EFFICIENT GENERATION AND VERIFICATION OF 3D VELOCITY MODELS - UK SOUTHERN GAS BASIN

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The need for robust 3D model-building technology and methodology to support 3D pre-stack imaging is well recognised within the seismic processing industry. What has received relatively less attention is a) development of techniques which maximise the value of the conventional 3D processing sequence; and b) critical evaluation of the performance of the ray trace algorithms which generate the traveltimes tables for the pre-stack migration "engines". Enhancements in these two areas are considered essential components in the creation of an economically viable 3D pre-stack processing product. In this paper we present a case history which specifically examines these issues.

The study area is the Lancelot Field, located in the U.K. southern gas basin. Structure at the objective (Permian) Rotliegendes formation consists of relatively planar, tilted fault blocks. The objective is overlain by Mesozoic grabens and mobile Zechstein Evaporites. This results in severe vertical and lateral variations in the 'overburden' velocity field. In the critical imaging areas, the major velocity boundaries correlate with steeply dipping geologic interfaces/faults. As a result, the full impact of associated traveltimes moveout variations occur well within the typical seismic spread length. The objective of this exercise was to develop an accurate 3D velocity model in preparation for a 'swath' 3D pre-stack imaging project.

Data Retention and Initial 3D Velocity Model Building

Most conventional 3D processing projects attempt to integrate some form of horizon mapping into the stacking velocity QC and migration model generation phases of the project. This process results in an initial 3D velocity model which is already closely tied to the 3D seismic data and, possibly, the 'best available' geophysical horizon interpretation. Significant cycle time and cost benefits may be realised if the information and data obtained from the initial model building and seismic pre-stack processing exercises is retained for later use.

However, per the objectives of advanced pre-stack imaging, 3D velocity models derived from conventional processing must be considered to be of limited value. Enhancements to the initial model building process, including validation and updating of the model, are considered prerequisites to utilisation of this velocity information in pre-stack imaging applications.

The main technical deficiencies of 3D velocity models generated in a conventional 3D processing flow tend to fall into two categories:

a) *Time Surfaces*

The interpreted time horizon surfaces are generally derived from pre-existing 2D or 3D 'brute' stack data. Even if final 3D migrated time surfaces are available, there will invariably be some degree of imaging error in the structurally complex areas.

b) *Velocity Information*

The RMS velocity analysis process is inherently unreliable in structurally complex areas and, in addition, velocities are generally not *initially picked* in a 3D horizon consistent manner. Also, no information is provided with respect to interformational velocity gradients.

Preservation of the pre-stack processed seismic data requires significant additional expense during the conventional processing phase, to allow for the *possibility* of future 3D pre-stack imaging projects. It is suggested that this cost can be justified on both technical grounds and future potential cost savings (of reprocessing from field tapes); and therefore should be incorporated, *as standard policy*, in the specification of the conventional processing project. These data retention procedures are considered to be critical in a) maximising the value of time domain pre-stack processing and b) providing more favourable economics for any future 3D pre-stack imaging work.

In the processing of the Lancelot dataset, interpreted migrated time and interval velocity surfaces generated from the existing dense grid of 2D seismic and well data were utilised to generate synthetic 3D RMS velocity curves at every 'real' RMS velocity analysis location (on a 500 m x 500 m grid). The synthetic RMS velocity curves were superimposed onto the actual semblance analysis panels used in the velocity picking process. The result was 3D horizon consistent picking during the initial velocity analysis. This was followed by conventional horizon-consistent velocity QC prior to stacking, 3D interval velocity model building, and velocity scaling prior to the post-stack time migration. Prior to the initiation of the pre-stack imaging project, a 'fast track' 3D interpretation of the critical velocity surfaces was performed on the 3D time migrated data. The interpreted migrated time surfaces were then merged with the interval velocity surfaces, and depth converted, to create a initial 3D velocity/depth model.

Large (crossline) tidal currents in the study area resulted in significant feathering of the seismic streamer; affecting most of the data acquired. In addition, substantial crossline structural dip was mapped within the survey area. As a result, 2D processed sail lines were considered insufficient for the pre-stack model verification stage. The conventional processing of these data included 3D-DMO. In order to take maximum advantage of the conventional processing flow, a scheme was devised to utilise these partially (time) migrated data. Upon completion of the conventional pre-stack processing, a selection of 3D-DMO common offset plane (unstacked) 2D bin lines were saved to tape. Inverse inline 2D DMO ('un-DMO') was then applied to these data for use in the pre-stack model verification step. At the same time, the edited and navigation merged pre-stack data, processed through to DBS, were output and transcribed to D2 mass media for use in the full 3D pre-stack imaging project.

Validation of the Velocity Model and Pre-Stack Imaging Algorithms

As described in the previous section, an initial 3D velocity/depth model was created in association with the conventional processing sequence. Prior to utilisation of this model for 3D pre-stack imaging, validation of the RMS derived velocity field was required. This was accomplished through 2D pre-stack depth migration of the un-DMO processed 2D bin line in the centre of the 3D swath, using the initial 3D velocity field.

The ray tracing step of the depth migration is a *Runge-kutta* technique which generates the traveltimes and parameter tables for the migration operator. The depth migration operator employed was a Kirchhoff based algorithm which works in the common offset domain.

Common image gathers were selected from the dataset at specified locations along the line with finer sampling in the more complex areas. Residual wavefront curvature analysis of common image gathers (Al-Yahya 1989, Deregowski 1990) produced by the 2D pre-stack depth migration provided the velocity information which was used to update the initial 3D velocity/depth model. Additionally, focus panels (Yilmaz and Chambers, 1984; Faye and Jeannot, 1986) were generated at these locations to provide additional velocity information and confirm the velocity modifications.

Even though the input 3D velocity field was a highly detailed and tightly constrained model, significant modifications were still required. Analysis of the image gathers from the initial migration indicated that where the velocity/depth model (and associated geology) was relatively simple and flat lying, the RMS derived interval velocities were generally within the limits of accuracy of the pre-stack migration velocity analysis techniques. However, in structurally complex areas (in the vicinity of the graben) the image gathers displayed a significant degree of residual moveout. Revisions to the interval velocity fields of over 300 m/s (5% - 9% of the total field) were required within, and adjacent to, the main graben area. These corrections were consistent with predictable errors associated with the RMS velocity analysis procedure used in the generation of the initial 3D velocity/depth model. Model updating was performed via the conventional approach of model building/verification in an iterative layer by layer downward process.

The process of analysis and calculation of a new velocity model highlighted the major limitation of these techniques and the entire updating method. Although the velocity analyses were performed, and updates applied, at closely spaced surface locations along the line, the information contained within any particular panel of data is derived from a much wider area, as determined by the ray tracing step. In the presence of strong lateral velocity variation, it becomes impossible to accurately update a given part of the model by analysis of the panel at that location alone. In these areas, velocity modification performed at any particular location only has a direct, predictable, effect on the near offset traces at that location. Data contained in the further offset traces is affected by modifications performed on other panel locations. The aperture of influence is dependent upon the spread length and structural complexity. The problems encountered in this 2D experiment would be further exacerbated in the full 3D environment. On the Lancelot dataset, this problem was only partially resolved through a manual trial-and-error iterative approach. The preferred method would be to utilise the travel time information derived from the ray tracing to perform a tomographic inversion of the velocity error information (Lafond and Levander, 1993).

Secondly, another significant problem was encountered in the vicinity of the graben margins. The ray-tracing in this zone became unstable at the critical fault boundary. This resulted in shadow zones within the data and degraded the migrated image; exactly where precise traveltimes information was required. Although some of these problems appeared attributable to the model building process itself, and could therefore be legitimately minimised through smoothing, the velocity contrast across the fault zone is explicitly defined by well data, and represents a real geologic velocity boundary.

Conclusions

Resolution of the data integration, data retention, velocity analysis and traveltimes computation issues discussed in this paper is considered critical in improving 2D and 3D pre-stack imaging technologies. In this study area, deficiencies in existing imaging tools were detected precisely where they are most needed (and potentially most cost effective). The limitations demonstrated using 2D algorithms are of even greater significance in the full 3D pre-stack environment.

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