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Acquisition and processing pitfall with clipped traces in surface-wave analysis

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ABSTRACT

Multichannel analysis of surface waves (MASW) is widely used in estimating near-surface shear (S)-wave velocity. In the MASW method, generating a reliable dispersion image in the frequency–velocity (f–v) domain is an important processing step. A locus along peaks of dispersion energy at different frequencies allows the dispersion curves to be constructed for inversion. When the offsets are short, the output seismic data may exceed the dynamic ranges of geophones/seismograph, as a result of which, peaks and (or) troughs of traces will be squared off in recorded shot gathers. Dispersion images generated by the raw shot gathers with clipped traces would be contaminated by artifacts, which might be misidentified as Rayleigh-wave phase velocities or body-wave velocities and potentially lead to incorrect results. We performed some synthetic models containing clipped traces, and analyzed amplitude spectra of unclipped and clipped waves. The results indicate that artifacts in the dispersion image are dependent on the level of clipping. A real-world example also shows how clipped traces would affect the dispersion image. All the results suggest that clipped traces should be removed from the shot gathers before generating dispersion images, in order to pick accurate phase velocities and set reasonable initial inversion models.

1. Introduction

Rayleigh (1885) waves are dispersive in all earth models except for the situation of an elastic half-space. They are usually characterized by relatively low frequency, low velocity and high amplitude (Sheriff, 1991). Phase velocity of Rayleigh waves can be used to obtain shear (S)-wave velocities, which is a fundamental physical parameter for near-surface investigations. Multichannel analysis of surface waves (MASW) is a mature method which has been widely used in recent years (Xia et al., 1999; Ivanov et al., 2006; Socco et al., 2010). A shot gather can be transformed into the frequency–velocity (f–v) domain (McMechan and Yedlin, 1981; Yilmaz, 1987; Park et al., 1998; Xia et al., 2007; Luo et al., 2008) to obtain an image of generated surface-wave energy, on which phase velocities of surface waves can be determined. Complete and distinct dispersion energy is necessary for picking accurate phase velocities and setting an initial model for inversion. Rayleigh waves possess the properties that asymptotes at the low and high frequencies of the fundamental and higher modes are associated with the S-wave velocities of the half-space and the surface layer, respectively. The initial model can be determined when the measured dispersion curve clearly shows the asymptotes on both ends (Xia et al., 1999). Picked phase velocities will affect the investigation depth and model resolution. Inversion of phase velocities of surface waves can produce S-wave velocities. The difference between inversion results obtained by the MASW method and borehole measurements is approximately 15% or less when higher modes are available (Xia et al., 2009).

Impulsive sources (weight drops or hammers) and swept-frequency sources (a vibrator) are always used to impart seismic energy. Vertical component geophones are usually used as receivers in the active-source MASW method. When a hammer hits on a metal or plastic plate in contact with the surface, the distance between the shot and the first receiver, called the nearest offset, is better set to be half to the maximum investigation depth (Xia et al., 2006). Meanwhile, dense receivers are required to prevent spatial aliasing of data. Due to short offsets and high energy of the sources, recorded seismic data may exceed the dynamic range of the recording system (geophones and/or the seismograph). This will produce clipped waves

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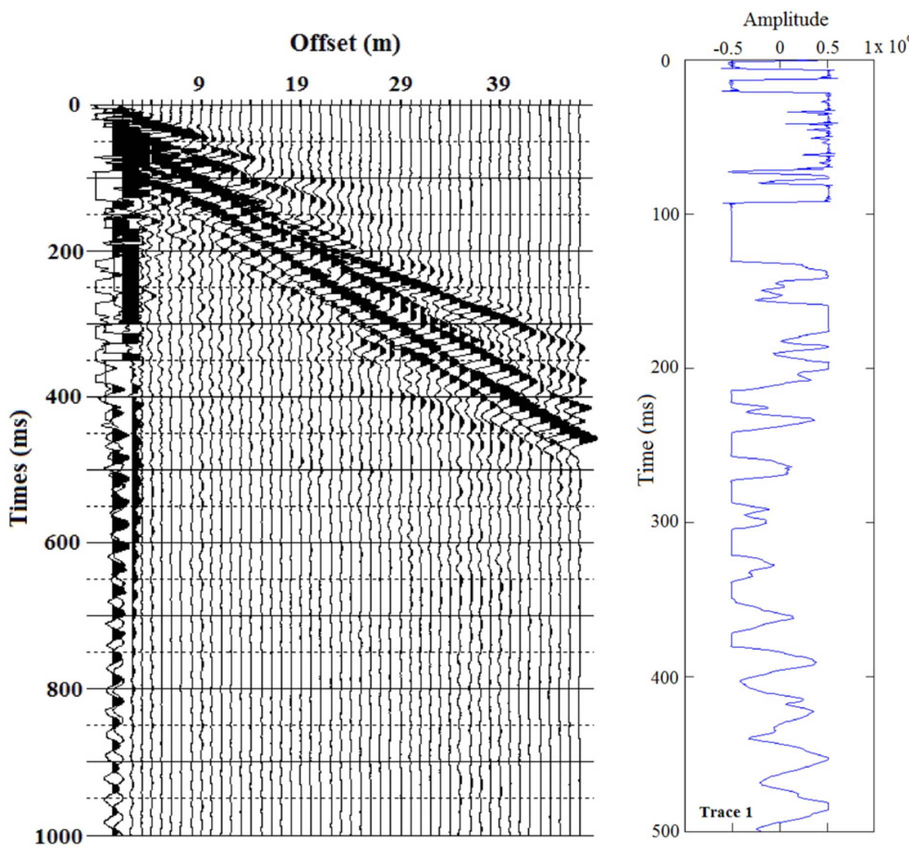

Fig. 1. Raw data (left) acquired in Nantong (China) by using 48 4.5-Hz vertical-component geophones on an interval of 1 m. The source was a hammer vertically impacting a metal plate. Trace one (right) with clipped waves in it.

whose peaks and (or) troughs have been squared off in near-offset traces (Fig. 1). The probability of clipped wave forms in recorded shot gathers mainly depends on the dynamic ranges of the geophones and/or the seismograph.

Deconvolution with clipped traces will generate split energy trends, which will lead to misinterpretation as a stratum or other anomaly (Galbraith and MacMinn, 1982). The processing of clipped seismic traces will create artifacts that could be misinterpreted as high-frequency reflections in shot gathers and stacked sections (Sloan et al., 2008). This paper focuses on a potential pitfall caused by shot gathers that contain clipped traces which may produce artifacts on the dispersion images in the MASW method. Numerical tests prove that picking phase velocities on the dispersion images will be difficult and of lower confidence when a dispersion image has artifacts caused by clipping wave in low-frequency and high-frequency ranges. An example of real world data gives evidence that clipping traces will affect the dispersion image and should be removed before generating dispersion images.

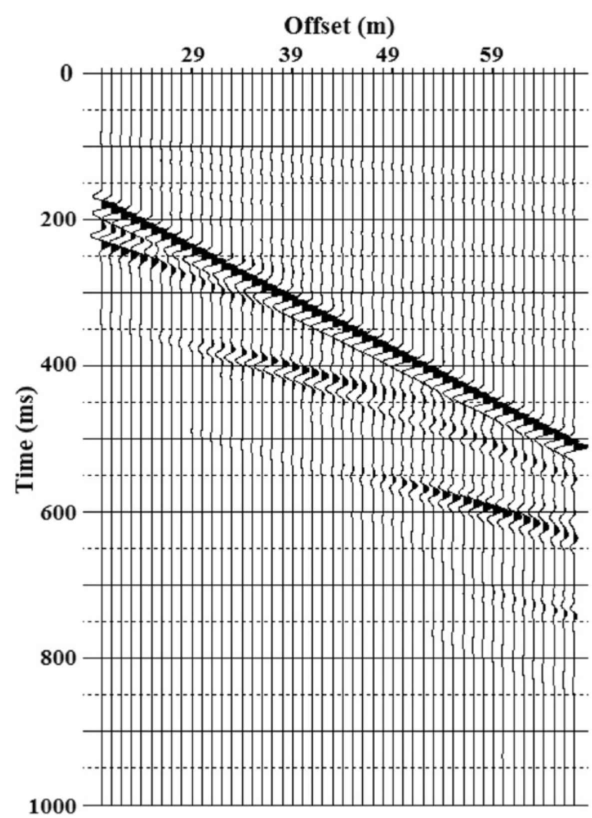

Fig. 2. A numerical shot gather of the two-layer earth model (Table 1).

Table 1
Parameters for a two-layer model. Vp, Vs, ρ, and h represent P-wave velocity, S-wave velocity, density, and thickness, respectively.

	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	h (m)
1	480	150	1820	10
2	900	450	2090	∞