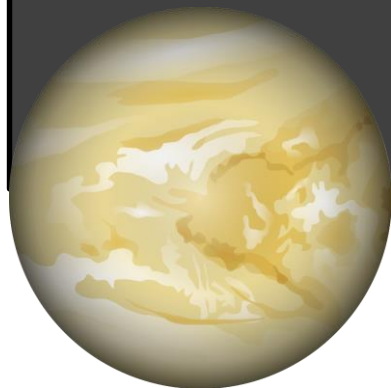
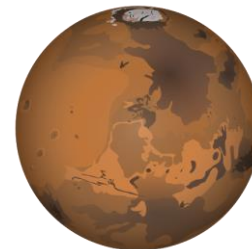




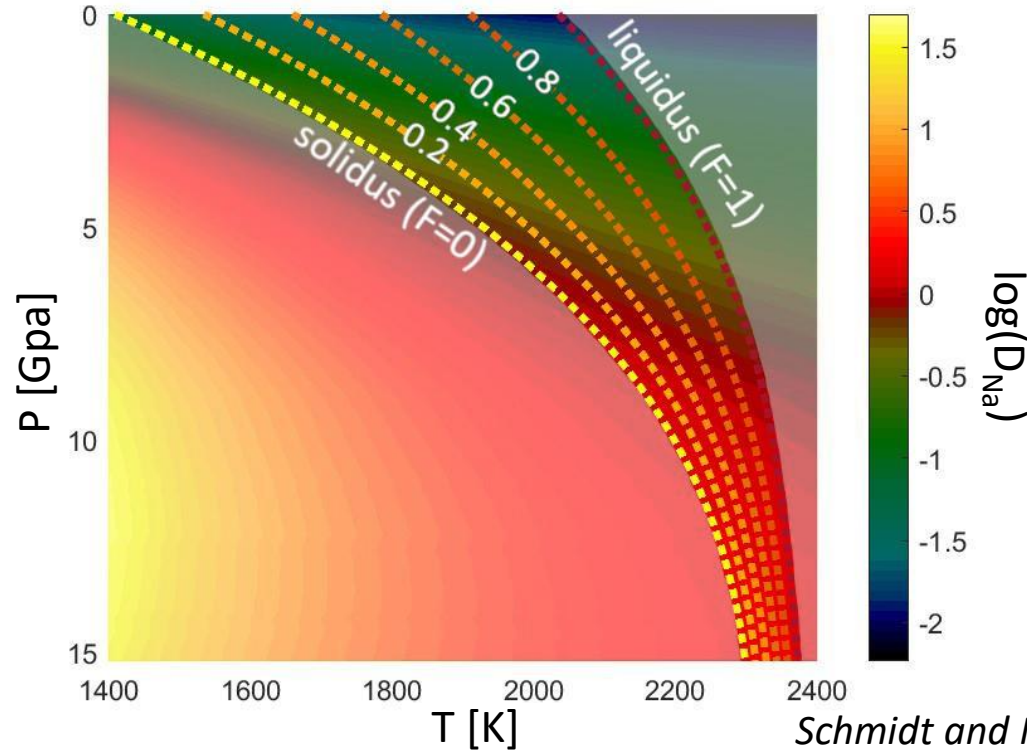
Applying locally calculated partition coefficients for radiogenic heat sources and volatiles to interior evolution models of terrestrial planets



Julia M. Schmidt and Lena Noack
Freie Universität Berlin, Germany



Partition Coefficient – The influence of P and T



Schmidt and Noack (2021)

**For Sodium in
Cpx/melt:**

From 0-15 GPa along
the peridotite solidus:

➤ Changes up to 2
orders of magnitude!

Local P-T dependent partition coefficient calculations could have an impact on the modeled redistribution of an element and therefore (for HPE and volatiles) on the thermal evolution and outgassing of a planet. Here, we apply a P-T dependent partitioning code to a 1D interior evolution code.

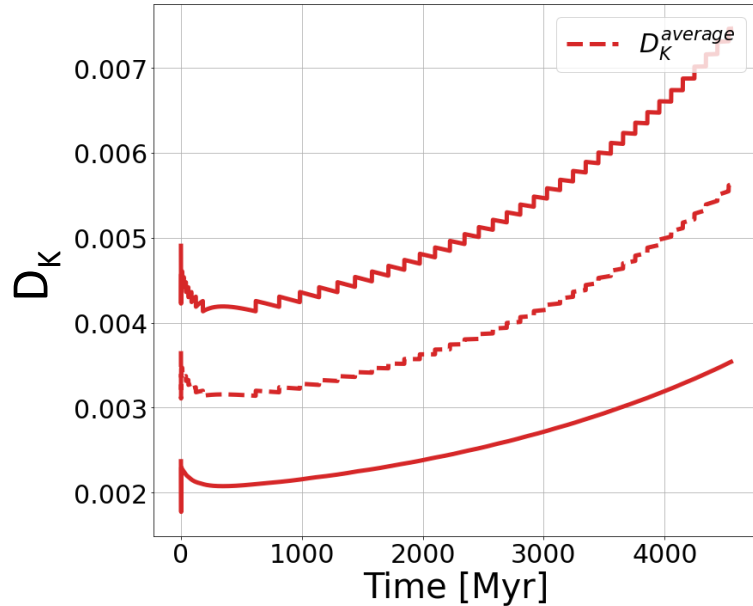
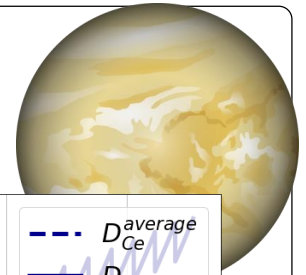


Partitioning inside the melt zone of Venus

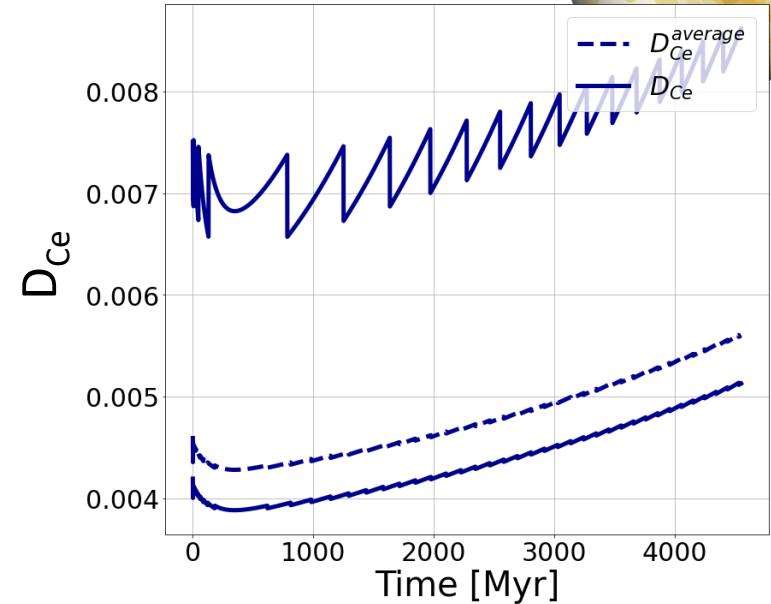
Cpx/melt partition coefficients

Potassium

Cerium/H₂O



→ Max diff. ~52%



→ max. diff. ~ 40%

For the P-T range of a melting zone inside Venus, cpx/melt partition coefficients vary for Potassium ~52% and for Cerium ~40%. Potassium is an important heat producing element (HPE) and Cerium has the same partitioning behavior as H₂O inside the upper mantle.

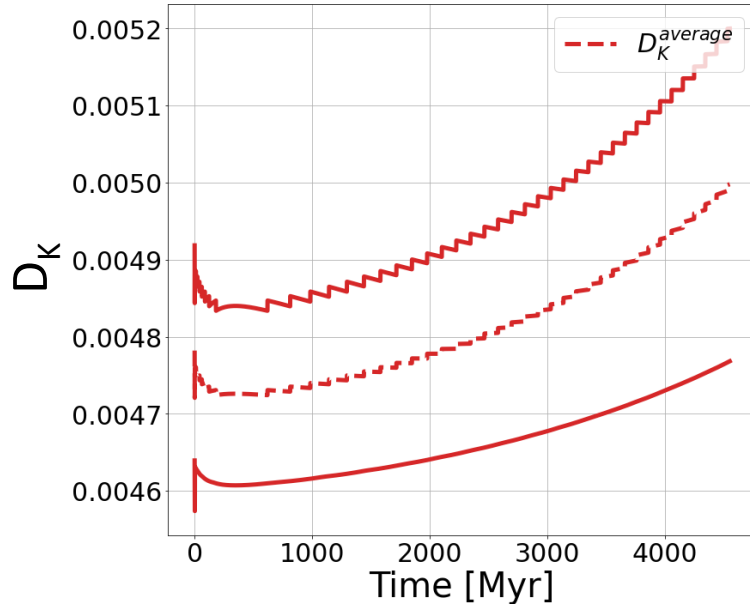


Partitioning inside the melt zone of Venus

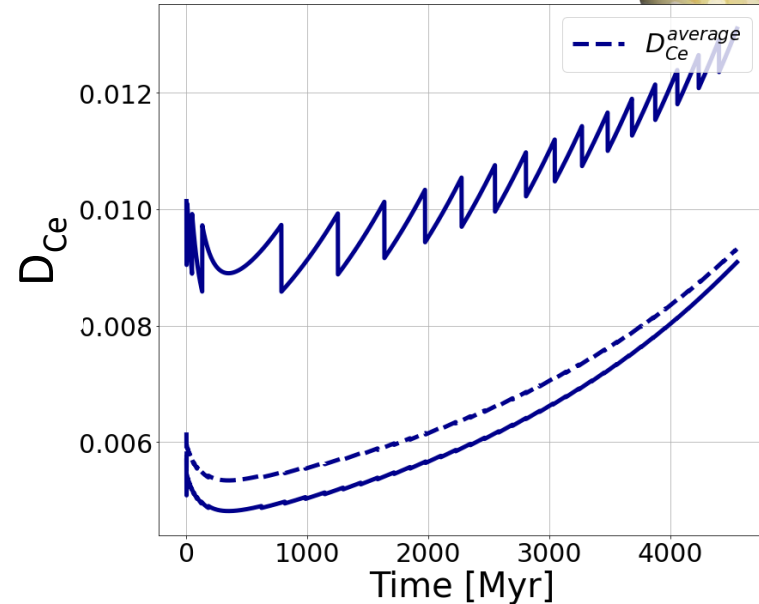
Bulk partition coefficients

Potassium

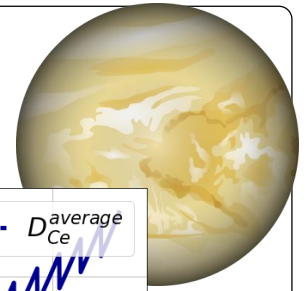
Cerium/H₂O



→ Max diff. ~8%



→ max. diff. ~ 30%



For the same melting zone inside Venus, bulk partition coefficients only vary for potassium ~8% and for Cerium still ~30%. Thus, the impact of the model seems to be small for HPE but larger for water.



Influence of mantle starting temperature

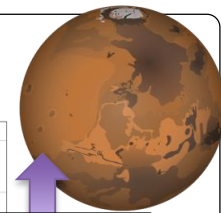
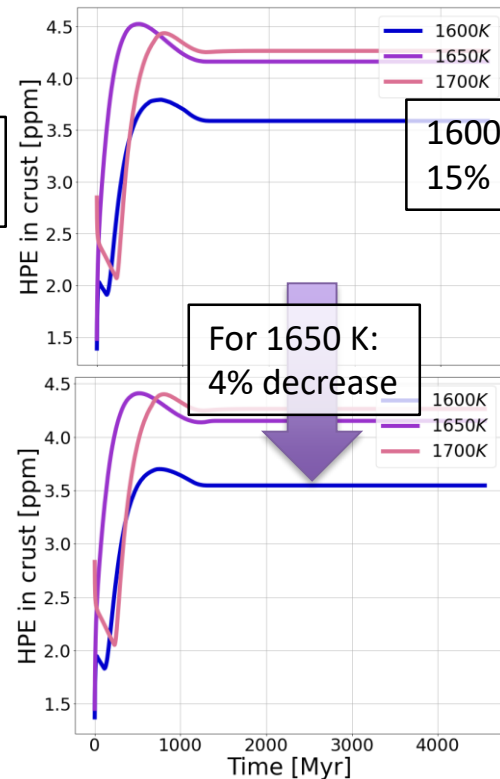
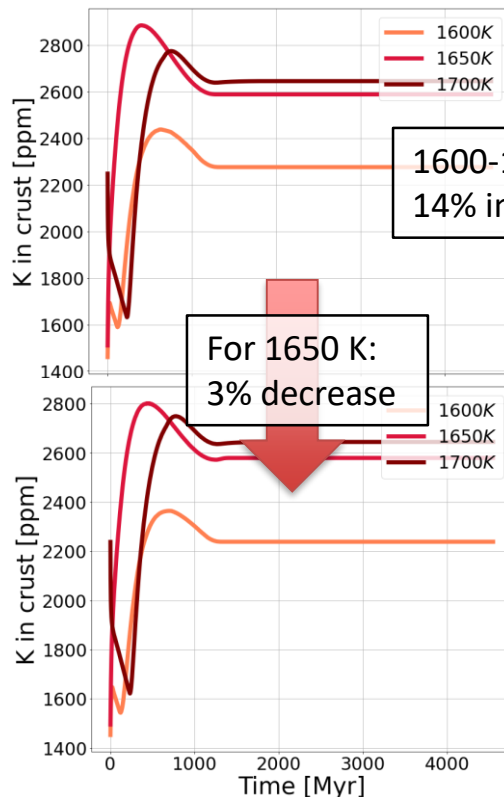
Fixed literature Ds

$$\eta_{\text{ref}} = 10^{21} \text{ Pa s}$$

P-T dependent Ds

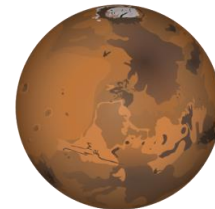
$$\eta_{\text{ref}} = 10^{21} \text{ Pa s}$$

Taylor et al. (2006):
2000-6000 ppm K on
Martian surface



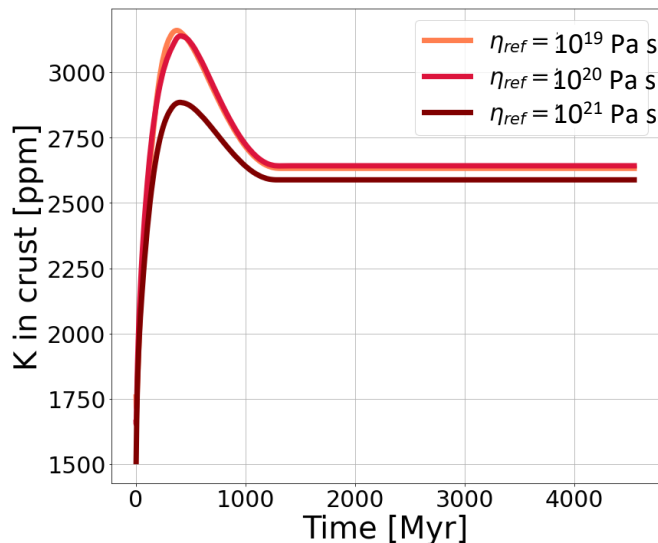
Mars is a smaller planet with a much smaller melting zone than Venus, so the impact will be even smaller for this planet. For a model with a T_{m0} of 1650 K, we get a 3-4% decrease for redistributed total K and HPE. However, if we increase the T_{m0} 100 K, we get a 14% and 15% increase in redistributed elements.

Influence of reference viscosity

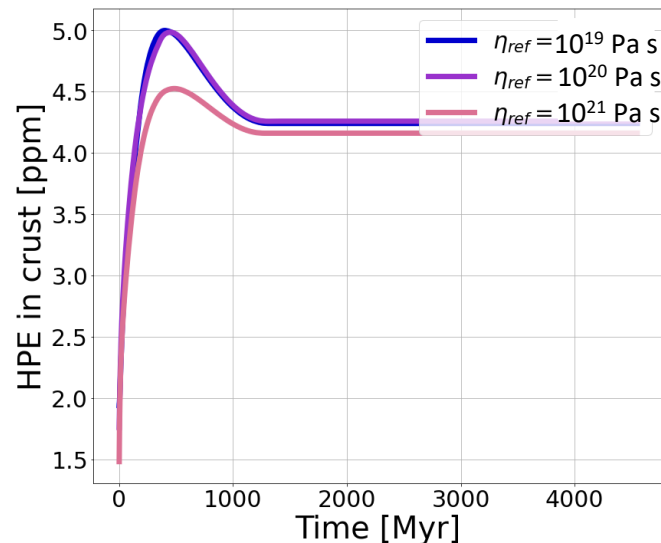


Fixed literature D s

$T = 1650 \text{ K}$
 10^{19} Pa s



~3% change

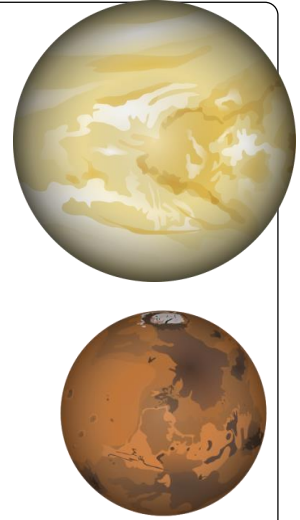


~3.5% change

In contrast to the mantle starting temperature, the reference viscosity η_{ref} (used to calculate the viscosity with the Arrhenius law of diffusion creep) has only a very small effect on the amount of the redistributed elements.



Conclusions



- ❖ Calculations for Cerium (H_2O) have a larger impact on the **bulk partition coefficients** than for HPE.
- ❖ Partition coefficient calculations have a **larger effect on the HPE and volatile redistribution** for planets with **larger melting ranges**.
- ❖ For smaller planets with smaller melting ranges, **other starting parameters have a larger impact** on the redistribution:
 - Small effect of calculated D_s and reference viscosity
 - Largest impact with changing **mantle starting temperature**



References

Schmidt, J.M. and Noack, L. (2021): *Clinopyroxene/Melt Partitioning: Models for Higher Upper Mantle Pressures Applied to Sodium and Potassium*, International Journal On Advances in Systems and Measurements, 14 (1&2), 125-136.

Taylor, G.J. et al. (2006): *Bulk composition and early differentiation of Mars*, J. Geophys. Res., 111, E03S10.

Wood, B. and Blundy, J.D. (2021): *A predictive model for rare earth element partitioning between clinopyroxene and anhydrous silicate melt*, Contrib Mineral Petrol (1997) 129, 166-181.

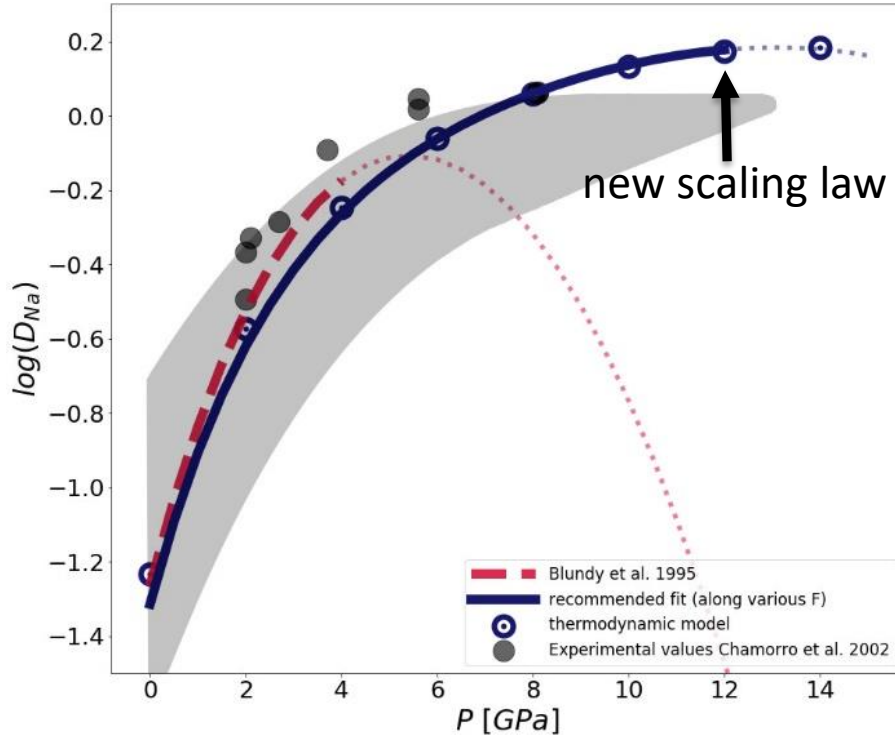


Additional Material



Parameterization results

Schmidt and Noack (2021)



New scaling law:

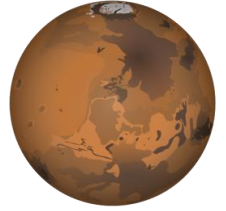
$$D_{Na} = \exp\left(\frac{2183 + 2517P - 157P^2}{T} - 4.575 - 0.5149P + 0.0475P^2\right)$$

- ❖ Along the solidus: Fits well very well to thermodynamic model
- ❖ Rises up to 12 GPa
- ❖ Fits very well to literature data

D_{Na} scaling law used to calculate D_{Na} in cpx/melt. We can use D_{Na} as a reference to model partition coefficients for other trace elements.



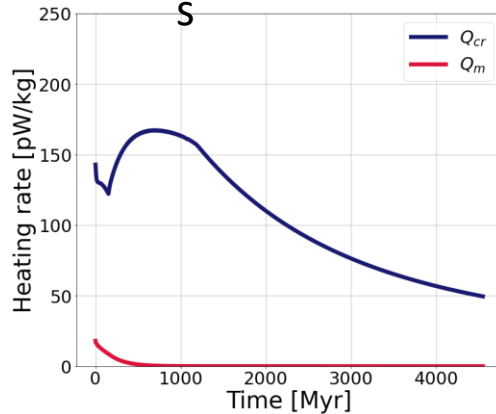
Influence of reference viscosity in the 1D model



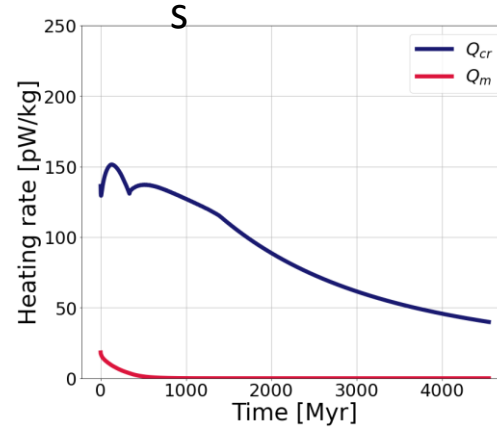
Fixed literature D_s

$T = 1650 \text{ K}$

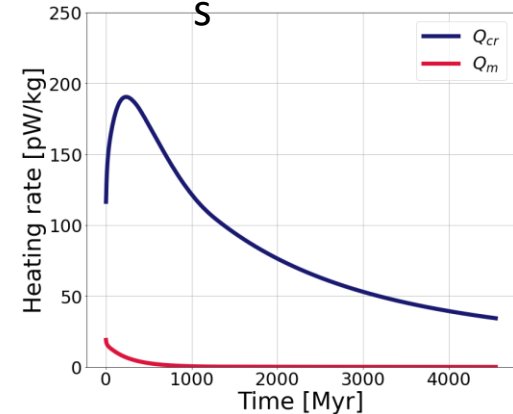
$\eta_{\text{eff}} = 10^{19} \text{ Pa}$



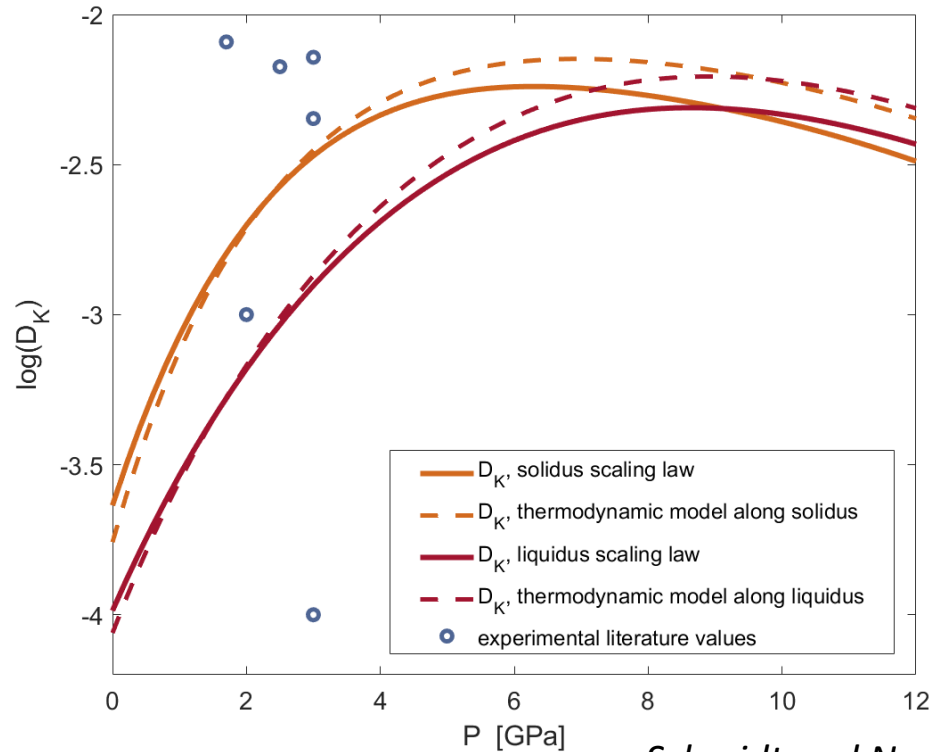
$\eta_{\text{eff}} = 10^{20} \text{ Pa}$



$\eta_{\text{eff}} = 10^{21} \text{ Pa}$



Potassium partitioning (Cpx/melt)



Schmidt and Noack (2021)



Partition Coefficient Modelling

Model by Wood et al. (1997):

$$D_i = D_0 * \exp \left[\frac{-4\pi E_{M2} N_A \left[\frac{r_0}{2} (r_0 - r_i)^2 + \frac{1}{3} (r_0 - r_i)^3 \right]}{RT} \right]$$

Partition coefficients of different charges vary depending on E and r_0

