The determination of diffusion profiles in small samples: a comparison of micro-beam techniques

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The determination of chemical diffusion profiles in high pressure samples produced in multi-anvil experiments requires a micro-analytical technique with high spatial resolution such as secondary ionisation mass spectrometry (SIMS) or laser ablation inductively couple plasma mass spectrometry (LA-ICP-MS). Experiments were carried out in order to investigate the transport properties of silicate liquids at high pressure and temperature. Under investigation were both ionic self-diffusion and the chemical diffusion of trace elements.

In this study, the determination of the chemical diffusion of trace quantities of Ni and Co and the self-diffusion of network-modifying ions Ca^{2+} and Mg^{2+} were carried out in samples of $CaMgSi_2O_6$ (diopside) composition liquid, synthesised at high pressure and temperature. The self-diffusion profiles were defined by changes in the abundance of enriched isotopes, in this case ^{44}Ca and ^{25}Mg. LA-ICP-MS and SIMS have been used to determine the self-diffusion of Ca^{2+} and Mg^{2+} while the chemical diffusion profiles of Ni and Co have been determined by LA-ICP-MS only.

Even with automated sampling, the acquisition time required for the analysis of a diffusion profile using point analyses is on the order of hours for both SIMS and LA-ICP-MS. In order to reduce the acquisition time of the analyses using LA-ICP-MS two different analytical procedures have been tested and compared: 1) traditional single spot analyses and 2) rapid line scanning. The latter technique reduces the acquisition time approximately 15 times compared to single spot analyses.

The two procedures produce profiles that are in good agreement with each other and also with those derived from point analyses using SIMS. These results indicate that the use of rapid line scans to determine diffusion profiles provides a power way to reduce analysis time.

Crystal ages as tracers of rhyolite differentiation and storage

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Besides providing evidence for magma residence times, the ages of individual accessory phases like zircon and allanite are passive tracers of silicic magma evolution. General observations for rhyolites from dating individual crystals (Reid et al., 1997; Brown and Fletcher, 1999; Reid and Coath, 2000; Vazquez and Reid, in press; Simon and Reid, this volume) include: 1) Late entrainment of crystals from earlier episodes of magmatic activity and from country rocks, likely during magma ascent and eruption, is evidenced by the lack of juvenile crystal rims and by the presence of inherited radiogenic Ar (major mineral phases; e.g., Gansecki et al., 1998). These factors emphasize the need to interpret “old” mineral ages with caution; 2) Similar-age populations between successive effusive eruptions (e.g., post-caldera Long Valley and Yellowstone) suggest repeated tapping of the same magma reservoir, but do not require the system to have been molten throughout the repose interval; 3) Lack of crystal memory from one eruption to the next in other cases (e.g., Bishop Tuff, Yellowstone) provides strong evidence for new episodes of rhyolite differentiation; 4) Accessory phases may have protracted, and probably episodic, growth histories (e.g., Whakamaru, Toba). Considered together with the likelihood that the main increment of accessory phase growth accompanies initial saturation, accessory phase sizes have uncertain value as indicators of their ages; 5) Ages of the oldest cognate crystals can approach those of the previous rhyolite eruption, suggesting renewed silicic magma differentiation and/or emplacement soon after evacuation of the magma reservoir; 6) Relatively youthful mean crystallization ages and evidence for resorption of the cores of older grains suggest that voluminous rhyolites may develop relatively rapidly with respect to the duration of silicic magmatism. Hence, average rhyolite accumulation rates are probably not equivalent to long-term eruption rates. Either major eruptive episodes are the product of a “grand cycle” of differentiation or regular silicic magma production is accompanied by a quasi-steady-state flux of melt from the molten to mushy portion of the magma reservoir.

References

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