Effects of Lateral Variations in Megaregolith Thickness on Recorded Seismic Signals. Jean-Francois Blanchette-Guertin[1], Catherine L. Johnson[1,2], Jesse F. Lawrence[3]. [1]University of British Columbia (2020-2207 Main Mall, Vancouver, BC V6T1Z4, CANADA; jguertin@eos.ubc.ca), [2]Planetary Science Institute (1700 Fort Lowell, Suite 106, Tucson, AZ 85719), [3]Stanford University (397 Panama Mall, Mitchell Building, Room 360, Stanford, CA 94306).

Overview: Seismic signals recorded during the Apollo Passive Seismic Experiment were greatly affected by the scattering of seismic energy in the Moon's interior, which most probably occurs within the near surface megaregolith layer [e.g., 1,2]. Here we use a modified phonon synthetic seismogram method to investigate the effects of laterally varying megaregolith thickness on the propagation of seismic energy, and on the resulting seismic signals recorded at various epicentral distances from the source. A major objective of this project is to identify conditions under which seismograms recorded at the surface are less likely to be affected by high levels of scattering, and for which secondary arrivals containing important information about interior structure can be more readily identified. Such studies will help optimize the design of future non-terrestrial seismic surveys to maximize scientific return.

We present here two simple cases: **A**) a 4°-diameter basin, centered at 20°, underlain by a 5 km thick megaregolith, surrounded by a much thicker 30 km thick megaregolith; and **B**) a 40°-diameter basin centered at 60° with effectively no underlying megaregolith (i.e. no receiver-side scattering), surrounded by a 30 km thick megaregolith. These two scenarios are intended as proxies for younger impact basins supported (at least in part) by crustal thinning beneath the basin, and with less subsequent impact resurfacing and megaregolith production than older surrounding terrain.

We have computed synthetics for surface events (impacting the top of our 30 km-thick megaregolith) as well as for 1000 km deep events (analogous to lunar deep quakes). The examples shown here have a very simple background velocity model, using a constant velocity throughout the planet, in order to isolate the effects of the megaregolith on the signals. Investigations of the effects of other velocity and scattering structures are currently underway.

The Modified Phonon Method: The phonon method used is similar to the one described in [3], in which a large number of seismic packets are tracked as they travel through a planetary interior. In the megaregolith, the phonons encounter randomly oriented scatterers every δ_{sc} m, where δ_{sc} is randomly sampled from a power-law distribution. The phonons are stochastically scattered, or not, based on the scattering probability and on the velocity and density perturbations associated with the scatterer. These perturbations are picked randomly and were on average ±15% of the background values for the models presented here. This favors forward scattering of the phonons, (vs. backscattering) as can be observed below.

Results: Figure 1 shows selected radial synthetic seismogram traces for the two models, for both impact and deep events. The amplitudes in each trace have been normalized such that the root mean squares of all traces are equal.

All impact-derived signals exhibit strong scattered codas, even for those recorded in the basins, which makes it very difficult to identify wave arrivals except for the initial P-wave. This is mainly due to the fact that all the energy in the case of impacts is first scattered near the source. In the two models shown here, source-side scattering is strong enough to hinder wave arrival picking even if there is no receiver-side scattering. Note that no noise or instrument effect(s) were added to the synthetics, which would add further uncertainty to the P-wave arrival time picks.

Synthetics are much cleaner in the case of deep events, where most of the energy is allowed to first travel without scattering in the mantle before reaching the receivers. In model A, a much thinner scattering layer under the basin is sufficient to greatly reduced the scattered coda amplitude of the signals and to allow clear P- and S-wave arrival picks. However, all receivers within the basins are sufficiently close to the basin edge that scattered energy leaks in and is recorded at later times, masking lower amplitude secondary arrivals.

For larger basins such as that shown in model B the records of deep events at stations in the basin interior are even cleaner than for model A. (Note that only half of the basin is shown in Fig. 1). In particular, the basin is now large enough that leaked energy effects from the thick megaregolith near the basin edges diminish significantly toward the center of the basin. In this particular model case, lower amplitude secondary arrivals, such as the SS-wave arrivals (Fig. 1) are preserved.

Other results, not shown here, indicate that signals recorded in basins with a thin megaregolith are much cleaner for all types of events for which there was no source-side scattering. These could be events near the

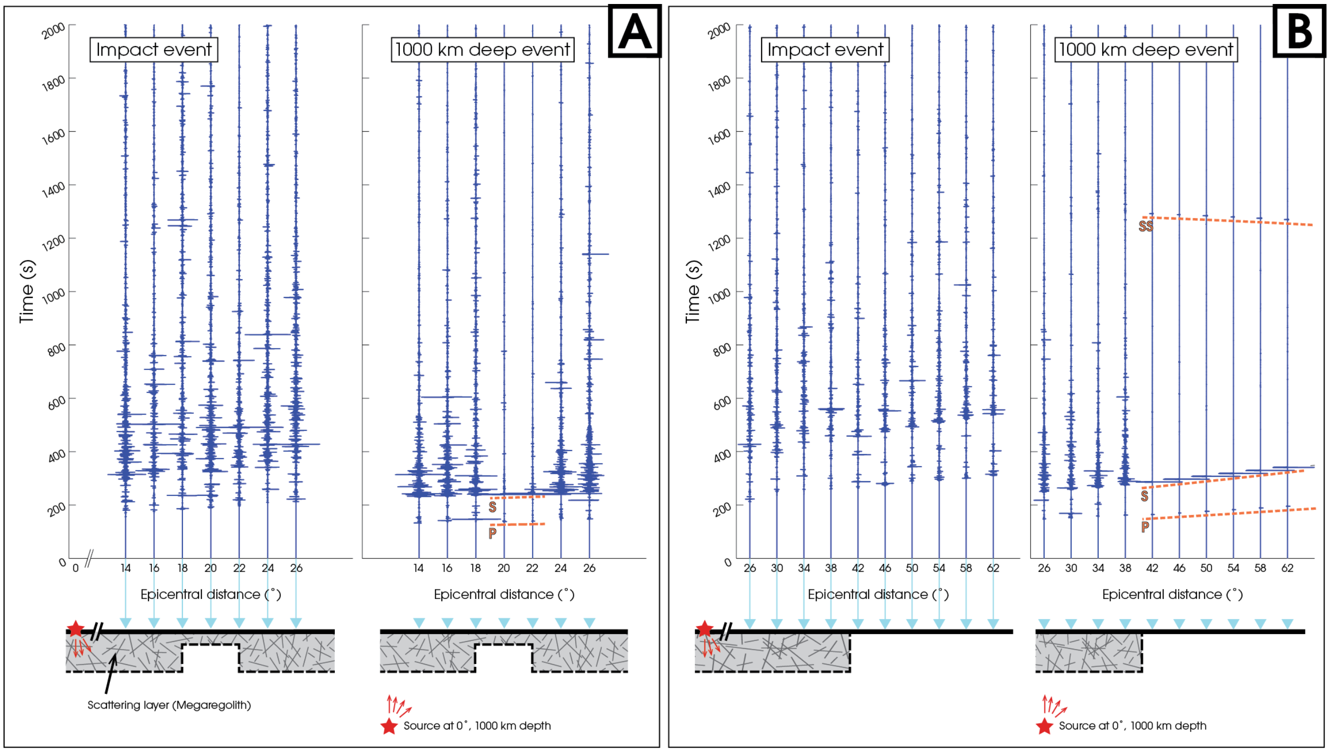

Figure 1: Synthetic seismogram traces for two simple models (only the radial component of the synthetics is shown): A) a 4˚ basin centered on 20˚ and B) a 40˚ basin centered on 60˚, only half of which is shown here. The bottom sections are schematic representations of the laterally varying megaregolith thickness, with the locations of sources (red stars) and receivers (blue triangles). Some clearly identifiable wave arrivals are shown (orange dashed lines). All traces have been normalized by their root mean squares.

surface but underneath the megaregolith (perhaps analogous to lunar shallow quakes) or impacts into a region with a very thin megaregolith.

The effect of the dominantly forward-scattering vs. back-scattering may be important in the case of the smaller basin (model A). The receivers located at epicentral distances of 18˚ and 22˚ both sit on the edge of the basin, however, the seismogram at 22˚ is much cleaner, due to the fact the seismic energy travels mostly away from the source located at 0˚, such that the receiver at 18˚ is more affected by forward-scattered energy from the edge of the basin than the receiver at 22˚ is affected by back-scattered energy from the opposite edge.

Discussion and Summary: Our modeling to date does not take into account several structures that could affect the scattering characteristics of the recorded signals. The following effects were neglected to minimize computational requirements for our initial study, but they could have important effects: (1) Surface topography. This could intensify or decrease scattering, especially near the basins edges or near the seismic receivers [4]. (2) More realistic interior velocity profiles. In particular near-surface low velocity layers have been observed to significantly affect the resulting coda [3, 4]. We are currently investigating suites of 1D velocity models, including ones that incorporate a shallow low velocity layer into this study.

Our results indicate that basins with much thinner subsurface megaregolith layers than the surrounding region can yield seismograms with significantly less scattered energy than from stations on the surrounding terrain. Small basins could allow identification of direct wave arrivals, but not necessarily of secondary wave arrivals because of leaked scattered energy from the basin edges. Larger basins with thin megaregolith could be better suited to detect primary and secondary wave arrivals. Detailed examination of 1D velocity models, variations in scattering layer properties as well as laterally varying velocities will lead to a more thorough understanding of how and where to pick optimal locations for future seismic stations in highly scattering environments.

References: [1] Latham, G. et al. (1972), *Science*, 167(3918). [2] Blanchette-Guertin, J.-F. et al. (2012), *JGR*, doi: 10.1029/2011JE004042. [3] Blanchette-Guertin, J.-F. et al. (2013), *LPSC 44*, #1719. [4] Schmerr, N. et al. (2011), LPSC 42, #1961.