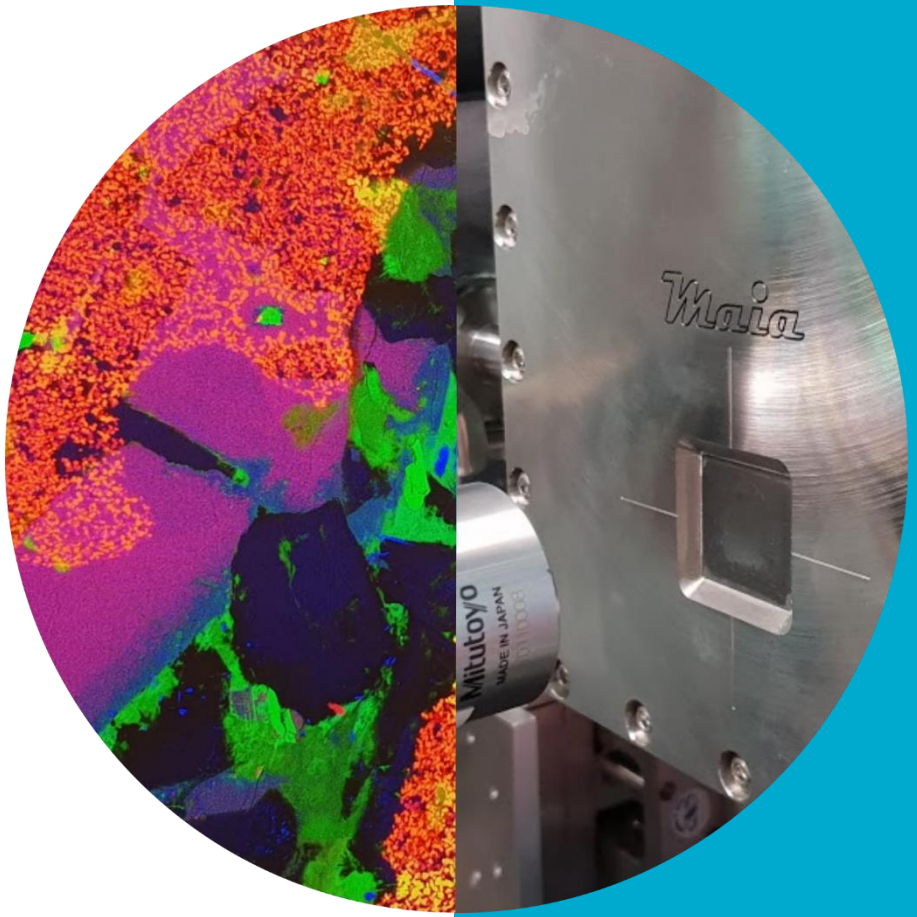
XFM technologies in Earth Sciences:

Volcanoes, Metals, Life and Death

Louise Schoneveld| Steven Barnes | Siyu Hu



Understanding our Earth using X-rays

Volcanoes
Metals
Exploration

Using **XFM** technologies at **varying energies** to understand how magmas form and as an exploration tool for Nickel

Louise Schoneveld

Volcanoes
Metals
Extinction

Using **XFM paired with µCT** to understand how platinium group minerals form and give us clues to the biggest mass extinction on earth

Steve Barnes

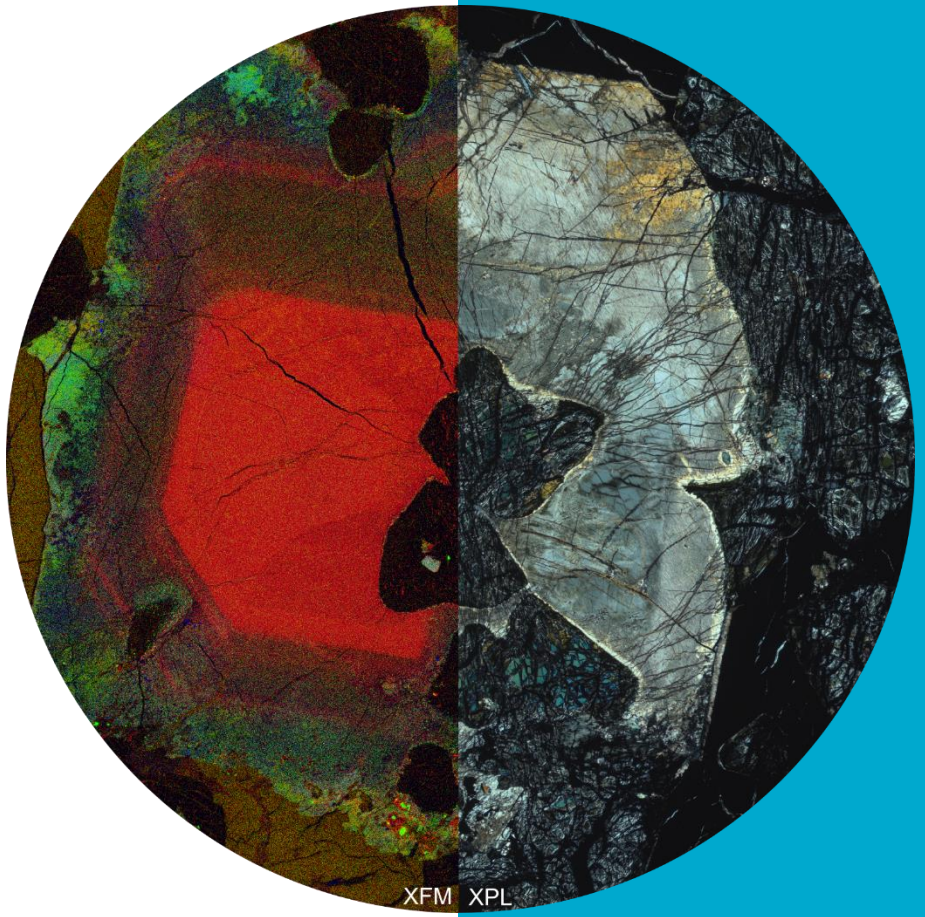
Volcanoes
Metals
Early Life

Using **XFM and XANES** to understand undersea volcanoes and give us clues into early life on earth

Siyu Hu

Using pyroxene as an exploration tool for Nickel

Louise Schoneveld | Research Scientist



thevisualcapitalist.com

NICKEL

THE SECRET DRIVER OF
THE BATTERY REVOLUTION

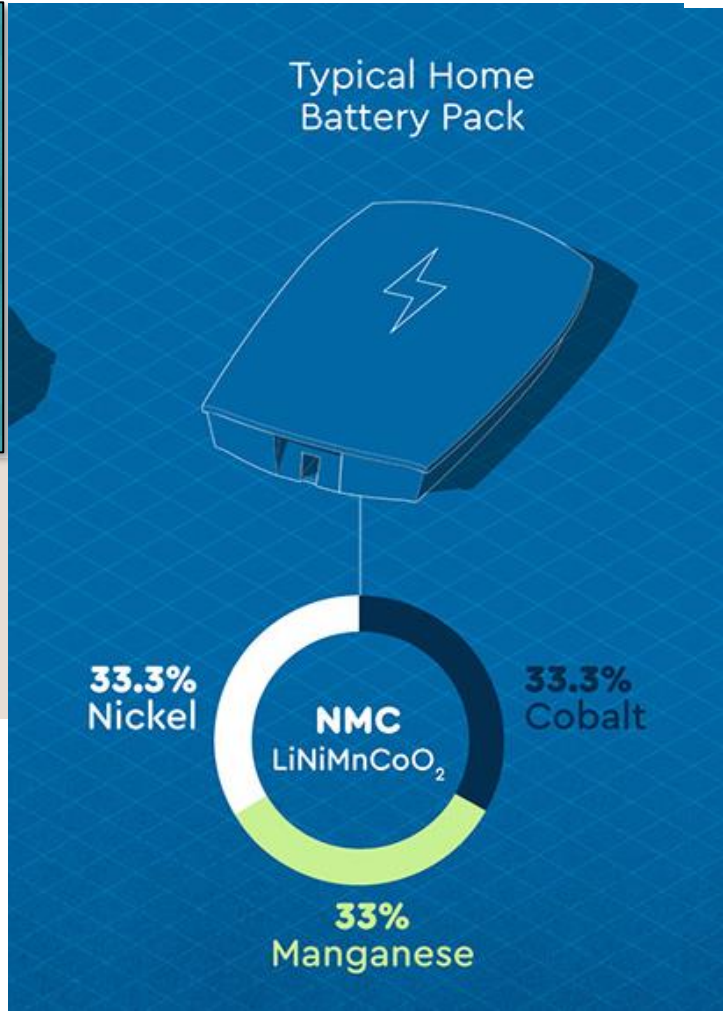
Lithium-ion batteries are growing at spectacular rates, the role of nickel is significant in lithium-ion batteries and the concentration of nickel is increasing because it increases energy density and gives greater range.

- Eddy Haegel, BHP Nickel President

In August 2017, mining giant BHP Billiton announced it would invest

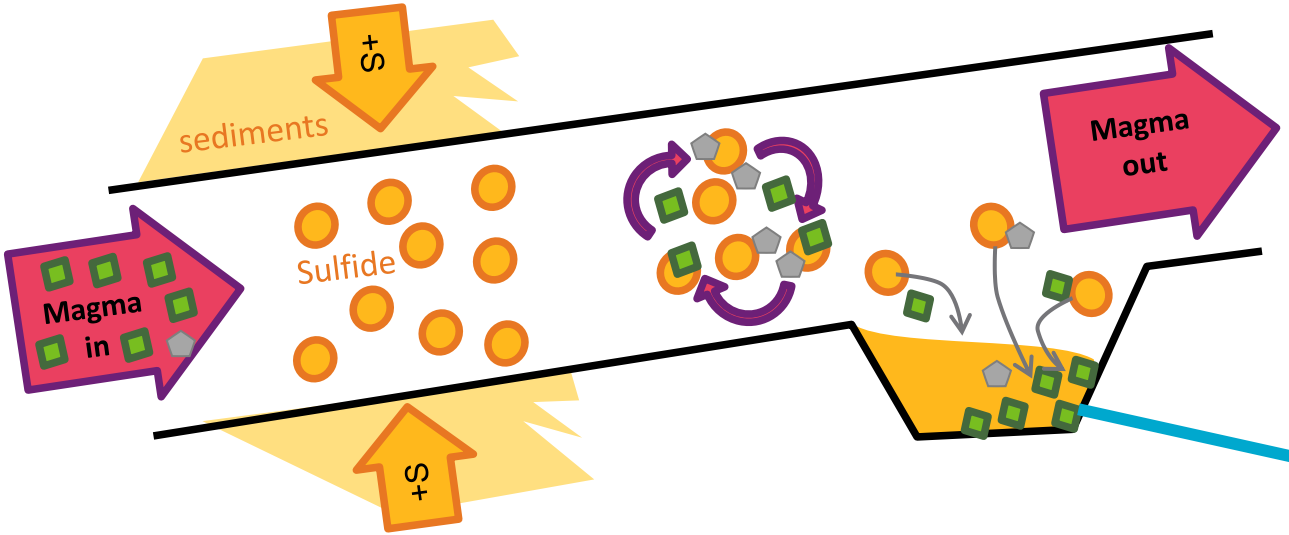
$43.2 MILLION

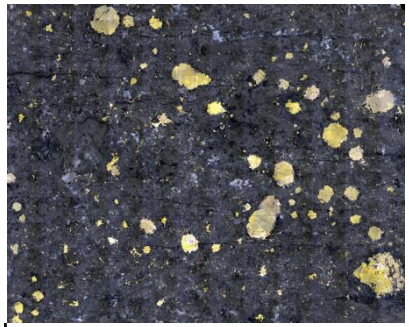
to build the world's biggest nickel sulfate plant in Australia.

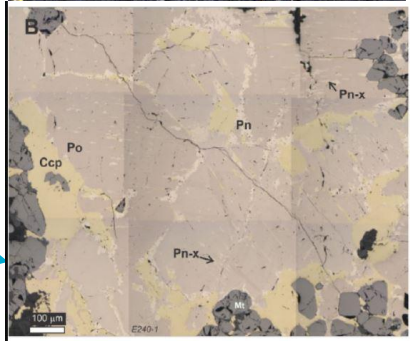


Recipe for Magmatic Sulfide Deposits

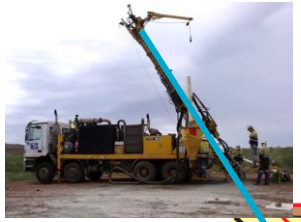
1) **Saturate** the magma with sulfide
2) **Concentrate** Ni, Cu, PGE in the sulfides in magma freeways
3) **Accumulate** the sulfides

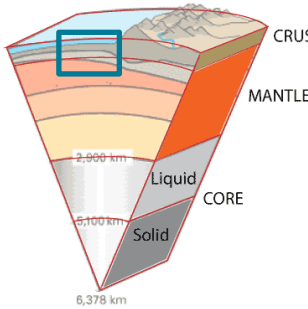


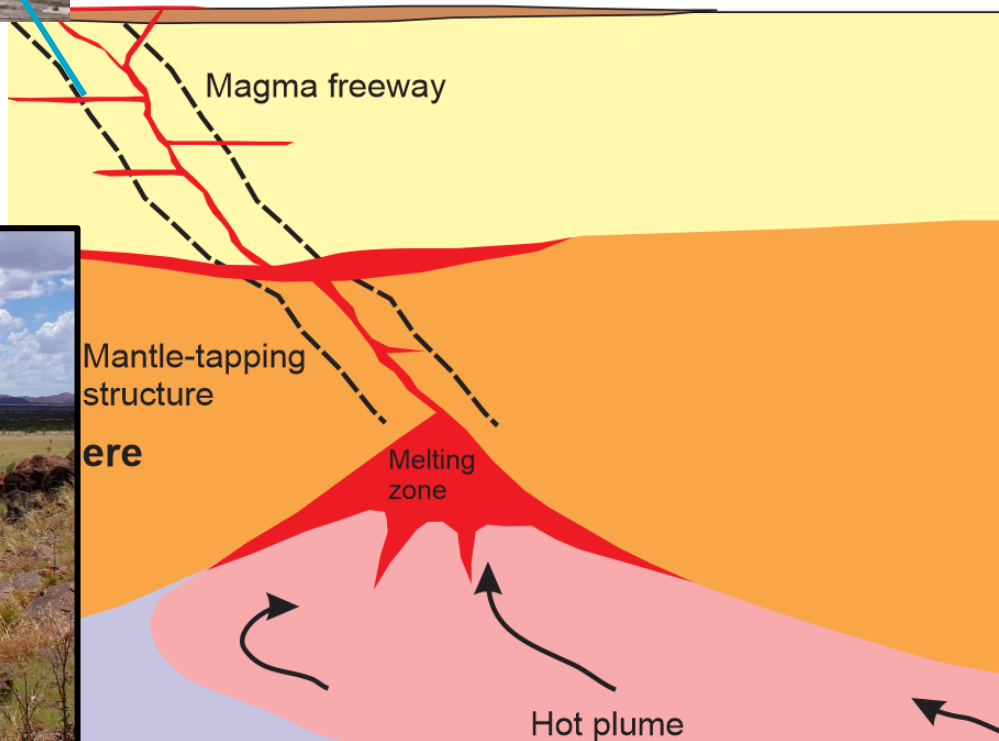




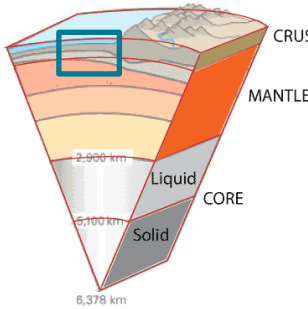
Searching for magma freeways



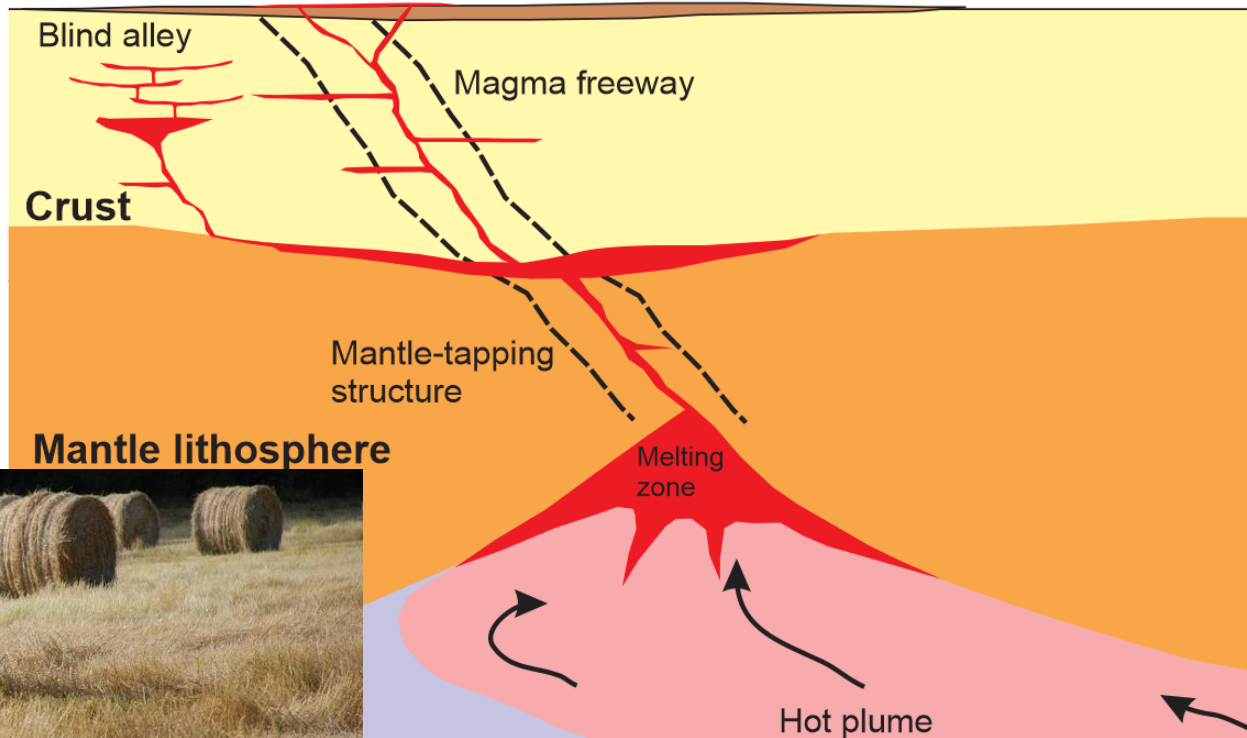




Searching for magma freeways

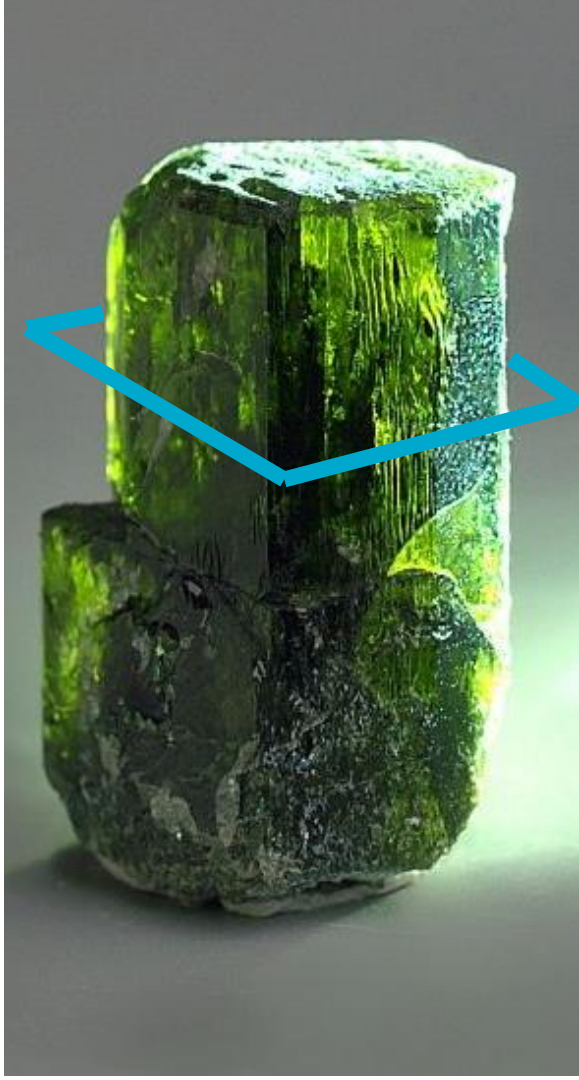


Needle in a field of haystacks type problem

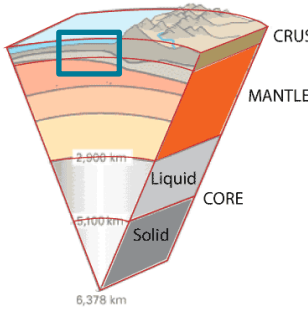


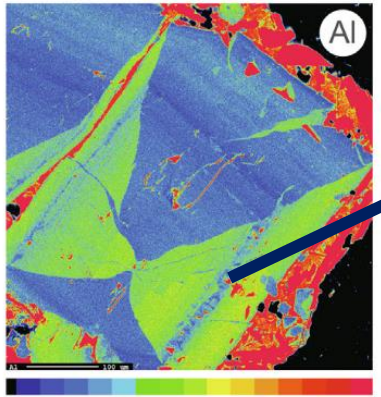
Why Pyroxene?

- Very common mineral
  (~11% of crustal minerals)
- Wide range of stability
  (mafic to intermediate magmas)
- Rapid growth



Pyroxene: Time capsule for magma histories

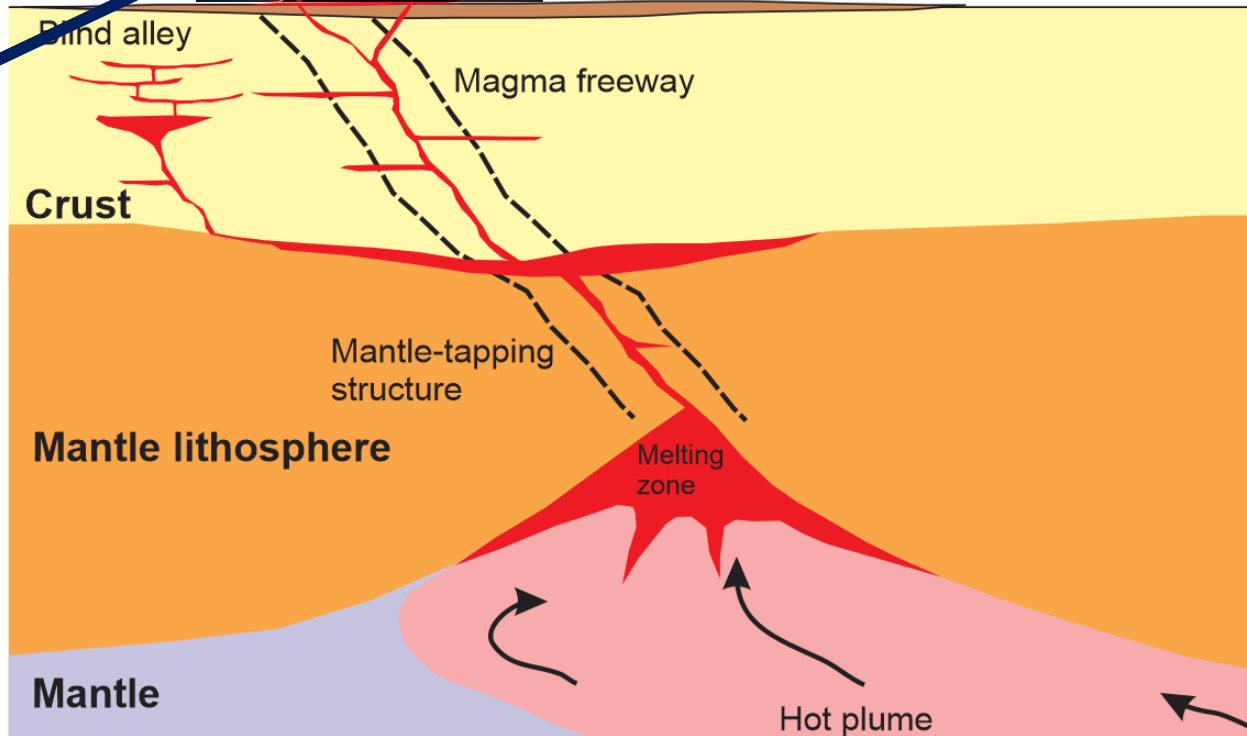




Volcanic example; **Ubide et al. 2019**

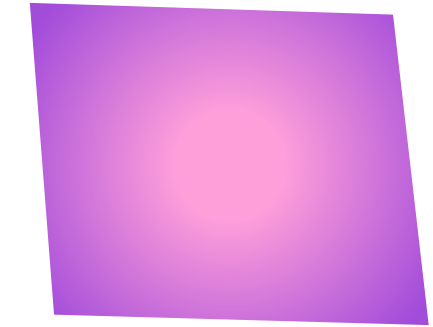
Microprobe maps take a
very long time
Specific crystal orientation needed

XFM mapping is the solution!

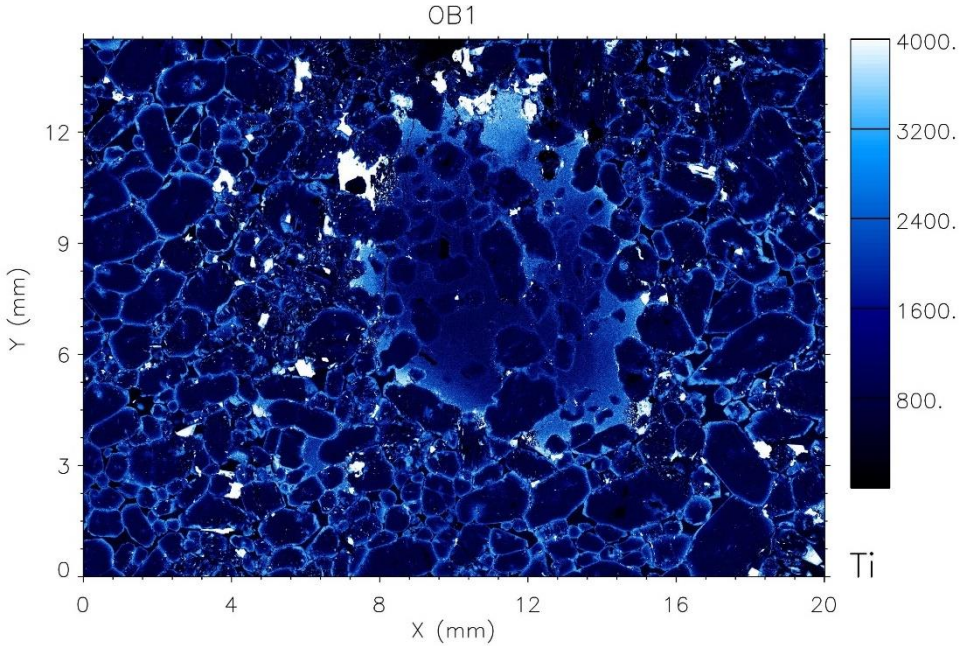


Normal Zoning

Zoning due to normal trapped liquid reactions in crystallising systems. Diffuse change from rich core to poor rims for Cr, and reversed for the incompatible elements.

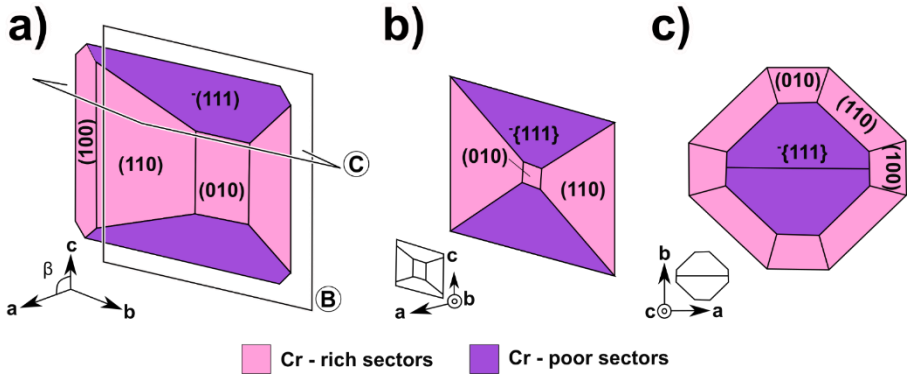


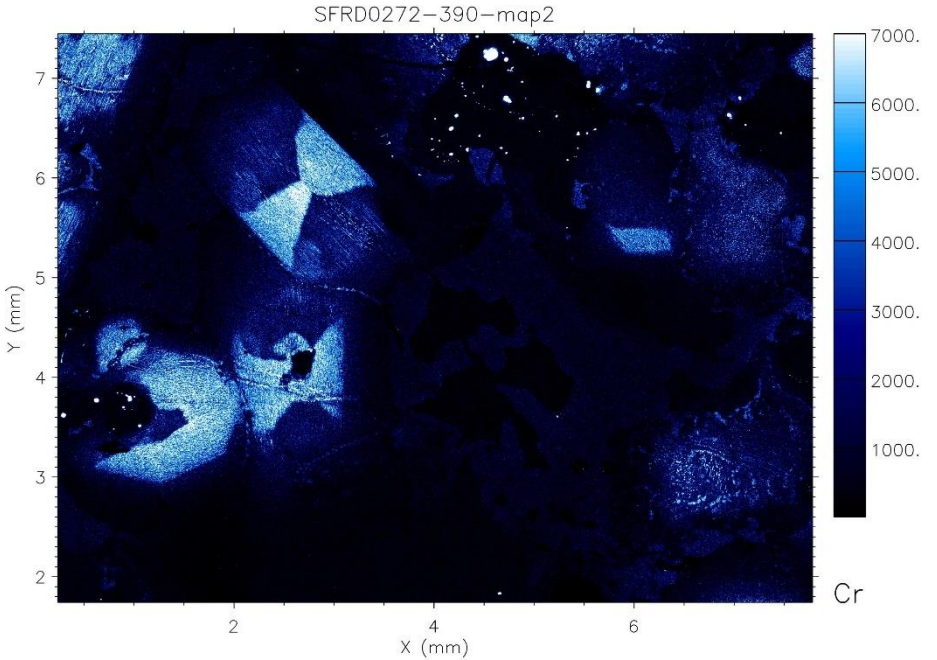
Cr - rich sectors Cr - poor sectors



Sector Zoning

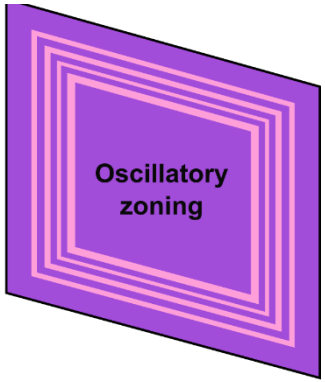
Sector zoning is a common phenomena in lunar, terrestrial and experimental pyroxene. Represents **rapid growth**

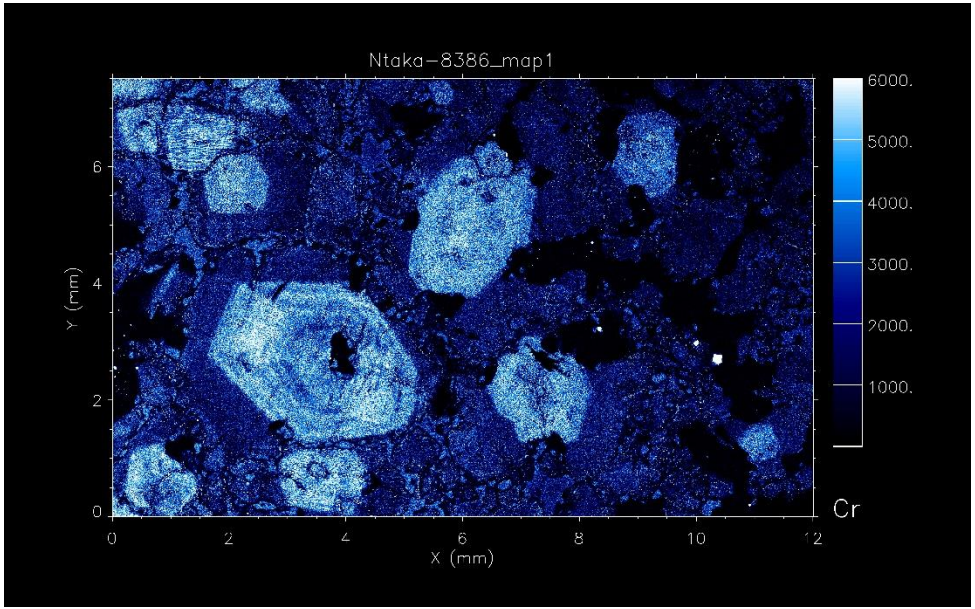




Oscillatory zoning

Represent fluctuating magma conditions
Crystallisation faster than diffusion rate

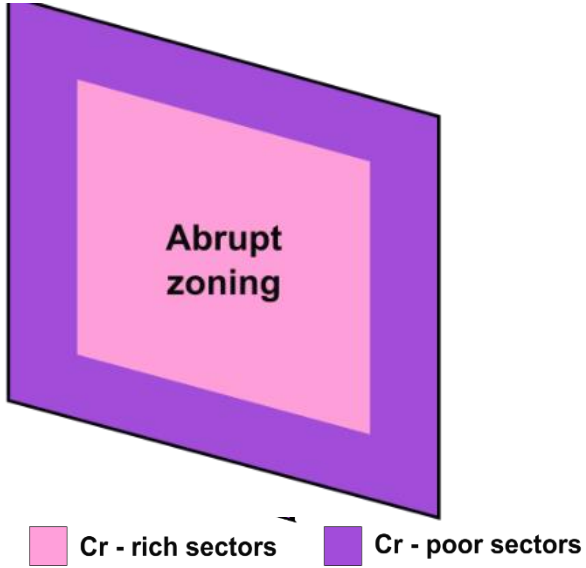


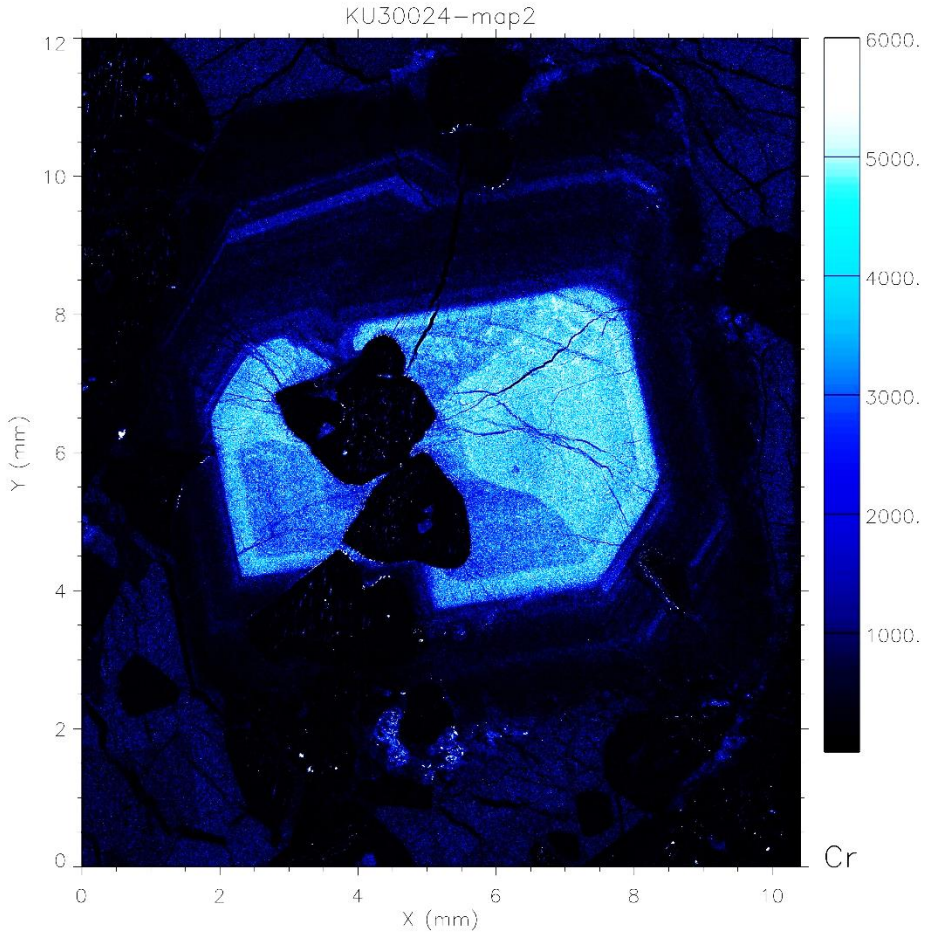


Cr - rich sectors Cr - poor sectors

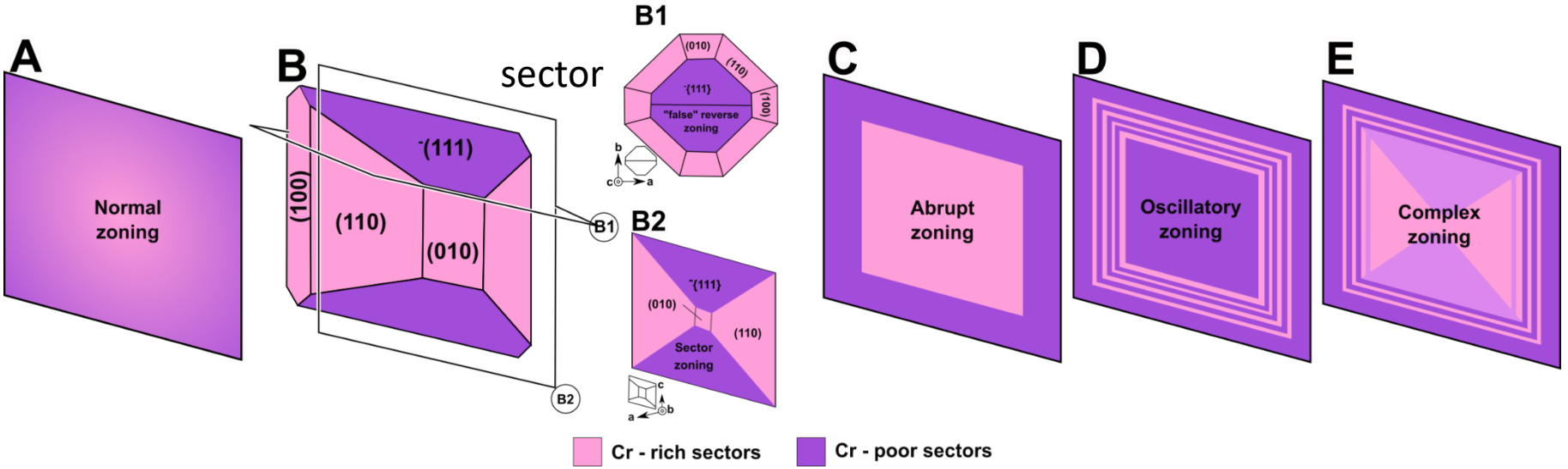
Abrupt zoning

Sudden change in chemistry/conditions

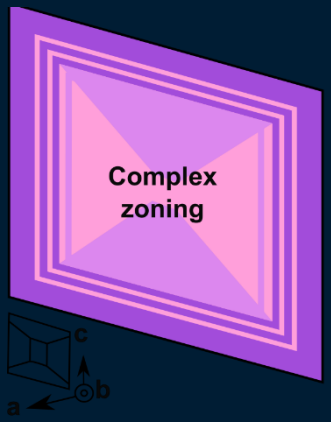


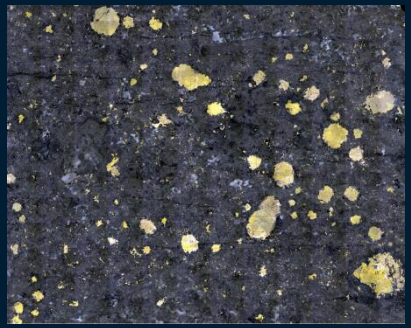


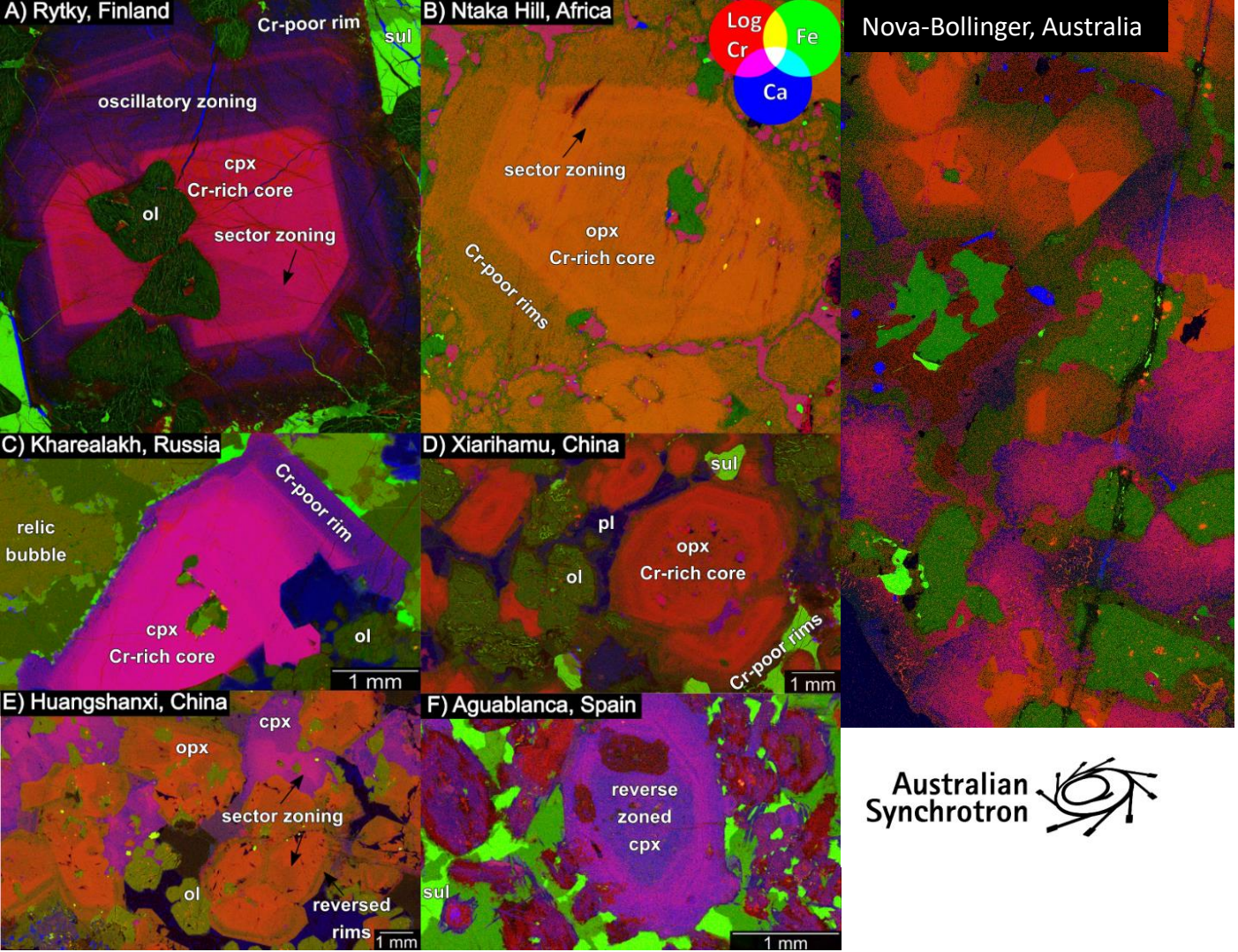
Cr zoning – a record of crystallisation history



Complexly zoned pyroxene in Nickel sulfide deposits





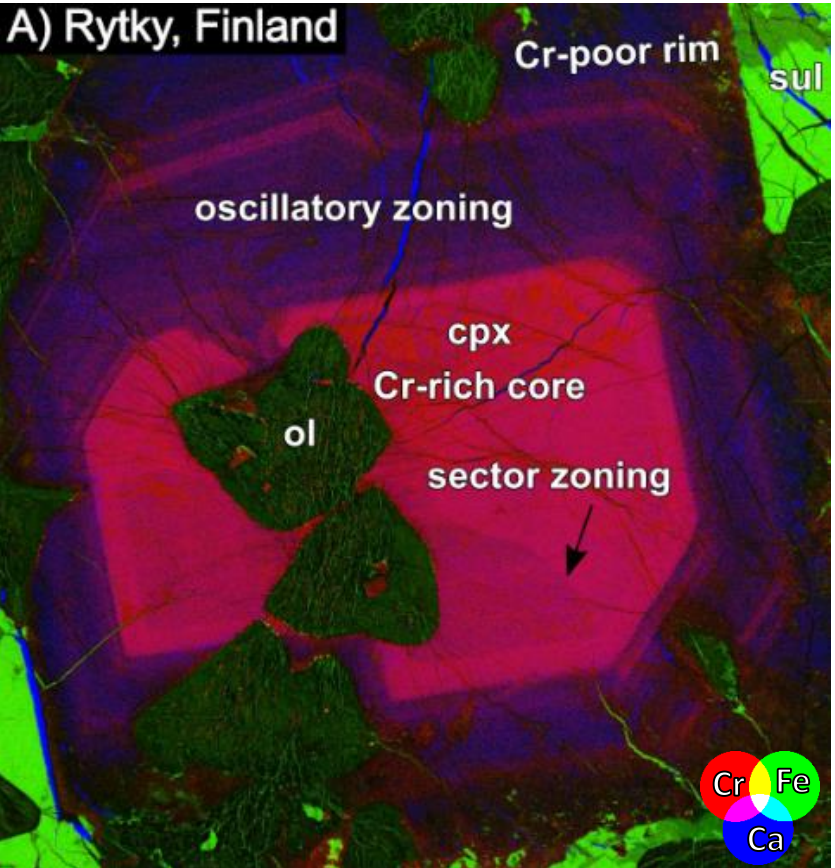


Australian Synchrotron

OPEN ACCESS

https://doi.org/10.3389/feart.2020.00256

From this crystal…



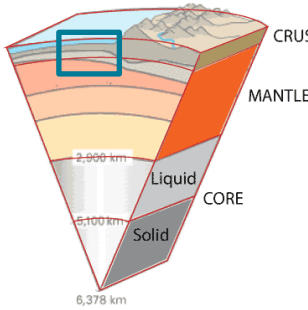
We can make some inferences of the history of the magma:

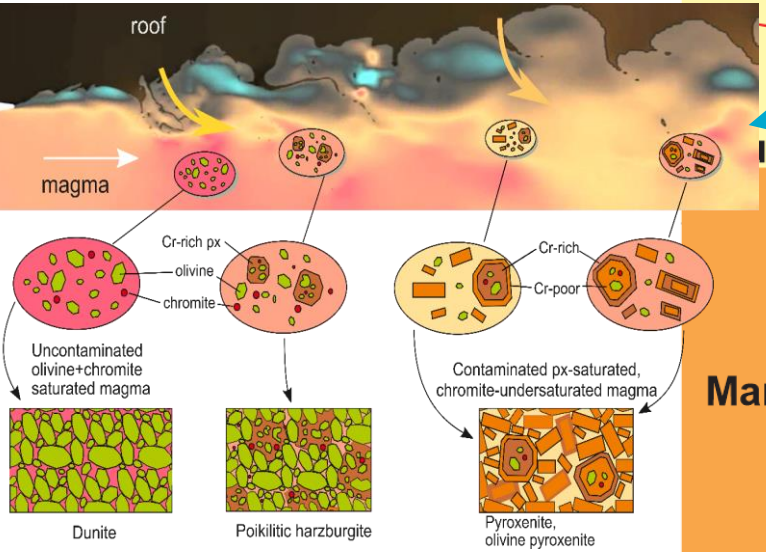
1. Fast growth of clinopyroxene

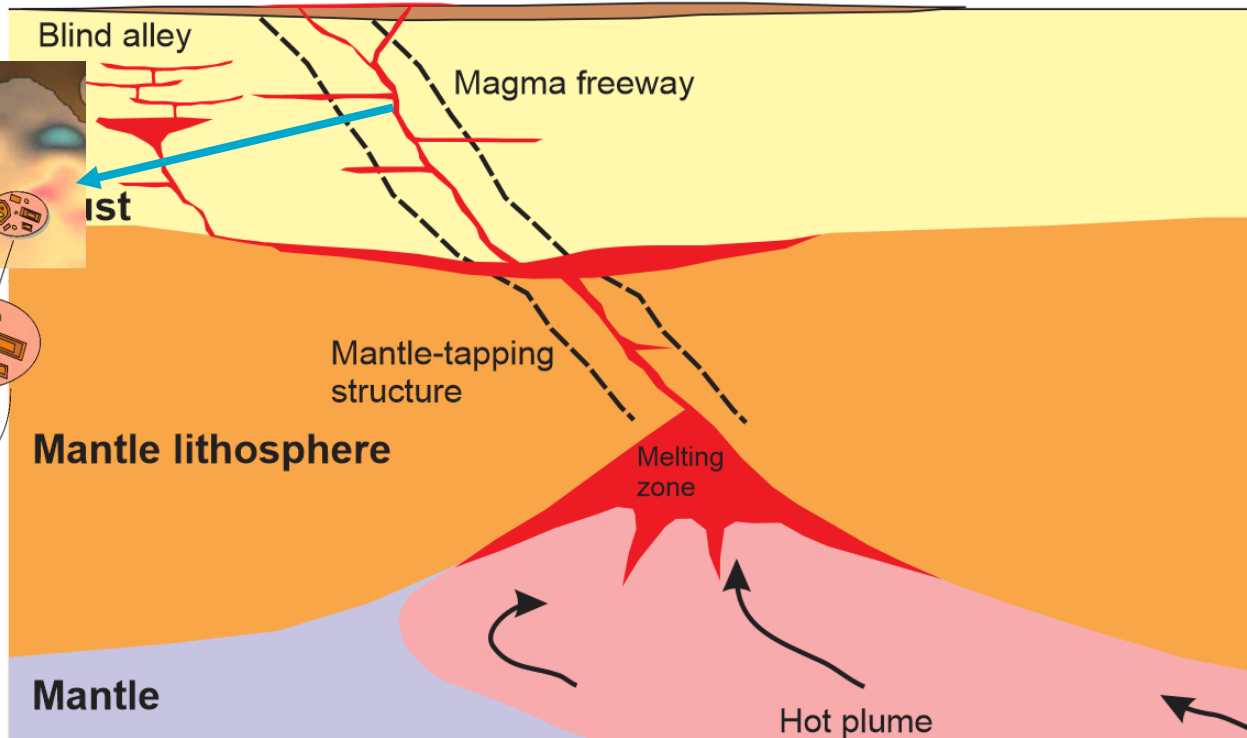
2. Abrupt change in magma chemistry

3. Further cyclic changes in chemistry

We've found our magma freeway!

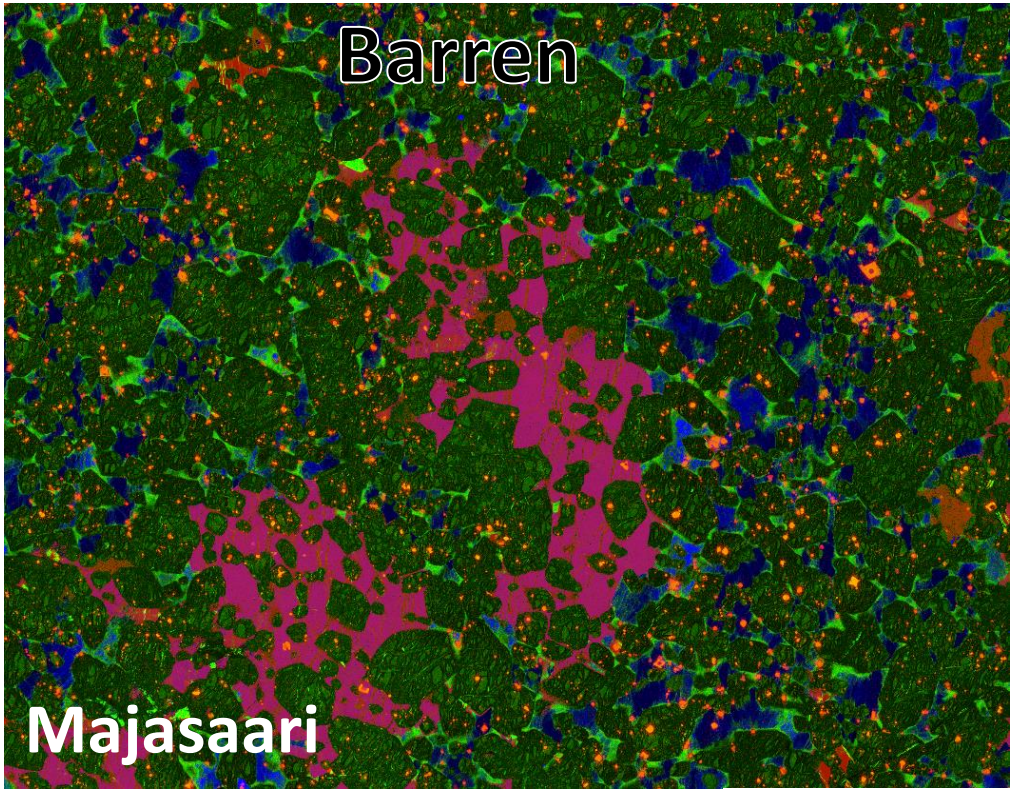






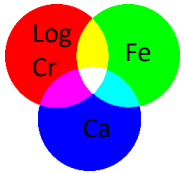
Barren intrusions do not show complex zonation

Kotalahti Nickel Belt, Finland



What if the zoning is there, we just can't see it?

18500 eV



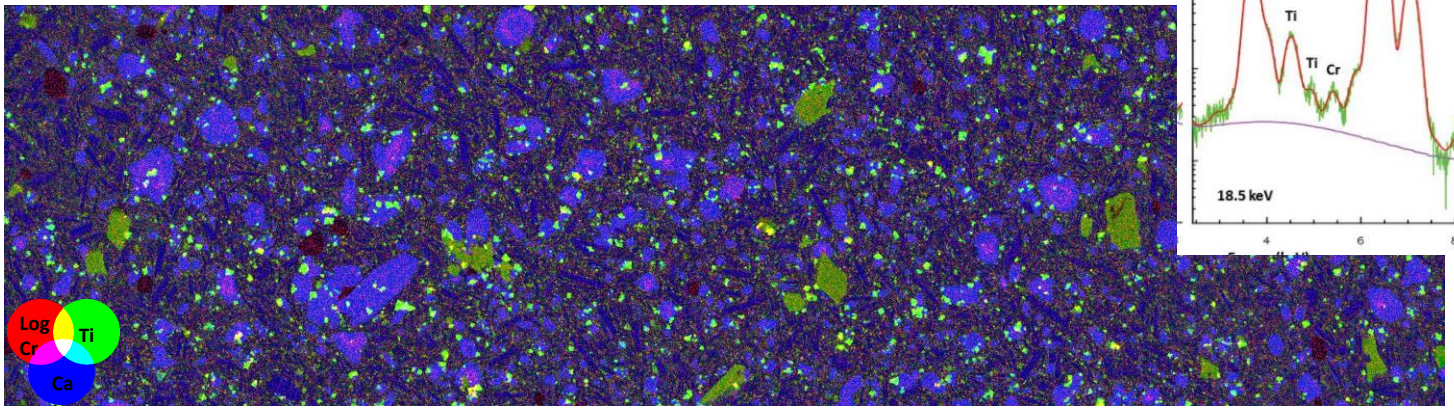
Australian Synchrotron

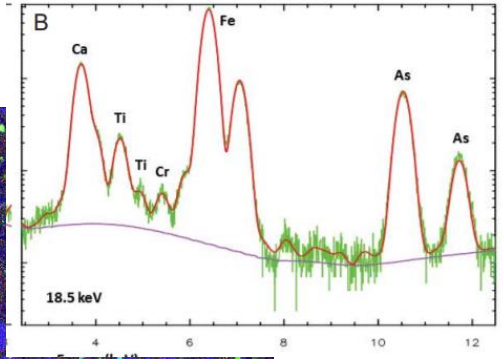
Zoned pyroxene in volcanic samples

Oscillations are common in volcanic settings

basaltic bomb from the 1974 flank eruption at Mt Etna (Sicily, Italy)

Standard energy 18500eV





Australian Synchrotron

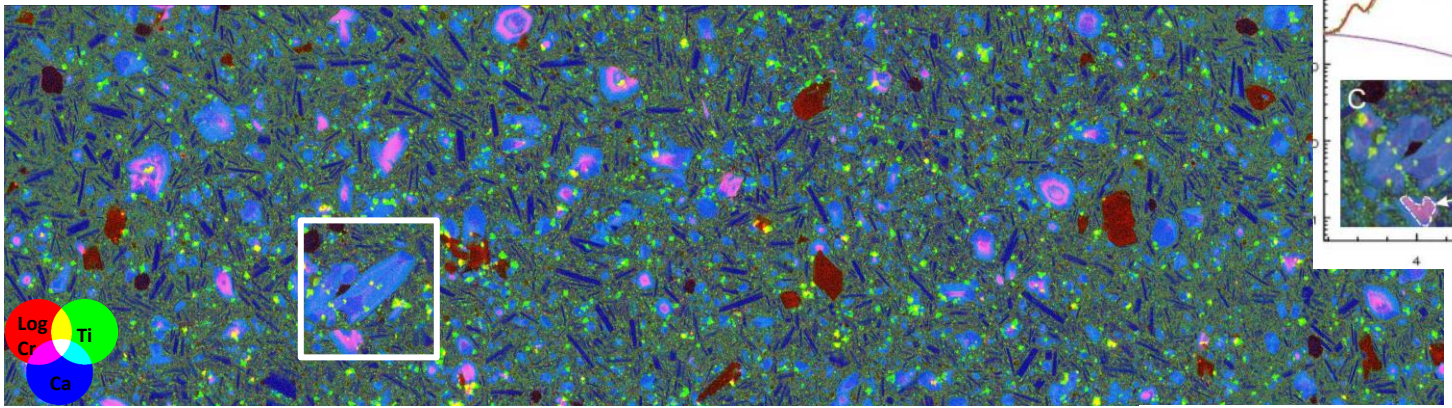
Sample: Ubide, T., Mollo, S., Zhao, J.-x., Nazzari, M. and Scarlato, P. (2019) Sector-zoned clinopyroxene as a recorder of magma history, eruption triggers, and ascent rates. Geochimica et Cosmochimica Acta.

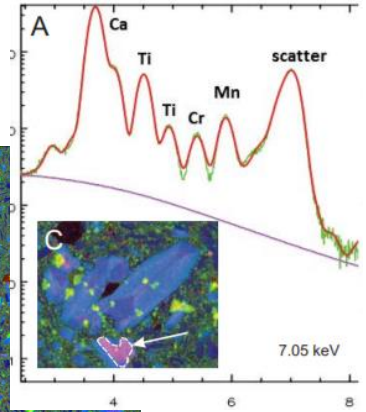
Zoned pyroxene in volcanic samples

Oscillations are common in volcanic settings

basaltic bomb from the 1974 flank eruption at Mt Etna (Sicily, Italy)

lower energy 7050eV





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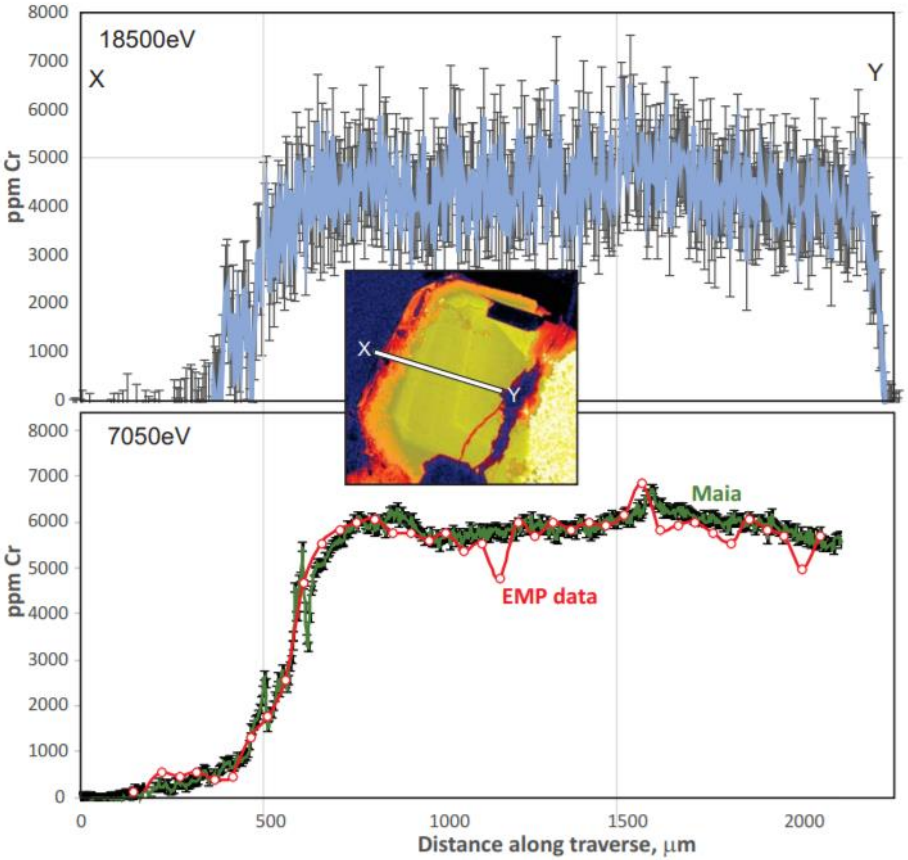
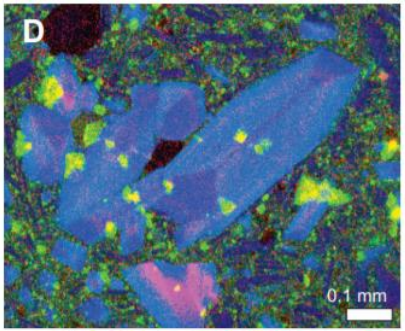
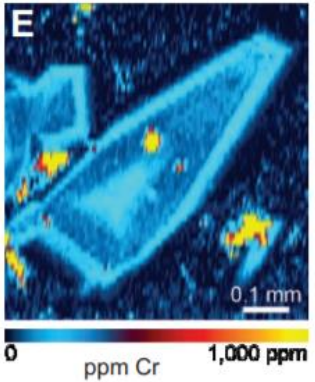
Sample: Ubide, T., Mollo, S., Zhao, J.-x., Nazzari, M. and Scarlato, P. (2019) Sector-zoned clinopyroxene as a recorder of magma history, eruption triggers, and ascent rates. Geochimica et Cosmochimica Acta.

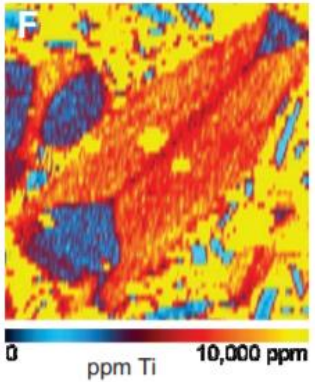
Scanning below the Fe Edge



LA-ICP-MS





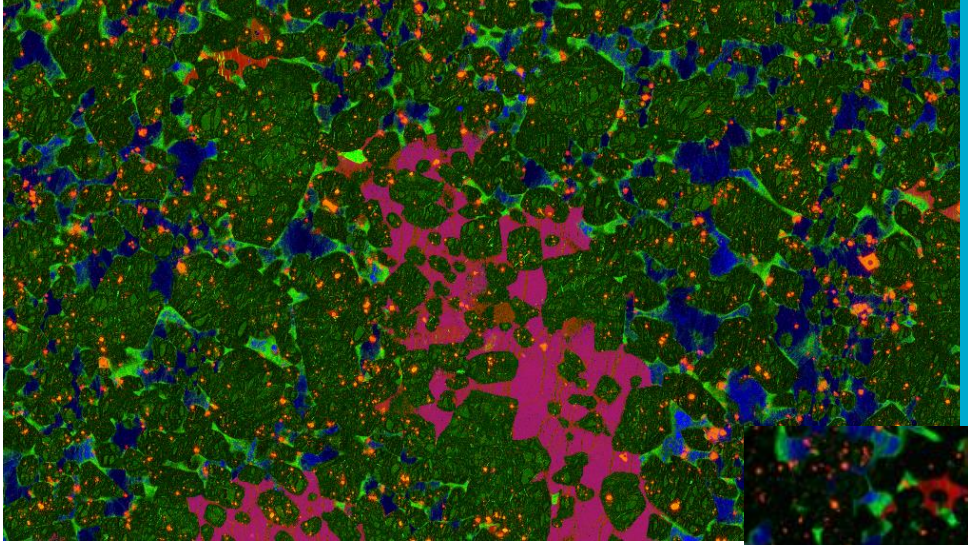


Method

Barnes et al. 2020,
American Mineralogist
DOI: 10.2138/am-2020-7228

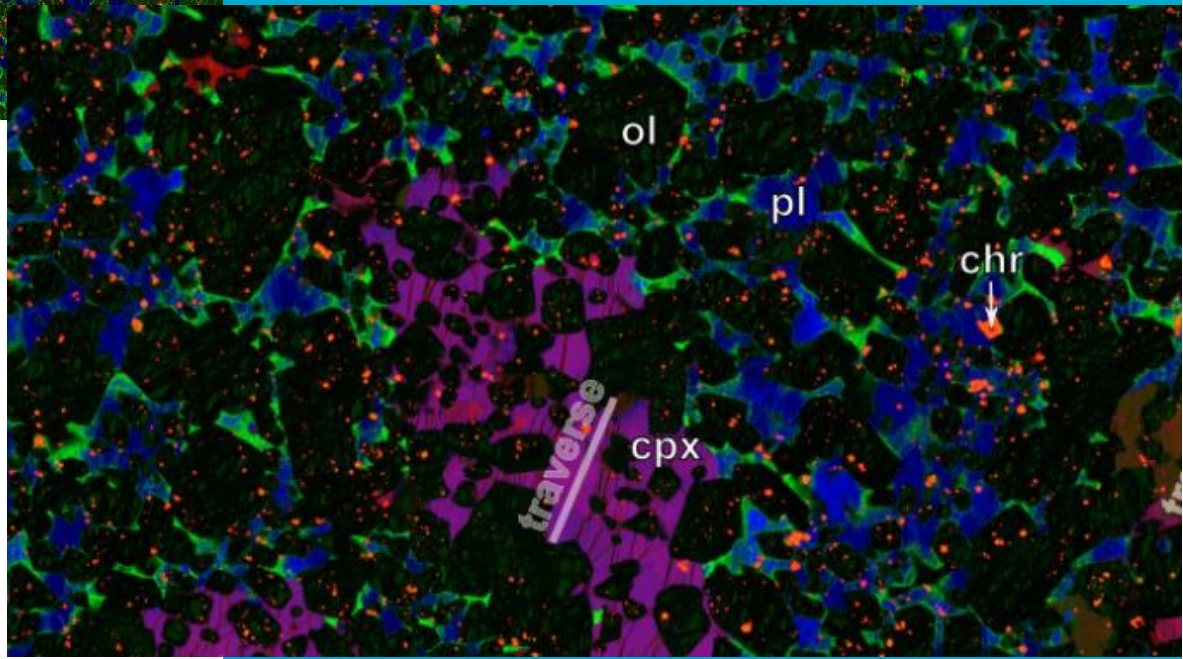
Low Energy mapping allows for higher sensitivity for Cr and Ti

(let's check those barren samples again..)



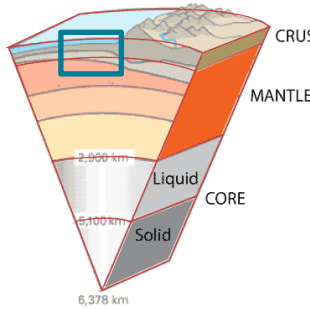
High Energy ^^

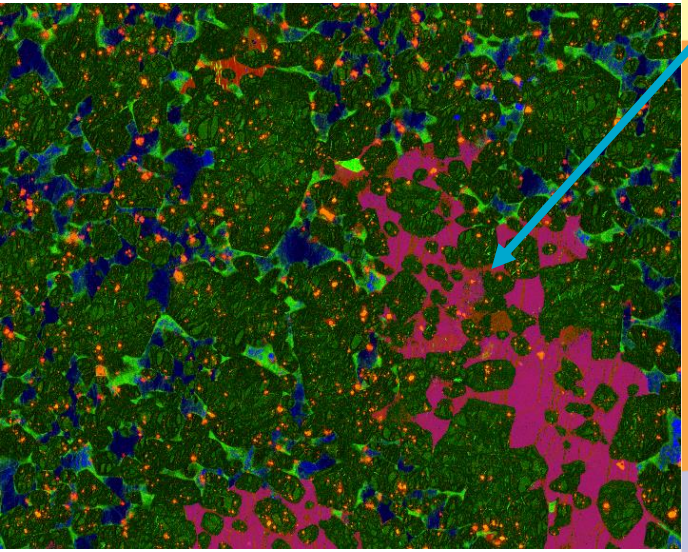
Low Energy vv

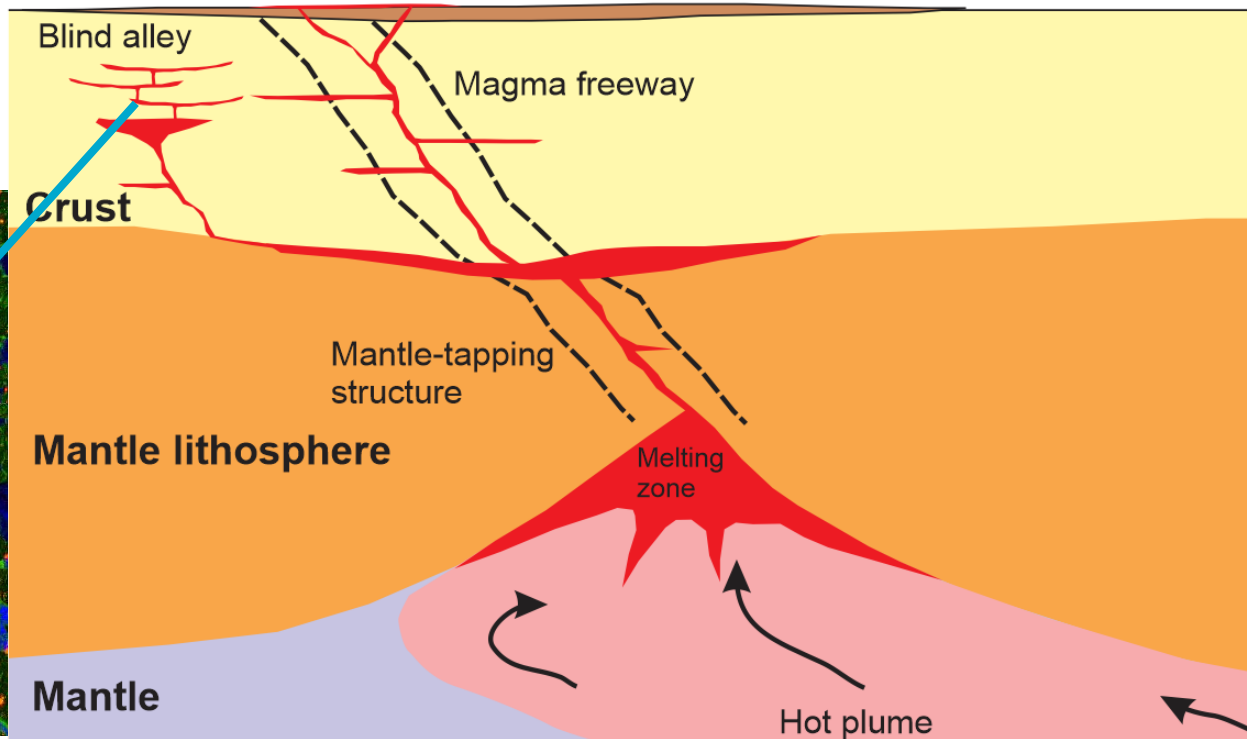


No complex zonation in barren intrusions

Searching for magma freeways

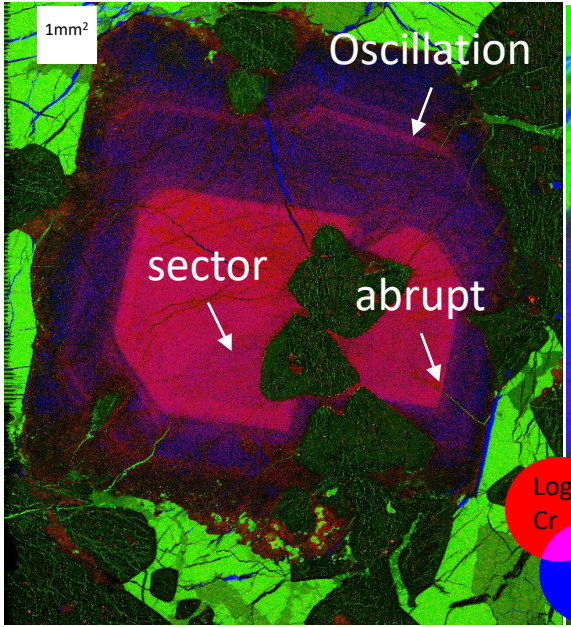




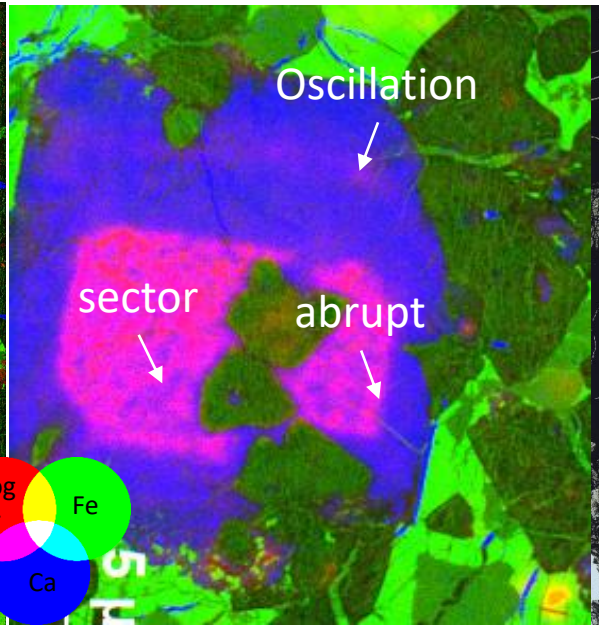


Applicability as a fertility indicator tool: zoning you can see

Kotalahti - Finland

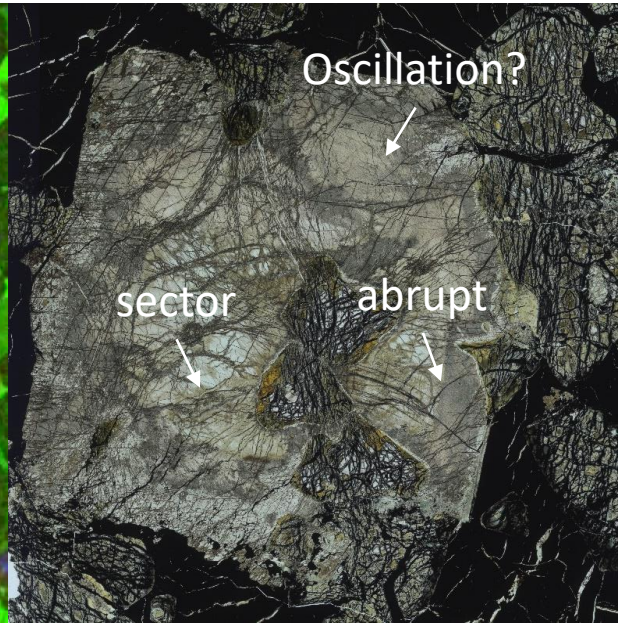


Aus. Synchrotron



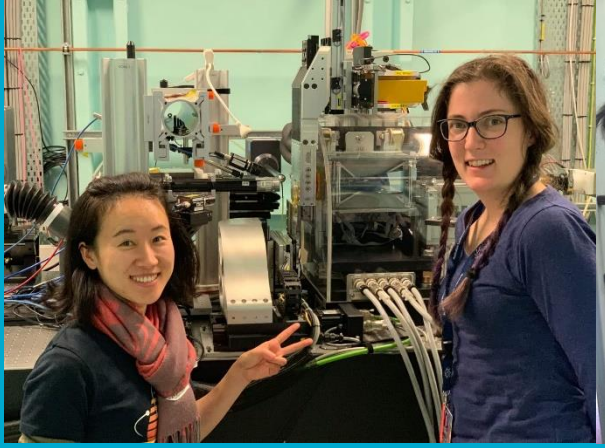
Desktop XRF

Bruker Tornado



PPL, thin section

Searching for magma freeways



Special thanks to everyone who helped gather this data

David Paterson, Chris Ryan, Margaux Le Vaillant, Teresa Ubide, Valentina Taranovic

Further questions, feel free to contact me:

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