

Supplementary data 3

Equations and models

Water diffusion in minerals

We apply the diffusion equation of [Shewmon \(1983\)](#) to model the H diffusion in olivine, following the method of [Peslier et al. \(2008\)](#). The diffusion coefficient of hydrogen in opx and olivine, assuming isotropic diffusion along the E// α , E// β and E// γ direction of the optical indicatrix. The diffusion parameter for opx are $10^{-14}\text{m}^2/\text{s}$ at 900°C , $10^{-13}\text{m}^2/\text{s}$ at 1000°C and $10^{-12}\text{m}^2/\text{s}$ at 1000°C ; The diffusion parameter for olivine are $0.5 \times 10^{-12}\text{m}^2/\text{s}$ at 900°C , $0.5 \times 10^{-11}\text{m}^2/\text{s}$ at 1000°C and $0.5 \times 10^{-10}\text{m}^2/\text{s}$ at 1000°C ([see compilation by Tian et al., 2017 and references therein](#)) ; R = the gas constant ($0.00831451 \text{ kJ K}^{-1} \text{ mol}^{-1}$) and T = the temperature (K). The diffusion modelling of H loss is based on 1-dimension diffusion equations for a sample of finite size surrounded by an infinite medium containing no H ([Shewmon, 1983](#)):

$$[3] \quad C = \frac{4C_0}{\pi} \sum_{j=0}^{\infty} \frac{1}{2j+1} \sin\left[\frac{(2j+1)\pi X}{h}\right] \times e^{-\left[\frac{(2j+1)\pi}{h}\right]^2 Dt}$$

where C = the hydrogen concentration at the grain edge (M), C_0 = the maximum initial concentration of hydrogen (M), X = the distance from the olivine edge (m), D = the diffusion coefficient of hydrogen, assumed to be independent of hydrogen concentration (m^2/s), and h = the width of the diffusion profile from olivine edge to the other edge (m).

The calculation was done for the first eight terms and started converging after five iterations. For each olivine profile, we calculated two H diffusion profiles in 2 perpendicular directions (pairs of α , β and γ): first using water contents calculated using the absorbance of olivine core (i.e. C_0 = absorbance measured) and then assuming that the initial water content was 20% higher than that measured in the core (i.e. C_0 = absorbance measured + 20%).

Partition coefficient between pyroxene and melt

We apply the equation O'Leary et al. (2010) to calculate the partition coefficient between opx and cpx with melt:

$$D_{H_2O}^{Opx/Melt} = \exp \left(-5.66 + 8.4 \times [IVAl]_{Opx} + 10 \times [Ca]_{Opx} \right)$$

$$D_{H_2O}^{Cpx/Melt} = \exp \left(-5 + 6.3 \times [IVAl]_{Opx} - 1.2 \times [Ca]_{Cpx} + 1600/T \right)$$

Note that temperature is in Kelvin.

We apply the method of Liang et al. (2013) to calculate the theoretical partition coefficient of REE between opx and cpx using the spreadsheet provided in the supplementary data to calculate $D_{REE}^{Cpx/Opx}$ (<https://doi.org/10.1016/j.gca.2012.10.035>).

$$D_{REE}^{Cpx/Opx} = \exp \left(\frac{B_{REE}}{T} - A_{REE} \right)$$

Where A and B are coefficient determined through pyroxene-melt partitioning experiments.

Water behavior during partial melting

We used melting equations of Shaw (1970):

$$\text{Batch melting [4]: } C_{res} = \frac{C_0}{1-F} \cdot \frac{D-FP}{D+F(1-P)}$$

$$\text{Non-modal fractional melting [5]: } C_{res} = \frac{C_0}{1-F} \cdot \left(1 - \frac{PF}{D} \right)^{\frac{1}{P}}$$

where C_{res} is the concentration in the residue (M), C_0 is the concentration in the source (M), D is the initial bulk partition coefficient of water, P is the bulk partition coefficient for the proportion of minerals entering the melt and F is the melt fraction.

The modal composition of the source and the proportion of mineral entering the melt are from Johnson et al. (1990) and correspond to the partial melting in the garnet stability field of a fertile peridotite. We chose the mineral/melt water partition coefficients at 3 GPa determined by Tenner et al. (2009), which are close to the starting pressure of melting that initially formed the Tok cratonic mantle (i.e. ≤ 3 GPa (Ionov et al., 2005)).

The viscosity of olivine aggregate

The effective viscosity (η_{eff}) is defined as the ratio of the shear stress τ to the shear strain rate $\dot{\epsilon}$ (in s^{-1}):

$$[5] \eta_{\text{eff}} = \frac{\tau}{\dot{\epsilon}}$$

where ($\dot{\epsilon}$) for an olivine aggregate is estimated using the equation of (Li et al., 2008):

$$[6] \dot{\epsilon} = A_{\text{cre}} \tau^{n_1} \left[\left(e^{(C_0 + C_1 \ln C_{\text{OH}} + C_2 \ln^2 C_{\text{OH}} + C_3 \ln^3 C_{\text{OH}})} \right)^r \times e^{\left(\frac{Q + PV_{\text{cre}}}{RT} \right)} \right]$$

The parameters used for wet dislocation creep are $A_{\text{cre}} = 90 \text{ MPa}^{-(n_1+r)} \text{ s}^{-1}$, with a stress exponent derived from linear fit of experimental stress dependence on strain rate $n_1 = 3.5$, the water fugacity exponent $r = 1.2$, the shear stress $\tau = 0.3 \text{ MPa}$, the activation energy $Q = 480 \text{ kJ.mol}^{-1}$, the activation volume $V_{\text{cre}} = 1.06 \times 10^{-5} \text{ m}^3.\text{mol}^{-1}$; P , T and R are respectively the pressure (in kPa), temperature (in K), and the gas constant ($8.314 \text{ J.mol}^{-1}.\text{K}^{-1}$); C_{OH} is the water content in H per 10^6 Si . The water content (in ppm H_2O) was calculated using a SiO_2 content of 41.2 wt. %, which is the average SiO_2 content of olivine in this study.

References

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