We E06
Quantitative Interpretation of Broadband Seismic Data - Challenges and Solutions
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SUMMARY

Broadband seismic data will only deliver its full reservoir value if a quantitative interpretation is possible; I discuss some challenges and solutions to achieve this goal. Enabling a quantitative Broadband well-tie is a vital and the fundamental part of quantitative interpretation workflow for broadband seismic data. Without it we can simply not achieve value because we cannot incorporate some or all of the low frequencies. Appropriate data processing, and if required reprocessing, and further seismic data conditioning are also a prerequisite to make sure the S/N is high over all the bandwidth.
Introduction

The volumes of “Broadband” seismic data acquired and processed by the industry have grown rapidly, as the spectral content of this new quality seismic is demonstrably superior to conventional seismic, both at the low and high frequency end of the spectrum. This fantastic technology race and the ongoing competition to provide “better-wider” bandwidth is still largely (in the author’s opinion), an acquisition and processing phenomenon. But what is the real benefit for the interpreter, what value has been delivered? The industry is now focussing on this challenge and the question was recently asked with more upstream tune (SEG broadband workshop, Utah, July 2014): does broadband seismic add extra value?

Provided that the acquisition and processing of broadband seismic data is derived in an amplitude preserving manner, it is then very tempting indeed to perform AVO/AVA type seismic inversion: the increased spectral content means that we can rely more on the seismic and less on background models, the construction of which is the topic of much and continuing debate (Naeini and Hale, 2014). Seismic inversion is the industry workhorse to compute elastic properties of the earth which can then be used to derive reservoir facies and Net Pay. The logic behind this very abridged reservoir characterisation workflow is simple: good quality seismic input results in good quality and more reliable reservoir parameter estimation. This could potentially deliver the added value of broadband seismic but it is not all roses as there are some challenges.

We are now in an optimum time to focus on understanding what the “added value” is that broadband can deliver for quantitative interpretation, seismic geomechanics and time lapse applications. It is beyond the scope of this paper to address all aspects of this technology hence I focus on the fundamental challenges of tying broadband seismic data to well scale information and data conditioning before inverting broadband seismic data.

Challenge 1: well-tie

To perform seismic inversion, the wavelet which maps the well data onto the seismic data is to be estimated first. This process is often called well-tie and here is where we encounter the first and perhaps the biggest problem. As the broadband seismic now goes to such low frequencies (1 - 2 Hz), we need the relevant log data (Vp, Vs and density) to span 100’s, indeed 1000’s of meters, and this is seldom the case: the wavelet (both in terms of amplitude and phase) cannot therefore be determined at the important low frequency end! It is therefore easy to see the dilemma: in one hand we want to use as much low frequency from seismic data as possible so that the inversion relies less on the background model but in the other hand we cannot practically feed them into the inversion process as the wavelet is not reliable at the low end due to the short length log data.

White and Naeini (2014) discussed this in detail and as far as the author is concerned there are no other references in the literature with regards to what White and Naeini called “broadband well-tie”. They indicated that the problem is a reliable measure of the decay of seismic spectra towards zero frequency even for conventional bandwidth but more acute for broadband seismic data where the decay becomes too sharp from 2 Hz to zero frequency. White and Naeini (2014) proposed to measure the low frequency decay of the spectrum from seismic data itself by means of multi-taper spectral analysis and then merge it onto the wavelet spectrum.

Direct estimation of the low-frequency phase is not possible from a well-tie. The estimated phase at zero frequency is either 0° or ±180°, depending on whether the sum of wavelet coefficients happens to be positive or negative. White and Naeini (2014) proposed a relationship between the phase at zero frequency and the decay rate at the low frequencies as: ±n*90°+n*60°/Oct. Thus estimation of the amplitude decay becomes doubly important since it gives a clue to the phase at zero frequency. The phase can then be interpolated to the nearest reliable low-frequency estimate.
This formula can of course be unrealistic sometimes. The pragmatic option is then either to use a constant phase wavelet or trial and error tests for phase at zero frequency. The constant phase uses fewer degrees of freedom than estimating a phase spectrum and has some empirical basis in that, after processing, the phase of seismic wavelets is often approximately constant across the seismic bandwidth.

These are all initial research findings and more work is currently undergoing on this topic for a more global solution. However, the observation so far is promising. Figure 1 compares the inversion result

Figure 1 Acoustic impedance and residual of seismic inversion for a broadband seismic data using a traditional well-tie wavelet (top) and broadband well-tie wavelet (bottom).
using a wavelet from traditional well-tie and broadband well-tie. Note that the input broadband seismic is unchanged for both scenarios. It can be observed that the low frequency residual is effectively reduced when broadband wavelet is used. This essentially means that broadband well-tie is the key to get the best value of broadband seismic data for reservoir characterisation.

**Challenge 2: seismic data conditioning**

There is no doubt, as mentioned before, that better quality seismic result in better inversion products. In terms of broadband seismic this is more problematic. The rich low frequency content of broadband seismic data requires extra care and QC during processing. It is often these low frequencies which are highly contaminated by low frequency noise such as swell noise. Apart from that the deghosting operation can potentially boost the noise and also the presence of residual bubble/multiples can lead to misinterpretation. Figure 2 shows a far stack section before and after removing the residual ringing events at the target level.

![Figure 2](image.png)

*Figure 2* raw far stack (left) shows residual energy (potentially multiples) shown by arrows contaminating the reservoir level. This was effectively removed after revisiting the processing flow.

This residual noise shown by arrows caused anomalous energy in the impedance properties (see figure 3). After attenuating the residual energy and conditioning the seismic data further the outcome acoustic impedance and Vp / Vs attributes were more realistic and match the well data agreeably. Note that the geology here is a thick shale unit with almost no coherent seismic energy surrounding a sand body. This makes inversion really sensitive to the S/N. The lessons learnt after all was to QC the data carefully especially at the low end of the spectrum, apply further seismic data conditioning and if required contact your processing team. Although nothing new in this but to get a better value from broadband seismic this needs to become a common practice.

**Conclusions**

Broadband well-tie is the fundamental part of quantitative interpretation workflow for broadband seismic data. A practical approach to get a broadband wavelet based on spectral analysis was introduced and showed a promising result on a real data example. Without broadband well-tie the leakage of low frequencies into the residual section is evident. Also it was shown how an effective focus of seismic data conditioning at low frequencies’ and at the target level can help to stabilise the prestack seismic inversion further.
Figure 3 AI and Vp/Vs attributes from prestack inversion using raw seismic (left) and conditioned seismic (right).

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References
