
The determination of the thickness and volume of volcanic deposits on planetary crusts is an important step in assessing the timing, location, and significance of internal activity and thermal history. A review of the approaches to determine volumes and thicknesses is given elsewhere. Also described there is a method to determine volumes and thicknesses using topographic maps of unflooded regions and artificially flooding the known topography, tracking area covered, total and average thicknesses, and volumes. Lunar highland terrain flooded in such a manner shows average lava thicknesses of at least 2 km.1

One of the major difficulties in determining volcanic deposit thicknesses in many lunar maria is the fact that they occupy relatively young lunar basins. The relative youth of the basins means 1) that there are fewer post-basin craters that can be used to determine basalt thickness by conventional methods,2 and 2) that the geometry of the young basins is sufficiently deep so that many craters are completely covered. The purpose of this paper is to report on the artificial flooding of two areas in order to obtain thickness and volume estimates for multi-ringed basins flooded by mare deposits.

The major topography of multi-ringed basins, as revealed by the relatively unflooded Orientale basin3,4,5,6 consists of an inner depression several kilometers deep, surrounded by an extremely irregular and rough topography comprised of basin rings and associated facies within the major scarp defining the basin (the Cordillera Mountains for Orientale). Some basins are flooded out to this outer scarp (Imbrium, in many places, for example), others are flooded only to the major second ring (Serenitatis7), while others are flooded primarily in the inner depression (Orientale8 and Nectaris). Two separate areas are treated here: the Orientale basin, and the Archimedes-Apennine Bench region, which represents the region between the second and third basin rings in Imbrium.

Topography for the Orientale basin was derived from a series of limb profiles and is consistent with topography determined from other sources.4,6 Data exist for only slightly over half the basin; this topography was assumed to be characteristic of the rest of the basin and the values in Fig. la,b reflect flooding of the whole basin. Since the basin interior is known to vary in morphology from east to west,5 actual topographic data from the west would undoubtedly modify details of the curves, but the general shapes would very likely remain the same. The interior of Orientale contains maria perhaps up to one kilometer thick,6,8 and several thinner patches at the base of the second and third rings.8 Using a computer-generated topographic map derived from these data, the present topography was flooded and the volumes and area covered were tracked at one kilometer intervals. The area covered as a function of each additional km is shown in Fig. 1a. The flooding takes place in two major stages. The inner depression of Orientale is covered at an area of about 80 x 10^3 km^2 and a lava thickness of between 3 and 4 km. The inner Roche Mountain ring (peak ring) is reached at an area of about 180 x 10^3 km^2 with an additional 2 km of lava added. In this first stage the emphasis is on filling of the pronounced inner topographic depression: three-fourths of the total thickness is added during this stage (about 6 km); however, less than one-third of the total area and less than one-half the total volume are added. The second stage emphasizes the flooding of the region between the inner depression and the basin-defining scarp (Cordillera Mountains). An additional two kilometers is required to flood the basin to the Cordillera ring.
LAVA FLOODING OF IMPACT BASINS

Head, J.W.

point only a few peaks are present in the basin interior and parts of the Cordillera ring are flooded (the map pattern is similar to that seen in southern Mare Imbrium in the Carpathian Mt.-Copernicus region). The addition of these two kilometers triples the area covered by lava, and doubles the volume of lava in the basin (Fig. 1a,b).

A further assessment of the second stage of fresh basin flooding can be obtained by analysis of the Archimedes-Apennine Bench region. This is a relatively unflooded region of the Imbrium basin lying between the second ring and the outer (third) Apennine Mountain ring. Some mare deposits exist in the area and the region may have been the site of post-Imbrium, pre-mare, volcanism; thus, estimates for lava filling are probably conservative. A region centered on Palus Putredinis (NASA MAP LM41, MONTES APENNINUS, 1:IM SCALE) was artificially flooded at 300 m intervals using procedures described elsewhere. Over one-half the total area was covered by the addition of 900 m of lava. An additional 1800 m were required to cover most of Montes Archimedes (a portion of the second basin ring). At the termination of flooding, several small areas of Montes Archimedes (standing 200-400 m above the surrounding plain) and the vast majority of the Apennine Mountains remain unflooded. Total thickness to flood to this level is 2.7 km. Average thickness of lava (total volume/total area) is 1.99 km.

Discussion and Conclusions - The relatively unflooded and fresh basin geometry of Orientale and parts of Imbrium provide insight into lava thicknesses in flooded parts of similarly fresh basins. Inner basin fill could be up to 8 km thick in a basin such as Orientale, with average thickness within the peak ring between 4 and 5 km. Thus, the load on the lithosphere represented by this material is clearly concentrated in the basin interior. In addition, if relatively old lavas are exposed on the surface of the maria, it is very likely that they also have filled in this part of the basin interior, and that their volumes are thus considerably greater than implied by their present surface exposure area. Average thicknesses required to cover topography around the outer shelves of the basins is around 2 km. Average values for the inner and outer parts of extensively flooded fresh basins are considerably greater than values for which extensive vertical mixing of the submare material might be expected. Average thickness values in older, more degraded basins should be less. Despite locally great thicknesses, the total volume of lava in the lunar maria still appears to be less than 1% of the total volume of the lunar crust.

Figure 1a

Figure 1b

Figure 2a

Figure 2b