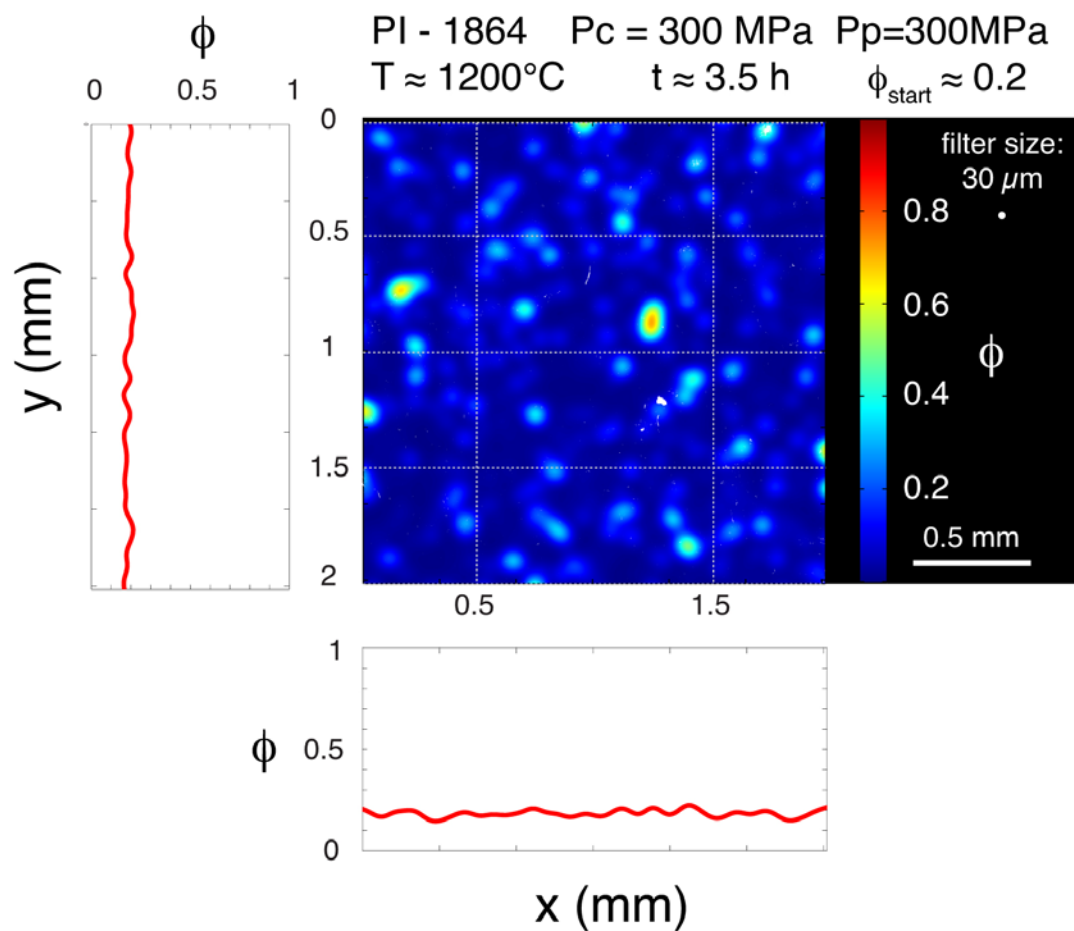## Supplementary information - Figures

Figure DR1: Melt distribution map of the starting material obtained by manually segmenting optical images of etched samples. The resulting binary image of the melt was smoothed with a Gaussian filter with a 30-µm diameter and contoured. Red lines show the variation of integrated melt fraction along the *x*- and *y*-axes normalized to a melt fraction of 0.2.

Supplementary information - Movies
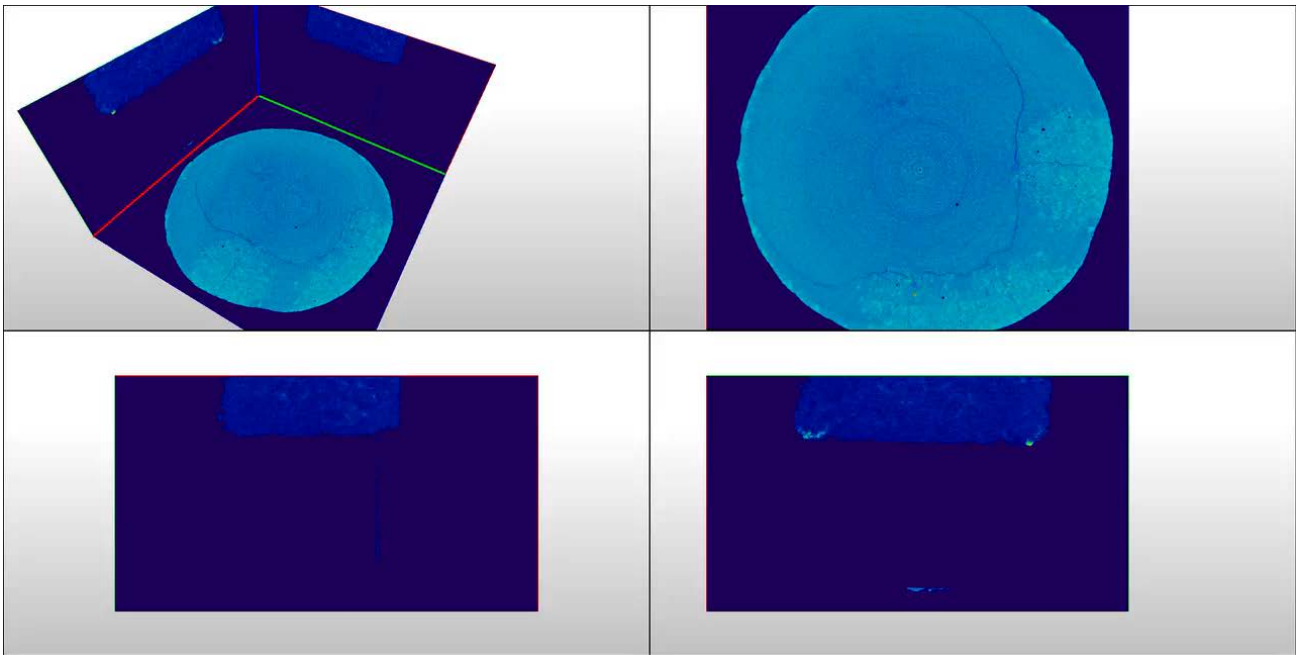
Video DR1: X-ray CT scan of a sample with the melt doped with ytterbium (#961). Melt reservoir is at the bottom, partially molten rock is in the middle, and porous sink is at the top. Note the bubbles in the melt that mark the interface between the melt source and the partially molten rock. Further, note the olivine phenocrysts at the entrance to the through-going channels. Channels in the partially molten rock are brighter than the surrounding rock. Finally, note that the channel density decreases with increasing distance from the melt-rock interface. X-ray CT images were obtained with a North Star Imaging CT equipped with a Feinfocus FXE x-ray source and a Dexela 2923 detector at 140 kV and 144 µA achieving a 4.5 – 5.5 µm voxel size.

Supplementary information - Tables

Variable	Value	Comment	Reference
μ (Pa s)	75 & 33	1200 & 1250°C	*Giordano et al. 2008*
k_{M-10} (m²)[&]	2.62E-14	s = 2.6, C = 58, ⟩ = 0.2, d_{equ} = 10 μm[#]	*Miller et al. 2014*
$k_{W\&W-10}$ (m²)	4.00E-15	s = 3, C = 200, ⟩ = 0.2, d_{equ} = 10 μm[#]	*Wark and Watson 1998*
k_{M-3} (m²)	2.36E-15	s = 2.6, C = 58, ⟩ = 0.2, d_{equ} = 3 μm[#]	*Miller et al. 2014*
$k_{W\&W-3}$ (m²)	3.60E-16	s = 3, C = 200, ⟩ = 0.2, d_{equ} = 3 μm[#]	*Wark and Watson 1998*
		Cpx d_{equ} (μm) = 3.2, Reaction Layer ⟩ = 0.4, 50:50 vol%	
SSA (m²/m³)*	3.75E+05	Ol:Cpx	
⟩ $_{fuid}$ (kg m⁻³)	2777		
⟩ $_{cpx}$ (kg m⁻³)	3200		
Cpx diss rate, *R* (m s⁻¹)	4E-9 & 5E-8	1200 & 1250°C	*Chen and Zhang 2009*
R_{eff} (kg m⁻² s⁻¹)	1.28E-5 & 1.6E-4	1200 & 1250°C	
D (m²s⁻¹)	1E -13 & 1E-12	SiO_2 diffusion in melt at 1200°C & 1250°C	*Morgan and Liang 2003*

 # - eq. 2
* - assuming cubic
grains
& - value used for calculation

Table DR1: Values used for calculating the equilibration length and Damköhler and

Péclet numbers

Supplementary information – *Da #, L_{eq}* and *Pe #* calculation

To calculate the Péclet number, *Pe,*

$$Pe = \frac{w_0 L}{D},$$

Damköhler number, *Da,*

$$Da = \frac{R_{eff} L}{\rho_{fluid} \phi_0 w_0},$$

and equilibration length, L_{eq},

$$L_{eq} = \frac{\rho_{fluid} \phi_0 w_0}{R_{eff}},$$

for our experiments, we needed to estimate the following quantities:

1) w_0 – Background fluid movement velocity

To estimate the background fluid movement velocity, we assume that w_0 equals the Darcy flux divided by the initial melt fraction, $w_0 = q/\phi$. We calculate the melt viscosity, μ, at experimental conditions using the melt viscosity model published by *Giordano et al. 2008* where the only input parameters are melt composition (measured with the electron microprobe) and temperature (controlled during the experiment). Further, we control the pressure gradient in our experiments, as we know the length of our samples and the pressure difference between confining and pore pressure in the porous sink. Finally, to estimate the permeability of our partially molten rock, we use a common porosity – permeability relationship, $k = \dfrac{d^2 \phi^s}{C}$, with published values of C and s based on the recent work of *Miller et al. 2014* (Tab. DR1). We measure the 2-D grain size (defined as the equivalent diameter of a circle, d_{equ}) of Ol and Cpx of the starting material on BSE-SEM images, and we use a melt fraction of 0.2 which is based on the weighted amount of alkali basalt added to the Ol:Cpx mixture before the hot-press. Since our rock has a bi-modal grain size distribution (Ol ≈ 11 μm, Cpx ≈ 3 μm) and two different phases with different wetting properties, our calculated values for permeability likely represent an upper bound. Depending on the used permeability porosity – relationship, that is, the values of C, s, and grain size, permeability can vary by up to 2 orders of magnitude (Tab. DR1).

2) R_{eff} - Effective reaction rate constant

The effective reaction rate constant is defined as $R_{eff} = R \times \rho_{solid} \times SSA$, where R is the linear dissolution rate, ρ_{solid} is the density of the dissolving solid, and SSA is the specific surface area available for reaction. For R we use published values for the rate of Cpx dissolution in a basaltic melt at 1200°C and 1250°C (Tab. DR1, *Chen and*

Zhang 2009). As an estimate for the SSA, we calculate the surface area to volume ratio of Cpx crystals (mean grain size $d_{equ\ Cpx} \approx 3.2$ µm) assuming cubic grains as $6/d_{equ\ Cpx} = 1.875 \times 10^6$ m^2/m^3. The partially molten rock is formed of a mixture of 50:50 vol% of Ol and Cpx, and we assume that only Cpx is taking part in the reaction. Further, we assume that only 40% of the Cpx grain boundaries are wetted by melt (the melt fraction in the reaction layer is ~0.4). This calculation results in a value for SSA of 37500 m^2/m^3, which, when multiplied by the density of Cpx and linear dissolution rate of Cpx, gives values of R_{eff} of 1.28×10^{-5} and 1.6×10^{-4} kg m^{-2} s^{-1} at 1200° and 1250°C, respectively (Tab. DR1).

3) *L* - Length scale of interest

Our length scale of interest is sample length parallel to the fluid flow (Tab. 1).

4) *D* – diffusion / dispersion of the fluid

The parameter D describes how quickly a perturbation in the fluid front spreads out laterally. In absence of any better constraints, we use the diffusivity for SiO_2 in alkali basalt as constrained by *Morgan and Liang 2003*, 10^{-12} m^{2}s^{-1} at 1250°C and 10^{-13} m^{2}s^{-1} at 1200°C.

Supplementary information – References

Giordano, D., J. K. Russell, and D. B. Dingwell (2008), Viscosity of magmatic liquids: a model, *Earth Planet. Sci. Lett.*, *271*(1), 123–134.

Chen, Y., and Y. Zhang (2009), Clinopyroxene dissolution in basaltic melt, *Geochim. Cosmochim. Acta*, *73*(19), 5730–5747.