Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-11 Room:201A Time:May 23 11:45-12:00

Early formations of lunar impact basins inferred from their viscoelastic states: Implication for the heavy bombardment

Shunichi Kamata[1]*, Seiji Sugita[1], Yutaka Abe[1], Yoshiaki Ishihara[2], Yuji Harada[1], Noriyuki Namiki[3], Takahiro Iwata[4], Hideo Hanada[5], Hiroshi Araki[5]

[1]Univ. of Tokyo, [2]AIST, [3]Chiteck, [4]JAXA, [5]NAOJ

Formations of impact basins are major geologic processes that had occurred on the early Moon [e.g., 1]. Because the upper part of the Moon probably cooled rapidly during its early history, the viscoelastic relaxation of topography would have occurred more vigorously immediately after the basin formation than later [e.g., 2]. Consequently, topographic undulations both at the surface and at the Moho (i.e., the boundary between the crust and mantle) around impact basins would reflect the thermal state of the lunar interior during basin formation ages. Thus, global survey of deformation states of impact basins is important for investigating the early thermal state of the Moon.

Using recent Kaguya geodetic data, Kamata et al. [3] investigate viscoelastic states of major lunar impact basins and obtain upper limit values for surface temperature gradient and for temperature at the Moho. However, no significant information about the thermal state for impact basins earlier than pre-Nectarian (PN) 5 is obtained. In this study, we investigate the thermal structure that can reproduce current crustal structures around early PN impact basins.

Our results indicate that a Moho temperature higher than the solidus of peridotite is necessary to reproduce early PN impact basins when the surrounding crustal thickness is thinner than 60 km. Both our crustal thickness model and a recent crustal thickness model based on LRO and GRAIL data [4] suggest that surrounding crustal thicknesses around degraded impact basins are less than 60 km. Consequently, if such degraded topographies for early PN "basins" are actually remnants of ancient impact basin topographies, the mantle underneath these basins around their formation ages may be partially melted. This result further suggests that the timing of the complete solidification of the lunar magma ocean corresponds to the boundary between PN 4 and 5. Considering the duration of liquid magma ocean [e.g., 5], this boundary is about 4.1-4.3 Gy ago.

An important implication for the impact history of the Moon is obtained from our results. Based on Apollo sample analyses, a large increase in impact flux on the Moon around 3.9-4.1 Gy ago is proposed [e.g., 6]. This event is often called the Late Heavy Bombardment (LHB) and is very important for understanding the surface environment of the early Earth and the dynamical evolution of the Solar System [e.g., 7]. The absolute formation ages of impact basins, however, are still controversial [e.g., 8]. Because of this, the impact rate on the Moon during the LHB is highly unknown. Ryder [9] suggests an extremely large impact rate during the LHB and suggests that almost all impact basins are formed during the LHB. This speculation, however, is not consistent with our result because our results suggest that 20 out of 45 impact basins are formed before 4.1 Gy ago. This result is further consistent with recent E-belt impactor model [10, 11].

References:

[1] Wilhelms (1987). U.S. Geol. Surv. Prof. Pap. 1348. [2] Solomon et al. (1982). JGR, 87, 3975?3992. [3] Kamata et al. (2013). JGR, 118, doi:10.1002/jgre.20056 (in press). [4] Wieczorek et al. (2013). Science, 339, 671?675. [5] Meyer et al. (2010). Icarus, 208, 1?10. [6] Tera et al. (1974). EPSL, 22, 1?21. [7] Gomes et al. (2005). Nature, 435, 466?469. [8] Stoffler et al. (2006). Rev. Min. Geochem., 60, 519?596. [9] Ryder (2002). JGR, 107, doi:10.1029/2001JE001583. [10] Bottke et al. (2012). Nature, 485, 78?81. [11] Morbidelli et al. (2012). EPSL, 355-356, 144?151.

Keywords: Impact basin, Thermal evolution, Viscoelasticity, Magma ocean, Late Heavy Bombardment