NEW ESTIMATION OF LUNAR MARE BASALT THICKNESS BASED ON PARTIALLY BURIED CRATERS. J. Du, W. Fa, M. A. Wieczorek, M. Xie, and M.-H. Zhu, 1Institute of Remote Sensing and Geographical Information System, Peking University, Beijing, China (jundu@pku.edu.cn), 2Université Côte d’Azur, Observatoire de la Côte d’Azur, CNRS, Laboratoire Lagrange, Nice, France, 3Lunar and Planetary Science Laboratory, Macau University of Science and Technology, Taipa, Macau.

Introduction: Lunar mare basalts are magmatic materials that were generated by partial melting of the mantle. The thickness of mare basalts is of great scientific significance as it can be used to constrain the thermal evolution of the Moon [1]. Mare basalt thicknesses can be estimated using several different techniques, such as lava flow front height measurements [2], impact cratering techniques [3], subsurface radar sounding [4], and geophysical techniques [5]. Many of these techniques are model-dependent, and the results vary from several meters to several kilometers.

Among these methods, the morphology of partially buried craters is one of the simplest methods for mare basalt thickness estimation. On the Moon, the continuous ejecta of normal, unflooded craters usually extend about one crater radius from the crater rim. If the distal, low-elevation ejecta were flooded later by basaltic lava flows, the extent of the continuous ejecta would be smaller and there would be an abrupt transition between the ejecta and lava flow in both elevation and albedo maps. For these craters, the mare basalt thickness can be estimated using the difference in the heights of the rim (which is known for fresh craters [6]), and the surrounding region [3].

Using topography from the Apollo stereo-images, De Hon estimated the basalt thickness in the eastern mare basins to be 200–400 m [3]. However, lunar craters suffer from continual meteoroid bombardment, and as a result, the crater diameter increases and rim height decreases over time [7–9]. In such a case, if the rim height of a fresh crater were used to estimate the mare basalt thickness, the thickness would be overestimated [10].

Recently acquired remote sensing data with unprecedented spatial resolution and quality make it possible to re-assess mare basalt thicknesses using partially buried craters. In this study, we constructed a new global database of partially buried craters using the recent orbital data, and then estimated the mare basalt thicknesses using a model that includes the degradation of topographic relief over time [7].

Mare Basalt Thickness Estimation Method: The principle of mare basalt thickness estimation in our study is based on numerically modeling the elevation, flooding, and degradation of impact craters (Fig. 1). After a crater forms (red), it begins to erode by meteoroid bombardment (green), which is modeled as a diffusive process with a corresponding topographic diffusivity [7]. At a given time (which can be estimated, e.g., from crater-counting), the basaltic lava flow floods and embays the crater, leaving only the rim crest protruding above the mare plains (blue). After flooding, the crater continues to degrade to its present state (magenta). By modeling the topographic profiles in the above processes, mare basalt thickness can be estimated by minimizing the difference between the observed (black) and modeled crater profiles.

To estimate mare basalt thickness, a fresh crater profile is required as the initial condition. We selected 37 of the freshest craters from an optical rayed crater database [11] and produced six types of fresh crater profiles, including simple, transitional, and complex craters over maria and highlands. In our study, the crater profiles extend three crater radii from the crater center, and the best-fit basalt thickness is found by using the sequence quadratic polynomial optimization algorithm that searches for the global minimum in the model parameter space [12].

Results: To identify partially buried craters over the maria, we examined all the craters larger than 1 km in diameter in reflectance (LROC/WAC [13]), topography (SELENE–LRO merged SLDEM [14]), and composition (SELENE/MI [15]) maps. In total, 76 partially buried craters with completely exposed rim crests were identified. The crater diameters range from 1.4 to 43.5 km, and the craters are in general distributed uniformly across the maria (Fig. 2).

Fig. 1. Case study of the crater Helicon: modeled and observed topographic profiles.
Fig. 2. Spatial distribution of the estimated basalt thicknesses, superposed on a mare basemap (gray) [16] with basaltic units outlined in white [17].

The inverted basalt thicknesses vary from 2 to 447 m, and the median value is 85 m (Fig. 2), which is significantly smaller than that obtained without considering the rim erosion process (162 m). This reduction in the estimated basalt thickness is ~20–40% of the previously predicted basalt thickness in the eastern mare basins [3]. Taking the crater Helicon (one of the most eroded craters) as an example, the best-fit profile suggests that the inverted basalt thickness is 316 m (Fig. 1), which is significantly smaller than 485 m if crater degradation is not considered [3].

**Discussions:** We compared our basalt thickness estimates with those obtained from crater excavation depth, radar sounding data, lava flow front heights, and other geophysical techniques. For the region near Bobillier crater, our result (109 m) agrees with those derived from crater excavation depths (71–209 m) and radar observations (100–210 m) [4]. In the interior region of Lee M crater, our result (22 m) is slightly smaller than the estimate using lava flow front height measurements (30–60 m), and this discrepancy may arise from the natural variability of lava flow thicknesses. For the Seleucus crater region, our inverted basalt thickness (447 m) is much larger than that derived from the gravity and topography technique (160 m) [5]. These two results, however, represent different spatial scales: our result is for a region of three crater radii (66 km), whereas the result from the gravity and topography analyses is for a region covering ~660 km [5].

With knowledge of the surface area, thickness, and exposure age of a specific basaltic unit, we are able to calculate the cumulative basalt volumes as a function of time, and the eruption rate, which is simply the derivative of the cumulative plot (Fig. 3). The cumulative basalt volumes serve as a lower limit, since there are many basaltic units where no partially buried craters exist. The eruption rate is found to decrease with time with a main peak at ~3.7 Ga and a secondary peak at ~3.45 Ga, implying that the interior of the Moon was gradually cooling down [17]. As a byproduct of this study, we can also constrain the diameter- and temporal-dependences of topographic diffusivity. Our initial results imply that the topographic diffusivity increases with crater diameter but is approximately invariable with time.

**Conclusions:** In this study, a global database of partially buried craters was constructed, and a revised basalt thickness estimation method was developed that takes into account the crater degradation process. Our estimated basalt thicknesses are significantly smaller than those obtained without considering crater degradation. The derived eruption rate of lunar mare basalts deceased with time, indicative of a cooling process for the interior of the Moon across the lunar history.

![Eruption rate of mare basalts](image-url)

**Fig. 3. Eruption rate of mare basalts.**