Velocity/Depth Model Building leading to 3D Prestack Depth Migration in the Santos Basin - a case study

Graham Hodgkiss, Jason Sun Veritas DGC, Singapore

Abstract

In this paper, we present a workflow for performing 3D prestack depth migration using data from the Santos Basin. Deep water data from this region is characterised by a sediment layer of varying thickness exhibiting severe structural dips and faulting. This overlies a sequence of halite/anhydrite layers which, in turn, sit above potentially prospective hydrocardon bearing intervals. Each 'macro' lithologic unit presents challenges for successful depth imaging and, specifically, accurate velocity depth model building requires a phased approach in which the workflow is tailored to specific regions of the subsurface. In this case history, descriptions are given of the methodology used to construct velocity depth models covering areas in excess of 1000 sqkm. Results of this process are presented together with images from the subsequent prestack migration. These are contrasted with previous results obtained from 2D and 3D work. Subsequent work involved an analysis of anisotropy as a potential factor during the model building process and its associated impact on the final image. The importance of an integrated model building, interpretation and visualization environment is illustrated using examples from the crucial stages during the project

Introduction

3D seismic data have been acquired over extensive areas in the Santos Basin, offshore Brazil. Interpretation and prospect evaluation of this data has been mostly based on time domain processing with subsequent depth conversion based on velocities derived from this processing. However, while data from the Santos Basin appears to bear many similarities to, for example, deep water GOM, accurate velocity model building presents specific challenges to address the complex geology. A simplified seismic cross section is shown in figure 4. A sediment layer, exhibiting variable depth, overlays a sequence of salt/anhydrite layers which, in turn, lay above deeper prospective sediments. Complex structural features associated with all of these lithologies coupled with associated velocity variations, suggest that significant improvements in the deeper image may be obtained using Pre-Stack Depth Migration (PSDM) once an accurate velocity/depth model has been generated. Previous attempts to explore this processing route in 2D suffered from the inability to accurately define the complex sediment/salt interface that determines the travel paths to deeper reflectors. As a result, subtle structural alignments in the final image may be incorrect and predicted depths may not match actual values.

We work with data from several blocks in the Santos Basin area as shown in figure 3. Although these areas contain varying degrees of structural and lithological complexity, a general worklow has been established that addesses the requirements for building velocity/depth models for the subsequent imaging step.

Method

We break the velocity/depth model generation process into 3 phases. Each phase has to be completed and the accuracy of the results confirmed before moving to the next phase. This flow is shown in figure 1 below. The sediment velocity model incorporates an accurate definition of the water bottom interface and a procedure for delineating the lateral and vertical variations in velocity. Initial estimates for these variations are obtained

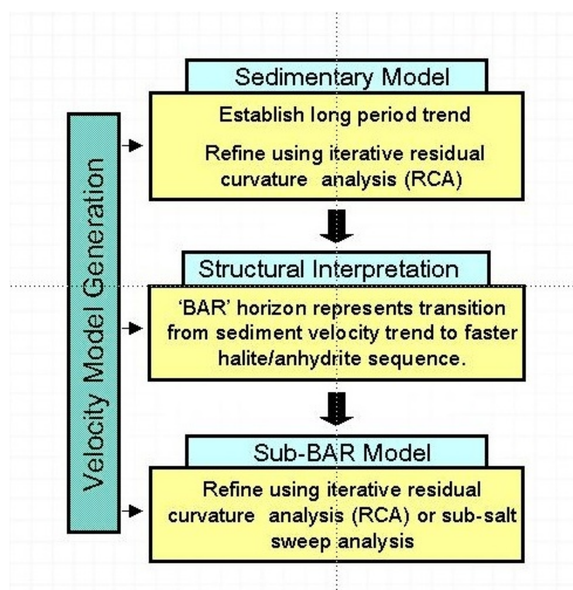

Figure 1 – Stages in generating velocity/depth model for Santos Basin data.

from time processing. Errors associated with long wavelength variations are removed by an iteration of velocity analysis employing simple vertical update or 1D tomography methods. More detailed refinement is performed using iterative grid tomography. This is a global implementation that uses prestack gathers migrated using an existing model to derive velocity updates to incorporate into a new model. The technique uses the degree of residual moveout on common image gathers (CIGs) to calculate the degree and location of necessary velocity changes. This Residual Curvature Analysis (RCA) tomography uses an automatic picker to identify strong reflection events using a grid of regularly spaced gathers. The residual moveout statistics, together with an estimate of the local dip of the reflector are input to a non-linear inversion scheme to solve for the necessary velocity changes. In practice this process has to be repeated a number of times in order for the model to converge to an acceptable version. The RCA workflow is illustrated in figure 2 below.

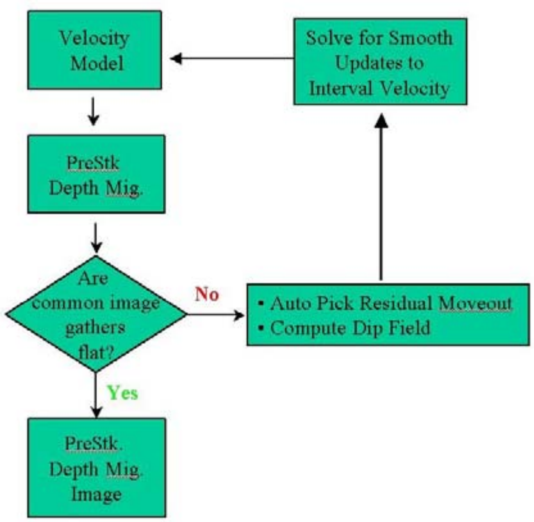

Figure 2 – Workflow for iterative RCA tomography.

Once the sediment model is considered final, the velocity contrast boundary between sediment and underlying salt layers needs to be accurately defined. This is done by performing an interpretation of the seismic event using a volume of data in depth, migrated with the final sediment volume. This is typically done from a limited offset stack derived from a grid of prestack depth migrated gathers. The resulting horizon exhibits severe topological variations as the salt layers alternate between deep and shallow environments. The complexity of the final surface is illustrated in the perspective display shown in figure 5.

The final phase of the model building workflow involves determining velocity variations in the sub BAR region. This is accomplished by initially flooding with a constant velocity appropriate to the halite and anhydrite layers. This 'half-space' model is used to generate a further iteration of CIGs which are subject to RCA tomography described above. Only minor changes are expected in those parts of the model defining the salt layers themselves, however deeper sedimetary layers should contain subtle velocity variations which will require careful parameterisation in the tomography. Furthermore, as depth increases, residual moveout discrimination becomes less sensitive and alternatives to RCA tomography have to be considered.

Results

Following completion of the model building process, data from several areas of the Santos Basin were processed using Kirchhoff prestack depth migration. This involves generating travel times through the model and subsequent summation of contributing input data to the specified output locations. A mixture of target lines and full data cubes were processed in this way. Migration parameters such as aperture, dip limits and anti-aliasing filters were chosen to optimize the final result.

It is clear from the model building phase that accurate refinement of the sediment overburden velocity field is crucial in obtaining a well focused and correctly orientated migrated stack. Relatively subtle changes in velocity in this zone can give rise to cumulative differences in the vertical and lateral position of deeper reflectors. Accurate delineation of potential targets in terms of structural orientation and closure requires these errors to be kept as small as possible. Similarly, the sub BAR zone, particularly the deeper sediment layers, requires careful attention to accurate velocity refinement.

An example of the improvements in structural imaging after full PSDM model building and migration is shown in figure 6. This data is from the BMS-10 area. The original processing, on the left, shows unrealistic residual 'structure' beneath the deep sediment basin. After careful model building, a more geologically plausible structure is obtained, faulting is better defined and amplitudes more consistent.

Conclusions

Successful depth imaging of data in the Santos Basin requires careful attention to velocity/depth model building procedures. Integration of the appropriate velocity analysis technique, 3D horizon interpretation and accurate migration algorithm is required for an optimum result. The work performed during this study further indicated that anisotropy played a part to varying degrees in the velocity analysis and subsequent imaging step. Further tests are being conducted to determine the importance of this attribute.

Acknowledgments

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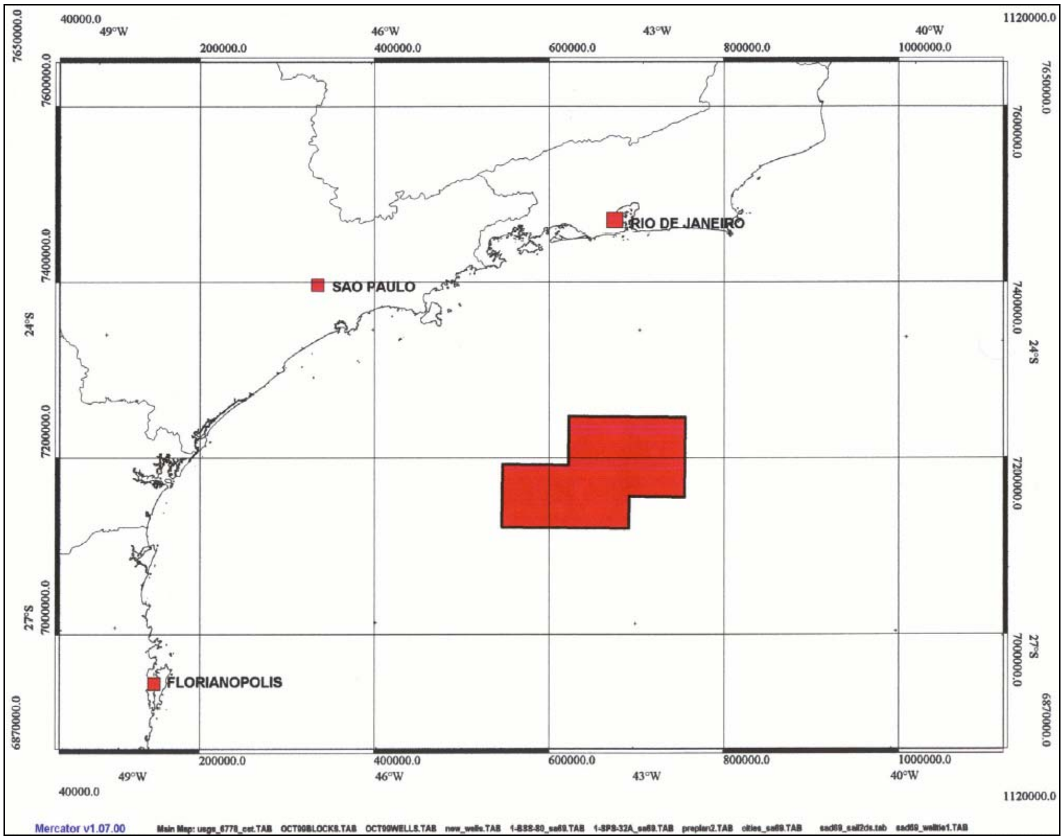

Figure 3 - Santos 3D phase II seismic survey area is located offshore Brazil

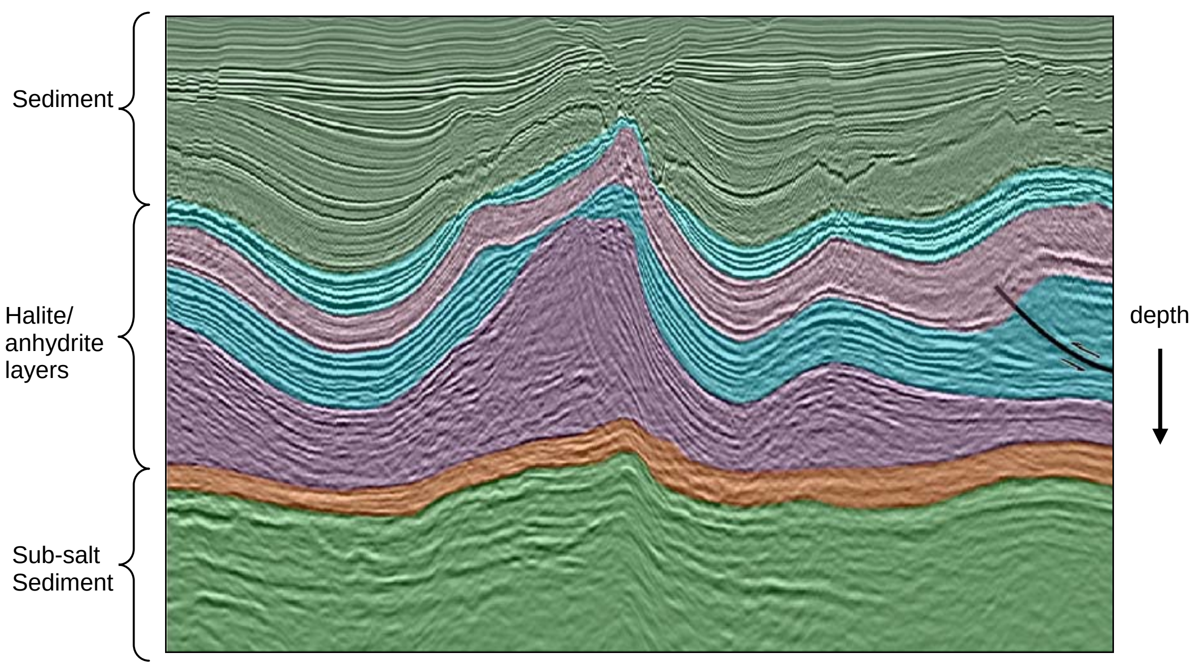

Figure 4 – Vertical cross section showing typical layering

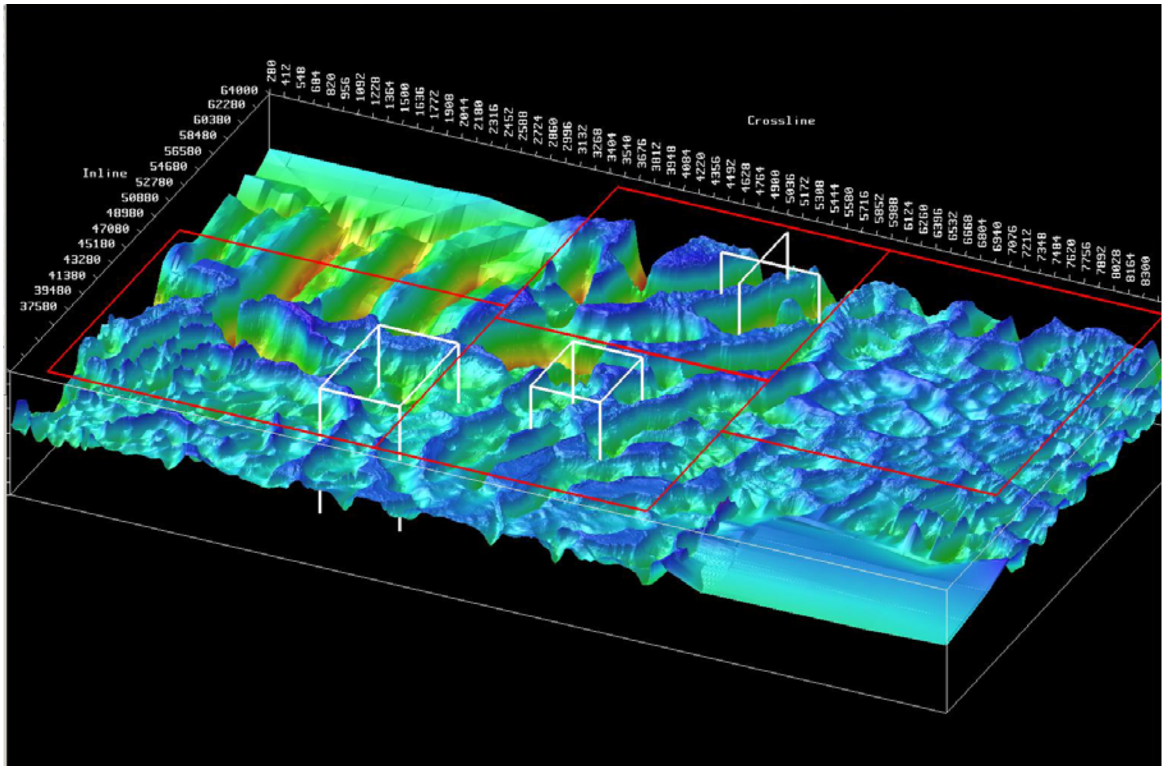

Figure 5 – Block boundaries, study areas and interpreted top salt ("BAR") surface

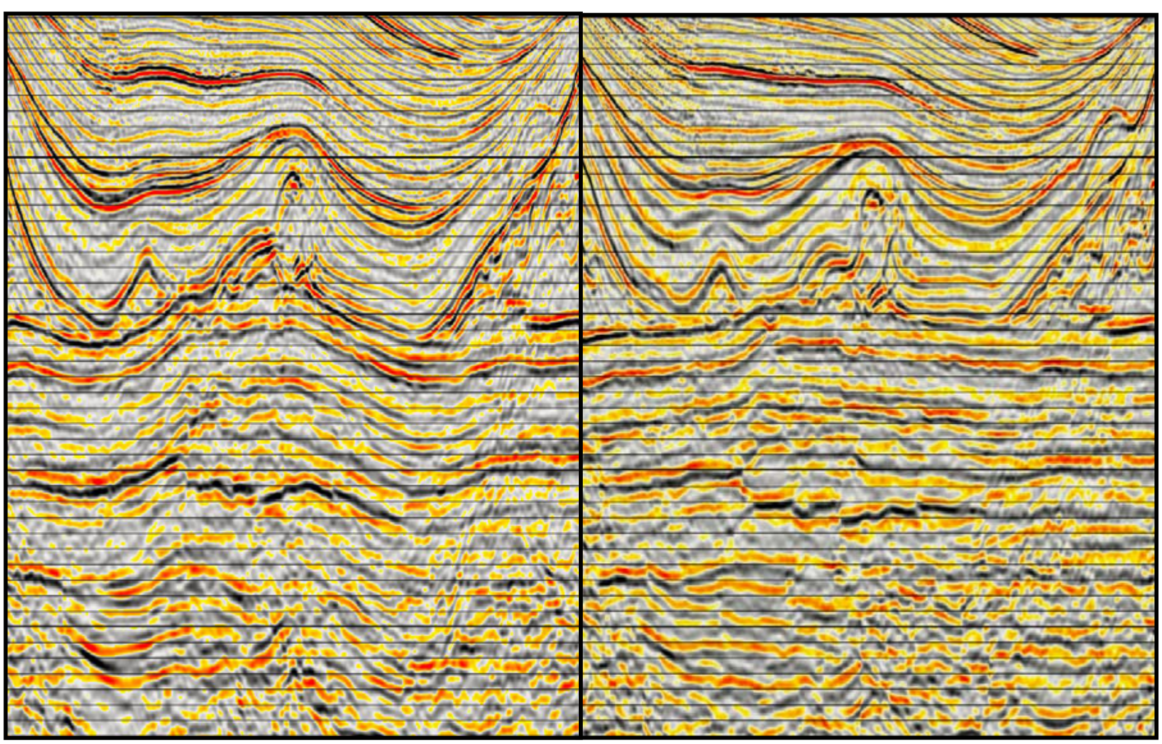

Figure 6 Comparison of previous time processing (left) and PSDM (right). Both sections displayed in depth.