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Time sections from synthesized shot gathers at Valhall

ABSTRACT

NMO-stack, using a velocity model generated with active seismic surveys, was performed on synthesized shot gathers produced from the Valhall passive seismic array. Inline sections show strong events with minor to no topography. The events are completely discontinuous across the cross-line direction and uninterpretable on time slices. While some events are can be tracked between sections, some events appear/dissappear completely. While aliasing could be the cause, the apparent dips of these events are geologically unreasonable.

Various muting and modeling excercises were performed using the kinematics of the energy from the production facility 40 km away from the array. Shot gathers were modeled, windowed and muted, before NMO-stack processing to compare to original results. These exercises show that the direct arrival and ringing correlation side-lobes are a coherent noise source that gives rise to the events that would be believable on 2D sections.

INTRODUCTION

After synthesizing shot gathers from the passive data collected by the Valhall subsea array, the traces were sorted, normal moveout (NMO) applied, and stacked. A similar processing flow with the same data was described by Hohl and Mateeva (2006). Several coherent, roughly flat events are imaged in all time windows over which the raw data were subdivided for processing.

Of paramount concern with this workflow is the presence of the strong direct arrival from 40 km away from the array investigated in the previous chapter. Thus, the origin of the event is not at the location of the source traces used for correlation to produce synthesized shot gathers. Therefore, the kinematics impilicit in sorting to common-midpoint coordinates (CMP) are not appropriate for this event. Thus, the event is a strong coherent noise source for both sorting and NMO.

Several methodologies were employed to investigate whether the events in the stacked sections are actual subsurface reflections or the coherent stack of the distant production noise. Comparative volumes of NMO-stacked data were generated in an attempt to identify the nature of the events. Two main efforts were employed: Constant water velocity NMO, and various modeling and muting experiments using the inversion results described in the previous chapter.

NMO-STACK TIME SECTIONS

Figure 1 shows strong coherent events in inline sections after NMO-stack using a velocity model provided by BP. The shot gathers were synthesized with the spectral whitening correlation strategy explained in the previous chapter. The left images were generated using 9 hours of raw data from February 15, 2004. The right images used 5 hours of data 25 hours later. The two volumes were processed identically. The upper rows are sections extracted from the 3D cube at the central CMP in the cross-line direction and bandpassed from 10 to 25 Hz. The bottom sections were extracted from the next cross-line CMP, +150 m. The shallow geology under the array consists of very flat, continuous layers. These NMO-stack results have no continuity on time-slice panels, and the events change radically in character and timing between adjacent cross-line CMP locations. Some events appear with no correlation between cross-line locations. Other events are correlable between the two sections, though move approximately 0.25 s. Assuming that the events are aliased in the cross-line direction, this is an apparent velocity of 600 m/s which is too slow to be believable. The strength of the events is also suspicious as the shot-gathers shown in the previous chapter contain no apparent energy at small time other than the strong event from the distant production facility.

Figure 2 used the data from the beginning of the recording period, left column of Figure 1, and a constant water velocity for the NMO correction. The two panels correspond to the cross-line sections displayed above. Coherent events are present, but have troubling characteristics again. There is still no consistency of events in the cross-line direction. Figure 3 is a time slice through the same data cube at 0.4 s. There is no consistency in the cross-line direction, while individual lines along the CMP-X directions show the continuity associated with the clear events in Figure 2.

Figure 2 does show that NMO with water velocity drastically changes the events that coherently stack compared to Figure 1. The sections are obviously different. Despite the fact that the synthesized shot gathers did not capture the apex of the hyperbola due to the distant noise source, the water velocity NMO was close enough to destroy almost all the energy in Figure 1.

The inversion described in the previous chapter provides very accurate prediction of the kinematics of the strong event in the correlated gathers. Figure 4 shows two correlated shot gathers. The first is muted to the arrival time of the distant noise source. Notice that there are significant correlation side-lobes that remain in the section. The bottom panel shows a narrow pass-window selected around the arrival. A third data set was also generated by convolving the forward modeled direct arrival with a wavelet.

Figure 5 are inline time sections exploring the relationship of the direct arrival from the distant production facilities to the events observed in Figure 1. The top-left panel is the same as Figure 1. The top-right panel used the muted data from the top of Figure 4. The bottom-left panel used the data from the bottom of Figure 4. The final section is the result of processing the forward modeled shot gathers. The difference between the first two panels is nearly impossible to find. The bottom two panels also show several similar features.

In contrast to the results above, Figure 6 compares a muted shot gather generated with the

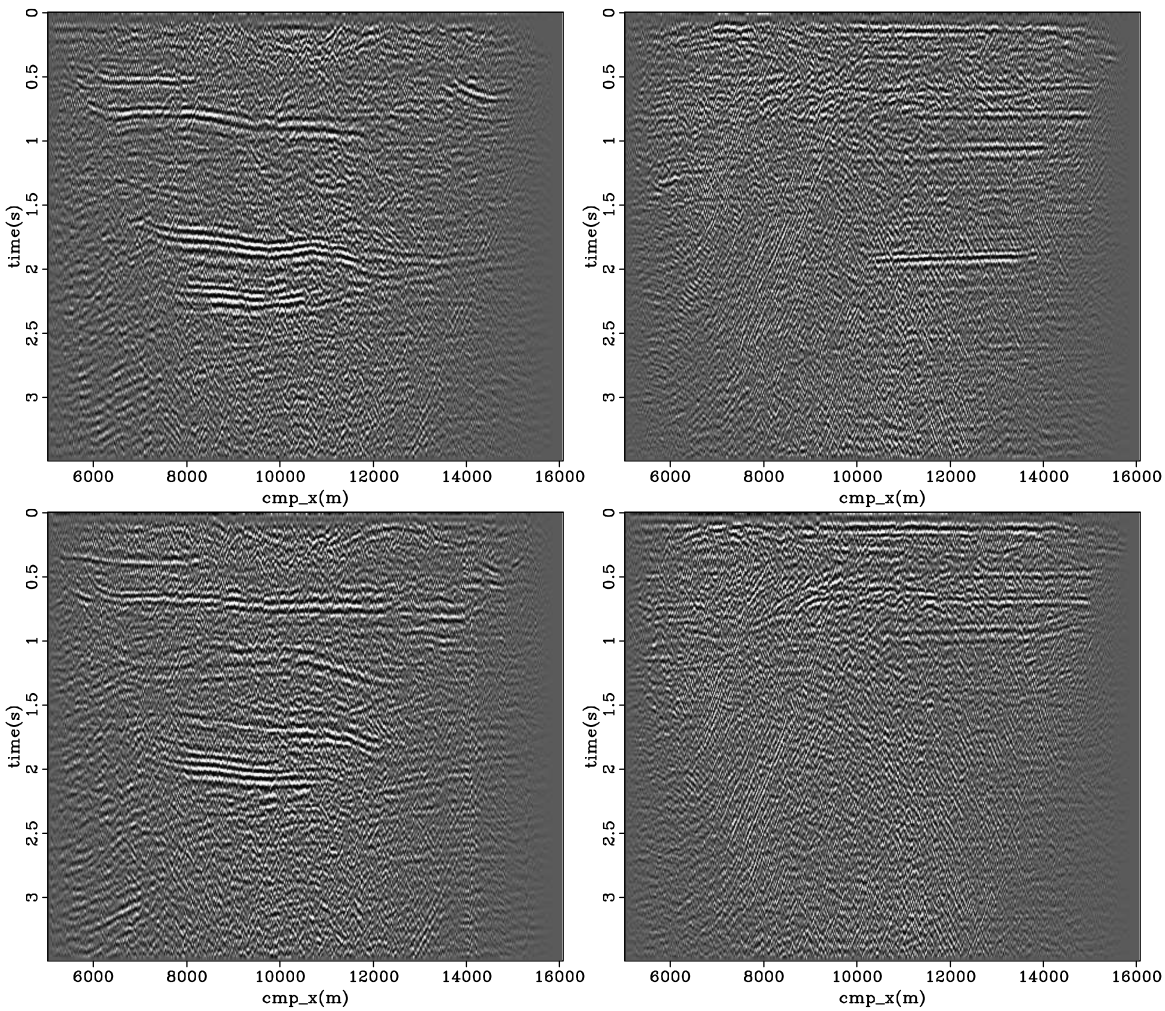

Figure 1: NMO-stacked inline sections from the center (top) of the Valhall array, and (bottom) the neighboring cross-line CMP (+150 m). Left and right columns were processed identically using data collected 25 hours apart in February, 2004. events [NR]

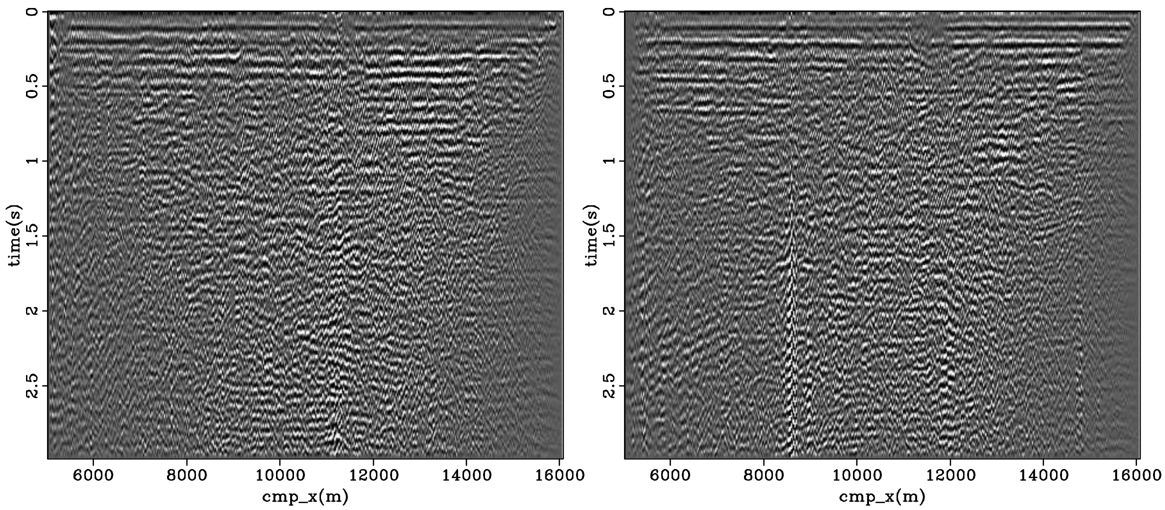

Figure 2: Inline sections corresponding to the data on the left of Figure 1 using constant water velocity for NMO. water [NR]

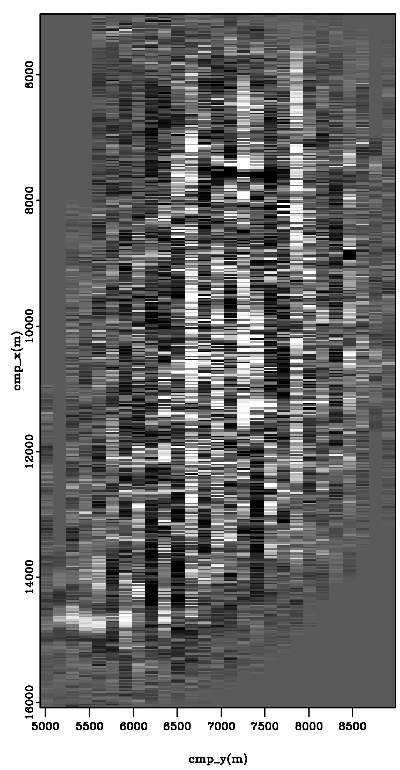

Figure 3: Time slice, 0.4 s, through the NMO-stacked cube using water velocity. No continuity exist across the panel, while individual lines in the CMP-X direction show some continuity. waterslice [NR]

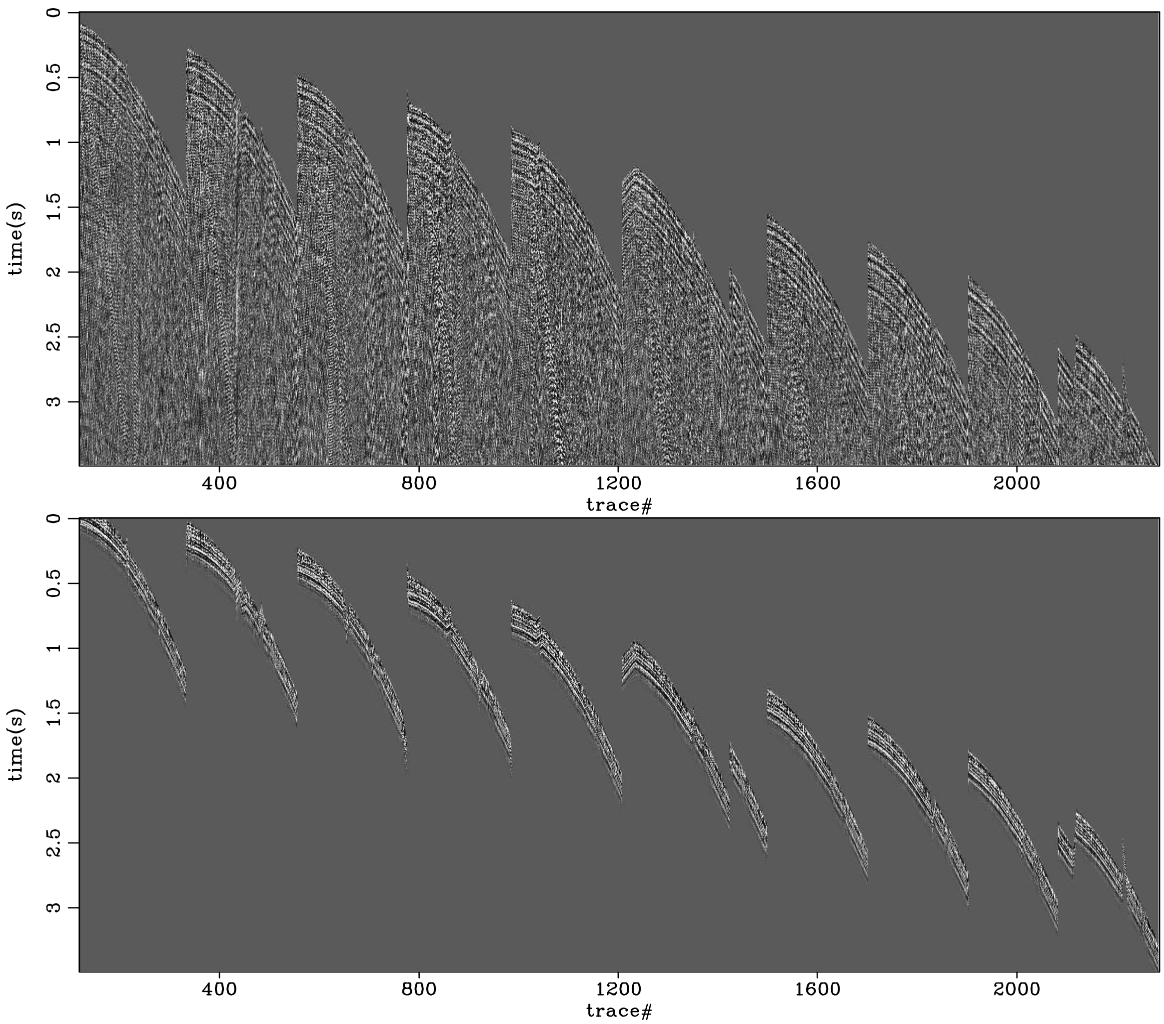

Figure 4: Two shot gathers used to test the origin of the events in Figure 1. Top panel is muted to the kinematics of the distant noise source. Bottom panel is a narrow window around the modeled event. modldat [NR]

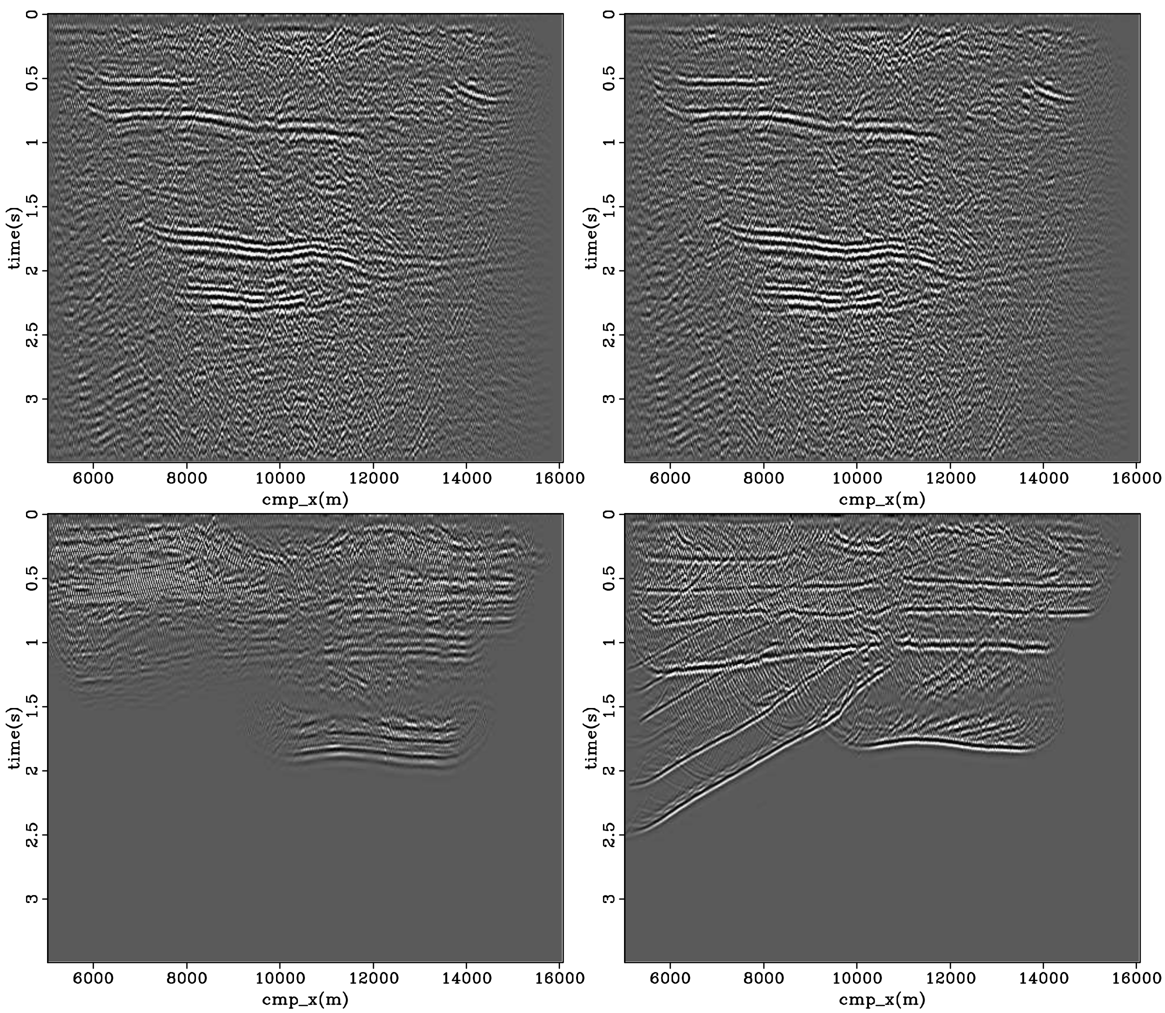

Figure 5: NMO-stacked sections from center cross-line location, where data where (top to bottom) muted to the direct arrival, windowed around it, and a modeled direct arrival. evnttest [NR]

first 9 hours of passive data, Figure 4 top, with one from data collected 25 hours later, bottom panel. In contrast to the top panel, the data from a day later do not suffer as much from the ringing correlation side-lobes. The mute leaves a small amount of the direct arrival, but this time does a much better job at removing most of the energy associated with the direct arrival. Figure 7 compares the NMO-stacked sections created with the the data in the previous figure. All of the obvious flat events have been successfully eliminated.

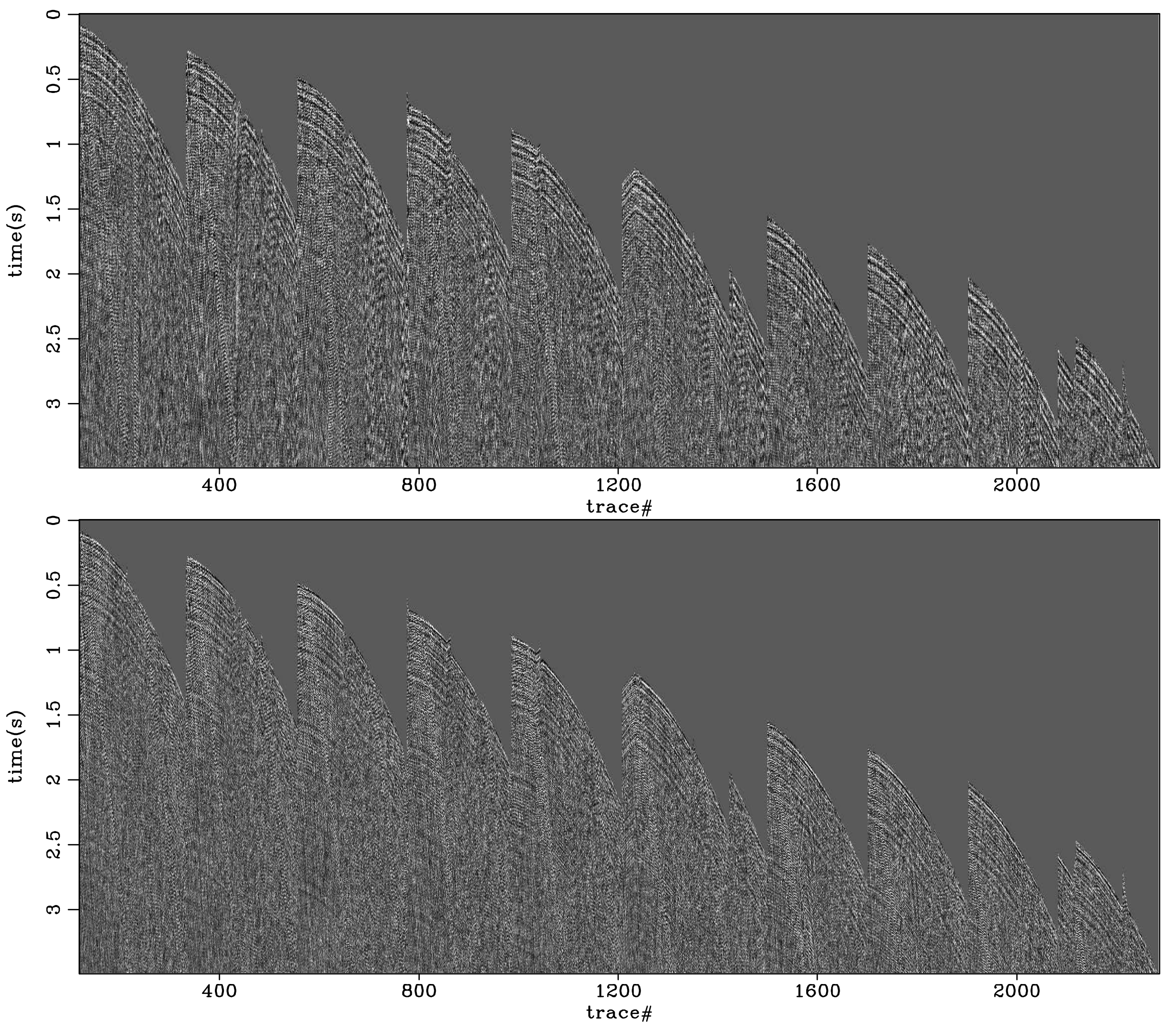

Figure 6: Top:Muted shot gather corresponding to the first 9 hours of data (Figure 4 top). Bottom: Muted shot gather generated with 5 hours of data 25 hours after those used to create the top panel. modldat2 [NR]

DISCUSSION AND CONCLUSIONS

NMO-stack of the whitened, correlated passive data from the Valhall OBC array produces strong events on inline sections. Other authors have interpreted these as geologic information after processing only 2D subsets of the data (Hohl and Mateeva, 2006). Very good imaging

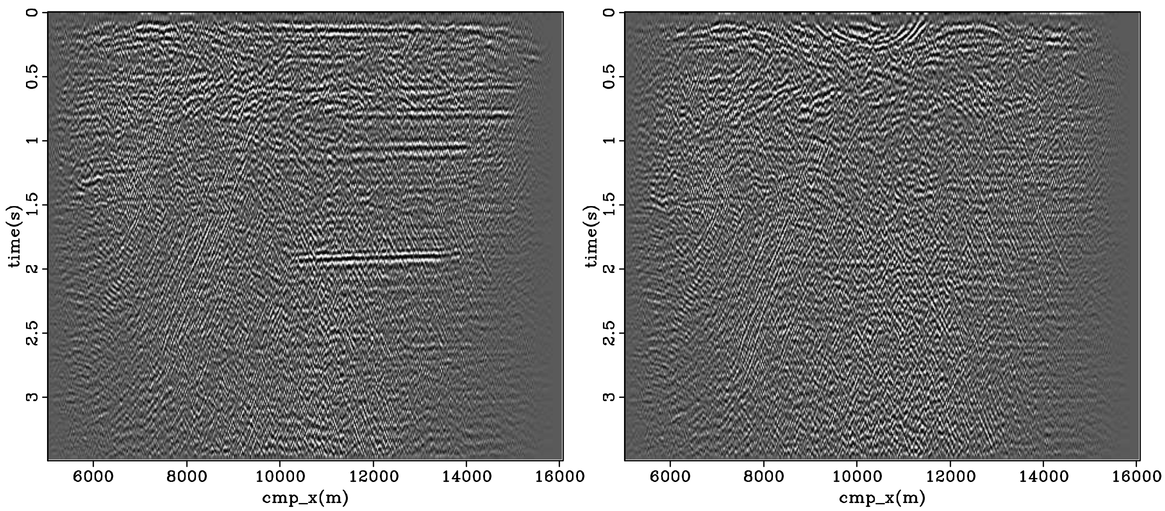

Figure 7: NMO-stacked sections from center cross-line location generated from data a day after those used for Figures 4 and 5. Muting down to the direct arrival (Figure 6) successfully eliminates all coherent events. evnttest2 [NR]

from many active surveys has been carried out at the location that shows the shallow geology to be very flat and uniform in both map directions. The time sections shown above however have several unbelievable characteristics that lead me to conclude that these are coherent noise rather than genuine subsurface information.

Of paramount importance, the same section produced with the same processing flow using different windows of the available data (separated by 25 hours) have dramatically different events. The OBC cables are buried approximately 1 m beneath the sea floor. Thus, within the first 2 samples (10 m depth), the interval velocity model has values in excess of 1600 m/s which is much too fast to correctly NMO the direct arrival that arrives at water velocity (1450 m/s). By performing constant velocity (1450 m/s) NMO, all of the spurious events are removed from the stacked section.

Because the kinematics of the direct arrival in the shot gathers are well constrained, it was possible to mute, model, and window around the event before NMO-stack. Using the gathers generated with the first section of data, the muted volume was barely distinguishable from the result produced with the full data. However, the section produced with a short time window around the event was very comparable to that produced by forward modeling the event. The final observation that links these two facts was provided by performing similar experiments with data from 25 hours later. The NMO-stacked section produced with the muted gathers had no evidence of the events seen in previously. Finally, comparing the shot gathers produced from the two data subsets showed that there is significant ringing (correlation side-lobes) present in the gathers produced with the data from early time. The conclusion from these facts is that the direct arrival form the distant production facilities is the cause of the events in the stacked sections and that the correlation side-lobes lead to coherent stacking of strong events that are not related to true subsurface information.

These experiments lead me to conclude that the strong events revealed by sorting the gathers to CMP coordinates, NMO, and stack are artifices of the coherent noise event generated by a production facility 40 km away from the Valhall array. While there may be subsurface information in the time domain gathers, it is weak and distributed amongst the volume to make it uninterpretable in both the shot domain and the CMP domain. Simple processing with NMO and stack does not reveal subsurface information, but rather coherently preserves an artifact that looks very believable on 2D sections.

REFERENCES

Hohl, D. and A. Mateeva, 2006, Passive seismic reflectivity imaging with ocean-bottom cable data: SEG Technical Program Expanded Abstracts, **25**, no. 1, 1560–1564.