EPSC Abstracts
Vol. 7 EPSC2012-637-1 2012
European Planetary Science Congress 2012

Raditladi and Rachmaninoff basins: Numerical modelling

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Abstract

Mercury hosts the largest population of peak-ring basins among all the rocky planets and satellites of the Solar System. Among the database of such structures, we take into analysis two recently imaged peak-ring basins, Raditladi and Rachmaninoff, both located in the northern hemisphere and about 300 km in diameter.

In this work, we present the numerical simulations carried out through the iSALE shock code, along with the comparison with observations, in order to shed light on the primary impactor source of these basins.

1. Introduction

Raditladi and Rachmaninoff are two Hermean basins observed for the first time by the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) spacecraft of the NASA Discovery Program.

The two basins appeared very interesting beacuse they appeared remarkably young, notwithstanding the quite large dimensions ([5]). Their presumed young age together with its large sizes poses challenging questions on the impactor population responsible for their formation, since very few asteroids are presently known to have sizes large enough to originate such basins.

1.1 Rachmaninoff

Rachmaninoff is a 290 km-diameter peak-ring basin, located at 27.6° N, 57.6° E. It shows a rim crest crisp and well preserved, while most of the basin walls are modified into terraces. Its interior is characterized by a 136–km–diameter peak–ring structure, extended smooth plains filling its floor, and several discontinuous and concentric graben, possibly due to the uplift and extension of the basin floor ([9]).

1.2 Raditladi

Raditladi is a 257 km-diameter peak-ring basin, located at 27.0° N, 119.0° E west of the Caloris basin. Raditladi contains an interior peak–ring structure that is slightly offset and ~125 km in diameter, and its floor is partially filled with smooth, bright plains material that embays the rim and the central peak ring, inside which troughs are arranged in a partially concentric pattern ([3]). The basin walls appear to be degraded, with terraces more pronounced within the north and west sides of the rim ([8]). The hummocky continuous ejecta blanket with no visible system of rays surrounds the basin and extends up to 225 km from the basin rim.

2. Numerical Modelling

Numerical modelling was performed through iSALE shock physics code (e.g., [1], [2], [11]), that is well tested against laboratory experiments at low and high strain-rates ([11]) and other hydrocodes ([6]).

For both the basins, we considered a similar setup. We hypothesize a rock projectile, strikes the surface at 30 km/s (typical velocity on Mercury's orbit accounting for the 45° impact angle) ([4]). The target is made up by a 40-km basaltic layer, overlying a dunite 70-km thick mantle. The thermodynamic behavior of each material is described by tables generated using the Analytic equation of state (ANEOS). In addition, a constitutive model is necessary to account for changes in material shear strength resulting from changes in pressure, temperature and both shear and tensile damage ([2]). However, in the case of large impact crater formation, this must be supplemented by a transient target weakening model, called acoustic fluidization model, that facilitates the gravitational collapse responsible for the development of central peaks and terraced walls ([10]). This one is implemented in iSALE using the "block-model", which is mainly controlled by the viscosity and the decay time.

We had carried out a series of simulations over a broad parameters range with the goal to fit the DTM profiles obtained from the data acquired during the MESSENGER flybys ([7]).

4. Summary and Conclusions

In this work, we have investigated via numerical modelling the impact process of two interesting peak-ring basins on Mercury, Rachmaninoff and Raditladi, which were found to originate long after the Late Heavy Bombardment, at a time when the primary source of impactors was a NEO-like population.

The projectiles responsible for Rachmaninoff and Raditladi formation resulted to be in the range of 13-15 km, in quite well agreement with [5], who gave instead their esteem on projectiles dimensions on the basis of scaling laws considerations.

My best–fit model reproduces both the rim and peak–ring diameters derived from DTM profiles, whereas the depth of the final crater is overestimated, suggesting to take into account other acting mechanisms, like dilatancy or melt production.

Acknowledgements

We gratefully acknowledge the developers of iSALE, including Gareth Collins, Kai Wünnemann, Boris Ivanov, Jay H. Melosh, and Dirk Elbeshausen (see www.iSALE-code.de).

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