Isotopic monitoring of magma mingling at Chaos Crags, Lassen Volcanic Park, Ca.

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Introduction

Twenty years of high precision bulk geochemical analyses, while broadening our overall understanding as to the role of contributing components, has failed to provide a complete model for magma genesis at convergent margins. In particular, magma chamber processes have yet to be fully understood and quantified. Using Chaos Crags in the Lassen Volcanic National Park as an example, we propose to achieve a quantitative understanding of the mingling process, its effects on bulk chemistry, and its overall importance to the sustained evolution of the southernmost volcanic edifice of the Cascade Range.

Chaos Crags is composed of at least two coexisting magmatic components now represented as mafic inclusions (the mafic component) in a silicic host (the differentiated component). The presence of host crystals in the inclusions and the coexistence of fresh and resorbed phenocryst phases indicates that phenocryst populations have been exchanged between inclusion-forming and host magmas. The importance of this observation is that mingling can be recognized on a mm-scale (the size of the crystal). The inclusions have $^{87}Sr/^{86}Sr$ ratios which are distinct from the host dacite. Micro-drilling of a plagioclase xenocryst has revealed a significant range in $^{87}Sr/^{86}Sr$ ratios across the crystal and a large difference from its basaltic andesite inclusion. We hope to be able to constrain the timescales of magma mingling using detailed microsampling and diffusion parameters of Sr through plagioclase xenocrysts in inclusions. Our results are expected to help us understand the evolution and emplacement mechanisms of the Crags magma system, and can be generalized to volcanic arcs (especially continental margin) worldwide.

TABLE 1. Whole-host and whole-inclusion $^{87}Sr/^{86}Sr$ analyses for different domes of the Chaos Crags volcanic complex

dome	host	inclusion
0	0.704061±10	0.703738±10
	0.704025±10	0.703696±10
1	0.704056±9	0.703751±9
2	0.704028±11	0.703779±11
3a	0.703976±9	0.703707±10
3b	0.703988±9	0.703891±10
	0.703975±10	0.703766±14
	0.703982±15	0.703756±13
	0.703953±15	0.704080±15
	0.703998±14	0.704084±13
Plag	0.703987±15	0.704048±14
4	0.703972±9	0.704159±10

Methodology

A low blank micro-sampling and chemical processing procedure has recently been set up for isotope analyses of small samples at UCLA. The procedure comprises a micro-drill having a vertical-mounted drill bit which can be moved up and down relative to an x-y stage. Solid, diamond-tipped drill bits, which range in outside diameter from 0.25–0.51 mm, are used. Samples are prepared for microsampling by cutting c. 1-2 mm wafers. The wafers can be polished and phases analyzed on the electron probe prior to drilling. The drill is used on mm-sized xenocrysts of plagioclase from which several pits across the crystal are drilled to analyze for isotopic heterogeneities. A drop of water is placed on the drill site and then, as the drill quarries a pit, a slurry is created. The slurry is removed, dried down and weighed, spiked with pure 84Sr and dissolved. Sr separation takes place in micro-columns using a stripping technique. The sample is processed for thermal ionization mass spectrometry.

Results

Micro drill sampling has enabled us to examine the scale of mixing and chemical (isotopic and

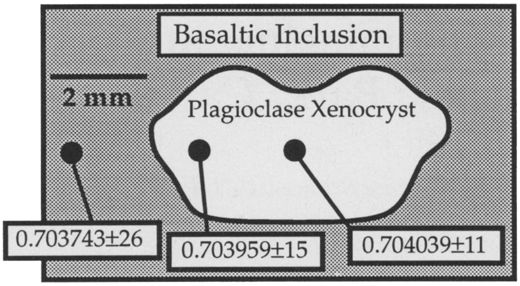

FIG. 1. Schematic diagram of a Chaos Crags xenocryst in a mafic inclusion. The black dots represent drill pits from the microsampling technique.

elemental) disequilibrium. Initial results, performed on a heterogenous xenocryst from the dacite dome of Cerro Chascon, north Chile, demonstrated the existence of measurable within-crystal variations. In this trial run, 8 pits were drilled across the crystal giving $^{87}Sr/^{86}Sr$ ratios ranging from 0.709206 ± 13 near the core to 0.708502 ± 14 near the rim. A chemistry Sr blank of 100 pg was measured, amounting to less than 0.5% of the Sr analyzed in the micro samples which weighed from 0.1 to 0.5 mg.

This technique was then applied to the Chaos Crags volcanic complex. We perfomed bulk analyses of host and inclusion of Chaos Crags domes to determine the extent of difference in $^{87}Sr/^{86}Sr$. The Chaos Crags dome complex consists of five extrusive dacite domes having variable amounts, types and sizes of mafic inclusions. The results of the whole rock work show that the initial dome inclusions have the most primitive $^{87}Sr/^{86}Sr$ ratio and the host dacite the most evolved (Table 1).

Through time as the domes extrude, (0-4) the difference in the ratios between the domes becomes smaller (Table 1). This suggests that mixing between end-members is becoming more thorough before eruption.

The micro-drilled sample was taken from a dome whose whole-host $^{87}Sr/^{86}Sr$ ratio is 0.704061 ± 10 whereas the whole-inclusion is 0.703738 ± 10. A plagioclase xenocryst was micro-sampled across the crystal and yielded the results shown in Figure 1. Sr concentrations remained relatively constant across the crystal at *c.* 725 ppm, compared to *c.* 260 ppm in the mafic inclusion. The variations in isotope ratios are interpreted to reflect an approach to equilibration through diffusion at magmatic temperatures. Diffusion was effectively arrested when the lava was extruded and chilled.