The application of seismic interferometry in oil and gas geological survey on the periphery of Songliao Basin

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SUMMARY

Seismic data collected in volcanic rocks coverage area has weak energy and low signal to noise ratio. These characteristics cause severe problems for seismic exploration. Many geophysicists try to solve these problems and propose many methods. Some of them focus on the acquisition method to improve the signal to noise ratio of data in the step of data acquisition. The others focus on the processing method to improve the data .In this paper, we focus on the processing method and try to apply the seismic interferometry to volcanic rocks coverage collected on the periphery of Songliao Basin to improve the signal to noise ratio and the resolution.

Key words: Seismic processing, seismic interferometry, Songliao Basin.

INTRODUCTION

The proposition and application of seismic interferometry promotes the study of seismic wave propagation. Seismic interferometry can generate new seismic data from the original data. Specifically speaking, the source can be redatumed to the receiver location. The geometry can get closer to target zone. So the imaging precision can be improved dramatically. At the meantime, since the geophone becomes the virtual source, the illumination area can be enlarged. In practice, it is very hard to collect zero offset data. Using seismic interferometry can eliminate the effect of offset and generate the zero offset data. Also, based on seismic interferometry, many methods are proposed or improved.

Seismic interferometry has become very popular in recent years. Many passive applications have been proposed, such as earthquake coda interferometry (Snieder et al., 2002), surface-wave tomography (Shapiro et al., 2005; Gerstoft et al., 2006), body-wave interferometry (Roux et al., 2005; Miyazawa et al., 2008), or reflection seismic interferometry (Draganov et al., 2007). Wapenaar et al. (2010a, 2010b) give a review of seismic interferometry theory and its recent advances. De Ridder and Dellinger (2011) demonstrated passive interferometric imaging of Scholte-wave velocities using a few hours of data. Using local earthquakes, Minato et al. (2012) imaged the oceanic crust surface using a 3D array of OBS.

Controlled-source seismic interferometry has been used in vertical seismic profiling (Bakulin and Calvert, 2006), inverse vertical seismic profiling (Yu and Schuster, 2006), and crosswell data (Minato et al., 2011). This method is also applied in OBS or ocean-bottom cable (OBC) data: Mehta et al. (2007) illustrate the improvement in virtual source method (Bakulin and Calvert, 2006) after wavefield separation using synthetic data; elastic interferometry theory was proposed by Gaiser and Vasconcelos (2010) and applied in OBC data in shallow water for retrieving P-waves and P-to-S waves using refraction interferometry. Haines (2011) applied interferometric processing to deep- water OBS data using a large OBS array to image the shallow subsurface. Carriere and Gerstoft (2013) used OBS interferometry for deep-water subsurface imaging. Bharadwaj et al. (2012)
generated supervirtual traces in OBS to increase signal-to-noise ratio (S/N) and facilitate the traveltime picking of far-offset traces and head waves.

In this paper, we focus on the processing method and try to apply the seismic interferometry to volcanic rocks coverage collected on the periphery of Songliao Basin to improve the signal to noise ratio and the resolution.

THEORY

Seismic interferometry is based on extracting the Green's function that characterizes wave propagation between two receivers by cross correlating the wave fields recorded by these receivers. A general derivation of the Green's function retrieval process between two receivers is based on the reciprocity theorem (Wapenaar, 2004; Schuster, 2009). In this paper, we focus only on the crosscorrelation-type interferometry, which is based on the far-field approximation. In the frequency domain, the kinematic responses of seismic retrieval using the cross-correlation-type interferometry can be written as:

$$\begin{aligned} & d(x_B|x_A,\omega) + d^*(x_B|x_A,\omega) \\ & = \int d(x_B|x_s,\omega) d^*(x_A|x_s,\omega) dx_s \end{aligned} \quad (1)$$

Here, the coordinate left of the vertical line represents the receiver position, and the coordinate at the right is the source position. x_s is the source position at the surface. The asterisk * represents the complex conjugate.

According to equation 1, the virtual shot gather can be obtained by cross correlating the responses recorded at different locations and stacking over source locations.

Seismic interferometry can not only be used in time-space domain but also in Radon domain. Firstly, the original data is transformed from time-space domain to Radon domain. Then the virtual shot gathers can be obtained by crosscorrelating and summing in Radon domain. Yi Tao (2013) applies seismic interferometry to plane-wave domain to avoid the spurious arrivals. Heng Zhu (2015) applies seismic interferometry to the parabolic Radon domain to suppress the effect of noise.

The theory of seismic interferometry in Radon domain can be written as follows:

$$d(x_B|x_A,\omega) + d^*(x_B|x_A,\omega) = \int u_B(q,\omega)u_A^*(q,\omega)dq \qquad (2)$$

Here, omega is the angle frequency, d(x,ω)is the recorded data, u(q,ω) is the transformed data, q represents the ray parameter for linear Radon domain or the curvature of the parabola for parabolic domain. x is the spatial variable denoting source positions.

MODELING EXAMPLE

The model we used has four horizontal layers. The first layer is a 100 m thick low velocity layer with V=1500 m/s, the second layer has V=2500m/s, the third layer has V=3500m/s and the last layer has V=4500m/s. 250 receivers are located at depth z=100m with equal spacing of 10m and the first receiver located at x=0 m.150source locations are at the free surface (z=0) and shot interval is 10 m. Noise is added to the modeling data to simulate the real data that has low signal-to-noise ratio. The results are show as follows:

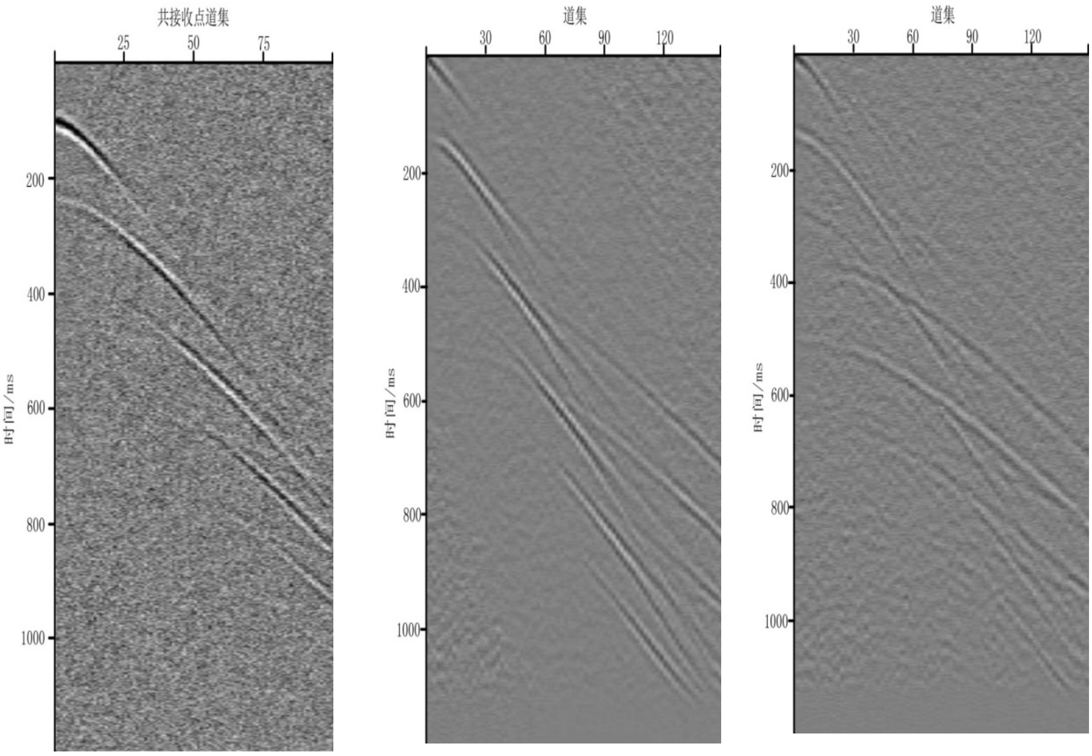

Figure 1. Comparison of virtual shot gathers obtained by using time-space domain and linear Radon domain interferometry. (a)The original data with SNR=2. (b) The time-space domain interferometry. (c) The linear Radon domain interferometry.

Through comparison, we can see that the zero offset data can be obtained from the original data which is non-zero offset. And the signal-to-noise ratio can be improved with seismic interferometry.

Especially, the linear Radon domain interferometry can suppress the noise dramatically, the reflect wave become more clear. In the future, we will try to apply this method to the real data that is collecting the periphery of Songliao Basin.

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