3-D prestack wave-equation migration of North Sea common-azimuth data *Louis Vaillant, Paul Sava, Biondo Biondi and Henri Calandra*

3-D prestack common-azimuth depth migration has strong potential for accurately imaging complex media and correctly handling multi-pathing. Here, we apply the technique to a North Sea real data containing a salt dome. The results obtained demonstrate the suitability of the method for complex media. A detailed analysis of associated angle-domain common-image gathers shows opportunities for improving the velocity model.

Introduction

Wave-equation migration techniques have enjoyed a renewed interest since the shortcomings of Kirchhoff migration are becoming apparent, e.g. O'Brien and Etgen (1998). Moreover, powerful computing resources now make 3-D prestack depth migration feasible with such techniques. Based on a recursive extrapolation of the recorded wavefield, wave-equation migration methods are potentially better able to handle multi-pathing problems induced by complex velocity structures. Thus, they offer an attractive alternative to Kirchhoff methods (Mosher et al., 1997). Additionally, finite frequency wave propagation is modeled avoiding asymptotic approximations.

Common-azimuth migration (CAM) is a 3-D prestack depth migration technique based on the wave equation (Biondi and Palacharla, 1996). It exploits the intrinsic narrow-azimuth nature of marine data to reduce its dimensionality and thus manages to cut the computational cost of 3-D wave-equation imaging significantly.

Preprocessing and migration

Since we use a wave-equation approach, we must transform the data to a regular grid: CAM operates in the frequency-wavenumber domain, and requires Fourier transforms along all axes. In contrast, Kirchhoff algorithms can handle irregular geometries without the preprocessing described here.

We apply azimuth moveout (AMO) to perform this regularization (Biondi et al., 1998). It also allows local coherent stack of the data. AMO has a non-negligible computational cost in the whole imaging process (about 10-20% of the migration cost). With less accuracy, one can instead use a simple normalized binning procedure.

The processing begins by gridding the whole volume and then applying a simple sequence NMO/AMO/NMO^{-1} to regularize the data. This gridding concurrently allows data resampling in common-midpoint and offset at the limit of aliasing, in order to reduce the cube dimensions and lower computational cost.

Application to real data

To test the method, Elf Aquitaine provided us with an interesting dataset recorded in the North Sea, which shows a salt dome and other 3-D structures. The complexity of the wave propagation in the medium, resulting from high velocity contrasts, both lateral and longitudinal, yields multi-pathing and illumination problems. It makes this model a serious challenge for imaging.

The migrated volume covers an area of 10.5×4km, down to 2.7km in depth. It includes the top of salt, the salt flanks, and the beginning of an overhang. The velocity model, courtesy of Elf Aquitaine, was obtained by reflection tomography using the SMART[1] method (Jacobs et al., 1992).

For migration, we used 6 reference velocities in the extended split-step scheme of CAM. With data dimensions indicated in Table 1, the 3-D prestack common azimuth migration ran in 26 days on 4 processors of our SGI Power Challenge (18 MIPS R8000 Processors, 2 Gbytes of memory).

Table 1:	Number of samples					
	Cmp-X	Cmp-Y	Depth	Offset	Frequencies	Velocities
Subset	525	160	216	64	150	6

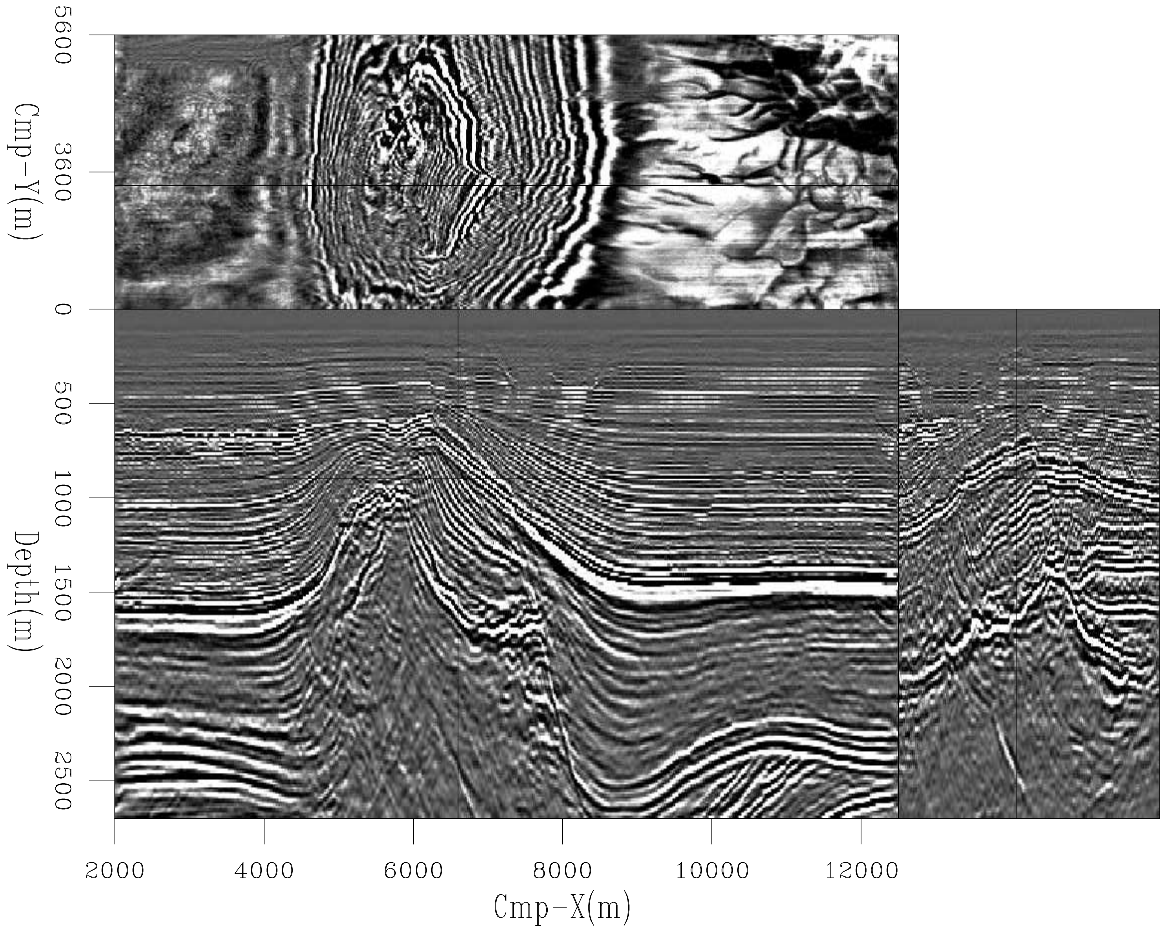

Figure 1: Sections of the migrated data at location: depth=900m, Cmp-X=6600m, Cmp-Y=3400m.

Discussion of the results

Figure 1 shows a typical set of sections in the middle of the migrated cube. In the in-line section, the shallower part (above 1500m) reveals high frequency details accurately imaged. The migration

[1]Sequential Migration-Aided Reflection Tomography - KIM (Kinematic Inversion Methods), IFP consortium

enhanced a graben structure, with normal faults and rocked blocks, around location Cmp-X=8000m, close to the top in the sand layer. The horizontal section at depth 900m highlights complex patterns inside the tertiary layer, imaged with a high resolution. Those can be interpreted as turbidite channels. The imaging of the salt body is satisfactory, with sedimentary layers clearly bent against the salt flank on the left-hand side.

Seismic imaging can be sketched as a two-step process: velocity estimation and migration. All modern migration algorithms require a simple and reliable way to extract prestack information for velocity estimation and updating. For this purpose, 3-D angle-domain common-image gathers can be easily computed in the wavenumber domain from the output of CAM (Prucha et al., 1999). Those panels enhance valuable information for analysis when the velocity model is complex and induces multi-pathing.

Figure 2 shows the same in-line section as before (Cmp-Y=3400m), with examples of the angle-domain common-image gathers that can be obtained from the migrated image. Unlike the image in Figure 1, the section is not a stack over the angle axis but instead a near-angle image. Even if it increases the noise level, it also displays more events (like the event marked "R") that are not stacked coherently because the velocity model is not perfect.

We can see from the analysis of common-image gathers that the velocity model obviously needs further improvements. Figure 3 shows the salt boundaries in the migrated section superimposed on the velocity model we used for imaging. Performing accurate imaging, especially deeper in the model, requires a more precise relocation of the major reflectors, such as the salt edges, with respect to the velocity model. For this purpose, the information provided by the common-image gathers can be reinvested in a residual migration process to improve the focusing of the migrated sections. The next step, which is less straightforward, is to update the velocity model from the perturbation between the starting and the improved images (Biondi and Sava, 1999).

Conclusion

Real data offers an opportunity to test our imaging techniques further. Common-azimuth migration is an attractive method for seismic imaging in complex media and remains a subject for further research. Its computational cost, illustrated in this particular example, can make it an attractive alternative to widespread Kirchhoff methods. The imaging of the North Sea data reveals lithologic structures focused with high resolution. Angle-domain common-image gathers highlight imaging insufficiencies around the steepest parts of salt flanks. They also offer opportunities for residual migration and velocity estimation.

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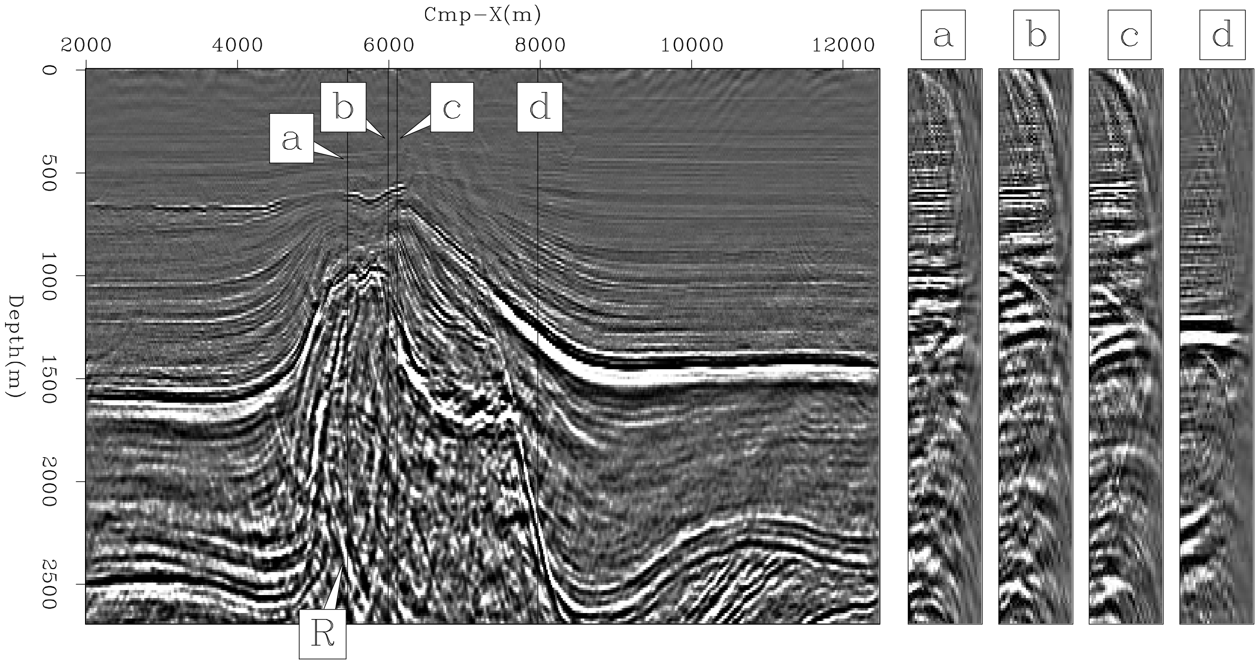

Figure 2: In-line near-angle section at location Cmp-Y=3400m with angle-domain common-image gathers (a), (b), (c) and (d). "R" represents a reflector that disappears in the stacked image.

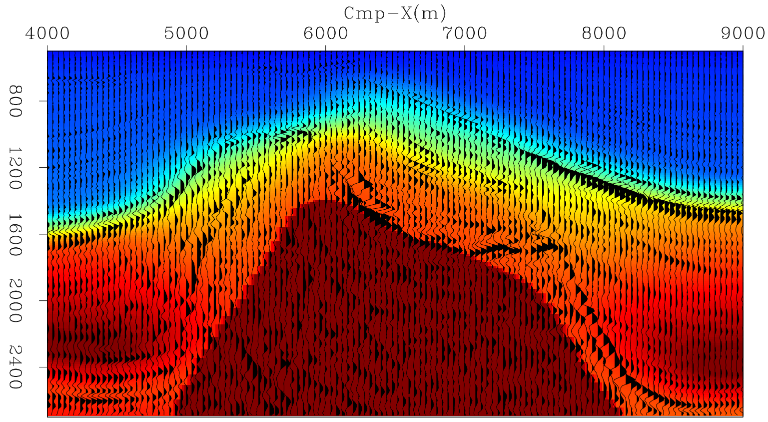

Figure 3: Close-up of the salt body. The near-angle migrated section has been superimposed on the velocity model. The important shifts between the edges of the velocity model and the salt boundaries yield inaccurate imaging as shown in some common-image gathers.