Survey design and acquisition of a 4-C ocean-bottom seismometer survey over the White Rose oilfield, offshore Newfoundland

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ABSTRACT

CREWES, in conjunction with Husky Energy and Dalhousie University, has successfully acquired a 4-C seismic survey over the White Rose field, offshore Newfoundland. To our knowledge, this is the first 4-C ocean-bottom seismic reflection survey acquired in Canada.

Twenty-one ocean bottom seismometers (OBS) were deployed at fifty-metre receiver spacing to form a single 2-D receiver line of one kilometre length. The OBS were deployed in about one hour. Twelve eight-kilometre shot lines, at 50 to 200 metre shot line spacing, were acquired parallel to the receiver line at a rate of about 1 line every 75 minutes. All the OBS were recovered over a period of 10.5 hours, and data was successfully recovered from twenty of these. When binned with 25x25-metre bins, twelve CMP stacked sections were obtained, with a maximum fold of twenty-six. Asymptotic binning, assuming a Vp/Vs value of 3.1, resulted in eleven converted wave stacks with a maximum fold of sixty-eight. We plan to return to the White Rose area to acquire a larger survey with upgraded OBS in the spring or summer of 2003.

INTRODUCTION

The White Rose field is located in the Jeanne d'Arc basin, east of St. John's Newfoundland (2002-011 Line 2, Figure 1). Production is from a Cretaceous sandstone (Avalon Formation), at approximately 2.9-kilometre depth (Hoffe et al., 1999). It is difficult to image this reservoir on conventional marine seismic due to the presence of high amplitude water-column and peg-leg multiples, and the presence of gas clouds within the sediments (Hoffe et al., 1999). Multicomponent ocean bottom data may resolve these problems, since dual-sensor summation can be used to reduce the effect of receiver side multiples, and P-S converted waves are generally insensitive to the presence of gas (Hoffe et al., 1999, 2000).

A four-component ocean-bottom-cable (4-C OBC) survey has been proposed for the White Rose field (Hoffe et al., 1999), however, this plan has been put on hold due to the high cost of moving equipment to the study area from the Gulf of Mexico. Fortunately, Dalhousie University and the Geological Survey of Canada (GSC) were planning to acquire a MARIPROBE crustal refraction line (2002-11 Line 1, Figure 1) using four-component ocean bottom seismometers (OBS), and agreed to shoot a second line with much smaller receiver spacing over White Rose (2002-11 Line 2, Figure 1), time permitting. The White Rose survey was successfully completed over the course of three days in May of 2002.

EQUIPMENT AND ACQUISITION

Description of equipment

Ocean bottom seismometer surveys can be acquired from any ship that has a flat deck, a crane, and towing capabilities. In this case, the offshore research and survey vessel CCGS Hudson was used (Figure 2). The source for this survey was a 1986 cubic inch five air-gun array (owned by the GSC) towed 25 metres behind the CCGS Hudson and 7.5 metres below the ocean surface (Jackson et al., 2002). A shot every 30 seconds at a speed of 3.5 knots gives a shot spacing of roughly 50 metres (Jackson et al., 2002).

Twenty-one ocean bottom seismometers (10 owned by the GSC, 11 by Dalhousie University; Figure 3) were used. Each OBS carries a hydrophone and an oil-filled three component geophone package (Dalhousie Seismic Group, 2002). These autonomous units are attached to steel weights with rope, and dropped into the water to sink to the sea floor. Accuracy of positioning depends on water depth and local currents. The maximum operational depth of these instruments is six kilometres, but was closer to 120 metres for the White Rose survey. Digitized data are stored as 2 Mb files on a 1 Gb hard-drive, so data is not lost in the event of battery failure. Pre-processing is required to combine these files, and to convert continuous seismic recordings to individual SEG-Y shot records. Data can be recorded continuously for up to nine days, depending on the sample rate and dynamic range (12 or 16 bit) chosen (Dalhousie Seismic Group, 2002). When the survey is complete, the OBS are signalled to detach from the weights, and float to the surface where they can be recovered. Failing this, the OBS will detach from the weights at a preset time. During this cruise, the OBS were deployed twice for two separate surveys, with a 100% recovery rate.

Description of survey

Due to time limitations, it was decided to shoot a 2-D seismic line centred on Husky Energy's L-08 well. A receiver line consisting of twenty-one ocean bottom seismometers was laid out over one kilometre at fifty-metre receiver spacing as planned (Figures 4 and 5). This operation took about one hour. In contrast, retrieval took around ten and a half hours. Data was successfully downloaded from twenty of the twenty-one OBS.

Since the target is at about three kilometres depth, the initial shot line should extend at least this distance to either side of the receiver line. In this survey, an 8-kilometre shot line at 50-metre shot spacing provides 3.5-kilometre source-receiver offsets either side of the receiver line (Figures 4 and 6). Four short (1.5 km long) source lines at 50-metre shot line spacing were to be acquired parallel to the receiver line, followed by as many eight kilometre-long shot lines at 200-metre shot line spacing as possible (Figure 4).

A total of twelve eight-kilometre shot lines were acquired in a spiral pattern starting above the OBS positions at a rate of one line every 75 minutes. Twenty-one shot lines were planned, but production was halted early due to ship problems (Jackson et al., 2002). Shot line spacing varied from 50 to 200 metres, resulting in the midpoint distribution shown in Figure 6. P-P CMP and P-S asymptotic binning at Vp/Vs=3.1 with 25x25-metre bins gives the fold distributions shown in Figure 7. The data are being processed by personnel at Dalhousie University, Sensor Geophysical and CREWES.

FUTURE WORK

Although the survey was successful, some problems exist with the data. Specifically, the OBS are designed for wide angle crustal refraction work where high frequencies are not expected. Thus, the presence of built-in 30-Hz lowpass filters, which were accidentally not turned off on all of the instruments prior to acquisition of the White Rose survey. Also, high amplitudes were clipped, possibly due to insufficient dynamic range in the A/D converters.

We hope to return to the White Rose area with upgraded equipment and more ship time in order to acquire a larger survey in the spring/summer of 2003. The P-P and P-S (asymptotic) fold distribution modelled for the 2002 survey assuming twenty-one shot lines had been possible is shown in the left column of Figure 8. It is known that this survey could have been acquired in three days, so N equivalent surveys will take 3N days to complete. The right-hand column shows a similar survey, but with sixty-three receiver locations forming a three-kilometre-long receiver line. If limited to twenty-one OBS, this survey could be achieved by deploying the OBS three times and repeating the shot line pattern. Another option would be to lay out the receiver lines parallel to each other, at some offset determined by the expected P-S fold coverage. Yet another would be to acquire additional surveys at right angles to the original.

Alternatively, the OBS could be positioned to form a 3-D receiver patch of four receiver lines with five OBS in each (Figure 9). At a receiver spacing of 250 metres and a receiver line spacing of 200 metres, an area of 1000x800 metres of sea floor can be covered. Twenty-one eight kilometre shot lines are used in this design, ten at 200-metre shot line spacing, and eleven at 100-metre spacing, 100 metres from the receiver lines.

Since this has the same number of shots over the same area as the 2-D survey, we expect this survey could be acquired in three days.

This survey could be repeated a number of ways, possibly in combination with the 2D design. Figure 10 shows the result of repeating the receiver layout in a zig-zag fashion, such that top corner of the receiver patch becomes the location of the opposite bottom corner upon repetition. The shot pattern remains centred over the receivers for this figure.

ACKNOWLEDGEMENTS

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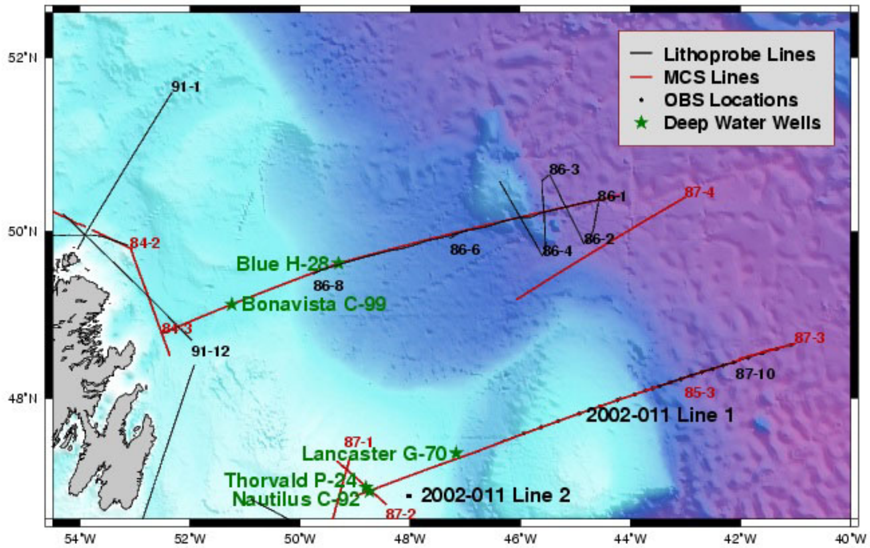

FIG. 1. Map of survey area (Dalhousie Seismic Group, 2002). 2002-011 Line 1 is a MARIPROBE crustal refraction line, which was acquired prior to 2002-011 Line 2 (this paper).

FIG. 2. Offshore research and survey vessel CCGS Hudson towing an air-gun array (Photo courtesy of Dr. Keith Louden).

FIG. 3. Ocean bottom seismometer. (Dalhousie Seismic Group, 2002)

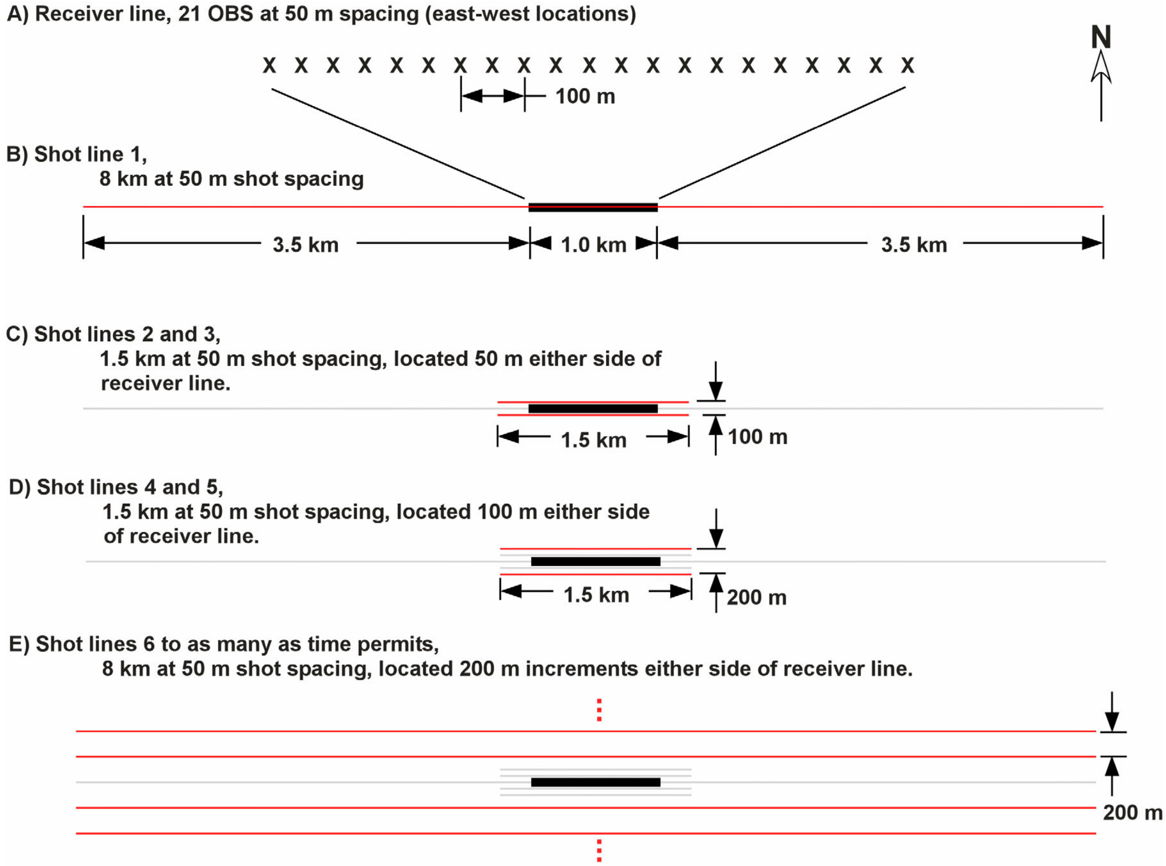

FIG. 4. Proposed geometry for White Rose OBS survey. This set of figures was sent to Dr. Keith Louden just before sailing, and appeared in the May/June 2002 issue of CREWES News.

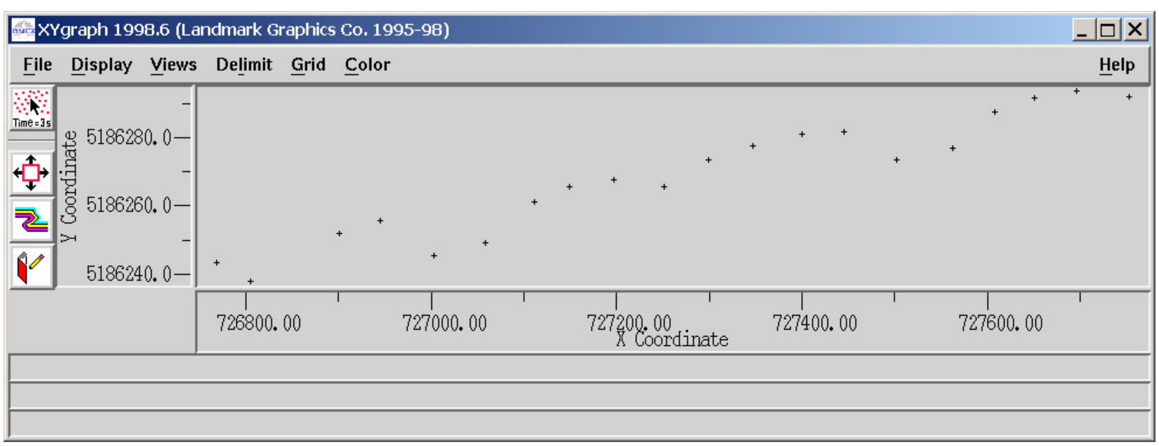

FIG. 5. Actual receiver locations for White Rose 2002 (vertically exaggerated). Twenty-one OBS were deployed; data was recovered from twenty of these (compare with Figure 4A).

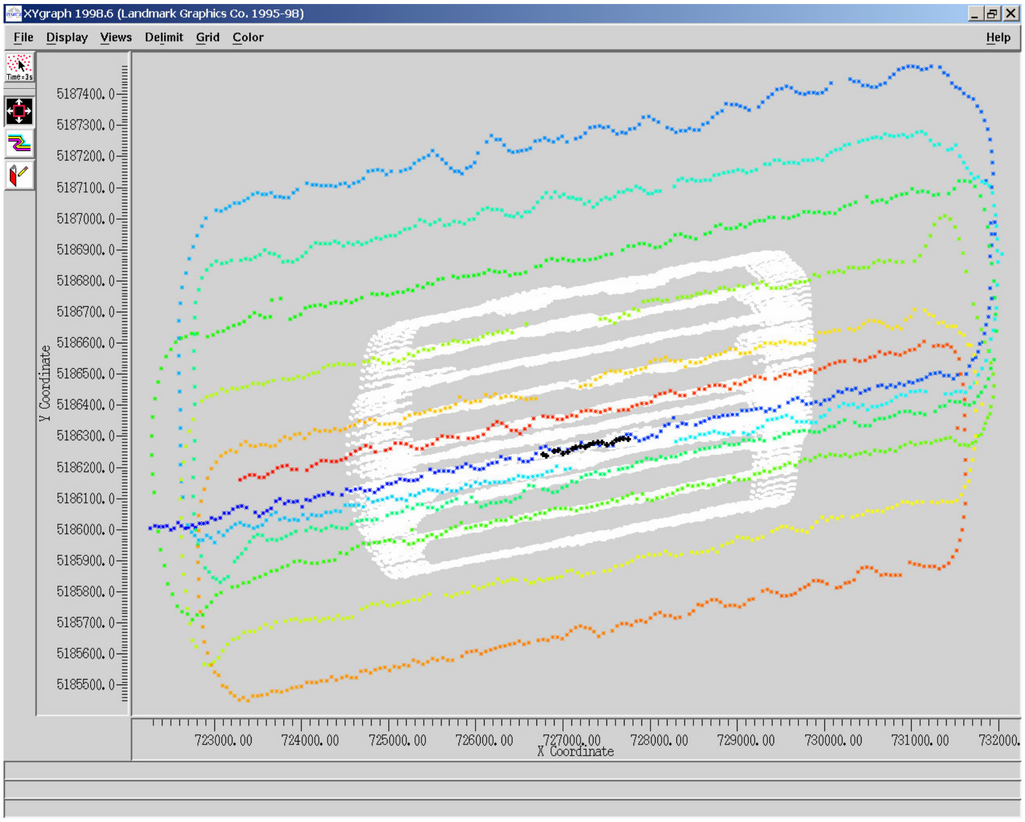

FIG. 6. Source, receiver and midpoint locations for White Rose 2002 (vertically exaggerated). Sequential shot points are colour coded from blue to red; Receiver locations are shown in black, midpoints in white (compare with Figure 4).

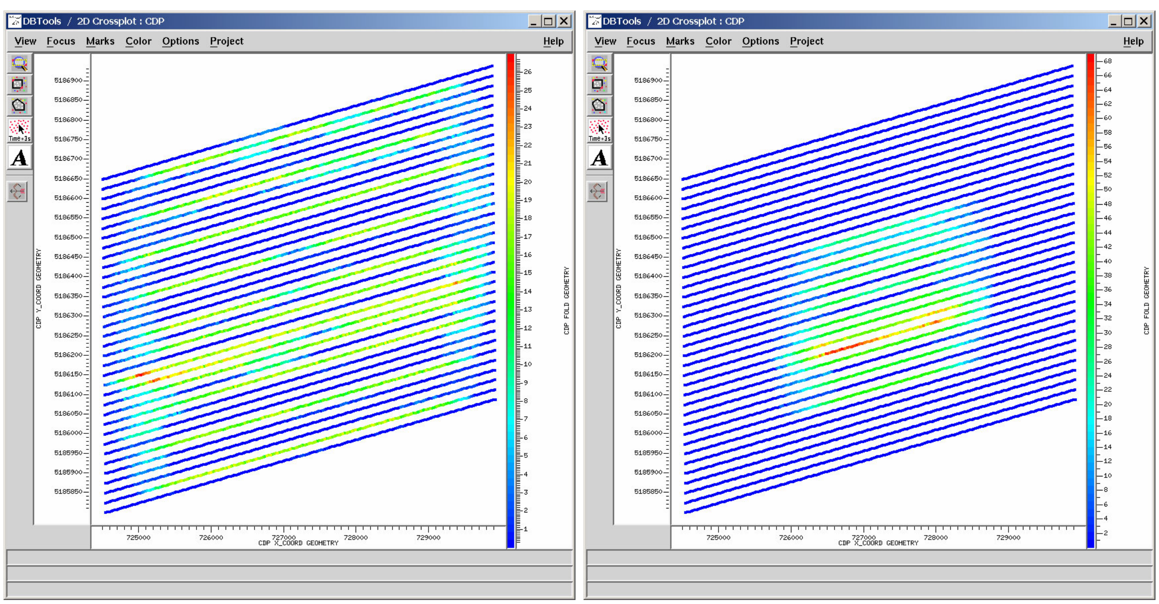

FIG. 7. Comparison of P-P (maximum fold is 26, left) and P-S asymptotic binning assuming Vp/Vs is 3.1 (maximum fold is 68, right) for 25x25 m bins (vertically exaggerated). Fold varies from blue (zero fold) to red (maximum fold).

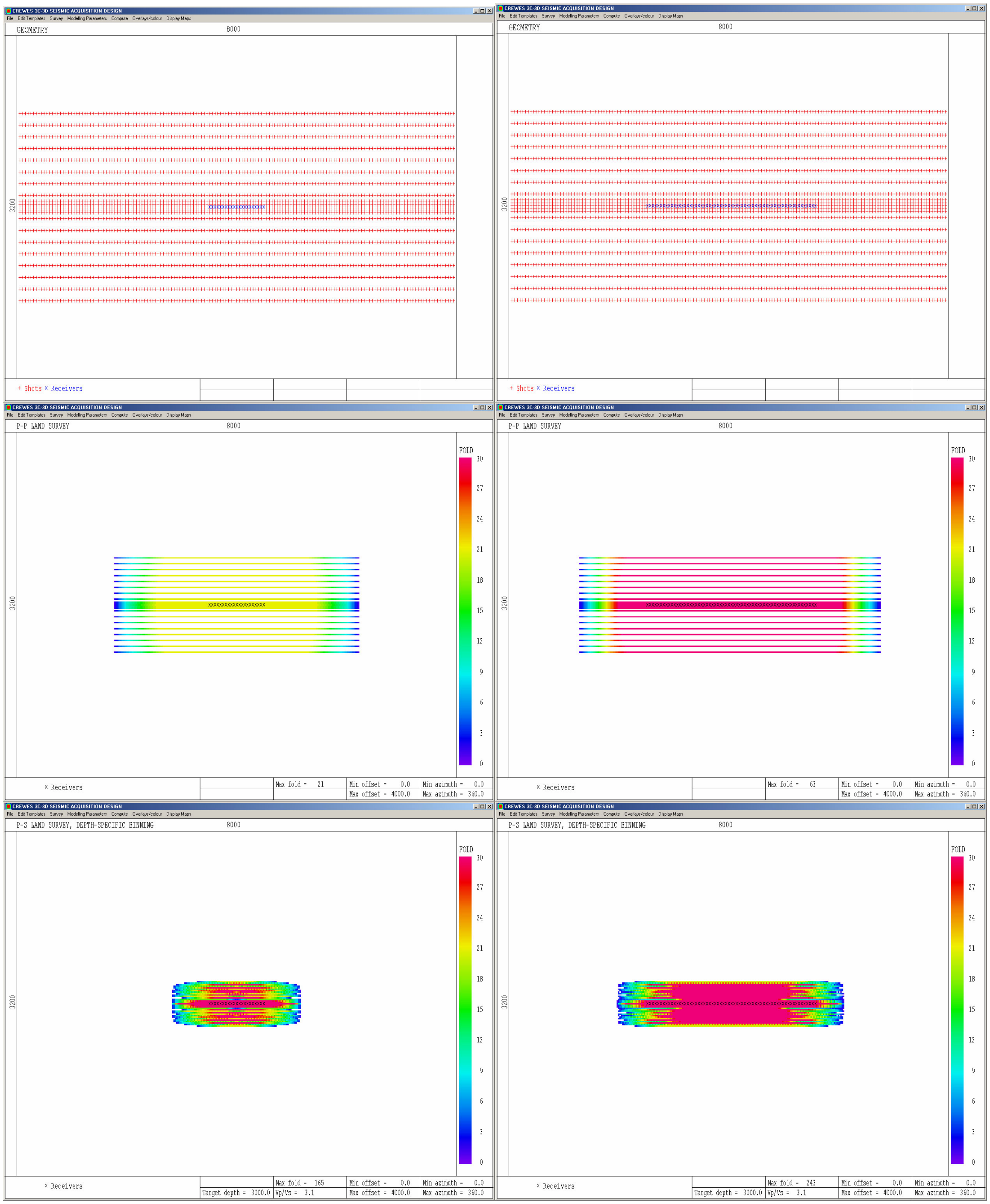

FIG. 8. Comparison of 25x25 metre bins for P-P (middle row), and P-S depth specific (Vp/Vs=3.1; bottom row) binning for the survey geometry shown (red=shots, blue=receivers; top row). The left column represents White Rose 2002 if twenty-one shot lines had been acquired. The right column shows the result of having a three kilometre receiver line (sixty-three OBS, or three deployments of twenty-one OBS). Thirty fold or greater is represented by red on the fold maps. Source-receiver offsets are limited to four kilometres.

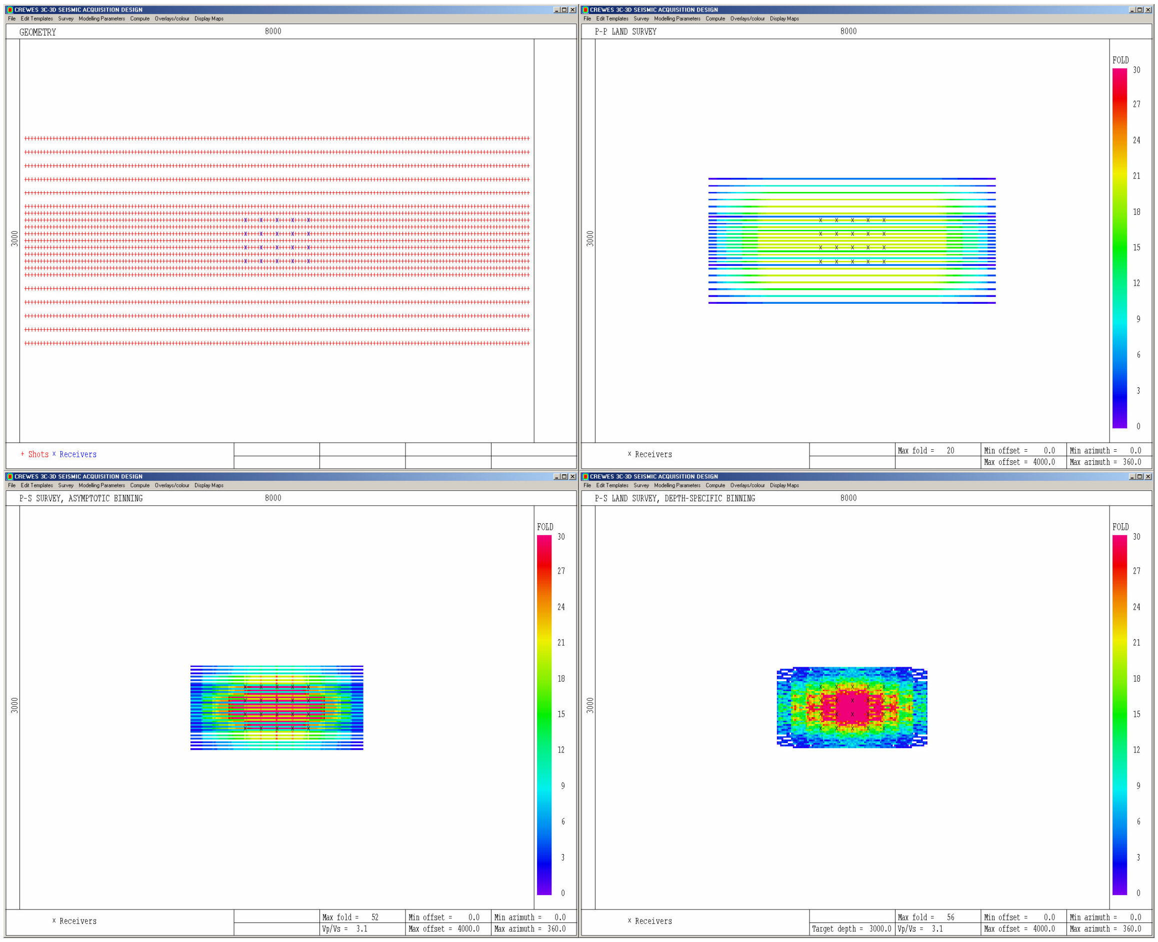

FIG. 9. Proposed 3-D receiver layout (top left, receivers in blue, shots in red), and resulting fold for 25x25 metre bins. Top right is P-P CMP binning bottom left is P-S asymptotic binning (Vp/Vs=3.1), and bottom right is P-S depth specific binning (Vp/Vs=3.1, target depth =3.0 kilometres). Thirty fold or greater is represented by red on the fold maps. Source-receiver offsets are limited to four kilometres.

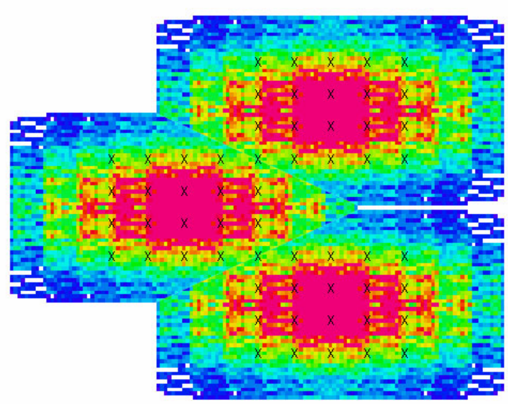

FIG. 10. Depth specific fold map resulting from repeating the survey shown in Figure 9 three times. The fold where the three surveys overlap is lower than it should be, due to the manner in which this figure was constructed.