# Active seismic exploration on the Moon: Investigation of water ice deposit near the Moon’s polar region

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We have been designing and developing an active seismic exploration package with seismometers, active seismic source and anchoring system. Our seismic exploration package was designed to investigate from shallow formation (i.e., ice saturation) to deep formation (i.e., thickness of regolith) of the Moon. Here we present the basic concept of our seismic exploration package and its experimental results.

The active seismic source is designed so that we can control the generated waveform. We usually use continuous waveform with wide frequency range. By stacking the continuously-generated waveforms, we improve signal-to-noise ratio of the seismic signal. Thus, less-energy waveform derived from small-size motor (or piezoelectric element) could be utilized for the exploration of deeper formation. By recording the source signal by seismometer array, we investigate the subsurface structure and properties. If both lander and rover have active source and seismic array, we can apply multiple seismic exploration methods such as (1) surface wave analysis, (2) seismic refraction analysis and (3) seismic reflection analysis. We can explore relatively shallow formation including ice distribution via (1) surface-wave analysis. A small amount of frozen water can lead to large S-wave velocity increases. Therefore, the S-wave velocity distributions derived from surface-wave analysis could provide useful information to reveal ice saturation in shallow formation. Using (2) seismic refraction (tomography) analysis, we investigate P-wave and S-wave velocity distribution between lander and rover. (3) Seismic reflection analysis can be used to investigate formation boundary beneath the rover (and lander). Because one of the major problems in planetary exploration is the coupling between the instruments and the ground, anchoring mechanism should be further considered.

To evaluate our active-source seismic exploration system, we conducted seismic exploration in the test field in Japan Aerospace Exploration Agency (JAXA). The test field is filled with loose sands of ~50cm thickness. In this experiment, we conducted seismic survey with several acquisition parameters. When we applied the active seismic survey for small-size receiver array, we retrieved clear shot gather. We further calculated dispersion curve from the shot gather and obtained S-wave velocity profile beneath the array using GA inversion. The S-wave velocity in shallow formation was accurately estimated and continuously increases for depth direction, suggesting that ice can be identified as anomalous high S-wave velocity via our seismic system.

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