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Moon: Basin-Forming Impacts in Scale, Time, and as Thermal and Mass Input

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A striking feature on the lunar surface is the population of impact basins. These large-scale structures have diameters of several 100 to >2000 km and their signature is clearly visible in present-day observables such as the gravity field. The chronology of lunar basins is essential for understanding the age of the lunar surface and its early evolution. We introduce new basin size-projectile size scaling relationships derived from numerical modelling. We make use of the size relation between diameters of inner ring, Bouguer gravity anomaly, main ring, and the result of the numerical simulations suggesting a size link between Bouguer gravity anomaly and transient crater diameter. Thus, we have a reliable tool set to evaluate the sequence of basin forming events in time, determine the thermal anomaly introduced, ejecta distributions, and the mass delivered to the Moon.

We explore how large basin-forming impacts affected the internal evolution of the Moon, which is inevitably linked to the surface, e.g. via volcanism and heat loss. Recently proposed global lunar evolution models can explain various observations on the present-day Moon, but do not, or only partly, consider the thermal input of large basin-forming impacts. Therefore, we couple here the thermochemical evolution of the Moon with its early bombardment. We use the mantle convection code StagYY to model the long-term evolution of the Moon. In order to investigate the role of impact processes, we consider an insulating (low thermal conductivity) ejecta blanket (representing the lunar regolith) with variable thickness and degree of insulation as well as the impact-induced heat anomaly. To determine the ejecta cover we use recent scaling law that links ejecta thickness to the distance to the rim of the source basin. The impact-induced heat anomaly is determined by performing basin formation modeling using the shock physics code iSALE.

Our results with a single impact event indicate that the shock-induced impact heating leads to a sudden increase in mantle temperature and surface heat flux as well as basaltic melt production, in particular for the largest impacts. These effects are rather short-lived ($\sim$50-100 Myrs) and present-day impact-induced temperature or heat-flux anomalies are very small. However, the overall effects are somewhat enhanced with multiple impacts at different times consistent with the lunar bombardment history.
The presence of insulating ejecta further enhances the long-term effects of the lunar bombardment and increases present-day mantle temperatures more substantially depending on the assumed thermal conductivity of the lunar regolith and if the ejecta blanket forms a global cover or not.

The new scaling relations also allow comparison of the crater record with candidate projectile populations, such as the main belt asteroids. We are facing the challenge, that all relationships are described by smooth functions, while the observed basin and crater record shows an offset at about 200 km crater diameter. Thus, for reliable mass estimates, we will elaborate on and refine the determination of the final impact structure diameter at the transition between basin-scale and complex craters.