Variable line intervals in orthogonal geometry

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In a highly interesting paper Winter et al. (2014) discuss high-density vibroseis acquisition on Alaska's North Slope. In their survey design they opted for a shotpoint sampling (27.5 ft) that was four times denser than the receiver sampling (110 ft) along their respective acquisition lines. This was done in an effort to balance the source effort to the receiver effort. An advantage of this approach was also that ice-break noise can be removed from the densely sampled common receiver gathers "by standard noise-burst attenuation procedures. Ice breaks are disorganized in the receiver domain" (Winter et al., 2014, p.559). On the other hand, shot-generated low-velocity noise is coherent in shot and receiver gathers and is organized in a circular cone in the cross-spread. For optimal removal of this type of noise, dense symmetric sampling would be required.

An aspect not discussed in the paper is that the conventional acquisition as well as the new high-resolution acquisition use variable shot-line and receiver-line intervals. Apparently this is quite a common procedure on the North Slope (and elsewhere?). A few other papers also mention variable line intervals. Musser (2000) recommends variable line intervals for better statics coupling (I doubt whether this really helps statics). Bouska (2009) used wavy receiver lines with 450/550 m alternating receiver line intervals, but did not give a reason for the variability of the line intervals.

Another reason to use variable line spacings may be "breaking the periodicity" which reduces the visibility of the acquisition footprint. With variable line intervals there are more different offset samplings of the various bins than in a regular geometry. Indeed, the periodicity effect is reduced, but it does not mean that amplitude effects due to differences in sampling disappear; they will just be distributed more irregularly. On top of that, prestack noise removal, prestack migration and higher folds of modern acquisition also mitigate the effects of acquisition on amplitude.

In this note I analyze some properties of orthogonal geometry with variable line intervals with special emphasis on consequences for OVT-processing.

Analysis of variable line intervals in orthogonal geometry

For this analysis I use the conventional geometry listed in Table 1 of Winter et al. (2014). Source and receiver intervals are both 110 ft. The receiver-line intervals alternate between 770 and 880 ft; the source-line intervals alternate between 880 and 990 ft. So, in both cases the differences between the intervals are only one source or receiver position. The template consists of 22 receiver lines with 238 receiver positions each. Hence, the spread length is independent of line interval with maximum inline offset being 238 * 110 / 2 = 13090 ft.

The combination of two different source-line intervals with two different receiver-line intervals leads to four differently sized areas between adjacent acquisition lines as illustrated in Figure 1. Despite the irregularity of the geometry, total fold in the fullfold area of the geometry is constant and equals 154 as illustrated with Figure 1. Similar as in regular geometry the crossline fold equals half the number of receiver lines in the template, or 22/2 = 11. The inline fold equals half the spread length divided by the average shot-line interval: 2*13090/(990+880) = 14.

There are two different cross-spreads in this geometry. If the receiver-line interval above the receiver line of the cross-spread equals 880 ft, the maximum crossline offset in the positive direction equals 880 +

5 * (880+770) = 9130 ft and it is 770 + 5 * (880+770) = 9020 ft in the negative direction. For cross-spreads with a receiver-line interval of 770 ft above the receiver line of the cross-spread, the maximum crossline offsets are 9020 ft in the positive direction and 9130 ft in the negative direction. In the inline direction all cross-spreads are symmetric.

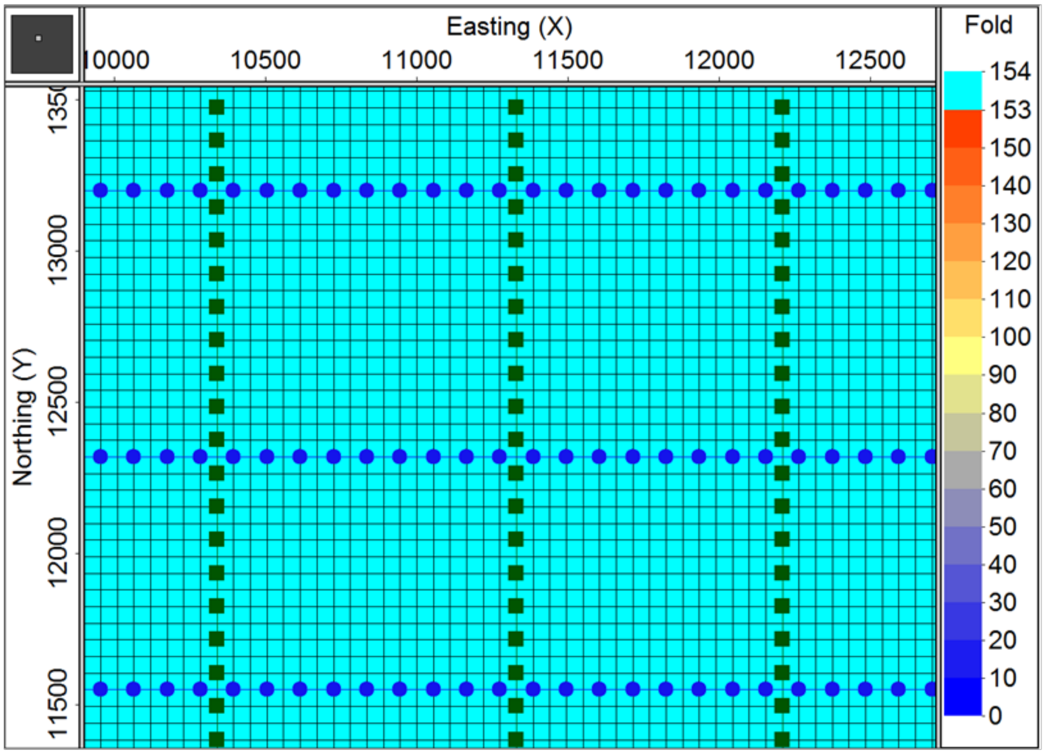

Fig. 1. Representative part of fullfold area of discussed orthogonal geometry with variable line intervals. The number of receiver stations between shot lines alternates between 9 and 8; the number of source positions between receiver lines alternates between 7 and 8. As a consequence the number of bins between adjacent acquisition lines varies between 4 * (9*8, 9*7, 8*8, and 8*7). This geometry has four different "unit cells".

The midpoint area of each cross-spread measures 13090 x 9075 ft, or, divided by binsize 55 ft, the midpoint area measures 238 x 165 bins. With inline fold 14 and crossline fold 11 this provides 238/14 x 165/11 = 17 x 15 bins for each single-fold offset-vector tile (OVT; see Vermeer, 2012, for more details on OVT gathers) in a 154-fold geometry. In other words, each cross-spread can be subdivided in as many OVTs as the fold of the geometry. However, because the cross-spreads are not distributed uniformly across the area due to the variable line intervals, this size of OVT cannot be used to select single-fold subsets of the geometry as illustrated in Figure 2. The selected OVT has size 17 x 15 bins, but does not provide regular single-fold coverage.

Yet, it is possible to make single-fold tilings using complete cross-spreads. It can be shown that taking every 14-th cross-spread in the inline direction and every 11-th cross-spread in the crossline direction, complete single-fold coverage can be generated. This explains the regular fold as shown in Figure 1. However, tilings of complete cross-spreads are not suitable for migration-velocity analysis or for other techniques commonly used with OVT gathers.

The best way to simulate OVT-gather processing is to exploit the distribution of offset vectors in each bin of the fullfold area of the geometry. Figure 3 shows that the offset vectors are distributed in a rectangular 14 x 11 point pattern, corresponding to inline and crossline fold. In processing, correspond-

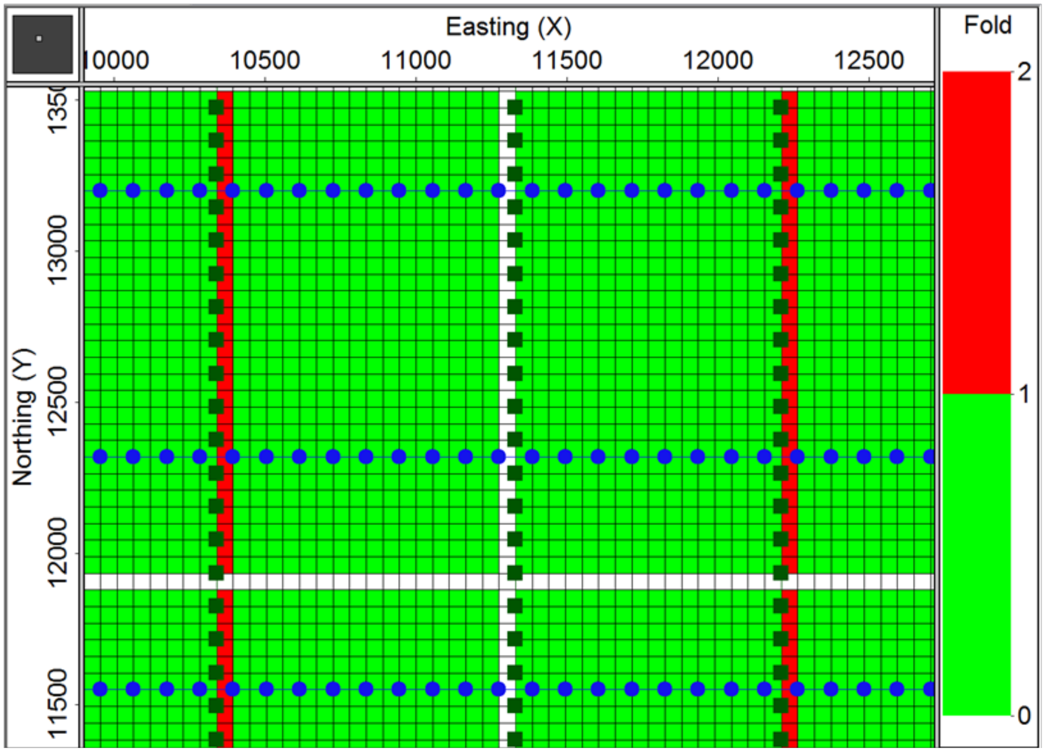

Fig. 2. Fold-of-coverage for offset-vector tile with inline offsets 11220 – 13090 ft and crossline offsets 7430 – 9080 ft (range of offsets is twice width of OVT). It is not possible to obtain regular single-fold coverage using this method of data collection.

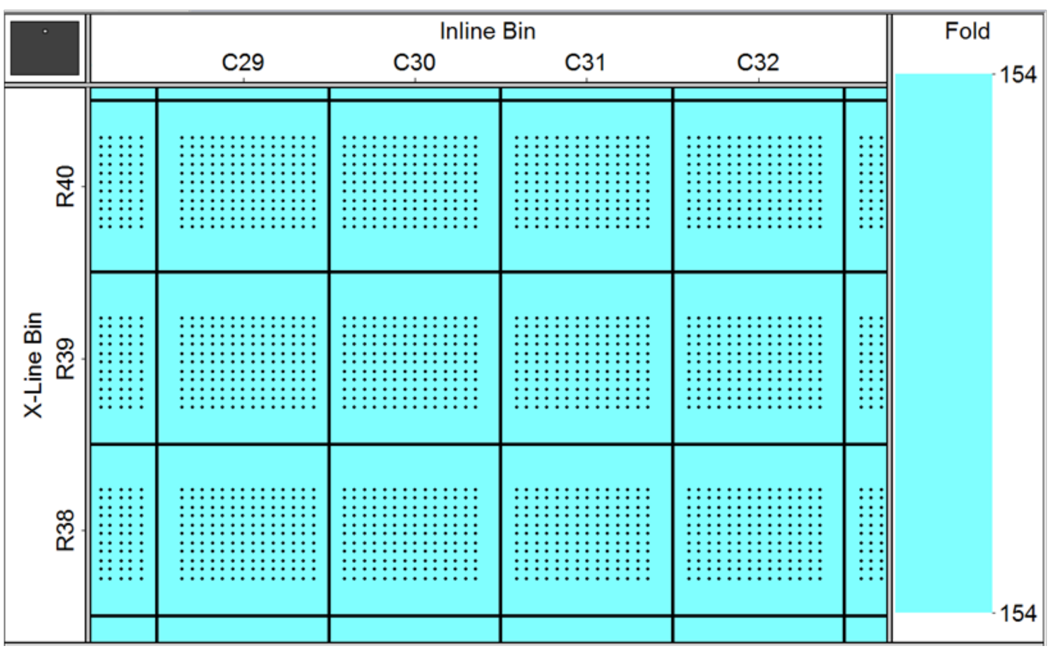

Fig. 3. Offset-vector distribution in bins of fullfold area of geometry. The axes in each bin represent inline offset and crossline offset, respectively. The position of the whole group of offset vectors changes from bin to bin, but each individual position can be used to collect single-fold data with minimal variations in offset vector. The distances between neighboring offset-vector positions in a bin correspond to the variable line intervals in inline and crossline directions.

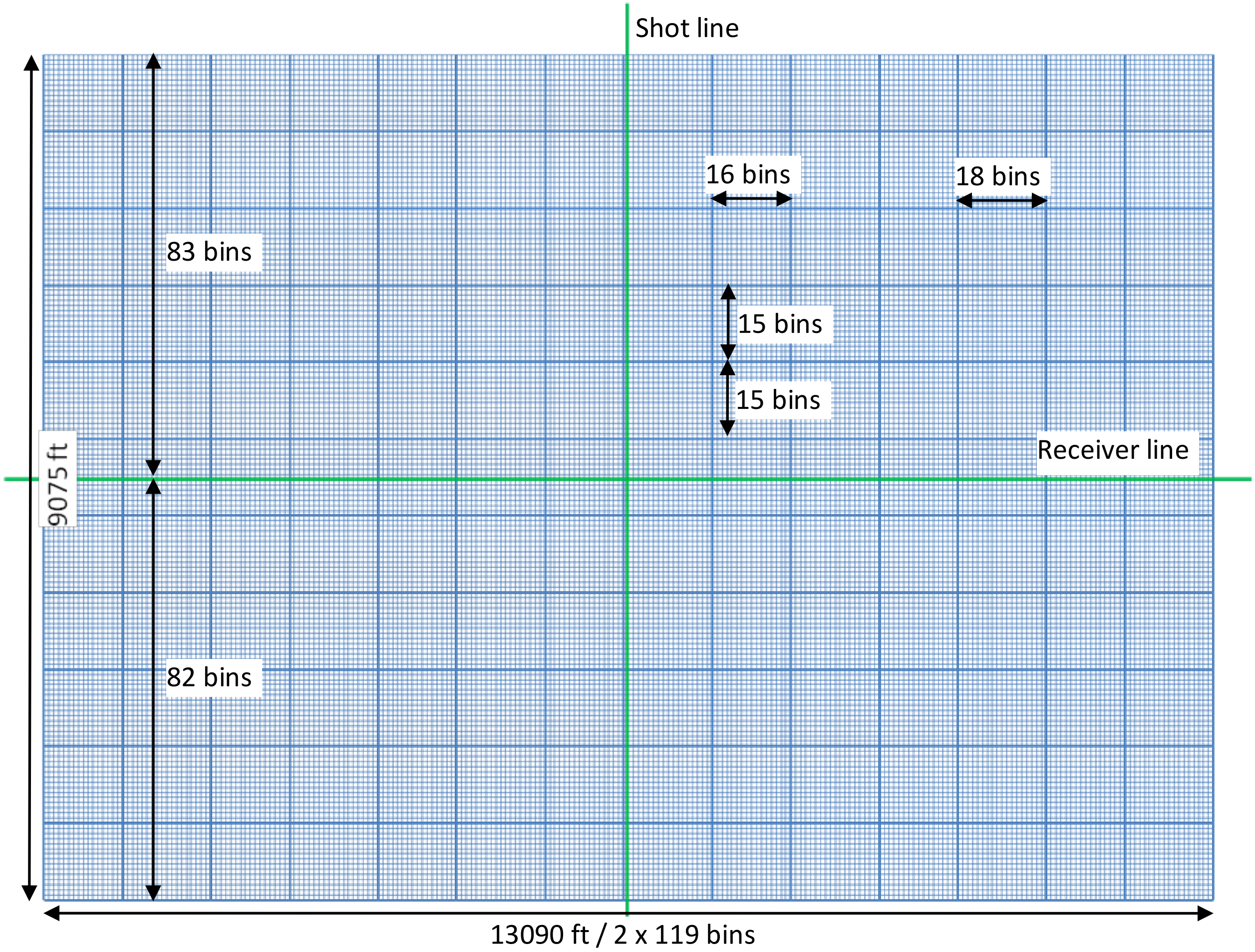

Fig. 4. Midpoint area of cross-spread with one potential tiling in OVTs. In the inline direction tiles with width 18 and 16 bins alternate. In the next cross-spread with the same receiver line the subdivision will be mirrored with respect to this one with OVT width of 18 bins in the first column. The width of the OVTs in the crossline direction is always 15 bins; this cross-spread has 83 bins above the receiver line, but the next cross-spread in the crossline direction has 82 bins above its receiver line.

ing points can be selected from all bins providing single-fold coverage with a limited range of offsets and azimuths. Each "OVT gather" obtained in this way consists of continuous pieces from cross-spreads (as in regular geometry), but now the size of the tiles varies in a way as described in Figure 4.

Conclusion

A geometry with regularly varying line spacings as discussed in this note has rather peculiar properties. Yet, it is quite easy to generate OVT gathers from this geometry by exploiting the distribution of the offset vectors in each bin in a matrix with dimensions inline fold x crossline fold. Just selecting the same matrix point from all bins produces one of the OVT gathers. In the discussed example with variations in line spacings of only one shot-station interval and one receiver-station interval there are no serious disadvantages of this variability in line intervals. The main disadvantage is that the largest line intervals determine the range of offsets contributing to each OVT gather. On the other hand, there are no significant advantages of this type of geometry either (as far as I can see).

References

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Acknowledgment

Figures 1-3 were made with Omni 3D®, a Gedco software package.