

# Preconditioning of Seismic Data Prior to Impedance Inversion

By SATINDER CHOPRA and RITESH KUMAR SHARMA

The calibration of seismic data with the available well control is an important step that provides the link between seismic reflections, their stratigraphic interpretation and subsequent prediction of reservoir and fluid properties.

The standard practice to do this has been to produce synthetic seismograms from well logs with a bandwidth similar to that of the seismic data. The synthetic traces are produced by picking up the sonic and density logs for a well and calculating the reflection coefficients. These reflection coefficients are then convolved with a suitable zero or minimum phase wavelet and choosing a frequency response similar to that of seismic.

The wavelet could also be extracted from the seismic data. Thereafter, the synthetic seismogram is displayed in the same polarity as the seismic and either overlaid or inter-fixed on the seismic data at the location of the well, after making a shift adjustment in time. Such a correlation helps to quickly identify individual reflections, which can then be interpreted on the seismic data.

The frequency content of surface seismic data varies with time due to attenuation or other effects, so generally we see higher frequencies in shallow intervals that are gradually lowered with increasing times. In Figure 1 we show a seismic section over a 1s interval, but higher frequencies in the upper 500ms and lower frequencies in the lower 500ms are seen. This can be seen on the wavelets that are extracted in the upper and lower intervals and the frequency spectra generated for the two intervals, as shown in the insets.

## Synthetic Seismograms

A synthetic seismogram generated using the wavelet from the shallower interval would exhibit a reasonable frequency match in the upper interval,

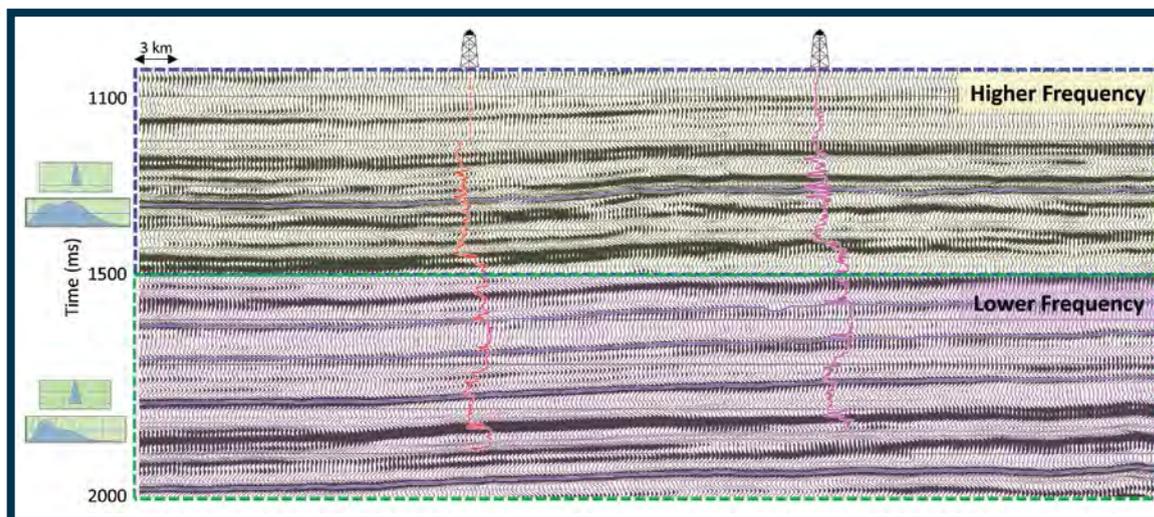


Figure 1 – Figure shows a segment of a seismic section passing through two wells, wherein the upper half exhibits higher frequency and the lower half shows lower frequency. The frequency spectra and the extracted wavelets from the two intervals are shown to the left. The impedance logs at the location of the wells are shown overlaid.

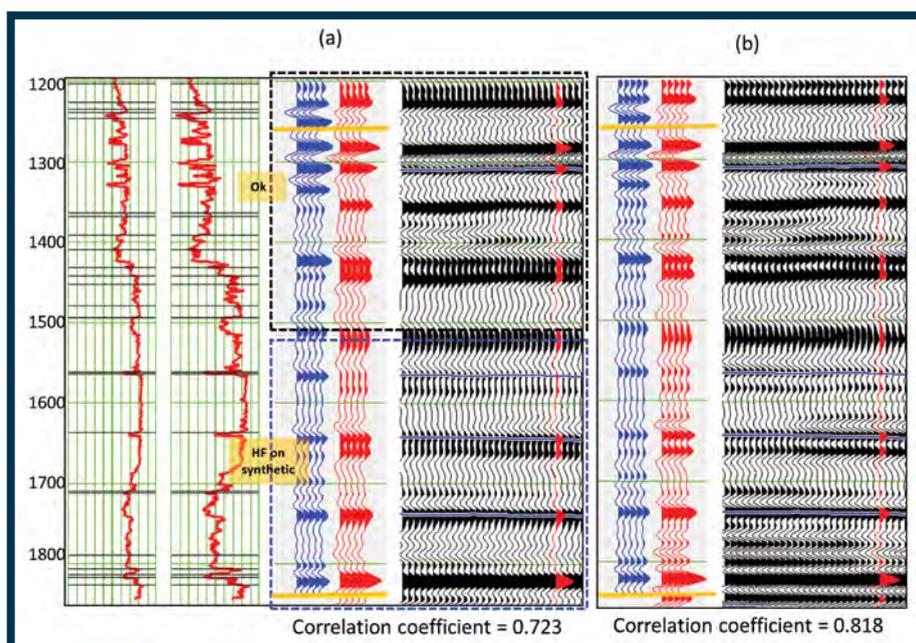


Figure 2 – (a) Creating a synthetic seismogram using the wavelet extracted from the upper half of the seismic section shows a good correlation with the real seismic data for the upper window. We do however notice higher frequency on the lower half of the synthetic seismogram. (b) Generating a synthetic seismogram using a wavelet extracted from seismic data after running thin-bed reflectivity inversion. The correlation coefficient calculated between the synthetic and the real seismic data traces, before and after thin-bed reflectivity inversion on seismic data between the windows indicated with the yellow bars is shown to increase from 0.723 to 0.818.

but will show a higher frequency content for the lower interval as compared with the seismic data. We show this in Figure 2, where in (a) we have the P-velocity and density logs used for generating the synthetic traces in blue. These are compared with the real seismic traces in red, and the correlation coefficient between them is 0.723. Notice in the

shallow portion highlighted with the black dashed box, the frequency content between the synthetic and the real traces seems similar. However, in the lower portion highlighted with the blue dashed box, the synthetic traces seem to exhibit a somewhat higher frequency (HF) content. As mentioned above, this is because the wavelet extracted from the

upper interval was used for generating the synthetic seismogram.

One way to address this problem would be to extract an average wavelet over the full window and then generate a full-window synthetic seismogram that could be correlated with the seismic. However, this would have a lower resolution in the upper window and a higher resolution in the lower window, something that is contrary to what we expect.

Another way that could be adopted is that separate wavelets are extracted in the upper and the lower windows and separate synthetics are generated and compared. As well, the inversions would need to be performed in separate windows, which is time-consuming. In such an exercise, we can expect to see lower resolution in the lower window compared to the upper window.

If we go back and examine the input seismic data, we see that the bandwidth of the data is somewhat narrow, with the peak frequency at 12 or 15 Hz and noise after 60 Hz. Also, the frequency spectrum shows a roll-off after 30 Hz. In figure 3a we show a segment of a seismic section from the input data, and the frequency spectrum is shown in the inset. To be able to extract some more information from the data, we should at least be able to make the frequency spectrum look flatter.

We achieve this with thin-bed reflectivity inversion, a process that extracts time-varying wavelets from

**Continued on next page**

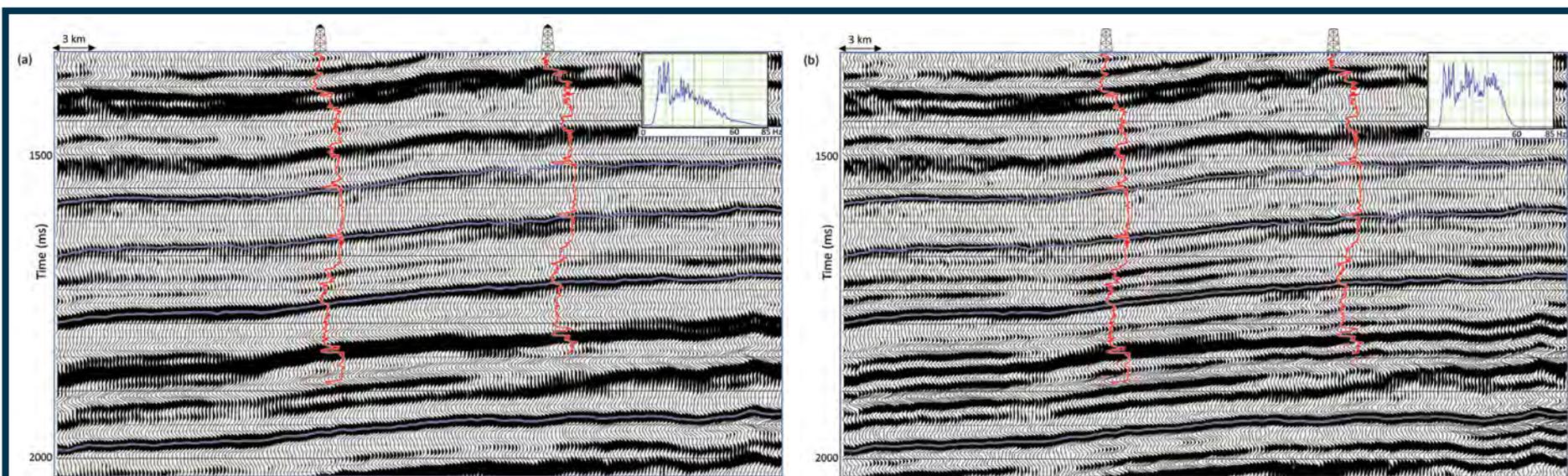


Figure 3: Segment of a seismic section from the (a) input seismic data, and (b) input seismic data with thin-bed reflectivity inversion and filtered to the same bandwidth as the input seismic data. The frequency spectra in the insets show the bandwidth of the seismic data as 5-10-50-60 Hz but that of the filtered thin-bed reflectivity inversion is now seen as flatter.

Continued from previous page

the seismic data and using principles of spectral inversion produces sparse reflectivity estimates. The advantages include being able to pick up more reflection detail, to perform more accurate interpretation on seismic volumes obtained by convolving reflectivity volumes with wavelets of higher bandwidth than the input data, and to visualize subtle anomalies when some attributes are run on thin-bed reflectivity inversion output. More detail on this method and its applications can be picked up from the Geophysical Corner columns in the May 2008 and July 2009 issues of the EXPLORER.

Enhancing Bandwidth

We put the input seismic data through thin-bed reflectivity inversion and derive the reflectivity volume. In principle, once the reflectivity volume is derived from the seismic data, it is possible to filter it back to a frequency bandwidth higher than the input seismic data. But there

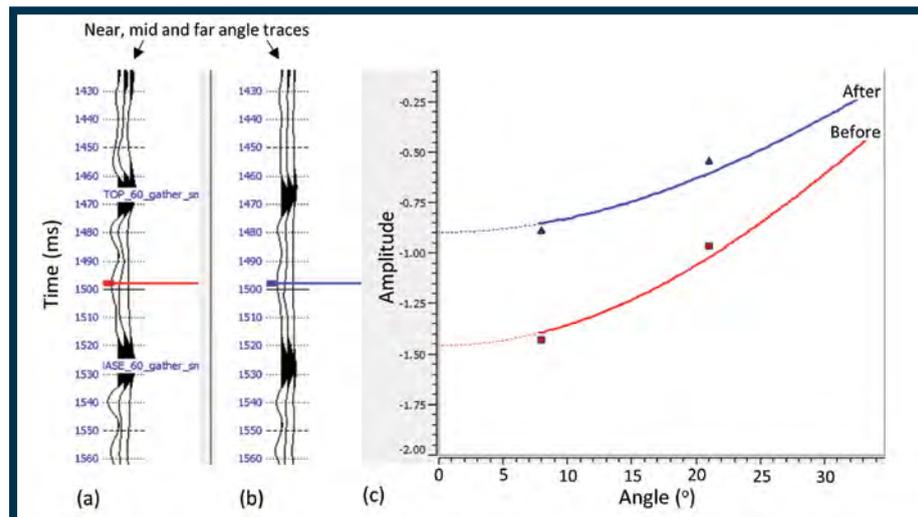


Figure 4: The angle stack traces for a short time window, created for data before (a) and after thin-bed reflectivity inversion (b) are shown to the left, where the red and blue bars mark similar events. The amplitudes of these similar events are plotted as a function of angle to the right in (c). Notice that while there is a small change in the amplitude of the events after thin-bed reflectivity inversion, the relative amplitude variation with angle is very similar.

are some seismic interpreters in our industry who are not comfortable with the idea of enhancing the bandwidth of the data beyond the recorded

frequencies. Keeping that in mind, here we filter the derived reflectivity volume to the same bandwidth as the input seismic data (i.e. 5-10-50-60 Hz).

The seismic section equivalent to the section shown in figure 3a is shown in figure 3b. Notice the improvement in the resolution detail, which is also seen on the frequency spectrum shown in the inset. The amplitudes of the frequencies beyond 25 Hz have been enhanced so that the spectrum now looks flatter. The correlation with the impedance logs also looks much better. We show a section of the data after thin-bed reflectivity inversion in figure 2b, where the synthetic seismogram generated from the well log data shows a better correlation with the seismic data. The correlation coefficient is now seen increased from 0.723 to 0.818.

The preservation of amplitude variation, both in the post-stack and the pre-stack seismic data, is usually a matter of concern for seismic interpreters. This is important for all AVO analysis work as well as impedance inversion performed on the seismic data. We picked up the pre-stack seismic data for a data volume from central Alberta, and after

See Jump, page ##

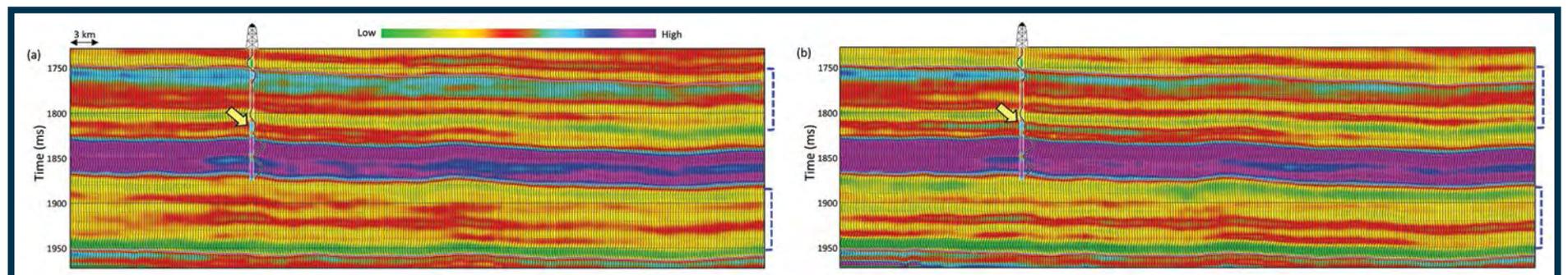


Figure 5: Segments of P-impedance sections generated using (a) the input seismic data, and (b) the data with thin-bed reflectivity inversion. The impedance log at the location of the well is shown as a curve, as a color strip. Notice the yellow arrows indicating the mismatch between log and the inverted impedance in (a) and a much better match in (b). Also, the intervals indicated to the right with dashed blue braces indicate the zones that show more well-defined events in terms of impedance in (b).

## Jump from page ##

conditioning of the gathers, generated the near-, mid- and the far-angle stacks.

### Simultaneous Inversion

This is the input required for simultaneous inversion, which we have discussed earlier in our article published in the June 2015 issue of the EXPLORER. In figure 4 we show the amplitude variation of the near-, mid- and far-angle traces for one such gather for two equivalent events, before and after thin-bed reflectivity inversion. We notice, that though there is a small change in the amplitude of the events after thin-bed reflectivity inversion, which is expected, the relative amplitude variation with angle is very similar.

Finally, simultaneous inversion was run on the pre-stack data after preconditioning and thin-bed reflectivity inversion run on angle stacks. The result of the impedance inversion in the form of P-impedance sections, before and after thin-bed reflectivity inversion are shown in figure 5a and b. The overlaid

impedance logs are shown as curves as well as colored strip logs. Notice the mismatch indicated with the yellow arrow between the log and the inverted impedance values in figure 5a, whereas it shows a reasonably good match between the two in figure 5b. Also, in the intervals indicated by the dashed blue braces to the right, many of the events are seen better well-defined and more focused in figure 5b than figure 5a.

We thus conclude from the above exercises that the varying frequency content in seismic data can pose problems while carrying out synthetic seismogram correlation to seismic data. The roll-offs that are seen on the frequency spectra of input seismic data can be flattened out with the application of thin-bed reflectivity inversion. This application is a post-stack process but can be fruitfully run on the near-, mid- and far-offset stacks, which then can be put through simultaneous impedance inversion. The results of such exercises can lead to more accurate interpretations, which obviously help the bottom-line.

We thank Arcis Seismic Solutions, TGS, for allowing us to present this work. 

Foundation