Processing Land Broadband Data: Challenges that Oman Surveys Present and how they Are Addressed

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Summary

A set of land broadband seismic data from Oman is presented. They belongto a few dense wide azimuth surveys which were recently recorded using a 1.5Hz-86Hz sweep.We show how the quality of the broadband signal can be effectively controlled at each processing step in such surveys. The aspects in which the low frequencies differ from standard frequencies are presented and the benefits of applying octave dependent processes are discussed.

The ability to acquire and image high quality low frequencies on marine data sets has been demonstrated for sometime. We illustrate via these examples that this goal can also be achieved on land data.

Introduction

Since 2011, Petroleum Development Oman has been acquiring low frequency seismic data using 1.5Hz -86Hz sweeps instead of the previously standard 6Hz-86Hz sweeps. These recent surveys are also characterized by their high density (the fold, in a 25m x 25 m bin, is typically greater than 8000) and their full azimuth coverage (up to 6.5km cross line offset). When it comes to time processing of such data, three questions arise: 1) How can we effectively assesthe quality of the recorded low frequencies at each processing step? 2).What are the properties of the low frequency signal and low frequency noise and how could this knowledge impact the processing parameters?, 3) How can we improve the consistency and stability of low frequencies? For the latter, we will look at the benefits of applying frequency specific surface consistent operators.

Where is the low frequency signal?

The low frequency signal doesn’t stand out on raw land records as ground roll is very dominant. Low frequency content of ground roll is useful for surface wave inversion but potentially degrades the stack image and masks the primary energy. After compensating for the geophone low frequency response, it would seem that only environmental low frequency noise is boosted. However, looking at a stack after full pre stack time migration, the low octaves display clear consistency with the geology and with the higher octaves. Still the low frequencies naturally don’t dominate the seismic cube (ideally as close to the reflectivity as possible). They appear more strongly after inversion processes (Full Waveform Inversion, acoustic, elastic…). That is why we need to color the data towards the low frequencies in order to effectively control their consistency with the geological structures. One possible technique is to apply colored inversion operators based on the measurement of spectra on impedance logs at wells. A second technique consists of balancing the octaves individually to the same amplitude level before merging them. Both methods reveal the rich (up to 6 octaves) broadband content of the data and give a new look at the seismic sections (Fig 1 & Fig 2). These volumes can be directly interpreted.

What is specific about low frequency signal and noise?

As seen on raw records, the signal to noise ratio of linear noise and environmental noise seems significantly degraded for the low frequencies. We show on a north Oman example that inappropriate dip filters or adaptive subtraction operators could damage the weak low frequency signal. The dispersive nature of the ground roll must also be taken into account during the analysis and attenuation of linear noise.

Generally, the signal and noise separation on low frequencies requires longer analysis windows and longer operators. For example, impulsive noise can only be detected within a time window greater than the period of the noise. Also, the length of coherency enhancement filters can be increased for the low frequencies because they have lower lateral resolution. This requires prior splitting of the data into octaves, applying octave dependent filters, and finally merging the results back together.
As far as multiples are concerned, low frequencies can show a different pattern than higher frequencies. Interestingly on one low frequency data set from South Oman which is heavily contaminated by a curtain of internal multiples, structures which are almost invisible on standard octaves appear much more clearly on lower octaves. We discuss if this information can be exploited for guiding the de-multiple processes.

Stabilizing the low frequencies with surface consistent operators

On land data, the characteristics of the noise (multiples, ground roll,..) most often depend on the shallow subsurface conditions. Heterogeneities in the shallow subsurface also yield wavelet distortions. These distortions can be corrected by computing and applying surface consistent operators.

The consistency of surface related amplitude changes across the full frequency range was checked on one of the land broadband surveys. After splitting pre stack data into eight octaves, the average amplitude of each trace was measured within a defined time window showing a good signal to noise ratio. These gains were decomposed into three terms: a global term, a source term and a receiver term. Then we looked at the correlation of the source/receiver gains of each individual octave with the source/receiver gains computed on the dominant octave. Whereas the correlation was very good for higher octaves (>8Hz), a strong decoupling was observed for lower octaves.(see Fig 3).

Regarding the phase, we show how applying a surface consistent phase correction improved the phase stability of low octaves and their consistency with the higher octaves. Unfortunately, the absence of long, good quality reflectivity logs prevented us from computing the final phase adjustment.

This example demonstrates the importance of applying frequency dependent surface consistent operators,in order to avoid unpleasant surprises at the inversion stage.

Conclusion

The challenges in processing low frequency land data have been discussed through the presentation of a few examples from the Sultanate of Oman. We have seen that good quality broadband signal can be achieved and can be enhanced by applying relatively simple coloring techniques after imaging. In order to preserve the low frequency signal, careful parameterization of de-noising processes is required. The stability of low frequencies is significantly improved by applying surface consistent, frequency dependent operators. The benefit of acquiring and processing low frequency land data will fully materialize when the reflectivity volume is transformed into an acoustic or an elastic volume through inversion processes.

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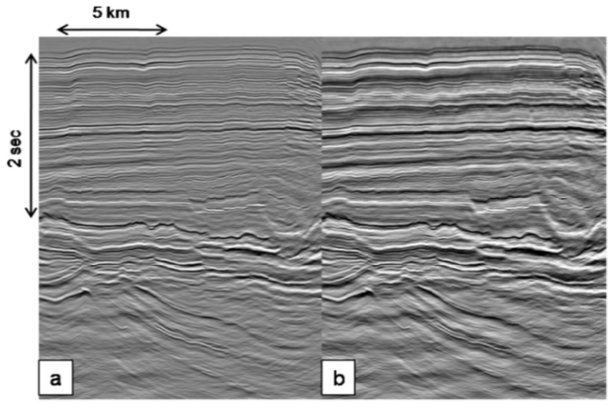

Figure 1 *Section through a stack after migration: before octave balancing (a), after octave balancing (b).*

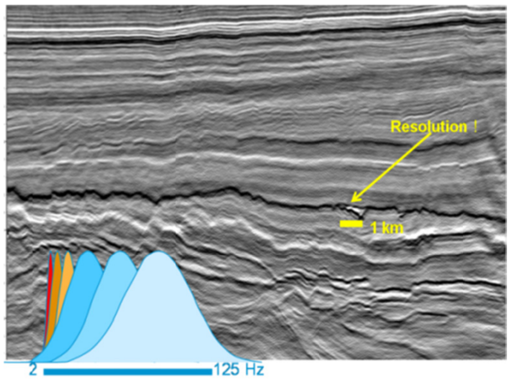

Figure 2 *Section through a North Oman cube after octave balancing.*

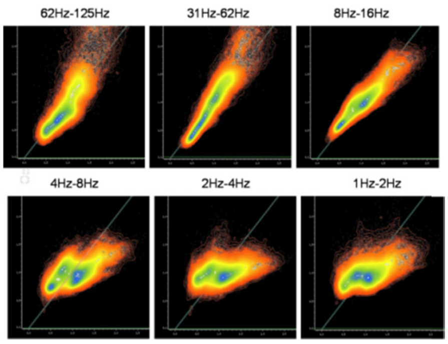

Figure 3 *Correlation of shot gains computed for different octaves. X axis : gains computed for the dominant 16Hz-31Hz octave. Y axis: gains computed for the octave mentioned above each individual graph.*