Velocity Estimation in Complex Chalk

Mick Sugrue[1], Ian F. Jones[1], Emma Evans[1], Stuart Fairhead[2], Gary Marsden[3]

1: GX Technology, 180 High Street, Egham, Surrey TW20 9DN, UK
2: Amerada Hess Corporation, USA
3: Amerada Hess A/S, Denmark

2004 CSEG National Convention

Abstract

Here we consider a North Sea study where our initial approach was to build the subsurface model using interpreted horizons as a guide to the velocity update. This is common practice in the North Sea, where the geology 'lends itself' to a layer-based model representation. In other words, we encourage preconceived bias, as we consider it to be a meaningful geological constraint on the solution.

However, in this instance we had a thick chalk sequence, wherein the vertical compaction gradient changed subtlety, in a way not readily discernable from the seismic reflection data. As a consequence, imposing the explicit top and bottom chalk horizons, with an intervening vertical compaction gradient (of the form $v(x,y,z) = vo(x,y) + k(x,y).z$), lead to a misrepresentation of the subsurface.

To address this issue, a gridded model building approach was also tried. This relied on dense continuous automatic picking of residual moveout in CRP gathers at each iteration, followed by gridded tomography, resulting in a smoothly varying velocity field which was able to reveal the underlying local changes within the chalk.

Introduction

Current practice in velocity model building usually resorts to one of two approaches: the layer-based and the gridded (Jones, 2003a). The layer-based approach is typical of say a North Sea type environment, where sedimentary interfaces delimit changes in the velocity field. The gridded approach is adopted in environments such as found in the Gulf of Mexico, 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 iso-velocity contours sub-paralleling the sea bed.

In the example considered here, which is typical of many North Sea fields, we have a thick chalk sequence, with a vertical compaction gradient within the chalk. The nature of these compaction gradients can be quite complex, with many subdivisions that are not obviously manifest in terms of a clear seismic response. Due to compaction within the chalk, we can move from a near constant velocity regime in the uppermost part of the chalk, to a steep compaction gradient regime, and then back to a constant (high) velocity region at the base of the chalk, where the chalk has been compressed as much as it can be by the overburden pressure.

Two classes of error can occur in building a model for such chalk bodies:

1. The internal layering in the chalk may not be sufficiently well represented in the layered model, due to the difficulty in picking a clear event when we have a change in compaction gradient rather than a sharp change in reflectivity

2. Errors in the estimate of the values for the compaction gradient can manifest themselves as apparent anisotropy (Alkhalifa, 1997; Jones, et al, 2003b)

Both of these errors will result in sub-optimal imaging, including the lateral mispositioning of faults (Alkhalifa & Tsvankin, 1995; Hawkins, et al, 2001)..

North Sea Example

The real data shown here comes from an area with a benign flat lying overburden.

The initial model building was performed using iterative CRP scanning with a layered model incorporating the top and base chalk as the main velocity contrasts, with a single compaction gradient within the chalk (figure 1).

Upon completion of the layered model building, a gridded update (Hardy, 2003) was employed to investigate detailed changes within the chalk. The gridded model is shown in figure 2. The portion outlined in the box, where we observe the greatest changes in the velocity model, is used for the detailed figures shown in figure 3. We see: 3a: the layered model, 3b: the gridded model, 3c: the preSDM from the layered model, 3d: the preSDM from the gridded update.

We observe that the upper part of the chalk is better described by a near-constant velocity region, and that the strong gradient regime commences deeper within the chalk. Importantly, the vertical compaction gradient is not constant laterally across the chalk body: when building a layered model, it is usual to keep a constant gradient in a given layer, as we seldom have sufficient well control to justify lateral variation in layered models. In the region with gas leakage, where the faulted chalk thins, we observe the greatest impact of the gridded update.

Discussion

We will address strategies for building models for complex chalk geology, and contrast results for manual update in a layered model building scheme, with a dense auto-picking-driven gridded tomographic approach. The influence of anisotropy on gradients will also be addressed.

Background Reading

Al-Chalabi, M., 1974, an analysis of stacking, rms, average, and interval velocities of horizontally layered ground. Geophys. Prosp., 22, 458-475.

Alkhalifah, T., & Tsvankin, I., 1995, Velocity analysis for transversely isotropic media; Geophysics, 60, no.5, 1550-1566.

Alkhalifah, T., 1997, Velocity analysis using nonhyperbolic moveout in transversely isotropic media; Geophysics, 62, no.6, 1839-1854.

Hardy, P.B., 2003, High resolution tomographic MVA with automation, SEG/EAGE summer research workshop, Trieste.

Hawkins, K., Leggot, R., Williams, G., & Kat, H., 2001, Addressing anisotropy in 3D pre-stack depth migration: a case study from the Southern North Sea. The Leading Edge, v20, No.5, pp528-543.

Jones, I.F., 2003a, A review of 3D preSDM velocity model building techniques First Break, v21, No.3, pp45-58.

Jones, I.F., Bridson, M.L., & Bernitsas, N.X., 2003b, Anisotropic Ambiguities in TI Media. First Break, v21, No.4, pp31-37.

Thomsen, L, 1986, Weak elastic anisotropy; Geophysics, 51, no.10, 1954-1966.

Acknowledgements

The authors wish to thank the Amerada Hess UK, and partners for kind permission to use their data.

Figure 1, 3D layered model: a benign overburden over a complex chalk layer

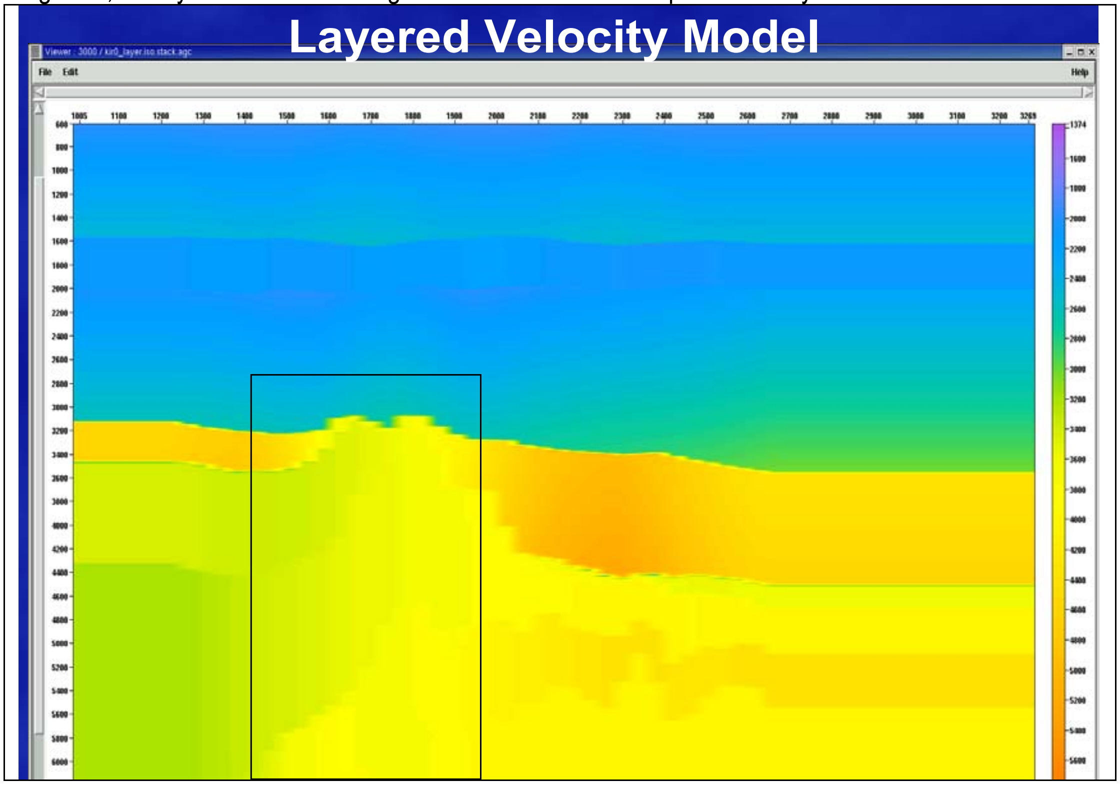

Figure 2. The gridded tomographic model. The box highlights the segment used in fig.3. where greatest changes are seen

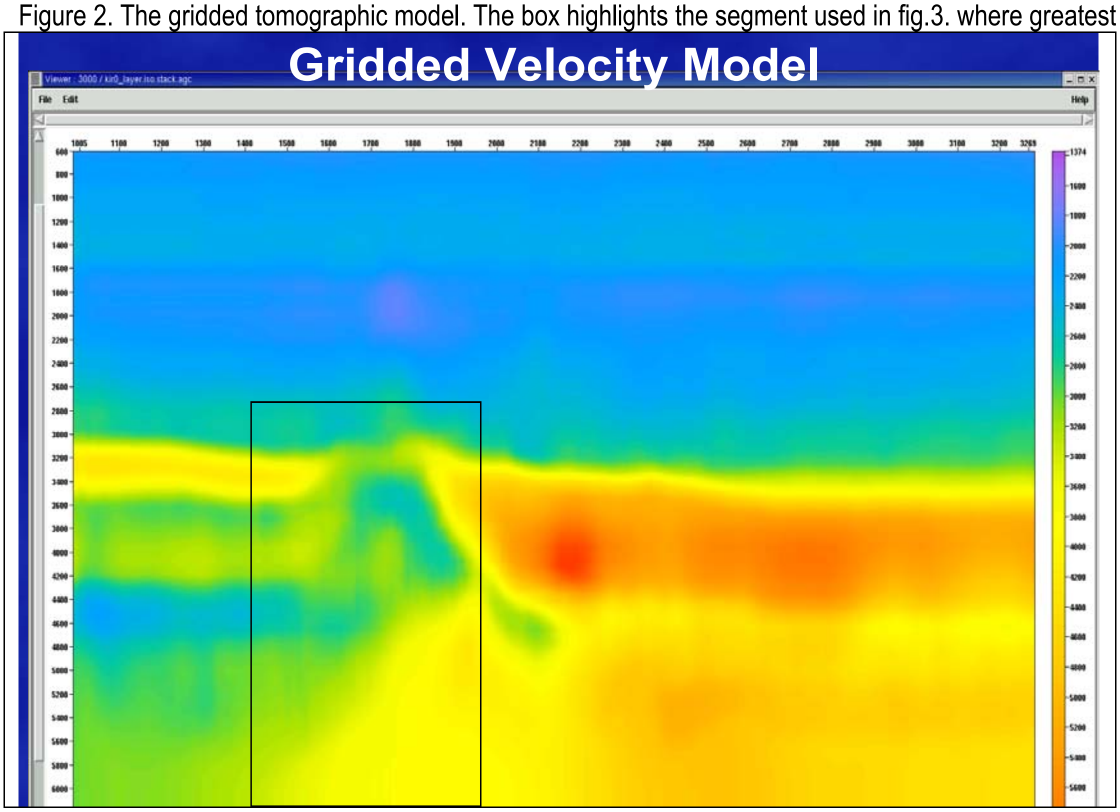

Figure 3. a: the layered model, b: the gridded model, c: the preSDM from the layered model, d: the preSDM from the gridded model