THERMAL AND VOLCANIC EVOLUTION OF SMALL PLANETARY BODIES: ROLE OF IMPACT PROCESSES THROUGH SHOCK HEATING AND INSULATING EJECTA DEPOSITS

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Introduction: The cooling history of condensed cosmic bodies (let it be a small planet or an asteroid) determines its tectonic and volcanic evolution and is thus very important for explaining the bodies' present state. Planetary cooling is controlled by the efficiency of heat transport, composed of thermal convection in icy or silicate mantles, thermal diffusion across internal boundary layers such as the lithosphere or crust as well as secular cooling (due to the decreasing concentrations of radiogenic isotopes). However, the steady and continuous rate of thermal evolution of planetary bodies in the solar system has been punctuated by impact and collision processes, in particular during the early stages of planetary evolution.

Impacts transmit energy to the target body and cause substantial melting due to shock heating [1,2]. We do not consider the most extreme impacts like the Moon-forming event here, but several impacts in the bombardement history have probably been large enough to melt large fractions of the target mantle (up to the scale of magma oceans), which may explain the origin of some first-order features like the Martian crustal dichotomy, and subsequent formation of the Tharsis volcanic province [3,4] or the filling of some lunar impact basins with mare basalts [5]. Impact heating may also change convective planform [6] and even penetrate into the core [7], thus, modifying core heat flow and perhaps causing cessation of the Martian dynamo [8].

Such dramatic consequences usually require giant impacts, which are limited to early stages of planetary evolution, after which heavy bombardement ceased. However, impacts also affect the long-term cooling history, since they excavate target material, which finally forms poorly conductive ejecta deposits [1] that cause thermal insulation and make planetary cooling less efficient. [9].

For instance, the Moon is most likely covered with a several km thick layer of megaregolith, which can sufficiently prevent cooling and may explain the presence of young lava flows [10]. Recently, a megaregolith layer has also been suggested to moderate Mercury's surface heat flow, which places bounds on the content of heat producing elements in the interior [11].

This study: Origin and timing of many geological and volcanic features (e.g. the lunar mare basalts) on planetary surfaces still remain controversial, at best. While the possible importance of large impacts in explaining such features has been demonstrated, their effective role in planetary cooling and thus the lifetime of tectonic activity is not yet well-enough understood. Moreover, the lack of direct observations and measurements, make the properties of insulating ejecta deposits not well-known. For simplicity, there are usually assumed to be spatially uniform, which is unlikely to be the case and questions e.g. the validity of proposals of bulk heat flux and subsurface Thorium distribution for the Moon [12].

In this study, we aim for a more self-consistent coupling of the effects of impact cratering, i.e. shock heating and insulation by ejecta blankets and the cooling of the impacted body in order to shed light on the role of a planet's bombardement history in its thermal and volcanic evolution.

Methodology: Our methodology is twofold: *(i)* self-consistent formation of the ejecta blanket caused by impact craters, *(ii)* thermal evolution of the target body. For the latter, we will use the shock physics hydrocode *iSALE-2D* [e.g.,13-15], which allows for estimating the post-impact energy budget and also the ballistic trajectories of ejecta material, i.e. ultimately the deposition location and local thickness of the ejecta blanket. Its thermal conductivity will assumed to be constant in the initial calculations here, but more complexity will be included later.

Thickness and effective conductivity determined as a function of impact properties then characterize a (partial or global) layer of megaregolith that is plugged into the mantle convection code *StagYY* [16].

This will be combined with the heat anomaly caused by impact itself due to shock heating, which can be obtained from the pre-calculated hydrocode models. With that, we can study the cooling history of a generic target body including conductive, convective, and secular cooling as well as impact heating and megaregolith insulation.

While we ultimately want to incorporate bombardement sequences that can be inferred from crater chronology [17], we start here with a single impact (and its subsequent ejecta deposition) on a target body with size and structure of the Moon (Fig.1).

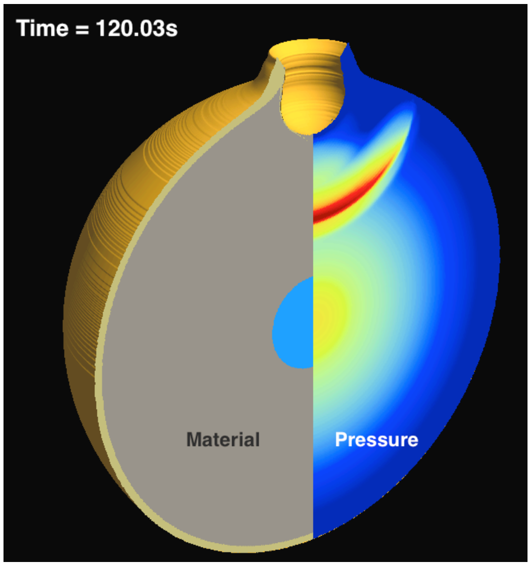

Fig. 1: Impact on a Moon-like target, modeled using iSALE-2D. The shock front is clearly visible in the pressure field.

Results and Expectations: Since this project has just been initiated, we will present preliminary proof-of-concept results. Based on previous findings [e.g., 9-12], we expect insulating regolith layers to have significance in the cooling history of target bodies as large as the Moon and Mercury. This should lead to spatially heterogenous cooling visible in surface heat flux with potential implications for spatial heterogeneity in volcanic activity.

Future Directions: Besides systematic variation of the input parameter space in our simple setups, we will in future refine our approach by assuming different target bodies in terms of size and structure, and by assuming a whole bombardement history of multiple impacts [18]. Further steps will include the improved estimation of effective conductivity by considering the role of packing fraction and compaction of the insulating layer [19].

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Acknowledgment: TR and SCW receive funding from the Research Council of Norway through the Centre of Excellence funding scheme, project number 223272 (CEED) and are supported by the IS-DAAD mobility grant NFR244761/F11. KW, RL, and MS are supported by the IS-DAAD mobility grant 57159947. The authors further like to acknowledge the *iSALE* core developers, including Gareth Collins, Dirk Elbeshausen, Boris Ivanov and Jay Melosh.