[GC]3-D Acquisition Design Philosophy – Part 3: Is Stacking Fold Acceptable?*

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Stacking Fold

This article is the third of a four-article series – this topic considers Part 3 and Part 4 labeled on the Figure 1 flow chart of 3-D seismic design methodology.

Stacking fold is the number of field traces that are summed during data processing to create a single image trace positioned at the center of each bin. At any stacking bin coordinate, the stacking fold inside the bin varies with depth. Referring to Figure 2, when a stacking bin is centered about a deep reflection point B, the stacking fold is a maximum at depth B because the largest number of source and receiver pairs can be utilized to produce individual reflection field traces inside the bin.

The number of source-receiver pairs that can contribute to the image at B is typically confined to those source and receiver stations that are offset horizontally from B a distance that is no larger than depth Z2 to reflection point B. Thus, distances CE and EG shown on Figure 2 are each equal to Z2.

Using this offset criterion to determine the number of source-receiver pairs that contribute to a seismic image at any subsurface point, the stacking fold at depth Z2 would be N2 – because N2 unique source-receiver pairs can be found that produce distinct field traces reflecting from point B.

When the stacking bin moves to a shallower depth Z1, the stacking fold decreases to a smaller number N1 – because only N1 source-receiver pairs generate field traces that reflect from A and still satisfy the geometrical constraint that the source-receiver pairs are offset a distance DE (or EF) or less that does not exceed depth Z1.

In a 3-D context, stacking fold is the product of in-line stacking fold (the fold in the direction that receiver cables are deployed) and cross-line stacking fold (the fold perpendicular to the direction that receiver cables are positioned). Defining F as 3-D stacking fold, FIL as in-line fold and FXL as cross-line fold, this principle leads to the design equation:

(1) F = FIL x FXL.

To build a high-quality 3-D image, it is critical to not only create a proper stacking fold across the image space but also to ensure the traces involved in that fold have a wide range of offset distances and azimuths. Equation 1 provides no information about the distribution of source-to-receiver offset distances or azimuths that are involved in a stacking fold. If it is critical to know the magnitudes and azimuth orientations of source-receiver offsets, then commercial 3-D design software must be used.

Offset analysis is a topic that goes beyond the scope of this discussion, which is structured to provide simple explanations of the basic principles of 3-D seismic design. All discussions of 3-D stacking fold will be based totally on equation 1. It is the simplicity of this equation that makes it appealing to use to explain to non-geophysicists how stacking fold and 3-D recording geometry link together.

2-D vs 3-D Stacking Fold Considerations

In 2-D and 3-D acquisition geometry, in-line stacking fold FIL is a function of two geometrical properties:

- The number of active receiver channels.
- The ratio of the source-station interval and the receiver-station interval.

Specifically, in-line stacking fold is given by the equation:

(2) FIL = (1/2) (Number of receiver channels) X [(receiver-station interval)/ (source-station interval)].

In 2-D seismic profiling, the source-station interval is usually the same as the receiver-station interval, making the ratio term in the square brackets equal to unity. However, in 3-D profiling, the source-station spacing along a receiver line is the same as the source-line spacing, which is several times larger than the receiver-station spacing. For example, if the receiver-station spacing is 110 feet, and the interval between the source lines is 1,320 feet, then there is a source station every 1,320 feet along each receiver line – and the square bracket term in equation 2 has a value of (1/12).

The in-line fold for 3-D data acquisition is thus considerably less than it is for 2-D recording geometries. In this hypothetical example, it is 12 times less. Cross-line stacking fold FXL – created by a 3-D acquisition geometry – is controlled by the number of receiver lines that are incorporated into the 3-D recording swath and is given by:

(3) FXL = (1/2) (Number of receiver lines in recording swath).

Final Step

The last step in the 3-D design procedure (Part 4 of Figure 1) is to compare the designed stacking fold with the predefined stacking fold that is desired. A key question at this stage is, "How do you preselect a stacking fold that is appropriate for comparison?"

There are several ways to answer this question. The ideal situation is to have access to 3-D seismic data previously recorded near the prospect area. If those data have good signal-to-noise character, then one should simply define the stacking fold that was used in recording these older 3-D data as being the stacking-fold objective for the new 3-D data acquisition program.

If the signal-to-noise character of these pre-existing 3-D data is not acceptable, a higher stacking fold should be considered. If only 2-D seismic data are available in the area of interest – and these 2-D data adequately image the subsurface geology – a popular design guideline is:

(4) 3D stacking fold = (1/2) (2D stacking fold)

This is a statement of a commonly observed condition that 3-D stacking fold often needs to be only one-half the value of 2-D stacking fold to cause 3-D data to have equivalent signal quality. If neither 2-D nor 3-D data are available, the only recourses are to ask advice of people who have recorded data in the area – or to guess.

If the calculated stacking fold is significantly different from the intended value of stacking fold, then the design procedure must be repeated. In this second iteration, one or more of the critical geometrical parameters (source/receiver-station spacings, source/receiver-line spacings or recording swath size) must be adjusted to cause the stacking fold to converge toward the desired value. Because of the simplicity of the method described in this article series, designs can be iterated easily and quickly.

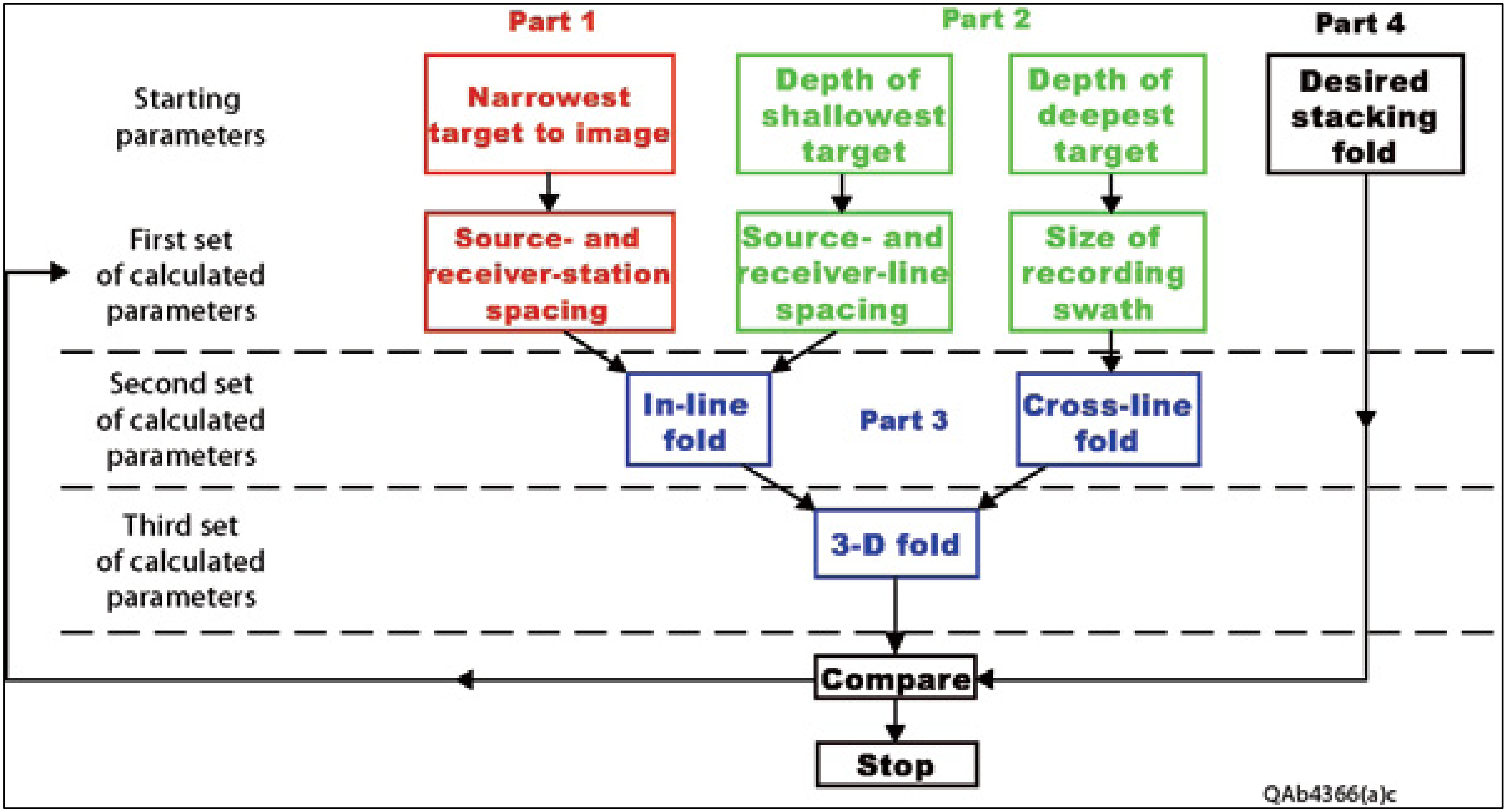

Figure 1. Planning steps that can be followed to design a 3-D seismic acquisition geometry. This article discusses the topics identified by the areas labeled Part 3 and Part 4.

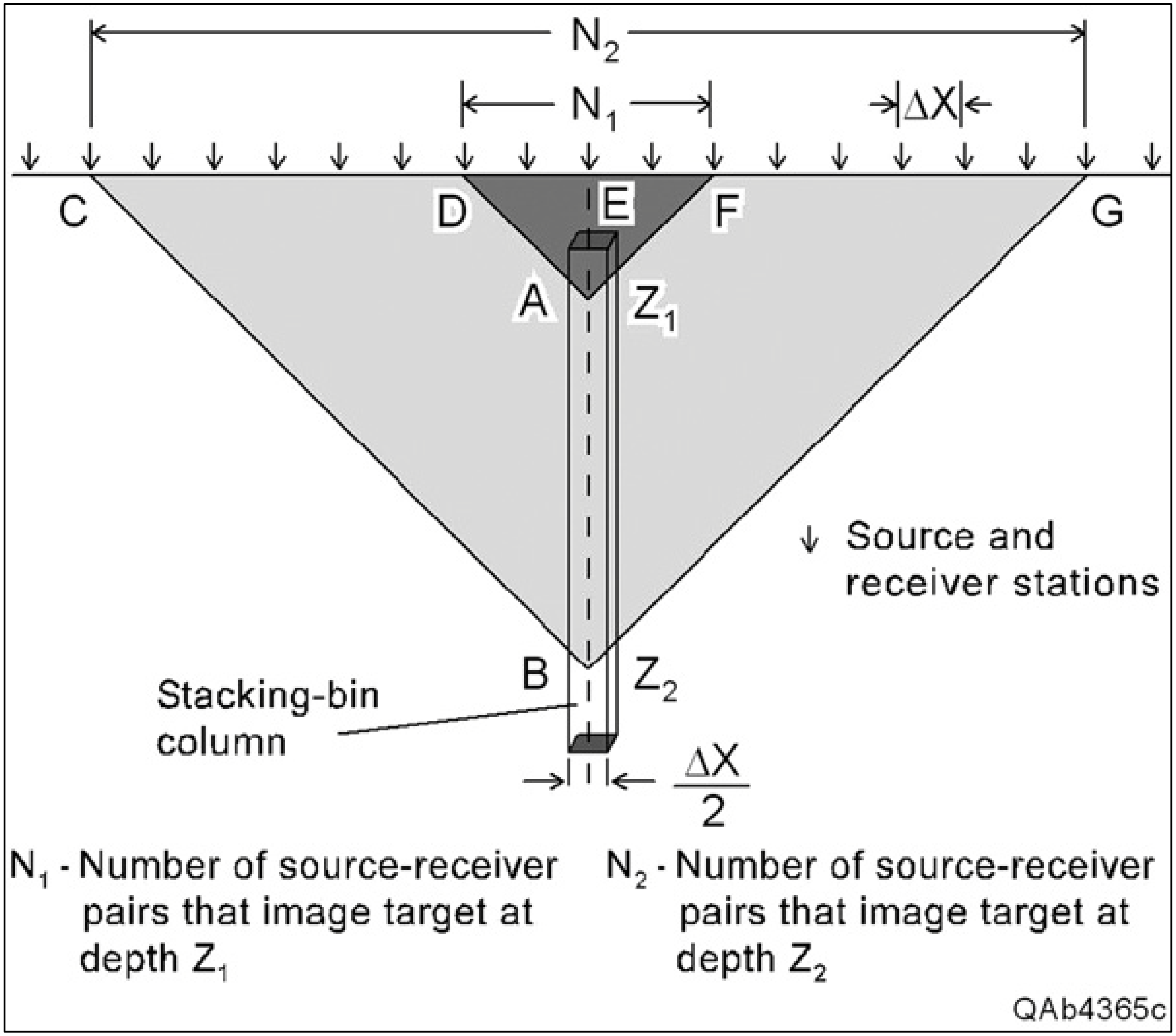

Figure 2. Vertical variation in stacking fold. The source-station and receiver-station spacings along this profile have the same value Δx, which results in a stacking bin width of Δx/2. The vertical column shows the coordinate position of one particular stacking bin. For a deep target at depth Z2, the stacking fold in this bin is a high number because there is a large number (N2) of source-receiver pairs that produce a raypath that reflects from subsurface point B. Only one of these raypaths, CBG, is shown. For a shallow target at depth Z1, the stacking fold is low because there is only a small number (N1) of source-receiver pairs that produce individual raypaths that reflect from point A. One of these shallow raypaths, DAF, is shown. When a 3-D seismic data volume is described as a 20-fold or 30-fold volume, people are usually referring to the maximum stacking fold that is created by the 3-D geometry, which is the stacking fold at the deepest target.