

Supplementary figures

to

"Combined Fe-Mg chemical and isotopic zoning in olivine constraining magma mixing-to-eruption timescales for the continental arc volcano Irazú (Costa Rica) and Cr diffusion in olivine"

by

Martin Oeser, Philipp Ruprecht, and Stefan Weyer

Figure S1

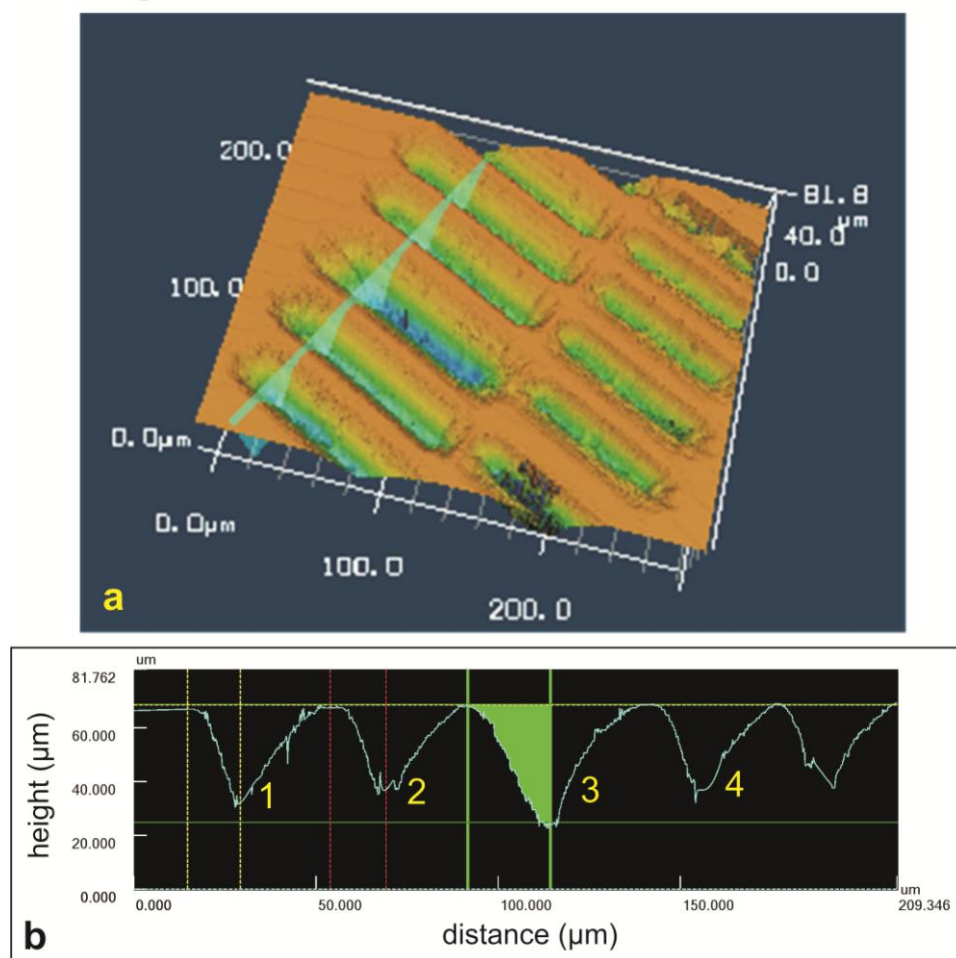


Figure S1. (a) 3D-image of laser ablation lines after in-situ analyses of Fe-Mg isotopes. Image was acquired with a Keyence VK-X 3D Laser Microscope at the Institut für Bodenkunde, Leibniz Universität Hannover. (b) Height vs. distance-plot of the profile shown in (a), illustrating the Gaussian shape (in cross-section) of the laser ablation lines which is a combined effect of the position of the focal point of the laser beam (100-150 μm below the sample surface) and of the near-Gaussian beam profile of the femtosecond-laser. Numbers 1-4 in (b) correspond to the lines for which time-resolved $^{56}\text{Fe}/^{54}\text{Fe}$ and ^{56}Fe signal data are shown in Fig. S2.

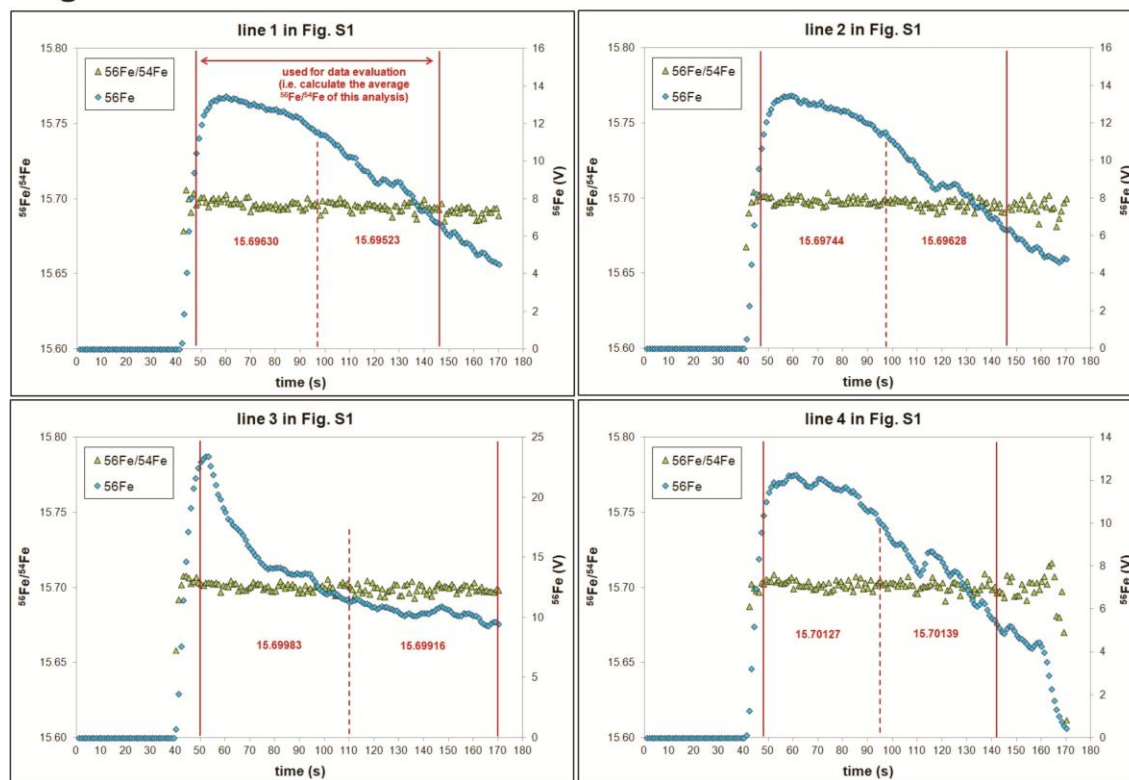
Figure S2

Figure S2. Time-resolved $^{56}\text{Fe}/^{54}\text{Fe}$ and ^{56}Fe signal data for the four laser ablation lines shown in Fig. S1, illustrating that the deepening of the LA line with time does not produce any significant isotope fractionation (despite a strong decrease of the ^{56}Fe signal). In each plot, the values left and right of the dashed red line are the average $^{56}\text{Fe}/^{54}\text{Fe}$ ratios calculated from the first 50-60 seconds and the following 50-60 seconds of the ablation signal, respectively. Data for which the ^{56}Fe signal was below ~ 6 V were excluded from the data evaluation.

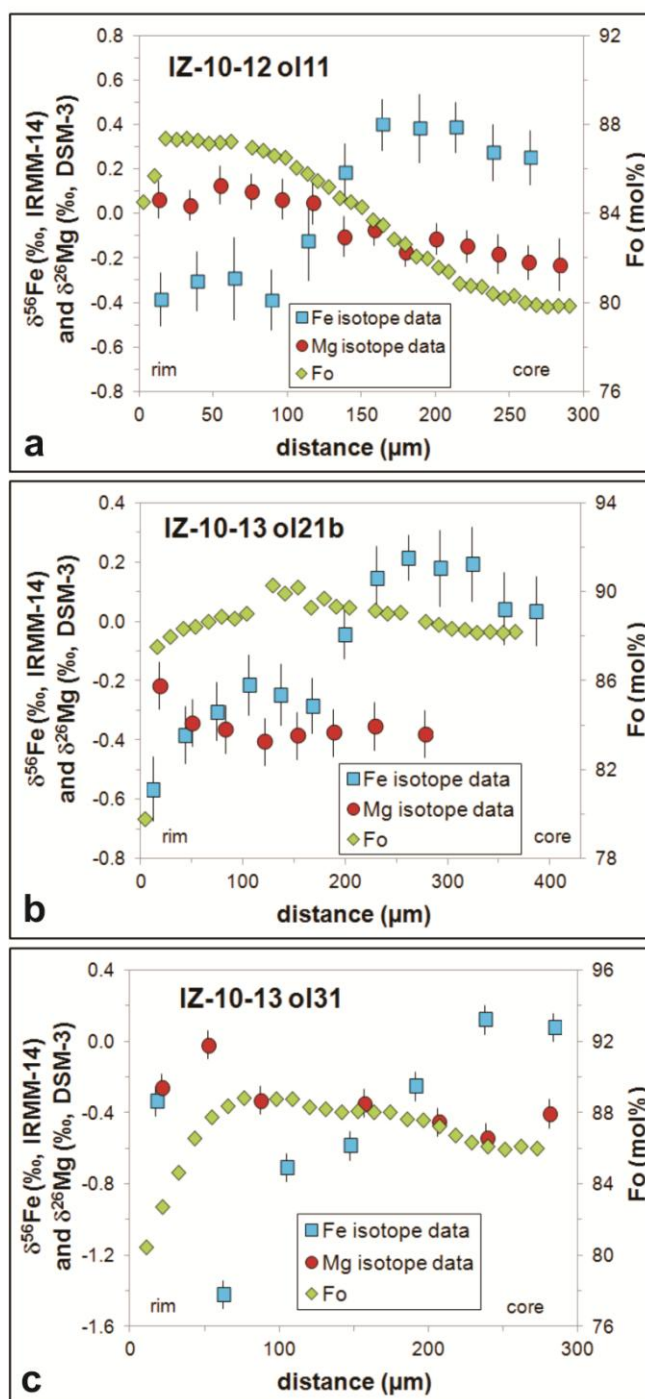
Figure S3

Figure S3. Fe-Mg chemical (expressed as Fo) and isotopic profiles for three complexly zoned olivines analyzed in this study. All olivines show strong coupling of Fe-Mg chemical and isotopic zoning (especially for Fe isotopes), indicating equilibration by Fe-Mg inter-diffusion. Sample material of olivine crystals IZ-10-12 ol11 and IZ-10-13 ol21b was ablated by line scans perpendicular to the chemical zoning. Error bars represent the analytical uncertainty (2 SD) during one analytical session.

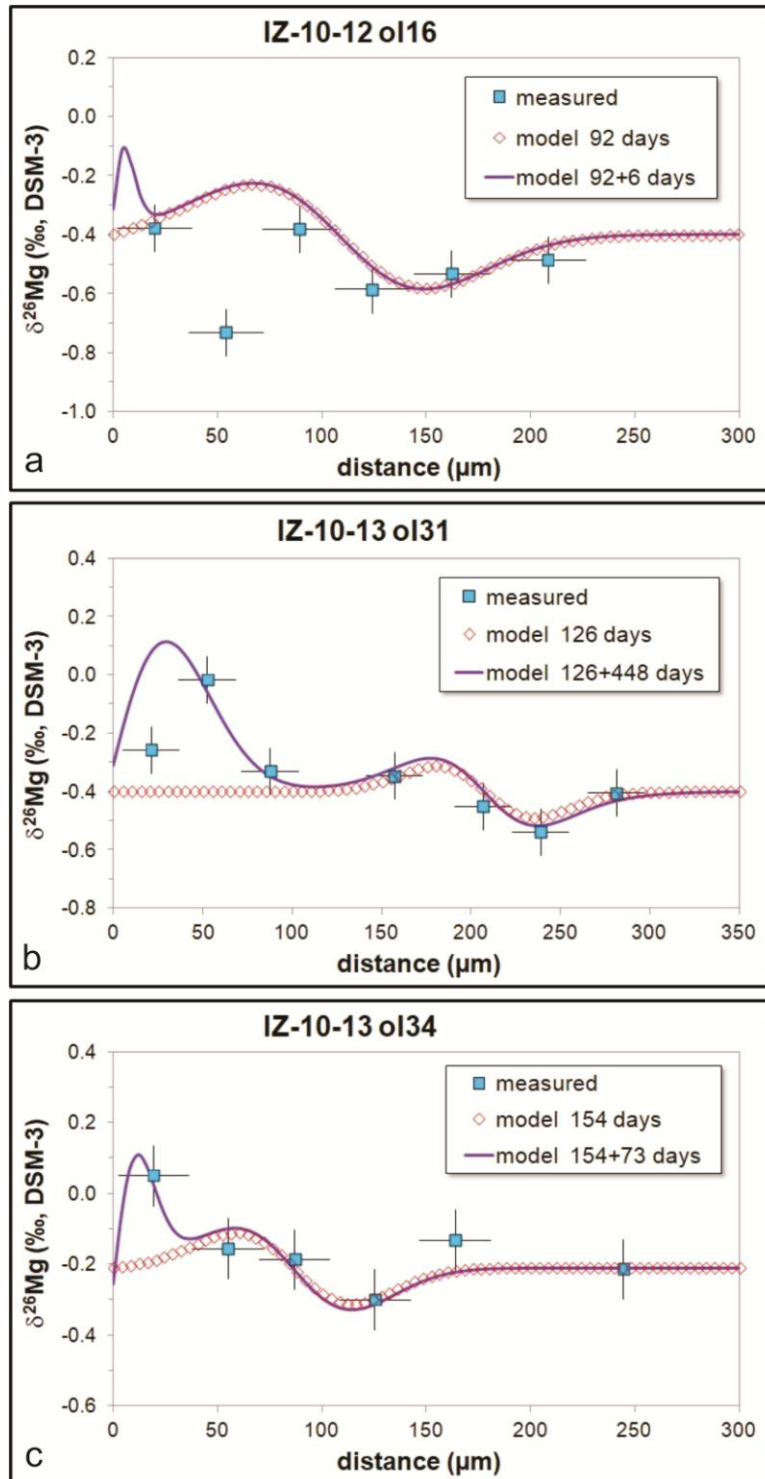
Figure S4

Figure S4. Results of the stepwise diffusion modeling approach used in this study for three complexly zoned olivine crystals (focusing on Mg isotopic zoning here), assuming a model of instantaneous growth of a Mg-rich layer and subsequent Fe-Mg inter-diffusion for diffusion episode 1.

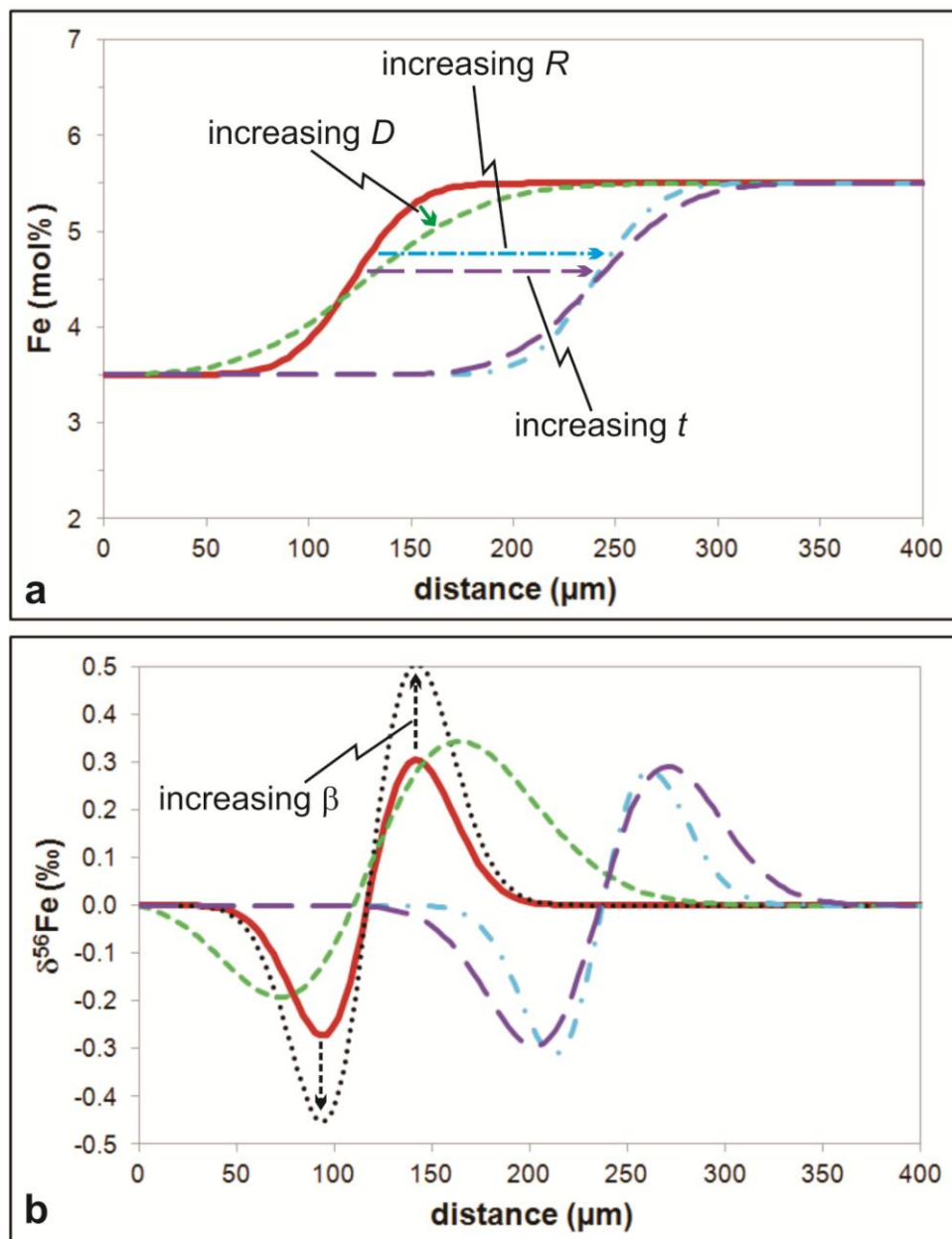
Figure S5

Figure S5. Effects of changing the diffusion coefficient (D), the crystal growth rate (R), the timescale (t), and β on the shapes of the simulated chemical (in **a**) and isotopic (in **b**) profiles in the second model for diffusion episode 1 (growth and simultaneous diffusion). Compared to the initially simulated profiles (thick red lines), D was increased by a factor of 4 (i.e. the ratio R/D decreased; dashed green lines), R was increased by a factor of 2 (i.e. R/D increased; dotted dashed blue lines), t was increased by factor of 2 (purple dashed lines), and β was increased from 0.15 to 0.25 (dotted black line in **b**). Note that changing β does not affect the shape of the chemical profile; hence, this simulation is not shown in (a).

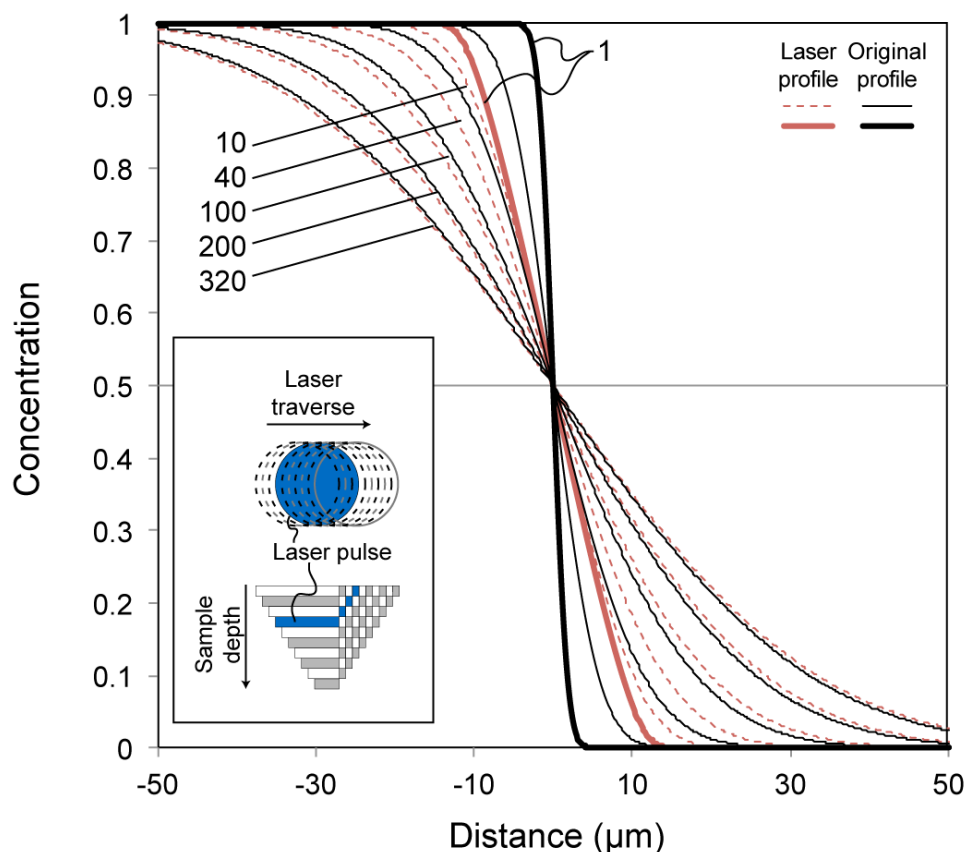
Figure S6

Figure S6. Comparison of original (“true”) zoning profiles (black) and how continuous scanning laser acquisition introduces a smearing affect (red, see Fig. S7b). Curves are shown for a variety of profile lengthscales that for example could represent diffusion lengthscale of distinct elements with different diffusivities but for one specific timescale. In this case, the labels represent relative differences in diffusivity compared to the near-step function ($D=1$). We present this analysis in respect to changing diffusivity because the comparison $D_{\text{Fe-Mg}}/D_{\text{Cr}}$ and other ratios is comparing profile lengths that have evolved over the same timescale and therefore changes in D cause a variation in zoning profiles in the studied Irazú olivines. Insert: Step-wise laser progression with each pulse leads to a step-wise sampling of the olivines.

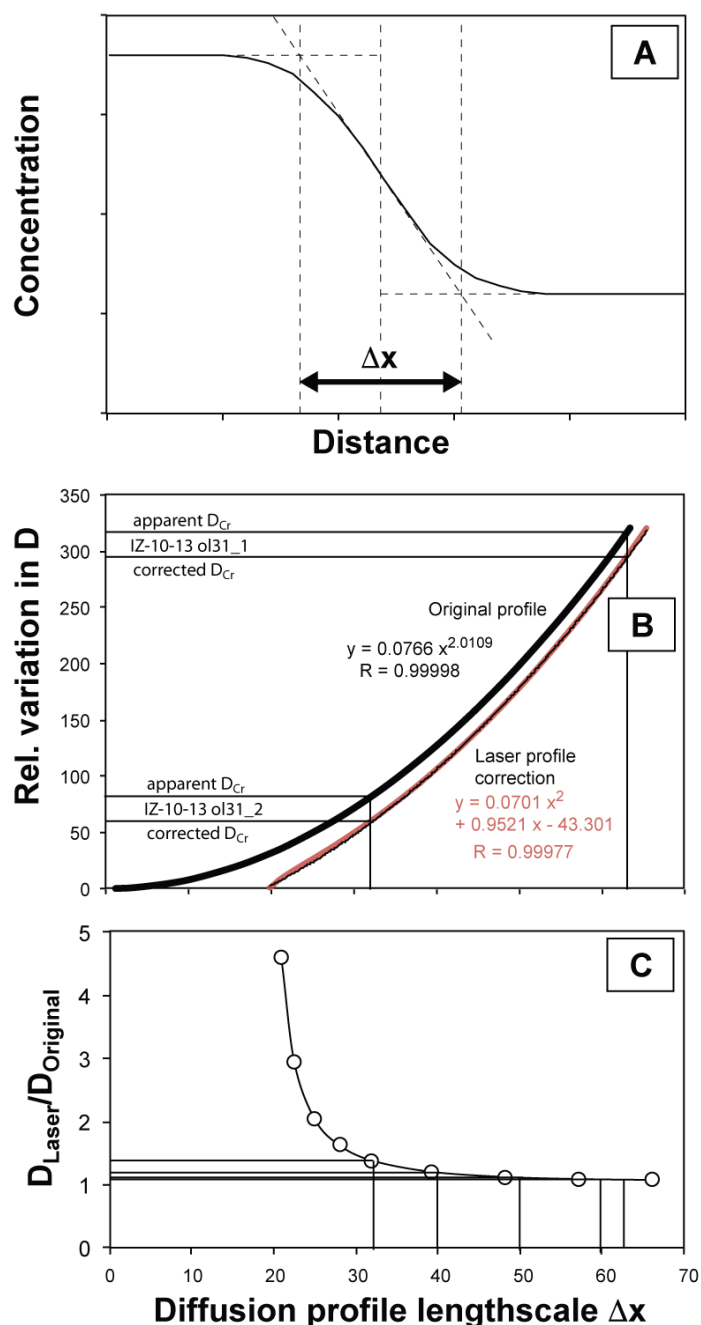
Figure S7

Figure S7. (A) Method to estimate the zoning profile lengthscale Δx . (B) Apparent relative diffusivity for a given lengthscale Δx of profiles in Fig. S6. A quadratic regression is shown for the apparent D (note, the slight deviation of the exponent from 2 is probably an artifact, see Bradshaw and Kent 2017) and polynomial approximation for the corrected D providing a relationship to correct for smearing effects. The latter approximation is only valid for lengthscales $\Delta x < 100\mu\text{m}$ as our analysis was not extended beyond that lengthscale. (C) Correction factor to adjust calculated diffusivities for smearing affects.

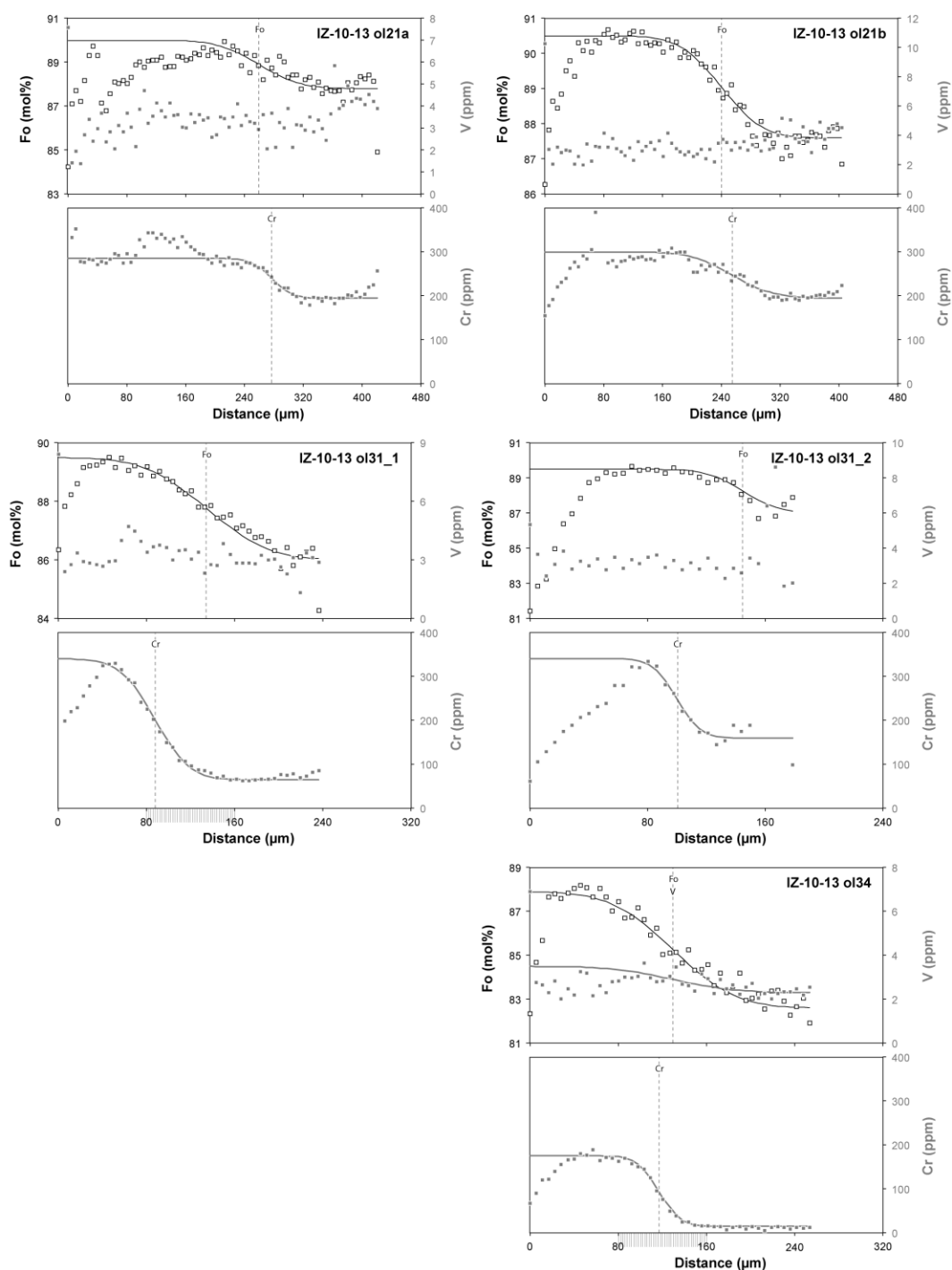
Figure S8

Figure S8. LA-ICPMS rim-to-center analyses for Fo (white squares) as well as Cr and V (gray squares). Calculated diffusion profiles used for the relative determination of elemental diffusivities are shown as black (Fo) and gray (Cr, V) lines. Profiles were calculated separately for each element with a step profile. Step location was chosen to minimize misfit for the respectively element. Near-rim zoning is ignored as it probably includes effects of fractional crystallization.