Conventional wisdom

The main reason for not covering conventional 3D seismic survey design in the course "Fundamentals of 3D seismic survey design" is my pursuit of a higher goal: Make sure to acquire seismic data that are most suitable for imaging and noise suppression. Imaging as well as noise suppression perform best if they can exploit proper spatial sampling and corresponding spatial continuity of the acquired data.

Conventional survey design focuses on the collection of data in bins and the effects of stacking. Although stacking is a powerful noise suppression process, it is by no means the only process that works. But if one designs a 3D survey according to 3D symmetric sampling principles one can benefit of the spatial continuity of the data as well as of the stacking process. The stack responses of Figure 3.18 (Vermeer, 2002) demonstrate that symmetrically sampled data rank among the best. Using smooth acquisition lines rather than conventional offsetting and skidding techniques ensures that data are acquired that can be interpolated and regularized not only in the common shot gathers, but also in the common receiver gathers. What else can I say? … read the book.

In the following I will give comments to some "Conventional wisdom".

• "One of the easiest ways to significantly improve offset domain sampling is to change traditionally straight shot lines into a 'bricklayer' pattern"

This statement stems from the times when the number of available channels was still quite limited, and narrow geometries were the only viable geometries. Indeed, as comparison of Figure 3.18c with 18a shows, narrow brick is better than narrow straight. However, for wide geometries there is no difference between straight and brick geometries. Brick geometries still have the advantage of a more regular build-up of fold than straight geometries (average fold as a function of time is the same for equivalent geometries, but the spread around average is less with brick). On the other hand, the common receiver gathers in the brick geometry are strongly discontinuous, decreasing the ability for prestack noise suppression, interpolation and regularization and producing artifacts in prestack migration.

• "Wide azimuth surveys tend to have poorer distribution of offsets than do equivalent fold narrow azimuth surveys"

When comparing parallel geometry with orthogonal geometry this is a true statement. High fold parallel geometries (and these geometries tend to have always high fold) have a regular offset distribution leading to a very good stack response. Also their common receiver gathers can be look-alikes of the common shot gathers. On the other hand, wide orthogonal geometries have better stack response than narrow orthogonal geometries. This is because the narrow geometries have an offset distribution with clustered absolute offsets and regular large intervals between the clusters, leading to peaks in the stack responses with corresponding wavelengths that can escape suppression in the stack. For instance, in geometry 1 of Table 3.1 (see bottom of next page) there is a constant increment of 400 m in the inline offset of the traces in each bin (for each increment there are two traces because the crossline fold is 2). Given the small variation in crossline offset, this means that the absolute offset also tends to increase with increments of 400 m. This nearly constant interval shows up as a peak in the stack response at $k = 1/400\ \text{m}^{-1}$ as shown in Figure 3.18a. The crucial difference with wide geometries is that these have a wider range of crossline offsets, leading to more or less random behavior of the absolute offsets for which the stack responses are computed. In the wide geometries there is no serious offset clustering anymore. Not recognizing that orthogonal and parallel geometries have different properties has led to the recommendation that orthogonal geometries should preferably be narrow like the parallel geometries.

• Midpoints should be concentrated in bin centers

When stacking traces it is of utmost importance that they represent the same geology so that geology is enhanced and noise is suppressed. Therefore, in the days that DMO and prestack migration were not available or at least not part of the intended processing sequence, nor any suitable interpolation technique was used, it was important that the traces to be stacked had their midpoints as close as possible together. At least this optimized the chance that like geologies were being stacked. However, these considerations do not play a role anymore in current days. Either DMO or prestack migration will be applied. In prestack migration one can specify the position of the output points, making them perfectly regular, and if the velocity model is correct, like geologies will end up in the same output points. In the past, DMO produced output traces with a lot of midpoint scatter. This degraded the resulting stack. However, nowadays all contractors have a resampling procedure that redistributes the output traces across a regular output grid (see also Section 9.4.1 in Vermeer, 2002). What remains to be done is to ensure regularly sampled input traces for DMO and prestack migration for optimal image forming. That regularity is ensured by symmetric sampling, but not with concentrating midpoints in bin centers. Often it will be necessary to further regularize the input data in processing and that can best be done if the data have been sampled along smooth acquisition lines.

• Offset distributions in bins should be as regular as possible

Anstey introduced the stack-array approach which required regular sampling of offsets in 2D lines for optimal suppression of ground roll in combination with field arrays. After Anstey's publication Ongkiehong and Askin, and Vermeer were allowed by Shell to publish their views on 2D sampling, views which were not all that different from those of Anstey. Yet, there was an important difference between symmetric sampling as introduced by me in "Seismic Wavefield Sampling" and the stack-array approach. In symmetric sampling the starting point is proper sampling of shot and receiver gathers leading automatically to regularly sampled offsets for each midpoint, whereas in the stack-array approach the offset distribution itself was the starting point. (Symmetric sampling also calls for equal shot and receiver arrays, whereas Anstey never mentioned shot arrays.) When moving to 3D everybody wanted to apply the lessons learnt from 2D to 3D. For most this meant that regular offset distributions in bins were to be aimed for. However, a regular offset distribution for wide orthogonal geometries is not possible and it is not to be aimed for. (It may still be aimed for in parallel geometry.) Instead, similar as in 2D symmetric sampling, in 3D proper sampling of common shot gathers and of common receiver gathers should be aimed for, together with a proper choice of shot and receiver line intervals. This will lead automatically to the best geometry design.

• Fold depends on binsize

Fold-of-coverage at any time level in orthogonal geometry can be written as the quotient of "area of cross-spread " and "area of unit cell". The area of the cross-spread only depends on maximum inline and maximum crossline offsets and the area of the unit cell only depends on the line intervals. Cordsen et al. (2000) use the formula Fold = SD * NC * B^2, where SD is number of shots/m^2, NC is number of channels and B^2 is binsize. This is a misleading formula, because one might be led to believe that fold is proportional to binsize, but of course SD * NC is inversely proportional to binsize. This can be seen from the formulas in Table 4.5 (Vermeer, 2002): Fold = SD * NC * B^2 = $1/(\Delta s\ S) * 2X_{max,i}/\Delta r\ 2M_x * \Delta s\ \Delta r/4 = M_i\ M_x$. Hence, whether the same cross-spread is sampled with fine or coarse station spacings, fold will not be different, but trace density will be different. It is sometimes stated that fold is increased by increasing the binsize. Effectively, this may enlarge the *stacking* fold, but not the fold-of-coverage. Binsize enlarging is always a poor man's processing step.

• Bin fractionation provides higher resolution

Bin fractionation centers midpoints of traces in sub bins rather than in the natural bin centers. This is achieved by shifting sampling positions of shots and receivers in neighboring lines with respect to each other. Hence, it increases midpoint sampling density and many geophysicists have believed that this would increase resolution. However, the technique does not improve the sampling of individual cross-spreads, which are the basic entities to be used in prestack migration. Hence the resolution will not improve. This is discussed in more detail in Section 8.3.8 of Vermeer (2002).

References

Cordsen, A., Galbraith, M., and Peirce, J., 2000, Planning land 3-D seismic surveys: Soc. Expl. Geophys.

Vermeer, G.J.O., 2002, 3-D seismic survey design: Soc. Expl. Geophys.

Table 3.1 Parameters of 3-D geometries

Id	Name	Cross-line x in-line fold	Receiver-line interval	Shot-line interval	Aspect ratio	Figure
1	4-line orthogonal	2 x 15 = 30	200 m	200 m	0.13	3.18a,b
2	4-line brick	2 x 15 = 30	200 m	200 m	0.13	3.18c,d
3	4-line double zigzag	2 x 15 x 2 = 60	200 m	200/2 m	0.13	3.18e,f
4	12-line orthogonal	6 x 6 = 36	450 m	450 m	1.0	3.18g,h

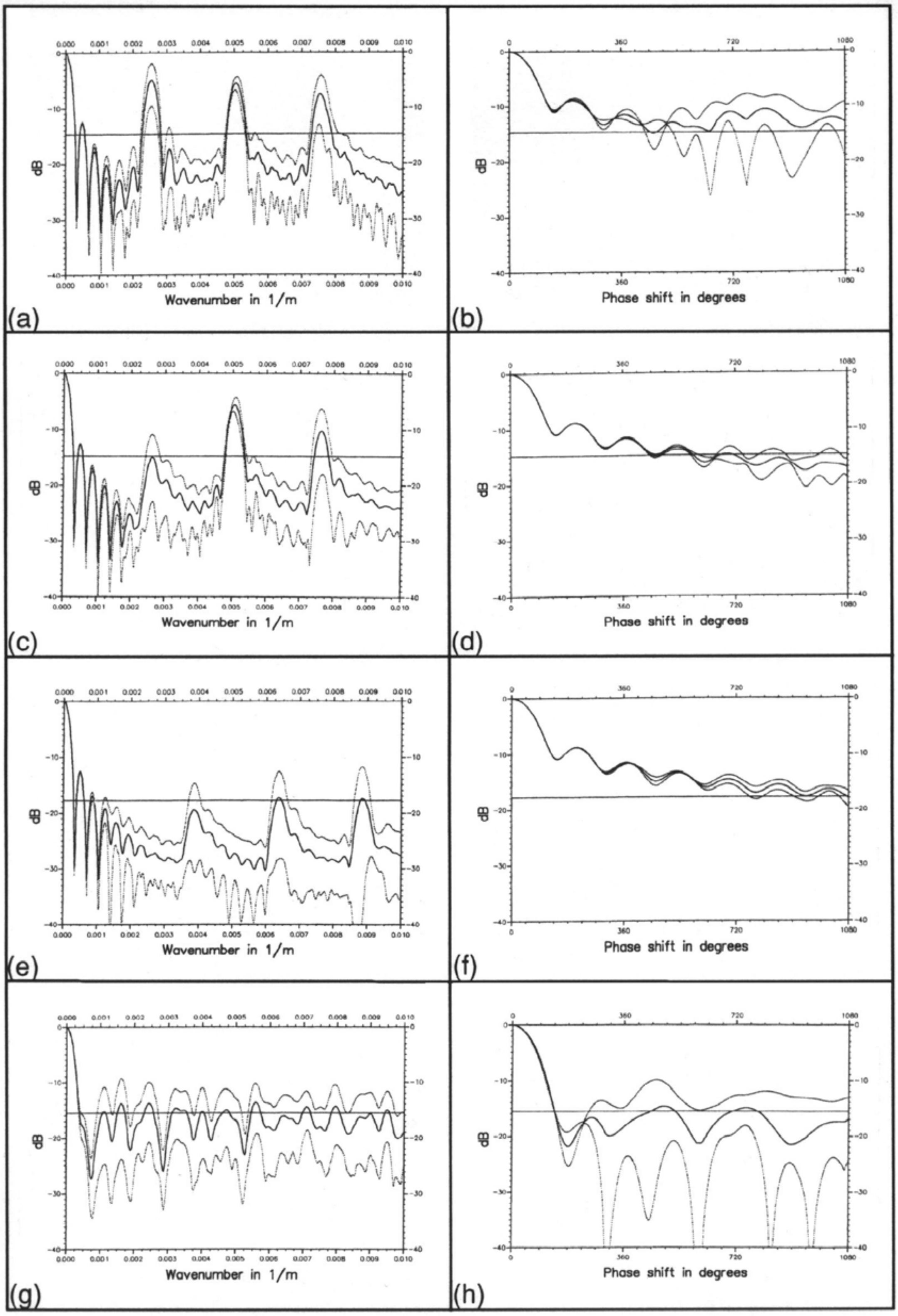

FIG. 3.18. Average stack responses (heavy lines) for the four acquisition geometries listed in Table 3.1. Standard deviations in each average are indicated as well. Left column: amplitude of stack response for linear noise suppression. Right column: amplitude of stack response for suppression of multiples with small differential moveout. (a, b) narrow orthogonal, (c, d) narrow brick, (e, f) double zigzag, (g, h) wide orthogonal.