Cable Noise Analysis and Suppression in DAS-VSP Data*

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Abstract

The Distributed Acoustic Sensing (DAS) VSP technology for seismic data acquisition has rapidly developed recently. In order to improve the quality of DAS-VSP data, the cable noise has to be suppressed. Firstly, the noise is analyzed, and then a suppression method is presented based on the result of the analysis. Finally, the method is tested by a Walkaway-VSP data in Bohai Bay Basin.

In a single shot record of DAS-VSP data, we can recognize several waves, such as downgoing and upgoing P-wave, but we also find that there are high level noises in the record. We analyze the noise period of regular cable noise by statistical method. For each seismic trace, the maximum time of recognizable period is read firstly, and then maximum period numbers are counted. Finally, we calculate a single noise period. In each seismic trace, wavelet extraction includes the following: finding the wavelet in each period, calculating these wavelets to normalize wavelets, and then stacking all wavelets to an average wavelet. The Cable noise attenuation law is dependent on optical fiber materials and length. According to a lot of tests and research, we proved that the best fitting method was not exponential fitting, but base fitting.

According to the analysis result, the cable noise can be fitted by first break time, first break amplitude, noise period, average wavelet and attenuation parameter. The raw wavefield is subtracted by synthetic noise wavefield, and then leaves residual wavefield. By comparison two autocorrelation data of raw wavefield and residual wavefield, the sidelobe of residual wavefield autocorrelation is much less than raw wavefield; the suppression method is proved to be effective and feasible.

As a regular noise, the cable noise can be accurately fitted, and it can be separated from raw wavefield by subtraction method.

Summary

The Distributed Acoustic Sensing (DAS) technology for seismic data acquisition has rapidly developed recently. The DAS-VSP is a special

seismic method. In this method, the fiber cable is placed in borehole, and the cable noise is recorded together with seismic waves.

In order to improve the quality of DAS-VSP data, the cable noise has to be suppressed. Firstly, the noise is analyzed, and then a suppression method is presented, based on the result of the analysis. Finally, the method is tested by a Walkaway-VSP data in Bohai Bay Basin. It shows that this method is quite valid for the cable noise suppression.

Introduction

DAS-VSP seismic acquisition is a new rapid seismic acquisition technique (Mateeva et al., 2012, 2014), but it has high level noise (Lesnikov et al., 2014). In 2014, a DAS-VSP was acquired at X1 well of Bohai Bay Basin (Gan Yu et al., 2015). In this test, the fiber cable was placed in a deep well with depth of more than 4000m.

The main parameters are as below:
- Observation method: Walkaway-VSP.
- Observation range: 0m to 4004m.
- Spatial Sampling: 0.25m.
- Temporal Sampling: 1ms.

In this test, the total Walkaway-VSP shots are 356, and each shot is exploded by 6kg TNT in 15m deep hole.

Data analysis

Wavefield analysis

In a single DAS-VSP shot record, we can recognize several waves, such as downgoing and upgoing P-wave, but we also find that there are high level noises in the records (Figure 1).

The analysis shows that:

- The downgoing P-wave is clearly visible, but its first break is not clear.
- The upgoing P-wave is clearly visible, but it is disturbed by strong noise.
- The downgoing and upgoing Ps-wave is visible.
- Less multiple waves.
- Cable noise is the mainly disturbance.

Noise period analysis

We analyze the noise period of regular cable noise by statistical method. For each seismic trace, the maximum time (T_{max}) of recognizable period is read firstly, and then maximum period numbers (n_{max}) are counted. Finally, we calculate a single noise period (T), it is expressed as follows:

$$T = T_{max}/n_{max} \qquad (1)$$

Significantly, there is more than one noise period in some traces.

Noise wavelet analysis

In each seismic trace of raw wavefield, wavelet extraction includes the following: finding the wavelet (W_i) in each period, calculating these wavelets to normalization wavelets (W_i'), then stacking all wavelets to an average wavelet (W_{ave}); it is expressed as follows:

$$W_{ave} = 1/n_{max} \cdot \sum_{i=1}^{n_{max}} W_i' \qquad (2)$$

Because some traces have more than one noise periods, these traces have different wavelets.

Noise attenuation law analysis

Cable noise travels in optical fiber. Its attenuation is different from seismic wave attenuation. The attenuation law is dependent on optical fiber materials and length. According to numerous tests and research, we proved that the best fitting method was not exponential fitting, but base fitting. When the noise travels time (t), the raw amplitude (A_0) at the position of first break is decreased to new amplitude (A_t); it is expressed as follows:

$$A_t = A_t \cdot x^t \qquad (3)$$

Where x^t is attenuation factor; x is the base number of the factor. It can be calculated by attenuation curve statistic (Figure 2).

Suppression Method

Noise fitting

According to the result of the analysis, the cable noise (N) can be fitted by first break time (T_0), first break amplitude (T_0), noise period (T),

average wavelet (W_{ave}), and attenuation parameter (x^t).

$$N = \sum_{i=1}^{n_{max}} (A_0 \cdot x^{(T_0+(i-1)T)} * W_{ave}) \qquad (4)$$

Using the formula to each seismic trace, the noise wavefield is synthesized ([Figure 3](#)).

Noise reduction

The raw wavefield (S) is subtracted by synthetic noise wavefield (N), leaving residual wavefield (S_{res}) ([Figure 4](#)).

$$S_{res} = S - N \qquad (5)$$

Comparing the wavefield in [Figure 1](#) and [Figure 4](#), obviously cable noise is effectively suppressed, and the upgoing wave is clearer in the residual wavefield.

Quality Control

It is well known that autocorrelation is an effective method for checking the regular noise suppression. [Figure 5](#) shows two autocorrelation data of raw wavefield and residual wavefield. By comparison, the sidelobe of residual wavefield autocorrelation is much less than raw wavefield; the suppression method is proved to be effective and feasible.

Conclusions

According to cable noise analysis and suppression, this study reached the following conclusions:

- As a regular noise, the cable noise can be accurate fitting, and it can be separated from raw wavefield by subtraction method.
- Comparing the residual wavefield and raw wavefield, the upgoing wave is clearer. Result of autocorrelation quality check shows that the cable noise is effectively suppressed.
- Cable noise analysis and suppression are a key step in the DAS-VSP data processing, and they are the first step of the whole processing flow. After that, through conventional processing steps, the final VSP image can be obtained ([Figure 6](#)).

Acknowledgements

Selected References

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Mateeva, A., J. Lopez, H. Potters, J. Mestayer, B. Cox, D. Kiyashchenko, P. Wills, S. Grandi, K. Hornman, B. Kuvshinov, W. Berlang, Z. Yang, and R. Detomo, 2014, Distributed acoustic sensing for reservoir monitoring with vertical seismic profiling: Geophysical Prospecting, v.62/4, p. 679-692.
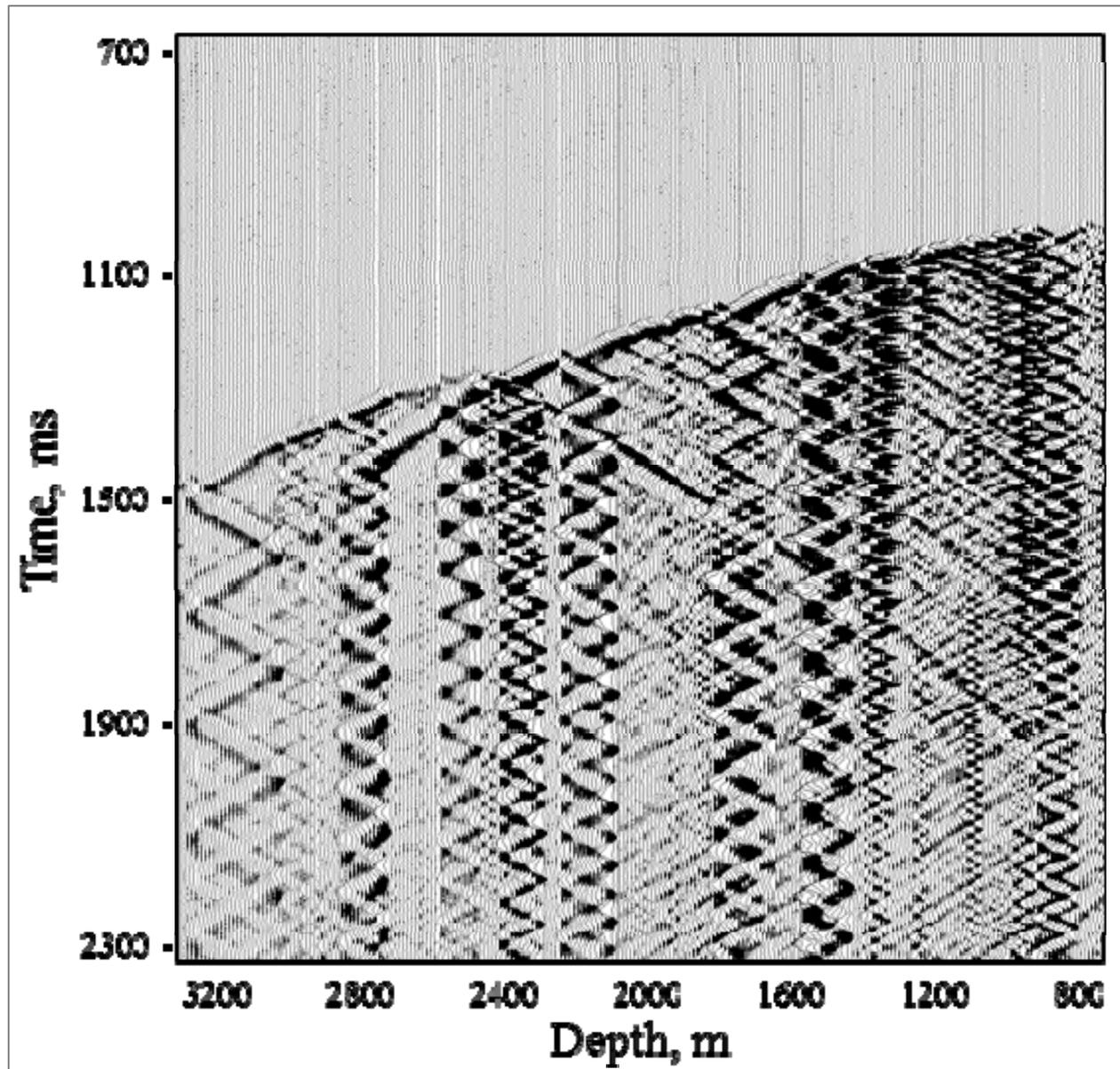
Figure 1. Raw VSP data by DAS acquisition.
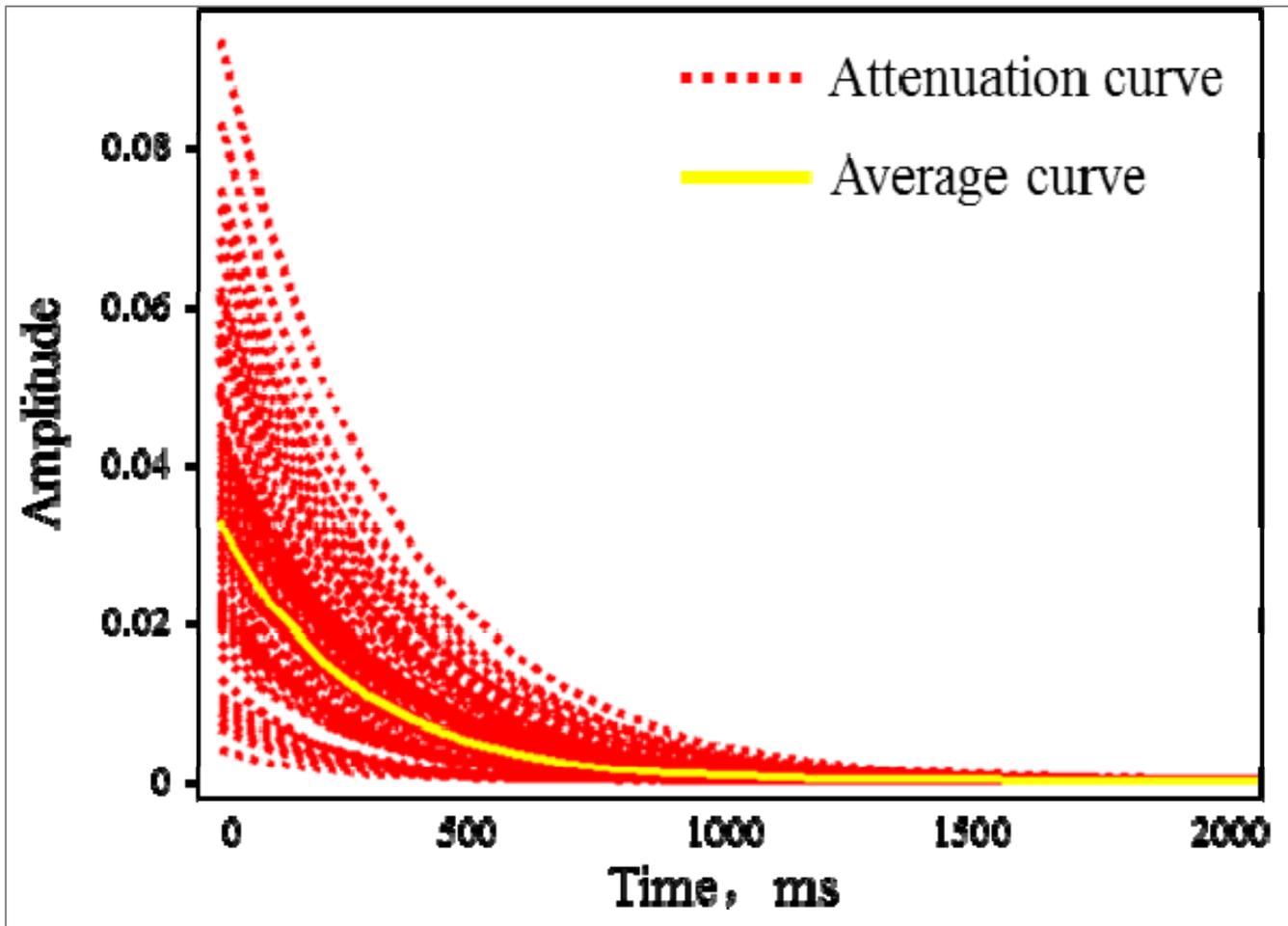
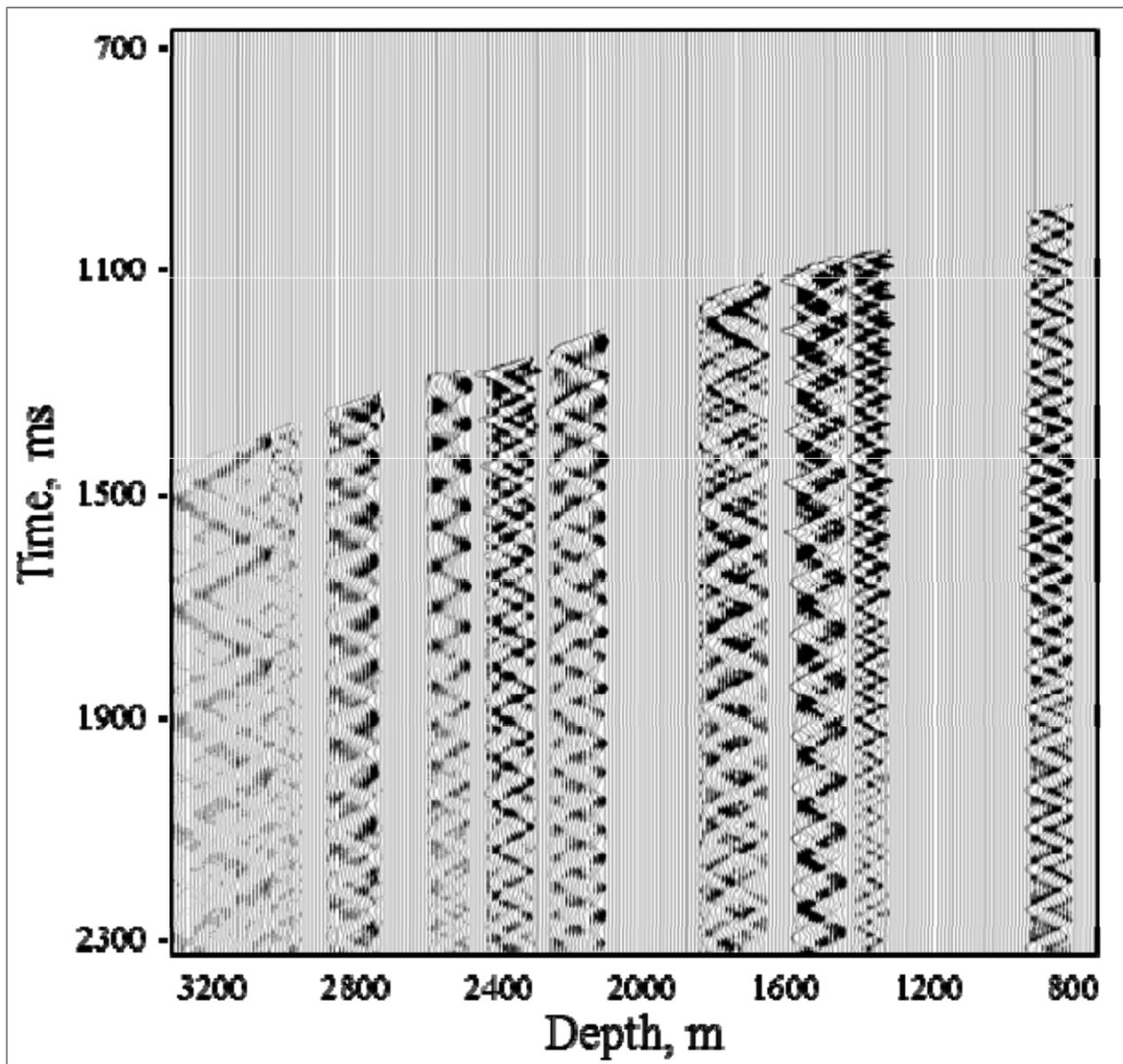Figure 2. Attenuation curve and average curve.
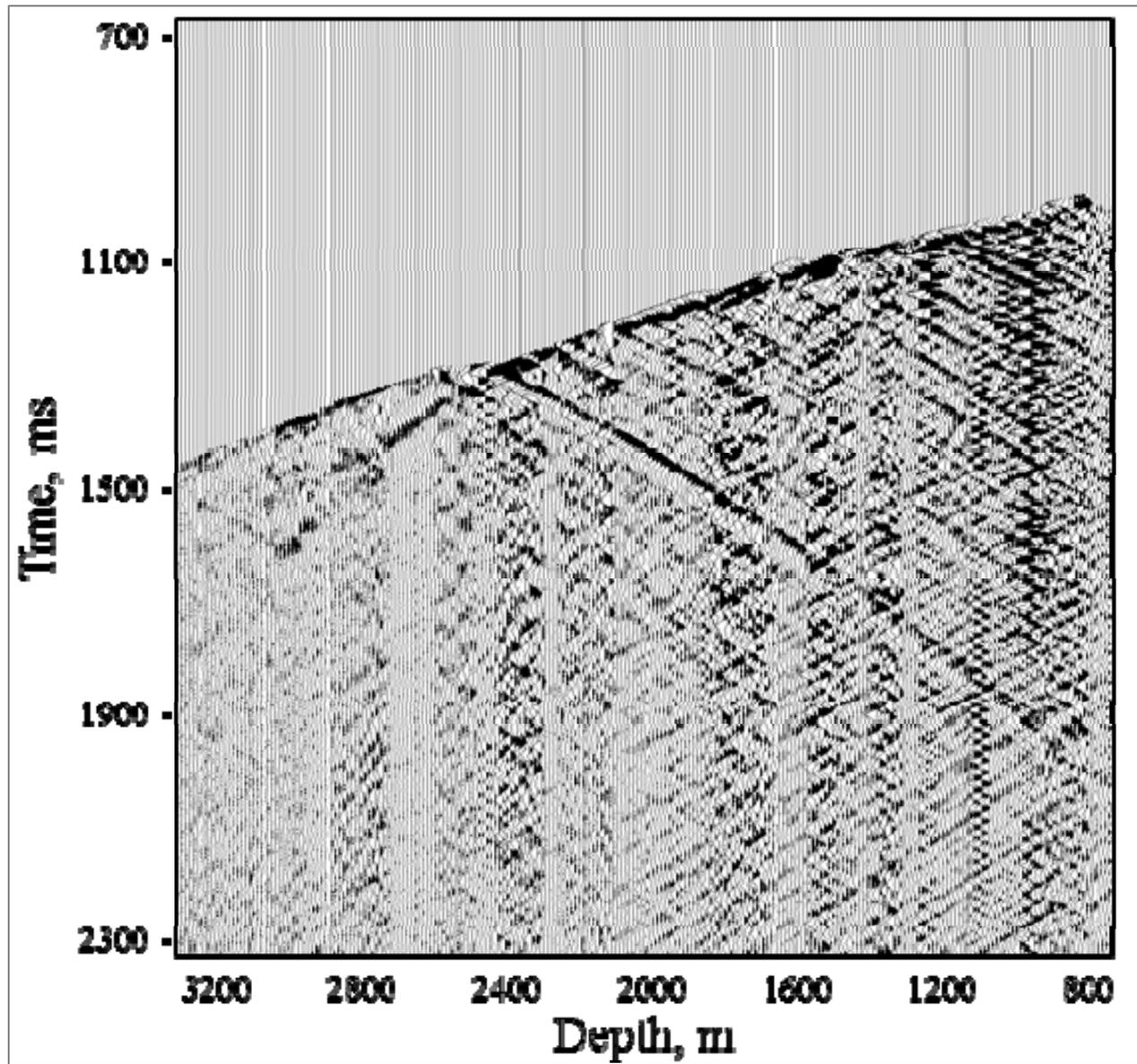
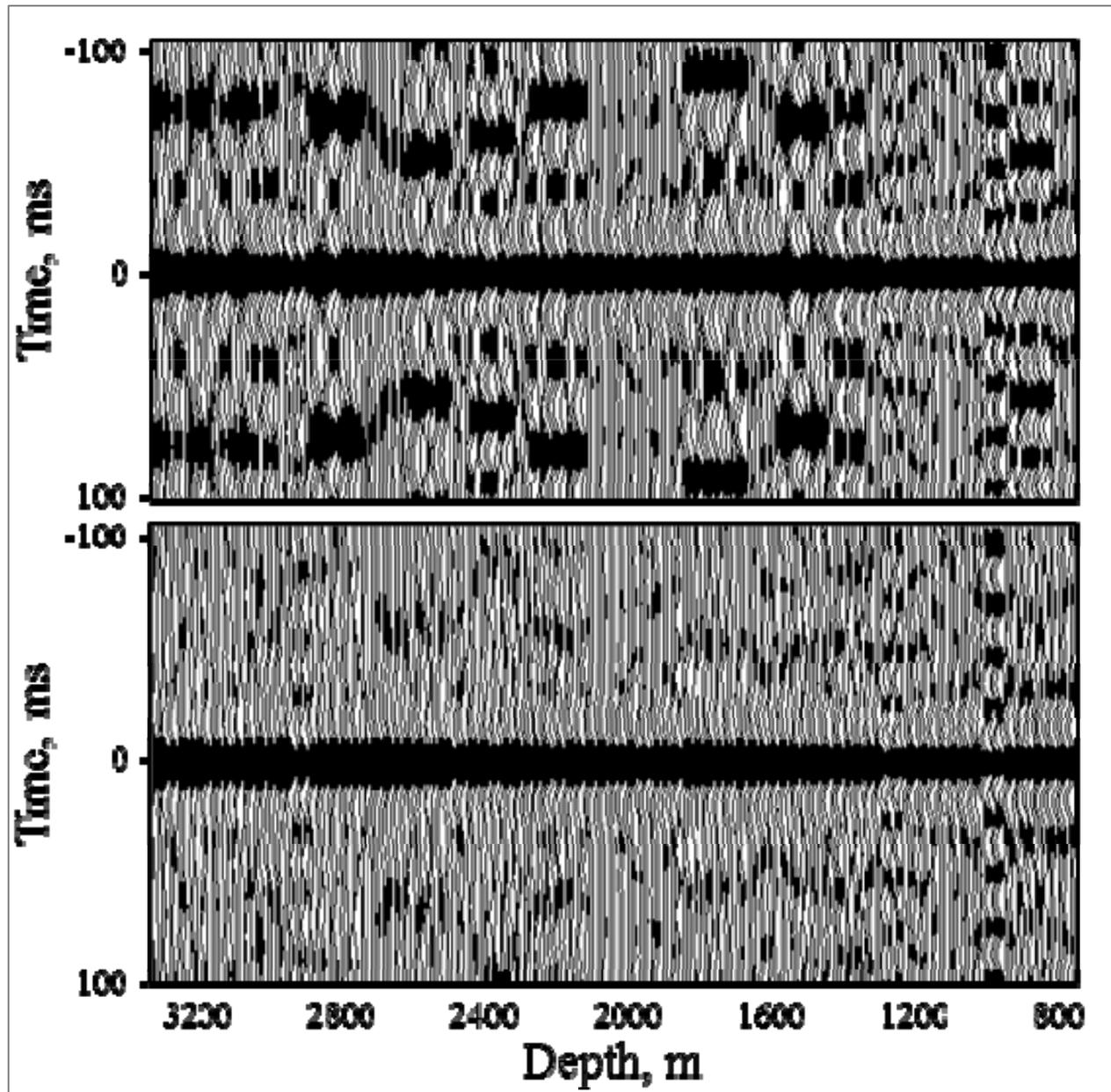Figure 3. Synthetic noise wavefield.

Figure 4. Residual wavefield.

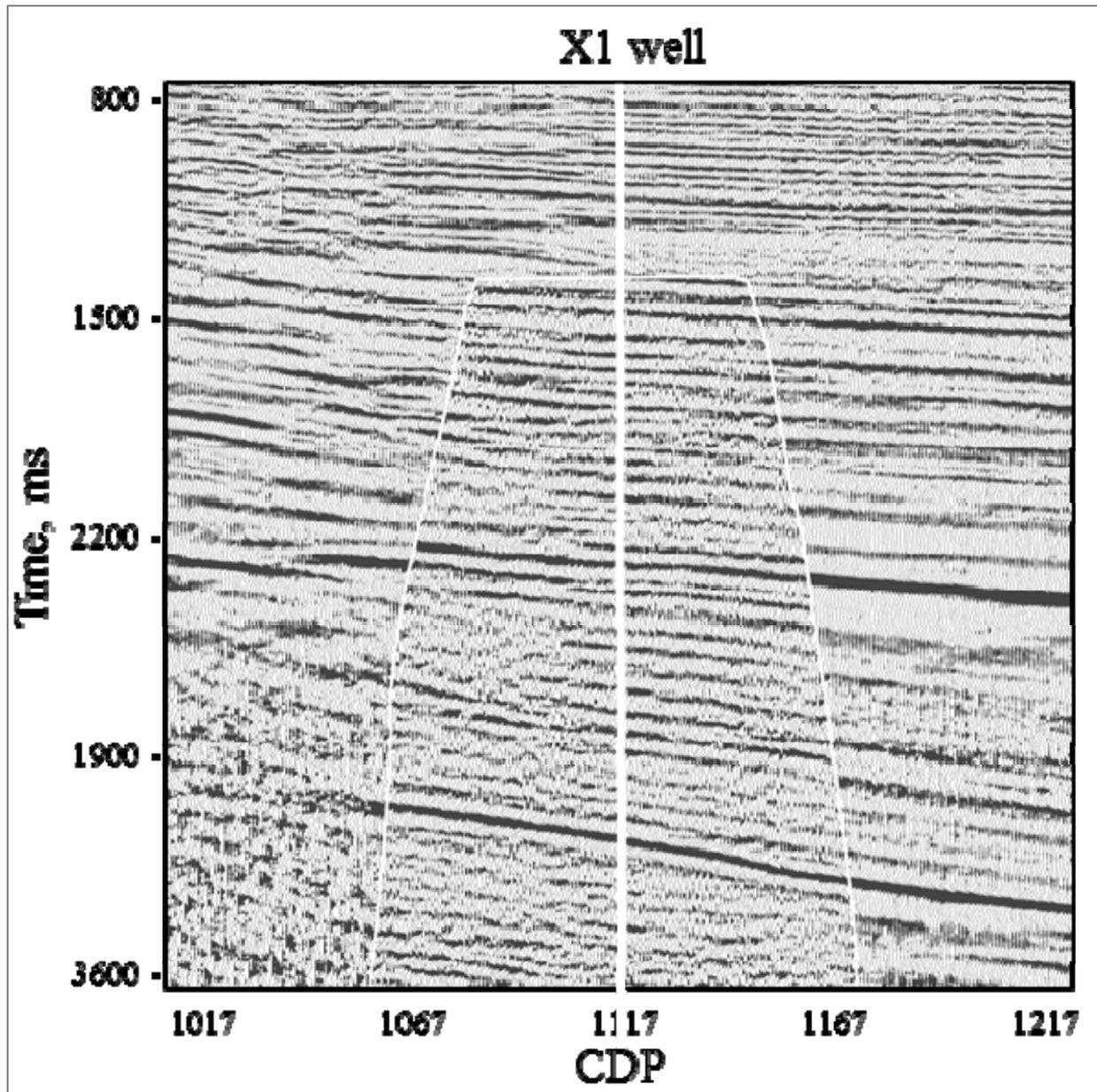Figure 5. Autocorrelation data of raw wavefield (top) and residual wavefield (bottom).

Figure 6. DAS-VSP image (center) insets into seismic profile (background).