Detailed 3D Anisotropic Pre Stack Depth Migration Imaging Over Mature Quirk Creek Gas Field, Southern Alberta

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Background

Even though the Quirk Creek field was discovered more than 30 years ago and has been producing ever since there were a lot of unanswered questions about the geometry of the main structure and its relationship with surounding structures. In order to shed new light on the structural elements of this mature field a new 3D seismic survay was aquired and subsequently processed to pre-stack time migration. The new pre-stack time migrated cube revealed many structural details previously undetectable on the grid of 2D seismic data sets and allowed for detailed structural interpretation across the whole 3D survey. Because of the extremely complex nature of the main structure, where several carbonate imbricants of Mississippian age were inserted into younger clastic Cretaceous rocks, questions were raised about proper temporal and lateral positioning of the deeper Mississippian imbricants as well as the capability of pre-stack time migration to acurately image the deep Devonian section.

In order to answer some of the above questions Imperial Oil decided to do pre-stack depth migration of the 3D data set starting from the same input data as for pre-stack time migration. Pre-stack time migration data, numerous well log information from within the 3D survey and detailed structural interpretation were used to guide and quality control the pre-stack depth migration velocity model building and imaging.

Pre-Stack Depth Migration (PreSDM) approach and methodology

As in time domain migration, a Kirchhoff summation algorithm was chosen for velocity model building and depth imaging procedures. Existing well sonic logs showed the difference of the velocity of propagation of seismic waves between Cretaceous clastic and older predominantly carbonate rocks of well over 1000 m/s.

The main goal of the PreSDM was to derive a precise interval velocity model clearly separating the two main lithologic units and image as much structural detail within the two as posible.

For the initial interval velocity model, a two domain, layered model was derived by using the average velocities observed on the well velocity logs. The boundary separating the two domains approximately represents the envelope of carbonate to clastics interface as interpreted by Imperial Oil.

The strategy for the velocity model building (VMB) was as follows:

- Update interval velocity in the shallow Cretaceous domain in a gridded isotropic fashion until a good correlation with pre-stack time migrated data is achieved
- Separate the clastic section into geologicaly meaningful domains and introduce the Thomsen anisotropic parameters
- By working on selected target lines scan for the various Epsilon values while keeping the Delta parameter constant
- After deciding on the Epsilon parameter value scan for various Delta parameter values and choose the one giving the best overall image and tie to the existing well logs
- Compare isotropic versus anisotropic depth imaging results and decide which one is more suitable for continuation of the velocity model building and depth imaging process
- Iterate on improving the imaging of the Cretaceous section until completely satisfied with the imaging quality of this part of the survey
- Move to the deeper predominantly carbonate section and work on improving the image quality and structural interpetation right down to the basement until completely satified with the results
- Test hypotheses during the VMB process with respect to possible gelogical scenarios

Given the structural complexity of the survey and yet very good signal to noise ratio of the input seismic data, it was decided that various means of the VMB should be used separately or in conjunction with each other. The VMB methods used during the course of the project were; Auto Picking followed by High Resolution Reflection Tomography , classic vertical updating by correcting the residual depth error on image gathers and Alpha Scanning followed by Multi Thin Layer (MTL) interval velocity model updating.

However, as expected, most of the velocity model updates and imaging improvements during the course of the project were obtained by utilizing the Alpha Scanning and MTL method. The other two methods were used to refine the already good velocity model updates obtained by Scanning, either on the larger, grid based scale (tomography), or by working on the small details whithin the particular velocity domain (flattenning of the image gathers).

The Results and Conclusions

After nine successful velocity model updates and extensive structural interpretation scenario tests on the southern part of the 3D survey, a final anisotropic PreSDM interval velocity model and corresponding image of the Quirk Creek 3D data set was obtained.

By comparing the imaging results of the PreSDM 3D data set with all the supporting data available at the beginning of the project, clearly satisfactory result were obtained:

- Very good imaging of the Cretaceous strata led to reliable determination of the anisotropic parameters and structural interpretation
- The application of the Thomsen anisoptropic parameters in the clastic section of the PreSDM interval velocity model led to a very good tie with all existing well logs (15 in total) down to the main clastics-carbonate interface and, in the case of deeper wells, multiple geological markers. Also reliable, scenario tested, structural delineation between the clastic and carbonate strata was achieved.
- The overall structural interpretation and vertical and lateral positioning of the numerous carbonate imbricants of Mississippian age was either confirmed or substantialy improved in regard to the pre-stack time migration result
- The imaging of the Devonian and older geological units was imroved by iteratively combining the derivation of a high resolution anisotropic interval velocity model and detailed structural interpretation of the overlaying strata

References

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Avramovic, V., and Lines, L.R., 2004, Practical Demonstration of Automatic Picking and High Resolution Reflection Tomography with land data examples, FFRP Research Report, Volume 10

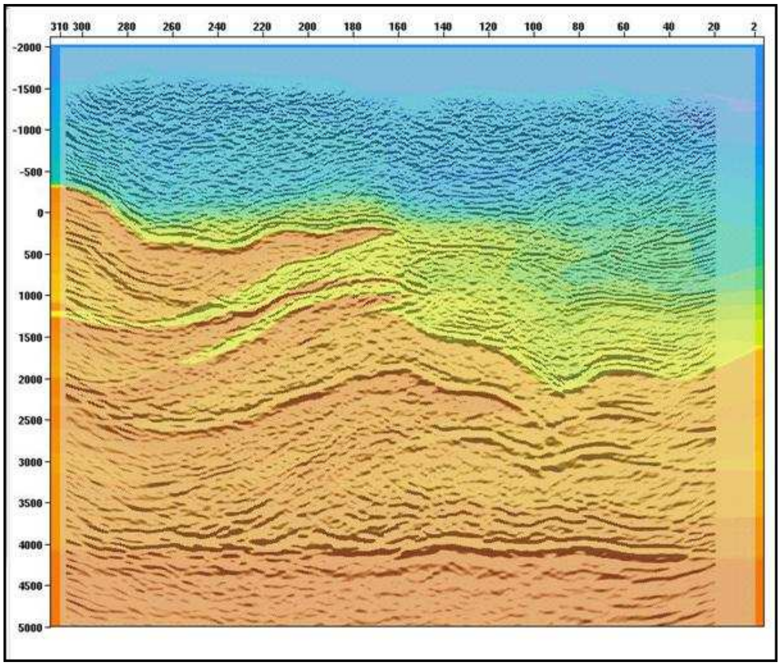

Figure 1: PreSDM Inline 120 with final velocity model overlay

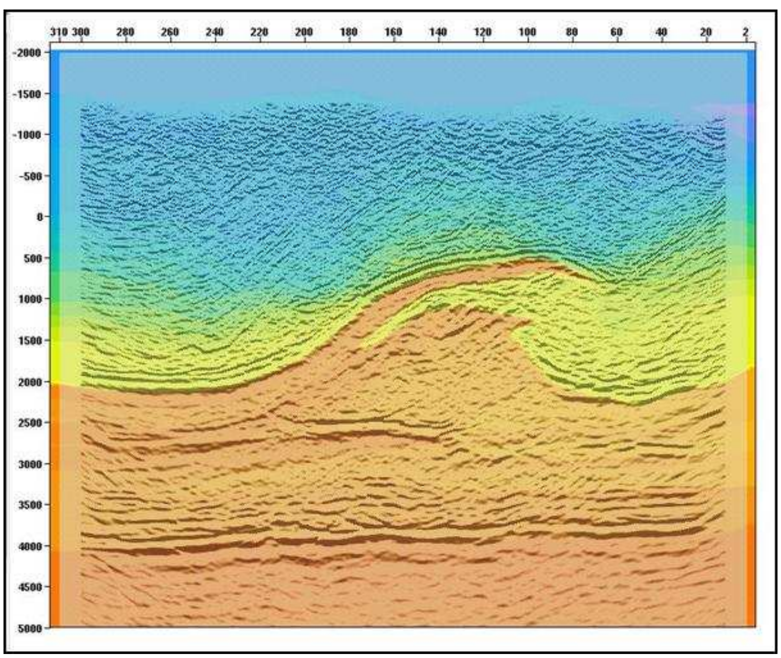

Figure 2: PreSDM Inline 320 with final velocity model overlay

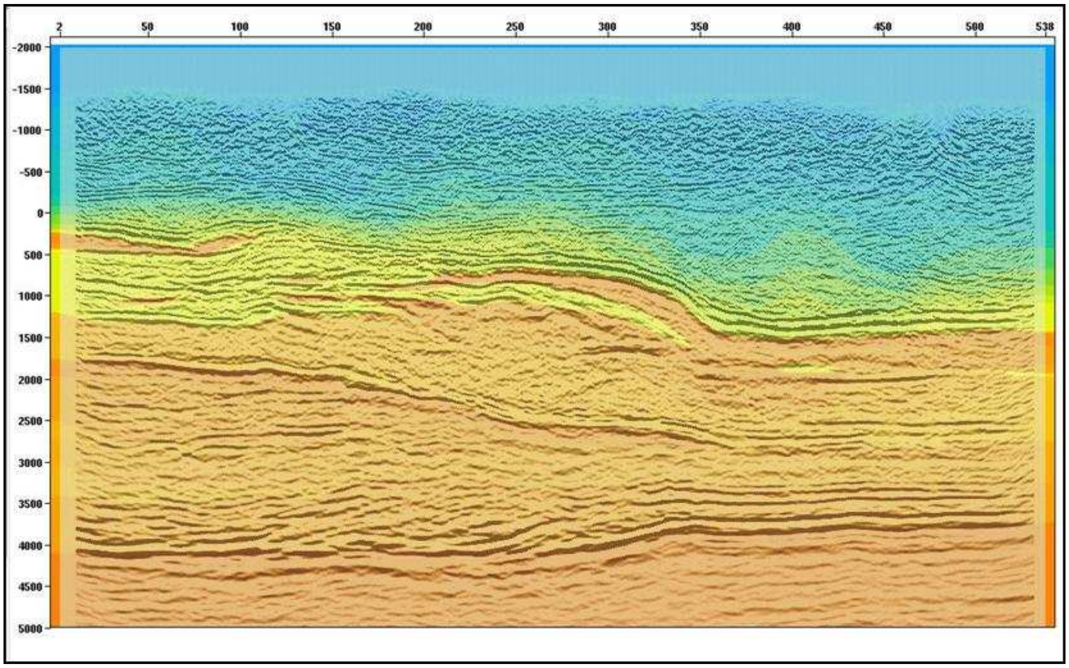

Figure 3: PreSDM Crossline 160 with final velocity model overlay