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FDM Simulation of Scatterings Observed in Moonquake Coda Waves

TARO OKAMOTO[1], NAOKI KOBAYASHI[1]
[1] *Department of Earth and Planetary Sciences, Tokyo Institute of Technology*

The moonquake seismograms obtained by the Apollo seismograph network are the only ones that have been successfully recorded so far on a extra-terrestrial body. There are several types of moonquakes (e.g., the deep-focus and the shallow-focus moonquakes), but the moonquake seismograms have the following distinct characteristics irrespective of the types. (1) They show very long coda waves that continue for several tens of minutes after the initial phases. (2) The maximum amplitude does not occur at the initial phase onset, but it usually occurs after the onset: i.e., there is a 'rise time' for the seismic waves to develop to the maximum amplitude. In other words, the envelope of the seismogram shows a shape like a 'spindle'. These characteristics indicate that the scattering effect is very strong and the attenuation is very weak in the shallow part of the Moon. The scattering phenomena have been studied by many researchers by applying the diffusion process, and the diffusion coefficients as well as the mean free paths of the diffusion process were estimated as the indicators of the material properties of the shallow part of the Moon. These properties probably reflect the degree of fracture and fragmentation associated with the impact cratering, but the correspondence between the indicator (i.e., diffusion coefficients) and the actual material parameters remains to be investigated. In order to directly correlate the degree of the scatterings and the material properties, we tried to simulate the coda wave by a direct 2D finite difference method. In our simulation, we assumed a layered random media in which the seismic velocity fluctuated randomly. The randomness was described by a spatial auto-correlation function for the velocity distribution. We assumed a Gaussian function for our study. Although our simulations are limited to 2D geometry and to SH problems, we suggest the following based on the results for a deep-focus moonquake. (1) A very large fluctuation in the random velocity distribution is required in order to explain the characteristics of the first 300s of the observed S-wave amplitude: the standard deviation may be up to 40% of the mean velocity. (2) Thin low-velocity surface layer is very important in considering the duration and the strength of the coda waves. Such a layer with a thickness of 1km was assumed in our model based on the seismic experiments conducted on the Moon by the astronauts. For models with the thin surface layer the coda wave got longer than that for models without the layer because the seismic waves were effectively trapped in the low-velocity surface layer.