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Conditioning poorly sampled gathers for pre and post stack analysis

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Introduction

The analysis of seismic waveforms at long offsets is commonly regarded as a key approach to imaging sub-basalt geology. Such arrivals, typically comprising mode converted energy, have apparent velocities that are slower than those targeted in conventional reflection methods. Often the acquisition sampling and geometry are inadequate to correctly spatially sample these arrivals. In addition poor sampling of source generated noise can further degrade both pre and post-stack data. Noise in the form of multiple reflections and refractions can dominate arrival times and offsets common to key critical and post critical reflections. Degradation usually emanates from two causes, the spatially aliased and the non-spatially aliased energy. This paper uses examples to demonstrate the suppression of this aliased energy and shows how with careful processing, the quality of the stack can be significantly improved. In addition, suppression of the aliased energy is shown to provide better performance in the removal of non-aliased multiple, improving pre-stack data analysis. Although the examples shown in this paper do not include sub-basalt investigations, the same techniques have been used in and are applicable to such investigations.

Background

Advances in the understanding of the effects of sampling seismic data (Vermeer, 1990; Hampson, 1994; Davies and Hampson, 1997) and the introduction of techniques that allow interpolation beyond aliasing (Spitz, 1991; Jakubowicz, 1994) have enabled the use of 'stack array' geometry (Anstey, 1986) to significantly suppress noise, without degradation to signal. Consequently new acquisition geometry can be designed to optimise pre and post stack data. In addition, existing surveys acquired with sub-optimum geometry can be re-processed to provide a pseudo 'stack array'. Fundamental to understanding these processes is the analysis of stacking diagrams in both 2D space and the 2D wave number Fourier equivalent. The reader is urged to also consider the Fourier equivalents (Vermeer, 1990; Hampson, 1994; Davies and Hampson, 1997).

Aliased multiples in pre stack data

In the first example, pre-stack data is to be used to investigate the cause of anomalous high amplitude reflections in the stack. Although multiples do not appear to significantly penetrate the stack, the pre-stack data shows strong aliased and non-aliased multiple contamination (figure 1a). The aliased noise particularly impairs the analysis at wide angles. In this towed streamer acquisition geometry the source and receiver intervals were Δx_s=30.48 m and Δx_r=15.24 m respectively. In the shot domain, Δx_r is sufficient to prevent significant spatial aliasing of the steeply dipping refractions and multiple. However, in the receiver domain, the trace sampling $\Delta x_s=2\Delta x_r$ halves the spatial bandwidth causing aliased energy to overlap with non-aliased signal. In the CDP gather where the offset sampling $2\Delta x_h=4\Delta r$ or 60.96 m the Nyquist bandwidth is reduced further, significantly increasing the amount of aliasing. Indeed, the gather is dominated by noise (figure 1a).

Processing can be used to unwrap and remove the aliased noise. Using interpolation that is able to unwrap the aliased energy, new traces are inserted between existing traces. Application to a receiver gather has the effect of reducing Δx_s=30.48 m to $\Delta x_s'$=15.24 m. In addition a spatial anti-alias filter can be applied to remove the unwrapped energy. After re-sorting back to the shot records the same spatial antialias filter can be applied. Dropping every alternate trace increases Δx_r=15.24 m to $\Delta x_r'$=30.48 m to form a pseudo stack array geometry. Finally, re-sorting into CDP gathers gives a new offset sampling $2\Delta x_h'=\Delta x_h$ or 30.48 m. The source, receiver, offset and midpoint gathers now have adequate spatial sampling and are free of aliased noise. Further more, non-aliased multiple is now clearly defined (figure 1b), improving the performance of further demultiple processes. Figure 1c shows the result after predictive de-convolution has been applied in the τ-p domain.

Conclusions

Using a combination of interpolation to unwrap aliased energy and the application of spatial anti-alias filters, good pre-stack gathers can be formed from poor acquisition geometry. There are a number of benefits. First the stack is improved and in some cases shows dramatic improvement. Secondly, the pre-stack gathers

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and in particular the CDP gathers can be freed from aliased noise. Thirdly, the performance of additional pre-stack processes can be significantly enhanced. In addition, even with stack array geometry, where source and receiver group lengths are the same as Δx_s and Δx_r respectively, aliased energy can still penetrate the stack. The arrays do provide some attenuation of the aliased noise but are inferior to true anti-alias filters. Using interpolation to first unwrap the noise, digital anti-alias filters can then be applied before de-sampling back to the original geometry. Such processes are not a substitute for adequate acquisition sampling of the noise in source, receiver, midpoint and offset domains, however, the techniques can be used to recover good data from poorly acquired legacy data and to help moderate acquisition costs for newly acquired data.

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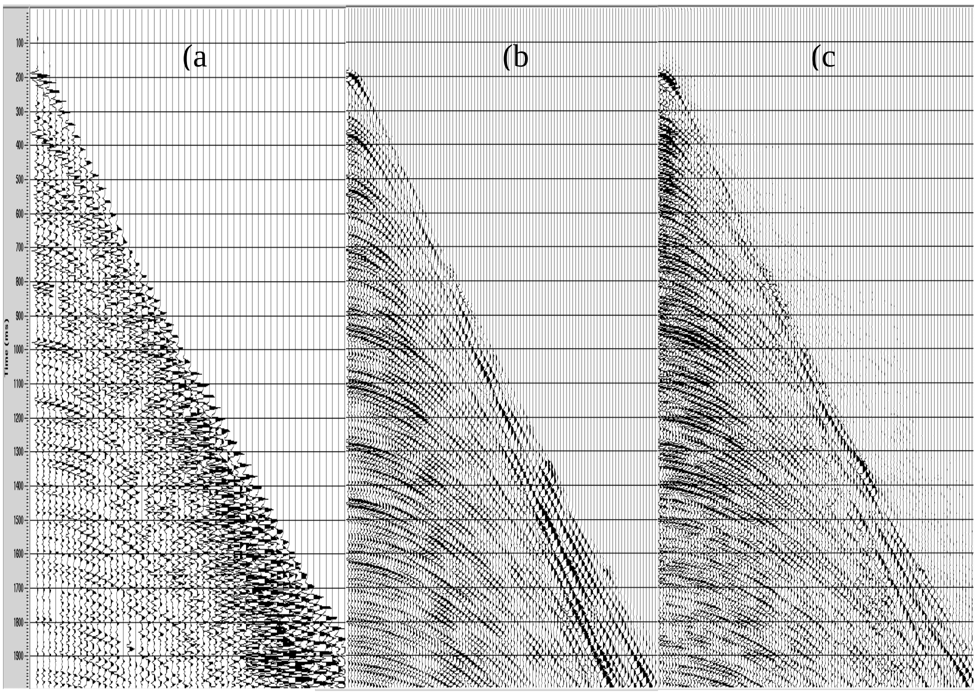

Figure 1: (a) Raw CDP gather from acquisition geometry $\Delta x_s=2\Delta x_r$. (b) After resampling to pseudo stack array $\Delta x_s'={}^1/_2\Delta x_r'$. (c) After further predictive deconvolution in τ-p