Thicknesses of lunar lava flows: Comparison of layered mare units with terrestrial analogs

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Abstract. The Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) returns images with greater than 0.5 meter resolution, revealing layered deposits in the lunar maria. Many layers are interpreted to be sequences of basalt flows in the walls of impact craters and in pit craters, thought to be skylights above ancient lava tubes. Since the Apollo era, remote sensing and ground observations have estimated thicknesses of mare basalt flows to range from less than one meter up to 60 m or greater. Recently, thicknesses of individual layers measured using LROC NAC imagery of both pit craters and impact craters ranged from 2–14 m. Caution must be exercised in the interpretation of surface processes from morphologies of features that are close to the limits of resolvability because our knowledge of surface processes, including lava flow emplacement, on the Moon is not fully developed.

We have conducted terrestrial analog studies to assess the accuracy of basalt flow thickness measurements in high-resolution lunar imagery. We mapped layered basalt flow sequences in valley walls in the Wai'anae and Ko'olau Ranges of O'ahu, Hawai'i, using WorldView-2 satellite images. Subsequent fieldwork allowed for validation of image interpretations through thickness measurements of in situ lava flows. Of the eight transects studied at three field locations, seven revealed WorldView-2 imagery average thickness estimates that were greater than average thicknesses measured in the field. Average image-derived to field-observed thickness ratios varied up to 6.3. A primary reason for this overestimation by remote sensing analysis is that many outcropping layers within a transect contain more than one individual flow, a distinction that is not visible in satellite imagery. The dense cores of 'a'ā flows are commonly resistant to erosion and provide protection for underlying layers, particularly more easily eroded pahoehoe flows or 'a'ā clinker, leading to single outcrops which contain several lava flow units.

LRO NAC image measurements of layered mare basalts in the walls of impact craters provided flow thicknesses 2–5 times greater than those derived from images of the O'ahu study sites. Lunar outcrops may contain more than one individual flow similarly to terrestrial outcrops, suggesting that estimates of lunar flow thicknesses are greater than actual flow thicknesses. Therefore, interpretations of lava flows in high-resolution lunar imagery may underestimate the number of flows present in a layered sequence and consequently overestimate the flow thickness. Current measurements of lava flow thicknesses derived from planetary images should be interpreted as maximum thicknesses. The accuracy of mare flow thickness measurements has broad implications for lunar exploration, for understanding of the thermal evolution of the Moon, and for the preservation potential of exogenous volatiles implanted in lunar paleoregoliths that were subsequently covered by active basalt flows.