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Time scales and petrogenesis of silicic magmas

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Understanding the origin, transport, and storage of silicic magmas is very important for a large variety of processes: from constraining the formation and tectonics of the continental crust, to mitigating the effects of their commonly explosive eruptions. Most constraints on how silicic magmas are generated are typically obtained from geochemistry (trace elements and isotopes), but the inferences are in many cases ambiguous, because the parents from which the silicic magmas differentiated or the nature of the protolith that was melted are poorly constrained. Here we report the results of a detailed petrological, mineralogical, and textural study of two silicic eruption products that show evidence of their origins and time scales of storage before eruption. A rhyodacite from the Southern Andean Volcanic Zone in Chile (1960, Cordon Caulle eruption) contains plagioclase phenocrysts that range in composition between An40 and An60 but some crystals have also cores of up to An90. Clinopyroxene and orthopyroxene are irregularly zoned and clinopyroxene contains submicrometer exsolution lamellae of orthopyroxene. The high An cores and the exsolution lamellae indicate that parts of the phenocryst are xenocrystic, and we think that are probably the restite of dehydration partial melting of amphibolite source rock. The time scale since the partial melting episode and eruption can be obtained by modelling the zoning patterns of pyroxenes and plagioclase and indicate less than about 1000 years. Some rhyolites from Yellowstone (260 ka, Scaup Lake flow) show mineral assemblages that are also complexly zoned, including textures of clinopyroxene with exsolution lamellae of pigeonite and multiple resorption surfaces in sanidine. We interpret these observations as indication that these Yellowstone rhyolites were generated by partial meting of a plutonic (or slowly cooled) protolith.This is in accord with the results of previous studies that suggest partial melting of hydrothermally altered rocks using oxygen isotopes studies (e.g., Bindeman and Valley, 2001). Modeling the clinopyroxene zoning indicates times of 1000 to 10000 years between partial melting and eruption. These findings show that careful petrological studies may yield direct insights about the origin and time scales for the formation of silicic magmas which are very difficult, or impossible to obtain by any other means. Fondecyt grant No. 1060187 is acknowledged.

Bindeman, I., and Valley, J. (2001): Low delta 18O rhyolites from Yellowstone: magmatic evolution based on analyses of zircons and individual phenocrysts. J. Petrol. 42: 1491-1517.