Planetary seismic tomography: Earth and Moon

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Seismic tomography can be applied not only to Earth, but also to other planets if seismic events occur within a planet and seismometers can be installed on the planetary surface to record the seismic waves which propagate inside the planet. The terrestrial seismic tomography has been very successful in the last two decades from local to global scales, which has lead to a revolution in Earth sciences. However, there has been almost no application of seismic tomography to other planets. The only exception is Zhao et al. (2008) who tried to determine the first seismic tomography of the Moon. They estimated 3-D P and S wave velocity and Poisson's ratio structures of the lunar crust and mantle down to 1000 km depth under the near-side of the Moon by applying a seismic tomography method (Zhao, 2004) to the moonquake arrival-time data recorded by the Apollo seismic network operated during 1969 to 1977. Their results show that significant lateral heterogeneities may exist in the lunar interior. Because there is no plate tectonics in the Moon, the lateral heterogeneities may be produced at the early stage of the Moon formation and evolution, and they have been preserved till today. There seems a correlation between the distribution of deep moonquakes and lateral velocity variations in the lunar lower mantle, suggesting that the occurrence of deep moonquakes may be affected by the lunar structural heterogeneity in addition to the tidal stresses. Although this is an experimental work and the result is still preliminary, it indicates that tomographic imaging of the lunar interior is feasible.

The Apollo seismic network consisted of only four stations, which were not sufficient to locate the moonquakes precisely. The large uncertainties in the moonquake hypocenter locations and arrival-time data have prevented us from determining a precise tomographic image of the lunar interior at the current stage. The lunar tomography, however, has some advantages over the terrestrial tomography because moonquakes occur down to over 1100 km depth (note that the lunar radius is 1738 km), thus seismic waves from the deep moonquakes can sample a large fraction of depth range in the lunar interior even with a local seismic array, which is very favorable from a viewpoint of seismic tomography. In contrast, earthquakes occur only down to 670 km depth (1/9 of the Earth's radius), and so deep Earth tomography cannot be determined without a global seismic network.

Because of the limitations of the Apollo seismic data, the present tomographic study of the Moon (Zhao et al., 2008) has to be considered as an experimental work. Future lunar explorations, such as the Japanese Lunar-A mission in which a penetrator-based deployment of seismic stations was planned in both the near-side and far-side of the Moon, are expected to provide better seismic data enabling us to determine a reliable tomographic image of the lunar interior.

References

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