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Seismic Imaging and Inversion of Lithospheric Structures beneath the Korean Peninsula

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Reservoir Imaging with Seismic & EM technology

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1. Abstract

Modern seismic imaging and inversion methods play an important role in understanding the Earth's interior and its behavior by establishing more accurate subsurface velocity models. This study presents the results of the model update and interpretation of lithospheric structures beneath the Korean Peninsula. Tao et al. (2018) conducted a full waveform inversion and determined a seismic model of the upper mantle beneath eastern Asia, FWEA18 (Full Waveform inversion of East Asia in 2018). This model gives large-scale structures and physical properties of them beneath this extensive area. However, there is a limit to show smaller-scale seismic structures of the Korean peninsula due to the sparse data in that region.

Song et al. (2018) recorded seismic noise data in 2014 and applied seismic interferometry and reflection processing methods to image them. In this study, we enhanced the three 2D seismic images and determined the seismic models with small geological features not shown in the FWEA18 model. First of all, the main problem of this seismic imaging was its low signal-to-noise ratio (SNR) of recorded noise data. By applying the same seismic acquisition geometry to the FWEA18 model, we generated noise-free synthetic seismic traces and improved the SNR of existing data. Since the data distribution of the FWEA18 model was less dense than our receiver distribution, we applied the interpolation method based on seismic trace regularization using Delaunay triangulation to this model (Yeeh et al., 2018) in this imaging process.

After we obtained the better post-stack seismic images, we conducted the L2-norm model-based impedance inversion from these images and obtained the P-impedance model, the product of Vp (P-wave velocity) and density. From our model, we estimated more accurate Vp, Vs (S-wave velocity), and density values of the crust and mantle of the peninsula using the linear relationships among three physical properties shown in FWEA18. Furthermore, we were able to observe geologic features and their local depth changes such as Moho and mid-crust low-velocity zones. In conclusion, we improved the resolution of the seismic model and this model allows us to interpret more intense structures and understand their tectonic behaviors.

2. Study Area

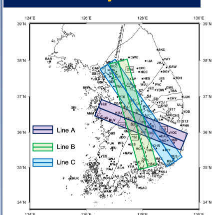

Figure 1. 2D seismic survey lines on the seismic stations of the Korea Meteorological Administration (KMA) network (modified from Hong et al., 2009).

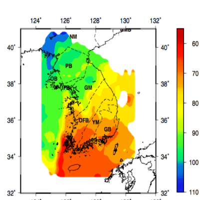

Figure 2. 2D Topography map of the Lithosphere-Asthenosphere boundary beneath the Korean Peninsula (from Lee, 2016).

Seismic Data Acquisition

Receiver Type	Vertical component (Kinemetrics ES-T)
Average Spacing	30 km
Number	115 (Four data of poor quality were excluded in a total of 119 receivers)
Recording Time	60 seconds
Sample Rate	20 Hz (Sample interval = 50 milliseconds)
Data Type	Continuous (for a 1-year period, January 2014 – December 2014, UTC)

3. Seismic Data Processing

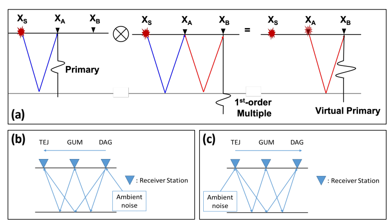

Figure 3. Schematic diagram of the seismic interferometry method (a) and the seismic acquisition strategy for 2D post-stack seismic images ((b) and (c)). Note that all of the ambient noise can be stacked because the signals from different sources show the same mid-point reflection events.

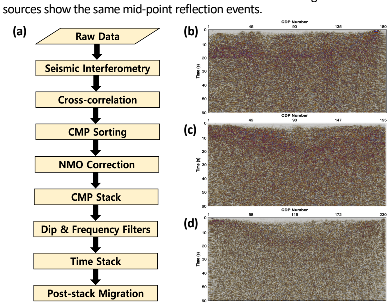

Figure 4. The workflow of seismic data processing (a), and 2D seismic sections of Line A (b), Line B (c), and Line C (d). Note that we can observe sub-horizontal events which can be interpreted as Moho (at 10 s) and LAB (at 20 s).

4. Post-stack Seismic Inversion

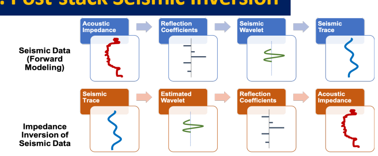

Figure 5. Theoretical diagrams of seismic data acquisition (or forward modeling) and post-stack impedance inversion of seismic data.

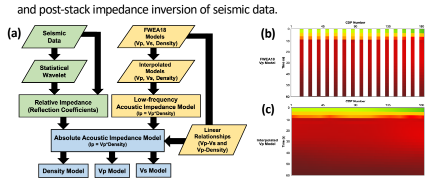

Figure 6. (a) Inversion strategy by using the seismic data and FWEA18 models, (b) original FWEA18 Vp model in Line A, (c) Interpolated Vp model from (b).

5. Results

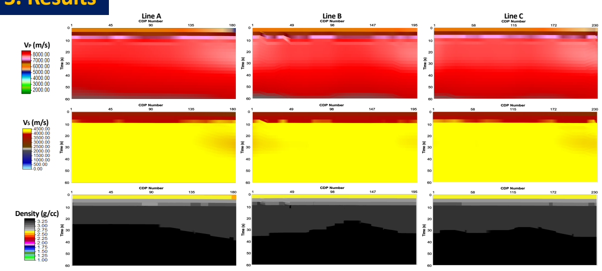

Figure 7. Initial seismic velocity and density models for the background models of the model-based impedance inversion. Note that these are developed by interpolation of the original sparse FWEA18 model based on the seismic data acquisition geometry.

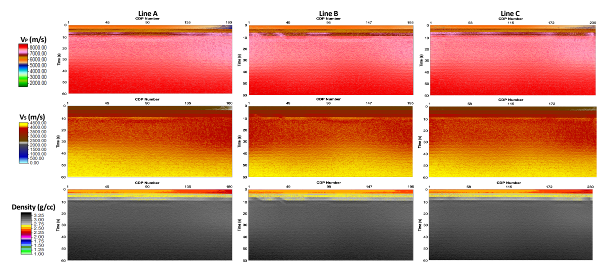

Figure 8. Inverted seismic velocity and density models from the initial models (Figure 7) and the post-stack seismic data (Figure 4). Through the linear relationships of Vp-Vs-density in the FWEA18 research, we can estimate the Vp, Vs, and density variations from the inverted impedance model.

6. Conclusions

- In this study, we applied the seismic interferometry method to ambient noise data to image the upper mantle structures beneath the southern part of the Korean peninsula.
- The 2D post-stack seismic images from the seismic data show sub-horizontal events which indicate subsurface boundaries such as Moho at 10 s and LAB near 20 s.
- As the information on the Korean peninsula of the FWEA18 model is ambiguous and sparse, we developed this model with this seismic data by using the trace interpolation and post-stack inversion methods.
- In conclusion, we improved the resolution of the seismic model higher than the original FWEA18 model. Also, this model can help us to interpret more intense structures and understand the velocity and density changes of the upper mantle underneath the peninsula.

7. References

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8. Acknowledgement

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