Binning considerations for a sparse 4C-3D seismic geometry

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ABSTRACT

We consider a generic 4C-2D geometry that consists of two parallel ocean bottom cables (OBCs) 2.5 km apart. These cables can be shot in-line and processed as separate 2D lines. If additional source lines are added perpendicular to the OBCs, a 3D survey can be acquired. However, due to the distance between the cables, a substantial zero-fold area will be present between the receivers if depth specific converted wave binning is used. The preferred way to improve this geometry is the addition of a third OBC. If this is not possible, 3D binning results in additional high-fold 2D lines, which may be a desirable addition for interpretation purposes. However, comparison between additional P-P and P-S lines gained in this manner will be difficult, since they will not be spatially coincident.

SURVEY DESCRIPTION

We consider a generic sparse survey design (Figure 1) together with P-P and P-S (depth specific) fold coverages derived for a target at three kilometers depth, using Don Lawton's Design 3C-3D software. Parameters used for the modeling process are shown in Table 1.

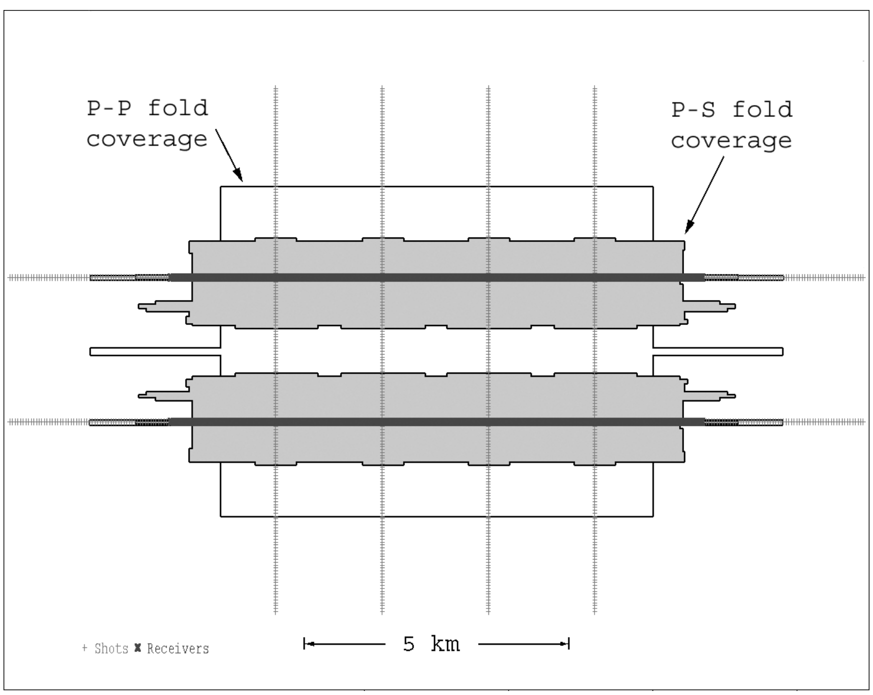

FIG. 1. Geometry of the 3D survey. The P-P fold coverage takes into account a 100 m water column (compare with Figure 2). The P-S fold coverage shown is for depth specific binning for a target at 3 km depth, 100 m water column, and a Vp/Vs of 3.0 (Compare with Figure 3c).

Table 1: 4C-3D survey parameters

Parameter	Value
Receiver interval	50 m
Receiver line spacing	2500 m
Receivers per line	201
Source interval	50 m on the half station
Source line spacing 1	2500 m, azimuth 90
Shots per line 1	322, azimuth 90
Source line spacing 2	2000 m, azimuth 0
Shots per line 2	182, azimuth 0
Water depth	100 m

FOLD MAPS (P-P OBC, P-S DEPTH-SPECIFIC OBC)

For a target at two kilometers depth, P-P OBC binning at the natural bin size of twenty-five by twenty-five meters and no limit on offsets, results in an area of approximately two kilometers by two and a half kilometers at nine fold, roughly half what is required. Also, there are nine cross-lines (perpendicular to the cables) that consist of entirely empty bins (Figure 2a). If the bin size is doubled, the fold can be increased to better than thirty fold over the same area (Figure 2b). Realistically, it must be assumed that not all offsets will be useable when processing. Limiting the maximum offset to five kilometers results in a decrease in fold, but a respectable coverage of fifteen fold or greater over an area of size by two and half kilometers (Figure 2e). Increasing the target depth to 3 km does not significantly change this result (Figure 2g). Note the presence of low-fold cross-lines and high-fold in-lines within the fold coverage. This effect is most prominent halfway between the receiver lines and parallel to them, where it will be possible to process two additional adjacent high fold lines (up to about 212 maximum fold).

Depth specific binning provides better sub-surface images from P-S data than asymptotic binning (Lawton and Hoffe, 1999), For this geometry, depth specific binning for a target at two kilometers depth results in two symmetric 3D volumes, separated by zero-fold bins parallel to the OBCs (Figure 2b). In comparison with the P-P binning, it should be noticed that there are still zero-fold bins within the 3D volumes, but they are no longer linear. Again, doubling the bin size to fifty by fifty meters improves to the fold to thirty or better in most bins, and replaces zero-fold bins within each volume with low-fold bins (Figure 2d). The effect of limiting offsets to five kilometers is lower fold over the same area (Figure 2f). Finally, increasing the target depth to three kilometers results in a broader pattern, with lower fold (ten fold or better over most of the area). Also, the region between OBCs containing zero-fold bins decreases noticeably (Figure 2h).

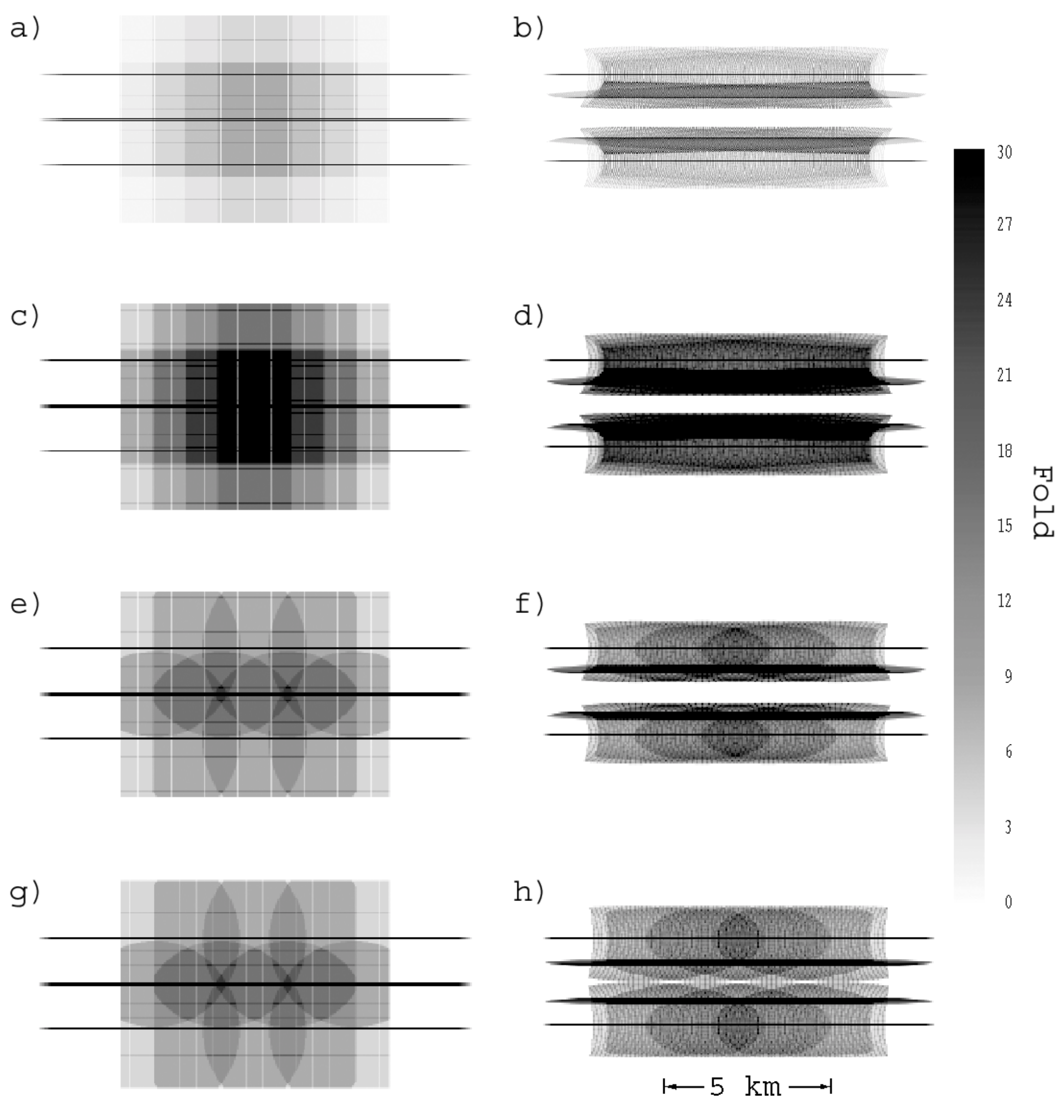

FIG. 2. Comparison of fold maps for P-P mode binning (Figures 2a, 2c, 2e and 2g) and P-S mode depth specific binning (Figures 2b, 2d, 2f and 2h) for the geometry shown in Figure 1. Water depth=100 m (all figures), target depth = 2000 m (Figures 2a–2f) or 3000 m (Figures 2g and 2h), bin size=25x25 m (Figures 2a and 2b) or 50x50 m (Figures 2c-2h), RMS Vp/Vs=2.0 (Figures 2b, 2d, 2f, 2h), maximum offset is unlimited (Figures 2a-2d) or 5000 m (Figures 2e-2h).

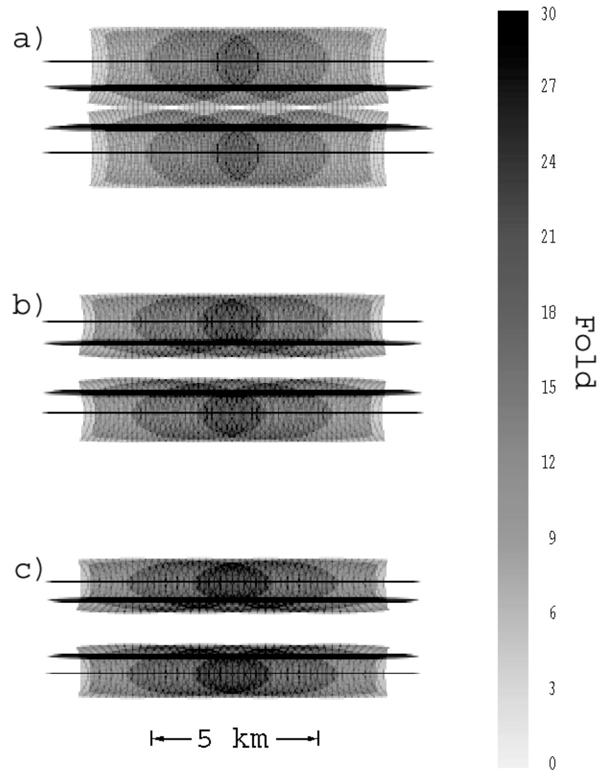

FIG. 3. The effect of changing Vp/Vs for a target at 3000 m. Figure 3a has a Vp/Vs of 2.0, Figure 3b has a Vp/Vs of 2.5, Figure 3a is the same as Figure 2h at a Vp/Vs of 3.0.

Increasing Vp/Vs ratio causes reflection points to move towards the receivers. In general, the areal extent of bins that have non-zero fold decreases, while the overall fold in each bin increases (Figure 3). Increasing target depths cause reflection points to move away from the receivers, towards the asymptotic binning positions (not shown).

OFFSET AND AZIMUTH DISTRIBUTION

It is important to consider the offset (P-P and P-S processing) and azimuth distribution (primarily P-S processing) in each bin. For P-P OBC binning with a target at three kilometers and offsets limited to five kilometers, the near offsets are shown in Figure 4a (compare with Figure 2g). Bins with near-zero offsets lie along each receiver line, in circular patterns centered on the intersections of the ocean bottom cables with the perpendicular source lines. Far offsets in each bin range from near zero to five thousand, but are in general greater than about two thousand meters (Figure 4c). A good range of offsets can be expected in less than half of the bins (Figure 4e).

Converted wave depth specific binning results in the near offsets shown in Figure 4b. As expected, the shortest source-receiver offsets are 1) found along the OBCs, and 2) distributed in an elliptical pattern, centered on the intersection of the source and receiver lines. Unfortunately, the bins with the highest fold (compare with Figure 3c) will not contain good near-offset information for velocity analysis. The far offset plot shows that roughly half the bins will not have offsets greater that fifteen hundred meters (Figure 4d). Finally, the few bins that will have a good range of offsets are centered on the intersection of the receiver lines with the source lines (Figure 4f).

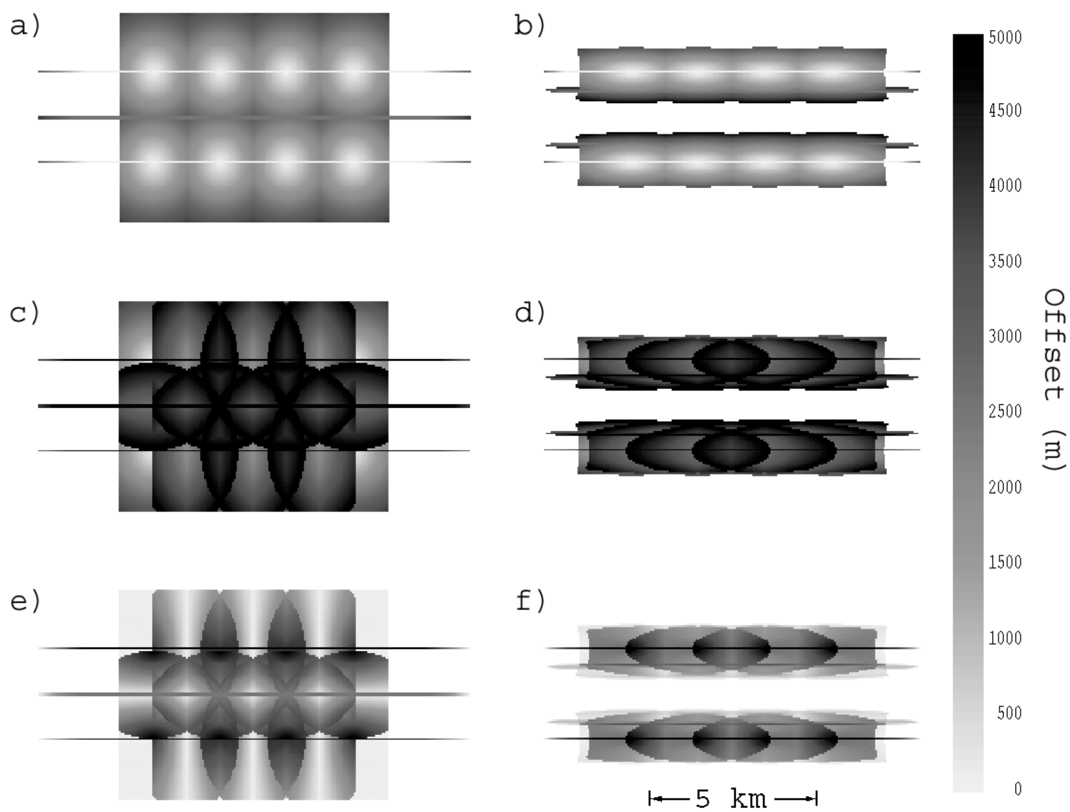

FIG. 4. Offset distribution for P-P binning (Figures 4a, 4c and 4e) and P-S depth specific binning (Figures 4b, 4d and 4f). Figures 4a and 4b show near offsets, 4c and 4d show far offsets and 4e and 4f show the offset range. Survey parameters are the same as for Figures 2g and 2h, with the exception that Vp/Vs = 3.0.

Figure 5 shows the fold in each bin for P-P OBC binning, based on source-receiver azimuths of zero to three hundred and sixty degrees in forty-five degree increments, with offsets limited to five thousand meters (compare with Figure 2g). It is clear from this display that only a few bins at the center of the survey will contain a good range of azimuths. Indeed, by taking the intersections of Figures 5a-5h, we can show that none of the bins have a full range of azimuths, and only a small percentage have as much as half the range (Figure 6).

Interestingly, three areas that have roughly northwest to northeast azimuths are centered between the ocean bottom cables and the perpendicular source lines (black in Figure 6), where a poor range of offsets is expected everywhere but on the horizontal line through each area (compare with Figure 4e). The two areas with roughly northeast-southwest azimuths are centered on the two central source lines that are perpendicular to the receivers.

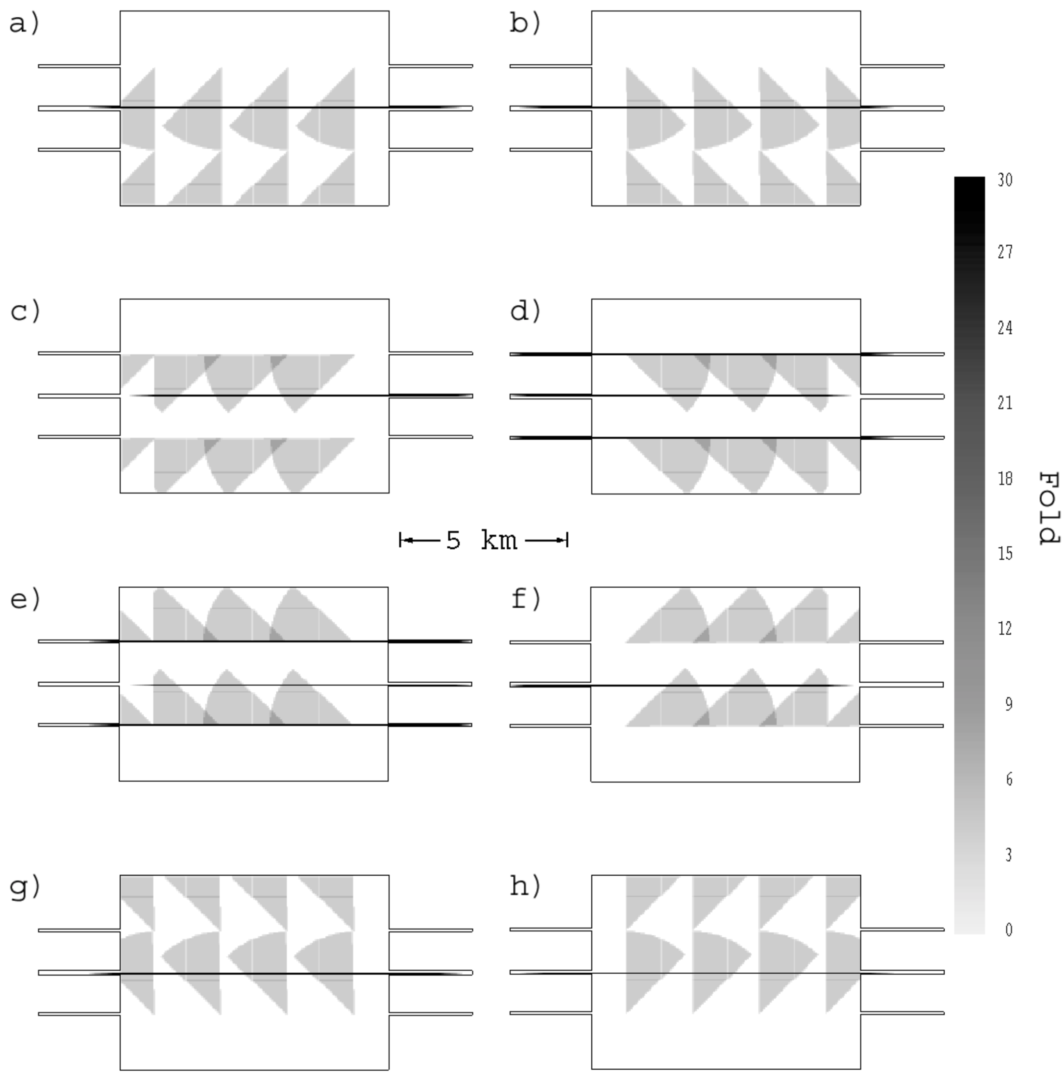

FIG. 5. Azimuthal distribution for 45 degree swaths from the P-P OBC binning shown in Figure 2g. Figure 5b = 1-45^O, Figure 5d=46-90^O, Figure 5f=91-135^O, Figure 5h=136-180^O, Figure 5g=181-225^O, Figure 5e=226-270^O, Figure 5c=271-315^O and Figure 5a=316-360^O.

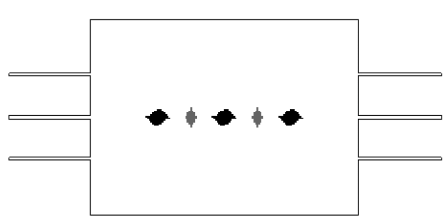

FIG. 6. Intersection of bins shown in Figures 5. No bins have full azimuthal coverage, those shown in black have azimuths 316-45^O and 136-225^O (Figures 5a, 5b, 5g and 5h). Those in gray have azimuths 46-135^O and 226-315^O (Figures 5c, 5d, 5e and 5f).

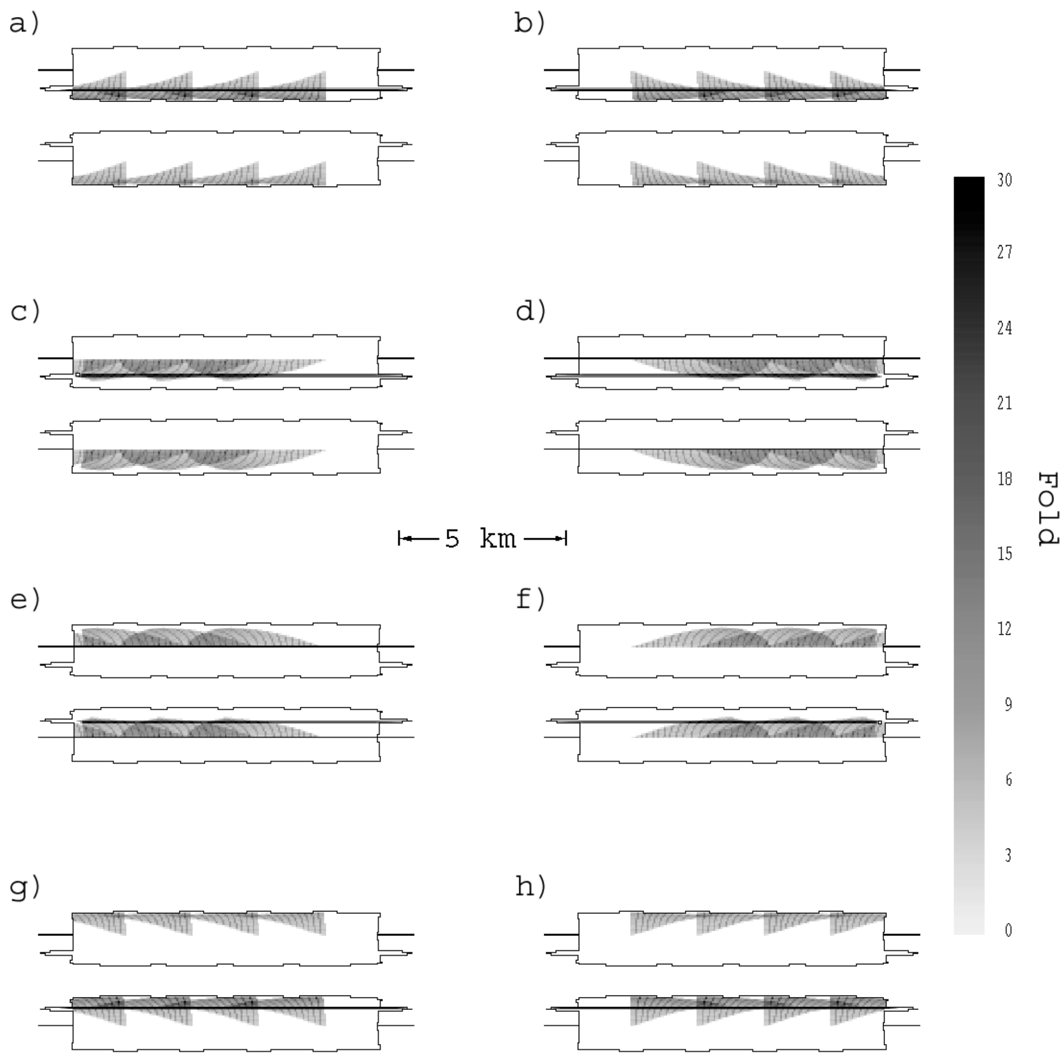

FIG. 7. Azimuthal distribution for 45 degree swaths from the P-S depth specific binning shown in Figure 3c. Figure 7b = 1-45^O, Figure 7d=46-90^O, Figure 7f=91-135^O, Figure 7h=136-180^O, Figure 7g=181-225^O, Figure 7e=226-270^O, Figure 7c=271-315^O and Figure 7a=316-360^O.

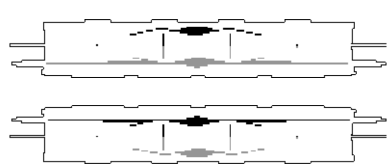

FIG. 8. Intersection of bins shown in Figures 7. No bins have full azimuthal coverage, those shown in black have 90-270^O (Figures 7f, 7h, 7g and 7e), those in gray have 271-89^O azimuths (Figures 7c, 7a, 7b and 7d).

Similarly, Figure 7 shows forty-five degree swaths of azimuths for the P-S depth specific binning. Once again, there are no bins containing a full range of azimuths. However, some bins do contain a half range (black and gray areas in Figure 7). Unlike the results for the P-P binning, these areas are symmetric about two axes bisecting the survey geometry.

DISCUSSION AND CONCLUSIONS

Assuming that the number of receivers and shots is constrained by time or money, the survey could be modified to generate a continuous P-S volume by moving the ocean bottom cables (OBCs) closer together. As shown in Figure 9, the cables would have to be five hundred meters apart for a target at 3 km depth and RMS Vp/Vs of 3.0. This measure will not improve the overall fold, offset range, or azimuth distribution of the data. Alternatively, the source and receiver lines could be laid out at right angles as shown in Figure 10. If more equipment is available, the addition of a third OBC is preferred (Figure 11).

Without modification, the initial survey design could be processed at fifteen fold (or better) with 50x50 m bins, assuming offsets up to five thousand meters are useable. This fold is not as high as was hoped for, but could be increased by using a larger bin size. The disadvantage of this will be decreased lateral resolution. Studies that depend on a good range of azimuths will not be possible. High fold in-lines observed between the ocean bottom cables represent an inexpensive way to increase 2D coverage available from this survey.

REFERENCES

Lawton, D. C., and Hoffe, B. H., 1999, Some design issues for 3C-3D OBC seismic data: CREWES Research Report **11**, 227-236.

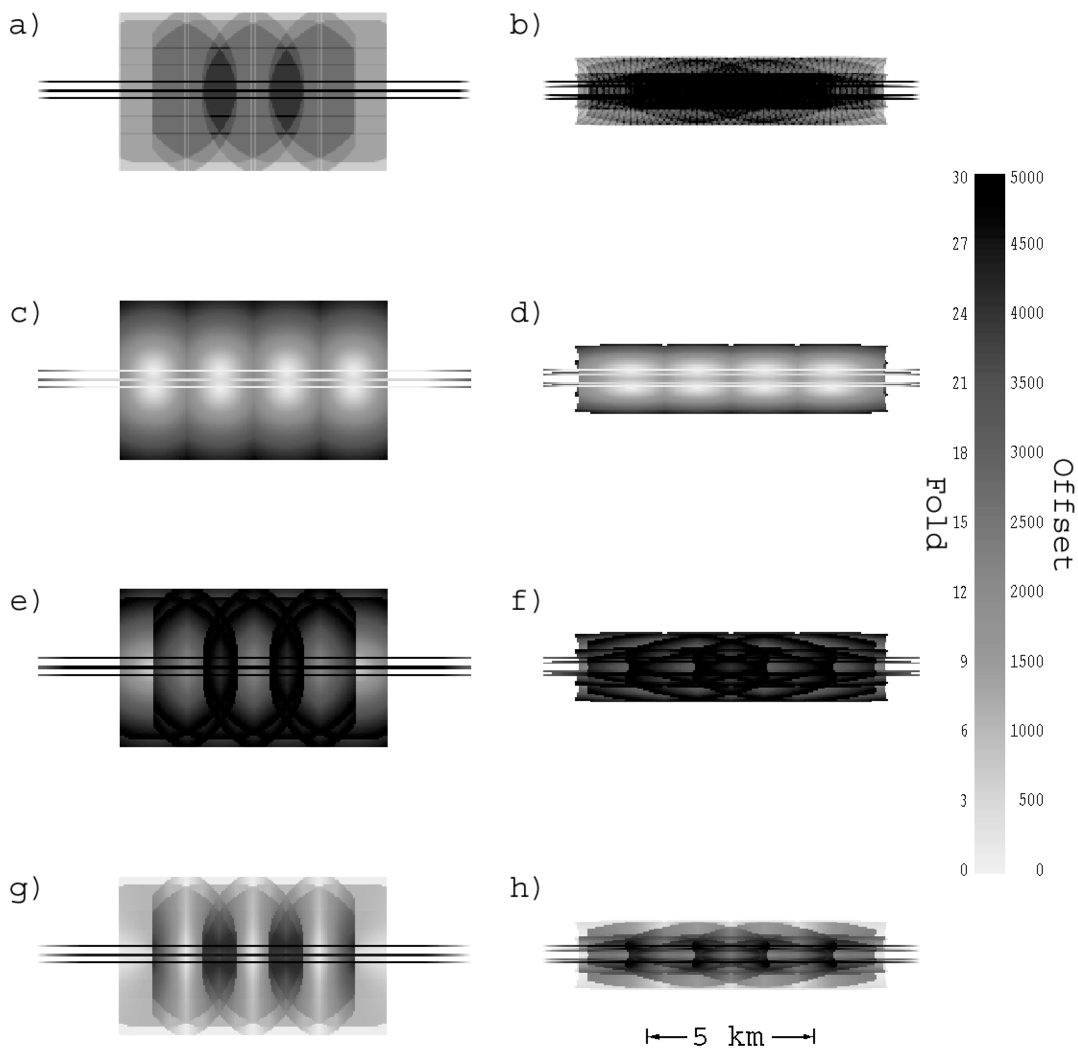

FIG. 9. Comparison of fold maps for P-P OBC binning (Figure 9a) and P-S mode depth specific binning (Figure 9b) for a geometry similar to that shown in Figure 1. Source and receiver line spacing has been reduced to 500 meters from the 2500 meters shown in Figure 1. All other aspects of the geometry remain the same. Near offsets, far offsets and offset ranges are shown for P-P OBC binning (Figures 9c, 9e and 9g) and P-S depth specific OBC binning (Figures 9d, 9f and 9h). Binning parameters, target depth and Vp/Vs ratio are the same as for Figures 2g and 3c.

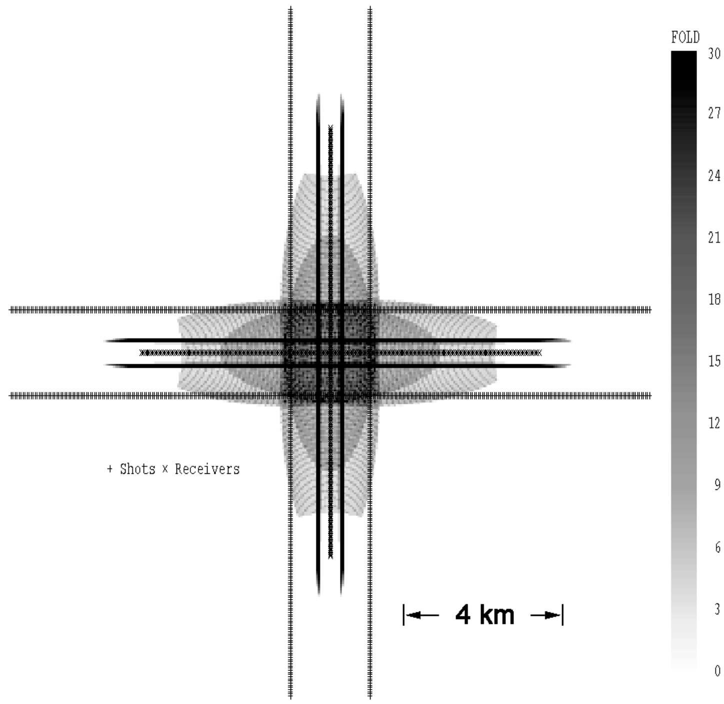

FIG. 10. P-S depth specific fold map for a 3 km target, 50x50 m bins, and Vp/Vs of 2.0. This design has 64.4 km of source lines, compared with 68.6 km for the design shown in Figure 1.

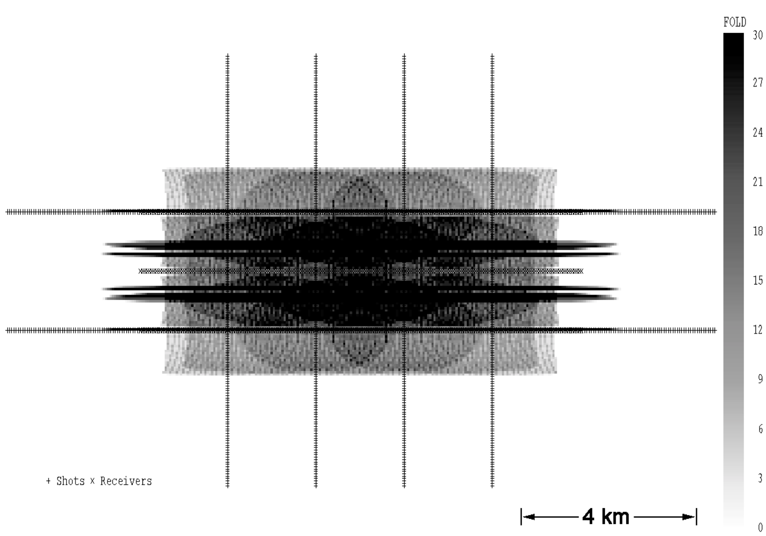

FIG. 11. P-S depth specific fold map for a 3 km target, 50x50 m bins, and Vp/Vs of 2.0. This design has an additional OBC centered between the two shown in Figure 1. The addition of a single OBC significantly improves the fold coverage (compare with Figure 2h).