Seismic Reflection Results: Stewart Gulch Region, Boise, Idaho

Report Prepared for The Terteling Company
Boise, Idaho

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ABSTRACT

High-resolution seismic reflection data were acquired in the foothills north of Boise, Idaho, to develop a better understanding of the hydrogeologic framework in the Stewart Gulch region. Reflections from within the Terteling Springs Formation and the underlying volcanic rock sequence provide a picture of a faulted basin along Stewart Gulch. A change in reflector character along the Stewart Gulch seismic line is consistent with a facies transition from mudstones to sandstones of the Terteling Springs Formation. A major offset (~90 m) fault is interpreted on two adjacent seismic lines along Stewart Gulch. The apparent strike of the fault is east-west trending. The Miller Gulch seismic profile, south of Stewart Gulch, shows a back-tilted basin structure. The frequency character of the Miller Gulch seismic section suggests mudstones dominate the sedimentary package along the length of the profile.

INTRODUCTION

Seismic reflection methods for imaging the upper few hundred meters have expanded in recent years due to advances in microelectronics, acquisition and processing methods, and an increased need to understand engineering, environmental and hydrogeologic problems in the near-surface. When combined with local well logs and regional geologic maps, high-resolution seismic reflection data can help identify changes in stratigraphy, map overburden thicknesses, and locate structures (i.e. faulting and folding) that may have a significant impact on the hydrologic flow of a region. In this paper, we use the seismic reflection technique to image a sedimentary and volcanic rock sequence near Boise, Idaho. The seismic images shed light on the hydrogeologic framework of the region.

The seismic survey was conducted in the Stewart Gulch region, a drainage located north of Boise, Idaho (Figure 1). The near-surface stratigraphy consists of Quaternary alluvial sediments that rest on the Terteling Springs Formation. This formation grades from predominately mudstone in the southwest to predominately sandstone in the northeast (Wood and Burnham, 1992), as shown in Figure 2. An upper Miocene volcanic assemblage appears regionally below the basin sequence, and the Idaho Batholith lies below the volcanic rock assemblage.

The seismic survey consists of three lines shot across Stewart Gulch and Miller Gulch (Figure 3). The goal of the survey was to image the sedimentary-volcanic sequence in the area and to help locate a new water well for the Terteling Ranch. Since the direction of hydrologic flow in the region is generally down the drainages (southwest) and since

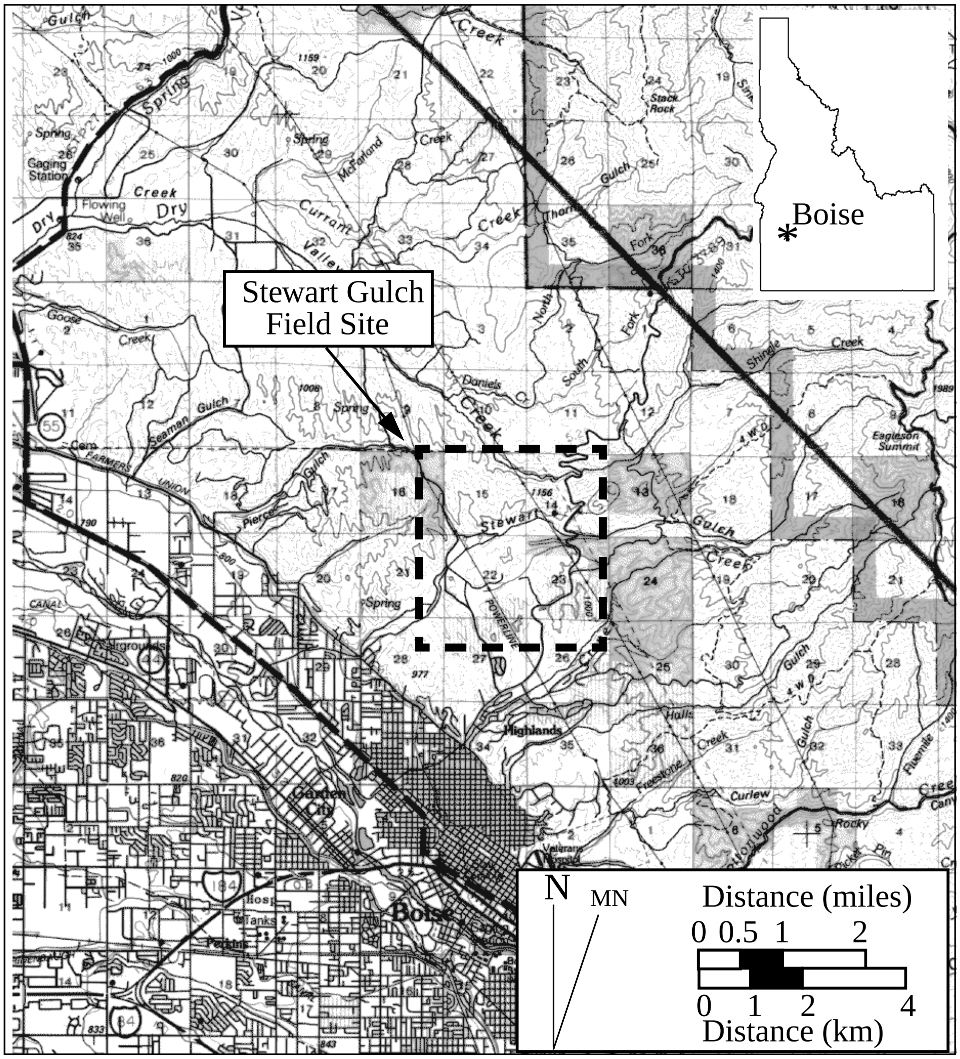

Figure 1. Location map for Stewart Gulch and the seismic reflection lines with relation to the city of Boise. Figure modified from 1:100,000 Idaho Transportation Department map, Boise, Idaho.

most of the flow is controlled by permeable sedimentary units and faults (generally northwest trending), the seismic lines were oriented northeast/southwest along Stewart Gulch and Miller Gulch to assess major structural and stratigraphic trends.

SEISMIC REFLECTION ACQUISITION PARAMETERS

A series of walkaway tests were performed to determine the acquisition parameters for the three seismic reflection lines. The walkaway tests were conducted in May 1996 (Liberty, 1996), and the profile data were collected in September 1996. The same shot and geophone spacing was used for each profile. The geophone spacing was 3 m with a near offset of 30 m; the shot spacing was also 3 m (on geophone locations). A repeatable accelerated weight-drop (i.e., elastic wave generator (EWG-I) from Bison Instruments, Inc.) was used as the seismic source. To increase the signal-to-noise ratio, the data from 9 weight drops for each source location were averaged. The data were recorded with a 48-channel Bison seismograph, 10 Hz geophones, 32-500 Hz field filters, and a 0.5 ms sample rate. The optimum-window technique (Hunter and Pullan, 1984) was used to record reflections from 50-250 m depth. Off-end recording resulted in nominal 24-fold data. With

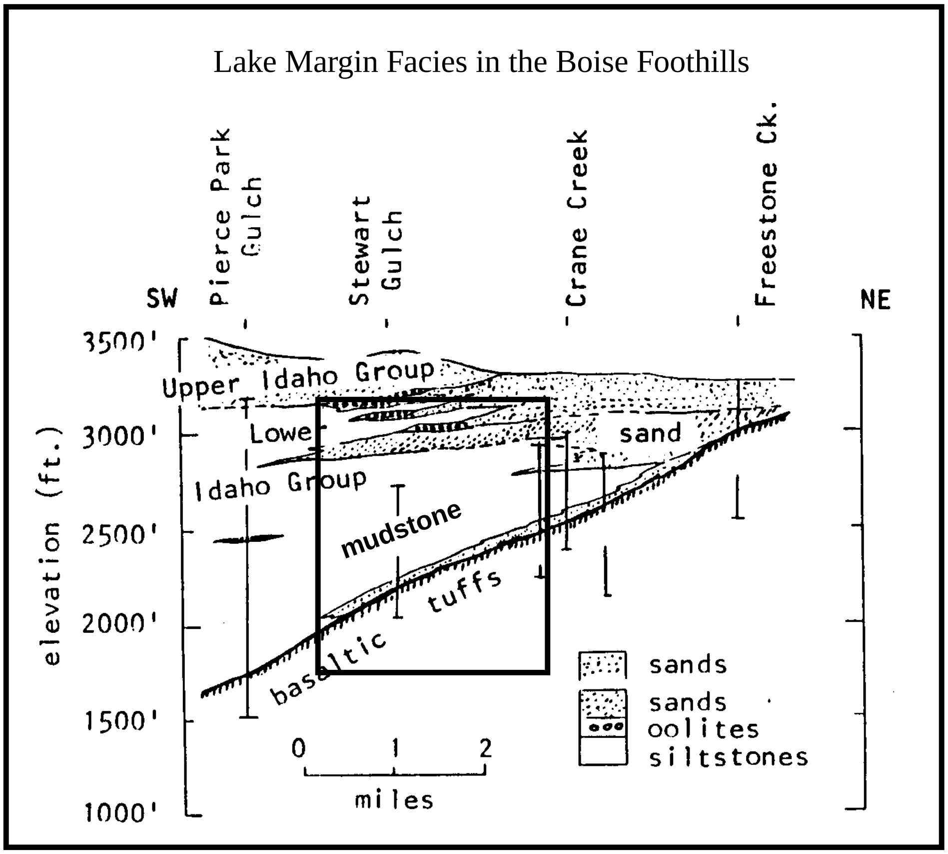

Figure 2. Cross-section depicting the shallow stratigraphy near Stewart Gulch in the Boise foothills (box shows field site location). Elevations near the seismic lines vary from 2800 to 3100 ft. Figure modified from Gallegos and others (1987).

these acquisition parameters, high-resolution reflection energy with frequency content as high as 200 Hz was recorded.

PROCESSING SEQUENCE

The shot gathers were downloaded from the seismograph to a DEC Unix workstation and input to Landmark's ProMAX seismic processing package. A generalized processing flow for all three lines is summarized in Table 1. Processing parameter values (i.e. trace edits, normal move-out and migration velocity corrections, and statics) were selected to optimize each stacked section. Migrated sections are presented to more accurately locate reflector positions in the subsurface and improve spatial resolution, and unmigrated sections are presented to highlight diffractions due to fault boundaries and to identify migration artifacts. Migration artifacts commonly appear as coherent, semi-circular reflectors or "smiles" on short, hi-resolution seismic lines due to edge effects and low seismic fold.

SEISMIC REFLECTION INTERPRETATION

Airstrip seismic line

The Airstrip seismic reflection line follows the eastern border of an airstrip on the Terteling property (Figure 3). The line begins 72 m southwest of the Windsock well, and

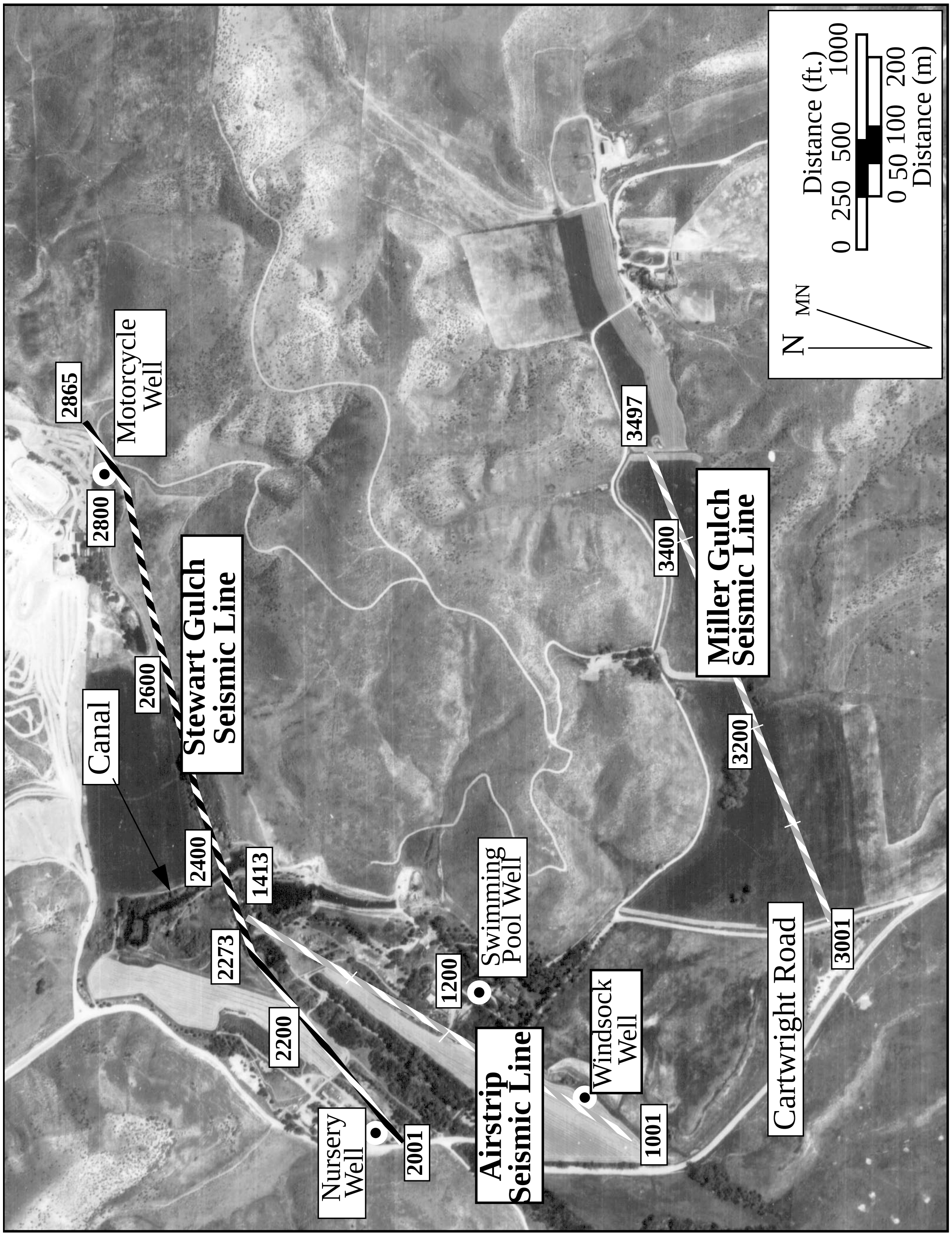

Figure 3. Aerial photograph of the Stewart Gulch area showing the locations of the seismic lines and prominent landmarks. All seismic lines were located on the Terteling Ranch. Stewart Creek parallels the Stewart Gulch seismic line (defined by the line of trees).The site is located in northwest Boise, Idaho (see Figure 1). Numbers in boxes represent CDP numbers on the seismic sections.

TABLE 1. Processing flow for the seismic reflection data. The data were processed using Landmark's ProMAX processing system on a DEC UNIX workstation.

PROCESSING STEP	DESCRIPTION
Data Input (Bison Format)	3 m station spacing; EWG-I source (9-stacks per station);10 Hz geophones, 32-500 Hz field filters, and a 0.5 ms sample rate.
Geometry	Acquired with a Topcon GTS-4A total station.
Trace Edits	Manually selected bad traces generated from system/cultural noise.
Spectral Shaping Filter (60-180 Hz)	Balances the frequency spectra from 60-180 Hz to boost high frequency reflection signal.
Air Blast Removal	Removes coherent, high-amplitude, ground coupled air wave.
Spike and Noise Burst Attenuation	Removes spurious noise bursts from electronics or cultural noise.
Bottom Mutes	Remove dominant surface wave energy from the shot gathers.
Top Mutes	Refraction and waveguide reverberation energy removal.
Elevation Statics	Near-surface velocity correction to move seismic data to a flat datum.
Common Midpoint (CDP) Sort	Sort from source to midpoint gathers
Velocity Analyses	Iterative analysis to optimize reflection coherence.
Residual Statics Corrections	Up to a 3 ms correction per trace to increase coherency in the stack.
Normal Moveout (NMO) Correction	Applied NMO corrections based on optimum stacking velocities.
CDP Ensemble Stack	Sum common midpoints to mimic a cross-section profile.
F-K Migration[a]	Places reflectors in proper spatial position on the stacked sections.
Amplitude Gain (AGC) - 100 ms	Compensate for amplitude loss due to spherical divergence, scattering and intrinsic attenuation.

a. This step does not apply to unmigrated sections.

ends at the stream bed in Stewart Gulch 620 m to the northeast. The end of this line corresponds to CDP 2340 on the Stewart Gulch line (discussed below).

The unmigrated seismic section is shown in Figure 4. Clearly visible is a strong amplitude reflection package from CDP 1011-1300 at 200-230 ms two-way travel time (TWTT). This reflection package disappears east of CDP 1300. Another strong amplitude reflection package appears at 110-130 ms TWTT from CDP 1320-1413. Additional coherent reflections also appear shallower in the section. Lithologic logs from two nearby wells are projected on the reflection section with the depth converted to TWTT based on a velocity of 1800 m/s. The 1800 m/s velocity estimate is based on the average RMS stacking velocity calculated from the data. The lithologic logs are corrected for the elevation from the datum on the section. An exact correlation between the coherent seismic reflections and the lithology would not be expected until the seismic section has been depth corrected using a more accurate velocity model (instead of the constant velocity model used). The time-to-depth conversion on all stacked sections (Figures 4-11) is relative to the elevation of a flat datum, or pseudo-surface.

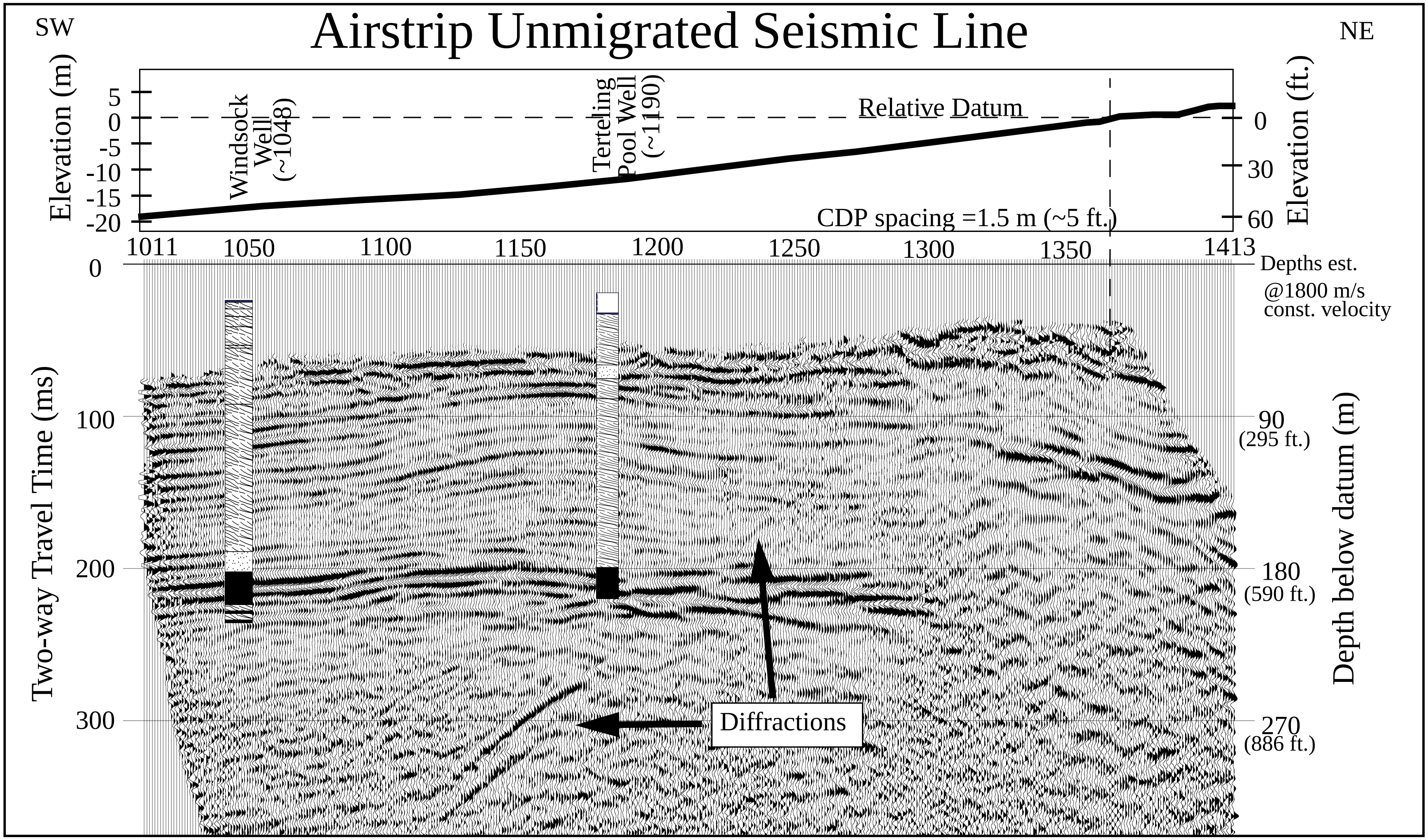

Figure 4. Airstrip unmigrated seismic section. Elevation is plotted above the section and nearby wells are projected on the section. The stippled patterns in the well logs represent a sandstone dominated facies; the sinuous line pattern represents a mudstone dominated facies; and the solid black fill represents the volcanic rock assemblage. Note the diffraction tails from the termination of reflecting units; the apex of these diffractions defines fault locations. The section is plotted with no vertical exaggeration.

The migrated seismic section from the Airstrip profile (Figure 5) shows the reflectors in their correct spatial position (assuming a 2-D structure). The large amplitude reflection package appears to correlate with the volcanic rock sequence observed on both nearby lithologic logs. The reflections associated with the volcanic rock sequence appear to be discontinuous across the section, suggesting that faults are present. Since the Boise valley is controlled mostly by extensional tectonics, normal faulting is presumed. This extensional style matches the sense of offset on the major offset fault (CDP 1310-1330) with an apparent dip of 75 degrees on the fault surface and offsets of approximately 90 m. Smaller offset faults are also interpreted based on the expected faulting style of an extensional province.

Coherent reflections above the interpreted volcanic rock sequence can be attributed to changes in the acoustic properties of the mudstones in the Terteling Springs Formation. Based on the Windsock lithologic and geophysical logs (Figure 4), these reflections can be attributed to sand/clay interbeds and sand/shale interbeds. Note the anticlinal structure in the seismic section between CDP 1100-1200. Since the structure of the deeper volcanic rocks does not mimic this pattern, and the reflection pattern changes up-section, this feature cannot be attributed to a seismic processing artifact (i.e. refraction statics or a velocity anomaly) and is most likely a primary sedimentary structure.

Stewart Gulch Seismic Line

The Stewart Gulch seismic line extends from Cartwright Road to the Nursery well (CDP 2028) to just past the Motorcycle well (CDP 2846) as shown in Figure 3. There are two jogs in the seismic line due to natural obstacles along the profile, but the line maintains an east-northeast orientation. To limit vertical exaggeration in plots, and to minimize elevation static corrections, the data were processed and displayed as two profiles.

Figures 6 and 7 show the unmigrated data for the two line segments. In Figure 6, a strong reflection package is visible at 210-240 ms TWTT between CDP 2010-2100. To the northeast, a similar strong reflection package is apparent at 100-140 ms TWTT. The same reflector can be traced across the section shown in Figure 7. At the northeastern end of this line, the reflector shows a 5 degree apparent dip to the southwest.

Shallower in the sections, a series of coherent flat-lying reflections can be traced from 50-200 ms TWTT from CDP 2010-2100. From CDP 2150-2250, the reflectors appear to dip to the east 10-15 degrees. Northeast of CDP 2250, the reflections become less coherent and are characterized by lower frequencies, and appear to represent reflectors dipping gently to the west (Figure 7).

The deeper, high-amplitude reflection package shown on the migrated seismic sections (Figures 8 and 9) correlates with the depth to the top of the volcanic rock assemblage shown on the lithologic logs from the Nursery well, the Motorcycle well, and a constant RMS velocity of 1800 m/s (calculated from the data). This strong reflection package disappears to the northeast of CDP 2100 below 200 ms TWTT, but appears continuously from 100-140 ms TWTT to the eastern boundary of the seismic line. A similar offset pattern is documented on the Airstrip seismic line at CDP 1320 and suggests a large offset normal fault (~90 m offset) near CDP 2100 on the Stewart Gulch seismic line. Smaller offset faults are also visible on the migrated stacked sections to the east of the major offset fault. The reflectors above the volcanic rock assemblage appear flat lying to the west of the

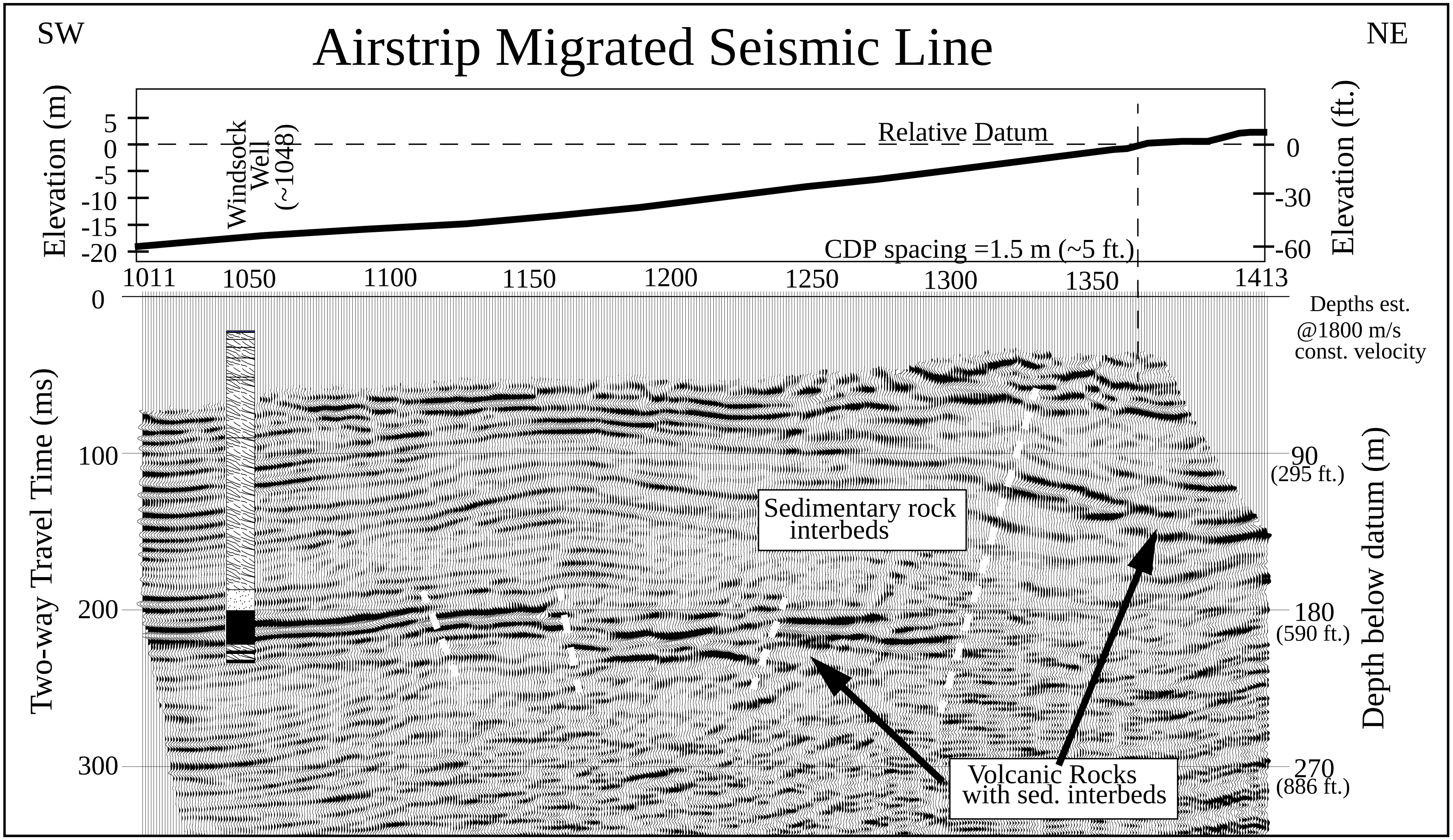

Figure 5. Airstrip migrated seismic section with overlaid interpretation. The strong amplitude reflection package is interpreted as the top of a volcanic rock sequence which is overlain by fine-grained sedimentary rocks. This interpretation is supported by local lithologic logs (patterns described in Figure 4). A faulted anticlinal structure is also apparent in the upper sedimentary package at CDP 1170. The Terteling Pool well was removed from the section since it is out-of-plane. The section is plotted with no vertical exaggeration.

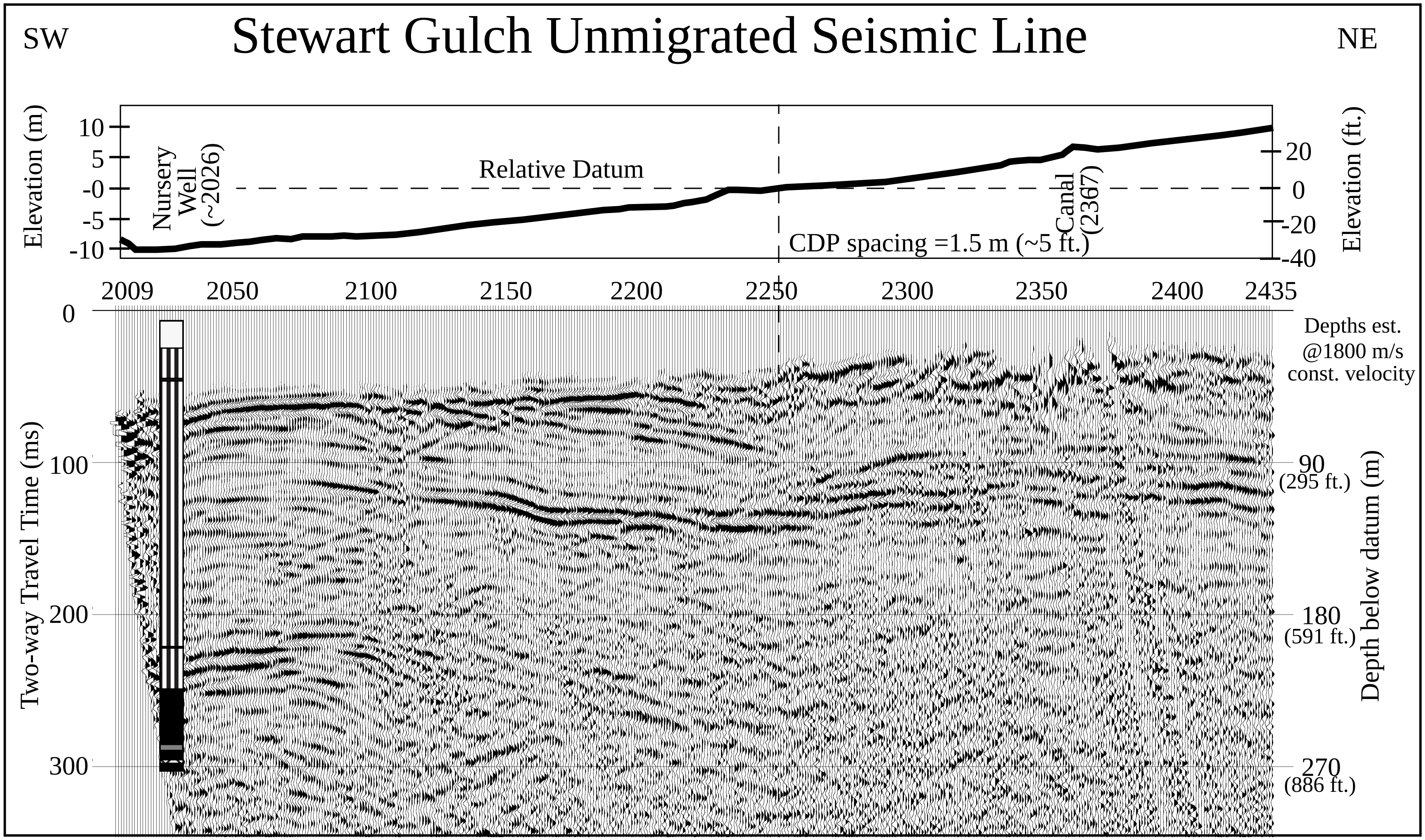

Figure 6. Seismic reflection profile from the western half of the Stewart Gulch seismic line. The datum crosses the profile at CDP 2255. The section is plotted with no vertical exaggeration and well log patterns are described in Figure 4.

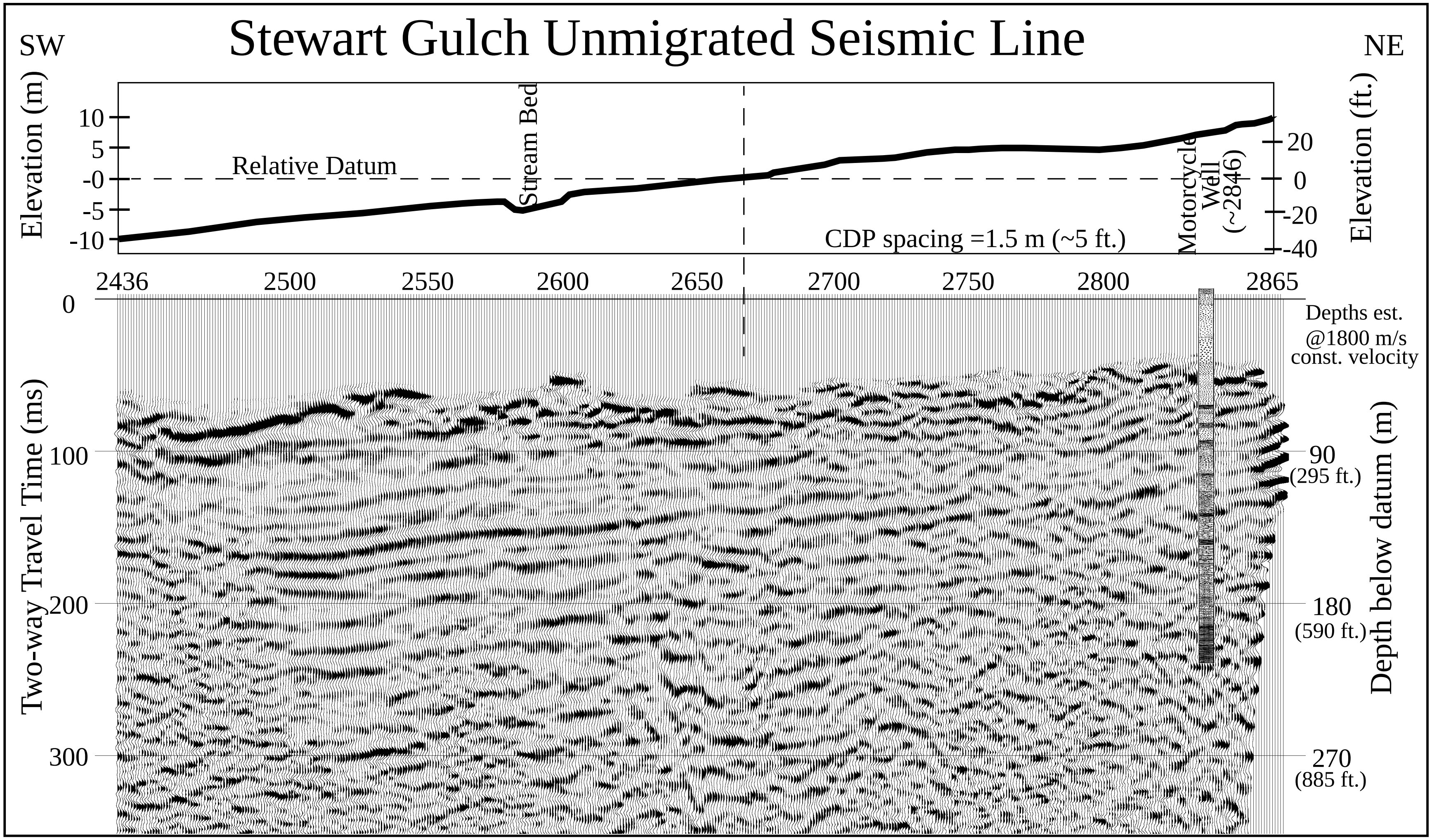

Figure 7. Seismic reflection profile from the eastern half of the Stewart Gulch line. The datum crosses the line at CDP 2667. The datum for elevation statics is 38 ms less than the datum on Figure 6. The section is plotted with no vertical exaggeration and well log patterns are described in Figure 4.

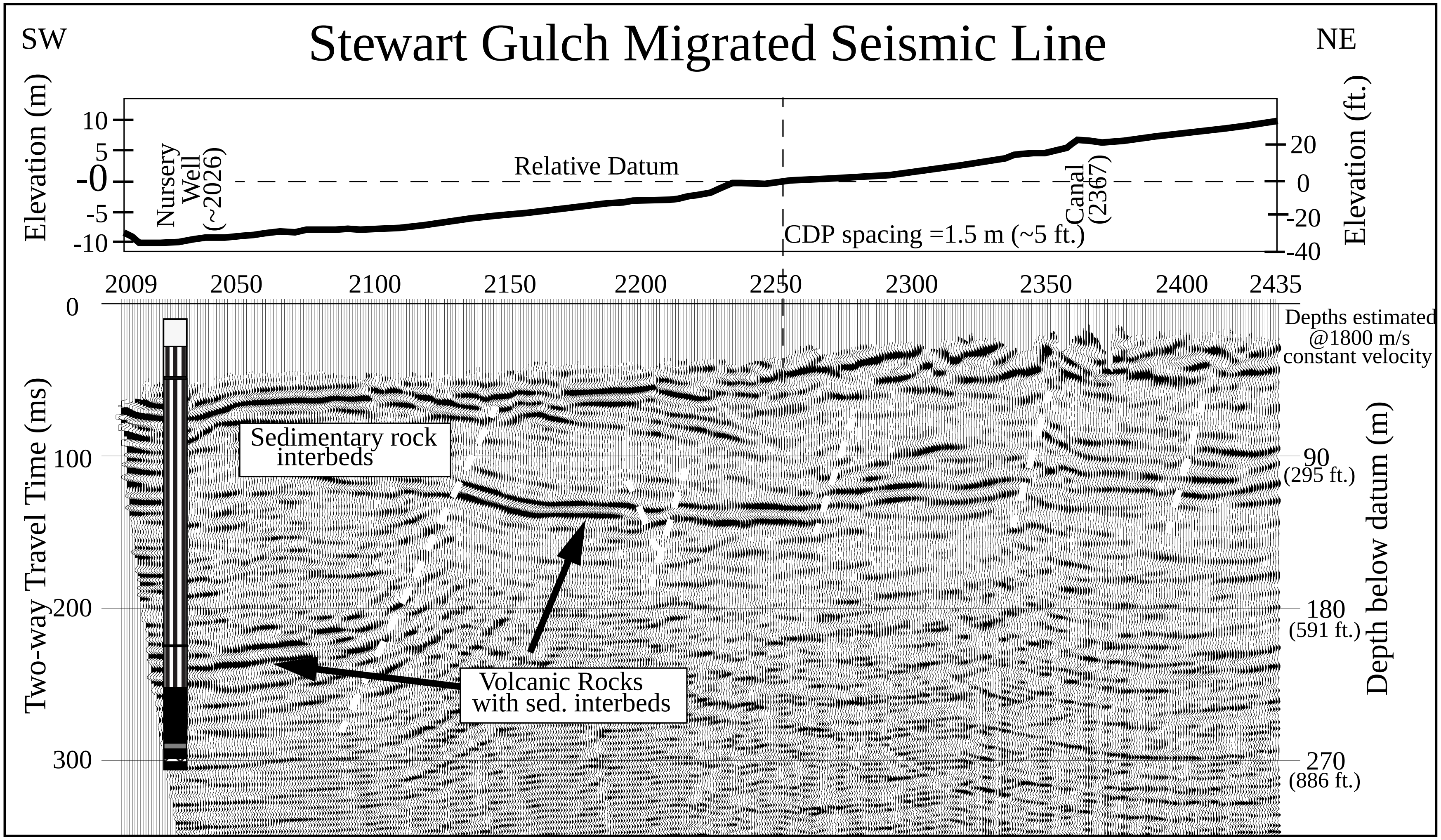

Figure 8. Migrated seismic reflection profile from the western half of the Stewart Gulch seismic line.The high-amplitude reflection package is interpreted to be due to the interface between near-surface sedimentary rocks and deeper volcanic rocks assemblage (from the Nursery well lithologic log). The section is plotted with no vertical exaggeration and well log patterns are described in Figure 4. Note the coherent “smile” artifacts from the migration process.

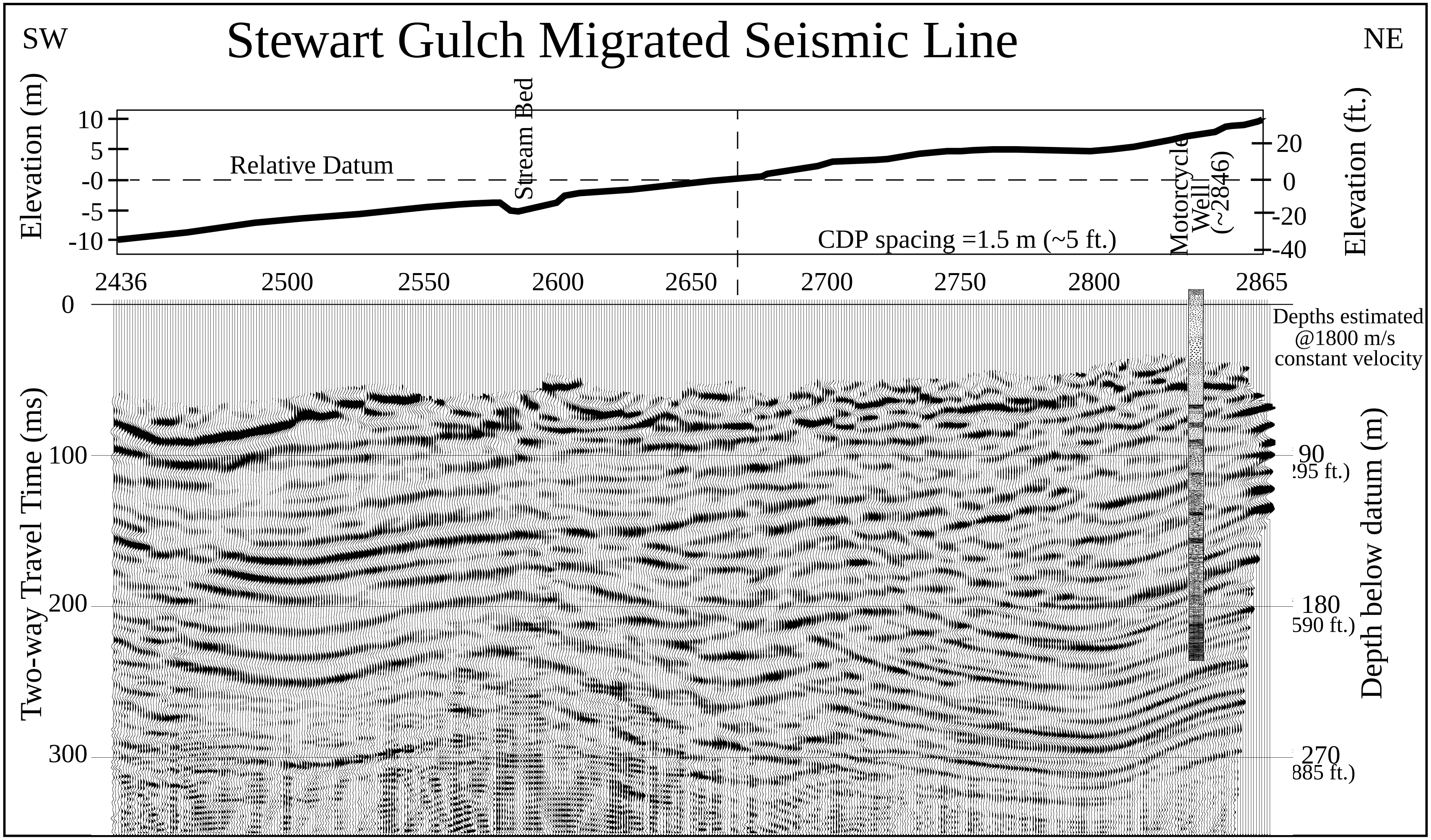

Figure 9. Migrated seismic reflection profile from the eastern half of the Stewart Gulch line. The lithologic log from the Motorcycle well is projected on the section. The datum crosses the line at CDP 2667. The section is plotted with no vertical exaggeration and well log patterns are described in Figure 4. Note the coherent “smile” artifacts from the migration process.

major normal fault, but tilt northeast on the northeast side of the fault. This northeastern dip in the sedimentary rock units is supported by field mapping in the nearby foothills north of the Nursery well (S. Wood, personal comm.). Here a 25-30 degree dip is observed in the Terteling Springs formation along a road cut and suggests a back-tilted fault block. The change in reflector coherence and frequency content to the northeast across the Stewart Gulch seismic line is attributed to a change in the dominant lithology of the Terteling Springs formation from the mudstones in the east to the sandstones in the west (Wood and Burnham, 1997).

Miller Gulch Seismic Line

The Miller Gulch seismic reflection line extends from the driveway across two alfalfa fields to the eastern property boundary as shown in Figure 3. The placement of the seismic line in Miller Gulch was designed to cross an inferred fault identified by a line of trees (springs) extending across Stewart Gulch and Miller Gulch.

The high-amplitude reflection package on the Miller Gulch seismic reflection line varies from 180-240 ms TWTT, as shown in Figure 10. This reflection package appears to dip to the west on the western portion of the line, and to the east on the eastern portion of the line. Lower amplitude coherent reflections also appear above this marker horizon and dip in the same general direction as the marker horizon.

Although there is no well control along this seismic line, the position and character of the high-amplitude reflection package is consistent with the interpreted volcanic rock assemblage noted on the Airstrip and Stewart Gulch seismic lines. No major offset in the high-amplitude reflection package is observed on the Miller Gulch migrated seismic line (Figure 11), suggesting that the major fault observed on the Airstrip and Stewart Gulch seismic lines does not cross the Miller Gulch line. Smaller offset faults are interpreted in the seismic section, based on offsets in the basal reflection package and overlying reflectors. The major offset feature in the Miller Gulch seismic line is interpreted between CDP 3250-3350. The seismic section shows the fault intersecting the surface at CDP 3325. This is near the line of springs crossing Stewart Gulch and Miller Gulch.

DISCUSSION

The three seismic reflection profiles presented in this paper show the structure of the northern edge of the Snake River Plain basin near Boise. The basin generally deepens to the southwest along the profiles, and includes extensional style faulting and tilting of the sedimentary rock and volcanic rock sequence. The major east-west trending fault (offset ~90 m down to the south) is a surprise for it is not indicated by geologic mapping (S. Wood, personal comm.). Local northwest trending faults are suggested from regional mapping (Burnham and Wood, 1992) and from a set of aligned springs that cross Stewart Gulch and Miller Gulch. The seismic data that cross the springs image these faults in the subsurface. On the Miller Gulch seismic line, an interpreted northwest trending fault intersects the surface near the line of trees that parallel the springs (Figure 3). Although the inferred offset of this fault is less than 20 m, the fault appears to have surficial expression. Faults interpreted along the Stewart Gulch seismic line near the projected springs show similar offsets to the Miller Gulch profile in the volcanic rock sequence, but reflections from basin sediments are difficult to identify due to decreased resolution in the section.

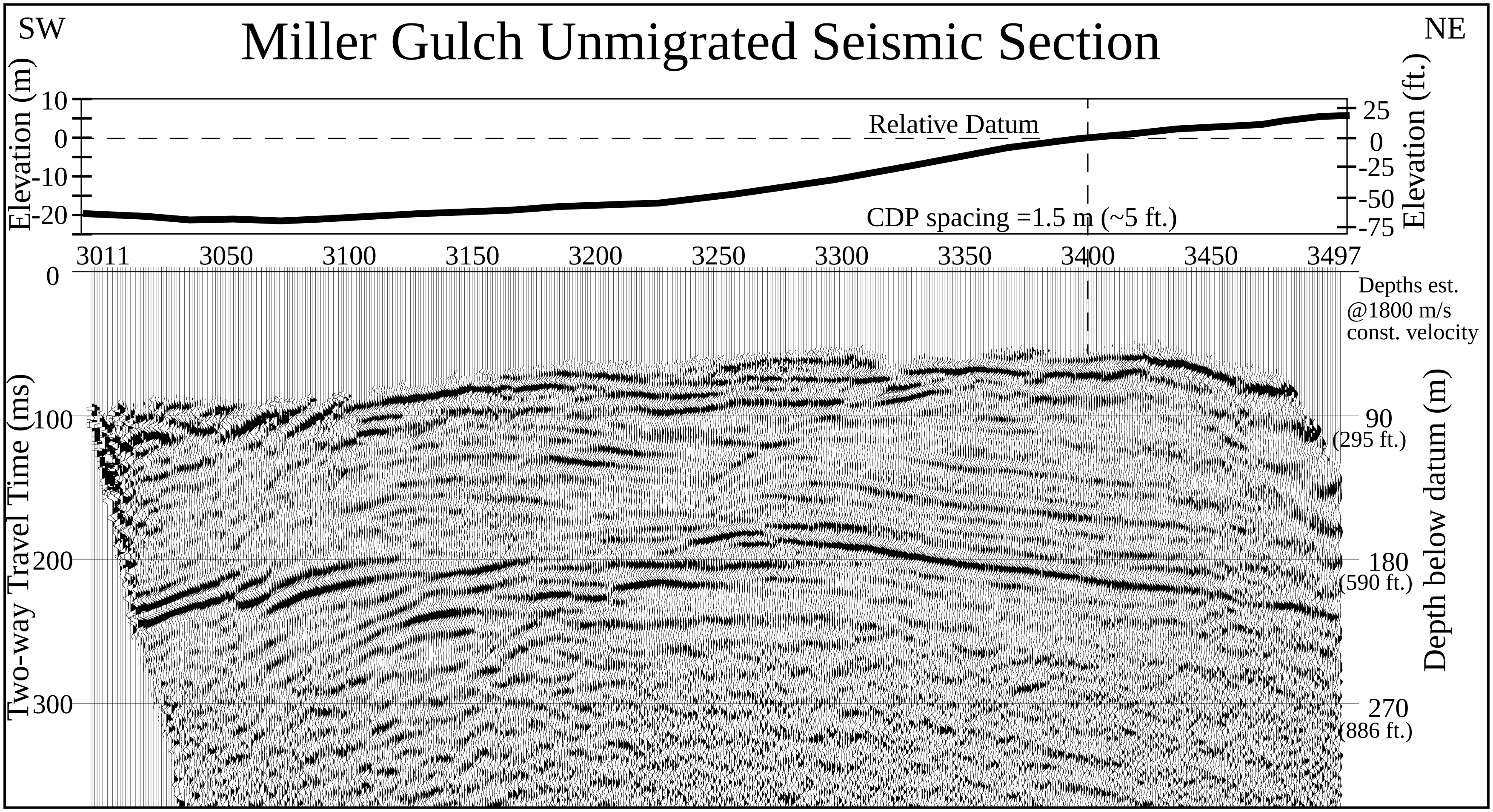

Figure 10. Unmigrated seismic reflection profile from Miller Gulch. Note the strong reflection package from 190-230 ms TWTT. There is no well control in the region. The section is plotted with no vertical exaggeration.

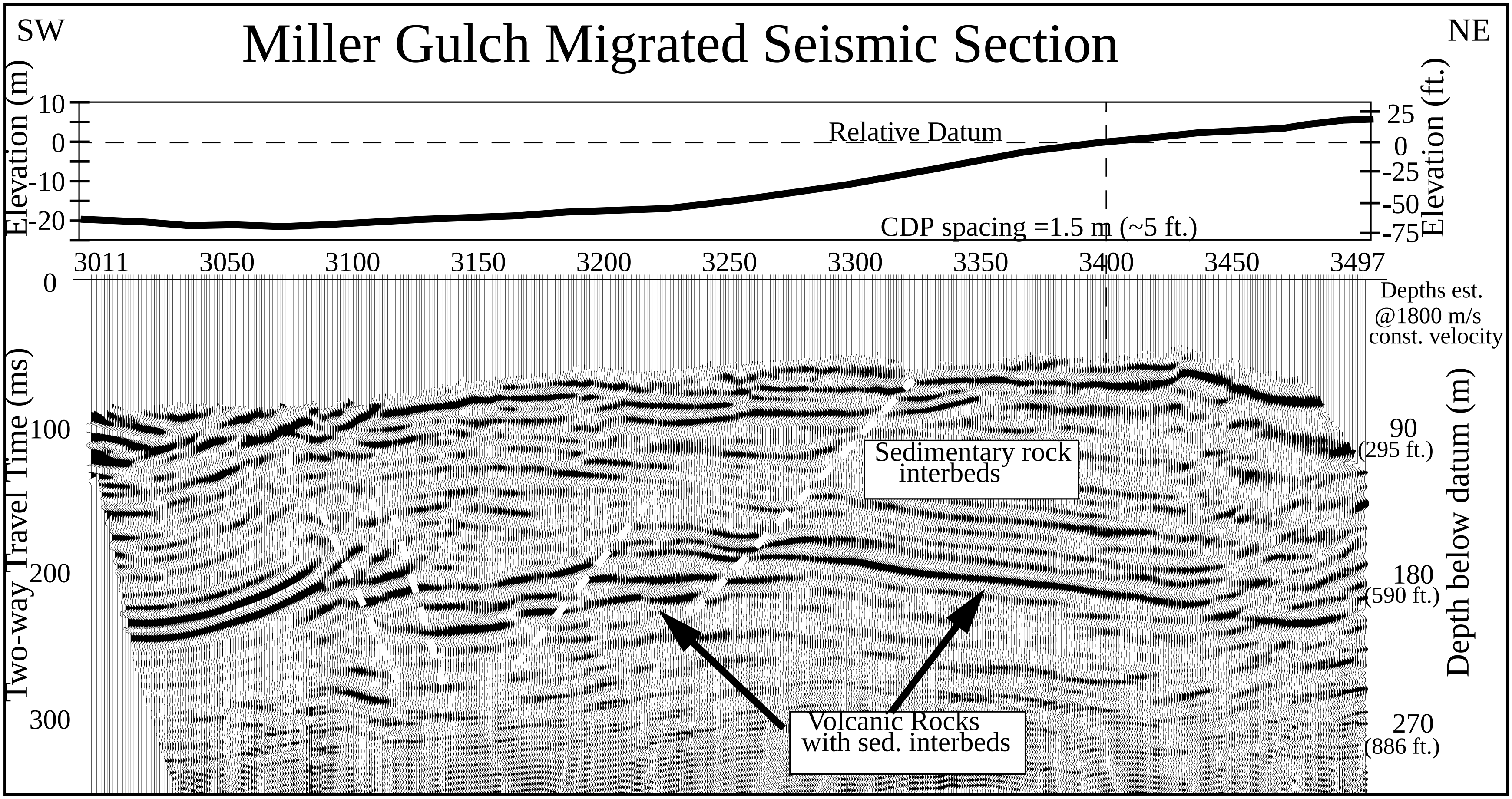

Figure 11. Migrated seismic reflection profile from Miller Gulch. The high-amplitude reflection package is interpreted as the interface between interbedded sedimentary rocks and a volcanic rock assemblage. This interpretation is based on an extrapolation of the geology from the Stewart Gulch and Airstrip seismic lines. The section is plotted with no vertical exaggeration. Note the coherent “smile” artifacts from the migration process.

There is no evidence for faulting in the younger Pierce Park sands along this trend to the north of Stewart Gulch, suggesting the fault is not recent in age.

A change in the frequency content of the seismic data along Stewart Gulch is consistent with the mapped lithology change across the section. The lithology from the nearby wells and from the regional geologic map (Wood and Burnham, 1997) suggest a gradation from mudstones in the east to sandstones in the west. This frequency change may be attributed to increased intrinsic attenuation in the sandstone facies relative to the mudstone facies. A similar change in frequency content has been observed in other seismic data collected in the valley, including a seismic profile near downtown Boise (Liberty, 1996), where the lithologic logs on opposite sides of a fault suggest similar facies changes.

CONCLUSIONS

Three seismic reflection lines provide subsurface control of major acoustic boundaries in Stewart Gulch and Miller Gulch in the foothills north of Boise. A major normal fault crosses the two northern profiles in Stewart Gulch with an approximate east-west strike. Smaller offset faults can also be identified on each line, although the true strike and dip of these faults is difficult to determine due to limited subsurface control. A change in frequency content across the Stewart Gulch seismic profile suggests that this attribute may be sensitive to facies changes. This suggests that possibilities exist for seismic mapping of the extent of local aquifers in the Boise valley. Additional research is necessary to test this hypothesis.

ACKNOWLEDGEMENTS

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