Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 617

No Correlation Between the SiO_2 Content of Erupted Magma Type (basalt-andesite-dacite) and Crustal Thickness (~30-50 km) Along the Mexican Volcanic Arc

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Numerous studies in the literature argue that there is a strong correlation between the average SiO_2 content of arc magmas and crustal thickness. The model most commonly invoked to explain this trend describes the arc crust as a density filter to mantle-derived arc basalts. The general idea is that basaltic melts are preferentially erupted through relatively thin and dense oceanic crust, whereas they tend to stagnate at regions of neutral buoyancy near the base of thicker, more sialic continental crust. The model further assumes that mafic magmas under thick continental crust must differentiate toward less dense, more silicic compositions before ascent of magma to the upper crust and surface can resume. Here it is illustrated, using the Mexican volcanic arc, that the purported correlation between the silicic composition of arc magma and crustal thickness is not as robust as commonly thought. It is also shown that the concept of the arc crust as a density filter to mantle-derived arc magmas is flawed, as it does not account for the substantial effect of small amounts of dissolved water on reducing the density of mafic magmas.

The Mexican volcanic arc spans ~1000 km from the Pacific Ocean to the Gulf of Mexico. Crustal thickness is estimated (from gravity data and topographic elevations) to increase systematically from ~30-35 km in the west to ~45-50 km near Mexico City. Volcanic edifices fall within three broad categories: (1) large andesite-dacite stratovolcanoes (~20-500 km^3), (2) broad, andesitic shield volcanoes (~1-10 km^3), and (3) cinder and lava cones, with a median size of ~0.1 km^3. Discrete lava flows, erupted either from these central vents or along fissures, are typically <= 1 km^3. A first-order evaluation of erupted volumes clearly demonstrates that the first two categories of volcanic edifices are the dominant contributors to the total volume of erupted magma during the Quaternary period. Smaller, cinder and lava cones and discrete lava flows contribute < 20% of the total volume and yet account for most of the petrologic diversity. Nearly all of the high-MgO (> 8 wt%) lavas, for example, are found as small cinder and lava cones. The general conclusion is that magmas of andesite-dacite composition are overwhelming dominant from the west coast to Mexico City, irrespective of crustal thickness. Similarly, the occurrence of high-MgO arc lavas exhibits no correlation with crustal thickness. The eruption of high-MgO lavas through continental crust as thick as ~45-50 km is readily explained by their water contents, estimated to range up to at least 3-4 wt% (based on melt inclusions in olivine phenocrysts). The effect of dissolved water is to dramatically reduce melt density from 2.87 g/cm^3 under anhydrous conditions to 2.52 g/cm^3 at 4 wt% H_2O. Models of integrated crustal density near Mexico City suggest minimum water contents of ~2 wt% to allow buoyant ascent of primitive basalt. An alternative model, therefore, is to view the arc crust not as a density filter but rather as a thermal filter to hydrous, mantle-derived basalts. The hydrous nature of the basalts not only renders them less dense, but also more likely to "freeze" in the lower crust because of rapid crystallization of hornblende. The abundance of andesite-dacite can then be explained by partial melting this amphibole-rich, lower mafic crust when subsequent, mantle-derived basalts are intruded.