Design specifications for a 4-C ocean bottom sensor (OBS) survey at White Rose field, offshore Newfoundland

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ABSTRACT

The CREWES project has been collaborating with Dalhousie University in acquiring ocean-bottom seismic data on the eastern Coast of Canada. In addition, we have been investigating the possibility of a multicomponent survey with Husky Energy over the White Rose field in the Jeanne d'Arc basin, offshore Newfoundland. It may be possible to acquire OBS data in conjunction with Dalhousie University in a proposed summer 2002 cruise offshore Newfoundland. To this end, we are beginning to design possible surveys. A 2-D survey with twenty-five metre shot spacing and two hundred metre receiver spacing could be acquired in less than four hours. A bin size equal to one-eighth the source spacing (twenty-five metres) results in a maximum P-P fold of 35, and P-S depth-specific fold of 31.

A 3D design consisting of twenty ocean bottom sensors at one kilometre spacing (twelve square kilometre patch), centred in a forty-two square kilometre patch of source lines (nine seven kilometre long source lines at zero degrees azimuth and nine six kilometre long source lines at ninety degrees azimuth) is preferred. This design results in a maximum P-P fold of ninety and P-S depth specific fold of seventy-two, for a one hundred and twenty-five metre bin size (one-eighth the receiver spacing).

INTRODUCTION

The White Rose field is located in the Grand Banks, east of St. John's Newfoundland. Production is from a Cretaceous sandstone (Avalon Formation), at approximately 2.9 km depth. The P-P seismic reflection character of this reservoir can be compromised, due to 1) low acoustic impedance between the reservoir sandstone and overlying shales (Nautilus Formation), 2) high amplitude water-column multiples and peg-leg multiples, and 3) the presence of gas clouds within the Cretaceous and Tertiary sediments (Hoffe et. al, 1999).

A four-component ocean bottom cable (4-C OBC) survey has been proposed for the White Rose field (Hoffe et. al, 1999), with the objective of improved imaging of the reservoir with converted wave (P-S) data. The four components are x, y, z (geophones), and pressure (hydrophone). Better resolution in comparison with streamer data may be expected because, 1) the receivers are on the ocean floor, 2) water-column multiples can be suppressed by summing the geophone and hydrophone data, and 3) sediments can often be better imaged in the presence of gas by converted-wave data (Hoffe et al., 1999). These arguments also apply to a four-component ocean bottom sensor (4C OBS) survey over the field. A successful OBS survey will provide additional support for the proposed OBC survey.

SURVEY CONSTRAINTS

For the proposed survey, twenty-one ocean bottom sensors (OBSs) and two days (twenty hours) of ship time are assumed to be available. The ship is capable of 6 km/h towing an air-gun array. For a shot every 50 m, this implies a maximum source line length of 120 km or 2400 shots (Table 1).

A 4C-2D survey is expected to illuminate a target at three kilometres depth over a length of four kilometres at a minimum of twenty fold. A 4C-3D survey should do the same for at least a nine square kilometre area. Since the number of available receivers is limited, the receiver interval will have to be quite large in order to image targets of this area and depth.

It is known from earlier surveys that source-receiver offsets greater than about 2500 metres are not useable (Hoffe et. al, 1999). For this study, offsets will be limited to an optimistic 3000 metres. The water column at White Rose is about 120 metres deep (Hoffe et. al, 1999), and this is taken into account for both P-P and P-S binning. Since the P-P image of the target reservoir is not expected to be excellent, we will concentrate on optimizing the design for P-S binning.

Table 1. Source, receiver and time constraints

Constraint	Value
Ship time	20 hours
Ship speed	6 km/hour
Total source line length	120 km
Source interval	50 m (assumed)
Maximum number of shots	2400
Maximum number of OBS	21

4C-2D design

At a spacing of 200 m, 21 OBSs can be laid out over 4.2 km of sea floor. If the source line is extended an additional 3.0 km at each end, a 2D line of 10.2 kilometres length results, well within the total source line length (Table 1). If the line is shot twice to achieve a shot spacing of 25 m, the total source line length will be 20.4 kilometres. At 6 km/h, this survey can be acquired in 3.4 hours.

Figure 1 shows the effect of bin size on P-S depth specific fold. The natural bin size of 100 m (half the receiver spacing) results in high consistent fold. Decreasing bin size results in lower fold and the appearance of high frequency fold variations from trace to trace. The best compromise between fold and lateral resolution is a bin size equal to one-eighth the receiver spacing (25 m). The maximum fold will be 31 for P-S depth specific binning (Figure 1), and 35 for P-P OBC binning (not shown).

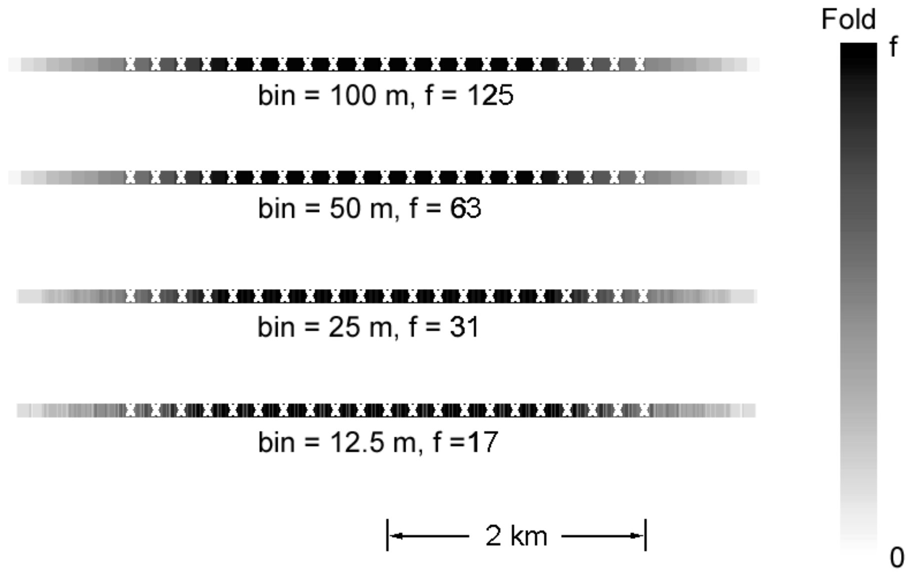

FIG. 1. Effect of bin size on P-S depth specific fold for 2D design with shots every 25 m (shots not shown), receivers every 200 m (white X's). Parameters: 120 m water column, Vp/Vs of 2.0, Source-receiver offsets limited to 3000 m. **f** is maximum fold.

4C-3D designs

Twenty OBSs at a receiver interval of one kilometre can be laid out over 4x3 = 12 square kilometres of sea floor (White X's, Figures 2 and 3). If source lines extend 1.5 kilometres beyond the receivers (compare with OBC survey design of Hoffe et al., 1999), the area of the resulting survey will be 7x6 = 42 square kilometres. Allowing source lines at 0 and 90 degrees azimuth, the number of shot lines in one direction (m in Equation 1) depends on the number of shot lines in the other direction (n).

$$7m + 6n <= 120 \tag{1}$$

If all shot lines are perpendicular to the receiver lines, m=0 and n = 20, and the total source line length is 120 kilometres. A source line spacing of 350 m results in a survey area of 6x6.65 square kilometres. This will be referred to as Design 1 (Figure 2). For m = n = 9, a total source line length of 117 kilometres results. With a source line spacing of 500 metres, and a line on every receiver station and half-station, a survey area of 6x7 square kilometres is obtained. This will be referred to as Design 2 (Figure 3).

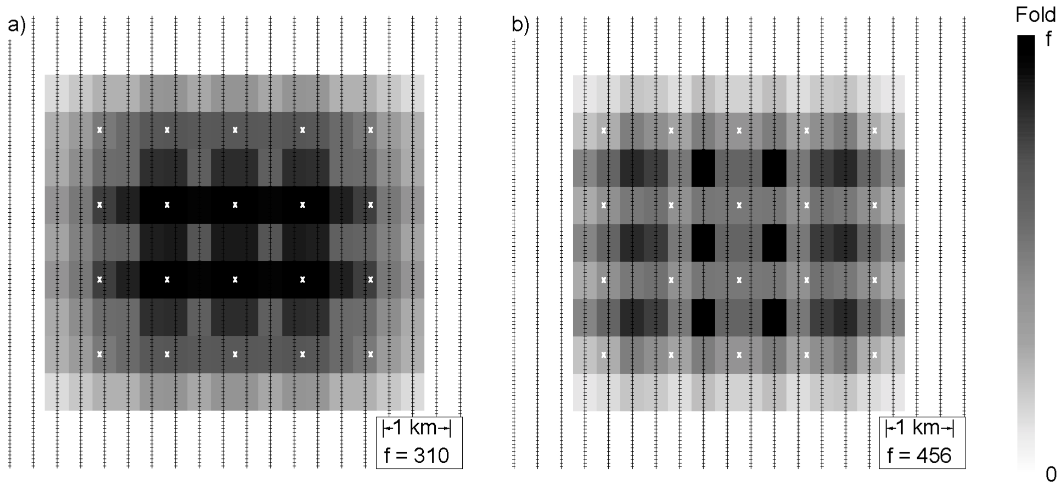

FIG. 2. Design 1. Shot interval is 50 m, receiver interval is 1000 m, water column is 120 m, target depth is 3000 m, source-receiver offsets are limited to 3000 m, and bin widths are 350x500 metres (source line spacing by half receiver spacing). Figure 2a) P-P fold. Figure 2b) P-S depth specific fold for Vp/Vs of 2.0.

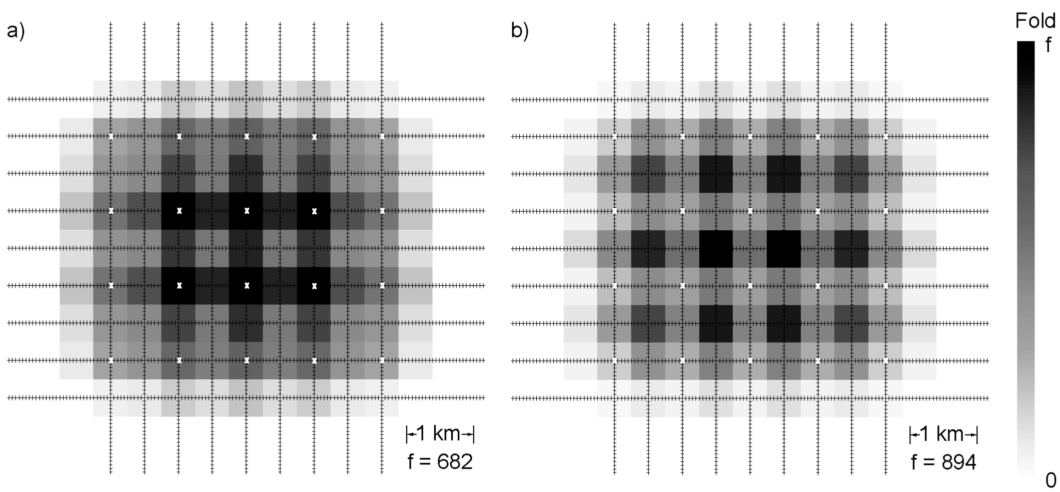

FIG. 3. Design 2. Shot interval is 50 m, receiver interval is 1000 m, water column is 120 m, target depth is 3000 m, source-receiver offsets are limited to 3000 m, and bin widths are 500x500 metres (source line spacing by half receiver spacing). Figure 3a) P-P fold. Figure 3b) P-S depth specific fold for Vp/Vs of 2.0.

A comparison of fold versus decreasing bin size is shown in Figure 4. The effect of decreasing bin size is 1) decreased fold, 2) reduced coverage, but 3) improved lateral resolution. At the smallest bin size tested, Design 1 results in discontinuous fold coverage with zero-azimuth zero-fold trends (Figure 4). Design 2 is preferred for small bin sizes, since it results in better continuity across (ninety degrees azimuth) the volume (Figure 4). The smallest bin size that results in continuous fold coverage for Design 2 is 125x125 square metres, or one-eighth the receiver spacing (Figure 4d).

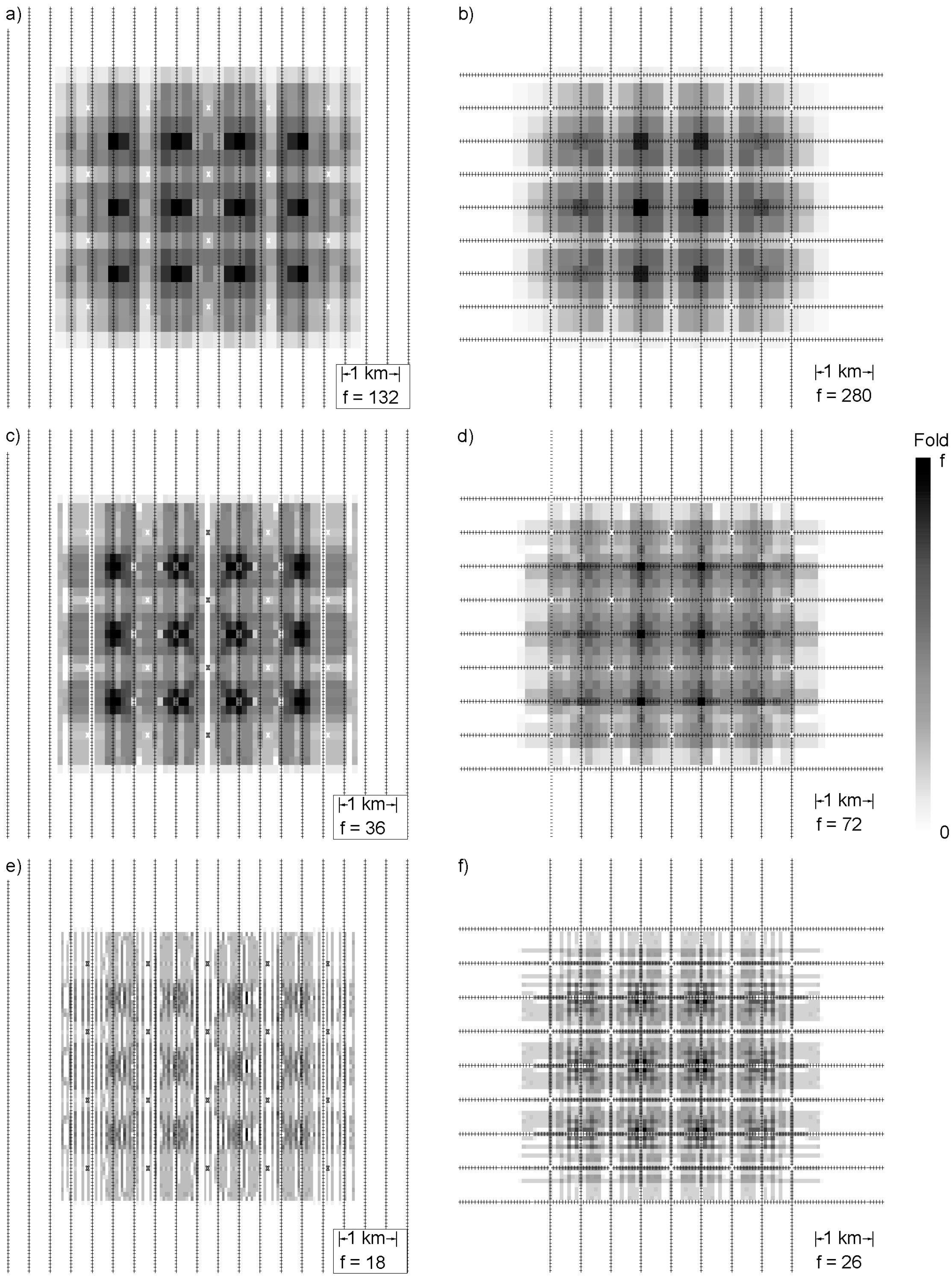

FIG. 4. Effect of decreasing bin size. Figures 4a (175x250 m^2), 4c (87.5x125 m^2) and 4e (43.25x62.5 m^2) show P-S depth specific fold for Design 1 (compare with Figure 2b). Figures 4b (250x250 m^2), 4d (125x125 m^2) and 4f (62.5x62.5 m^2) show P-S depth specific fold for Design 2 (compare with Figure 3b).

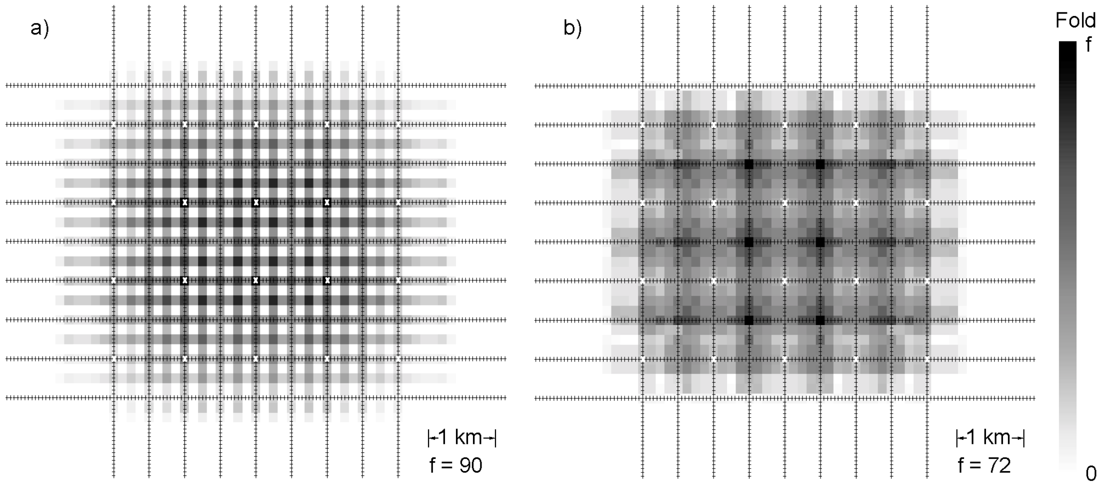

FIG. 5. Comparison of P-P (Figure 5a) and P-S fold (Figure 5b is same as Figure 4d) for Design 2 with 125 metre bins. Compare with Figure 3.

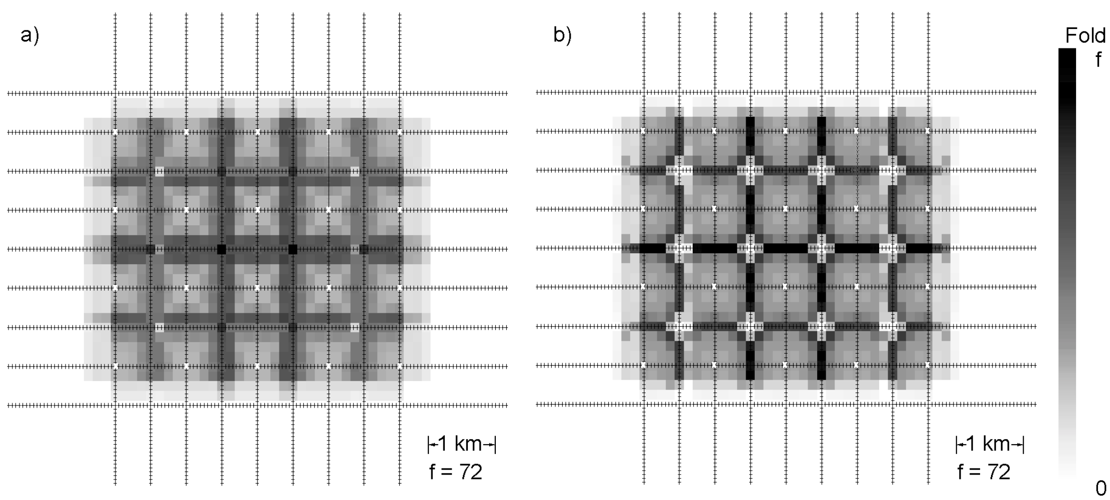

FIG. 6. Effect of increasing Vp/Vs for Design 2 with 125 m bins. Vp/Vs = 2.0 (Figure 5b), Vp/Vs = 2.5 (Figure 6a). Vp/Vs = 3.0 (figure 6b).

Figure 5 shows a comparison of the P-P and P-S depth specific fold coverage for Design 2 with 125 metre bins. The P-P coverage will consist of seventeen in-lines and seventeen cross-lines of up to 90 fold. This will be easily comparable to the processed P-S volume.

Up to this point, a Vp/Vs of 2.0 has been assumed. In marine environments this ratio could be as high as 3.0 or more. The effect of increasing Vp/Vs on Design 2 is to move the depth specific conversion points (DSCP) away from the receivers (Figure 6). At a Vp/Vs of 3.0, this results in high fold concentrated on the source lines positioned halfway between the OBSs (Figure 6b)

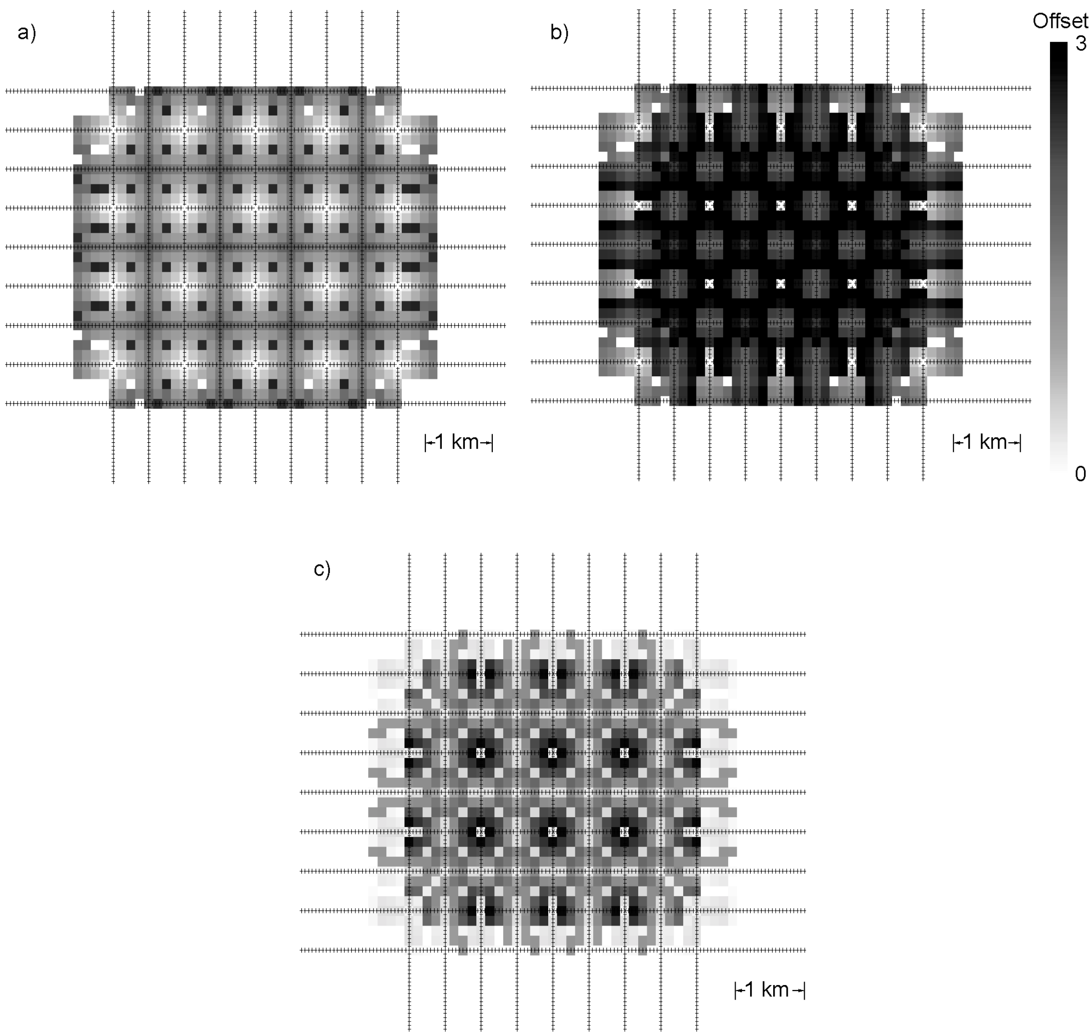

FIG. 7. Near offsets (Figure 7a), Far offsets (Figure 7b) and Offset Range (Figure 7c) for Design 2 with a 125 m bin size, P-S depth specific binning for Vp/Vs = 2.0.

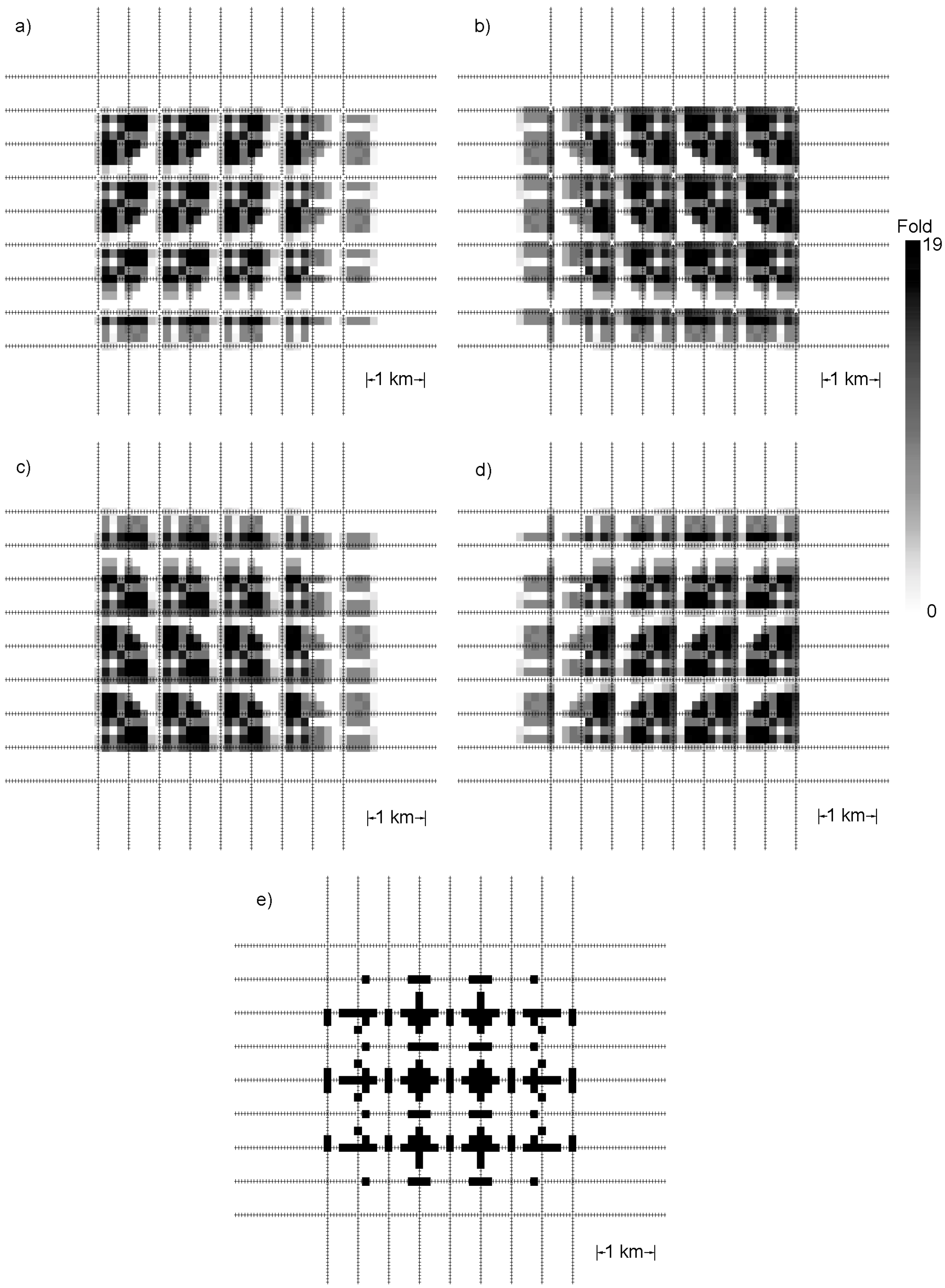

FIG. 8. P-S azimuth distribution for Design 2 with a 125 m bin size. Figure 8b) 0-90 degrees, Figure 8d) 91-180 degrees, Figure 8c) 181-270 degrees, and Figure 8a) 271-360 degrees. Figure 8e) shows bins with full azimuth range (intersection of Figures 8a-8d).

Figure 7 shows the near and far offsets in each bin for P-S depth specific binning. As expected, zero offsets are concentrated around the OBSs, with the largest near offsets in bins halfway between receivers (Figure 7a). Bins with the best-offset range for velocity analysis are positioned around the OBSs, one or two bins away (Figure 7c). A good range of azimuths will be present (Figure 8), including a fair number of bins between OBS locations containing a full range of azimuths (Figure 8e), possibly enough for azimuth dependant studies.

DISCUSSION

2D-4C and 3D-4C surveys have been designed given the constraints of twenty-one ocean bottom sensors and 120 kilometres total source line length. A 2D survey with receivers every 200 metres centred on a 10.2 kilometre source line with shots every 25 metres and a bin size of 25 metres can be acquired in less than four hours. This design results in a 35 fold (maximum) P-P stack, and 31 fold (maximum) P-S depth specific stack, taking into account a water depth of 120 metres, a target depth of 3000 metres, and assuming that Vp/Vs is 2.0.

We would prefer to acquire a 3D-4C survey. The preferred design for this is twenty ocean bottom sensors at one kilometre spacing (12 km^2 patch), centred in 42 km^2 of source lines (nine 7 km long source lines perpendicular to the receiver lines, and nine 6 km long source lines parallel to the receivers). This design results in a 90 fold (maximum) P-P volume, and 72 fold (maximum) P-S volume for 125x125 m^2 bins. The total source line length for this design in 117 km, which is 3 km less than the total allowed. However, the design will have to be modified if the 120 km must include any extra distance travelled by the ship between source lines.

ACKNOWLEDGMENTS

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