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Resolution analysis of shallow marine seismic data acquired using an airgun and an 8-channel streamer cable

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ABSTRACT

We conducted a high-resolution seismic survey off Yeosu, Korea, using a 30 in^3 small airgun as a seismic source and an 8-channel streamer cable with a 5 m group interval as a receiver, to find out the proper acquisition and processing parameters at the study area where shallow sedimentary layers were well deposited. The data were digitally recorded with a shot interval of 2 s and a sample interval of 0.1 ms using an in-house PC-based acquisition and processing system. The quality of the subsurface image depends on the acquisition parameters such as the sample interval, common midpoint (CMP) interval and CMP fold. To understand the effects of these parameters, we resampled the field data with various sample intervals, CMP intervals and CMP folds and processed the data. The analysis results show that thin layers of 70–80 cm thickness at a depth of 30–45 m from the sea bottom can be imaged with good resolution and continuity using acquisition parameters with a sample interval of less than 0.2 ms, a CMP interval of shorter than 2.5 m and a CMP fold of greater than 4. The data quality of the shallow marine seismic survey is greatly enhanced through multichannel data processing flows such as spiking deconvolution, frequency filtering and careful static correction. Our results demonstrate that very high-resolution seismic reflection images can be made from 8-channel data recoded with high sample rates and processed with appropriate parameters.

1. Introduction

High-resolution shallow marine seismic surveys have been conducted for the exploration of marine resources, the mapping of shallow sedimentary layers and engineering applications. These surveys are distinct from the traditional seismic reflection surveys for oil exploration in that they require higher horizontal and vertical resolutions (Mosher and Simpkin, 1999) and are usually performed economically on a small-scale. Traditionally, high-resolution marine seismic data are acquired using a single channel analog method. Since the 1990s, high-resolution marine seismic data have been acquired digitally (Lee et al., 1996; Lericolais et al., 1990), using multichannel systems (Lee et al., 2004; Morend et al., 2002; Nissen et al., 1999; Pugin et al., 1999).

For detailed imaging of the subsurface structure, high frequency sources such as a chirp have been used (Gutowski et al., 2008; Vardy et al., 2008). However, the penetration of the seismic energy from such high frequency sources is not very deep. For deeper penetration, boomer (Davies and Austin, 1997; Marsset et al., 1998; Missiaen, 2005; Müller, 2005; Müller et al., 2002, 2009), sparker (Marsset et al., 2004) and airgun (Lee et al., 2004; Morend et al., 2002; Pugin et al., 1999; Scheidhauer et al., 2005) sources have been used. In studies where airgun sources were used, the capacity of the airgun was small (1–40 in^3). The sample interval was 0.1–0.5 ms and 3–16-fold stacking was performed.

In this study, we designed and conducted a high-resolution shallow marine seismic survey using an airgun and a multichannel streamer cable for the purpose of understanding appropriate acquisition parameters for high-resolution imaging of subsurface structures. To achieve high vertical resolution considering the penetration depth, we selected a single airgun as a seismic source. To obtain a high frequency signal and a high S/N ratio, we used a high-resolution 8-channel streamer cable. To verify the ability to image the detailed subsurface structure, we selected the survey area off Yeosu, Korea, where stratified thin sedimentary layers were deposited. We recorded digital seismic data using a short firing interval and a short sample interval to achieve high horizontal and vertical resolutions through a PC-based system (Lee et al., 1996, 2004). We produced high-resolution seismic sections after the multichannel data processing and analyzed the distinguishable thickness of the thin layers from the detailed seismic image. The analysis results revealed the effects of various acquisition parameters such as the sample interval, common midpoint (CMP) interval and CMP fold, on the resolution.

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2. Data acquisition

The field survey was carried out offshore near Yeosu, Korea, as shown in Fig. 1, to test an effect of acquisition and processing parameters. Various stratified thin sedimentary layers were deposited in this area, so that we could test the production of a detailed seismic image after data acquisition and processing. We acquired 240 L-km seismic data composed of 7 lines using R/V Tamhae II seismic vessel of Korea Institute of Geoscience and Mineral Resources (KIGAM). The layout of the high-resolution seismic survey is shown in Fig. 2, and the connection of the equipment is shown in Fig. 3. The equipment and acquisition parameters used for the survey are listed in Table 1.

The seismic source was a 30 in^3 airgun, and the receiver was a 40 m long 8-channel streamer cable with a group interval of 5 m, as shown in Table 1. The offset distance between the source and the first channel was 20 m. The vessel speed was 9 km/h (~5 knots) and the shot time interval was 2 s corresponding to a distance of approximately 5 m. We recorded data digitally with a sample interval of 0.1 ms and a record length of 1 s. We selected the shortest shot interval and the highest sample rate possible, to achieve high horizontal and vertical resolutions. We chose an airgun as the source due to the energy level and clear waveform relative to other seismic sources.

We used a PC-based digital acquisition system, KDAPS (KIGAM Data Acquisition and Processing System) to record 8-channel data in SEG (Society of Exploration Geophysicists)-Y format. An A/D (analog-to-digital) converter was mounted on the PC. Trigger and reflection signal cables were connected to the A/D converter as shown in Fig. 3. We also used a thermal recorder and an analog bandpass filter, as shown in Fig. 3, for real-time signal monitoring. We plotted the analog seismic signal of the nearest channel on thermal paper.

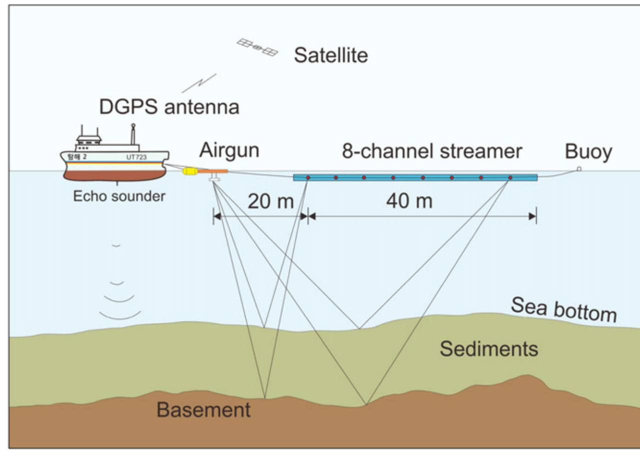

Fig. 2. Layout of the high-resolution seismic survey using an airgun and an 8-channel streamer cable.

3. Data processing

The processing sequence (Table 2) includes basic processing procedures such as gain recovery, deconvolution, frequency filtering, CMP sorting, NMO correction, static correction and stacking. Fig. 4 presents the results of each processing step for Line A–A′. The location of the line is shown in Fig. 1. The length of the Line A–A′ is approximately 12 km. The total survey time is 80 min, and the data includes 2400 shots (shot point (SP) 6601–9000). The average vessel speed is approximately

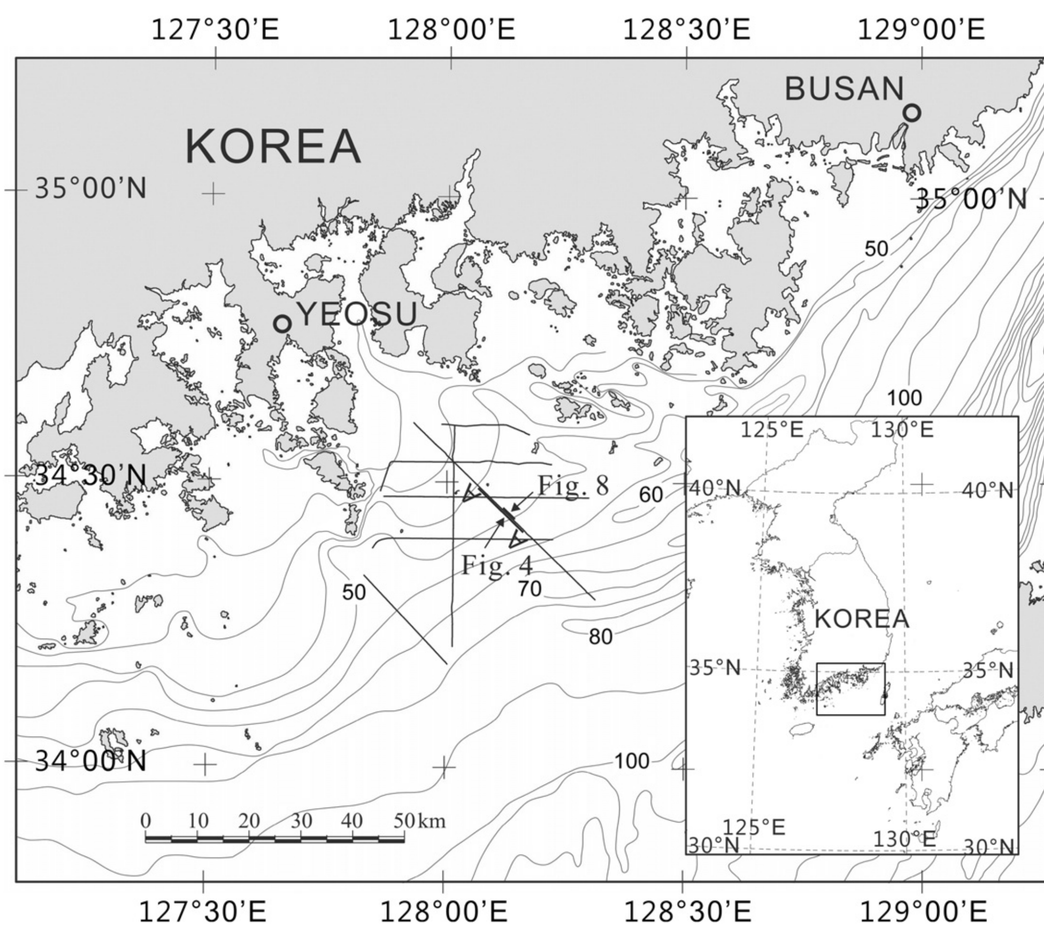

Fig. 1. Field survey area off Yeosu and seismic track line.