HOW THICK ARE LUNAR MARE BASALTS? F. Hörz, NASA Johnson Space Center, Houston, TX 77586

Quantification of the total volume of basaltic melts which flowed onto the lunar surface and which preferentially accumulated inside the major impact basins (= mare) is fundamental to our understanding of lunar thermal and petrogenetic evolution. Because basaltic surfaces are photogeologically recognized with relative ease, the total surface area occupied by mare basalts is fairly well established at \( \approx 6.3 \times 10^6 \text{km}^2 \) or \( \approx 17\% \) of the total lunar surface (1). The somewhat elusive parameter to complete accurate volume determinations therefore remains the absolute depth(s) of basaltic mare fill. Two types of mare basins must be distinguished (1,2,3): (a) relatively old, irregular structures with generally shallow basalt fills (e.g., Fecunditatis, Nectaris, Procellarum) and (b) relatively young circular basins with deep interior fills (e.g., Imbrium, Serenitatis and Crisium). Head (1) estimates the shallow maria to occupy \( \approx 4.6 \times 10^6 \text{km}^2 \), while the "deeper" fills make up the remaining \( \approx 1.7 \times 10^6 \text{km}^2 \). According to (1), the total mare basalt volume is \( \approx 10 \times 10^6 \text{km}^3 \), using 1000 m and \( \approx 5900 \) m average basalt thicknesses for the shallow and deep basin fills, respectively.

DeHon (3,4) determined detailed mare basalt thicknesses and produced isopach maps for most of the shallow basins by measuring the rim height of "ghost craters," inundated but not completely filled with basalt. This report expands on DeHon's work by modifying and reevaluating his preferred model crater geometry, which is that for the most pristine and unmodified crater structures as determined by (5). It is our view that such "ghost" craters displayed a wide range of degradational states at the time of basalt flooding; not all of them were perfectly fresh as assumed by DeHon. Therefore a population of 72 highland craters \( \approx 10-100 \) km in diameter was selected at random and their rim heights relative to the surrounding terrain were obtained using LTO maps (1:250 000 scale); typically 3-5 profiles per crater were generated. Fig. 1 illustrates the results for (a) individual profiles, (b) averages for each crater and (c) compares these data to the fresh crater geometries of (5, 6). Furthermore, curves are shown (75%, 50%, 25%) which simply express the craters' degradational state in terms of decreased rim height (= x%) relative to the fresh case (= 100%) of (5). Relative decrease of rim height was computed for each individual crater and the results are summarized in differential and cumulative form (Fig. 2). Assuming that our random crater population is indeed representative for all lunar craters, it can be seen that the "median" lunar crater will have a rim height which is only about 58% of the original one. The above measurements imply that DeHon's basalt thicknesses may be as much as a factor of 2 too high. The isopach maps of DeHon were thus reduced by a factor of 2 and planimetric results of corresponding thickness estimates are given in Fig. 3. These thicknesses are substantially smaller than the average thickness of 1000 m used by (1); corresponding basalt volume estimates of (1) for the shallow basins may have to be decreased by factors of 3-5.

These overall basalt thicknesses are surprisingly shallow. They are, however, in our view, consistent - if not supported - by a variety of other lunar observations, i.e., sample evidence, regolith evolution models and remote sensing studies as briefly outlined in the following: As illustrated

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in Fig. 4 (from 7) the amount of highland derived lithologies decreases exceedingly rapidly in soils from adjacent mare basalt surfaces to a value of 15-25%, the typical amount of highland "contamination" for intrabasin landing sites on basaltic substrates. These findings can be extended to all mare basins via remote geochemical sensing (e.g., 8,9). Thus regoliths on basaltic substrates are substantially contaminated by lithologies of anorthositic and gabbroic affinities, i.e., typical highland components. Previous studies (7, 8,9) indicate a lack of large scale geochemical gradients at highland/mare contacts which argues against efficient lateral transport of highland lithologies across mare surfaces. Furthermore similar conclusions may be derived from IR spectral and color ratio measurements (e.g., 10 and 11): In order to match remote spectral data as precisely as is routinely done with photogeologic terrains, significant lateral transport could not have occurred even between adjacent basalt-types; otherwise the contacts would be more smeared and fuzzy. Additional evidence against significant lateral transport over distances >>10 km is also indicated by the cratering calculations of (12 and 13). Most importantly, (14) finds only <1% of basaltic components in our only bona fide highland landing site, i.e., Apollo 16.

Given the above qualitative evidence for relatively inefficient lateral transport, a vertical mixing of highland components underlying the basaltic fill appears highly probable. Consulting the Monte Carlo calculations on lunar regolith evolution by (13), average source depths for such substrate materials are on the order of 100 m [see Fig. 5; (15) adopted from (13)]. Thus if(!) vertical mixing plays any role at all in contaminating basaltic regoliths with appreciable amounts of highland components, basalt depths of >500 m present great difficulties (see 13).

In conclusion it is suggested that previous mare basalt thickness estimates are too high, in particular for the old, irregular basins; for the younger, circular basins, basalt thicknesses are unknown but could be significantly shallower than the estimated ~6 km (1). If part of the basalt fill were replaced by a thick, coherent sheet of impact melt at the crater bottom, the mascon constraints on the previous basalt estimates would be partially alleviated. The newly obtained basalt thicknesses together with a somewhat irregular relief of the basin floors at the time of basalt extrusion not only allow approximately the proper degree of vertical mixing, but this mechanism very conveniently accounts for the surprisingly homogeneous distribution of non-basaltic contaminants, because it operates on local scales via a large number of relatively modest sized impact craters.

References:
Fig. 1: Rim height measurements for a random population of craters >10 km in diameter.

Fig. 2: Frequency of occurrence of various degradational states (differential histogram and cumulative curve).

Fig. 3: Cumulative surface percent occupied by basalt of various thicknesses.

Fig. 4: Isotopic composition of highland and mare basalts from (a) and (b). Source depth(s) of various volume fractions of regolith for (a) and (b). Isotopic composition of highland and mare basalts from (a) and (b). Source depth(s) of various volume fractions of regolith for (a) and (b).

Fig. 5: How thick are lunar mare basalts?