EXAMPLE OF STRATEGIES IN 3D STACKING VELOCITIES INVERSION

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Abstract

Several software tools have been developed by the industry in the last few years to build up the depth- or time-migration velocity model using travel times or stacking velocities.

The Elf Enterprise Geoscience Research Centre has created its own programme called "SuperDix" to invert stacking velocities in 3D in terms of a depth macro-model. Our experience in utilising this tool on actual data sets led us to several practical conclusions that will be presented here. The main issues we will discuss based on actual data sets include :

- the validity of the stacking velocities to be inverted;
- the macro-model parameterisation; in particular we will discuss the choice between local and global inversion;
- the importance of the DMO simulation;
- the importance of a vertical gradient in the macro-model;
- the flexibility offered by the use of a well-adapted 3D modeller.

Main features of SuperDix

SuperDix is a 3D velocity-inversion software package that uses as a standard input both stacking velocities picked after DMO and maps of time-migrated picks. 3D gridding and visualisation facilities are based on the *gOcad*TM 3D modeller.

Time horizons are time-demigrated using the actual migration velocity field and depth-remigrated for a series of given interval velocity functions. Offset ray tracing is then carried out on each individual model, accurate DMO emulation is applied on modelled travel times to compute synthetic stacking velocities at each original stacking-velocity location. All these operations are done in a fully 3D sense.

This allows the computation of a cost function measuring the mismatch between actual and synthetic stacking velocities weighted by the difference between synthetic and actual zero-

offset travel times. A conventional optimisation routine yields the interval velocity that minimises this cost function.

Finally the time horizon is depth map-migrated with the optimum interval velocity function in order to create the final depth macro-model.

The macro-model is parameterised as follows : each layer of the model can be arbitrarily divided into patches; then for each patch the instantaneous velocity function is defined as $V_0 + kZ + \Delta V(x,y)$, where k is the classical compaction factor with V_0 being the surface reference velocity, and $\Delta V(x,y)$ is an interval velocity perturbation term. During inversion only V_0 and k are generally inverted, the perturbation term being considered as input.

Discussion

Analysis of data to be inverted :

Figure 1 is a *gOcad*TM 3D view of the stacking velocity field as it has been picked on a 3D survey (crosses); each value is then extended in space in its own "zone of influence" without interpolation and colour coded. The time-migrated horizons have also been added. Quality (proper sampling and consistency) of the field can thus be assessed visually in 3D. The figure shows for instance the inconsistent spacial variations of stacking velocities (see horizontal and vertical cross-sections) even in flat areas. This illustrates the fact that the data to be inverted must be handled with care. Smoothing or median filtering may not always be an adequate way of editing them. Solutions like increasing the density of analyses or systematically reviewing the picking should be considered.

Global versus local inversion :

The flexibility of SuperDix resides in the fact that the inversion procedure can be organised in different ways. The model is always constructed in a layer stripping way, but a given layer can be inverted "globally" meaning that a single cost function is computed for the whole layer, or

"locally" which means that a layer is subdivided into patches that are inverted separately. An other option is to invert several layers "globally" in one run.

The advantages and drawbacks of each technique will be illustrated in relation to the parameterisation of the interval velocity field.

Global inversion is interesting as a first trial to diagnose problems. Figure 2 for instance displays a depth layer after global inversion. Stacking velocity misfits are vertically projected onto the depth surface for diagnosis. This picture is used to define patches for local inversion. Global inversion is particularly interesting when the reliable stacking velocities are scarcely distributed.

Local inversion allows a much simpler parameterisation of velocities, thus improving the stability of the whole inversion process. All individual inverted interval velocities must then be merged together in order to create the complete interval velocity function for the whole layer. It is not recommended that this process be done blindly. On the contrary a lot of interpretive information can be added at this stage.

Importance of DMO :

The influence of DMO on stacking velocities is well-known. Two strategies are currently used in the industry to take it into account during the inversion process : pick an extra set of stacking velocity analyses for which DMO has not been applied and compare the picks to synthetic stacking velocities computed through CMP ray-tracing; or, alternatively compute CRP (common reflection point) travel times to simulate the application of the DMO operator before computing the stacking velocities. This approach is more practical, less expensive but probably less accurate.

Our approach in SuperDix consists in computing offset rays and applying the actual DMO operator to the corresponding times and time-dips, thus accurately emulating the processing undergone by the data being inverted.

Vertical velocity gradients :

The vertical gradient is definitely part of the geological *a priori* information that must be used during inversion. It can also be seen as a way of introducing layer heterogeneity in the macro-model, thus taking into account to a

certain extent the discrepancy between average and RMS velocities.

Our experience shows that introducing a vertical gradient is not only a very realistic way to explain apparent lateral velocity variations in a layer which varies in depth and thickness, but it also improves the convergence of the inversion. This is illustrated in figure 3 which displays the results of three inversions done with three gradient values (0, 0.3, 0.55) on a set of patches located about a salt dome. A gradient of 0.3 yields the most homogeneous V_0 map (top) and the smallest cost function, whereas the regional geological background suggests a compaction factor of 0.55.

Conclusion :

Nowadays it is commonly accepted that inversion requires a great deal of interaction with the interpreter. It will become clear from the different examples shown in the presentation that firstly an inversion tool must be very flexible in order to cope with the interpreter's knowledge or comments; secondly that a 3D modeller with well adapted functionalities like 3D interpolation and visualisation or projection on a given surface of related properties, is a convenient way to have the interpreter interacting in the inversion process.

Finally, in our (still limited...) experience inversion is easier in 3D than in 2D since more *a priori* information can be introduced, provided that well adapted tools are available.

List of figures :

Fig. 1 : Input data to the SuperDix inversion software package are time migrated horizons and stacking velocity picks .

Fig. 2 : Global inversion of a layer.

Fig. 3 : Local inversion and influence of the vertical gradient parameter.

Acknowledgments :

The authors would like to thank Pierre Thore who actively participated in the development of the SuperDix software package. The authors are also grateful to Elf for their authorisation to publish this work.

$k=0.0$ $k=0.3$ $k=0.55$

Figure 3 : Influence of the vertical gradient k during local inversions. The V_0 map is plotted at the surface. The stacking velocity misfit is projected onto the depth surface. An optimum k of 0.3 can be found, that minimizes both the misfit and the spatial variation of V_0 .

Figure 1: **gOcad**TM view of the stacking velocity information and the time migrated horizons. This data set is standard input to SuperDix.

Figure 2: Results of global inversion for a layer. The stacking velocity misfits are vertically projected onto the depth surface for diagnostic purposes. (See figure 3 for colour scale).