An Interpreter's Guide to Successful Prestack Depth Imaging

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Prestack depth migration often gives a readily observable improvement in imaging and a significant reduction in drilling risk compared to time imaging. However, running a successful depth imaging project is significantly more challenging than running a time imaging project, and because of this, the occasional project does not achieve the imaging objectives. The risk of a project failing can be minimized by careful selection of a service provider, who can demonstrate a track record of depth imaging success and can deploy experienced depth imaging professionals, and by embarking on a project without undue constraints that may compromise the imaging. Once the project has started, key factors are good communication, timely sharing of information, a suitable velocity and anisotropy strategy, and proactive QC. The success of the project can be evaluated by QC of final migrated gathers, the quality of the final stack image, and by the accuracy of the well ties.

Introduction

Over the last three years, there has been a large increase in the number of depth imaging projects run in Calgary. Prestack depth migration (PSDM) often gives a significant improvement in imaging and positioning in the Foothills, higher resolution imaging in the Plains, and increased confidence in the volumetrics of deepwater reservoirs (Figure 1). The increased processing cost compared to conventional time imaging is often rated as "excellent value for money", and "more than offset by the reduction in drilling risk" (Stratton and Vermeulen, 2006). With the increased demand for depth imaging, more and more providers are offering this service. Unfortunately, not all projects are as successful as they should be. At the December 2006 CSEG Lunchbox Geophysics meeting 'Strange but True Stories of Prestack Depth Imaging', Rachel Newrick of Nexen estimated that "1 in 10" depth imaging projects were unsuccessful, a sentiment shared by a number of interpreters in the audience. The challenge, clearly, is to move the success rate for depth imaging projects from 90% to 100%. In this paper, I discuss the lessons that have been learned from running and supervising depth imaging projects over the last 10 years.

The Differences Between Time and Depth Imaging Projects

Prestack depth imaging projects start off essentially the same as prestack time imaging projects, but with loftier goals such as "improve the imaging over the previous time processing", and "position the target correctly both vertically and horizontally". The processing workflows diverge when the data are ready for migration. Time imaging has one, or possibly two, passes of migration velocity model building, then final migration and post-migration processing. Depth imaging, on the other hand, needs many passes of migration velocity model building and migration before proceeding through

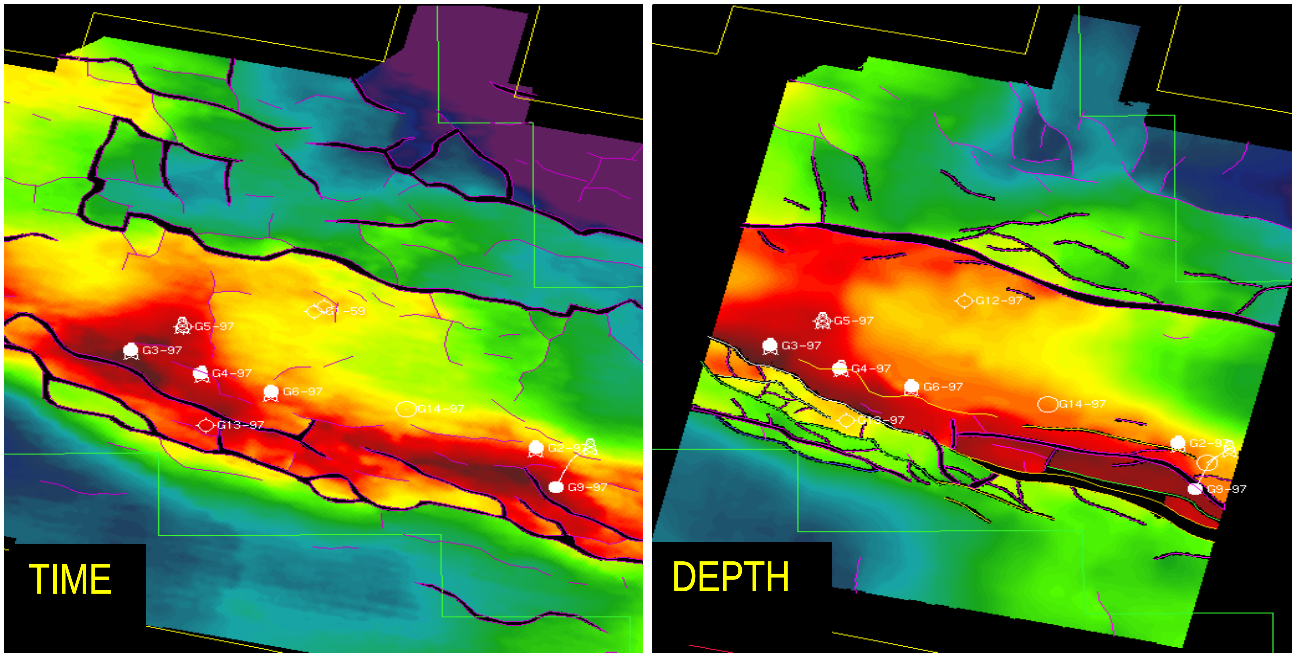

Figure 1. Top of reservoir interpretation after time processing and depth reprocessing. Reprocessing improved the fault imaging, and added an extra 50% of reserves (Kemme et al., 2000).

post-migration processing. The strength of prestack time migration is that the imaging is kept in the time domain where insensitivity to errors in the migration velocity field result in a small loss of focusing that can be relatively easily recovered from (or hidden) using post-migration processes. Prestack depth migration is a more accurate migration that is much more sensitive to the choice of migration velocity field. The good news is that prestack depth migration will give a better result (better structural imaging and positioning, better resolution of faults, and improved amplitudes on reflectors) if the migration velocity field is adequate. The bad news is that, as the depth image outputs in the depth domain, small velocity errors manifest themselves as positioning errors. For example, a +5% bulk error in the migration velocity field will make the wells mistie in depth by +5%. Lateral positioning errors are also likely to be present which will have significant consequences for the design of well trajectories. A localized zone of bad velocities would result in some (hopefully recognizable) false undulation in the structure and/or unrecoverable defocusing of the stack image.

What to Consider Before Embarking on a Depth Imaging Project

Production prestack depth imaging is a relatively new service compared to prestack time imaging. The quality of depth imaging depends on the suitability of the selected workflow and other considerations, as illustrated by Figure 2. To get the best depth image, it is recommended that a contractor is selected from those with a mature, proven depth imaging and velocity/anisotropy model building workflow for your basin, and who can make available experienced depth imaging staff. You should also beware that external constraints applied to depth imaging projects can compromise the final result. For example, selecting isotropic depth imaging as a means of economy in an area known to be anisotropic may not yield a fit-for-purpose result. Also, delays in providing access to information such as interpretations and well logs at the start of the project will increase the time it takes to build the migration velocity model.

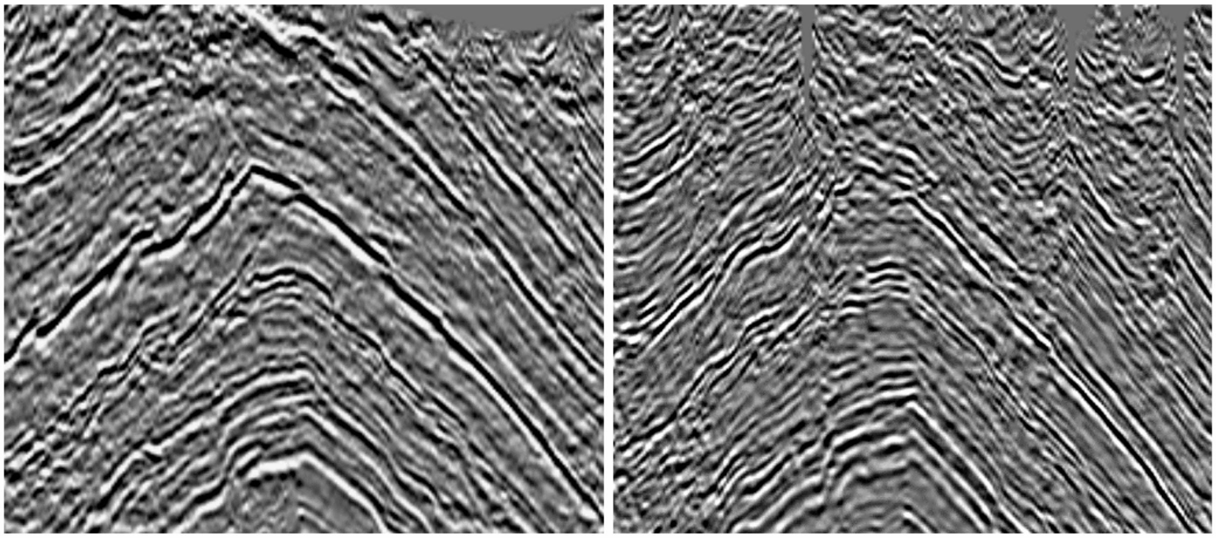

Figure 2. A Canadian Foothills comparison of the same dataset reprocessed using prestack depth migration by two of Calgary's largest depth imaging contractors. Adapted from S. Charles et al. (2006).

Velocity and Anisotropy Model Building Strategies

There are a number of different strategies available for building migration velocity models and migration anisotropy models. An appropriate strategy and good velocity and anisotropy models are required to get the best depth image.

You can consider the end members of the velocity model building spectrum to be the layer-based interpretation style of velocity model building and the grid-based tomographic velocity inversion technique. Both work well under different conditions, and both have advantages and disadvantages. With layered models, any problems in the interpretation will adversely affect the final image. With grid-based tomography, care must be taken not to push the spatial resolution of the inversion too hard and introduce unrealistic velocity changes. The layer-based approach would be recommended for very simple areas, as well as areas of extreme complexity and poor signal-to-noise ratio. A tomography approach would be recommended in areas of moderately high complexity and good signal-to-noise ratio. Recently, the so-called 'hybrid tomography' technique has been used to bridge the gap between these approaches.

There are a number of flavors of anisotropy (VTI, HTI, and TTI) that can be incorporated into the depth migration. Normally, we observe that the more sophisticated the use of anisotropy, the better the imaging. In particular, you should expect to get an improvement in the imaging of steeply dipping reflectors and fault planes, as well as an improvement in the horizontal and vertical positioning of your image when anisotropy is used. If you have dipping reflectors, you need TTI anisotropy for optimal imaging and positioning.

What to Watch Out for When Running a Depth Imaging Project

Once you have chosen a service provider and reduced your risk by making sure that they have the appropriate strategies, tools, skill level, information, and time needed to achieve the imaging goals, the project starts. The key to success at this stage is good and continual communication between the processor and the interpreter. The interpreter will be able to help the processor build a geologically plausible velocity model that produces a geologically plausible structural image. During the project, the processor and interpreter should compare at each stage of velocity model building both migrated stacks and gathers to those output at the previous stage(s). The image should improve and the gathers should get flatter after every update. The interpreter is also expected to provide quantitative mistie information to help the processor update the velocity model.

Quality Control (QC) of the Final Velocity Model and Migration

When the velocity model building process has finished, how can we objectively evaluate the output of the final migration? From a processing perspective, the answer to this question is more qualitative than quantitative. The wells should tie vertically (within, say, 1.5%) and laterally (within a couple of traces), the velocities and stack should both be geologically plausible, and the gathers coming out of the final migration (before residual moveout correction) should generally be flat. Of course, the recurring question when QC'ing gathers is, "how flat is flat enough"? There is no easy answer to this question. Typically, a stage will be reached during the model building process when the gathers do not continue getting 'flatter', and so long as the majority of the gathers appear to be flat, then this should be a sufficient validation of the model. It is normal to see small areas where the gathers are not quite flat, and this may more likely be caused by shorter wavelength velocity or anisotropy changes than the detail built into the migration velocity and anisotropy models.

The final uncertainty of the imaging increases with distance away from the control points such as wells used for velocity model building. You can independently estimate the uncertainty by withholding a well and checking the depth misties of the final section against the withheld well. Note that this comes at a cost, as these well depths could have been used to constrain the velocity model.

Conclusions

It is not easy to run a successful depth imaging project. There is no substitute or shortcut for experience. A number of practical suggestions are made to ensure that the best possible outcome will result from your project, including:

- Choose a service provider with a track record of depth imaging success in the basin in which you are working and one that has the tools needed to satisfy your imaging objectives.
- Check that staff with suitable depth imaging experience are involved in the project.
- Work closely with the processor to establish and maintain good communication, and ensure that the processor gets all of the information that is requested in a timely manner.
- Be active in the QC of the project as it is running, because you, the interpreter, will often know better than the processor whether or not the image is improving.

References

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