PSDM Success in the Cuban Fold and Thrust Belt

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Summary

The 3D Prestack Depth Migration (3D-PSDM) is a powerful tool used to image the geology below the earth's surface. Successful depth imaging projects strongly depend on two aspects: an accurate algorithm and a detailed depth velocity model. In this paper, we will show CGG's capabilities in both these aspects. The major steps of a 3D-PSDM project will be explained through synthetic and real data examples. Moreover, the application of 3D dip modeled PSDM on offshore Cuban data will be presented. By comparing 3D Prestack Time (PSTM) with 3D Prestack Depth migrated data, we will show the significant improvement obtained using 3D-PSDM. Finally, we will give a brief overview of the drilling successes thus far.

Introduction

The geology of Cuba's north shore is complex – a fold and thrust belt that formed as the result of collision between the Cuban island arc and the southern margin of North America (Schenk, 2000). Hydrocarbon traps are encountered in stacked thrust sheets of Jurassic/Cretaceous carbonates that are overlain by sediments containing multiple unconformities (Baker, 2001). The reservoirs are exploited using highly deviated and horizontal wells drilled from on shore.

The Block 7 3D seismic data was acquired from January to June 2003. Approximately 475 km^2 of data were recorded in a rectangular shape 7km wide and 65 km long. The goal was to image the carbonate thrust sheets to define producing fields, identify new prospects and clarify the relationships between them. 3D–PSDM is especially useful in the presence of strong lateral velocity variations and complicated geological context, like the Cuban fold and thrust belt, where complex wavefields are generated. The processing program called for time processing to be carried through to PSTM and to be followed by PSDM.

Velocity Modeling

As always, the critical first step of the depth migration process is to derive an appropriate velocity model for the shallow data. Since none of the deviated wells penetrated the shallow layers, the starting model was derived solely from prestack time migration velocities. Gradients and V_0 were extracted for the two distinct layers above the carbonates and used for the initial model and depth migration. Careful gather analysis suggested that the two planned layers from water bottom to the top of carbonates were insufficient for modeling the complex geology. At this early stage, we changed the scope of the project and added another velocity layer in the shallow section. Several iterations were required to construct the velocity model above the carbonates. Each depth iteration consists of residual moveout (RMO) analysis, 3D tomographic inversion to update the layer velocities, Kirchhoff depth migration and updating horizon geometries.

The carbonate interpretation was particularly difficult. Well data and area knowledge were instrumental in making a geologically sound interpretation. Using the same methodology, RMO analysis and tomography, the carbonate velocities were updated and the data were migrated before the final base of carbonate horizon was picked and the velocity model was finalized.

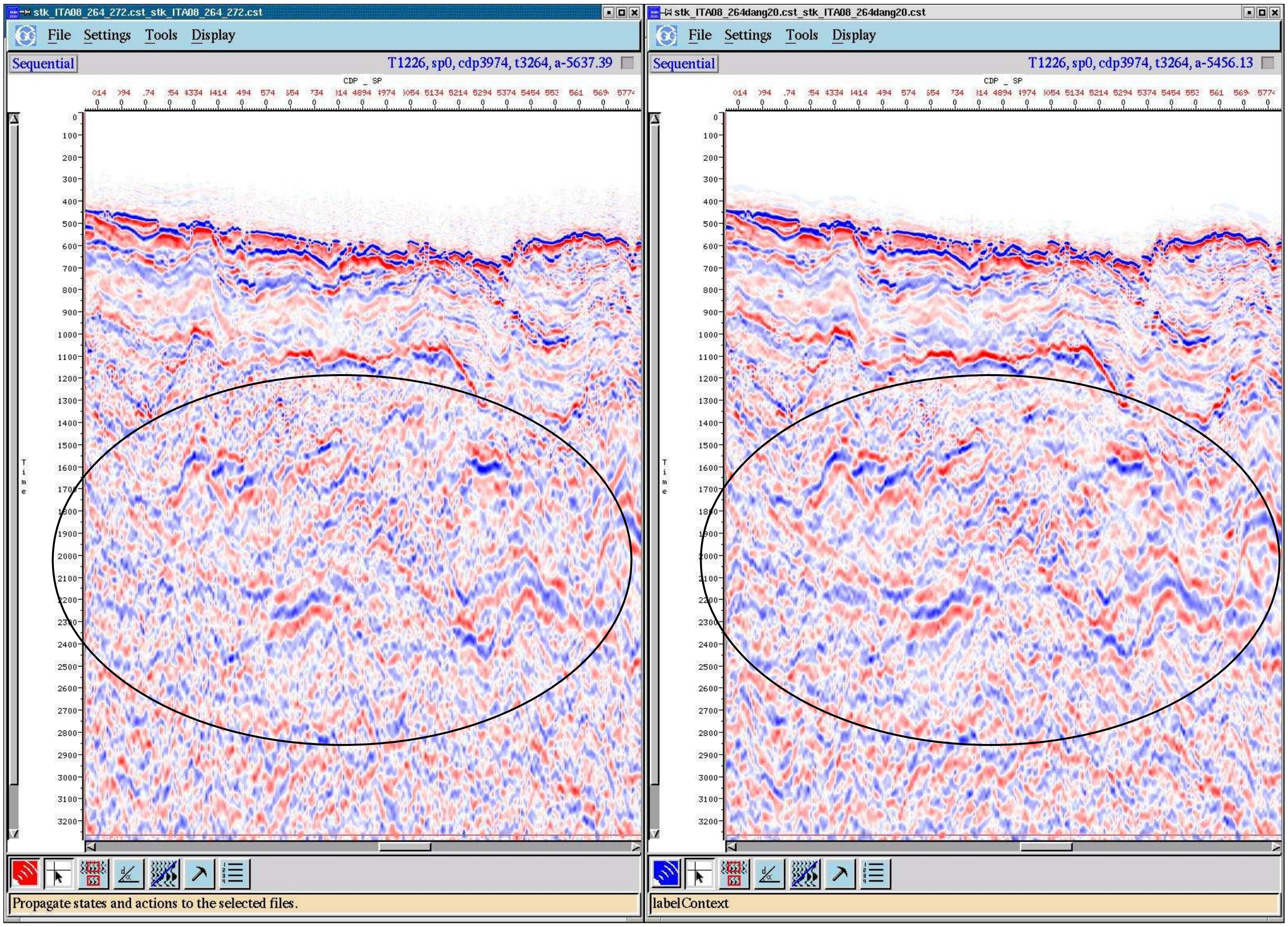

Figure 1: PSDM comparison without (left) and with (right) dip model migration applied.

Final Depth Migration

We decided to employ a dip model PSDM algorithm in the final migration. This migration uses the interpreted horizons to define the local dip and reduce migration noise by focusing the operator aperture in a direction perpendicular to the geological structures. The risk with this approach is that events with dips that are not modeled may not be imaged very well. Several tests with varying degrees of severity were produced. Since the primary goal was to image the carbonate thrust sheets with well-known dips, we were able to choose a relatively severe application and reduce the noise significantly (figure 1).

Comparisons show the significant improvement of the PSDM image over the PSTM (figures 2 and 3). Increased continuity is apparent and appreciated at all levels, and is vital to any interpretation attempting to unravel the complex geology of the carbonate thrust sheets.

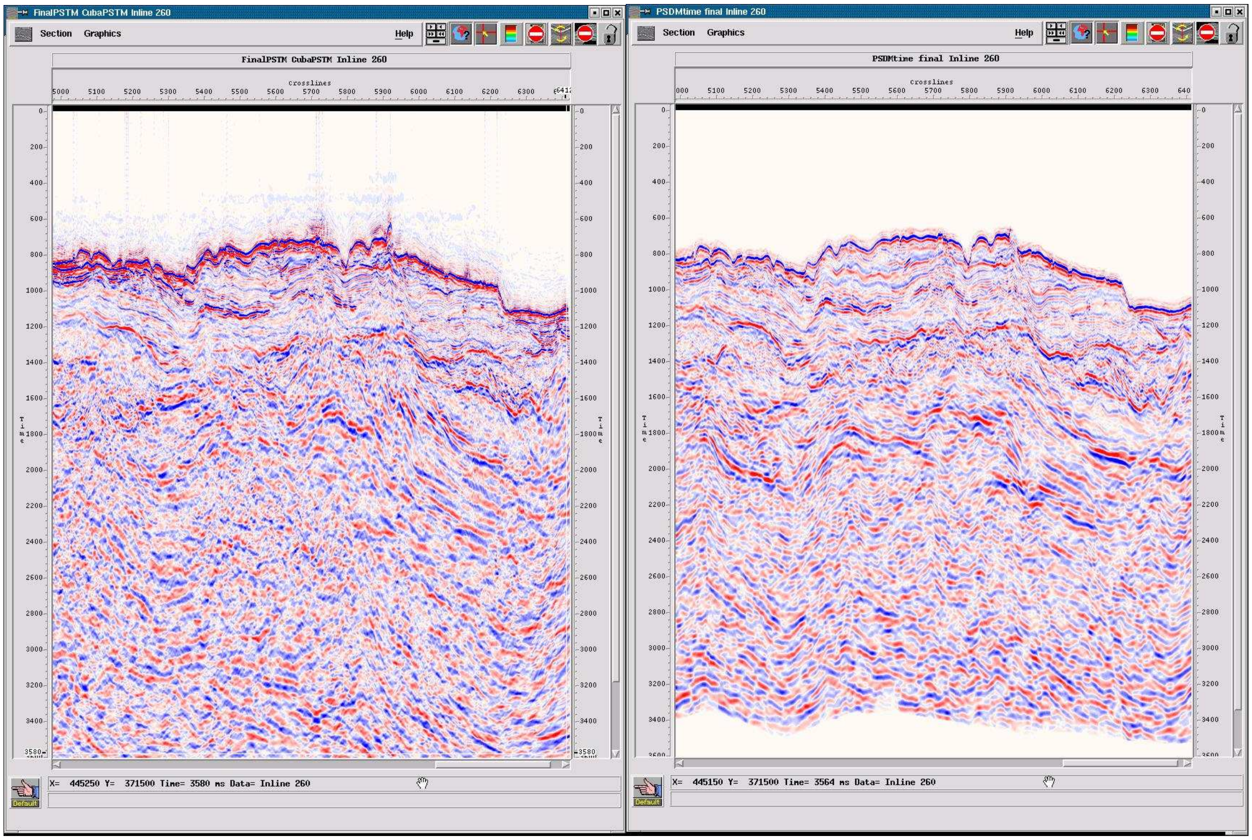

Figure 2: Inline comparison of PSTM (left) and PSDM converted to time (right).

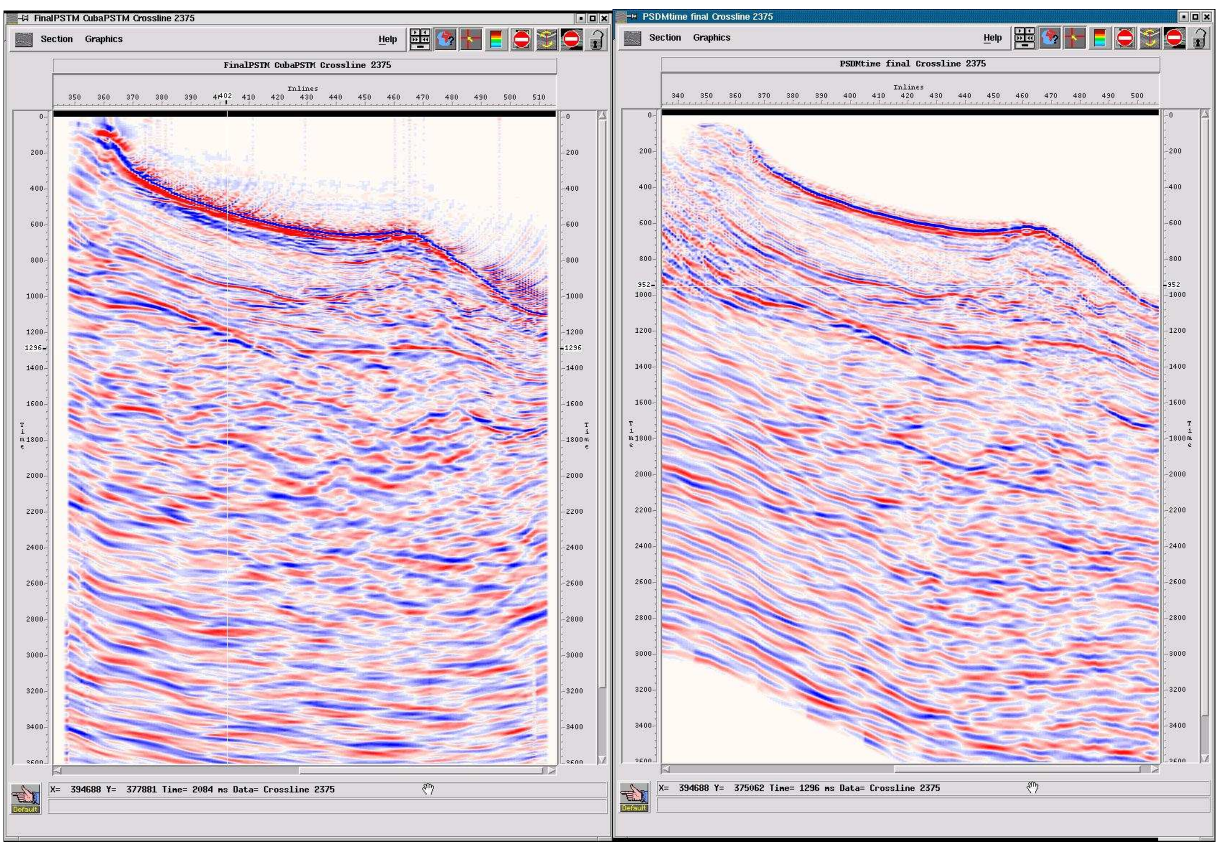

Figure 3: Xline comparison of PSTM (left) and PSDM converted to time (right).

Conclusions

The depth migration was a success for several reasons. The working environment was one in which the clients' open communications, commitment, and flexibility allowed the data to determine the workflow. With careful model building and the application of the most current PSDM technologies, the result was a properly imaged seismic volume of a complex fold and thrust belt region.

To date, several successful wells have been drilled on the 3D interpretation of Block 7. Ongoing development has significantly increased the potential size of the of the Seboruco field. Moreover, the recently announced Santa Cruz exploration discovery could measure up to 20 km^2 (Pebercan, 2004).

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