**Anisotropic Prestack Imaging In Practice**

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**ABSTRACT:** Conventional prestack depth migration involves building a velocity model for the subsurface using velocities that are assumed to be isotropic. When the earth is anisotropic, it is impossible for this conventional earth model to correctly predict the seismic raypaths and hence to accurately migrate the recorded data. Common problems with conventional prestack depth migration are overcorrected common-image point gathers and depth misties with available well data. Applying anisotropic prestack depth migration involves making some assumptions about the symmetry of the anisotropy and then determining the vertical velocity and the anisotropic parameters, delta and epsilon. These parameters were determined using a combination of well information, higher moveout analysis and migration scans. The results of a successful anisotropic prestack depth migration tie the available well information, have flat common-image point gathers and have higher resolution and improved focusing.

**KEY WORDS:** anisotropy, prestack depth migration.

**INTRODUCTION**

Prestack depth migration is a commonly used seismic data processing tool whenever imaging is complicated. More conventional processing flows make numerous assumptions that effectively limit effectiveness to areas with small lateral velocity variations. No such assumptions are made in prestack depth migration. Assuming the geoscientist can accurately determine the detailed velocity model, the prestack depth migration can accurately focus the recorded energy and produce a precise image. However, conventional prestack depth migration still contains assumptions that can hinder accurate focusing of the recorded seismic energy. One significant assumption is that the layers and blocks of interval velocities making up the velocity model are isotropic. This means that it is assumed that the instantaneous velocity of sound in these layers is independent of the propagation direction. However, it is well known that rock layers in sedimentary basins are commonly anisotropic (Thomsen, 1986).

The goal of velocity model building in prestack depth migration is to define a model accurately enough so that the raypaths of the seismic energy can be well defined. When the velocity model is good enough to accurately predict the true path of the rays, it can be used to precisely focus the energy from the many soundings into a migrated image. If the velocity model assumes isotropic propagation, whereas the reality is anisotropic, then the estimated raypath locations cannot be completely accurate and the migrated image will lose precision. In practice, there are two common signs that anisotropy is needed in the velocity model. Firstly, the resulting depths achieved from the prestack depth migration do not tie with those measured by drilling and, secondly, the common-image point gathers might only flatten on the nearer traces during model building (Meek et al., 2002). Correct inclusion of anisotropy into the velocity modelling can correct both of these problems. Including anisotropy in the velocity model building process can be difficult, and is best achieved with the assistance of well information. The result can be a more precisely focussed image for better interpretation and more reliable amplitude characteristics.

**RESULTS OF CONVENTIONAL VELOCITY MODEL BUILDING**

One of the objectives of conventional (isotropic) velocity model building for prestack depth migration is to achieve flat common-image point gathers by iteratively updating the velocity model and migrating. Even after considerable work and many iterations, it can be found that no velocity change seems to be able to flatten the farther offsets of the common-image point gathers. The gathers shown in Figure 1 are typical of this situation – the near offset traces are flat, but the energy is overcorrected on the farther offsets. Residual over-correction of the far offsets is a common sign of anisotropy. It can never be corrected when the building blocks of the velocity model are isotropic. It is imperative to incorporate anisotropic layers in the velocity modelling to resolve this problem.

**DEFINING THE ANISOTROPY**

After observing the effect of anisotropy, it must be defined so that it can be incorporated in the velocity model and raytracing required for prestack depth migration. Anisotropy occurs whenever the instantaneous velocity of sound varies with propagation direction. Obviously, this has
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The potential to be highly variable and complicated. At present, anisotropic processing techniques usually make very simplifying assumptions. It is often assumed that the anisotropy has transverse symmetry, with either vertical (VTI), horizontal (HTI) or tilted (TTI) orientation. VTI is the most common assumption for sedimentary basins, as it implies that the vertical and horizontal instantaneous velocities define the axis of symmetry, which is a likely result of thin beds that have been deposited horizontally. Even after the simplifying assumption of VTI symmetry has been made, the vertical velocity and the anisotropy parameters delta and epsilon are required to define the effect of the anisotropy (assuming that the anisotropy is weak – see Thomsen, 1986). Delta is the ratio that relates the vertical velocity and the imaging velocity (i.e. the velocity that apparently focuses the seismic data for the shorter offsets), epsilon is the ratio that relates the vertical velocity and the horizontal velocity. An accurate vertical velocity in combination with correct deltas will result in depth images that tie the available well data. Correct epsilons will ensure that the migrated gathers are flat at the farther offsets (e.g. Hawkins et al., 2001, Hawkins et al., 2002,). The vertical velocity was derived through careful analysis of all available well information. The deltas and epsilons were defined through inversion of second and fourth order moveout information. This approach uses the moveout equations of Alkhalifah & Tsvankin (1995) and Grechka & Tsvankin (1997). Short acquisition cables made it difficult to derive stable epsilons by pure fourth order analysis. Hence, additional migration scans with varying epsilons were required to finetune the results. Subsequently, the vertical velocity was updated using multiple iterations of layer based manual velocity analysis and tomography in order to account for regional velocity variations and velocity anomalies associated with shallow gas and faulting.

RESULTS OF ANISOTROPIC PSDM

Figure 2 shows the resulting common-image point gathers after the application of anisotropic prestack depth migration. The gathers are now flatter on the farther offsets because the anisotropic velocity model is capable of correctly defining the true raypaths of the seismic energy. When the true raypaths are known, it is possible to correctly locate the unmigrated seismic data in its required migrated (image) location. This also means that all offsets are now being more correctly focussed and hence not deteriorating the amplitude characteristics. Once anisotropy has been incorporated into the model, further refinements can be made with the use of layer based manual updating and residual curvature analysis (RCA) tomography. The tomography is a global model updating procedure that can provide further refinements of

![Figure 1. Selected common-image point gathers after conventional, isotropic prestack depth migration. The isotropic velocity model was the result of two iterations of vertical updating and one iteration of tomography. Notice how all of the farther offsets tend to display overcorrected energy. The near offset here is 167 m and the far offset is 2492 m.](image1)

![Figure 2. The same common-image point gathers as shown in Figure 1, but after anisotropic prestack depth migration. Delta and epsilons are time variant with deltas ranging from 0.04 to 0.06 and epsilons ranging from 0.03 to 0.17. Notice that the farther offsets are generally much flatter](image2)
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the velocity model. It is capable of making detailed updates that are very difficult to achieve with iterative manual updating. Figure 3 shows migrated common-image point gathers before and after RCA tomography. The gathers have become even flatter and more focussed – a good indication that the tomographic updates are helpful.

CONCLUSION

Conventional prestack depth migration uses isotropic velocity models, however, the real situation in sedimentary basins is commonly anisotropic. The effects of anisotropy are often seen as residual far-offset curvature on common-image point gathers and misties of depth migration outputs with available well data. These effects are signs that the velocity model is inadequate for the purpose of accurate depth migration. Improved depth imaging is achieved by incorporating anisotropy into the velocity modelling and the prestack depth migration. At present, anisotropy is introduced under simplified assumptions (usually VTI symmetry) and two simple parameters, delta and epsilon. These parameters can be defined by careful analysis of available well and seismic information. This approach presents a practical way to determine and apply anisotropic prestack depth migration. The results of applying anisotropic prestack depth migration are flatter common-image point gathers and accurate ties with well data. However, these are just signs of more accurate migration and better all-round focussing. This commonly leads to observations of improved resolution (Meek et al., 2002) and superior continuity and amplitude integrity.

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REFERENCES

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