Non-Linear tomography for time imaging

G. Lambaré* (CGGVeritas), N. Deladerrière (CGGVeritas), Y. Traonmilin (CGGVeritas), J.P. Touré (CGGVeritas), J. Le Moigne (CGGVeritas) & P. Herrmann (CGGVeritas)

SUMMARY

Velocity model building for time imaging generally involves an iterative process involving several loops of PreSTM, picking, and velocity update. We propose a new approach allowing the full interpretation of kinematic information picked on PreSTM gathers in a single loop. We determine the effective \((V, \theta)\) velocity model using a slope tomography. The kinematic information picked on PreSTM gathers, i.e. dips and residual move-out, is demigrated to get kinematic information in the un-migrated domain, as required by our slope tomography. Considering that a single picking step is required, our picking must be as accurate as possible. Approaches involving volumetric picking of dips and scanning of parametric RMO curves can be used but we also discuss the benefit of using a multi-dimensional dip picking tool. Such a tool insures spatial consistency, allows introducing dip variation with offset and it is not penalized by parametric RMO curves. We present an application to a field data demonstrating the ability of our approach to fully interpret kinematic information in a single tomographic step.
Introduction

Velocity model building, in time and in depth, generally involves several loops of prestack migration, picking, and velocity update. In depth non-linear tomographic approaches have been proposed for accurately solving the velocity update from a single picking (Guillaume et al., 2008; Lambaré 2008; Adler et al., 2008). When starting from initial prestack migration results a demigration step is performed in order to convert kinematic information picked in the migrated domain into kinematic information in the un-migrated domain. These are what we call “kinematic invariants” because they do not depend on the velocity used for the initial migration (Guillaume et al., 2008).

We propose here to extend non-linear slope tomography in depth (see Lambaré 2008 for a review on slope tomographic methods) to 3D velocity model building in time. Our new approach uses locally coherent events picked in the PreSTM, the PreSDM or even in the un-migrated domains. Compared to the approach we presented in Lambaré et al. (2008), which also involved some local slope tomography, we have now a fully 3D slope tomographic tool allowing for a joint estimation of the effective velocity and anellipticity fields.

Non-linear time tomography for effective velocity update

Kinematic information for slope tomography consists of locally coherent events in the prestack un-migrated domain. Consider the 2D case for simplicity (Figure 1). The locally coherent events are characterized by their central position \((r,s,T_{\text{obs}})\) and by their local slopes in the un-migrated data-cube \((\text{slope}_m = \partial T_{\text{obs}}/\partial m, \text{slope}_h = \partial T_{\text{obs}}/\partial h)\) \((m\) denotes for mid point position and \(h\) for offset).

For a given velocity model these events can be kinematically migrated in time. We then obtain the location and dip of the associated migrated facet and even the
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dRMO = \frac{\partial T_{\text{sr}}}{\partial h} \bigg/ \frac{\partial T_{\text{mig}}}{\partial h} - \frac{\partial T_{\text{obs}}}{\partial h}\bigg/\frac{\partial T_{\text{mig}}}{\partial h},
\]
where \(T_{\text{sr}}\) denotes the travel time used in the time migration (Chauris et al., 2002). A slope tomographic tool can be built to minimize the square of \(dRMOs\) or even the square of slope misfits, \(\Delta \text{slope}_h = (\partial T_{\text{sr}}/\partial h - \partial T_{\text{obs}}/\partial h)\). This has been developed in depth (Guillaume et al., 2008), it is here developed in time.

Our 3D slope time tomographic tool is based on a fully non-linear iterative scheme converging to the velocity model best minimizing the \(\Delta \text{slope}_h\) of the migrated facets (Figure 2). Its inputs are locally coherent events in the un-migrated domain. In our processing sequence they can be picked either in the PreSDM or PreSTM domain (Guillaume et al., 2008; Lambaré et al., 2007). The smooth effective velocity and anellipticity models are described in a sparse way by cardinal cubic Bsplines functions.
and we compute numerically Fréchet derivatives of data, i.e. $\partial T_{sr}/\partial h$, with respect to velocity and anellipticity parameters. We use finally a quasi-Newton scheme based on LSQR for the non-linear optimisation, with an appropriate regularization.

**Automated picking strategies**

In the example presented here picking is done on an initial PreSTM result. Two types of automated picking have been tested. The first one involves a volumetric dip picking on the migration stack and for the RMO a scanning by polynomial curves (Siliqi et al., 2007). Such an automatic picking is robust and in used in many velocity model building applications. It exhibits however several drawbacks when using non-linear slope tomographic tools, which require the most accurate picking as possible. First no variation of the dip with offset is considered (Figure 3). Second parametric curves may have difficulty fitting observed RMO curves (Figure 4).

**Figure 2:** Non linear velocity update in our 3D time slope tomography.

**Figure 3:** variation of dips with offset. Common offset PreSTM sections for $h=550$ m (Left) and $h=3050$ m (Right) A time shift has been introduce to compensate for the RMO. Three events have been highlighted exhibiting changes of the dips versus offset. For the one on the left we have reported an estimation of the dip in depth.

**Figure 4:** comparison of automated RMO picking. Center) the CIGs. Left) the corresponding RMO curves obtained by scanning of polynomial curves. Right) the corresponding dRMO picked by multi-dimensional dip picking. Note that with our slope tomography there is no need to consider RMO curves, but only small portions of them.

Considering this we have tested a new automated picking tool based on a multi-dimensional volumetric dip picking (Traonmilin et al., 2009). Unlike the previous tool where dRMO was obtained...
differentiating the parametric curves, this tool directly provides the local dips of the reflected events observed in the PreSTM dataset (dipX, dipY and dRMO). It solves for conflicting dips and also provides a skeleton for the tomographic inversion. The advantages of the tool are that dips are computed for each common offset panel, that there is no limit regarding the allowable RMO (Figure 4) and finally the volumetric picking of the RMO helps to stabilize the process.

Field data example

This new approach was carried out on a dataset provided by Edison. Figures 5 and 6 show the initial PreSTM, i.e. common offset section 550 m and associated CIGs, respectively. Since the velocity model was only preliminary, some further flattening of CIGs is necessary.

![Initial PreSTM image for offset 550 m.](image)

![Initial PreSTM CIGs corresponding to figure 5. Maximum offset is 4km.](image)

Figure 7 shows the CIGs obtained using automated multidimensional dip picking (Figure 4 Right) on the initial PreSTM results, the kinematic time demigration and finally our slope tomographic tool. We see that from a single picking we have been able to directly estimate the effective velocity model best flattening the PreSTM CIGs.
Conclusion

Velocity model building for time imaging can take advantage of the approaches developed for velocity model building in depth. We show here how a non-linear slope tomography in time allows solving the velocity model building in time in a single tomographic step.

Acknowledgment

We thank Edison International, Petrosea and Petrobras for the authorization to show the field data example, and CGGVeritas for support in presenting this work.

Figure 7: PreSTM with the velocity models obtained with our slope tomography from data picked with an automated multidimensional dip picking tool (Figure 4 Right).

References


