Ground Roll Attenuation Applying Adaptive SVD Method in the Radial Domain

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Abstract

The Radial Transform is a technique that maps the amplitudes of the seismogram from the usual distance-time domain (XT) to the angle-time, or velocity-time domain (RT). This rearrangement of the data turns linear events, as ground roll, direct waves and refracted waves into vertical events, with low frequency, and conserves the shape and frequency of sub-horizontal events. The Singular Value Decomposition (SVD) can be applied as a horizontal coherence filter, usually being used after the NMO correction, in the XT domain. This paper discusses the joint of the radial transform with the adaptive SVD method for ground roll filtering.

Introduction

The ground roll is a dispersive linear noise that hides the reflections of the seismogram, caused by the Rayleigh wave, with low frequency, low velocity and high amplitude. This noise needs to be filtered because its presence lowers the signal/noise ratio, making the velocity analysis more difficult and impairing the quality of the stacked section.

The Radial Transform method was introduced by Ottolini, 1979, and Claerbout, 1983, for seismic migration, separating up-going and down-going waves and for imaging algorithms. Henley, 1999, used the radial transform for seismic processing, transforming the data, from the distance-time domain (XT) to the velocity-time or angle-time domain (RT), making linear events show up as vertical events with low frequency and conserving the structure and frequency of the sub-horizontal events. Because of this change in the frequency of the data, Henley, 2000, used the low cut filtering in the RT domain for coherent noise attenuation.

The SVD filtering (Singular Value Decomposition) is used for enhancing the spatial coherence of reflections and also for filtering many kinds of noise (Freire, 1986, Bekara and Van Der Baan, 2007, Porsani et al., 2013). The method proposed by Porsani (2010) works with a moving window that runs through the whole data, after the normal move-out correction. The NMO correction turns the reflections horizontal, and the SVD extracts the central trace of the band, reconstituting the trace with the first K eigenvalues.

As the Radial Transform remaps the structure of the seismic data, in this paper, we propose the joint of the SVD method and the radial transform, discussing the use of this processing before and after the NMO correction.

The Radial Transform

The Radial Transform (RT) is an amplitude rearrangement of the seismic data $S(x,t)$, usually placed in the distance-time domain (XT), to the angle-time or velocity-time domain (RT). This process can be described as equation (1) (Henley, 1999):

$$\mathbf{R}\left\{S(x,t)\right\} = S'(v,t') \Rightarrow \mathbf{R}^{-1}\left\{S'(v,t)\right\} = S(x,t) \qquad (1)$$

The parameters t' and v are described in (2) as:

$$t' = t - t_0\ ,\ v = \frac{x - x_0}{t - t_0}. \qquad (2)$$

For re-arranging the amplitudes of the data, the interpolation method used is described in equation (3). This method could transform the data back and forth, with minimal loss of signal and structure of the data (Manenti et al., 2011).

$$\tilde{A} = w_1 A_1 + w_2 A_2 \rightarrow w_i = \frac{{d_i}^{-2}}{{d_1}^{-2} + {d_2}^{-2}}, \qquad (3)$$

where d_1 and d_2 are the distance from the desired position to the sample, along the x-axis.

The SVD Filtering

The SVD method consists in decompose a matrix A into three different matrices. Two orthonormal matrices, U and V, will have the eigenvectors of the matrix A, and one matrix Σ, with the singular values in the main diagonal. This decomposition can be shown in (4):

$$\mathrm{A} = \mathrm{U}\Sigma\mathrm{V}^T. \qquad (4)$$

The singular values of A in Σ are arranged in a decreasing order of magnitude, which means that $|\sigma_1| \geq |\sigma_2| \geq ... \geq |\sigma_n|$.

Porsani et al. (2009) proposed a method where for each trace in the seismogram that we want to filter, a group of neighbor traces can be collected, forming a moving window. This window can be decomposed with the SVD method and after that, a restitution of the central trace is made, using the first K eigenimages, as in (5):

$$\tilde{d}(t, x_j) = \sum_{k=1}^{K} \sigma_k u_k(t) v_k(x_j). \qquad (5)$$

Methodology

The radial transform reorganizes the angles of the data, and because of that, the transform tends to increase the angle of shallower hyperboles. Consequently, some information is lost in the filtering, and the quality of the final stacked section may not be as good as it could.

This paper discusses the comparison of the SVD filtering in the RT domain before and after the NMO correction, and because of that, two flowcharts are used. The flowchart #1 in Figure 2, shows the steps adopted in the processing. The data was pre-processed (geometry, editing and mute), then the Direct RT was applied. In the radial domain, the SVD Method filtering was applied, with the first eigenimage conserved only. After the filtering, the inverse radial transform was applied, returning the data to the distance-time domain. The result of the inverse radial transform was sorted into CMP families, then, the velocity analysis was made. After this procedure, the NMO correction was applied, followed by the stacking process.

Flowchart #2 follows #1 on the first step, after this, the data was sorted in CMP families and the NMO correction was applied and the data was sorted back to shotgather. The direct RT was applied to the data and the SVD filtering was used in the radial domain. The data was returned to the XT domain after the inverse radial transform was applied. Then, the inverse NMO correction was applied, followed by the CMP families sorting and the velocity analysis. Once with the velocity analysis done, the NMO correction was used, followed by stacking.

Both methods were applied in the Line 5090 of the Tacutu Basin. The data contains 179 shots with 96 channels, 1001 samples with sampling interval of 4 ms in a symmetric split-spread geometry with offsets from -2500 m to -150 m and from 150 m to 2500 m, with 50 m interval between geophones. The distance interval of the shots is 200 m, and a CMP coverage of 12 fold.

Results

In the original data in Figure 3a, the direct radial transform was applied, followed by the SVD filtering. The result of the filtering pre and pos NMO are shown in Figure 3b and 3c and the respective differences between the result and the original data can be seen Figure 4a and 4b, respectively. The average amplitude spectrum of both processes is shown in Figure 1, where the filtering in both cases has lowered the amplitude of the low frequency of the data. In Figure 5 the stacked sections of the original, and filtered before NMO correction and filtered after NMO correction data are shown. With these results, we can see that both filtering have good results in the data, but the SVD filtering after the NMO correction gives us more continuous reflections. This aspect can also be seen in a detail scale, as in Figure 6.

Conclusions

The use of the SVD filtering in the radial domain showed up to be a good alternative for seismic processing. Since the SVD filtering has the characteristic of using spatial coherence for filtering and with the radial transform, the method showed good results either before and after the NMO correction, but with more quality of the stacked section with the method applied after the NMO correction.

References

Bekara, M. e Baan, M. V., 2007, Local singular value decomposition for signal enhancement of seismic data, Geophysics, 72, pp. 59-65.

Claerbout, J. F., 1983, Ground-Roll and Radial Traces., Stanford Exploration Project Report, SEP-35, pp. 43-53.

Freire, S. L. M., 1986 Aplicações do método de decomposição em valores singulares no processamento de dados sísmicos., Tese de Doutorado, Universidade Federal da Bahia, Salvador, Brasil.

Henley, D. C., 1999, The radial trace transform: an effective domain for coherent noise attenuation and wavefield separation., In: Expanded Abstract, 69th Annual SEG Meeting., pp. 1204-1207, SEG.

Henley, D. C., 2000, More radial trace domain applications., Crewes Research Report Volume 12, pp. 1-14.

Manenti, R. R., Silva, M. G. and Porsani, M. J., 2011, Atenuação do ground-roll utilizando a transformada radial e a decomposição SVD, expanded abstract: 12th International Congress of the Brazilian Geophysical Society.

Ottolini, R., 1979, Migration of Radial Trace Sections., Standford Exploration Project Report, SEP-20, pp. 97-115.

Porsani, M. J.; Silva, M. G.; Melo, P.E. M. and Ursin, B., 2009, Ground-roll attenuation based on SVD filtering., In: *Expanded Abstract, 79th Annual SEG Meeting*., pp. 3381-3385, SEG.

Porsani, M. J., 2010, An adaptive local-slope svd filtering approach to enhance events on seismic section: SEG Expanded Abstracts, 29, 3717-3722.

Porsani, M. J., Ursin, B, Silva, M. G. and Melo, P. E. M., 2013, Dip-adaptive singular-value decomposition filtering for seismic reflection enhancement., EAGE, 61, pp. 42-52.

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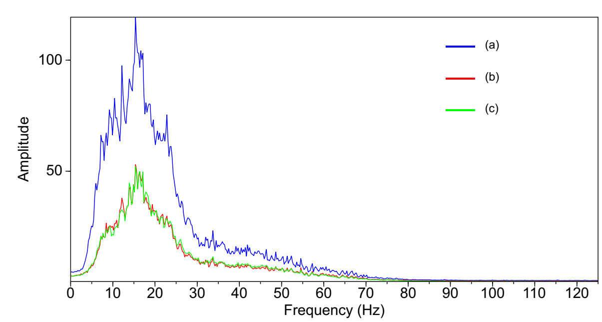

Figure 1: Average Amplitude Spectrum. Original shot-gather in (a), filtered before NMO correction in (b), filtered after NMO correction (c).

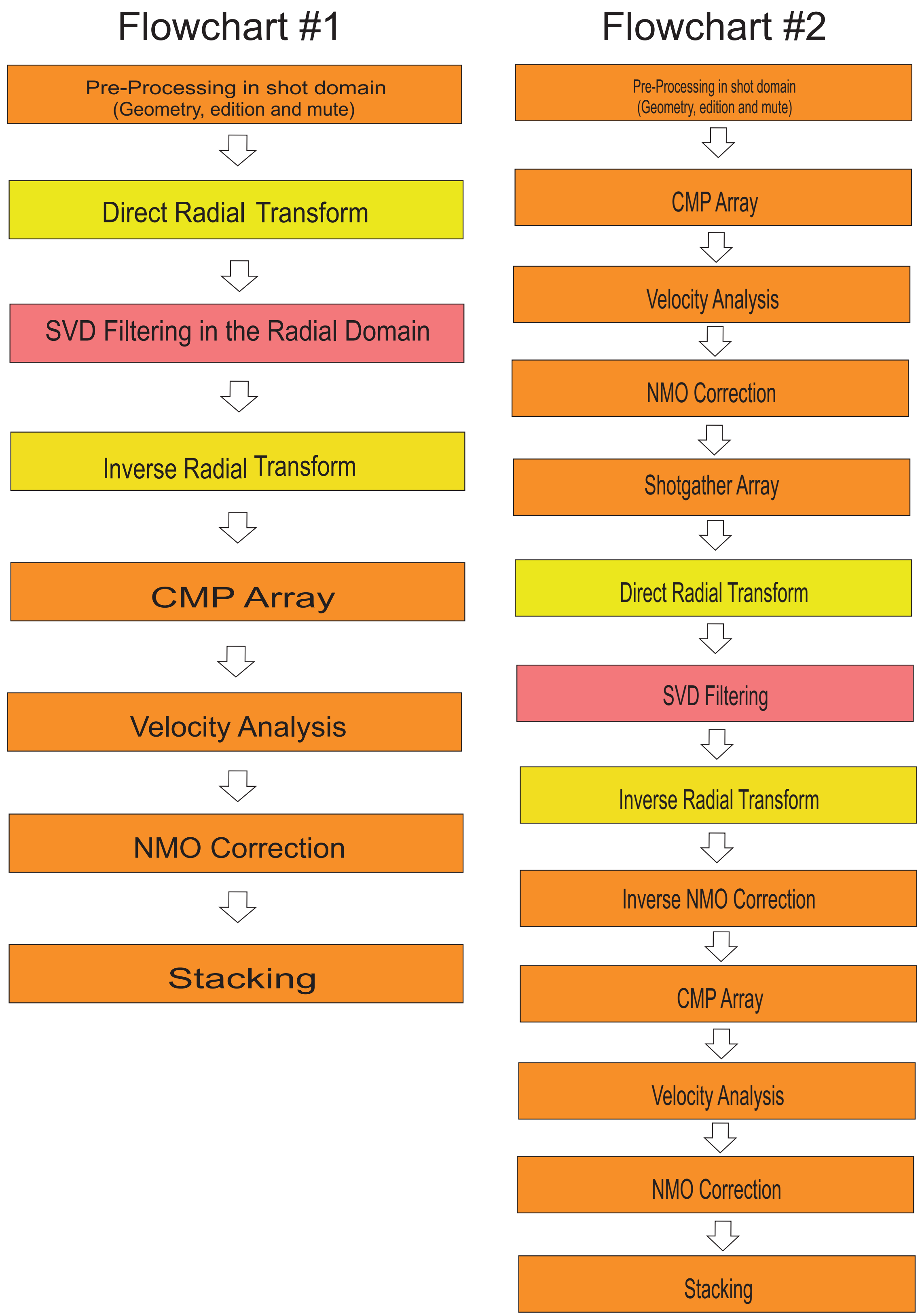

Figure 2: Flowcharts followed in this paper.

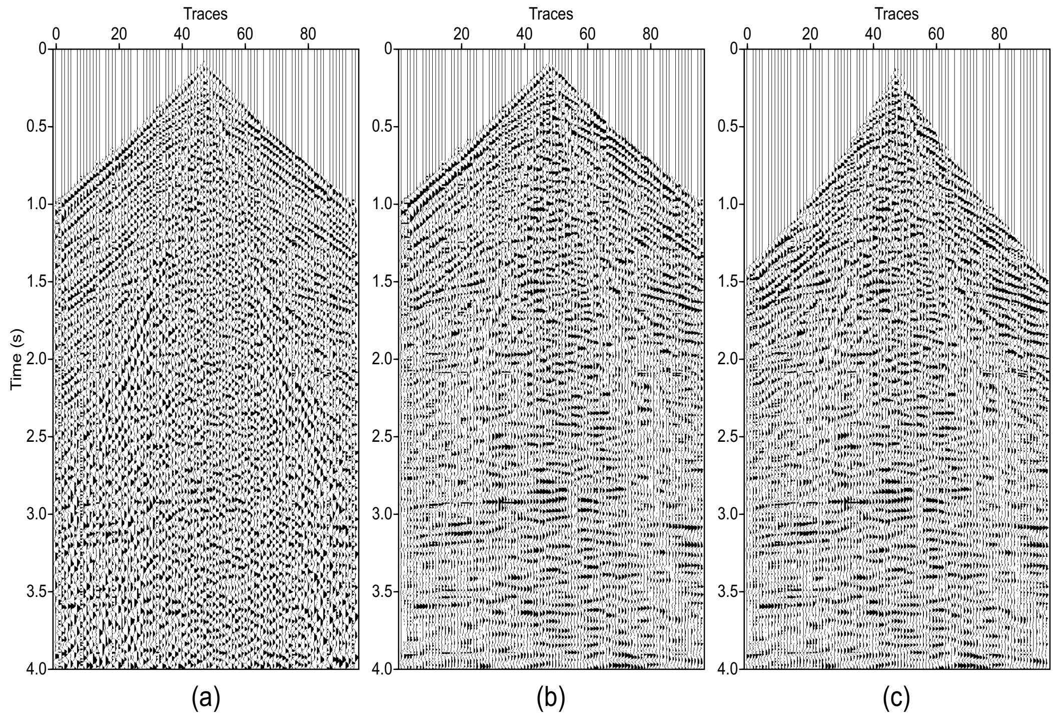

Figure 3: (a): Original shot-gather, (b): filtered before NMO correction, (c): filtered after NMO correction.

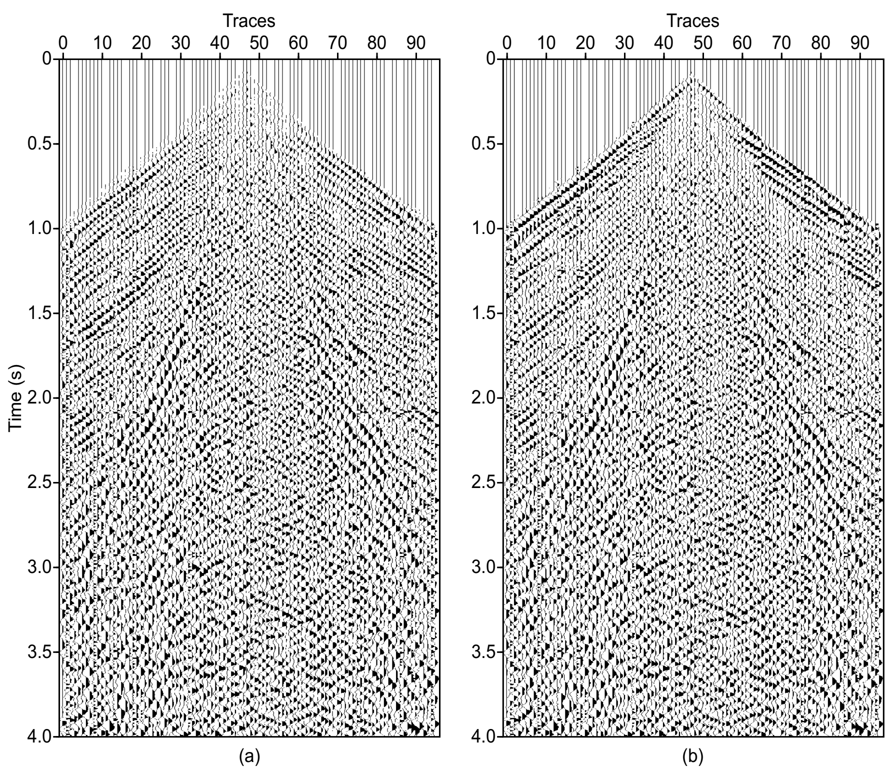

Figure 4: (a) Difference between 4a and 4b; (b) difference between 4a and 4c.

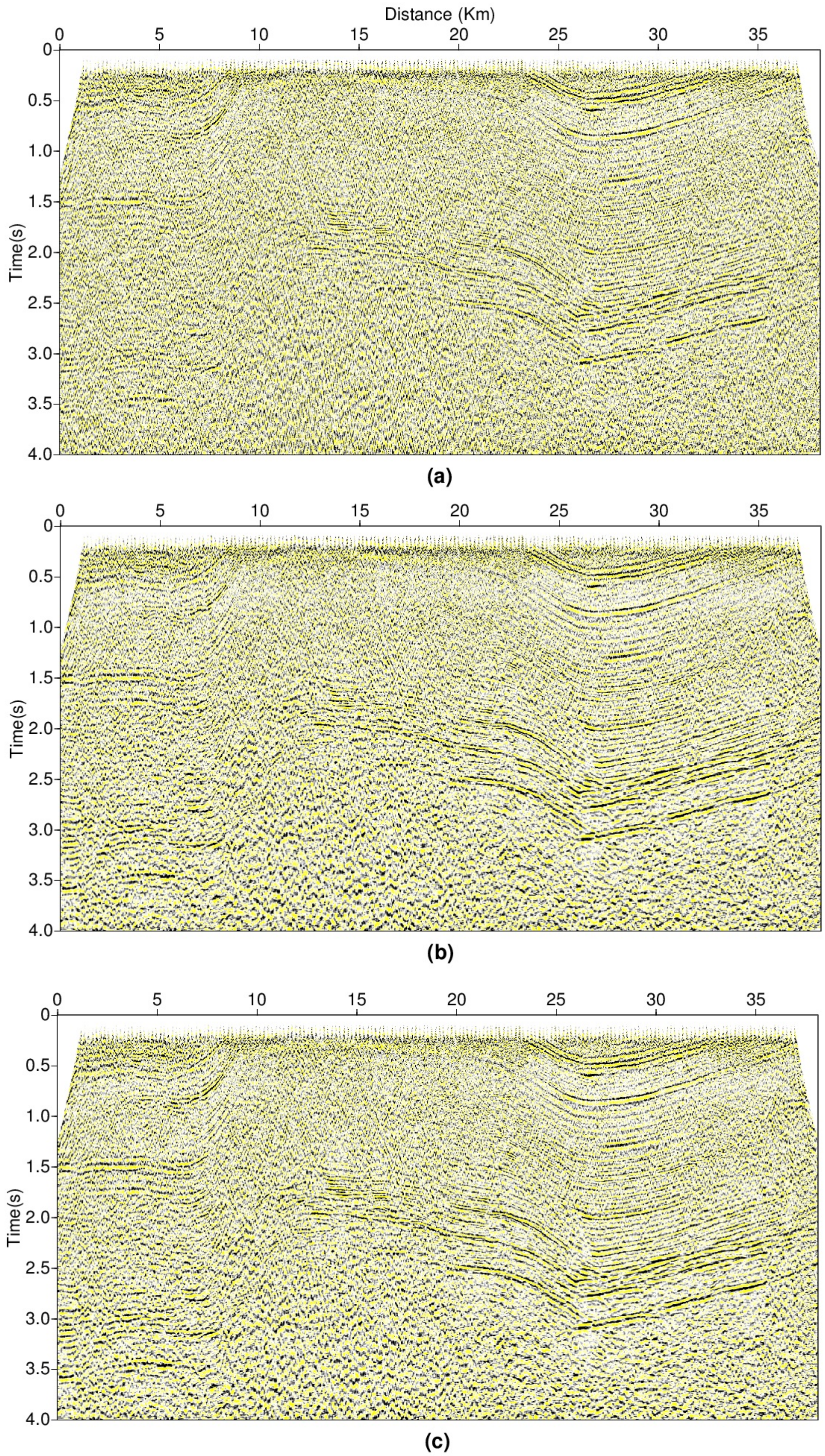

Figure 5: Stacked section: (a) original; (b) filtered before NMO correction; (c) filtered after NMO correction.

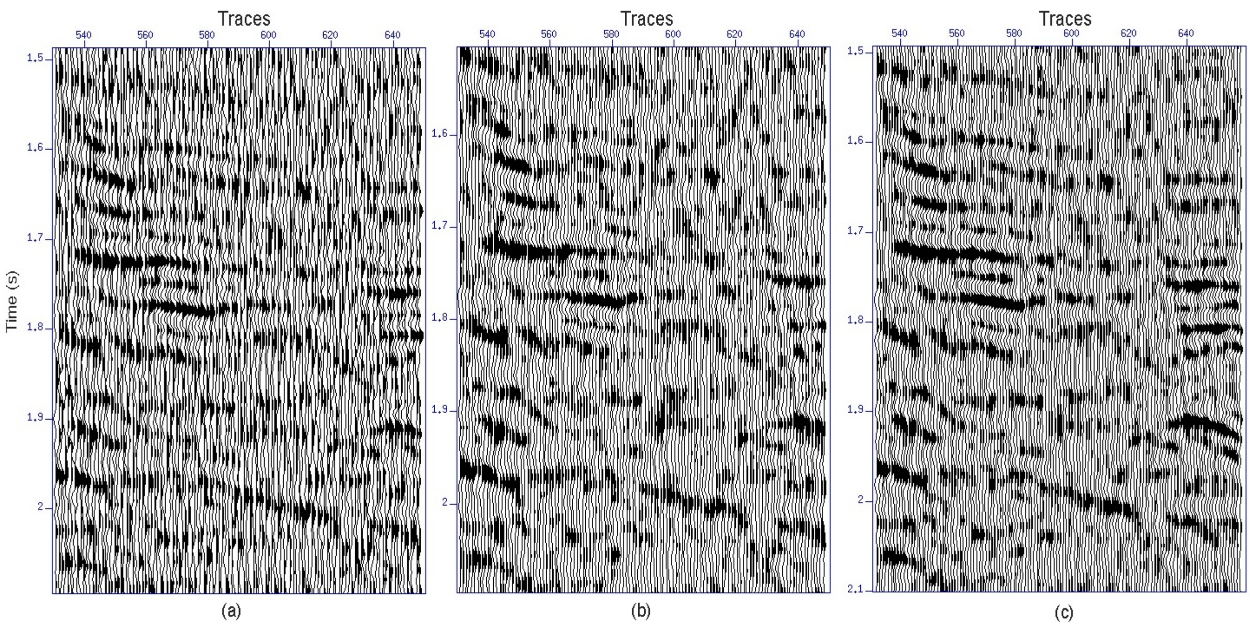

Figure 6: Detail of the stacked section: (a) original; (b) filtered before NMO correction; (c) filtered after NMO correction.