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3D Poststack Interval Velocity Analysis using Diffractions

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SUMMARY

A practical method for applying 3D interval velocity analysis in the depth migrated domain using poststack data as input is presented. The method takes advantage of the unique appearance of migrated diffractions in the Local Angle Domain. Diffraction energy is used in an iterative manner to update the three-dimensional subsurface interval velocity model.

Introduction

Recent advances in seismic data acquisition techniques, mainly in 3D, provide new possibilities for improving our ability to correctly image complex geological structures. To guarantee this improvement, accurate interval velocity analysis techniques must be employed.
One of the limitations of conventional velocity analysis techniques is claimed to be the fact that they relate the velocity errors to acquisition geometry (Reshef and Rueger, 2008). In order to overcome these limitations it was suggested to perform the analysis in the Local Angle Domain (Bleistein et al., 2005, Koren et al., 2007, 2008). In this domain, each depth point is characterized by four different angles which are reduced to two (scattering and dip angles) when 2D data are considered.
After migration of 2D data, it was shown that diffractions can be easily distinguished from reflections when the Common Image Gathers (CIGs) represent the structural dip angle as a function of depth. By taking advantage of these dip-angle gathers, Reshef and Landa (2009) presented a method for performing migration velocity analysis using diffractions.
In the following we extend the idea of using diffraction for interval velocity analysis to 3D. We describe how poststack data can be used as input to a detailed analysis and discuss some practical aspects of the proposed method.

Advantages of using diffractions for interval velocity analysis

There are several reasons which promote the idea of using diffractions for 3D velocity analysis. First, diffractions are true three-dimensional events with no preferred spatial orientation. Unlike reflections, they can be represented by a single ray path between the depth image point and the surface. During velocity analysis in the post-migration domain, diffractions will provide better control on directional errors, compared to reflections which may combine errors from two different paths.
If velocity analysis is performed in the depth-image domain, only three parameters (depth, azimuth and dip-angle) are required to define the migrated CIGs. From a practical point of view this is a significant advantage when compared to the five parameters needed for the analysis of reflections. Finally, the most attractive feature of the dip-angle CIGs is the fact that they can be produced from single offset data, or in other words – from stacked sections.
The process of generating the CIGs is simple. We apply standard Kirchhoff-based 3D PSDM to a stack volume. For each depth point, only a single traveltime function is required to migrate a single trace. Unlike the conventional process of generating CIGs, no summation is applied to the migrated data. The process becomes a mapping operation from the acquisition coordinate system into the LAD system (Koren et al., 2007) which is only three-dimensional for diffraction data. Velocity error detection and model updates are performed with respect to the parameters describing the image domain.

Velocity analysis procedure

When diffractions are used for velocity analysis, it is recommended to apply the analysis to CIGs located in the vicinity of the surface projection of the diffraction apex (Reshef and Landa, 2009). One way to select the analysis locations is by looking for closed events on time slices. Figure 1 demonstrates the selection process by showing a specific diffraction (marked by the black arrow on all three displays) that was marked as a preferred location for the analysis.
The concept of using diffraction for poststack velocity analysis is demonstrated in Figure 2. A crossline passing through the location of a 3D CIG is shown on top of the figure. A three-dimensional CIG was calculated at a specific surface location, marked by the black line over the top section. The effect of changing the velocity is represented by the four panels on the bottom. The panels are along

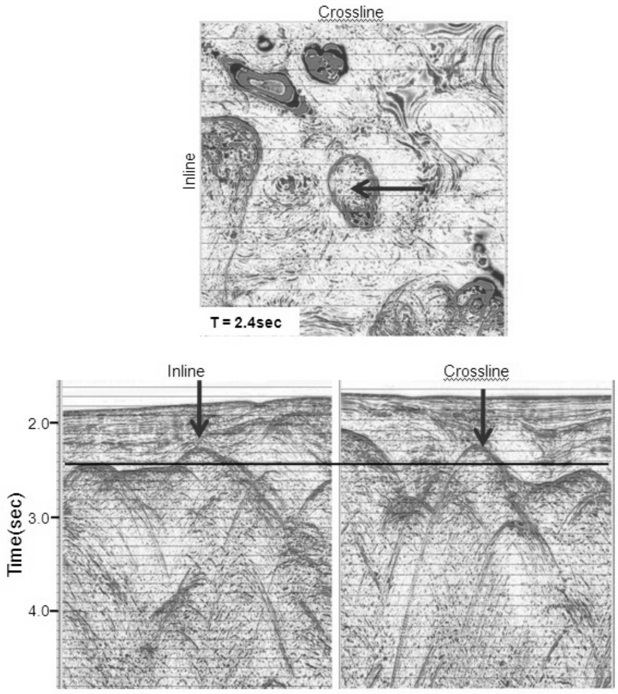

Figure 1 *Identifying a preferred location for CIG generation.*

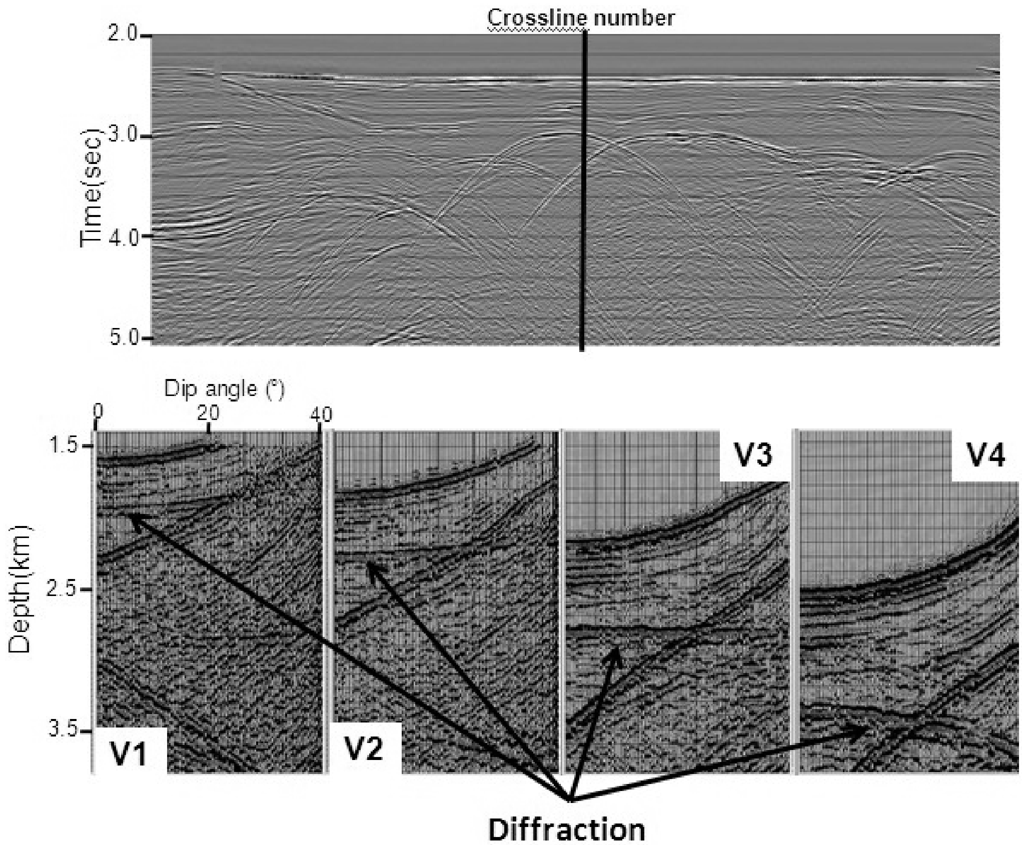

Figure 2 *CIG location (top) and a single azimuth dip-angle gather after migration with four constant velocities (bottom).*

the same azimuth. Each panel shows the CIG after migrating the stack volume with four constant velocities, increasing from left to right. Note that except for a vertical movement, the concaved shape

of the reflections (upper one is the water bottom reflector) does not change, while the diffraction changes its shape as the velocity increases. The flatness criterion, as a correct velocity indication, applies only to diffractions in this domain.
In complex areas it is expected that the velocity error will be azimuthally dependent. After a CIG is produced, at each depth level a semblance measure is calculated along the dip-angle axis for each azimuth. Figure 3 demonstrates the procedure. On the left, dip-angle panels are shown for 12 different azimuths. The diffraction close to the 3.2km mark (see black horizontal arrow on the figure), shows different flatness for each azimuth. The semblance measure is translated to a radial bar and displayed as a function of azimuth inside the unit circle shown on the right. The larger the bar, the more accurate is the velocity at this azimuth. If the CIG is positioned above the diffraction apex and the data were perfectly migrated, the semblance plot at the correct diffraction depth will show an equally filled circle. Even if the velocity is correct, reflections will result in a relatively small semblance measure since they always maintain their concaved shape.
Currently, velocity updates are performed by half-space scans and the model is built from top to bottom.

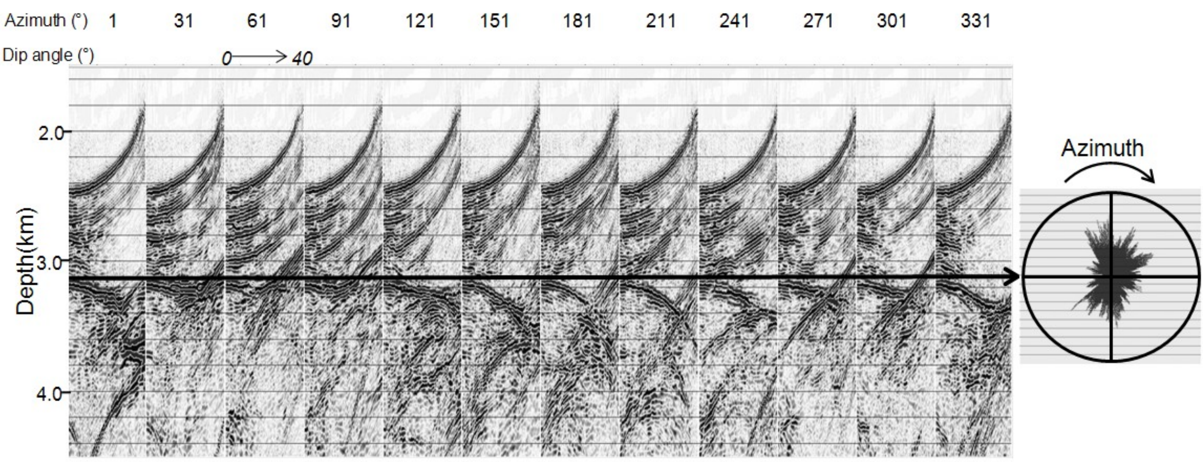

Figure 3 *A portion of a 3D CIG showing 12 different dip-angle gathers and the semblance measure along all azimuths at a depth of 3.2km.*

Selecting the optimal location for diffraction becomes non-trivial in situations where a large number of diffractions are concentrated in the same area. Figure 4, left, shows a portion of a stack section, collected on the earth's surface. Due to their long "tails", shallower diffraction events often mask the deeper ones. We suggest incorporating poststack datuming in the model building procedure. On the right side of Fig. 4 a datumed version of the stack is shown. The datuming is calculated to a constant depth and its purpose is only to provide a cleaner representation of the deep diffractions. Identification of locations for velocity analysis becomes easier. For a top-down model building strategy, datuming is an essential component. The cost of this extra operation is relatively small because it is applied to poststack data.

Conclusions

We presented a practical method to apply 3D interval velocity analysis in the depth migrated domain using diffractions as input data. The method takes advantage of the unique appearance of migrated diffractions in the Local Angle Domain. Migration of surface data to this domain is a mapping operation that does not apply summation when the CIGs are created.

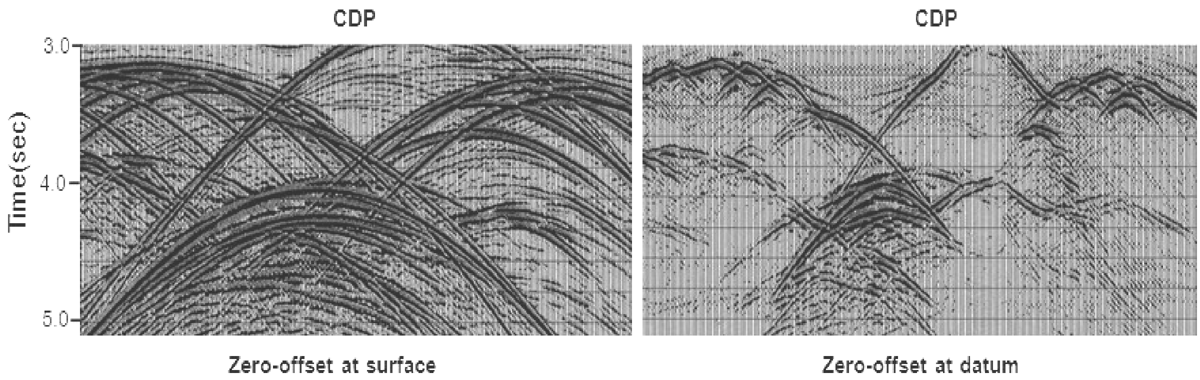

Figure 4 *The effect of datuming on diffractions.*

Due to the fact that the zero-offset diffractions are represented by a single ray path, they can be used as a reliable indicator for azimuthally dependent velocity errors.
It is well recognized that diffractions are not always maintained in stacked sections and even if they exist, their amplitudes are considerably smaller compared to the reflections.
It is therefore recommended that future work will concentrate on better separation of diffractions from reflectors and on the development of tomographic techniques for updating the velocity in the dip-angle domain.

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