Igneous Phase Diagrams:
Past, Present, and Future Directions

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EXPERIMENT AS AN AID TO THE UNDERSTANDING OF THE NATURAL WORLD*

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Fig. 1. Melting equilibrium diagram of the plagioclase feldspars.

Fig. 5. Equilibrium diagram of the system NaAlSiO₄-FeO-SiO₂.

The importance of volatiles

Dasgupta et al. (2013) *Nature*

Bowen (1954) *Proc Acad Nat Sci Philadelphia*
Igneous Phase Diagrams: state of the art*

* or science

Gualda et al. (2012) *Journal of Petrology*
So are we done?
Textures of granitic rocks

Pegmatite, Minas Gerais, Brazil

Granite, Nanga Parbat, Pakistan

Obsidian, Landmannalaugar, Iceland

Rhyolite, St Francois Mountains, MO
“Disequilibrium” phase diagrams

slow cooling (equilibrium)

melt

liquidus

melting point (congruent)
melt + crystals

crystals

fast cooling (disequilibrium)

melt

liquidus

glass transition (faster cooling = higher Tg)
glass

crystals

Speck et al. (2011) Astrophysical Journal
Crystal nucleation and growth

T (°C)

$T_{\text{liq}}$ and $T_{\text{sol}}$ are for 300 MPa

Data of Fenn (1977) *Canadian Mineralogist*, figure modified from Nabelek et al. (2010) *Contributions to Mineralogy and Petrology*
Phase diagrams and textures

Nabelek et al. (2010) Contributions to Mineralogy and Petrology
Metastable eutectics

Rietmeijer and Nuth (2000) EOS
Are cooling histories linear?

External factors (recharge?)

Internal factors (latent heat)

Matthews et al. (2012) Contributions to Mineralogy and Petrology

Latent heat vs sensible heat

SM glass
(heating)

“apparent” $C_P$ (J g$^{-1}$ K$^{-1}$)

0.0
-0.5
-1.0

0 200 400 600 800 1000 1200 1400 1600

Temperature (°C)

Synthetic Mercury analog basalt
(Alex Sehlke, Univ. Missouri)

glass transition

glass

melting

liquidus

liquid

crystallization
Recalescence in (Fe,Mg)SiO$_3$ melt

Video by Alex Sehlke, Univ. Missouri
Conclusions

• equilibrium model:
  Phase equilibrium experiments $\Leftrightarrow$ thermo measurements
  Internally consistent databases (ig-met convergence)
  Volatiles ($\text{CO}_2$, mixtures, …)

• disequilibrium phenomena:
  Metastability (the vitreous phase, eutectics, …)
  Cyclic thermal histories (recalescence, shear heating, …)
  Forward models must integrate $P-T-t-X$ information and feedbacks (ig-met convergence)

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