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Magmatic intrusions in the lunar crust

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Abstract

The lunar highlands are very old, with ages covering a timespan between 4.5 to 4.2 Gyr, and probably formed by flotation of light plagioclase minerals on top of the lunar magma ocean. The lunar crust provides thus an invaluable evidence of the geological and magmatic processes occurring in the first times of the terrestrial planets history.

According to the last estimates from the GRAIL mission, the lunar primary crust is particularly light and relatively thick [1] This low-density crust acted as a barrier for the dense primary mantle melts. This is particularly evident in the fact that subsequent mare basalts erupted primarily within large impact basin: at least part of the crust must have been removed for the magma to reach the surface. However, the trajectory of the magma from the mantle to the surface is unknown.

Using a model of magma emplacement below an elastic overlying layer with a flexural wavelength Λ, we characterize the surface deformations induced by the presence of shallow magmatic intrusions. We demonstrate that, depending on its size, the intrusion can show two different shapes: a bell shape when its radius is smaller than 4 times Λ or a flat top with small bended edges if its radius is larger than 4 times Λ [2]. These characteristic shapes for the intrusion result in characteristic deformations at the surface that also depend on the topography of the layer overlying the intrusion [3].

Using this model we provide evidence of the presence of intrusions within the crust of the Moon as surface deformations in the form of low-slope lunar domes and floor-fractured craters. All these geological features have morphologies consistent with models of magma spreading at depth and deforming an overlying elastic layer.

Furthermore, at floor-fractured craters, the deformation is contained within the crater interior, suggesting that the overpressure at the origin of magma ascent and intrusion was less than the pressure due to the weight of the crust removed by impact [3]. The pressure release due to material removal by impact is significant over a depth equivalent to the crater radius. Because many of these floor-fractured craters are relatively small, i.e. less than 20 to 30 km in radius, this observation suggests that the magma at the origin of the intrusion was already stored within or just below the crust, in deeper intrusions.

Thus, a large fraction of the mantle melt might have been stored at depth below or within the light primary crust before reaching shallower layers. This, in turn, should have influenced the thermal and geological evolution of this crust.

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References

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