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# Li behaviour during partial melting


**Elisa Oliveira da Costa**[1], Tom W. Argles[1], Leo M. Kriegsman[2,3], Barbara E. Kunz[1], Clare J. Warren[1]

elisa.oliveira.da.costa@gmail.com

1- The Open University

2- Naturalis Biodiversity Center

3- Utrecht University


## Introduction

Lithium has rapidly increased in relevance due to the green energy transition. Current models for the genesis of peraluminous granitoids and pegmatites - one of the main sources of Li - include the fractional crystallisation of melts derived from sedimentary protoliths (e.g., Linnen et al., 2012); the low-volume melting of Li-rich protoliths (e.g., Shaw et al., 2016); and the subsequent re-melting of S-type orthogneisses (Ballouard et al., 2024; Koopmans et al., 2024). Hence, understanding the behaviour of Li during partial melting is critical, regardless of the preferred model.

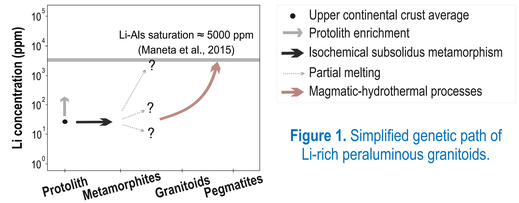


**Figure 1.** Simplified genetic path of Li-rich peraluminous granitoids.

Studies, however, have shown contrasting trends in melt Li concentrations during partial melting reactions due to the use of different distribution coefficient (Kd) sets.

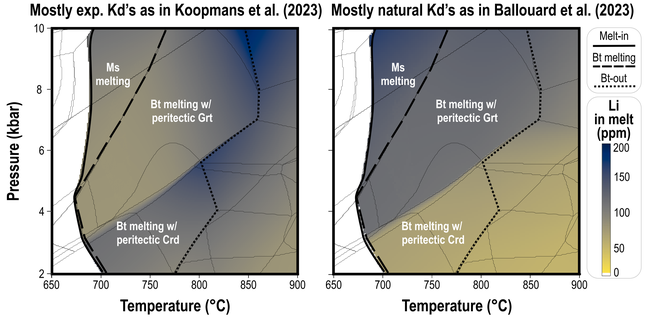


**Figure 2.** Lithium melt concentrations based on different partition coefficients sets.

In this study, we investigated Li behaviour during partial melting by comparing modelled melt and mineral concetrations estimated with different Kd's and natural Li concentration in the main mineral phases of pelitic migmatites.

## Material and Methods

**Literature and novel *in situ* mineral trace element concentrations and temperature estimates** in metapelitic migmatites. Novel data acquired by LA-ICP-MS at the Open University. Temperatures calculated using Na-in-Crd geothermometer (Tropper et al., 2018). Complete results in Costa (2025).

**Phase equilibria and trace element modelling** using MAGEMin (Riel et al., 2022). System and solution models as in White et al (2014). Trace element modelling in figures 5 and 6 used natural Kd's from Acosta-Vigil et al. (2012) or experimental Kd's from Icenhower and London (1995), and Evensen and London (2002; 2003). Starting Li concentration is 55 ppm (based on median Li in minerals - Fig. 3 and 4). Melt extractions at around 7 vol. % (Rosenberg and Handy, 2005).

## Results

### The main mineral hosts of Li

The main hosts of Li among the mineral phases stable in metapelites at suprasolidus conditions are (median, n):

- Cordierite (210 ppm, 336)
- Biotite (146 ppm, 830)
- Muscovite (33 ppm, 323)
- Garnet (13 ppm, 135)
- Alkali-feldspars (4.4 ppm, 100)
- Plagioclase (0.23 ppm, 195)

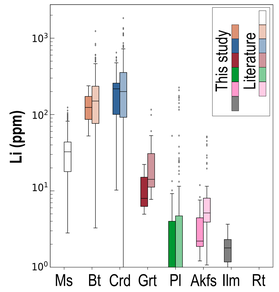


**Figure 3.** Box plot of Li concentrations in the main mineral phases of pelitic migmatites at suprasolidus conditions.

### Li concentration vs temperature

Our compilation confirms biotite and muscovite trends as in Kunz et al. (2022).

Our findings show cordierite Li concentrations decrease with increasing temperature as expected since: (1) Li exhange mechanism into Crd involves Na (Bertoldi et al., 2004); (2) Na is correlated to temperature (Tropper et al., 2018).

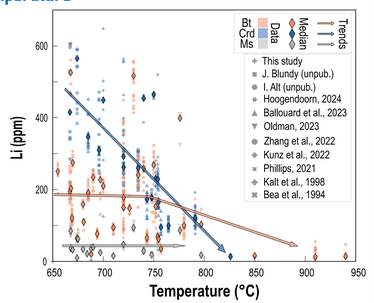


**Figure 4.** Li concentration trends in muscovite, biotite and cordierite.

### Modelled Li concentrations at 4 and 8 kbar without melt extraction

| | Experimental Kd's | Natural Kd's |
|---|---|---|
| **What reaction produces the most enriched melts?** | Bt-dehydration melting w/ peritectic Grt | Qz-Flds melt at 4kbar<br>Ms melts at 8 kbar |
| **What is the effect of cordierite?** | increase in melt Li (~50 ppm Δ to 8 kbar) | decrease in melt Li (~100ppm Δ to 8 kbar) |
| **Are natural mineral trends (figure 4) reproduced?** | Bt = yes<br>Crd = lower<br>Ms = higher | Bt = no<br>Crd = mostly<br>Ms = yes |

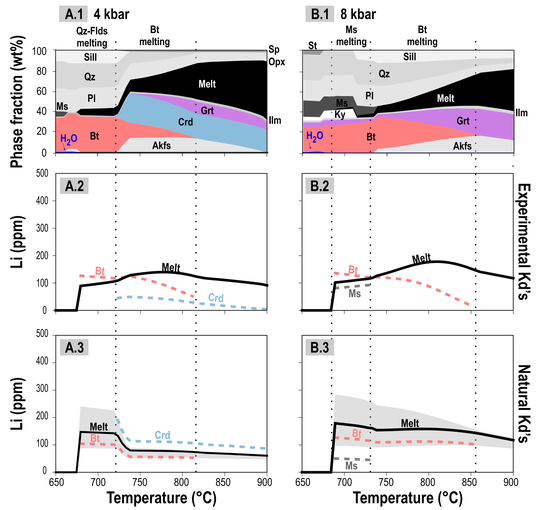


**Figure 5.** Cumulative phase proportions at (A.1) 4 kbar and (B.1) 8 kbar. Predicted melt and mineral using experimental (A.2, B.2) and natural Kd's (A.3, B.3).

### Modelled Li concentrations at 4 and 8 kbar with melt extraction

**What is the main effect of melt extraction?**

At 8 kbar, the experimental Kd's model reaches highest Li concentrations (300 ppm)

This happens because, at higher temperature, melts derived from biotite-dehydration melting are no longer being diluted by lower temperature melts derived from muscovite melting since they have been extracted.

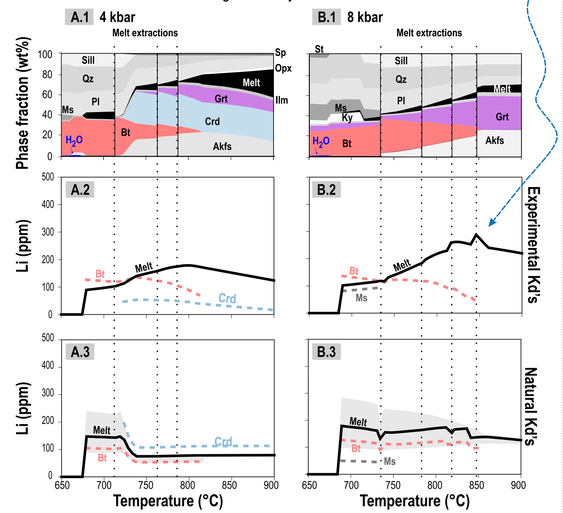


**Figure 6.** Cumulative phase proportions at (A.1) 4 kbar and (B.1) 8 kbar with melt extraction. Predicted melt and mineral using experimental (A.2, B.2) and natural Kd's (A.3, B.3).

## Discussion

### Why is contrasting Li behaviour predicted?

Based on the comparison between experimental Kd's (Fig. 7A), natural Kd's (Fig. 7B) and pelitic migmatites (Fig. 7C), these parameters might explain different Li behaviour during melting:

**(1)** Higher water content in experiments. Water increases melt $Na_2O$ contents (which can enhance Crd Li-Na exchange mechanism), and enhances Li diffusion due to depolymerization (Holtz & Johannes, 1991; Troch et al., 2024).

**(2)** Higher F in experimental Bt (only observed in some pelitic migmatites at~800 °C - Finch & Tomkins, 2017; Kunz et al., 2022). Flourine enhances depolymerisation (e.g., Giordano et al., 2004).

**(3)** Experimental starting compositions are unlike average pelites, and experimental Crd match only higher temperature natural Crd (>800 °C - Fig. 7D and E).

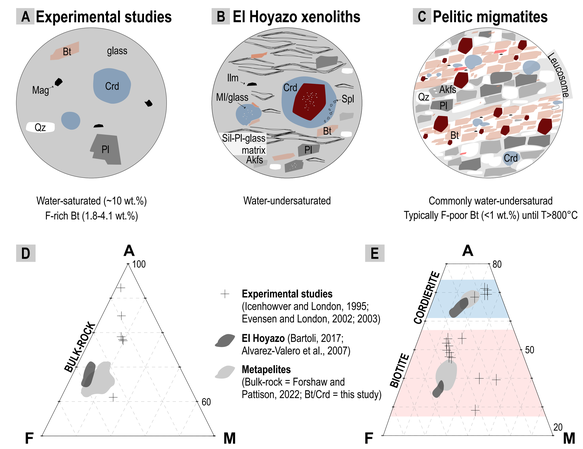


**Figure 7.** Key differences between (A) experiments, (B) El Hoyazo migmatitic xenoliths and (C) pelitic migmatites, particularly, (D) bulk-rock and (E) mineral chemistry.

## Conclusions

- The main hosts of Li in metapelites at suprasolidus are cordierite and biotite.
- The Li concentrations of cordierite and biotite vary with temperature.
- Experimental and natural Kd's indicate different reactions most effectively mobilise Li.
- The comparison of models with natural trends do not support one model or the other completely.
- Future studies are needed to test if/how these physicochemical parameters - system composition, and water and flourine contents - affect Li behaviour during pelite melting.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement no. 956125 within the Fluidnet project .