Stratigraphic characterization of the Heunghae Basin, Korea, using horizontal-to-vertical spectral ratio (HVSR) of microtremor records

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1. Introduction

- The depth of the boundary where a strong impedance contrast occurs was estimated using the horizontal-to-vertical spectral ratio (HVSR) method that contrasts the horizontal and vertical components of the seismic signal.
- The thickness of the sediment layer was estimated from the resonant frequency of the calculated HVSR.
- The depth of the sediment layer was estimated using the peak at the lowest frequency (f_1) and the second peak (f_2) on the HVSR curve, and the formula proposed by Lachet and Bard (1994).

2. Data

- The microtremor records were obtained using 115 geophones and 43 broadband seismometers with one accelerometer sensor.
- The geophones, with a spacing of approximately 500 m, were set to a sampling rate of 500 Hz, whereas the sampling rate for broadband seismometers and accelerometer seismometers is 100 Hz.
- Data from outside the Heunghae Basin were added using the permanent seismic station.

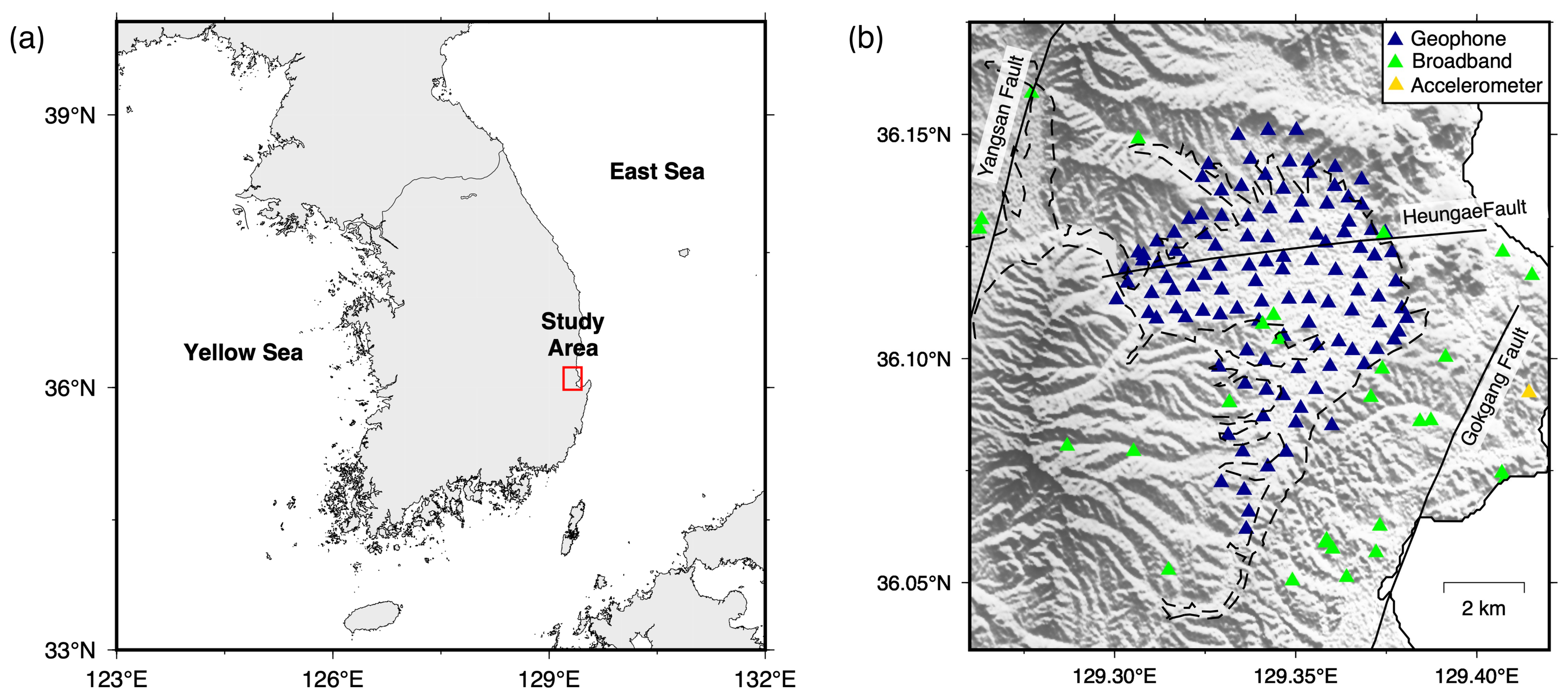

Figure 1. Maps of the study area. (a) A regional map indicating the study area. (b) A map showing the topography, faults, and location of seismic stations in the study area. The black dashed line represents the layout of the Heunghae Basin. The dark blue triangles indicate the geophones, the green triangles indicate the broadband seismometers and the gold triangles indicate the accelerometer stations.

- The geophone data were excluded from the first and last 5 minutes to avoid noise generated during installation and retrieval. The data length ranged from 2 to 26 hours, depending on the station.
- Data from the broadband and accelerometer stations were used for 24 hours long.

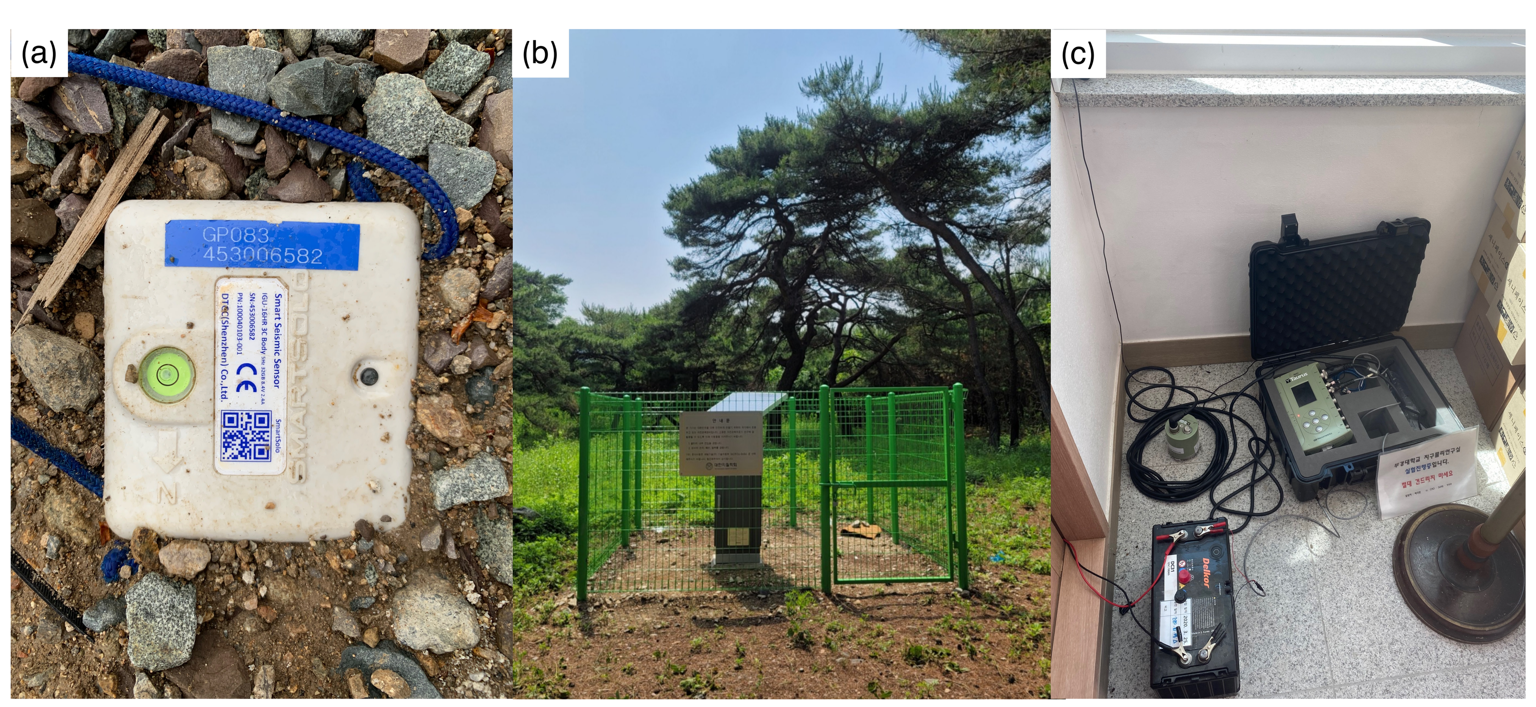

Figure 2. Example photos of the observation stations used for HVSR calculation. (a) Deployed geophone. (b) Broadband seismometer station. (c) Temporary seismic station.

3. HVSR analysis

- The resonance frequency of the HVSR curve is related to the depth of the boundary between the upper sedimentary layer and the bedrock, where a strong impedance contrast occurs.
- To minimize the influence of natural or artificial signals in the HVSR analysis, the frequency-domain window rejection algorithm proposed by Cox *et al.* (2020) was applied to exclude transient signals from the analysis.

$$HVSR(f) = \frac{\sqrt{EW \cdot NS}}{UD} \qquad \text{(Eq. 1)}$$

$$f_r = \frac{V_s}{4H} \qquad \text{(Eq. 2)}$$

EW: Spectral amplitude in the east-west direction
NS: Spectral amplitude in the north-south direction
UD: Spectral amplitude in the up-down direction

f_r: Resonance frequency of HVSR curve
V_s: Shear wave velocity of sedimentary layer
H: Thickness of sedimentary layer

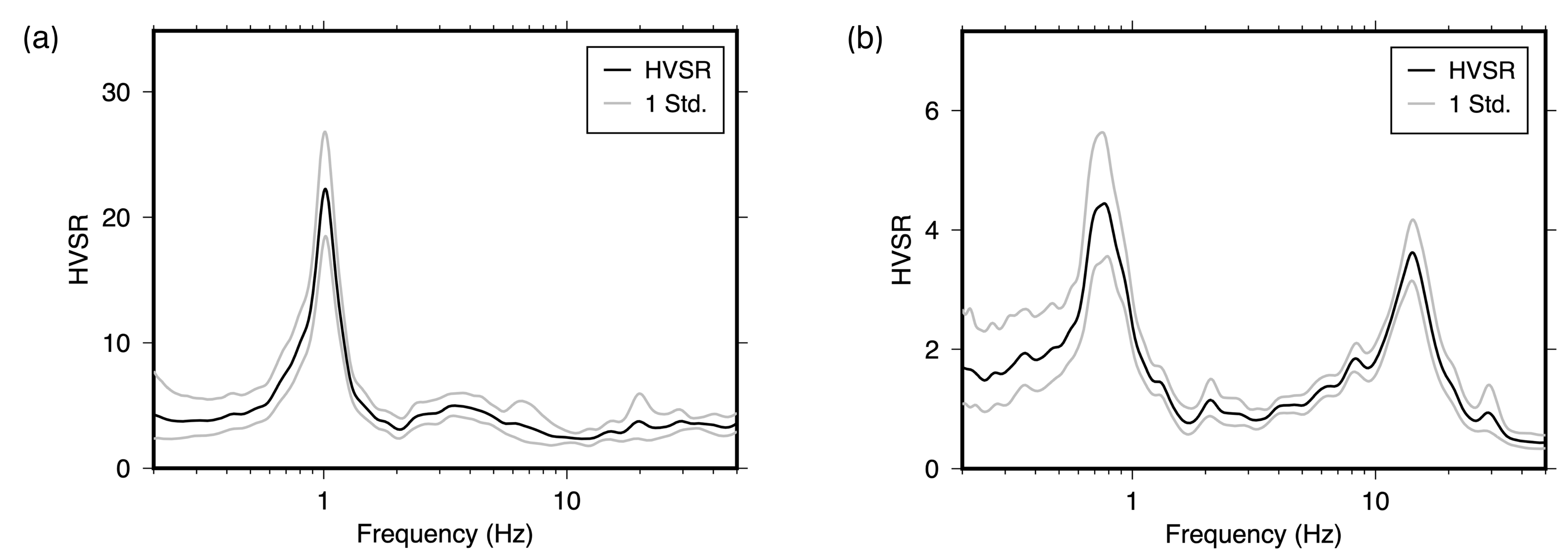

Figure. 3. Examples of typical HVSR curves (solid black line) and one standard deviation (solid grey lines). (a) A case showing a single resonance frequency. (b) A case showing two distinct resonance frequencies.

- The HVSR was calculated in the frequency range of 0.2–50 Hz, and analysis results showed that one or more distinct resonance frequencies were observed at most observation sites. Therefore, observation sites where distinct resonance frequencies were not observed were excluded from depth estimation according to the HVSR guidelines SESAME, 2004.
- f_1 was defined as the frequency with the maximum amplitude at the lowest frequency, and f_2 was defined as the frequency with the maximum amplitude at a higher frequency than f_1. The peak ranges of f_1 and f_2 are 0.37–5.58 Hz (only 2 out of 115 stations had f_1 frequencies of 12.46 and 16.11 Hz) and 1.03–46.87 Hz, respectively.
- The depth that corresponds to the resonance frequency was estimated using Equation 2, which was considered a strong impedance between the upper and lower layers. We utilized a shear wave velocity of 480 m/s proposed by the Geological Society of Korea (2019) for the sedimentary layer.

4. Result of HVSR

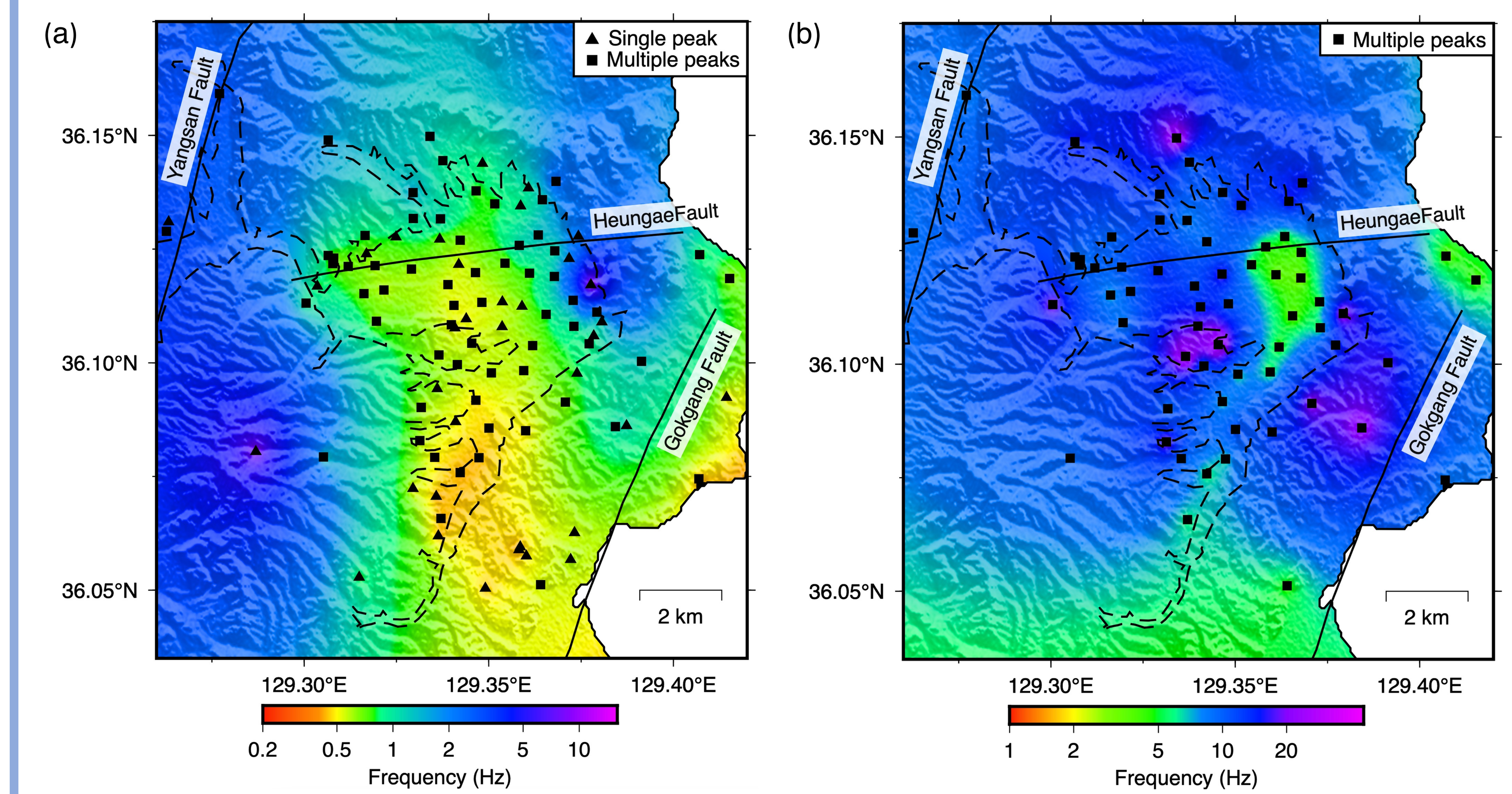

Figure. 4 Distribution of HVSR-derived resonance frequency. (a) The first peak frequency, f_1. (b) The second peak frequency, f_2.

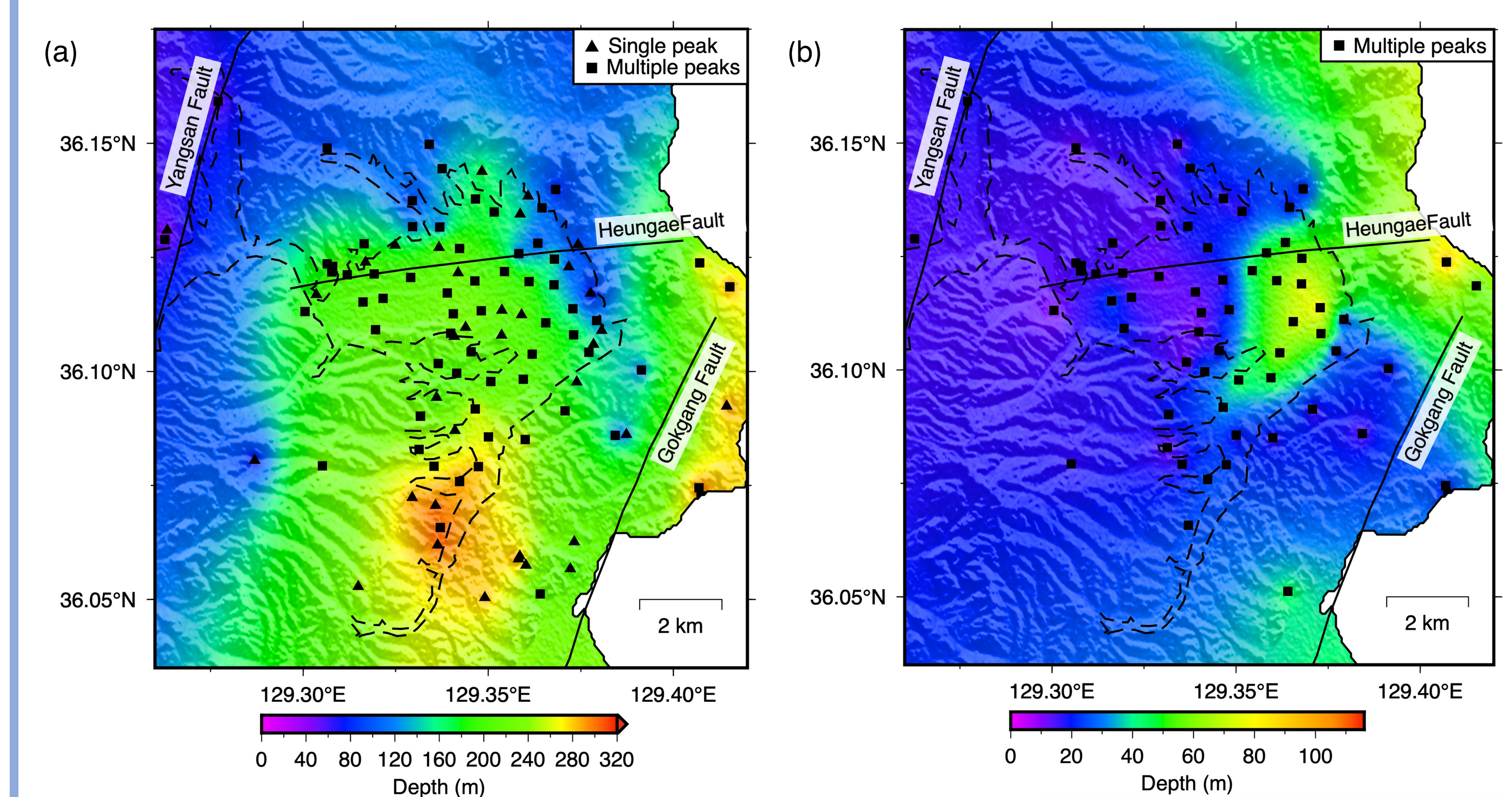

Figure. 5. Depth distribution estimated from HVSR peak frequencies. (a) Results of the depth estimation based on f_1. (b) Results of the depth estimation based on f_2.

- Although the numerical values of f_1 from Kang *et al.* (2020) and this study do not match exactly, it is consistent that the southern part of the Heunghae Basin is deeper than the northern part and that the sediment depth is deeper on the eastern coast.
- The regions exhibiting f_1 correspond to the areas overlain by Tertiary sediments or Quaternary alluvial deposits.

5. Summary

- HVSR was calculated using microtremor records data, and one or more distinct resonance frequencies were observed at most observation stations.
- We estimated the depth at which resonance frequencies occur relative to strong impedance
- The interior of the Heunghae Basin had lower f_1 than the exterior, and within the basin, the southern part had lower f_1 than the northern part.
- The actual depth of the boundary may differ from the results obtained in this study due to the lack of consideration of the spatial variability of shear wave velocity.

References

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