Pre-stack Simultaneous Inversion Errors – Relation to Deconvolution Phase Error

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This paper is a model based study illustrating pre-stack simultaneous inversion rock property estimate errors in response to quantified seismic wavelet phase error relative to the inversion wavelet.

Most seismic interpreters assume that modern deconvolution results in a zero phase wavelet convolved with the earth's reflectivity series but in the Western Canada sedimentary basin (WCSB) it is our experience that this is never accurate, and that the convolved seismic wavelet is actually mixed-phase. This paper investigates and quantifies some pre-stack simultaneous inversion (PSSI) rock property estimate errors that result from subtle to substantial deviations from zero phase in the convolved seismic wavelet.

A very simple, WCSB like, rock property model is created and combined with a common zero phase Butterworth wavelet to create Zoeppritz compliant offset gathers. These gathers are then inverted utilizing a pre-stack model-based inversion algorithm to produce an estimate of the original model rock properties. The gathers are then filtered with all-pass but phase altering filters and the subsequent gathers inverted with the same terms and parameters as the model gathers so that the only variable is the non-zero phase component of wavelet spectra. Average and RMS errors caused by the distorted wavelet are calculated from the distorted wavelet rock property estimates and compared to the amount of phase error in the seismic wavelet. Since the phase distortions are frequency dependent, the rock property estimate errors also have a frequency dependent element so that specific rock interval property errors are related to the frequency content associated with that interval.

The practical difficulties with deriving and extracting accurate, consistent, seismic wavelet phase are one of the most difficult aspects of the entire pre-stack inversion process. Obtaining a sufficiently accurate set of well logs is often the initial challenge. Unfortunately well logs don't always represent seismic velocities and densities very accurately due to near wellbore alteration of the rock properties, measurement error and dispersion differences resulting from different measurement frequencies for logs and seismic data. If other wells are obtained, the resultant wavelets are often significantly different. Common techniques of wavelet extraction, such as Wiener-Levinson inversion, stabilized by the addition of white noise, biases the resultant extracted wavelet phase estimates toward zero phase, which is generally the wrong result. This issue is particularly exacerbated in the low energy parts of the seismic data power spectrum, namely the low and higher frequency components where seismic noise also severely distorts true wavelet spectral estimates and wavelet phase errors are larger.

A surprisingly large average error in the inversion estimates results from subtle and difficult to extract phase errors in lower frequency parts of the phase spectrum while higher frequency phase distortion more directly impacts intervals rich in those frequencies.

Rock property estimates of most interest and value to interpreters are bulk density and Vp/Vs ratio with P-Impedance or S-Impedance often not being as informative. With real data, Vp/Vs ratio is most difficult to estimate accurately as it is the result of dividing the Zp estimate by the Zs estimate and will be strongly impacted by phase distortions. Density estimates being a direct output of the inversion are generally more robust. All other parameters used to describe the rock properties such as Poisson's ratio or the

Lamé parameters can be calculated from Vp, Vs and density so phase distortion errors will be impacted accordingly.

Improving rock property estimates is strongly dependent on accurate and stable deconvolution with correction for layering caused propagation effects and improved wavelet extraction algorithms which can incorporate the a-priori rock property knowledge (ie logs, geology) in effective ways.