A Southern North Sea Multi-Survey preSDM using Hybrid Gridded Tomography*

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Abstract

Exploration in the southern North Sea using conventional imaging techniques is hampered by complexities in the Mesozoic overburden and the Zechstein evaporites with dolomitic rafting overlying potential targets. 3D preSDM imaging has come into widespread use in recent years, in an attempt to resolve such problems.

Here we present case history from the ConocoPhillips acreage over block 49/14a, where a four survey merge covering some 430 km² was reprocessed to yield a coherent single input volume for 3D preSDM imaging.

Hitherto, a layer-based model building approach has been commonly used for North Sea type environments, where sedimentary interfaces delimit changes in the velocity field and the geology 'lends itself' to a layer-based model representation.

However, recent work in the North Sea has demonstrated the advantages of removing the constraints of a simple layer-based solution, so as to permit a gridded tomographic approach to uncover the more subtle lateral changes associated with variable chalk compaction regimes. In addition, the rapid vertical velocity variation associated with chalk and salt interfaces which do profit from an explicit layered velocity boundary, are addressed by incorporating layer constraints in the gridded model to produce a hybrid gridded tomographic solution.

With this in mind, we have opted here to use a hybrid gridded tomographic approach for the model building. As with any tomographic solution, the key to success lies in having very dense picking of reliable input data, with appropriate constraints. We employed dense continuous automatic picking of residual moveout in CRP gathers at each iteration, based on plane-wave destructors, followed by gridded tomography, resulting laterally in a smoothly varying velocity field. This approach offers the possibility of quicker model update, as we do not need one preSDM iteration for each 'layer' in the model. The resulting images show good resolution of the Zechstein and Rotliegendes section, much improved on vintage processing, and good well ties.

Introduction

One of the most time consuming challenges in this project was the integration of data from various vintage surveys shot at diverse azimuths. The main aim of the pre-processing work was thus to optimally prepare and combine the gathers from the different surveys for imaging. Treatment of differing noise characteristics, offset ranges, frequency content, and acquisition bin sizes all contributed to the demands of this task. Short period water bottom multiples contaminated the data, so great effort was expended in finding the optimum methodology to suppress them.

For North Sea type environments where sedimentary interfaces delimit changes in the velocity field and the geology ‘lends itself’ to a layer-based model representation, a layer-based approach to velocity model building has hitherto been commonly used. In other words, we have encouraged preconceived bias, as we consider it to be a meaningful geological constraint on the solution (Jones, 2003).

Conversely, the gridded approach to velocity model building is usually adopted in environments where the velocity regime is decoupled from the sedimentation, and is governed primarily by vertical compaction gradients (velocity increasing with depth), controlled by de-watering, with isovelocity contours sub-paralleling the sea bed.

However, a purely gridded tomographic approach (Sugrue et al., 2004) is sometimes unable to preserve rapid vertical variations in velocity, and moreover, for seismically transparent layers with large velocity contrasts, we still need to constrain the model with interpretational input (Evans et al., 2005). With this in mind, we have here adopted a modification to the purely gridded approach to incorporate layer constraints at major vertical velocity boundaries.

Styles of Layer Constraint for Hybrid Tomography

A hard constraint layer (such as at the sea bed, top and base chalk, or pickable near-surface channel), would result in the model being left unchanged in subsequent iterations ABOVE the picked layer. As such we move from a global tomography to a non-global tomography (but still use a gridded tomography with the layered constraint: i.e. the hybrid tomography).

A soft constraint layer would be used if the layer being picked was very uncertain, as is often the case for an ill-defined near-surface channel or the seismically transparent top-salt picks in the Zechstein sequence of the North Sea. In this latter case, we profit from having the salt velocity inserted in the model below the picked layer, which helps the convergence of the inversion, even though we allow the tomography to change both the velocity in the picked layer and the layer pick itself. In this case the model above the soft-constraint pick can change.

Velocity Model Building and Pre-Stack Depth Migration

The initial depth velocity model was built from stacking velocities converted to interval velocity in depth. The water bottom was picked and gridded as a hard constraint, based on an initial migration to create the water layer in the depth interval velocity model. Following this step, we proceeded to several iterations of hybrid gridded tomographic update (Hardy, 2003), as follows:

a) Run 3D preSDM on a specified grid, outputting full offset gathers (125*25 m).
b) Run a plane-wave autopicker (APK) on all gathers, to determine dip, coherency, and residual curvature fields.
c) Input APK picked data into tomography and update velocity field.

For the strong vertical velocity contrasts (and when anisotropy is to be incorporated), horizons are picked as a constraint on the gridded tomography (the hybrid approach). In total, three constraint layers were picked, where we anticipated significant vertical velocity contrasts. In these iterations, an additional step was performed:

d) Using the updated velocity from the previous tomographic update (c), run a new 3D preSDM outputting a restricted offset stack for the structural interpretation (on a 50 m * 50 m grid).

The autopicker is a proprietary GXT algorithm, based on plane-wave destructors (Claerbout, 1992; Hardy, 2003). A user-defined 3D probe containing trace portions for different CDP's and offsets is moved about the data. At each position, the slope along the CDP axis and residual curvature across the offset axis is computed (via least squares minimization). The quality of these estimates is also computed. As a result of this picking, a 3D slope field and residual move-out estimate are determined.

As a by-product of the autopicking, we also obtained a residual moveout (RMO) corrected stack of the image. This is a good indication of whether the autopicker has found the correct residual move-out in preparation for the tomographic update.

Following the autopicking, the tomography takes the RMO and dip field measurements in conjunction with weights based on the ‘quality’ of the autopicks, and generates a tomographic solution to minimize the residual moveout values (make the gathers flat and correctly position the data).

Following completion of the model building, an amplitude preserving 3D Kirchhoff pre-stack migration was performed outputting all gathers on a 12.5 m * 25 m grid.

Discussion

Results indicate that the data merge and pre-processing have been performed well, and that the depth images are superior to the vintage processing, especially in terms of delineation of dolomitic rafts, and in imaging the Rotliegendes targets.

Successive iterations of the tomography converged to a smooth representation of the sonic well log, even though this is not an explicit constraint of the update procedure (Figure 1). Good well-ties were obtained during the model building, and isotropic migration was thus employed (Figure 2). Although this is somewhat counter intuitive, as we expect an anisotropic overburden, it could be that correct incorporation of vertical compaction gradient information (recovered by the gridded approach) has removed some elements of apparent anisotropy, thus leading to the good well ties (Jones, et al., 2003).

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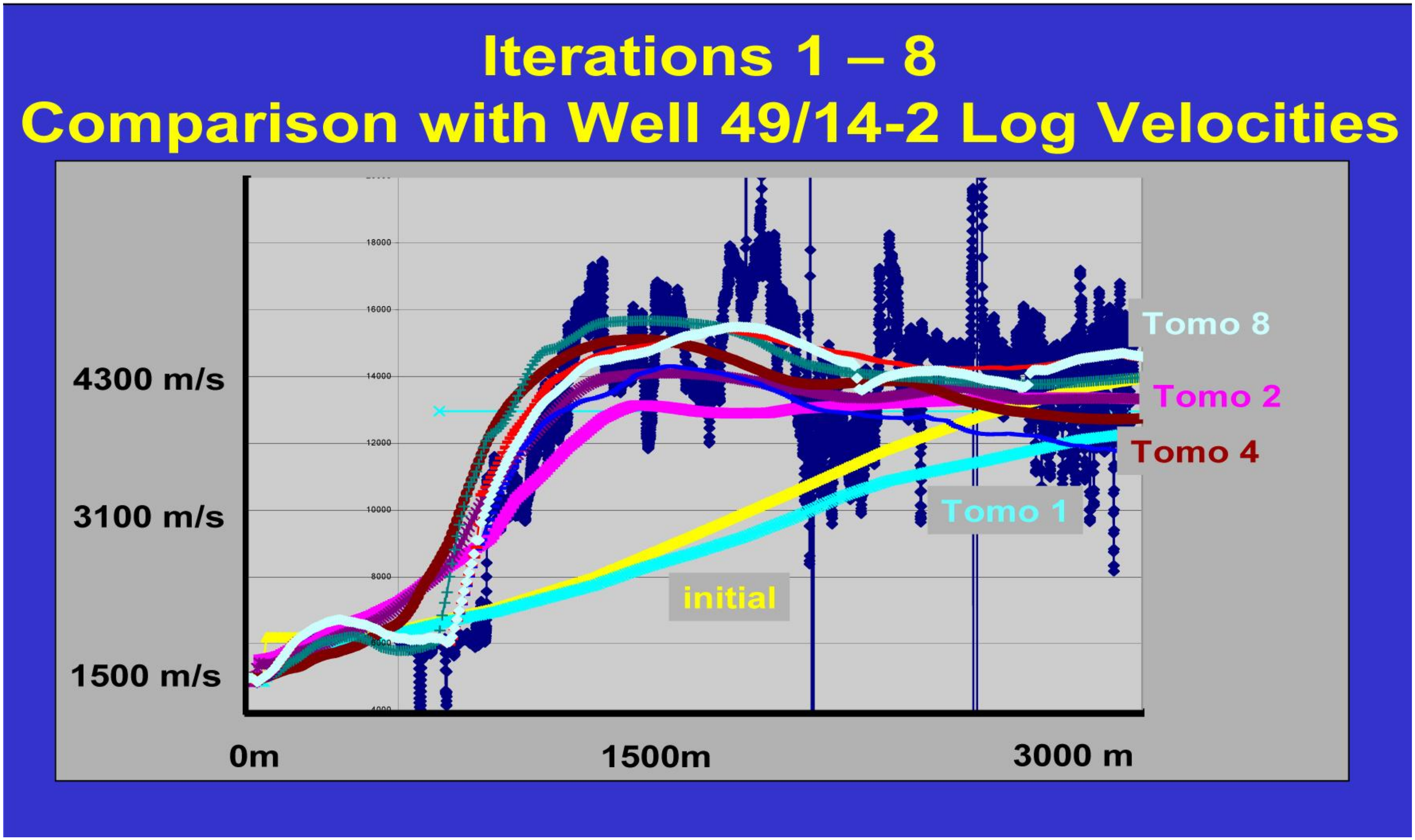

Figure 1. Sonic log compared to velocity profiles extracted from successive iterations of the tomography. The final iteration (8) resembles a smooth version of the sonic.

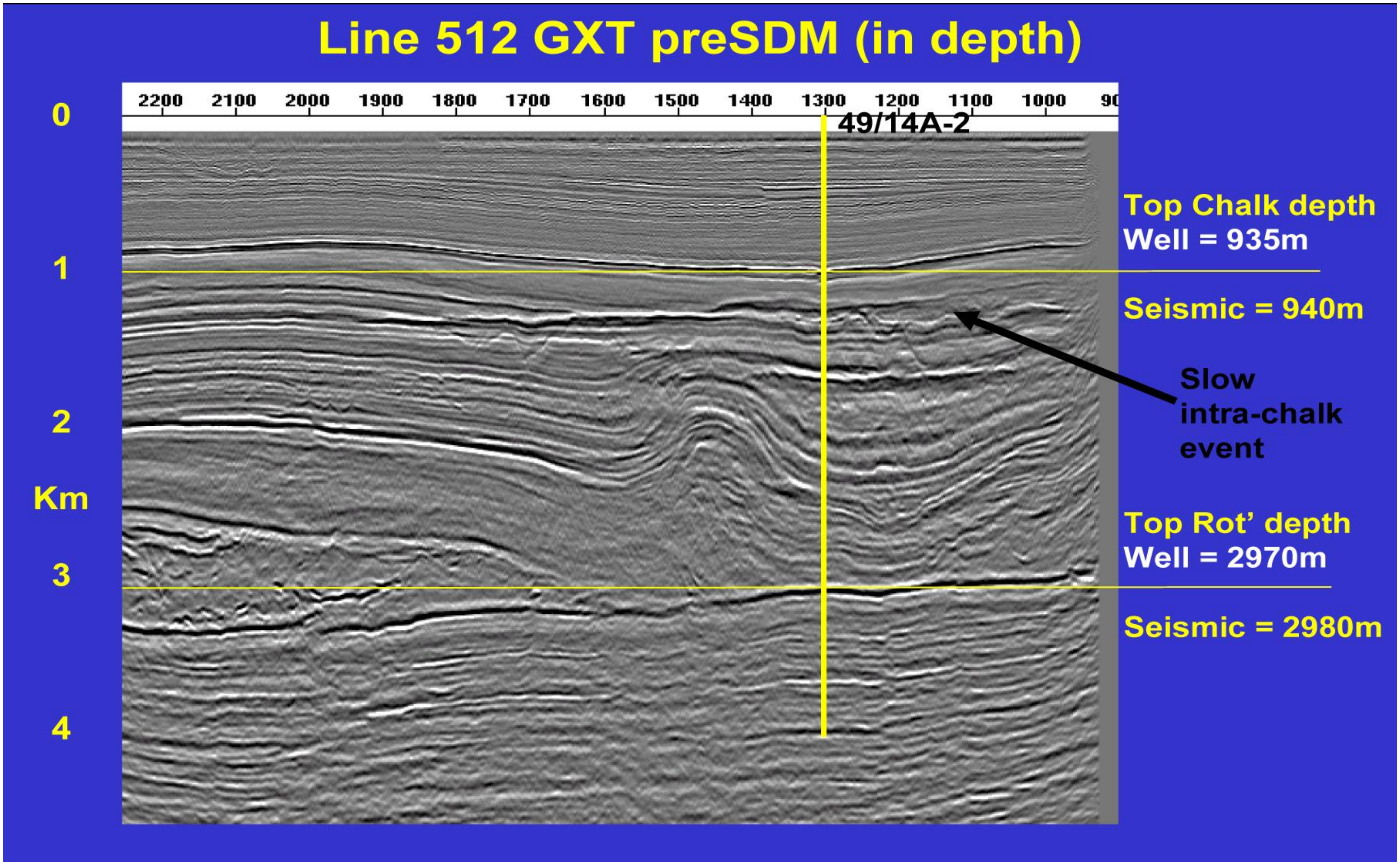

Figure 2. Final isotropic Kirchhoff preSDM, giving a good well tie.