4-C ocean-bottom seismometer data from the 2000 SCREECH Cruise, offshore Newfoundland

Robert R. Stewart, Jessica Jaramillo, and Carlos E. Nieto

ABSTRACT

A set of ocean bottom seismometers/hydrophones (OBS/H) transects was acquired in the summer of 2000 by an international group of institutes including Dalhousie University, Nova Scotia. The four-component (4-C) OBS instruments were deployed in water depths exceeding 4000m. An 8540 cm in. air gun array with the R/V Ewing provided the acoustic source. We have conducted a very preliminary analysis of several 4-C receiver gathers and interpret many of the events as reflections. The stacking velocities of the events on the vertical channel are quite low – around 2.0 km/s. The stacking velocities of events on the horizontal channel are even lower around 1300 m/s. We found an event on the horizontal channel that has many of the characteristics of a P-S wave.

INTRODUCTION

Multicomponent seismic data has produced some very exciting and useful images in the European North Sea. The multicomponent seismic technology of choice in the North Sea has been the ocean-bottom cable (OBC). The geology and seismic imaging problems on the Canadian East Coast bear some similarities to those in the North Sea. But, to our knowledge, there have been no OBC data acquired off the East Coast of Canada. However, there have been some 3-C VSP surveys in various wells in the region. In one case, from the H-20 well in the Whiterose field, offshore Newfoundland, converted-wave (P-S) data give indications of improvement over the conventional P-P data (D. Emery, Husky Energy, personal communication).

There is a great deal of hydrocarbon interest in the offshore regions of Canada including Nova Scotia, British Columbia as well as Newfoundland. Work commitments (for work in the initial 5 years of a 9-year licence) in the latest round of bids for Nova Scotia offshore parcels amounted to over ½ billion dollars (Petroleum Explorer, 2001a). Some bids included acreage in water depths of up to 3000 m. Considerations for hydrocarbon development in offshore British Columbia areas are also underway (Petroleum Explorer, 2001b).

Because of its considerable promise for enhanced seismic imaging, we are anxious to use the OBC method in the East Coast marine environment. To date, though, the method has been too expensive for a trial to take place. The main expense (several million dollars) is the mobilization of equipment from the Gulf of Mexico or the North Sea. So, until a capable vessel of opportunity or a very forward-thinking corporate champion arrives, we cannot directly test the technology. Nonetheless, four-component (4-C) seismic measurements are being made by a consortium of institutions in their study of the Atlantic Continental Margin (Louden and Funck, 2000). The field study under consideration took place in the Newfoundland Basin (Figure 1) from July 14 to August 2, 2000. It was conducted by scientists from Canada (Dalhousie University and Memorial University), Denmark (Danish Lithosphere Center), USA (Woods Hall Oceanographic Institution and University of Wyoming) and supported by R/V Oceanus scientific and technical personnel.

There were a number of objectives to the program including the characterization of the transitional crustal structure of the deep Newfoundland Basin as well as the eastern edge of the adjacent Grand Banks (Louden and Funck, 2000).

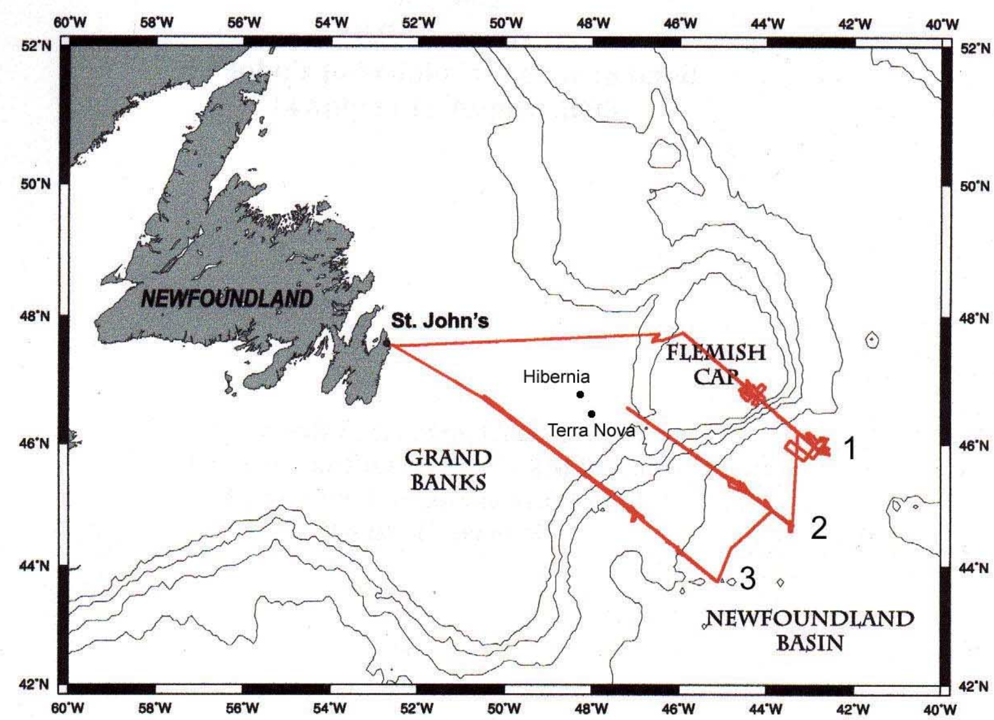

FIG. 1. Cruise location map with the three transects annotated (Louden and Funck, 2000).

To study the characteristics of the Newfoundland margin, they used reflection/refraction seismic experiments that employed arrays of ocean-bottom seismic instruments together with R/V Ewing's large, tuned airgun array and new 6 km long hydrophone streamer. The geology of the area (the Grand Banks and the Northeast Newfoundland Shelf from Laurentian Channel to southern Labrador, and the Flemish Cap) is a region with a series of interconnected Mesozoic sedimentary basins, separated by Precambrian and Paleozoic basement highs (GSC, 2001). It is a region of significant hydrocarbon interest.

EQUIPMENT

The equipment used to acquire the wide-angle data for this program, consisted of 29 ocean-bottom instruments, described as follows:

	Ocean bottom Instrument	OBS #	Deployment Range depth (m)	Comments
RECEIVERS	8 WHOI ORB,	1, 2, 3, 5, 6, 7, 8, 9	127-4738	Recorded a single-component (hydrophone sensor)
	7 WHOI OBH	16, 19, 20, 23, 25, 26, 27	152-4753	
	8 GSCA OBS	1, 2, 3, 4, 5, 6, 7, 8	71-4637	Recorded 4-components (hydrophone and three orthogonal 4.5 Hz geophone sensors)
	6 DAL OBS	A, B, C, D, E, F	72-4750	
SOURCE	R/V Ewing's 20-gun			8540 cubic inch (131 litre) airgun array

Table 1. Ocean-bottom hydrophones and seismometers used in the program.

To deploy this equipment and conduct the seismic survey, the program used two-ships: the R/V Oceanus deployed and recovered the OBS/H, while the R/V Ewing shot into the OBS/H and recorded the multi-channel seismic (MCS) data on its 480-channel, 6-km long streamer. In attempt to use the minimum transit times and maximize the survey time, the program was divided into three transects (Figure 2). We are only consider data from the third transect in this paper.

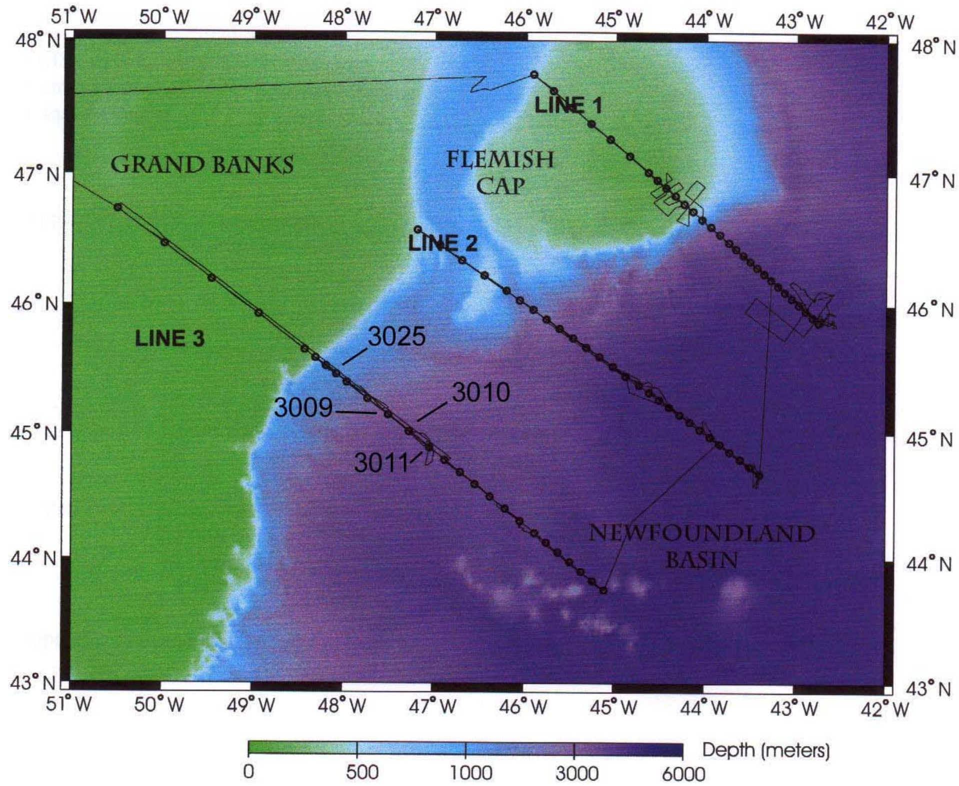

FIG. 2. Location of the seismic lines superimposed on top of the bathymetry map of the surveyed area (Louden and Funck, 2000).

Along each transect, R/V Oceanus deployed the OBS/H instruments and then R/V Ewing shot the transect. Over thinner crust in deep water, the instruments were more closely spaced (typically 9-12 km) and over the thick continental crust of Flemish Cap and the Grand Banks, the instruments were more widely spaced (20-50 km). On each transect, the OBS line was shot at a 200 meter shot spacing to minimize previous-shot noise. After the Ewing shot each OBS line, Oceanus retrieved the instruments and moved on to the next transect while Ewing returned along the transect shooting the MCS line at a 50-meter shot spacing.

R/V Ewing conducted additional MCS surveys along portions of each transect, in part while waiting for Oceanus to redeploy the OBS. These surveys concentrated first on acquiring MCS lines parallel to the main transect, and secondly on obtaining crossing lines. At times when the Oceanus was waiting for Ewing, it conducted heat-flow surveys on or near the main transects, or did magnetometer surveys if weather did not allow it to launch the heat-flow instruments.

	OBS deployed	Performance of data				Comments	Surveys
		Ok	Poor	Lost	No data		
Line 1	29 OBS	24	1	2	2	Loss 2 OBS instruments, recovered 27	12 stations for Magnetometer measurements in the south part of line 1, with two lines across the proposed MO anomaly. Heat flow measurements stand for improvements.
Line 2	27 OBS	24		2	1	3 OBS loss, recovered 24	
Line 3	26 OBS	22		1	2	1 OBH loss, 23 recovered. One of the instruments stopped recording	20 stations for Heat flow measurements along line 3 between OBS sites L3-11 and L3-12

Table 2. Recovered equipment description.

A very preliminary analysis has been made on four receiver gathers on transect 3.

Channel 1 on the four instruments is the hydrophone (Figure 3). Channel 2 is the vertical geophone component (Figure 4). Channel 3 is a horizontal geophone component (Fig. 5). Channel 4 is the other horizontal geophone component (Fig. 6). Basement velocities measured on the central and southeastern Grand Banks are 6000-6600 m/s (Sullivan, 1978). Velodities in the sediments are much less. The receiver at location #3090 appears to have the best signal-to-noise ratio, and the receiver at location #3110 has the worst signal-to-noise ratio.

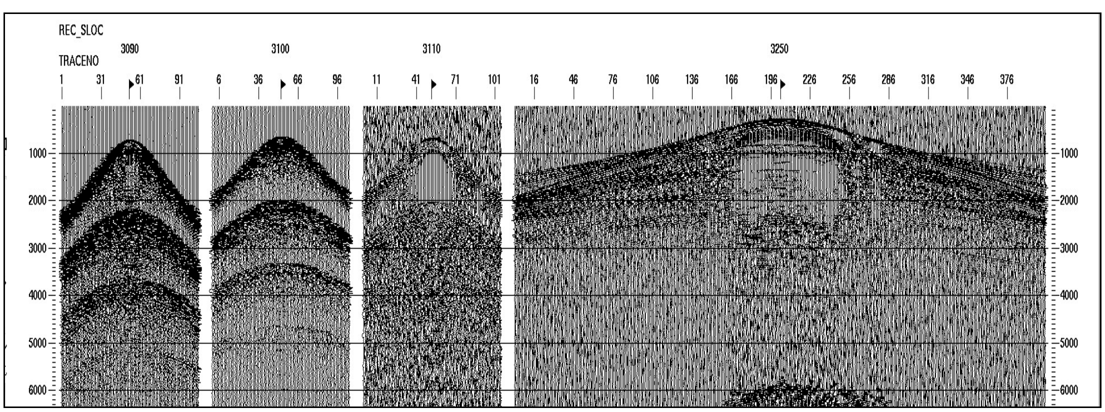

FIG. 3. Common receiver gathers for the hydrophone (pressure sensor), at locations 3090, 3110, 3100 and 3250.

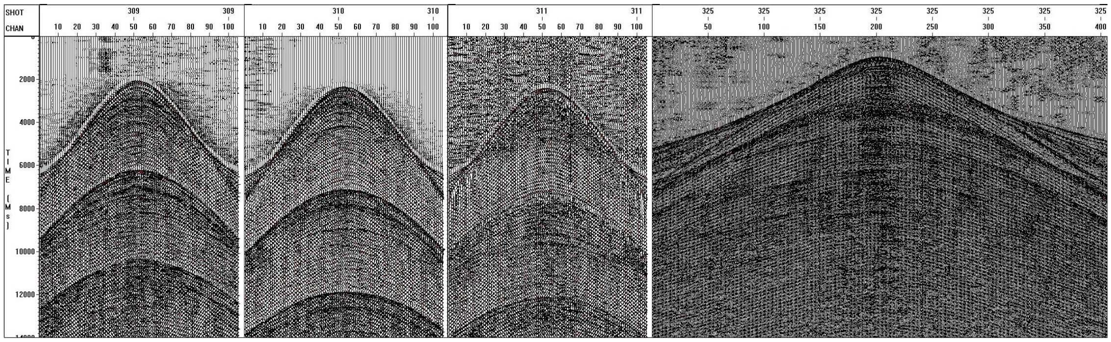

FIG 4. Common receiver gathers of the vertical component (V1), at locations 3090, 3110, 3100 and 3250.

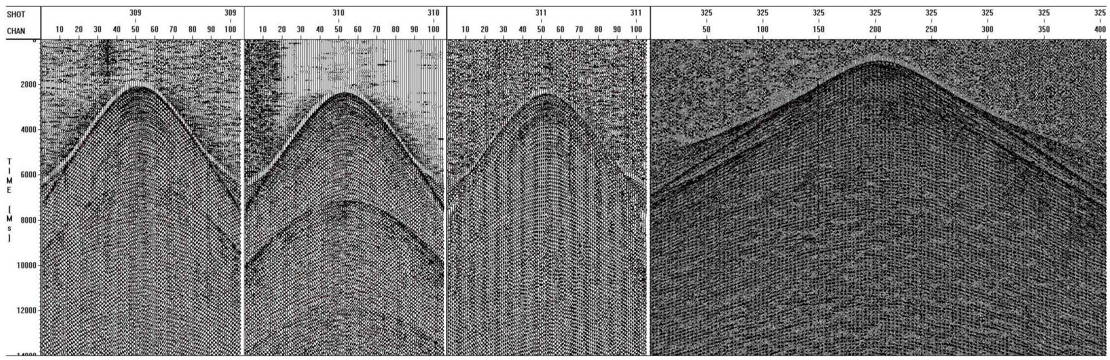

FIG. 5. Horizontal component (H1), receiver gathers for locations 3090, 3110, 3100 and 3250.

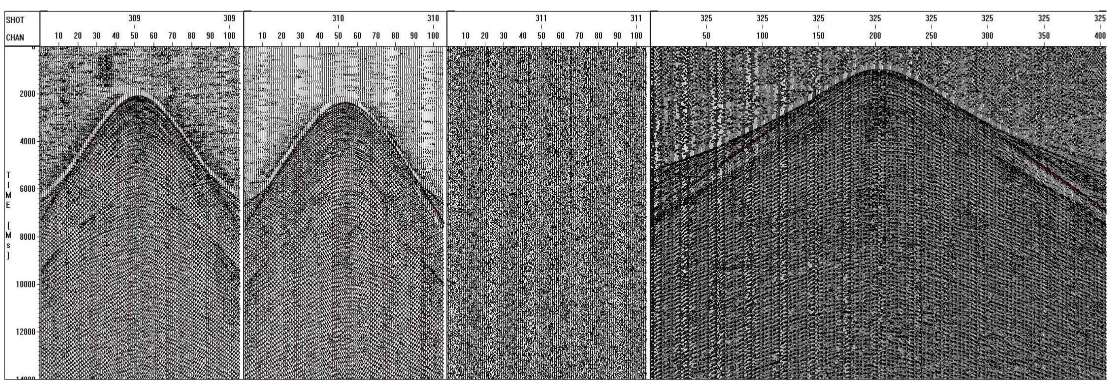

FIG. 6. Horizontal component (H2), receiver gathers for locations 3090, 3110, 3100 and 3250.

VELOCITY ANALYSIS

The receivers under consideration are at depths of about 3 km. Thus, elevation differences between the source behind the vessel and the OBS are considerable. However, Gulati (1998) showed that the standard hyperbolic moveout equation was still valid, with a reinterpretation of the terms, for cases where the shot and receiver were at different elevations. P-wave velocities in the neighbouring Hibernia field range from about 2035 m/s in the Tertiary up to 4320 m/s in the Lower Hibernia (Carter and Lines, 1999). The water layer has a velocity of about 1520 m/s. If we take a sub-seabottom velocity of 2500 m/s for a depth of 2500 m, we find that the RMS velocity, after Gulati (1998), through the water and that layer would be about 2000 m/s. This reflection would arrive at 4.0 s. We note in the velocity analysis of Figure 7, that there appears to be a reflector at 4.0 s with a velocity of about 1950 m/s.

Now, let's perform the same analysis for a P-S event. If we assume that the Vp/Vs = 3.0 for the sub-seabottom layer, then the converted wave event should arrive at 6.0 s. We do note on Figure 8 that there is an event close to 6.0 s. Furthermore, its amplitude builds with offset as we would expect from a P-S wave. Finally, after Gulati (1998), we calculate the converted-wave RMS velocity for an event at 6.0 s and find it to be 1460 m/s. This is close to the stacking velocity of 1490 m/s. This leads to the very exciting possibility that the OBS has recorded a strong converted-wave event.

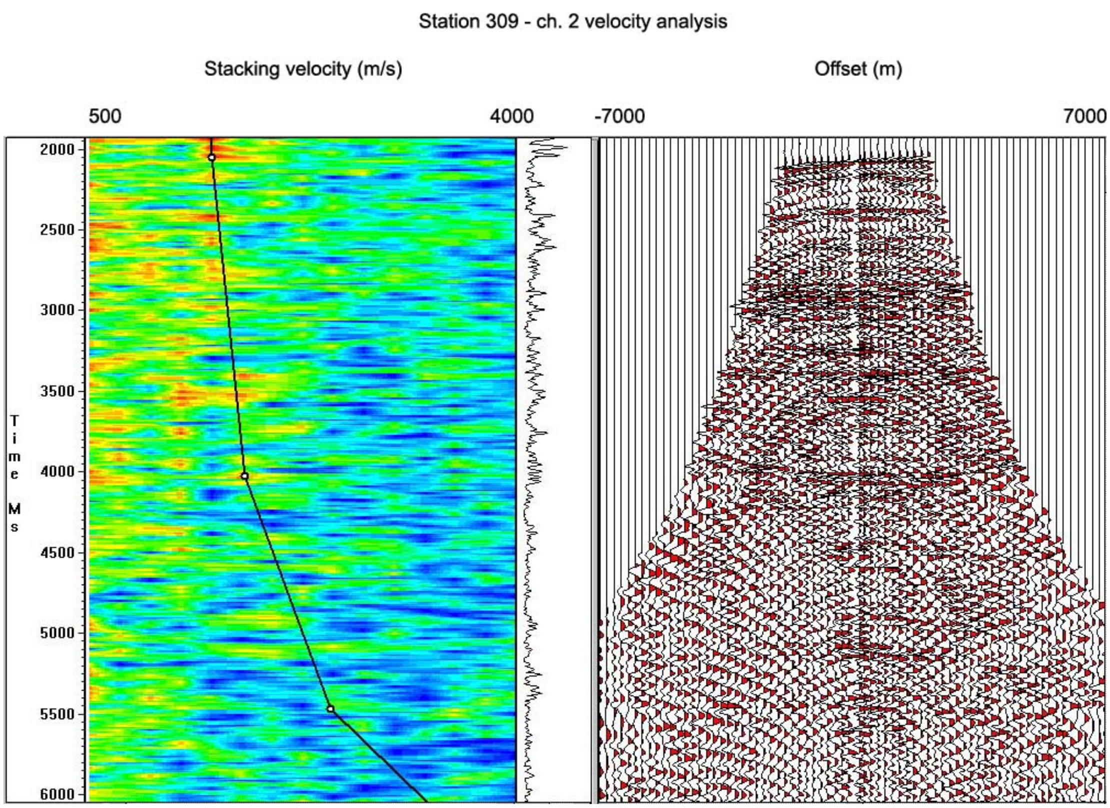

FIG. 7. Velocity analysis for the vertical channel (no. 2) at station 309. We note that the reflector at 4.0 s has a stacking velocity of about 1950 m/s.

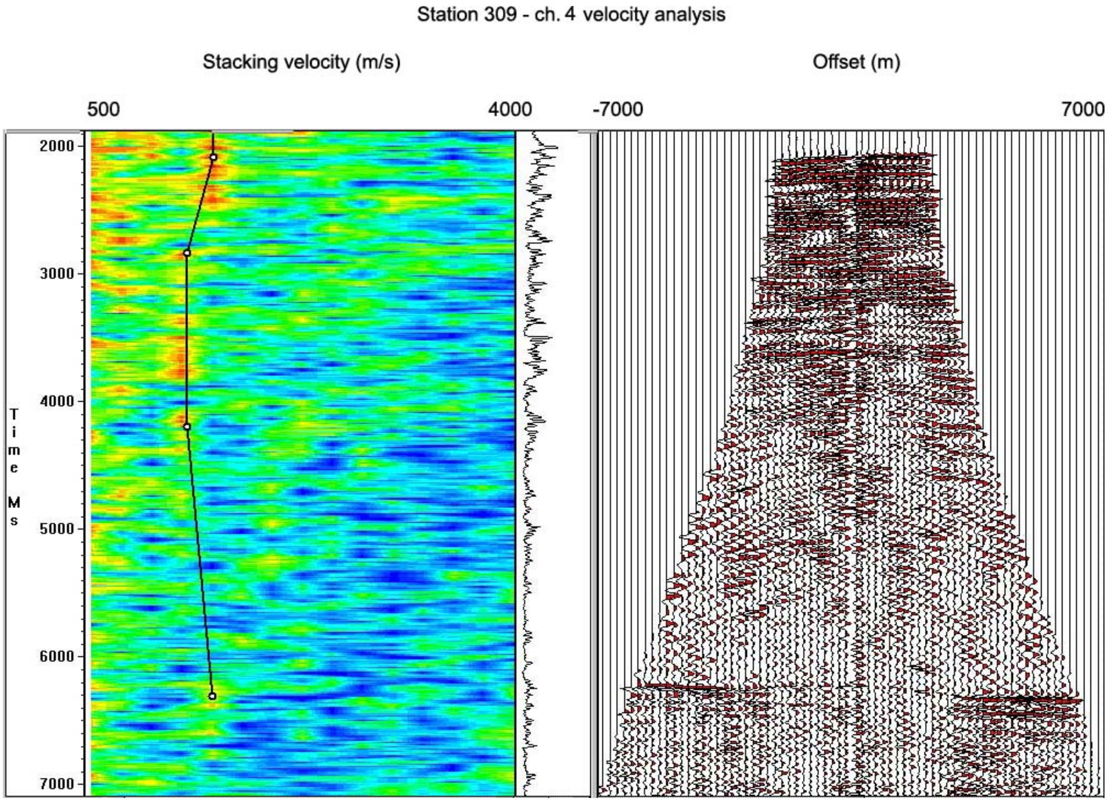

FIG. 8. Velocity analysis for the horizontal channel 4 at station 309. Note the event at just over 6 s that that builds with offset and may correspond to the event at 4 s in Figure 7.

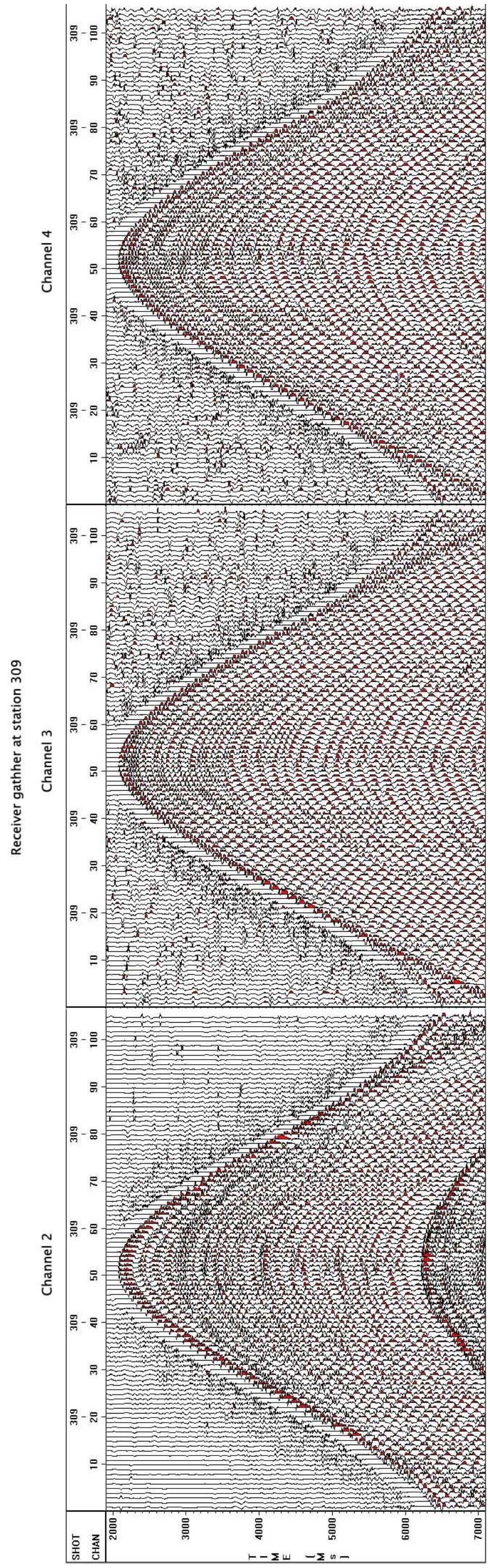

FIG. 9. The vertical and two horizontal channels for receiver 309.

CONCLUSIONS

We are conducting an analysis of data from the 2000 SCREECH marine cruise undertaken, in part, by Dalhousie University. The four-component data show numerous events. Many of these events are likely associated with source-generated noise. However, some others appear to be genuine reflections. One of the horizontal channels analysed shows a coherent event that has many of the characteristics of a converted (P-S) wave. We anticipate processing these data in considerably more detail in the coming months.

ACKNOWLEDGEMENTS

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