

Multi-component cubic oxide exsolution in synthetic basalts: Temperature dependence and implications for magnetic properties

Julie A. Bowles¹, Lisa Tatsumi-Petrochilos²,
Julia E. Hammer²,
and Stefanie A. Brachfeld³

¹ University of Minnesota, ² University of Hawaii, ³ Montclair State University

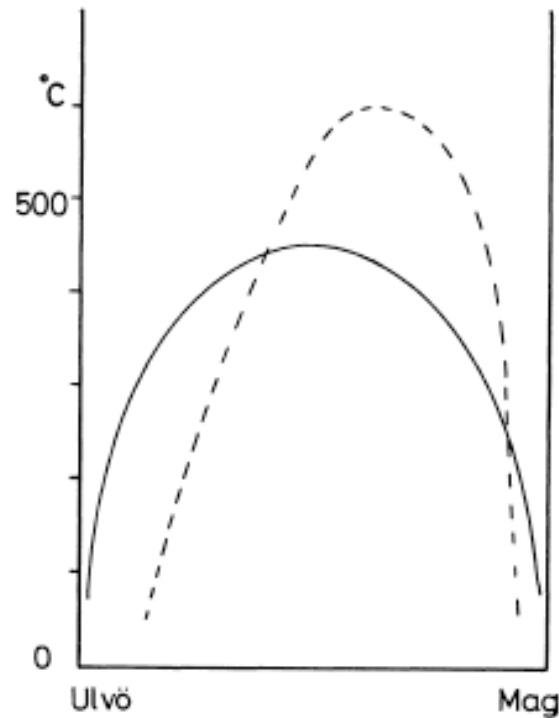
Motivation

1. Understand the possible role that cubic oxide exsolution may play in generating intense Mars magnetic anomalies
 - Start with two plausible bulk compositions (high Fe/Al, low Fe/Al)
2. Better understand kinetics of multi-component oxide exsolution, place constraints on the solvus in relation to ordering temperatures.

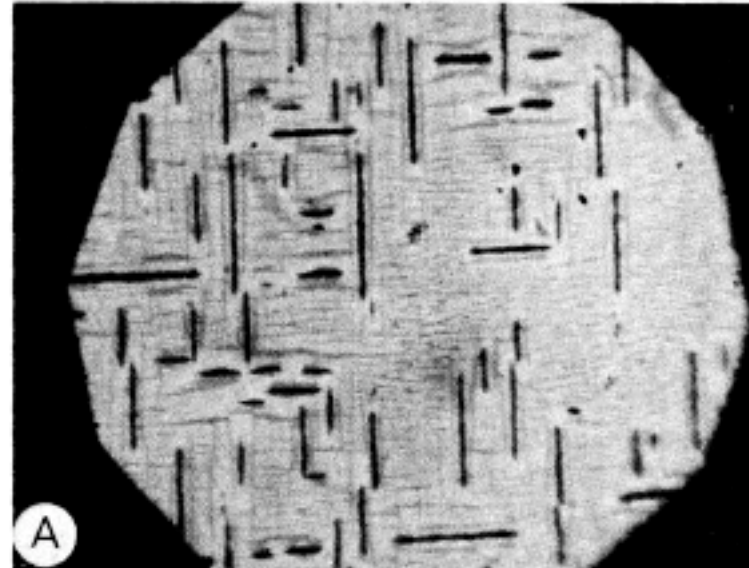
Outline

- Experimental procedure and results
- Conclusions
- Future, hypothetical conclusions brought to you by MagIC

Cubic oxide unmixing / exsolution



From Price (1981); dashed line from Vincent et al. (1957)



From Price (1981)

10 μm

Possible Results/Implications:

- Reduced magnetic grain size => stronger, more stable magnetization
- Increase in (maximum) Curie temperature

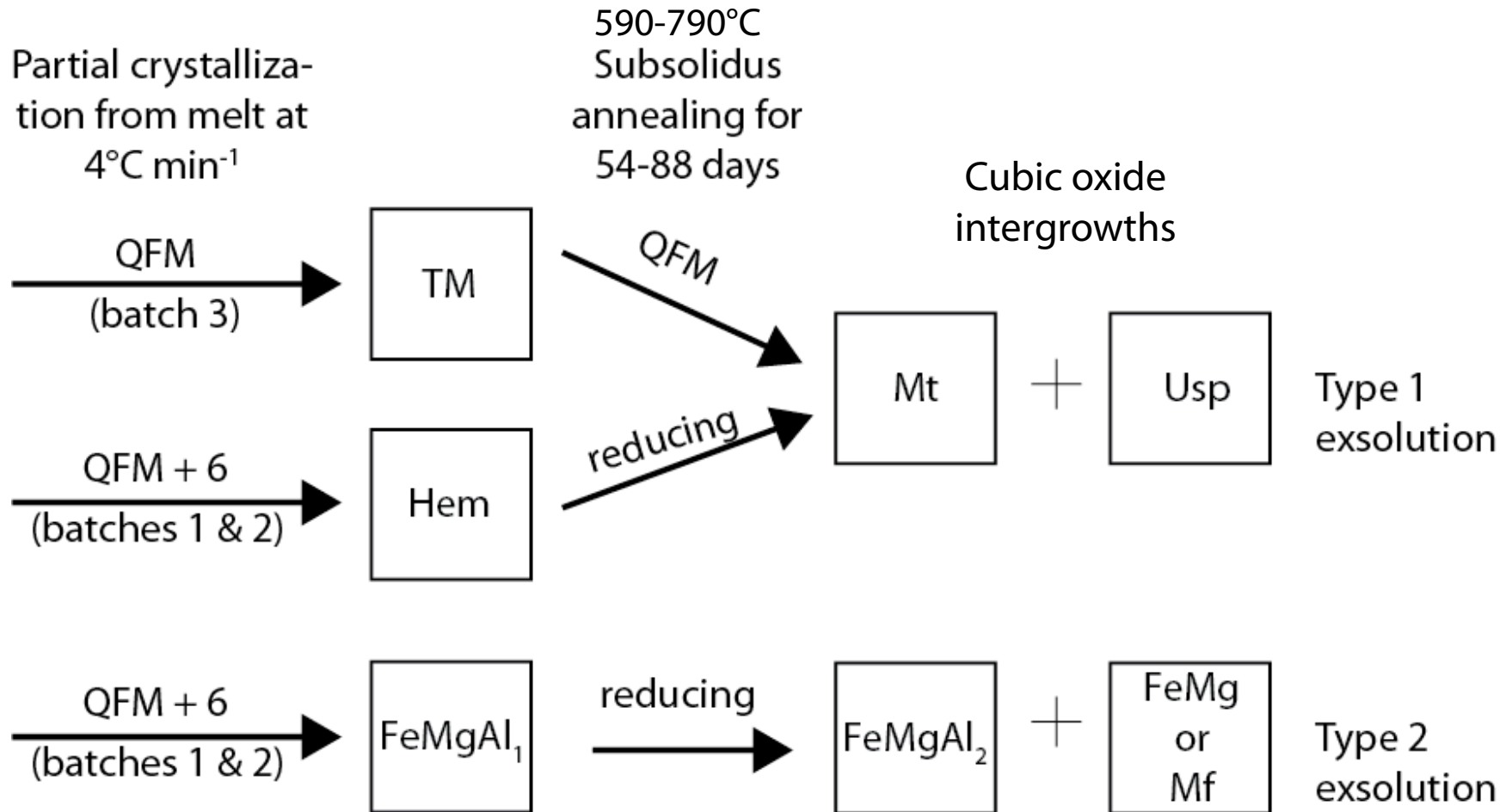
Experimental rationale

Exsolution in pure magnetite - ulvöspinel system occurs at temperatures too low to be viable on laboratory timescales. BUT:

- **magnetite (Fe_3O_4) - spinel (MgAl_2O_4)** solid solution:
<~1000°C (Harrison and Putnis, 1997)
- **magnetite (Fe_3O_4) - hercynite (FeAl_2O_4)** solid solution:
858°C (Deer, Howie, Zussman, 1992)

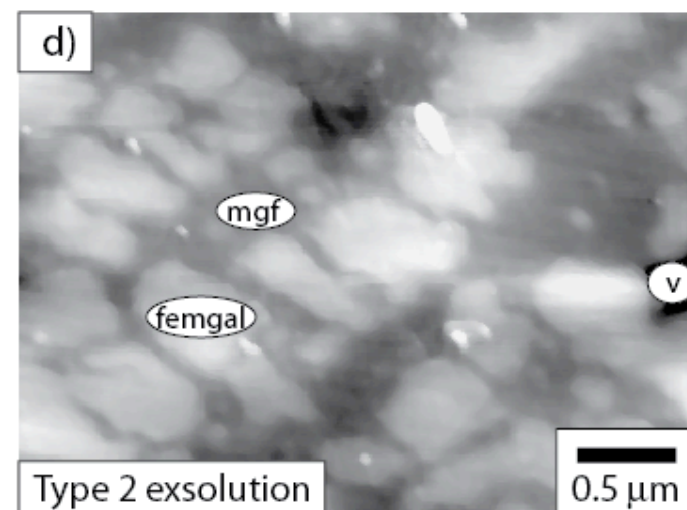
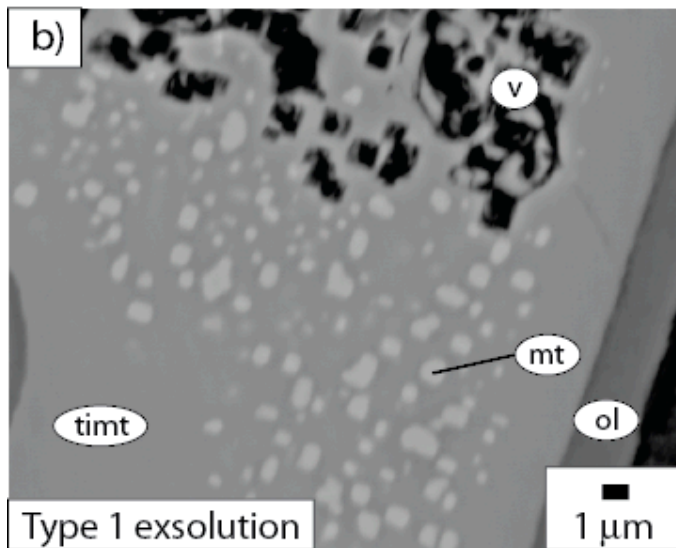
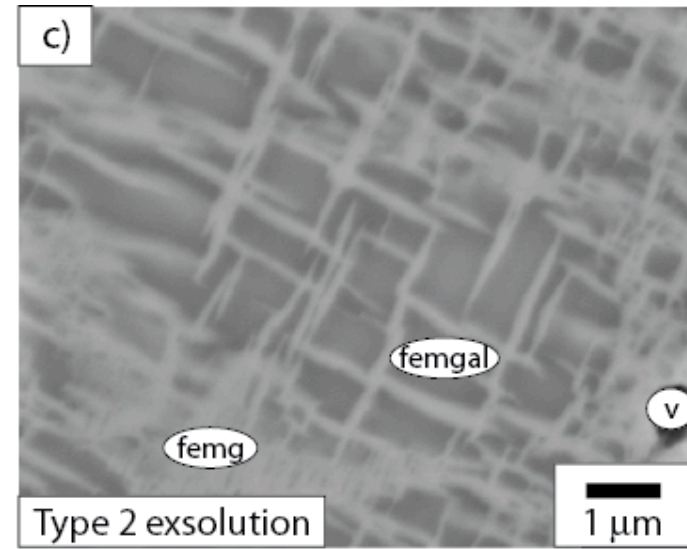
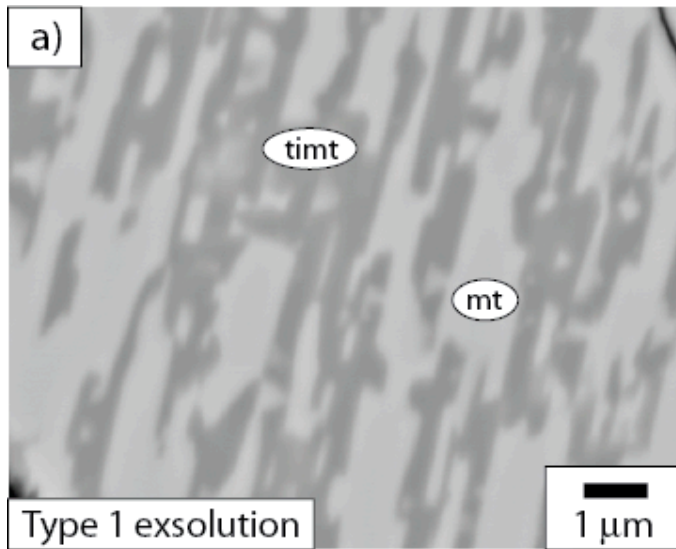
Our analog basalts have significant Mg, Al, and Cr substitution, in addition to Ti. This system may be approachable on laboratory timescales.

Experimental Workflow

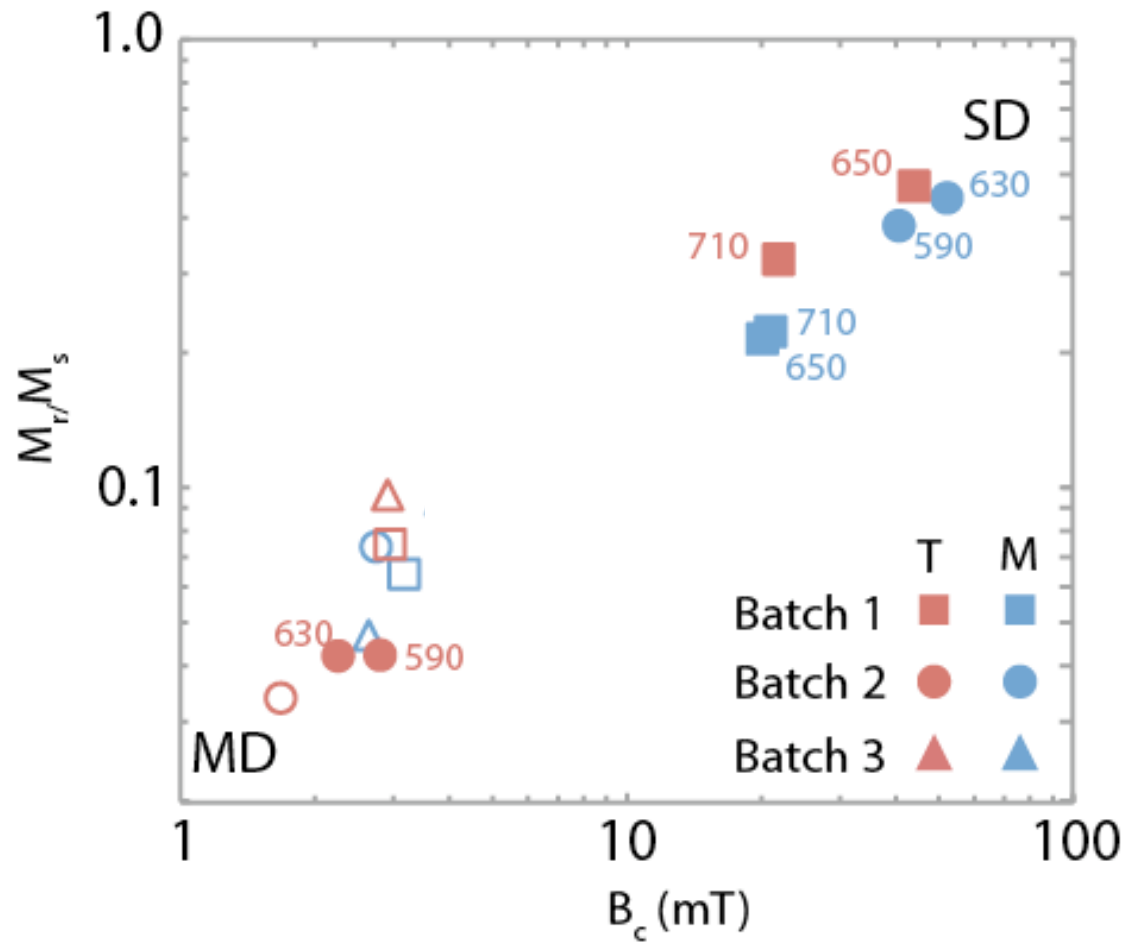


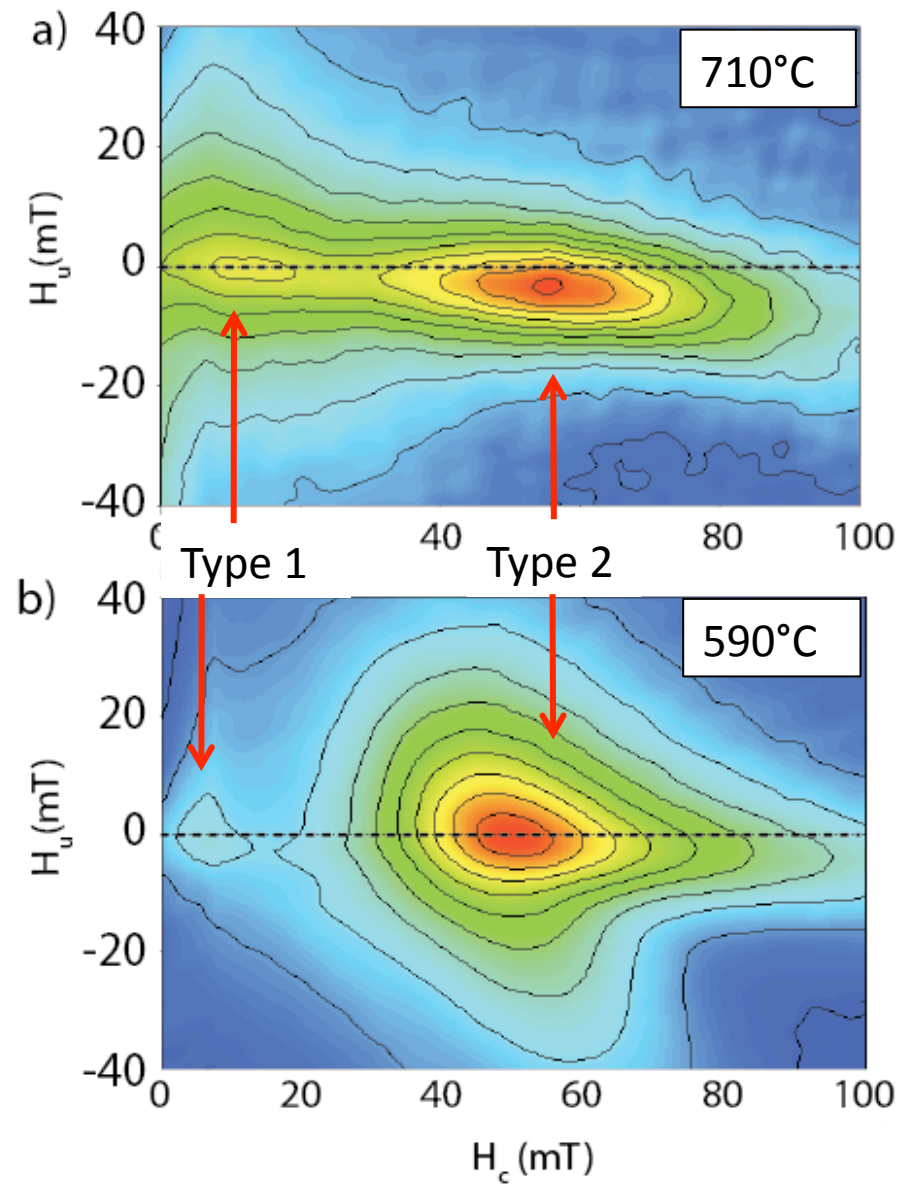
- Earth's mantle
- Meteorite fusion crusts
- Impact melts
- Alkalic ocean island gabbros
- Arc trachyandesite lavas

Exsolution types



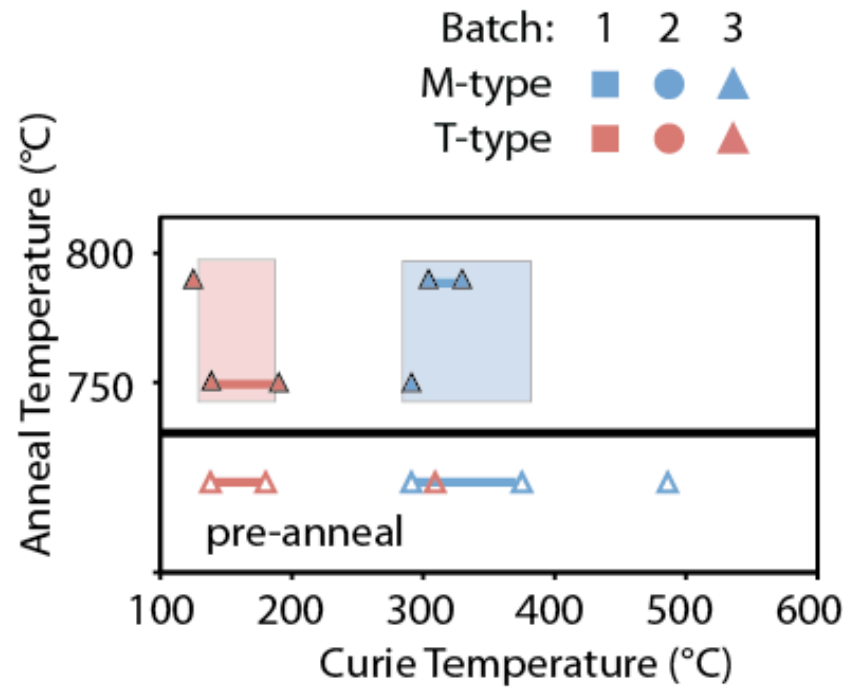
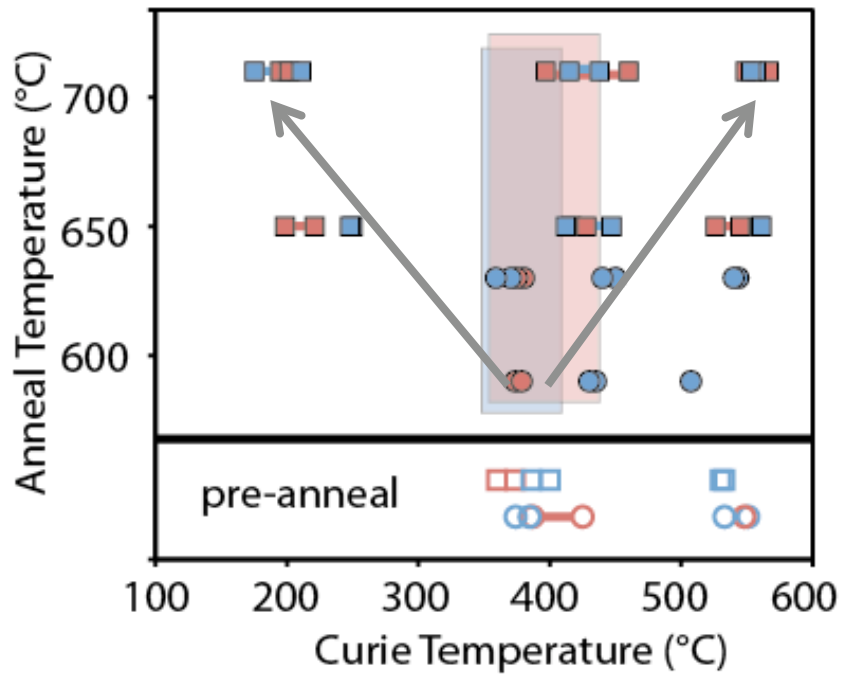
Domain state



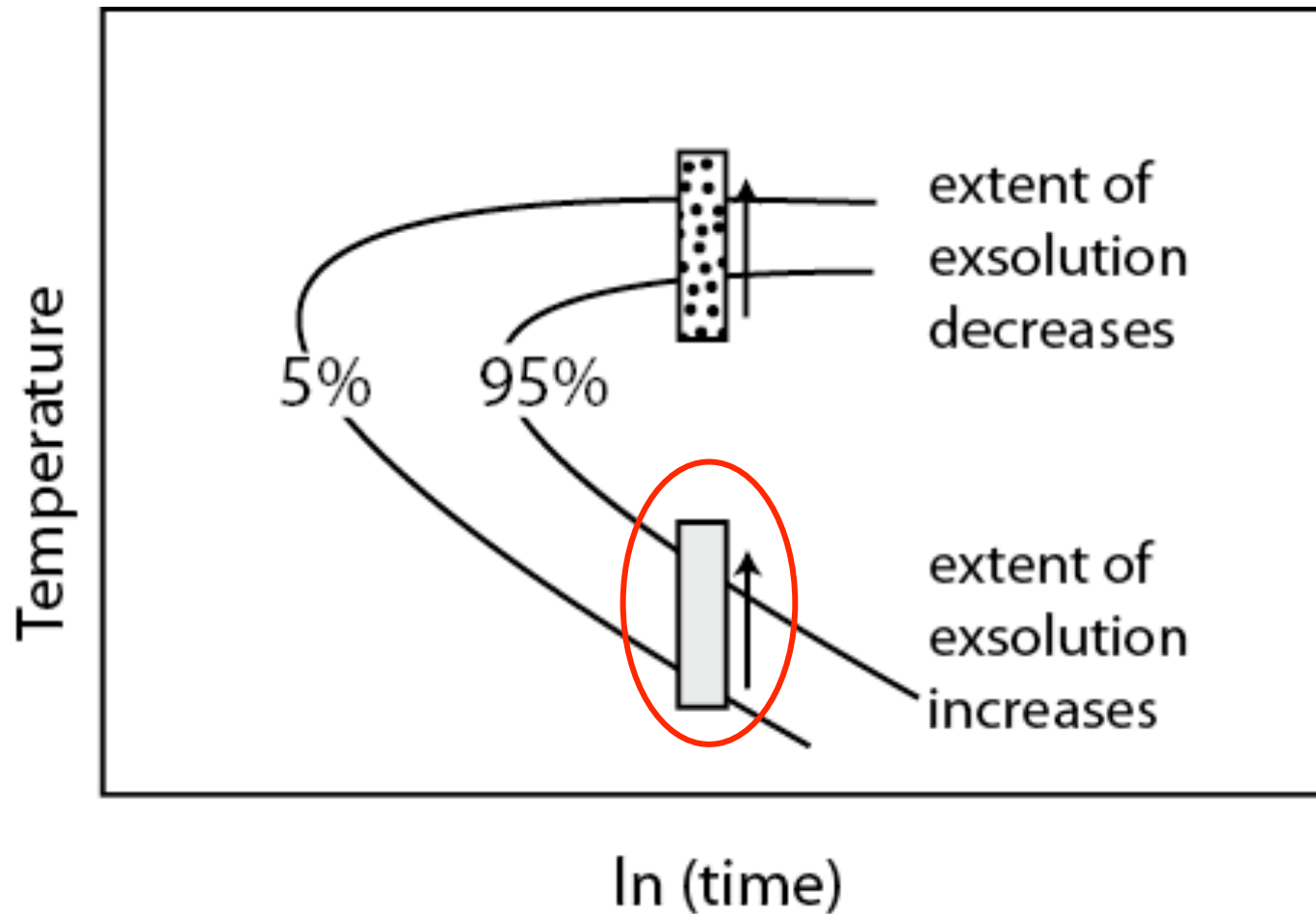


Processed with FORCinel (Harrison & Feinberg, 2008)

Curie temperatures



Constraints on multi-component solvus



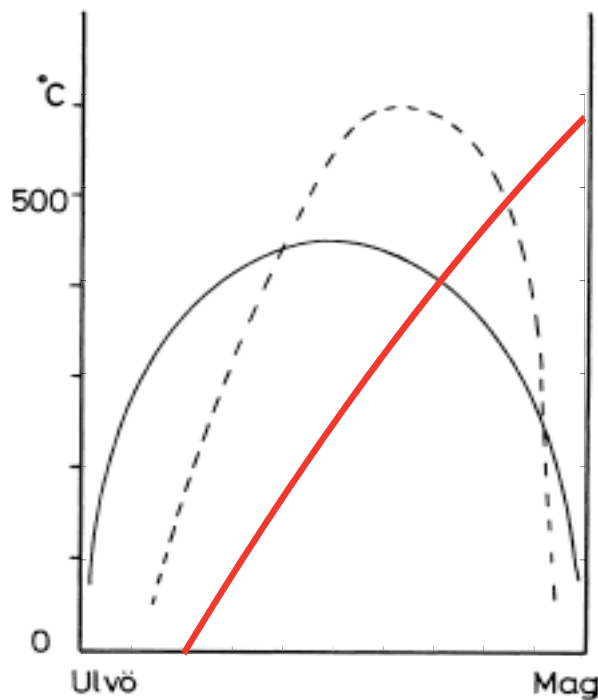
Anneal temperatures considerably lower than solvus temperatures.

Conclusions

- Both the time and temperature at which basalts undergo exsolution in nature can play a dramatic role in the resulting magnetization.
- With increasing anneal temperature, exsolution proceeds further to completion.
 - Anneal temperatures well below solvus.
- Solvus temperatures of the multi-component systems $\gg T_C$ of all cubic spinels.
 - Exsolved, impure titanomagnetite can carry a total or near-total TRM.

How could DB help?

- Ability to do rapid literature search for specific rock magnetic properties (e.g., SD, high T_C ...)
- Could you predict whether or not a specific composition carries a TRM or a CRM?

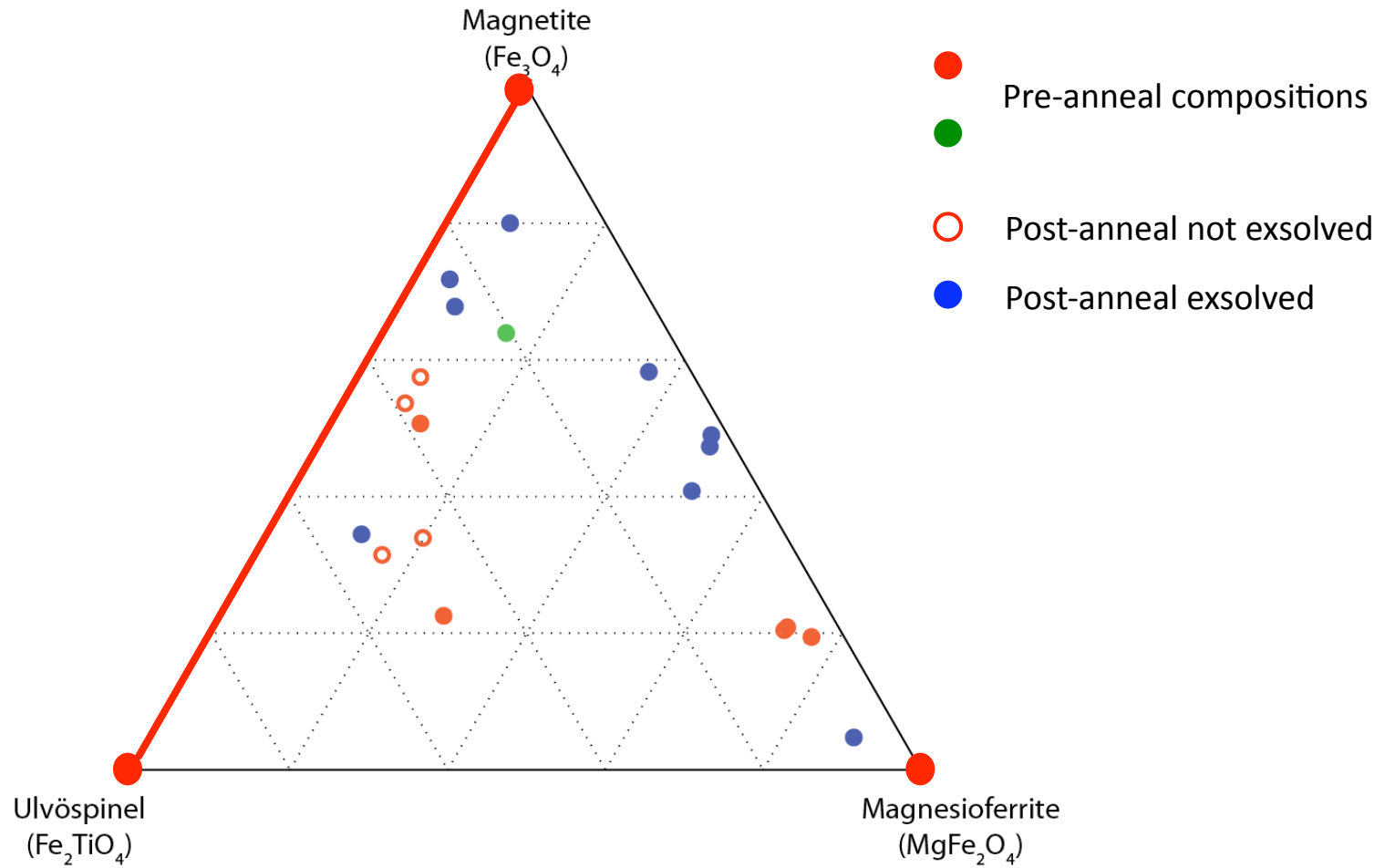


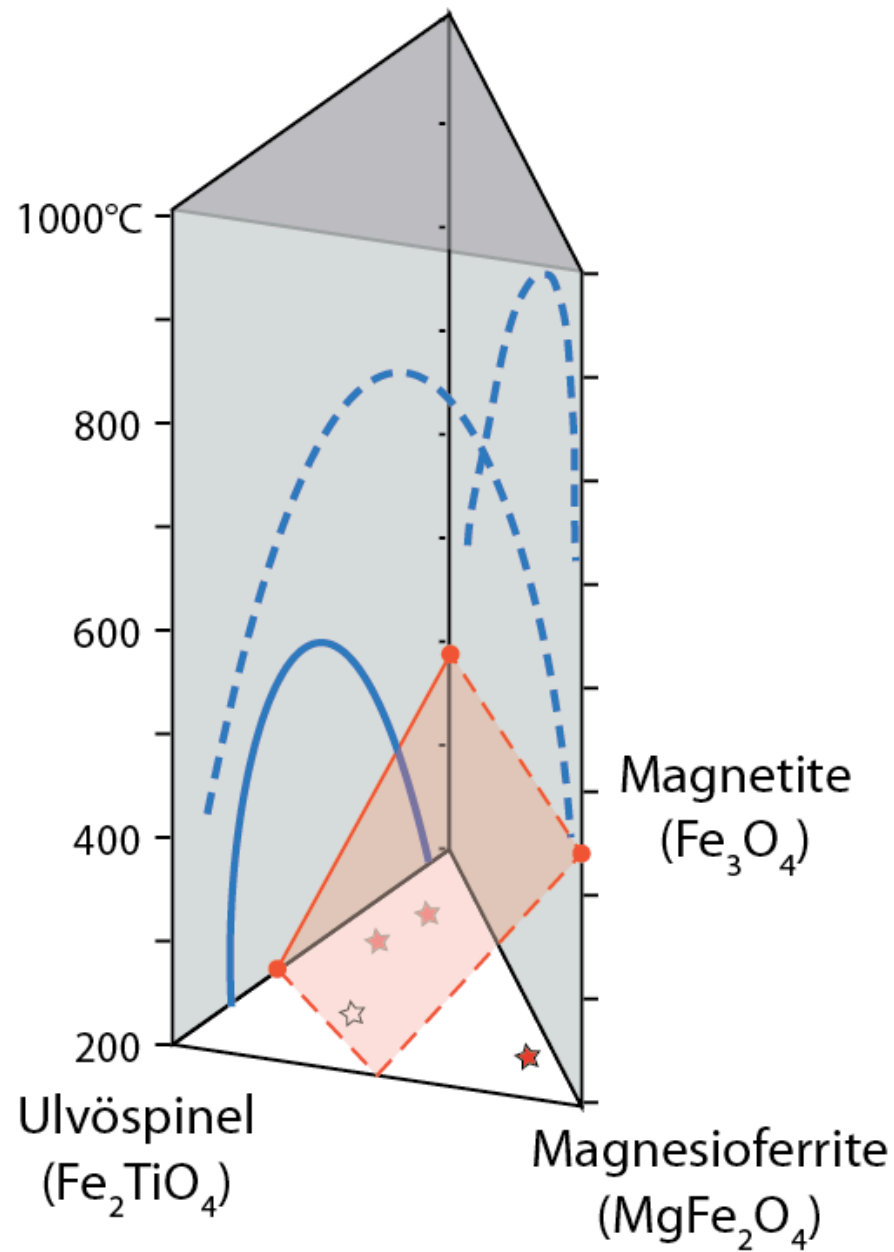
Can we start to make a similar plot in multi-dimensional space?

How could DB help?

- Ability to do rapid literature search for specific rock magnetic properties (e.g., SD, high T_C ...)
- Could you predict whether or not a specific composition carries a TRM or a CRM?
- Need to assign Curie temperatures to multi-component oxides.

Simple 3-component system





Advantages of database

Instead of undertaking a massive, time-consuming study, “crowd-source” it by taking advantage of ordering temperature data reported by others.

By storing actual data, individual investigators can reprocess in a standardized way or evaluate the reliability of reported T_C .

