



Probing the structure and porosity of the lunar highlands crust

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Impact cratering is held to be the primary mechanism responsible for regulating porosity in primordial planetary lithospheres, increasing porosity via fracturing and dilatant bulking and decreasing porosity via localized heating and compaction. Constraints on these processes, however, are limited to gravity profiles of four lunar craters and gravity and seismic observations of ~ 50 terrestrial craters, many of which have been substantially modified by erosion and weathering. The Gravity Recovery and Interior Laboratory (GRAIL) mission has afforded unprecedented insight into the structure of the lithosphere of the Moon. We use a Bouguer-corrected GRAIL gravity field to investigate the porosity associated with ~ 1200 complex lunar highlands craters. We find that the Bouguer anomaly (BA) of these craters is generally negative and scales inversely with crater size, implying that larger impacts result in more extensive fracturing and dilatant bulking. The BA of craters larger than ~ 93 km is independent of crater diameter, indicating that impact-generated porosity is truncated at depth. Considerable variability in the BA of craters is observed. Some craters, in fact, exhibit positive Bouguer anomalies. We find that positive values of the residual BA, the average BA within the crater rim less the average BA within an outer annulus from the outer flank of the rim to two crater radii from the crater center, correlate with high porosity in the surrounding crust. Our analysis shows that, whereas early impacts generally increased crustal porosity, when crustal porosity becomes too high, impacts reduce porosity, leading to the concept of a steady-state porosity, which we estimate to be $\sim 15 \pm 1\%$ for the lunar highlands. Knowledge of the extent and variability of crustal porosity is critical to understanding the thermal and geologic evolution of planetary bodies and to the ancient ecology of Earth.