Title:

Separation of anisotropy and structure during processing

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Introduction
The presence of anisotropy causes residual moveout (RMO) of the reflection events in a common mid-point gather, and, if uncorrected, will degrade the quality of the stacked results. Further complications may arise when coupled with the presence of dipping reflectors (structural variations). To compensate for these effects, various anisotropic dip-moveout (DMO) algorithms have been developed (Uren et al. 1990, Anderson & Tsvankin 1994). Here, we present a separation approach, which adds anisotropic RMO correction to the traditional processing sequence of normal moveout (NMO) correction followed by isotropic DMO (Hale 1984).

Theory and method
Consider a dipping layer with dip angle \( \phi \) in transversely isotropic media. The P-wave travel time from a surface source to a surface receiver with path length \( l \) can be decomposed into four different terms,

\[
t^2 = \frac{\phi^2}{v^2_{p0}} - \frac{\Delta t^2(\phi)}{v^2_{p0}} - \frac{l^2(\phi=0)}{v^2_{p0}} \zeta + 4th \text{ Order},
\]

where \( v_{p0} \) is the vertical P-wave velocity, and \( \zeta \) is a combination of Thomsen’s parameters (Thomsen 1986). The first term on the right of (1) is dip- and anisotropic-independent, and is referred to as the horizontal-isotropic term, the second term is the dip-isotropic term, and the third is the horizontal-anisotropic term, and so on. Progressing from left to right, each of these terms is normally an order of magnitude smaller than the previous one for dips less than about 30°. Because of this ordering we may compensate for each term individually during processing. For the first two terms, this is done by the conventional NMO correction followed by the isotropic DMO correction. The data now contain mainly the anisotropic contribution. This may then be corrected by the anisotropic RMO correction (Figure 1).

After isotropic DMO correction, we extract the residual moveouts (\( \Delta t \)) of the offset traces by cross-correlation with the pilot zero-offset trace. Following Li & Crampin (1993), in a transversely isotropic medium with horizontal layers, \( \Delta t \) can be expressed as

\[
\Delta t^2_i = x_i^2 \left( \frac{1}{v_h^2} - \frac{1}{v_{nmo}^2} \right) \sin^2 \theta,
\]

where \( x_i \) is the offset, \( \theta \) is the incidence angle at the reflection point, \( v_h \) is the horizontal velocity, and \( v_{nmo} \) is the NMO velocity. To estimate the amount of anisotropy we calculate the least-square solution for \( v_h \) using the given offset \( x_i \) and its residual travel-time \( \Delta t_i \). The incidence angle \( \theta \) is found by ray tracing through an initial velocity model built from \( v_{nmo} \) assuming a small magnitude of Thomsen parameter \( \delta \) (Thomsen 1986).

Results and conclusion
Figure 2 shows the effectiveness of this separation approach for a synthetic model containing a horizontal and a 30° dipping reflector with 25% anisotropy (ellipticity=0.388). The top event is from the horizontal reflector, and the bottom one is from the dipping reflector. The alignment of the bottom event (the dipping event) is improved after the additional anisotropic RMO correction.

We conclude that up to 30° of dip and 25% anisotropy, the effects of dip and anisotropy on moveout can be
decomposed into dip-related and anisotropy-related components, which may then be corrected separately by isotropic DMO and anisotropic RMO.

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References

Fig. 1: Processing flow

Fig. 2: Effects of the different corrections. Note that the alignment of the bottom event (the dipping event) is further improved by anisotropic RMO.