Enhanced velocity model building technique for prestack depth migration of complex 3D land datasets

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Abstract

Traditionally, velocity model building (VMB) techniques for prestack depth migration are based on flattening the gathers in the gather domain. This method has proven to be effective for 3D datasets with fairly good signal-to-noise (S/N) ratio. However, in complex areas with low fold and poor S/N ratio, this methodology becomes difficult to implement because the signal quality is generally poor, which can lead to in inaccurate velocity picks. In these challenging environments, GXT proposes an innovative approach where the velocity model building can be more accurate by using the stack data in velocity scans.

The concept was developed and successfully tested on a complex 3D land (thrust terrain) dataset where shallow diatomites have absorbed much of the seismic energy, resulting in low-quality gathers. By utilizing this approach, velocity scans of the stack data permit the interpreter to accurately pick seismic events on stack sections where reflections are more robust and continuous. Thus, a more representative velocity field can be determined.

Introduction

Prestack depth migration (PSDM) has become the investigative tool *de rigueur* in seismic exploration and production, particularly in areas of complex geology, such as beneath salt bodies. The velocity model is usually updated in the gather domain prior to stacking, where the correctness of the velocity model is gauged by the degree of reflector flatness upon depth migration. This approach performs best on data with good S/N in the gather domain, such as pre-processed (multiple-attenuated) 3D marine seismic data.

Conversely, poor S/N data restricts the effectiveness of velocity model building as it is difficult to flatten gathers that cannot be observed. Therefore, vertical (1D) velocity analysis by layer stripping methods becomes difficult to implement for cases such as complex land 3D data where elevation and undulating weathering layer statics can complicate the solution. Intrabed multiples can also mask attempts to build accurate velocity models. Clearly, the stack response provides an advantage because the interpreter can directly see the real time benefits of observing which particular velocity function(s) would result in displaying the best subsurface images of structures at different depth intervals.

In this paper, we describe and demonstrate a method whereby PSDM stacks are produced at small incremental velocities of an initial velocity field. By picking velocities on these stacks, we are more likely to derive a more accurate velocity model using the robust stack response.

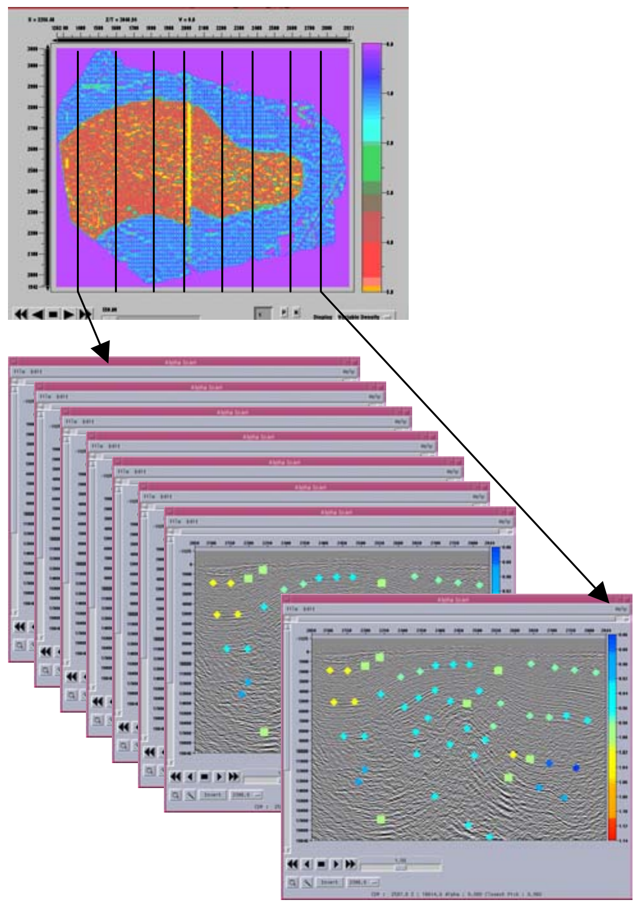


Figure 1. Schematic diagram shows selection of target lines used in the alpha scan tests.

Method

The velocity scan descibed here is defined as Alpha - a derivative of velocity. The scan is a series of stacks (target lines), which are depth migrated using constant alpha values generated by perturbing the initial velocity model (see Figure 1). The user picks the best-focused reflectors from the various alpha stack panels, resulting in a collage of alpha values that are then interpolated per target line. These interpolations are converted to 1D velocity analyses, ready for export into a 3D gridder for velocity model building.

With the initial 3D velocity model as alpha = 1.0 (meaning the stack was produced using this initial velocity model); the user can select the alpha increment. This increment depends on how accurate the initial velocity model is. A larger increment over a wider alpha range is recommended as a start for poor quality stack. Conversely, a smaller increment of 1% - 2% is recommended for cases where the original stack is already well-focused. Figure 2 illustrates a small series of alpha scans.

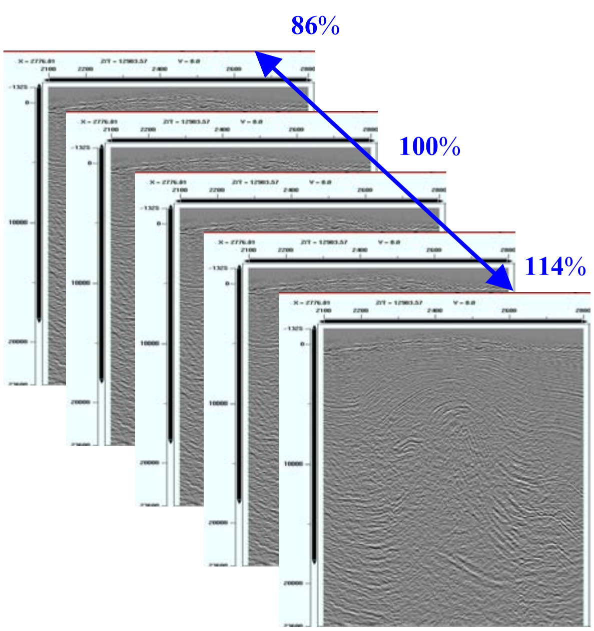


Figure 2. Alpha scans of a stack section perturbed +/- 14% of a base velocity function.

When scanning through the alpha stacks for a particular target line, the user will observe how reflectors will come into focus, i.e. show strongest amplitudes, at particular alpha values: The task is to pick the best-focused reflectors at their respective alpha values, and ultimately a mosaic of best-focused reflectors can be produced. These alpha values are then gridded for every target line and used to generate the next 3D velocity model and so forth until it converges. The alpha scan is an iterative process. The increment or range of alpha scans can eventually lessen the number of stacks that need depth migrating.

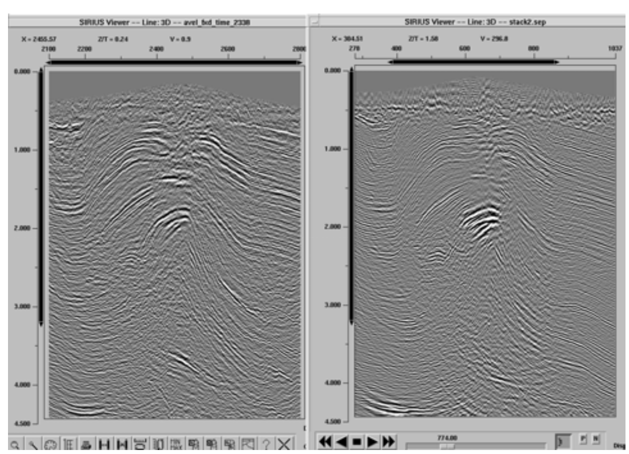
Data example

The technique is tested on a complex land 3D dataset where a shallow overburden of diatomites has absorbed much of the seismic signal, resulting in difficult 1D velocity updating on the gathers: This mature producing field has multiple pay zones. The reprocessing PSDM effort is to help identify several prospective targets, including better fault recognition and positioning.

The working dataset used for structural interpretation was a post-stack time 3D volume, as shown on the right hand side of Figure 3. Note the considerable improvement from applying PSDM (Figure 3, left), particularly on the flanks of the structure and in the core beneath its apex. A non-layered velocity model was derived using velocity scans (Figure 4).

In Figure 5, a close-up detail at the apex of the structure is shown, comparing post-stack time a) with the prestack depth image b) using a velocity field derived by the velocity scan. Clearly, improvements have been made in the structure’s inner core, and greater structural continuity and better positioning on the right hand side flank as well as greater definition on the left-hand-side.

We will present further data examples using this velocity model-building technique, and compare and contrast the velocity scan with traditional 1D updating and depth-domain tomography.



Prestack depth-to-time **Poststack time**

Figure 3 – Prestack depth migrated result from the alpha scans (left) converted to time, as compared to the initial post-stack time migrated result (right). Note considerable improvement in imaging the structure's apex and its flanks (2-3 seconds TWT)

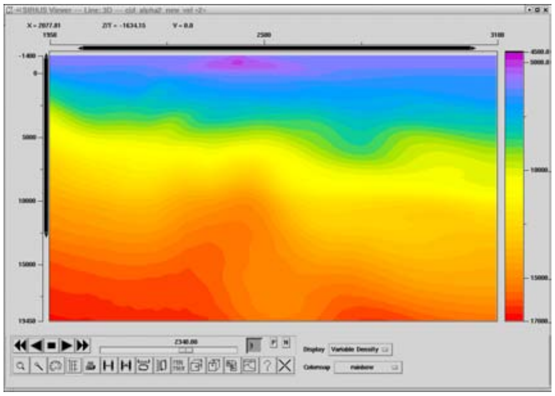
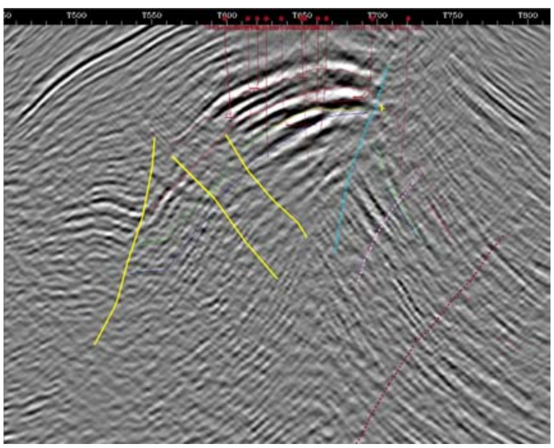
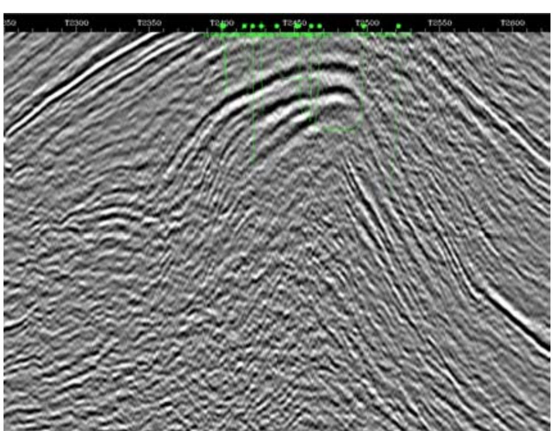


Figure 4 – Non-layered final velocity field derived from the alpha scan technique, used to generate the final prestack depth migration section presented in Figure 3.



(a)



(b)

Figure 5 – Close-up view of the section shown in Figure 3. (a) Shows the original fault interpretation on post-stack time section. However in (b) more detailed structural information gleaned in the prestack image (converted to time) may suggest a structural re-interpretation based on the improved image quality.

Conclusions

This paper describes a variant of 1D velocity model building method that is non-layered and based on stacks to derive more accurate velocity models for PSDM. The application of this methodology has proven to be effective on 3D land seismic data with low fold and poor signal-to-noise ratio.

Acknowledgments

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