

Experimental determination of trace element partitioning between pargasitic amphibole and hydrous silicate melt

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Introduction

To provide a better basis for assessing the role of amphibole in the trace element evolution of magmas, we have conducted experiments to determine the partition coefficients for Ti, Rb, Ba, Sr, Zr, Nb, Ta, Hf, Pb, U, and Th between pargasitic amphibole and a synthetic hydrous silicate liquid.

Experimental methods

Our starting material is similar to that used by Mysen (1978), and is broadly analogous to a K- and Fe-free andesite. At the run conditions of our experiments (1.5 GPa, 1000°C, nearly H₂O-saturated), pargasite and subordinate clinopyroxene are the liquidus phases. Starting materials were synthesized from oxides and carbonates; trace elements were added as dilute nitrate solutions. The samples were sealed in Pt capsules with 10 wt.% H₂O, and run in a piston cylinder apparatus ($f_{O_2} \sim$ QFM) using a *P-T* history designed to promote equilibrium growth of a few large crystals.

Electron microprobe analyses of the run products used a 20 μ m, defocused beam and a 10 nA or 5 nA beam current on crystals and glass, respectively. Trace elements were measured using a Cameca IMS-3F ion microprobe using a 15–50 nA O⁻ primary beam. For each sample, multiple spots on each phase were analyzed, and the results for each phase were averaged. Isobaric molecular interferences were minimized by the use of an energy-filtering technique.

Trace element concentrations were determined by comparing the ³⁰Si-normalized isotopic ratios of the samples to those of silicate mineral and glass standards. Our quench glass contains > 10% H₂O, and ion yields relative to ³⁰Si were higher in this hydrous glass than in an anhydrous glass of the same composition. The enhancement in yield is largest for Rb (+39%), Sr (+17%), and Ba

(+20%). For the other elements we report, the enhancement is < 10%. All glass analyses were corrected for this effect. The estimated combined error in the trace element concentrations is \pm 20%. Partition coefficients were calculated from the ratio of the average ³⁰Si-normalized count rate of an isotope in the amphibole to the average ³⁰Si-normalized count rate in the glass, correcting for the differences in Si contents and the difference in ion yields due to the effect noted above. Reported errors reflect propagation of the larger of the counting statistics errors or the 1 σ variability of the spot analyses.

Results and discussion

The run products consist of ~ 5 vol.% crystals in a homogeneous quenched glass (50.6 \pm 0.6% SiO₂, 0.17 \pm 0.02% TiO₂, 20.7 \pm 0.3% Al₂O₃, 4.0 \pm 0.1% MgO, 7.3 \pm 0.1% CaO, 3.6 \pm 0.3% Na₂O, ~ 14% H₂O; n = 30). Pargasitic amphibole (34.7 \pm 0.5% SiO₂, 0.33 \pm 0.03% TiO₂, 18.8 \pm 0.6% Al₂O₃, 19.3 \pm 0.3% MgO, 11.8 \pm 0.3% CaO, 3.2 \pm 0.5% Na₂O, ~ 3% H₂O; n = 22) is the dominant crystalline phase, and forms equant, 100–500 μ m, unzoned crystals.

Trace element concentrations and partition coefficients determined at three concentration levels, including near-natural abundances, are presented in Table 1. The agreement among the values at different concentrations is excellent, and indicates that Henry's law holds in these experiments. Our partition coefficient data are compared with recent determinations of amphibole-melt partitioning in nephelinitic and carbonate melts in Fig. 1. Although these data were obtained on quite different chemical systems, the three data sets are in general agreement, and show similar trends in relative partitioning behavior. Also shown in Fig. 1 is the range of published partition coefficients between clinopyroxene, the most common ferromagnesian silicate host phase for trace elements, and silicate melts. Rb, Ba, Nb,

TABLE 1. Trace element concentrations in glass (ppm) and partition coefficients with 1 σ errors

Element	Run D5		Run D50		Run D500		Wtd. Average $D^{\text{amph/melt}}$
	Conc	$D^{\text{amph/melt}}$	Conc	$D^{\text{amph/melt}}$	Conc	$D^{\text{amph/melt}}$	
Ti	770	1.92 ± 0.09	696	2.07 ± 0.19	692	1.92 ± 0.16	1.94 ± 0.09
Rb	2.48	0.13 ± 0.02	11.3	0.15 ± 0.03	129	0.15 ± 0.01	0.14 ± 0.01
Sr	12.3	0.29 ± 0.03	24.6	0.30 ± 0.05	223	0.29 ± 0.03	0.29 ± 0.01
Zr	70.3	0.22 ± 0.03	62.8	0.38 ± 0.23	57.5	0.30 ± 0.07	0.23 ± 0.08
Nb	12.7	0.19 ± 0.02	123	0.25 ± 0.10	3.43	0.20 ± 0.04	0.19 ± 0.03
Ba	11.0	0.10 ± 0.03	27.8	0.13 ± 0.03	260	0.13 ± 0.02	0.12 ± 0.02
Hf	5.04	0.40 ± 0.09	32.2	0.71 ± 0.42	1.58	0.57 ± 0.15	0.46 ± 0.16
Ta	11.1	0.21 ± 0.04	76.5	0.26 ± 0.13	-	-	0.21 ± 0.03
Pb	2.87	0.16 ± 0.04	10.3	0.13 ± 0.04	99.8	0.10 ± 0.02	0.12 ± 0.03
Th	3.72	0.015 ± 0.007	33.2	0.022 ± 0.018	314	0.020 ± 0.012	0.017 ± 0.004
U	2.86	0.011 ± 0.004	22.7	0.009 ± 0.004	201	0.008 ± 0.002	0.009 ± 0.001

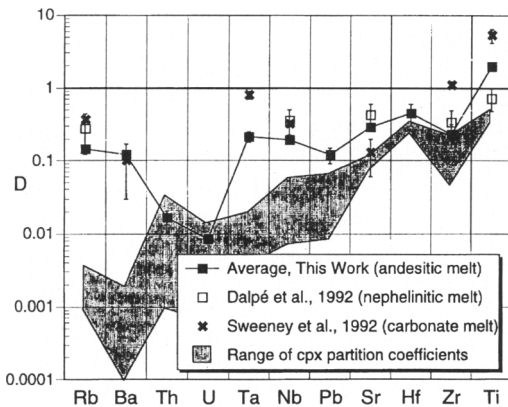


FIG. 1. Comparison of amphibole and clinopyroxene partition coefficients.

and Ta are dramatically less compatible in pyroxene than in amphibole, while other elements, such as Th, U, Hf, and Zr have similar compatibilities. Because of these differences, liquids produced by small degrees of partial melting of amphibole-bearing mantle sources, or by high-level fractionation of amphibole will have distinctively lower Th-normalized Rb, Ba, Nb, and Ta concentrations than melts from amphibole-free systems.

References

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