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Choosing the Proper Domain and Input Data for 3D Interval Velocity Analysis

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SUMMARY

In recent years exploration targets have become more challenging due to their deeper position and higher complexity. In order to map these targets correctly, accurate 3D PSDM is usually required. Interval velocity analysis in such areas becomes a critical process.
The major concept of most velocity analysis procedures is that after PSDM, common image gathers (CIGs) should be flat if the migration was carried out with the correct velocity function. When the CIGs contain non-flat events the problem is how to relate this non-flatness to errors in the given velocity function.
In this study we argue that in complex 3D geological areas, the conventional velocity analysis techniques impose strong restrictions on our ability to derive an accurate interval velocity model. CIGs calculated by 3D PSDM are usually presented and analyzed as simple 2D arrays with their vertical axis being the depth and the horizontal axis denoting the acquisition offset or the subsurface scattering angle. Recent studies showed that this simplification may lead to a severe loss of coherent energy needed for the analysis. Since true representation of an image depth point requires 4 parameters (angles), it means that when we treat the CIGs as 2D instead of 5D arrays, we must apply summation over several dimensions (i.e. angles). When the velocity is wrong, this summation can damage the quality of the CIGs and limit the process of velocity updating.
To avoid this undesirable summation, it has been suggested to use the depth image domain coordinate system for the construction of the CIGs. The CIGs in this domain are five dimensional and none of the acquisition parameters (source-receiver azimuth and offset, or cmp) is used for their parameterization. Besides being more accurate, these multi-dimensional CIGs offer additional information on subsurface features like structural dip and directional illumination. They also provide excellent parameterization for post-migration AVA and anisotropy analysis. However, for the iterative process of interval velocity analysis the use of these CIGs is practically impossible.

We present here a practical method to apply interval velocity analysis in the depth migrated domain using diffractions as input data. There are several reasons which promote the idea of using diffractions for 3D velocity analysis:

1. Diffractions are true 3D events
2. In the depth-image domain only three parameters (time/depth, azimuth and dip-angle) are required to define the CIGs
3. Single offset data may be used as input
4. If the single offset is the zero offset (poststack implementation), no summation is performed during the generation of the CIGs
5. Since diffractions are represented by singe ray-path, they offer better sensitivity to directional velocity errors.

Through analysis of simple examples, we first demonstrate how parameterization of the CIGs according to the acquisition azimuth of the migrated traces, may lead to a wrong velocity model. We then describe how migrated diffractions are represented in the multi-dimensional CIGs, for the cases of using correct and wrong migration velocities. Finally an efficient procedure for flattening migrated diffractions in the post-migrated dip-angle domain is presented. The sensitivity of the method to directional velocity errors is demonstrated using synthetic and real data examples.