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Addressing Obstacles to Adoption of Broadband Seismic by Asset Team Interpreters

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SUMMARY

Broadband seismic data is distinctively different from conventional 'band-limited' seismic data in appearance as a result of broader information content. Common reactions from interpreters encountering broadband seismic data for the first time are addressed. This paper illustrates these concerns and responds with suggestions to overcome these obstacles to broader adoption.

Broadband has been promoted as a resolution solution, causing interpreters to anticipate higher frequencies at depth than is possible given the frequency-dependent attenuation of the earth.

Broader frequencies result in a sharper wavelet with less side-lobe energy, causing some reflectors that were artifacts of side-lobe energy to disappear, radically changing the appearance but giving better ties to well data.

The additional low frequencies of broadband data are crucial in delivering more stable and higher fidelity inversion results. Popular frequency-related seismic attributes such as 'sweetness' are also significantly improved by the additional low frequencies.

Once seismic interpreters understand the reasons for the radically different appearance of broadband seismic data and start taking advantage of the additional information content and higher fidelity, it can be expected that this data will be demanded as standard.

Introduction

Broadband seismic data has already demonstrated some significant benefits for processing and quantitative interpretation. Several key technical advantages mean it ought to be rapidly embraced by the interpretation community and demanded as de facto standard for future acquisition. The industry leaders have acquired increasing volumes of broadband 2D and 3D surveys, yet few interpretation groups have got to use the data or appreciated its advantages. Why is this?

Broadband seismic data is distinctively different from conventional 'band-limited' seismic data in appearance as a result of broader information content. Three common initial reactions expressed by interpreters when interpreting deeper targets using broadband data are one or all of the following:
(1) "Where are the extra high frequencies I was expecting at my target level?",
(2) "Where have the other reflectors around my main markers gone?", or
(3) "The deep data looks 'wormy' so I filtered out the additional low frequencies"

The reasons for these concerns are examined and specific case examples, comparing collocated band-limited and broadband datasets, illustrate these concerns and demonstrate why acquired broadband data provides a superior product for the discerning seismic interpreter.

Example 1: Q-limited resolution at depth (Faroes-Shetland Basin 2D)

Concern 1 has arisen because the industry has promoted broadband as a "revolution in resolution". Many geophysicists seem to have forgotten about, or never fully comprehended, the effects of Q, the characteristic frequency-dependent attenuation of input signal by the 'earth filter'. Cosmetic post-processing that indiscriminately whitens final volumes has reinforced the notion that high frequencies can be preserved at depth. In reality low residual signal and relatively high background noise are both being boosted to give the superficial impression of more information content than is genuinely present. As a result the expectations are that an acquisition solution with more bandwidth, especially high frequencies, will produce an even higher frequency image at depth.

By comparing a fully-deghosted (source and receiver ghosts removed), broadband 2D line with a co-located 3D line extracted from a conventional, band-limited dataset a truer impression of the attenuation with depth of different frequencies can be gained (and subsequently compensate better for it). For the broadband seismic data a broader bandwidth of signal is injected into the subsurface using a multi-level source array (Parkes et al., 2011) and a broader bandwidth signal is recovered by wavefield separation from deep-tow dual sensor streamers. This gives fuller understanding of the frequency content that can be expected from deeper targets, and shows the strong attenuation of higher frequencies beneath dense volcanic layers at mid depths in this case. The equivalent line from legacy band-limited 3D superficially appears to have more frequency content at depth, but frequency decomposition into octave panels and signal-to-noise estimates show that there is less coherent signal in the deep section (and no genuine signal at the lowest frequencies with band-limited seismic).

Example 2: Disappearing side-lobe artifacts (Northern North Sea 3D)

Concern 2, an apparent loss of horizons with broadband data, arises when interpreters are not used to routinely using broadband data containing less side-lobe energy and more low frequencies. Reiser et al. (2012) illustrated that the corollary of a broader amplitude spectrum is a time-series wavelet with more signal concentrated at the wavelet maxima and significantly less side-lobe energy.
A recently acquired broadband 3D survey in the UK Northern North Sea allows comparison of the seismic response at Jurassic reservoir targets compared to a conventional 'band-limited' 3D dataset. The differences are striking (Figure 1). Superficially the broadband data appears to have 'lost' several strong reflections within the Upper Jurassic interval, sub-parallel to the strong Base Cretaceous unconformity boundary. These reflections were interpreted on the band-limited volume as genuine intra-Jurassic horizons, while the broadband volume shows fewer reflections, with distinctly different geometries. Detailed matching to well synthetics demonstrate that the broadband volume ties significantly better to the geological impedance boundaries in wells, with improvements in correlation coefficient (0.65 to 0.9) and reflections corresponding only to genuine impedance boundaries in wells.

Pre-stack seismic inversion of both broadband and band-limited inversions shows much more stable and geologically meaningful results from the broadband data that match extremely well to rock physics property distribution from the well log data. This additional fidelity and stability results primarily from the additional octaves of low frequency, and the improved signal-to-noise preserved within these lower octaves. More reliable low frequency signal from seismic data enables better seismic-rich low frequency models, that in turn contribute to inversion volumes driven more by seismic data than by the bias of a priori models and should thus be more reliable away from limited well control. Since relative elastic attributes such as these can be generated comparatively quickly and efficiently from conditioned angle stacks, they should be routinely made available to interpreters alongside reflectivity stacks. There is significant value in interpreting on combinations of various angles stacks and elastic inversion volumes simultaneously.

This same broadband dataset has then been band-limited by filtering out the additional octaves of low frequency and inversion and interpretation repeated. The results are significantly compromised by the absence of the rich low frequencies, and interpretation is more difficult, less efficient and less accurate compared to using broad bandwidth seismic data. Popular frequency-related attributes such are instantaneous frequency and 'sweetness' benefit from additional bandwidth, gaining clarity and precision, and these are obviously compromised if low frequencies in broadband data are filtered out.

Conclusions

Once seismic interpreters understand the reasons for the radically different appearance of broadband seismic data and start taking advantage of the additional information content and higher fidelity, it can be expected that this data will be demanded as standard. Simultaneous interpretation on reflectivity and inversion volumes can improve subsurface understanding and aid interpretation. Processors must be diligent to preserve a balanced spectrum of genuine signal appropriate to the target depth by appropriate depth-dependent Q-compensation.

References

Parkes, G. and Hegna S., [2011], A marine seismic acquisition system that provides a full 'ghost-free' solution. *81st SEG Annual International Meeting*, Expanded Abstract, 37-41.

Reiser, C., Bird, T., Engelmark, F., Anderson, E. and Balabekov, Y. [2012] Value of broadband seismic for interpretation, reservoir characterization and quantitative interpretation workflows. *First Break*, **30** (9), 67-75.

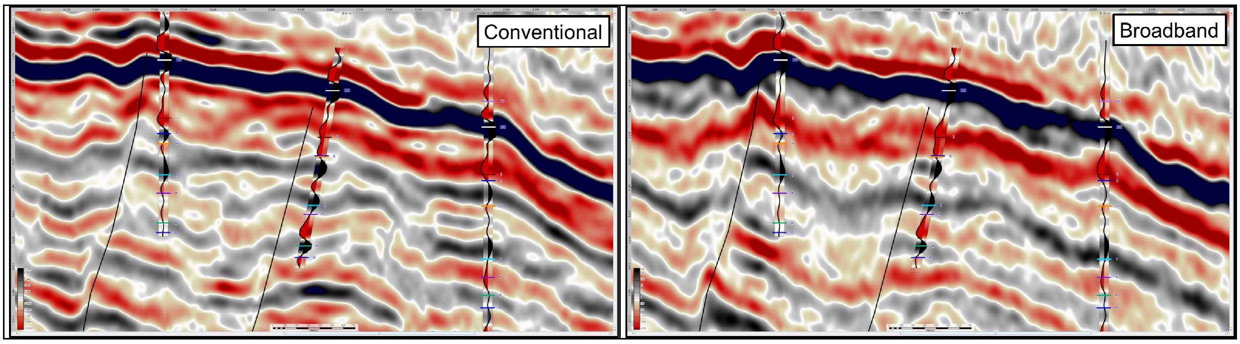

Figure 1 *Fullstack image with fullstack synthetic well ties for arbitrary 3D line through conventional band-limited seismic data (left) and broadband data (right). Strongest black event is Base Cretaceous unconformity (BCU). Note red events immediately below BCU on band-limited data that do not tie synthetics (generated using sharper, cleaner broadband wavelet)*