Evolution of Gas Content and Foam Distribution in Lunar Floor-Fractured Craters

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Lunar floor-fractured craters are a class of lunar craters comprising ~170 craters with anomalously shallow, and fractured floors. Recent morphologic studies have supported the hypothesis that floor-fractured craters were formed by the intrusion and evolution of a shallow magmatic body beneath the crater. Further support for this hypothesis comes from the association of volcanic morphologies such as pyroclastic deposits and mare deposits with the fractures of floor-fractured craters. Here we focus on the evolution of volatiles within these magmatic intrusions, including the formation of magmatic foam and the timing of intrusion degassing. The primary lunar magmatic volatile has long been identified as CO, produced by smelting reactions under specific pressure-sensitive condition. However, new analyses enabled by reexamination of Apollo samples of pyroclastic deposits have identified several additional contributing volatile phases including H_2O, S_2, F_2, and Cl_2. To begin constraining the volume of magmatic foam within the intrusion, we use the observed range of pyroclasts to calculate eruption velocity, and from the eruption velocity, calculate the magmatic volatile gas fraction and gas volume fraction. To use the crater Alphonsus as an example, the average dark halo crater radius is 3-4 km, which implies a gas volume fraction of 72.8% at the time of eruption. This is within the critical gas volume fraction range for initiating bubble collapse and eruption, and consistent with efficient volatile degassing and rapid foam formation during sill formation. New work on the ascent and eruption of dikes on the Moon proposes that the upper several kilometers of the dike will be composed of this magmatic foam. If the dike stalls in the upper few kilometers of the lunar crust, as in the case of lunar floor-fractured crater intrusions, the magmatic foam will concentrate in the center of the intrusion while the more degassed magma will spread laterally to form the initial sill. The magmatic foam will subsequently expand laterally to fill the entirety of the sill, and this process is likely to be quite energetic. Thus, we propose that the fractures hosting pyroclastic deposits likely form after the initial boundaries of the sill are established, but still during the overall process of sill formation. This process of outward foam expansion also explains the location of most pyroclastic vents and fractures, which are near the crater wall but not at edge of the sill where peripheral faults would be expected to form. The degassing events are likely to be localized events, leaving large volumes of magmatic foam in portions of the sill not adjacent to fractures. Support for this hypothesis comes from GRAIL Bouguer gravity data which shows evidence for high density anomalies, interpreted to be degassed basalts, beneath fractured floor regions and lower density anomalies, interpreted to be non-degassed basalts beneath regions lacking fractures. Ongoing work includes assessing the possibility of multiple eruptions from the same vent. This research makes several predictions about pyroclastic vent and fracture systems which could be tested by future exploration missions, such as the proposed mission to Schrodinger Basin.