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Influence of gassy sediments on low-frequency acoustic wave propagation in shallow water environments

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1. Introduction

As underwater sound waves propagate through an ocean waveguide, they interact with the bottom boundary layer, as well as the sediment below the ocean floor. In general, coastal ports and bay areas are environments in which the amount of organic matter introduced from the land is high, and fine sediments, such as silt and clay, are deposited. Gas bubbles form in the sediment as organic matter in the sediment layers is biochemically decomposed by bacteria.[1)] These bubbles act as an obstacle that scatters and attenuates incident sound waves, resulting in a loss of energy as the waves propagate to the water layer.[2,3)]

The study area was Yeongil Bay, located along the southeast coast of Korea, in which a large amount of organic matter is supplied to the bay from tributary streams. The sediment at the bottom of the bay is composed mostly of mud. Choi *et al.*'s seismic survey confirmed the presence of gas bubbles entrapped in the lower sediment layer of the experimental area.[4)]

In this paper, we present the effects of gas bubbles in sediment on low-frequency acoustic transmission loss measured in shallow water.

2. Field Measurements

2.1 Geological surveys

According to the existing research in the literature, Yeongil Bay is a region where various sedimentary environments coexist. To investigate the effect of marine gassy sediments on low-frequency acoustic wave propagation, a seismic survey using a sub-bottom profiler (Chirp III) was conducted to find the area where the gas bubbles was formed in the bottom of the experimental area.

Figure 1 shows the observed seismic profile along the survey line where the acoustic experiment was conducted. The sub-bottom characteristics of the experimental area were divided into non-gas and gas sediments, based on the vertical dotted line. In the non-gas region, layers below the sea floor were observed, whereas in the gas layer, no sub-layers were observed due to scattering and attenuation by the entrapped gas bubbles.

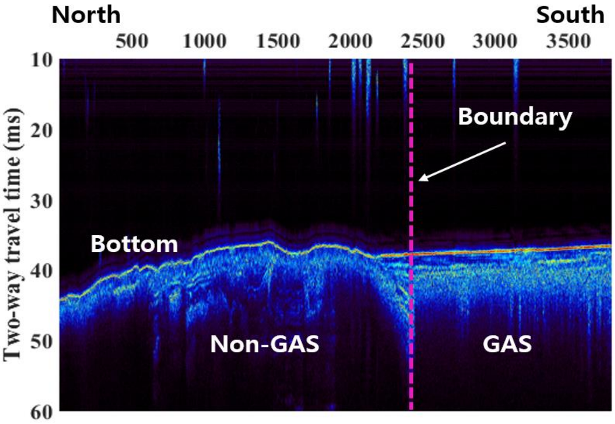

Fig. 1 Seismic profile of the experimental site along the acoustic survey track. The vertical axis represents the two-way travel time in milliseconds. The horizontal axis indicates the seismic shotpoint number.

2.2 Acoustic measurements

Acoustic measurements to investigate the characteristics of sound propagation in gassy marine sediment of the southeast coast of Korea were conducted in June 2017. For the measurements, a low-frequency sound source [SonarTech K-LOSS; **Fig. 2**(a)] was deployed from the stern of the R/V EARDO and towed at a depth of ~18 m. The signal transmitted from the sound source was received using two mooring systems, as shown in **Fig. 3**, each containing a hydrophone [RESON TC4032; Fig 2(b)] and a pressure sensor (RBRsolo).

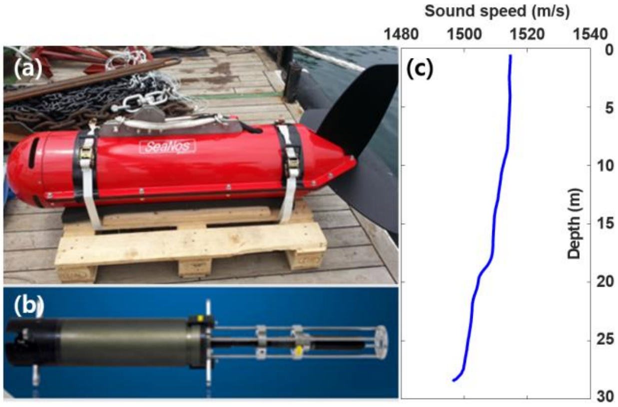

Fig. 2 (a) Low-frequency sound source. (b) Self-recording hydrophone system. (c) Sound speed profile obtained by CTD.

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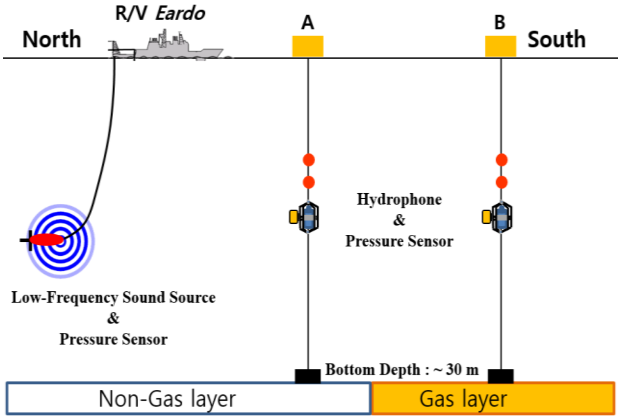

Fig. 3 Experimental layout for measuring the propagation loss due to the effects of gassy sediments.

One hydrophone–pressure sensor system was installed on the gas layer, and the other installed on the non-gas layer. Each hydrophone was operated at a depth of ~ 15m. During the acoustic measurements, a sound speed profile was acquired based on conductivity–temperature–depth (CTD) measurements. The sound velocities near the sea surface and seabed were measured at 1514 m/s and 1496 m/s, respectively. As shown in Fig. 2(c), the negative sound speed gradient measured at the experimental site caused the sound waves generated in the water to be refracted downward. Notably, the acoustic propagation was greatly influenced by the bottom interacting paths.

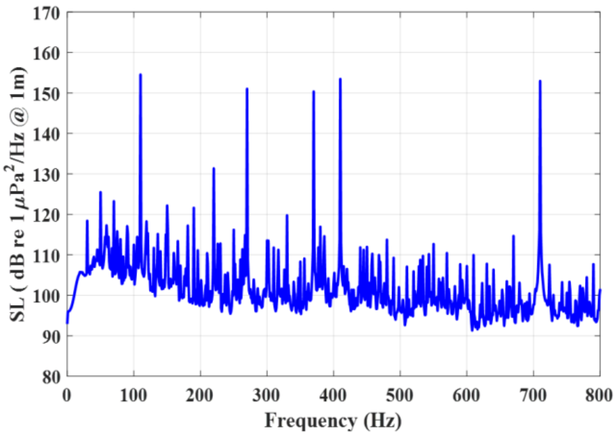

Fig. 4 Acoustic source level of a superimposed sinusoidal signal transmitted from the sound source.

A superimposed acoustic signal composed of the sum of narrow-band sinusoidal signals of 110, 270, 370, 410, and 710 Hz was transmitted continuously during the acoustic propagation experiment. **Figure 4** shows the acoustic source levels expressed as the power spectral density (PSD) with a 1-Hz band; the levels were calibrated at sea using a standard hydrophone prior to acoustic experiments. To investigate the characteristics of sound propagation with respect to the presence of gassy sediment below the sea floor, the survey line was about 6 km.

3. Results

To understand the propagation characteristics of the low-frequency band by gas sediments, the sound source moved from the north to the south, as shown in Fig. 3. **Figure 5** shows the frequency-dependent received levels (RLs) obtained from the hydrophone deployed in the area of non-gas sediments. The RLs gradually increased with approach to the hydrophone, and reached its highest level at the closest point of approach (CPA) nearest the hydrophone. The RLs from the CPA to the boundary line separating the gas area decreased with the same slope. However, after the sound source entered the area where the gas layer was present, the reduction ratio of the RLs decreased rapidly, due to the effects of the gas bubbles in the sediment.

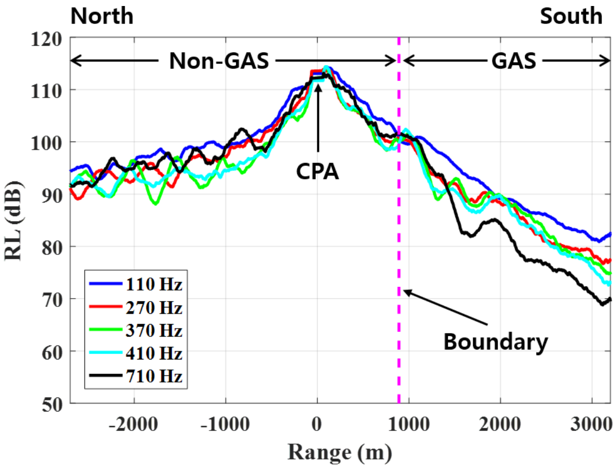

Fig. 5 Comparison of frequency-dependent received levels in regions where gas bubbles were present (gas) or not (non-gas) in the sediment.

Acknowledgment

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