SHOCK AND DEFORMATION HISTORY OF THE ANCIENT LUNAR CRUST BASED ON NUMERICAL IMPACT MODELLING AND IMPACT STATISTICS

Katarina Miljković[1], Ian Gerrick-Bethell[2,3], Stephanie C. Werner[4], [1]School of Earth and Planetary Science, Curtin University, Perth, Australia (katarina.miljkovic@curtin.edu.au; aaron.cavosie@curtin.edu.au), [2]Earth and Planetary Sciences, University of California, Santa Cruz, [3]School of Space Research, Kyung Hee University, Korea (igarrick@ucsc.edu), [4]Centre for Earth Evolution and Dynamics, University of Oslo, Oslo, Norway (stephanie.werner@geo.uio.no)

Introduction: The largest crater- or basin-forming events, although least frequent, are associated with the first ~700 Myr of the solar system evolution. They formed in then young crust, and their morphology shows peak-ring or multi-ring structures atypical for a smaller, simple or complex, craters. Their formation also involves a significant structural rise of deep-seated material, including upper mantle as well as extreme crustal ejection, fracturing and stratigraphic overturn [1-2]. Recent high-resolution GRAIL-gravity survey of the Moon produced an updated lunar basin catalogue, containing approximately 60 impact basins from this epoch [3]. Gravity data has also allowed for additional limits to sizes of these basins [1] as well as understanding the formation of lunar basins, particularly their rings [4]. These advancements place constraints on the level of shock and deformation caused by the largest impact bombardment in the early lunar crust.

For the most heavily cratered terrain on the Moon, the crater equilibrium onset diameter is at least 10 km [5]. This means that if no other geological processes interfered, the entire ancient crust (or, at least the lunar highlands) was struck at least once by an impactor forming a crater that is 10 km in diameter (not including more frequent bombardment by smaller impactors). Therefore, it is unlikely that impact basins could have been in equilibrium as well, even if one includes the furthest reach of their ejecta. However, shock effects in the ancient lunar crust were caused by the largest impactors, causing the most drastic changes in the crust, including regional crustal re-mixing and ejecta deposition over the largest distances.

Method: We focus on a range of lunar basins, starting with the South Pole-Aitken basin, the largest lunar basin, and investigate the entire range of lunar basins, including the level of shock and deformation experienced during cratering and crustal ejection. To simulate lunar impact basin formation, we used the iSALE-2D hydrocode, a multi-material, multi-rheology finite difference shock-physics code used for simulating impact processes in geologic media [7-9]. This code has been extensively used for modeling impact basin formation on the Moon [1-2,4,6,10-15], and was benchmarked against other hydrocodes [16].

Results: Numerical modelling of peak-ring basin formation showed that the peak ring forms from the material that is part of the central uplift outwardly thrust over the inwardly collapsing transient crater rim. Simulations of lunar basin formation showed that the peak or inner ring in peak-ring or multi-ring basins, respectively, is composed of the overturned crust and deep-seated material, possibly from the upper mantle [2,6]. In contrast, the outer rings (that form in multi-ring basins) likely form as normal faults, without causing significant change in stratigraphy [4]. Our preliminary results: (a) investigate shock and deformation levels of the early and late ejecta in lunar basins, and (b) review crustal re-mixing and changes in crustal stratigraphy during basin formation.

Conclusions: Impact basin formation as well as ejecta formation were extensively modelled. The shock pressures and material deformation at each cratering stage experienced were recorded in detail. We aim to produce a comprehensive shock and deformation history of the ancient lunar crust based on the impact modelling and impact statistics.

References:

[1] K. Miljković, et al. (2016) *J. Geophys. Res*, 121, 1695-1712. [2] K. Miljković et al. (2017) *Geophys. Res. Lett.,* 44, 10,140–10,146. [3] G.A. Neumann et al. (2015) *Science Adv.*, 1:e1500852. [4] B.C. Johnson et al. (2016) Science, 354, 441-444. [5] Z. Xiao and S. Werner (2015) *J. Geophys. Res*, 120, 2277-2292. [6] K. Miljković et al. (2015 *Earth Planet. Sci. Lett.*, 409, 243–251. [7] A.A. Amsden et al. (1980) *Report LA-8095*, Los Alamos National Laboratories, N. Mex., 105 pp. [8] G.S. Collins et al. (2004) *Meteorit. Planet. Sci.*, 39(2), 217–231. [9] K. Wünnemann et al. (2006) *Icarus*, 180, 514–527. [10] R.W.K. Potter et al. (2012a) *Icarus* 220, 730 [11] R.W.K. Potter et al. (2012b) *Geophys. Res. Lett.*, 39, L18, 203. [12] R.W.K. Potter et al. (2013) *J. Geophys. Res: Planets*, 118, 963–979. [13] R.W.K. Potter et al (2015) In: *Meteorite Impacts and Planetary Evolution V*, 518, 99–113. [14] H.J. Melosh et al. (2013) *Science*, 340, 1552–1555. [15] M.-H. Zhu et al. (2015) *J. Geophys. Res. Planets*, 120, 2118–2134. [16] E. Pierazzo et al. (2008) *Meteorit. Planet. Sci.*, 43, 1917–1938.

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