Time scales of mafic-silicic magma interactions

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Physical and chemical interaction between mafic and silicic magmas is considered to be a main process for triggering silicic explosive eruptions and for transferring geochemical signatures from the mantle to the crust. Here we determine the time scales between mafic-silicic encounters and eruption by exploiting the fact that during such interactions, compositional and temperature gradients are established and their decay will be governed by kinetic laws. Specifically, we model the Fe-Mg zoning patterns of olivine and thermal equilibration from a compositionally (dacite to andesite) and thermally (850 ^{o}C-950 ^{o}C) zoned eruption of Volcán San Pedro (36 ^{o}S, Chilean Andes). For modeling olivine we account for the anisotropy of Fe-Mg diffusion and for the effects of multiple dimensions, aspects that were largely neglected in previous works. Timescales for olivine-melt equilibration range from ~ 1 year for the silica-rich dacite to ~ 50 years for the andesite, whereas thermal constrains suggest homogenization times of a few years. This range of time scales reflects that the reservoir was intruded several times by mafic inputs: the first one some decades prior to eruption and the last one ~ 1 year. These time scales are longer than the days to weeks proposed for mafic intrusion triggering an eruption and can, instead, be correlated with cases where deformation of the volcanic edifice is not immediately followed by eruption. They thus help to associate surface precursory activity with deep magmatic processes and contribute to volcanic risk mitigation. On the other hand, these year to decadal times for producing andesites are much shorter than the 1-100 ky inferred from U-series disequilibria data for closed-system fractionation to produce similar magmas at subduction-zones.

Overview of silicic volcanism of the Snake River Plain – Yellowstone (SRPY) province

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The SRPY province is characterized by large volume bimodal basalt-rhyolite volcanism. The latter defines a diachronous pattern with temporal migration of source areas from SW Idaho to Yellowstone between 15 – 2 Ma for inception of activity. In any given eruptive center, duration of silicic magmatism was typically 2-3 Ma. This pattern (main trend) is consistent with migration of N. America over a deep thermal source (plume?) now located beneath the Yellowstone region. However, rejuvination of silicic magmatism in the west and central SRP requires modification of this model to include elements of lithospheric extension. Basaltic magmatism is invoked as the impetus for large scale crustal anatexis to produce the rhyolites, although effusion of basaltic lavas largely post-dates silicic activity owing to the crustal 'density filter'.

Bulk compositions of the rhyolites mimic that of average crust and Pb isotopic data are consistent with an ancient source, but Sr and Nd isotopic data preclude direct melting of the Precambrian basement underlying much of the province. Moreover, sharp isotopic discontinuities across the Mesozoic $^{87}Sr/^{86}Sr$ = 0.706 line (W. Idaho suture zone) imply lateral variation in source lithology consistent with Phanerozoic accreted terranes to the west. SRPY rhyolites likely contain a significant juvenile component - either younger crustal source material (e.g., Idaho batholith) or inputs of SRP basalt (or both). Because individual SRPY centers display different compositional patterns, there appear to be many variations on this theme. Most of the 'main trend' rhyolites are anhydrous, pyroxene-bearing, metaluminous with moderate silica (ca. 70-73%), and yield T estimates approaching 900°C or higher; such magmas form by H2O-undersaturated melting in response to heating by basaltic magmas. Anomalously young rhyolites in the central SRP become progressively cooler and more hydrated (amph- ± bi-bearing) as they evolve to higher silica (>74%). Considerations regarding volume production of main trend rhyolites and energetics of magma production suggest minimal mafic magma input rates approaching estimates for oceanic hot spot tracks.