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A study on long-range propagating underwater acoustic waves observed with large-scale cabled ocean bottom seismic observation network

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1. Introduction

Submarine volcanic eruptions are sometimes observed with hydrophones by detecting underwater acoustic waves triggered by the eruptions that have propagated over long ranges through the deep-sea sound channel (Sound Fixing and Ranging, SOFAR channel). In the case of the eruption of "Fukutoku-Oka-No-Ba" submarine volcano located in the southern part of the Ogasawara Islands, or the Bonin Arc (**Fig. 1**, a), acoustic waves associated with the eruption were detected by hydrophones moored at three points in the sea off Wake Island, about 2680 km east-southeast of "Fukutoku-Oka-No-Ba"[1)]. Meanwhile, the author detected the acoustic waves the same eruption by analyzing the ground motion waveforms observed with ocean bottom seismometers (OBSs) of the large-scale cabled ocean bottom seismic observation network "S-net"[2)] deployed along the Japan Trench, offshore east of Japan[3)].

For many months since August 2022, the underwater acoustic waves propagating from south have been intermittently observed by the OBSs of the "S-net". The amplitude of the signal observed at each station is much larger than those. They are clearly visible on the raw waveforms, while in the case of "Fukutoku-Oka-No-Ba" the signals associated with eruption were unrecognizable on the raw waveforms.

In this study, through the analysis of those prominent signals along with other observations, the long-range propagating underwater acoustic waves observed with "S-net" are examined.

2. Data and analysis

"S-net" is a a large-scale cabled ocean bottom seismic observation network consisting of 150 observation stations installed by the National Research Institute for Earth Science and Disaster Resilience (NIED) over a vast sea area from the Nemuro Peninsula in Hokkaido to the Boso Peninsula in Chiba Prefecture, central Japan.

In S-net, a velocimeter and an accelerometer are attached to each station in the same way for each of the three components in arbitrary direction. In this study, the velocimeter is used. The vertical component is calculated based on the direction of gravity measured by the accelerometer[4)] and used for analysis. The sampling frequency is 100 Hz.

Among the intermittently observed prominent underwater acoustic waves propagating from south since August 2022, the three days from November 3 to 5, 2022 when many events were visible in the original waveform are analyzed. Gravity components in order to calculate vertical component of the velocimeter are obtained by time-averaging accelerometer data for 3 hours from 00:00 JST on November 3rd.

As a report on marine volcanic activity during the period, colored water on the sea surface was confirmed by a Japan Coast Guard aircraft after August 2022 at Kaitoku Seamount[5)] (Fig. 1, b). In the previous study[6)], assuming that the signal source is at the position of Kaitoku Seamount, the propagation time to each observation point is calculated. Comparing the calculated and observed arrival time differences, they are found to be inconsistent. Then, based on the observed arrival time difference and by using the cosine law in spherical trigonometry, the location of the sound source is estimated to be on the trench slope near the southern end of the Ogasawara Islands (Fig. 1, c). The sound speed is assumed to be 1472 m/s, based on Ref. 3.

Meanwhile, it is pointed out that this series of signals was associated with the activity of the Ahyi submarine volcano in the Northern Mariana Islands (Fig. 1, d), based on observations by a hydrophone array installed off Wake Island[6)]. So, assuming that the signal source is at the Ahyi submarine volcano, the propagation time to each observation point is calculated. In **Fig. 2**, the time axis of the waveform for each station is shifted by the propagation time and arranging them in order of propagation distance. It can be seen that the appearance positions of the signals are vertically well aligned, suggesting that the Ahyi submarine volcano matches as sound source. Considering the positional relationship between the S-net as an array and the sound source, the difference from the estimated location seems to be within the range of error.

In Ref. 7, it is also reported that observations by the hydrophone array off Wake Is. detected underwater acoustic waves that are presumed to be associated with volcanic activity at Kaitoku Seamount. Accordingly, the waveform analysis is

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conducted using the data observed on September 1, 2022, when there is a high probability that the signals from Kaitoku Seamount will be detected. The gravity component was obtained by time-averaging the accelerometer data for 3 hours from 00:00 JST on September 1, for the calculation of the vertical component of the velocimeter. This time, by comparing the spectrograms of the seismic waveforms with the time axis shifted by the propagation time for each observation point as conducted in Ref. 3, no signal corresponding to the volcanic activity of Kaitoku Seamount is detected. Next, the 5-10 Hz bandpass filter is applied to the original waveform. In **Fig. 3**, the time axis of the waveform for each station is shifted by the propagation time and arranging them in order of propagation distance. Although faint, a vertical line of signals around 12:21 can be recognized, corresponding to the volcanic activity of Kaitoku Seamount. At Kaitoku Seamount, notable eruptive activity like that at Fukutoku Okanoba has not been observed, but it is possible to detect similar volcanic activity with “S-net”.

3. Concluding remarks

The long-range propagating underwater acoustic waves observed with large-scale cabled ocean bottom seismic observation network "S-net" and their relation to the eruptions of submarine volcanoes are examined. Further study on other observed signals including earthquakes will be conducted.

Acknowledgment
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References

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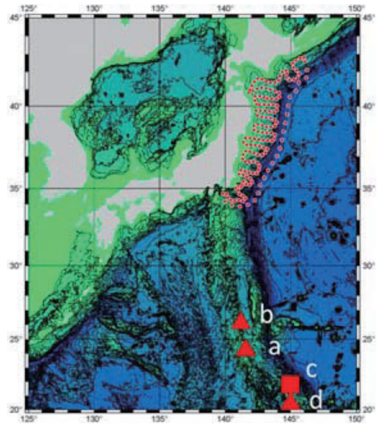

Fig. 1 Locations of S-net and volcanoes.
Red dots: S-net, a: Fukutoku-Oka-No-Ba, b: Kaitoku sea mount, c: Estimated sound source, d: Ahyi submarine volcano.

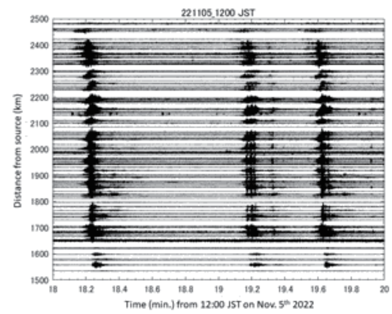

Fig. 2 Profiles of waveform of S-net stations. Horizontal axis is elapsed time from 12:00 JST on Nov. 5th 2022, projected in the source time.

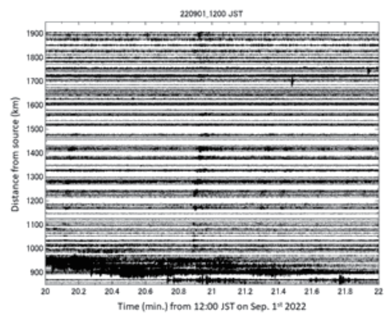

Fig. 3 Profiles of waveform of S-net stations. Horizontal axis is elapsed time from 12:00 JST on Sep. 1st 2022, projected in the source time.