Points-to-Ponder *(Continued from page 21)*

Answer: (By Anat Canning and Alex Malkin, Paradigm Geophysical Ltd.)

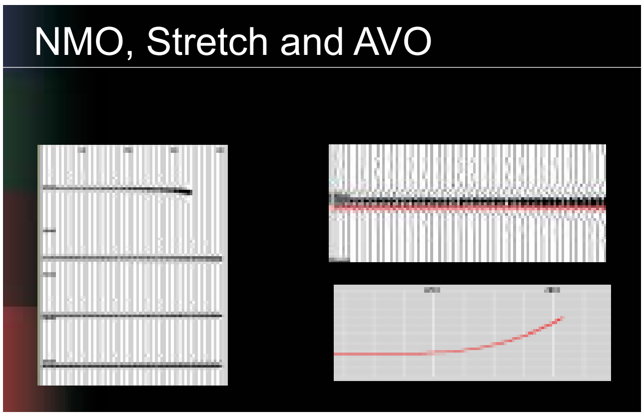
Let c be the normalized offset; $c=2h/v$ where h is half offset; t_0 the Zero-offset vertical time; v is the velocity (assumed constant), and T the travel time at offset c.
Then,

$$T = \sqrt{(t_0^2 + c^2)}, \qquad (1)$$

And the stretch factor is defined as:

$$dT / d\,t_0 = t_0 / \sqrt{(t_0^2 + c^2)}. \qquad (2)$$

As a result of equation (2), when we apply NMO correction to seismic data at every point, the waveform gets stretched as a function of offset and Time as shown in the figure below. This leads to lowering of resolution for large value of offset (c / t_0) and hence also in the stack response. What is worse, it leads to false AVO effect as shown in the figure below.

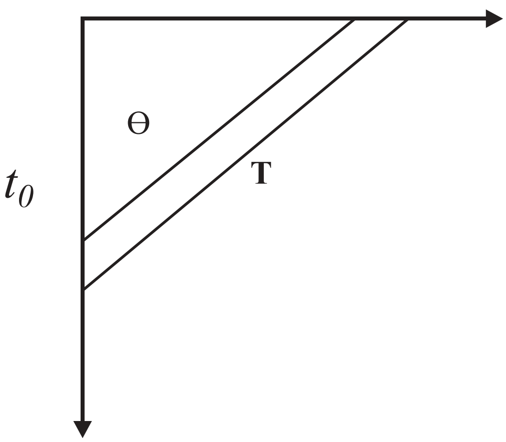


A way out is to work in the angle domain. It is seen from equation (2) above and the figure below that

$\cos(\theta) = t_0 / T$

and, therefore,

stretch $dT / d\,t_0 = \cos(\theta)$ independent of t_0



This analysis leads to the development of an un-stretching algorithm which operates in the angle domain, where the stretch is stationary. In this domain a single operator can be used for each trace. The convolutional model will be our starting point. Using this model the seismic trace at zero offset $f_0(t)$, is a convolution of the zero-offset reflectivity trace $r_0(t)$ with the wavelet w(t):

$$f_0(t) = r_0(t) * w(t) \xrightarrow{FT} \tilde{r}_0(\omega) \cdot \tilde{w}(\omega) \,. \qquad (3)$$

We assume that after NMO (and stretch), the seismic trace at angle of incidence □ is given by:

$$f_\theta(t) = r_\theta(t) * w_\theta(t) \xrightarrow{FT} \tilde{r}_\theta(\omega) \cdot \tilde{w}_\theta(\omega) \,, \qquad (4)$$

where is the stretched wavelet and (t) is the reflectivity at angle è. The objective of the un-stretching algorithm is to replace with the zero offset wavelet . Since in angle domain the stretching is constant and is given by:

$$dt_0 = \frac{dt}{\cos\theta} \,, \qquad (5)$$

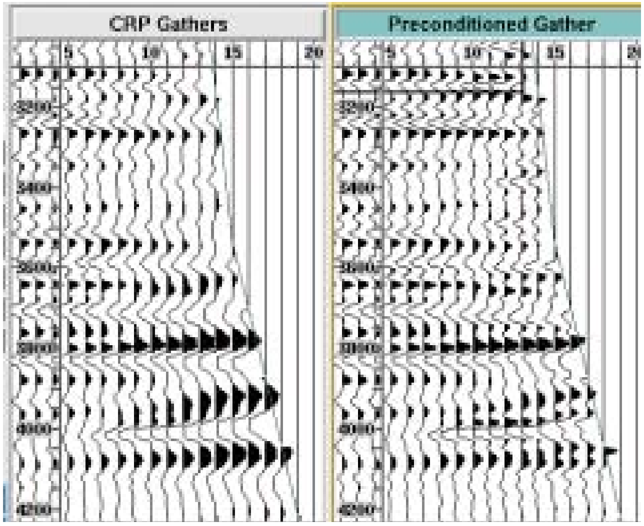
the stretched wavelet is a resampled version of the zero-offset wavelet :

$$w_\theta(t) = w\left(\frac{t}{\cos\theta}\right) \xrightarrow{FT} \tilde{w}(\omega \cdot \cos\theta) \,. \qquad (6)$$

Assuming that the zero offset wavelet *w(t)* is known, the un-stretching algorithm works a follows:

- → Convert data from offset to reflection angle
- → FFT
- → Apply the operator : $\dfrac{\tilde{w}(\omega)}{\tilde{w}(\omega \cdot \cos\theta)}$
- → FFT^{-1}
- → Convert from angle back to offset.

To obtain a wavelet an automatic wavelet estimation procedure is applied to the zero offset data. Spectral balancing and regularization is applied to the operator to avoid singularities and noise enhancements. An example of unstretching using the above algorithm is shown below. For more details, see ***Removing NMO/migration stretch effects for improved AVO analysis*** by Anat Canning and Alex Malkin in Proceedings of Hyderabad2008



a) Input angle gather b) Un-stretched angle gather

Editor's remarks: In presence of velocity gradient, the equation (2) gets modified as:

$$dT / d\, t_0 = \cos(\theta) + (c/ t_0) \cos(\theta)\; dc/ d\, t_0$$

which is no longer independent of t_0, and also adds to the NMO stretch. In addition to the angle gather approach by the author, there are other approaches to reducing NMO stretch. See, for instance, "Stretch-free stacking", Stewart R. Trickett in Proceedings of SEG Abstracts, 2003

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