Prestack Time Migration Responses of some 3D Geometries

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Introduction

The data acquired in a 3D seismic survey is often subjected to prestack time migration (PSTM) during processing. This important processing step moves reflection (and scattered) energy present on each recorded trace to its true sub-surface location, provided that lateral velocity changes are small.

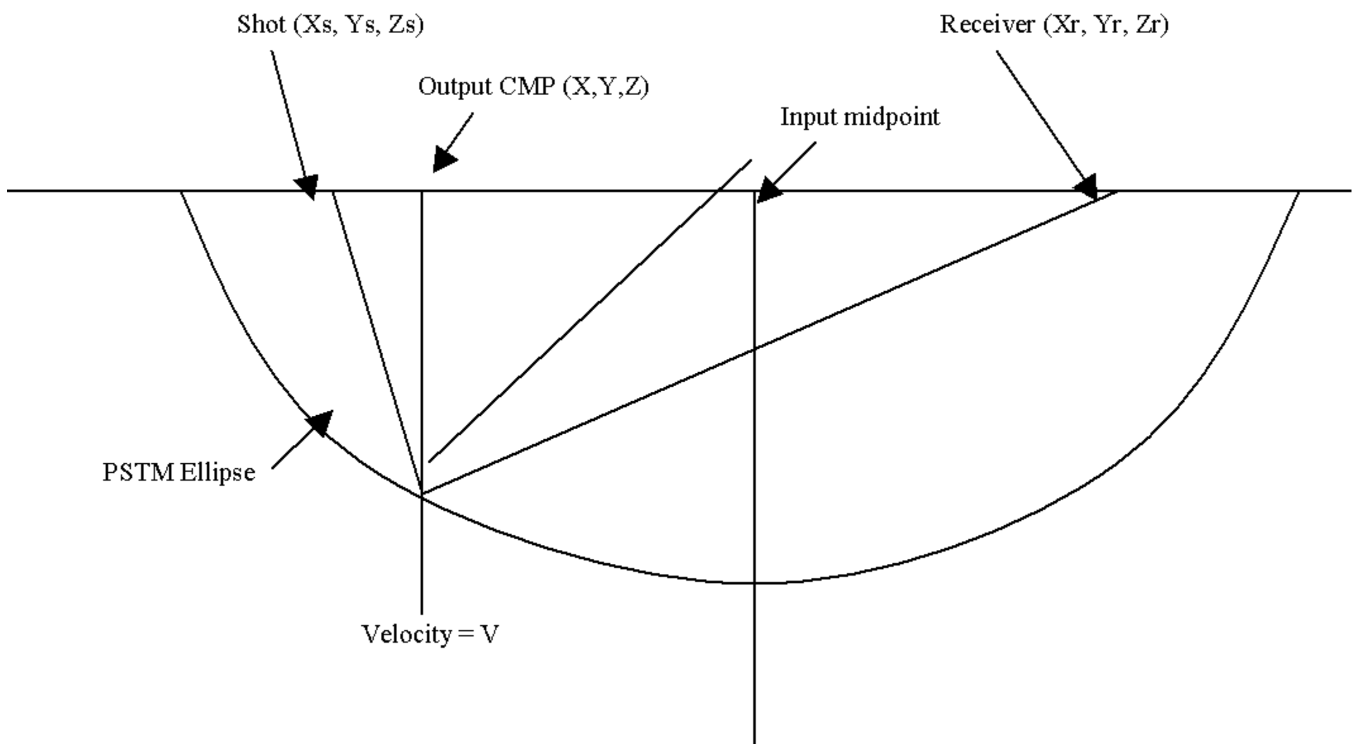

Figure 1

PSTM works by moving (smearing) energy from each sample of a trace along its prestack time migration ellipse (Figure 1). The ellipse becomes an ellipsoid in 3D seismic. Thus each output image trace is composed of samples that are the sum (stack) of many input samples – each of which has been moved along its migration ellipse.

The quality of the output migrated image (stacked samples) will depend on the distribution of the input contributions. Thus, different 3D geometry configurations (shot and receiver locations) will give rise to different qualities of migrated outputs.

In this paper the simplest situation is considered, where one sub-surface point (scatter point) is the only event of interest. Velocity to surface is held constant. The prestack time migrated output is then constructed in a series of surface “bins” surrounding the bin vertically above the scatter point. The ideal result is a single spike at the bin vertically above the scatter point and zeros everywhere else.

Because the geometries have limited fold, each output “image trace” (migrated output trace at each surface bin) is the sum of a finite number of contributions. Thus “constructive interference” is not complete and some residual noise will be present in the bins around the scatter point – and at times around the two-way time of the scatter point.

The extent of such “migration noise” can tell us how effective any given 3D geometry will image a single sub-surface point and will thus allow us to classify some geometries as better or worse at imaging than other geometries. A geometry that is bad at imaging will lead to a badly focused image (i.e. the correct image but surrounded by noise) as opposed to a geometry that is better at imaging, where the noise will be less and the image more focused.

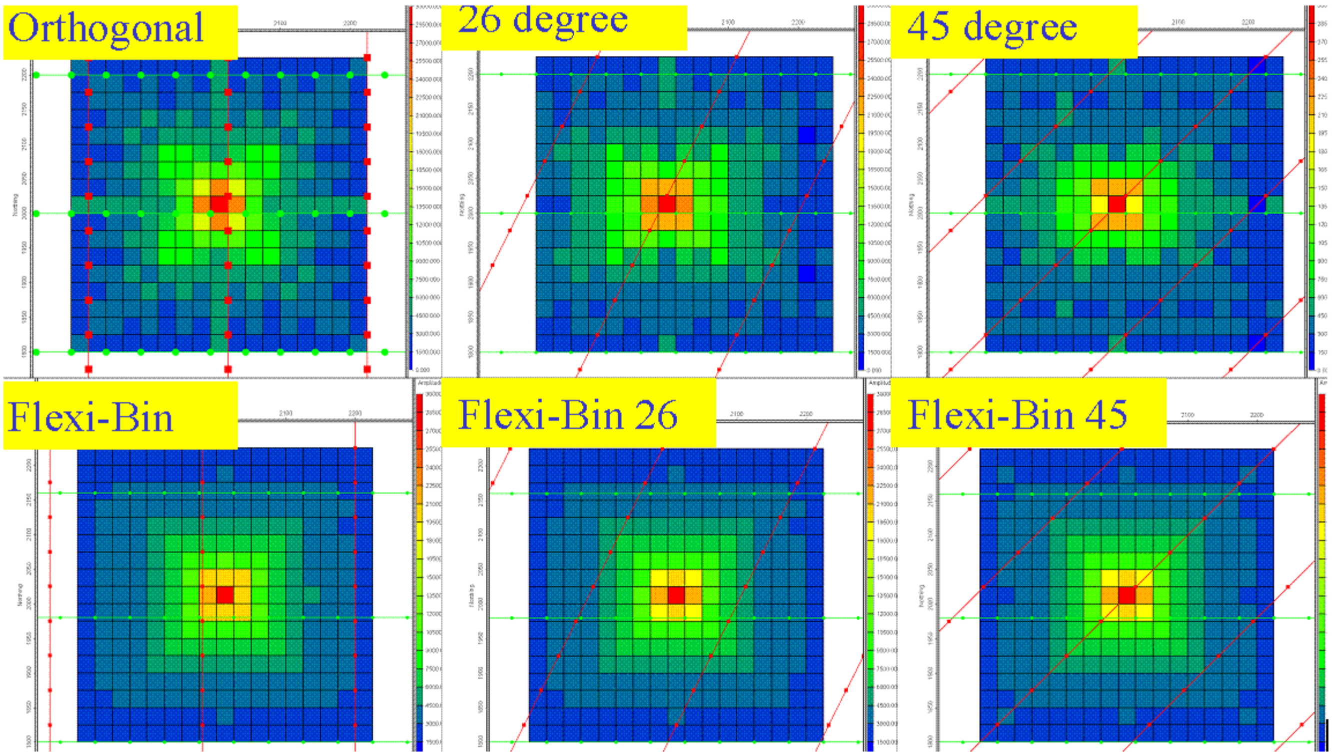

Figure 2 - PSTM Responses (Time Slices) centered on the time and position of the scatter point.

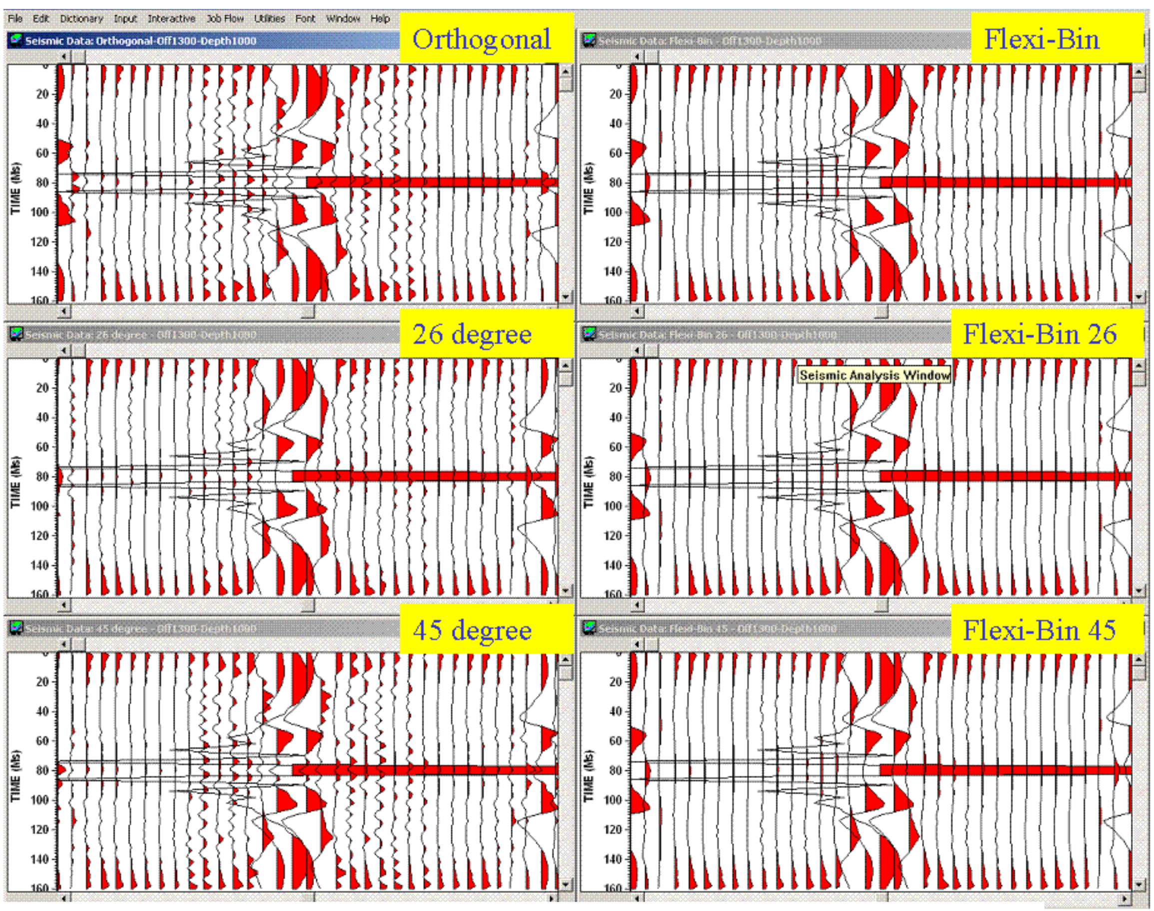

Figure 3 - PSTM Responses - central vertical line of output bins.

Description of geometries tested in this paper

6 different geometries were evaluated:
An orthogonal survey.
A survey with shot lines held at an angle of 26 degrees to the receiver lines.
A survey with shot lines held at an angle of 45 degrees to the receiver lines.
An orthogonal Flexi-Bin™ survey.
A Flexi-Bin™ survey with shot lines held at an angle of 26 degrees to the receiver lines.
A Flexi-Bin™ survey with shot lines held at an angle of 45 degrees to the receiver lines.

In all surveys the shot and receiver interval (inline) was 50m leading to a 25m CMP bin (25m surface bin for the purposes of prestack time migration).

The shot line and receiver line intervals for the first 3 surveys was 200m.
The shot line interval for the 3 Flexi-Bin™ surveys was 220m.
The receiver line interval for the 3 Flexi-Bin™ surveys was 180m.

In all surveys a patch of 12 lines of 64 stations was used.

The target was a scatter point at a depth of 1000m in the center of the survey (actually at coordinates 2012.5, 2012.5 to lie exactly in the center of a surface (image trace) bin). Velocity to surface was 3000m/s. Using a stretch factor of 20%, the maximum useful offset used in processing such data would be approximately 1300m.

Hence in calculating the PSTM responses, only offsets to 1300m were used corresponding to a circular patch. For this offset range, all of the geometries had a conventional CMP fold of close to 30 (range was 28 to 32).

Note that the parameters used in this paper are for comparison purposes only between the different geometries. They are not intended as a recommended choice for a slanted orthogonal design or a Flexi-Bin™ design.

Results of PSTM calculations

Figure 2 shows the time slice responses for the 6 geometries.

Figure 3 shows the responses taken from a vertical line of bins (North-South line) through the scatter point position. The large spike in the central bin (trace) is obviously the scatter point itself. It should be noted that the amplitudes of the “wiggles” around the central spike are less than 1 % of the central spike amplitude.

A study of the two Figures leads to the following conclusions:

- Different geometries have different PSTM responses.
- Slanted geometry responses (26 and 45 degree) are, in general, more asymmetric and distorted than straight geometries.
- The Flexi-Bin™ geometry response has a square symmetry as opposed to the orthogonal response, which has a more radial symmetry.
- The noise appears to be smallest on the Flexi-Bin™ geometry response. A quick analysis of the frequency content of the “noise” reveals that it is mostly in the 50 to 150Hz range and therefore possibly would not greatly affect conventional 3D seismic data.

The results above are preliminary and only begin to scratch the surface of this important topic. Namely, which geometry will give the best image? Much work remains to be done and will form the content of future papers.