Crustal S sources for komatiite-hosted Ni deposits:

Implications for sulfide transport, deposition, and exploration

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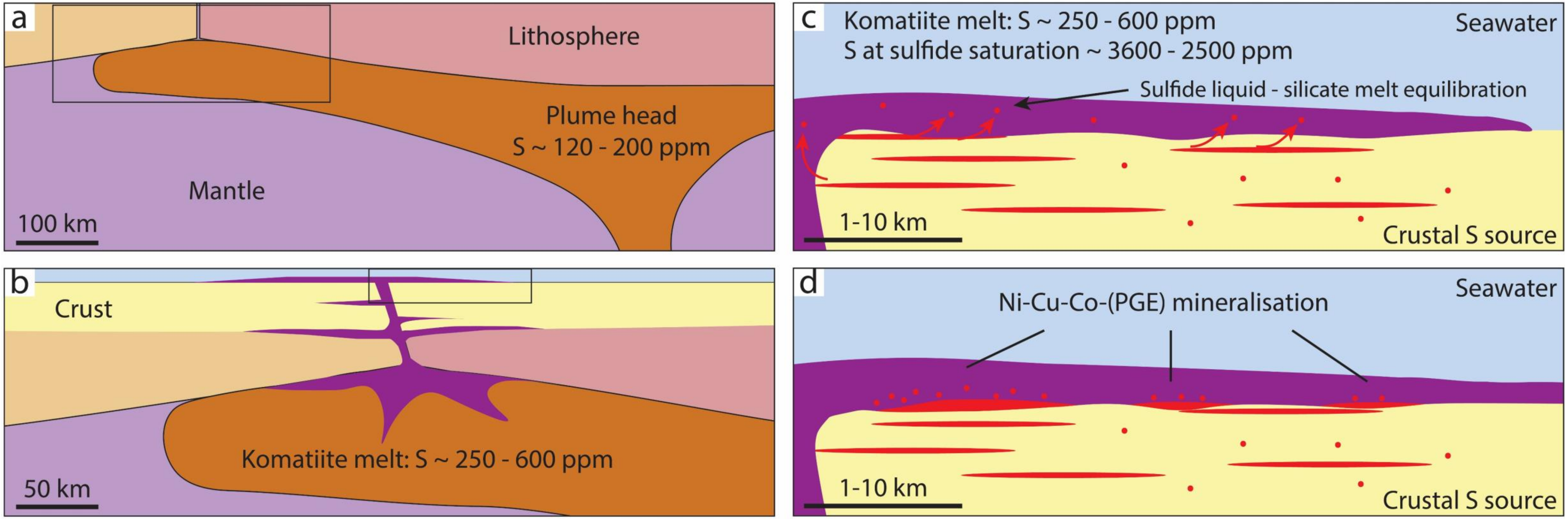
Komatiites need crustal S to form Ni deposits



Modified from Arndt et al. (2008); Barnes et al. (2016)

Tracking crustal S sources of komatiite-hosted Ni deposits may inform on:

- Favourable crustal S sources
- Distance from crustal S source to ore deposit
- Sulfide transport mechanisms
- **Implications for Ni exploration**

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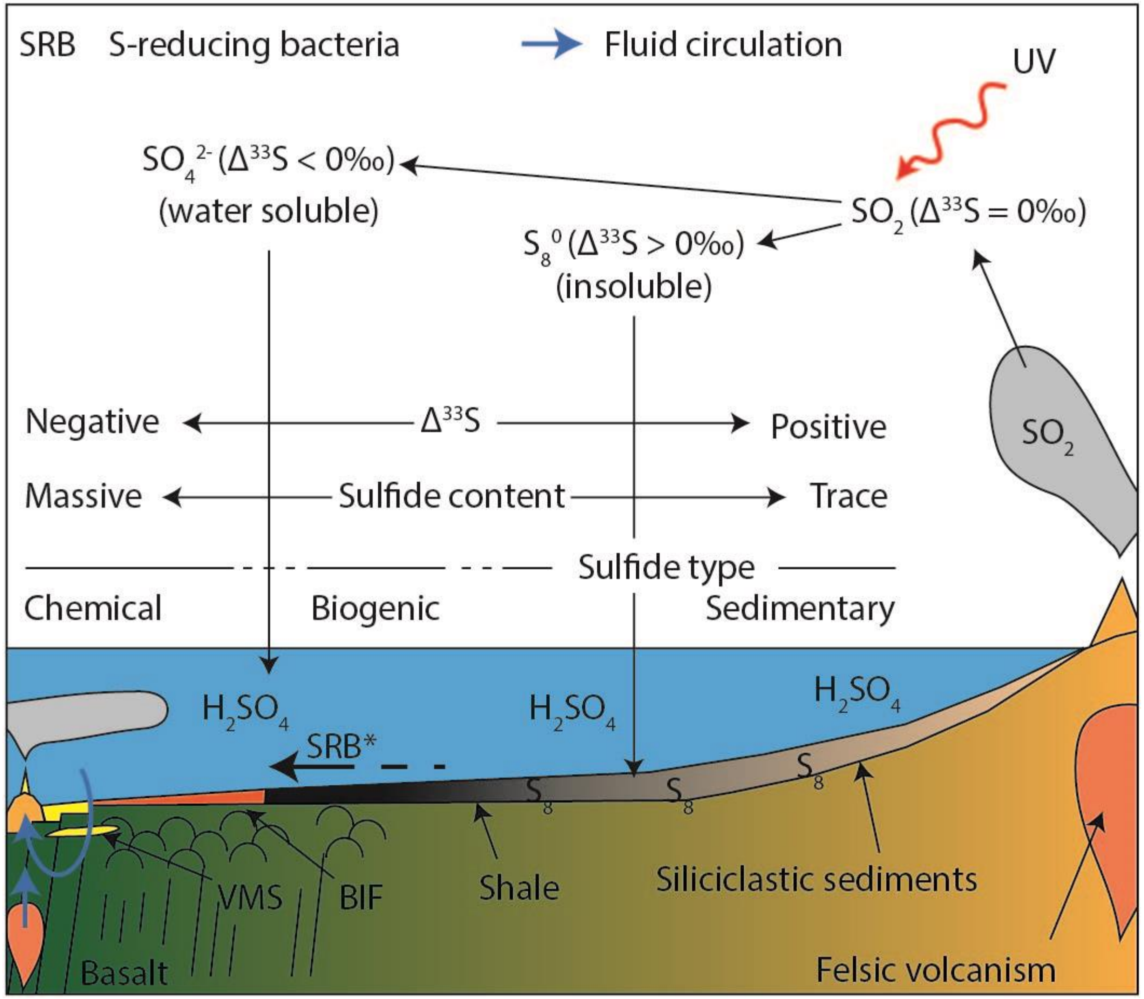
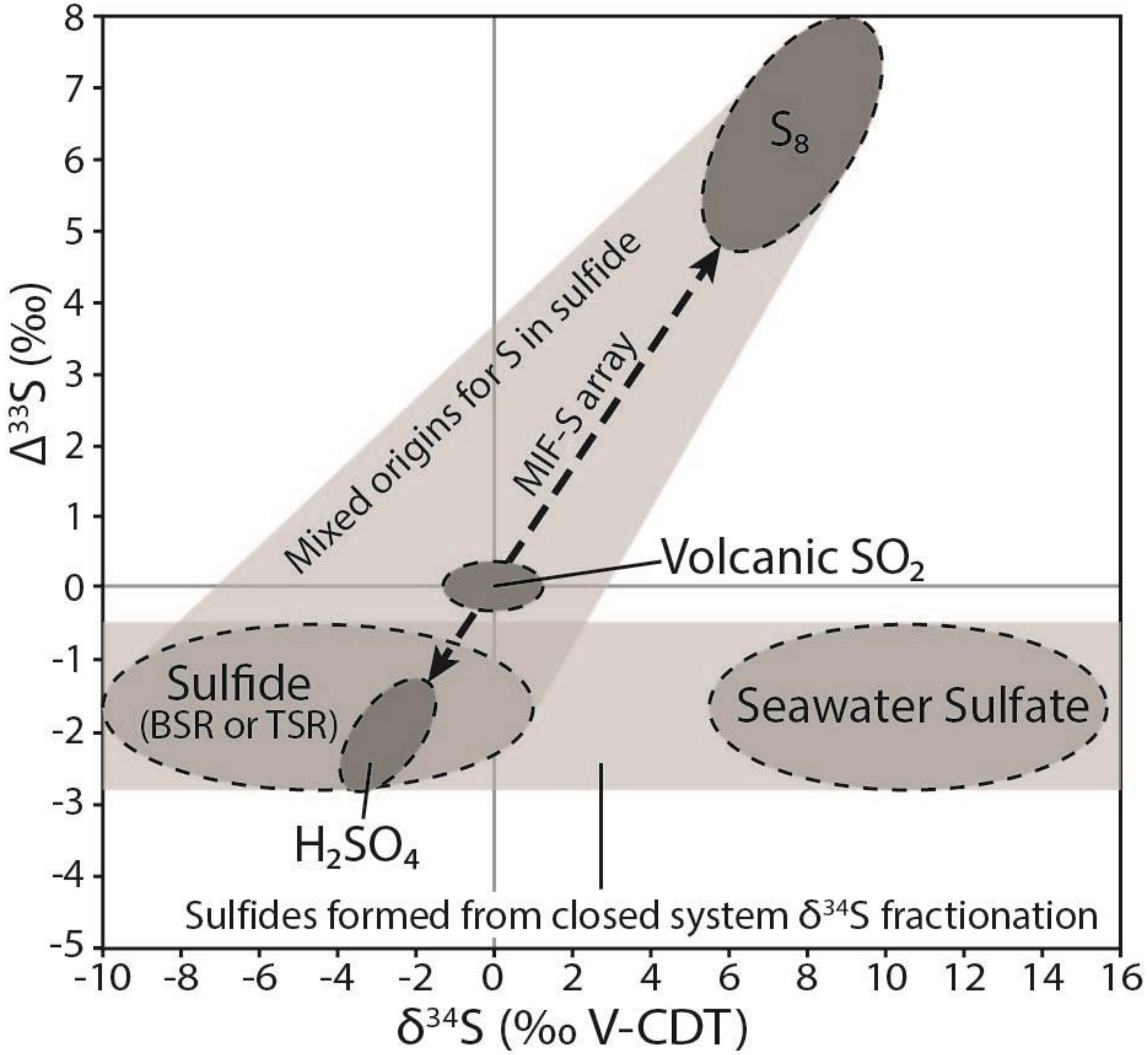
Tracking crustal S sources using MIF-S

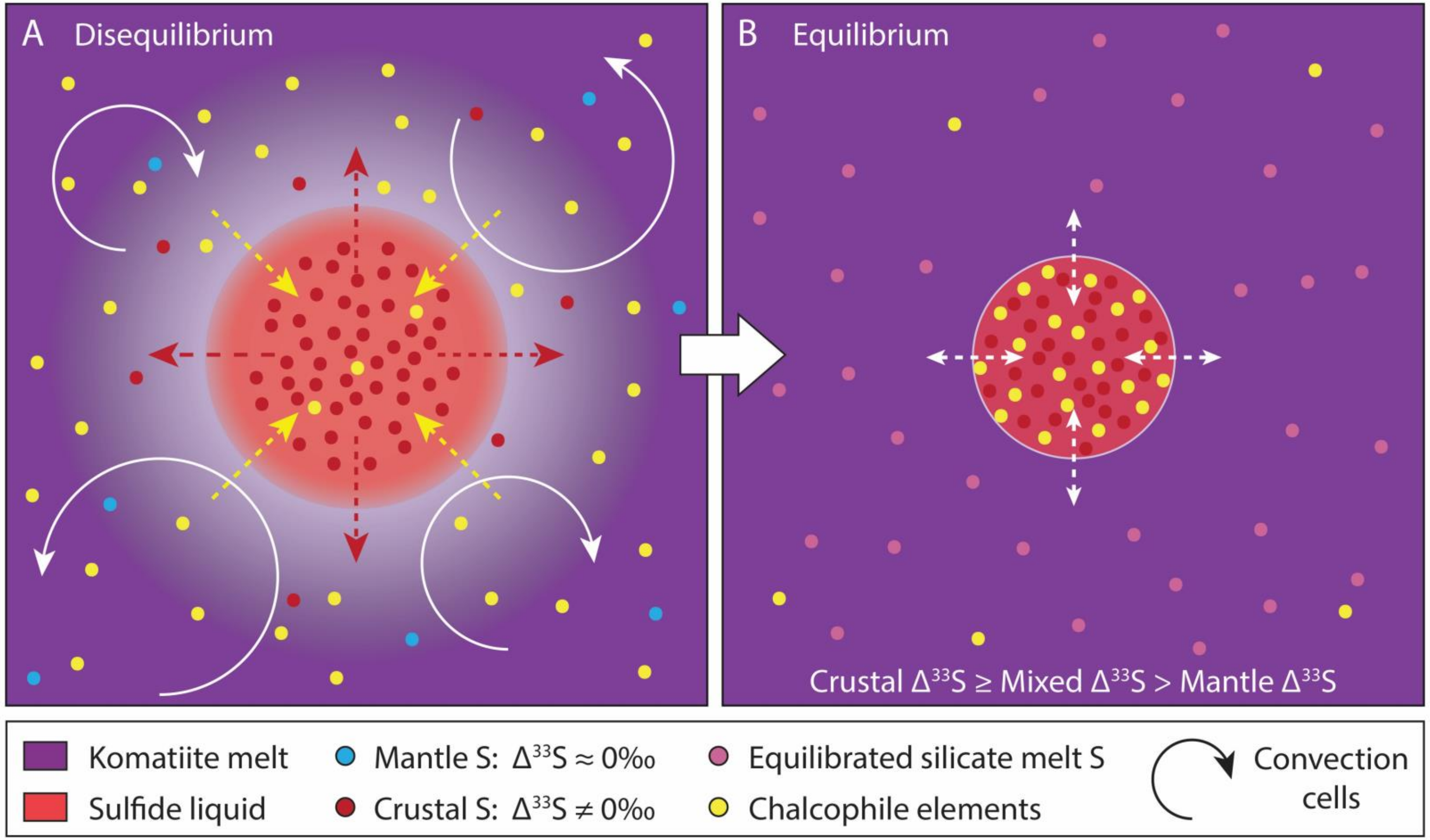


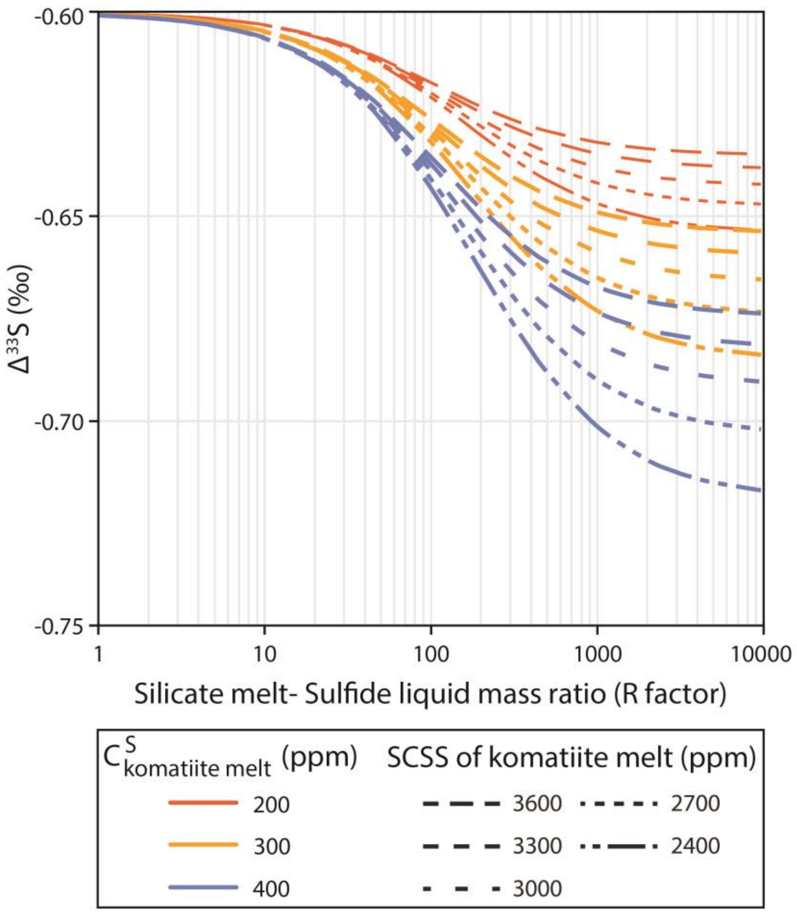
Modified from Bekker et al. (2009); Fiorentini et al. (2012)



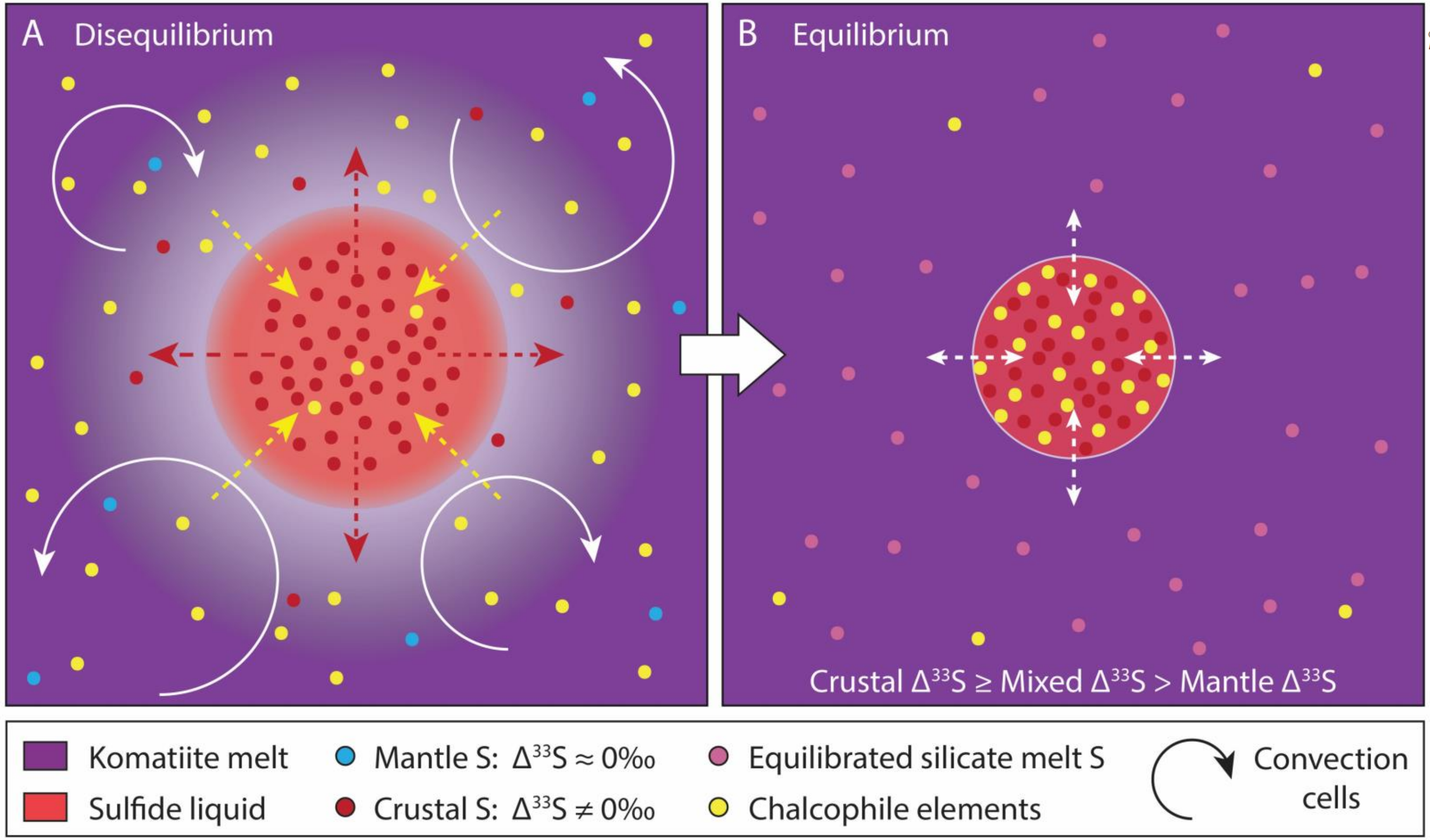
Modified from Ono et al. (2003)

Magmatic Ni sulfides preserve their crustal MIF-S signatures





Magmatic Ni sulfides preserve their crustal MIF-S signatures



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Decoupling of Sulfur Isotope Signatures from Platinum Group Elements in Komatiite-Hosted Ore Systems: Evidence from the Mount Keith MKD5 Ni-(Co-Cu) Deposit, Western Australia

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Abstract

Komatiites require external sulfur from country rocks to generate immiscible sulfide liquid, which concentrates metals to form economic nickel sulfide deposits. Although signatures related to mass-independent fractionation of S isotopes (MIF-S, denoted as $\Delta^{33}S$) may identify external S sources, their values may not be directly indicative of the S reservoirs that were tapped during the ore-forming process, because of dilution by S exchange between assimilated sulfide xenomelt and komatiite silicate melt. To quantify this process and be confident that MIF-S can be effectively used to track S sources in magmatic systems, we investigated the effect of silicate melt-sulfide liquid batch equilibration, using the proxy of silicate/sulfide mass ratio, or R factor, on the resulting MIF-S signatures of pentlandite-rich ore from the Mount Keith MKD5 nickel sulfide deposit, Agnew-Wiluna greenstone belt, Western Australia. We carried out in situ multiple S isotope and platinum group element (PGE) analyses on pentlandite from a well-characterized drill core through the deposit. The variability in Pd tenor and MIF-S signature suggests that these are decoupled during batch equilibration and that the latter is not controlled by metal-derived R factor. Rather, the observed spread of MIF-S signatures implies that the sulfide xenomelt was initially heterogeneous and that chemical equilibration of S isotopes is incomplete as opposed to that of PGEs in a komatiite melt. Consequently, magmatic sulfides, which formed in the hottest, most dynamic, and likely fastest equilibrating magmatic systems on Earth, may still preserve their initial MIF-S isotope compositions, reflecting the range of crustal S reservoirs that were available upon komatiite emplacement.

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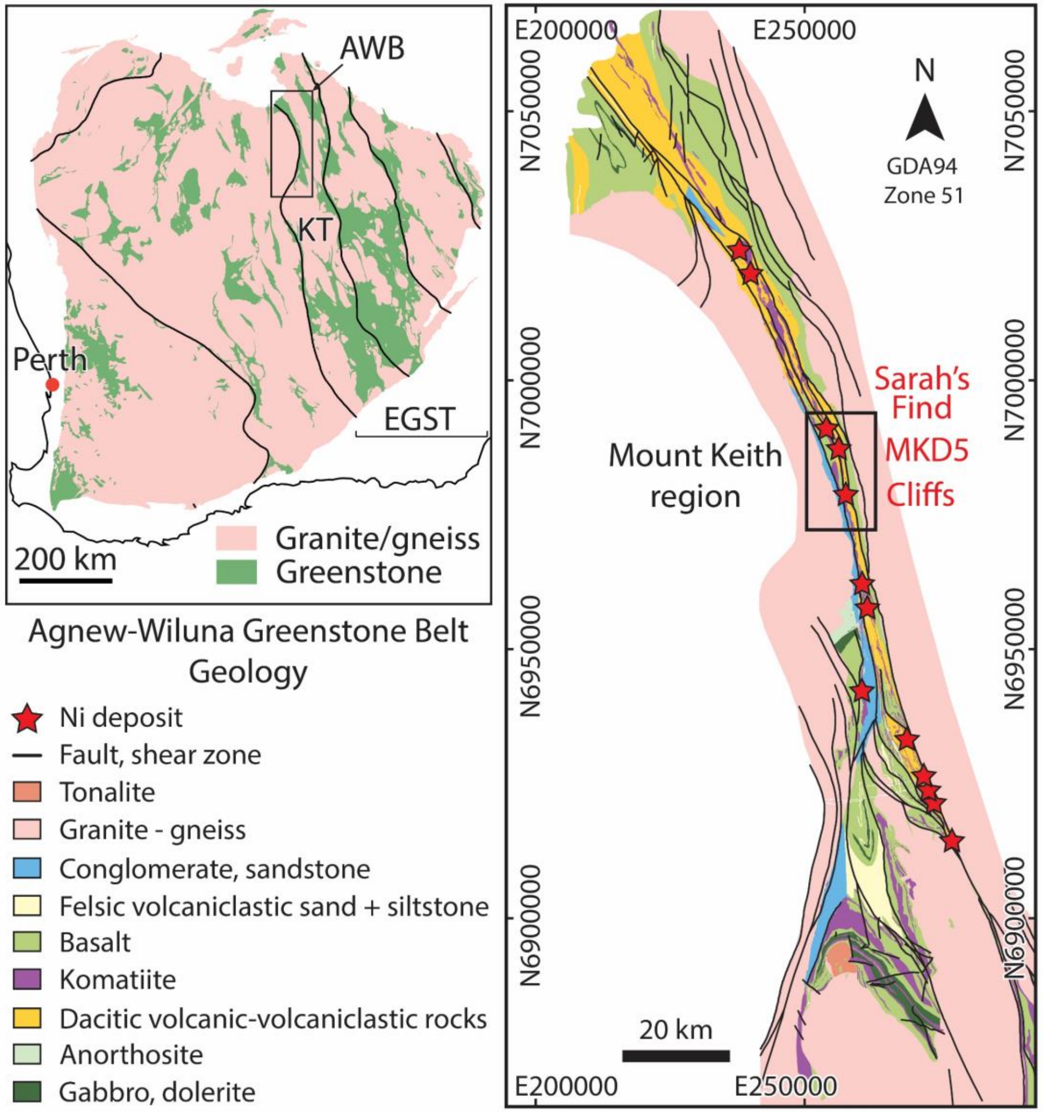
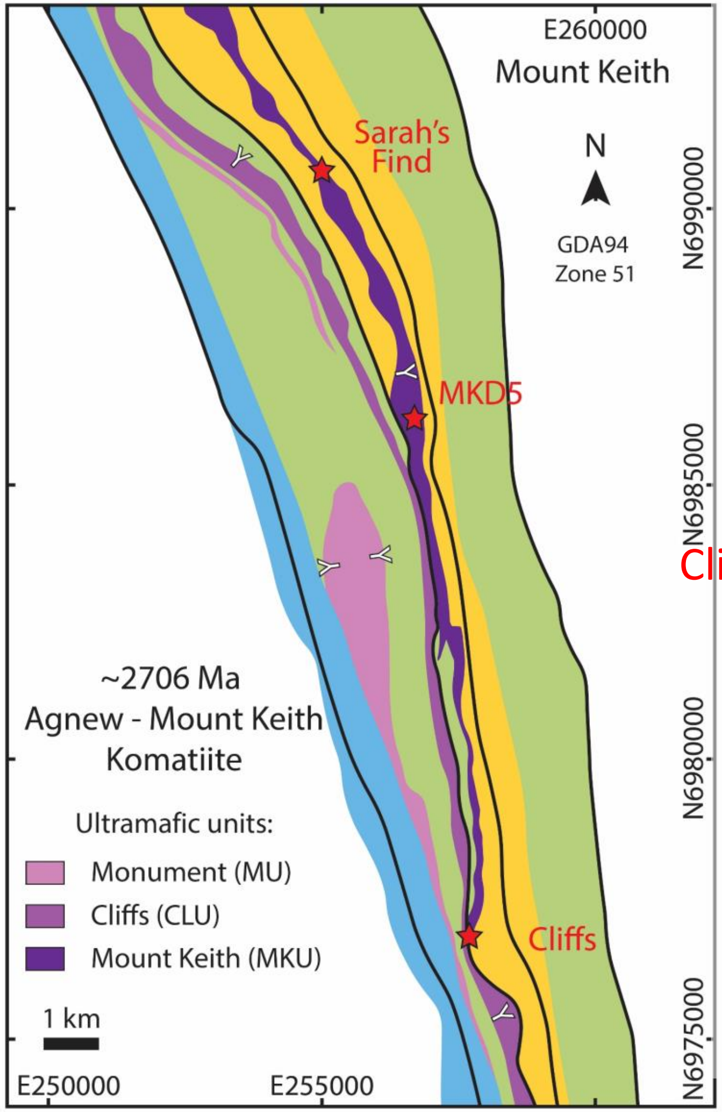
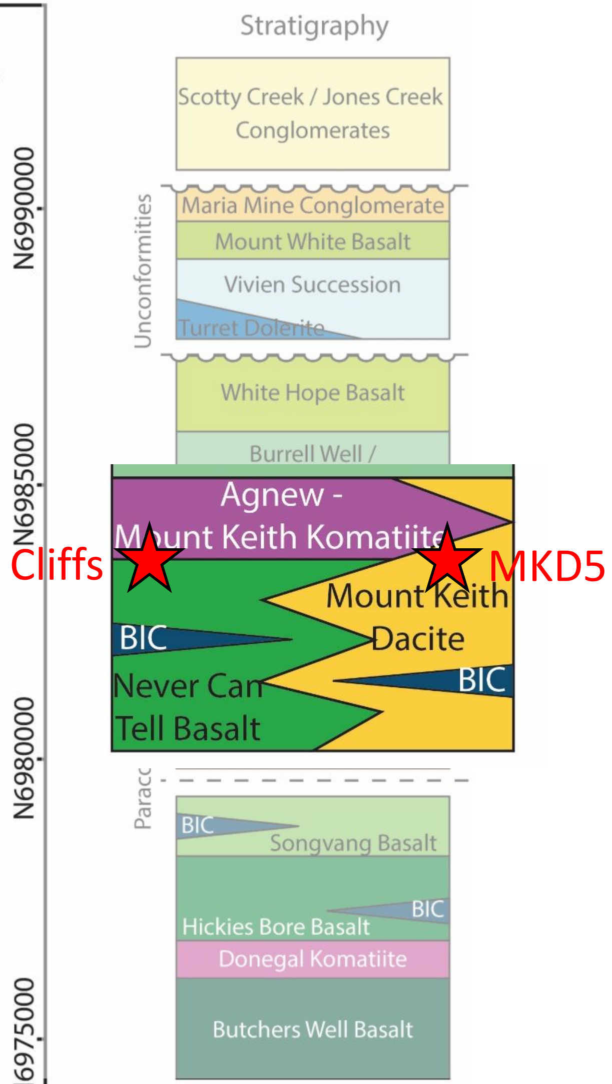
Ni deposits and crustal S sources in the Agnew-Wiluna Greenstone Belt



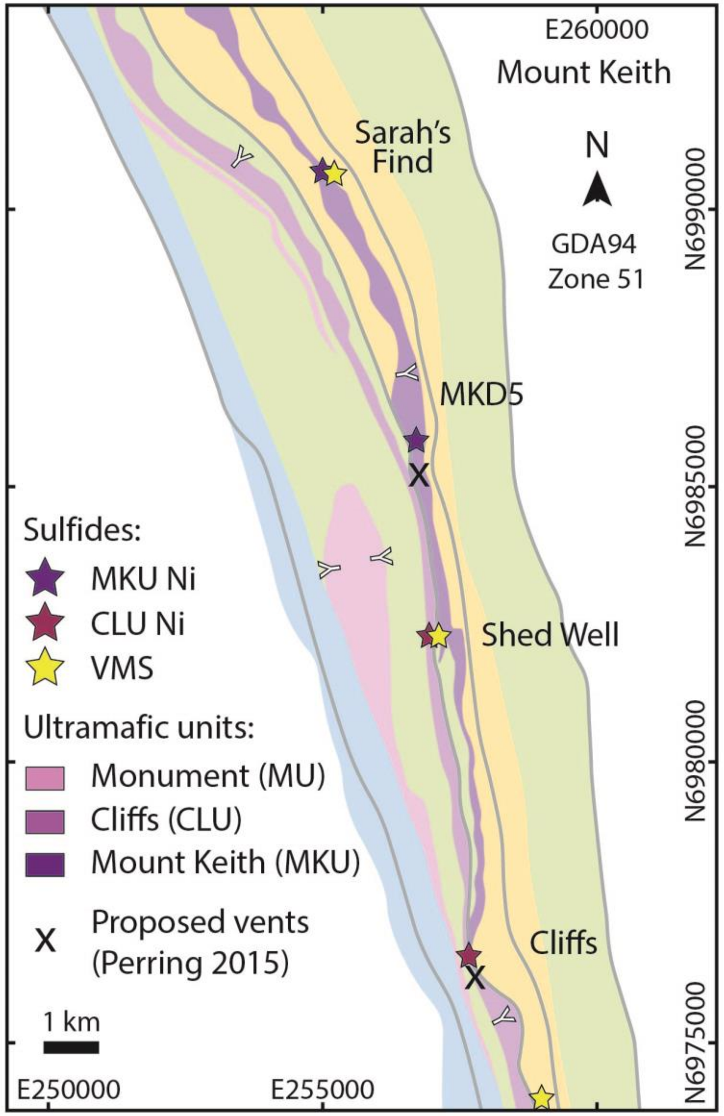




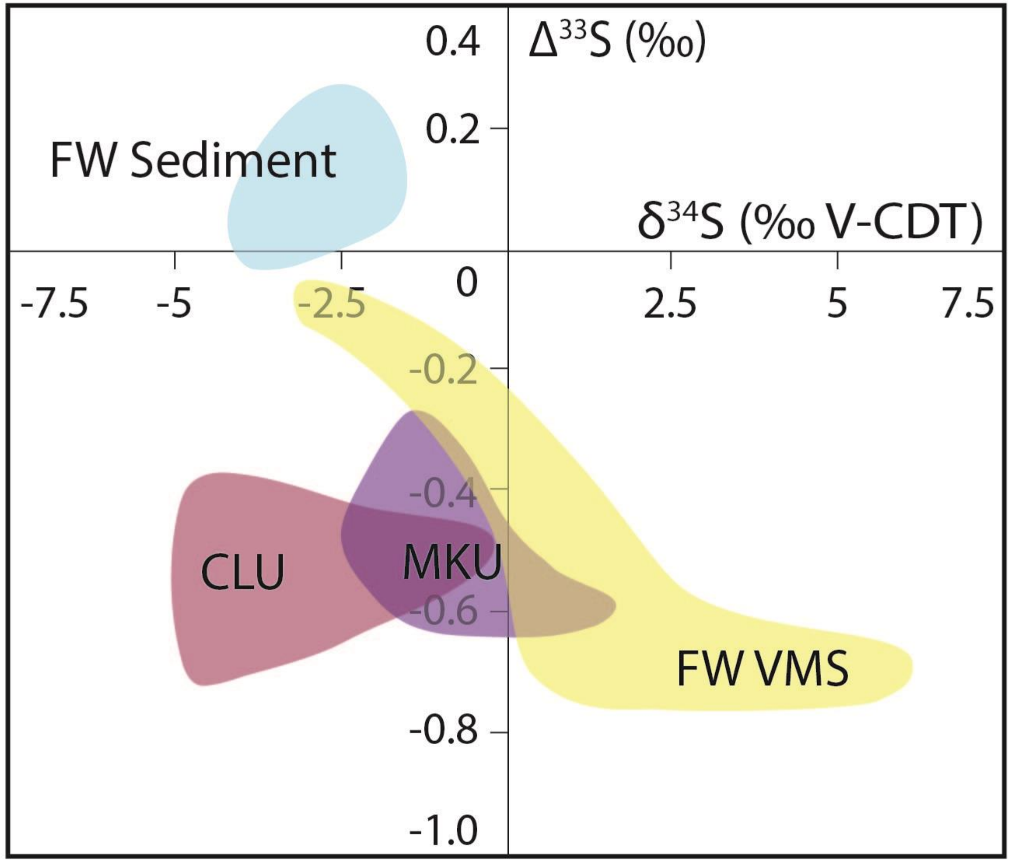
Modified from Beresford et al. (2004); Cassidy et al. (2006); Pawley et al. (2012); Martin et al. (2015) and Perring (2015)

Modified from Masurel et al. (2022)

The Cliffs and MKD5 Ni deposits and their crustal S sources



Modified from Perring (2015)



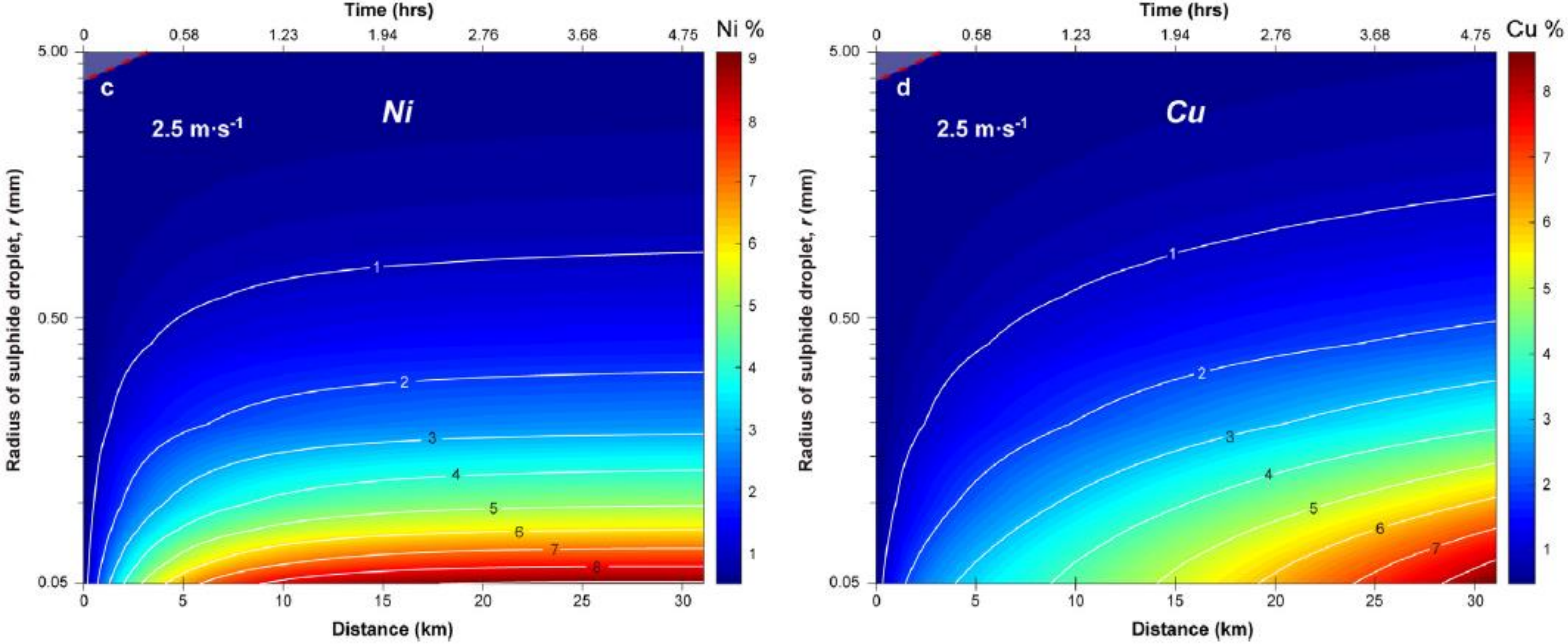
Modified from Fiorentini et al. (2012)

- MKU Ni sulfides formed proximal to VMS source
- CLU Ni sulfides formed distal to VMS source
- Felsic footwall are proximal to rift axis
- VMS sulfides more likely to form proximal to rift axis

→ Felsic hosted komatiite systems more favourable for Ni

The Cliffs and MKD5 Ni deposits and their crustal S sources

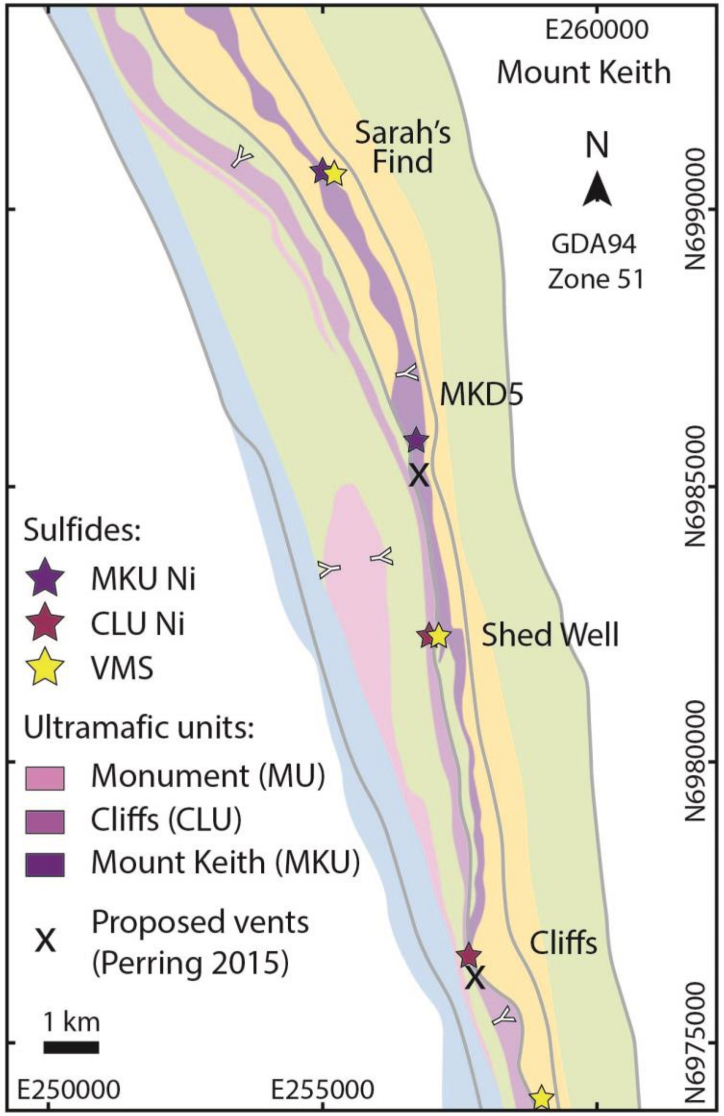
- Positive correlation between sulfide metal content (tenor) and transport distance in komatiite melt



Yao and Mungall (2021)

→ Cliffs Ni deposit should have higher metal tenors than MKD5 Ni deposit

The Cliffs and MKD5 Ni deposits and their crustal S sources



Modified from Perring (2015)

- MKD5 and Cliffs have similar metal tenors
- Both Ni deposits are proximal to proposed lava vents
- VMS style sulfides found in FW to Cliffs Ni deposit

(Perring 2015)

Is Cliffs Ni deposit also proximal to its S source?

Implications for metal enrichment process?

Are basalt-hosted komatiite systems also favourable in bimodal settings?

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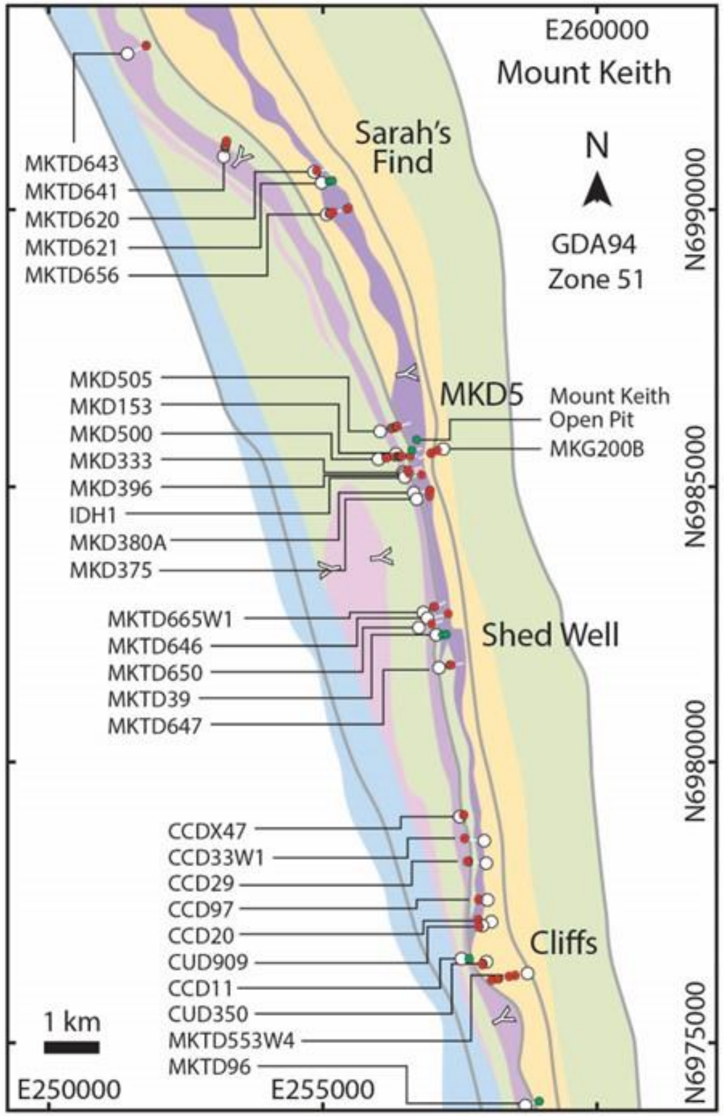
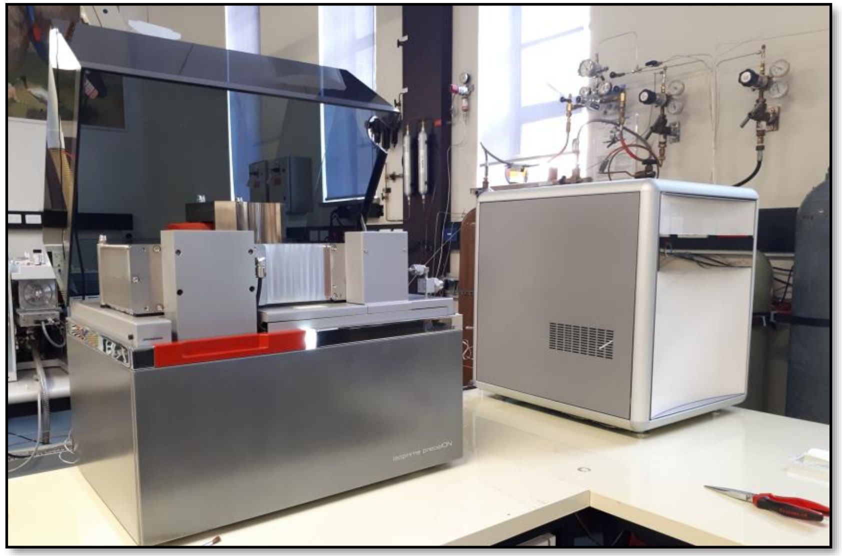
Materials and Methods



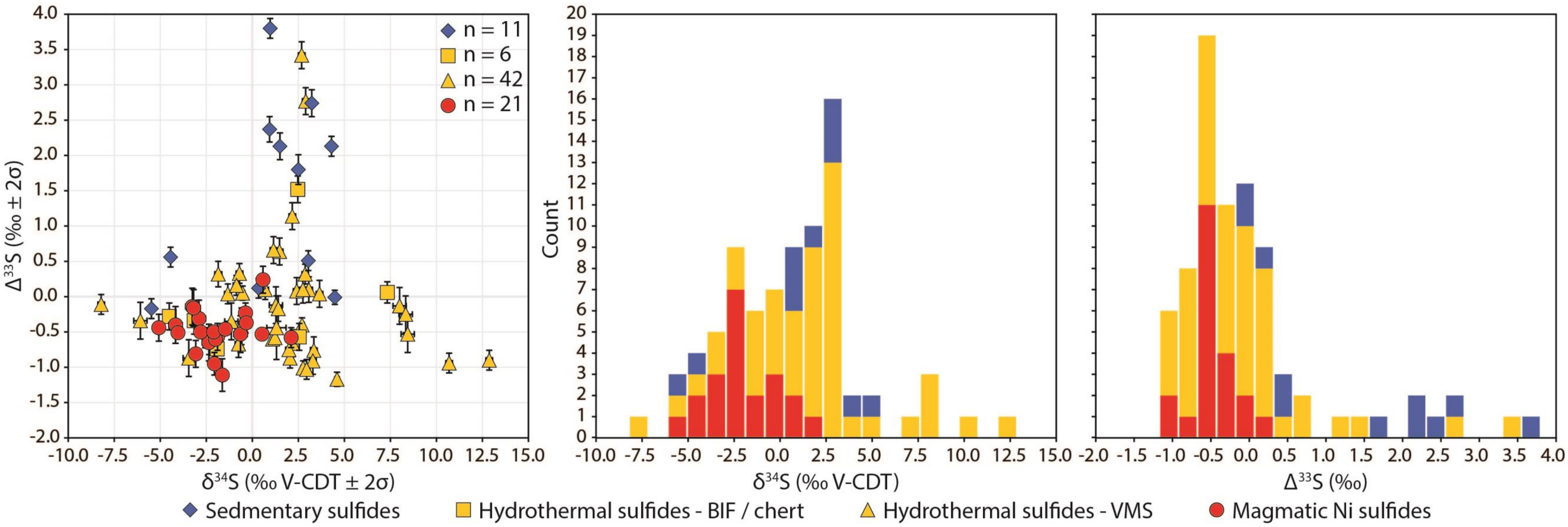
Modified from Perring (2015)

- 11 samples of sedimentary sulfides.
- 6 samples of BIF style sulfidic chert.
- 42 samples of VMS style sulfides.
- 21 samples of magmatic Ni sulfides.
- Analysis for ^{32}S, ^{33}S and ^{34}S by EA-IRMS.



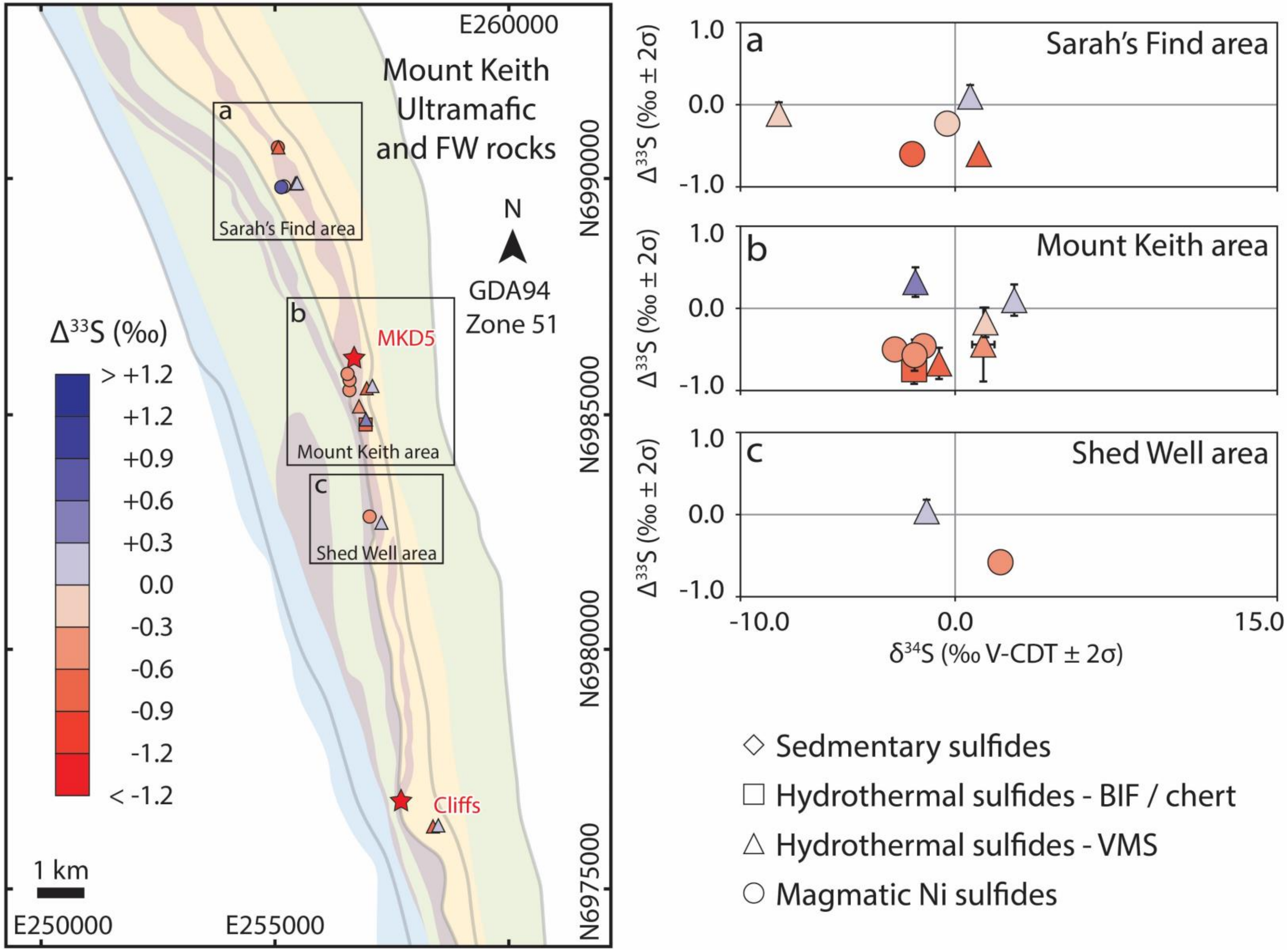
Photos courtesy of K. Baublys

Results



Magmatic Ni sulfides predominantly sourced vent proximal sulfidic BIF/chert and VMS style sulfides

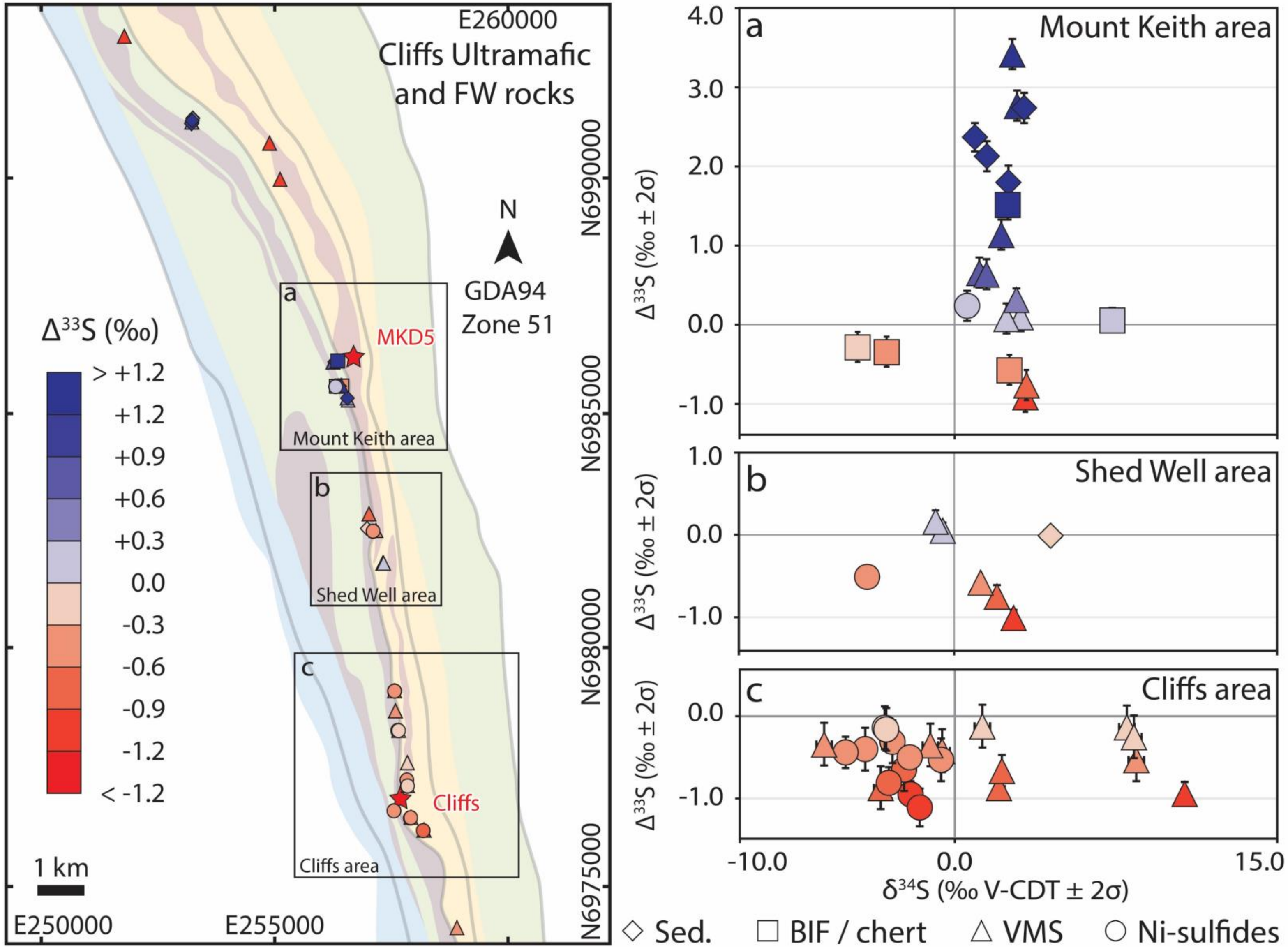
Spatial correlation of magmatic and crustal sulfides in MKU



Modified from Perring (2015)

- Magmatic Ni sulfides correlate well with crustal sulfides.
- Crustal sulfides are dominantly hydrothermal.
- Overall more vent proximal stratigraphic substrate.

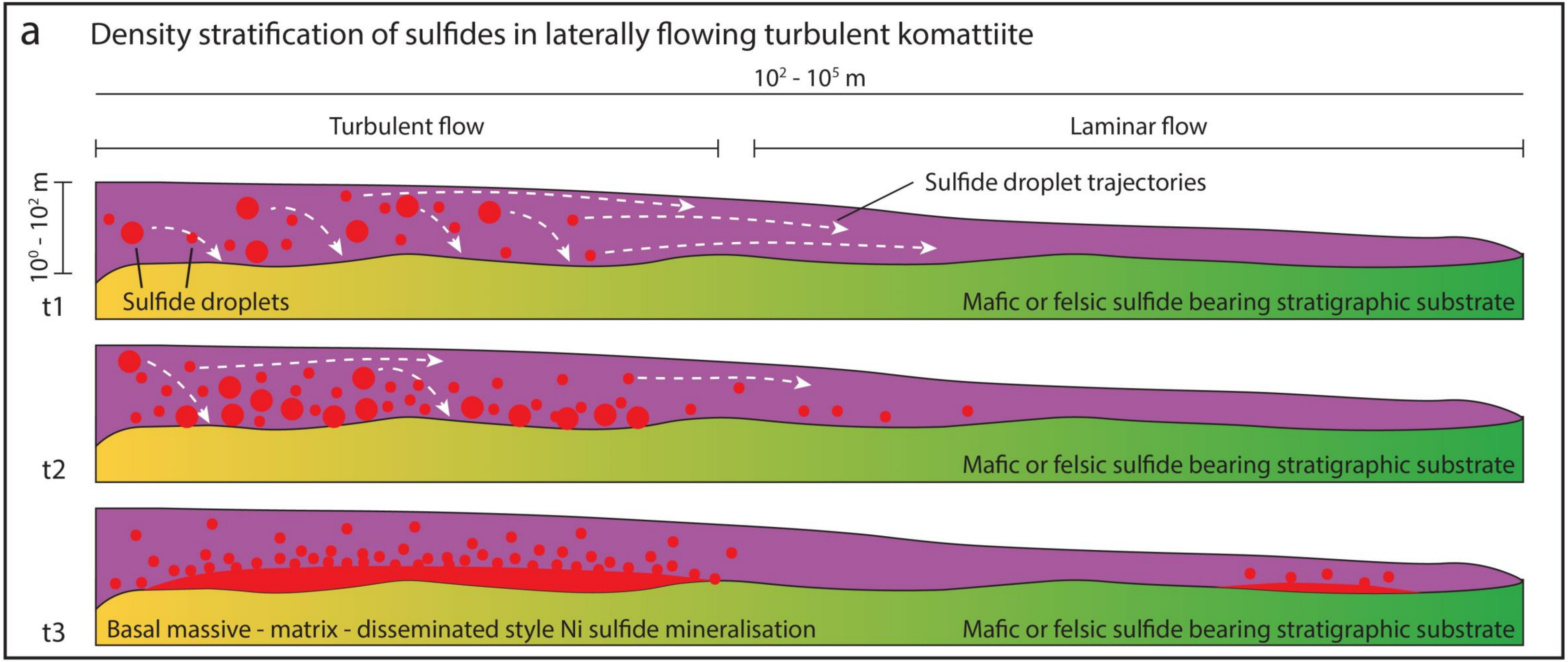
Spatial correlation of magmatic and crustal sulfides in CLU



Modified from Perring (2015)

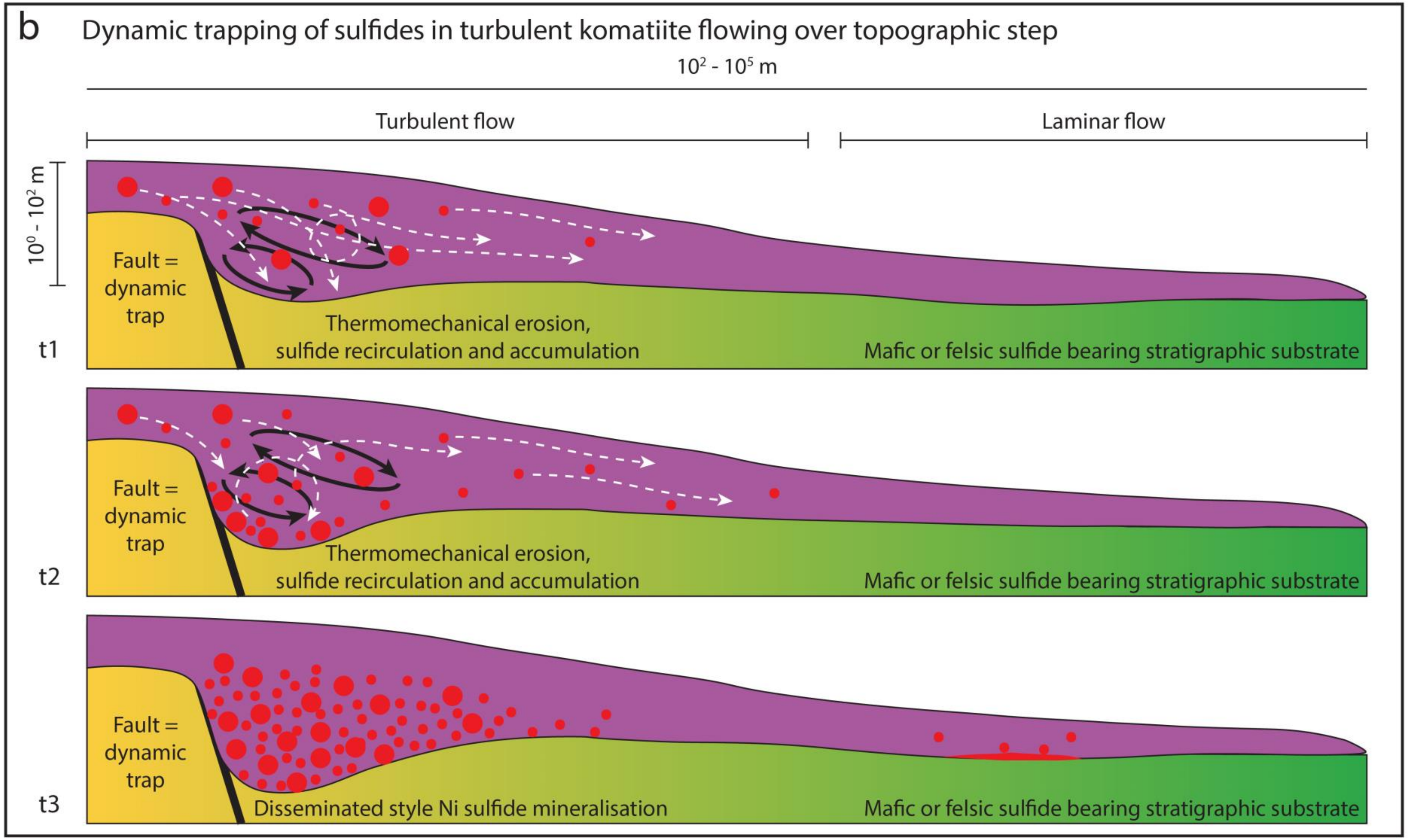
- N to S crustal sulfide trend:
  Dist. to ore = sedimentary
  Prox. to ore = hydrothermal
- Cliffs Ni deposit located on top of most hydrothermal vent proximal part of stratigraphic substrate.
- **Cliffs deposit also formed proximal to its S source**
- **What does that mean for transport of assimilated sulfides in komatiites?**

Implications for transport of assimilated crustal sulfides



Inspired by Yao and Mungall (2021; 2022)

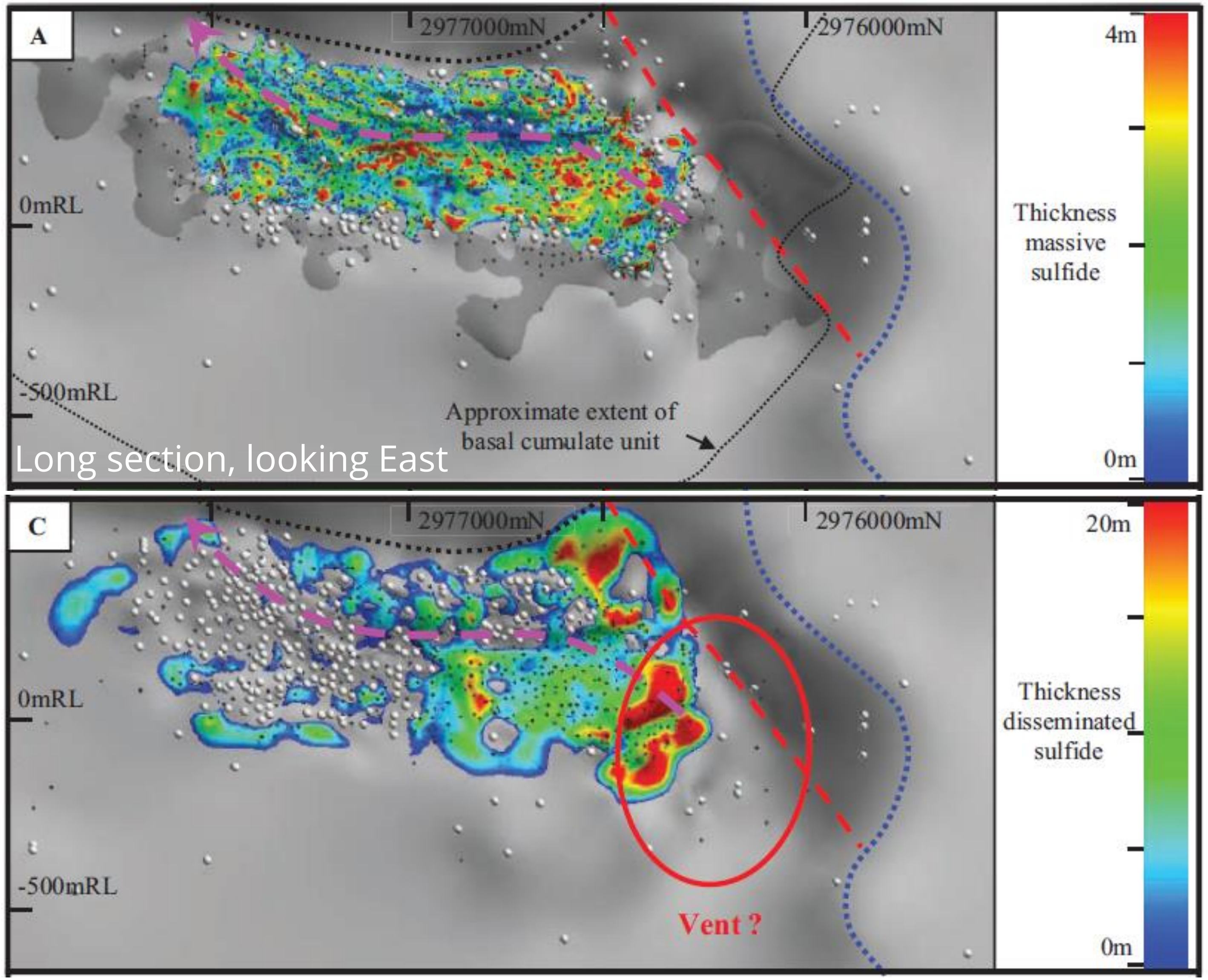
Implications for transport of assimilated crustal sulfides



Dynamic trapping and sulfide droplet recirculation may be an important metal enrichment process!

Inspired by Yao and Mungall (2021; 2022)

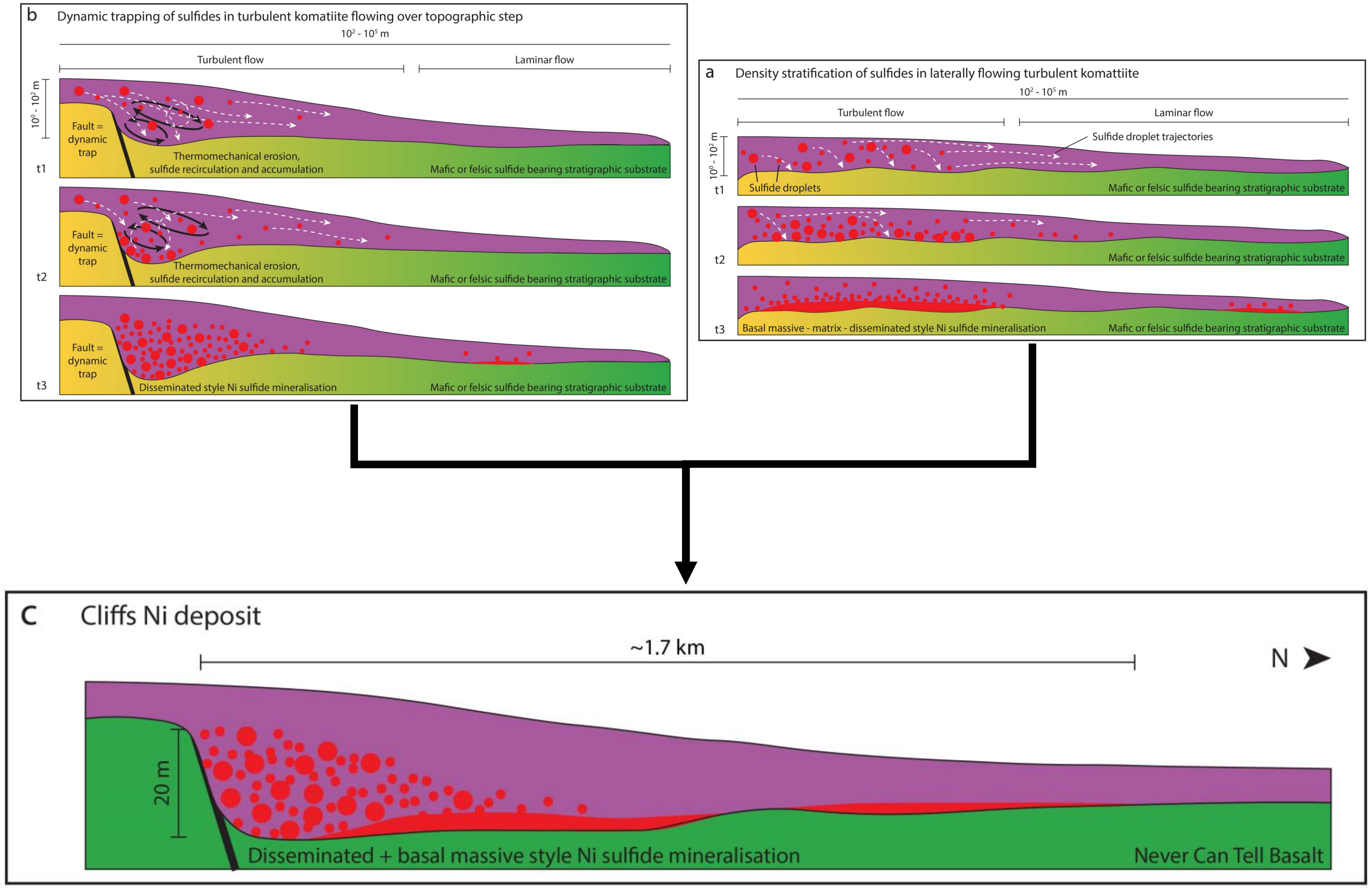
Dynamic metal upgrading during formation of Cliffs Ni deposit



Perring (2015)

- The Cliffs Ni deposit may have formed from pre-enrichment during dynamic trapping before deposition as a type I basal deposit.

Dynamic metal upgrading during formation of Cliffs Ni deposit



- The Cliffs Ni deposit may have formed from pre-enrichment during dynamic trapping before deposition as a type I basal deposit.
- Early growth faults:
  → Dominant host for hydrothermal sulfides i.e., the food for komatiites
  → Location for dynamic trapping and metal upgrading
- Explains metal tenors and proximity to crustal S source.

Mafic hosted komatiites may also be proximal and thus prospective in bimodal komatiite systems

Take home messages

- Dominant crustal S source: VMS style sulfides.
- Syn rift growth faults: Source for both S and dynamic trapping.
- Mafic hosted komatiites in bimodal settings:
  → May be more prospective for Ni than previously thought.
- Exploration may benefit from a VMS targeting approach.
- S isotopes: proxy towards favourable host rocks and syn rift growth faults.

- Virnes AB, Fiorentini ML, Caruso S, Baublys KA, Masurel Q, Thebaud N.
  Sulfur isotopes in Archaean crustal reservoirs constrain the transport and deposition mechanisms of nickel-sulfides in komatiites.
  Mineralium Deposita (**submitted for publication**)

Thank You!

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References