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SGW-47535
Revision 0

Measurement of Compressional-Wave Seismic Velocities in 29 Wells at the Hanford Site

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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PETERSEN SW

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Terms

bgs	below ground surface
BWIP	Basalt Waste Isolation Program
CCU	Cold Creek Unit
CS	carbon steel
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
OU	operable unit
PVC	polyvinyl chloride
RAD	radiation
SS	stainless steel

1 Introduction

Check shot seismic velocity surveys were collected in 100 B/C, 200 East, 200-PO-1 Operational Unit (OU), and the Gable Gap areas in order to provide time-depth correlation information to aid the interpretation of existing seismic reflection data acquired at the Hanford Site (Figure 1). This report details results from 5 wells surveyed in fiscal year (FY) 2008, 7 wells in FY 2009, and 17 wells in FY 2010 and provides summary compressional-wave seismic velocity information to help guide future seismic survey design as well as improve current interpretations of the seismic data (SSC 1979/1980; SGW-39675; SGW-43746). Augmenting the check shot database are four surveys acquired in 2007 in support of the Bechtel National, Inc. Waste Treatment Plant construction design (PNNL-16559, PNNL-16652), and check shot surveys in three wells to support seismic testing in the 200 West Area (Waddell et al., 1999). Additional sonic logging was conducted during the late 1970s and early 1980s as part of the Basalt Waste Isolation Program (BWIP) (SSC 1979/1980) and check shot/sonic surveys as part of the safety report for the Skagit/Hanford Nuclear project (RDH/10-AMCP-0164).

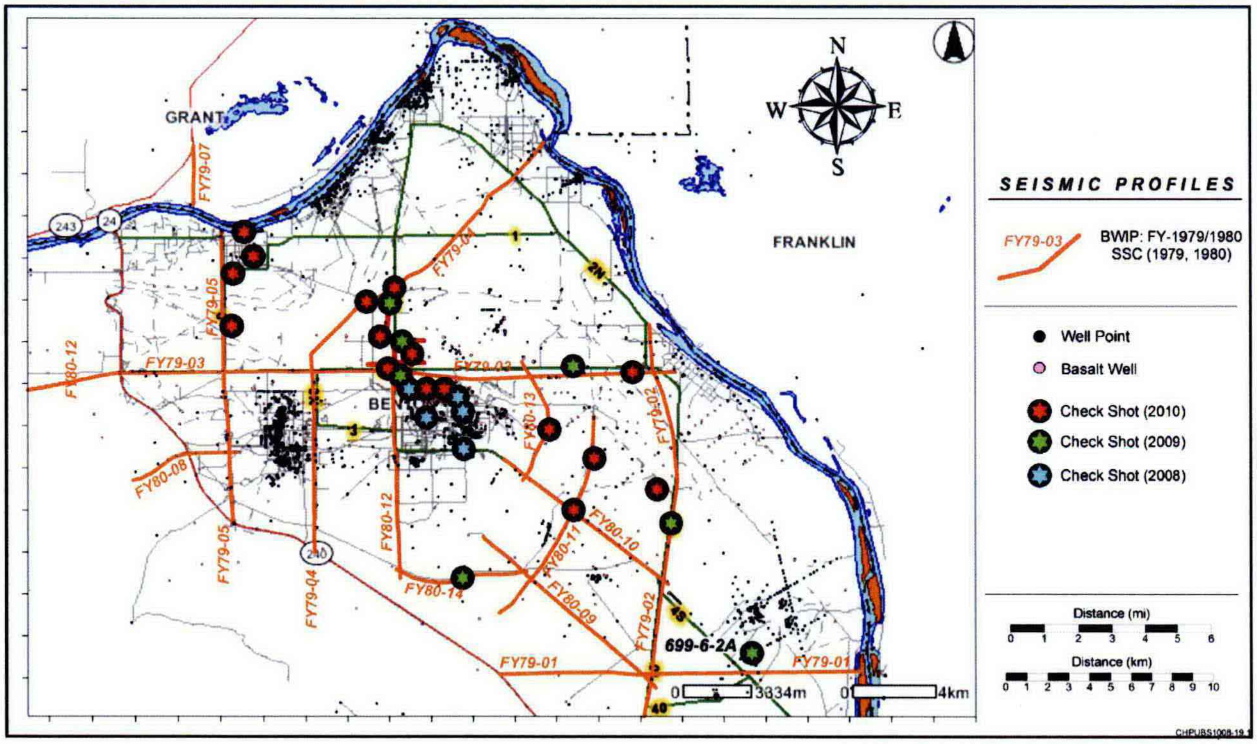

Figure 1. Check Shot Survey Well Locations

Check shot surveys are used to obtain an in situ measure of compressional-wave seismic velocity for sediment and rock in the vicinity of the well point, and provide the seismic-wave travel time to geologic horizons of interest. The check shot method deploys a downhole seismic receiver (geophone) to record the arrival of seismic waves generated by a source at the ground surface. The travel time of the first arriving seismic-wave is determined and used to create a time-depth function to correlate encountered geologic intervals with the seismic data. This critical tie with the underlying geology improves the interpretation of seismic reflection profile information.

Fieldwork for this investigation was conducted by in house staff during the weeks of September 22, 2008 for 5 wells in the 200 East Area (Figure 2); June 1, 2009 for 7 wells in the 200-PO-1 OU and Gable Gap regions (see Figure 3 and Figure 4); and March 22, 2010 and April 19, 2010 for 17 wells in the 200 East, 200-PO-1 OU, Gable Gap, and 100-B/C areas (Figure 2 through Figure 5). Logging support was provided by the Stoller Corp.

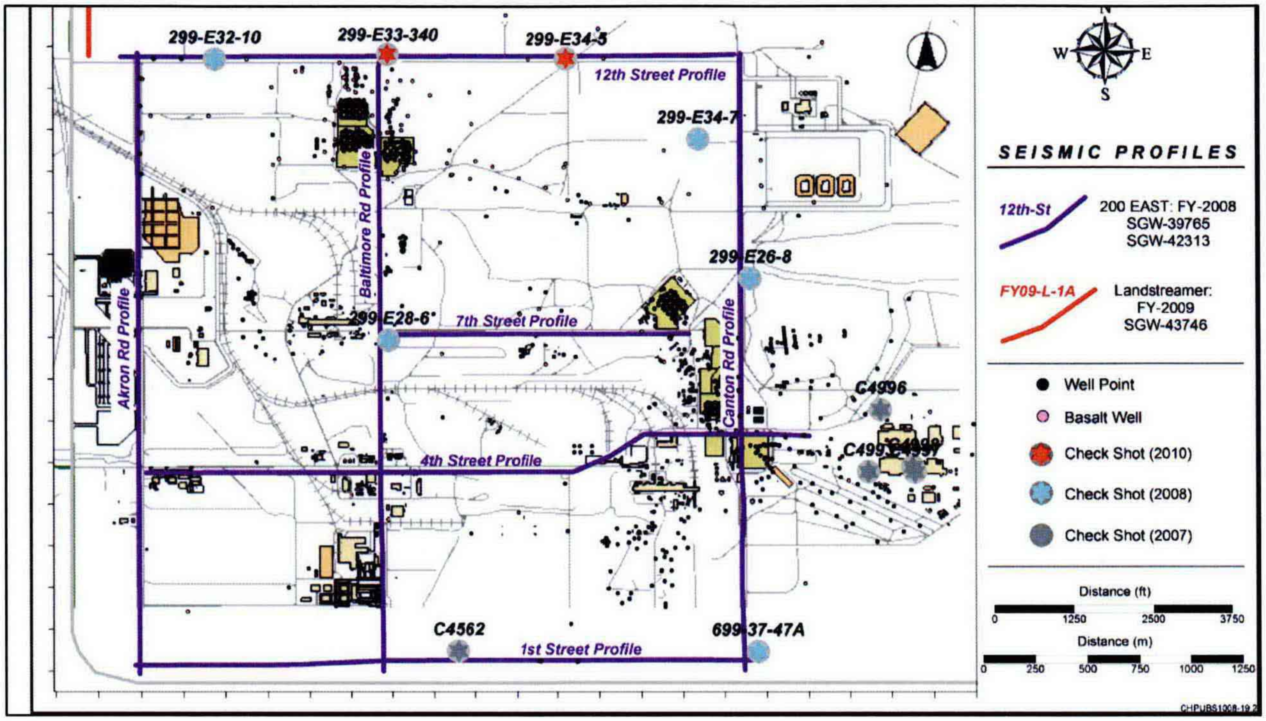

Figure 2. 200 East Area: Check Shot Surveys

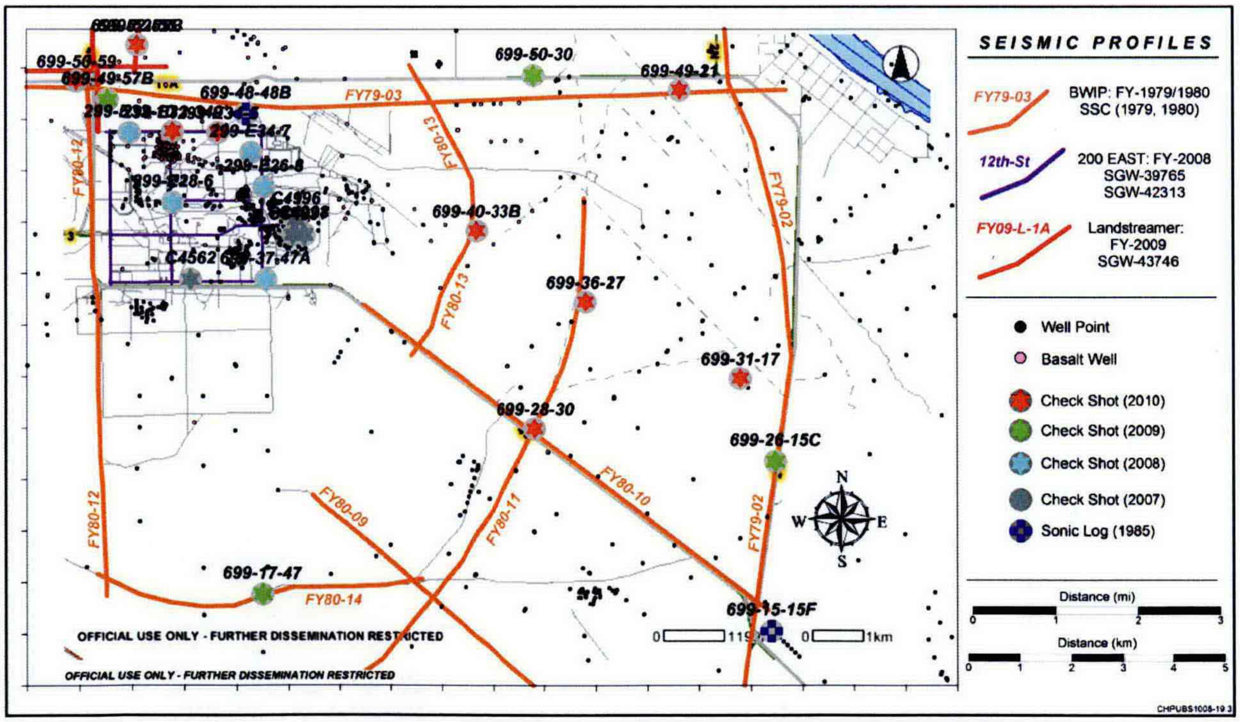

Figure 3. Check Shot Survey Well Locations

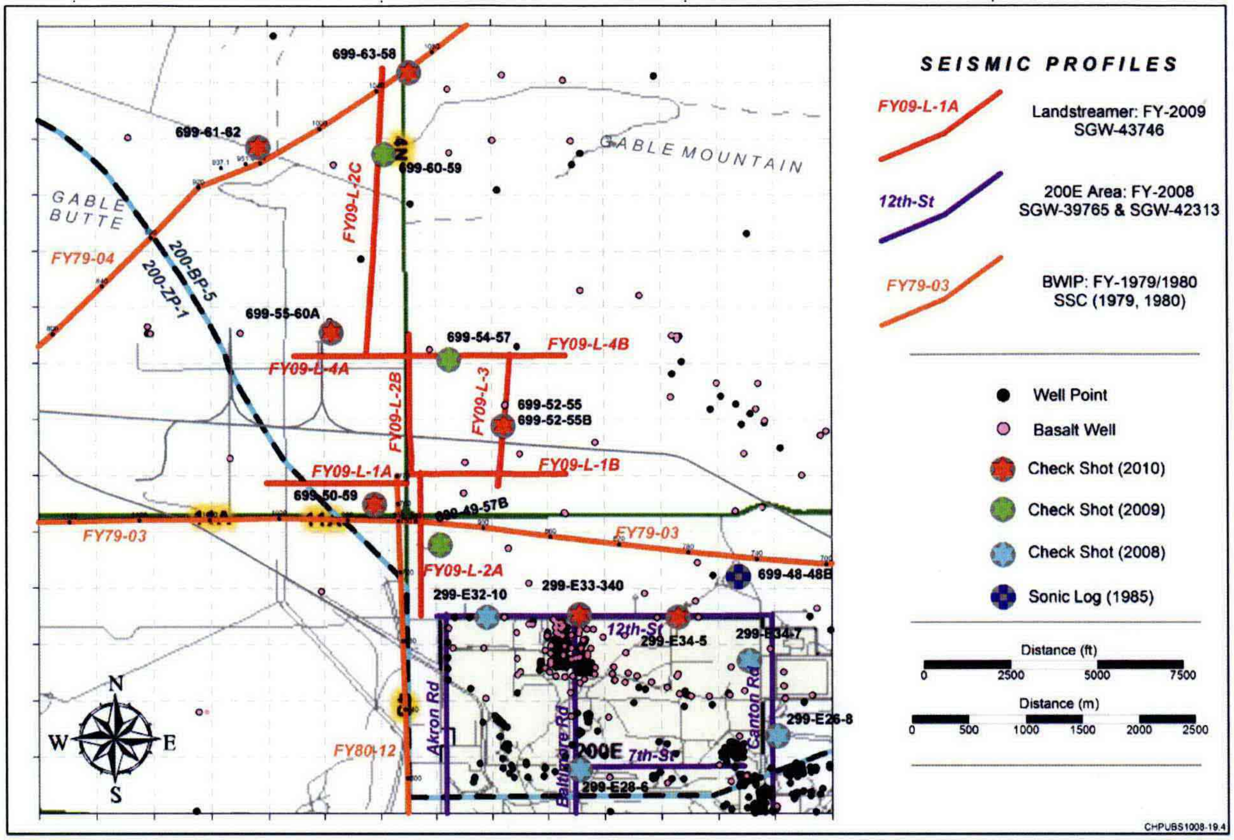

Figure 4. Gable Gap: Check Shot Survey Well Locations

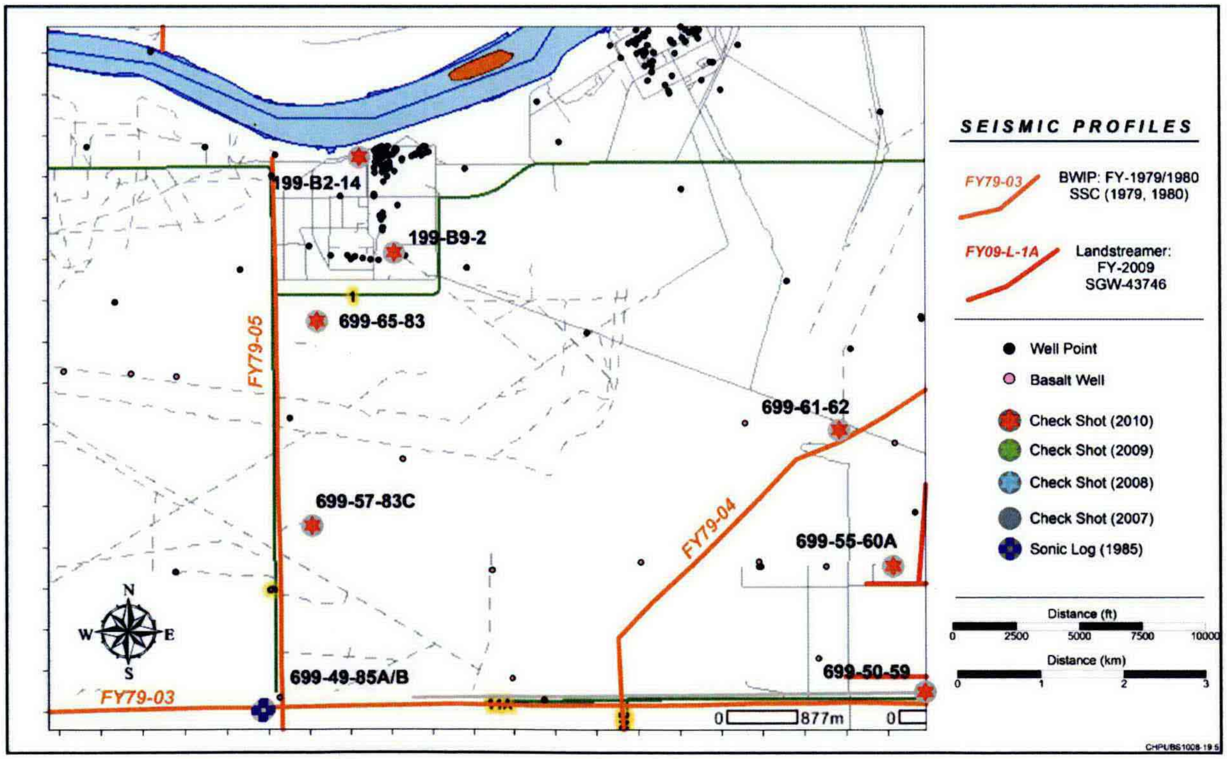

Figure 5. 100 B/C Areas: Check Shot Survey Well Locations

The initial scope of survey work was planned for Wells 299-E18-1, 699-2-E14, 699-12-18, 699-16-51, 699-42-30, 699-53-55B, 699-54-18D, and 699-84-34B. Well 299-E18-1 could not be entered due to bent casing (prevented removal of the pump), wells 699-12-18 and 699-42-30 could not be safely reached by the logging truck, Well 699-16-51 was decommissioned prior to survey start, Well 699-53-55B did not have its pump pulled, and Wells 699-2-E14, 699-54-18D, and 699-84-34B are artesian and capped with an igloo structure. Table 1 provides a list of wells that were surveyed and Figure 1 through Figure 5 show the well locations relative to the Hanford Site.

Table 1. Surveyed Wells

Well Name	Depth of Survey in m (ft)	Date of Survey	Geologic Units	Casing	Remarks
299-E26-8	122.5 (402)	24 Sep 2008	Hanford Basalt	8-in. CS	Results not geologic, casing tube-wave
299-E28-6	87.8 (288)	25 Sep 2008	Hanford	8-in. CS	Sledgehammer source, loss of signal below 88.4 m (290 ft) bgs, Basalt 110.6 (m) 363 ft bgs
299-E32-10	73.8 (242)	24 Sep 2008	Hanford	4-in. CS	Basalt: 74.7 m (245 ft) bgs
299-E34-7	61.6 (202)	23 Sep 2008	Hanford	4-in. CS	Basalt: 62.5 m (205 ft) bgs
699-37-47A	100.3 (329)	23 Sep 2008	Hanford Ringold	4-in. CS	Upper 15.2 m (50 ft) of Ringold
699-6-2A	22.6 (74)	3 Jun 2009	Hanford	8-in. CS	Well collapsed below 21.3 m (70 ft)
699-17-47	98.5 (323)	1 Jun 2009	Hanford Ringold (?)	4-in. CS	Casing tube-wave 15.2 m to 54.9 m (50 ft to180 ft); Basalt at 103.9 m (341 ft) bgs
699-26-15c	190.5 (625)	2 Jun 2009	Hanford Ringold (?) Basalt	4-in. CS	Basalt: 184.4 m (605 ft) bgs
699-49-57B	70.4 (231)	2 Jun 2009	Hanford Basalt	6-in. CS	Basalt: 49.4 m (162 ft) bgs and top-of-Interbed
699-50-30	43.9 (144)	4 Jun 2009	Hanford Ringold (?)	8-in. CS	Well plugged at 44.2 m (145 ft), possible Ringold near bottom
699-54-57	72.5 (238)	4 Jun 2009	Hanford Basalt	6-in. CS	Basalt: 55.2 m (181 ft) bgs
699-60-59	157 (515)	3 Jun 2009	Hanford Basalt	4-in. CS	Basalt: 54.9 m (180 ft) bgs Interbed: 140.8 m (462 ft) bgs
199-B2-14	21.6 (71)	23 Apr 2010	Hanford	4in. SS	Well plugged at 22.9 m (75 ft)

199-B9-2	33.3 (110)	21 Apr 2010	Hanford	4-in. SS	
299-E33-340	99,7 (327)	19 Apr 2010	Hanford Basalt	4-in. SS	Basalt: 68.9 m (226.1 ft) bgs Interbed: 93 m (305 ft) bgs
299-E34-5	55.2 (181)	22 Mar 2010	Hanford Near Basalt	4-in. SS	Basalt: 58 m (190 ft) bgs
699-28-30	54 (177)	23 Mar 2010	Hanford	6-in. SS	Hanford Cold Creek Units
699-31-17	182.9 (600)	24/25 Mar 2010	Hanford Cold Creek Unit Ringold Basalt	4-in. PVC	Basalt: 169. 2 m (555 ft) bgs
699-36-27	43 (141)	23 Mar 2010		6-in. CS	
699-40-33B	83.2 (273)	24 Mar 2010	Hanford Ringold	6-in. CS	Basalt: 84.7 m (278 ft) bgs
699-49-21	34.1 (112)	22 Mar 2010	Hanford	6-in. CS	Basalt: 45.7 m (150 ft) bgs
699-50-59	52.1 (171)	22 Apr 2010	Hanford Basalt	4-in. SS	
699-52-55	55.2 (181)	23 Apr 2010	Hanford Basalt	4-in. SS	
699-52-55B	75 (246)	20 Apr 2010	Hanford Basalt	4-in. SS	Measured top-of-interbed
699-55-60A	65.5 (215)	22 Apr 2010	Hanford	8-in. CS	
699-57-83C	125.3 (411)	21 Apr 2010	Hanford Ringold Basalt	4-in. CS	Sledgehammer source, loss of signal below 128 m (420 ft)
699-61-62	53.6 (176)	20 Apr 2010	Hanford Basalt	8-in. CS	
699-63-58	39.3 (129)	20 Apr 2010	Hanford Basalt	8-in. CS	
699-65-83	34.4 (113)	23 Apr 2010	Hanford	6-in. CS	

bgs = below ground surface
CS = carbon steel
PVC = polyvinyl chloride
SS = stainless steel

2 Equipment Procedures

Surveys conducted under this investigation employed the check shot survey method as defined under ASTM D-7400-08 and followed the procedures and survey setup outlined in SGW-39020. The check shot method involves placing a seismic receiver (borehole geophone) at various depths in a well, and measuring the time for seismic energy to travel from an impulsive seismic source located on the ground surface to the borehole geophone. Measurements of the compressional-wave (P-wave) were conducted under this investigation, and an impulsive source such as a weight drop or sledgehammer blow are used to generate the seismic wave.

Figure 6 shows a schematic of a typical check shot setup and the resulting seismic shot-record format used during this survey. The shot point (sledgehammer position) is offset from the well point in order to reduce the interference from seismic waves propagating down the casing (tube-wave). Using an offset shot point allows the seismic energy to broadside the well at shallow depths and delay the arrival of the casing generated tube-wave until after the direct arrival (diagonal path from shot to receiver position). The seismic energy is recorded by three receivers housed in the downhole geophone as indicated for receivers 10 through 12 in the example shot record (lower left corner of Figure 6).

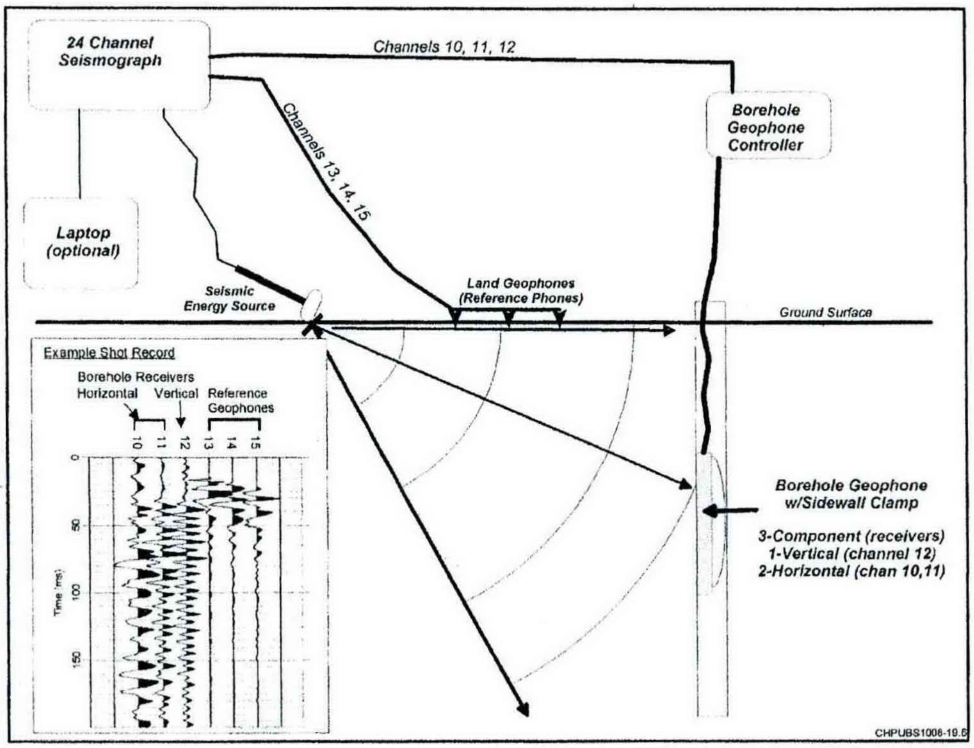

Figure 6. Check Shot Survey Setup and Example Shot Record

2.1.1 Equipment

Both the Geometrics'® StrataView and Geode 24-channel engineering seismographs were used to record the seismic data during the three survey rounds (Figure 7).

Data were recorded using a 0.125-millisecond (ms) sample interval and record lengths of 256 to 512 ms (1/4 to 1/2 second). Data were recorded unfiltered as site conditions did not exhibit noise levels (power-line, vehicular, or other sources) that could not be overcome by the energy source. A pre-trigger recording window of 10 ms was used to help identify noise conditions during the survey. Both seismographs allow for seismic signal capture and enhancement through a wide dynamic range (ability to detect low amplitude signals) and signal stacking capabilities. Signal stacking involves repeating a shot point one or more times for a given shot-receiver geometry in order to increase the amplitude of the resulting seismic signal and to suppress transient signals (noise) resulting from infrastructure (e.g., pumps) and vehicular activity.

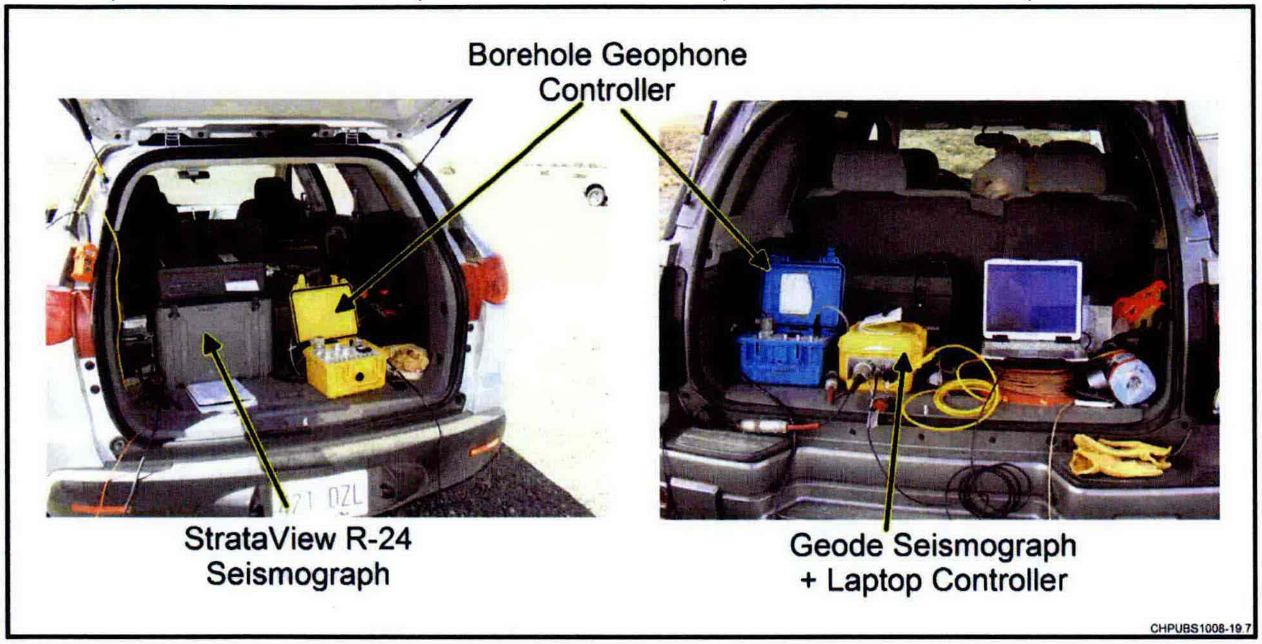

Figure 7. Borehole Geophone Controller

A Geostuff model BHG-2 receiver was used as the borehole geophone (Figure 8). The BHG-2 is a three-component (two horizontal and one vertical) sidewall clamping sonde employing 40-Hz receiver elements. The vertical component was recorded on channel 12, and the horizontal components were on channels 10 and 11. Conventional land geophones were used as reference receivers to ensure consistent shot timing during the survey. Seismic energy detected by reference geophones, Mark Products model L-12, was recorded on channels 13, 14, and 15 for the 1.5-m (5-ft), 3-m (10-ft), and 4.5-m (15-ft) offsets from the shot point.

For the FY 2008 and FY 2010 surveys, the seismic energy source was a 7.3-kg (16-lb) sledgehammer striking a 0.4-m (1.25-ft) diameter steel plate. For most cases, a stack count (signal enhancement) of two to three repeat strikes were required to detect the propagating seismic wave in the upper 45.7 m (150 ft) of the well; below 45.7 m (150 ft) in depth, stack counts ranged from 3 to 15 repeat shots, with progressively greater stack counts for greater depths. A 226.8-kg (500-lb) trailer-mounted accelerated weight drop source was used during the FY 2009 surveys with stack counts ranging from 1 to 4 (see Figure 9).

Figure 8. Geostuff Model BHG-2 Borehole Geophone (with Sidewall Clamp)

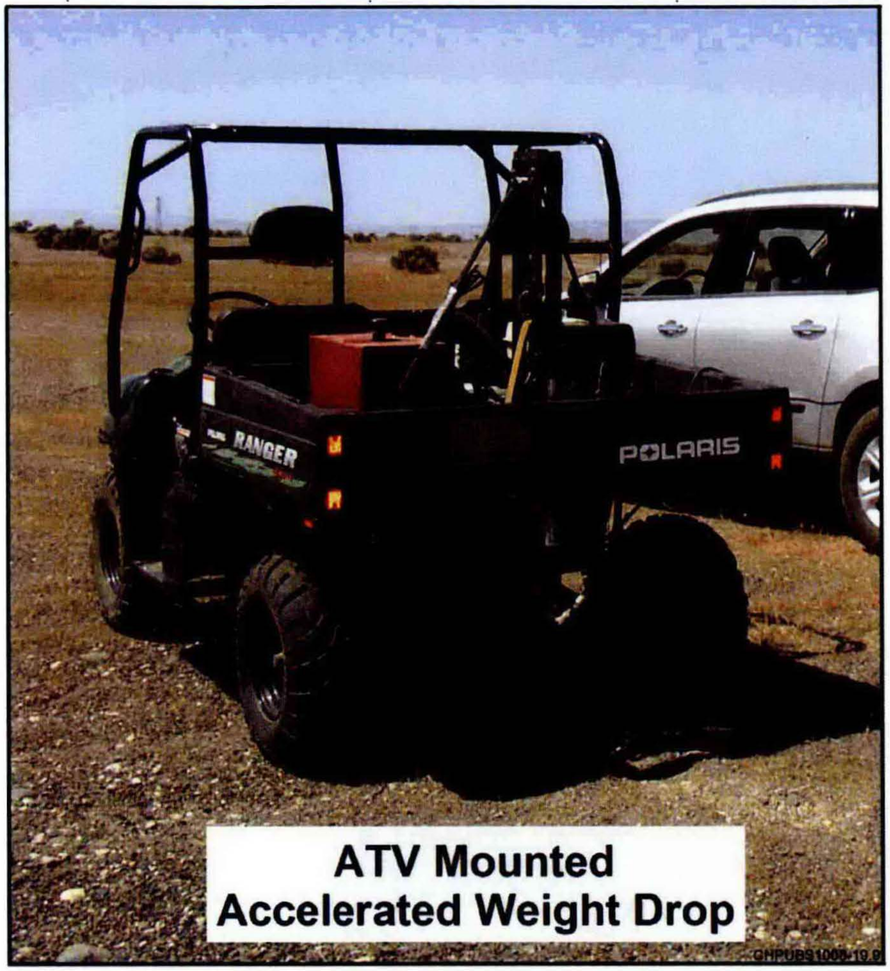

Figure 9. ATV Mounted Accelerated Weight Drop

Seismic signal proved difficult to detect and record in Wells 299-E28-6, 699-31-17, and 699-57-83C. For 299-E28-6, stack counts of 50-60 with the sledgehammer did not produce seismic signal below 88.4 m (290 ft), and the loss of seismic signal in Well 299-E28-6 is attributed to well construction rather than the underlying geology, where the construction resulted in poor coupling of the borehole geophone (or well) with the surrounding earth material. Seismic signal could not be recovered below 125 m (410 ft) for 699-37-83C (15.2 m [50 ft] below top-of-basalt). Extreme wind gusts and possible casing earth material coupling interfered with surveys in Well 699-31-17. Advanced filtering, though, allowed recovery of seismic signal to 182.9 m (600 ft) in depth. All three surveys used a sledgehammer source, and it is likely that an accelerated weight drop like that shown in Figure 9 would overcome the signal attenuation.

Raw, unfiltered signals acquired in the check shot survey were stored directly on either the seismograph or laptop hard drive in the SEG-2 industry standard format, and transferred to an auxiliary storage drive and then the Hanford Local Area Network at the end of each day for later analysis. Each stored shot record contains six traces of seismic data (see example shot-record in Figure 6). Shot data were composited by recording channel and receiver depth into raw shot records showing the change in seismic signal with depth. Filtered and unfiltered plots of the raw shot records are shown in Figure A1-through Figure A29 (Appendix A).

2.1.2 Procedures

Survey procedures followed steps defined in SGW-39020 and methodology specified in ASTM D-7400-08. For each check shot survey, the shot point was offset from the well casing, reference geophones were implanted at fixed distances from the shot point, and the borehole geophone moved down the borehole in 3-m (10-ft) increments. Deviations from the 3-m (10-ft) interval occur in wells 699-49-21, 699-40-33B, and 699-60-59. The first two wells used a 1.5-m (5-ft) interval in an attempt to refine Hanford units, and 6-m (20-ft) spacing was used through the approximately 61 m (200 ft) thick section of the Umatilla basalt in Well 699-60-59.

Shot points were offset from 3 m to 20 m (10 ft to-66 ft) from the well point in order to reduce the effect of tube-waves (seismic energy travelling up and down the well's casing). The three reference geophones were offset 1.5 m (5 ft), 3 m (10 ft), and 4.5 m (15 ft) from the shot point and were installed in-line between the shot and well. Two shot point locations (near and far) were used for wells 699-26-15C, 699-31-17, 699-50-59, 699-55-60A, and 699-57-83C in order to suppress tube-waves. For Well 699-26-15C, the tube-wave is readily identifiable as a high-velocity (quick) signal that departs from the direct wave arrivals (see Figure A8 in Appendix A). Moving the shot point offset from 7.6 m to 12.2 m (25 ft to 40 ft) results in a dramatic change in the tube-wave's arrival (delayed due to the increased shot-to-well distance) without negatively impacting the direct-wave (desired signal) travel time.

Pre-survey checks included verifying the operation of the sidewall clamping mechanism, the ability of the borehole geophone to detect a seismic signal while at the ground surface, and ability of the seismograph to trigger when the shot was triggered (sledgehammer impacting the strike plate). An ambient noise record was recorded at the beginning of each survey with the borehole geophone clamped near the top of the well's casing.

A pre-survey radiation (RAD) screen was conducted, and the well only entered if no RAD contamination was detected. Post survey, both the downhole geophone and cable were RAD wiped as they were removed from the well. The wipe, cable, and borehole geophone were screened for RAD contamination. RAD contamination was not detected during the surveys.

3 Analysis

Check shot data were analyzed using the following general steps:

1. Sort data into shot gathers based on receiver type. The result is six shot gathers per well survey consisting of vertical, two horizontal, and three reference (land-surface) components. The number of data channels per shot gather equals the number of depth points acquired for each well. Sorted data are stored in the Kansas Geological Survey modified SEG-Y seismic format (KGS, 1991).

2. Pick arrival time of the direct P-wave at each reference geophone and determine timing correction (if any).

   – Determine arrival time for each reference geophone and shot combination.

   – Determine reference arrival times for each of the three reference receivers. These values are either the mode (most common arrival time) or an average of the median and mean values if the data are not uni-modal.

   – Determine shot-timing variations based on the departure from the reference arrival time. Calculation is performed by subtracting the onset arrival from the reference arrival.

- Calculate a per-shot correction value based on an average of the departure for all three reference receivers.

3. Pick arrival-time of the P-wave at each borehole geophone depth point.
   - Low-pass and band-pass digital filtering was required to enhance the first arriving seismic signal.
   - Arrival time picks were based on both the unfiltered and filtered data.
4. Apply shot-timing corrections (if any) to the borehole arrival times.
   - Determine mode (most frequent) of arrival times for each reference geophone, or average the median and mean values if a mode cannot be determined.
   - Calculate departure (delta-time) from the mode.
   - Adjust shot point times based on departure (correct to mode).
5. Correct arrival time for "slant-path" effects due to the shot point being offset from the borehole.
   - Compute average velocity from shot point to borehole geophone depth-point.
   - Use the average velocity to compute a theoretical vertical travel time to this depth point.
   - The previous two steps are functionally equivalent to the cosine factor used in PNNL-16559.
6. Determine interval velocities for the corrected arrival time data.
   - Compute estimates of the interval velocity from point-to-point slope changes and running least-squares line-fits of 3, 5, 7, and 9 points. Also, perform automated forward and reverse scans to find significant breaks in velocities.
   - Compare the interval velocity estimates from the previous step with known changes in lithology and observed slope changes on the travel time data.
   - Manually pick changes in velocity based on observed slope changes, using both the velocity estimates and lithology as a guide.

Shot timing variations are primarily due to subtle changes in the shot point, either caused by slight changes in position of the plate (or impact point), or to differential compaction of the underlying sediment. In some cases, repeated sledgehammer impacts create a shallow depression in the ground surface, which slightly changes the shot receiver geometry. Figure 10 shows the shot records and arrival time picks for the near 1.5 m (5 ft) and middle 3 m (10 ft) reference geophones used for the Well 299-E34-7 check shot survey. Picked arrivals for traces 1 through 6 and 21 deviate from the near uniform time-picks between traces 8 and 20; thus, arrival times for shot points corresponding to these traces will need to be adjusted.

Timing corrections are calculated on a per-shot basis and computed using the difference between an empirically-determined reference arrival time and the arrival time pick for each reference receiver trace. The reference arrival time value is determined from the mode (most common arrival time), or from an average of the median and mean values if a mode cannot be determined. Per-shot timing corrections are based on an average of the correction values from all the three reference phones and applied on a trace-by-trace basis. For example, the amount of deviation for each of the seven traces identified in Figure 10 will be used to calculate timing corrections for each of the corresponding shot points with the correction equaling the amount of time-shift required to bring in-line with traces 8 through 20.

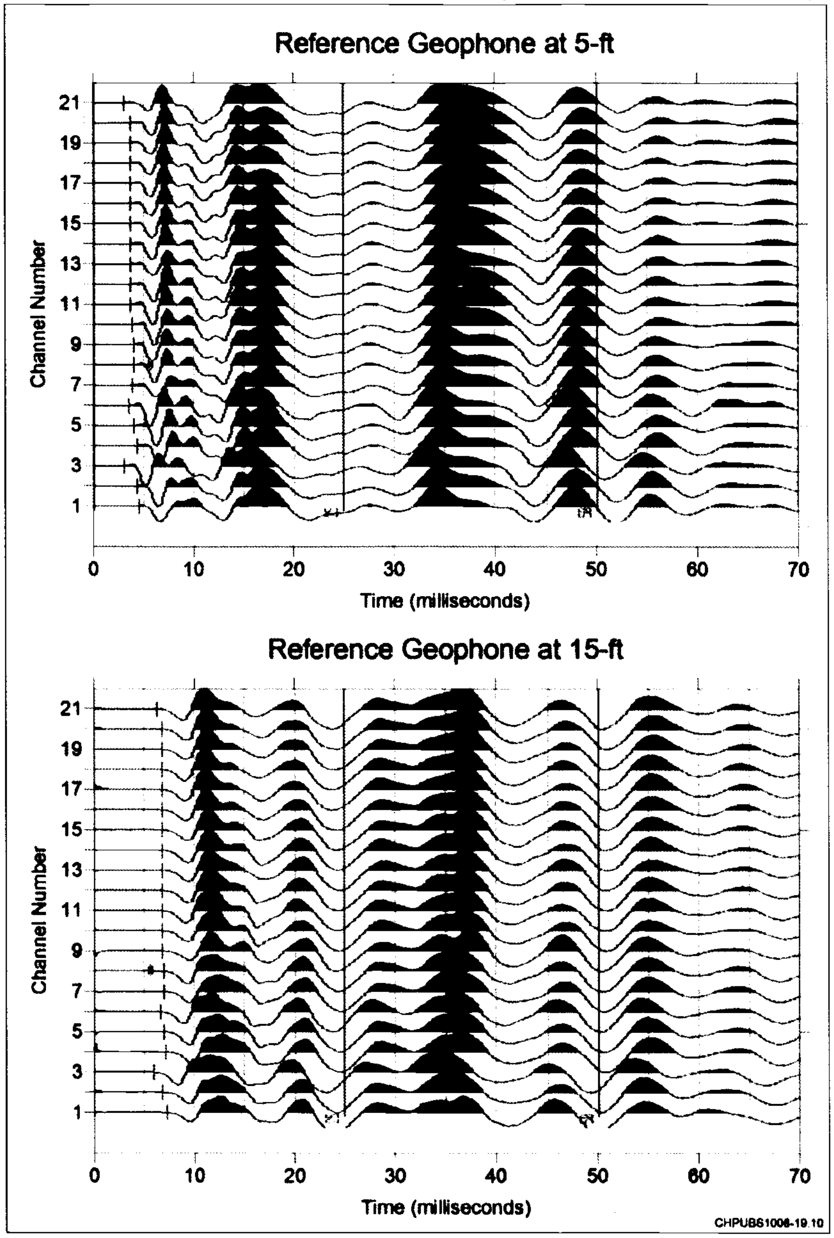

Figure 10. Well 299-E34-7: Reference Geophone Arrivals

Travel time picking focused on determining the first break (departure from zero amplitude) and used the commercial software SIPIK (Rimrock Geophysics, 1992). The time picking software employs zero-phase Sine-Butterworth low- and band-pass filters to reduce noise and/or enhance the seismic signal without destroying the original data. For some cases, a real-time convolution function using a boxcar operator was also employed to convert the first break into a peak (or trough) in order to aid in the identification of the first arrival. Time picks were initially based on the raw, unfiltered data and subsequently modified based on filtered signal. Quick toggling between the filtered and unfiltered shot records was conducted to ensure that the arrival time pick was not impacted by any filtering lag (time offset). Time picking was conducted on the sorted seismic data, which allowed visual tracing of the arrival of seismic signal with depth. The ability to trace the seismic signal from depth point to depth point (or from top of well to bottom) affords greater confidence in the resulting time pick data set.

Raw and filtered shot-records for the wells surveyed in September 2008, June 2009, and March and April of 2010 are shown in Figure A1 through Figure A29 (Appendix A). The data are displayed by trace number and travel time, with depth increasing from top-to-bottom of each plot. A heavy blue trace line is used to denote where the start of the seismic signal is interpreted, and light-blue colored dots indicate the travel time pick.

Measured travel times have to be corrected back to a true vertical travel time because the energy source was offset horizontally from well point (see Figure 6). The average velocity along the slant path (shot-to-receiver) is computed, and this average velocity is then used to compute a theoretical vertical travel time to the depth point. The following equations are used:

$$V_{avg} = (d^2 + s^2)^{1/2} / t_s$$

$$t_v = d/V_{avg} = t_s * d / (d^2 + s^2)^{1/2}$$

where:

d	=	depth to borehole geophone
s	=	shot point offset from borehole
t_s	=	measured travel time (corrected for shot timing)
V_{avg}	=	average velocity
t_v	=	corrected travel time

Interval velocities are determined by fitting least-squares lines on segments (breaks in slope) of the observed travel time with depth information. Figure 11 shows a typical travel time with depth plot and the resulting velocity with depth model. Significant changes in slope on the time depth plot are interpreted at 4.6 m (15 ft), 12.2 m (40 ft), 16.5 m (54 ft), 23.5 m (77 ft), and 32 m (105 ft) in depth and marked by the vertical dashed red lines. Least-squares line fits for the 4.6 m to 12.2 m (15 ft to 40 ft) and 16.5 m to 23.5 m (54 ft to 77 ft) depth intervals are shown as dashed blue lines with the resulting seismic velocity (change in depth divided by change in time). There will always remain some judgment when partitioning the time-depth information into discrete velocity layers, especially in unconsolidated sedimentary sequences where velocity contrasts may be low resulting in a relatively smooth change in travel time with depth.

A set of automated least-squares line fits, ranging from 3-point to 9-point running sequences, are used to reduce some of the potential bias when interpreting the time-depth graph. This initial set of velocity estimates is compared and adjusted using the geology observed for the well. Figure 12 shows results of the automated velocity scans for wells 299-E32-10, 699-49-57B, and 699-52-55B. In each case, velocity estimates are determined using point-to-point (straight-line slope) and a suite of running least-squares line-fits, each of 3, 5, 7, and 9 points. In addition, two additional velocity-break (slope-change) estimates are made using automated forward and reverse scans. Small scale deviations in travel time generally result in large swings in velocity for the point-to-point and 3-point (IntVel-P and IntVel-3), whereas the 7- and 9-point least-squares line-fits (IntVel-7 and IntVel-9) tend to produce overly smooth results which don't capture important velocity information at the shallow and deep ends of the time-depth curve. The final velocity (heavy blue line) represents a compromise solution that attempts to capture some of the subtle velocity detail and yet remain consistent with the underlying geology.

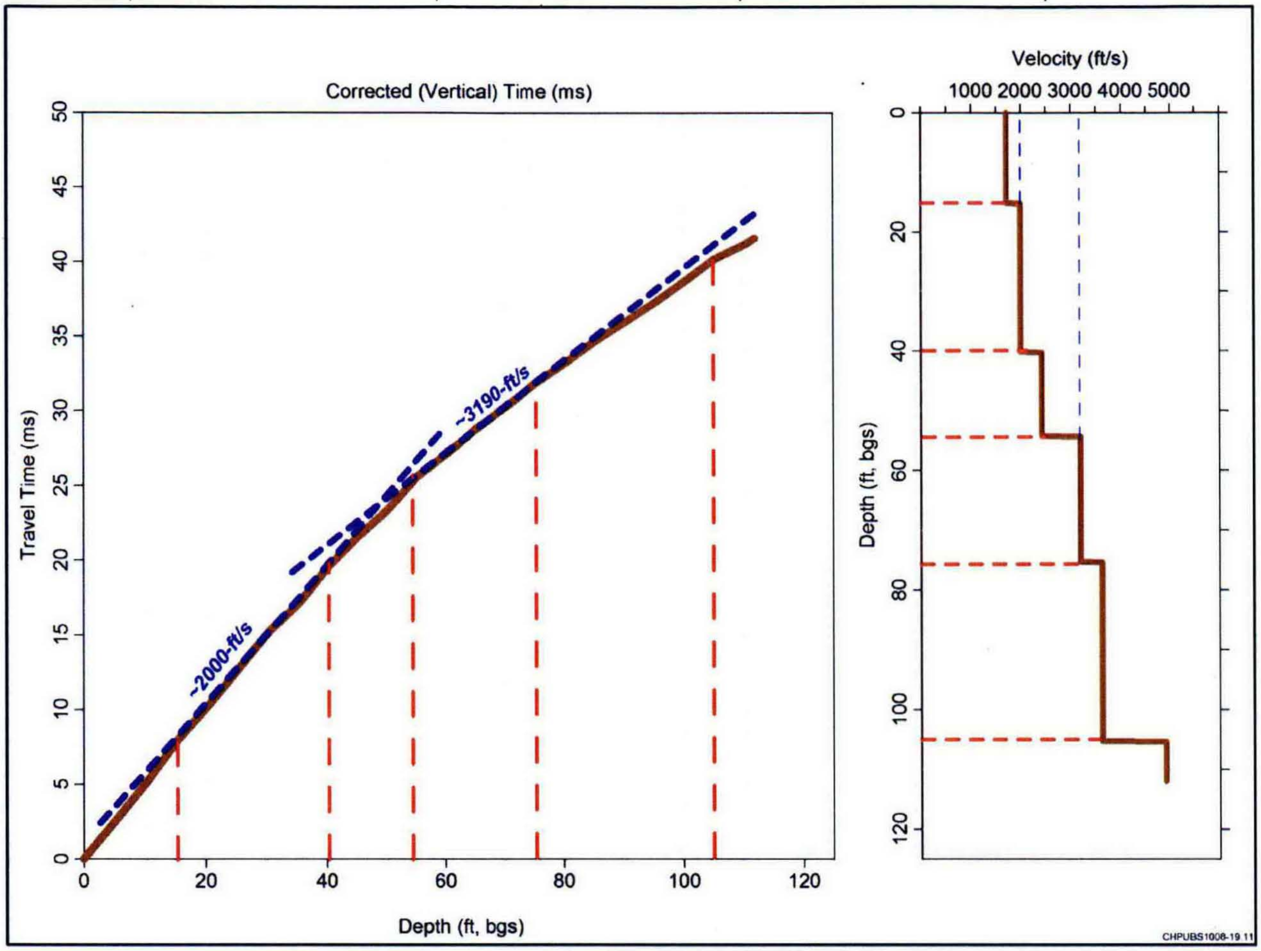

Figure 11. Converting Time-Depth to Velocity

4 Results

Figure 13 through Figure 41 show the calculated vertical travel time, interval velocity, available lithologic information, and natural gamma log data for the 29 wells. Driller's log descriptions were obtained from the Hanford Well Information System as either well summary or drilling log description data sets. Geologic information was obtained from the in-house Pacific Northwest National Laboratory-Hanford maintained TOPS data set (geologic tops) as well as where identified on the driller's logs. Natural gamma logs were obtained from the Hanford Environmental Information System database.

4.1 Well 299-E26-08

Well 299-E26-08 is located in the 200 East Area about 45.7 m (150 ft) east of and near the middle of the FY 2008 Canton Road seismic profile (SGW-39675) (see Figure 2). The well is located on a berm covering a waste transfer pipe with surface soils comprised primarily of sand. Pertinent information regarding the travel time to the top-of-Ringold and Basalt, as well as basalt inter-bed information, is potentially afforded by the well. Total survey depth was 121.2 m (400 ft) below ground surface (bgs).

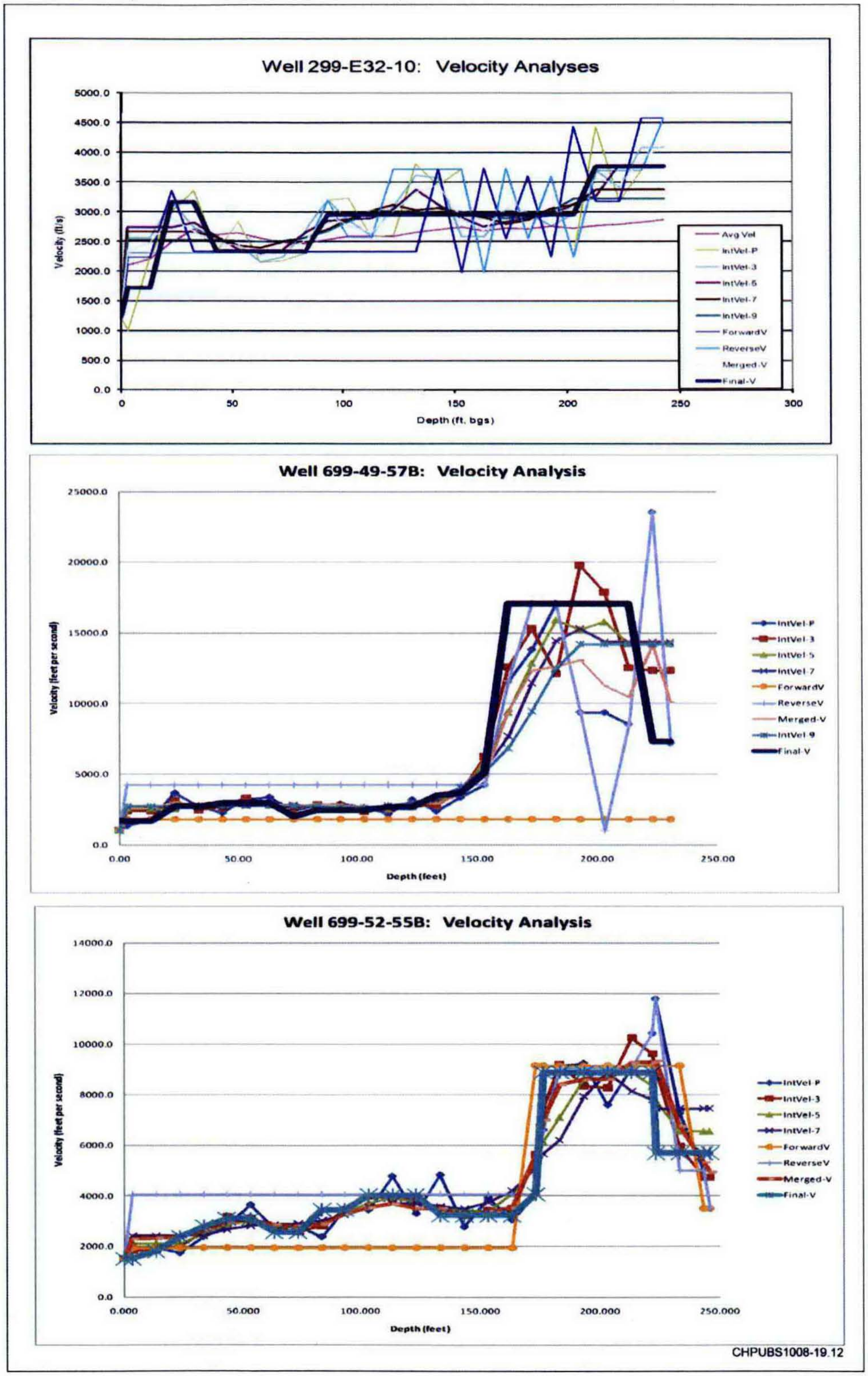

Figure 12. Example Velocity Scans

Figure 13 shows the resulting travel time measurements and estimated velocity, along with the natural gamma log, geology, and driller's description. Travel times appear to be unnaturally fast in the 15.2 m to 45.7 m (50 ft to 150 ft) depth interval and result in estimating a zone of extreme high velocity in the 30 m to 48.8 m (100 ft to 160 ft) depth interval. Above 15.2 m (50 ft) in depth, velocities are estimated to range from 448.1 m/s to 1,127.8 m/s (1,470 ft/s to 3,700 ft/s). The velocity estimate for basalt inter-bed zone is ~ 2,011.7 m/s (~6,600 ft/s), which is consistent with previously published results for inter-bed velocities underlying the Hanford Site (PNNL-16559). Velocity estimates for the basalt units range from 2,377.4 m/s to 3,048 m/s (7,800 to 10,000 ft/s).

One possible explanation for the unnatural high velocities is that the seismic energy traveled through some combination of the well casing and transfer pipe (within soil berm), and not directly through the sedimentary units. Casing size and well construction, however, cannot be the sole explanation as the similarly cased and constructed Well 299-E28-6 did not produce unreasonably high check shot velocities.

4.2 Well 299-E28-06

Well 299-E28-06 is located in the 200 East Area immediately to the southeast of the intersection of Baltimore Rd and 7th Street, and time depth information was obtained in the well used to support the interpretation of the corresponding FY 2008 seismic profiles (see Figure 2). The well is in an open area with primarily gravel and sand at the surface. Information regarding the travel time through Hanford sediments is provided by the check shot survey. Basalt was not encountered during the installation of this well, but it is estimated to be approximately 7.9 m (26 ft) below the well's bottom at a depth of 111.6 m (366 ft) bgs. Total well depth is approximately 103.6 m (340 ft) bgs, but the check shot survey was limited to approximately 88.4 m (290 ft) in depth due to severe attenuation of the seismic signal below this depth.

Figure 14 shows the resulting travel time measurements and estimates of velocity for this well, and the shot record and travel time picks are shown in Figure A2. Estimated arrival times to the predicted top-of-basalt are shown as dashed lines and were derived from sediment velocities obtained from check shot surveys in Well C4562 (Northland Geophysical, 2004).

The velocity structure shows a general increase with depth, starting near 304.8 m/s (1,000 ft/s) in the upper 1.5 m to 3 m (5 ft to 10 ft) and ending at ~1,066.8 m/s (~3500 ft/s) at 88.34 m (290 ft) in depth. Significant changes in velocity occur at approximately 7.6 m (25 ft) in depth (~579.1 m/s to 833 m/s [~1,900 ft/s to-2,700 ft/s]) and at 61 m (200 ft) in depth 833 m/s to 1,097.3 m/s (2,700 ft/s to 3,600 ft/s). The upper change likely corresponds to a change from gravel/cobbles to sands, whereas the lower change possibly indicates an increase in silt content.

4.3 Well 299-E32-10

Well 299-E32-10 is located near the northwest corner of the 200 East Area along 12th Street (Figure 2). The well is in an open area with primarily gravel and sand at the surface. Check shot surveys in this well provide travel time measurements through the Hanford units, to near the top-of-Basalt, and are used to support interpretation of the FY 2008 seismic profile along 12th Street. Basalt was encountered at approximately 75.6 m (248 ft) bgs, and total well depth is indicated as 75.6 m (248 ft). Check shot surveying was completed to approximately 74.1 m (243 ft) bgs.

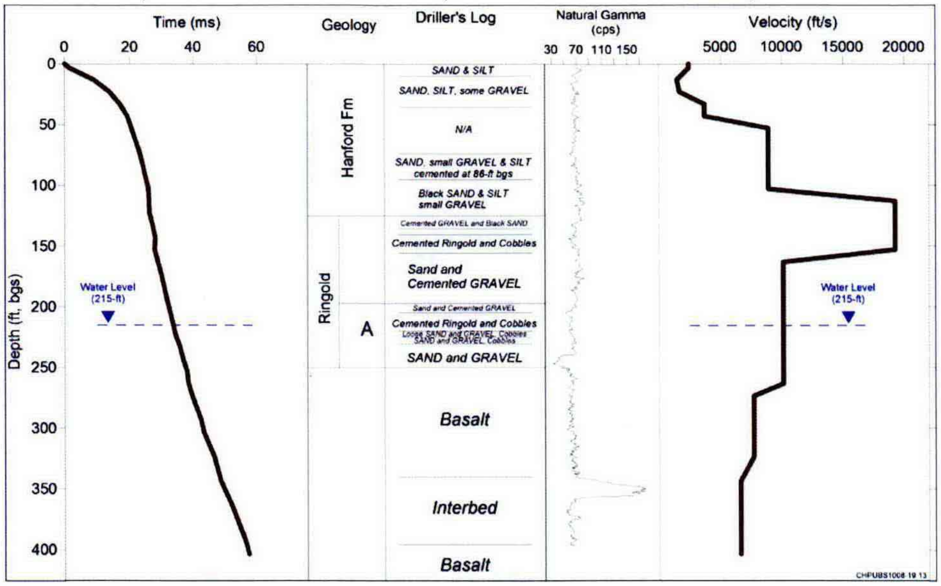

Figure 13. Check Shot Survey Results for Well 299-E26-08

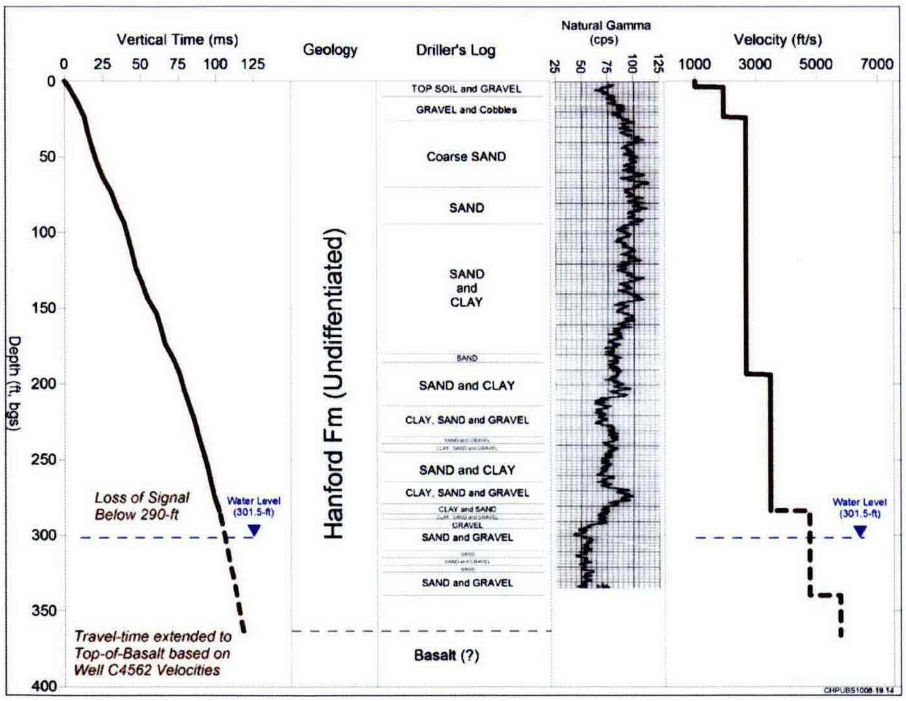

Figure 14. Check Shot Survey Results for Well 299-E28-06

Travel time and estimated velocities are shown in Figure 15, with significant breaks in travel time slope occurring at approximately 4 m (13 ft), 10.7 m (35 ft), 25.9 m (85 ft), and 61.9 m (203 ft) in depth (see Figure A3 in Appendix A for shot record). These breaks in slope are interpreted to represent overall changes in the subsurface velocity. A zone of relatively high velocity (for shallow depth Hanford sediments) occurs in the 4 m to 10.7 m (13 ft to 35 ft) depth range and is possibly correlative with a change in gamma response in the 6.1 m to 12.2 m (20 ft to 40 ft) depth range. Below this zone, velocities of approximately 701 m/s (2,300 ft/s) (10.7 m to 25.9 m [35 ft to 85 ft]), 91.4 m/s (3,000 ft/s) 25.9 m-60.1 m 85-200ft, and 1,128 m/s (3,700 ft/s) (61+ m [200+ ft]) are estimated for the remainder of the well.

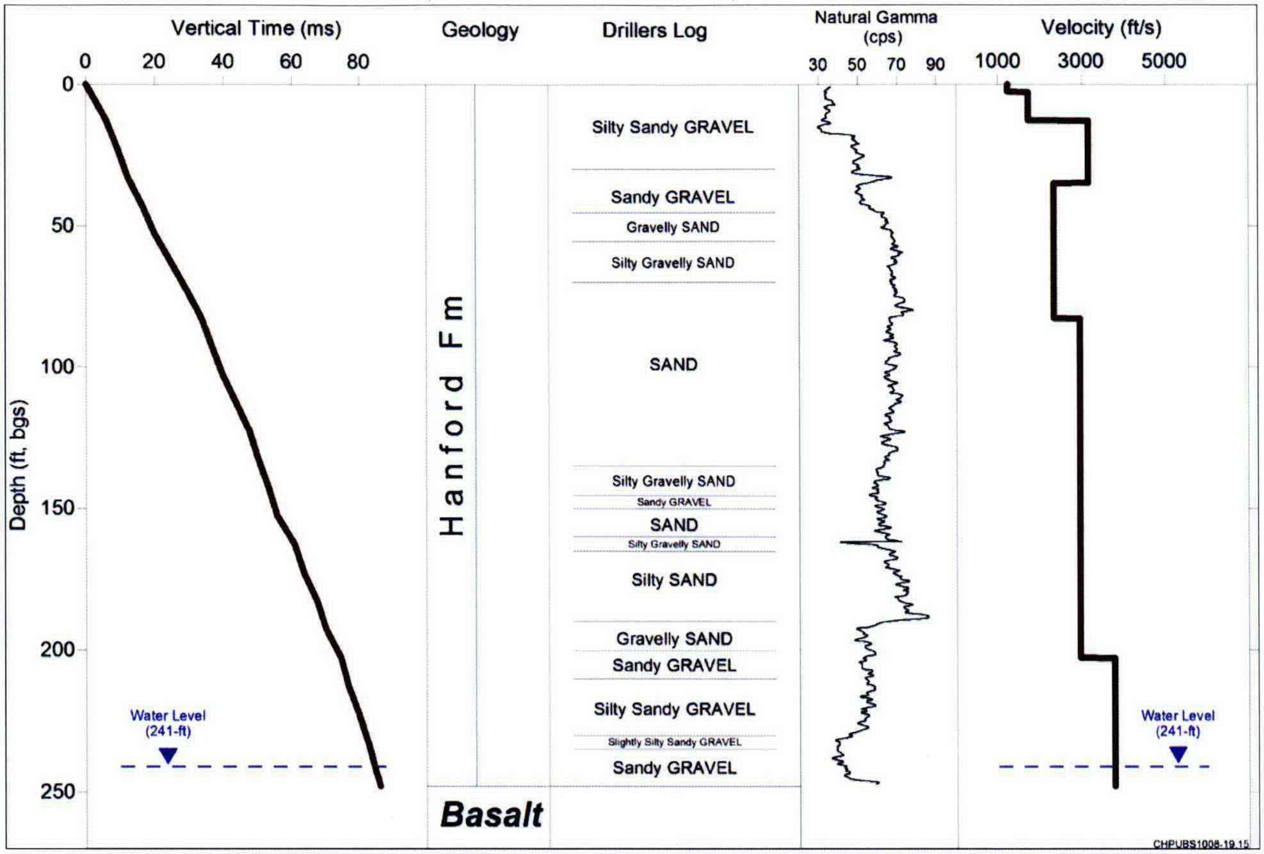

Figure 15. Check Shot Survey Results for Well 299-E32-10

The velocity increase at 61.9 m/s (203 ft) (from 91.4 m/s to 1,128 m/s [3,000 ft/s to 3,700 ft/s]) appears to be consistent with a sharp decrease in the gamma-log response (slightly higher and near 57.9 m/s [190 ft] bgs). It is not clear, however, whether or not the gamma-log change is geologic or well-construction related. Well construction records indicate that the well was drilled with a 27.3-cm (10.75-in.) temporary casing to approximately 49.4 m (162 ft) bgs, and a telescoping 22-cm (8.65-in.) temporary casing was extended to bottom 75.6 m (248 ft). A 10.2-cm (4-in.) stainless steel casing was installed with a 6 m (20 ft) screen interval from 68.6 m to 74.7 m (225 ft to 245 ft), and the annulus was filled with bentonite crumbles. The water level at the time of well construction was approximately 70.4 m (231 ft) bgs and is currently 73.5 m (241 ft) bgs (lower than the change in gamma log but unknown at time of logging).

4.4 Well 299-E34-07

Well 299-E34-07 is locate near the northeast corner of the 200 East Area approximately 396.2 m (1,300 ft) south of 12th Street and 198.1 m (650 ft) west of Canton Rd (Figure 2). The well is in an open area with primarily gravel at the surface. Check shot surveys measured the travel time through Hanford sediments to near the top-of-basalt. Basalt was encountered at approximately 62.5 m (205 ft bgs) during well installation and total well depth is approximately 62.2 m (204 ft bgs.) Check shot surveying completed to approximately 61.6 m (202 ft) in depth.

Travel time measurements and estimates of velocity are shown in Figure 16 along with the natural gamma log, geology, and driller's description. Significant breaks in the travel time slope occur at 4 m (13 ft), 12.8 m (42 ft), and 34.4 m (113 ft) in depth and represent changes in the velocity of the sediments (see Figure A4 for shot record). The upper 4 m (13 ft) is estimated at approximately 457.2 m/s (1,500 ft/s) in velocity, with velocity increasing to ~774.2 m/s (~2,540 ft/s) (4 m [13 ft] to 12.8 m [42 ft]), ~1,007.4 m/s (~3,305 ft/s) (12.8 m [42 ft] to 34.4 m [113 ft bgs]), and 1,156.4 m/s (3,794 ft/s) 34.4+ m (113+ ft). The change in velocity from 1,007.4 to 1,156.4 m/s (3,305 to 3,794 ft/s) coincides with the Hanford H2 to H3 geologic boundary.

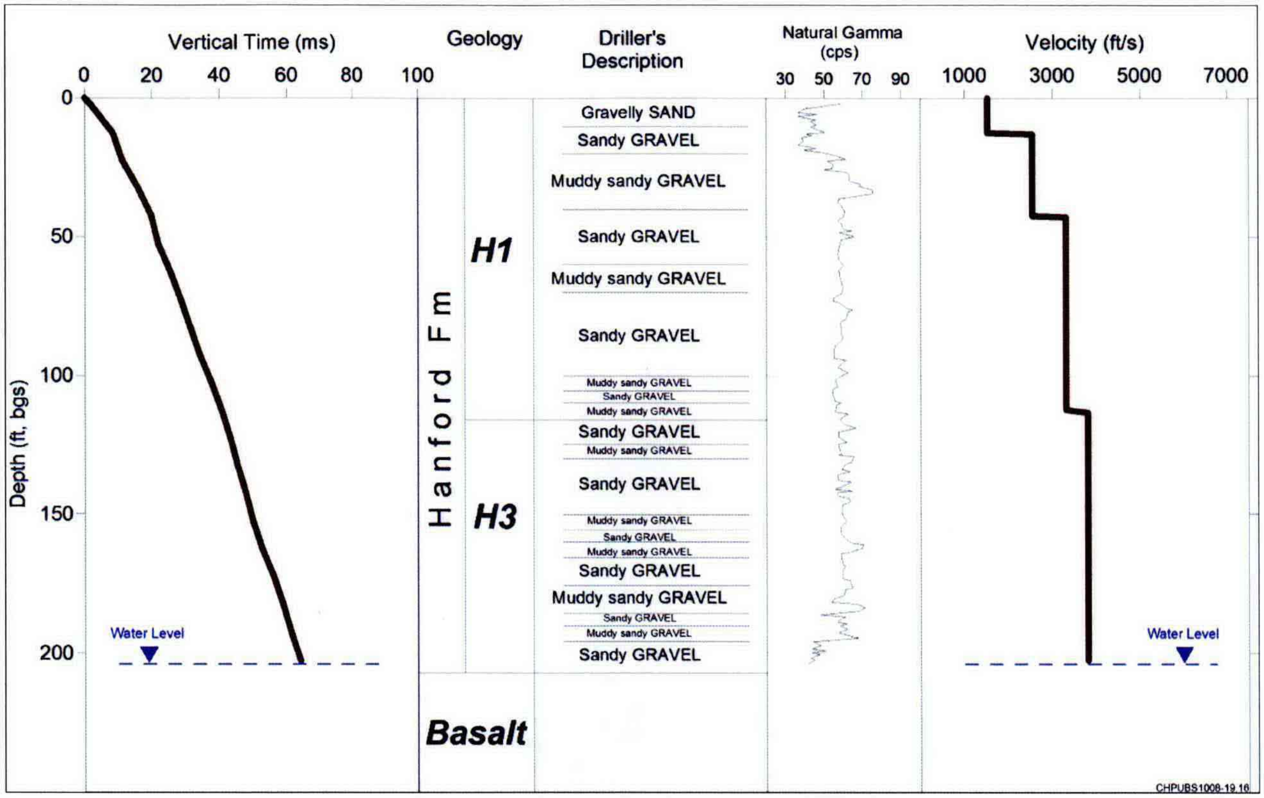

Figure 16. Check Shot Survey Results for Well 299-E34-07

4.5 Well 699-37-47A

Well 699-37-47A is located near the southeast corner of 200 East and about 76.2 m (250 ft) east of the south end of the FY 2008 Canton Rd seismic profile (Figure 2). The well is in an open area with primarily sand at the surface. Travel time through Hanford sediments and into the upper part of the Ringold Formation (Fm) is provided by the check shot survey in the well. The well was originally drilled into the underlying basalt 157.6 m (517 ft) bgs but was back-filled and screened in the upper Ringold Fm. Total well depth is approximately 103 m (338 ft) bgs, and check shot surveying was completed to 101.2 m (332 ft) in depth.

Figure 17 shows the travel time measurements and estimated velocities for Well 699-37-47A, as well as the associated gamma log and driller's description and geologic names of units encountered. Check shot survey results for Well C4562 (Northland Geophysical, 2004) were used to extend to the time-depth function to top-of-basalt. Changes in interval velocities are interpreted at 0.7 m (2.3 ft), 6.9 m (22.5 ft), 25.3 m (83 ft), 55.8 m (183 ft), and 91.4 m (300 ft) in depth from the travel time with depth curve. The subtle changes in interval velocity above 91.4 m (300 ft) in depth are likely correlative with changes in the sediment, though it is not clear whether the velocity increase (789.1 m/s to 982.7 m/s [2,589 ft/s to 3,224 ft/s]) at 55.8 m (183 ft) in depth correlates with a possible Hanford H2/H3 unit boundary. Ringold Fm E-unit sediments were encountered near the bottom of the hole and correlate with a change in velocity from 982.7 m/s to 1,189.0 m/s (3,224 ft/s to 3,901 ft/s).

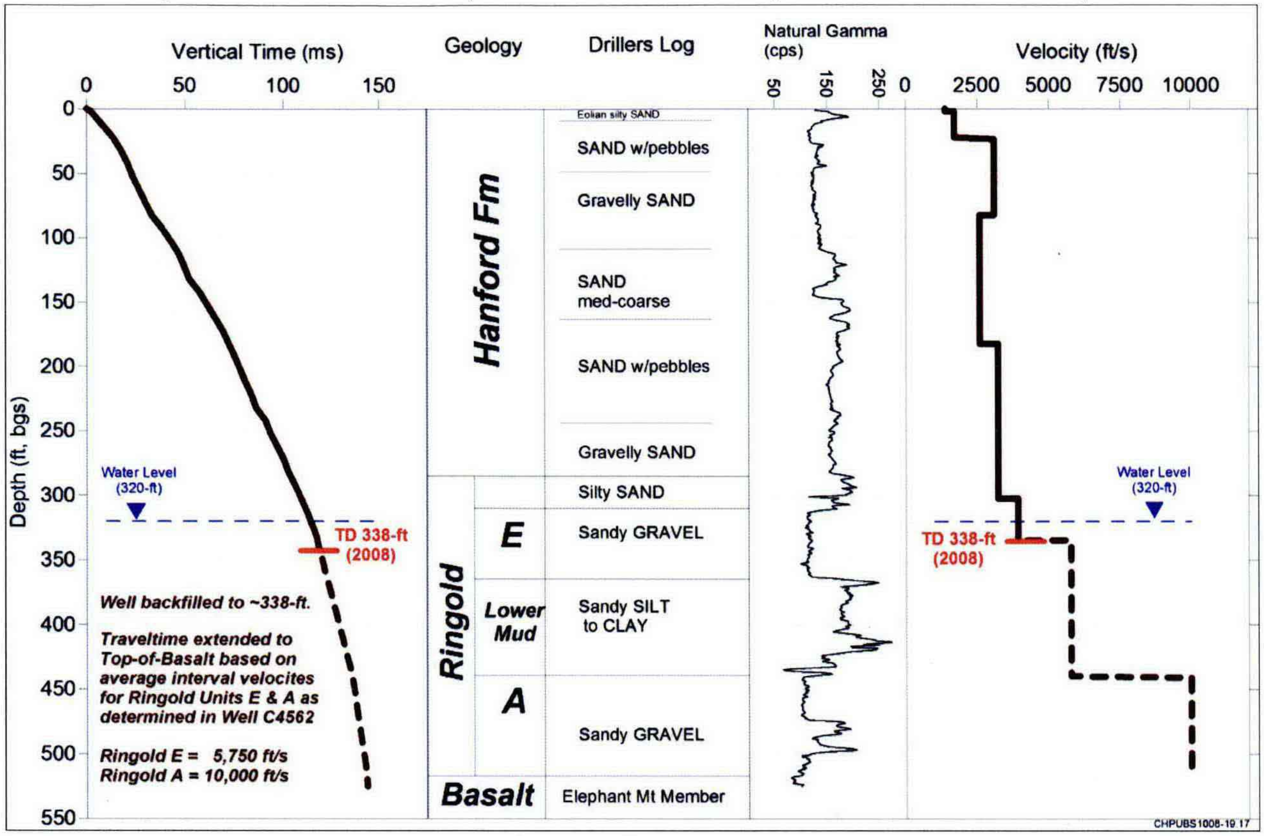

Figure 17. Check Shot Survey Results for Well 699-37-47A

4.6 Well 699-6-2A

Well 699-6-2A is located south of the Energy Northwest generating station, and about 914.4 m (3,000 ft) north of seismic station 440 of BWIP Profile FY79-01 (see Figure 1). The well is in an open area with primarily sand at the surface. Travel time through Hanford sediments is provided by the check shot survey in this well. The well was originally drilled into the underlying basalt (174.7 m [573 ft] bgs) and Ringold Fm with casing initially set to 141.4 m 464 ft (in upper Ringold Fm). Check shot surveying was only completed to 22.9 m (75 ft) in depth due to blockage within the well.

Results from the check shot survey in Well 699-6-2A are shown in Figure 18 along with the driller's description and geologic names of units encountered. Changes in interval velocities are interpreted at 2.3 m (14 ft), 10.7 m (35 ft), 18.3 m (60 ft,) and 19.8 m (65 ft) in depth based on changes in slope on the travel time with depth curve. Near-surface (upper 2.3 m [14 ft]) velocities are extremely slow (~326.1 m/s [~1,070 ft/s]) but increase to about 457.2 m/s (1,500 ft/s) in the 2.3 m to 12.2 m (14 ft to 40 ft) depth range. These values are consistent with dry, unconsolidated sands (Press, 1966). Velocities increase to about 762 m/s (2,500 ft/s) below 12.2 m (40 ft) and are probably a response to the gravel zone at 12.8 m to 13.7 m (42 ft to 45 ft).

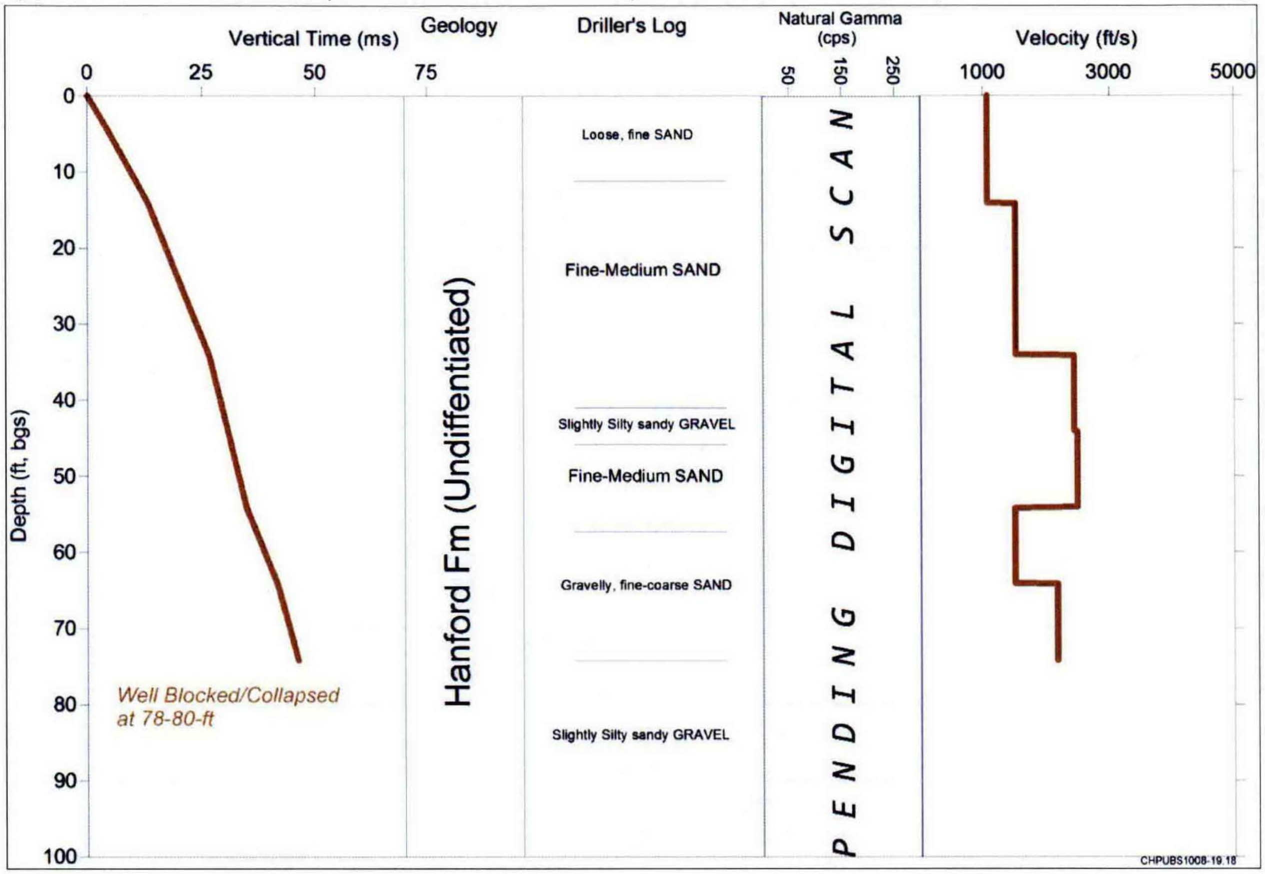

Figure 18. Check Shot Survey Results for Well 699-6-2A

4.7 Well 699-17-47

Well 699-17-47 is located on Army Loop Rd due south of 200 West and approximately 9.1 m (30 ft) south of seismic station 320 of BWIP seismic line FY80-14 (see Figure 3). Travel time through Hanford and Ringold sediments is provided by check shot measurements in the well. The well was originally drilled into the underlying basalt (104.2 m [342 ft] bgs) to a total depth of 393.9 m (1,292 ft). Check shot surveying was only completed to 98.5 m (323 ft) in depth due to presumed blockage in the well. Construction summaries for the well casing indicate that it telescopes from 6 in. to 3.5-in. in diameter near 105.2 m (345 ft), below where the blockage was encountered.

Figure 19 shows the travel time measurements and estimated velocities for Well 699-17-47, as well as the associated gamma log, driller's description and geologic names of units encountered. Changes in seismic velocity are interpreted at depths of 6.1 m (20 ft), 73.2 m (240 ft), and 89.6 m (294 ft), and these velocity changes likely correspond to changes in sediment type (e.g. from gravels to clays). The Hanford-Ringold interface is not documented, and tube-wave interference between 15.2 m (50 ft) and 54.9 m (180 ft) in depth (see Figure A7) precluded using the check shot data to help identify this interface. The change in velocity from 701 m/s to 1,097.3 m/s (2,300 ft/s to 3,600 ft/s) corresponds with the change from sands (3 m to 39.6 m [10 ft to 130 ft]) to cemented gravels (48.8 m to 70.1 m [160 ft to 230 ft]).

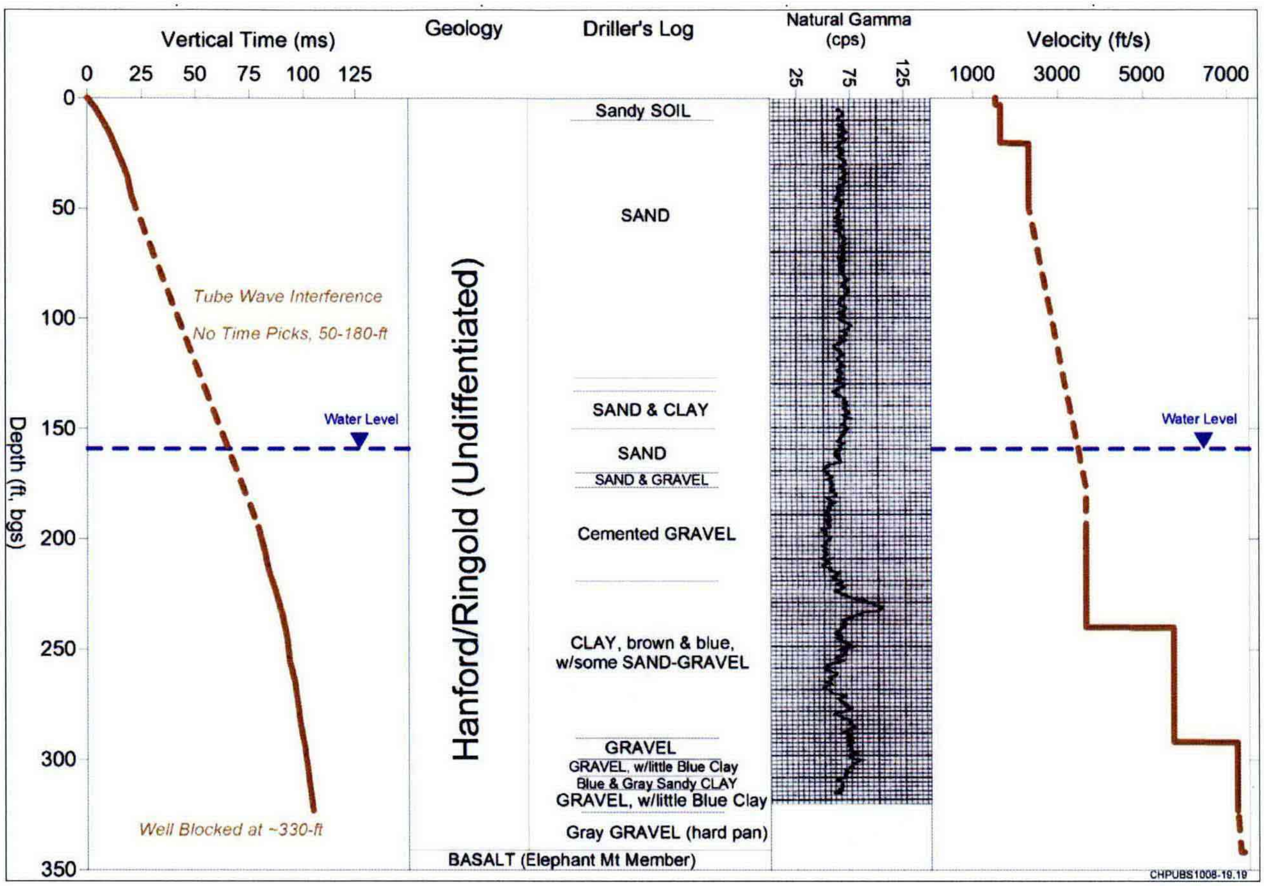

Figure 19. Check Shot Survey Results for Well 699-17-47

4.8 Well 699-26-15C

Well 699-26-15C is located about 2.8 km (1.75 mi) north of the Wye Barricade and approximately 12.2 m (40 ft) east of Route 2S, and is used to correlate subsurface geology with BWIP profile FY79-02 near seismic station 720 (Figure 3). Check shot surveys provide travel time measurements through Hanford and Ringold sediments, as well as into the upper 6.1 m (20 ft) of the underlying basalt. The well was originally drilled to a total depth of 192.0 m (630 ft) and encountered top-of-basalt at 184.4 m bgs (605 ft bgs). Check shot surveying was completed to 190.5 m (625 ft) in depth.

Check shot results for Well 699-26-15C are shown in Figure 20 along with the associated gamma log, driller's description and geologic names of units encountered. Seismic velocities rapidly increase in the upper 7.6 m (25 ft) from ~396.2 m/s (~1,300 ft/s) to over 1,828.8 m/s (6,000 ft/s), and remain above 1,524 m/s (5,000 ft/s) to the base of hole. The velocity increase near 7.62 m (25 ft) in depth is consistent with a change from unsaturated to saturated conditions. Decrease in velocity between 45.7 m (150 ft) and 61 m (200 ft) correlates with clay and silt zones indicated on the driller's description. Another decrease in velocity near 106.7 m (350 ft) in depth also corresponds to an interbedded clay-silt-sand sequence. Velocity of the upper 6.1 m (20 ft) of basalt is estimated at ~3,657.6 m/s (~12,000 ft/s).

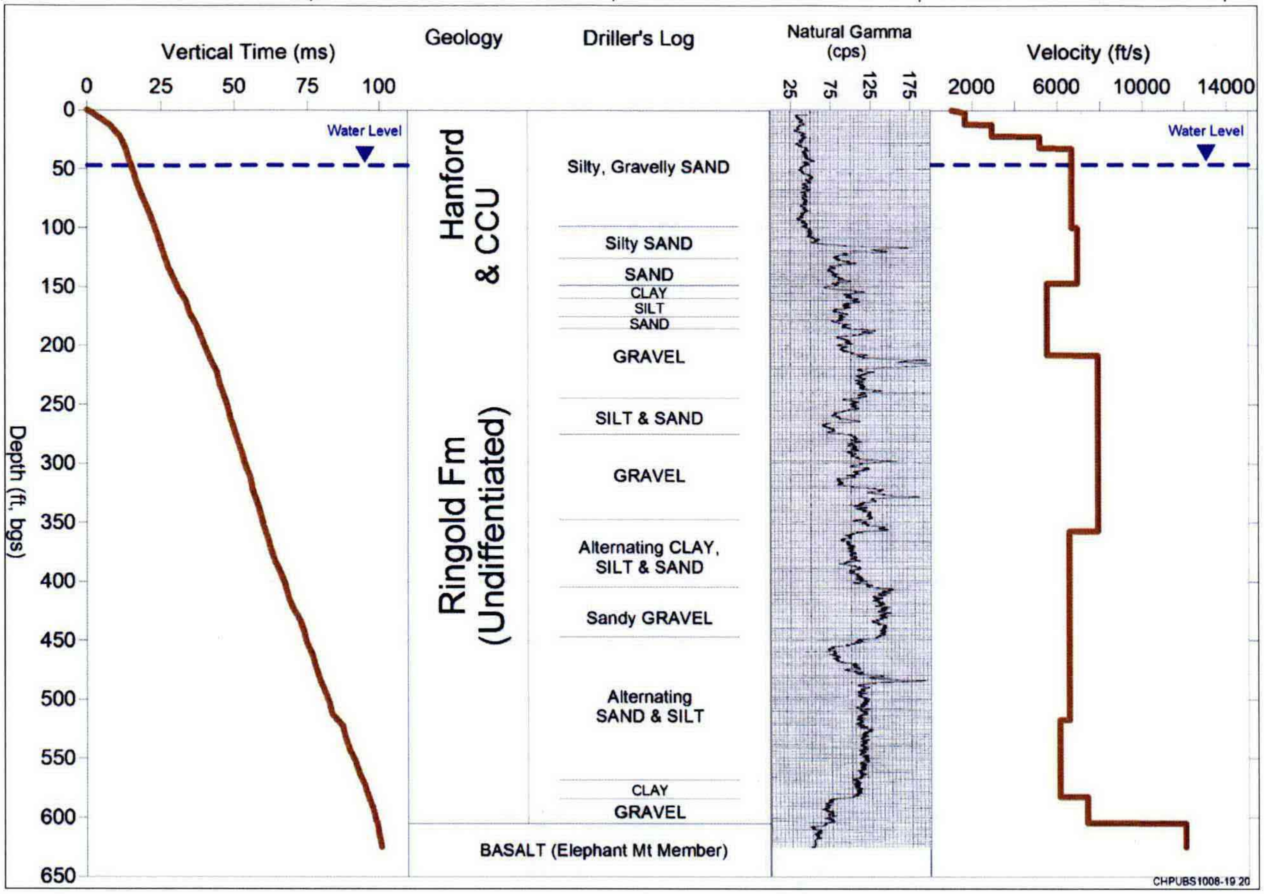

Figure 20. Check Shot Survey Results for Well 699-26-15C

4.9 Well 699-49-57B

Well 699-49-57B is located northwest of the 200 East Area and southeast of the intersection of Routes 11A and 4 (about 365.8 m (1200 ft) east of Route 4S and 304.8 m (1000 ft) south of 11A). Information from this well supports interpretation of BWIP profiles FY79-03 and FY80-12, and Landstreamer profile FY09-L-2A (SGW-43746) (see Figure 4). Check shot surveys provide travel time measurements through Hanford, the Elephant Mountain (Mt) basalt, as well as the upper 4.6 m (15 ft) of the Rattlesnake Ridge interbed. The well was originally drilled to a total depth of approximately 70.1m (230 ft) and encountered top-of-basalt at 49.5 m (162.5 ft). Check shot surveying was completed to the bottom of the well (70.1 m [230 ft]).

Check shot results for Well 699-49-57B are shown in Figure 21 along with the driller's description and geologic names of units encountered. Seismic velocities increase in the upper 4.6 m (15 ft) from ~426.7 m/s (~1,400 ft/s) to about 823 m/s (2,700 ft/s) to 883.9 m/s (2,900 ft/s), and remain in the 609.6 m/s (2,000 ft/s) to 823 m/s (2,700 ft/s) range until about 39.6 m (130 ft) in depth. This range in velocity is consistent with dry, unconsolidated sands. A velocity increase from ~810.8 m/s (~2,660 ft/s) to 1,051.6 m/s (3,450 ft/s) occurs between 39.6 m (130 ft) to 42.7 m (140 ft) and likely corresponds to the gravel units below 38.1 m (125 ft). Saturated gravels likely correspond with the increase in velocity to above 5,000 ft/s in the 3 m (10 ft) thick zone immediately above the basalt.

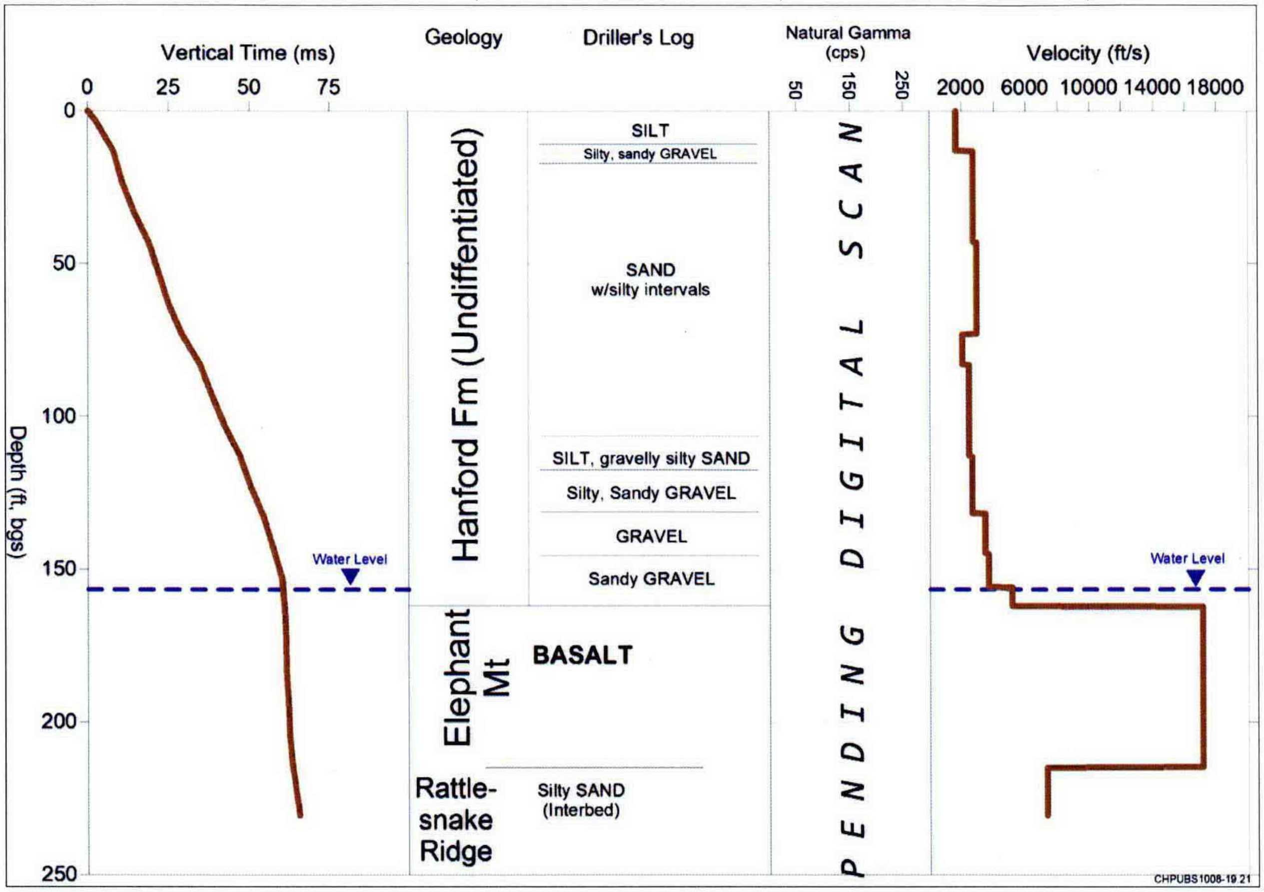

Figure 21. Check Shot Survey Results for Well 699-49-57B

Check shot measurements through the ~15.2 m (~50 ft) thick basalt zone estimate a seismic velocity of about 5,181.6 m/s (17,000 ft/s) for the basalt. The upper 4.6 m (15 ft) of the interbed is estimated at approximately 2,225.0 m/s (7,300 ft/s) in seismic velocity.

4.10 Well 699-50-30

Well 699-50-30 is north of Route 11A about 4.8 km (3 mi) east of the 200 East Area and check shot surveys in this well provide support for interpreting BWIP profile FY79-03 (see Figure 1 and Figure 3). Check shot surveys provide travel time measurements through Hanford and Ringold units that occur on the down thrown side of the May Junction Fault. The well was originally drilled to a total depth of approximately 115.8 m (380 ft), and was back-filled and plugged at 50.3 m (165 ft). Check shot surveys were conducted to ~ 43.9 m (~144 ft) in depth.

Results for Well 699-50-30 are shown in Figure 22 along with the associated gamma log, driller's description and geologic names of units encountered. Seismic velocities increase in the upper 4.3 m (14 ft) from ~609.6 m/s (~2,000 ft/s) to about 731.5 m/s (2,400 ft/s) to 853.4 (2,800 ft/s), and remain in this range until approximately 12.2 m (40 ft) in depth. Below 12.2 m (40 ft), velocities are estimated at ~1310.6 m/s (~4,300 ft/s) in a 7.6 m (25 ft) thick zone that appears to correspond to the bottom half of the clay zone indicated by the driller's log. Below 19.8 m (65 ft) in depth, changes in interval velocity appear to correlate with sediment changes from boulders (19.8 m [65 ft] to 27.4 m [90 ft]) to clays and gravel (27.4 m [90 ft] to 30.5 m [100 ft]) to fine sand (34.4 m [113 ft] to 42.7 m [140 ft]). Current interpretations place the top of Ringold near 23.4 (80 ft) bgs. Seismic velocities for the sandy clay zone below the water table are estimated at ~1,828.8 m/s (~6,000 ft/s).

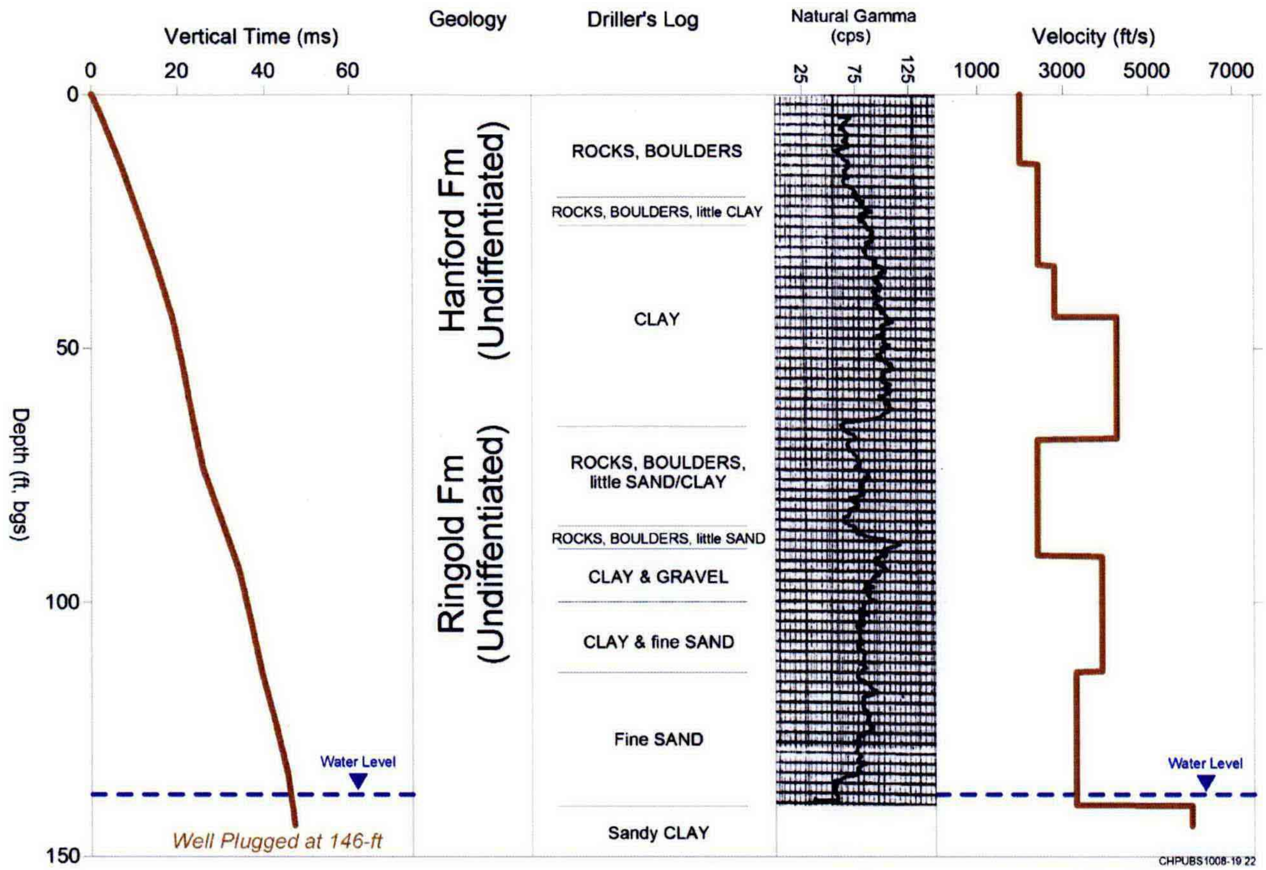

Figure 22. Check Shot Survey Results for Well 699-50-30

4.11 Well 699-54-47

Well 699-54-47 is located in the Gable Gap region, about 1.61 km (1 mi) north of the intersection between Route 11A and Route 4N (see Figure 1 and Figure 4). Check shot surveys in this well supports interpretation of Landstreamer seismic profile FY09-L-4B. Travel time measurements were conducted through sands and gravels of the Hanford Fm and include the upper 18.3 m (60 ft) of the underlying Elephant Mt basalt. The well was originally drilled to a total depth of approximately 97.5 (320 ft) and has been backfilled and plugged near 80.8 m (265 ft) in depth. Check shot surveys were only conducted to ~72.5 m (~238 ft) in depth.

Results for Well 699-54-57 are shown in Figure 23 along with the associated gamma log and driller's description and geologic names of units encountered. Seismic velocities between 4 m (13 ft) and 51.8 m (170 ft) in depth remain within a fairly narrow range of 1,005.8 m/s (3,300 ft/s) to 1,066.8 m/s (3,500 ft/s), consistent with dry gravels (Press, 1966). Measurements within the basalt indicate a seismic velocity of approximately 4,572 m/s (15,000 ft/s).

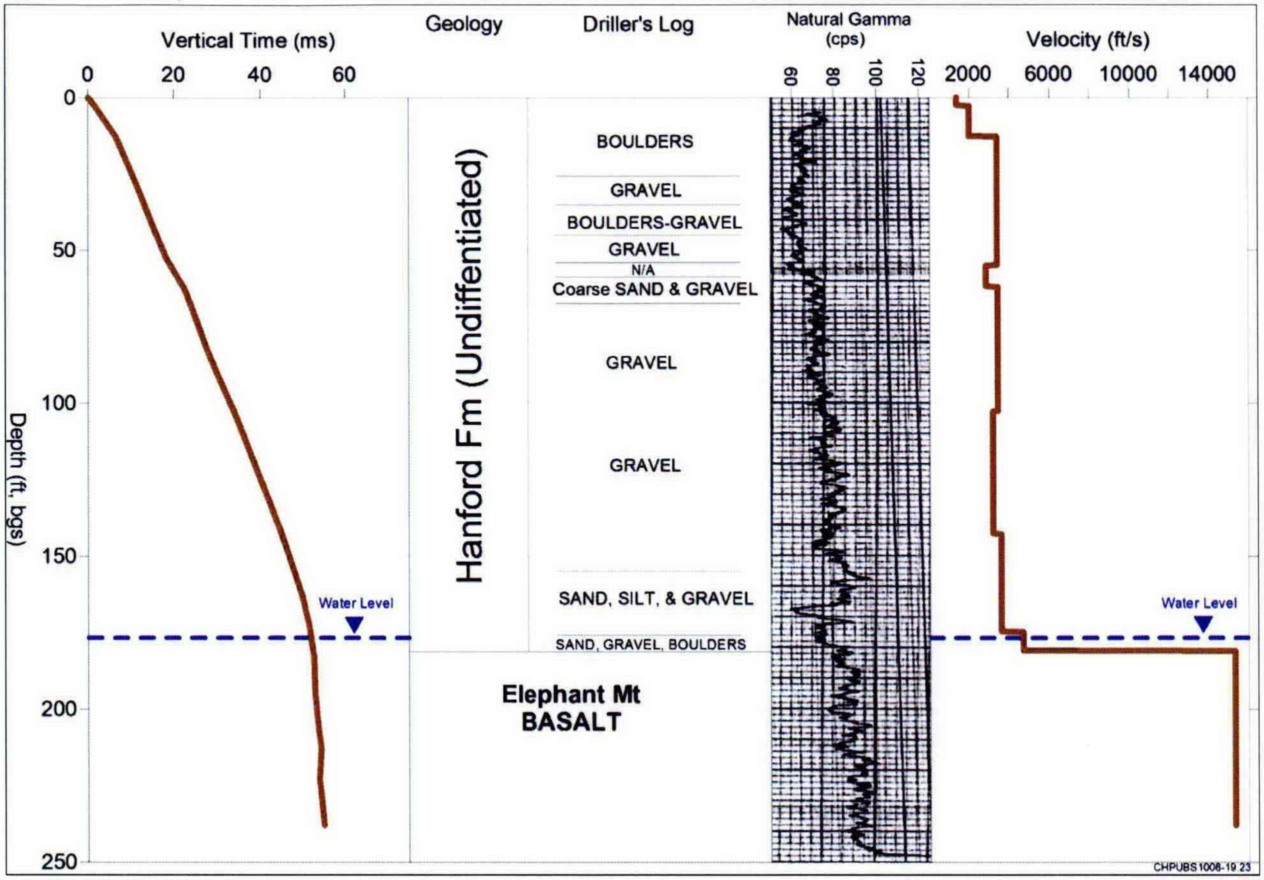

Figure 23. Check Shot Survey Results for Well 699-54-57

4.12 Well 699-60-59

Well 699-60-59 is located in the Gable Gap region about 3.2 km (2 mi) north of the intersection of Route 11A and Route 4N (see Figure 1 and Figure 4). Information from this well supports interpretation of Landstreamer Profile FY09-L-2C and BWIP Profile FY79-04. Check shot surveys were conducted through gravels of the Hanford Fm, the Asotin and Umatilla basalt units, and the upper Mabton Interbed. The well was originally drilled to a total depth of approximately 475.8 m (1,561 ft) and check shot surveys were conducted to ~157 m (~515 ft) in depth.

A summary of results for Well 699-60-59 is shown in Figure 24 along with the driller's description and geologic names of units encountered. Seismic velocities increase with depth, starting at approximately 487.7 m/s (1,600 ft/s) near the surface to about 914.4 m/s (3,000 ft/s) to approximately 15.2 m (50 ft) in depth. Below 15.2 m (50 ft), velocity of the gravel units is about 1,249.7 m/s (4,100 ft/s) (unsaturated) and 1,859.3 m/s (6,100 ft/s) (saturated).

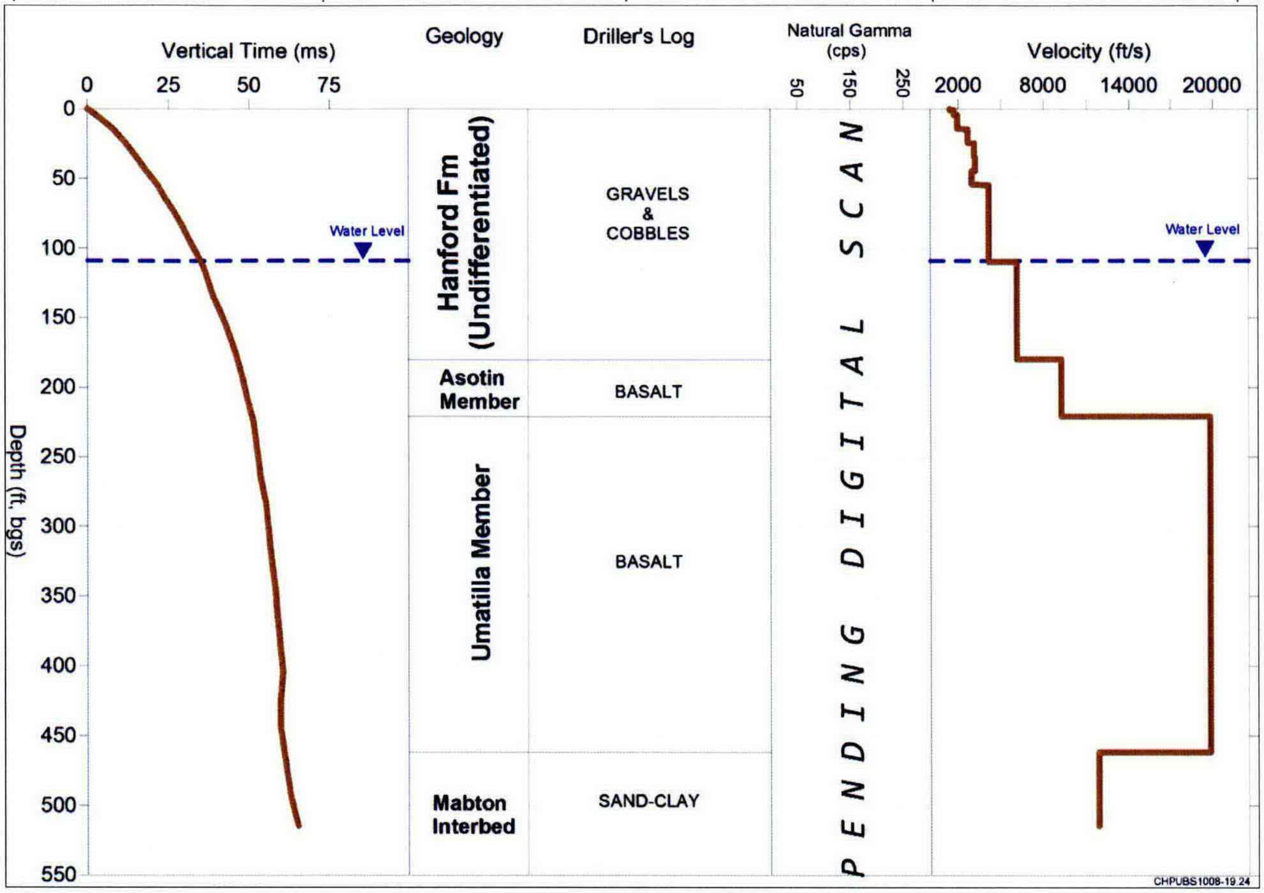

Figure 24. Check Shot Survey Results for Well 699-60-59

The approximate 6.1 m (20 ft) thick remnant of the Asotin basalt has a seismic velocity estimated at 2,804.1 m/s (9200 ft/s), which is lower than basalt velocities obtained in wells 699-49-57B (~5,181.6 m/s [~17,000 ft/s]), 699-54-57 (~4,572 m/s [~15,000 ft/s]), but consistent with estimates for wells 699-50-59 (~3,139.4 m/s [~10,300 ft/s]), 699-52-55B (~2,682.2 m/s [~8,880 ft/s]) and 699-63-58 (~2,651,8 m/s [~8,700 ft/s]). Seismic velocity of the Umatilla basalt is estimated at approximately 6,096 m/s (20,000 ft/s) which indicates an extremely competent geologic unit. The underlying Mabton Interbed is interpreted to have a seismic velocity of about 3,596.6 m/s (11,800 ft/s).

4.13 Well 199-B2-14

Well 199-B2-14 is located in the northern part of the 100 BC Area, and is used to provide interpretation support for BWIP Profile FY79-05 (see Figure 1 and Figure 5). Travel time measurements were only competed through gravels and sands of the Hanford Fm to a depth of 21.3 m (70 ft). The well was originally drilled to a depth of 48.2 m (158 ft) and encountered a mud unit near 43.9 m (144 ft) in depth. The well was subsequently back filled and plugged at ~22.9 m (~75 ft) in depth.

Results for Well 199-B2-14 are shown in Figure 25 along with the associated gamma log, driller's description and geologic names of units encountered. Seismic velocities increase with depth, starting at approximately 457.2 m/s (1,500 ft/s) near the surface to about 914.4 m/s (3,000 ft/s) to approximately 12.2 m (40 ft) in depth. Below 12.2 m (40 ft), sediment velocity is approximately 1,676.4 m/s (5,500 ft/s) and consistent with saturated gravels (Press, 1966).

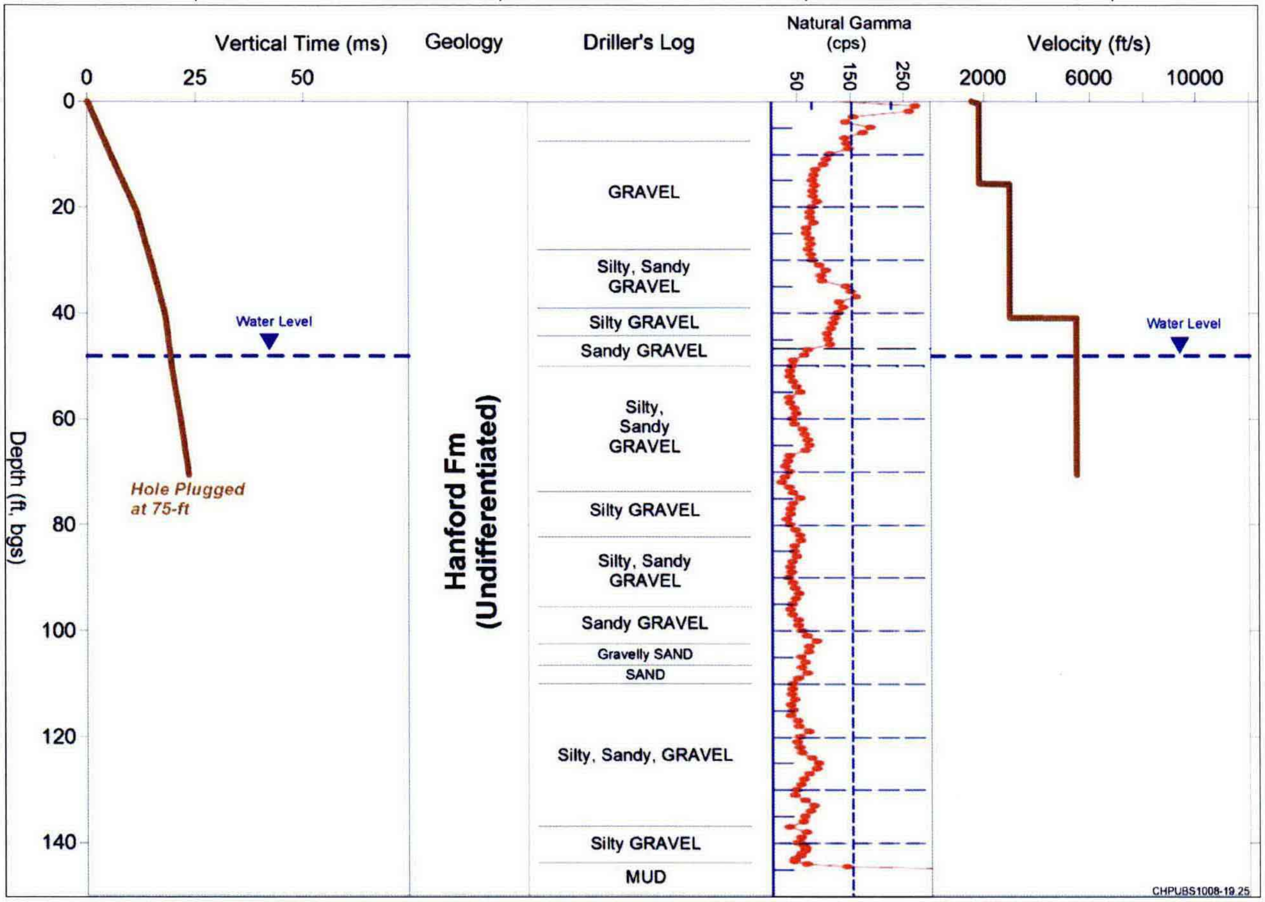

Figure 25. Check Shot Survey Results for Well 199-B2-14

4.14 Well 199-B9-2

Well 199-B9-2 is located in the southeastern part of the 100 BC Area, and provides interpretation support for BWIP Profile FY-9-05 (see Figure 1 and Figure 5). Travel time measurements were completed through Hanford gravels a depth of ~33.5 m (~110 ft). The well was originally drilled to a depth of 36 m (118 ft), and water occurs at approximately 29.3 m (96 ft) in depth.

Check shot results for Well 199-B9-2 are shown in Figure 26 along with the driller's description, natural gamma log and geologic names of units encountered. Seismic velocities of the unsaturated gravel units average around 670.6 m/s (2,200 ft/s) (0.6 m [2 ft] to 29 m [95 ft]) and show a total range in velocity from 563.9 m/s (1,850 ft/s) to 823 m/s (2,700 ft/s). The increase in velocity below the water table (1371.6 m/s [4,500 ft/s]) is consistent with saturated sediment values (Press, 1966).

4.15 Well 299-E33-340

Well 299-E33-340 is located north of the intersection of Baltimore Rd and 12th St in the 200 East Area (see Figure 1 and Figure 2). Check shot surveys in this well supports interpretation of the Baltimore Rd and 12th St seismic profiles acquired in FY2008. Travel time measurements were conducted through sands and gravels of the Hanford Fm, the Elephant Mt basalt, and the upper 4.6 m (15 ft) of the Rattlesnake Interbed. The well was originally drilled to a total depth of approximately 109.4 m (359 ft) and check shot surveys were conducted to about 99.7 m (327 ft) in depth.

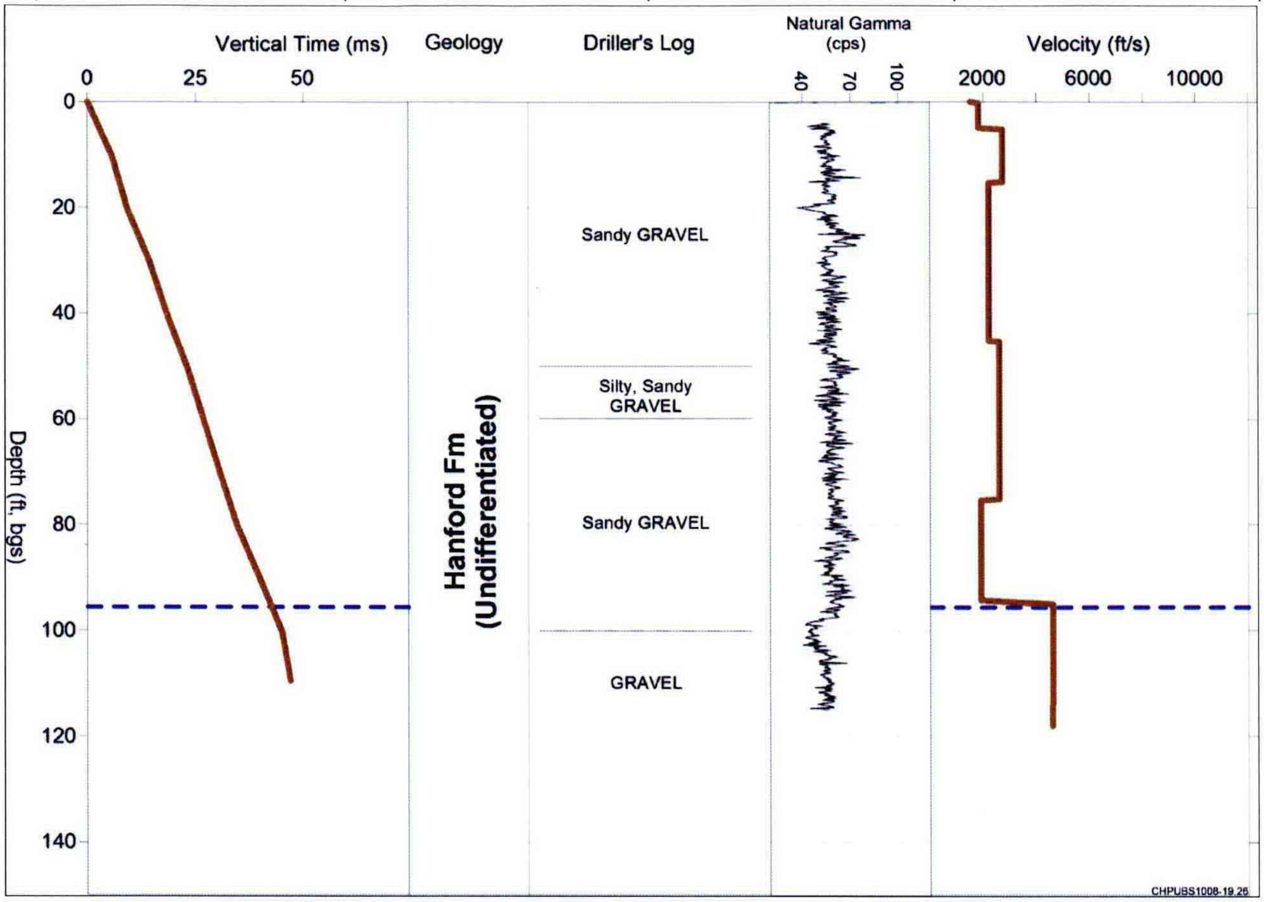

Figure 26. Check Shot Survey Results for Well 199-B9-2

Figure 27 shows the results for the check shot survey in 299-E33-340, along with the driller's description and geologic names of units encountered. Seismic velocities average about 792.5 m/s (2,600 ft/s) in the 3 m (10 ft) to 45.7 m (150 ft) depth range, and correlate with predominantly sand intervals with increases in silt and/or gravel content corresponding to zones with slightly increased velocity. Gravels and sandy gravels below 45.7 m (150 ft) in depth have a correspondingly increased seismic velocity of about 1,003,8 m/s (3,300 ft/s). The basal gravels immediately above the basalt (64 m [210 ft] to 68.9 m [226 ft]) show an increased velocity of 2,164.1 m/s (7,100 ft/s), which is most likely due to increased saturation levels associated with the water head. Velocity for the Elephant Mt basalt is approximately 3,749 m/s (12,300 ft/s), and the few check shot points in the underlying interbed indicate a seismic velocity of ~1,676.4 m/s (~5,500 ft/s).

4.16 Well 299-E34-5

Well 299-E34-5 is located in the northeastern part of the 200 East along 12th St (see Figure 1 and Figure 2), with check shot surveys in this well used to support interpretation of FY 2008 seismic profile collected along 12th Street. Check shot measurements were conducted through gravels and sands of the Hanford Fm. Well 299-E34-5 was originally completed to 58.1 m (190.5 ft) in depth, and encountered basalt at 57.9 m (190 ft). Total survey depth is approximately 55.2 m (181 ft) where the downhole geophone bottomed out in muddy material.

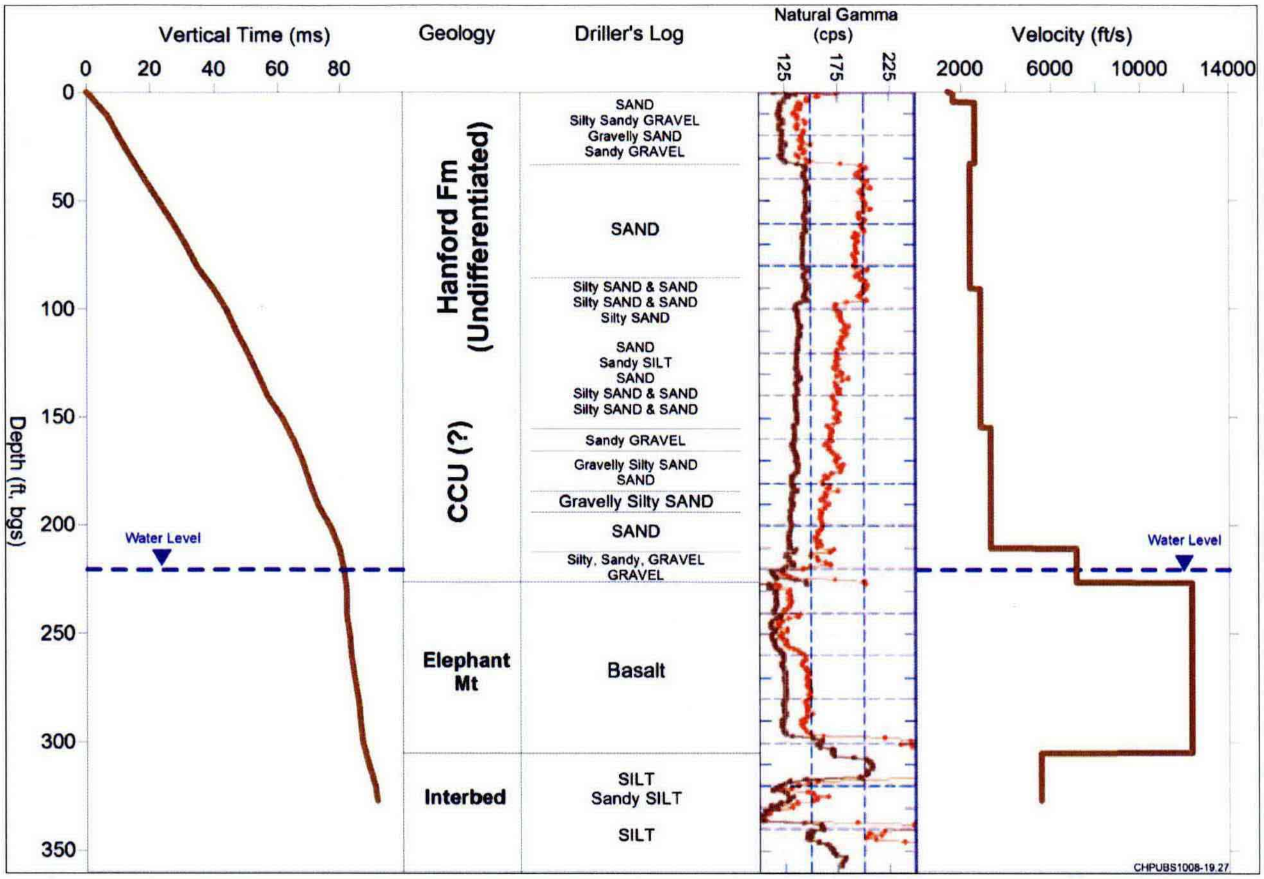

Figure 27. Check Shot Survey Results for Well 299-E33-340

Check shot results are shown in Figure 28 along with the natural gamma log, driller's description and geologic names of units encountered. Below 1.5 m (5 ft) in depth, seismic velocities range from 691.9 m/s (2,270 ft/s) to 1,084.5 m/s (3,558 ft/s), with changes in velocity possibly correlative with sediment type changes. Slight increases in velocity at 18.3 m (60 ft) and 42.7 m (140 ft) in depth correlate with changes in increases in the gamma-log. The entire check shot survey was completed in unsaturated sediments, and observed velocities compatible with published results.

4.17 Well 699-28-30

Well 699-28-30 is located in the 200-PO-1 OU along Route 4S, approximately 6.4 km (4 mi) southeast of 200 East and provides time-depth information for BWIP profiles FY80-10 and FY80-11 (see Figure 1 and Figure 3). Check shot surveys were conducted through sands and gravels of the Hanford Fm and possibly the pre-Missoula Cold Creek Units (CCUs). Well 699-28-30 was originally completed to a depth of 291.7 m (957 ft) and encountered basalt unit tops at 217.9 m (715 ft) and 275.8 (905 ft), but is apparently plugged at 53.9 m (177 ft).

Figure 29 shows the check shot results for Well 699-28-30 along with the driller's description and geologic names of units encountered. Seismic velocity show a general increase with depth, starting with value 335.3 m/s (1,100 ft/s) near the ground surface and increasing to 1, 036.3 m/s (3,400 ft/s) in the 18.3 m (60 ft) 24.4 (80 ft) depth range (corresponds to a change from sands to gravels). Velocities decrease to about 640.1 m/s (2,100 ft/s) for a silty gravel zone. Below the water table, saturated gravels have a seismic velocity of about 1,950.7 m/s (6,400 ft/s) which is consistent with published values for saturated gravels and sands.

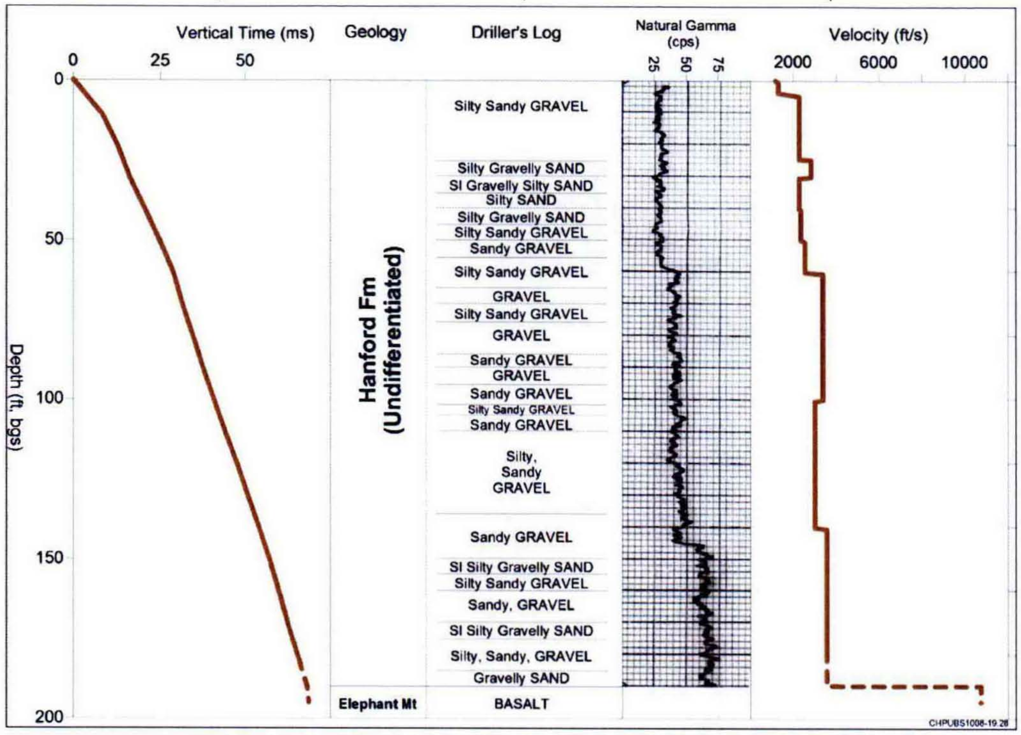

Figure 28. Check Shot Survey Results for Well 299-E34-5

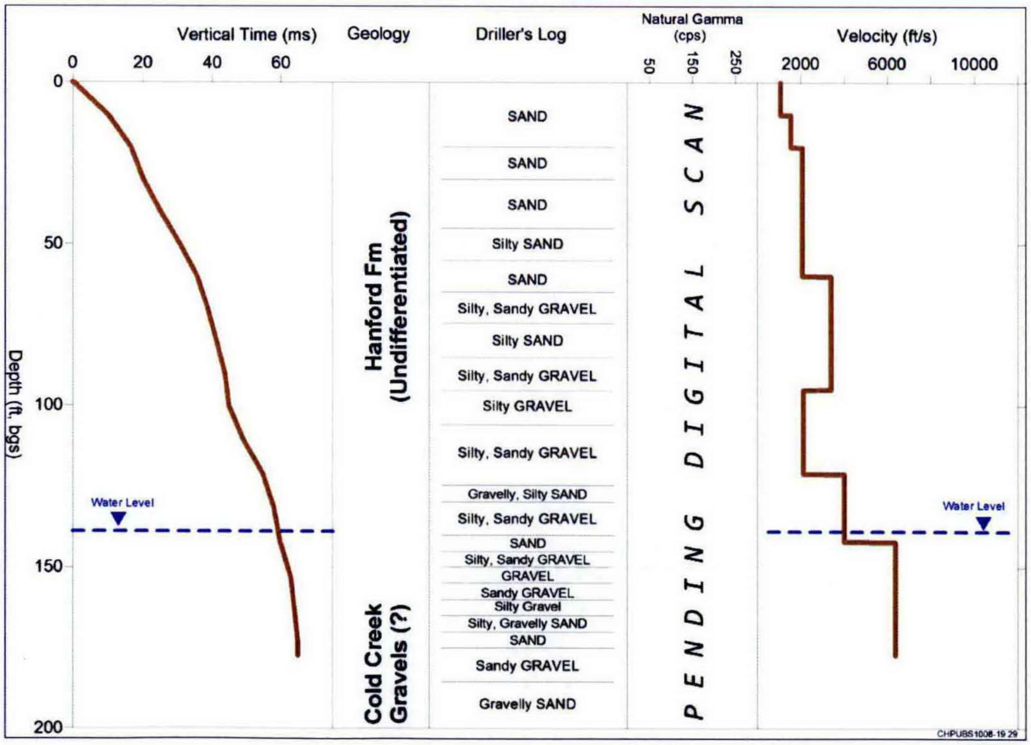

Figure 29. Check Shot Survey Results for Well 699-28-30

4.18 Well 699-31-17

Well 699-31-17 is located in the 200-PO-1 OU about 4.8 km (3 mi) north of the Wye Barricade along Route 2S (see Figure 1 and Figure 3). Surveys in this well support interpretation of BWIP Profile FY79-02, and provide travel time information to the top-of-basalt through Hanford, Cold Creek, and Ringold Units. The well was originally drilled to a total depth of approximately 195.1 m (640 ft), back filled to 192.9 m (633 ft), and check shot surveys were conducted to 182.9 m (600 ft) in depth.

Results for Well 699-31-17 are shown in Figure 30 along with the natural gamma log, driller's description and geologic names of units encountered. Seismic velocities increase quickly with depth in the upper 12.2 m (40 ft), starting at approximately 457.2 m/s (1,500 ft/s) near the ground surface and increasing to about 1,188.7 m/s (3,900 ft/s) at the water table (same depth as the Hanford – CCU contact identified on the driller's log). Seismic velocity increase to about 1828.8 m (6,000 ft/s) across the CCU-Ringold contact. Within the Ringold, velocities range from 1935.5 m/s (6,350 ft/s) to 2,712.7 m/s (8,900 ft/s). The zone of high-velocity between 39.6 m (130 ft) and 79.2 m (260 ft) correlates with a dominantly gravel zone. Seismic velocity within the upper 15.2 m (50 ft) of basalt is estimated at approximately 3,352.8 m/s (11,000 ft/s).

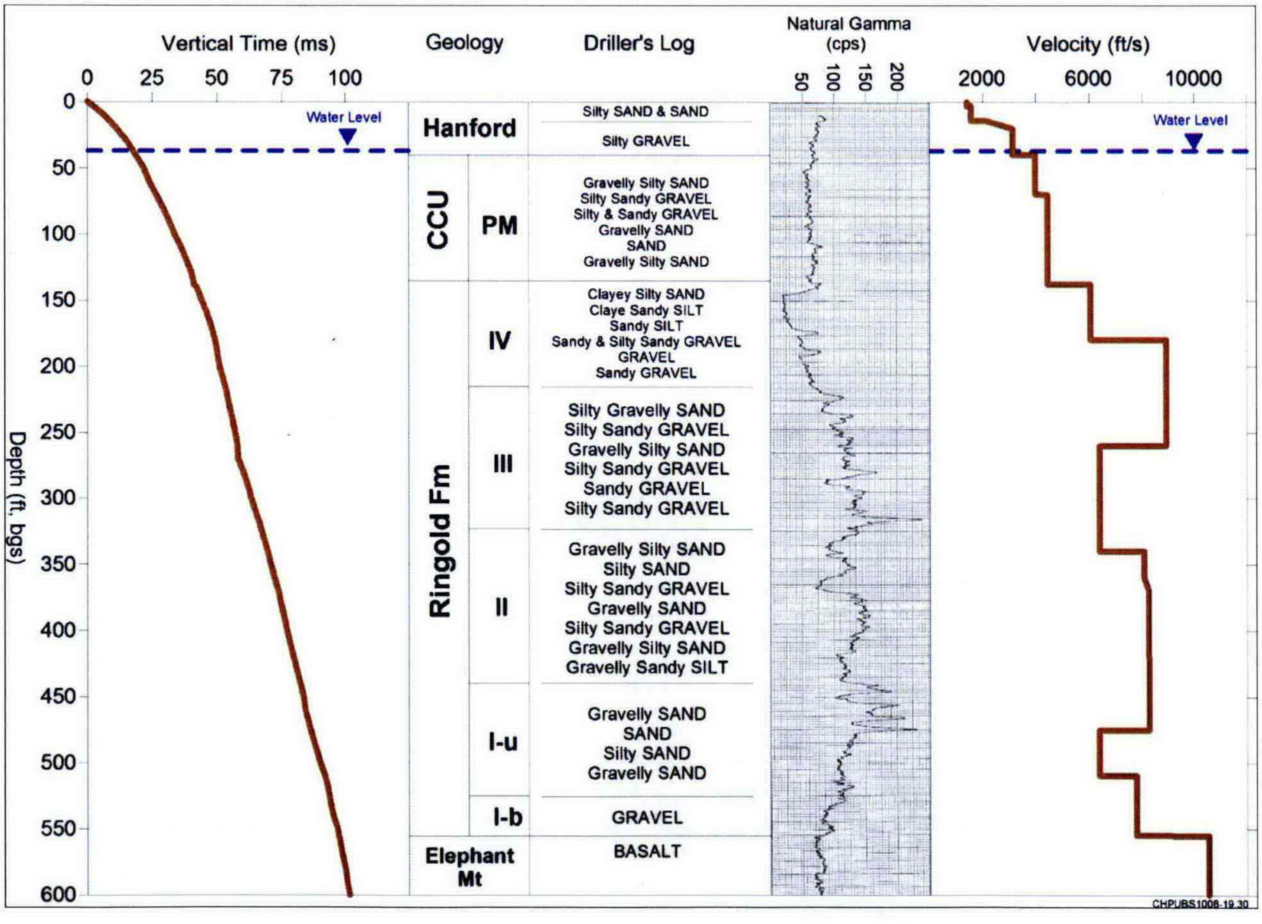

Figure 30. Check Shot Survey Results for Well 699-31-17

4.19 Well 699-36-27

Well 699-36-27 is located in the 200-PO-1 OU about 6.4 km (4 mi) east-southeast of 200 East (see Figure 1 and Figure 3). Check shot surveys in this well support interpretation of BWIP Profile FY80-11, and provide time-depth information through Hanford units and into the upper part of the Ringold Fm. The well is located on the down thrown side of the May Junction Fault. Travel time measurements were conducted through predominately sands of the Hanford Fm and from 18.3 m to 27.4 m (60 ft to 90 ft) into the Ringold Fm. Geologic information is not readily available for this well and is derived from Well 699-35-27 located about 396.2 m (1,300 ft) to the southwest and at approximately the same ground surface elevation. The well currently has a total depth of about 43.3 m (142 ft) and check shot surveys were conducted to 43 m (141 ft).

Survey results for Well 699-36-27 are shown in Figure 31 along with the natural gamma log, driller's description and geologic names of units encountered. Seismic velocities increase from about 396.2m/s (1,300 ft/s) at the ground surface to 640.1 m/s (2,100 ft/s) near the base of the sand unit at (12.2 m [40 ft]). An approximately 16.8 m (55 ft) thick zone of higher velocities (792.5 m/s to 1219.2 m/s (2,600 ft/s to 4,000 ft/s) likely corresponds to more gravel dominated facies. Velocities decrease below 28.7 m (94 ft) to 701 m/s (2,300 ft/s) at the top of a sand-silt sequence, increase to 1,066.8 m/s (3,500 ft/s) towards the base and into the upper part of a clay unit. Sediment velocities rise above 2,133.6 m/s (7,000 ft/s) near the water table, reflecting either the presence of a clay unit or increased saturation, or some combination of both. The change from Hanford to Ringold sediments likely marked by the zone of increased velocity near 12.2 m (40 ft) in depth.

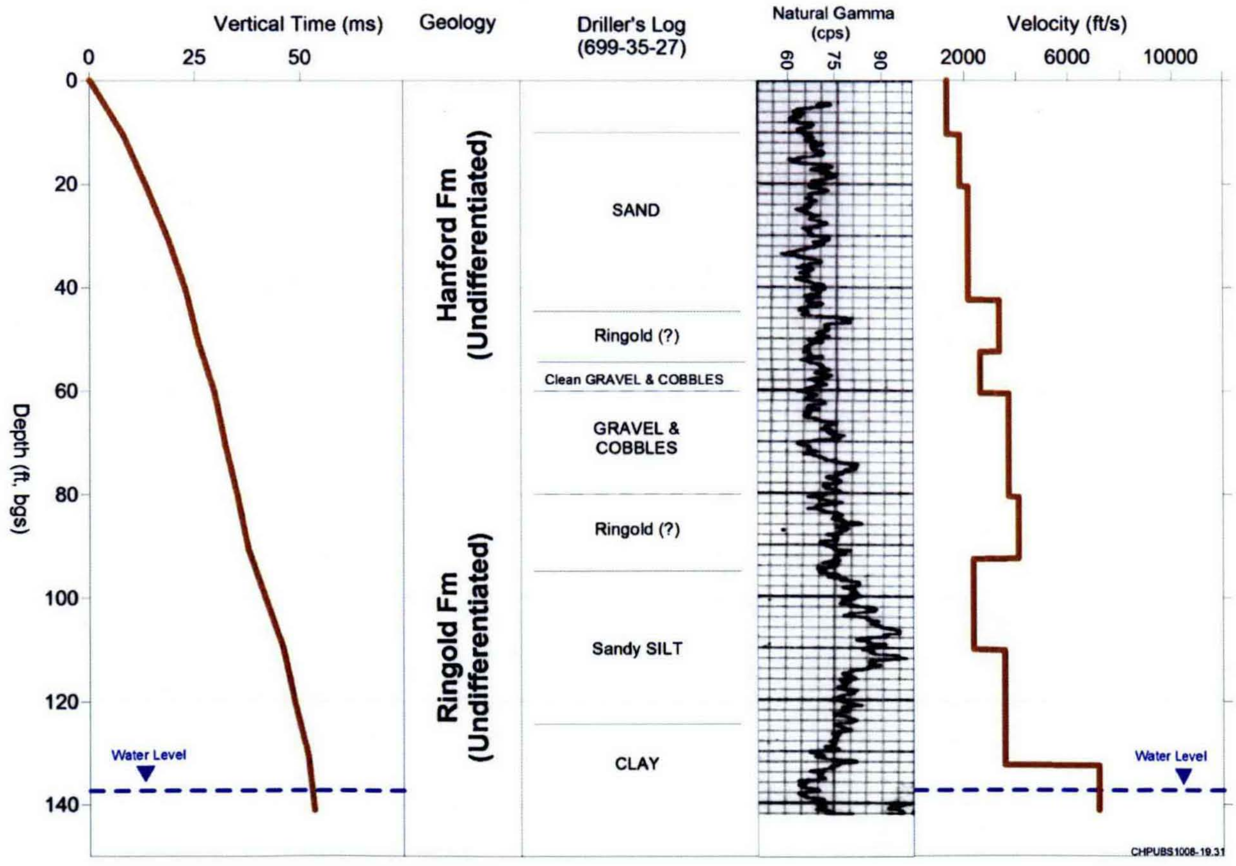

Figure 31. Check Shot Survey Results for Well 699-36-27

4.20 Well 699-40-33B

Well 699-40-33B is located in the 200-PO-1 OU, about 4 km (2.5 mi) due east of the 200 East Area (see Figure 1 and Figure 3). Check shot surveys in this well support interpretation of BWIP seismic profile FY80-13, and provides time-depth information for Hanford and Ringold units on the up thrown side of the May Junction Fault. The well was originally drilled to a total depth of 86.3 m (283 ft), encountered basalt at 84.7 m (278 ft), and is currently back filled to about 83.2 m (273 ft) in depth. Check shot surveys were also completed to about 83.2 m (273 ft).

Results for Well 699-40-33B are shown in Figure 32 along with the natural gamma log, the driller's description and geologic names of units encountered. The position of the Hanford-Ringold contact is not well documented, but is tentatively placed at the first mention of clay in the driller's description though this may be too low given the increase in velocity near 15.2 m (50 ft). Seismic velocities increase from about 518.2 m/s (1,700 ft/s) to 975.4 m/s (~3,200 ft/s) in the upper 15.2 m (50 ft) of the well where Hanford gravels are present. Relatively higher velocities (1,615.4 m/s [5,300 ft/s]) occur in a 6.1 m/s (20 ft) thick zone that may correlate with a gravel and sand zone near the likely base of the Hanford Fm. The water table is at the approximate depth of a lithologic change from sand and gravel to clays. Seismic velocities increase slightly across this interface (1,502.7 m/s (4,930 ft/s) above to 1589.5 m/s (5,215 ft/s) below). Within the basal part of the Ringold sediment column, seismic velocities increase to 2,529.8 m/s (8,300 ft/s) and 2,987 m/s (9,800 ft/s), perhaps indicating greater induration and consolidation of the gravel clay and gravel units.

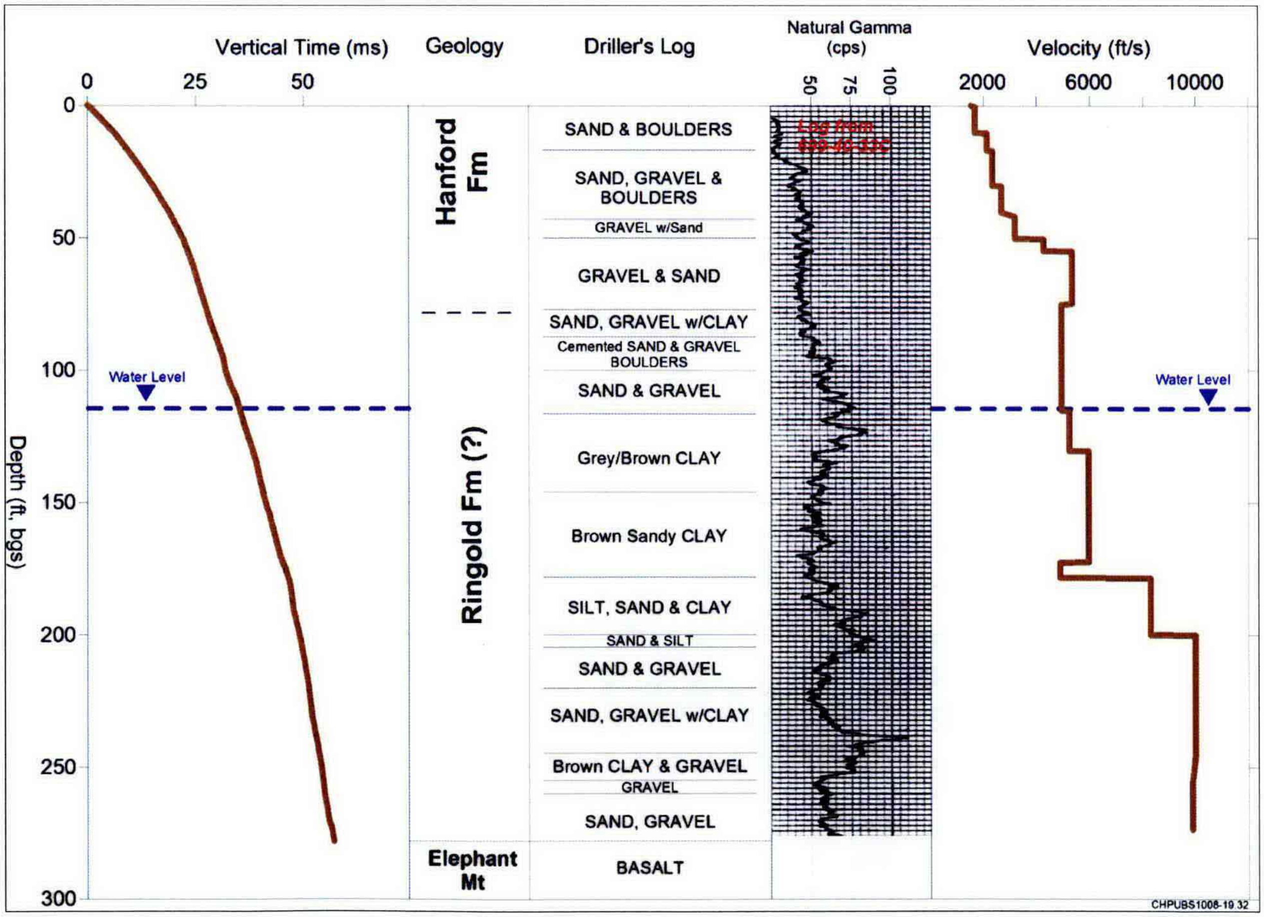

Figure 32. Check Shot Survey Results for Well 699-40-33B

4.21 Well 699-49-21

Well 699-49-21 is located along Route 11A approximately 8 km (5 mi) east of 200 East (see Figure 1 and Figure 3). The well is sited over the top of the southeast plunging Gable Mt anticlinal structure and provides time-depth information to support interpretation of BWIP seismic profiles FY79-03 and FY79-02. Travel time measurements were conducted through sands and gravels of the Hanford Fm, though the driller's log indicates a weathered lithic tuff near base of the well. The well was originally completed to a depth of 45.7 m (150 ft) bgs and was drilled into the upper 6.1 m (20 ft) of the underlying basalt. Total well depth is currently about 34.4 m (113 ft) and check shot surveys were conducted to a depth of 34.2 m (112 ft), which is about 5.5 m (18 ft) higher than the top-of-basalt.

Figure 33 summarizes results for Well 699-49-21 along with the natural gamma log, the driller's description and geologic names of units encountered. Seismic velocities increase monotonically with depth, starting at approximately 518.2 m/s (1,700 ft/s) near the surface to about 1,097.3 m/s (3,600 ft/s) at approximately 32 m (105 ft) in depth. Below 32 m (105 ft), either the presence of the lithic tuff and/or increased saturation is likely the cause of the increase in velocity to about 1,439.5 m/s (4,900 ft/s).

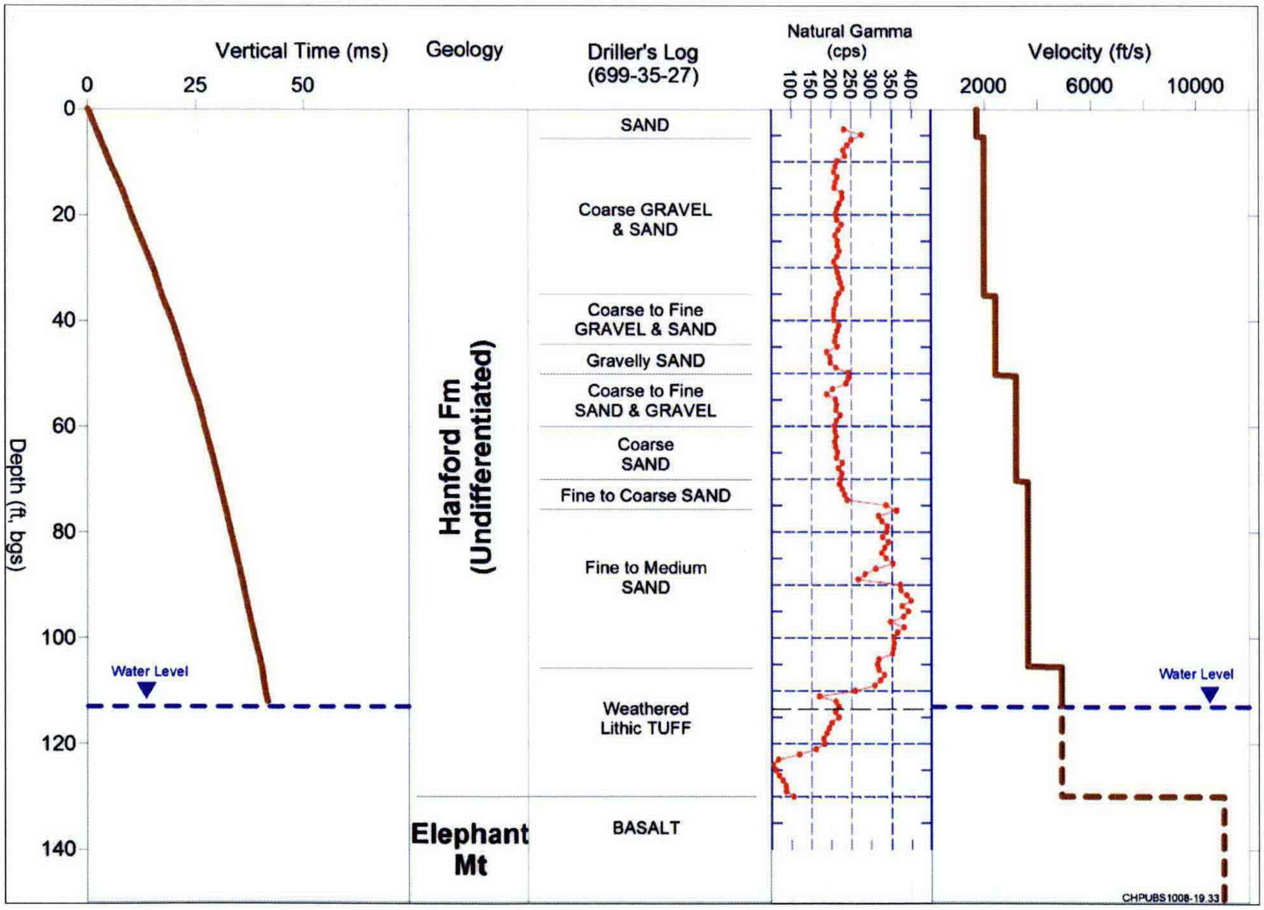

Figure 33. Check Shot Survey Results for Well 699-49-21

4.22 Well 699-50-59

Well 699-50-59 is located in the Gable Gap region and is part of 200-BP-5. The well is about 243.8 m (800 ft) west of the intersection of Route 11A and Route 4N (see Figure 1 and Figure 4). Check shot surveys in this well provide time-depth information to support interpretation of BWIP profiles FY79-03 and FY80-12, and Landstreamer profile FY09-L-1A. Travel time measurements were conducted through predominantly gravels of the Hanford Fm and into the upper few feet of the underlying Elephant Mt basalt. The well was originally drilled to 53 m (174 ft) in depth, and encountered basalt near 50.9 m (167 ft). Check shot surveys were completed to 52.1 m (171 ft).

Results for Well 699-50-59 are shown in Figure 34 along with the associated gamma log and driller's description and geologic names of units encountered. Seismic velocity of the near-surface material is about 457.2 m/s (1,500 ft/s), and increases monotonically with depth to about 21.3 (70 ft) where the seismic velocity of the upper gravel zone is approximately 1,158.2 m/s (3,800 ft/s). Below 21.3 m (70 ft), seismic velocities range from 914.4 m/s (3,000 ft/s) to 1,158.2 m/s (3,800 ft/s) until the basalt is encountered. The estimated seismic velocity of ~3,139.4 m/s (~10,300 ft/s) for the basalt is rather tenuous do to the short interval (1.2 m [4 ft]) measured. Results for Well 699-49-57B (about 762 m (2,500 ft) to the east-southeast) are significantly higher (5,212.1 m/s [17,100 ft/s]); however, surveys through the approximately 15.2 m (50 ft) thick section of basalt in Well 699-52-55B indicate a slightly slower basalt velocity of (2,708.1 m/s (8,885 ft/s).

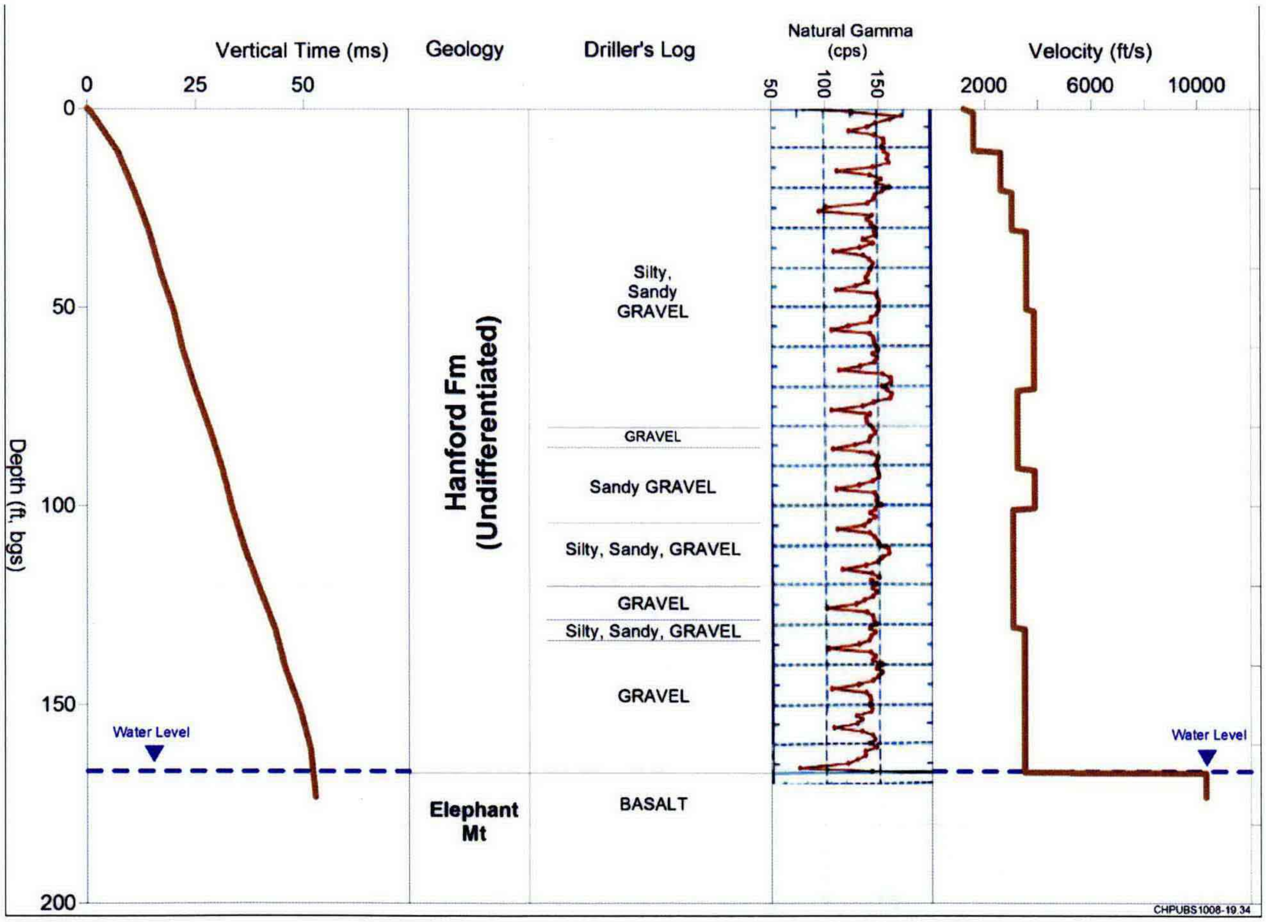

Figure 34. Check Shot Survey Results for Well 699-50-59

4.23 Well 699-52-55

Well 699-52-55 is located in the Gable Gap region within the 200-BP-5 OU. The well is located about 731.5 m (2,400 ft) north of Route 11A, and about 853.4 m (2,800 ft) east of Route 4N (see Figure 4). Check shot surveys in this well support interpretation of Landstreamer seismic line FY09-L-3 with travel time measurements conducted through sand and gravels of the Hanford Fm and into the underlying Elephant Mt basalt. The well was originally drilled to a total depth of approximately 55.8 m (183 ft) and check shot surveys were conducted to ~55.2 m (~181 ft) bgs. Basalt was encountered at approximately 53.9 m (177 ft) bgs.

Results for Well 699-52-55 are summarized in Figure 35 along with the natural gamma log, the driller's description and geologic names of units encountered. Seismic velocities within the upper 51.8 (170 ft) of the well range from 609.6 m/s (2,000 ft/s) to 1,127.8 m/s (3,700 ft/s), and can be loosely correlated with gross changes in sediment character. For example, the increase in velocity near 9.1 m (30 ft) in depth corresponds to a change from sands to gravels, and the subtle decrease near 45.7 (150 ft) corresponds to an increase in silt content (note the gamma log response).

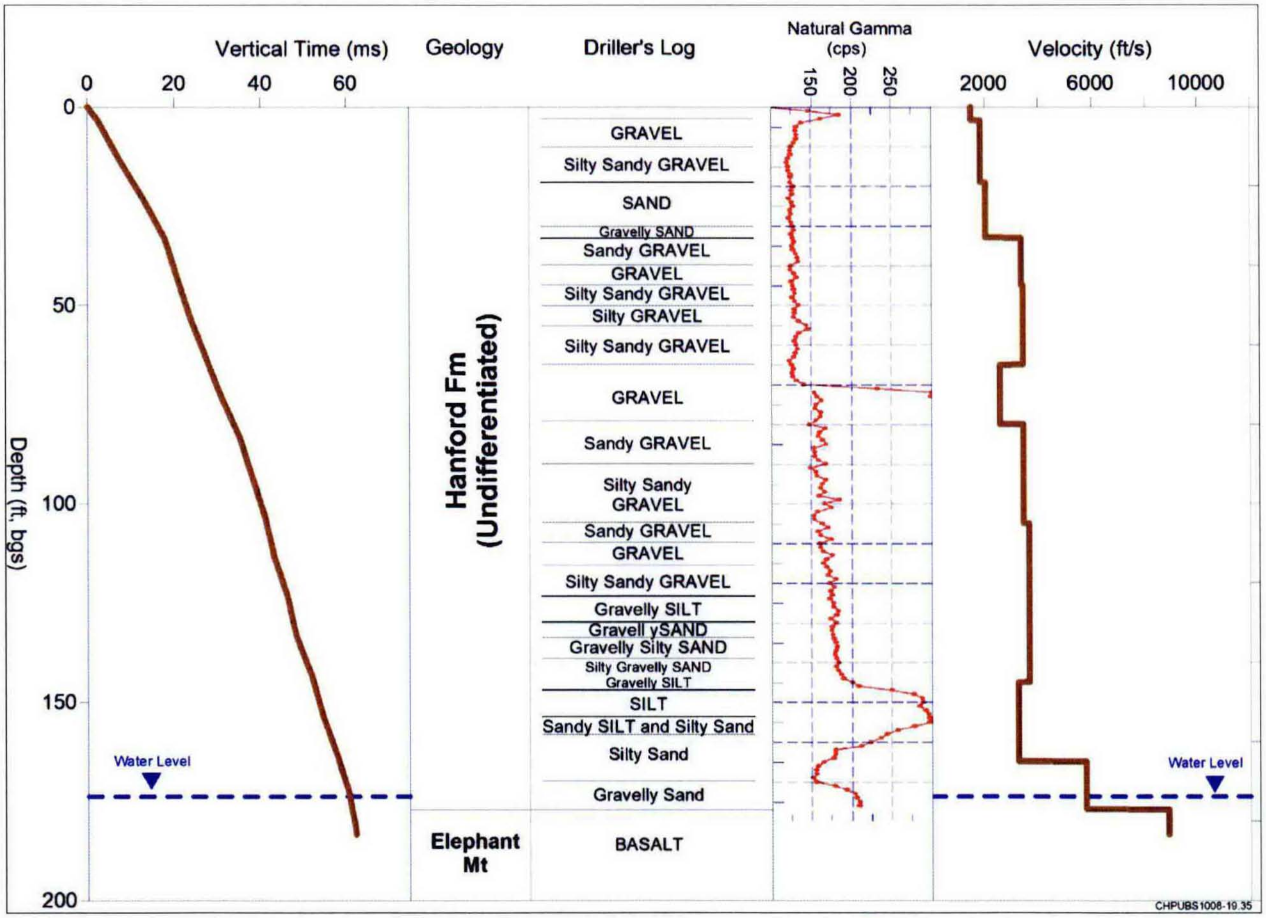

Figure 35. Check Shot Survey Results for Well 699-52-55

Estimates of the seismic velocity for the basalt remain tenuous due to the short section afforded by the well (<1.8 m [6 ft]). Results for Well 699-52-55B (about 3m [10 ft] to the south) indicate a relatively slow seismic velocity of ~2,575.6 m/s (~8450 ft/s) which is used for this well for plotting and display purposes.

4.24 Well 699-52-55B

Well 699-52-55B is located in the Gable Gap region within the 200-BP-5 OU (see Figure 1 and Figure 4). The well is located about 731.5 m (2,400 ft) north of Route 11A, and about 853.4 m (2,800 ft) east of Route 4N (see Figure 4). Check shot surveys in this well support interpretation of Landstreamer seismic line FY09-L-3 with travel time measurements conducted through sand and gravels of the Hanford Fm, through an approximately 15.2 m (50 ft) thick basalt zone, and into the upper 7 m (23 ft) of the underlying basalt-interbed. The well was originally drilled to a total depth of approximately 89.3 m (293 ft) with top and bottom of the basalt unit encountered at 53.8 m (176.5 ft) and 67.7 m (222 ft). Check shot surveys were conducted to well bottom of ~75 m (~246 ft) bgs.

Results for Well 699-52-55B are shown in Figure 36 along with the driller's description and geologic names of units encountered. Also shown is the natural gamma log for 699-52-55 (about 3m [10 ft] to the north). In the upper 15.2 m (50 ft), seismic velocities increase approximately 457.2 m/s (1,500 ft/s) to 945 m/s (3,100 ft/s), with changes in velocity interpreted at interfaces between gravel and sand zones, with a gravel zone between 10.1 m (35 ft) and 16.2 m (53 ft) having the highest seismic velocities. Seismic velocities decrease to ~670.6 m/s (~2,200 ft/s) in the upper 9.2 m (30 ft) of a sand and gravel sequence (16.2 m [53 ft] to 25.3 m [83 ft]) then increase to about 1,219.2 m/s (4,000 ft/s) in the more predominantly gravel lower section. Silt and gravelly sand zones from 44.2 m (145 ft) to 51.8 m (170 ft) have associated lower seismic velocities (~1,097.3 m/s [3,600 ft/s]).

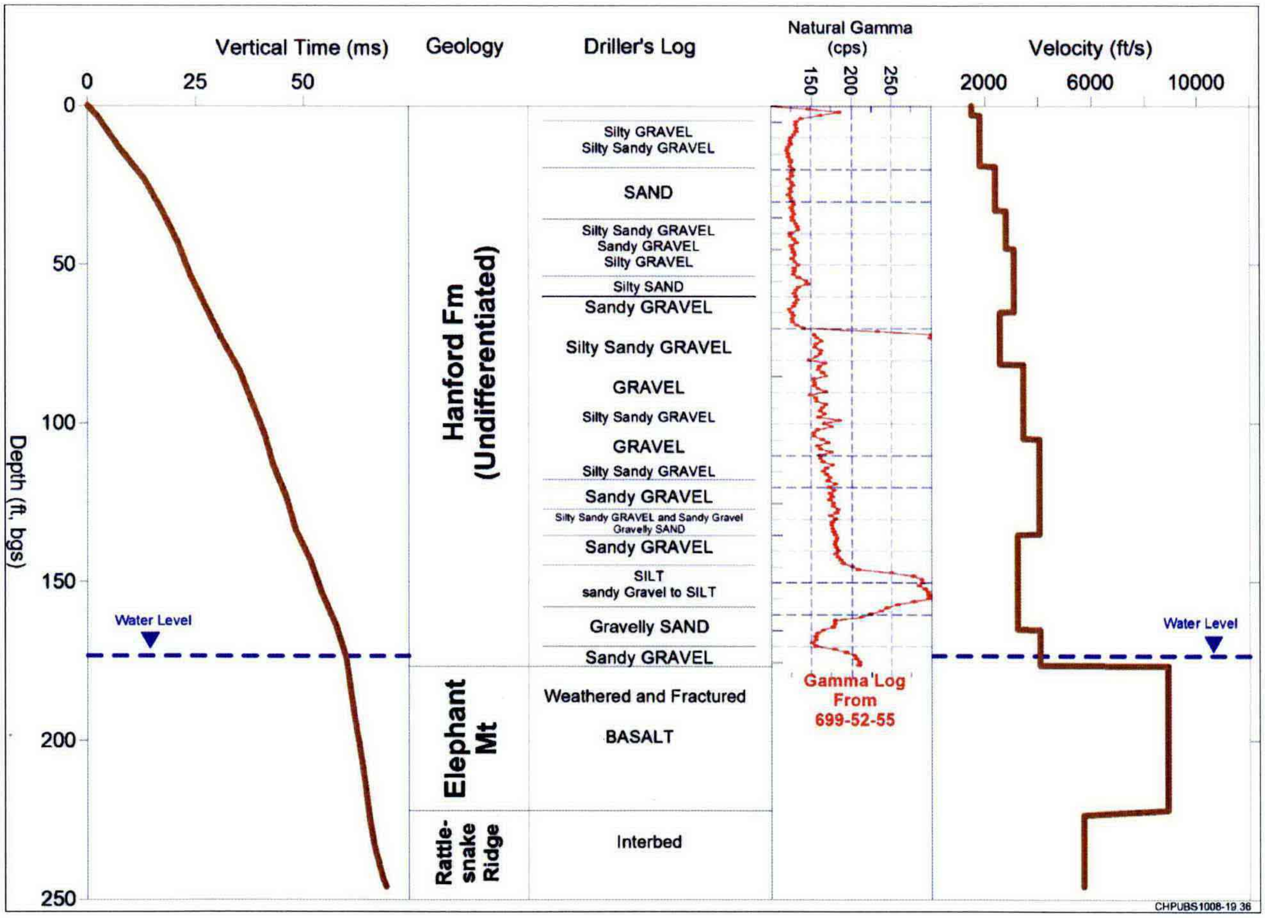

Figure 36. Check Shot Survey Results for Well 699-52-55B

A velocity of approximately 2,590.1 m/s (8,500 ft/s) is estimated for the 15.2 m (50 ft) section of Elephant Mt basalt sampled by the check shot survey. This is significantly lower than observed at wells 699-49-57B (~5,181.6 m/s [17,000 ft/s]) and 699-54-57 (~4,572 m/s [15,000 ft/s]), perhaps indicative of the weathering and fracturing observed in the driller/geologic log in the upper 6.1 m (20 ft). Seismic velocity of the underlying Rattlesnake Ridge interbed is estimated at approximately 1,981.2 m/s (6,500 ft/s).

4.25 Well 699-55-60A

Well 699-55-60A is located in the Gable Gap region and within the 200-BP-5 OU (Figure 1 and Figure 4). The well is sited about 1.61 km (1 mi) north of the intersection of Routes 11A and 4N, and approximately 640.1 m (2,100 ft) west of Route 4N (see Figure 4). Check shot surveys in this well support interpretation of Landstreamer seismic lines FY09-L-2C and FY09-L-4A with travel time measurements conducted predominantly through gravels of the Hanford Fm. The well was originally drilled to a total depth of approximately 71 m (233 ft), and check shot surveys were conducted to 65.5 m (215 ft) in depth.

Figure 37 summarizes results for the check shot surveys in Well 699-55-60A with a comparison to the driller's description and geologic names of units encountered. Seismic velocities increase in depth, from 487.7 m/s (1600 ft/s) to ~1,127.8 m/s (3,700 ft/s), within the upper 15.2 m (50 ft) of the well. Below 15.2 m (50 ft), but above the water table, estimated seismic velocities show more variation, ranging from a low of ~914.4 m/s (3,000 ft/s) (48.4 m [160 ft] to 51.8 m [170 ft] in depth) to a 6.1 m (20 ft) thick zone of high velocity (~1,981.2 m/s [6,500 ft/s]) at 16.8 m to 22.9 m (55 ft to 75 ft) in depth. These variations likely correspond to whether gravel or boulders dominate with higher-velocity zones corresponding to higher percentage of boulders. Below the water table, seismic velocities average about 2,133.6 m/s (7,000 ft/s) with a possible decrease to 1,828 m/s (6,000 ft/s) near the base of the survey.

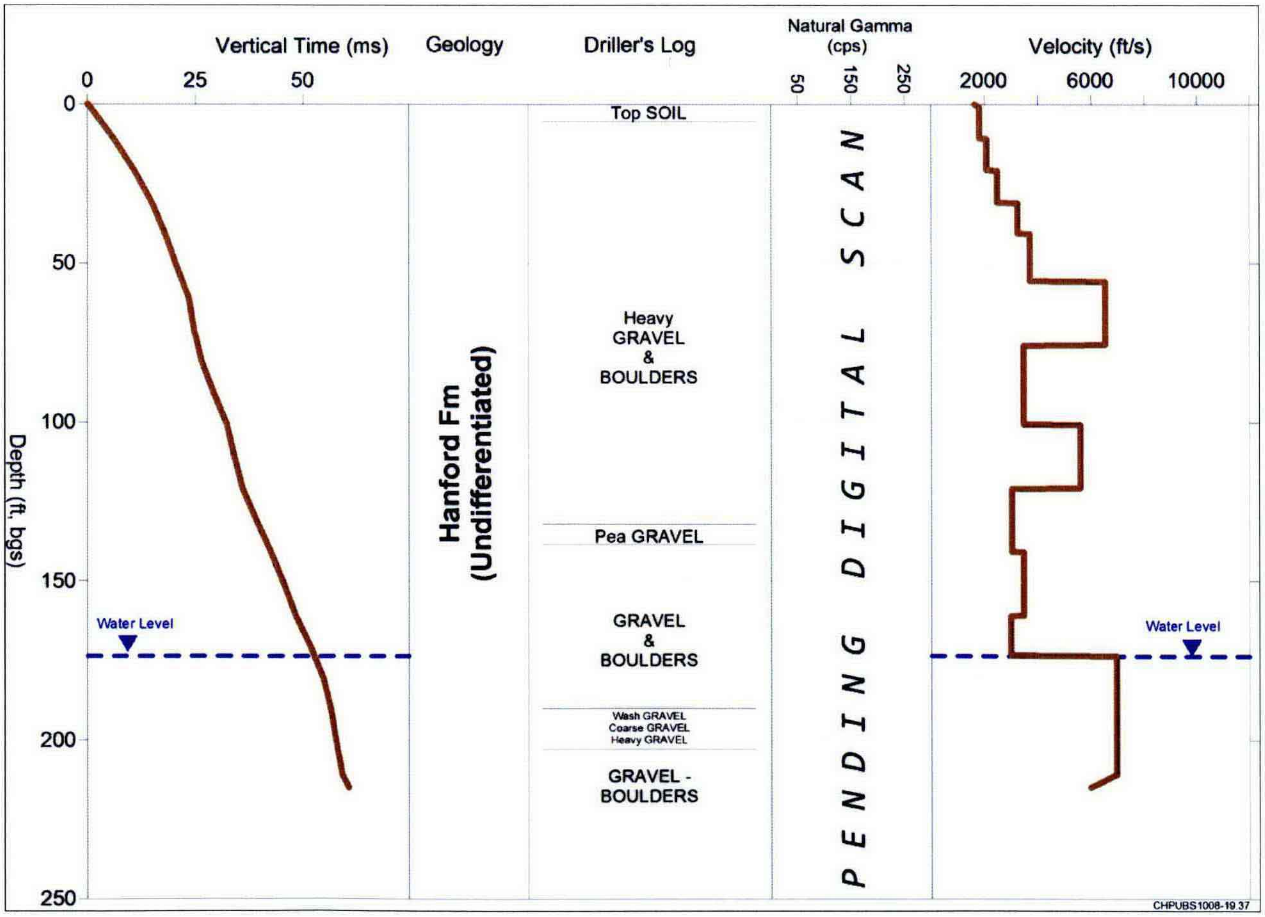

Figure 37. Check Shot Survey Results for Well 699-55-60A

4.26 Well 699-57-83C

Well 699-57-83C is located along Route 6 between the 100-BC and 200 West areas, about 2.4 km (1.5 mi) north of Route 11A (Figure 1 and Figure 5). The well is located south of the Gable Butte anticlinal structure and was installed to investigate the Columbia River basalt group. Check shot surveys support interpretation of BWIP seismic profile FY79-05. Travel time measurements were conducted through undifferentiated units of the Hanford and Ringold Fm, and into the upper part of the Elephant Mt basalt. The well was originally drilled to a total depth of approximately 1,076.9 m (3,533 ft). Check shot surveying could not be conducted beyond 173.7 m (570 ft) because the 5.1-cm (2-in.) inside diameter casing installed from 175.6 m (576 ft) depth to well bottom is narrower than the model BHG-2 downhole geophone. In addition, seismic energy generated by the sledgehammer source proved insufficient to investigate below 125 m (410 ft), and check shot results are presented to the upper part of the basalt unit.

Results for Well 699-57-83C are summarized in Figure 38 along with the associated gamma log(s), the driller's description and geologic names of units encountered. Gamma logging in 699-57-83C was only conducted within the Columbia River basalt group starting near 121.9 m (400 ft) in depth. Nearby Well 699-57-83A was gamma-logged to about 54.9 m (180 ft) bgs. Detailed information regarding the position of the Hanford-Ringold contact in Well 699-57-83C was not available. The driller's description for nearby Well 699-57-83A indicates a change from conglomerate to silt-sand facies near 61 m (200 ft) bgs.

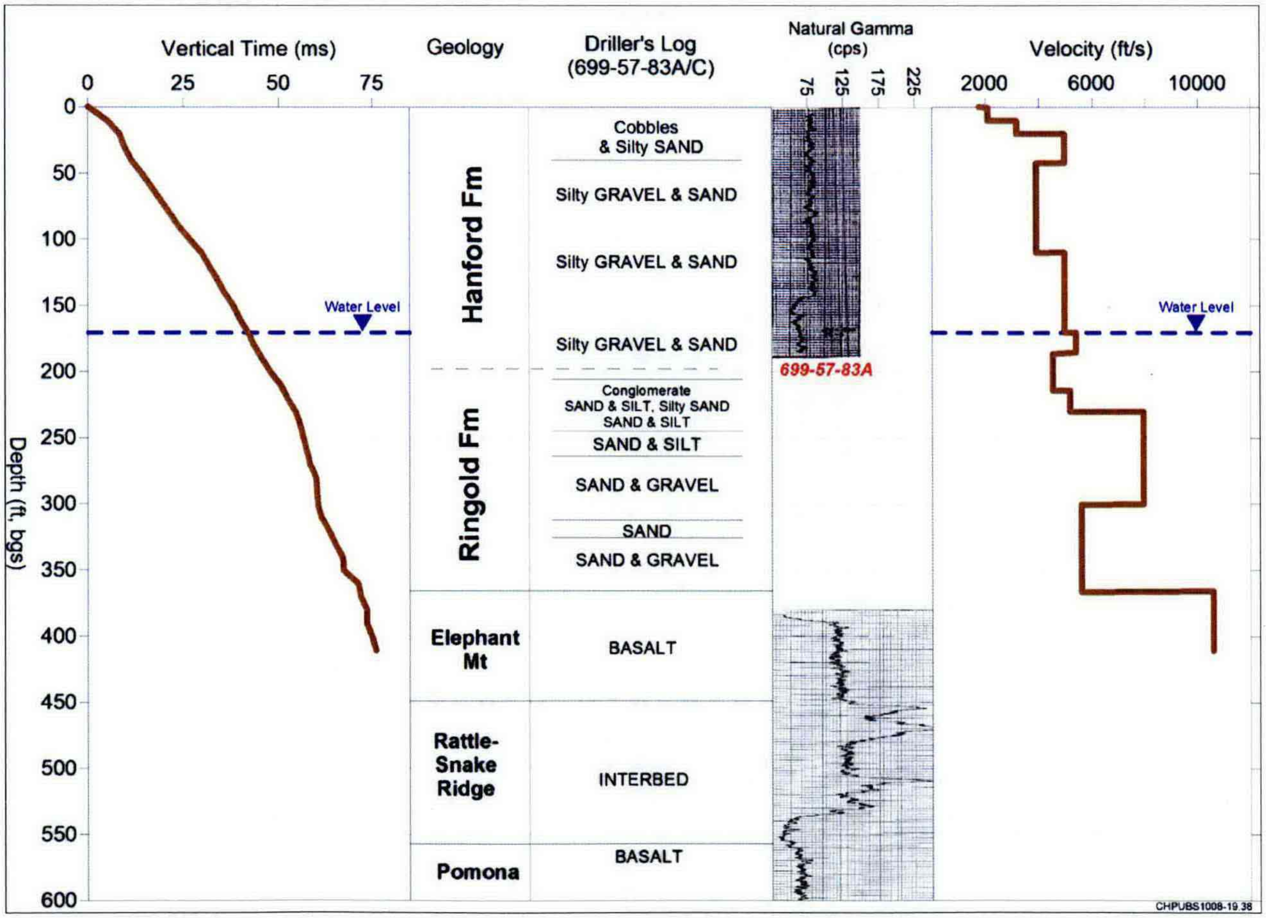

Figure 38. Check Shot Survey Results for Well 699-57-83C

Seismic velocities rapidly increase from approximately 548.6 m/s (1,800 ft/s) at the ground surface to almost 1,524 m/s at 6.1 m (5,000 ft/s at 20 ft) in depth. The underlying silty gravel and sand zone increases in velocity from 1,189 m/s to 1,509 m/s (3,900 ft/s to 4,950 ft/s), with a slight increase in velocity 1,615.4 m/s (5,300 ft/s) across the water table. The upper part of the Ringold (61 m to 70.1 m [200 ft to 230 ft]) averages about 1,524 m/s (5,000 ft/s) in velocity and is underlain by an approximate 21.3 m (70 ft) thick zone of high velocity 2,407.9 m/s (~7,900 ft/s). Seismic velocity for the basalt is estimated at 3,200.4 m/s (10,500 ft/s).

4.27 Well 699-61-62

Well 699-61-62 is located in the Gable Gap region about 3.2 km (2 mi) north of the intersection of routes 4N and 11A, and approximately 1,219.2 m (4,000 ft) east of Route 4N and north of the 100-BC cutoff road (see Figure 1 and Figure 4). Check shot surveys in this well supports interpretation of BWIP Profile FY-79-04. Travel time measurements were conducted through sands and gravels of the Hanford Fm, and possibly the Ringold Fm. Well 699-61-62 was originally drilled to 57.3 m (188 ft) in depth and encountered basalt at 54.1 m (177.5 ft). Well construction resulted in the well being back-filled and plugged at 54.6 m (179 ft) and check shot surveys were conducted to a depth of ~53.6 m (~176 ft).

Figure 39 summarizes check shot survey results for Well 699-61-62 and also shown are the names of geologic units encountered and the driller's description. Seismic velocities increase with depth, starting at approximately 457.7 m/s (1,600 ft/s) near the surface to about 1,066.8 m/s (3,500 ft/s) at approximately 3.66 m (12 ft) in depth. Below 6.1 m (20 ft), seismic velocities for the Hanford gravels and sands range from 762 m/s (2,500 ft/s) in a sand zone from 13.7 m to 15.2 m (45 ft to50 ft) to 1,402.1 m/s (4,600 ft/s) in a gravel zone at 22.9 m to 30.5 m (75 ft to 100 ft). The Hanford-Ringold contact likely occurs below the water table where seismic velocities range from 2,103.12 m/s to 2,255.52 m/s (6,900 ft/s to 7,400 ft/s).

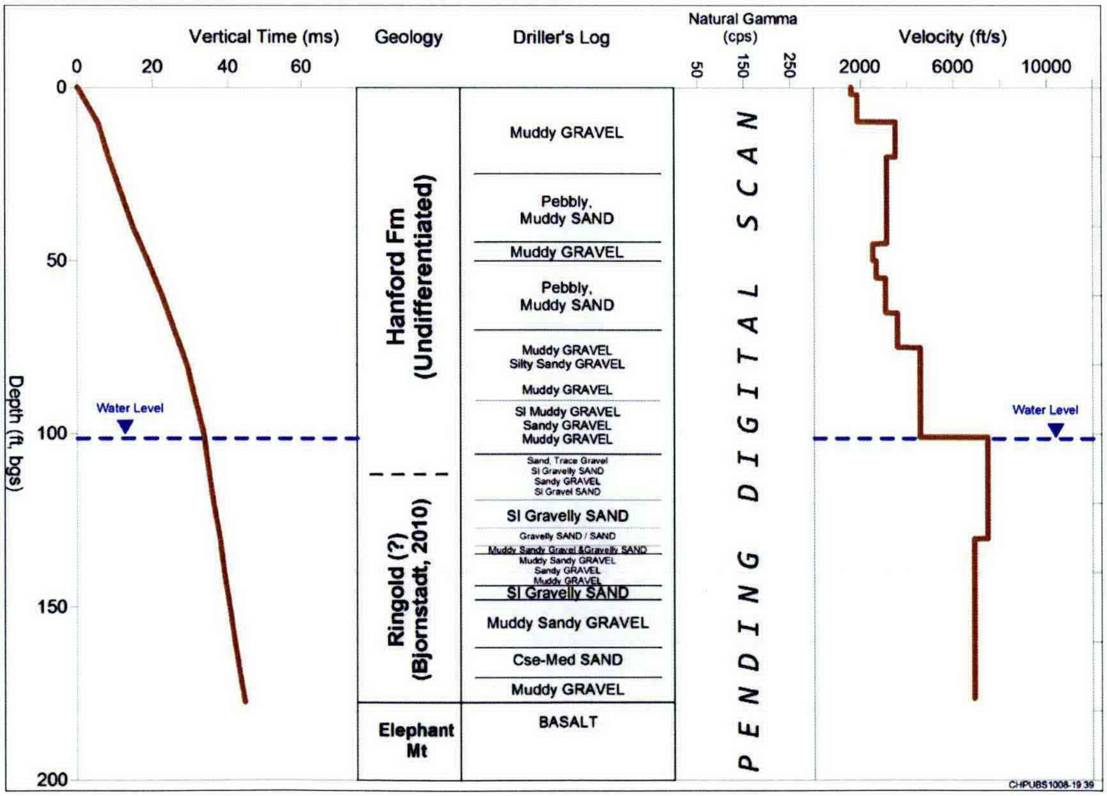

Figure 39. Check Shot Survey Results for Well 699-61-62

4.28 Well 699-63-58

Well 699-63-58 is located in the Gable Gap region along Route 4N about 4 km (2.5 mi) north of the intersection of routes 11A and 4N. The well is sited on the northern flank of the Gable Mt structure and serves to support interpretation of BWIP seismic profile FY79-04 and Landstreamer profile FY09-L-3 (see Figure 1 and Figure 4). Check shot surveys were conducted through sand, gravel, and cobbles of the Hanford Fm, and the upper 3m (10 ft) of the underlying Elephant Mt basalt. The well was originally drilled to a total depth of approximately 39.6 m (130 ft), and check shot surveys were conducted to 39.3 m (129 ft) in depth.

Results for Well 699-63-58 are shown in Figure 40 along with the driller's description and geologic names of units encountered. Seismic velocities increase monotonically with depth in the upper 12.2 m (40 ft), starting at approximately 411.5 m/s (1,350 ft/s) near the surface to about 823 m/s (2,700 ft/s) at 9.1 m to 12.2 m (30 ft to 40 ft). Below 12.2 m (40 ft), an approximate 12.2 m (40 ft) thick sequence of sand, gravel and cobble has a seismic velocity of approximately 1,036.3 m/s (3,400 ft/s), and sediment near and below the water level shows an increased seismic velocity of approximately 1,493.5 m/s (4,900 ft/s). The low velocity of 2,651.8 m/s (8,700 ft/s) estimated for the basalt is only based on three measurements in the upper 3 m (10 ft), but is consistent with results obtained in Well 699-52-55B.

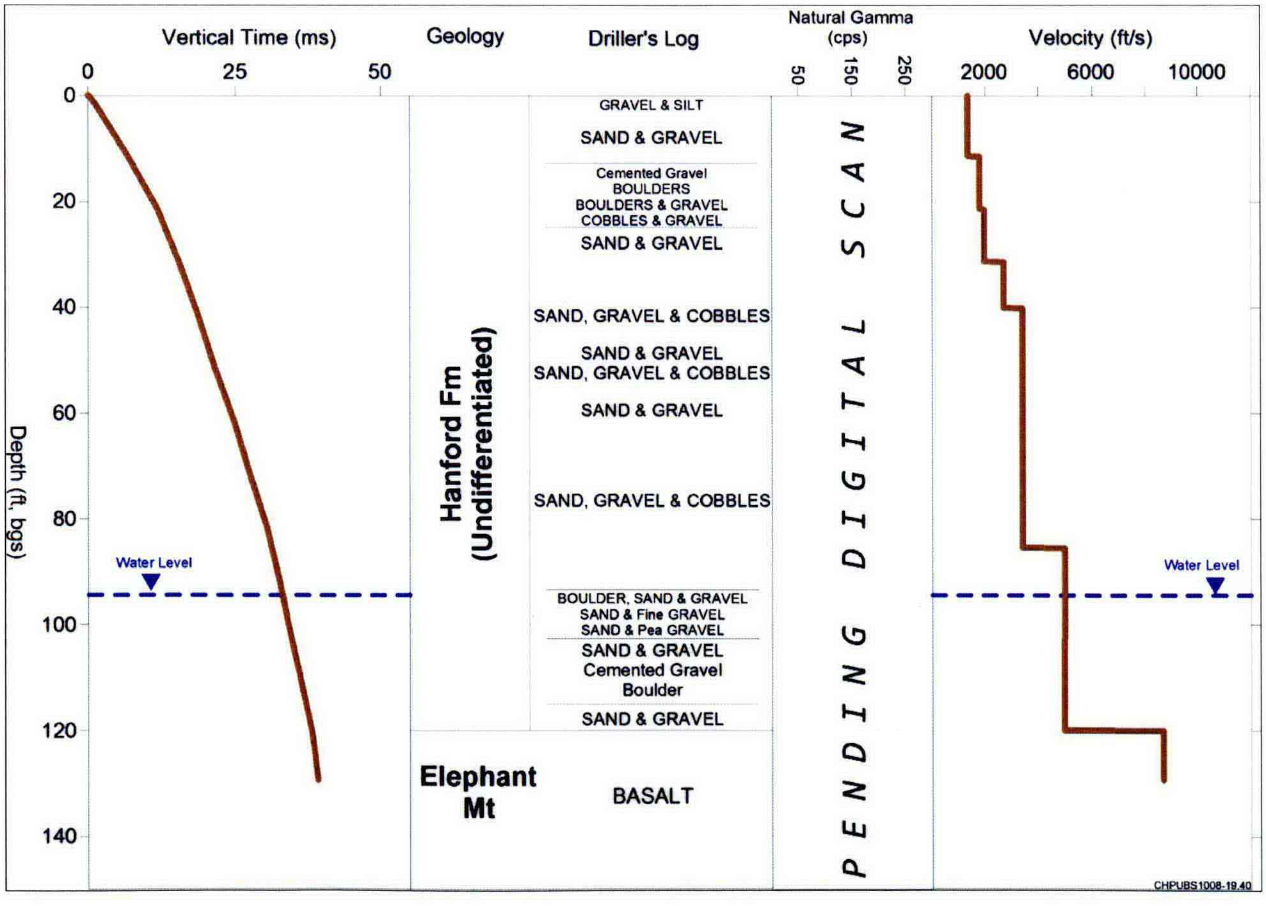

Figure 40. Check Shot Survey Results for Well 699-63-58

4.29 Well 699-65-83

Well 699-65-83 is located south of 100-BC and about 2.4 km (1.5 mi) south of the Columbia River. The well is sited on the northern flank of the Gable Butte structure and serves to support interpretation of BWIP seismic profile FY79-05 (see Figure 1 and Figure 5). Travel time measurements in this well were conducted through sands and gravels of the Hanford Fm to a depth of approximately 34.4 m (113 ft). The well was originally drilled to a depth of 36.9 (121 ft) and top-of-basalt is estimated to be 41.2 m to 45.8 m (135 ft to 150 ft) in depth.

Check shot results are shown in Figure 41 along with the associated gamma log and driller's description and geologic names of units encountered. Sand and gravel units in the upper 21.3 m (70 ft) have estimated velocities ranging from 1,800 ft/s to 2,500 ft/s. Below 21.3 m (70 ft), seismic velocities increase to ~1,219.2 m/s (~4,000 ft/s) above the water table and 2,072.6 m/s (6,800 ft/s) below the water table.

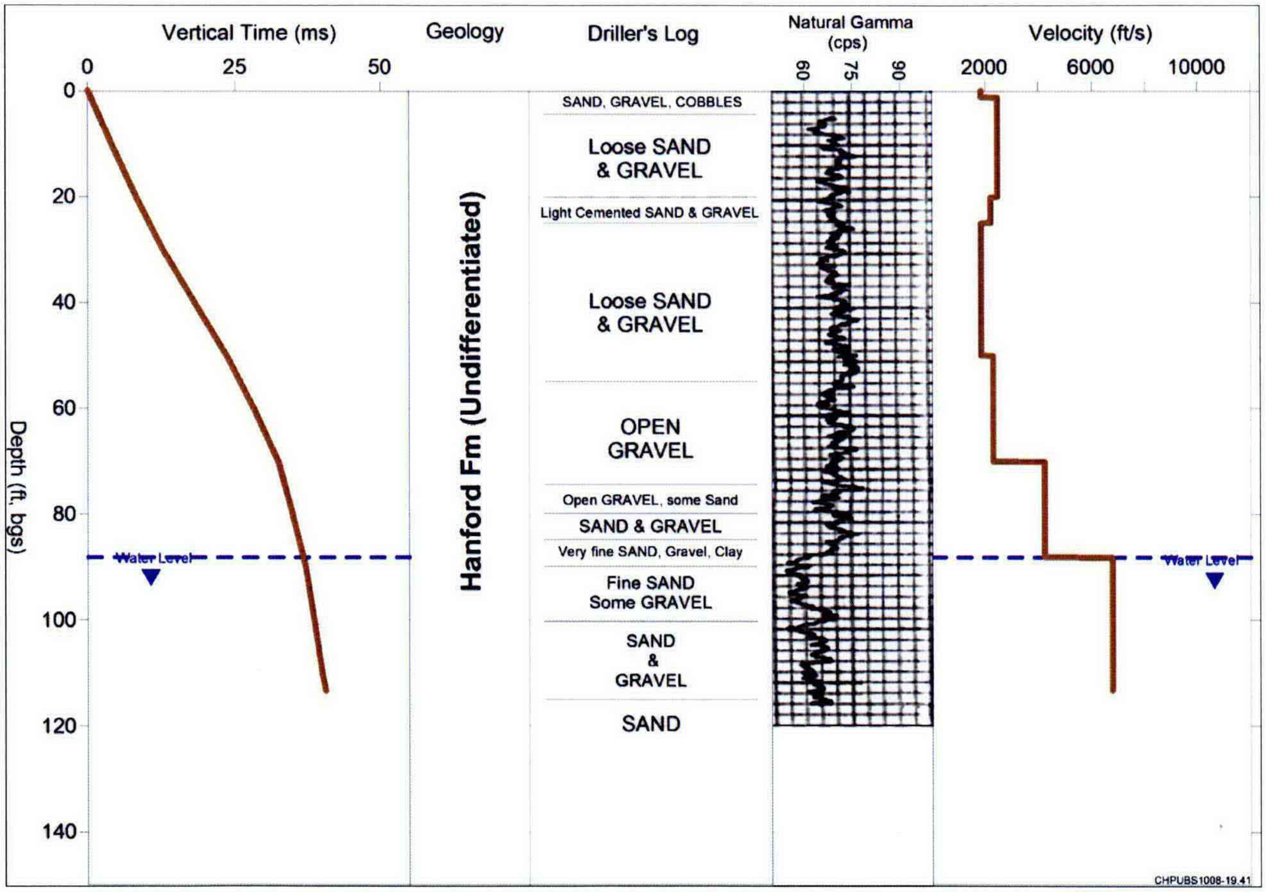

Figure 41. Check Shot Survey Results for Well 699-65-83

5 Discussion

Seismic velocity estimates obtained in the 29 wells are summarized in Figure 42 and Figure 43 in an attempt to identify whether velocity can be used as a diagnostic tool for differentiating the sediment facies at Hanford. In Figure 42, check shot derived velocities are plotted by well, geologic unit, and grouped into regional areas. At this time, derived velocities are only categorized by major geologic unit (Hanford, Ringold, and Basalt) and by whether the unit is above or below water table (unsaturated versus saturated).

It is a concern that velocity for a true sandy-gravel not be compared with that of a gravelly-sand where both units are listed by the drilling description as gravels and sands).

Seismic velocity for the unsaturated Hanford sediments in Figure 42 are predominantly below 1,066.8 m/s (3,500 ft/s), with higher derived values of 1,158.2 m/s to 1,920.2 m/s (3,800 ft/s to 6,300 ft/s) found in eight wells, with 699-26-15C and 699-55-60A yielding the highest values. Unsaturated Ringold units have velocities that are generally higher than Hanford, though significant overlap in range occurs in Wells 699-50-30 and 699-36-27. Velocities derived for saturated sediments for both the Hanford and Ringold Fms cluster in the 1,341.1 m/s to 2,590.8 m/s (4,400 ft/s to 8,500 ft/s) range. Significant overlap is observed, however, for Wells 699-57-83 and 699-26-15C.

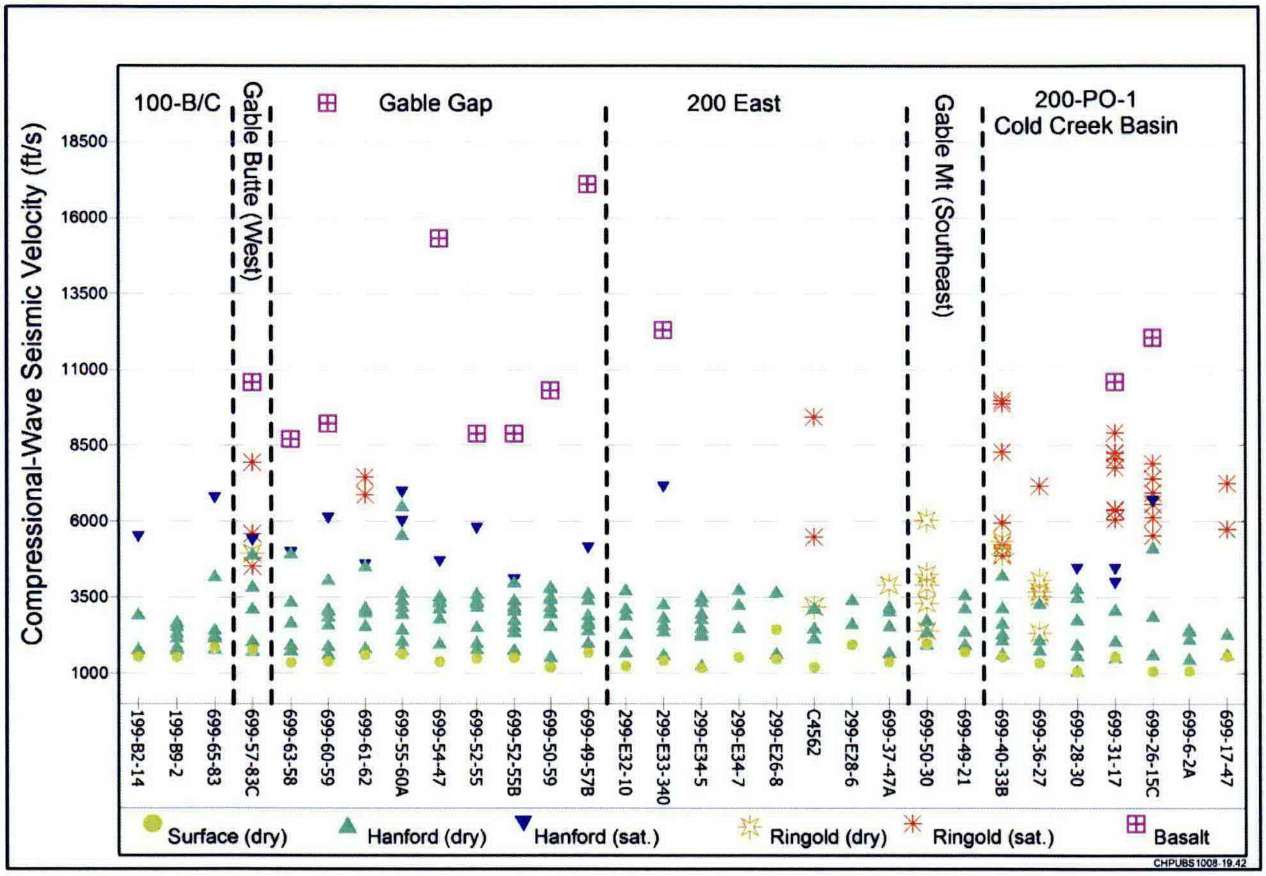

Figure 42. Seismic Velocities: 29 Check Shot Surveys, Fiscal Year 2008 to Fiscal Year 2010

Figure 43 summarizes statistical parameters (mean, standard deviation, etc) of the lithology and velocity information with the statistics table shown in the upper-left corner of the figure. Shown are the total range (minimum to maximum), the arithmetic average, median value, short-horizontal bars representing a standard deviation above and below the average of the mean and median, and normalized histograms of the velocities of saturated and unsaturated sediments (upper left corner). As expected, a clear separation between saturated and unsaturated sediment velocity occurs (velocity histograms) and confirms that seismic surveys should be able to detect the water table at Hanford in the sedimentary column.

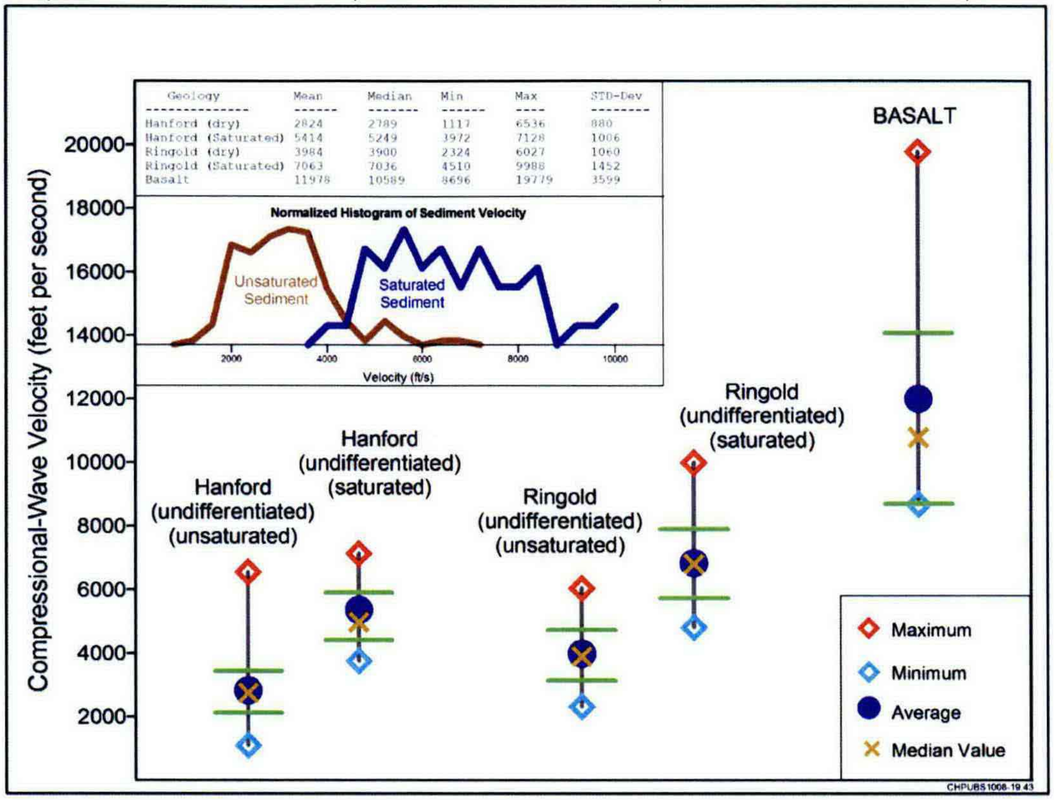

Figure 43. Seismic Velocities: 29 Check Shot Surveys, Fiscal Year 2008 to Fiscal Year 2010

Less certain is whether seismic velocity can solely be used to differentiate Hanford and Ringold units. Results from the check shot surveys suggest that Ringold (unsaturated) could be misidentified as Hanford (saturated) (or vice versa) if the position of the water table is not known (or used in the interpretation). Direct comparison of unsaturated Hanford and Ringold seismic velocities indicate an approximate 457.2 m/s to 609.6 m/s (1,500 ft/s to 2,000 ft/s) overlap between dominant velocities of both units, with Ringold sediments on average being about 457.2 m/s (1,500 ft/s) higher in velocity than Hanford units. The case for saturated sediments is even worse in terms of differentiation by seismic velocity, as the presence of water in unconsolidated coarse-grained sediments is the primary control governing the resulting velocity. Higher derived velocities within the saturated Ringold units are most likely the result of consolidation and induration where the cohesive matrix begins dominating the resulting seismic velocity.

A final caution must also be issued if blindly interpreting "high-velocities" as basalt. Derived velocities for Ringold units range up to ~ 3,048 m/s (~10,000 ft/s) and for basalt intervals, seismic velocities range as low as ~2,651.8 m/s (~8,700 ft/s). This yields the distinct possibly of a seismic reflector from an indurated Ringold unit with a high-velocity being incorrectly identified as top-of-basalt on a seismic section. Check shot information, with its strong tie to well bore geology, allows correlating seismic reflectors or interfaces against the underlying geology.

Examples of how specific geologic units are correlated with seismic sections using check shot information are shown in Figure 44 for short segments of FY 2009 and FY 2008 seismic profiles and BWIP profile FY79-02. Shown on each seismic section are the resulting velocity-time curves computed from the check shot survey information. For all three cases, the basalt surface is represented by strong reflectors that correlate with a sharp increase in interval velocity – from 914.4 m/s to 1,981.2 m/s (3,000 to 6,500 ft/s) above (sediment) to 3,048 m/s (10,000 ft/s) and greater for the basalt. For the FY 2009 seismic data, strong reflectors correlate with top-of-basalt as indicated by the check shot survey in Well 699-54-47. Top of basalt is indicated in the FY 2008 seismic data, and subtle changes in interval velocity within the sedimentary column appears to be loosely correlated with changes in seismic character, and tied to Hanford Fm sub-units. Time-depth information from Well 699-26-15C is used to correlate Ringold units with relatively strong reflectors that occur above the basalt surface.

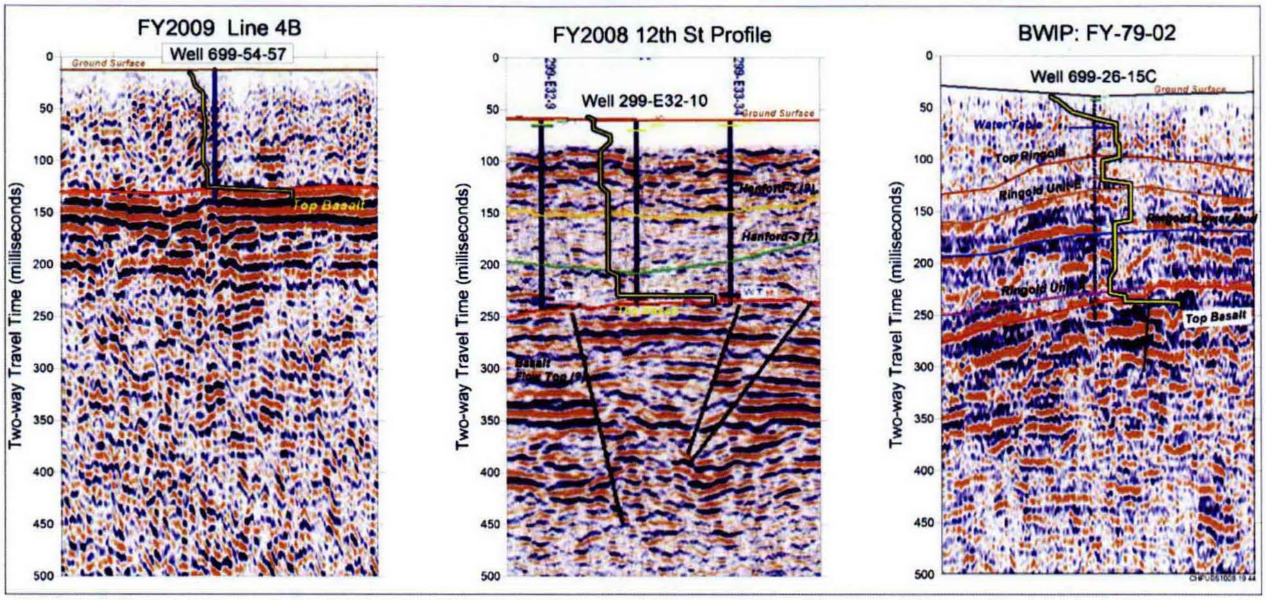

Figure 44. Check Shot Surveys, Geologic Units, and Seismic Reflectors

Figure 45 through Figure 47 are pseudo cross-sections showing changes in velocity for the 200 East, Gable Gap, and Cold Creek Basin (200-PO-1 OU) regions. Shown on each figure are the current position of the water table (dashed blue line), the top-of-basalt (dashed gray line), and an inset base map showing the cross-section line. These cross-sections illustrate both the vertical and horizontal variability in seismic velocity that can be expected at the Hanford Site. The 200 East cross-section suggests that seismic velocities for the unsaturated Hanford units are in the 762 m/s to 1,158.2 m/s (2,500 ft/s to-3,800 ft/s) range and that low-contrast (weak) reflection character should dominate the reflection sections. For Gable Gap (Figure 46), seismic velocities of the unsaturated Hanford units exhibit a broader range, but the Hanford velocity contrasts are also relatively low and should yield weak reflections.

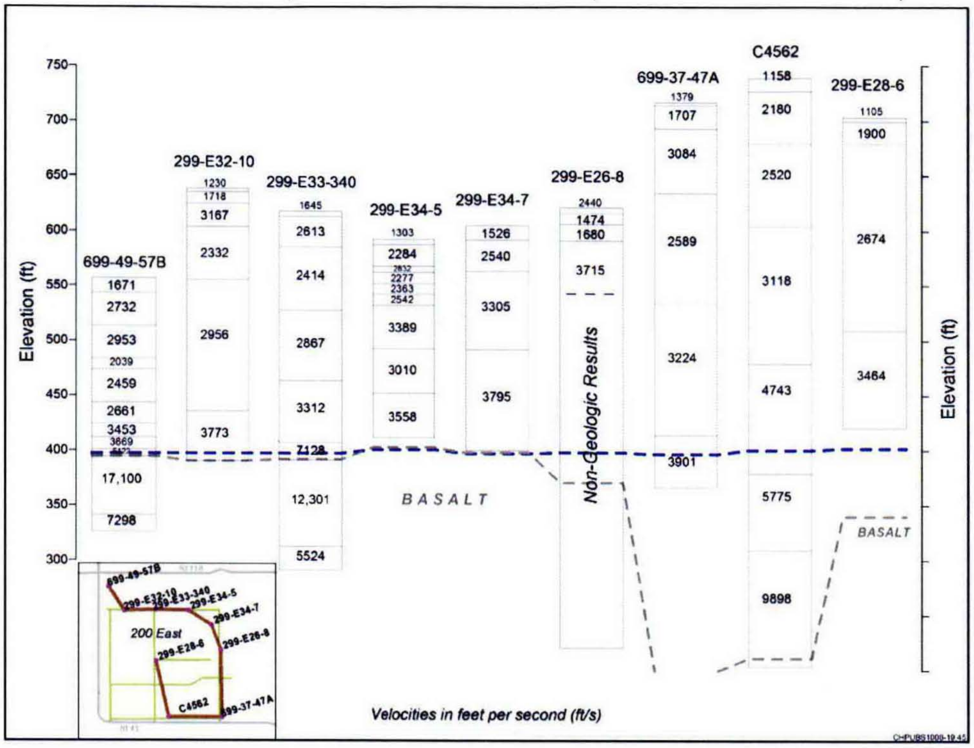

Figure 45. 200 East: Compressional-Wave Velocities

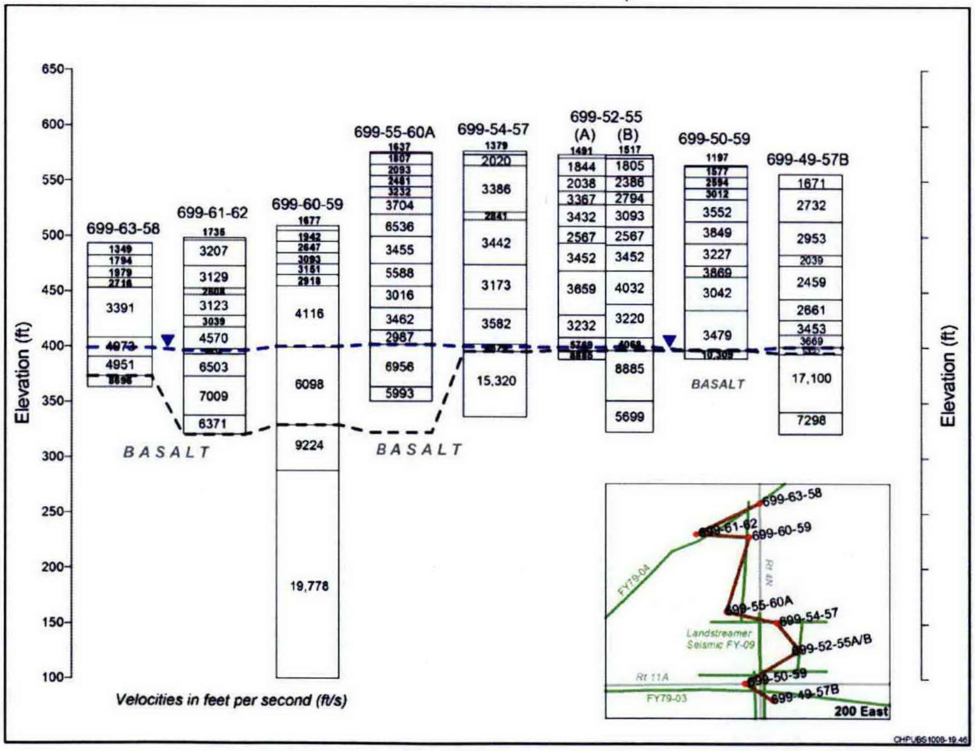

Figure 46. Gable Gap: Compressional-Wave Velocities

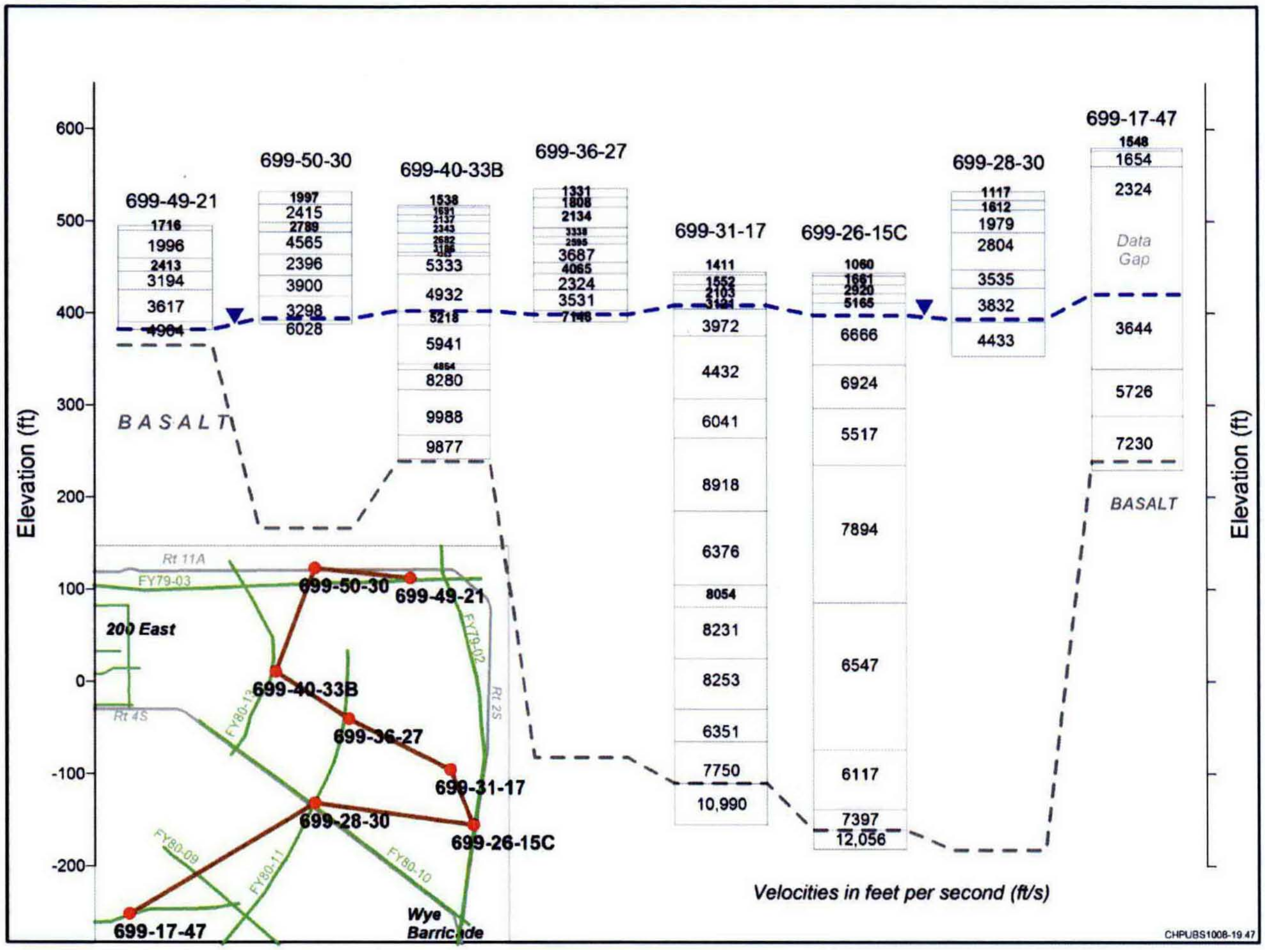

Figure 47. Cold Creek Basin: Compressional-Wave Velocities

The cross-section through the Cold Creek Basin (Figure 47) samples a larger amount of the saturated supra-basalt sedimentary section. The unsaturated-saturated interface is generally 457.2 m/s to 609.6 m/s (1,500 ft/s to 2,000 ft/s), and velocity contrasts intra-saturated sediment velocity contrasts can be upwards of 609.6 m/s (2,000 ft/s), which should yield strong intra-Ringold and Hanford/Cold Creek-Ringold reflections.

6 Recommendations

Check shot data should be used to help reprocess seismic reflection data collected in FY 2008 and FY 2009. The FY 2008 data did not have sufficient velocity information regarding Hanford units and focused on resolving top-of-basalt. A first pass at creating a depth section for the FY 2009 data yielded over-estimates of depth to basalt in structural or erosional lows. This was primarily caused by the use of incorrect velocity functions.

A more powerful energy source for future check shot surveys in wells deeper than 79.3 m (260 ft) should be considered. Results from the FY 2009 surveys indicate that the ATV mounted accelerated weight drop provided sufficient energy to a depth of 182. 9 m (600 ft) or more.

Future work will need to check the ROCSAN computer program and other data sets to allow further differentiation.

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Appendix A

Filtered and Unfiltered Plots of Raw Check Shot Records

A Filtered and Unfiltered Plots of Raw Check Shot Records

Raw and filtered check shot records for the wells surveyed in September 2008, June 2009, and March and April 2010 are shown in this appendix as Figure A1 through Figure A29. The data are displayed by trace number and travel time, with depth increasing from top-to-bottom of each plot. A heavy blue trace line is used to denote where the start of the seismic signal is interpreted, and light-blue colored dots or red hatch marks indicate the travel time pick.

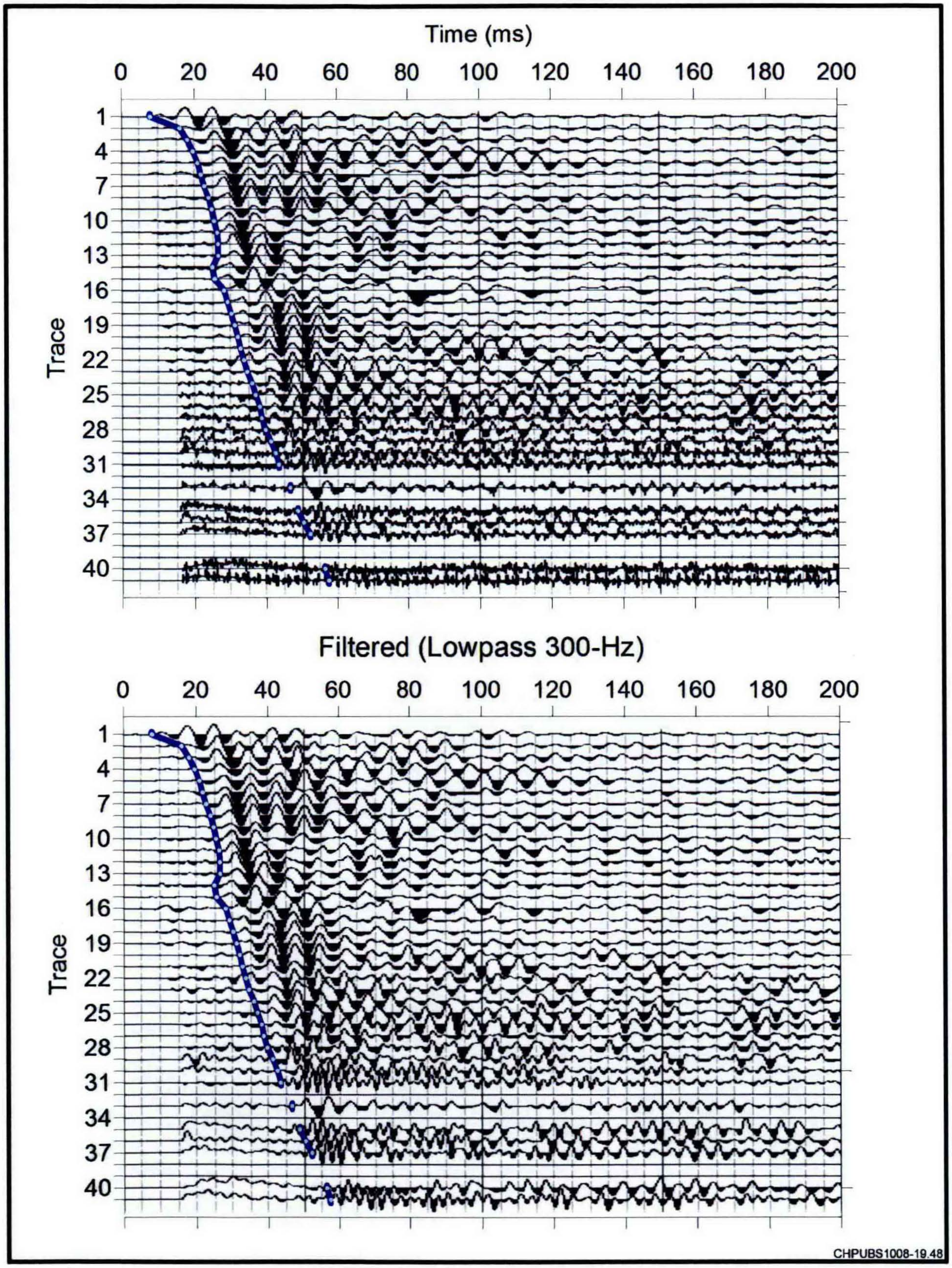


Figure A1. Check Shot: Well 299-E28-06

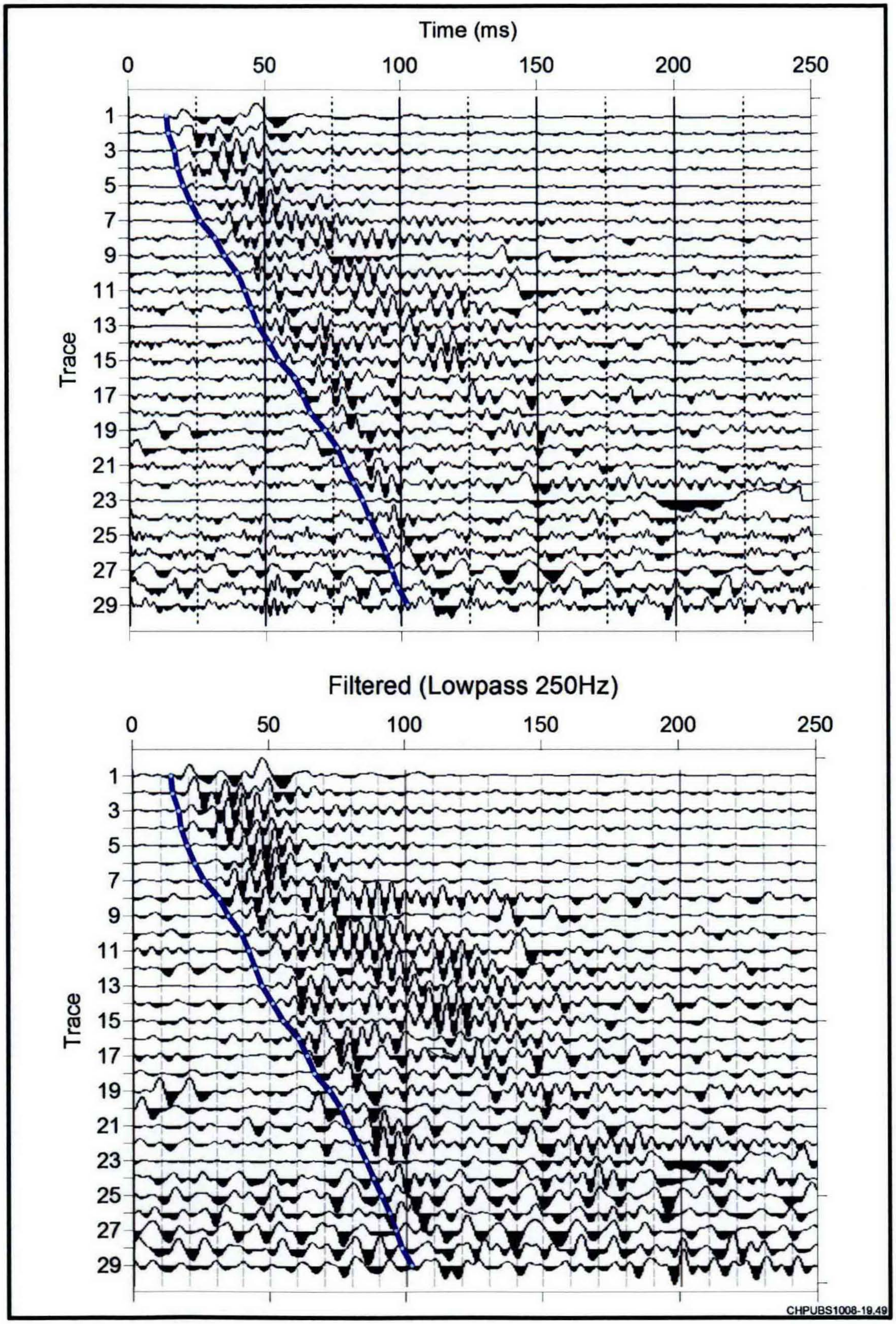


Figure A2. Check Shot: Well 299-E28-06

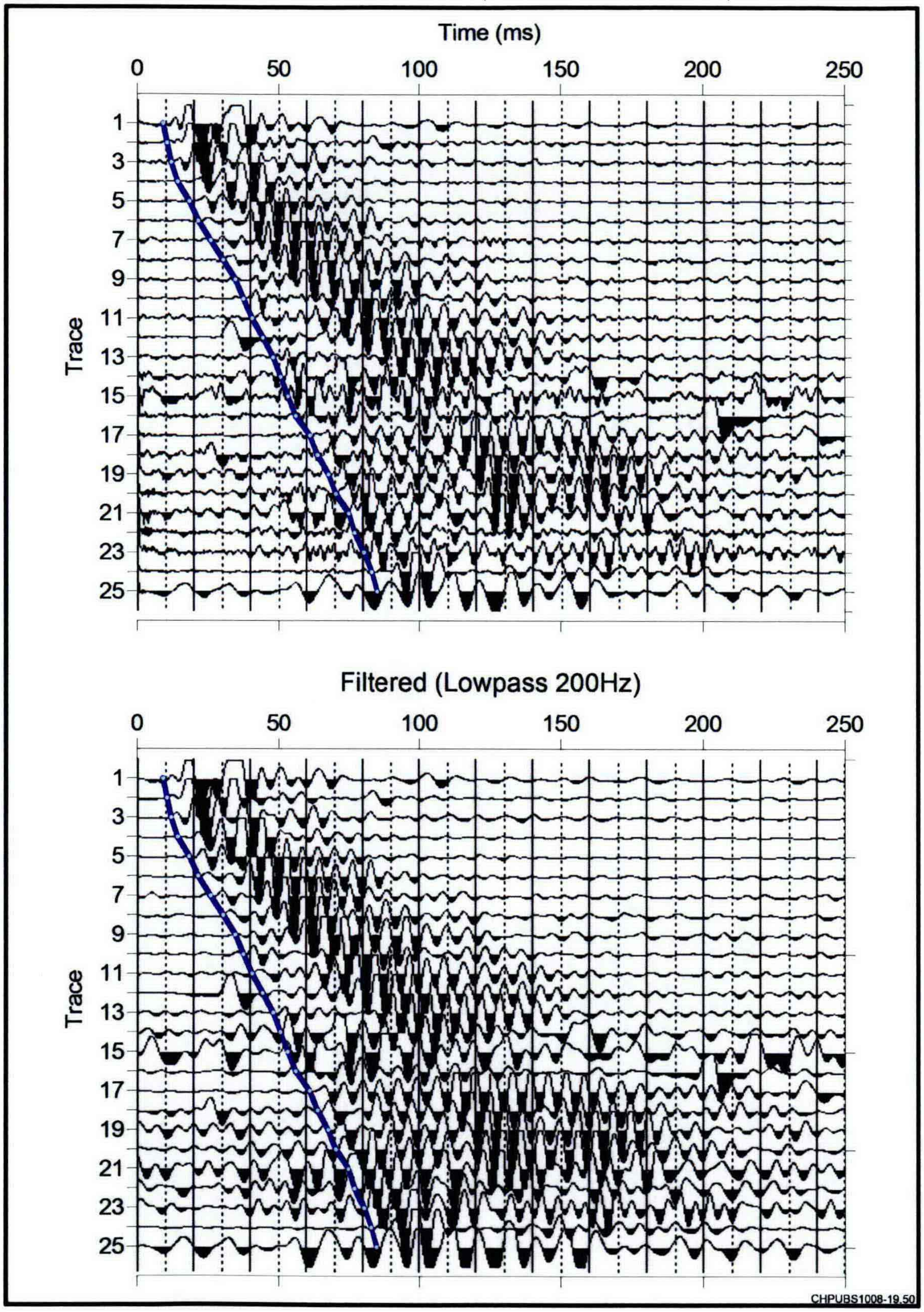


Figure A3. Check Shot: Well 299-E32-10

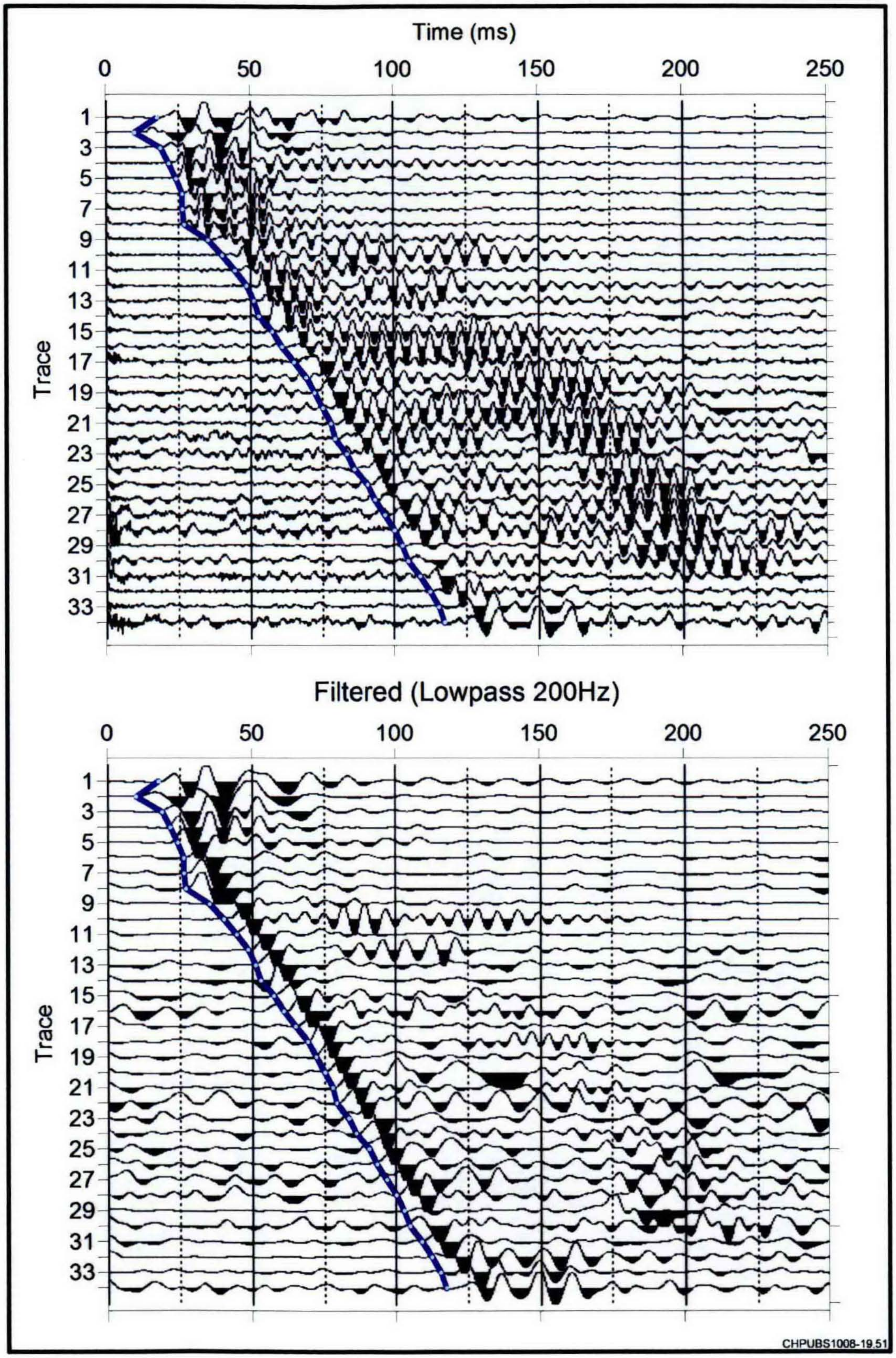


Figure A5. Check Shot: Well 699-37-47A

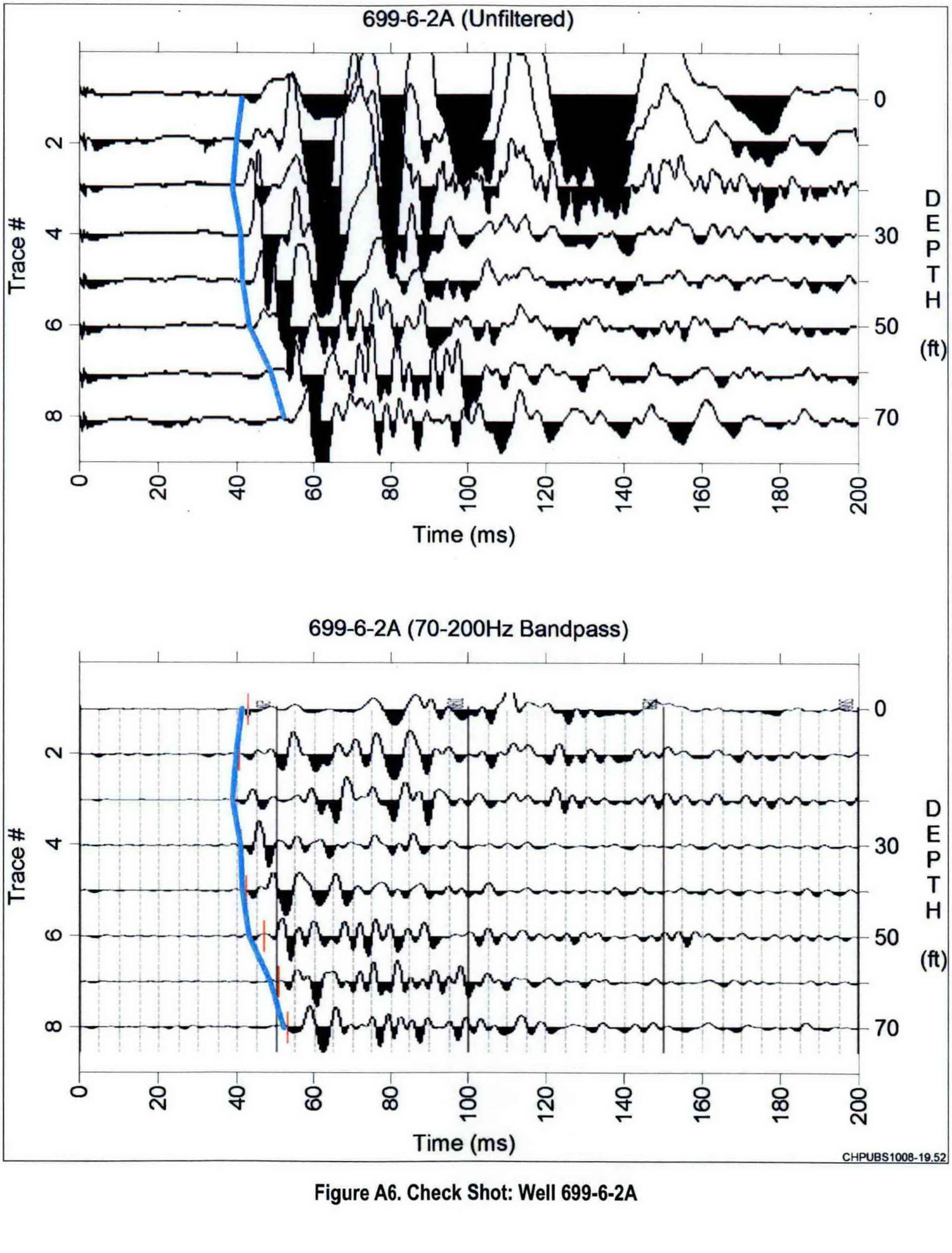


Figure A6. Check Shot: Well 699-6-2A

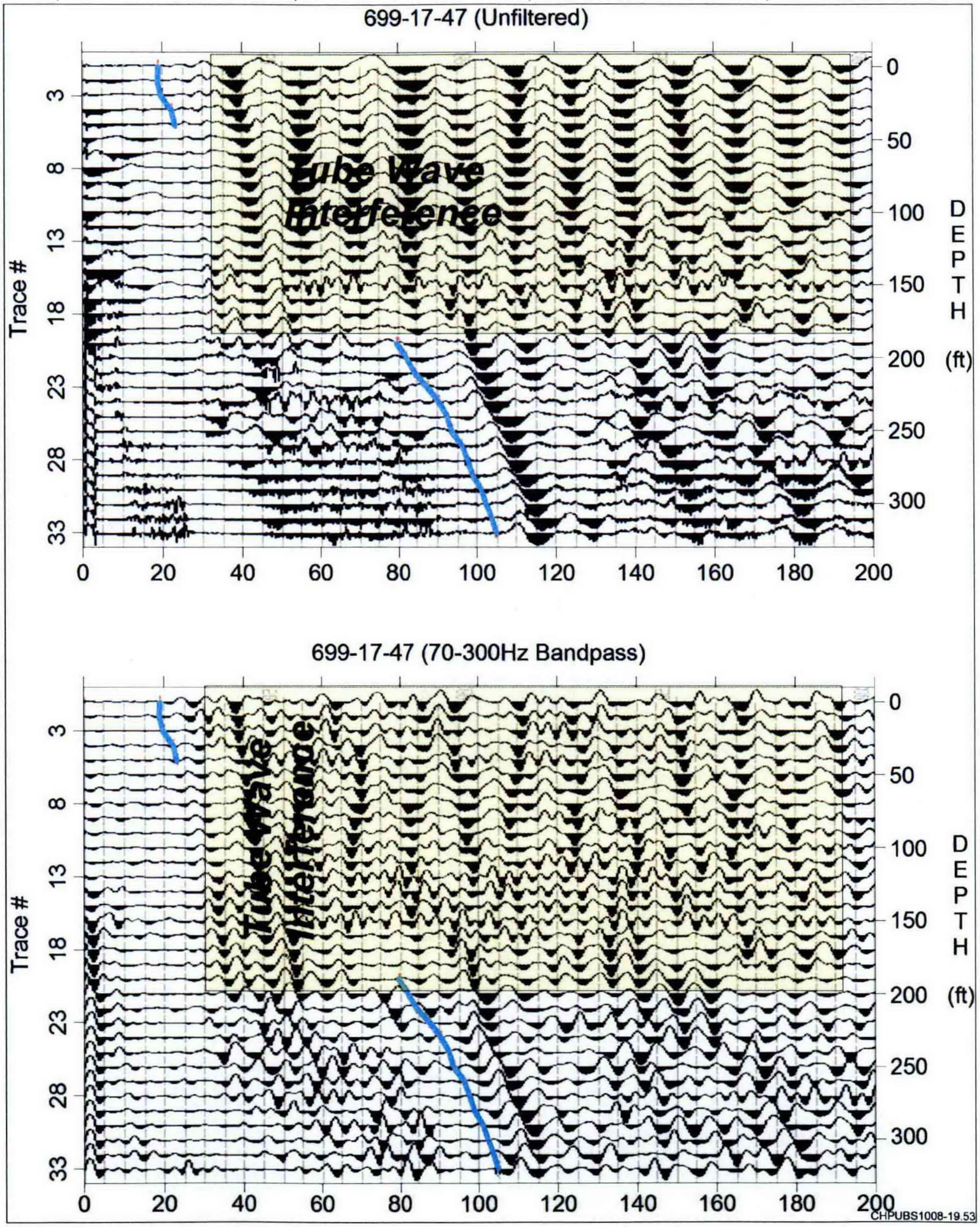


Figure A7. Check Shot: Well 699-17-47

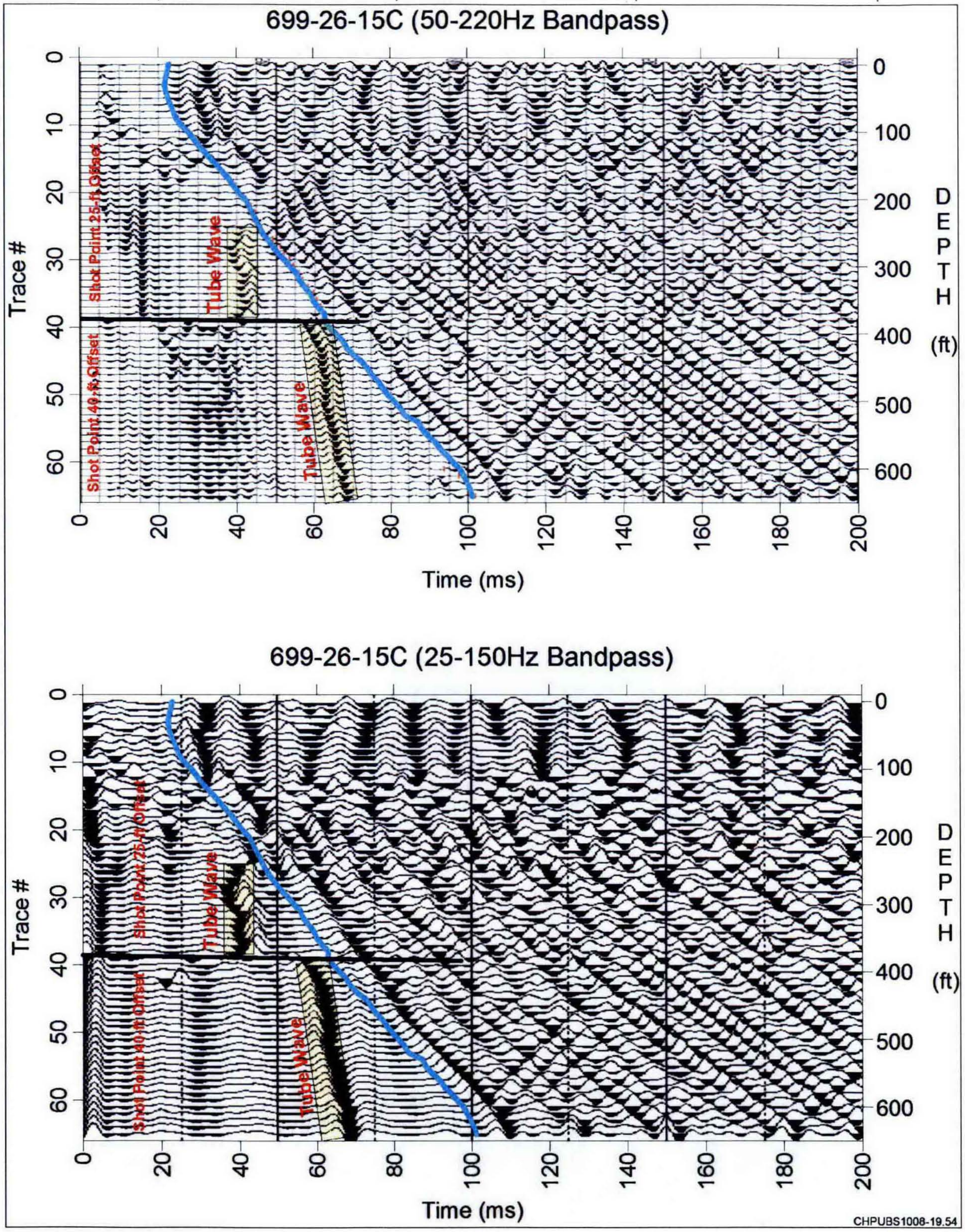


Figure A8. Check Shot: Well 699-26-15C

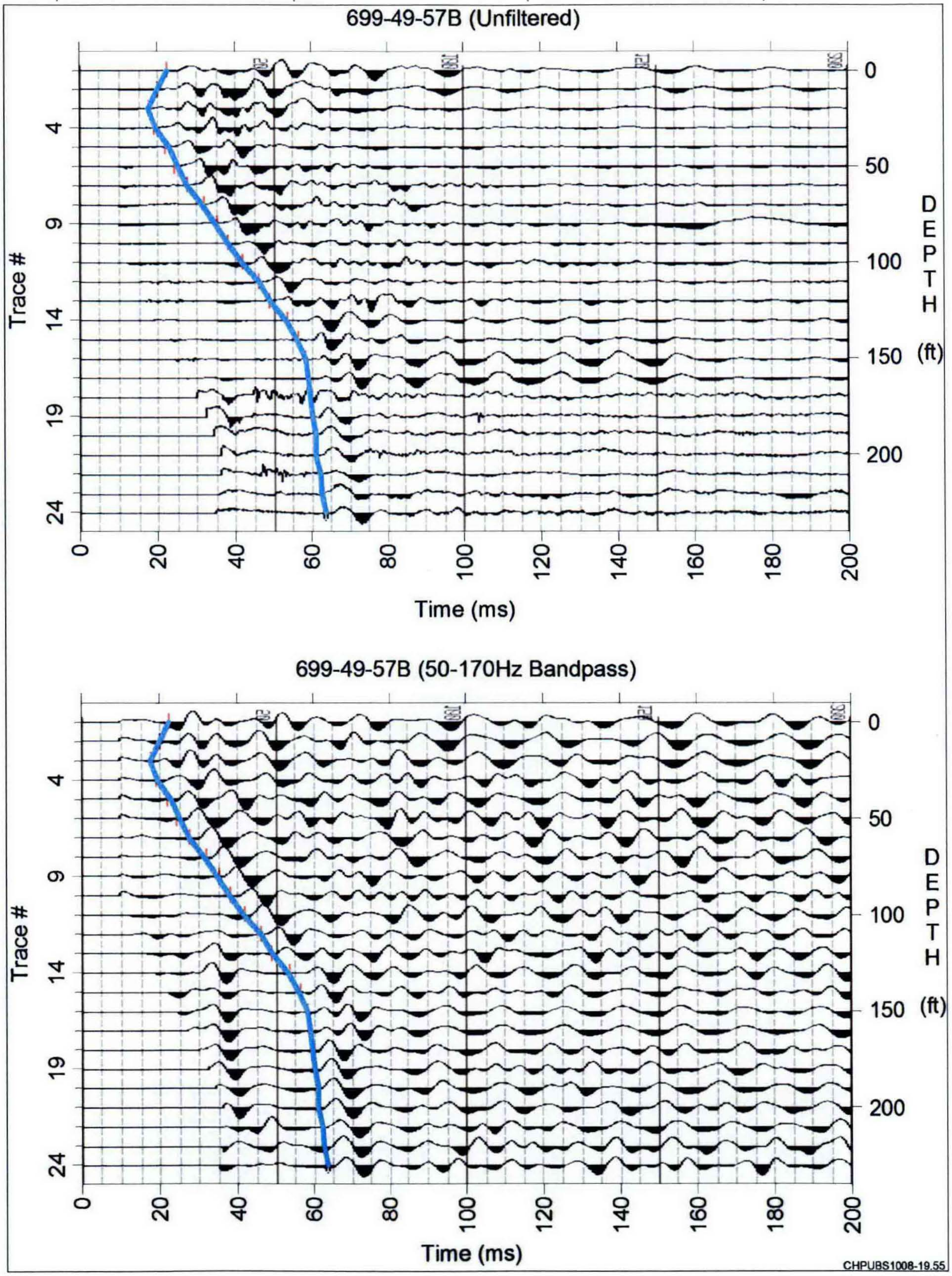


Figure A9. Check Shot: Well 699-49-57B

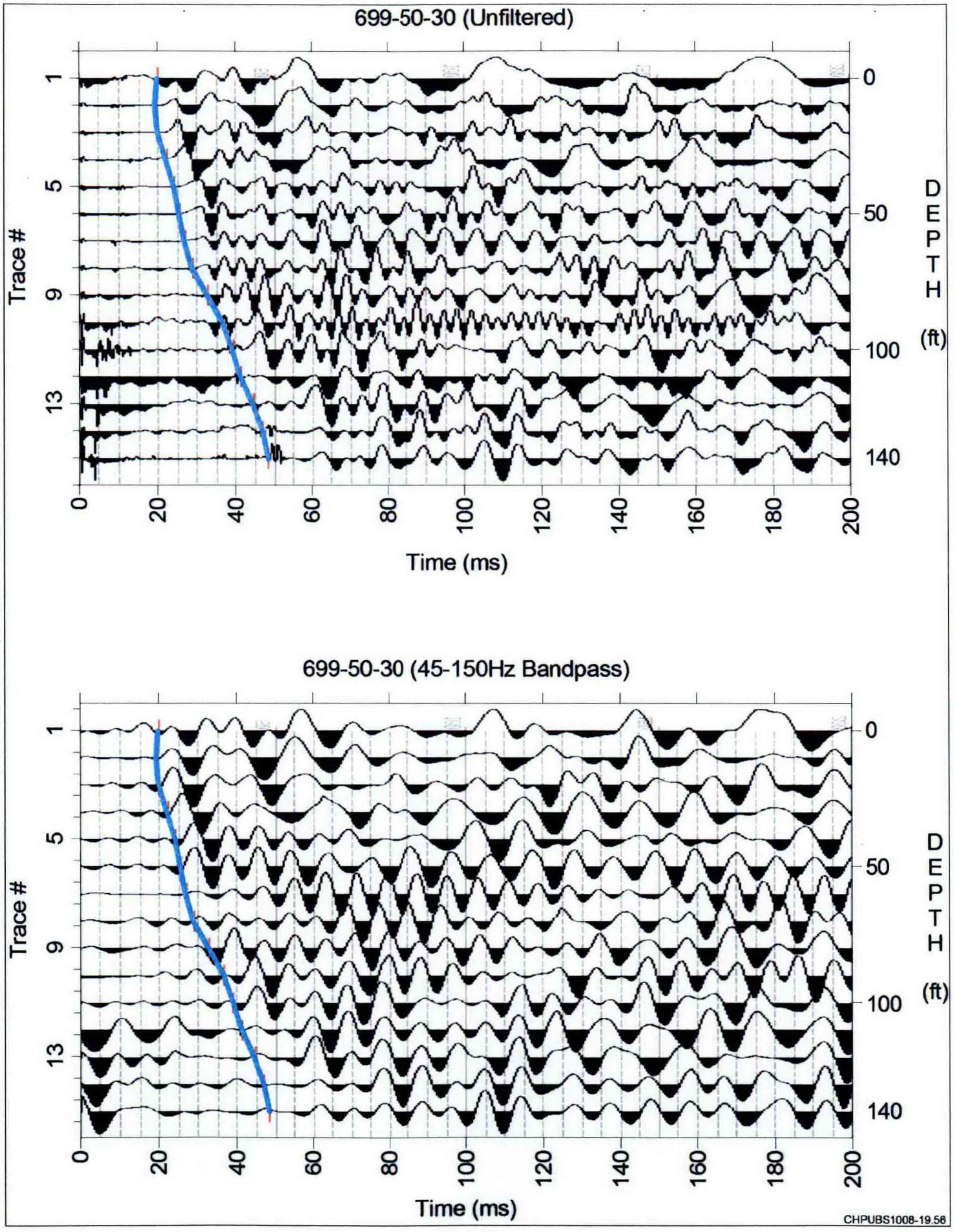


Figure A10. Check Shot: Well 699-50-30

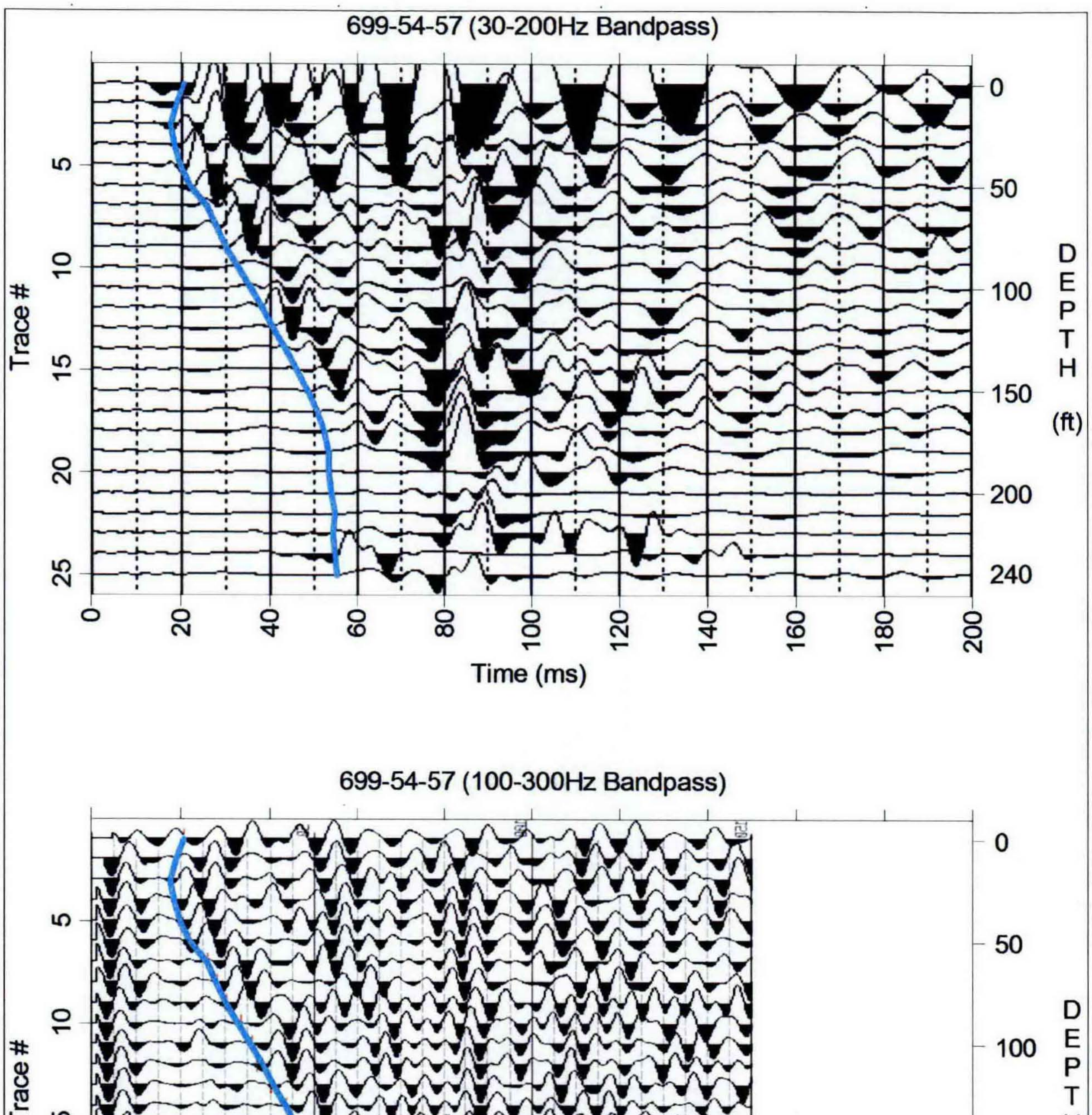


Figure A11. Check Shot: Well 699-54-57

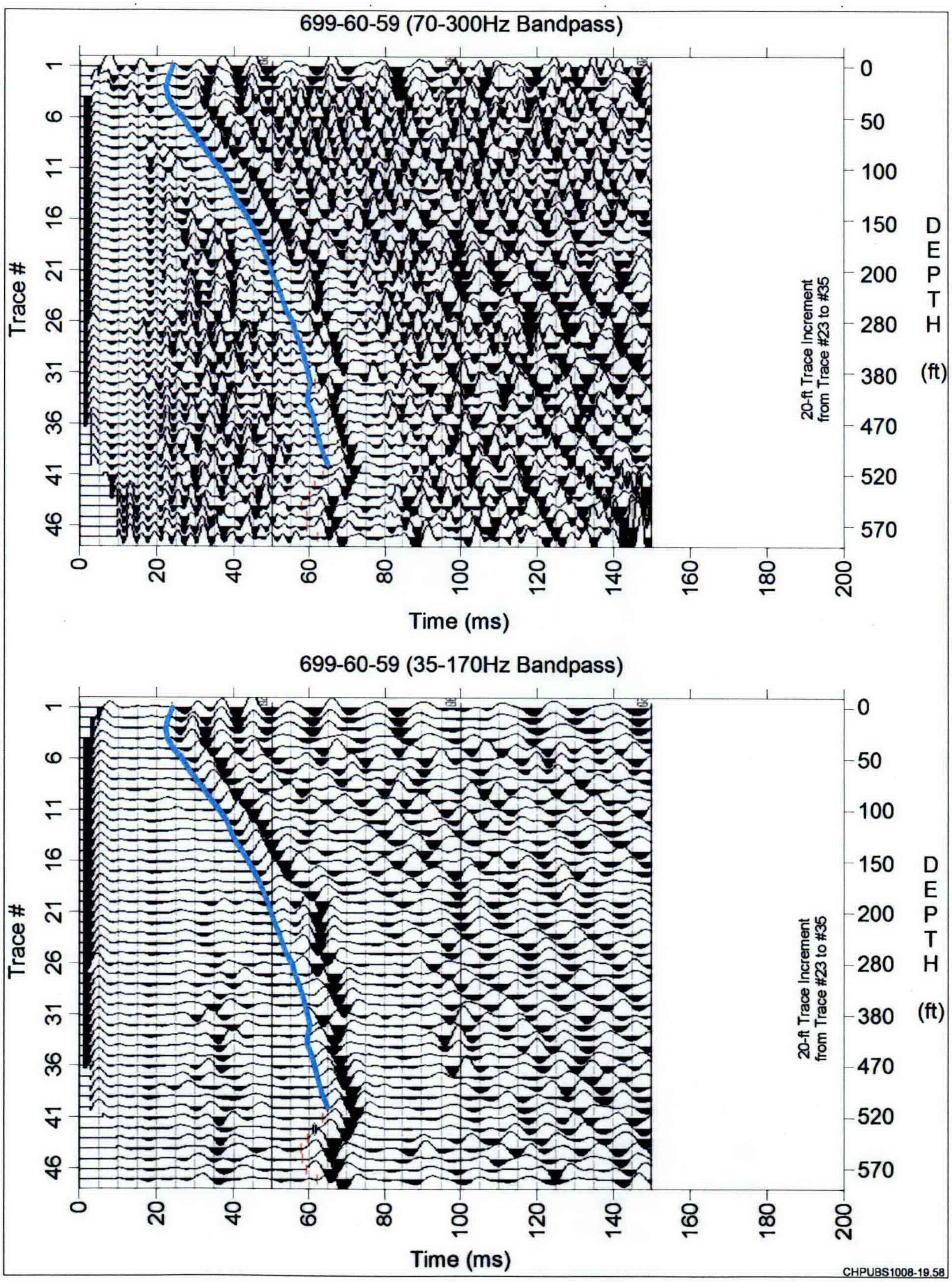


Figure A12. Check Shot: Well 699-60-59

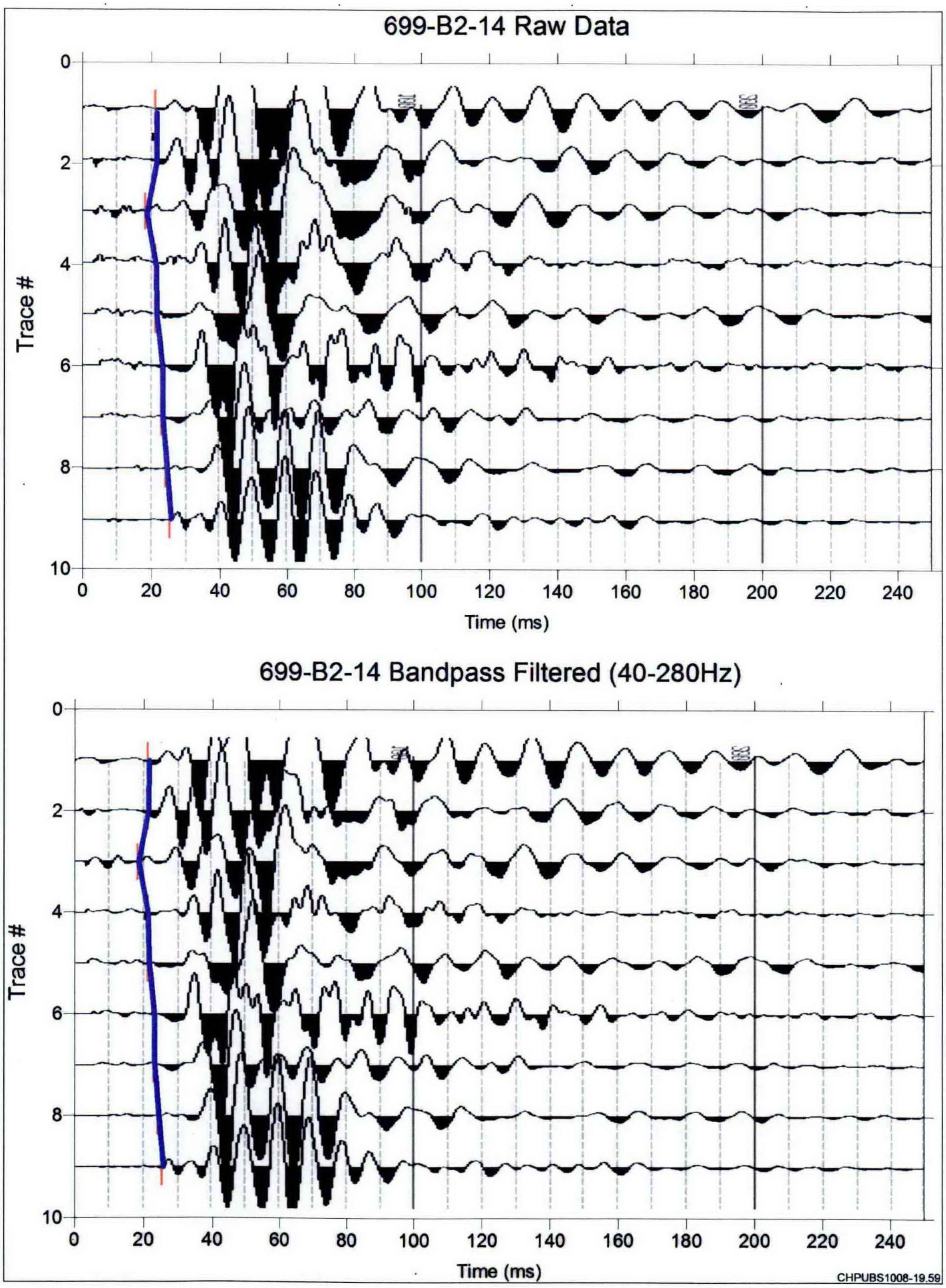


Figure A13. Check Shot: Well 699-B2-14

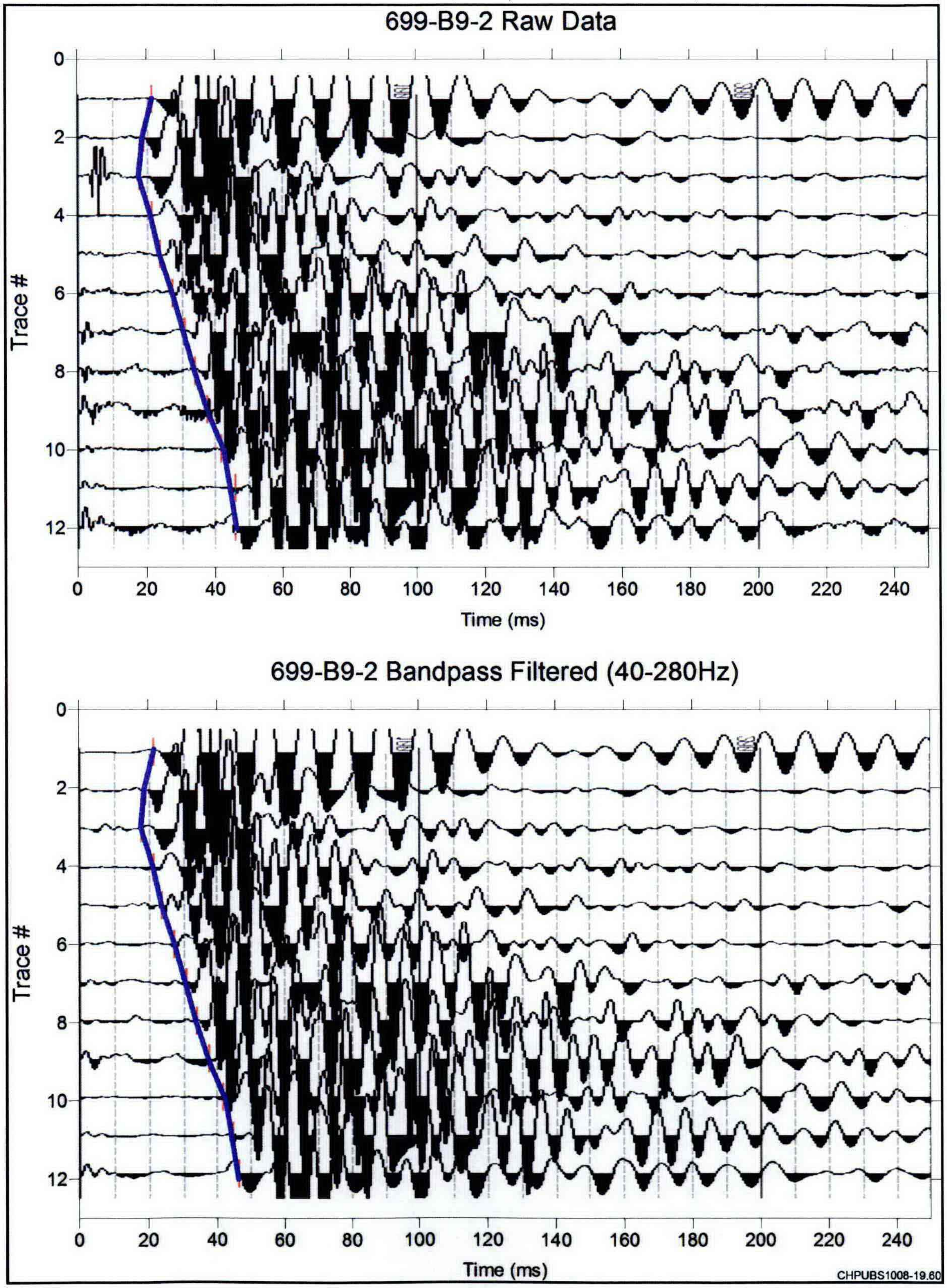


Figure A14. Check Shot: Well 699-B9-2

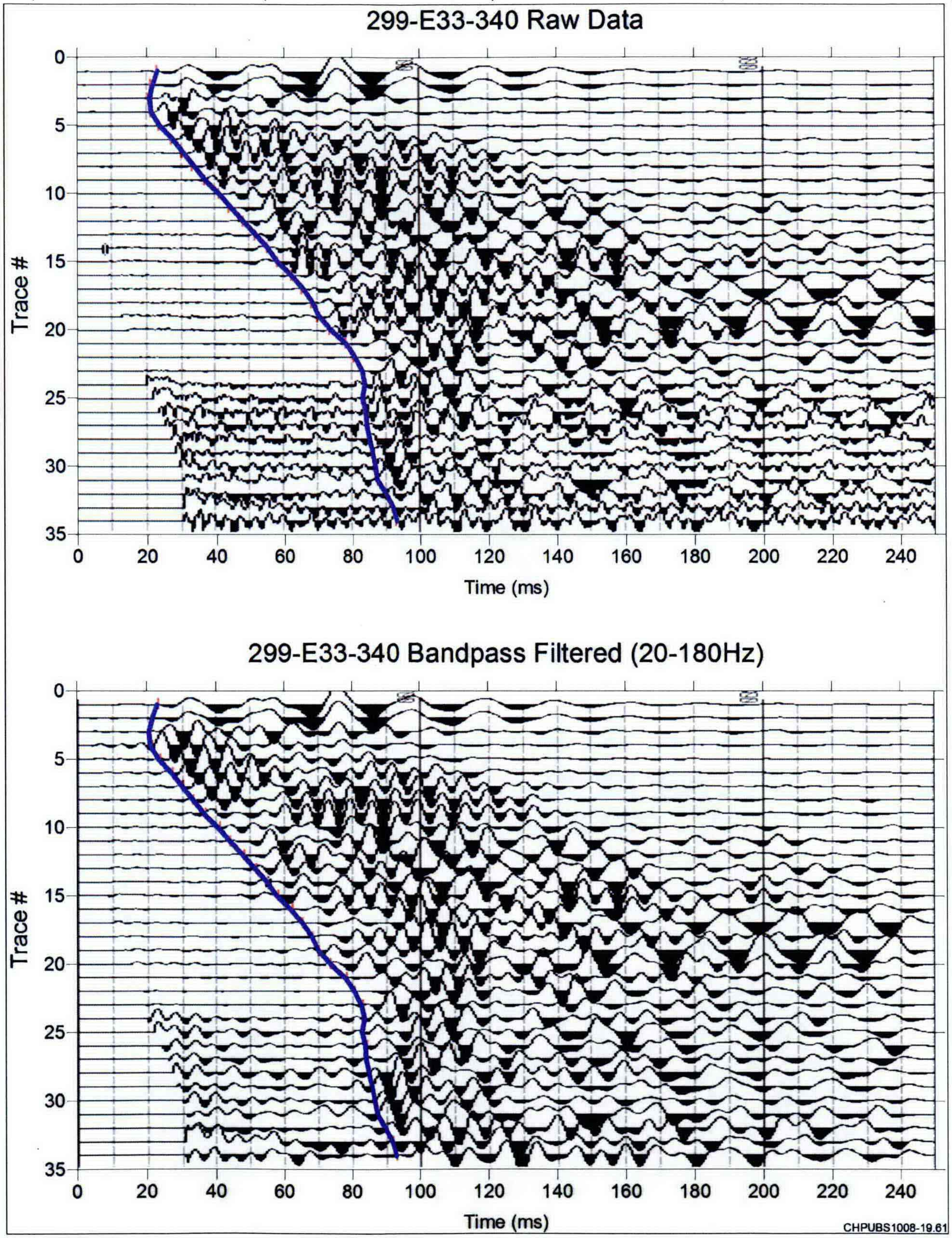
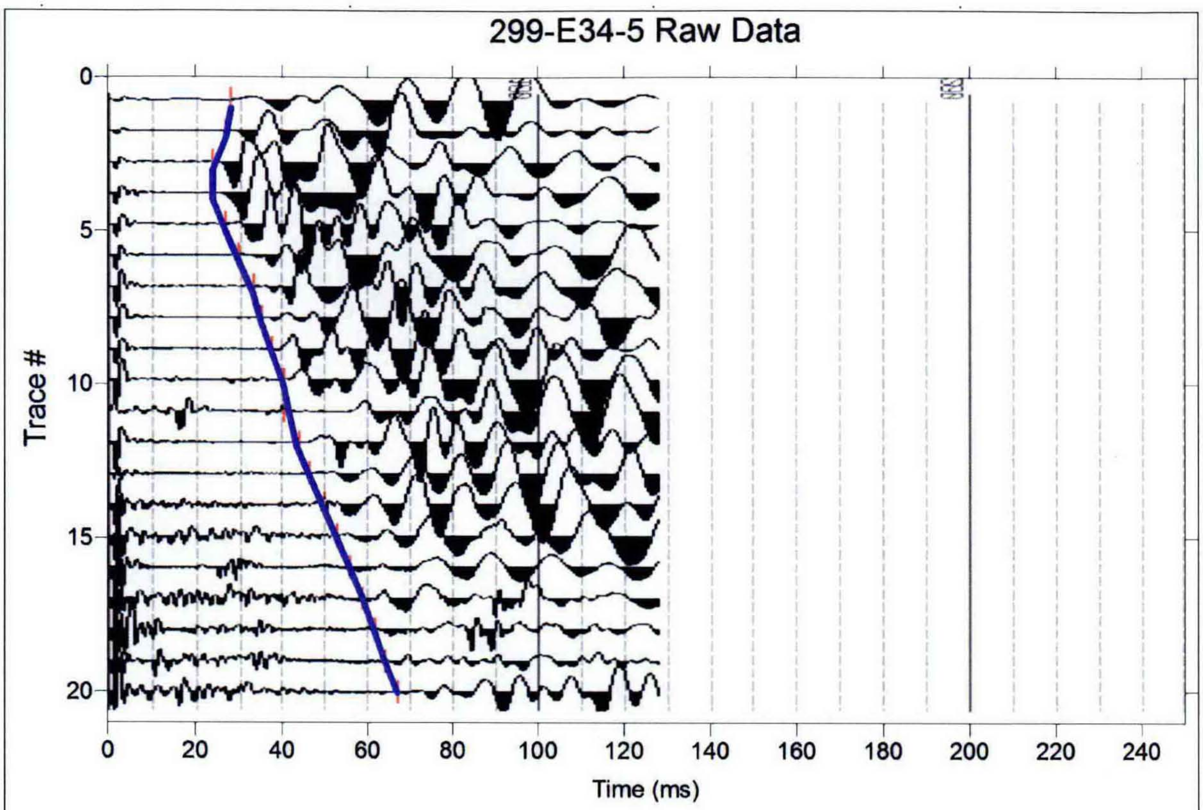


Figure A15. Check Shot: Well 299-E33-340



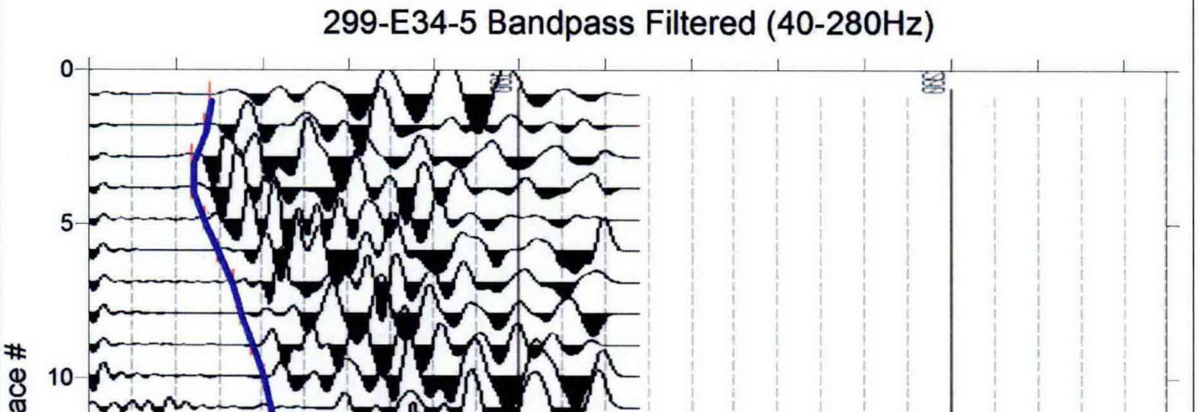


Figure A16. Check Shot: Well 299-E34-5

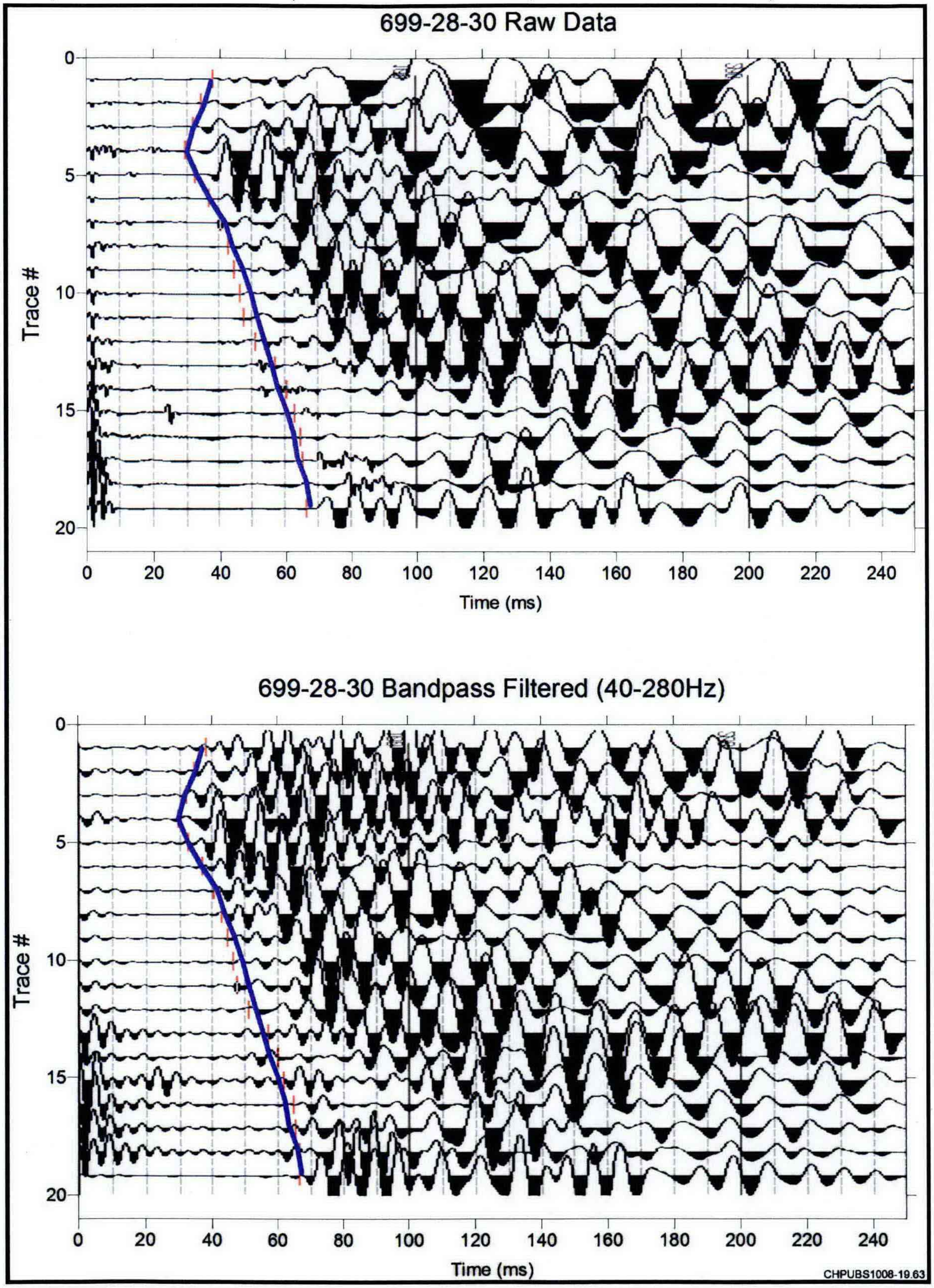


Figure A17. Check Shot: Well 699-28-30

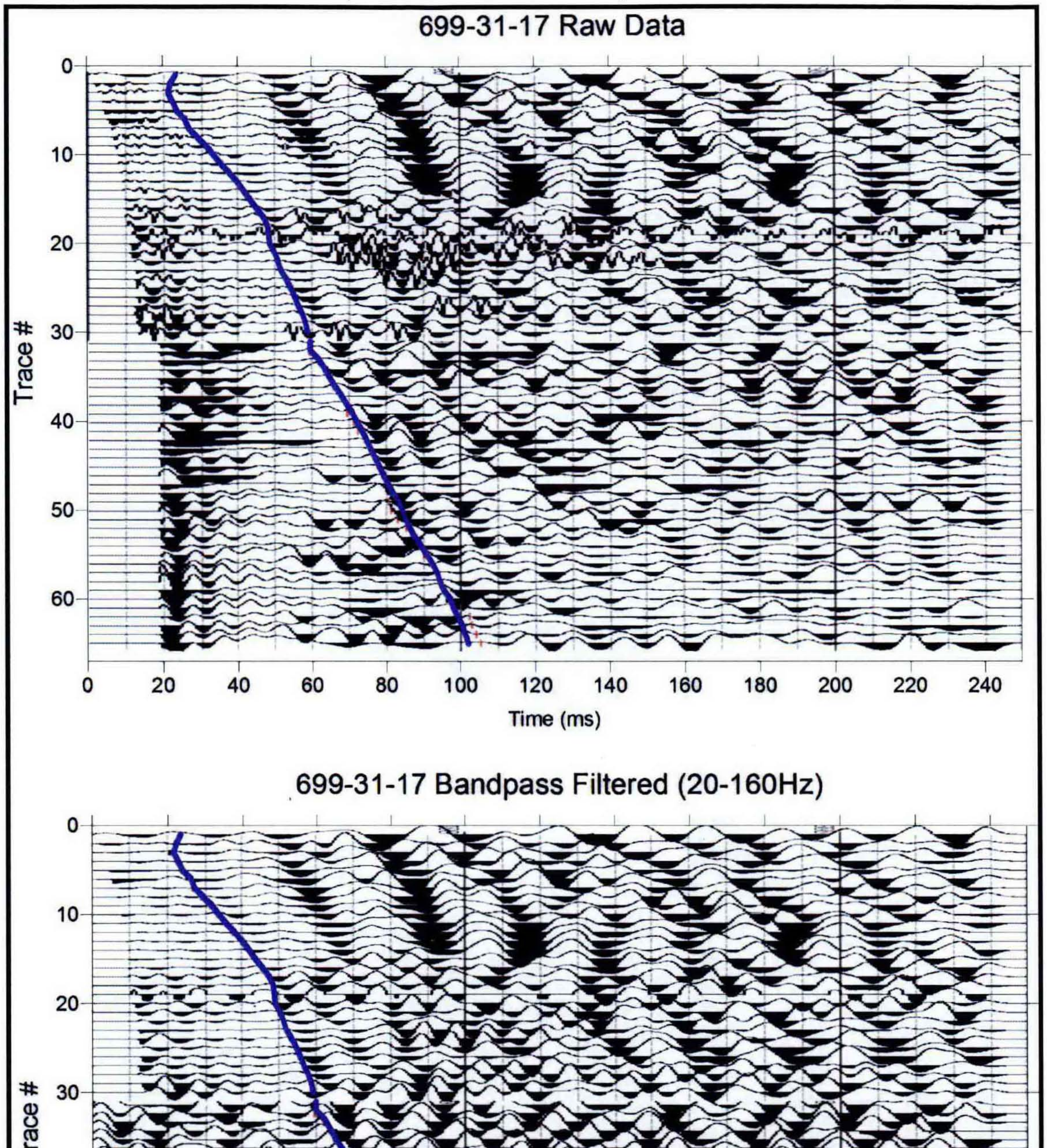


Figure A18. Check Shot: Well 699-31-17

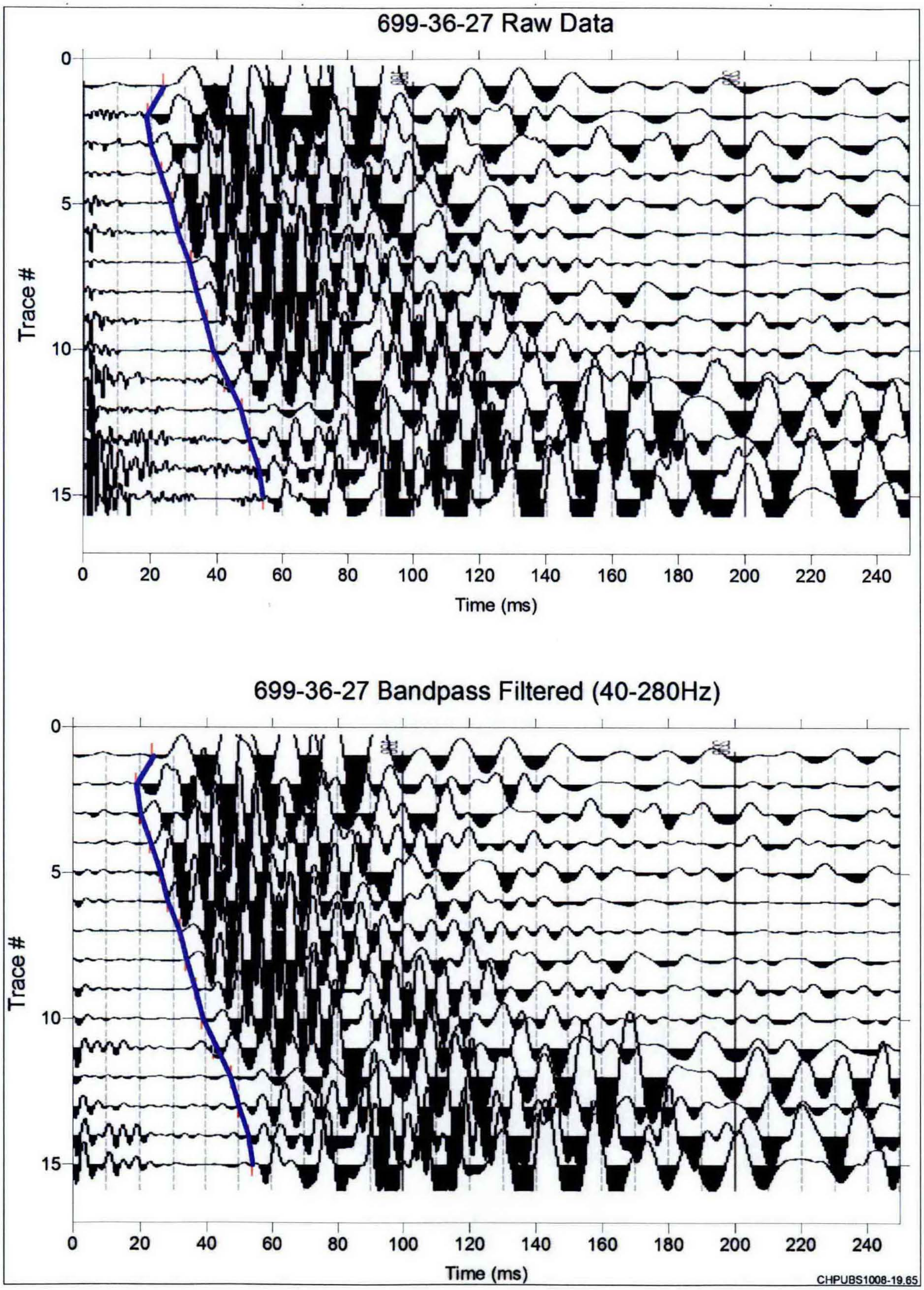


Figure A19. Check Shot: Well 699-36-27

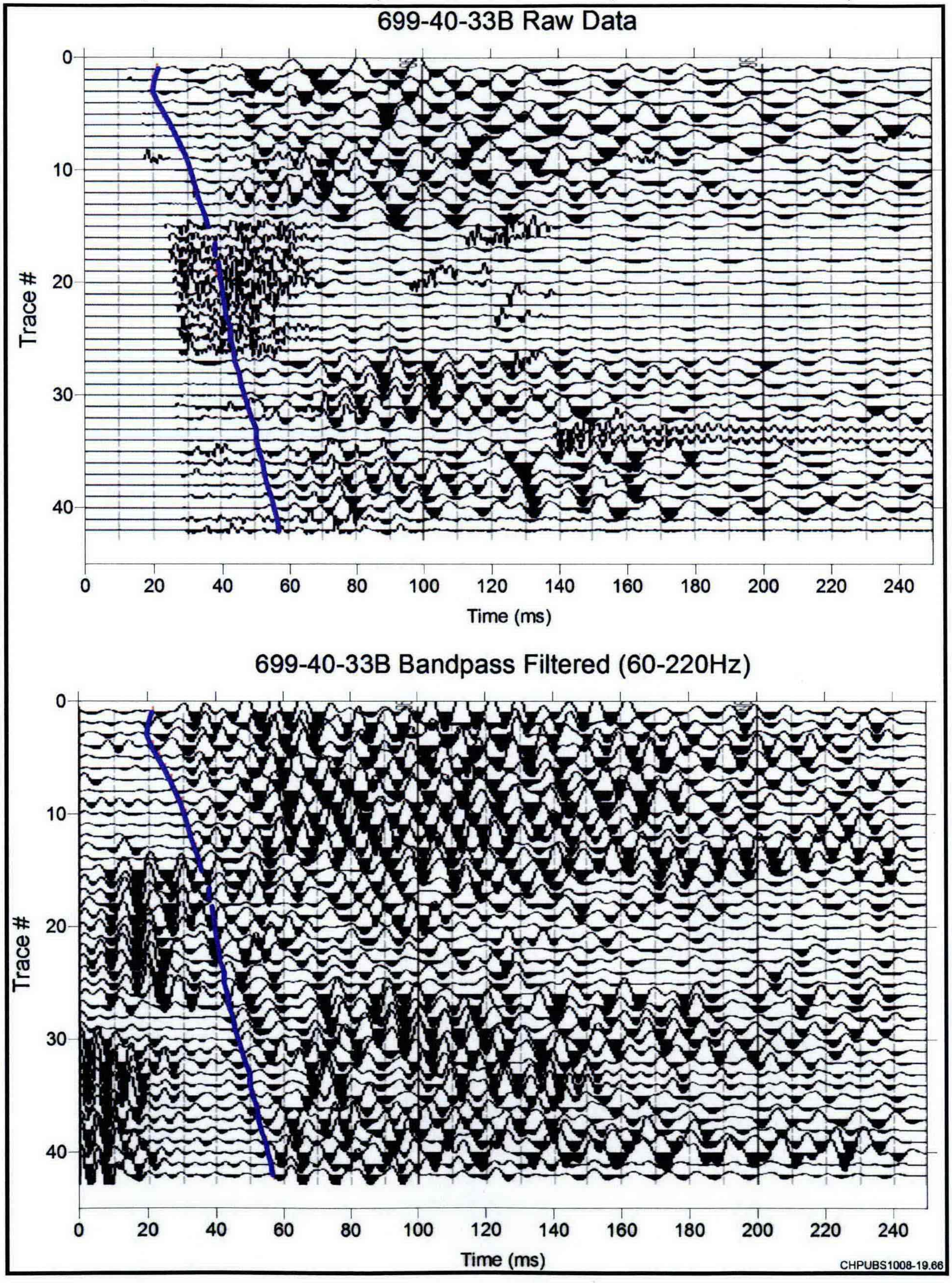


Figure A20. Check Shot: Well 699-40-33B

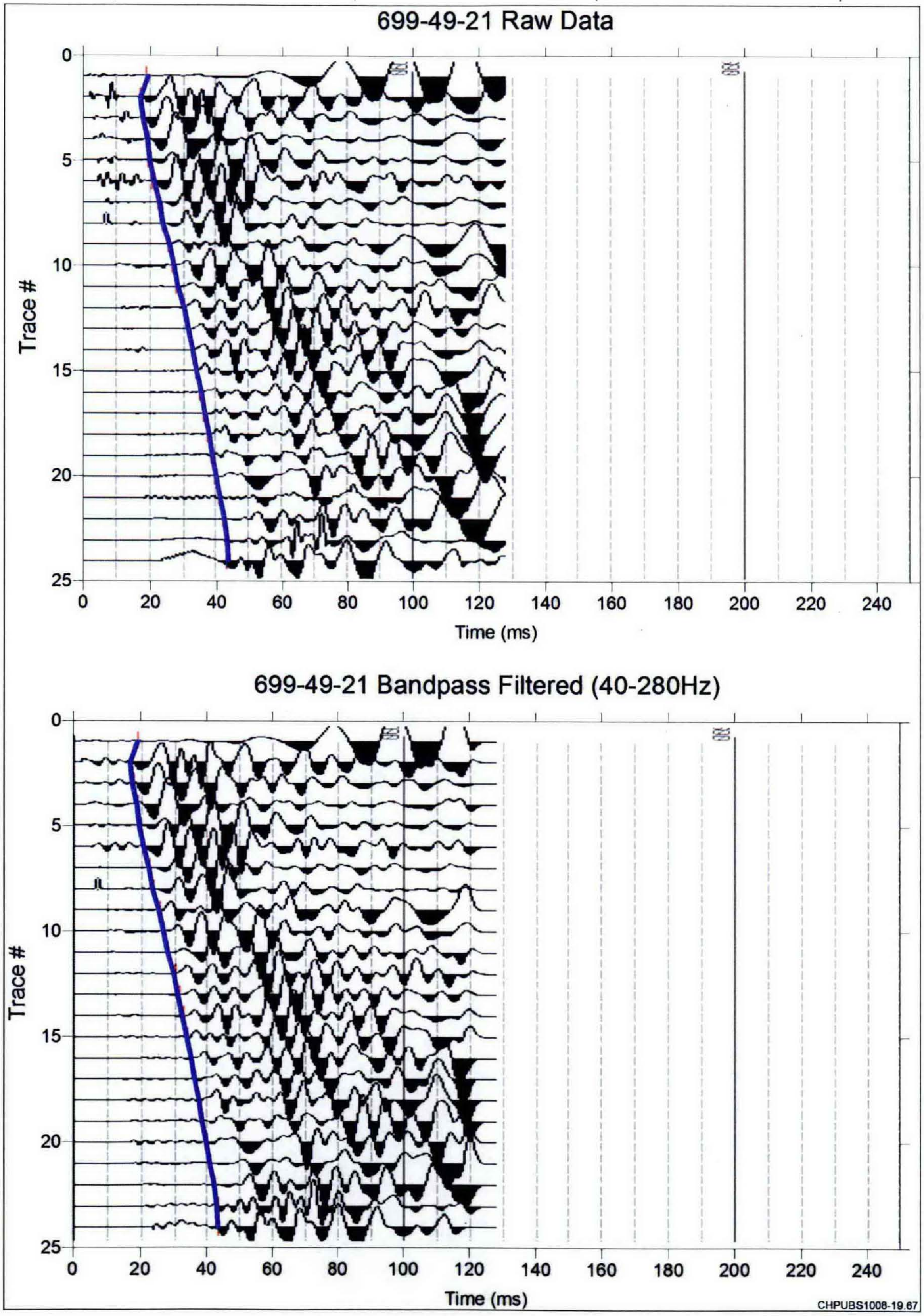


Figure A21. Check Shot: Well 699-49-21

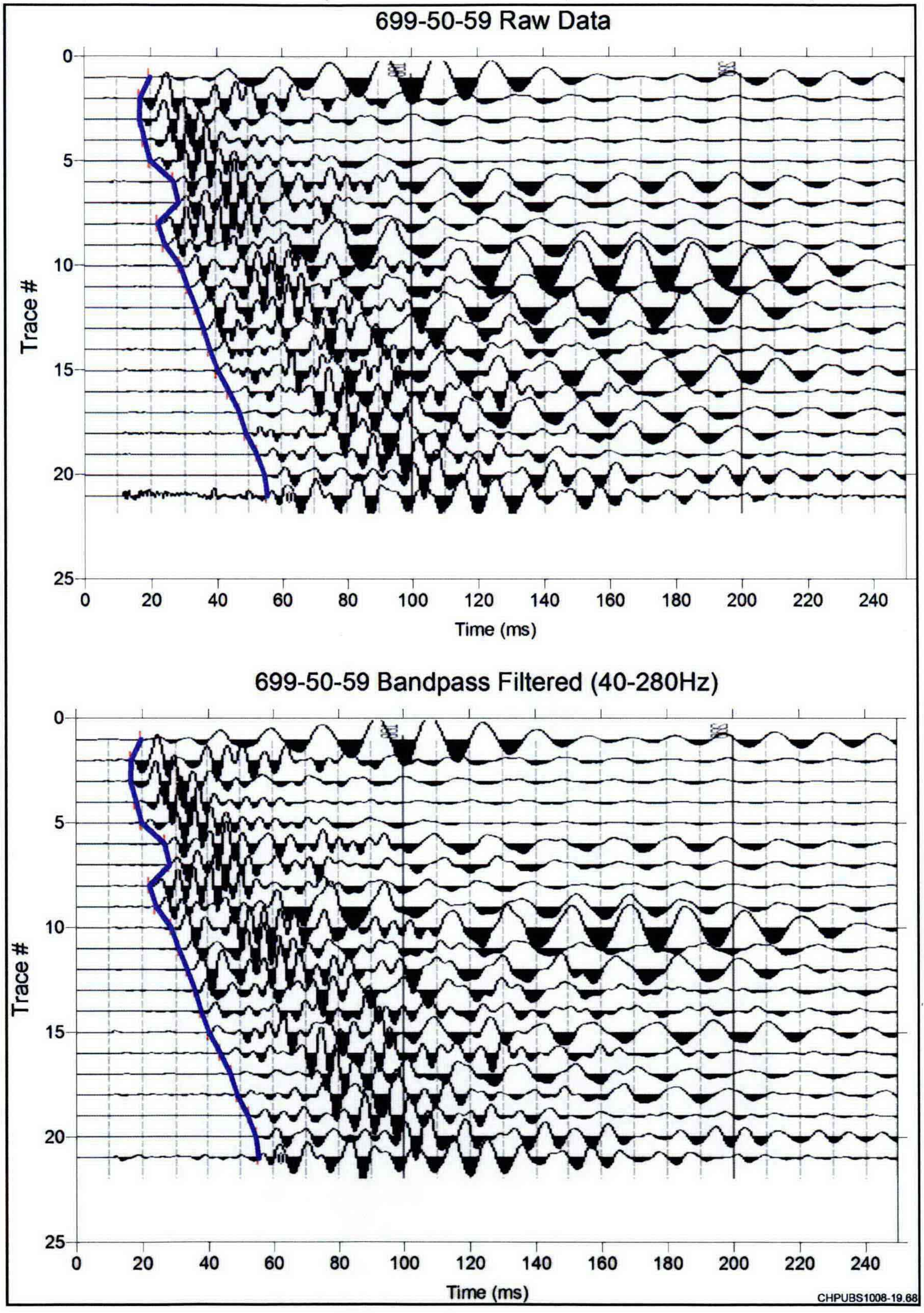


Figure A22. Check Shot: Well 699-50-59

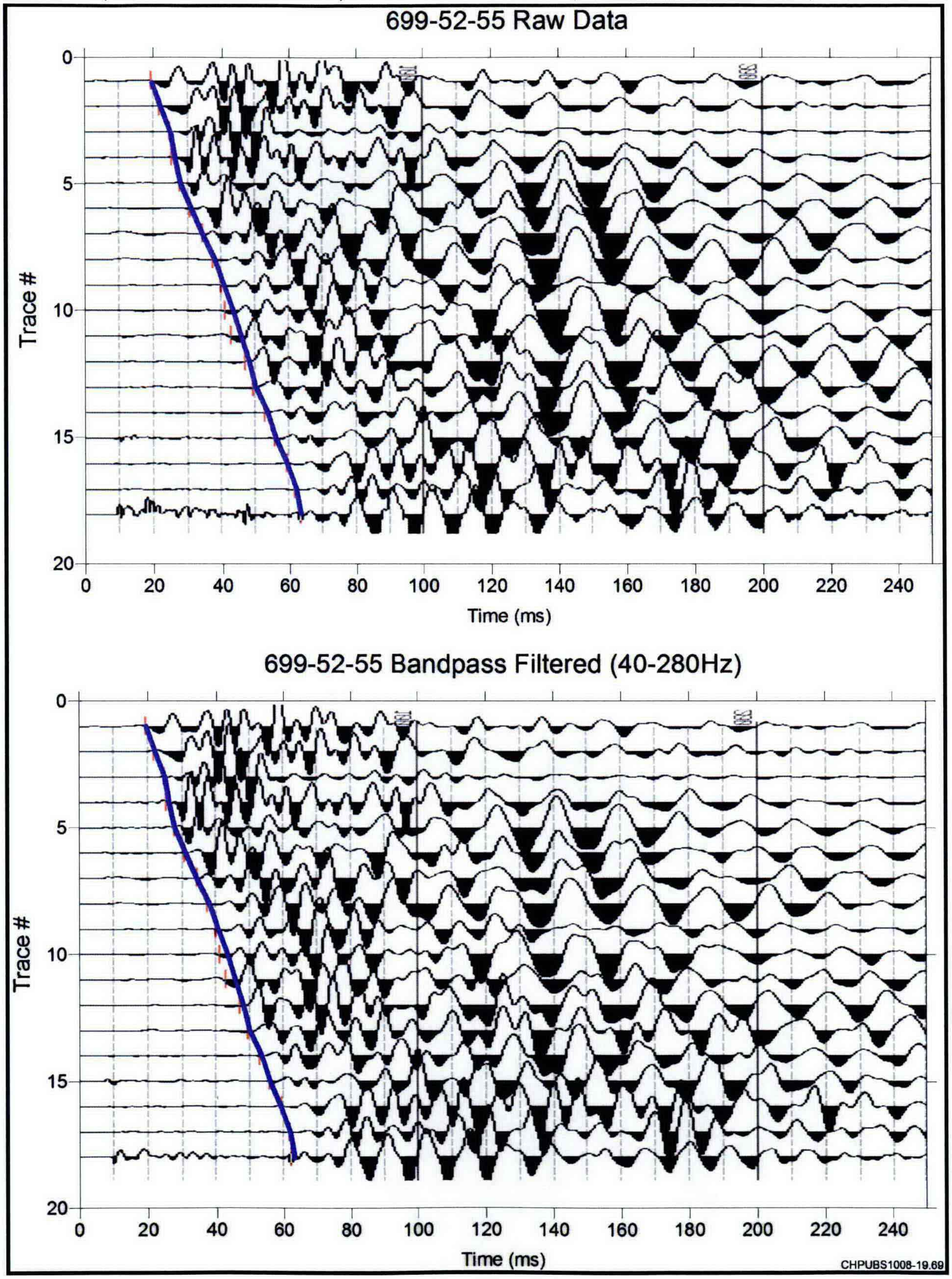


Figure A23. Check Shot: Well 699-52-55

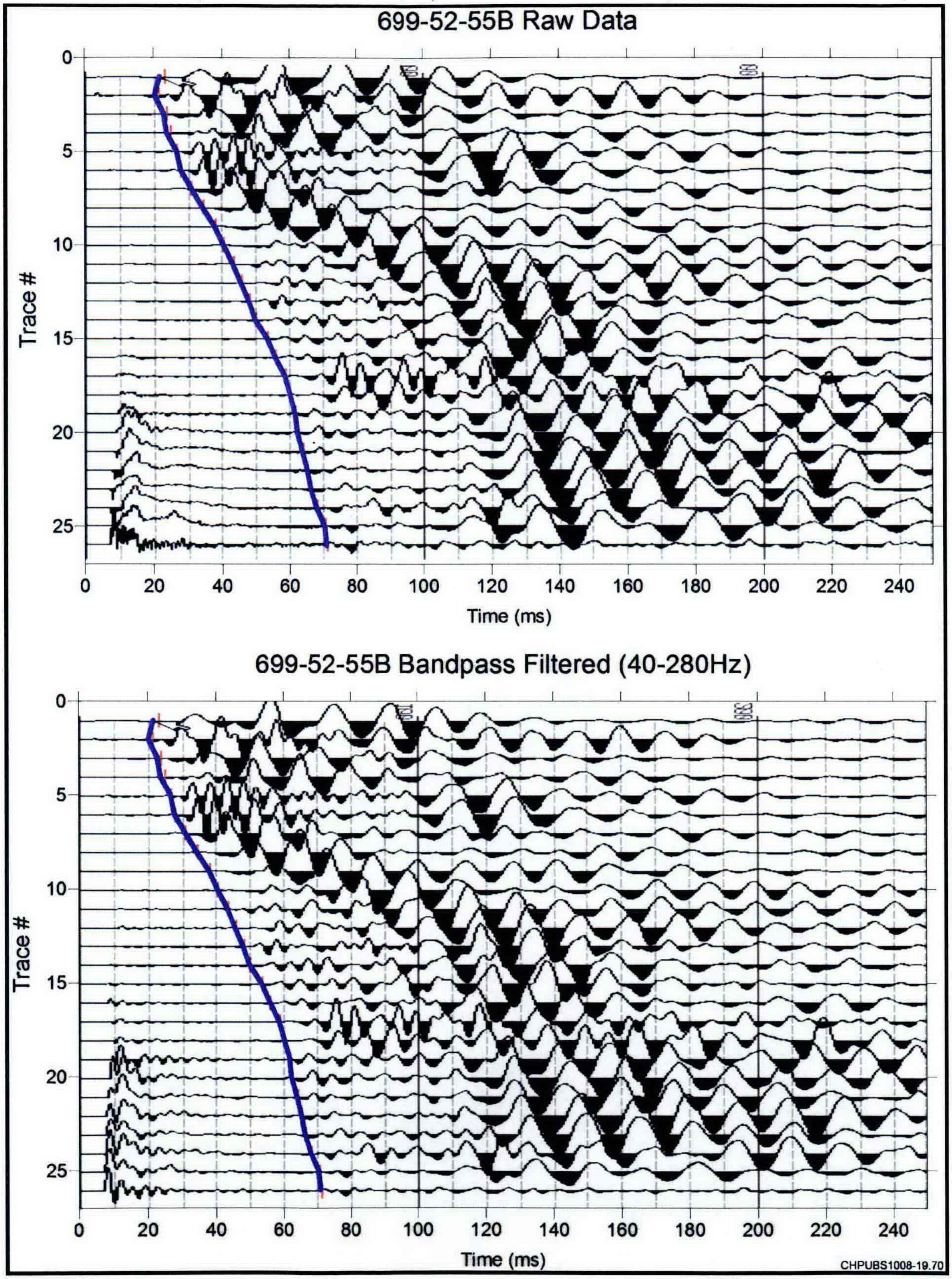


Figure A24. Check Shot: Well 699-52-55B

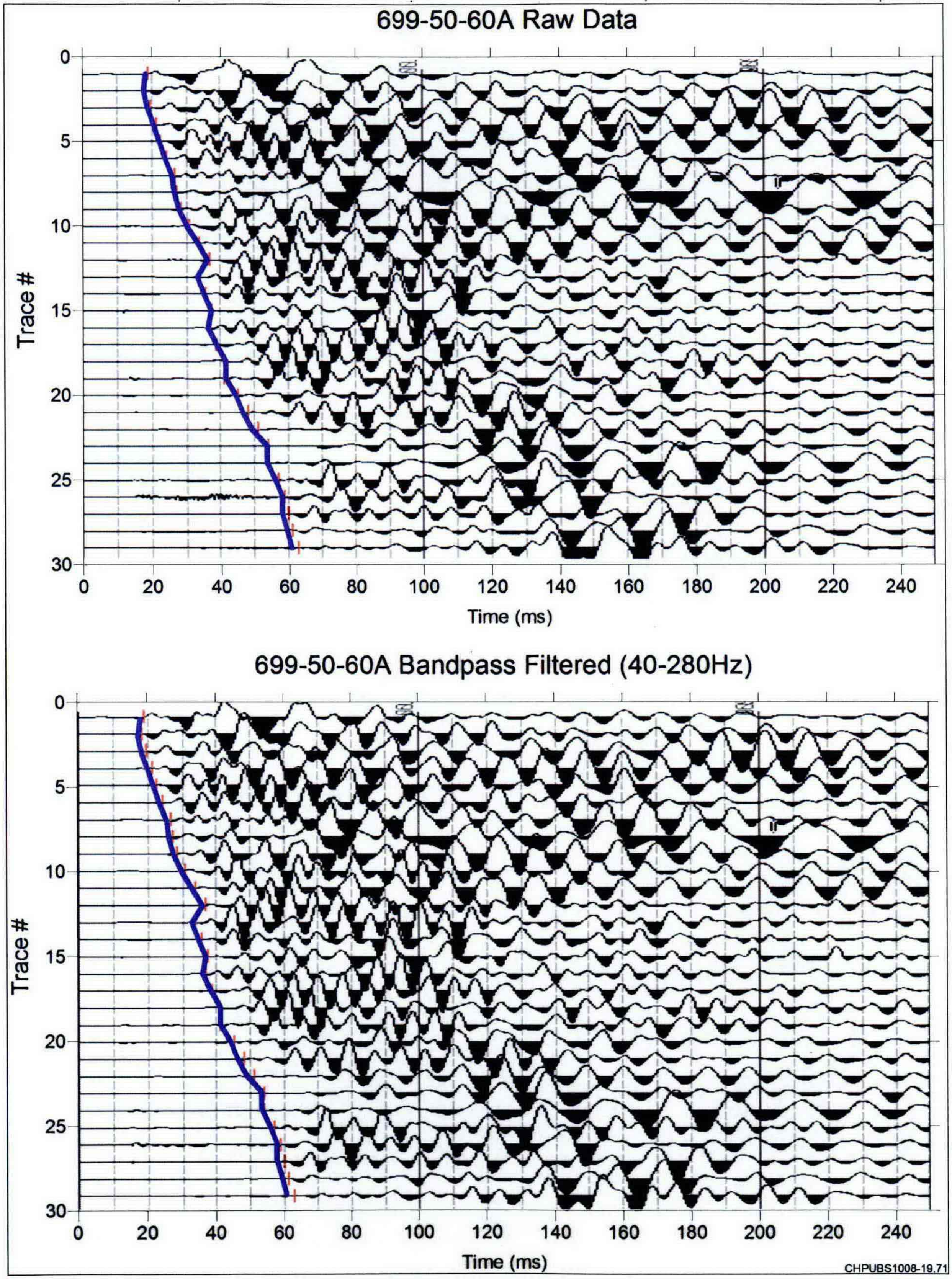


Figure A25. Check Shot: Well 699-50-60A

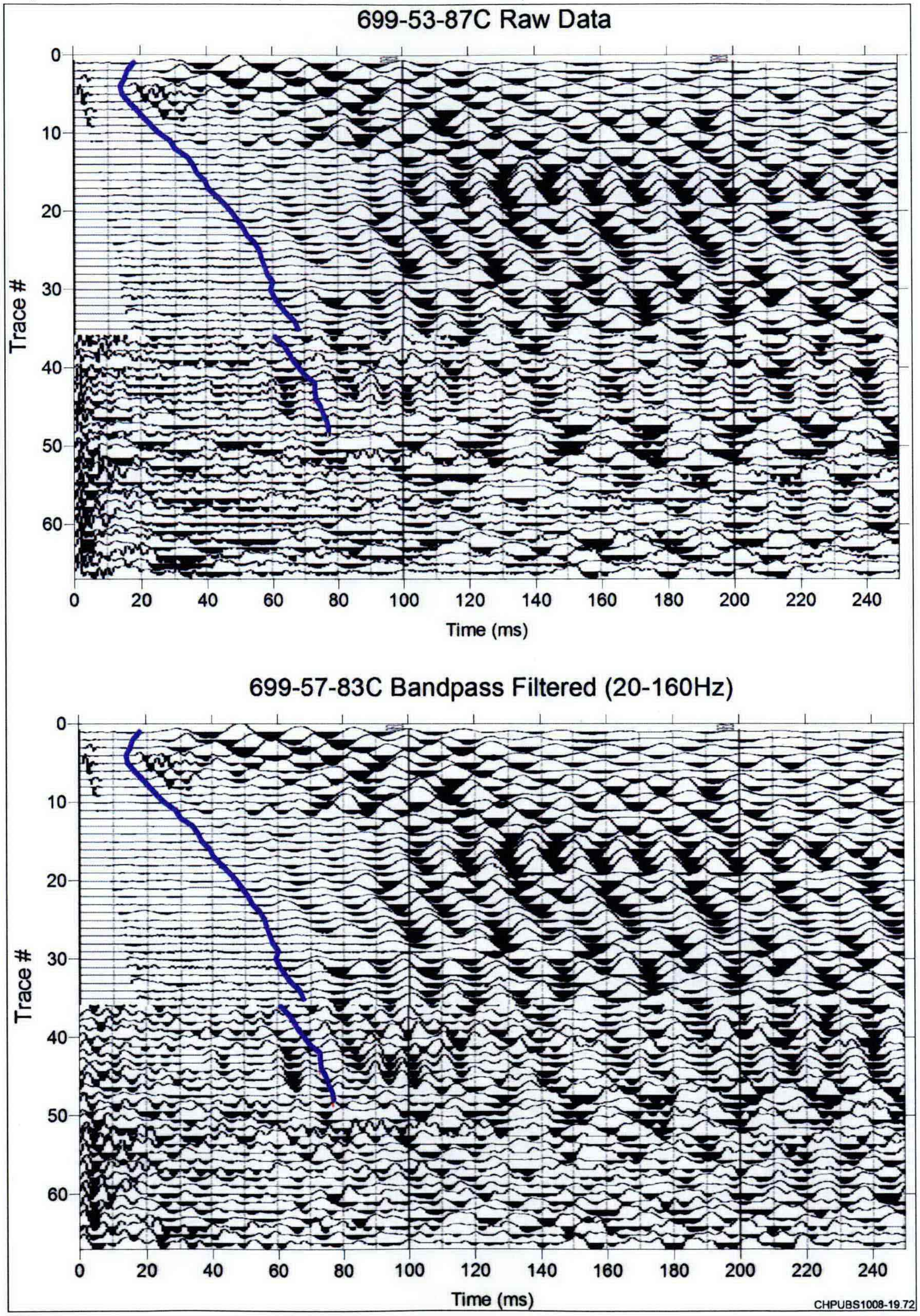


Figure A26. Check Shot: Well 699-53-87C

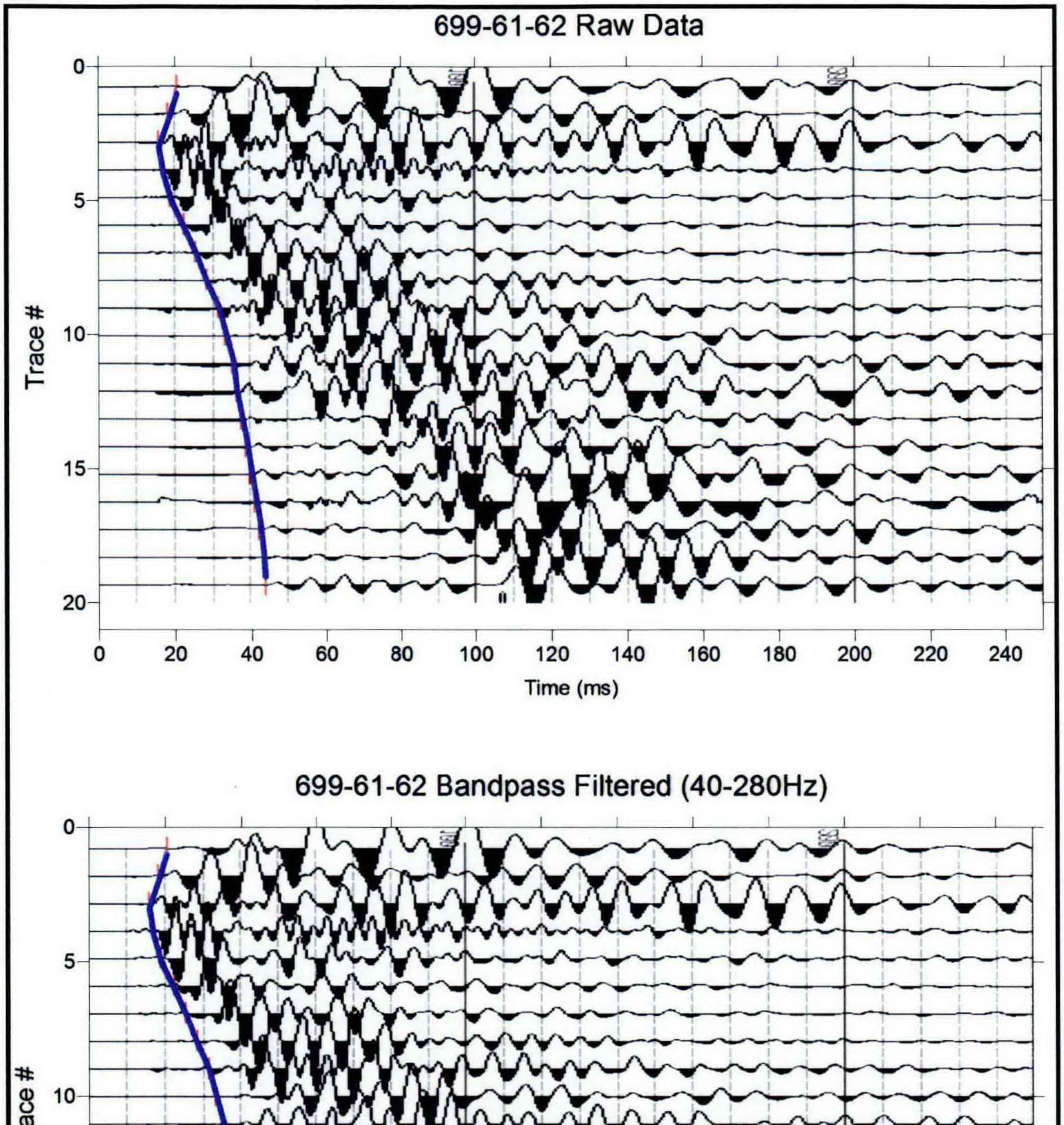


Figure A27. Check Shot: Well 699-61-62

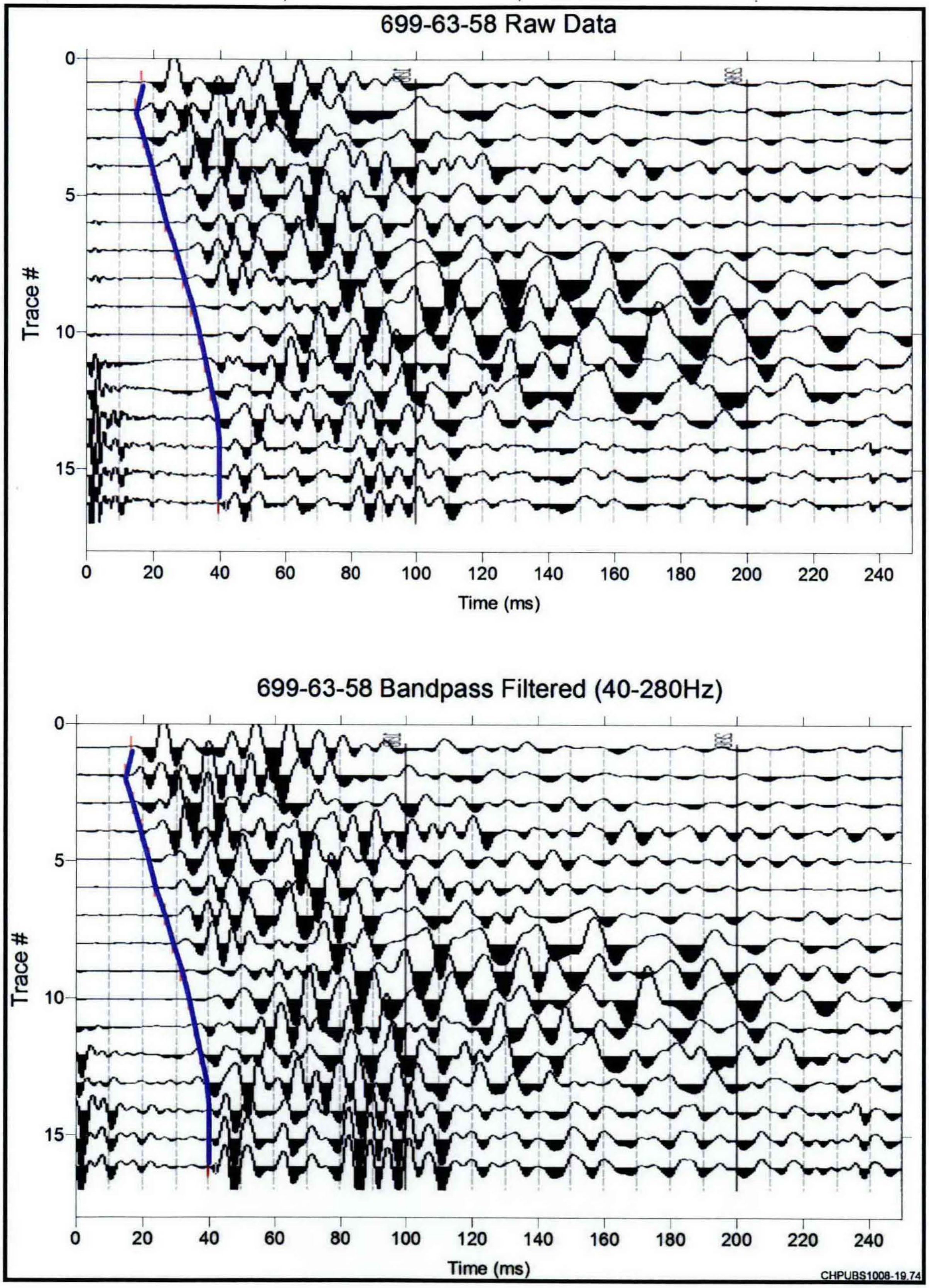


Figure A28. Check Shot: Well 699-63-58

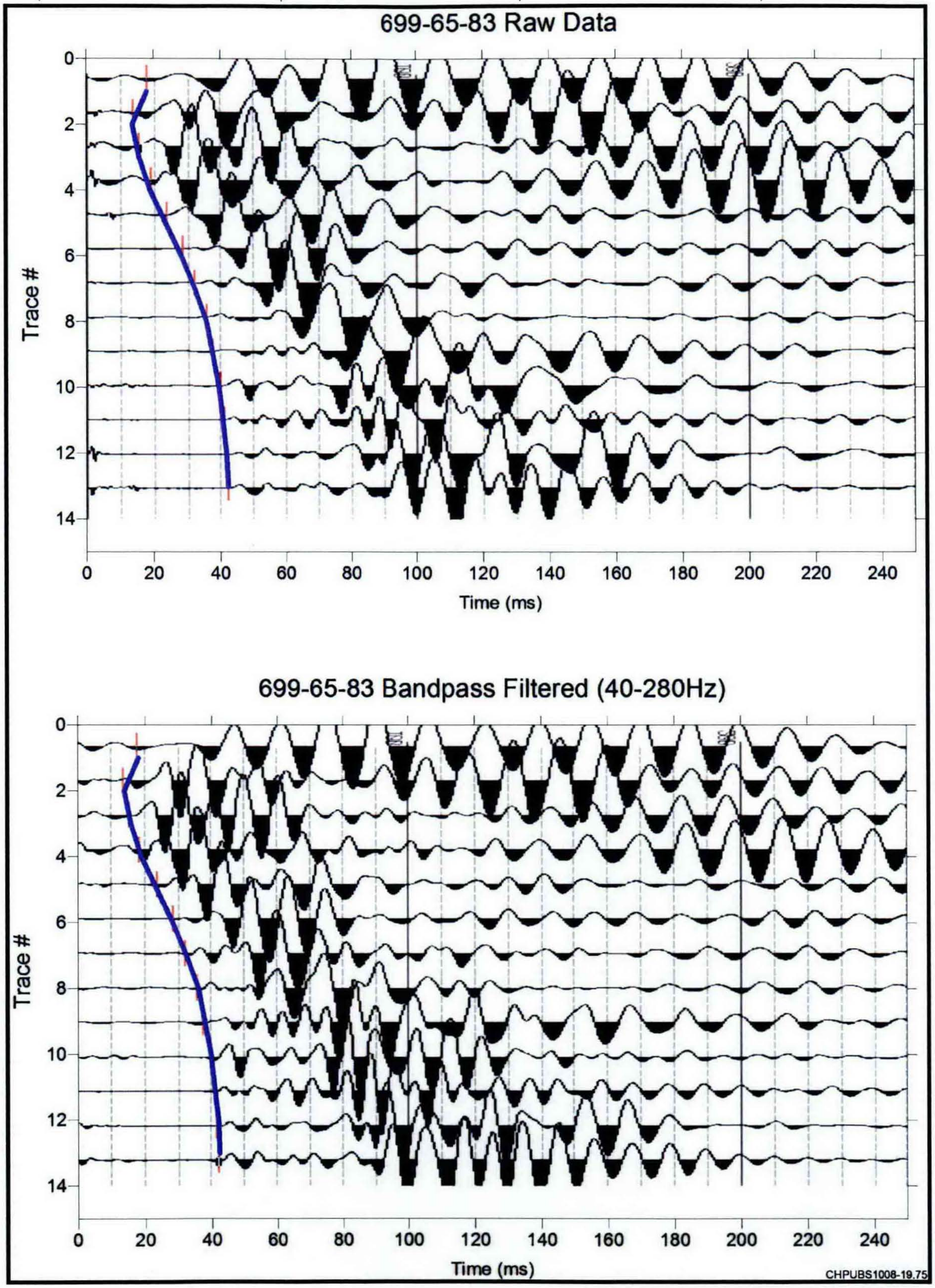


Figure A29. Check Shot: Well 699-65-83