, and hold harmless the State and the city or county against any and all claims arising out of any activity for which the permit is issued.

Permittee understands and agrees that it will comply with the obligations of Titles II and III of the Americans with Disabilities Act of 1990 in the conduct of the event, and further agrees to indemnify and save harmless the State of California, all officers and employees thereof, including but not limited to the Director of Transportation, from any claims or liability arising out of or by virtue of said Act.

33. **PRIVATE USE OF RIGHT OF WAY:** Highway right of way shall not be used for private purposes without compensation to the State. The gifting of public property use and therefore public funds is prohibited under the California Constitution, Article 16.

34. **FIELD WORK REIMBURSEMENT:** Permittee shall reimburse State for field work performed on permittee's behalf to correct or remedy hazards or damaged facilities, or clear debris not attended to by the permittee.

35. **NOTIFICATION OF DEPARTMENT AND TMC:** The permittee shall notify the Department's representative and the Transportation Management Center (TMC) at least 7 days before initiating a lane closure or conducting an activity that may cause a traffic impact. A confirmation notification should occur 3 days before closure or other potential traffic impacts. In emergency situations when the corrective work or the emergency itself may affect traffic, TMC and the Department's representative shall be notified as soon as possible.

36. **SUSPENSION OF TRAFFIC CONTROL OPERATION:** The permittee, upon notification by the Department's representative, shall immediately suspend all lane closure operations and any operation that impedes the flow of traffic. All costs associated with this suspension shall be borne by the permittee.

37. **UNDERGROUND SERVICE ALERT (USA) NOTIFICATION:** Any excavation requires compliance with the provisions of Government Code Section 4216 et. seq., including, but not limited to notice to a regional notification center, such as Underground Service Alert (USA). The permittee shall provide notification at least 48 hours before performing any excavation work within the right of way.

REGISTERED CIVIL ENGINEER

May 1, 2006

PLANS APPROVAL DATE

The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

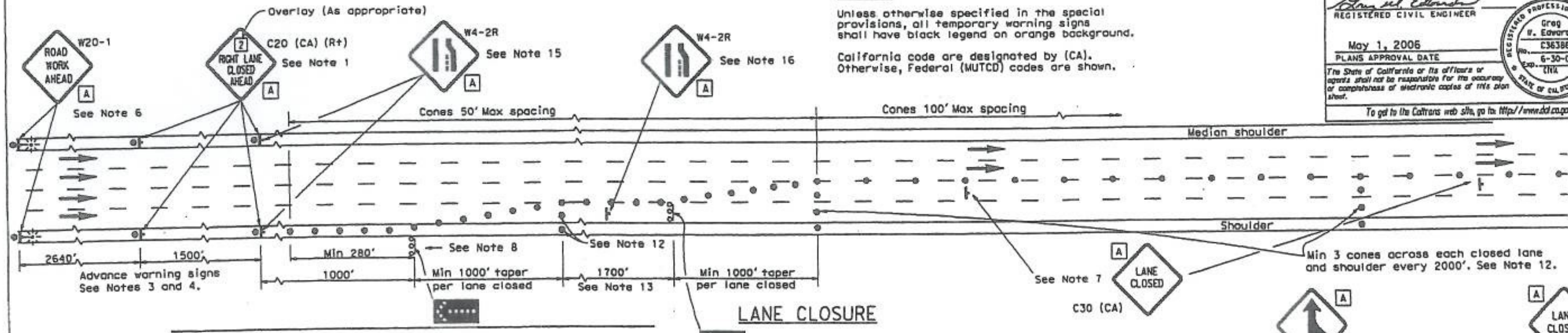
To get to the Caltrans web site, go to: http://www.dot.ca.gov

REGISTERED PROFESSIONAL ENGINEER Greg W. Edwards No. C36386 Exp. 6-30-06 CIVIL STATE OF CALIFORNIA

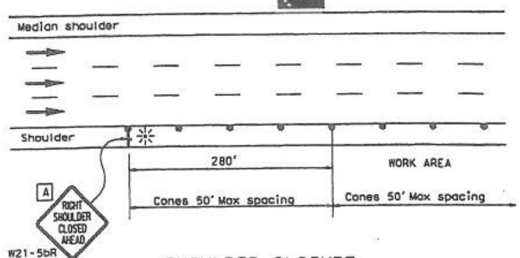
NOTES:

Unless otherwise specified in the special provisions, all temporary warning signs shall have black legend on orange background.

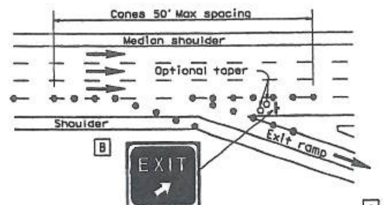
California code are designated by (CA). Otherwise, Federal (MUTCD) codes are shown.



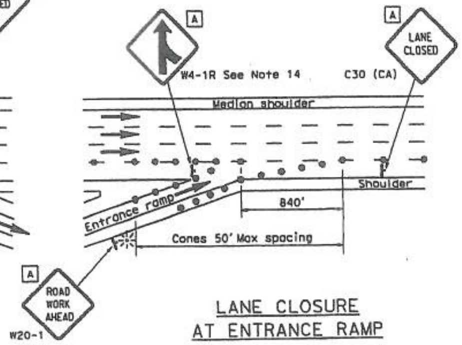
LANE CLOSURE



SHOULDER CLOSURE



LANE CLOSURE AT EXIT RAMP



LANE CLOSURE AT ENTRANCE RAMP

NOTES:

1. Median lane closures shall conform to the details for outside lane closures except that C20 (CA) (Lt) signs shall be used.
2. At least one person shall be assigned to provide full time maintenance of traffic control devices for lane closures.
3. Duplicate sign installations are not required:
   a) On opposite shoulder if at least one-half of the available lanes remain open to traffic.
   b) In the median if the width of the median shoulder is less than 8' and the outside lanes are to be closed.
4. Each advance warning sign on each side of the roadway shall be equipped with at least two flags for daytime closure. Each flag shall be at least 16" x 16" in size and shall be orange or fluorescent red-orange in color. Flashing beacons shall be placed at the locations indicated for lane closure during hours of darkness.
5. A C14 (CA) "END ROAD WORK" sign, as appropriate, shall be placed at the end of the lane closure unless the end of work area is obvious or ends within a larger project's limits.
6. If the W20-1 sign would follow within 2000' of a stationary W20-1 or C11 (CA) "ROAD WORK NEXT _______ MILES", use a C20 (CA) sign for the first advance warning sign.
7. Place a C30 (CA) sign every 2000' throughout length of lane closure.
8. One flashing arrow sign for each lane closed. The first flashing arrow sign shall be Type I. All others may be either Type I or Type II.
9. A minimum 1500' of sight distance shall be provided where possible for vehicles approaching the first flashing arrow sign. Lane closures shall not begin at top of crest vertical curve or on a horizontal curve.
10. All cones used for lane closures during the hours of darkness shall be fitted with retroreflective bands (or sleeves) as specified in the specifications.
11. Portable delineators, placed at one-half the spacing indicated for traffic cones may be used instead of cones for daytime closures only.
12. Unless otherwise specified in the special provisions, a minimum of 3 cones shall be placed transversely across each closed lane and shoulder at each location where a taper across a traffic lane ends and every 2000' as shown on the "Lane Closure" detail. Two Type II barricades may be used instead of the 3 cones. The transverse alignment of the cones or barricades on the closed shoulder may be shifted from the transverse alignment to provide access to the work.
13. Unless otherwise specified in the special provisions, the 1700' tangent shown along lane lines shall be used between the 1000' tapers required for each closed traffic lane.
14. Unless otherwise specified in the special provisions, the G84 (CA) and W4-1 signs shall be used as shown.
15. When specified in the special provisions, a W4-2 "LANE ENDS" symbol sign is to be used in place of the C20 (CA) "RIGHT LANE CLOSED AHEAD" sign.
16. The W4-2 "LANE ENDS" symbol sign shown at this location is to be used where the W4-2 sign is used as advance warning as described in Note 15.

SIGN PANEL SIZE (Min)

A	48" x 48"
B	54" x 48"

LEGEND

●	Traffic Cone
O	Traffic Cone (optional taper)
⊢	Temporary Sign
	Flashing Arrow Sign (FAS)
	FAS Support or Trailer
→	Direction of Travel
✳	Portable Flashing Beacon

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

TRAFFIC CONTROL SYSTEM FOR LANE CLOSURE ON FREEWAYS AND EXPRESSWAYS

NO SCALE

T10

2006 STANDARD PLAN T10

10-3-05

Encroachment Permit Work Scheduling Request Form

Caltrans

Submit request to schedule traffic control weekly, 7 days in advance, using this form. Submit to Permit Duty Station by FAX, **510-286-3960**, or E-mail: *Permit_Duty_Engineer@dot.ca.gov.* ***Reminder!*** - Notify Inspector listed on page 1 or 2 of your Permit. Check Permit Special Provisions for authorized **work hours**. Any deviation from the Permit must be requested in writing.
INSTRUCTIONS AND ABBREVIATIONS: See Procedures on reverse of this form (page 2).

1. Permit No.: ______________________ 2.Expiration Date: __________ 3. Request Date: __________
4. Caltrans Inspector: ______________________ 5. Requested Work Week: __________to__________
6. Route: __________ 7. County: ______________ 8. City or township:______________
9. ☐PostMiles or ☐Kilopost: From: _____ To: _____ 10. Existing Lanes (in each Dir): Dir____ Lns____/ Dir____ Lns ____
11. Describe Location (use landmark if necessary): From: ______________To: ______________
12 Name of Conventional Highway or Surface St:______________________
13. (a through k) Fill in or 'x' if applicable: (a) ☐ Divided Hwy *or* ☐ Undivided Hwy (b) ☐ Full-Closure ☐ 1 dir or ☐ both dir
(c)☐One-way Traffic Control: Only on "Undivided" Hwy (*Alternate use of same lane for both directions--hold trfc 5 –10 min w/flaggers*)
(d)☐Connector Ramp: (*State Highway #*) __________to (*State Highway #*) __________Closed ☐ *or* Lane #__________
(e)☐Off/ramp: *(Freeway to City St)* Ramp Name: ______________ Off/ramp Closed ☐ *or* Lane#:_______
(f)☐On/ramp: *(City St to Freeway)* Ramp Name: ______________ On/ramp Closed ☐ *or* Lane#:_______
(g)☐Divert Trfc or Contra Flow: Reconfigure lanes/divert trfc to Lane# ___in the ___ Direction; ___Lane(s) open ea direction.
(h)☐Intermittent Traffic Control (i) ☐Various Locations (j) ☐Long-Term (24⁺ hours continuous) ETO__________

(k) Year:			**Time**		**Dir**		* * * * * * **Restricted Lanes** * * * * * *															**Brks**		**Closure ID#**
From DATE	**To** DATE	**DAY(S)** SU-M-T-W-TH-F-SA	**24-HR CLOCK** Start (10-97)	Finish (10-98)	NB / EB	SB / WB	Full Closure See Detour	SHLDR L	SHLDR R	1	2	3	4	5	6	VL	Aux or Coll	CD or Med	TURN PCKT(S) L	TURN PCKT(S) R	Park Strip	5 to 15 Min	Roll-ing	***Caltrans*** *will complete & return*

14. Description of work/comments: ______________________________

15. Detour (*Required for full closure*): ______________________________

16. Contingency Plan: ______________________________
17. On-site during work (*circle if applicable*) CHP / PD / Other: ______________________________

18. Name:	**Permittee:**	**Contractor (if different than permittee):**
Address:		
On-site Personnel Contact Name(s) & Phone No.	**Name:**	**Name:**
	Office:	**Office:**
	Cell:	*Cell:*
	FAX:	**FAX:**

19. **"REAL-TIME" STATUS INSTRUCTIONS – PLEASE MAKE YOUR FIELD PERSONNEL AWARE & RESPONSIBLE!**
Permittee shall **STATUS** scheduled work **DAILY** via Caltrans 24-Hour Communication Center at **510-286-6359.** Status using Closure ID No(s) at the start of work, **(10-97),** and again when work is finished for the day, **(10-98).** To cancel **(10-22),** phone **510-286-6359** or fax to **510-286-6358** before the scheduled 10-97 time, but no later than 1 hour prior to the scheduled 10-98 time. Any **delay** in picking up your closure must be reported immediately to **510-286-6359** or Permit Inspector. See item 9 on reverse/page 2.

ENCROACHMENT PERMIT WORK SCHEDULING PROCEDURES

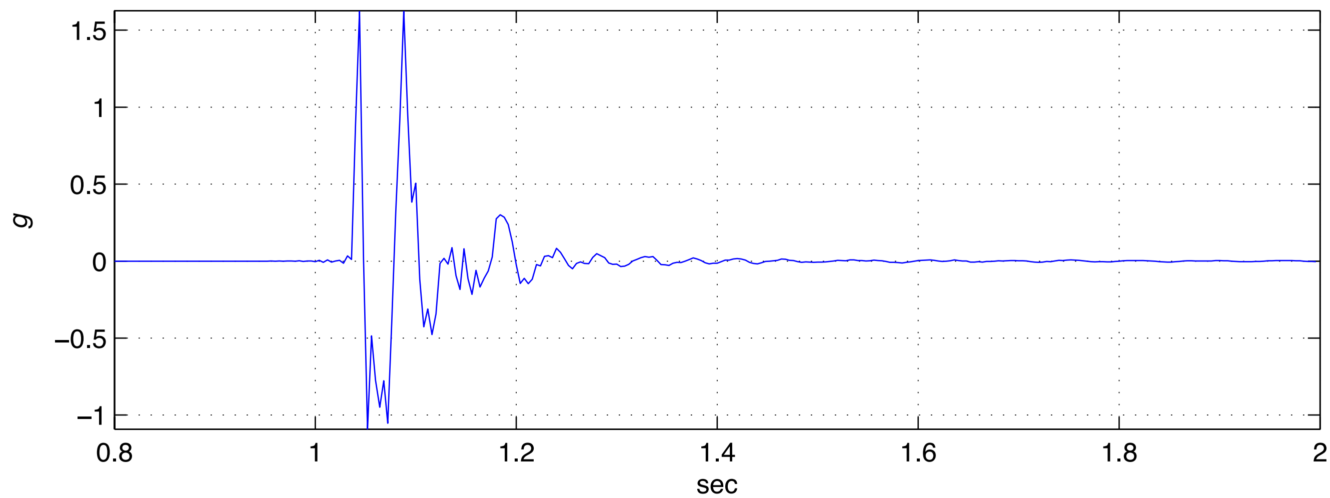
1. **INSTRUCTIONS:** **Fill in blanks or check appropriate boxes. Attach maps or diagrams, if** available. Enter **beginning day** through **ending day of work week** (M-T-W-TH-F-SA-SU). **Month/Day:** Enter month (1-12) and day (1-31) of requested week. **Start & Finish Time:** Use 24 hour clock format. **Read page 2** of your Permit Special Provisions for **hours** & days allowed. Separate lane closure #'s are required for each direction and facility. Use separate line for each. **Lanes are numbered in direction of travel from left to right,** excluding turn pockets; left being #1 or "fast lane". Check boxes under **RESTRICTED LANES** to indicate lanes or parts of highway to be closed. **"VL"(Various Lanes)** may be checked with note in Comments Section stating number of lanes to remain open at all times.
2. **ABBREVIATIONS:** **Aux**=auxiliary, **CD**=Center Divide; **Coll**=Collector; **Conn**=Connector; **Contra Flow**=Close 1 direction of traffic and divert to lane(s) in opposite direction or a turn lane. **Day of Week**=(M-T-W-TH-F-SA-SU); **Dir**=Direction (**NB**=North, **SB**=South,**WB**=West, or **EB**=East); **F/L**=fog line; **Lns**=Lanes; **L**=Left; **Med**= Median; **Off/R**=Off-Ramp; **On/R**=On-Ramp; **Park Strip**=Parking area parallel to lane; **Pckt**=Pocket; **Roll**=Rolling (for closure such as sweeping); **R**=Right; **Shldr**=Shoulder; **SR**=State Route; **V/L**=Various Lanes; **V/Loc**=Various Locations.
3. Requests for scheduling shall be submitted on this form via FAX to 510-286-3960, or, via E-Mail to *Permit_Duty_Engineer@dot.ca.gov*, or, through the designated State Representative (page 1 of permit).
4. All permitted work (**with or without traffic control**) is subject to advance scheduling on this form, seven (7)days in advance of the work week requested. Submittals and approvals shall continue on a weekly basis.
5. If work begins weekly on Sunday, the work week shall be Sunday through Saturday. If work week begins on Monday, the work week shall be Monday through Sunday.
6. Incomplete, illegible, or inaccurate requests may be returned for correction. Assistance for completing the request may be obtained from the designated State Representative.
7. Every attempt will be made to return timely requests with closure ID or work authorization numbers, to the Permittee by close of business on Thursday, prior to the scheduled work week. When deemed necessary to ensure public convenience, Caltrans may deny and/or reschedule the request.
8. All requests must include a contingency plan for restoring public traffic (i.e. reopening of a closed lane, ramp and/or shoulder) in the event of (1) CHP or the local authority requires opening due to an unforeseeable incident in the nearby vicinity, or (2) permitted experiences an equipment breakdown, shortage of or lack of production materials or any other failure which would otherwise delay restoring public convenience within the time limits specified in the permit. The contingency plan shall include availability of any proposed standby equipment and stockpiled materials that can be utilized for the immediate opening of closures when ordered by the State representative. Acceptance of the contingency plan by the Engineer shall not relieve the Contractor from the requirement of opening the restricted travel way to accommodate public traffic as specified in the lane closure hour's section of the permit provisions.
9. Caltrans will review and process the request by entering all information into the State-wide Lane-Closure System (LCS). This process generates a work authorization number*. This number will be entered on the request form and returned to Permittee as approval to proceed AND will be used to **"Real-Time Status"** on a daily basis. Permittee shall communicate with Caltrans 24-hour District Communication Center (DCC) via telephone at **510-286-6359** twice daily when working, or once daily if cancelled.
   a. When work begins (first cone down), Permittee shall contact Caltrans DCC and relay: **"(Closure ID #*) is 10-97".**
   b. When work ends (last cone removed), Permittee shall contact Caltrans DCC and relay: **"(Closure ID #*) is 10-98".**
   c. If the work is cancelled on any scheduled day, Permittee shall contact Caltrans DCC and relay; **"(Closure ID #*) is 10-22".** A "10-22" (cancellation) can be phoned at anytime before the scheduled "10-97" time, but no later than 1 hour prior to scheduled "10-98" time. You may be asked to fax confirmation of "10-22" to the **DCC FAX** at **510-286-6358.**
   d. During the work, any unexpected occurrences including delayed openings, accidents, etc., shall be communicated to Caltrans DCC @ **510-286-6359,** immediately.

   Avoid possible miscommunication when calling status. Use the **PHONETIC ALPHABET** to state your Closure ID:
   A = Adam, **B** = Boy, **C** = Charles, **D** = David, **E** = Edward, **F** = Frank, **G** = George, **H** = Henry, **I** = Ida, **J** = John, **K** = King, **L** = Lincoln, **M** = Mary, **N** = Nora, **O** = Ocean, **P** = Paul, **Q** = Queen, **R** = Robert, **S** = Sam, **T** = Tom, **U** = Union, **V** = Victor, **W** = William, **X** = X-ray, **Y** = Yellow, **Z** = Zebra. *Example:* P82CA="Paul 82 Charles Adam"
10. The intent of these procedures is to help ensure public convenience by identifying planned closures on the State Highway system, resolving potential conflicts, and disseminating all available **"REAL-TIME"** information, via the traffic media to all motorists, including but not limited to the public, CHP, local police and sheriffs' office, and emergency fire and rescue personnel.

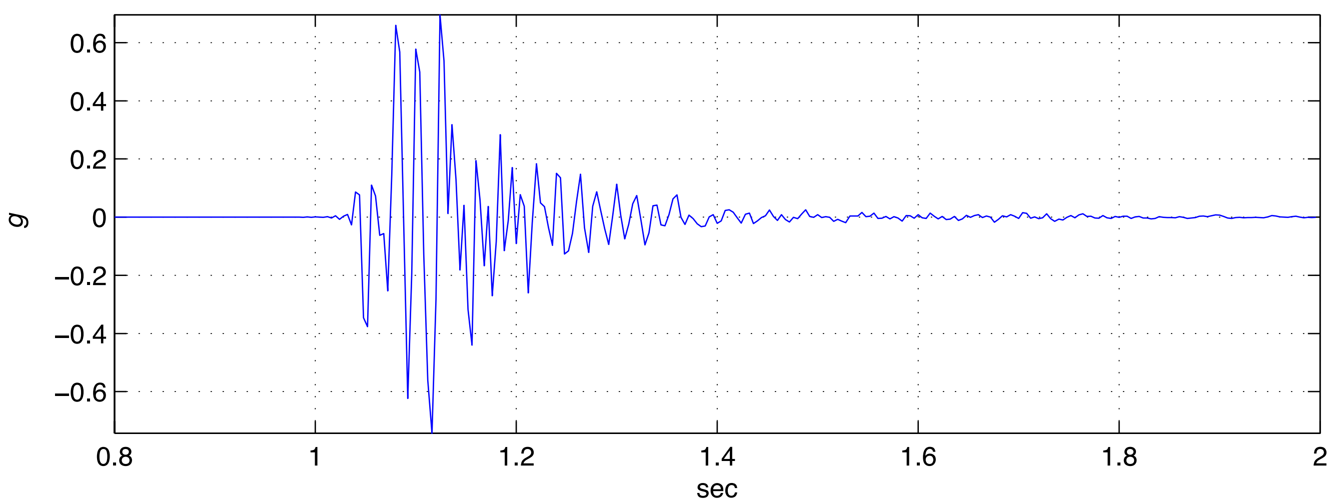
"closure ID number" is the same as "work authorization number"

Appendix 3a. Near Source Acceleration Plots
[From 6-component RefTeks]

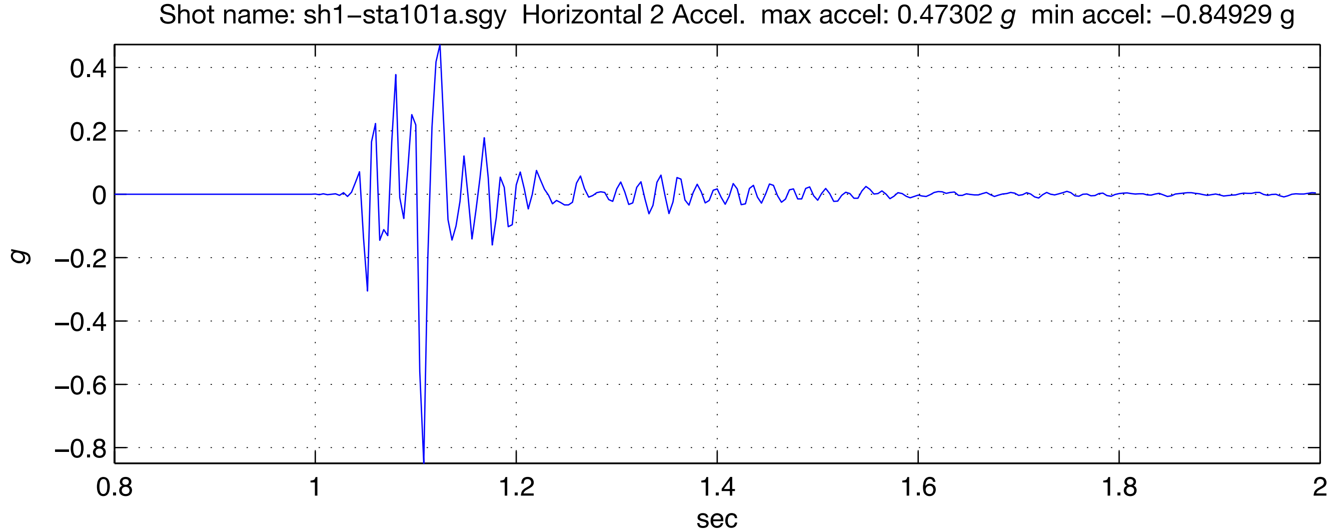
Shot name: sh1−sta101a.sgy Vertical Accel. max accel: 1.6255 *g*   min accel: −1.0911 *g*

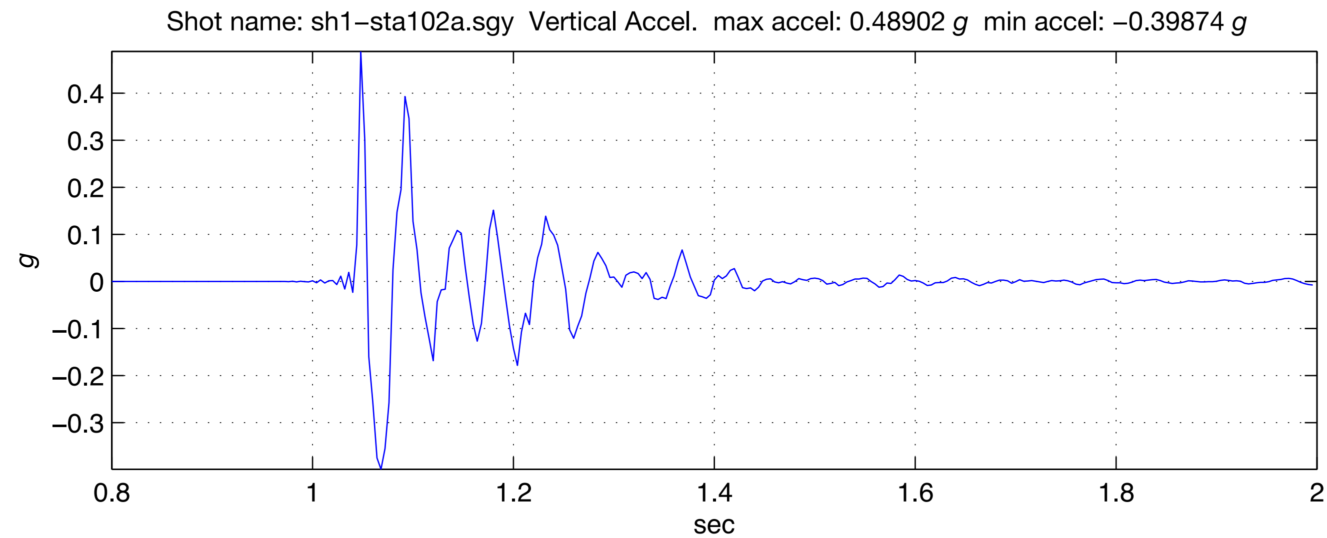


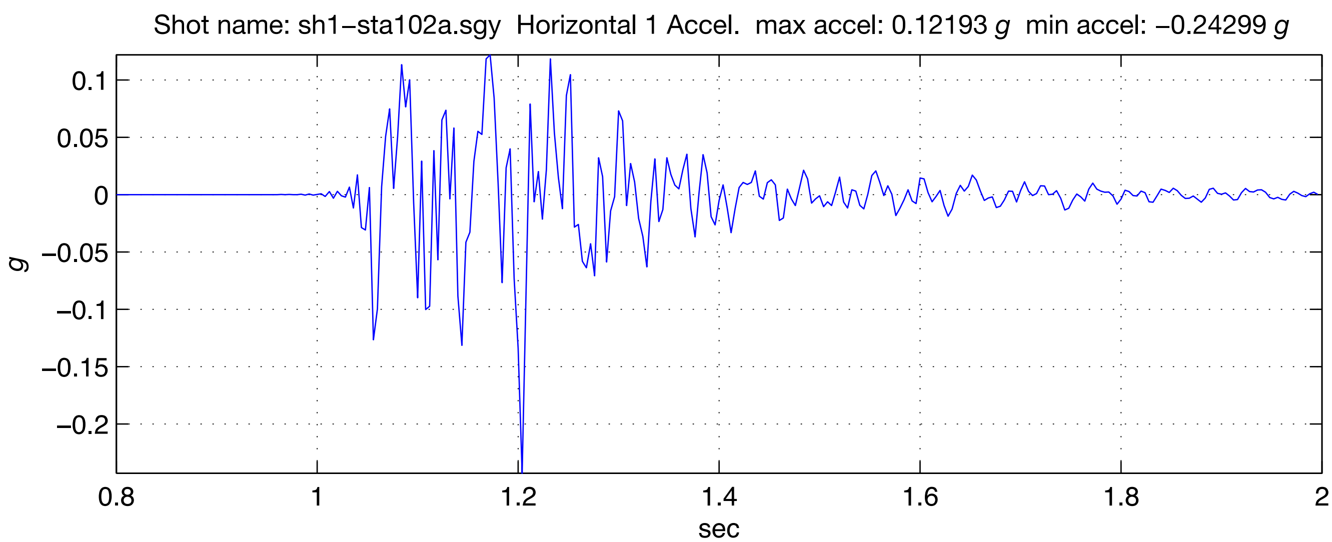
Shot name: sh1−sta101a.sgy Horizontal 1 Accel. max accel: 0.69566 *g* min accel: −0.74289 *g*

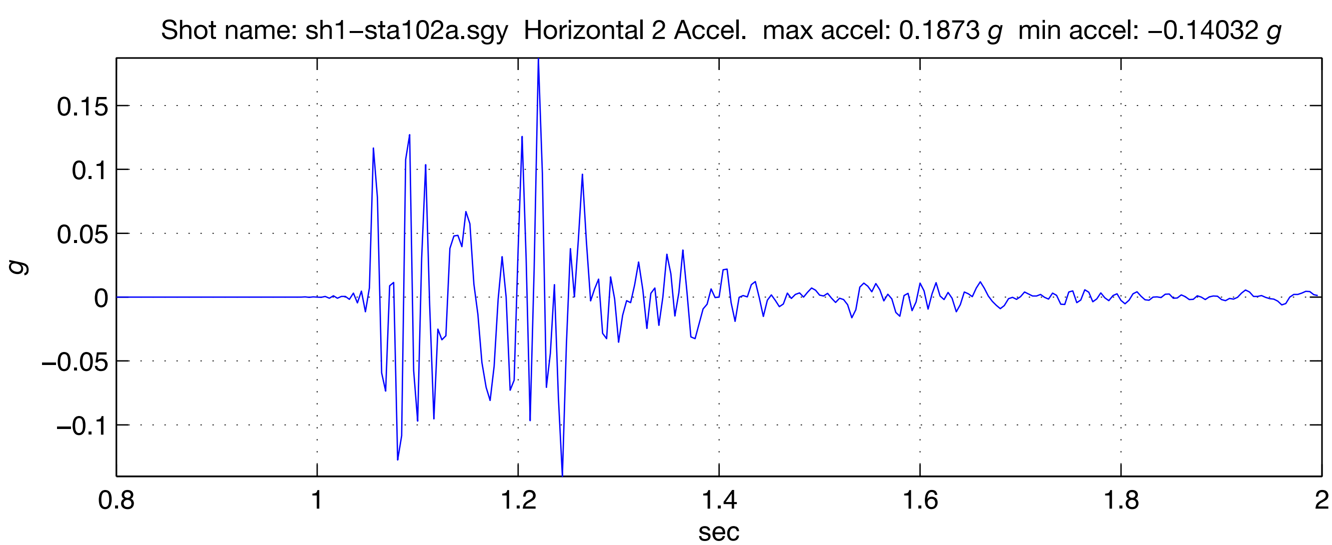


Shot name: sh1−sta101a.sgy Horizontal 2 Accel. max accel: 0.47302 *g* min accel: −0.84929 g

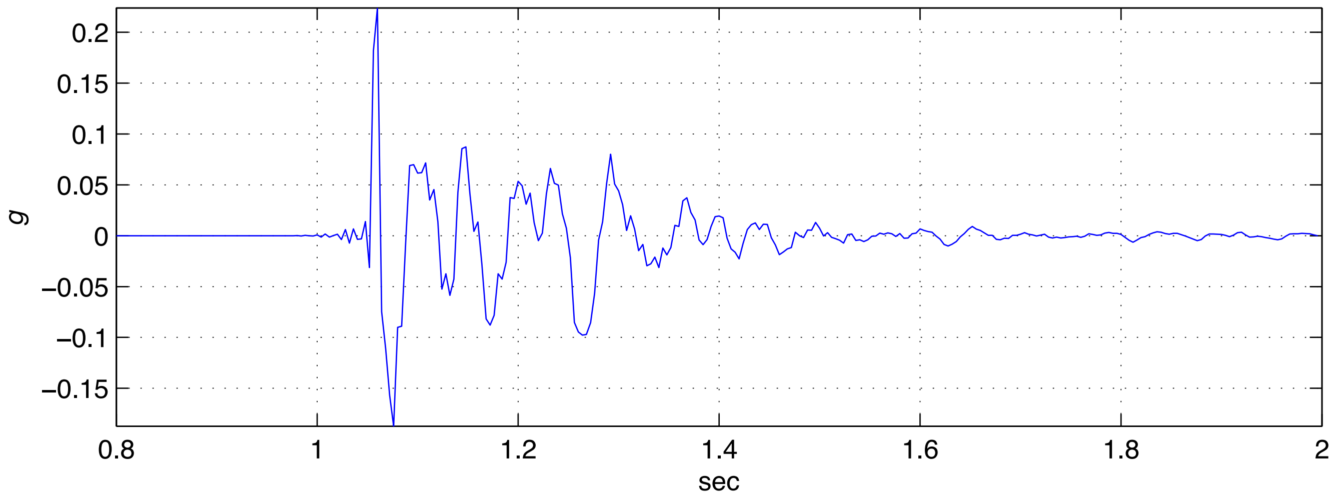



Shot name: sh1−sta102a.sgy Vertical Accel. max accel: 0.48902 g min accel: −0.39874 g
g
sec


Shot name: sh1−sta102a.sgy Horizontal 1 Accel. max accel: 0.12193 g min accel: −0.24299 g
g
sec


Shot name: sh1−sta102a.sgy Horizontal 2 Accel. max accel: 0.1873 g min accel: −0.14032 g
g
sec

Shot name: sh1−sta103a.sgy Vertical Accel. max accel: 0.22393 *g* min accel: −0.18716 *g*



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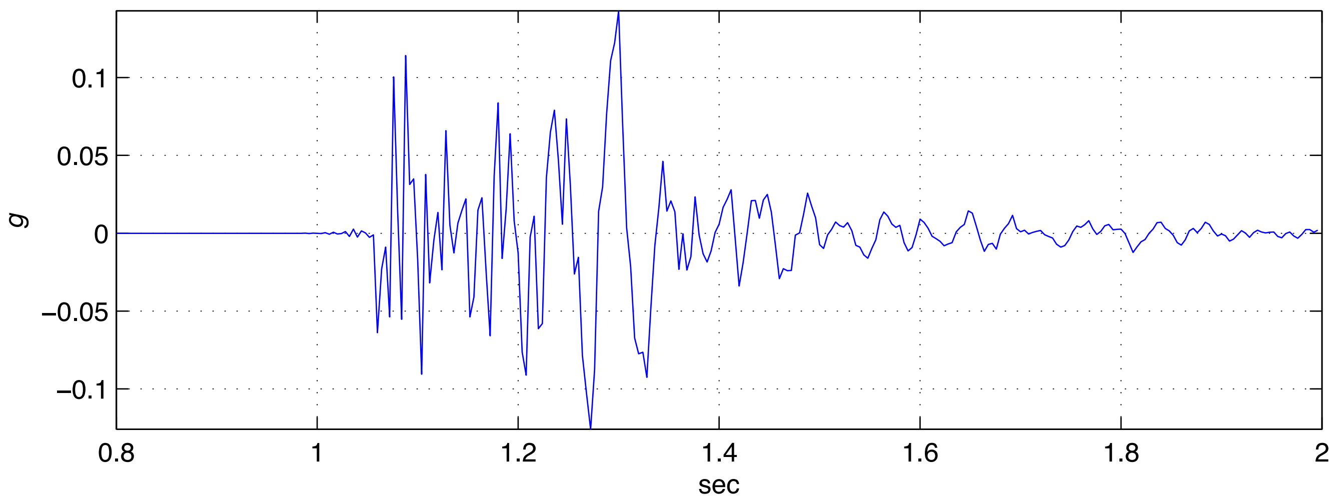

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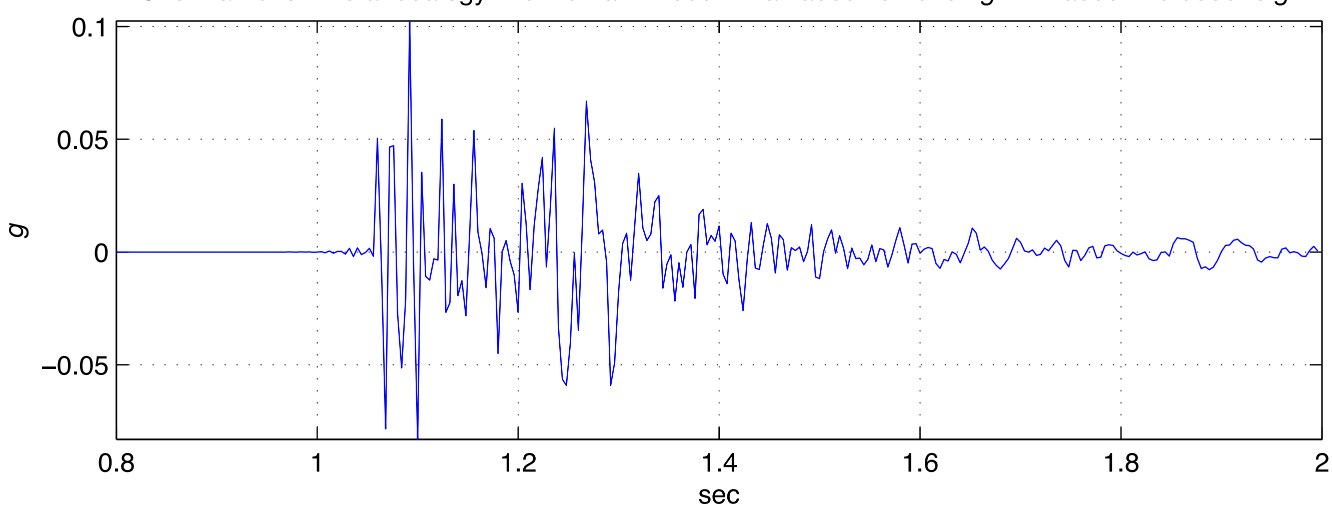

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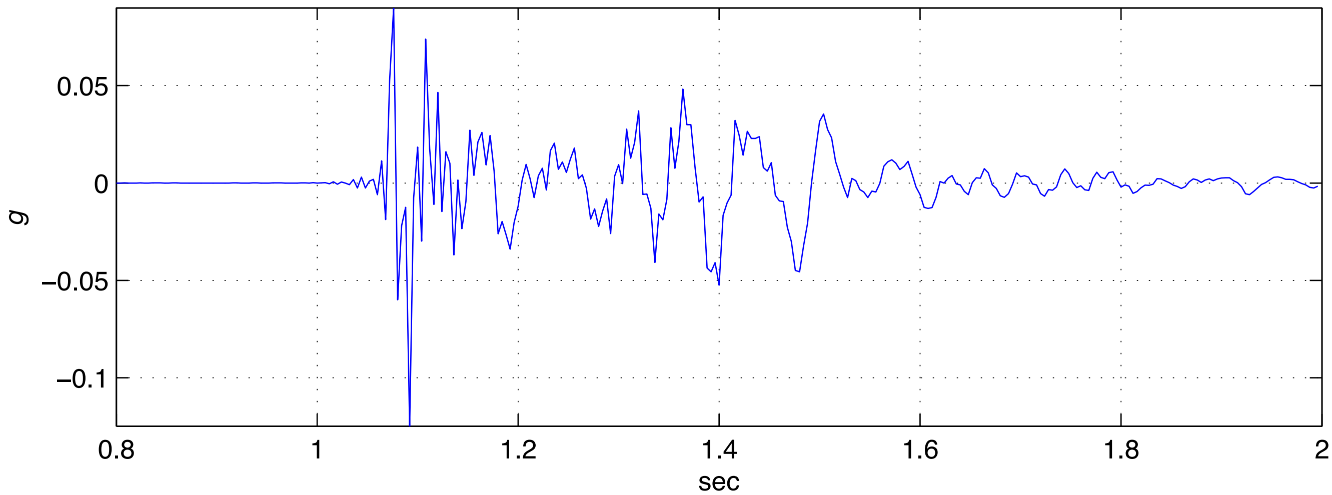

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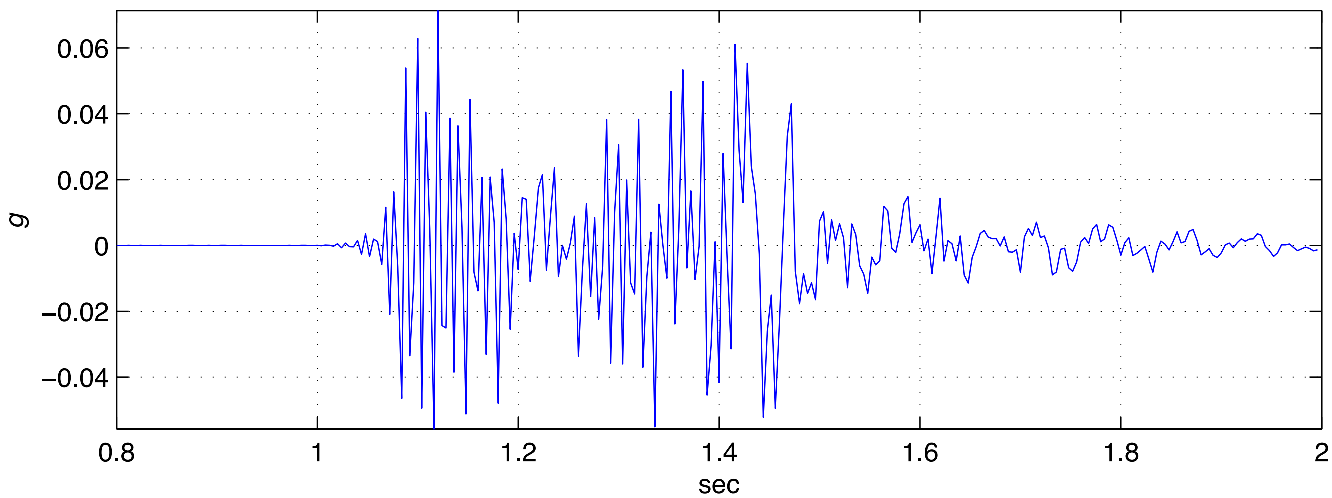
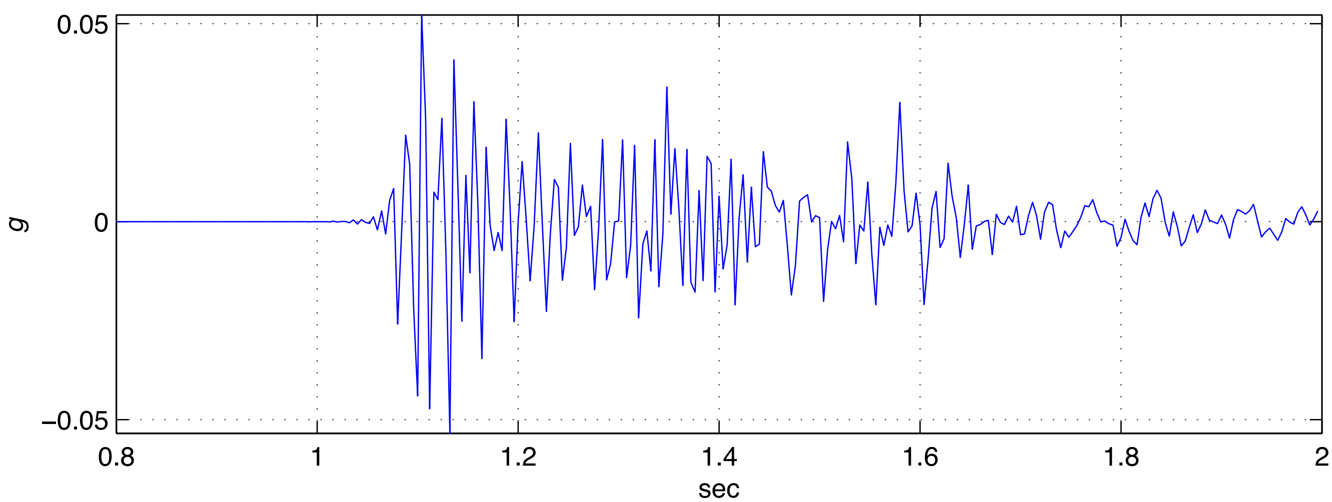
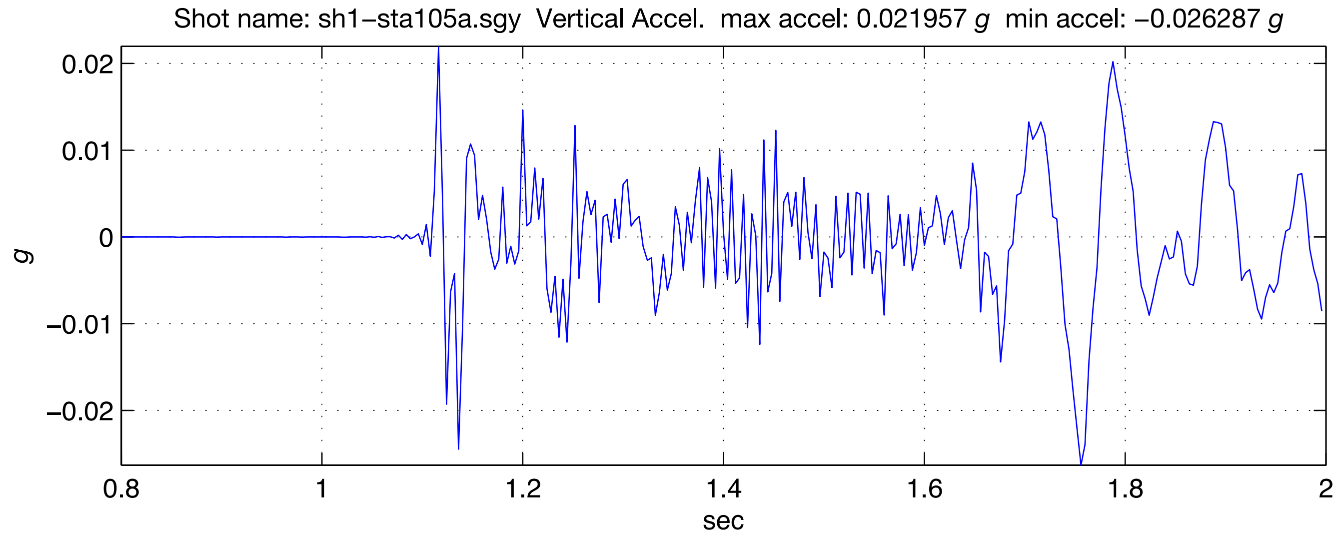
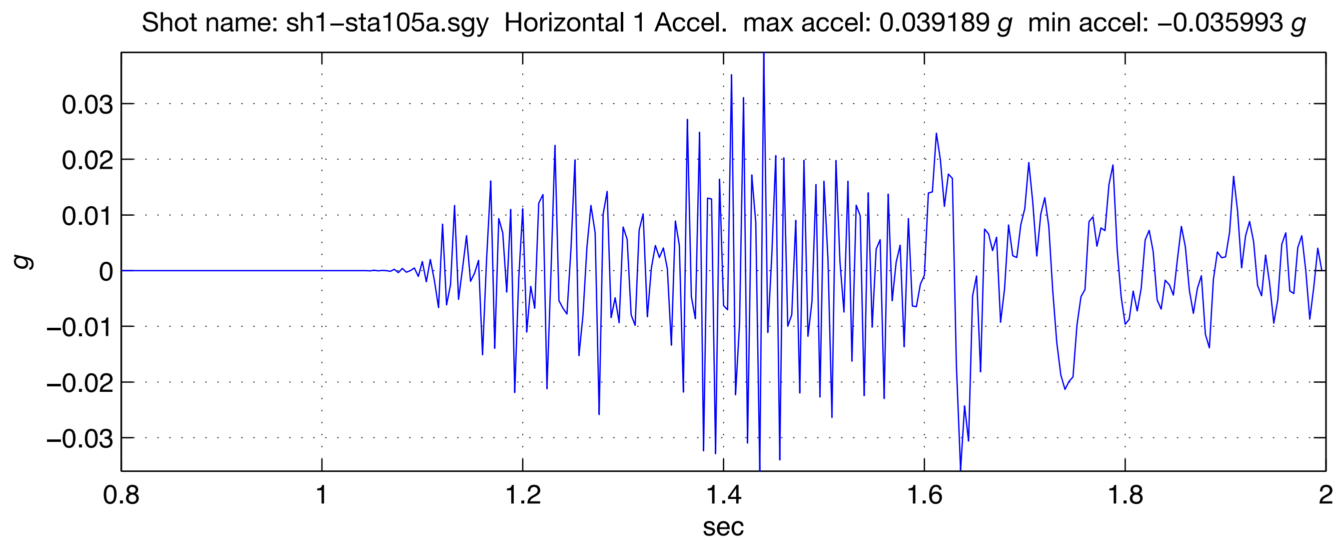
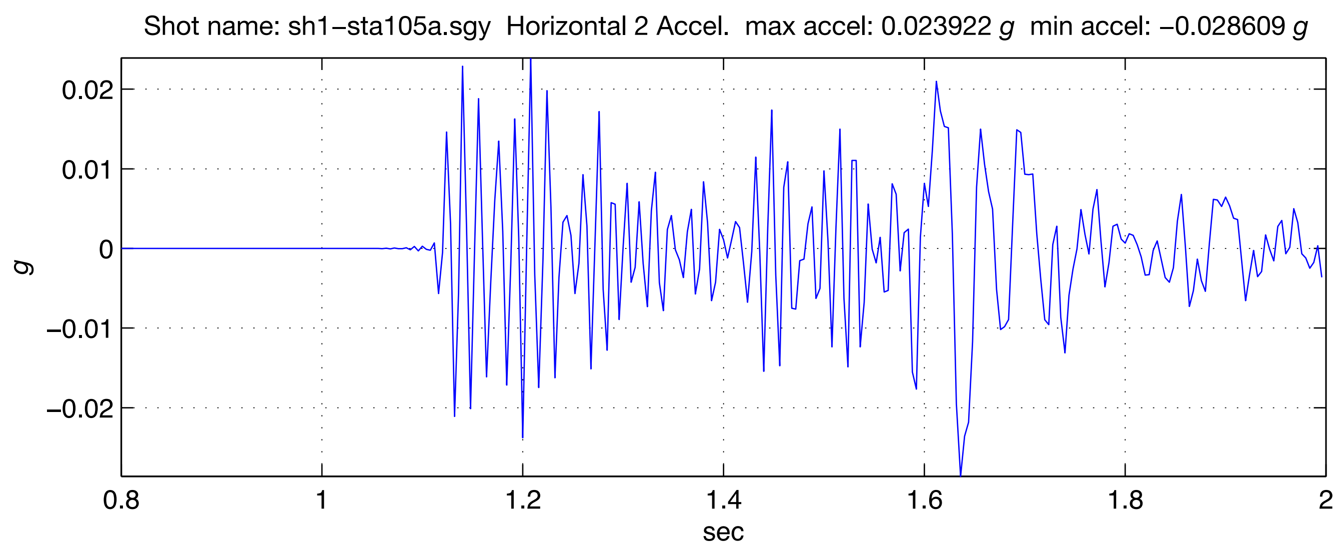


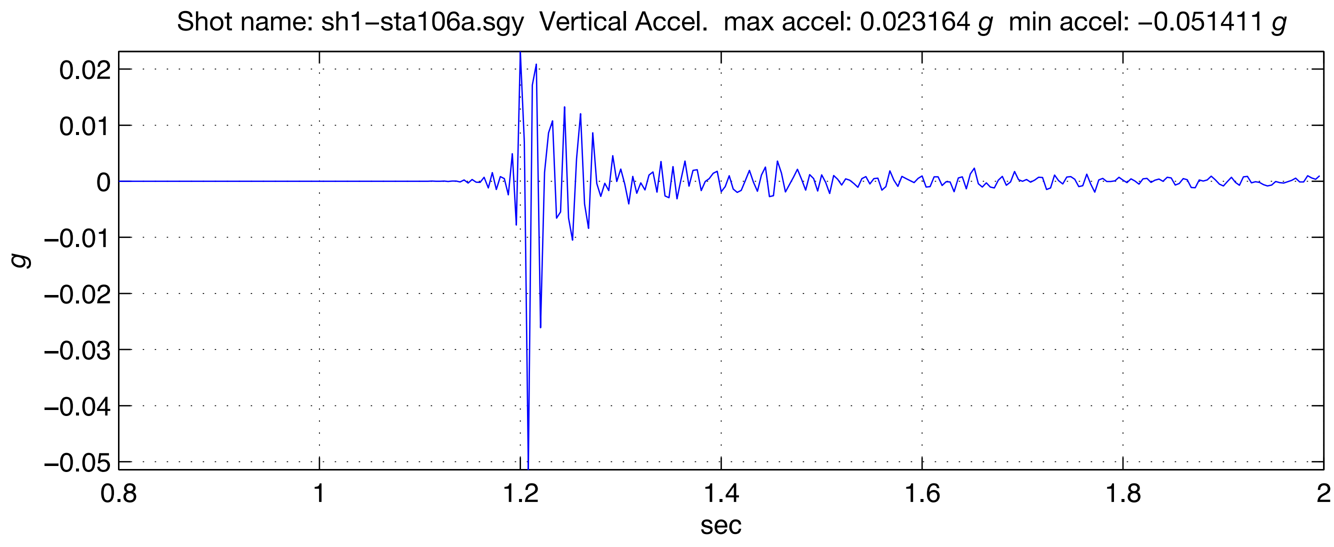
Shot name: sh1−sta104a.sgy Horizontal 2 Accel. max accel: 0.052224 *g* min accel: −0.053431 *g*

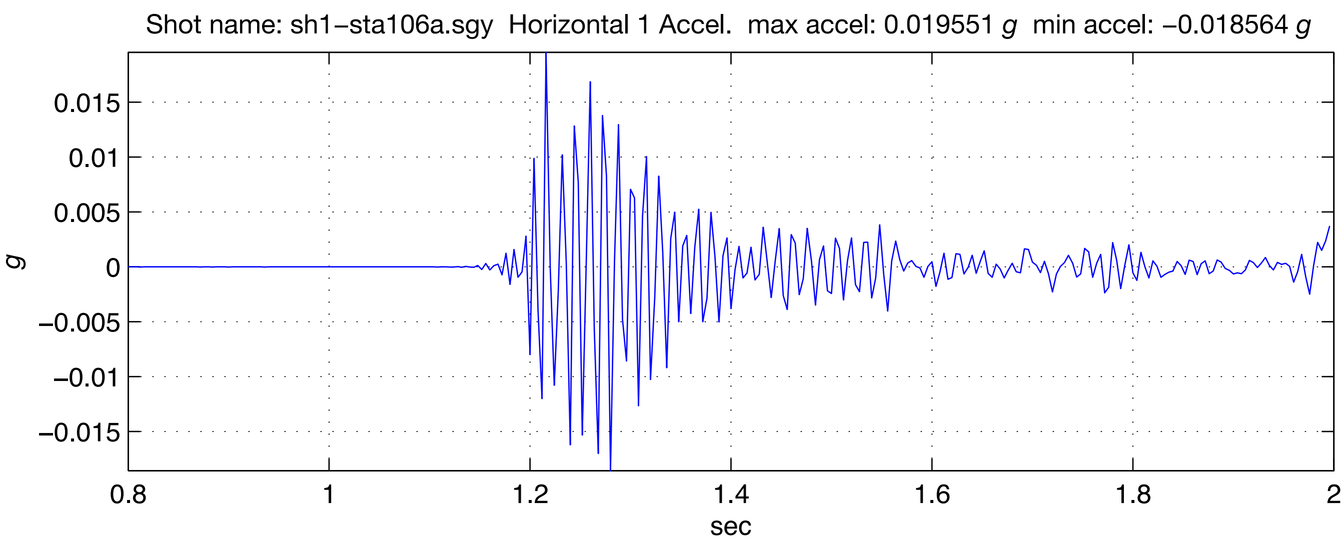


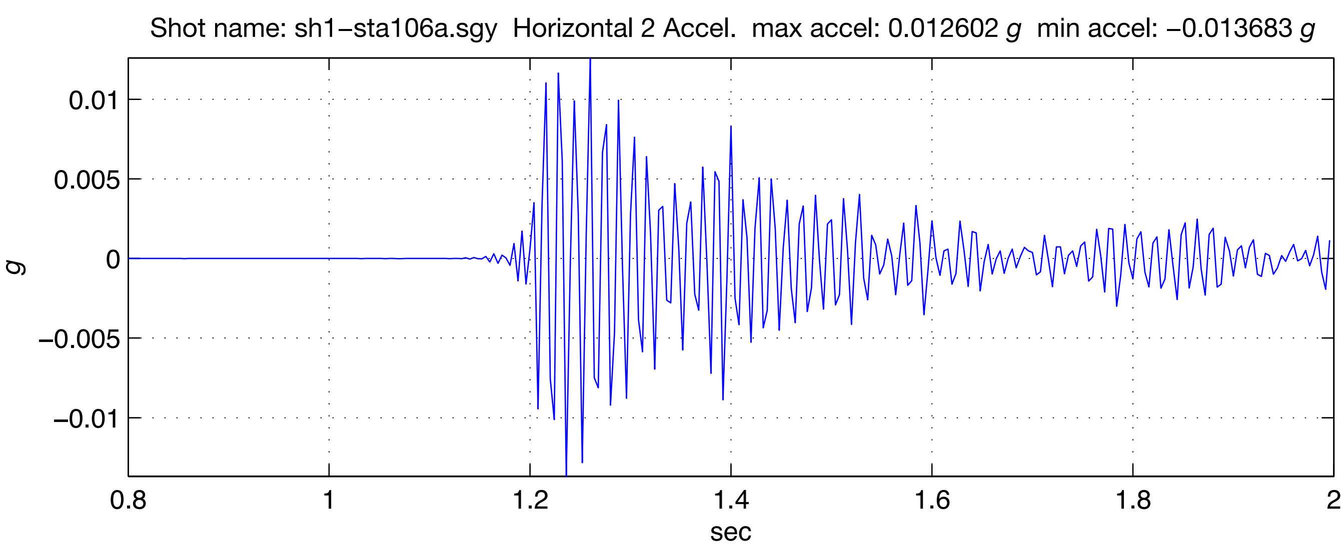

Shot name: sh1−sta105a.sgy Vertical Accel. max accel: 0.021957 g min accel: −0.026287 g
0.02
0.01
0
−0.01
−0.02
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

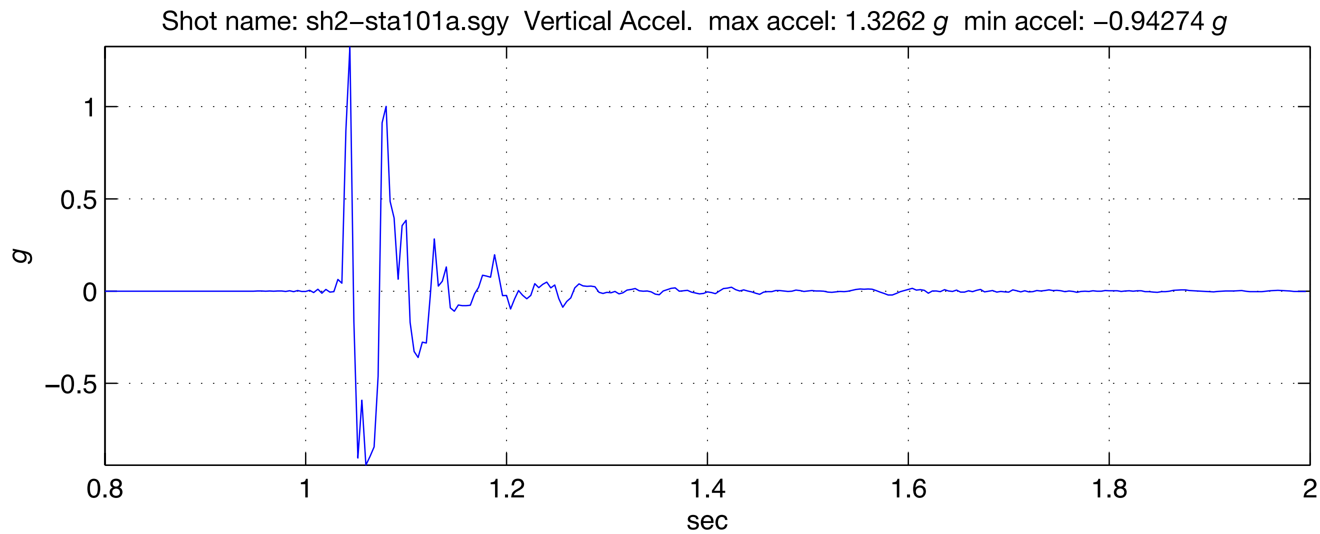

Shot name: sh1−sta105a.sgy Horizontal 1 Accel. max accel: 0.039189 g min accel: −0.035993 g
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

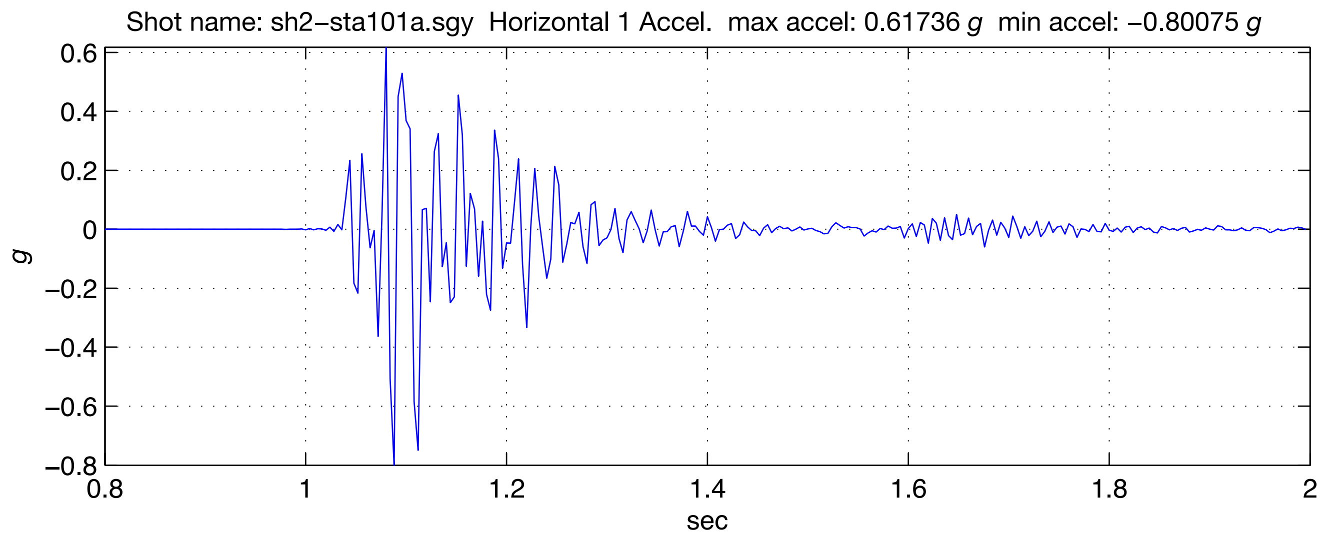

Shot name: sh1−sta105a.sgy Horizontal 2 Accel. max accel: 0.023922 g min accel: −0.028609 g
0.02
0.01
0
−0.01
−0.02
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

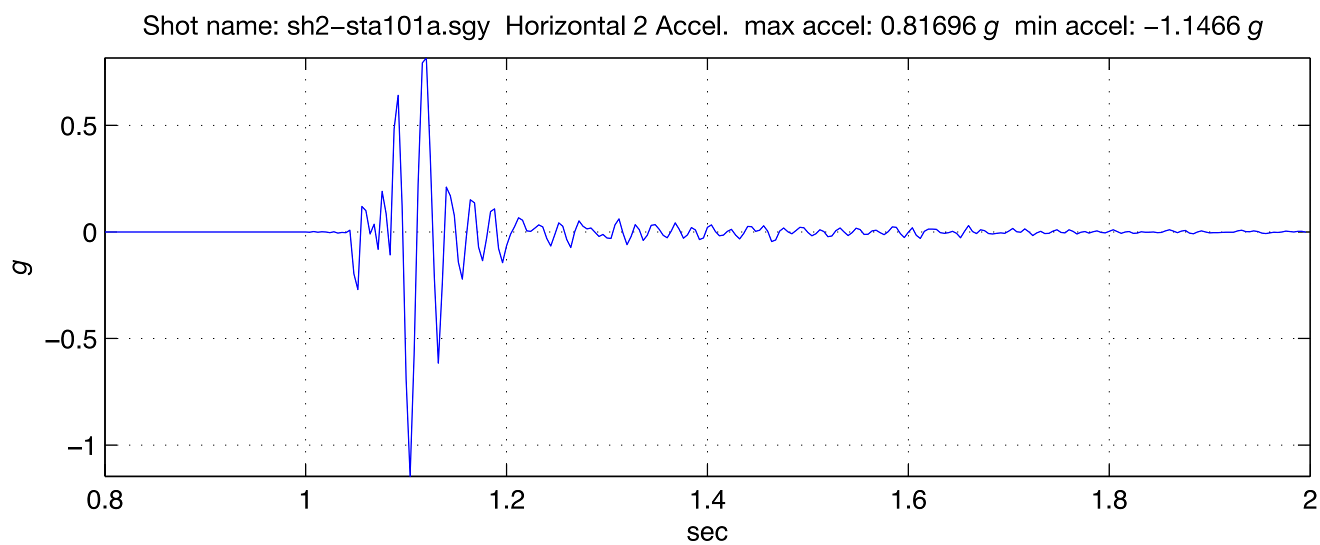

Shot name: sh1−sta106a.sgy Vertical Accel. max accel: 0.023164 g min accel: −0.051411 g
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

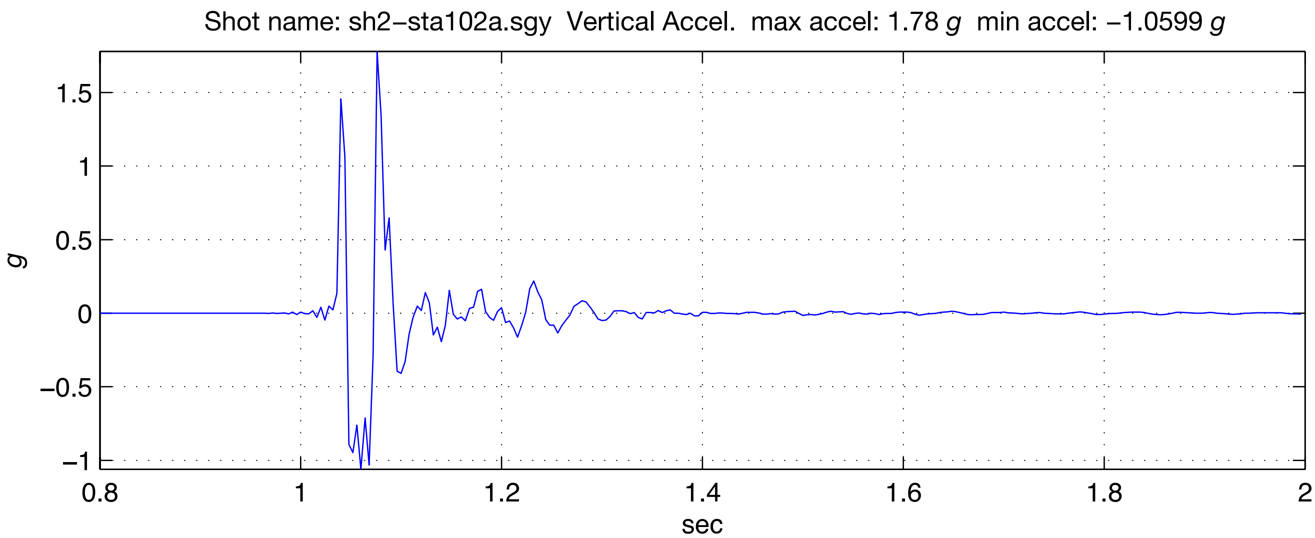

Shot name: sh1−sta106a.sgy Horizontal 1 Accel. max accel: 0.019551 g min accel: −0.018564 g
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

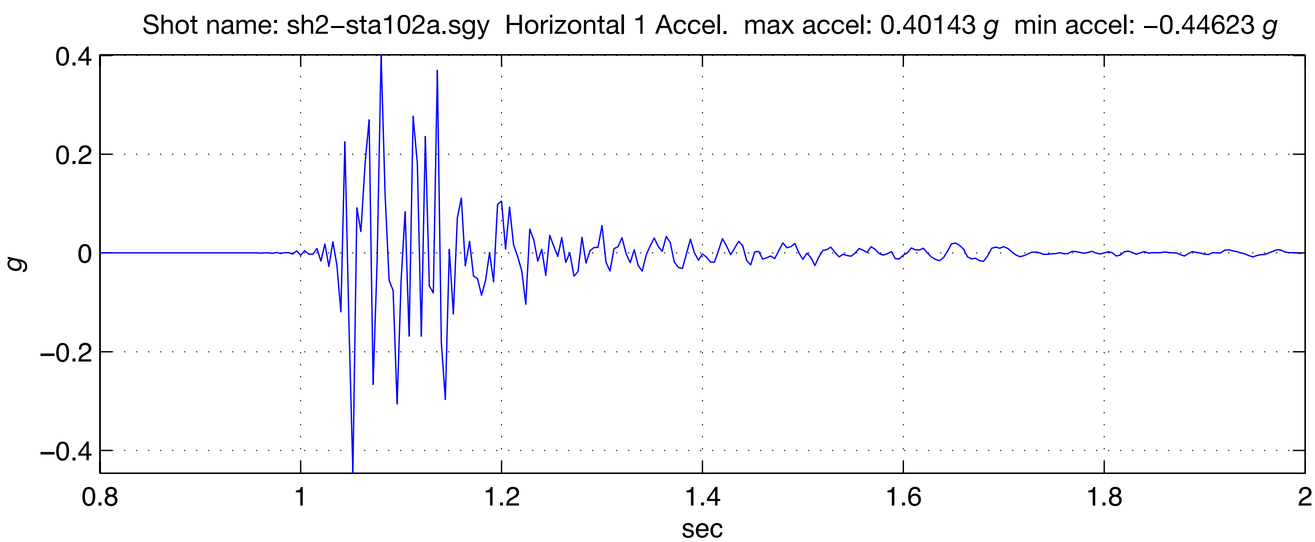

Shot name: sh1−sta106a.sgy Horizontal 2 Accel. max accel: 0.012602 g min accel: −0.013683 g
0.01
0.005
0
−0.005
−0.01
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

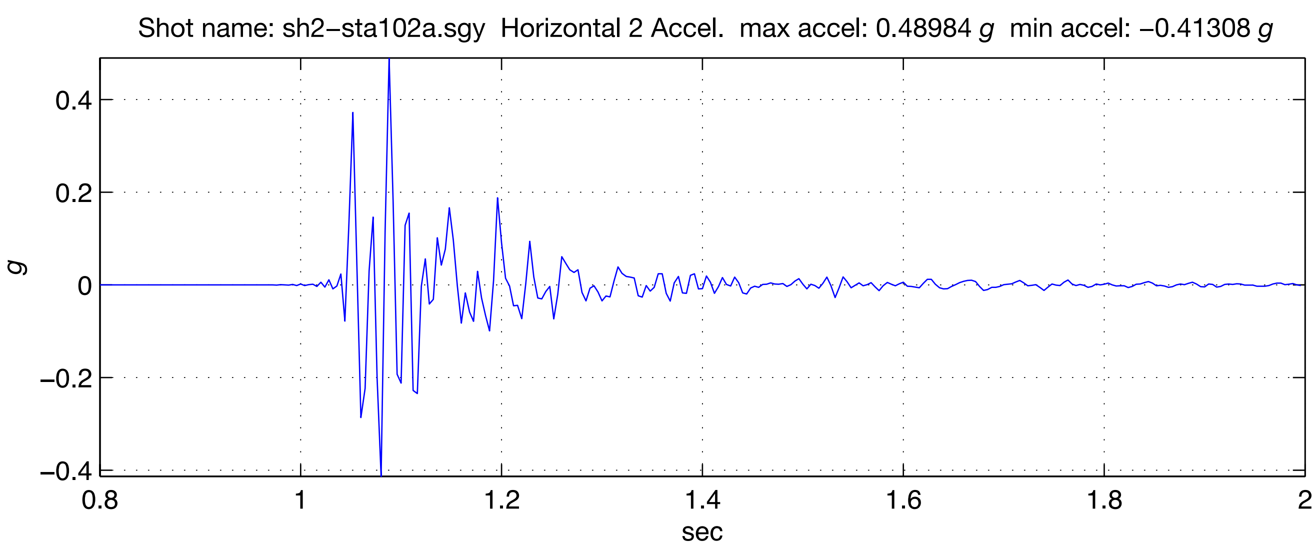

Shot name: sh2−sta101a.sgy Vertical Accel. max accel: 1.3262 g min accel: −0.94274 g
g
sec


Shot name: sh2−sta101a.sgy Horizontal 1 Accel. max accel: 0.61736 g min accel: −0.80075 g
g
sec

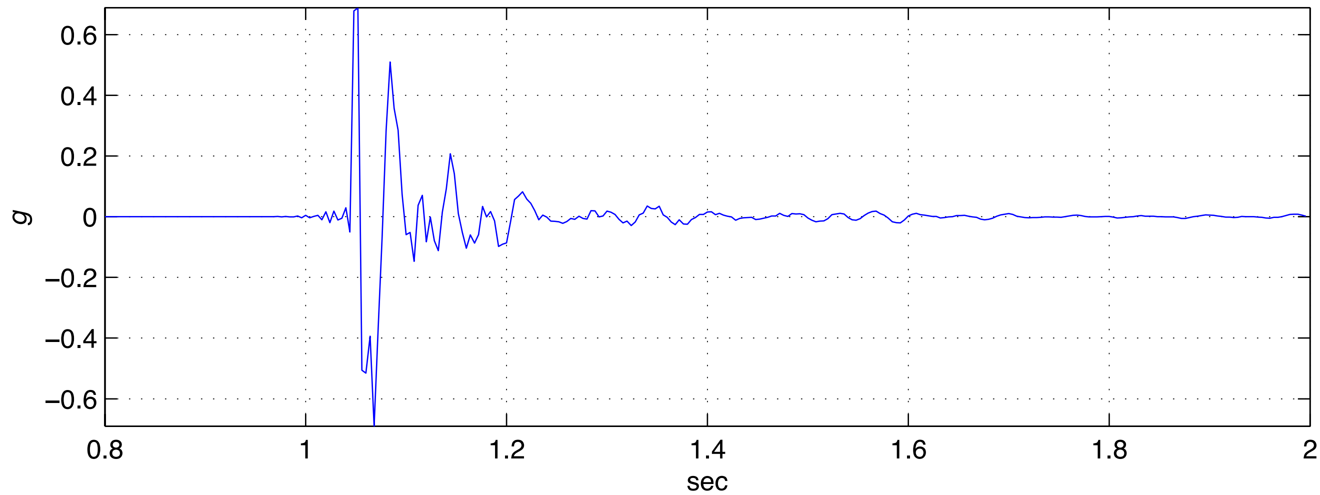

Shot name: sh2−sta101a.sgy Horizontal 2 Accel. max accel: 0.81696 g min accel: −1.1466 g
g
sec


Shot name: sh2−sta102a.sgy Vertical Accel. max accel: 1.78 g min accel: −1.0599 g
g
1.5
1
0.5
0
−0.5
−1
0.8
1
1.2
1.4
1.6
1.8
2
sec

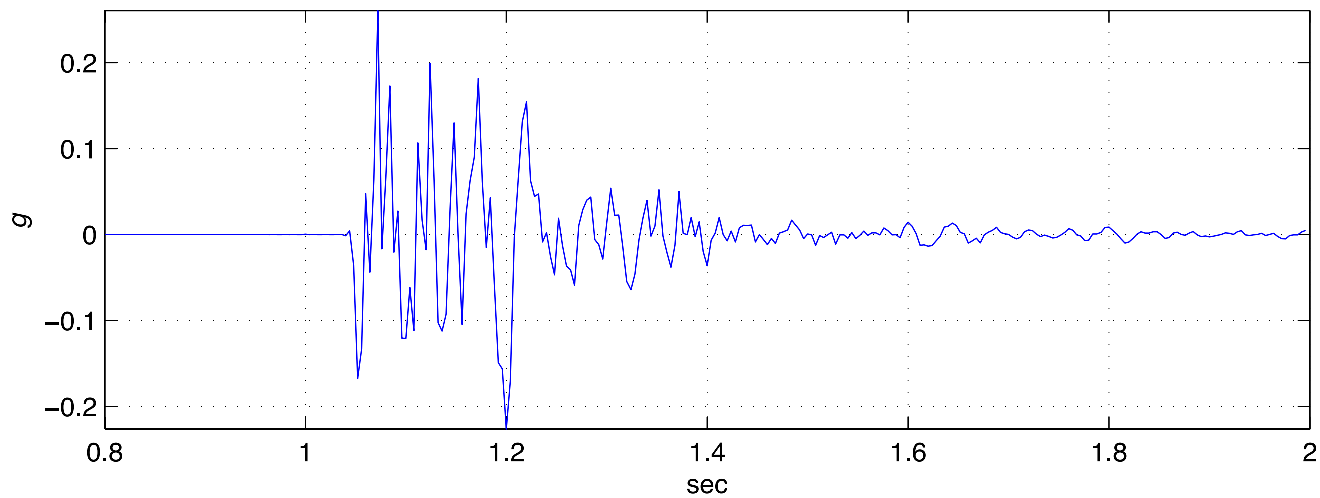

Shot name: sh2−sta102a.sgy Horizontal 1 Accel. max accel: 0.40143 g min accel: −0.44623 g
g
0.4
0.2
0
−0.2
−0.4
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh2−sta102a.sgy Horizontal 2 Accel. max accel: 0.48984 g min accel: −0.41308 g
g
0.4
0.2
0
−0.2
−0.4
0.8
1
1.2
1.4
1.6
1.8
2
sec

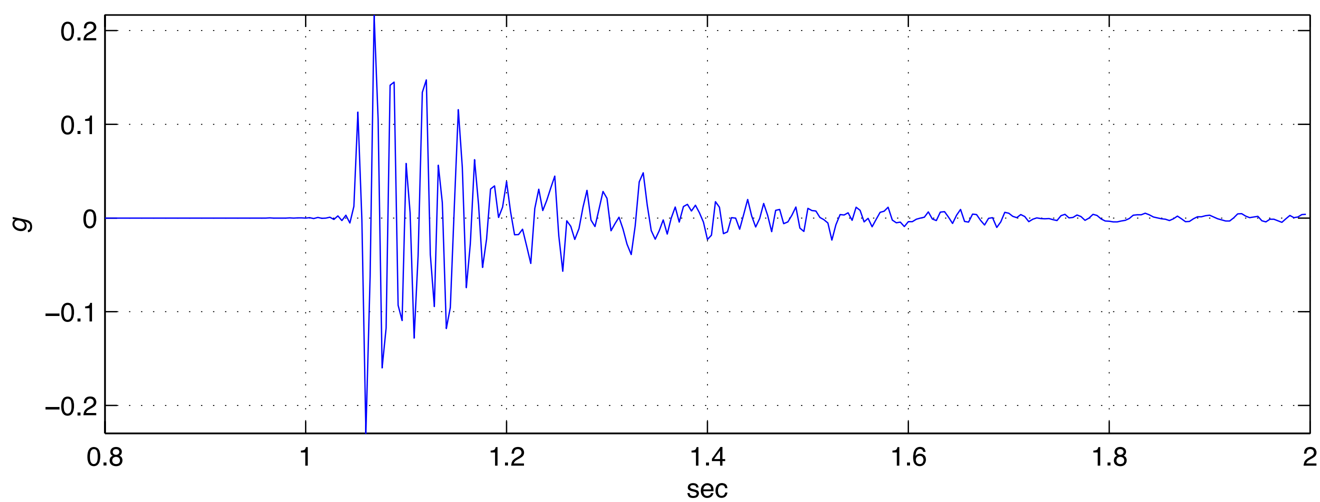
Shot name: sh2−sta103a.sgy Vertical Accel. max accel: 0.6879 *g* min accel: −0.69001 *g*

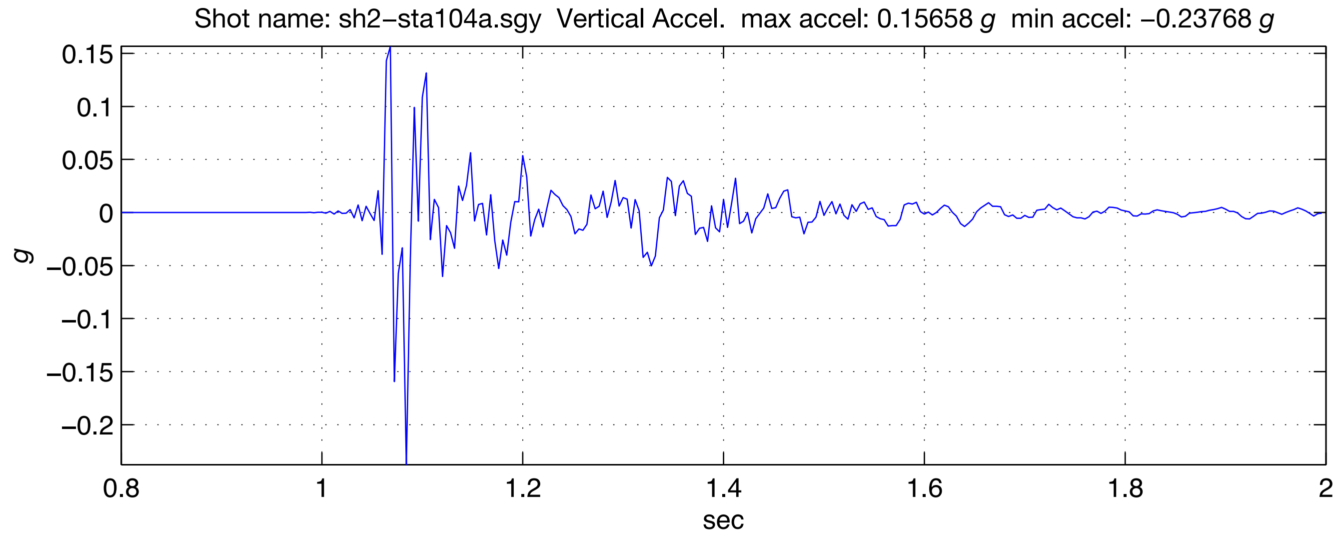


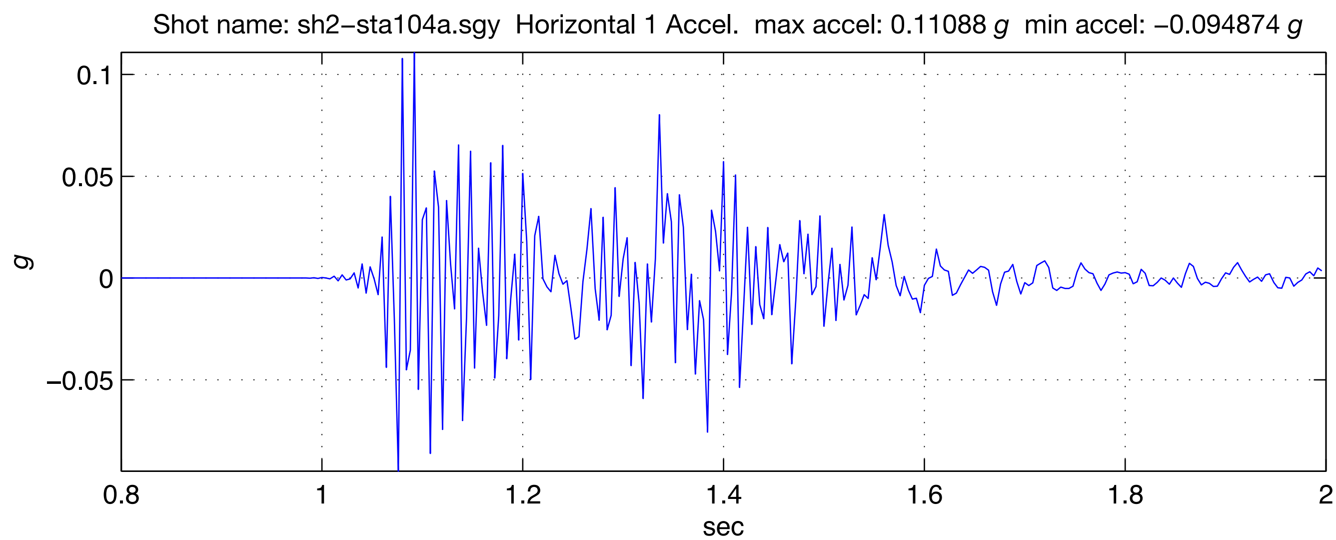
Shot name: sh2−sta103a.sgy Horizontal 1 Accel. max accel: 0.26058 *g* min accel: −0.22623 *g*

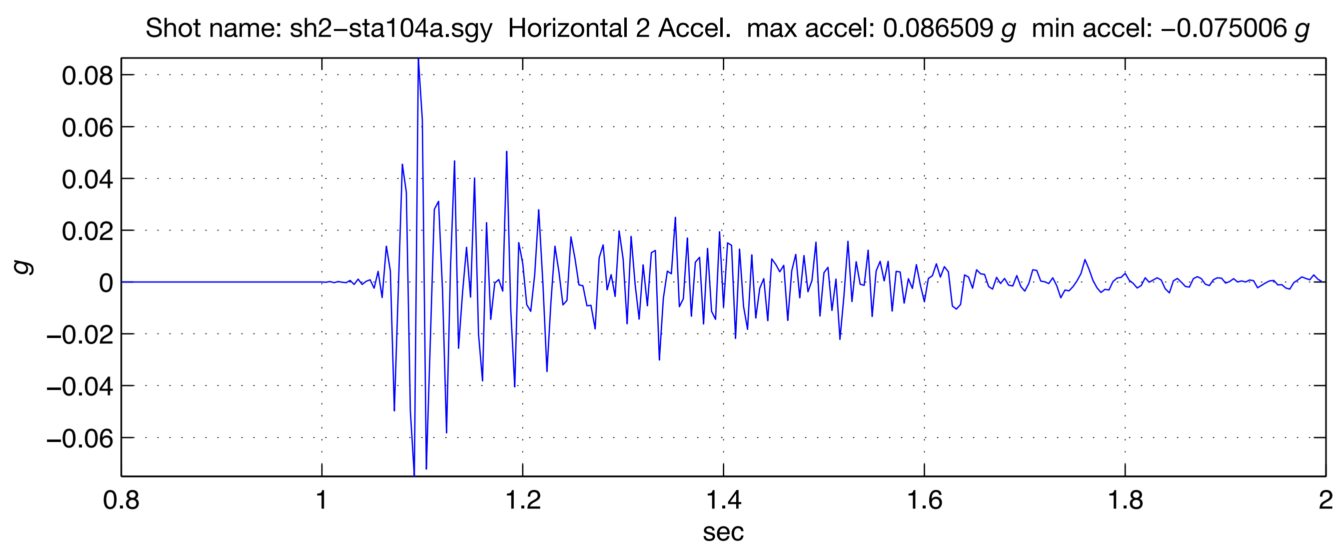


Shot name: sh2−sta103a.sgy Horizontal 2 Accel. max accel: 0.21667 *g* min accel: −0.22969 *g*

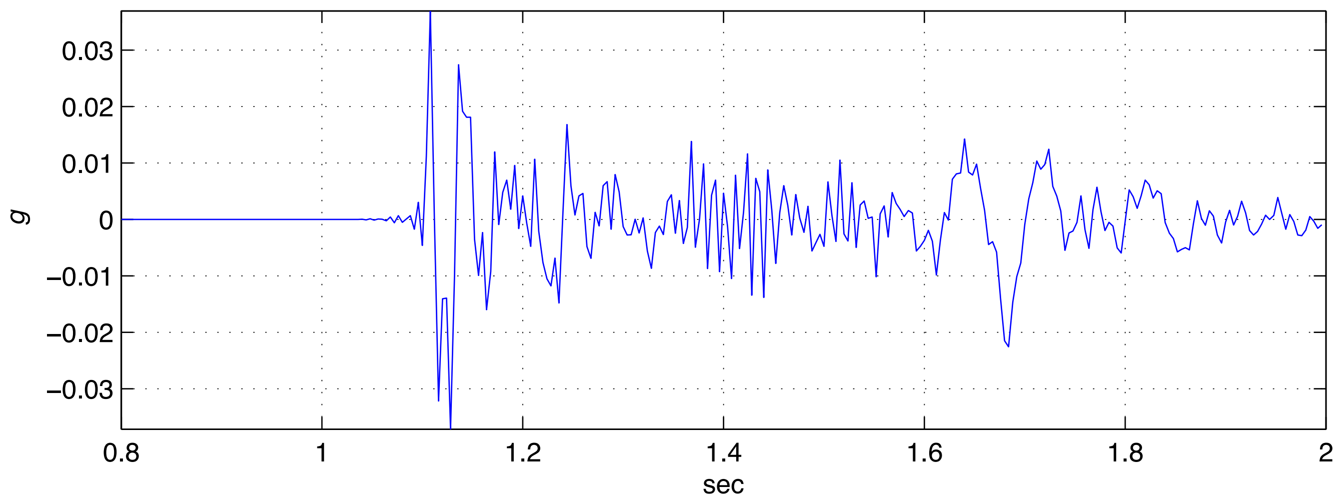



Shot name: sh2−sta104a.sgy Vertical Accel. max accel: 0.15658 g min accel: −0.23768 g
g
sec
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
0.8
1
1.2
1.4
1.6
1.8
2

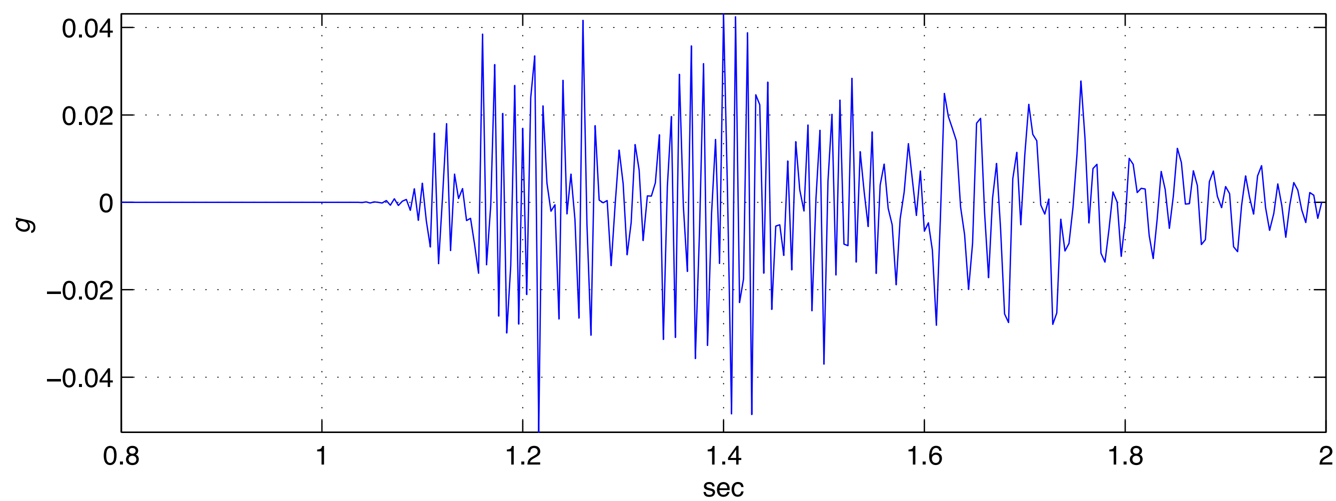

Shot name: sh2−sta104a.sgy Horizontal 1 Accel. max accel: 0.11088 g min accel: −0.094874 g
g
sec
0.1
0.05
0
−0.05
0.8
1
1.2
1.4
1.6
1.8
2


Shot name: sh2−sta104a.sgy Horizontal 2 Accel. max accel: 0.086509 g min accel: −0.075006 g
g
sec
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
0.8
1
1.2
1.4
1.6
1.8
2

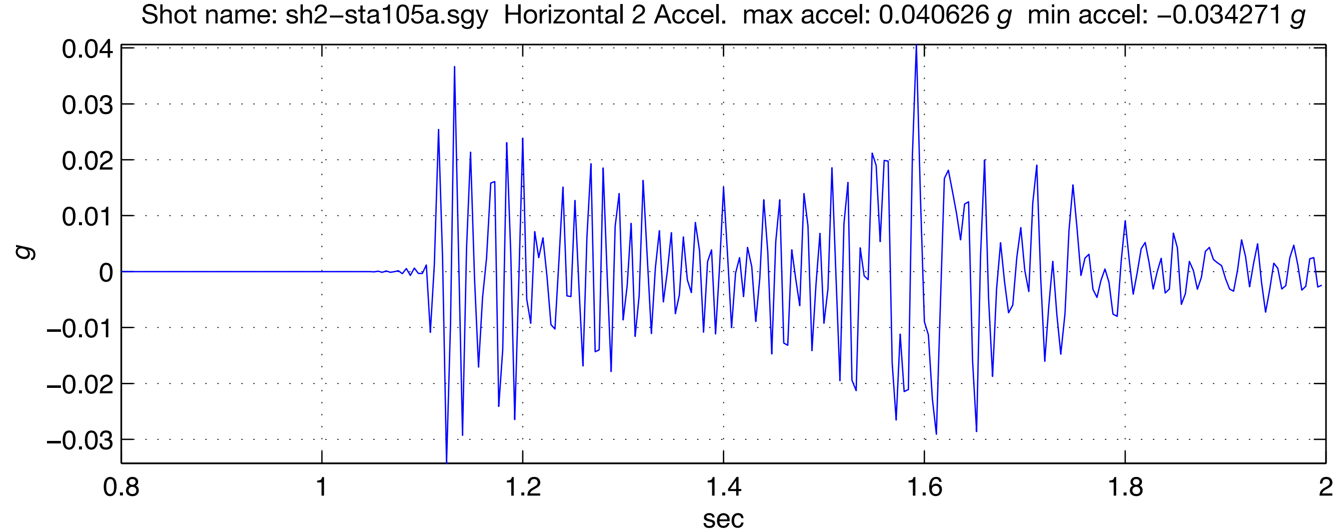
Shot name: sh2−sta105a.sgy Vertical Accel. max accel: 0.036959 *g* min accel: −0.037146 *g*



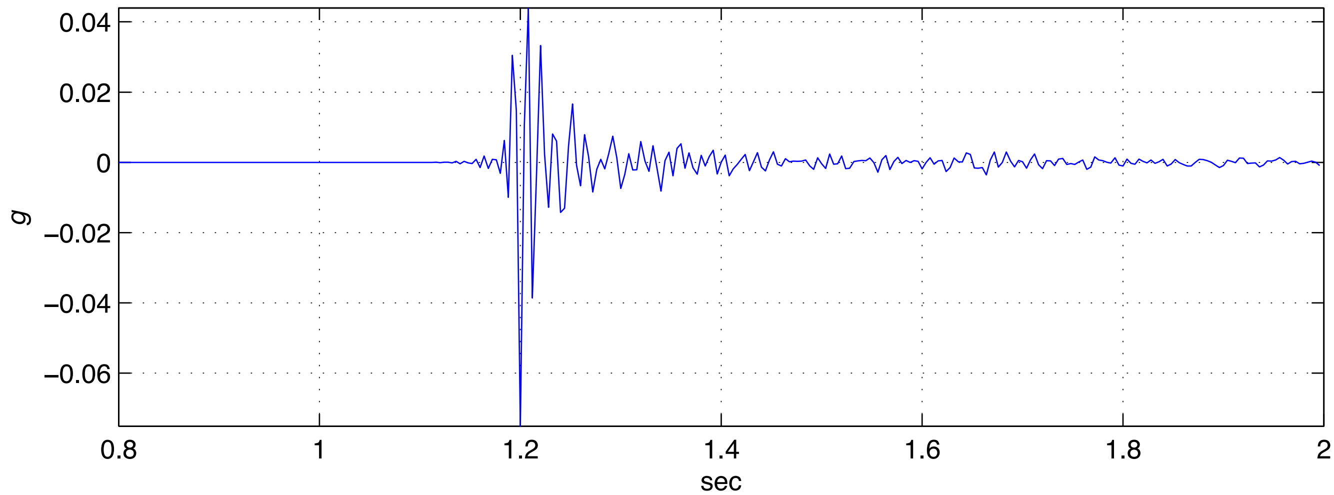
Shot name: sh2−sta105a.sgy Horizontal 1 Accel. max accel: 0.043144 *g* min accel: −0.052607 g



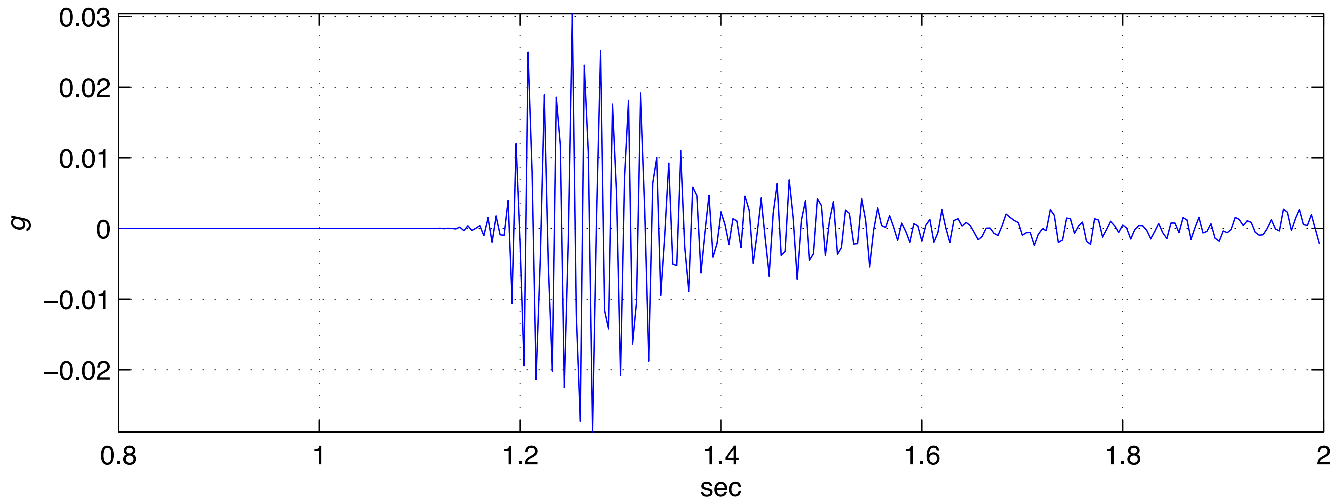
Shot name: sh2−sta105a.sgy Horizontal 2 Accel. max accel: 0.040626 *g* min accel: −0.034271 *g*



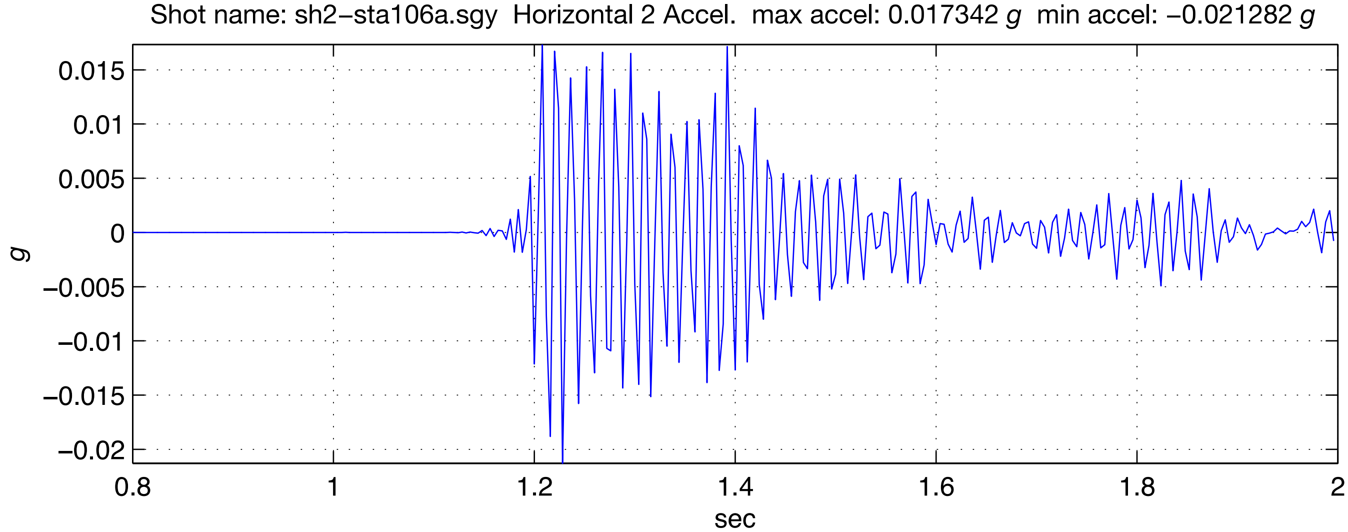
Shot name: sh2−sta106a.sgy Vertical Accel. max accel: 0.043975 *g* min accel: −0.075061 *g*

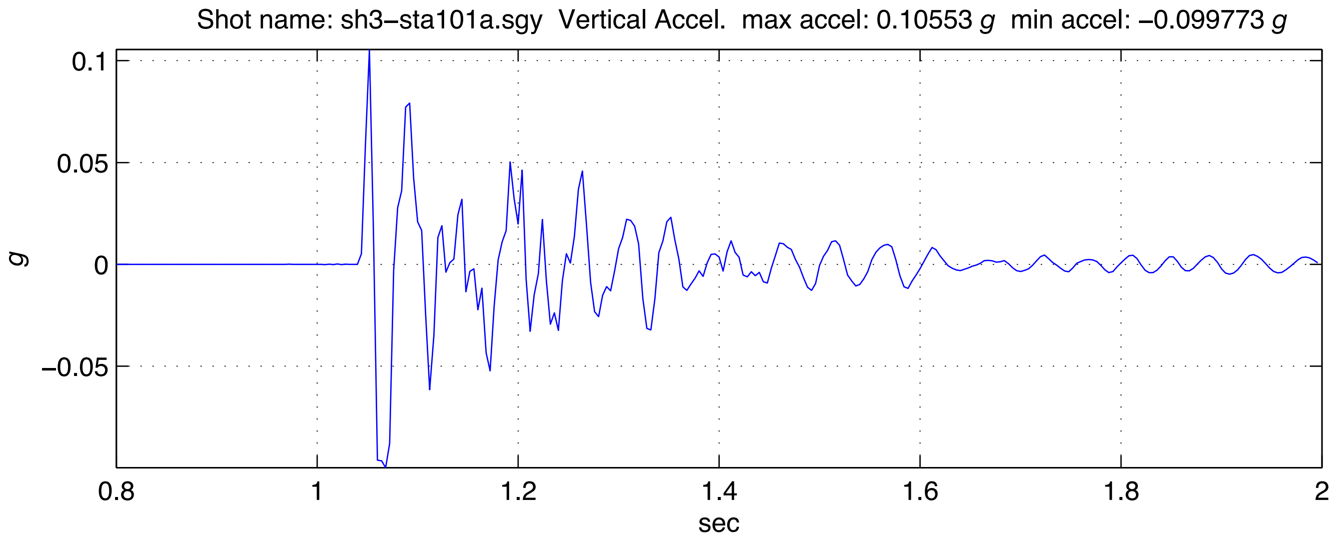


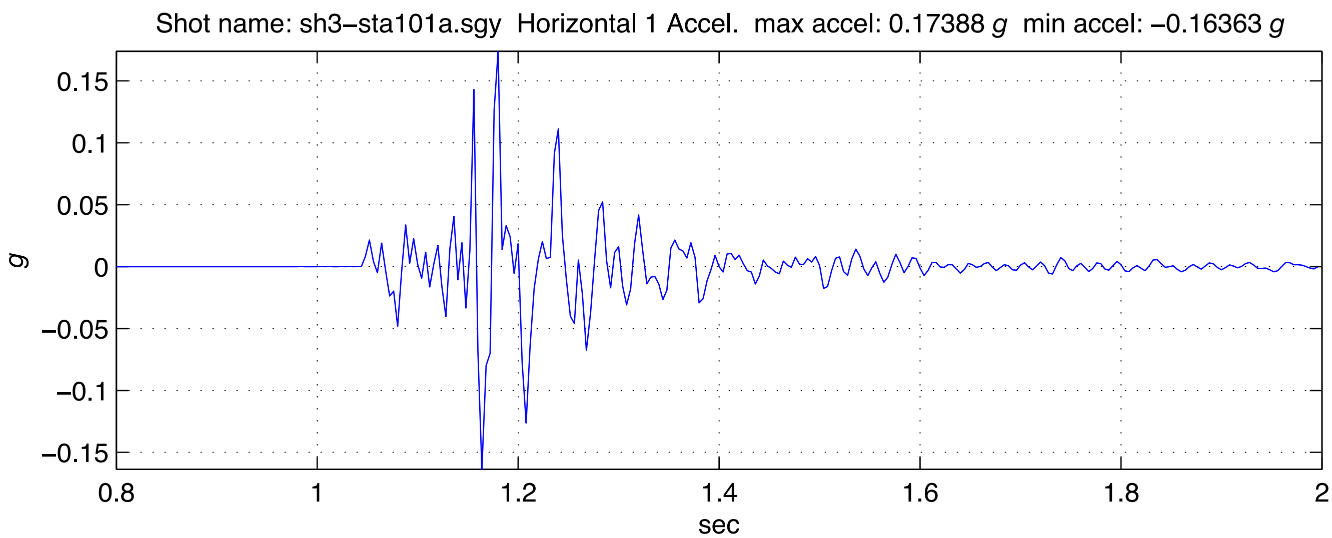
Shot name: sh2−sta106a.sgy Horizontal 1 Accel. max accel: 0.030439 *g* min accel: −0.028801 *g*

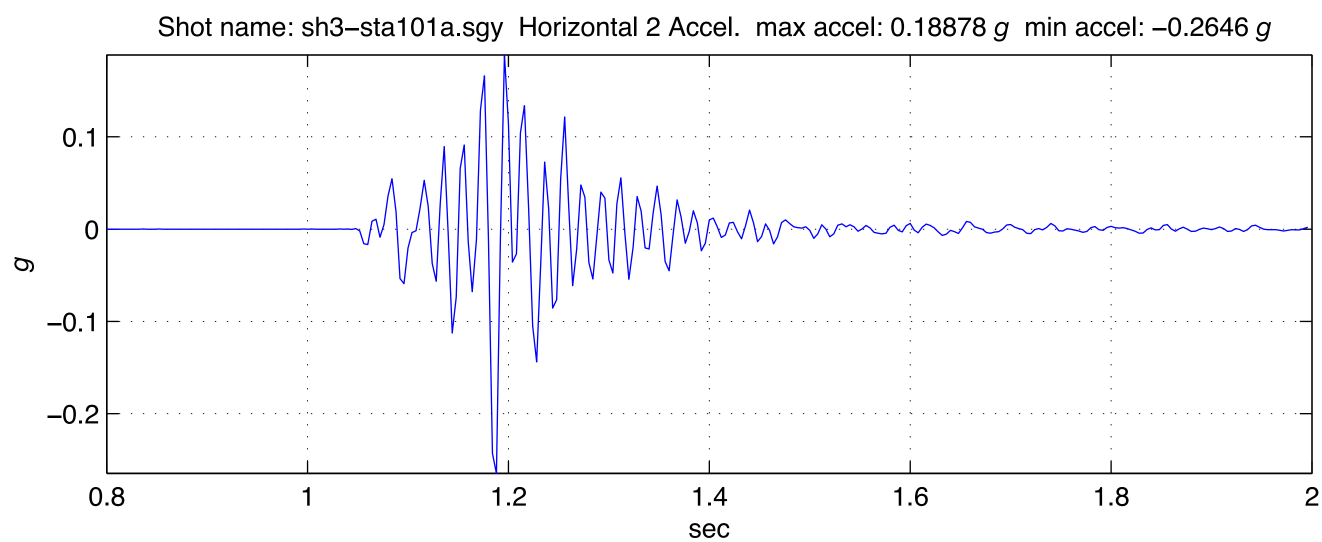


Shot name: sh2−sta106a.sgy Horizontal 2 Accel. max accel: 0.017342 *g* min accel: −0.021282 *g*

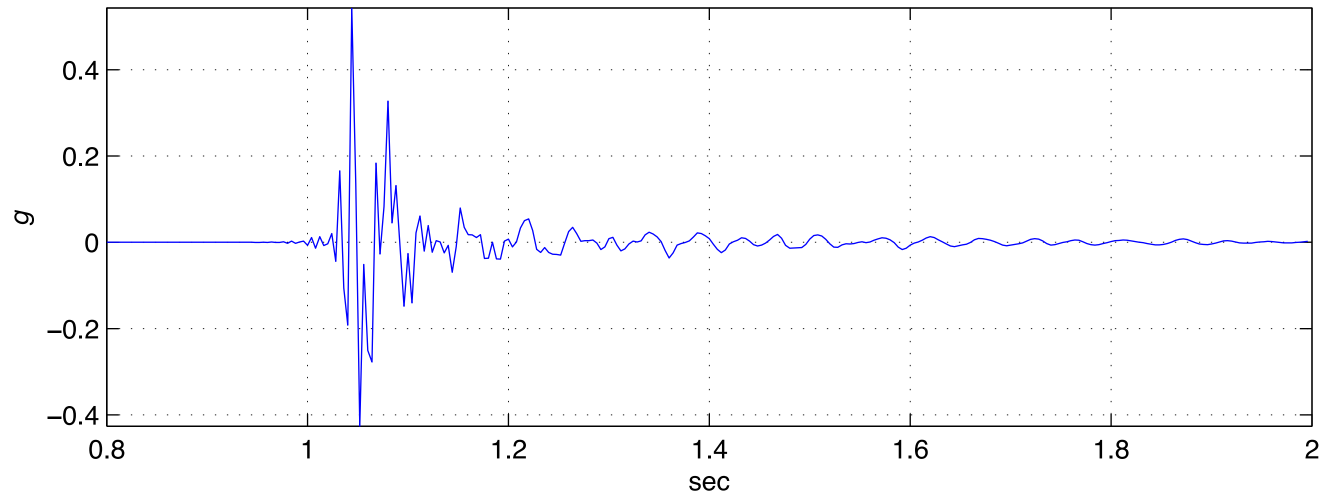



Shot name: sh3−sta101a.sgy Vertical Accel. max accel: 0.10553 g min accel: −0.099773 g
0.1
0.05
0
−0.05
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

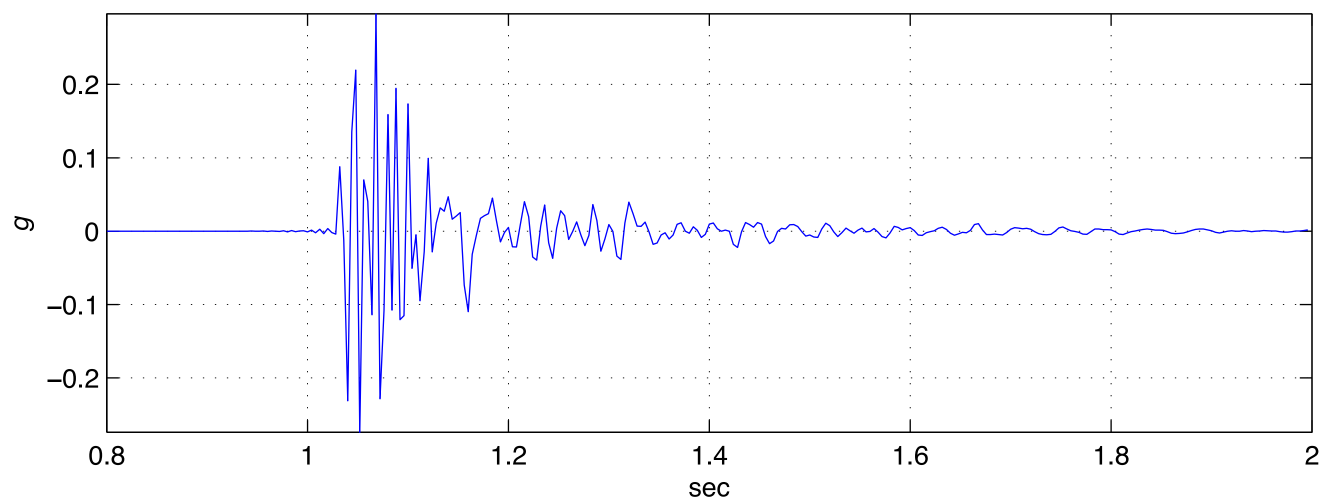

Shot name: sh3−sta101a.sgy Horizontal 1 Accel. max accel: 0.17388 g min accel: −0.16363 g
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
g
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh3−sta101a.sgy Horizontal 2 Accel. max accel: 0.18878 g min accel: −0.2646 g
0.1
0
−0.1
−0.2
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

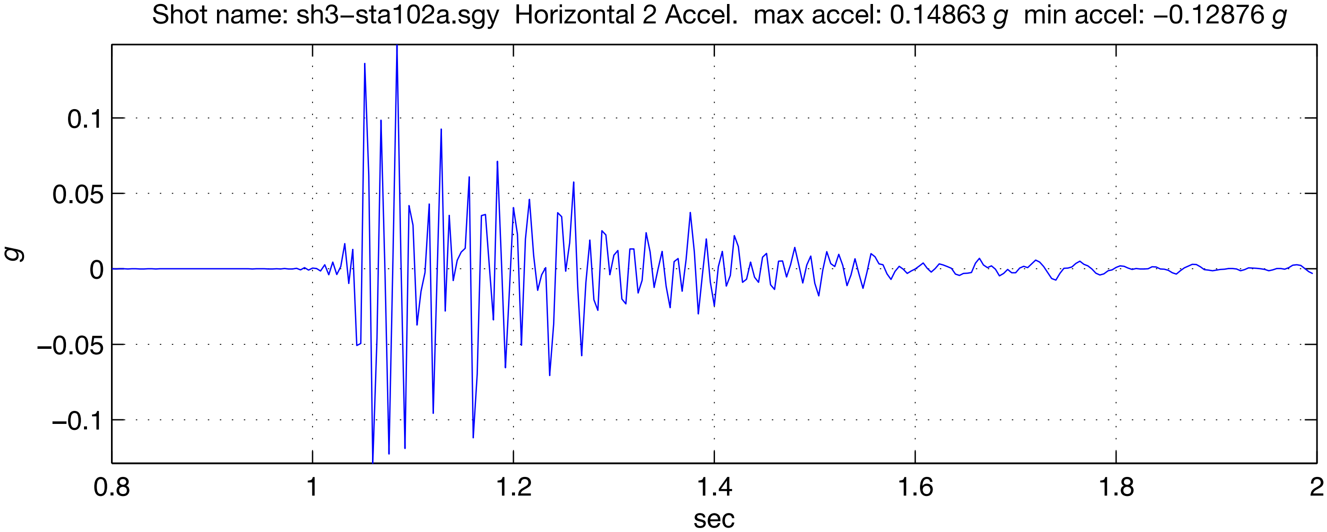
Shot name: sh3−sta102a.sgy Vertical Accel. max accel: 0.54318 *g* min accel: −0.42587 *g*

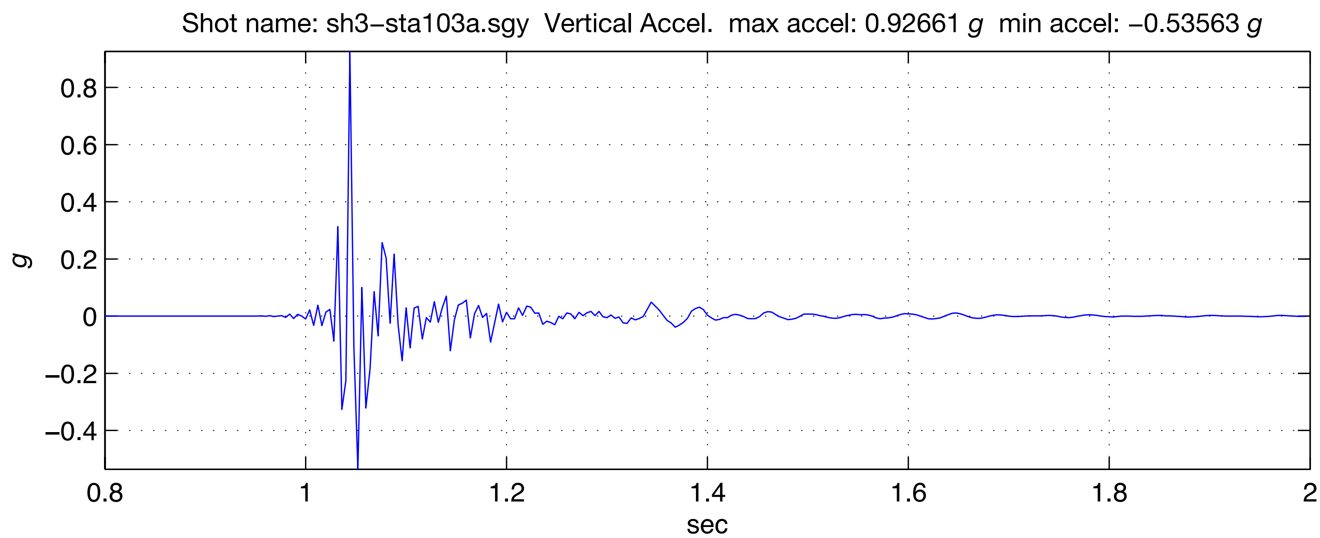


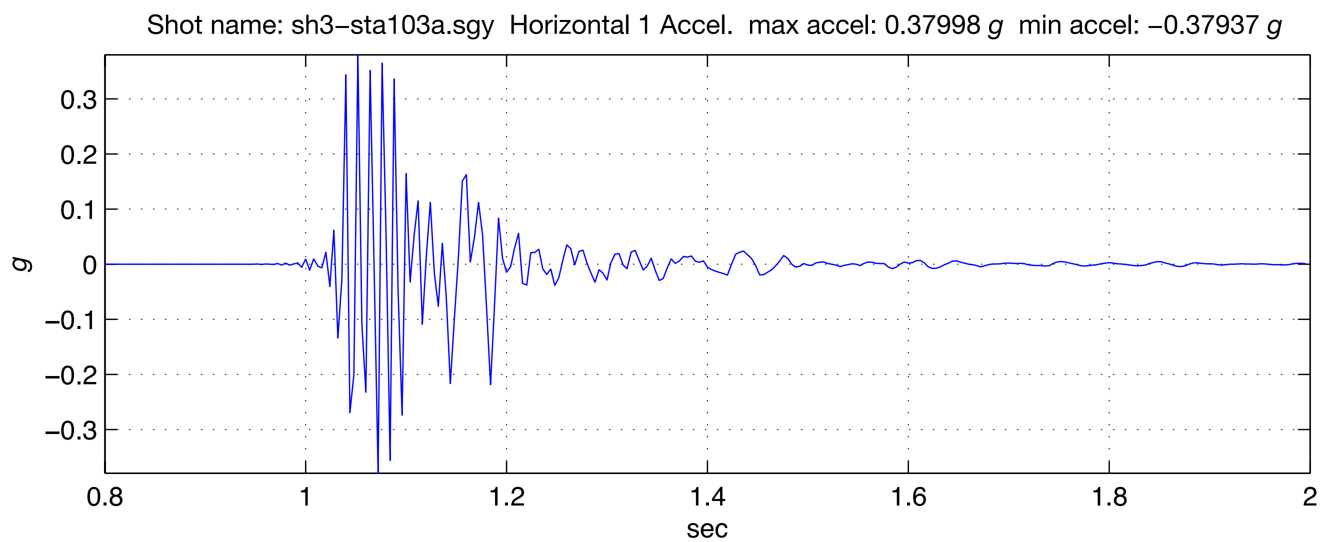
Shot name: sh3−sta102a.sgy Horizontal 1 Accel. max accel: 0.29632 *g* min accel: −0.27405 *g*

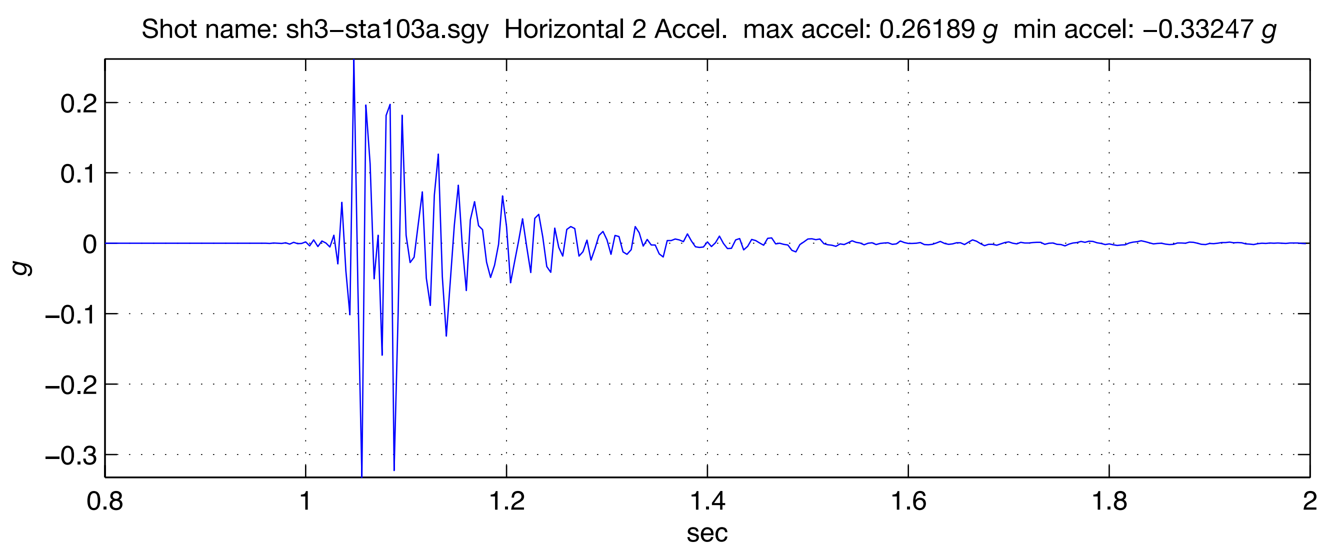


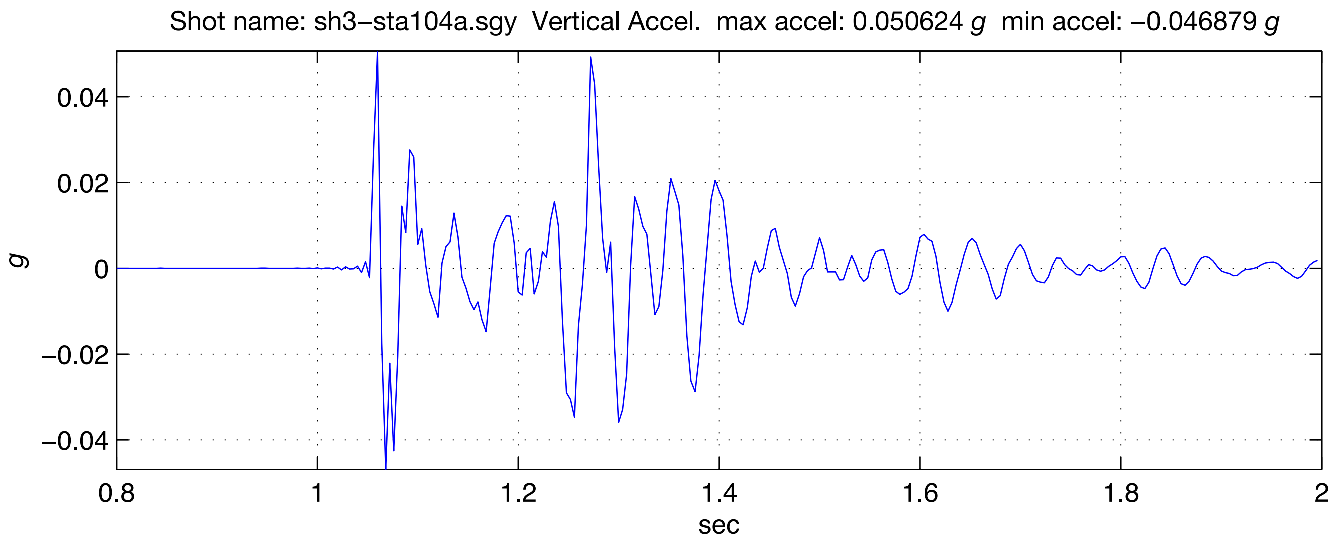
Shot name: sh3−sta102a.sgy Horizontal 2 Accel. max accel: 0.14863 *g* min accel: −0.12876 *g*

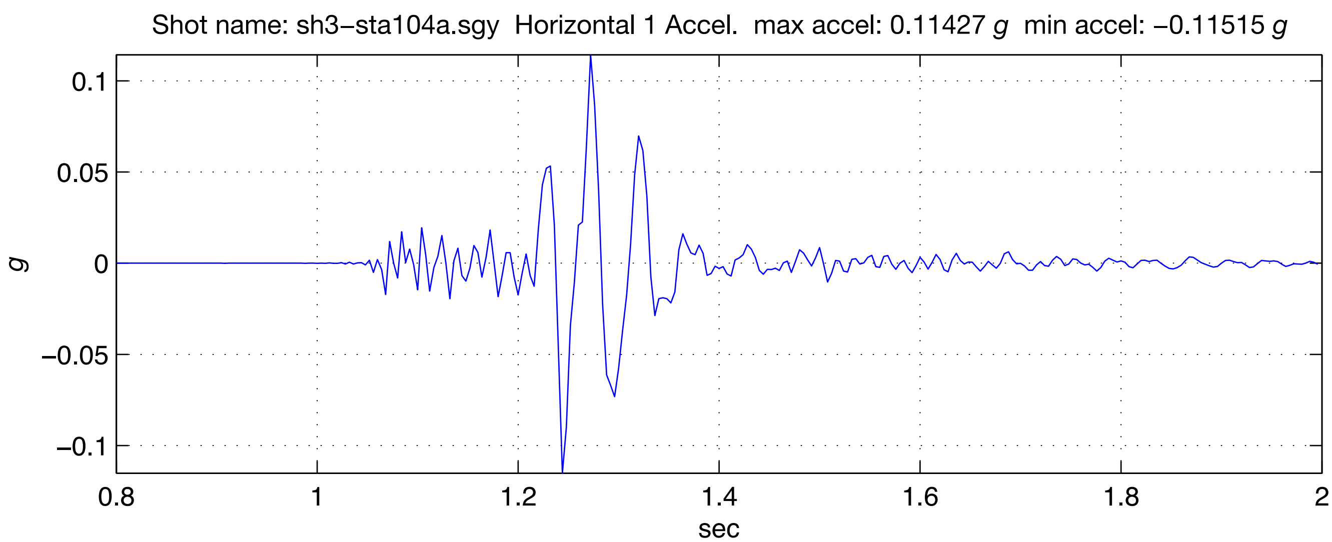


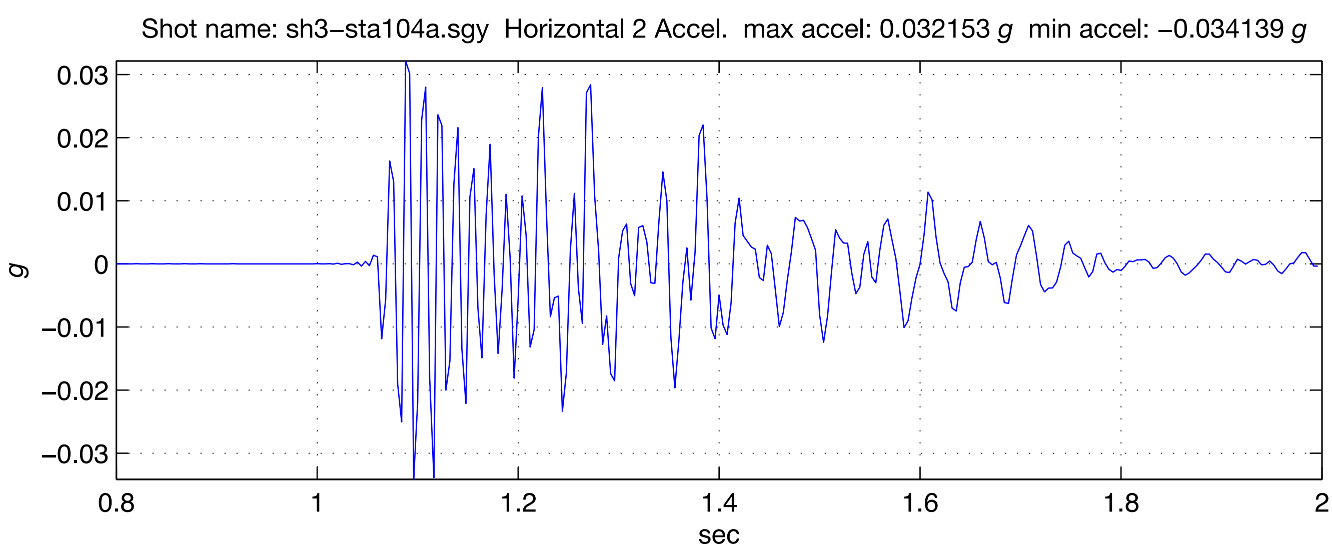

Shot name: sh3−sta103a.sgy Vertical Accel. max accel: 0.92661 g min accel: −0.53563 g
g
0.8
0.6
0.4
0.2
0
−0.2
−0.4
0.8
1
1.2
1.4
1.6
1.8
2
sec

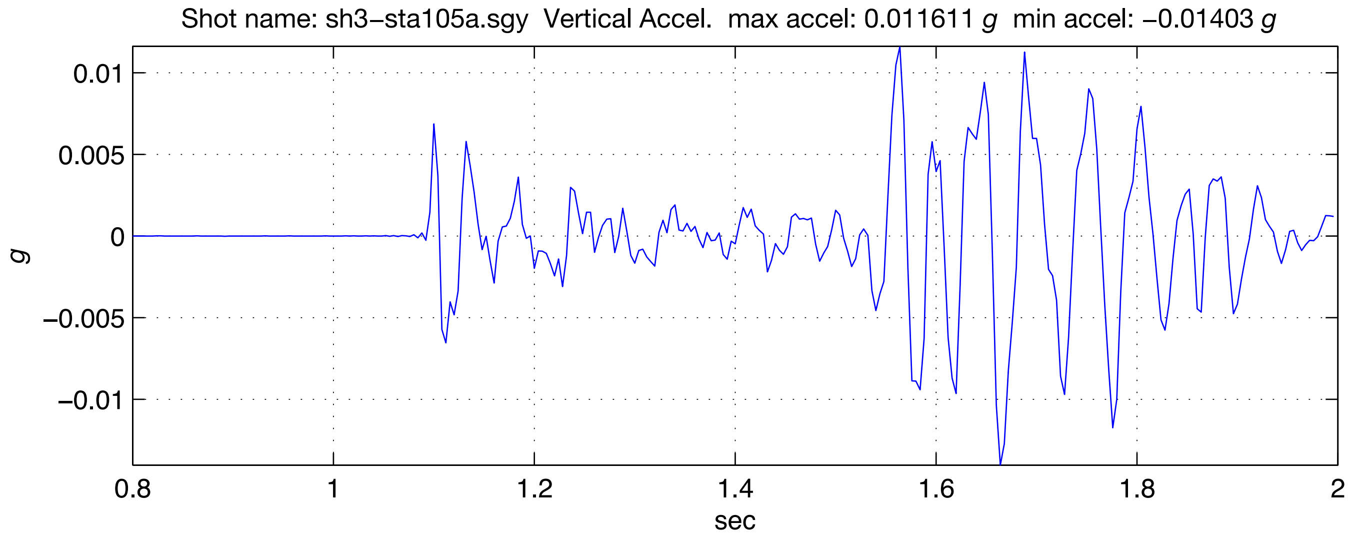

Shot name: sh3−sta103a.sgy Horizontal 1 Accel. max accel: 0.37998 g min accel: −0.37937 g
g
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
0.8
1
1.2
1.4
1.6
1.8
2
sec

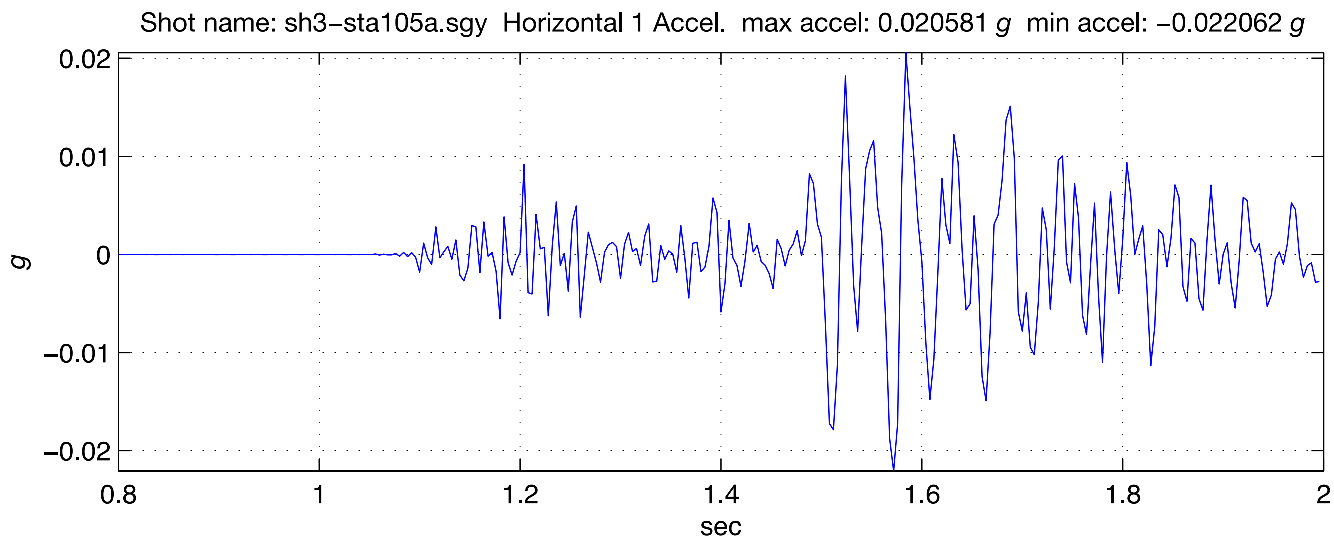

Shot name: sh3−sta103a.sgy Horizontal 2 Accel. max accel: 0.26189 g min accel: −0.33247 g
g
0.2
0.1
0
−0.1
−0.2
−0.3
0.8
1
1.2
1.4
1.6
1.8
2
sec

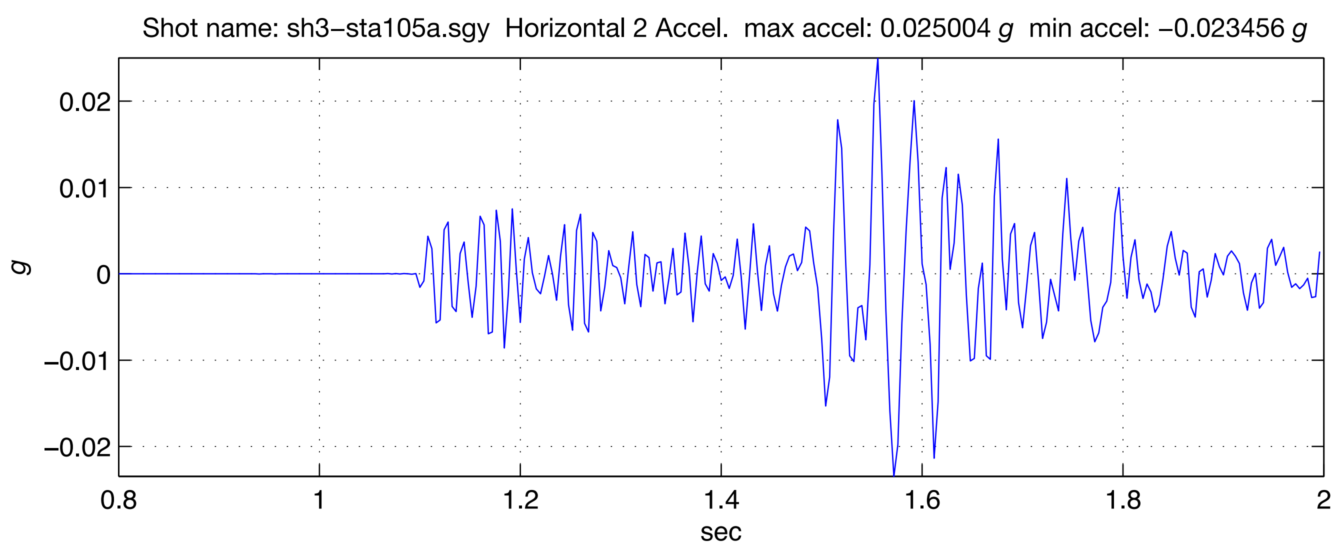

Shot name: sh3−sta104a.sgy Vertical Accel. max accel: 0.050624 g min accel: −0.046879 g
0.04
0.02
0
−0.02
−0.04
g
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh3−sta104a.sgy Horizontal 1 Accel. max accel: 0.11427 g min accel: −0.11515 g
0.1
0.05
0
−0.05
−0.1
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

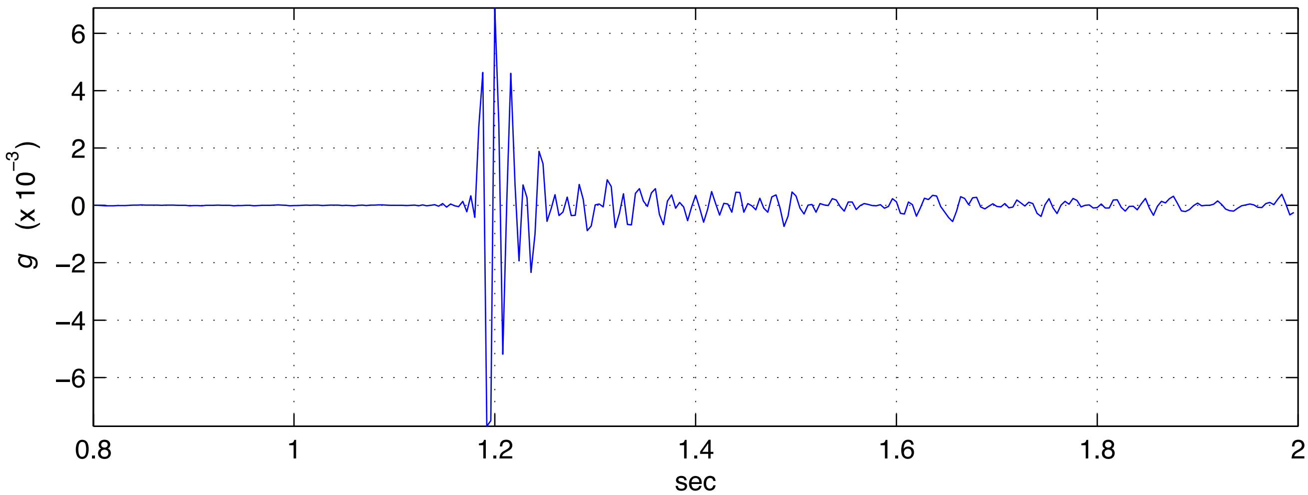

Shot name: sh3−sta104a.sgy Horizontal 2 Accel. max accel: 0.032153 g min accel: −0.034139 g
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
g
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh3−sta105a.sgy Vertical Accel. max accel: 0.011611 g min accel: −0.01403 g
0.01
0.005
0
−0.005
−0.01
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

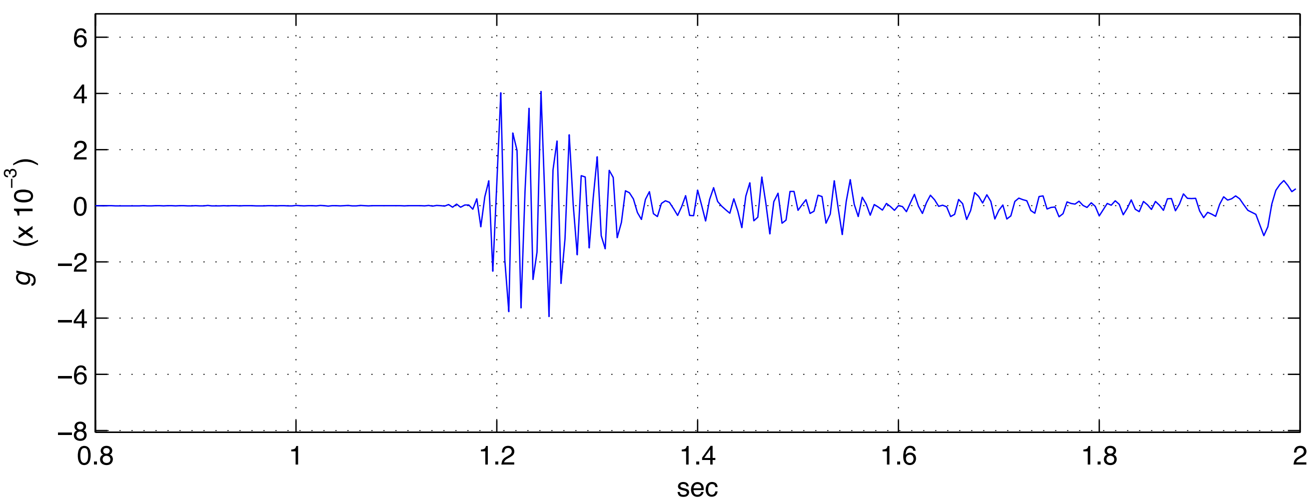

Shot name: sh3−sta105a.sgy Horizontal 1 Accel. max accel: 0.020581 g min accel: −0.022062 g
0.02
0.01
0
−0.01
−0.02
g
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh3−sta105a.sgy Horizontal 2 Accel. max accel: 0.025004 g min accel: −0.023456 g
0.02
0.01
0
−0.01
−0.02
g
0.8
1
1.2
1.4
1.6
1.8
2
sec

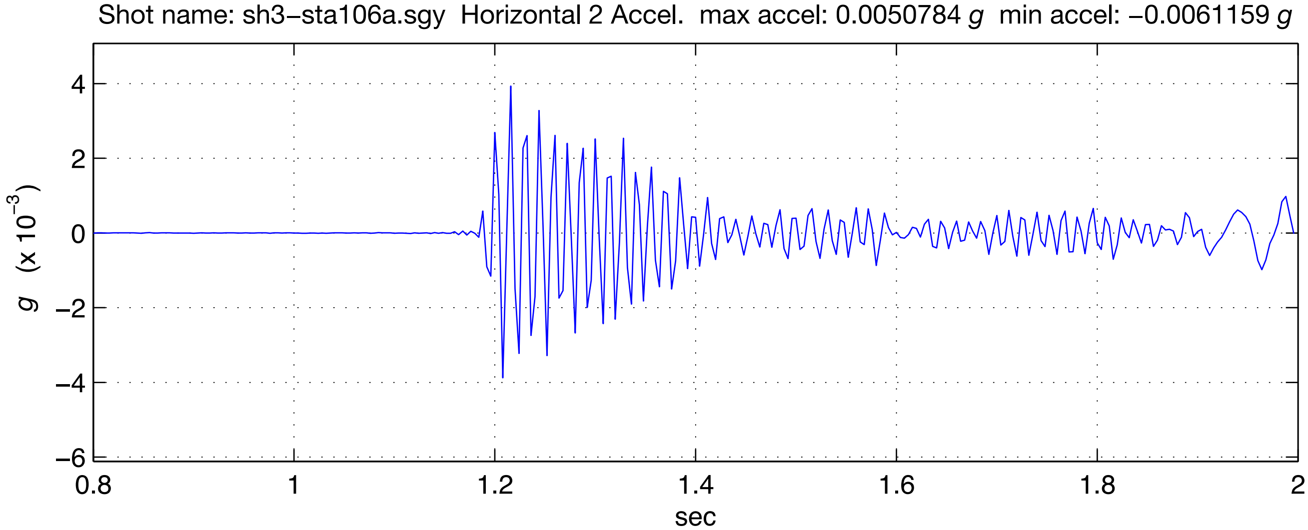
Shot name: sh3−sta106a.sgy Vertical Accel. max accel: 0.0068849 *g* min accel: −0.0076941 *g*



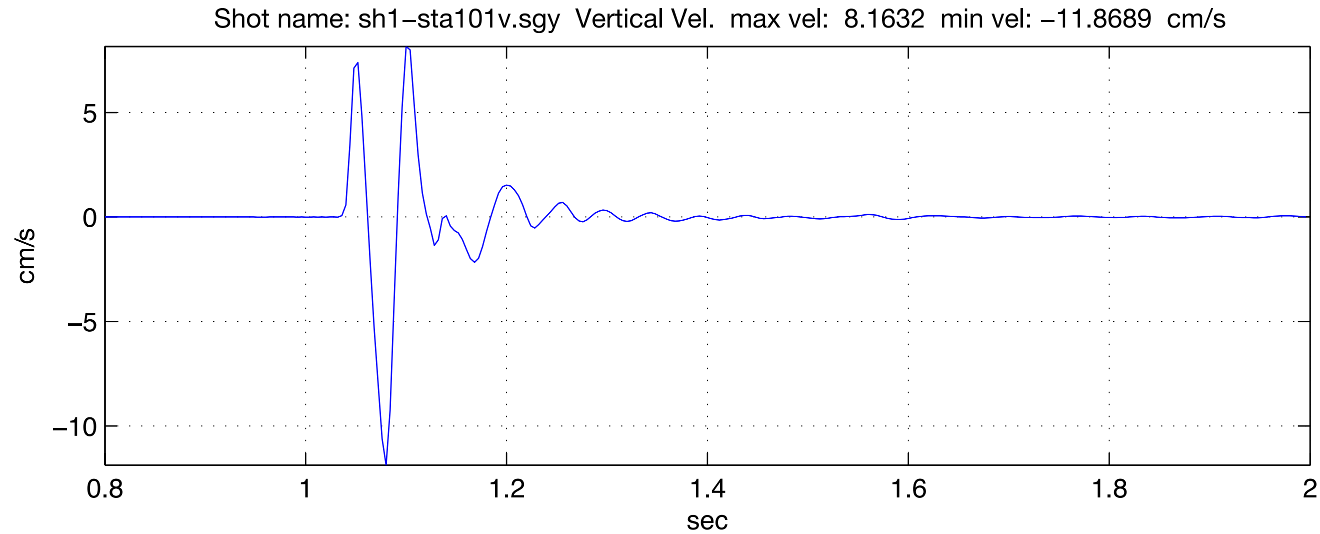
Shot name: sh3−sta106a.sgy Horizontal 1 Accel. max accel: 0.0068325 *g* min accel: −0.0080585 *g*

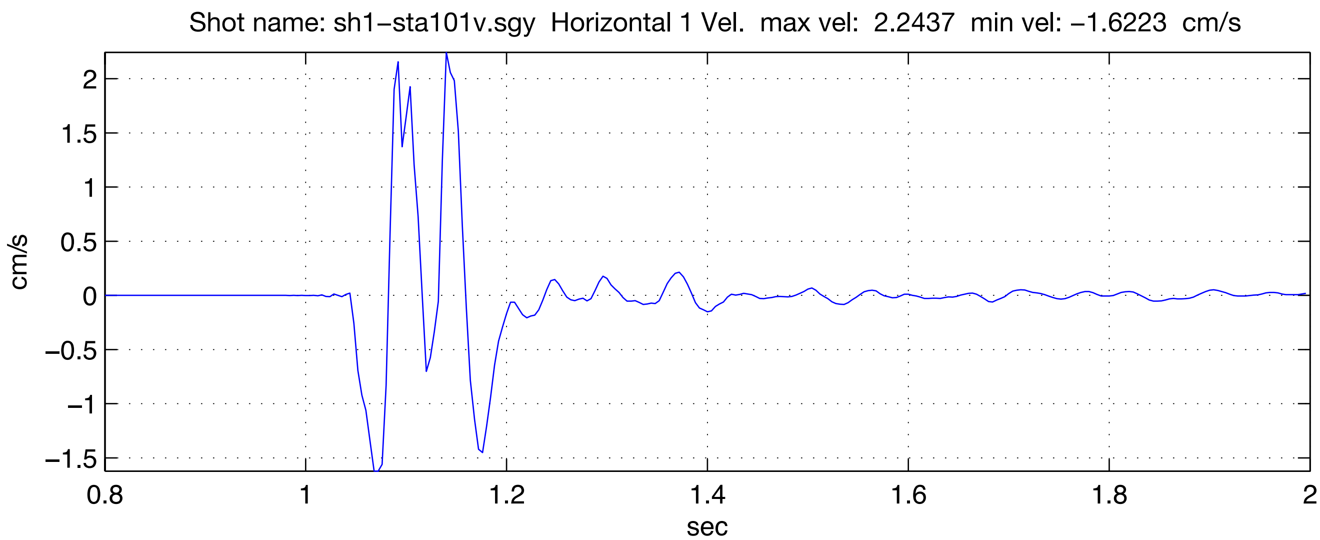


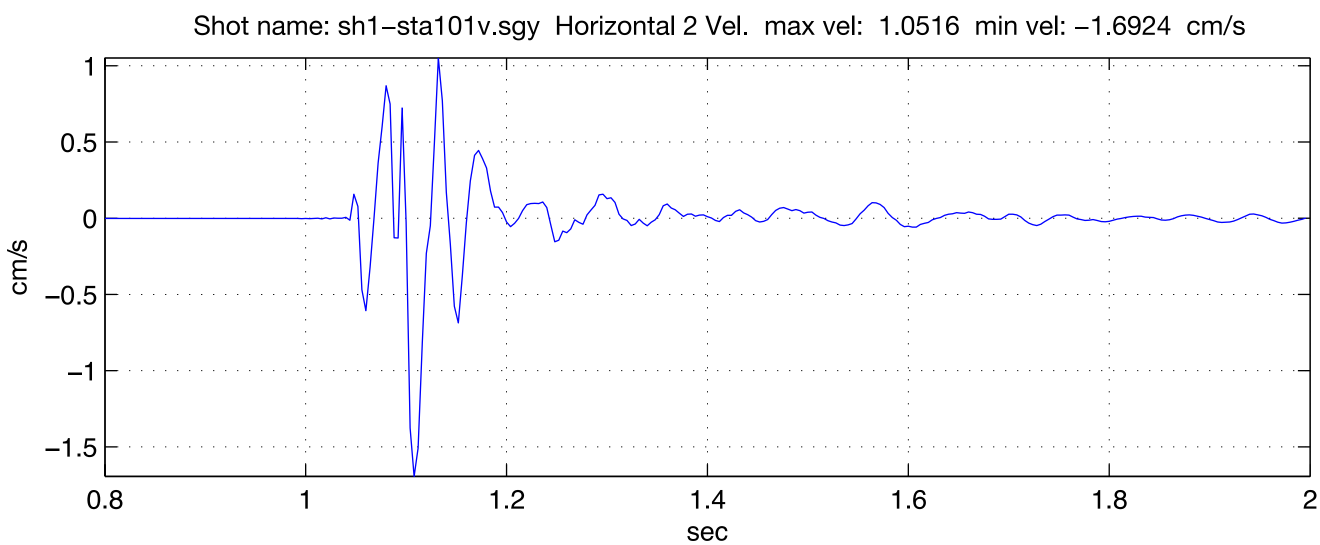
Shot name: sh3−sta106a.sgy Horizontal 2 Accel. max accel: 0.0050784 *g* min accel: −0.0061159 *g*

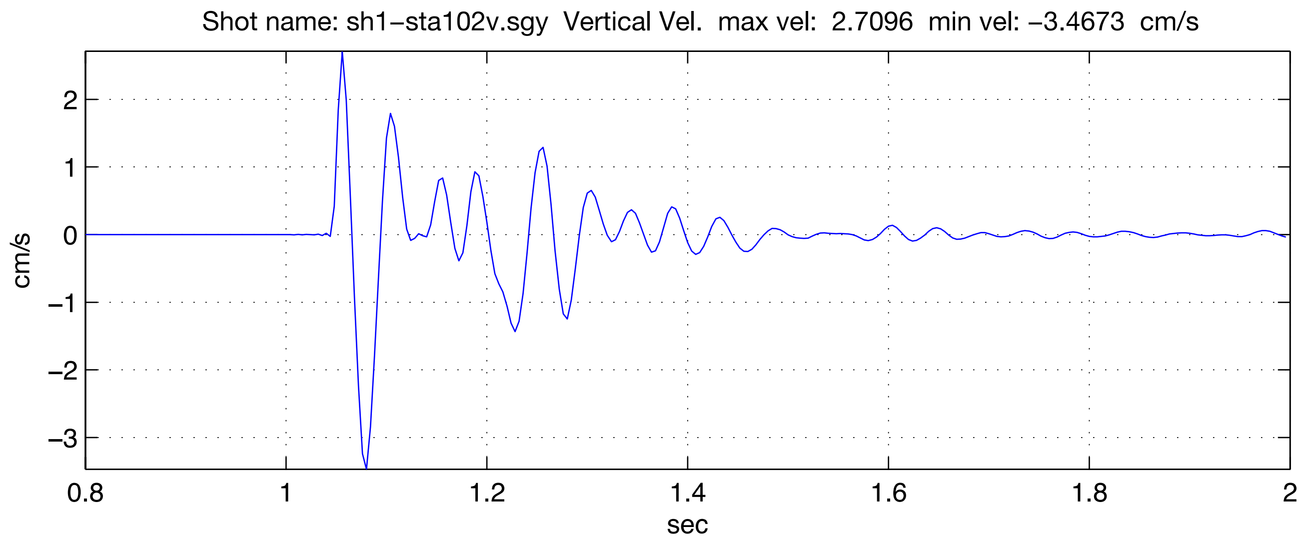


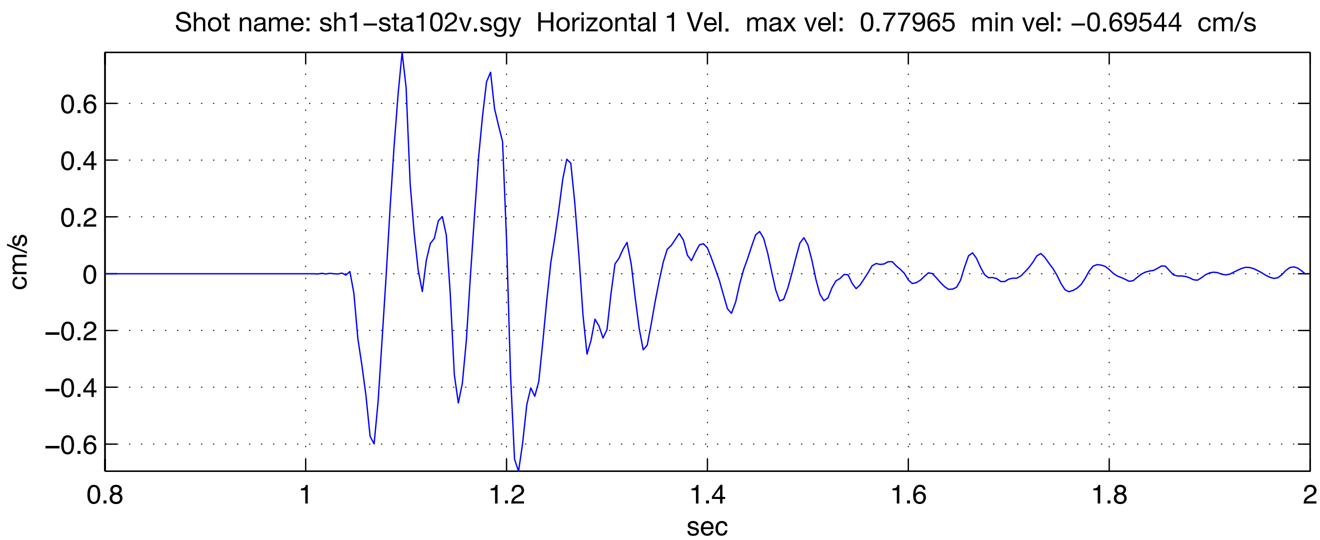
Appendix 3b. Near Source Velocity Plots
[From 6-component RefTeks]

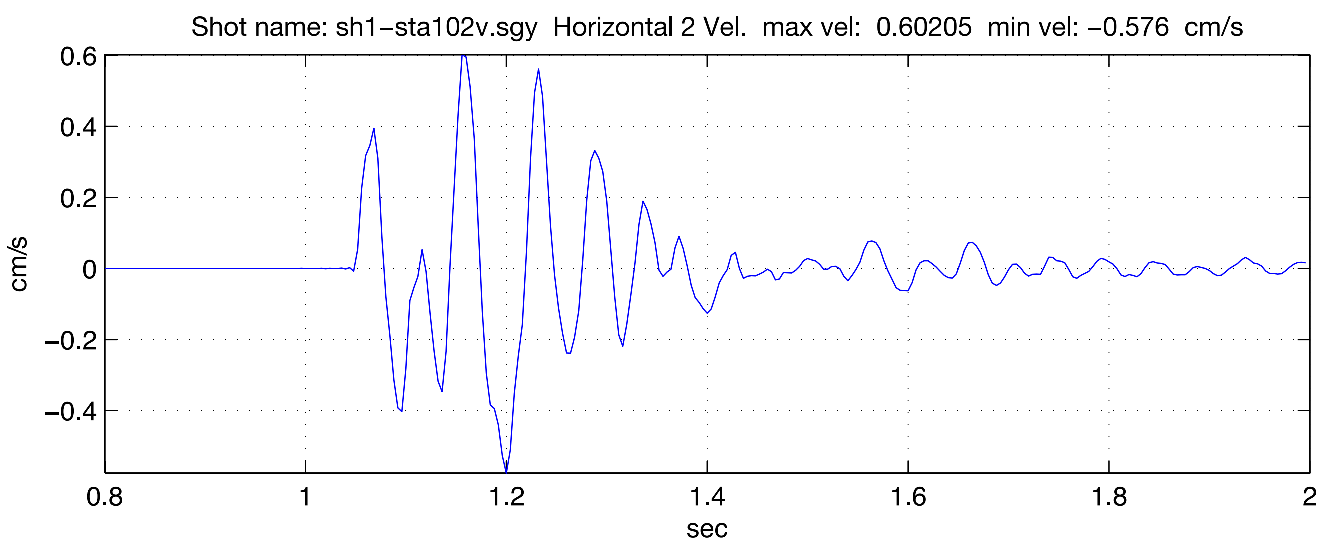

Shot name: sh1−sta101v.sgy Vertical Vel. max vel: 8.1632 min vel: −11.8689 cm/s
cm/s
5
0
−5
−10
0.8
1
1.2
1.4
1.6
1.8
2
sec

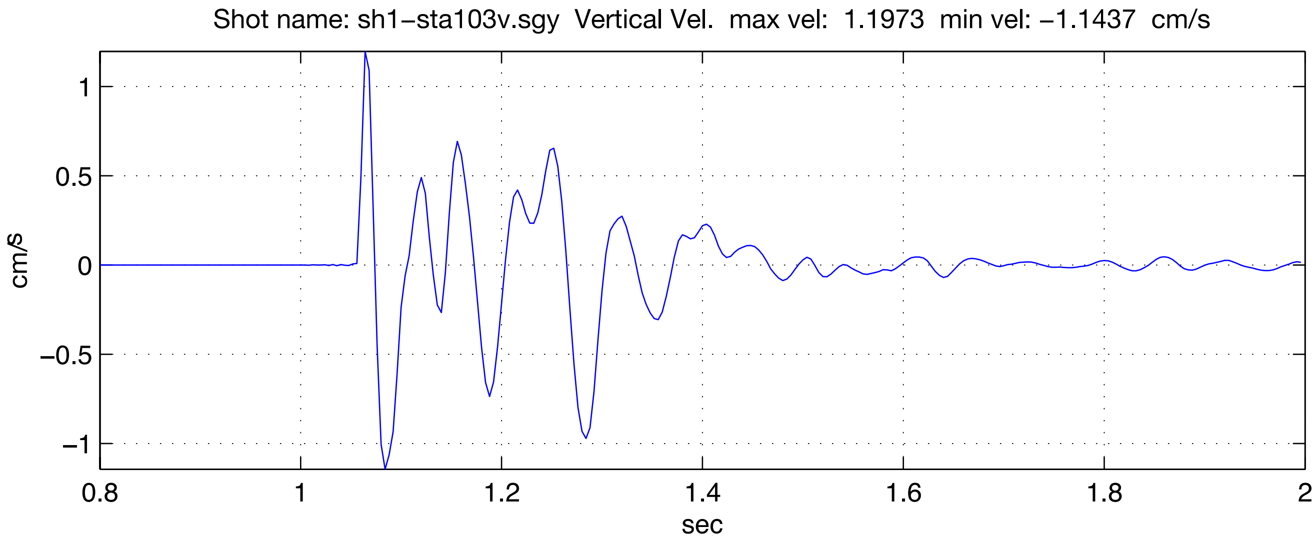

Shot name: sh1−sta101v.sgy Horizontal 1 Vel. max vel: 2.2437 min vel: −1.6223 cm/s
cm/s
2
1.5
1
0.5
0
−0.5
−1
−1.5
0.8
1
1.2
1.4
1.6
1.8
2
sec

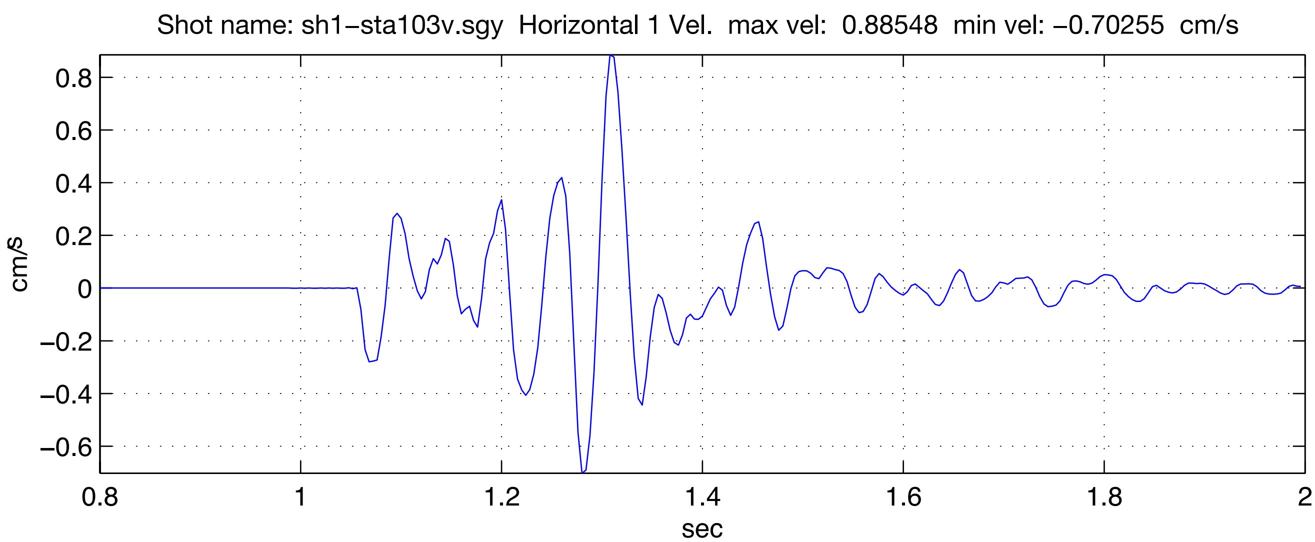

Shot name: sh1−sta101v.sgy Horizontal 2 Vel. max vel: 1.0516 min vel: −1.6924 cm/s
cm/s
1
0.5
0
−0.5
−1
−1.5
0.8
1
1.2
1.4
1.6
1.8
2
sec

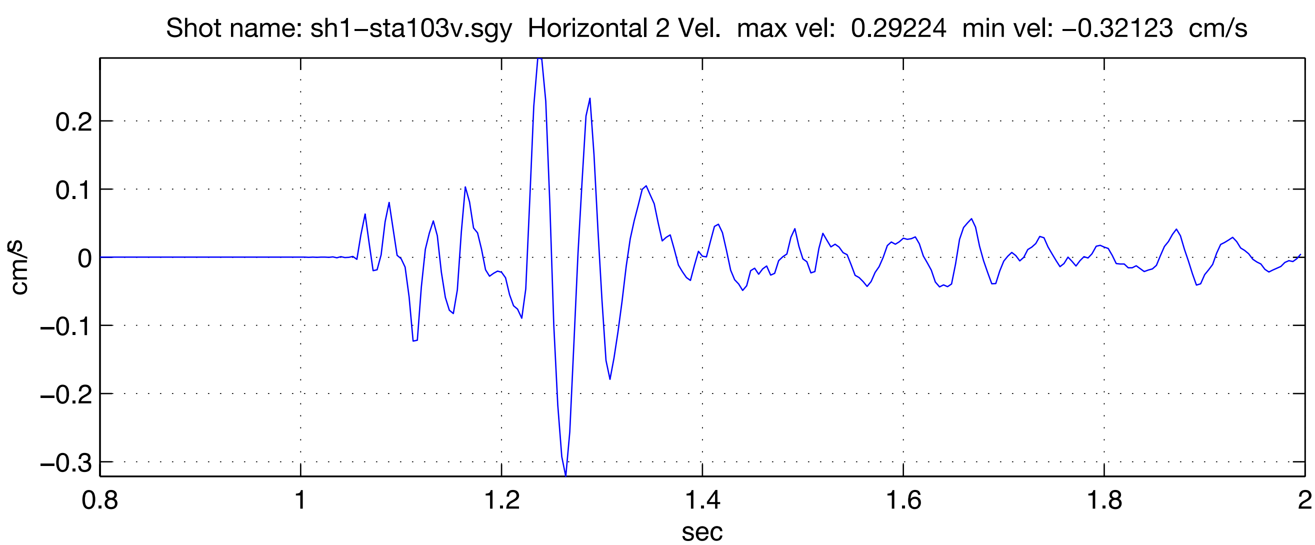

Shot name: sh1−sta102v.sgy Vertical Vel. max vel: 2.7096 min vel: −3.4673 cm/s
cm/s
2
1
0
−1
−2
−3
0.8
1
1.2
1.4
1.6
1.8
2
sec

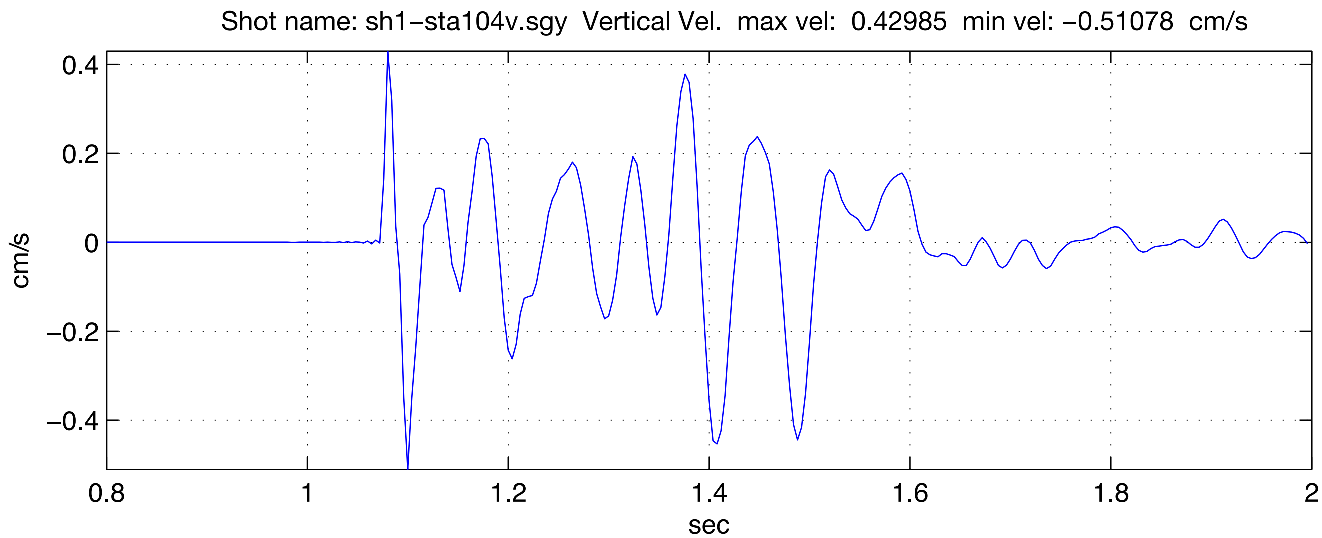

Shot name: sh1−sta102v.sgy Horizontal 1 Vel. max vel: 0.77965 min vel: −0.69544 cm/s
cm/s
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
0.8
1
1.2
1.4
1.6
1.8
2
sec

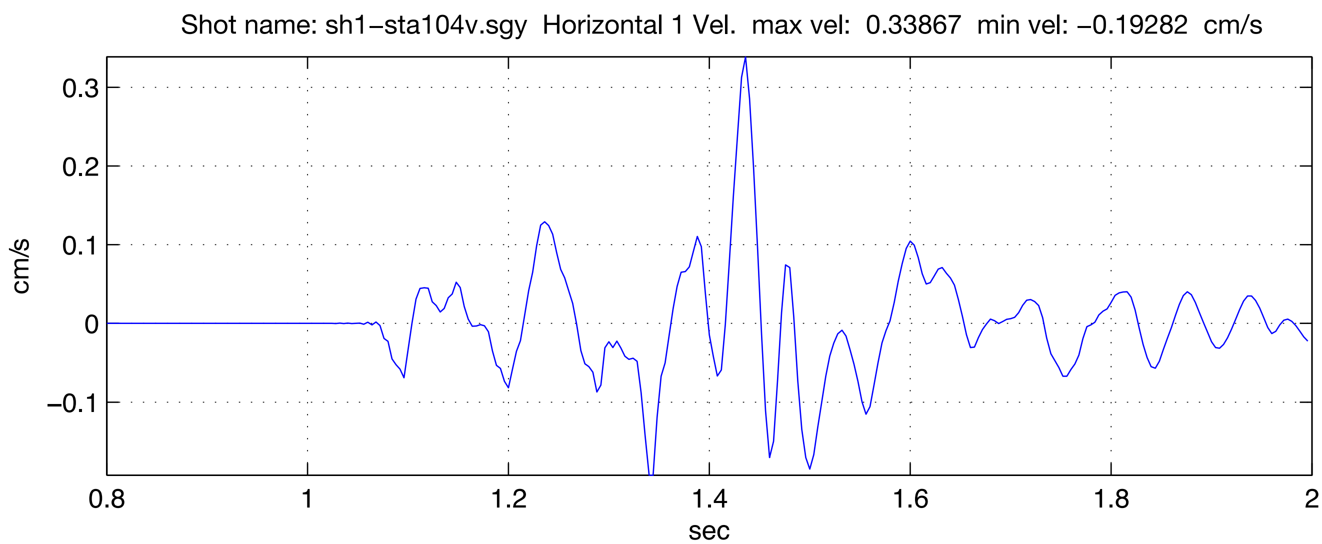

Shot name: sh1−sta102v.sgy Horizontal 2 Vel. max vel: 0.60205 min vel: −0.576 cm/s
cm/s
0.6
0.4
0.2
0
−0.2
−0.4
0.8
1
1.2
1.4
1.6
1.8
2
sec

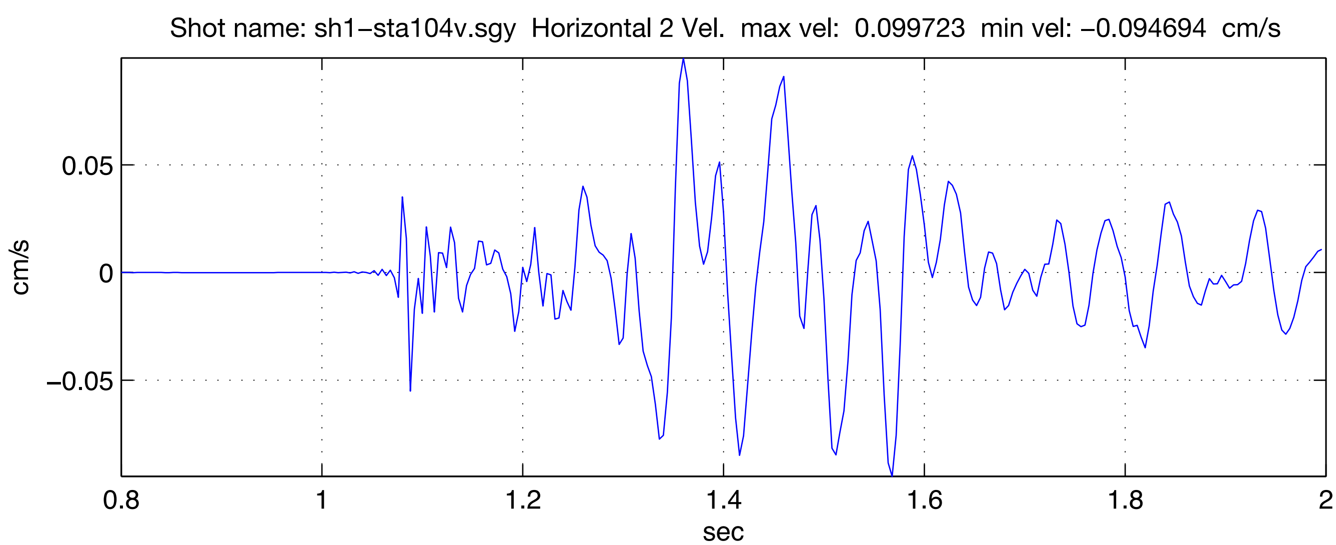

Shot name: sh1−sta103v.sgy Vertical Vel. max vel: 1.1973 min vel: −1.1437 cm/s
cm/s
1
0.5
0
−0.5
−1
0.8
1
1.2
1.4
1.6
1.8
2
sec

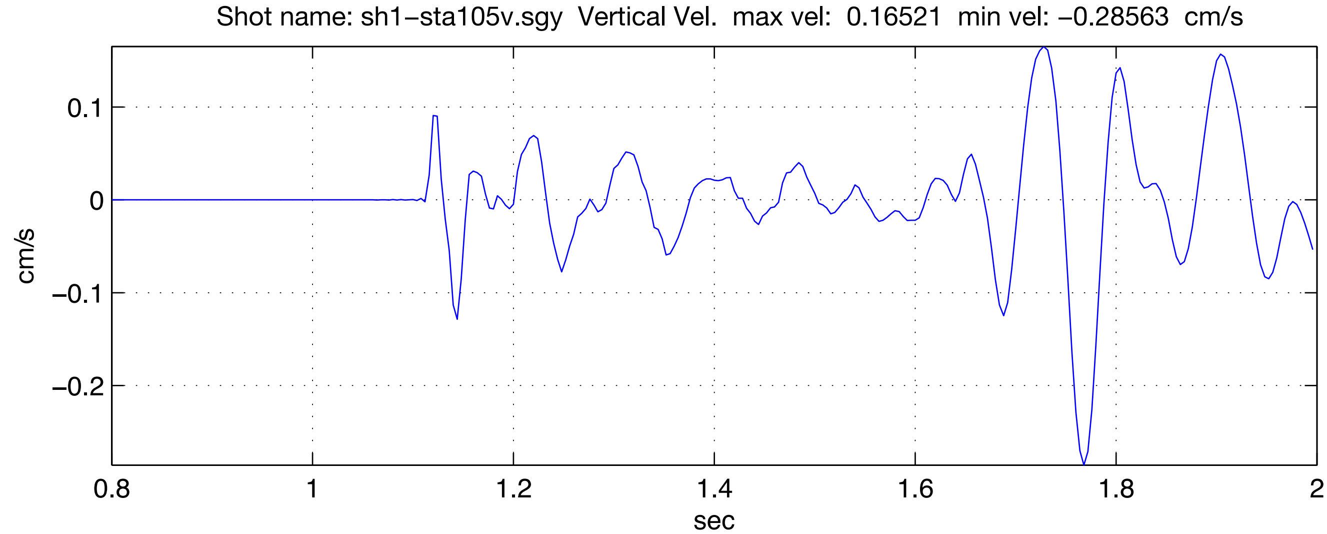

Shot name: sh1−sta103v.sgy Horizontal 1 Vel. max vel: 0.88548 min vel: −0.70255 cm/s
cm/s
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
0.8
1
1.2
1.4
1.6
1.8
2
sec

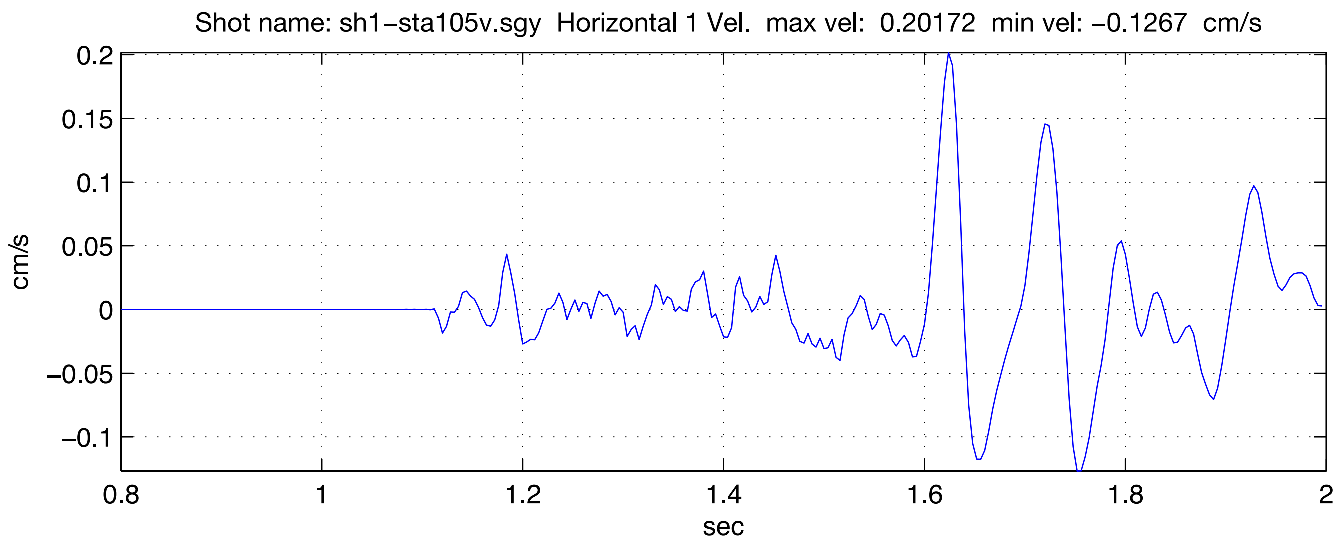

Shot name: sh1−sta103v.sgy Horizontal 2 Vel. max vel: 0.29224 min vel: −0.32123 cm/s
cm/s
0.2
0.1
0
−0.1
−0.2
−0.3
0.8
1
1.2
1.4
1.6
1.8
2
sec

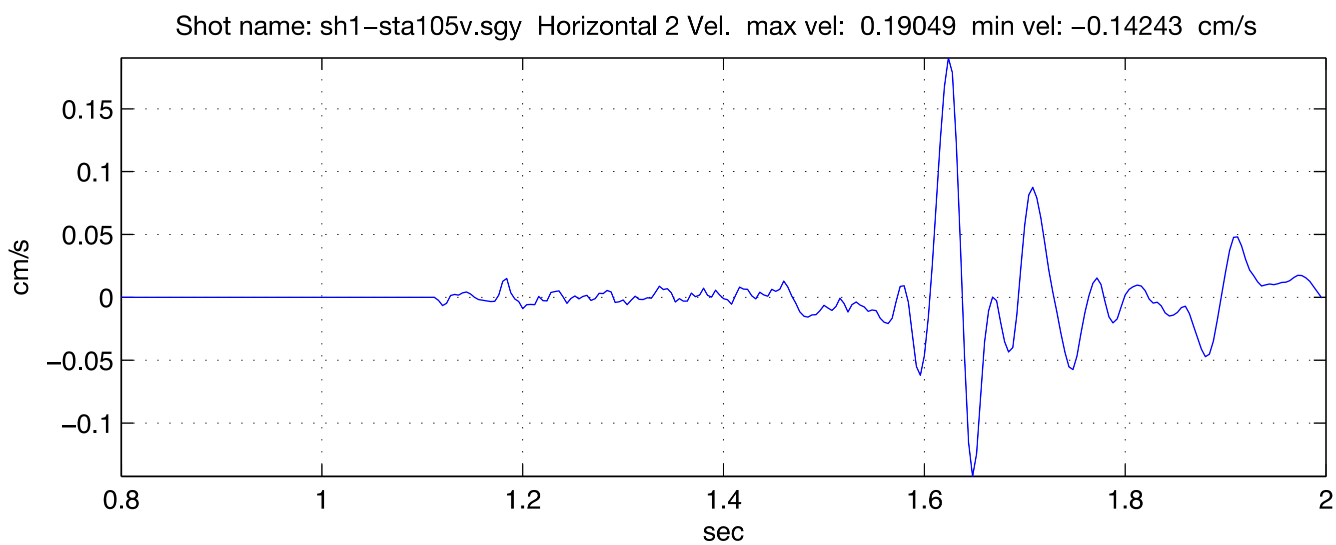

Shot name: sh1−sta104v.sgy Vertical Vel. max vel: 0.42985 min vel: −0.51078 cm/s
cm/s
0.4
0.2
0
−0.2
−0.4
0.8
1
1.2
1.4
1.6
1.8
2
sec

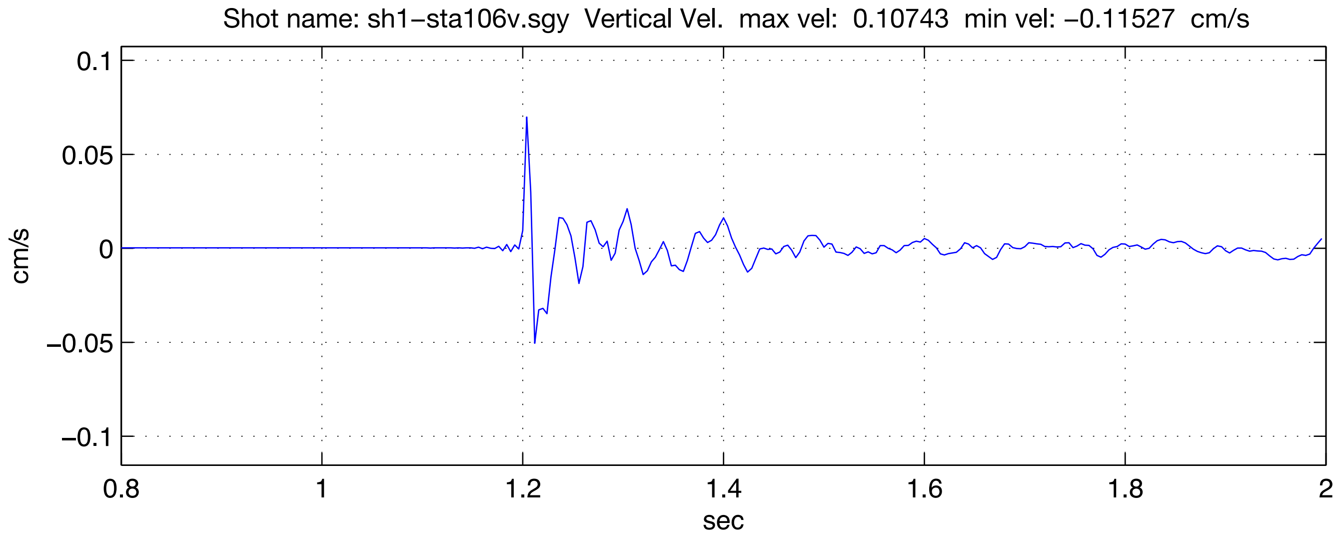

Shot name: sh1−sta104v.sgy Horizontal 1 Vel. max vel: 0.33867 min vel: −0.19282 cm/s
cm/s
0.3
0.2
0.1
0
−0.1
0.8
1
1.2
1.4
1.6
1.8
2
sec

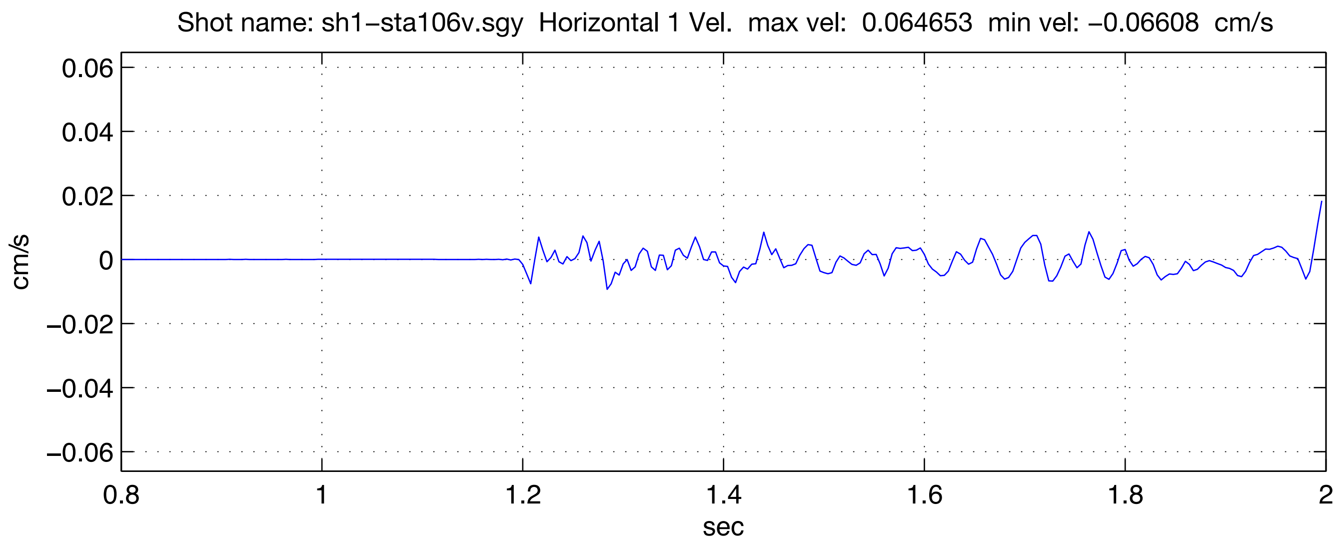

Shot name: sh1−sta104v.sgy Horizontal 2 Vel. max vel: 0.099723 min vel: −0.094694 cm/s
cm/s
0.05
0
−0.05
0.8
1
1.2
1.4
1.6
1.8
2
sec

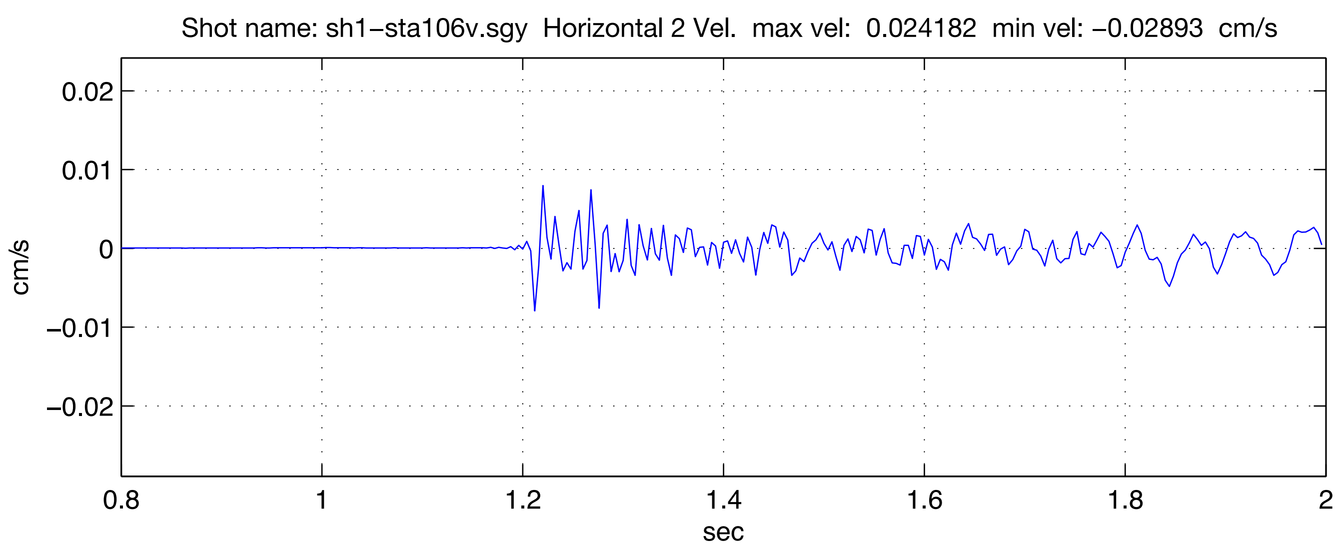

Shot name: sh1−sta105v.sgy Vertical Vel. max vel: 0.16521 min vel: −0.28563 cm/s
cm/s
0.1
0
−0.1
−0.2
0.8
1
1.2
1.4
1.6
1.8
2
sec

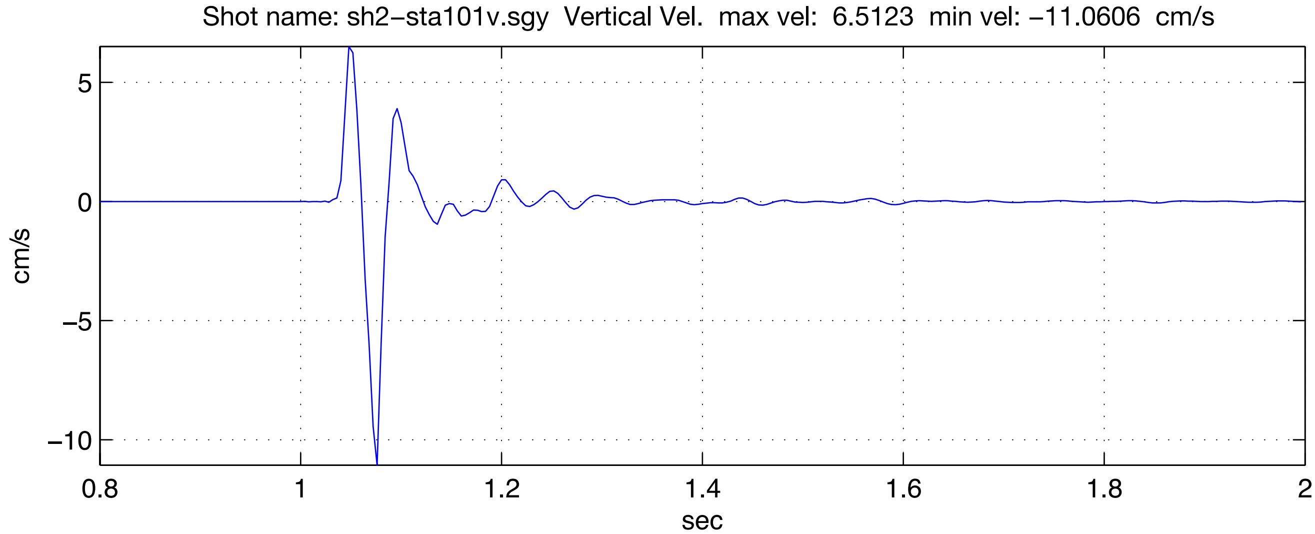

Shot name: sh1−sta105v.sgy Horizontal 1 Vel. max vel: 0.20172 min vel: −0.1267 cm/s
cm/s
0.2
0.15
0.1
0.05
0
−0.05
−0.1
0.8
1
1.2
1.4
1.6
1.8
2
sec

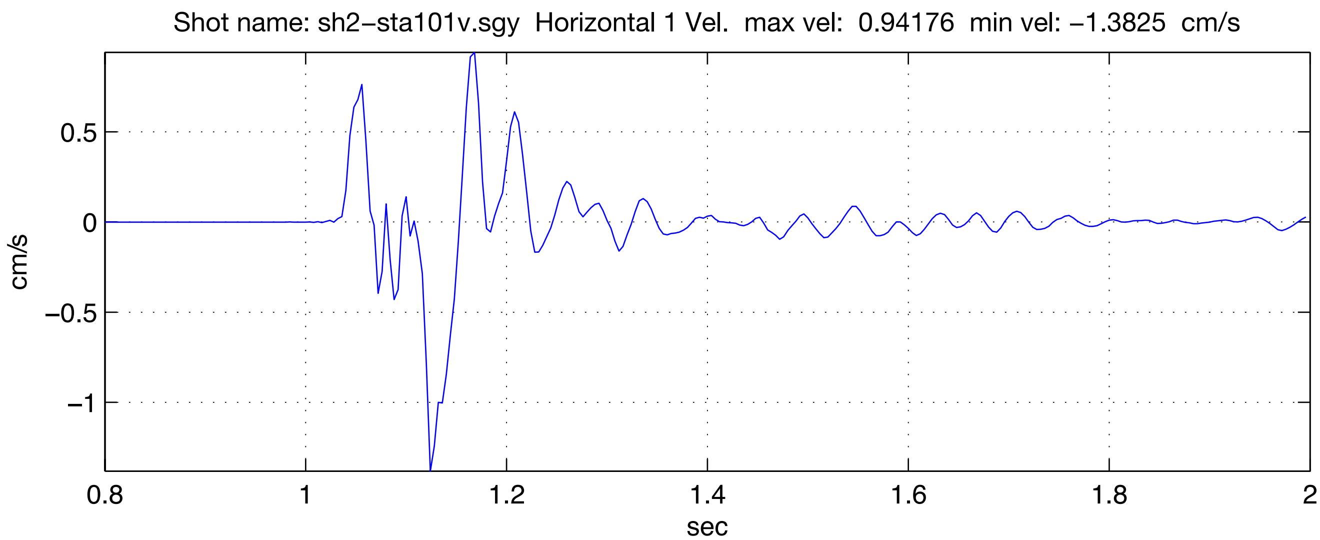

Shot name: sh1−sta105v.sgy Horizontal 2 Vel. max vel: 0.19049 min vel: −0.14243 cm/s
cm/s
0.15
0.1
0.05
0
−0.05
−0.1
0.8
1
1.2
1.4
1.6
1.8
2
sec

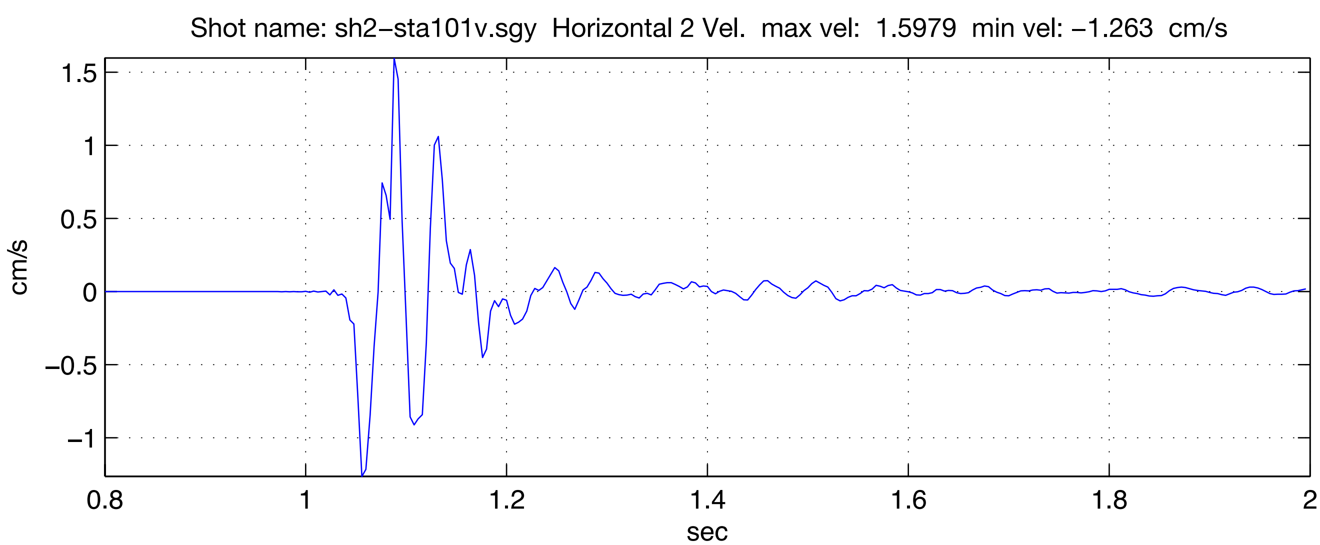

Shot name: sh1−sta106v.sgy Vertical Vel. max vel: 0.10743 min vel: −0.11527 cm/s
0.1
0.05
0
−0.05
−0.1
cm/s
0.8
1
1.2
1.4
1.6
1.8
2
sec

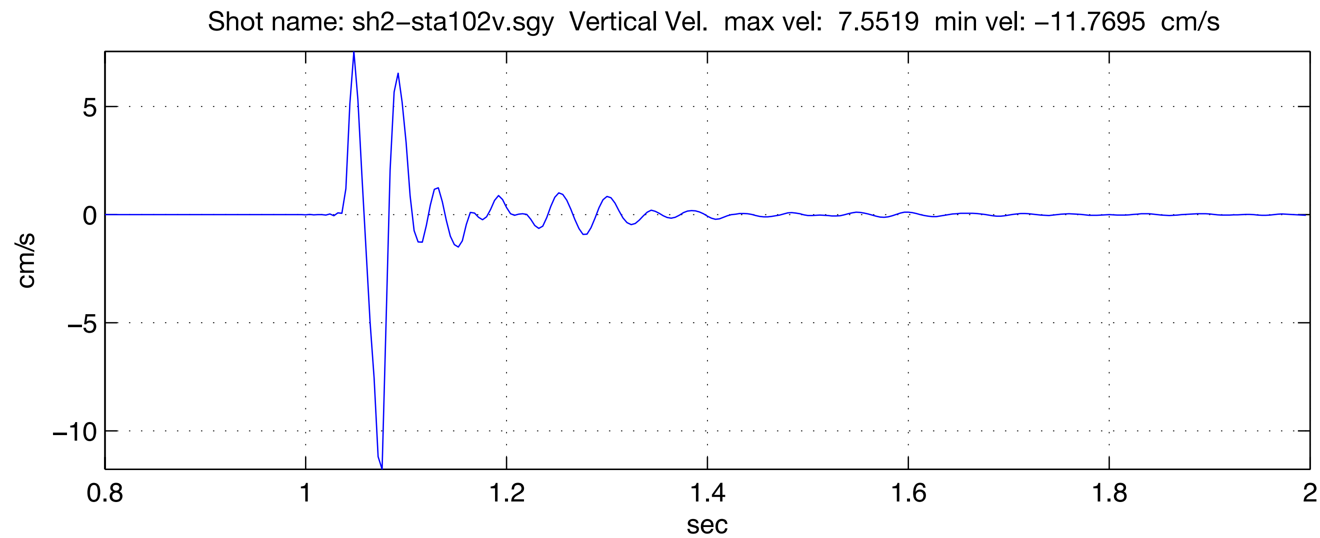

Shot name: sh1−sta106v.sgy Horizontal 1 Vel. max vel: 0.064653 min vel: −0.06608 cm/s
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
cm/s
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh1−sta106v.sgy Horizontal 2 Vel. max vel: 0.024182 min vel: −0.02893 cm/s
0.02
0.01
0
−0.01
−0.02
cm/s
0.8
1
1.2
1.4
1.6
1.8
2
sec

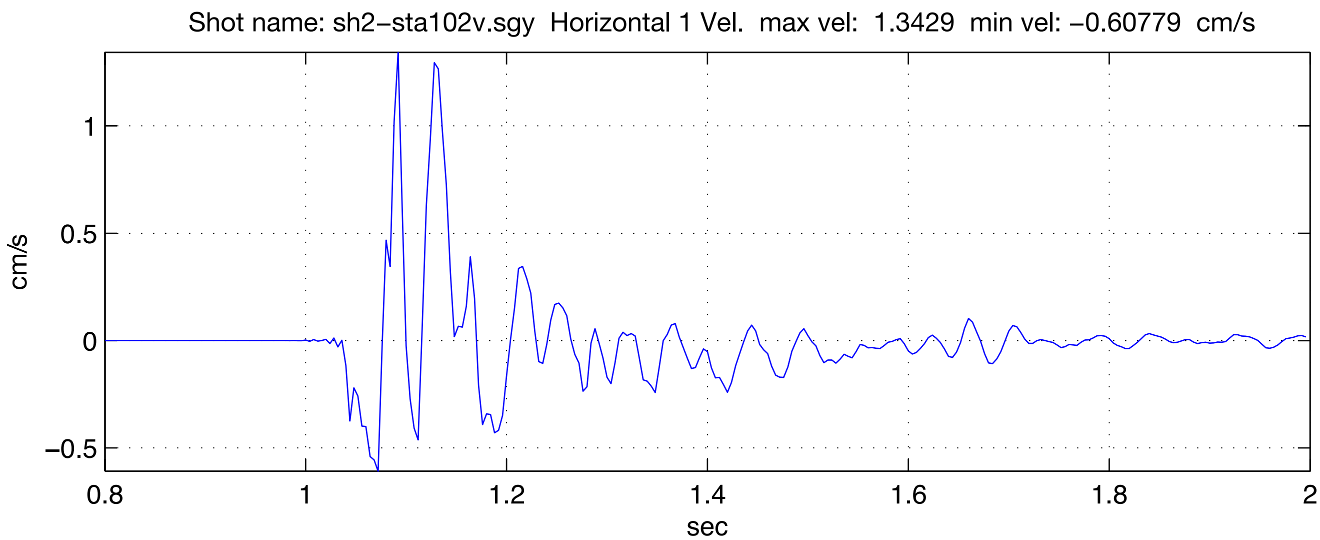

Shot name: sh2−sta101v.sgy Vertical Vel. max vel: 6.5123 min vel: −11.0606 cm/s
cm/s
5
0
−5
−10
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh2−sta101v.sgy Horizontal 1 Vel. max vel: 0.94176 min vel: −1.3825 cm/s
cm/s
0.5
0
−0.5
−1
0.8
1
1.2
1.4
1.6
1.8
2
sec

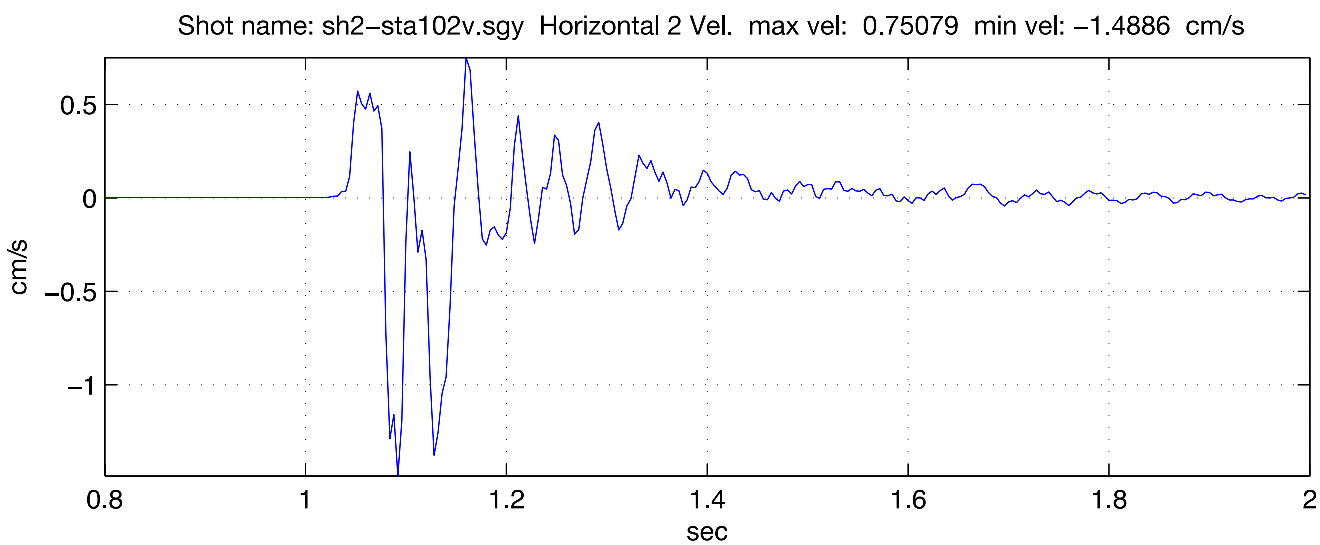

Shot name: sh2−sta101v.sgy Horizontal 2 Vel. max vel: 1.5979 min vel: −1.263 cm/s
cm/s
1.5
1
0.5
0
−0.5
−1
0.8
1
1.2
1.4
1.6
1.8
2
sec



Shot name: sh2−sta102v.sgy Vertical Vel. max vel: 7.5519 min vel: −11.7695 cm/s
cm/s
5
0
−5
−10
0.8
1
1.2
1.4
1.6
1.8
2
sec

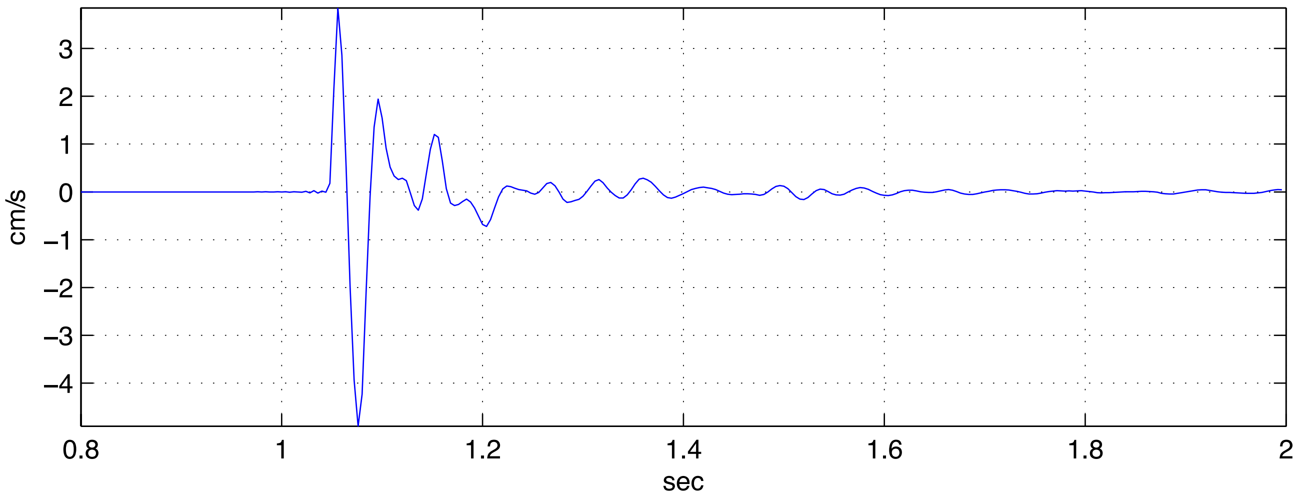


Shot name: sh2−sta102v.sgy Horizontal 1 Vel. max vel: 1.3429 min vel: −0.60779 cm/s
cm/s
1
0.5
0
−0.5
0.8
1
1.2
1.4
1.6
1.8
2
sec

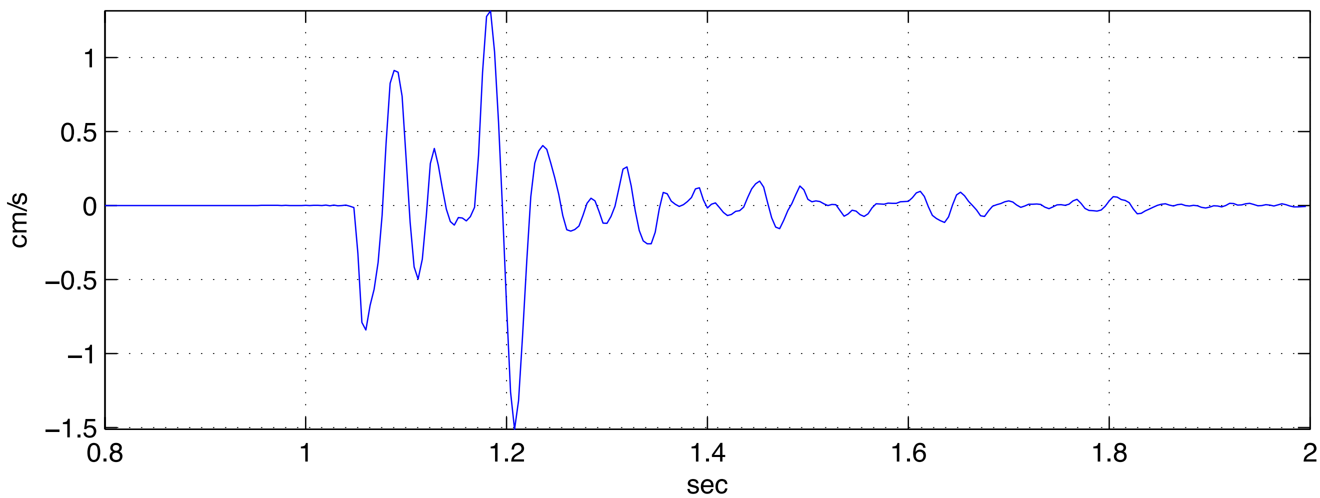


Shot name: sh2−sta102v.sgy Horizontal 2 Vel. max vel: 0.75079 min vel: −1.4886 cm/s
cm/s
0.5
0
−0.5
−1
0.8
1
1.2
1.4
1.6
1.8
2
sec

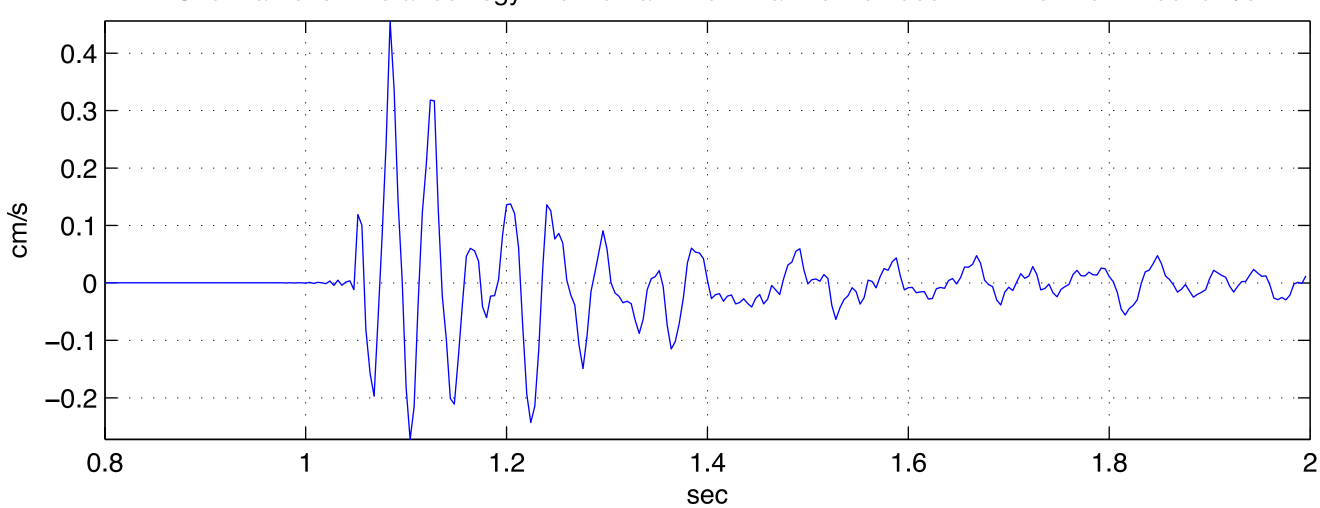
Shot name: sh2−sta103v.sgy Vertical Vel. max vel: 3.8488 min vel: −4.8978 cm/s



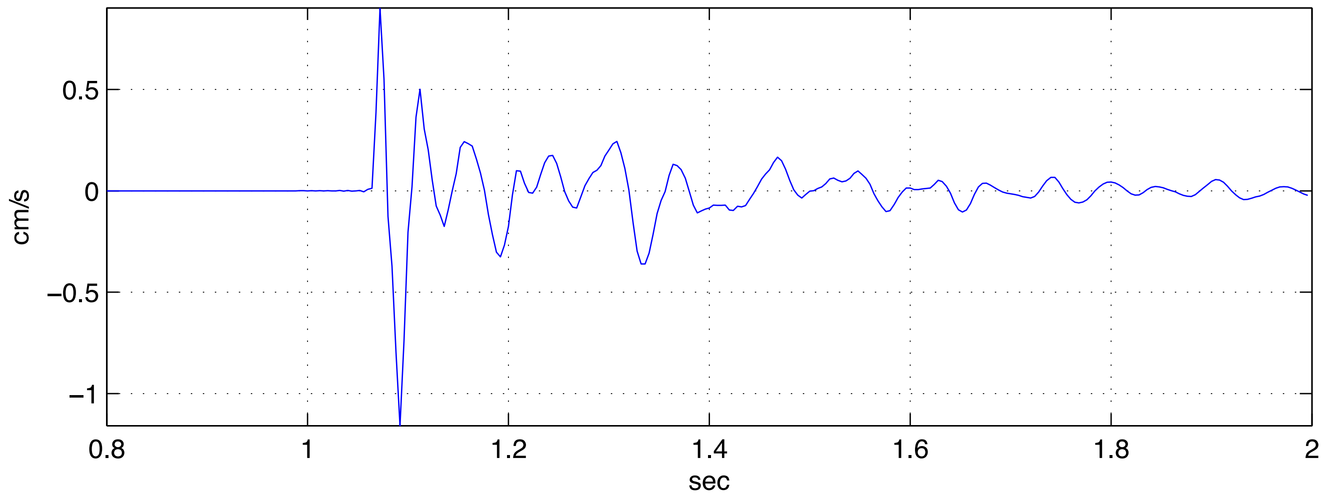
Shot name: sh2−sta103v.sgy Horizontal 1 Vel. max vel: 1.3154 min vel: −1.5118 cm/s



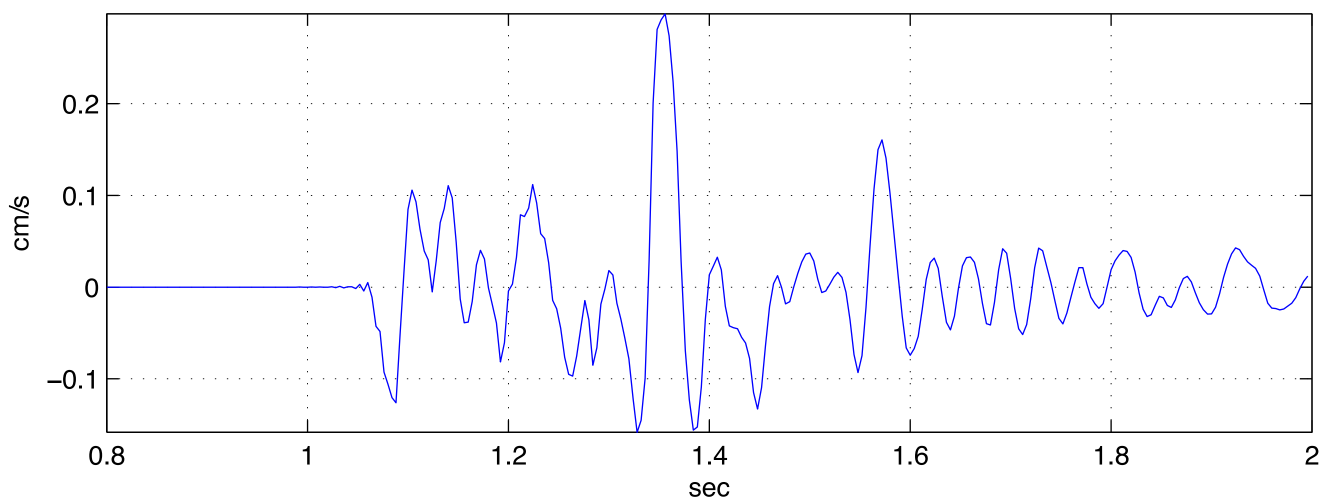
Shot name: sh2−sta103v.sgy Horizontal 2 Vel. max vel: 0.45631 min vel: −0.27236 cm/s



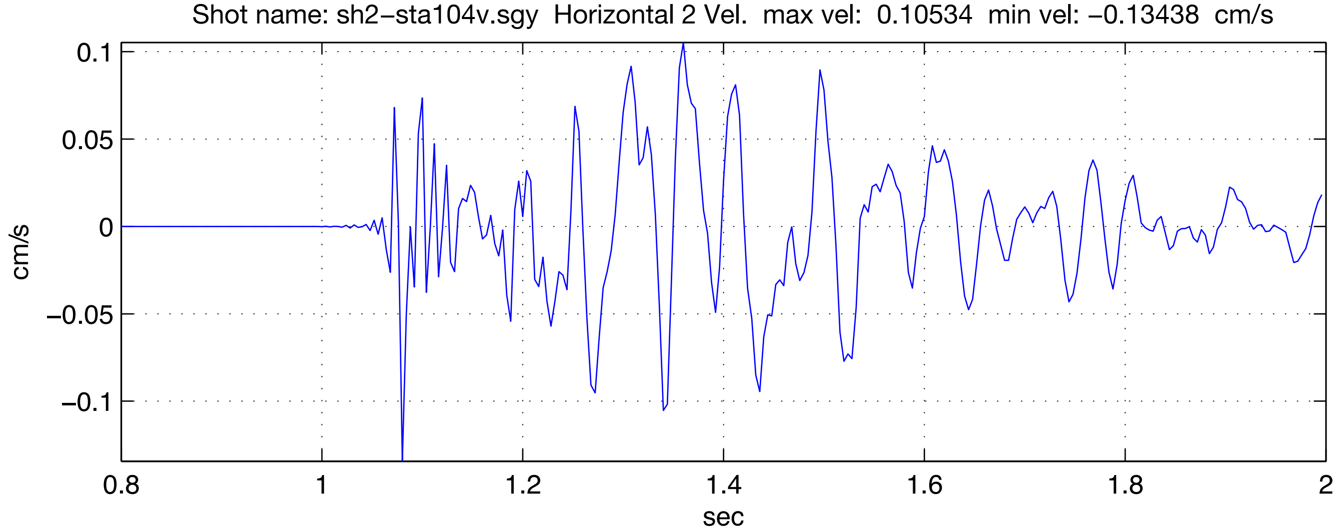
Shot name: sh2−sta104v.sgy Vertical Vel. max vel: 0.90221 min vel: −1.158 cm/s

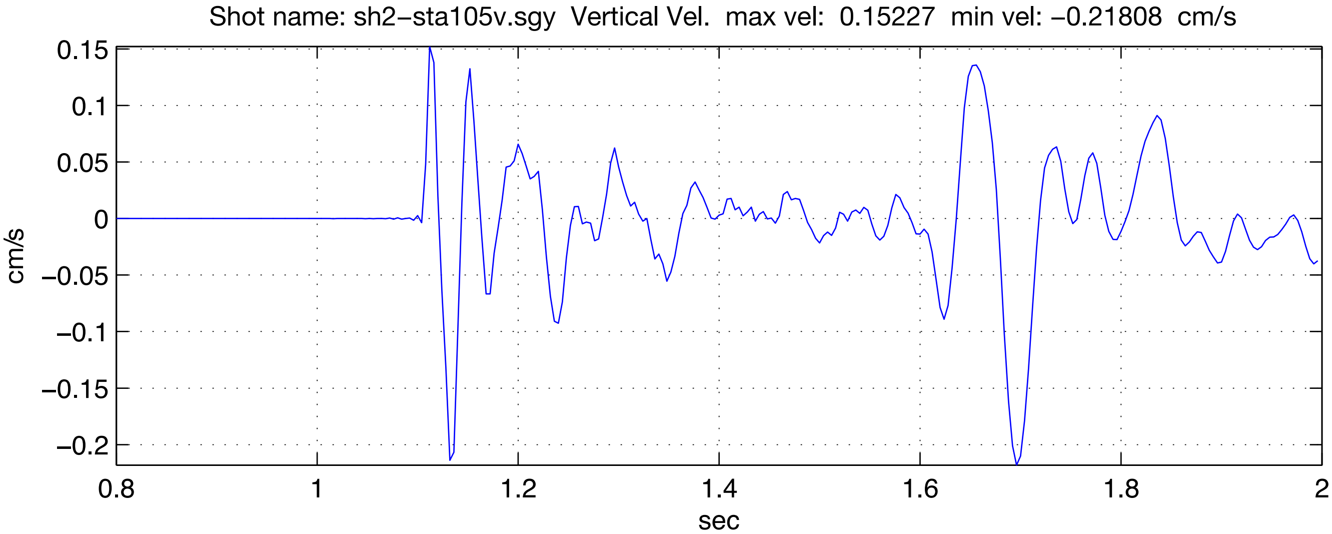


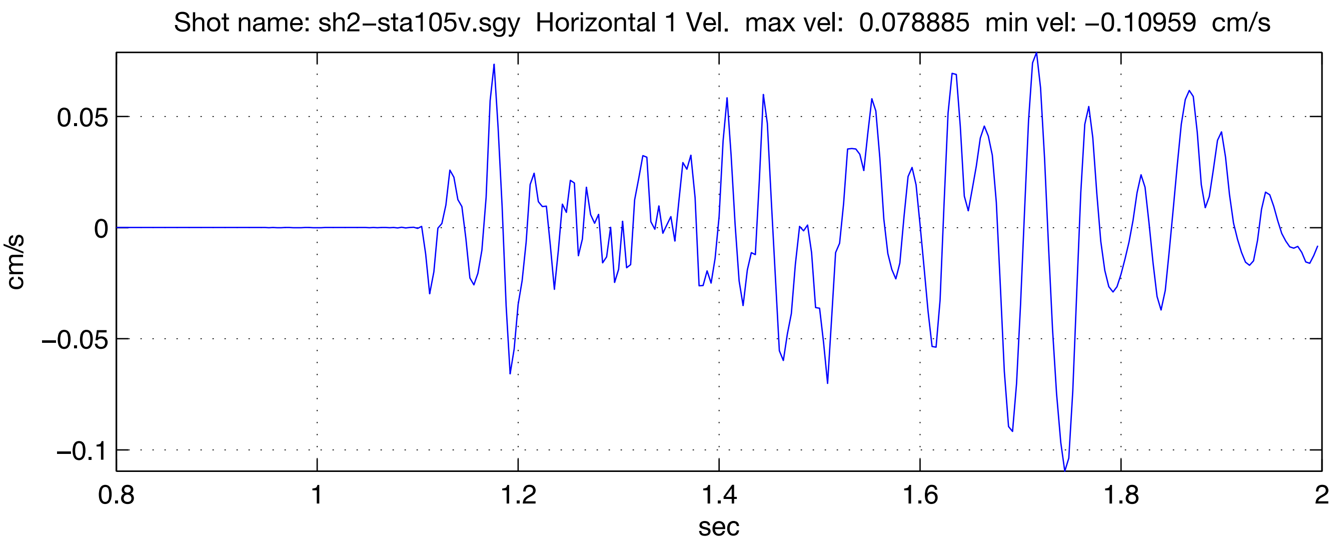
Shot name: sh2−sta104v.sgy Horizontal 1 Vel. max vel: 0.29801 min vel: −0.15816 cm/s

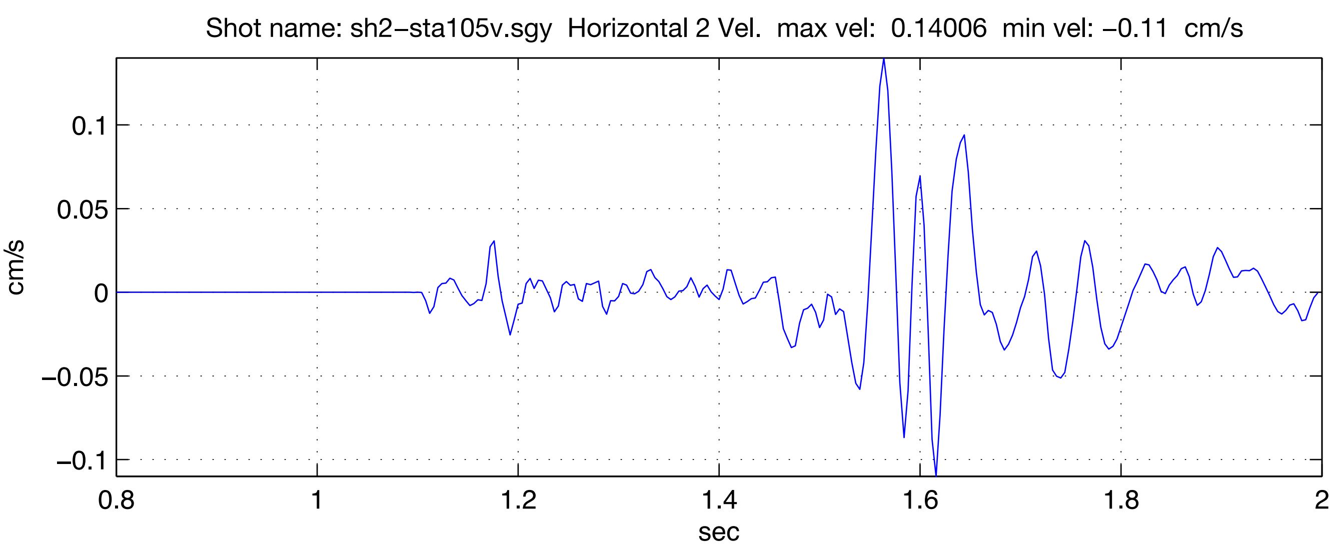


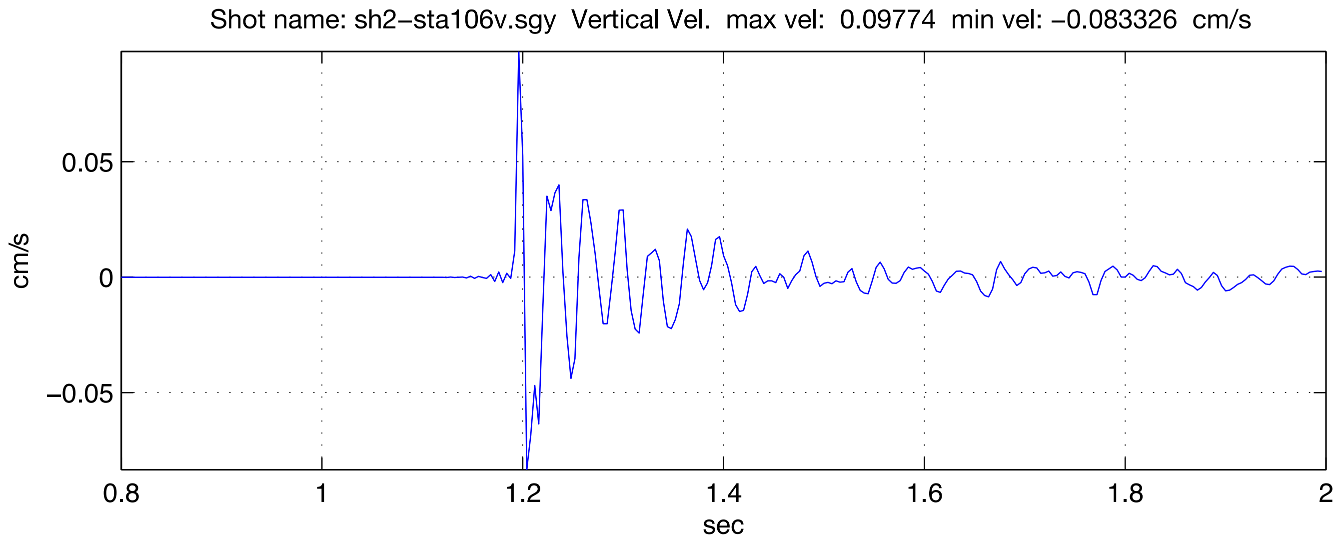
Shot name: sh2−sta104v.sgy Horizontal 2 Vel. max vel: 0.10534 min vel: −0.13438 cm/s

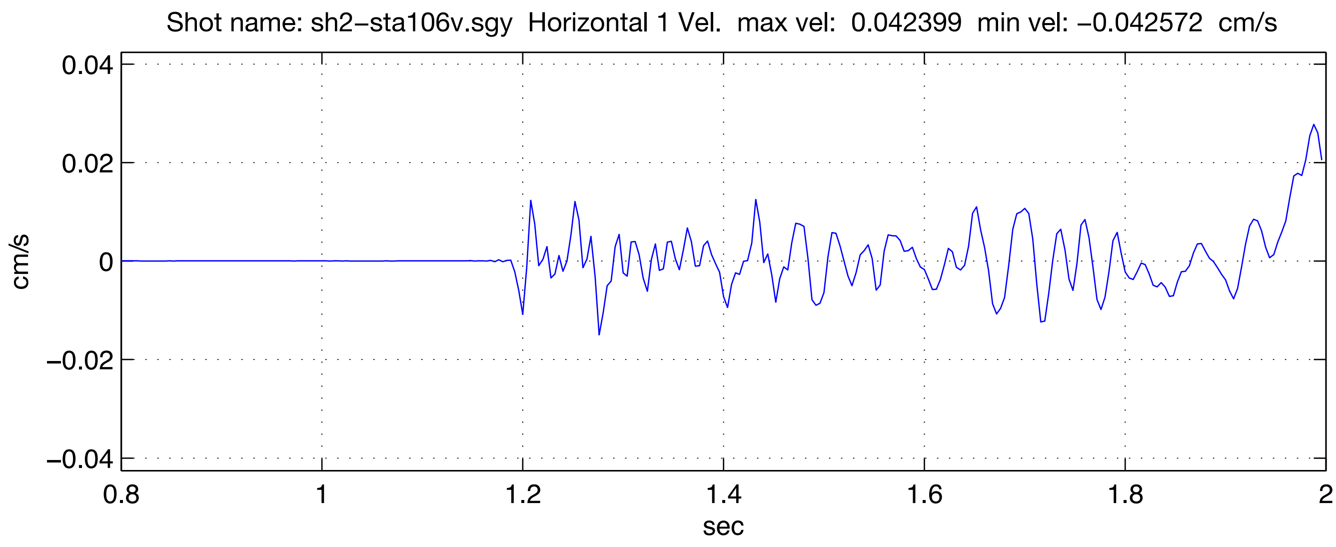


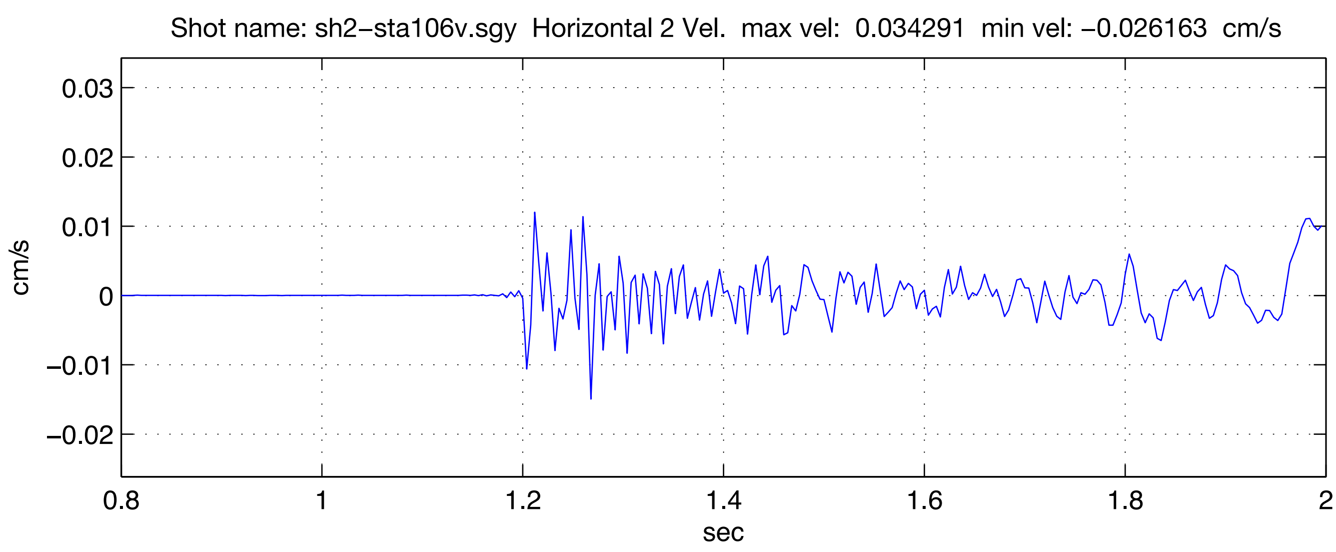

Shot name: sh2−sta105v.sgy Vertical Vel. max vel: 0.15227 min vel: −0.21808 cm/s
cm/s
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
0.8
1
1.2
1.4
1.6
1.8
2
sec

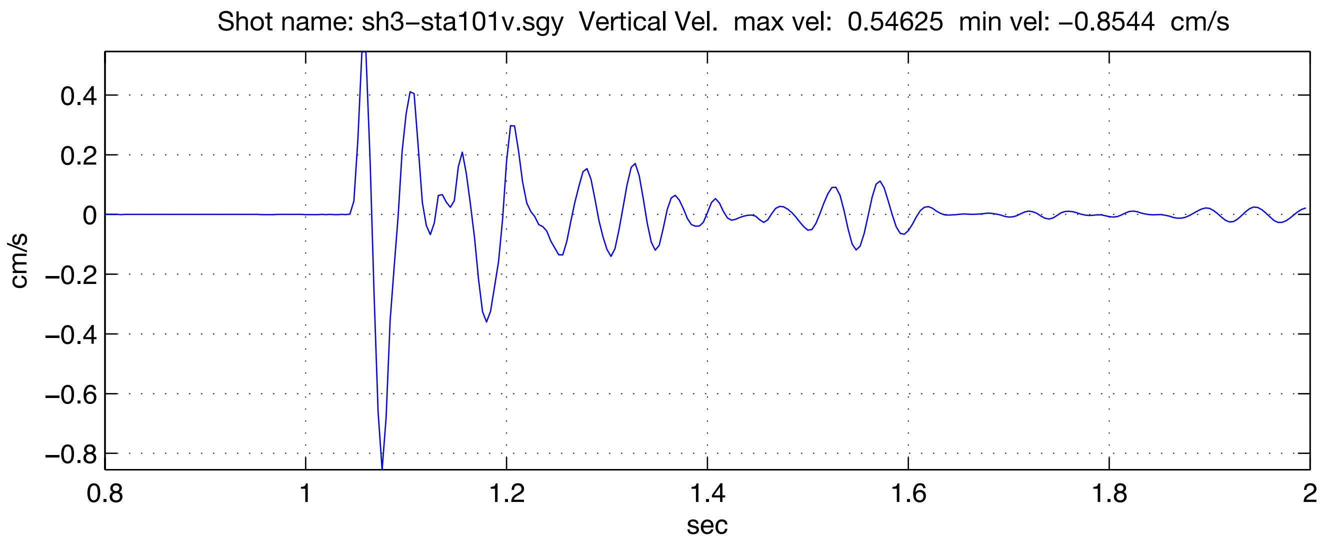

Shot name: sh2−sta105v.sgy Horizontal 1 Vel. max vel: 0.078885 min vel: −0.10959 cm/s
cm/s
0.05
0
−0.05
−0.1
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh2−sta105v.sgy Horizontal 2 Vel. max vel: 0.14006 min vel: −0.11 cm/s
cm/s
0.1
0.05
0
−0.05
−0.1
0.8
1
1.2
1.4
1.6
1.8
2
sec

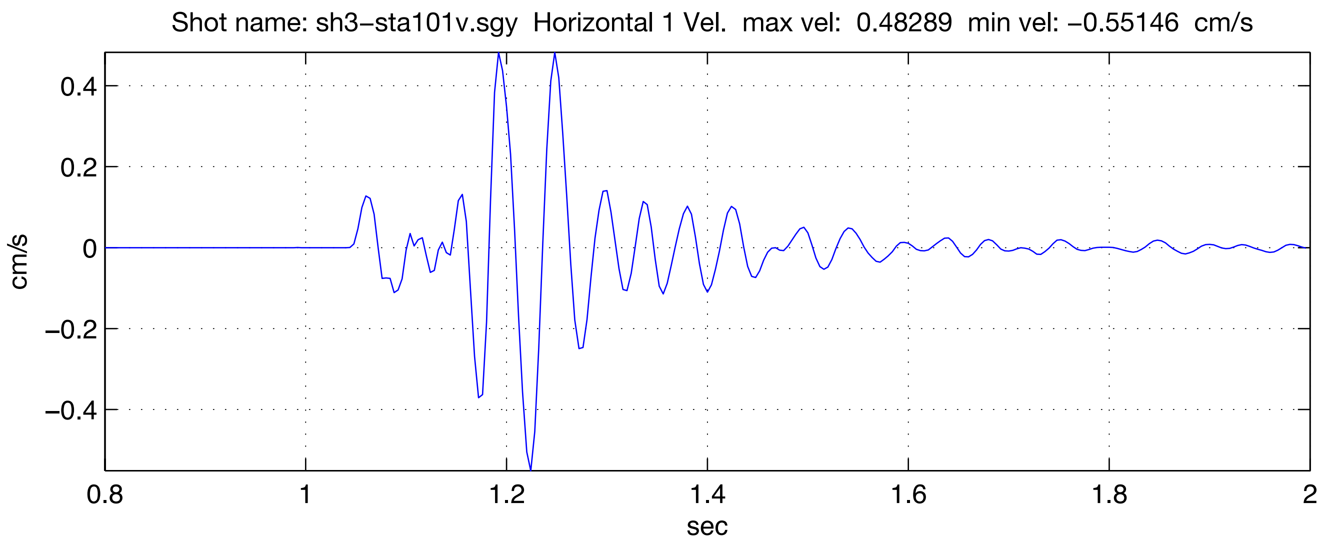

Shot name: sh2−sta106v.sgy Vertical Vel. max vel: 0.09774 min vel: −0.083326 cm/s
cm/s
0.05
0
−0.05
0.8
1
1.2
1.4
1.6
1.8
2
sec


Shot name: sh2−sta106v.sgy Horizontal 1 Vel. max vel: 0.042399 min vel: −0.042572 cm/s
cm/s
0.04
0.02
0
−0.02
−0.04
0.8
1
1.2
1.4
1.6
1.8
2
sec

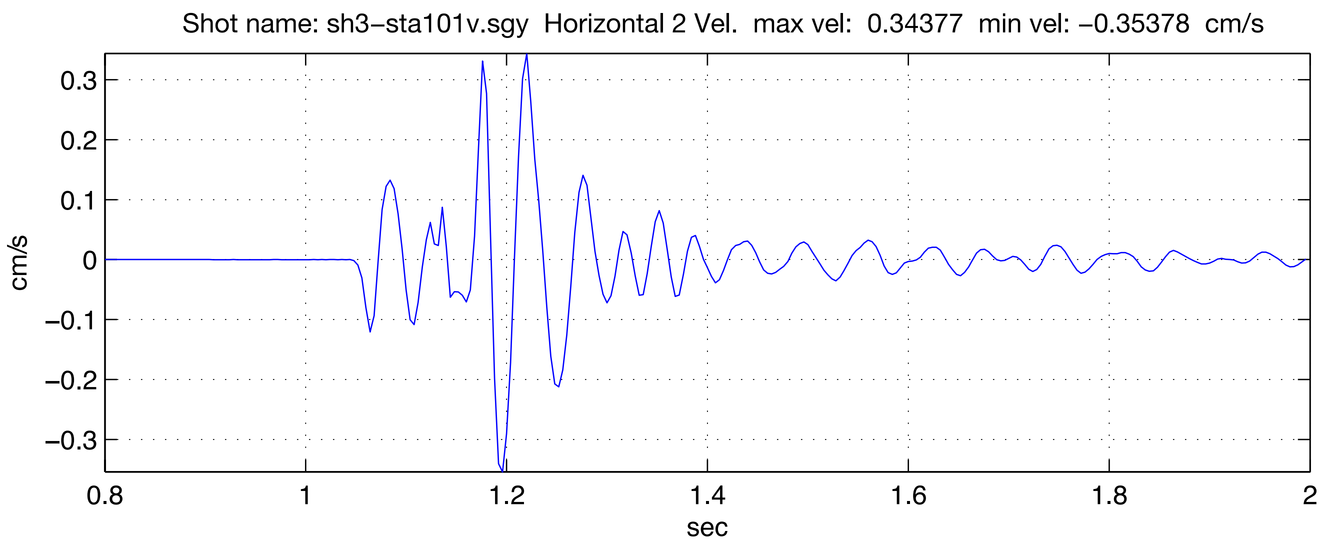

Shot name: sh2−sta106v.sgy Horizontal 2 Vel. max vel: 0.034291 min vel: −0.026163 cm/s
cm/s
0.03
0.02
0.01
0
−0.01
−0.02
0.8
1
1.2
1.4
1.6
1.8
2
sec



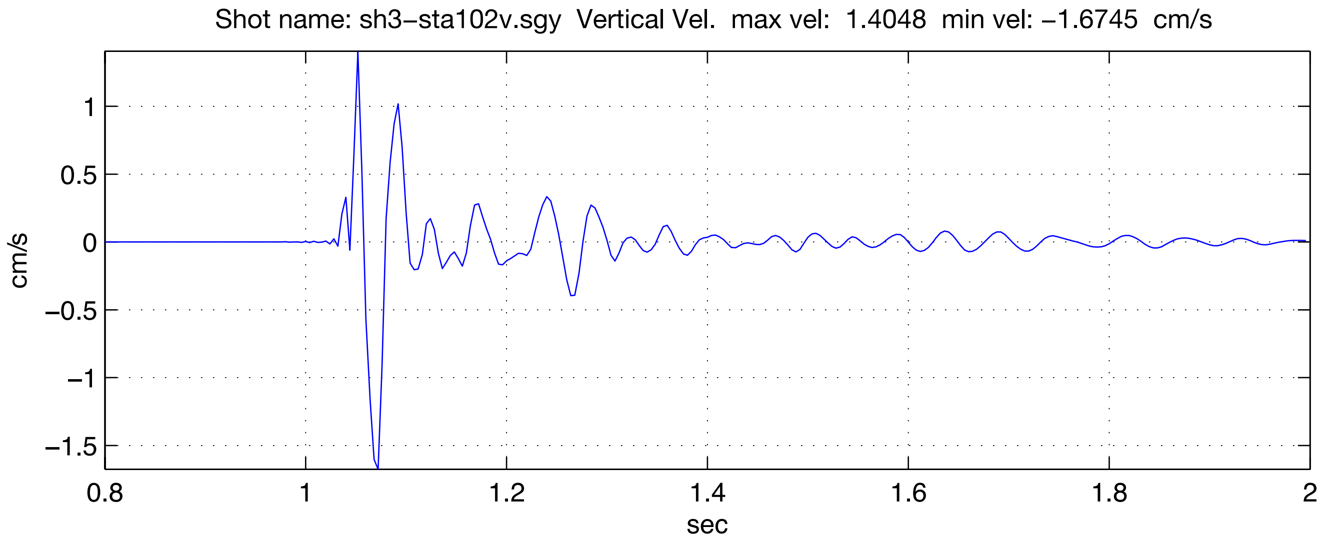
Shot name: sh3−sta101v.sgy Vertical Vel. max vel: 0.54625 min vel: −0.8544 cm/s
cm/s
sec



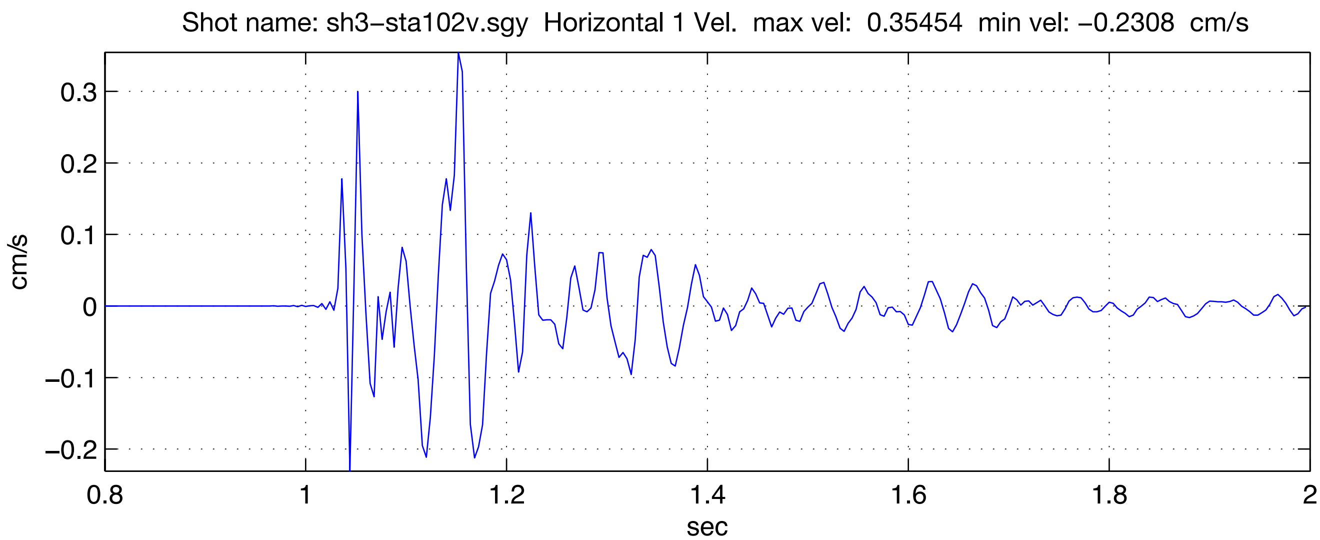
Shot name: sh3−sta101v.sgy Horizontal 1 Vel. max vel: 0.48289 min vel: −0.55146 cm/s
cm/s
sec



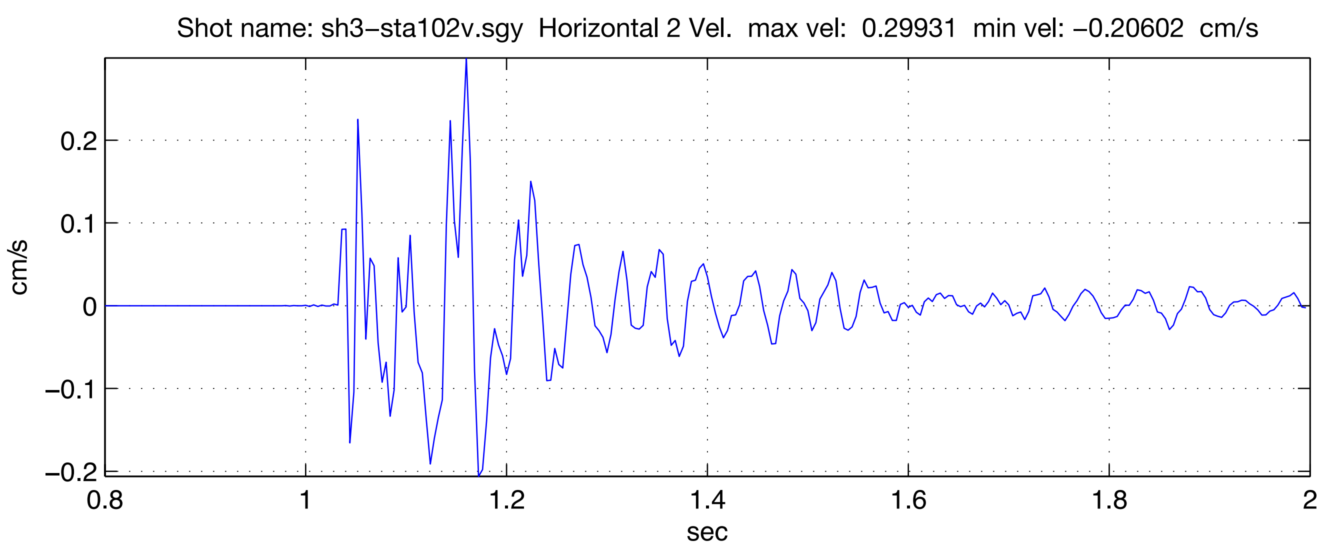
Shot name: sh3−sta101v.sgy Horizontal 2 Vel. max vel: 0.34377 min vel: −0.35378 cm/s
cm/s
sec



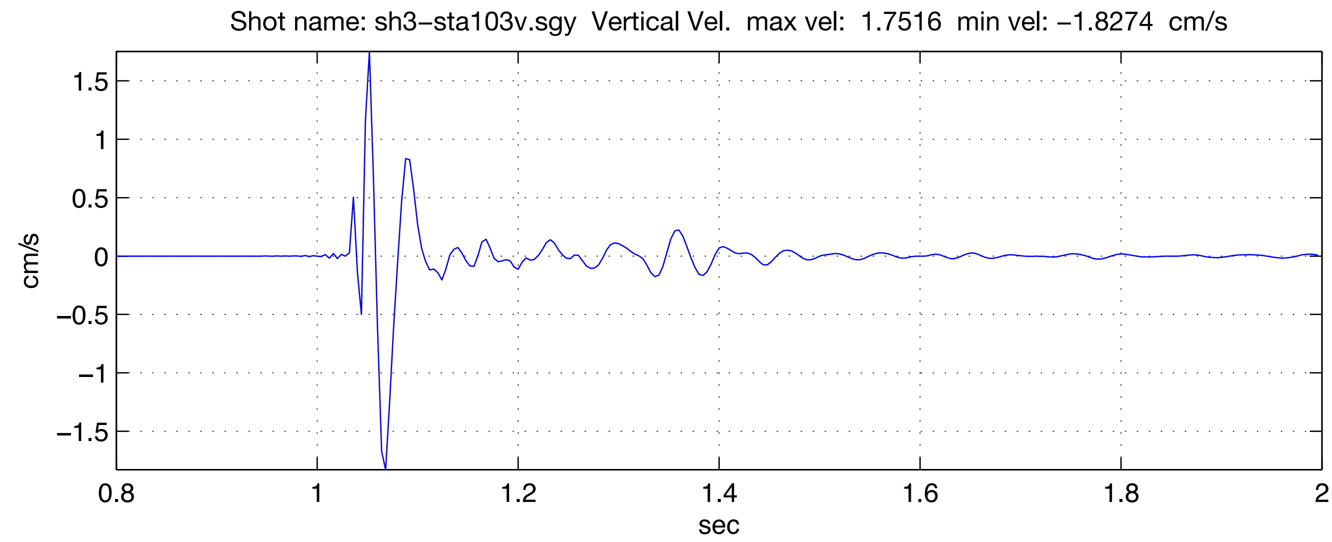
Shot name: sh3−sta102v.sgy Vertical Vel. max vel: 1.4048 min vel: −1.6745 cm/s
cm/s
1
0.5
0
−0.5
−1
−1.5
0.8
1
1.2
1.4
1.6
1.8
2
sec

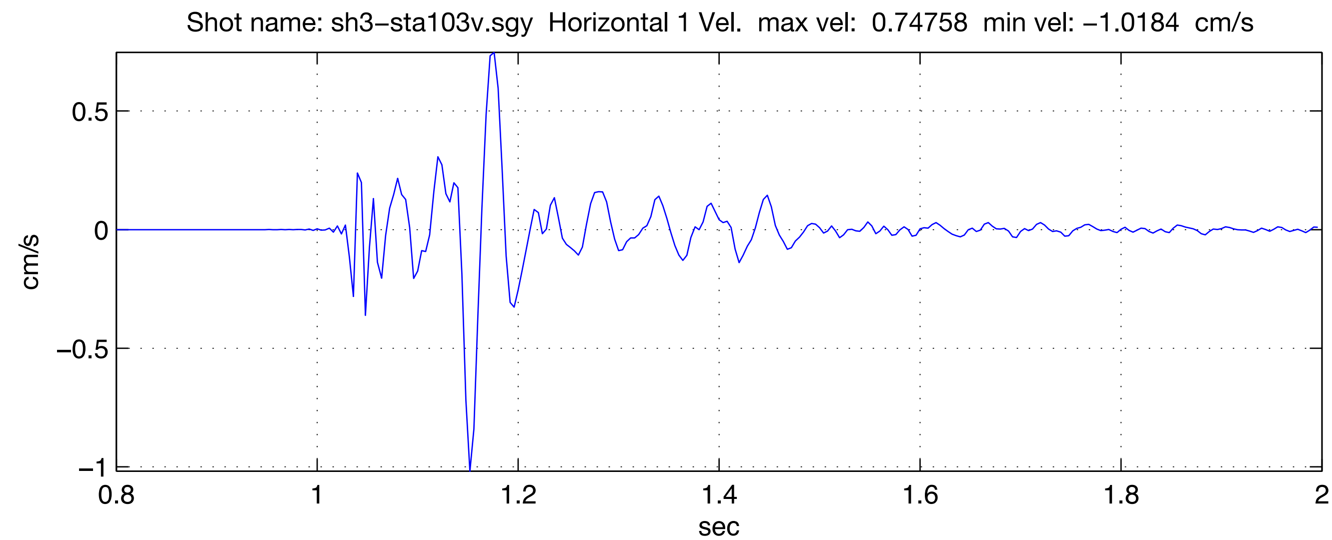


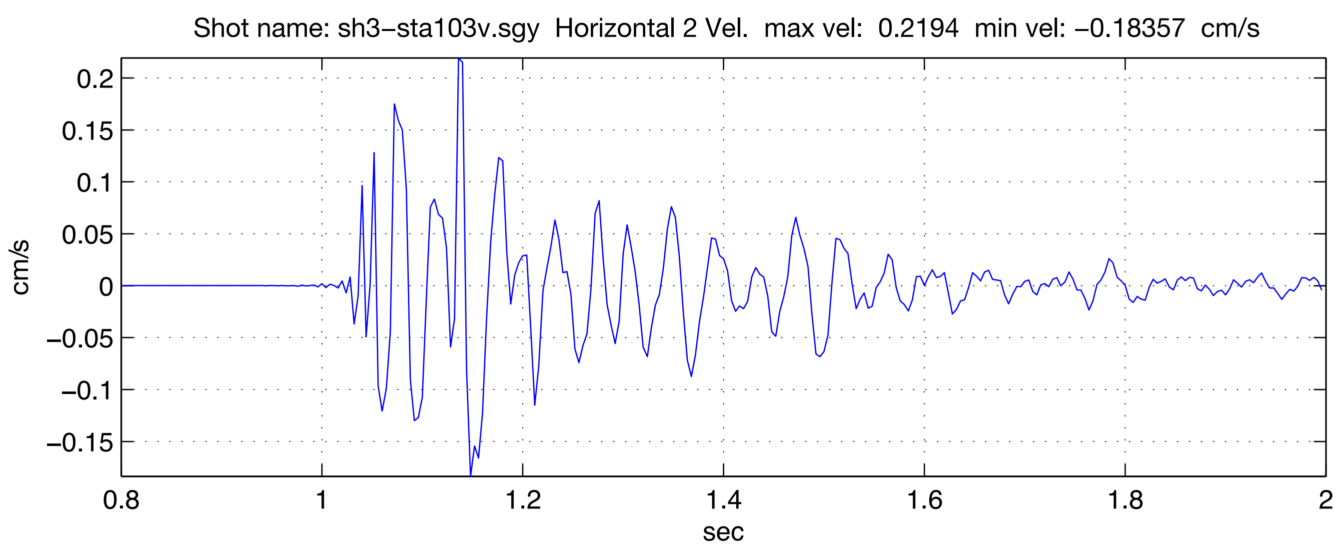
Shot name: sh3−sta102v.sgy Horizontal 1 Vel. max vel: 0.35454 min vel: −0.2308 cm/s
cm/s
0.3
0.2
0.1
0
−0.1
−0.2
0.8
1
1.2
1.4
1.6
1.8
2
sec

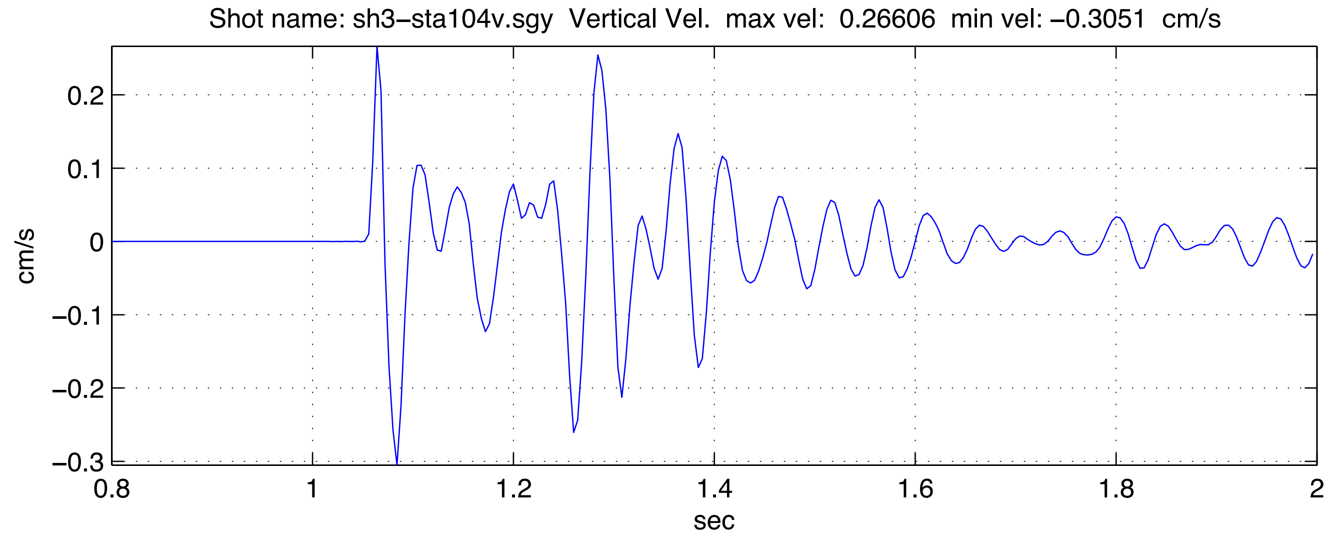


Shot name: sh3−sta102v.sgy Horizontal 2 Vel. max vel: 0.29931 min vel: −0.20602 cm/s
cm/s
0.2
0.1
0
−0.1
−0.2
0.8
1
1.2
1.4
1.6
1.8
2
sec

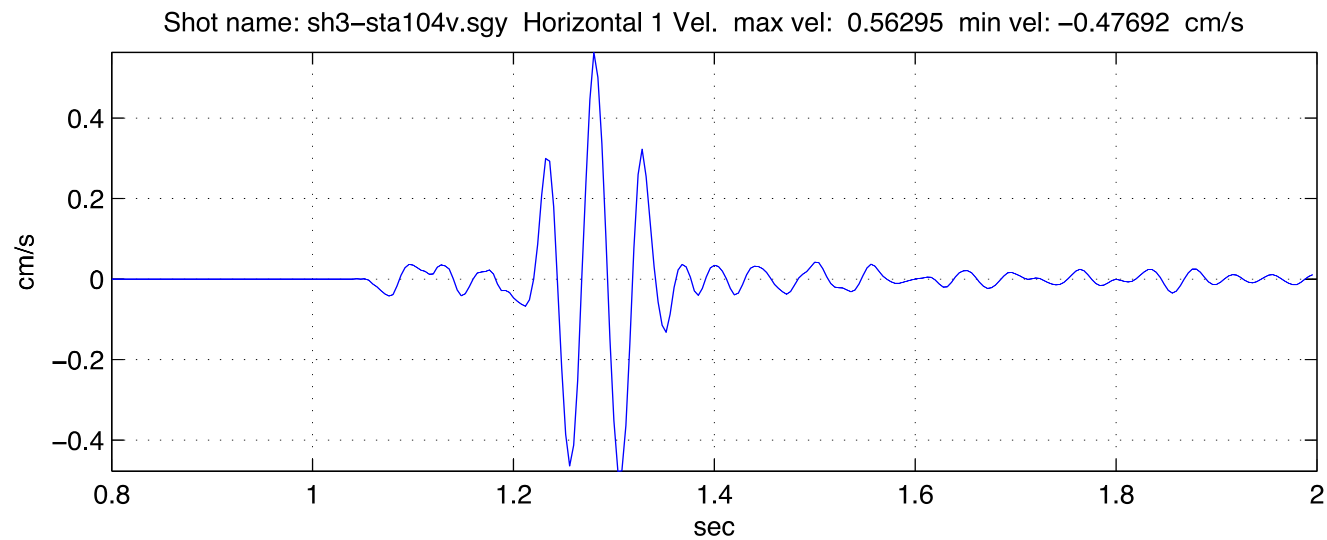

Shot name: sh3−sta103v.sgy Vertical Vel. max vel: 1.7516 min vel: −1.8274 cm/s
cm/s
sec


Shot name: sh3−sta103v.sgy Horizontal 1 Vel. max vel: 0.74758 min vel: −1.0184 cm/s
cm/s
sec

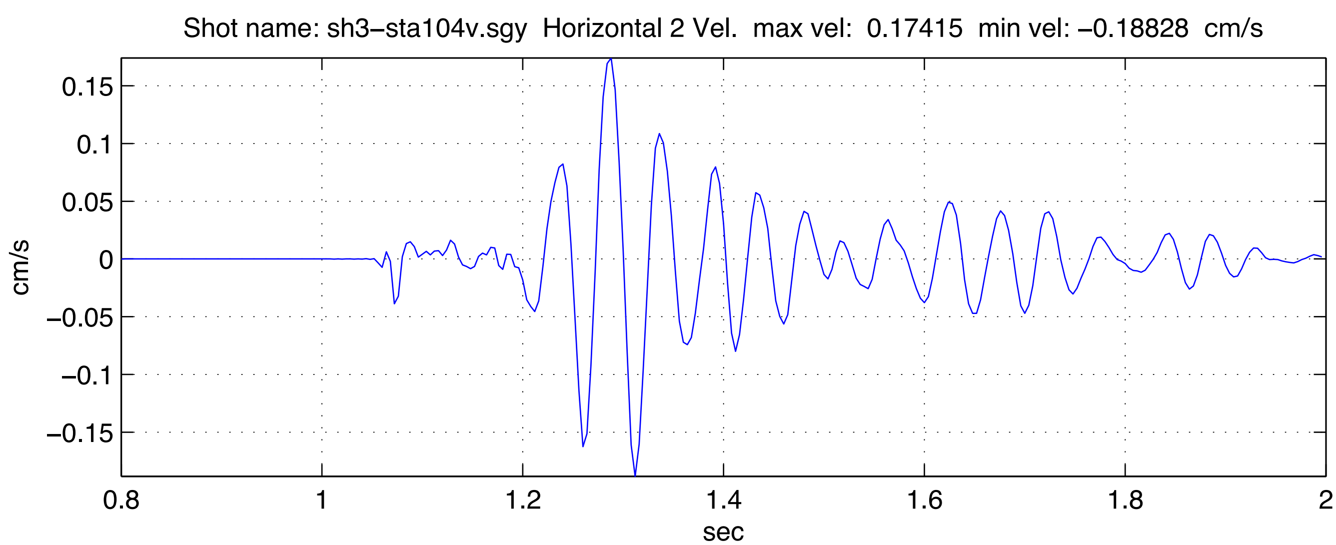

Shot name: sh3−sta103v.sgy Horizontal 2 Vel. max vel: 0.2194 min vel: −0.18357 cm/s
cm/s
sec



Shot name: sh3−sta104v.sgy Vertical Vel. max vel: 0.26606 min vel: −0.3051 cm/s
cm/s
sec

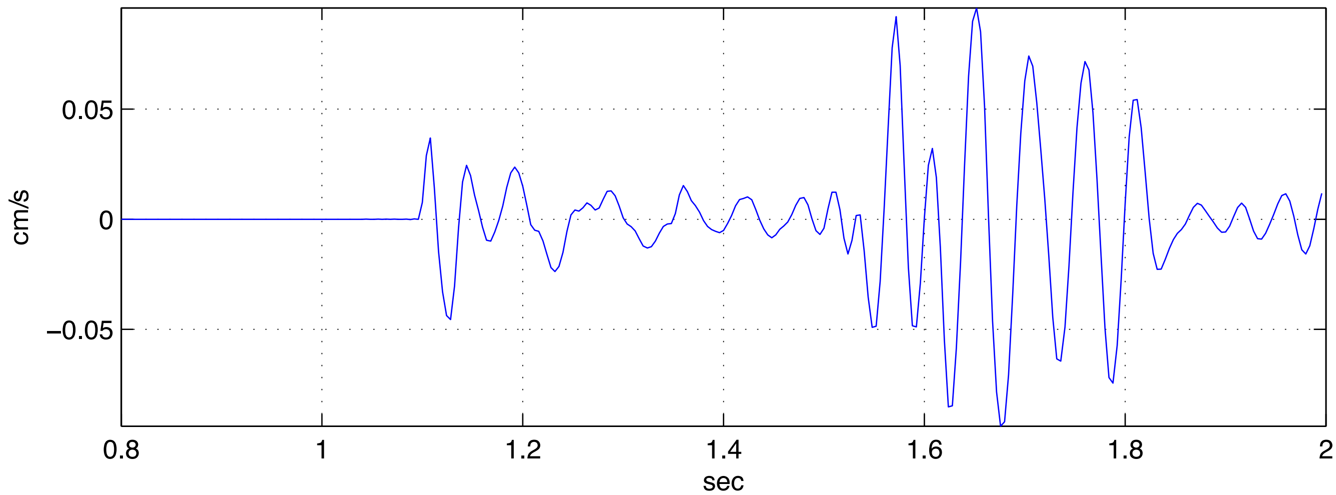


Shot name: sh3−sta104v.sgy Horizontal 1 Vel. max vel: 0.56295 min vel: −0.47692 cm/s
cm/s
sec

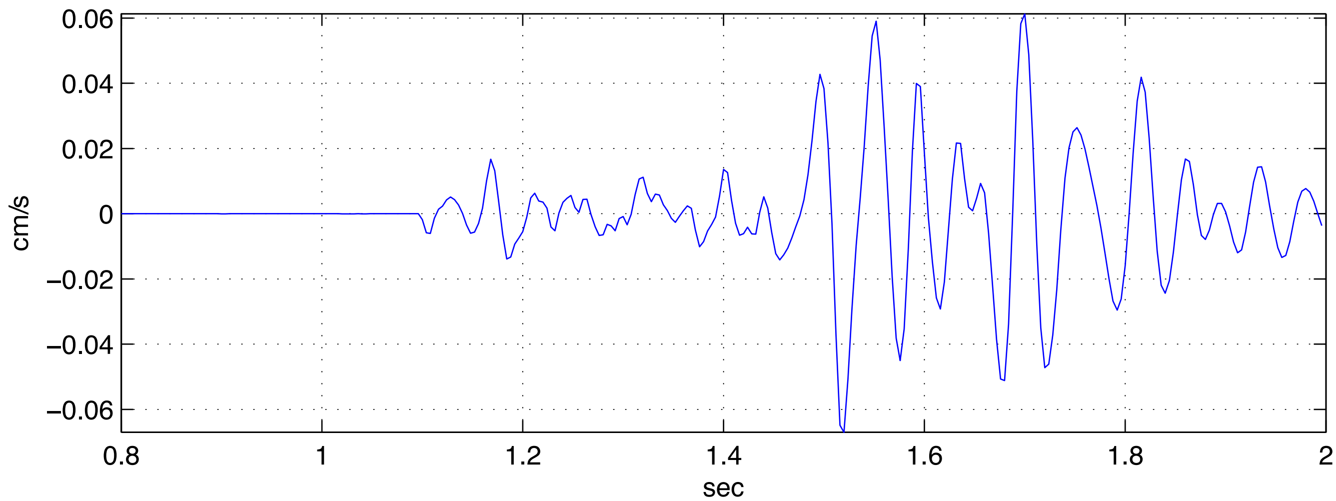


Shot name: sh3−sta104v.sgy Horizontal 2 Vel. max vel: 0.17415 min vel: −0.18828 cm/s
cm/s
sec

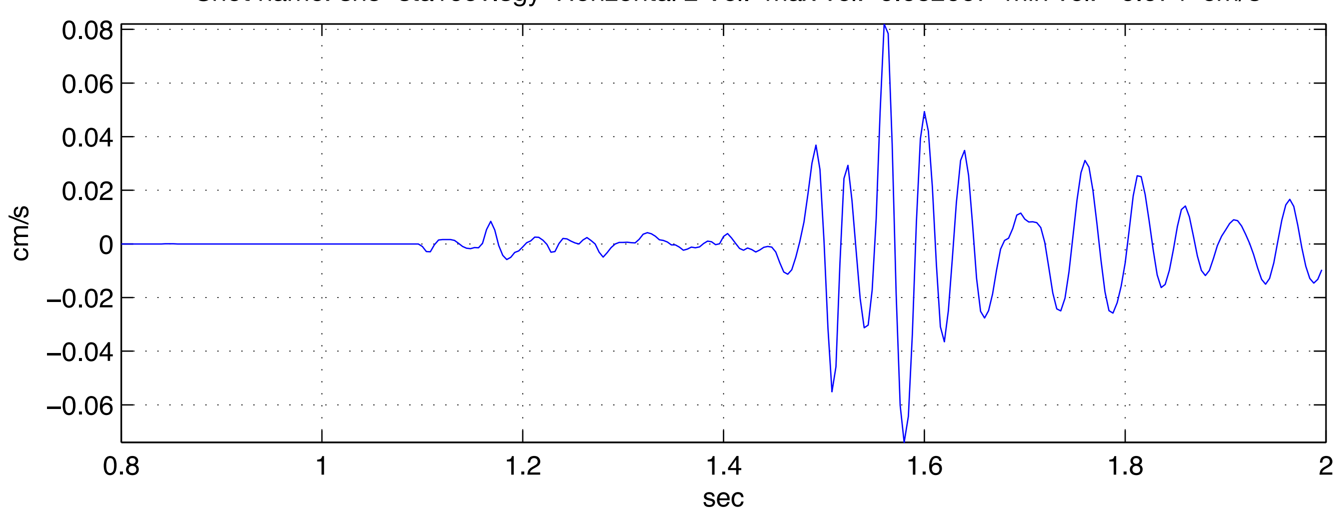
Shot name: sh3−sta105v.sgy Vertical Vel. max vel: 0.095994 min vel: −0.09395 cm/s

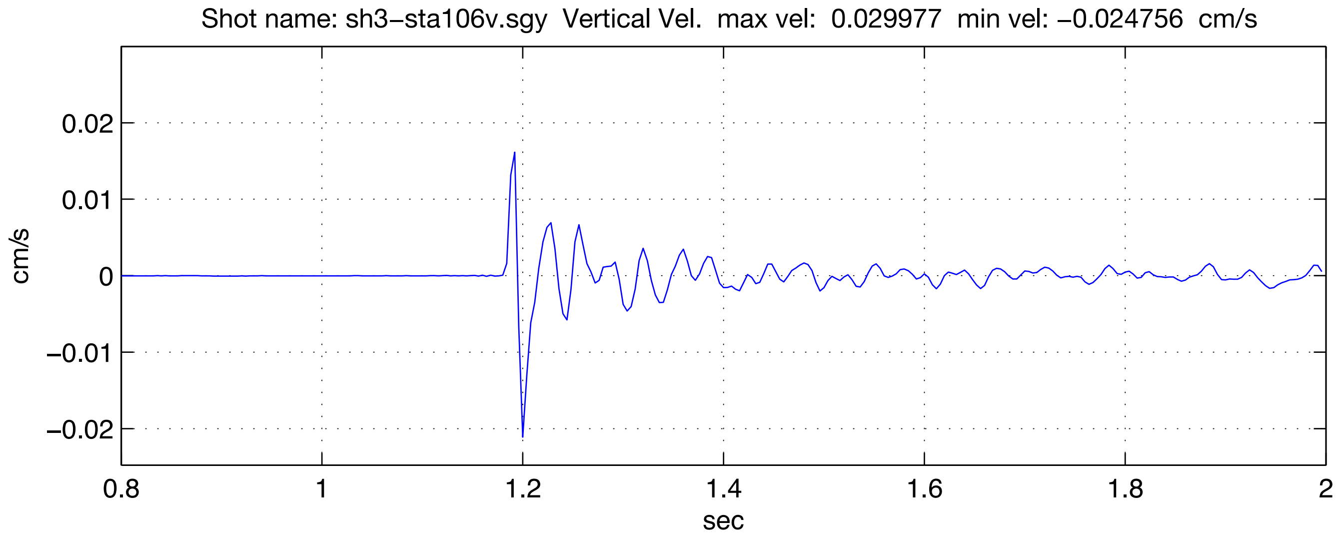


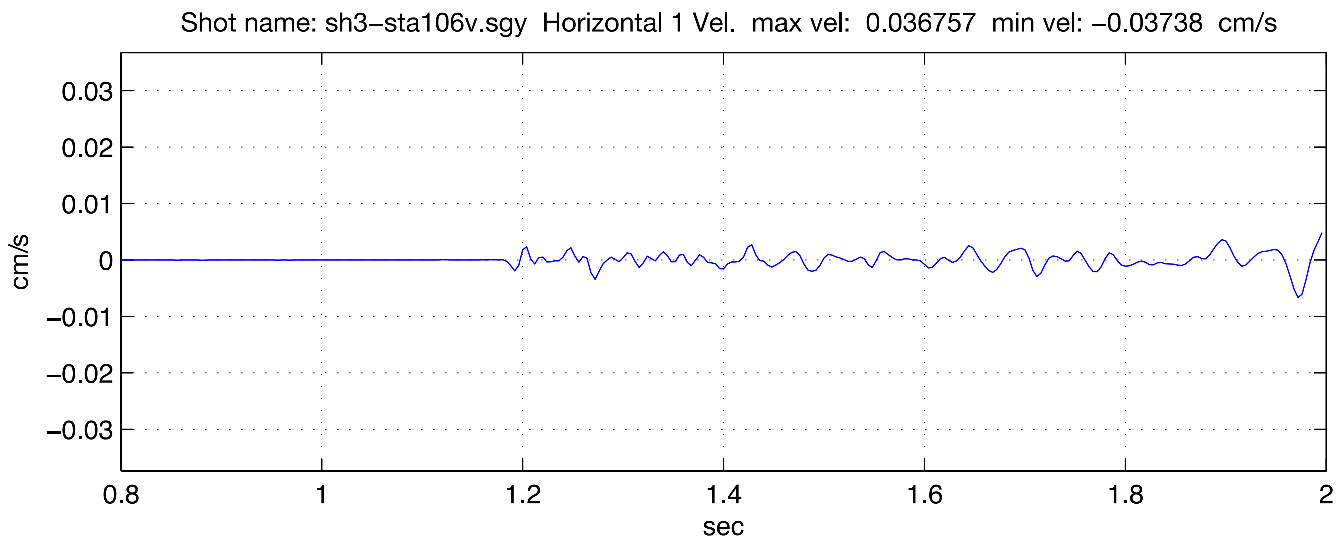
Shot name: sh3−sta105v.sgy Horizontal 1 Vel. max vel: 0.061303 min vel: −0.066998 cm/s

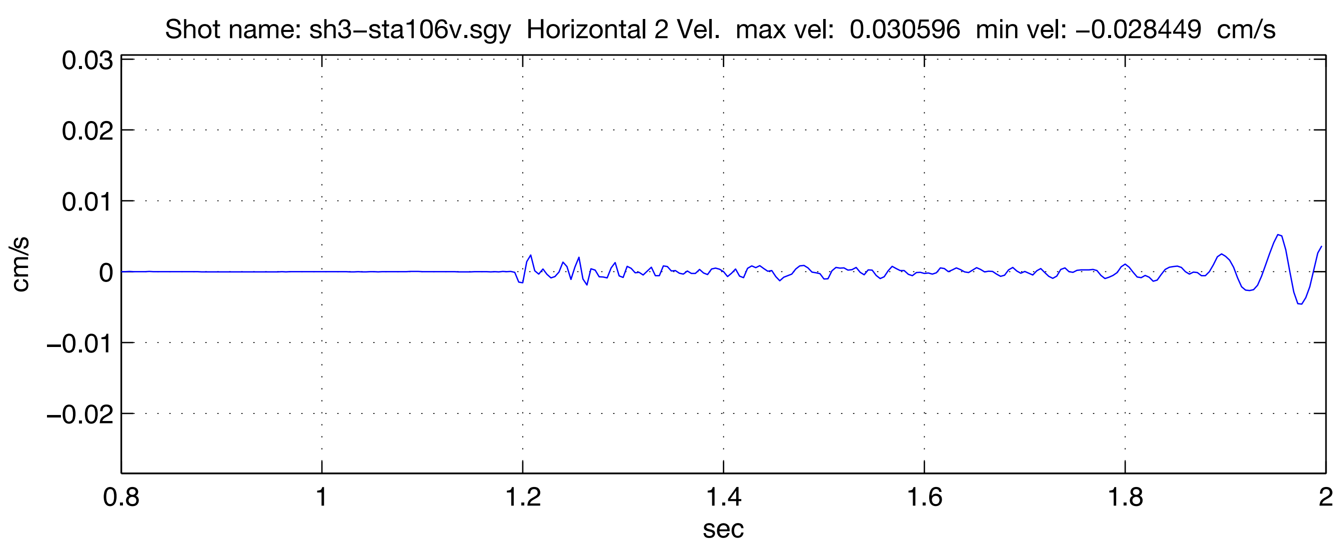


Shot name: sh3−sta105v.sgy Horizontal 2 Vel. max vel: 0.082067 min vel: −0.074 cm/s




Shot name: sh3−sta106v.sgy Vertical Vel. max vel: 0.029977 min vel: −0.024756 cm/s
cm/s
0.02
0.01
0
−0.01
−0.02
0.8
1
1.2
1.4
1.6
1.8
2
sec

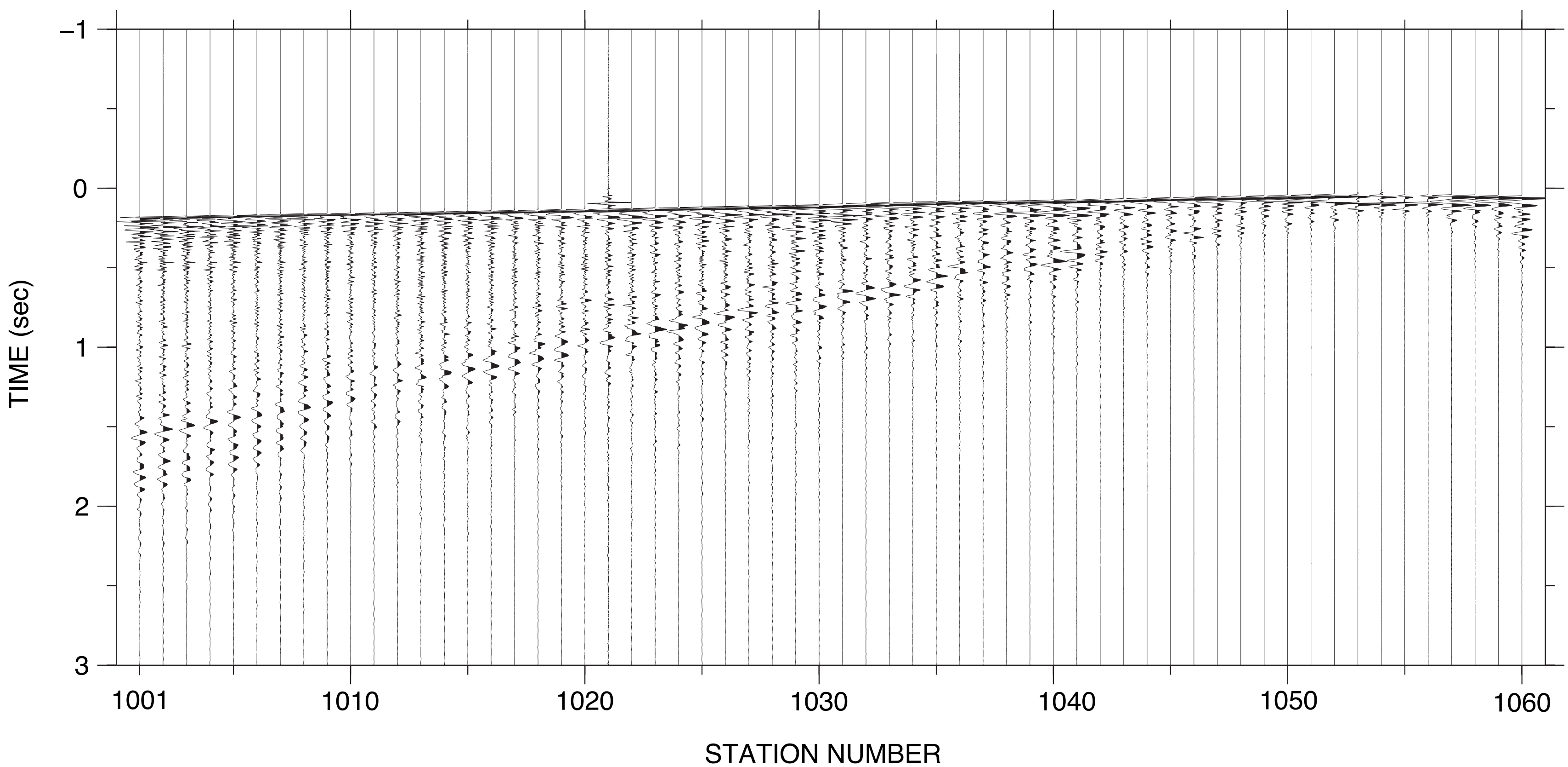

Shot name: sh3−sta106v.sgy Horizontal 1 Vel. max vel: 0.036757 min vel: −0.03738 cm/s
cm/s
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
0.8
1
1.2
1.4
1.6
1.8
2
sec

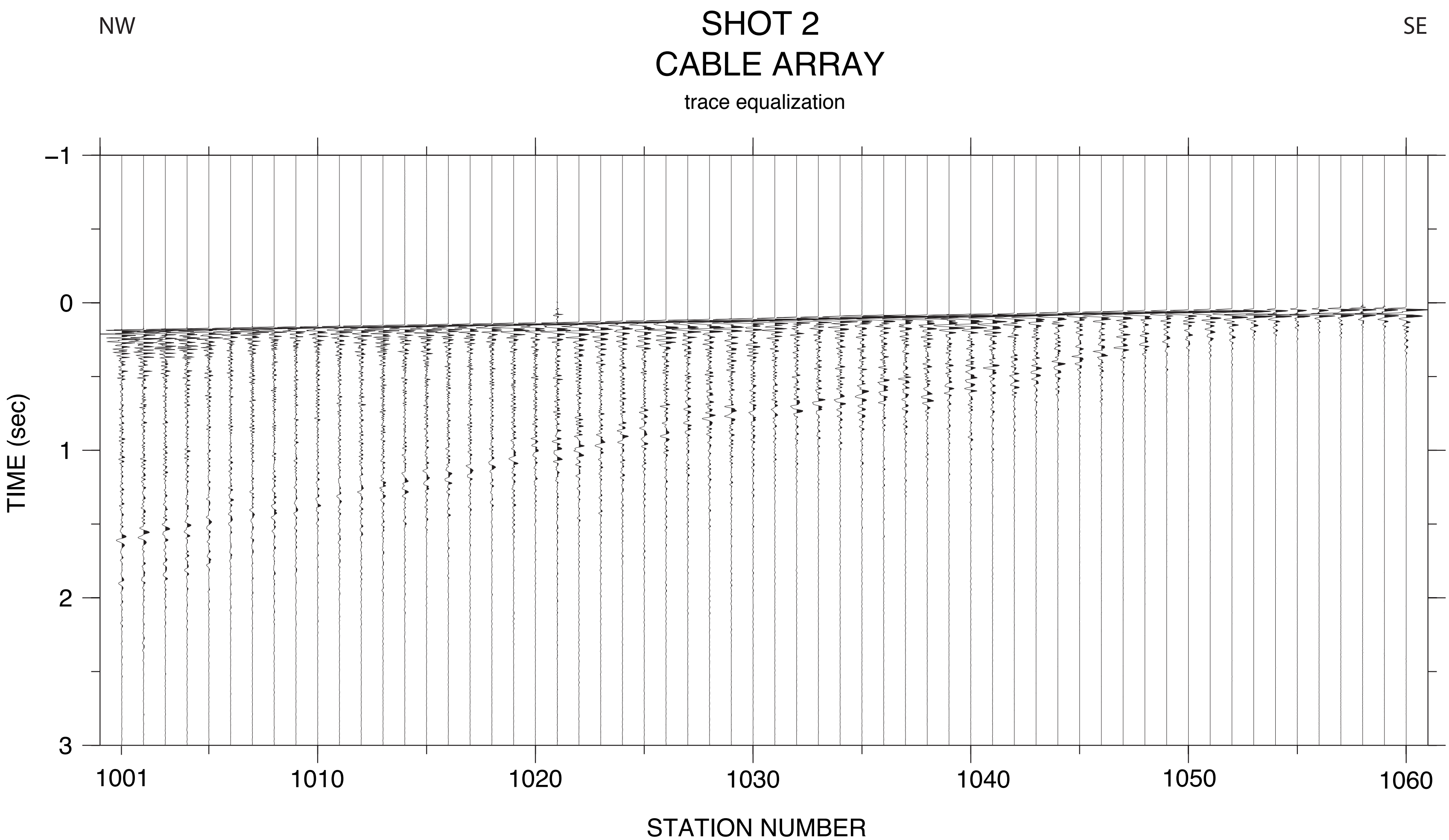

Shot name: sh3−sta106v.sgy Horizontal 2 Vel. max vel: 0.030596 min vel: −0.028449 cm/s
cm/s
0.03
0.02
0.01
0
−0.01
−0.02
0.8
1
1.2
1.4
1.6
1.8
2
sec

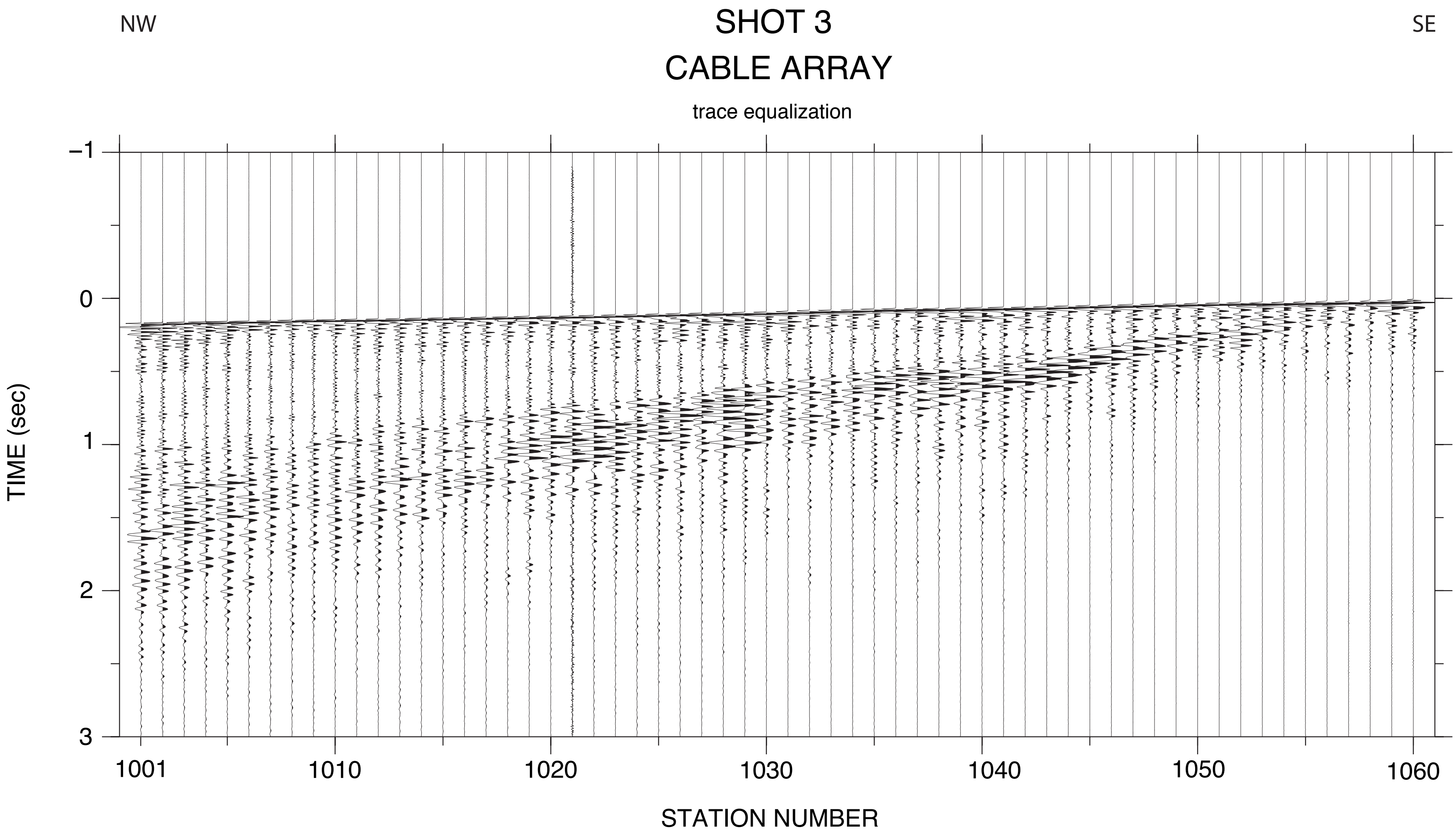
Appendix 4. Near Source High Resolution Receiver Velocity Plots
[Seismic traces are from the cabled array. Zero time is the moment of detonation of the shot.]

NW SE

SHOT 1
CABLE ARRAY
trace equalization




NW
SHOT 2
CABLE ARRAY
trace equalization
SE
−1
0
1
2
3
TIME (sec)
1001
1010
1020
1030
1040
1050
1060
STATION NUMBER

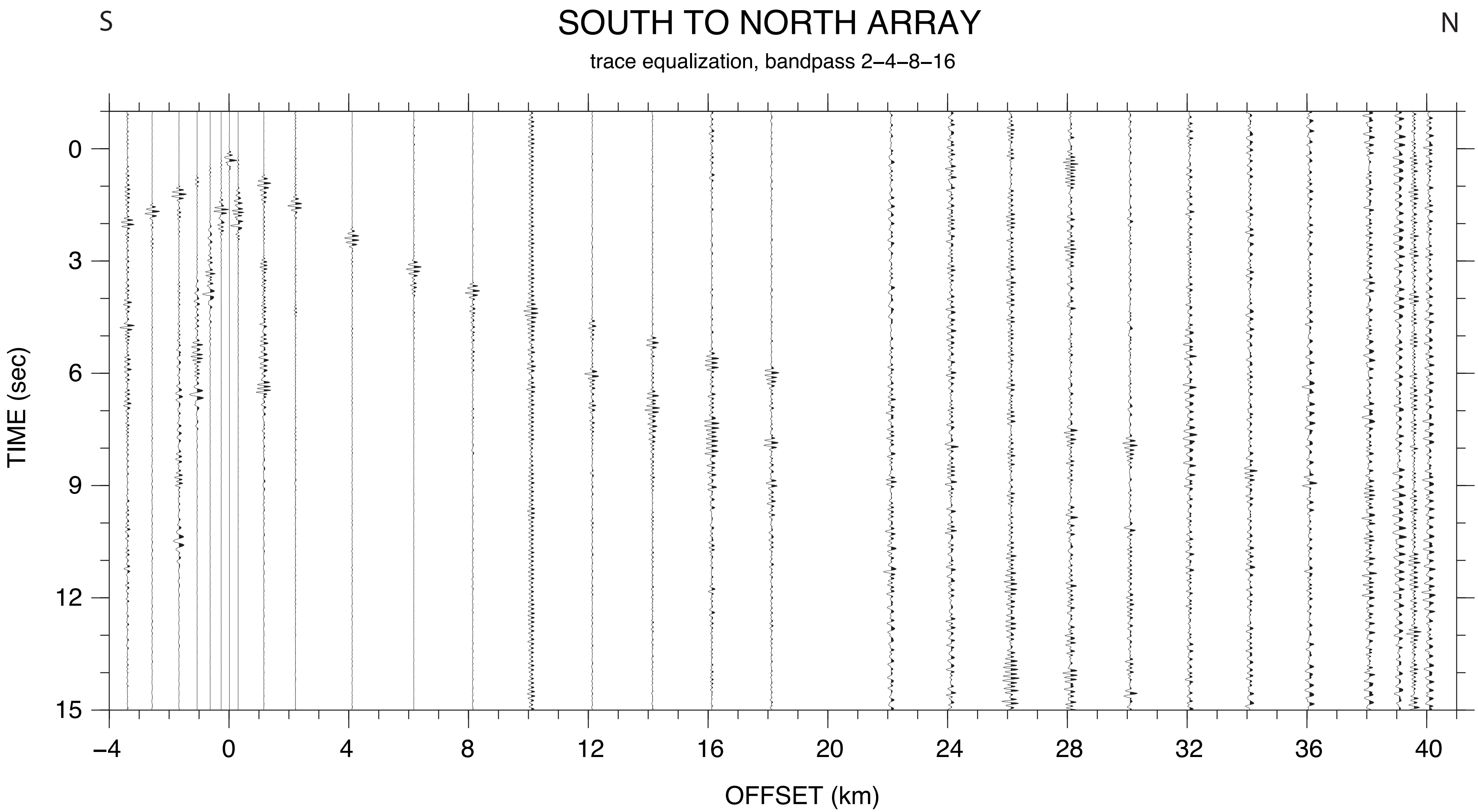

NW
SHOT 3
CABLE ARRAY
trace equalization
SE
TIME (sec)
−1
0
1
2
3
1001
1010
1020
1030
1040
1050
1060
STATION NUMBER

Appendix 5. Velocity Plots for N-S Linear Profile
[Near-field to far-field transition. Zero time is the moment of detonation of the shot.]

SHOT 1

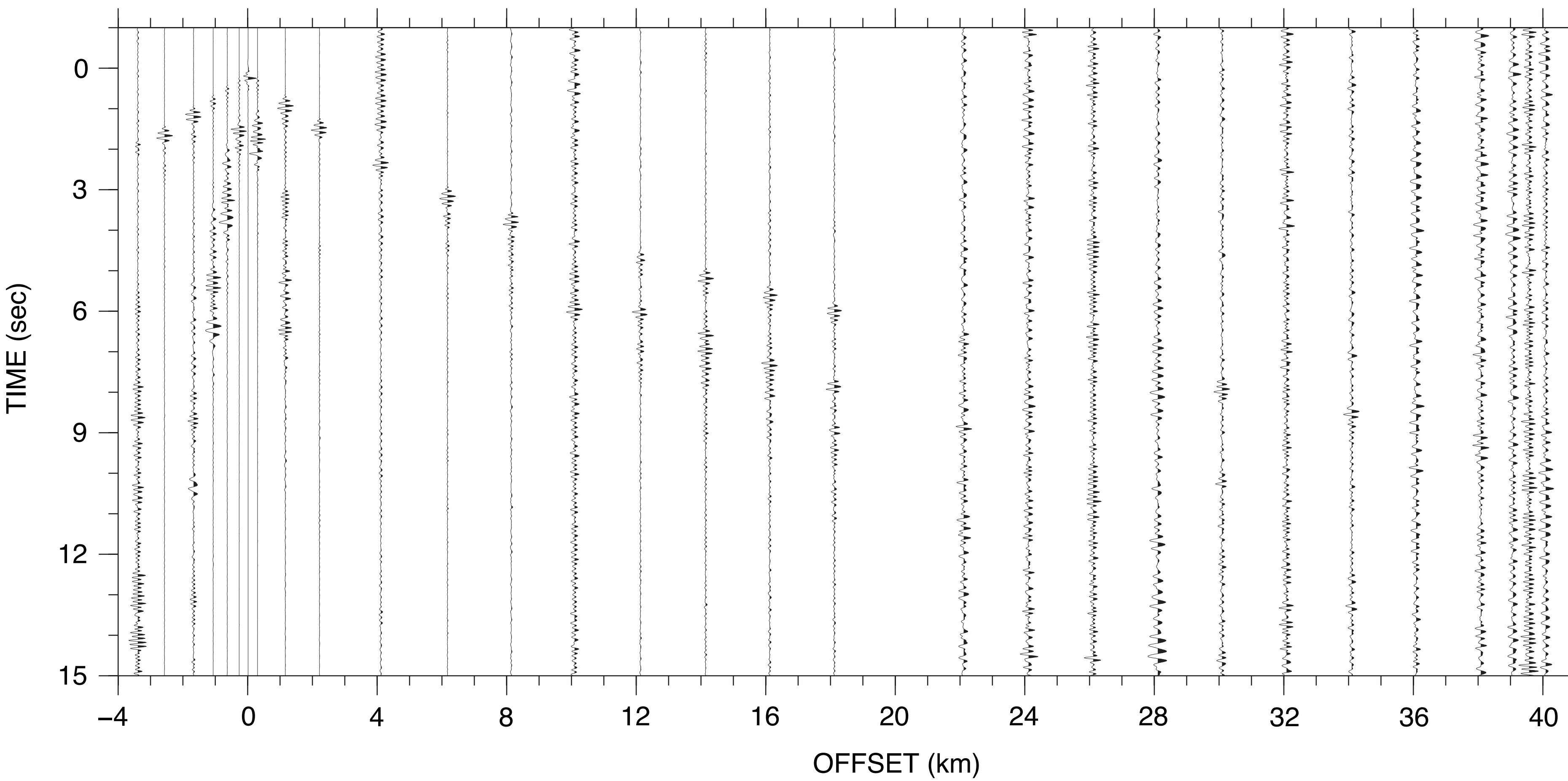
SOUTH TO NORTH ARRAY

trace equalization, bandpass 2–4–8–16



SHOT 2
SOUTH TO NORTH ARRAY

trace equalization, bandpass 2–4–8–16



SHOT 3

SOUTH TO NORTH ARRAY

trace equalization, bandpass 2–4–8–16