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Mapping the crust/mantle boundary with the Moon Mineralogy Mapper instrument data

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1. Introduction

Determining the composition and structure of the lunar crust is crucial to study its origin and evolution [5]. Several space missions were sent to the Moon in order to study its gravity field, which can be used to derive information about its crustal thickness [9]. Results from the Clementine mission (1990s) suggested a lunar crustal thickness varying between 20 and 120 km [6], and enabled studies of the mineralogy of the lunar crust [8]. From September 2011 to December 2012, the Gravity Recovery and Interior Laboratory (GRAIL) mission acquired more precise gravimetric data from the Moon. GRAIL data suggest a significantly smaller average lunar crustal thickness between 34 and 43 km depending on the model considered [9]. This survey aims to study the crust/mantle boundary region, and evaluate the lunar crustal thickness using impact craters as natural drill holes. To this end, the proximity to the mantle was calculated for all craters in the lunar crater database, using the method described in [4]. Craters that fall within a specific proximity range, diagnostic of the crust/mantle boundary region, and with preserved central peaks are selected for further investigations. The mineralogy of the selected craters central peaks is derived from the Moon Mineralogy Mapper (M^3) data [7] to evaluate the presence or absence of mantle material. One ultimate goal is to place constraints on the crust/mantle boundary depth and mineralogy, and assess which GRAIL model(s) best describe the Moon crust.

2. Approach

2.1 Proximity value

New crustal models were derived from the gravity measurement of the recent GRAIL mission to the Moon [9]. A set of 4 models is available making variable assumptions (crustal porosity, crustal thickness, mantle density, ...). For each model, pre-impact crustal thicknesses (calculated as in [4]) were compared to the estimated depth of origin of the central peak material. The proximity to the mantle is defined as the difference between the pre-impact crustal thickness, and the depth of origin of the material [1, 4]. In this study, the maximum depth of melting is assumed to be equal to the minimum depth of origin of the central peak material, as suggested by [3]. If the proximity has a negative value, the impact potentially exposed material from below the crust/mantle boundary in the central peak of the resulting crater. On the contrary, if the proximity value is positive, the mantle material should not have been excavated by the impact [4]. Therefore, the proximity value gives the original distance between the material of the central peak and the crust/mantle boundary, before the original layer was disturbed and uplifted by the impact.

2.2 Data

In order to map the crust/mantle boundary depth, a subset of craters with proximity values ranging between – 10 and + 10 km on the various GRAIL models was selected. For each crater, a combination of Lunar Orbiter Laser Altimeter (LOLA) and Lunar Reconnaissance Orbiter Camera (LROC) observations were used to verify the presence of a preserved central peak. The composition of the central peaks of these craters is being investigated with M^3 data.

M^3 is a hyperspectral imager onboard Chandrayaan-1 which acquired visible and near infrared (VNIR) reflectance data in 85 spectral channels spanning from 430 to 3000 nm. M^3 data are available over most craters of our selection with a spatial resolution of 140 or 280 m/pixel. The data used in this study are the Level 2 delivery from the Planetary Data System (PDS).

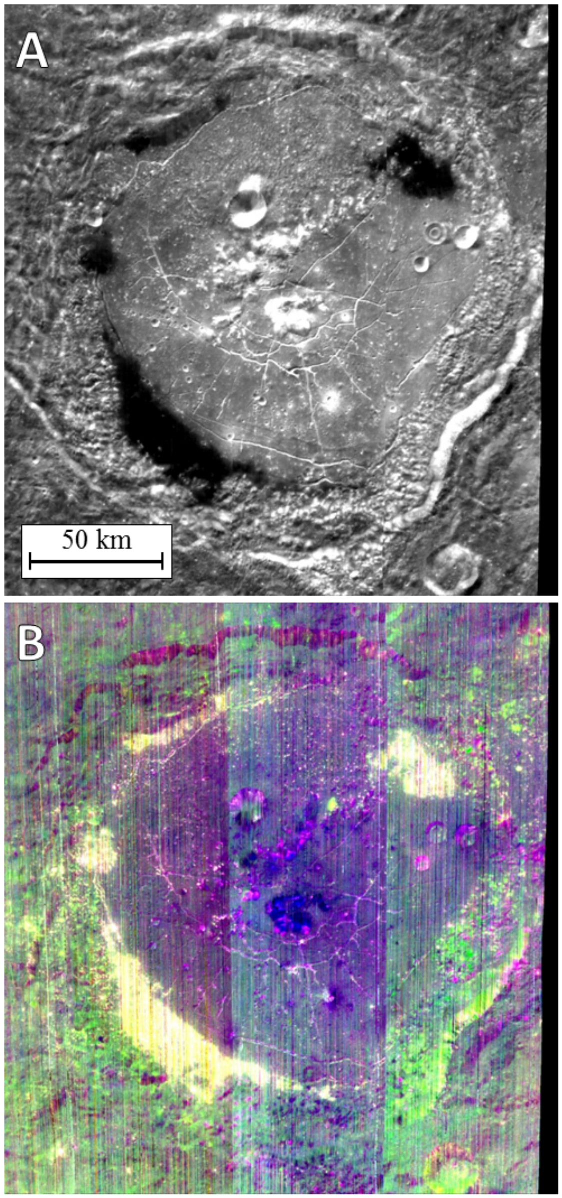

Figure 1: Humboldt crater M^3 mosaic. **A**: 1508 nm band; **B**: RGB colour composite of spectral parameters: R = integrated 1000 nm band depth, G = integrated 2000 nm band depth, B = 1250 nm band depth.

3. Preliminary Results

Figure 1 shows a M^3 frame (**A**) and a colour composite mosaic (**B**) of Humboldt crater. The selected colour composite displays parameters that should highlight olivine-rich outcrops in red, and plagioclase-rich outcrops in blue. Figure 1 shows a blue-coloured central peak, where the detection of plagioclase is confirmed by a diagnostic 1250 nm absorption band on the associated spectra [2]. Olivine has not been detected in Humboldt crater; therefore, mantle rocks have not yet been identified in this crater. Humboldt crater proximity value is slightly negative with GRAIL model 1 (M1) and 2 (M2), but within the error bar, and positive with GRAIL model 3 (M3) and 4 (M4). Therefore, it seems likely that the Humboldt impact did not reach the crust/mantle boundary.

Further work will extend the study with a larger amount of craters, and could first focus on craters in the vicinity that display lower proximity values than Humboldt crater.

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