

Multicomponent seismic survey at Spring Coulee: a data repeatability study

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ABSTRACT

A 3 km long 3-component seismic line was recorded at Spring Coulee, Alberta, using an Envirovibe source, with a nominal shot and receiver spacing of 10 m and a maximum useable source-receiver offset of about 1500 m. Offsets greater than 1500 m were limited primarily by wind noise overwhelming signal. The line was recorded twice over a time period of 10 days. The vertical and radial component data from the two surveys were processed using the same flows, but with independent static solutions and velocity analyses. Spring Coulee is a 'good' data area, with only a thin weathering layer, and P-P and P-S reflections from PreCambrian basement evident on processed sections. An nrms metric was used to assess the repeatability of shot gathers and processed P-P and P-S sections between the two surveys. For shot gathers, nrms values ranged from 0.3 to 0.9 for raw vertical component data, and 0.4 to 1.2 for radial component data (Figure 1). After an 8-12-50-60 Hz bandpass filter was applied, nrms values reduced by 0.2 for both vertical and radial component data, respectively. For migrated sections, nrms values for P-P data were about 0.4 in the high-fold, central part of the seismic line, but greater than 1.1 for P-S data. The poorer repeatability of the P-S data with respect to the P-P data is due to unresolved receiver static corrections and differences in ambient wind noise between the two surveys.

INTRODUCTION

The 2009 University of Calgary Geophysics Field School was held in late August though early September at Spring Coulee, near Cardston in Southern Alberta. The Field School, as well as CREWES, has been acquiring data in this area for the past two years, including single-component and multi-component data to test acquisition systems and also to explore for hydrocarbons in two sections of land over which the University owns the mineral rights. Primary objectives of the Field School have been to train students on the field acquisition of multicomponent seismic data and to provide datasets for subsequent data processing and data interpretation courses taken by the students in the University of Calgary Geophysics Program. We have also been able to use the data for research purposes within CREWES. In this case, we were interested in repeatability of multicomponent data for future timelapse seismic programs.

Background geology and the general interpretation of seismic data in the Spring Coulee area is reported in a companion paper by Ostridge et al. (this volume). This paper focuses on the repeatability of seismic data collected during this year's Field School program in which two different student groups collected 3-component data along the same line, but separated in time by 3 days. The acquisition parameters for the survey are shown in Table 1; the seismic line was slightly over 3 km in length and was recorded along an east-west road over gently undulating hills. The layout of the line is shown in Figure 1 and a view along the seismic line is shown in Figure 2. An irrigation canal at

about the 2 km mark was the only significant gap in the line. The first group of Field School students recorded the data from west to east, with the spread leading (east) whereas the second group recorded the line in the opposite direction with the leading spread to the west. The tail spread for both groups was somewhat variable in terms of live stations, depending on the efficiency of the student field crew.

Table 1. Acquisition parameters for the 2009 Geophysics Field School program

Parameter	Details
Source type	Envirovibe (8000 kg peak force)
Sweep	4 x 12 seconds, 10-150 Hz
Geophones	Single 3-component
Recording System	ARAM Aries
Geophone station interval	10 m
Shot interval	10 m
Sample interval	1 ms
Spread	Asymmetric, shot trailing
Maximum source-receiver offset	1600 m
Number of live stations	160 - 180

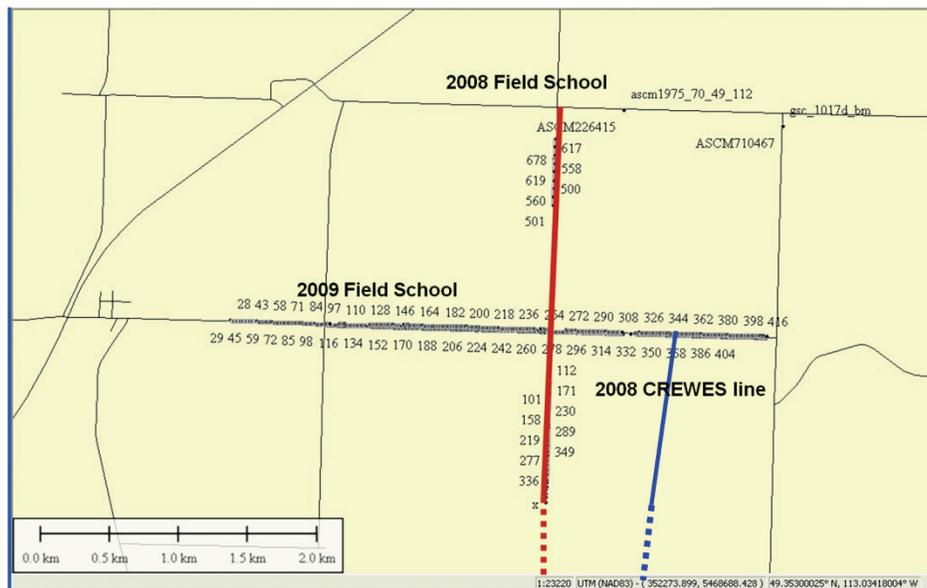


FIG. 1. Layout of 3-component seismic line at Spring Coulee.

A view along the seismic line is shown in Figure 2. The multicomponent data were recorded with analogue geophones using CREWES-designed cables that have a 6-pin takeout. At every 8th station there are 3 RAM boxes and batteries, one for each component (Figure 3). Colour-coded cables kept consistent line definitions. The horizontal components (arrowed) of each 3-C geophone were oriented west (H1) and north (H2).



FIG. 2. View along multicomponent seismic line at Spring Coulee. View is to the west.



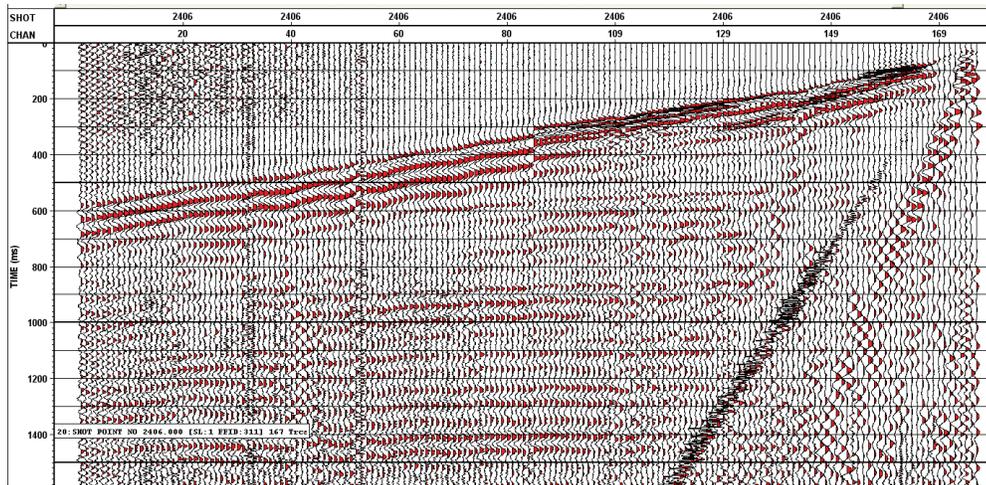
FIG 3. 3-component acquisition with each component defined as a separate ARAM receiver line.

RAW DATA REPEATABILITY

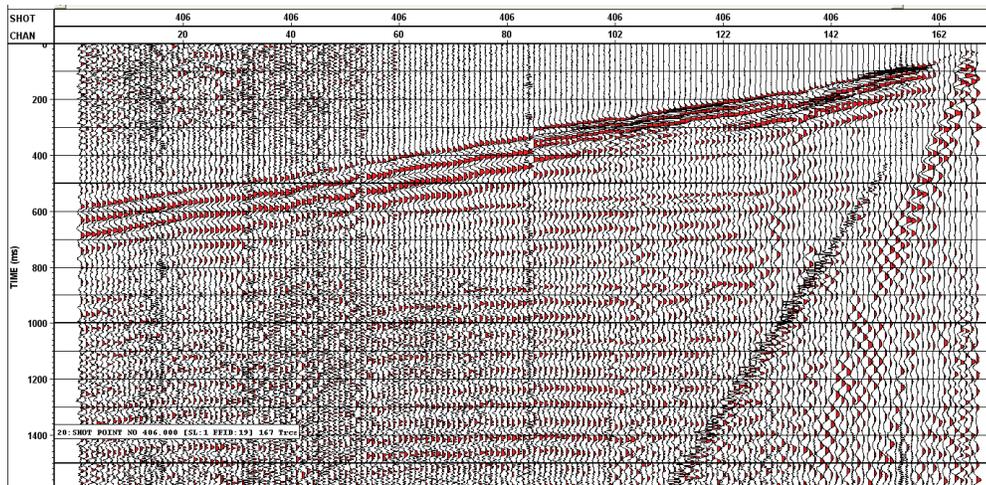
Since seismic data along the line were acquired twice, it provided a good opportunity to evaluate repeatability of multicomponent seismic data, as this is an increasingly important topic in timelapse seismology for tracking subsurface fluid flow. The datasets were assessed in terms of repeatability of vertical and radial component shot gathers, as well as migrated PP and PS section. The two lines of repeated seismic data were acquired about 3 days apart. Weather conditions were similar although windier conditions prevailed during the second survey.

Vertical component data

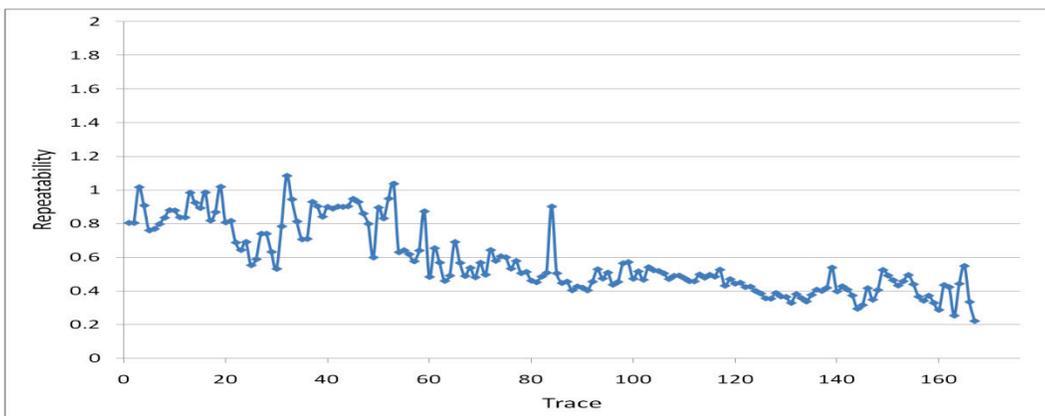
Figure 4 shows a raw repeated shot record collected from the two surveys.



(a)



(b)



(c)

FIG. 4. Raw vertical component repeatability: (a) line 1 shot gather; (b) line 2 shot gather; (c) nrms calculated over 0 – 1600 ms window.

The difference in wind noise is visible between Figures 4a and 4b. The nrms data displayed in Figure 4c were calculated using the definition of Kragh and Christie (2002). Toward the shot, nrms values are between 0.2 and 0.4, indicating good repeatability. At far source-receiver offsets, the nrms values increase to between 0.8 and 1.0, probably due to random wind noise differences. For comparison, Figure 6 shows that same data after an 10-15-55-60 Hz bandpass filter had been applied to the data prior to nrms calculations. The shot gathers are improved (Figures 6a and 6b and the nrms values are in the 0.2 to 0.4 range over a greater range of offsets than shown in Figure 4c. This confirms that it is probably wind noise that contributes most to reducing the repeatability between these shots.

Radial component data

Figure 7 shows raw shot gathers (with a 500 ms agc operator) of the radial component data from the repeated surveys for the same shot as shown in Figure 4. Clearly, the radial component data are much noisier than the vertical component data, with wind being the most obvious source. The nrms values for traces close to the shot are about 0.4 and increase to over 1.2 at the far offset, indicating that the data are dominated by random wind noise.

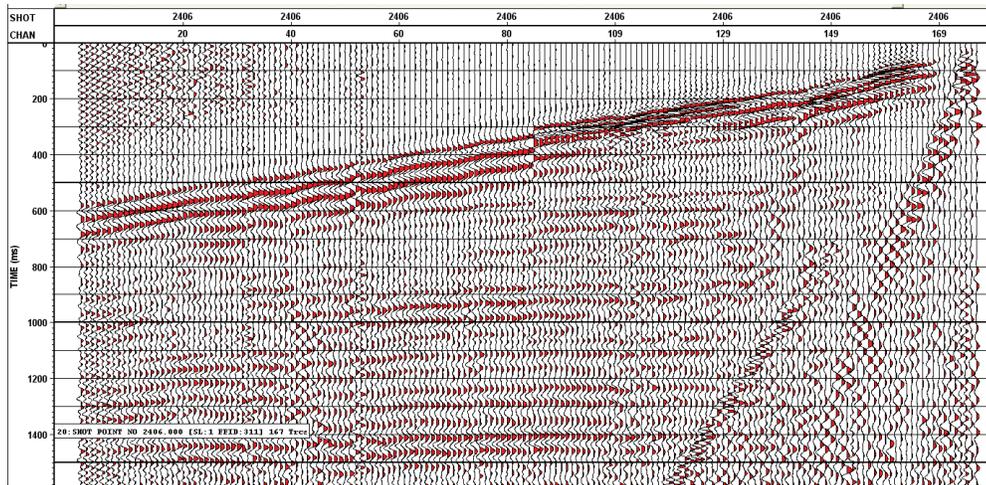
After applying an 8-12-50-60 Hz bandpass filter, P-S (converted wave) reflections are more visible on the shot gathers (Figure 8) and repeatability has improved to values of approximately 0.35 to 0.4 for near traces and 1.0 for far traces.

DATA PROCESSING

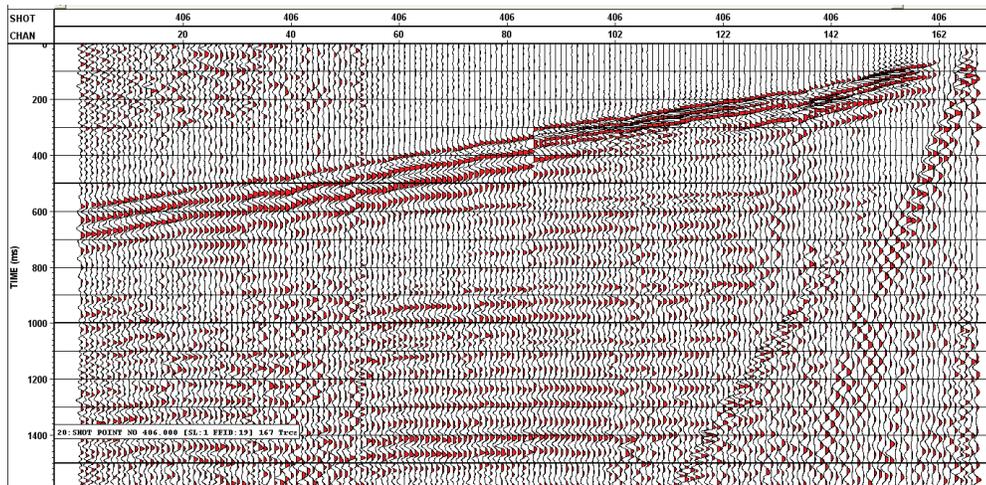
Figure 5 shows a planted 3-C geophone from the survey; single geophones were used at each station. The vertical and radial component data were processed through standard flows, although for the processed sections shown in this report, independent statics and velocity analyses were undertaken for the two lines for each component.



FIG. 5. Planted 3-C geophone



(a)



(b)

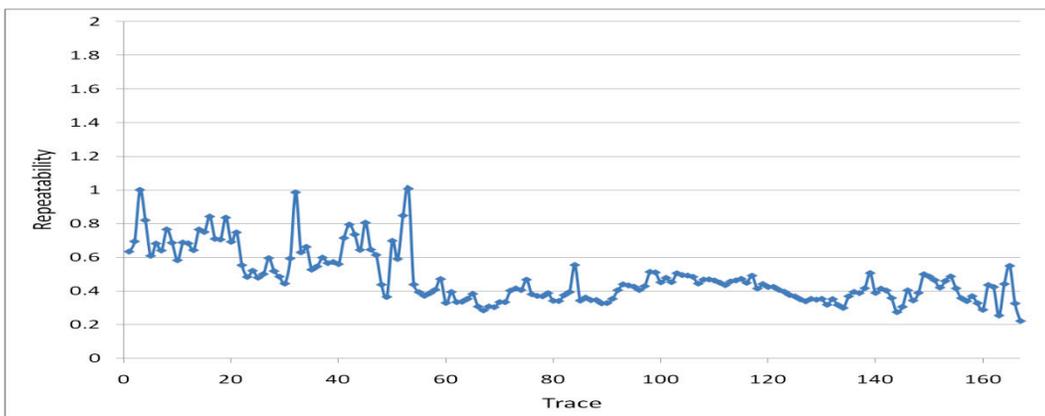
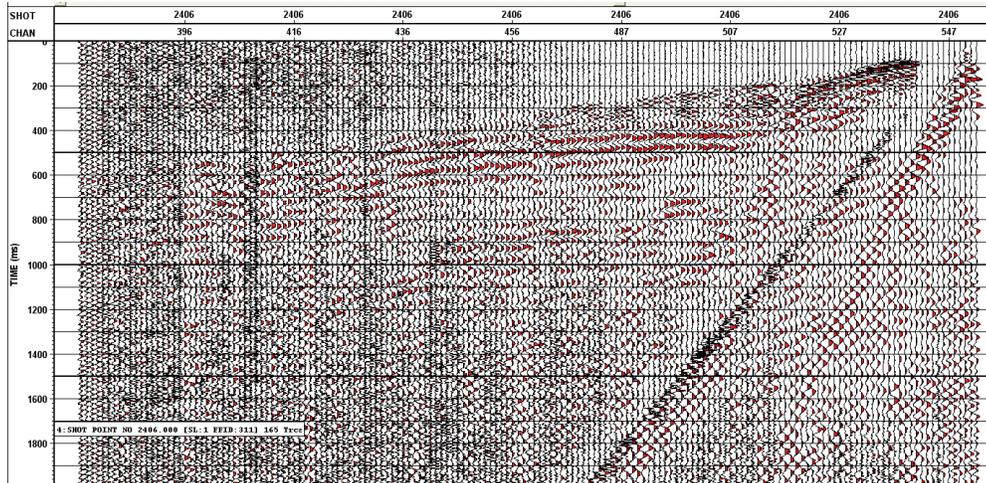
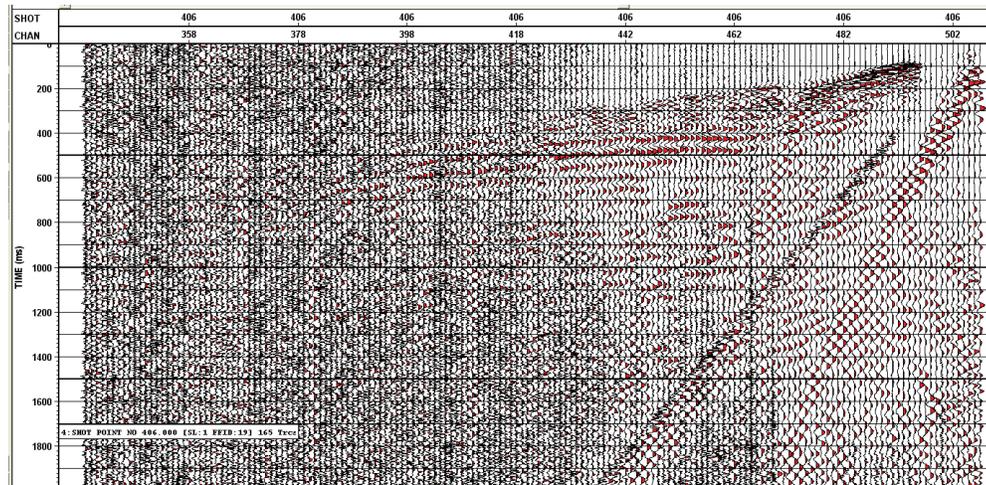


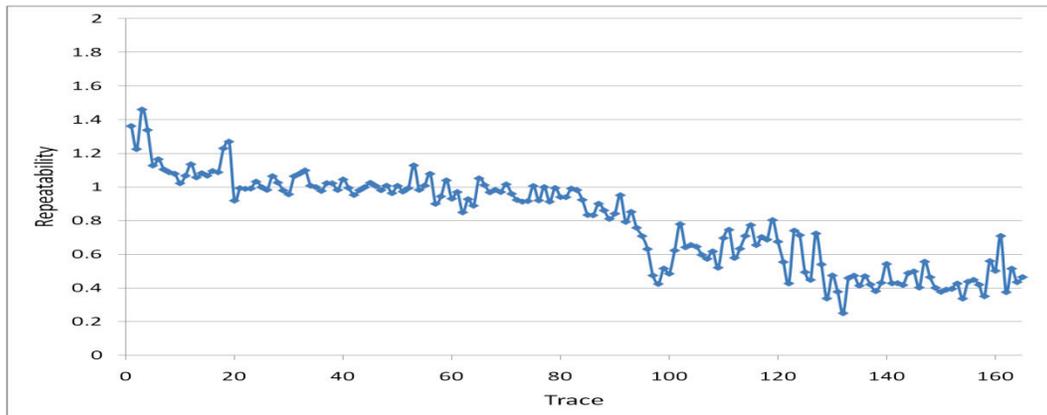
FIG. 6. Filtered vertical component repeatability: (a) line 1 shot gather; (b) line 2 shot gather; (c) rms calculated over 0 – 1600 ms window. Filter applied was 10-15-55-60 Hz bandpass.



(a)

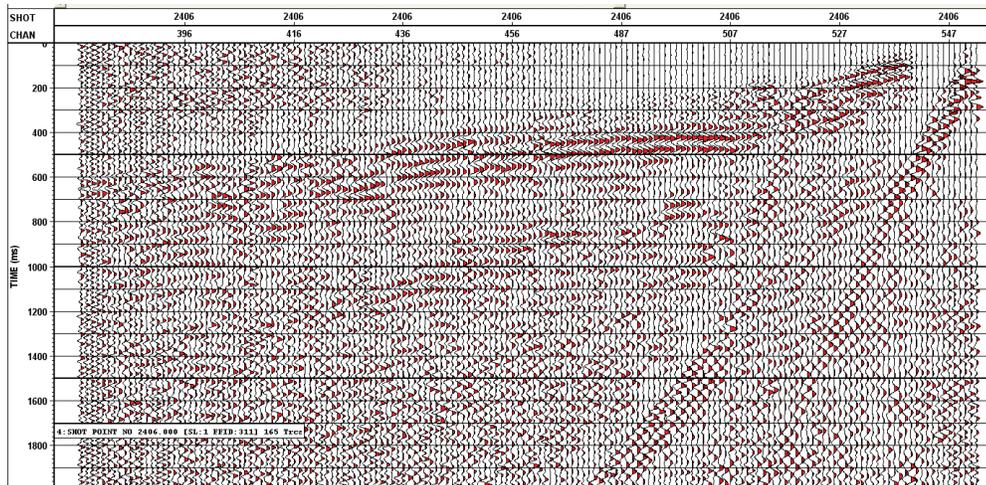


(b)

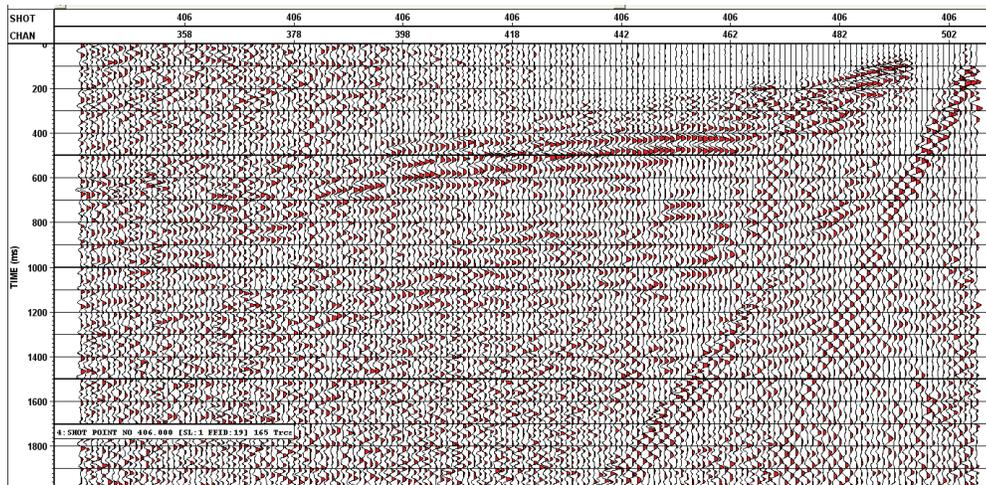


(c)

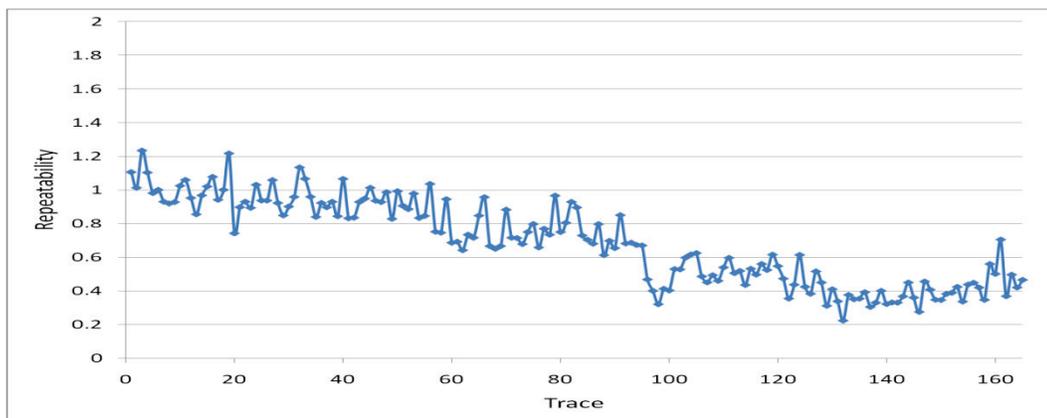
FIG. 7. Raw radial component repeatability: (a) line 1 shot gather; (b) line 2 shot gather; (c) nrms calculated over 0 – 2000 ms window.



(a)



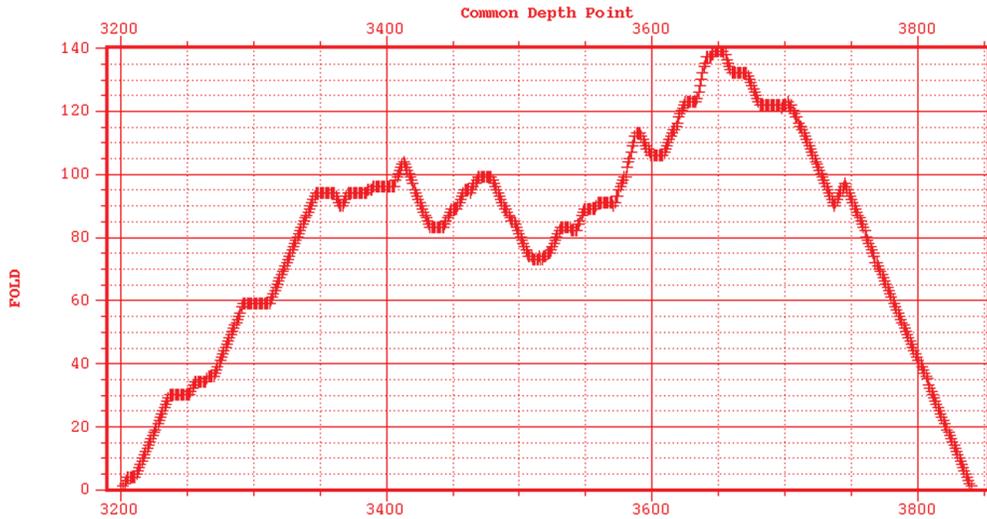
(b)



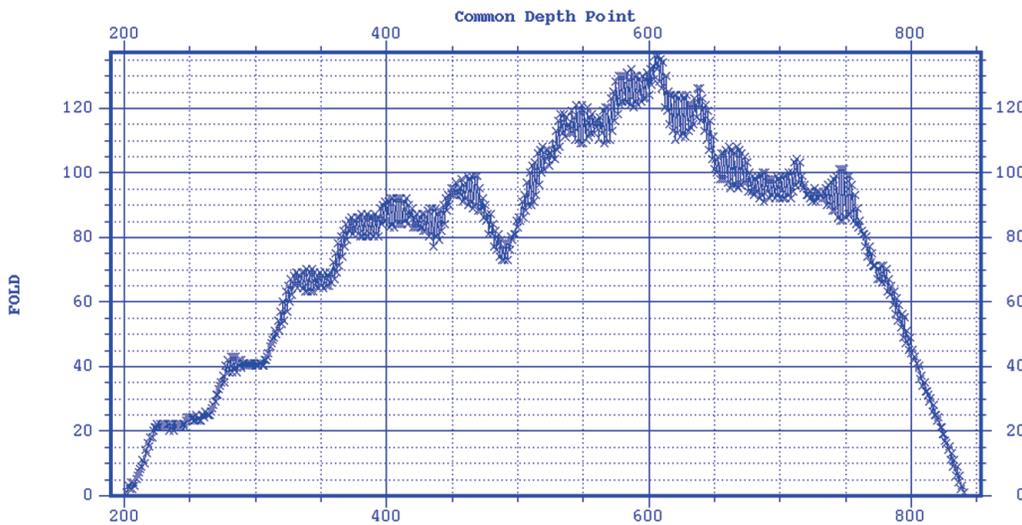
(c)

FIG. 8. Filtered radial component repeatability: (a) line 1 shot gather; (b) line 2 shot gather; (c) nrms calculated over 0 – 1600 ms window. Filter applied was 8-12-50-60 Hz bandpass.

Figure 9 shows the PP fold and PS fold (asymptotic binning) for the multicomponent survey, with maximum fold exceeding 100 in the central part of the seismic line.



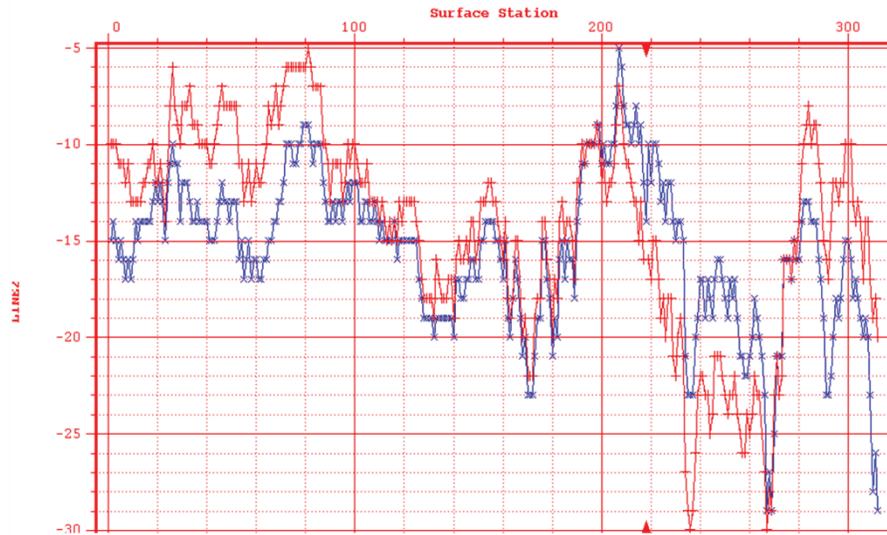
(a)



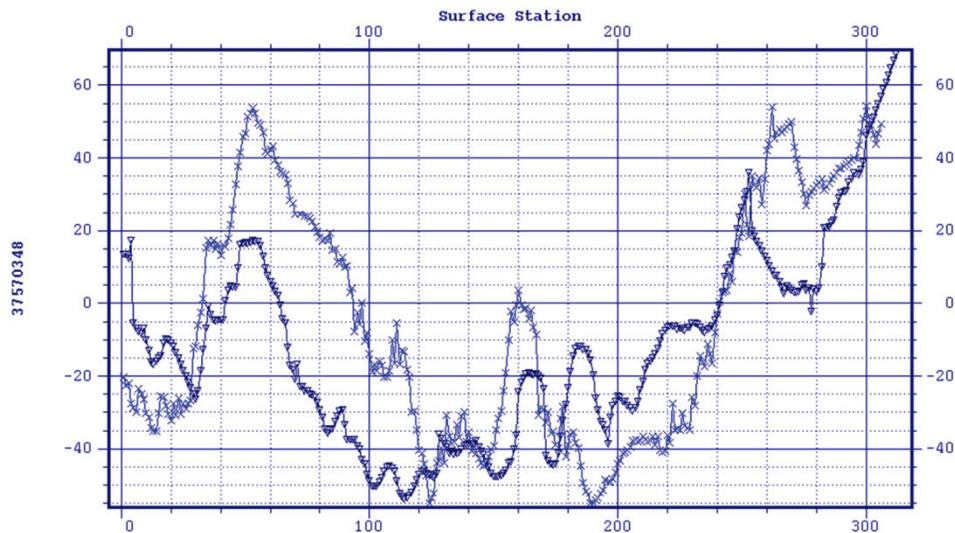
(b)

FIG. 9. PP and asymptotic PS fold for the 3-C survey

For the processed sections shown in the report, independent static solutions were obtained for the repeated surveys. Figure 10 shows the receiver statics for PP data and Figure 11 shows receiver statics for the PS data. For the P-wave data, receiver statics are within 5 ms, but vary up to 20 ms for the S-wave statics for the P-S data. The S-wave statics were determined from a high-amplitude shallow reflection on receiver stacks.



(a)



(b)

FIG. 10. Independent receiver static solutions for the repeated surveys. (a) P-wave receiver static; (b) S-wave receiver static.

Vertical component sections

Migrated sections from the processing of the vertical component data are shown in Figure 11, and repeatability is assessed through nrms values calculated over a data window from 400 to 1500 ms. The sections show clear differences in reflection times at the east (right) end, most likely due to different static solutions. These differences are also seen in nrms values which are about 0.4 in the central part of the line, but increase towards the ends, particularly the east end. Additional work will be done on these data, using a full 4D processing flow.

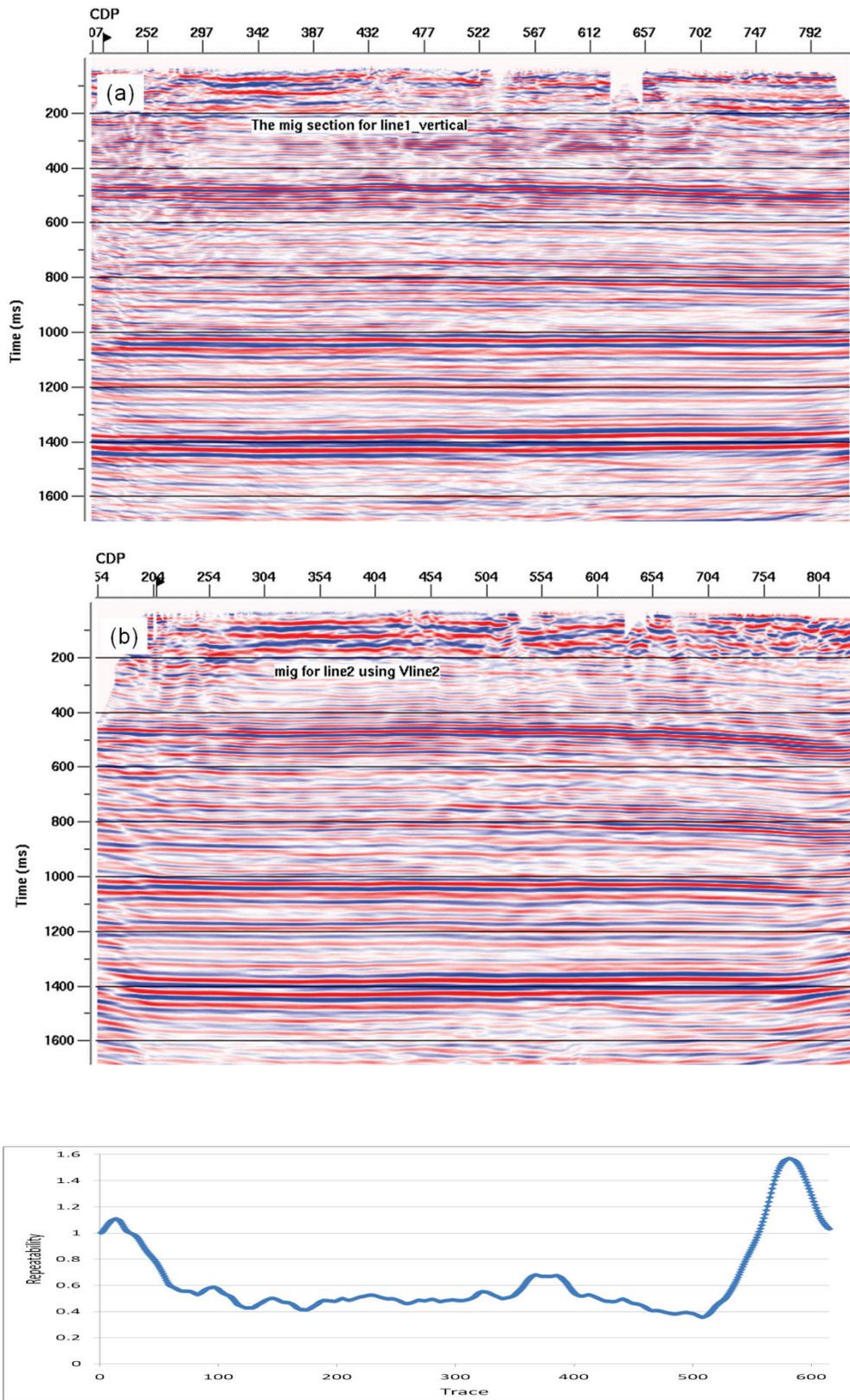
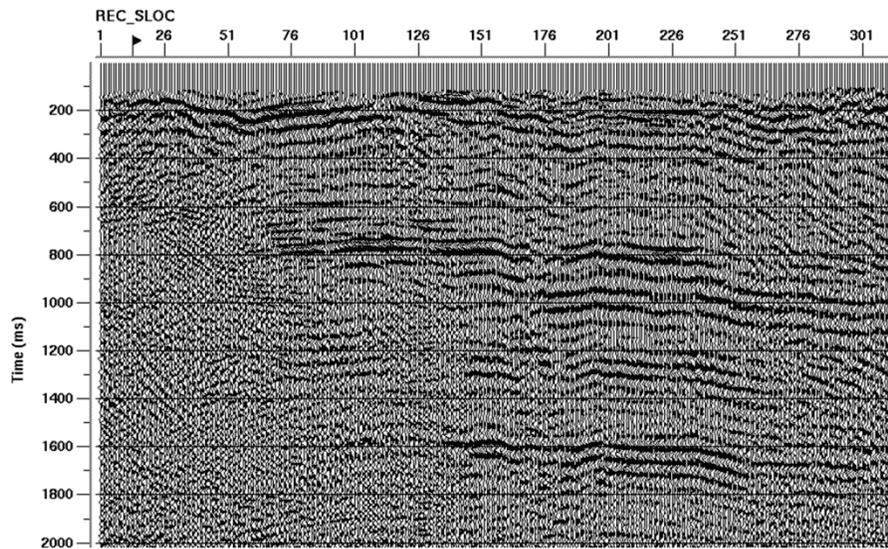


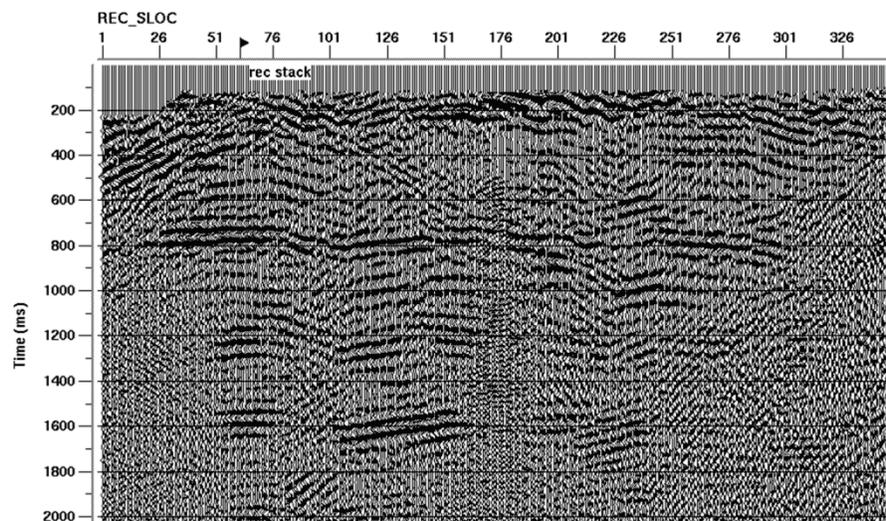
FIG. 11. Migrated vertical component sections showing baseline data (upper), repeated data (middle) and nrms data (lower).

Radial component sections

As seen in the raw shot records (Figures 7 and 8), the radial component data are very noisy, mostly due to wind noise. Conditions during acquisition of the second survey were windier than during the first survey and this is evident in all stages of data processing. The receiver static solutions shown in Figure 10 were derived from receiver stacks. Initial receiver stacks of the radial component data are shown in Figure 12.



(a)



(b)

FIG. 12. Initial radial component receiver stacks for (a) baseline and (b) repeat surveys. Differences are larger than anticipated.

The difference between the receiver stacks from the two lines is surprising and further studies will be undertaken to better understand the reasons. After asymptotic binning ($V_p/V_s = 2.1$) migrated PS sections were obtained, as shown in Figure 13.

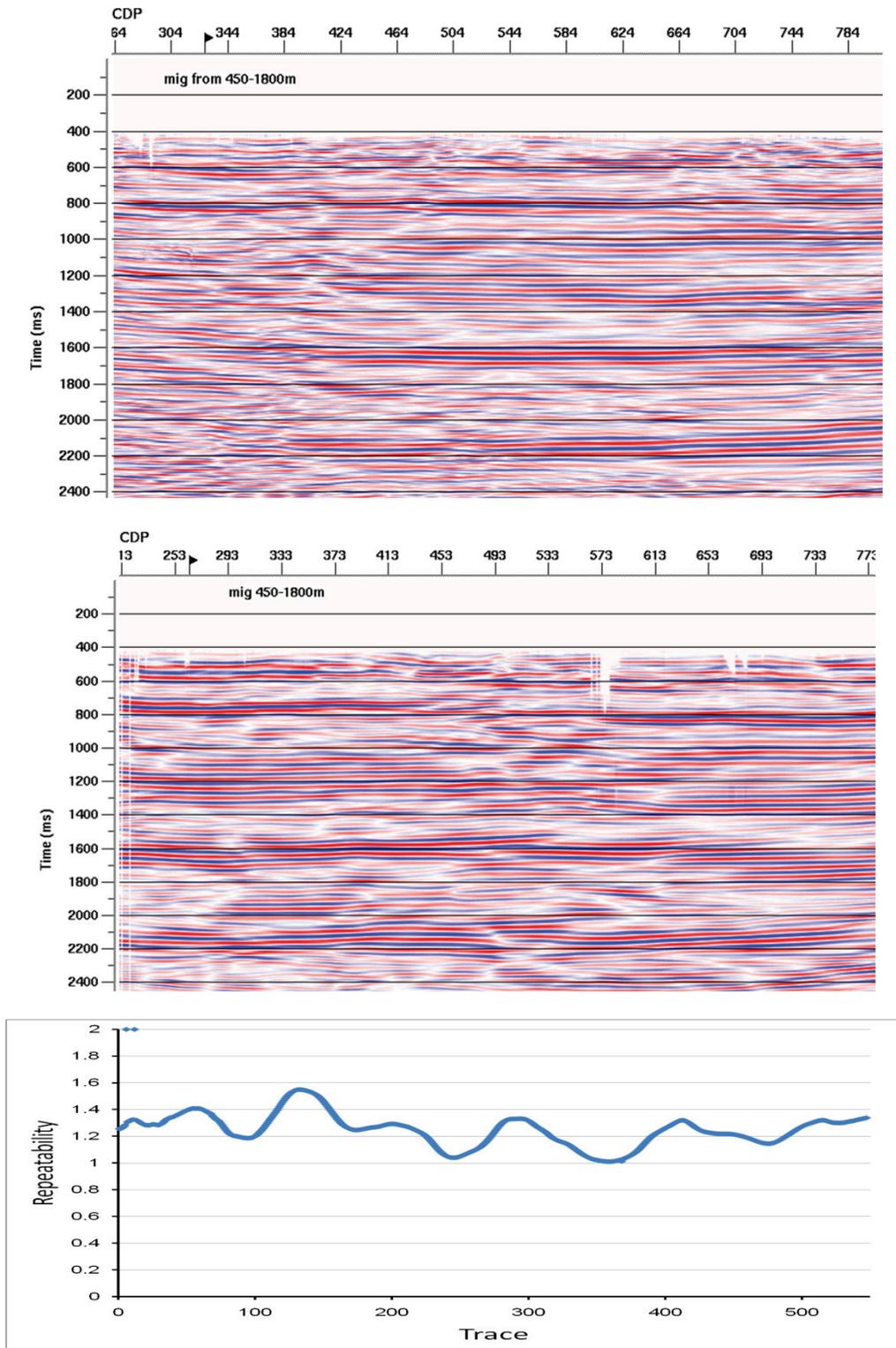


FIG. 13. Baseline (upper) and repeated (middle) PS sections with nrms repeatability (lower).

Repeatability is quite poor for the PS data, with nrms values averaging about 1.2. Unresolved noise, velocity and receiver static differences between the datasets are most likely the cause. A full 4D processing flow will be developed.

INTERPRETATION

In spite of the poor repeatability of the PS data, interpretable sections were obtained from the surveys. Figure 14 shows PP and PS data justaposed, with good correlations between some of the major reflections. Registration of the PP and PS sections shows that V_p/V_s in the shallow section is about 2.4, reducing to 2.0 in the deeper section. Figure 15 shows the shallow stratigraphy in the study area, with channel facies exposed in the cliff face and a relatively thin weathering layer.

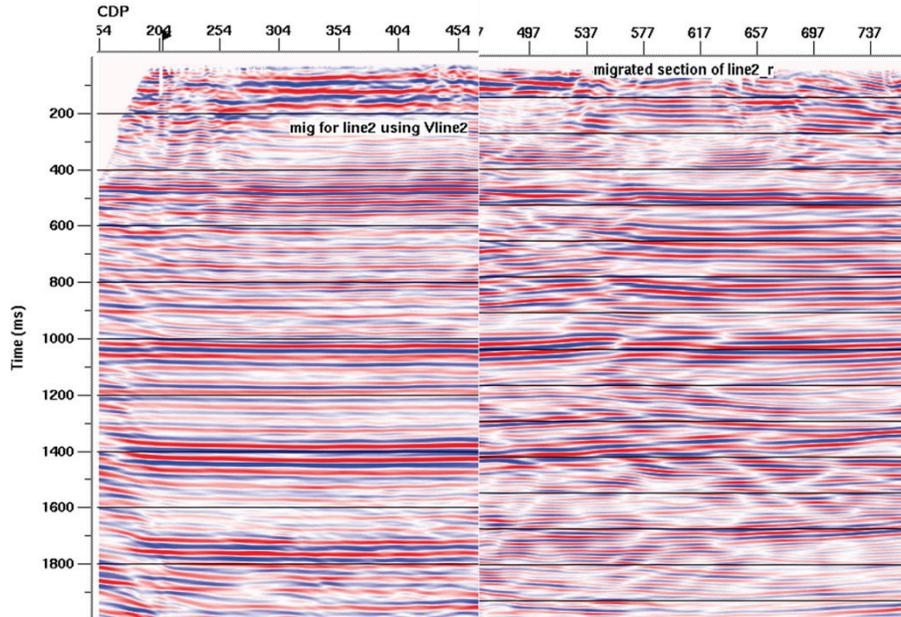


FIG. 14. PP (left) and PS (right) illustrating event registration.



FIG 15. Near-surface stratigraphy and relatively thin weathering layer at Spring Coulee

CONCLUSIONS

The 2009 field school program yielded high quality PP sections but poorer quality PS sections. The repeatability of the PP data was reasonably good, with nrms values around 0.4 in the high-fold part of the line. The repeatability of the PS section was poor with nrms values greater than 1. Although the processing flows for the repeated seismic surveys were very similar, differences in static solutions reduced the repeatability metric. Generally, the PS data are much noisier than the PP data, mostly due to wind noise. A more robust 4D processing flow will be established with the goal of minimizing nrms values of both the PP and PS sections.

ACKNOWLEDGEMENTS

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