Magma Reservoirs and Neutral Buoyancy Zones on Venus: Implications for the Formation and Evolution of Volcanic Landforms

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Fig. 4. Critical pressure levels during magma ascent. Nucleation and disruption levels in the rising magma are shown. Venus basalts with typical terrestrial volatile contents will nucleate volatiles but will not reach disruption levels.

Fig. 12. Summary illustration of the effects of the Venus environment on the location and development of deep magma reservoirs and shallow magma reservoirs at density traps, and the consequent edifice/reservoir relationships. A large deep reservoir (feature 1) forms at base of viscous lid from pressure-release melting of mantle plume. Reservoir is continually fed by buoyant rise of plume tail and builds to very large size. Overpressurization of reservoir by new magma pulses causes lateral dike propagation (feature 2) and formation of radial surface fractures and graben (feature 3). If large reservoir is buffered by continual magma supply, radial dikes may extend (feature 3) for many hundreds of kilometers (Parfitt and Head, submitted manuscript, 1991). Under some conditions, dikes will reach surface and cause eruptions. Large size of reservoir suggests that these eruptions will produce long flows and contribute to the building of a low edifice above the reservoir. Buoyant rise of magma to shallow neutral buoyancy zone (feature 4) creates shallow, smaller reservoir. Shallow reservoir overpressurization also causes lateral dike emplacement and eruption of smaller volume and extent (high atmospheric pressure inhibits gas exsolution at all depths, minimizing further vertical magma migration from reservoir). These also contribute to the building of the edifice, however, the reservoir does not migrate vertically rapidly and this grows larger and remains mostly in the prevolcano substrate (feature 4), leading to the broader, lower profiles typical of Venus volcanoes. Subsequent evolution of the plume and deep magma reservoir (decrease thermal flux and subsidence, cooling and magma volume decreases subsidence due to load, etc.) causes megacaldera formation. Relative processes in the shallow magma reservoir cause smaller calderas to form (feature 5). Large reservoirs enhance differentiation process (volatile enhancement, fractional crystallization, substrate remelting) which result in buoyant rise of magmas to produce domes of high viscosity material (feature 6).
neutral buoyancy (Christensen, 1982).

Figure 10. The relationship between the lithologic succession for the Bay of Islands ophiolite complex and the reconstructed depth range for the paleo-horizon of neutral buoyancy. The paleo-horizon of negative buoyancy lies above the sheeted dike complex, within the pillow basalts. (Profiles are based on laboratory-derived acoustic velocities and have been summarized in Christensen, 1978.)

Figure 11. The relationship between the lithologic succession for the Troodos, Cyprus, ophiolite and the reconstructed depth range for the paleo-horizon of neutral buoyancy. (Compressional and shear wave velocity profiles are based on laboratory-derived acoustic measurements as summarized in Christensen, 1978.)

This would correspond to the transition interval between the region of negative buoyancy (porous, fractured basalts) and the region of neutral buoyancy (sheeted diabase dikes).
excess pressures and large volumes required do not favor extrusion. The paucity of surface deposits, however, strongly suggests that these requirements have not commonly been met in the last 10–20% of lunar history, but the record should continue to be examined with the possibility of relatively recent events in mind (Schultz, 1990).

**IMPLICATIONS FOR SECONDARY CRUST FORMATION**

The lunar mare deposits represent the formation of secondary crust derived by partial melting of the mantle (Taylor, 1989). On the basis of our examination and review, some trends and themes emerge that are relevant to secondary crust formation (Fig. 7):

1) **Dominance of primary crust.** The Moon is dominated by primary (highland) crust in terms of surface area and volume. The primary crust forms a continuous outer shell, and there is no continuous section of secondary crust throughout the crustal column (as there is in the Earth’s ocean basins) except possibly as a plexus of dikes in the interior of the largest young impact basins. The secondary crust on the Moon is superposed on a platform of primary crust as a discontinuous veneer that is usually less than 10% of the total crustal thickness and only very

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**Fig. 7.** Diagrammatic representation of the emplacement of secondary crust: the lunar example. At step 1, early basaltic magmas rise diachronically to the density trap at the base of the crust. Those below topographic lows (thin crust) associated with lunar impact basins are in a favorable environment for dike propagation and extrusion of lavas to fill the basin interior. Dikes reaching the base of the thicker crust on the farside and parts of the nearside (step 2) at the same time, stall and propagate dikes into the crust, most of which stall and solidify in the crust and do not reach the surface. Variations in regional and local compensation produce a favorable setting for emplacement of some lavas in craters and the largest basins on the farside (step 3). With time, the lithosphere thins and ascending dikes stall at a rheological boundary, building up excess pressure to propagate dikes toward the surface. At the same time, loading and flexure of the earlier mare deposits creates a stress environment which favors extrusion at the basin edge (step 5); lavas will preferentially emerge there, flowing into the subsiding basin interior. The latest eruptions are deepest and require high stress buildups and large volumes in order to reach the surface; thus, these tend to be characterized by high volume flows and sinuous rilles (step 6). Ultimate deepening of source regions and cooling of the Moon causes activity to diminish and eventually to cease.