Duplex Wave Migration – Imaging Vertical Boundaries

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Abstract

Summary

Conventional 3D anisotropic prestack depth migration provides accurate structural boundary information for events with dips from 0 to about 75 degrees. For vertical or near vertical events conventional methods rely on turning wave technology that will only be accurate if the recording aperture is very large and the depth model is known to a very high degree of accuracy. Also, the energy to perform this imaging methodology will only be recorded if the velocity depth model is characterized by significant vertical velocity heterogeneity. Duplex Wave Migration is a newly developed technology that is capable of imaging only vertical events (plus or minus 15 degrees) and it does not require either a large recording aperture or any specific a velocity model that must have strong vertical velocity heterogeneity. This paper will provide the first examples of the use of this technology on North American data.

About the developers of the technology

Duplex wave migration is a patent pending technology that was invented by a company with roots in the Ukraine called TetraSeis Inc. Dr. Naum Marmalevsky and his research team have developed a practical Kirchhoff type application to image duplex wave energy. In the spring of 2005 TetraSeis Inc. and Kelman Technologies Inc. signed a co-development agreement with the aim of further developing the technology into a fully commercial product. Duplex wave migration services are now available to worldwide markets through KTI offices.

Introduction to duplex waves

Conventional Kirchhoff migration schemes assume that the kinematics of the ray path travel time calculations are such that the seismic energy bounces off of one and only one reflector before returning to the surface. A Kirchhoff type implementation of Duplex Wave Migration assumes that the seismic energy undergoes two bounces off of primary reflectors during its ray path before it returns to the surface. This secondary bounce energy appears (on a raw seismic record) to be some form of coherent noise, or offline artifact on the seismic record. Consequently it is stacked out when conventional imaging criteria are used.

However, if we re-define the kinematics of the problem we can stack (or image) the data in such a way that this duplex energy is re-enforced and the conventional single bounce energy is stacked out. When we impose this re-definition of the basic kinematics of the migration process on the seismic data the resulting 3D data cube contains vertical, or near vertical boundary information only. Therefore, through the use of duplex wave migration we can fill in the very information (dips from 75 to 90 degrees) that is missing from convention prestack depth migration results.

The figures below illustrate the basic concepts involved with a simple salt wall model. In figure 1 a salt dome with a vertical wall is illustrated along with near horizontal events that terminate at the salt wall boundary. Note the kinematics of the double duplex waves that undergo two bounces – the first one is off one of the horizontal layers and a second bounce is off the salt wall. There will also be the situation in which the ray path involves a bounce off the salt wall first and then is returned to the surface via a second bounce that is off one of the horizontal layers.

A full wave forward modeling program was used to acquire a 2D seismic data set over this model. Figure 3 shows shot records at shot points 1600 and 1700. Note the existence of the duplex wave energy which we might normally assume is some kind of coherent offline noise that we hope will simply stack out. Figure 2 illustrates the wave propagation images at times 1180 ms, 1280 ms and 1380 ms that were generated during the forward modeling process. The yellow arrow illustrates how the duplex wave energy is formed and propagated through the model along with the conventional single bounce energy.

Figure 4 shows a conventional depth migration. Of course, the near horizontal events are imaged very well. However, the vertical salt wall boundary is completely missing. There are three possible reasons for this as follows:

1. The vertical velocity heterogeneity is such that curved ray energy that bounces off of the vertical salt wall never reaches the surface.
2. If the curved ray energy does reach the surface the surface recording aperture may not be large enough to have recorded it.
3. If the curved ray energy was recorded the migration algorithm may not be robust enough to image a vertical boundary.

Note also, in figure 4, the horizontal events tend to bleed through the salt wall boundary. This is a basic property of conventional migration technology that makes the determination of the exact location of the salt wall boundary impossible. Figure 5, however, is the image produced by a duplex wave migration. This image contains only the vertical boundary information. The lateral positioning of the image is exactly at the correct station location, which is station number 1000. If we combine the information contained in both figure 4 and figure 5 we can re-construct the exact structural features of the salt dome.

<u>Examples of duplex wave migration on real seismic data</u>

Various case history results have been presented at previous geophysical conventions. All of these case histories have been generated on data from the former Soviet Union. In this paper we will present results from some North American data sets.

Duplex wave migration fits in the processing flow following conventional 2D or 3D prestack depth migration. The input data is the same data set and geologic depth model that is input to conventional depth imaging routines. The only additional information that must be supplied is the location of the sub boundary information that will be used as the generator of the duplex wave energy. The user can choose to use one or more sub boundaries.

Conclusions

The ability to accurately identify and locate vertical boundaries, such as carbonate thrust front edges in the Canadian Foothills, faults, fractures, and intrusive bodies has significant implications for exploration risk reduction. Efficient exploitation efforts require the building of detailed fault compartmentalization reservoir models and the information that can be derived from duplex wave migration will combine nicely with other more conventional sources of information. This is yet another component of the solution to the problem of building accurate geological models of hydrocarbon reservoirs that feature multi-scale fractures (faults and joints).

Seismic image building for side wall of the salt dome

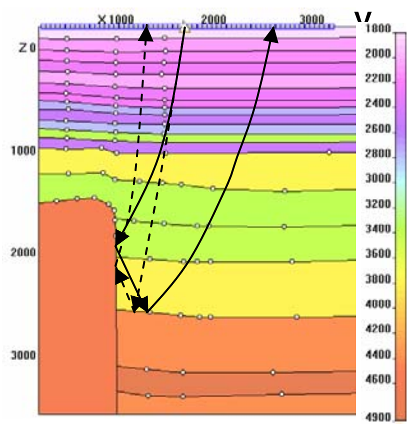

Figure 1. Source model - salt dome (with arrows are shown duplex reflections).

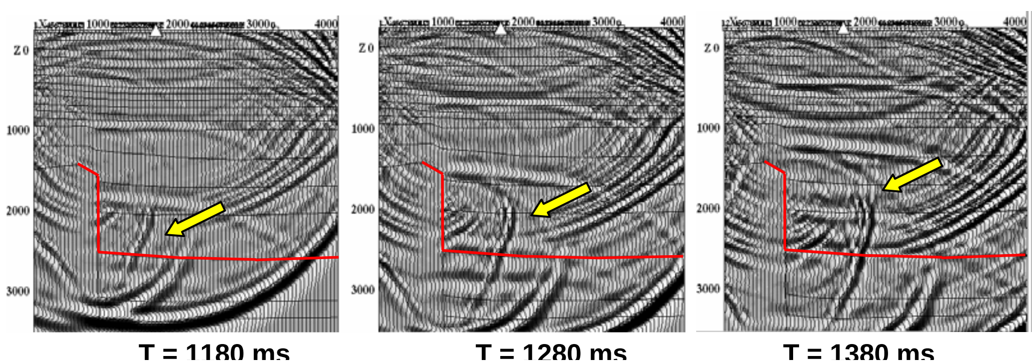

Figure 2. Seismic wavefield snapshots (with arrows are shown duplex reflections from boundaries highlighted with red lines).

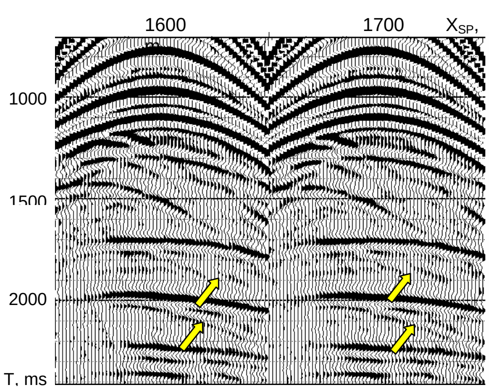

Figure 3. Synthetic shotgathers (with arrows are shown duplex reflections)

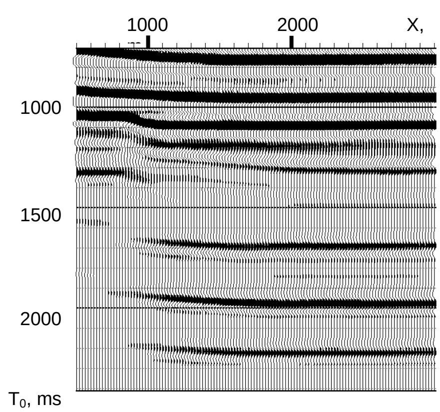

Figure 4. Seismic image of cross-section by conventional CSP migration.

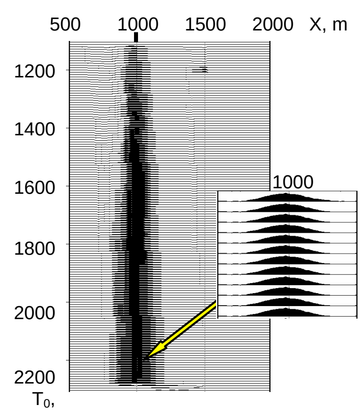

Figure 5. Seismic image of side wall of the salt dome by Duplex Wave Migration.