UiT The Arctic University of Norway

The geochemical signature of Cu mineralisation preserved in stream sediments from the Alta-Kvænangen Tectonic Window, Northern Norway

Master's thesis in Geology, GEO-3900, July 2021

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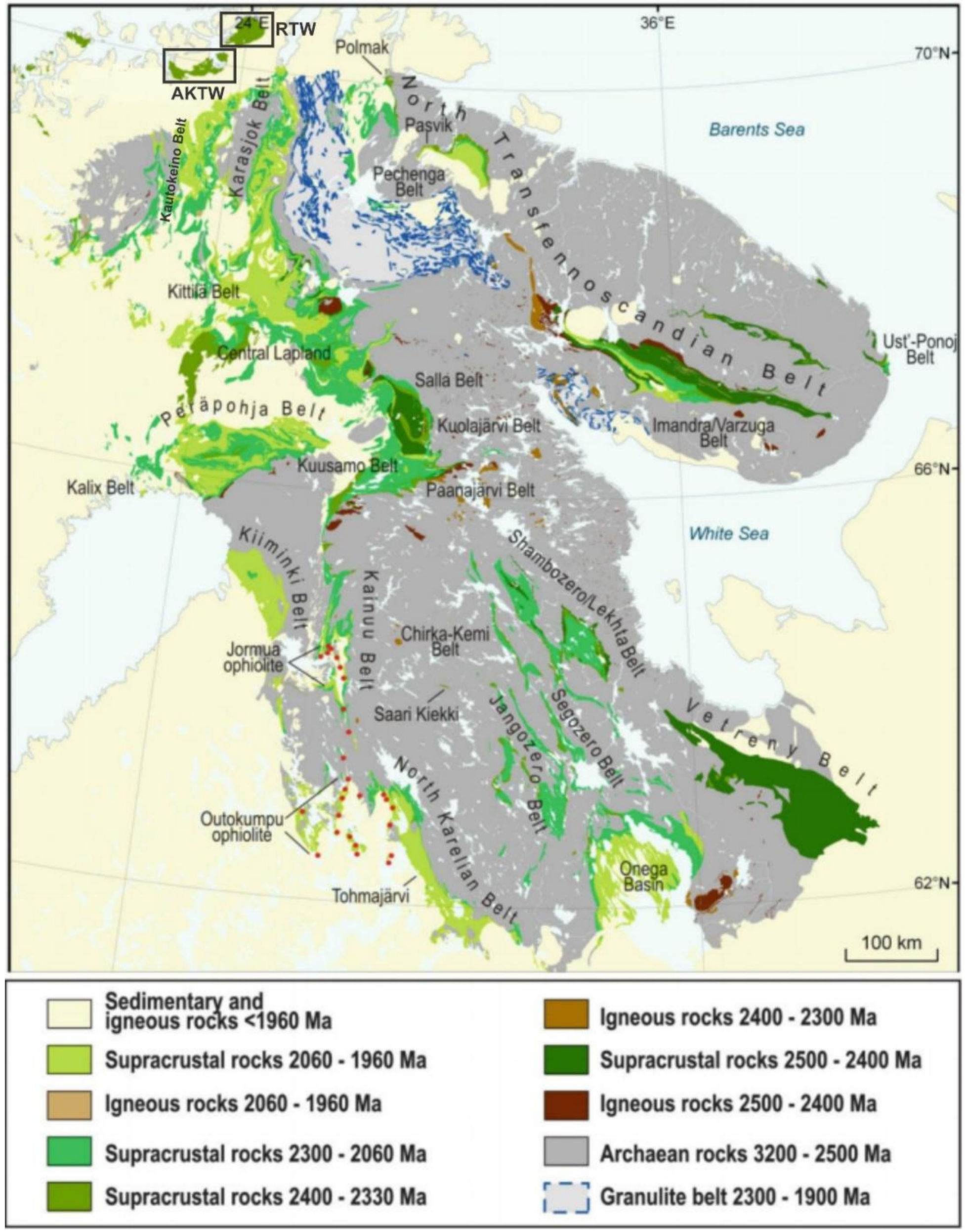
The Alta-Kvænangen Tectonic Window

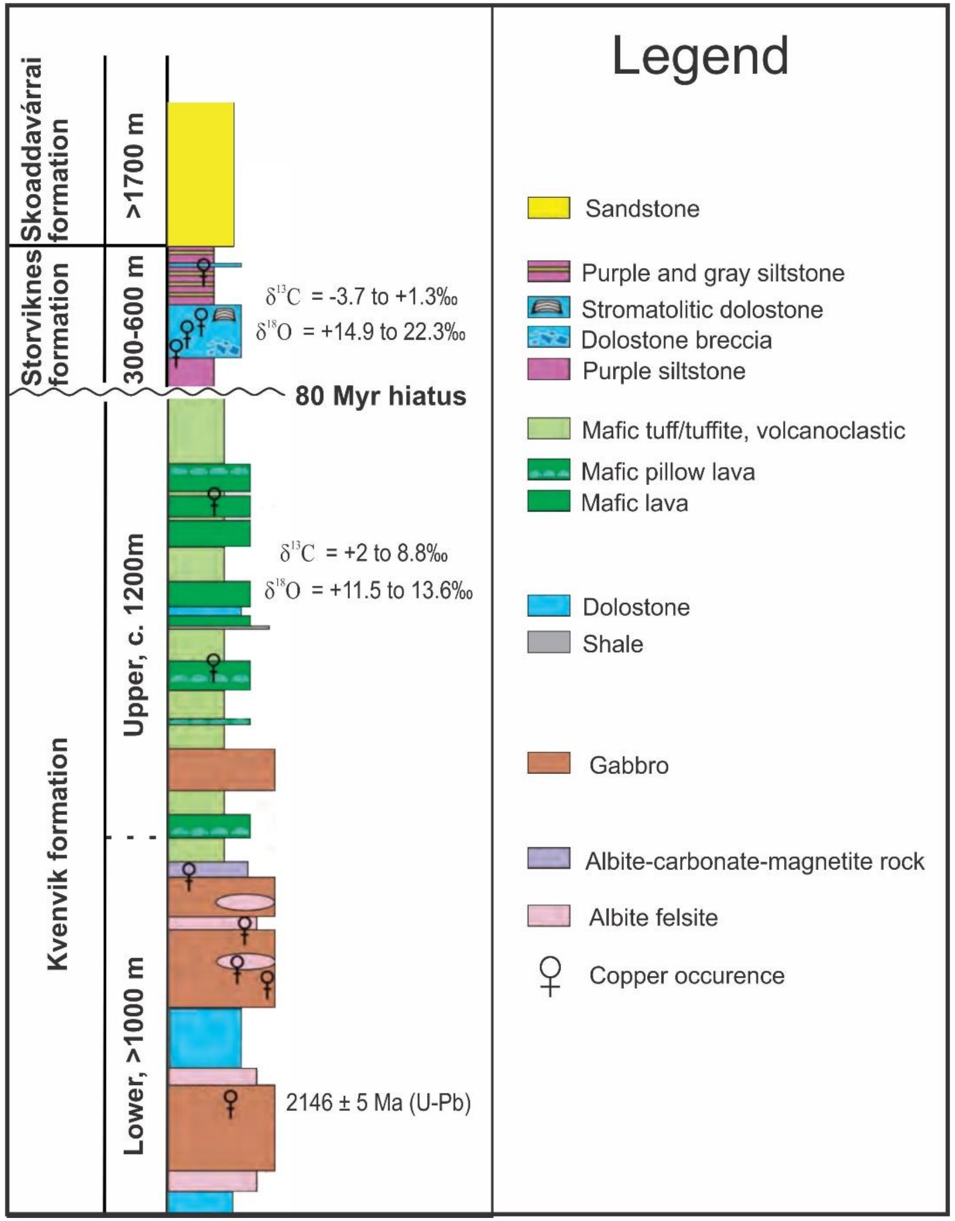
- Tectonic window exposed in the Caledonides of Northern Norway
- Hosts several Cu deposits
  - Hosted by both mafic rocks and sedimentary lithologies.



From Melezhik & Hanski (2013)

Kåfjord, the study area

- Raipas Supergroup
- Carbonate stable isotope compositions ($\delta^{13}C$, $\delta^{18}O$)
- Mafic rock- and sediment-hosted Cu mineralisation



Stable isotope compositions of carbonates from Simonsen (2021). Figure modified from Melezhik et al. (2015)

Purpose of the study:

Investigate whether the geochemical signature of Cu mineralisation is preserved in stream sediments in the AKTW, and if so to characterise that signature.

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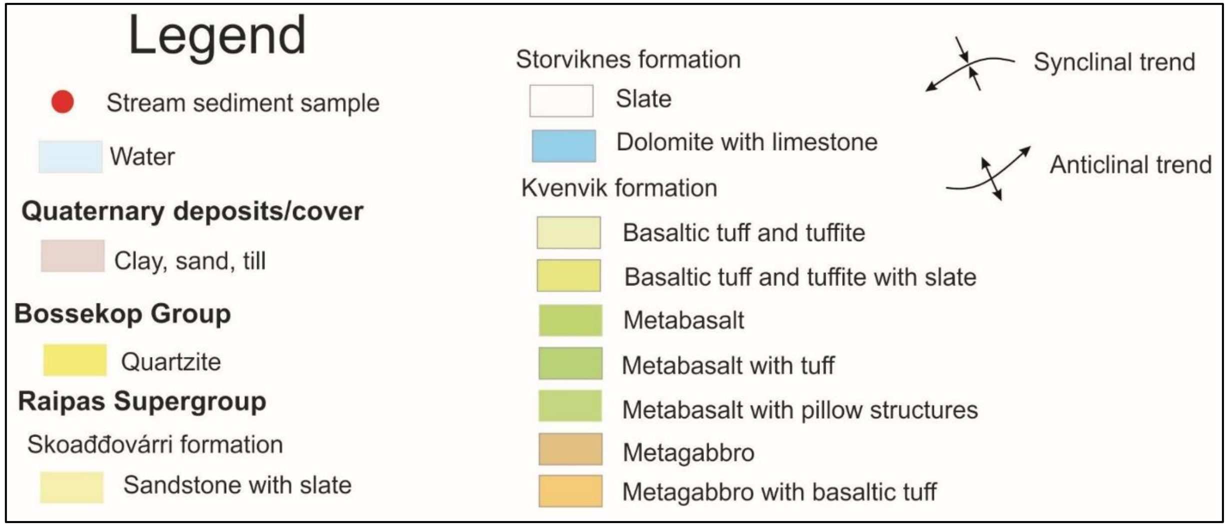
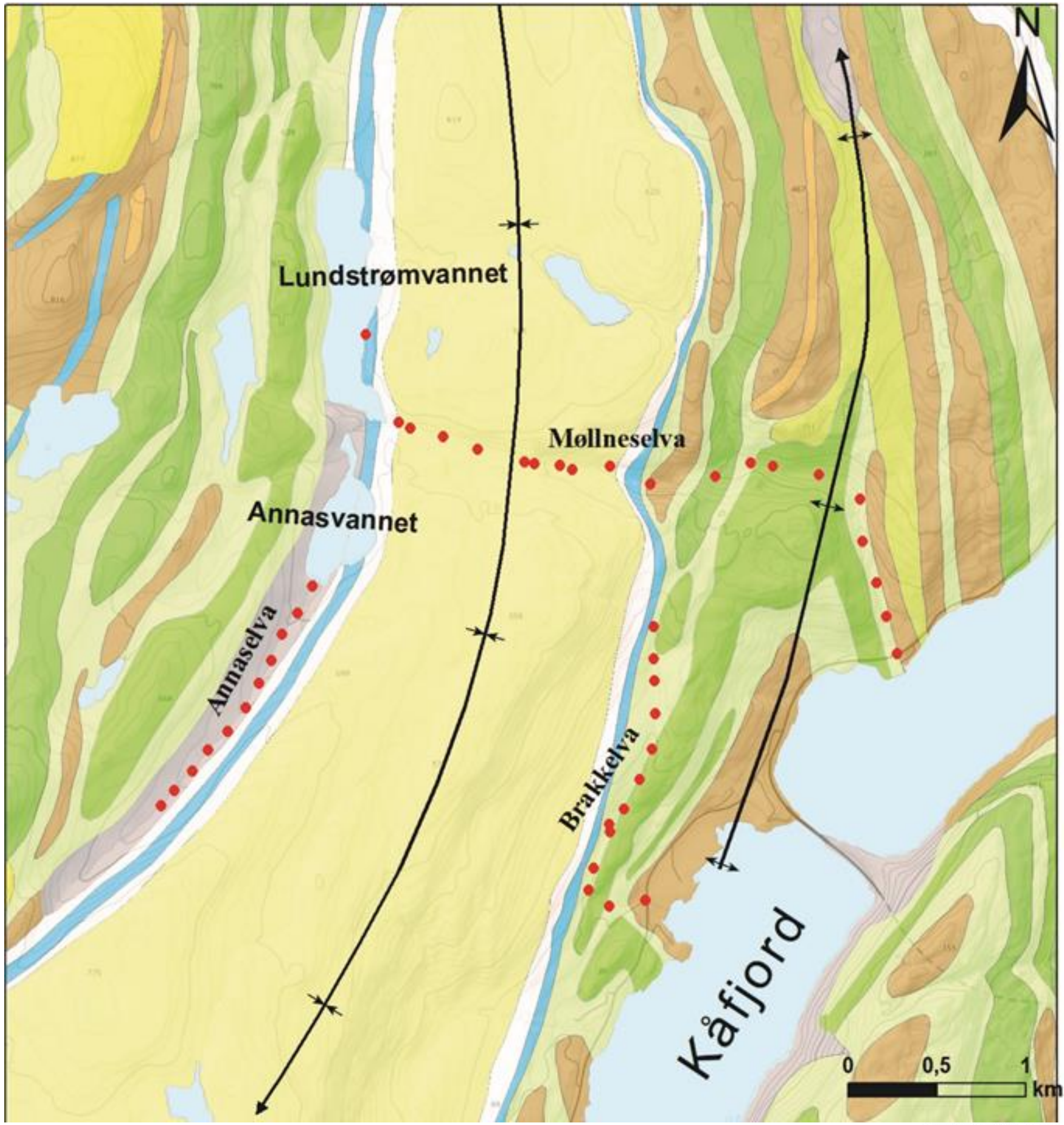
- Bulk chemistry of stream sediments
- Geochemical characteristics of heavy minerals
- Stable isotope composition of carbonates

Sampling of stream sediments

44 stream sediment samples:

1. Sediment-hosted Cu mineralisation
2. Mafic rock-hosted Cu mineralisation
3. Both the sediment- and mafic rock-hosted Cu mineralisation





Base map *modified after The Geological Survey of Norway (2021)* with structures from *Bergh & Torske (1988)*

Sieved fractions, additional preparation steps and methods

Fraction (µm)	Additional preparation	Method
<63		**Bulk chemistry**
63-125		
125-250	 Magnetic separation Picking of minerals	**Bulk chemistry** SEM-EDS LA-ICP-MS Stable isotope composition of carbonates
250-1000		
>1000		

Sieved fractions, additional preparation steps and methods

Fraction (µm)	Additional preparation
<63	
63-125	
125-250	**Magnetic separation** Picking of minerals
250-1000	
>1000	

- Minerals with different magnetic susceptibilities separated.
- Magnetite and Pyrrhotite extracted using hand held magnet.
- A magnetic separator used for the rest.

	Total range (Amps.)	Best range (Amps.)
Mag	<,01-,05	,01
Hem	,025-,50	,10-,30
Po	<,01-,70	,01-,05
Bn	,30-1,10	,60-,90
Ccp	,30-1,70	,70-1,30
Cct	>1,7	>1,7
Py	>1,7	>1,7
Cal, Dol, Mgs	>1,7	>1,7

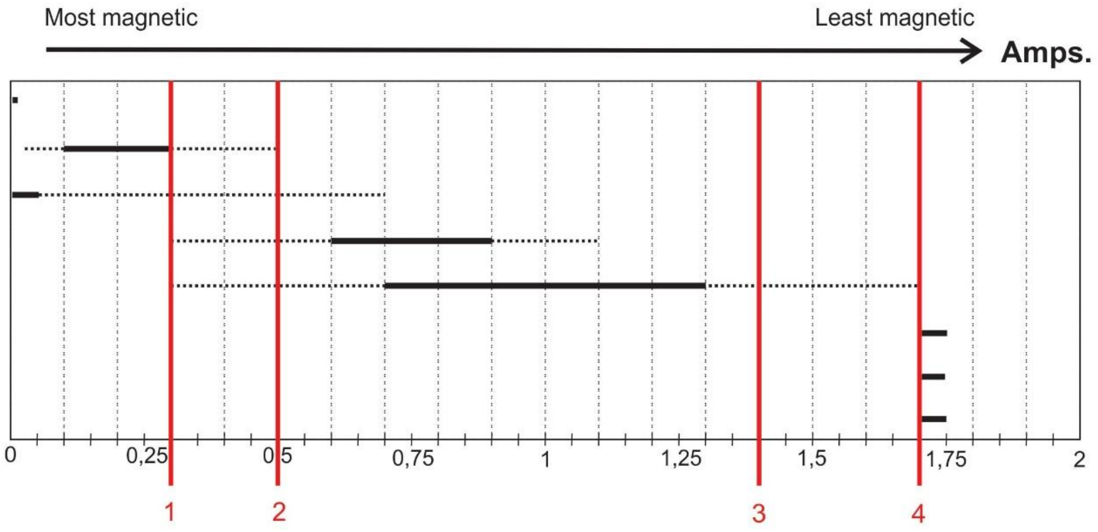
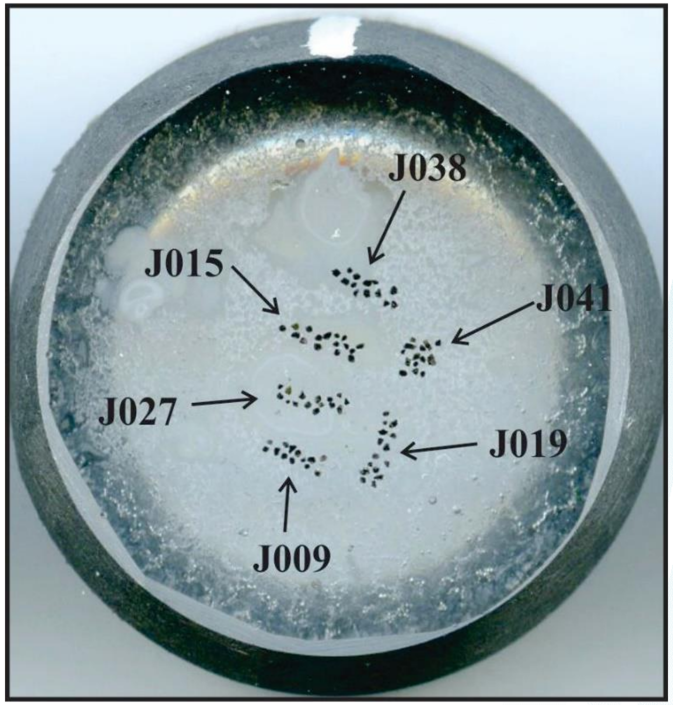


Figure modified after Rosenblum & Brownfield (2000).

Sieved fractions, additional preparation steps and methods

Fraction (µm)	Additional preparation
<63	
63-125	
125-250	Magnetic separation **Picking of minerals**
250-1000	
>1000	

- Hand-picking of minerals from magnetically separated fractions.
  - No further separation needed (e.g. heavy liquids).



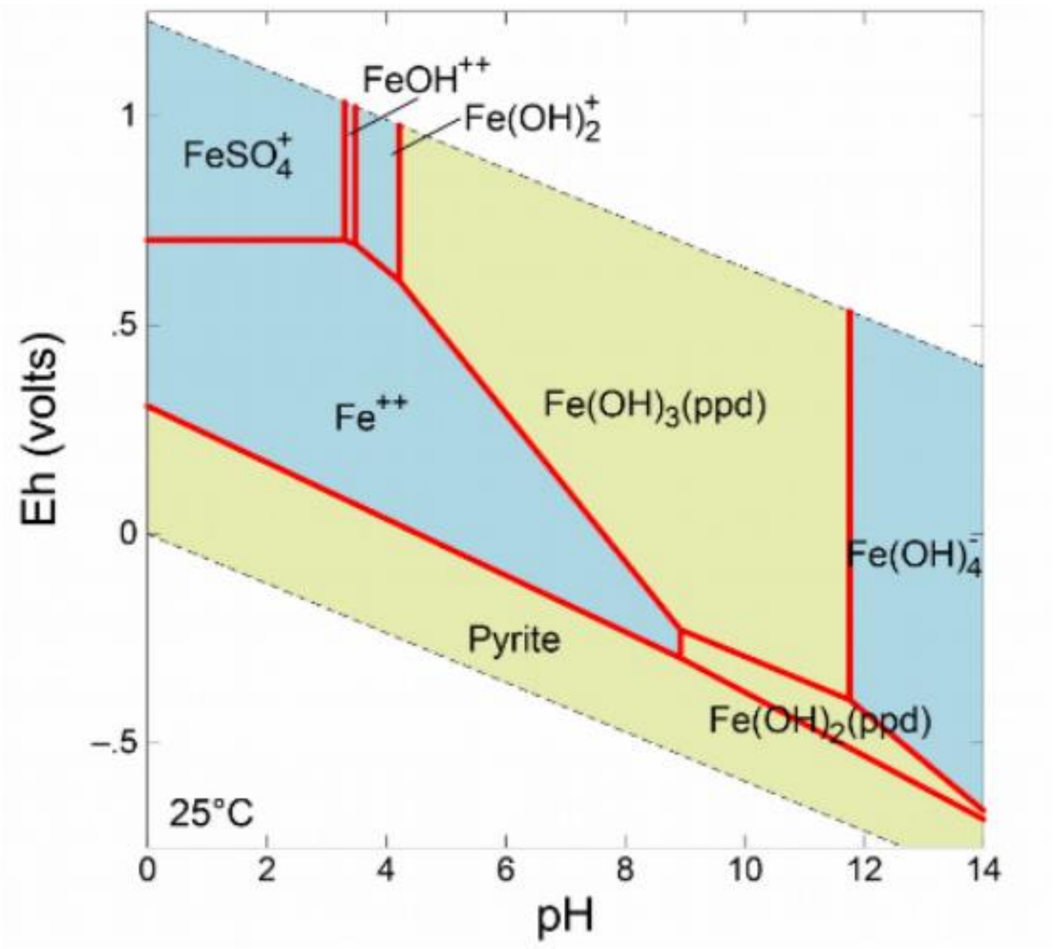
Grains of Mag separated from different samples (J015, J027, …)

Sieved fractions, additional preparation steps and methods

Fraction (µm)	Additional preparation	Method
<63		Bulk chemistry
63-125		
125-250	Magnetic separation Picking of minerals	Bulk chemistry **SEM-EDS** **LA-ICP-MS** **Stable isotope composition of carbonates**
250-1000		
>1000		

Physicochemical properties (Eh, pH)

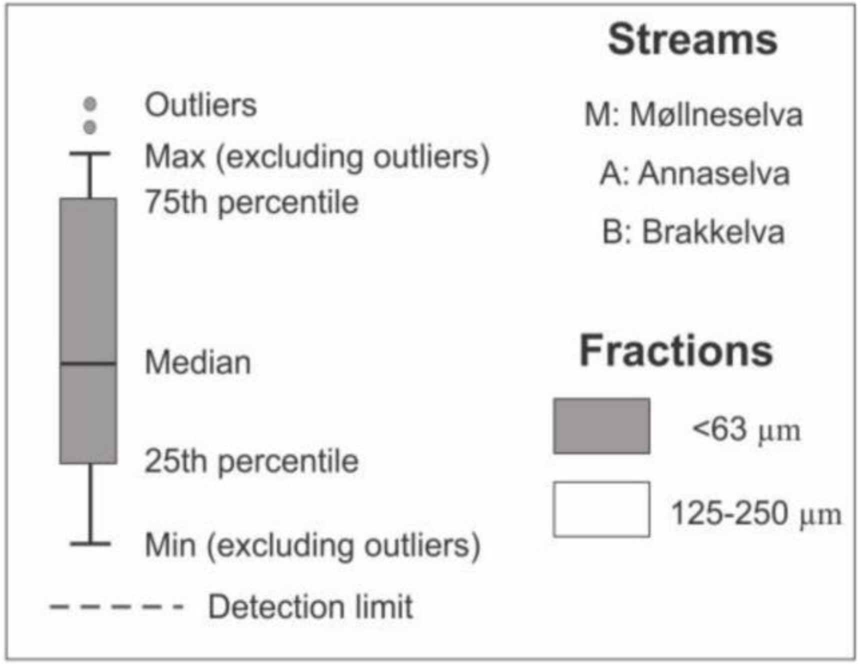
- Redox potential and pH measured in the pore water of 8 samples.
- Eh, pH and the solubility of minerals in surficial water.

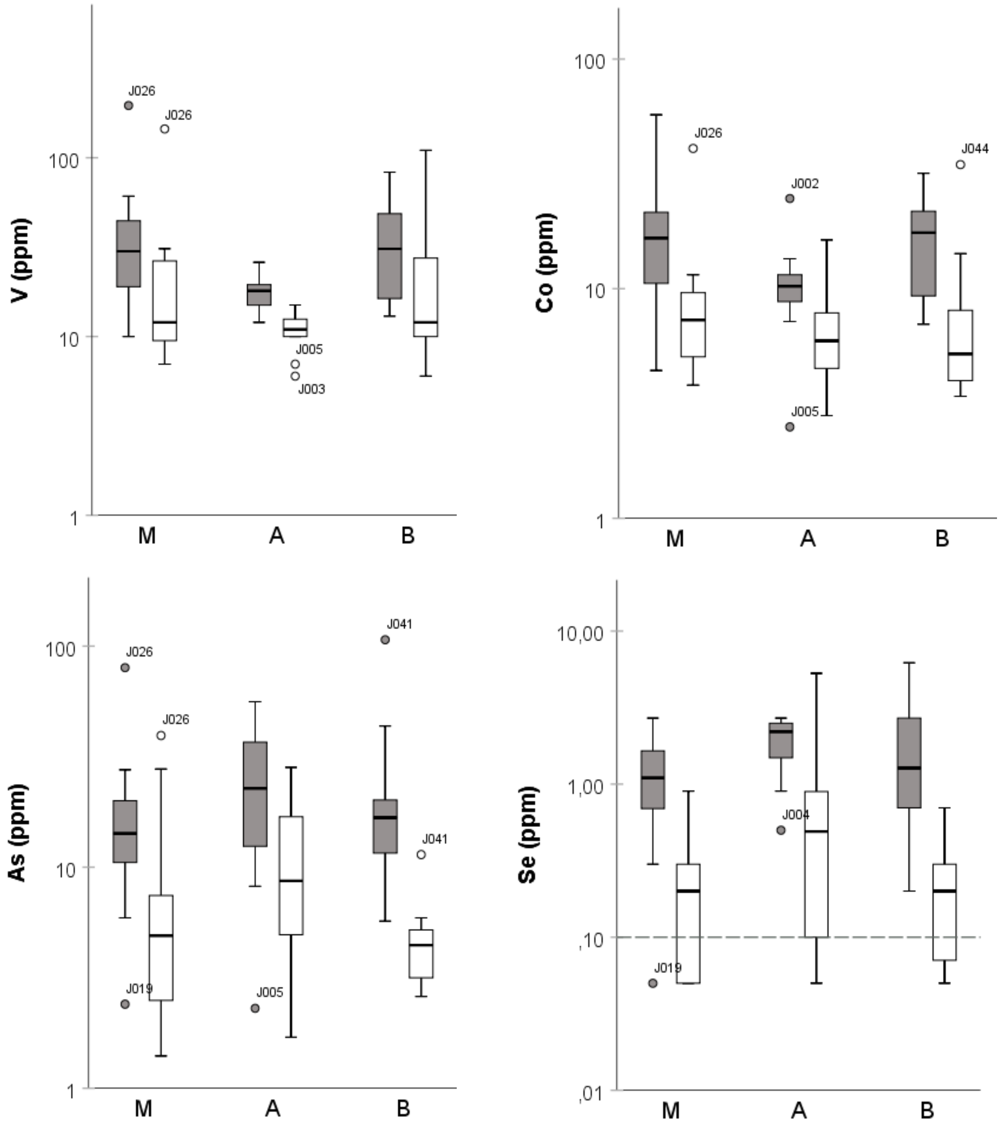


From Rose (2010)

Bulk chemistry of stream sediments

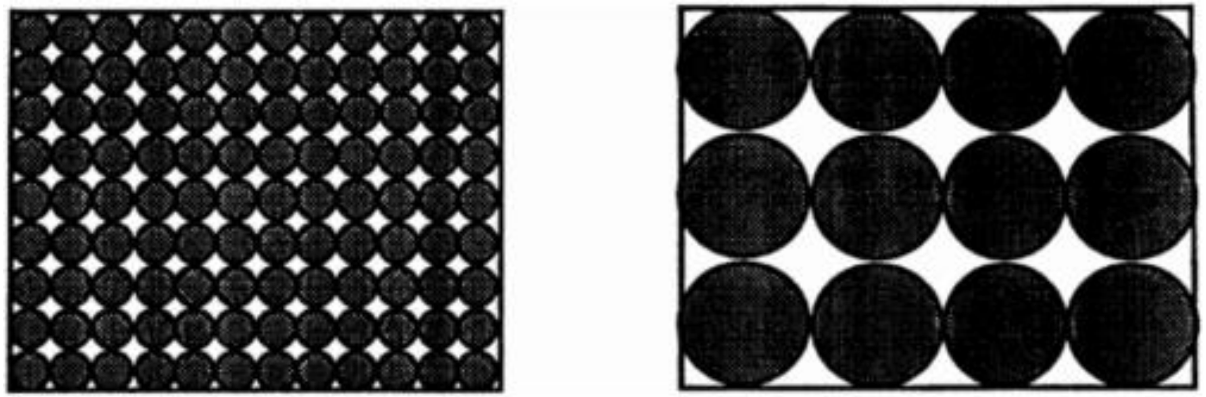
- <63 µm versus125-250 µm fraction.



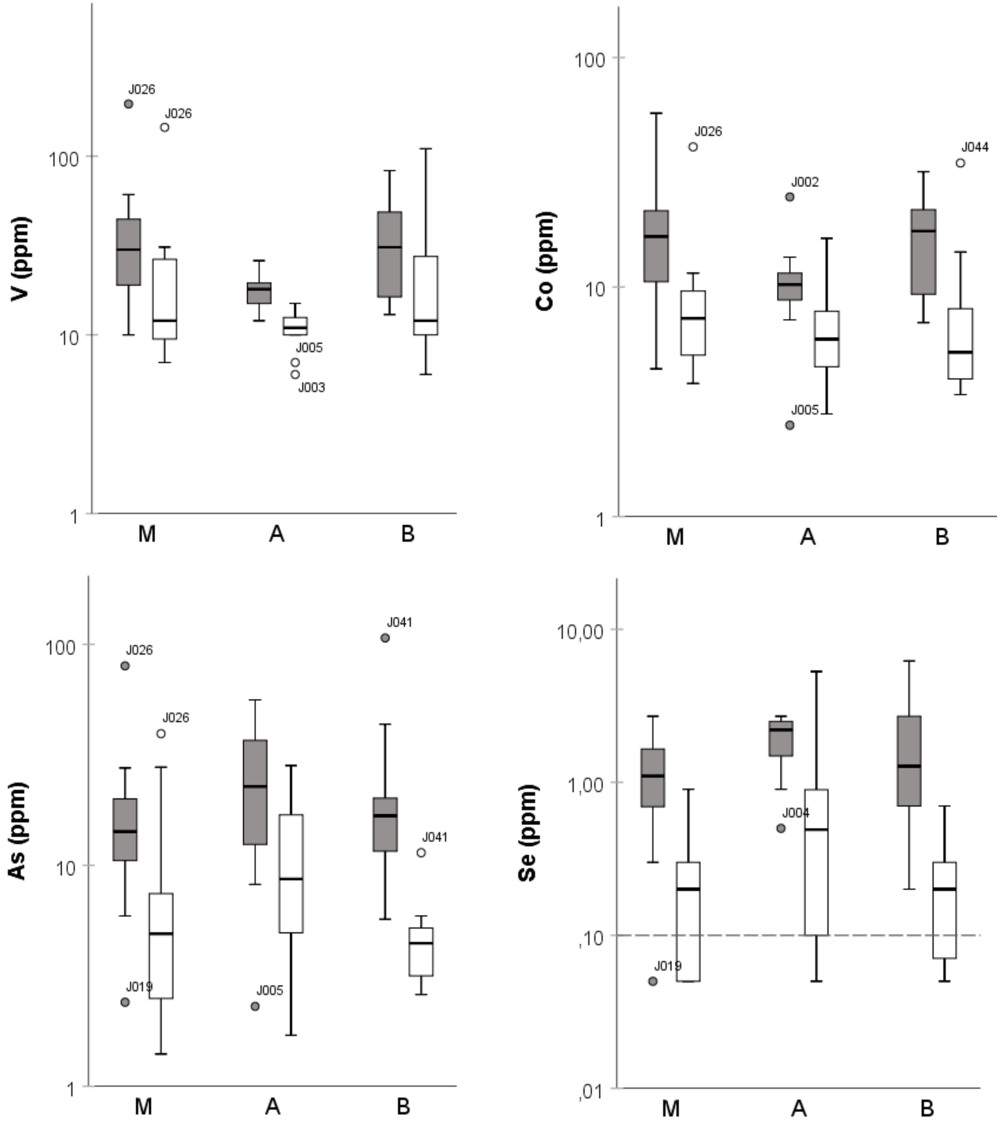


Bulk chemistry of stream sediments

- <63 µm versus125-250 µm fraction.
- Accumulation of dissolved elements on the surface of grains.

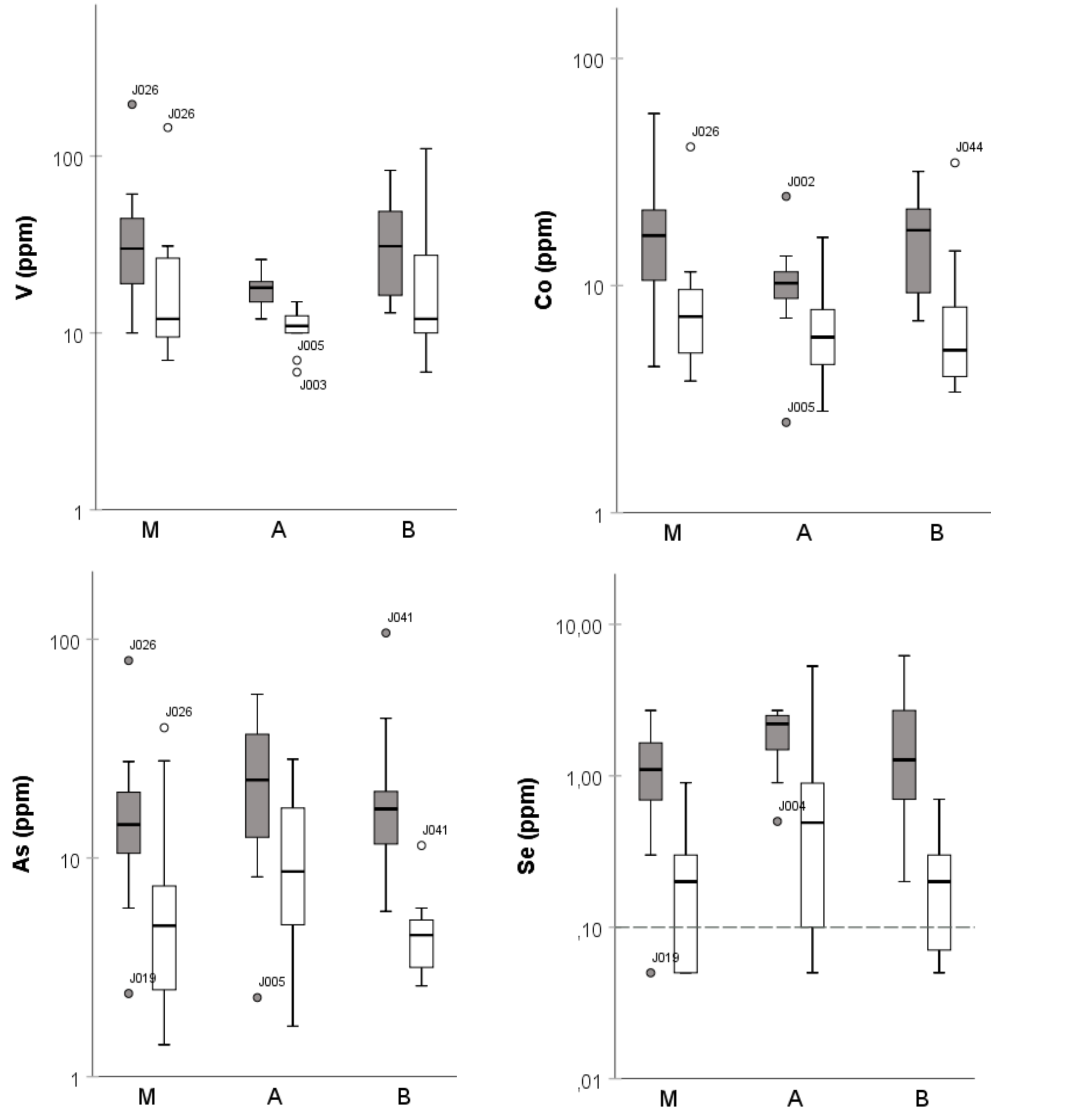


Schematic illustration of how the surface area of grains may vary for a given mass of sediments. From Horowitz (1991).



Bulk chemistry of stream sediments

- <63 µm versus125-250 µm fraction.
- Accumulation of dissolved elements on the surface of grains.
- Bulk chemistry of sediments from different streams.
  - Møllneselva (M) and Brakkelva (B) drain mafic rocks.
  - Annaselva (A) drain complex mineralisation (e.g. Se-rich sulphide phases) hosted by sedimentary lithologies.

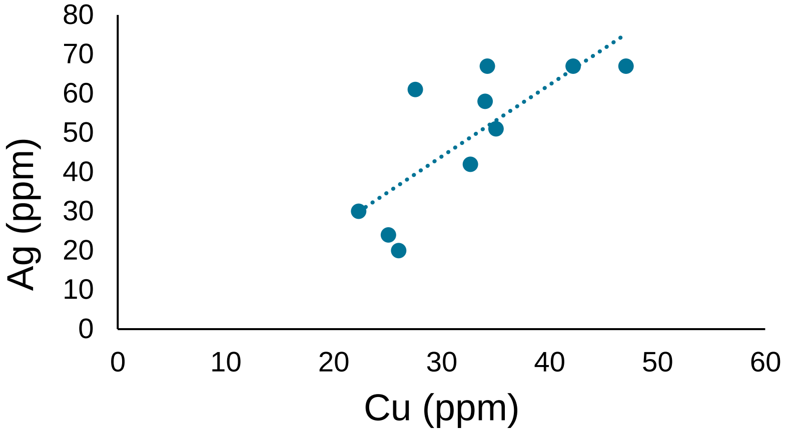


Pathfinder elements and correlation

- Cu correlates with chalcophile elements (e.g Ag, Zn, Mo).

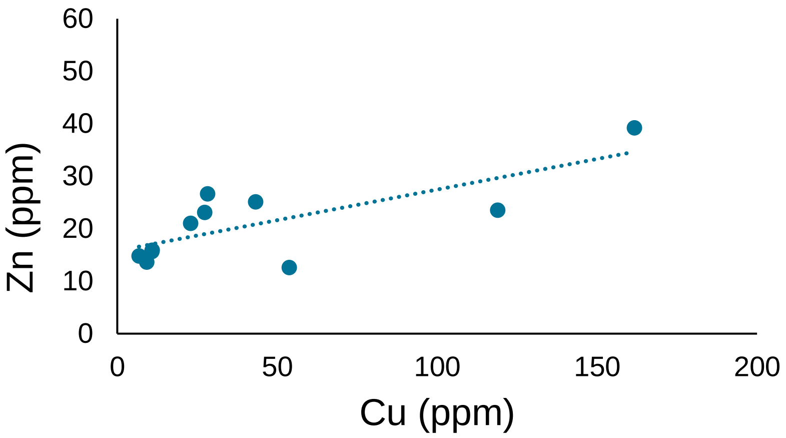
Draining carbonate lithologies

<63 µm fraction, Annaselva stream



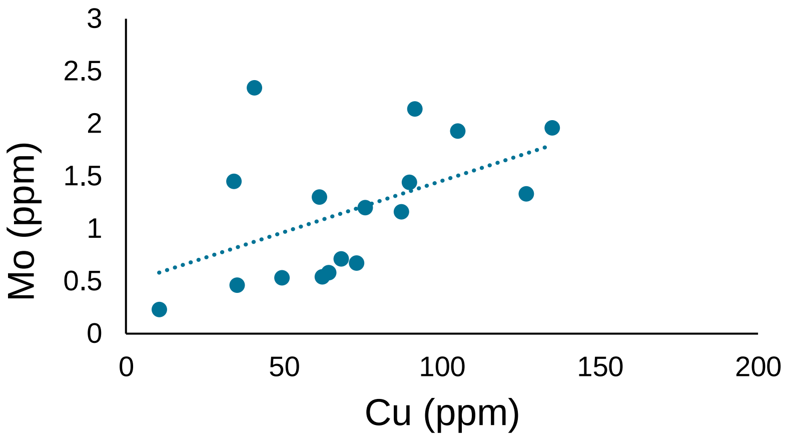
Draining mafic lithologies

125-250 µm fraction, Brakkelva stream



Draining all lithologies

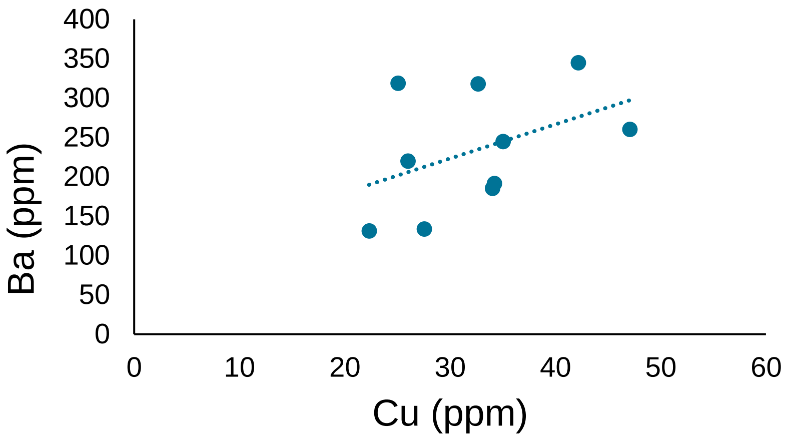
<63 µm fraction, Møllneselva stream



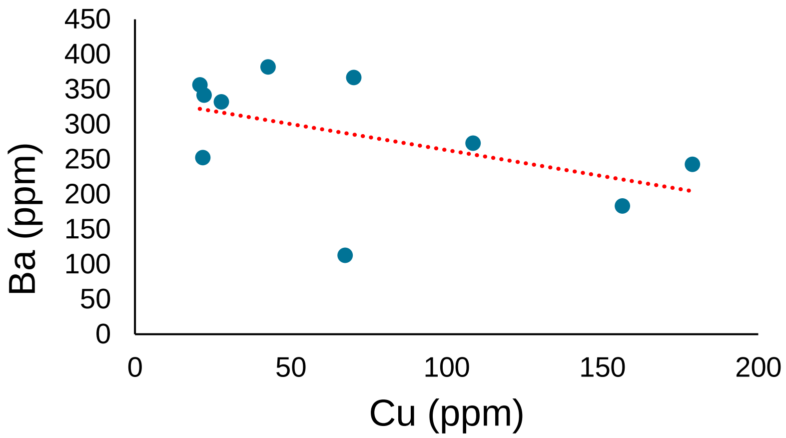
Pathfinder elements and correlation

- Cu correlates with chalcophile elements (.e.g Ag, Zn, Mo).
- Divalent cations, for example barium, may substitute Ca in $CaCO_3$ ($Ba^{2+} \leftrightarrow Ca^{2+}$).

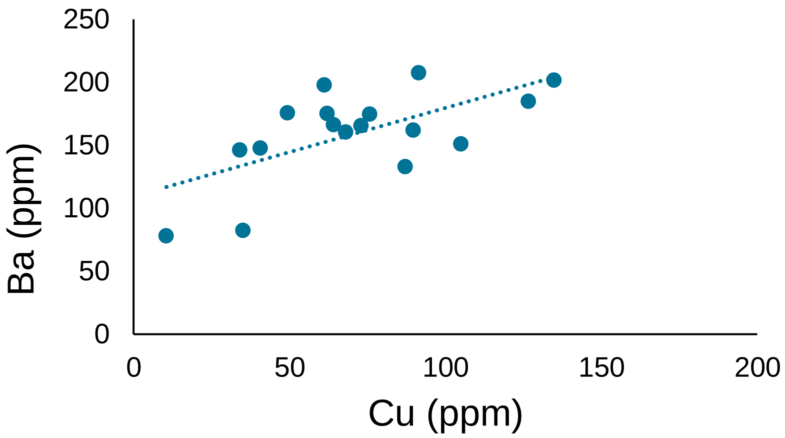
Draining carbonate lithologies
<63 µm fraction, Annaselva stream



Draining mafic lithologies
<63 µm fraction, Brakkelva stream



Draining all lithologies
<63 µm fraction, Møllneselva stream



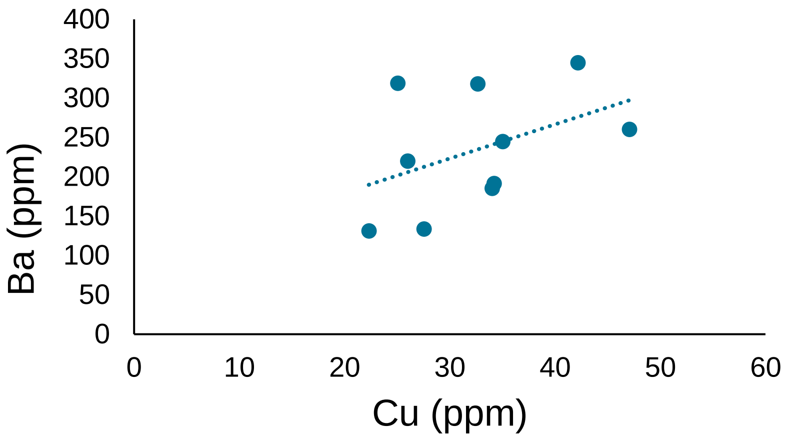
Pathfinder elements and correlation

- Cu correlates with chalcophile elements (.e.g Ag, Zn, Mo).
- Divalent cations, for example barium, may substitute Ca in $CaCO_3$ ($Ba^{2+} \leftrightarrow Ca^{2+}$).

Does the correlation reflect the Cu mineralisation occuring in carbonate-rich lithologies?

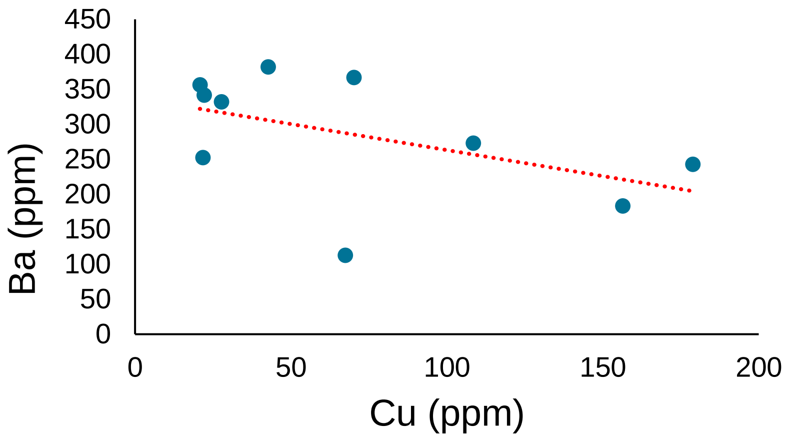
Draining carbonate lithologies

<63 µm fraction, Annaselva stream



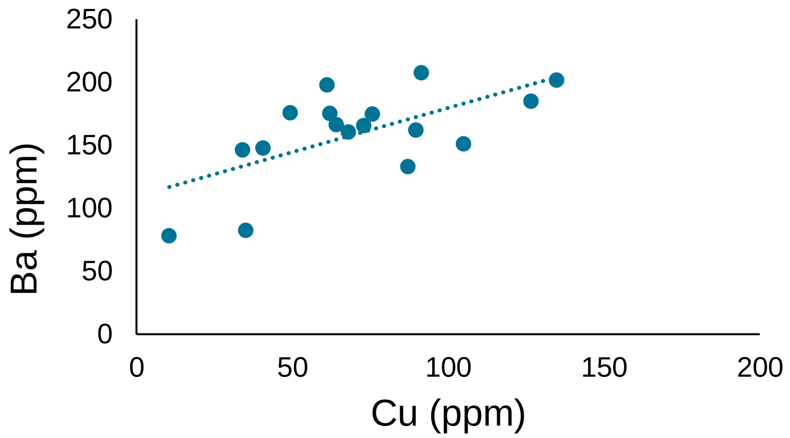
Draining mafic lithologies

<63 µm fraction, Brakkelva stream



Draining all lithologies

<63 µm fraction, Møllneselva stream

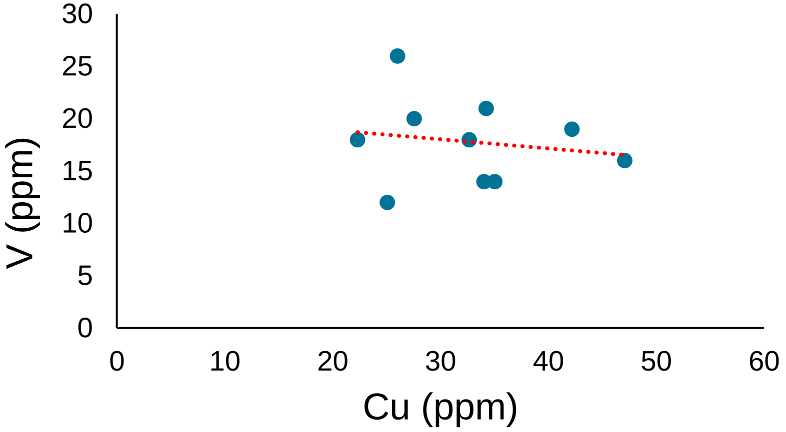


Pathfinder elements and correlation

- Cu correlates with chalcophile elements (.e.g Ag, Zn, Mo).
- Divalent cations, for example barium, may substitute Ca in $CaCO_3$ ($Ba^{2+} \leftrightarrow Ca^{2+}$).
- Similarily, the correlation between Cu and siderophile elements (V, Ni, Co) may reflect the mafic host rock lithology.

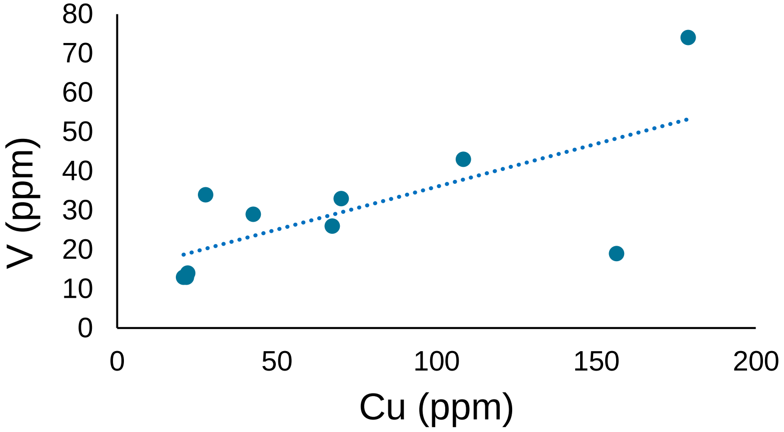
Draining carbonate lithologies

<63 µm fraction, Annaselva stream



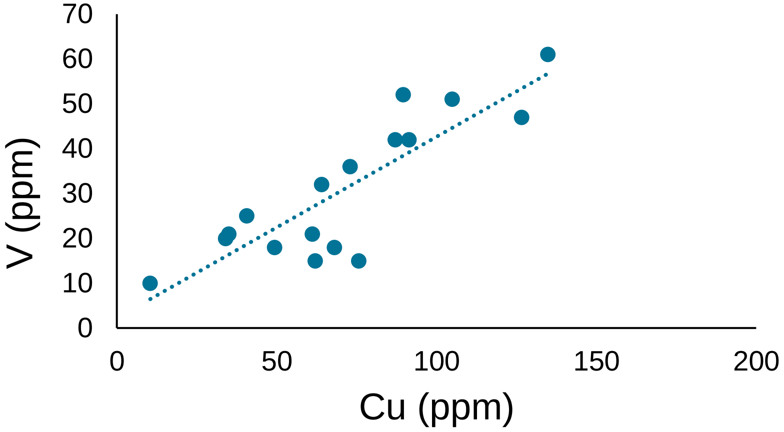
Draining mafic lithologies

<63 µm fraction, Brakkelva stream



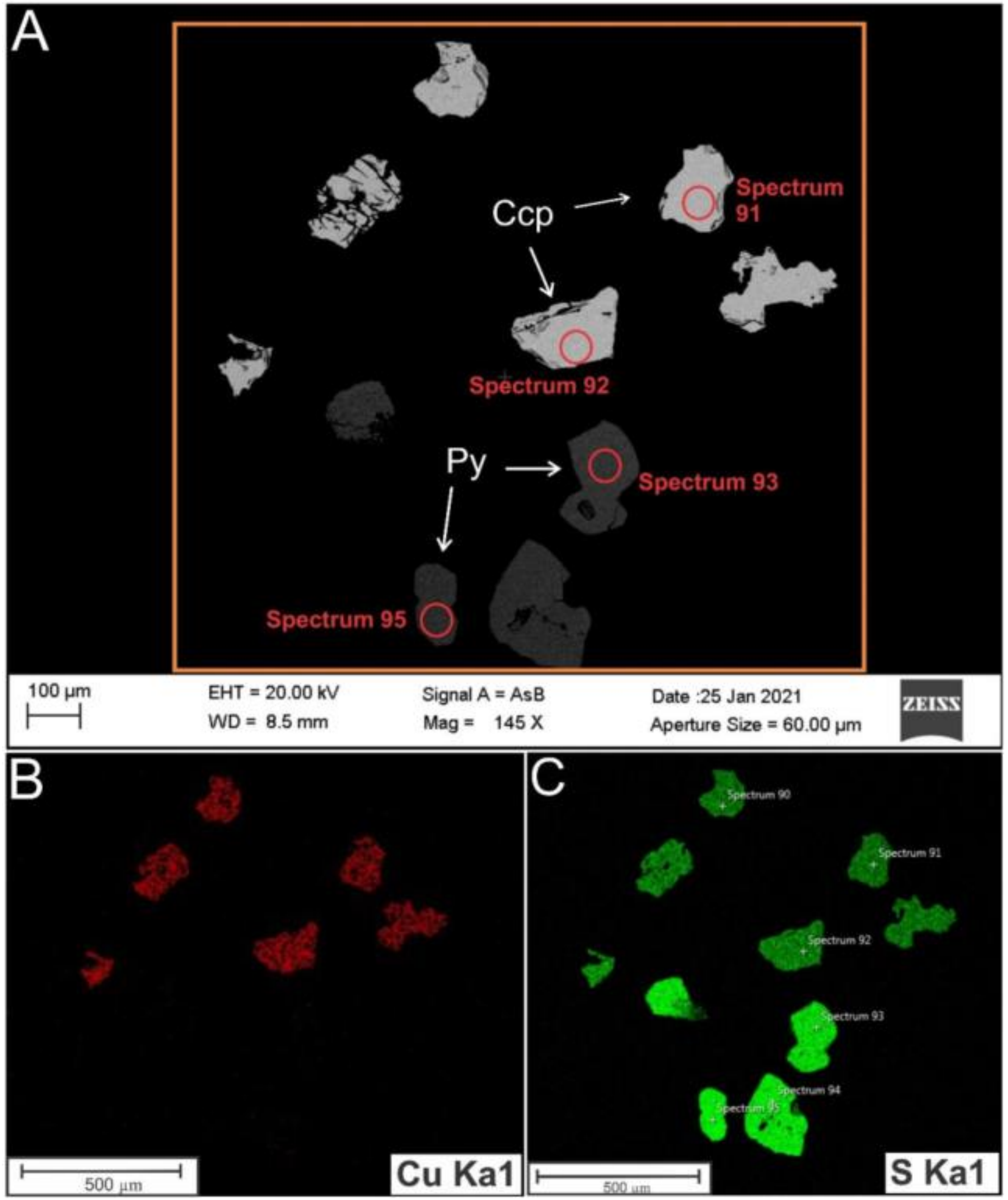
Draining all lithologies

<63 µm fraction, Møllneselva stream



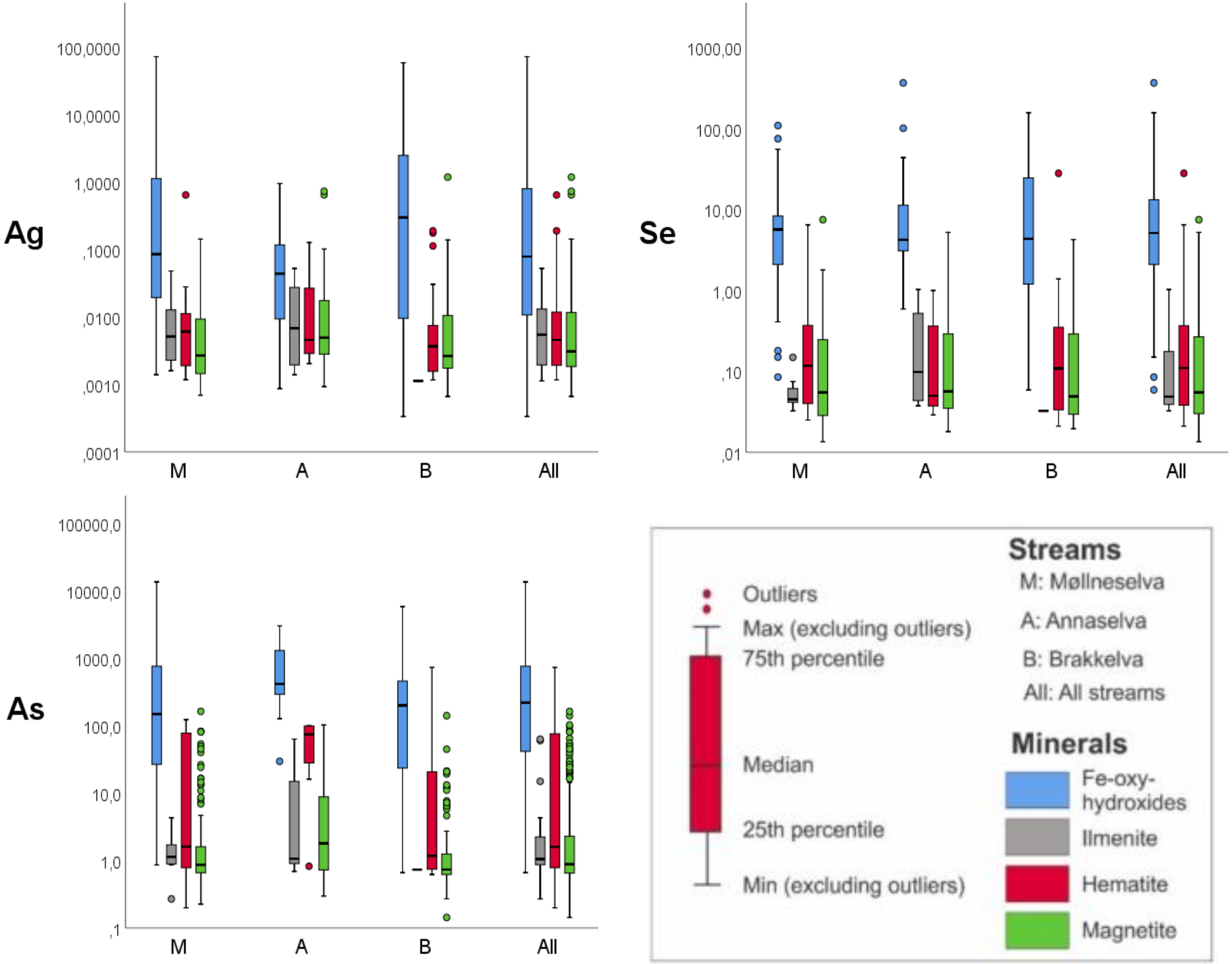
SEM-EDS analyses of heavy minerals

- Confirm the mineralogy of grains.
- Select grains to be analysed by LA-ICP-MS.
- Determine internal standards (wt.% Fe).



LA-ICP-MS of heavy minerals

- Oxides analysed:
  - 76 Fe-oxy-hydroxides
  - 18 ilmenite
  - 59 hematite
  - 351 magnetite



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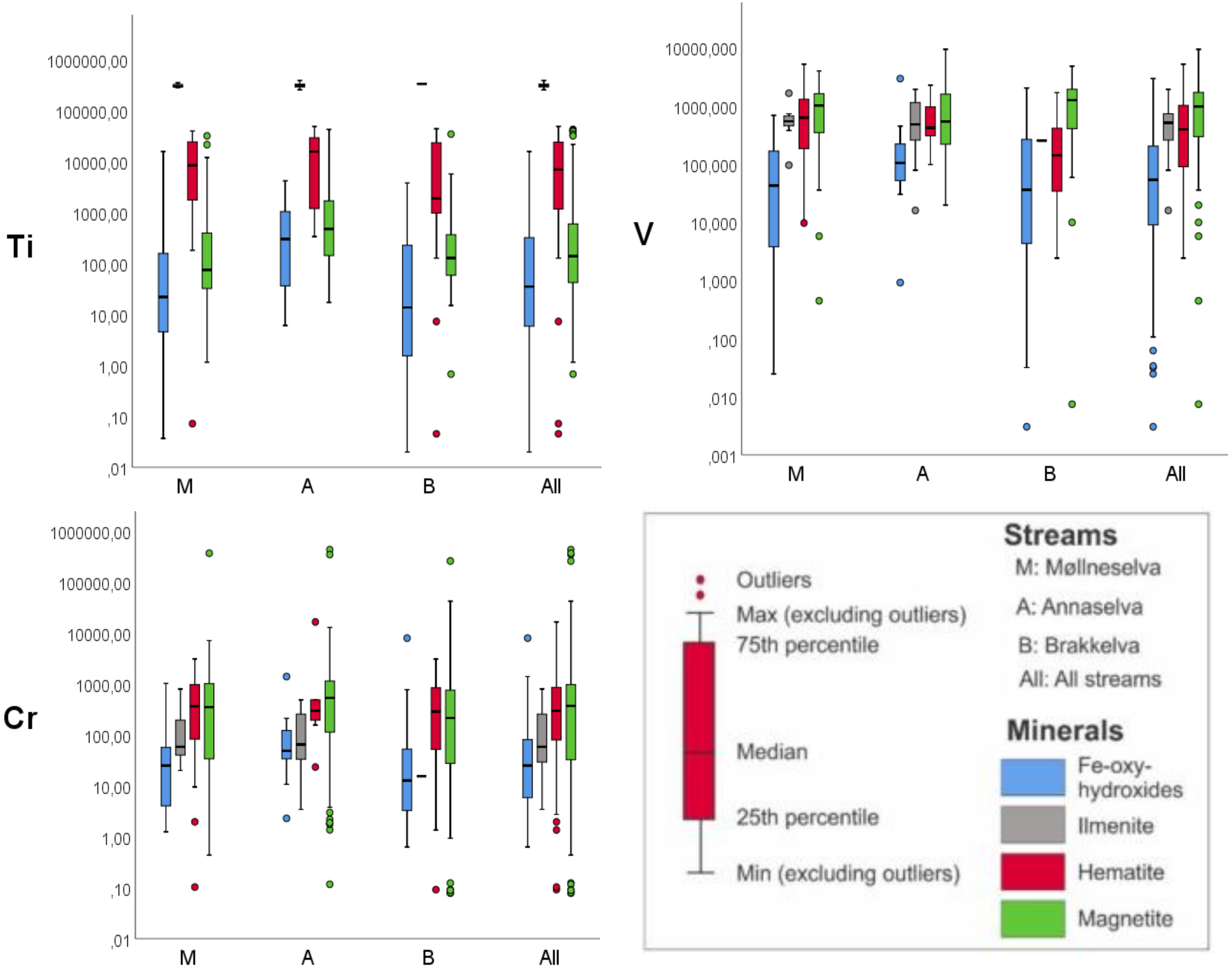
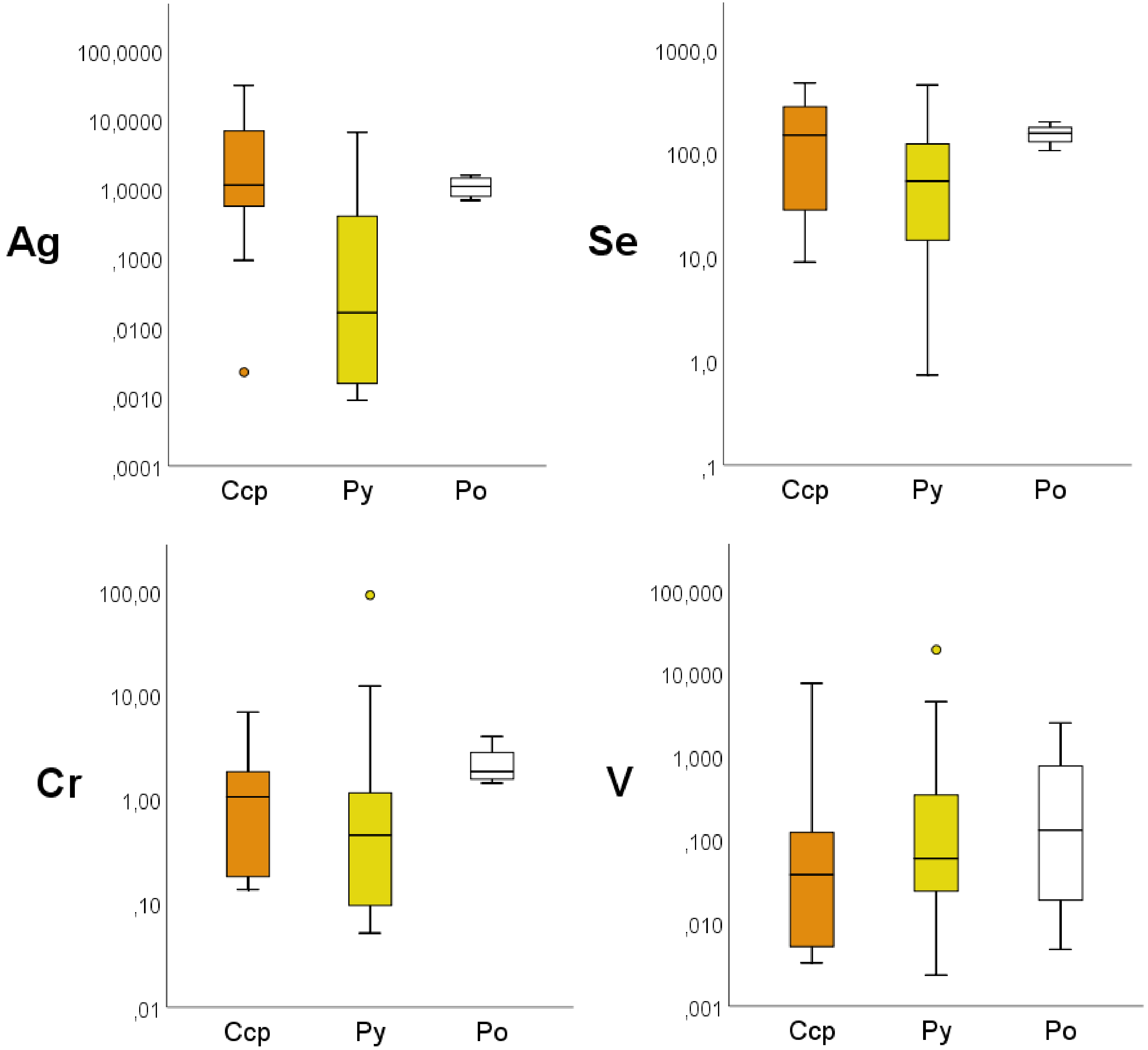


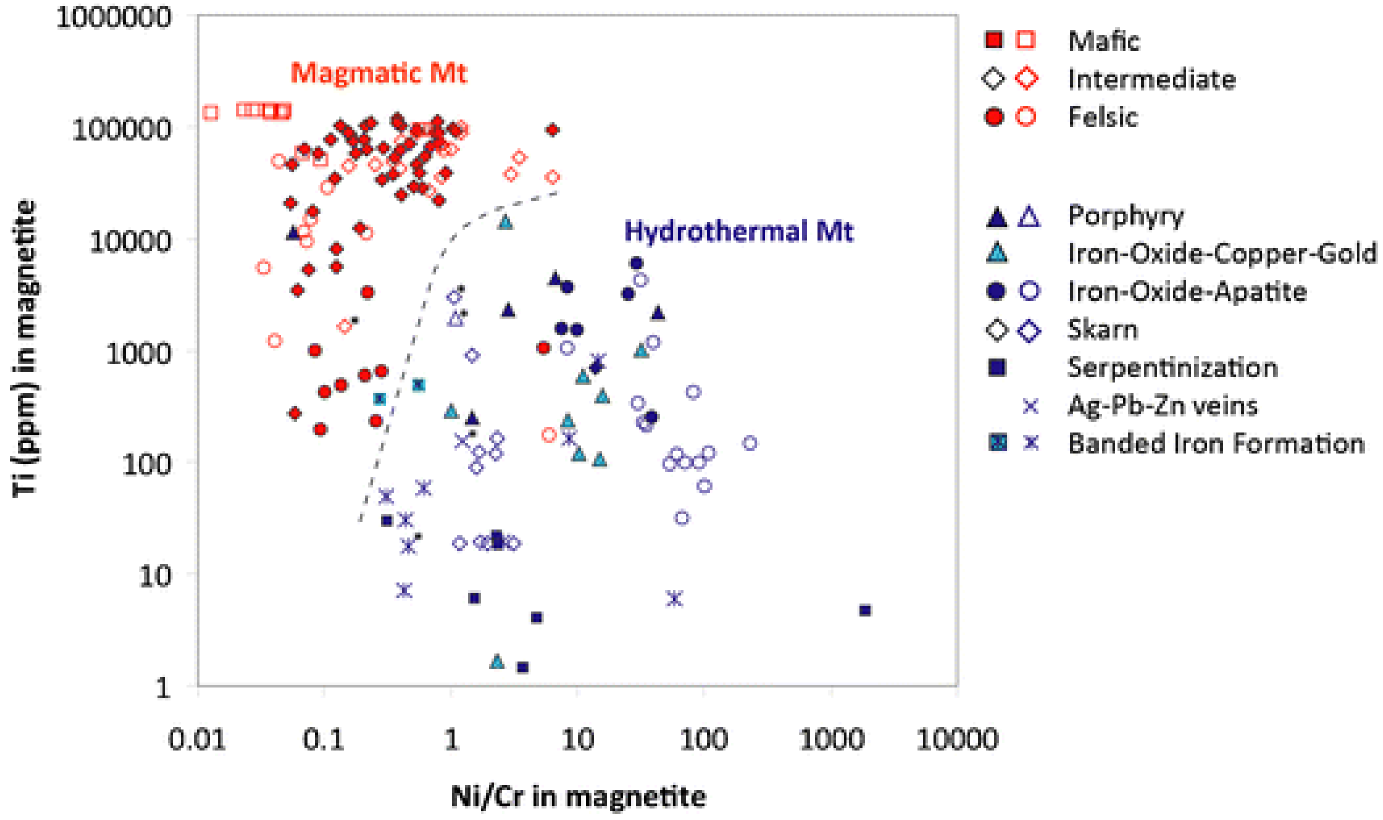
LA-ICP-MS of heavy minerals

- Sulphides analysed:
  - 32 chalcopyrite
  - 39 pyrite
  - 4 pyrrhotite



Indicator minerals, LA-ICP-MS of heavy minerals

- Composition of minerals can differ with respect to the environment in which they are formed in.
  - Example: Magnetite of magmatic/hydrothermal origin.

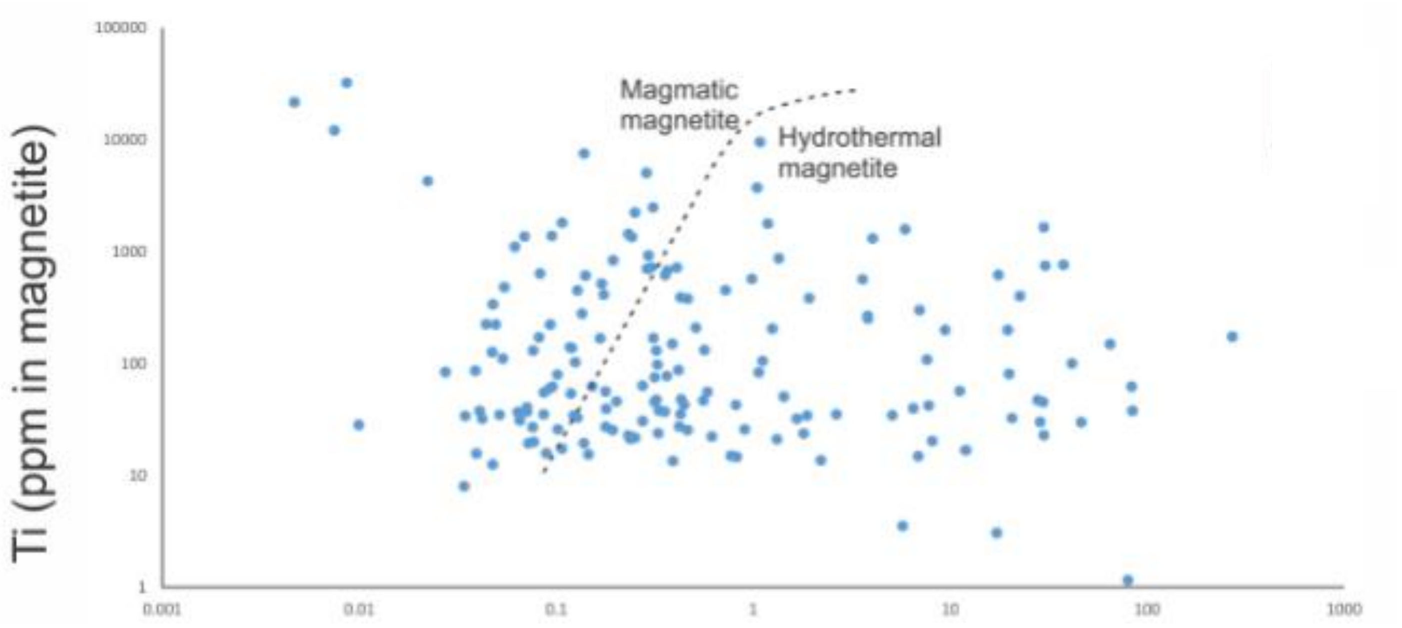


From Dare et al. (2014)

Indicator minerals, LA-ICP-MS of heavy minerals

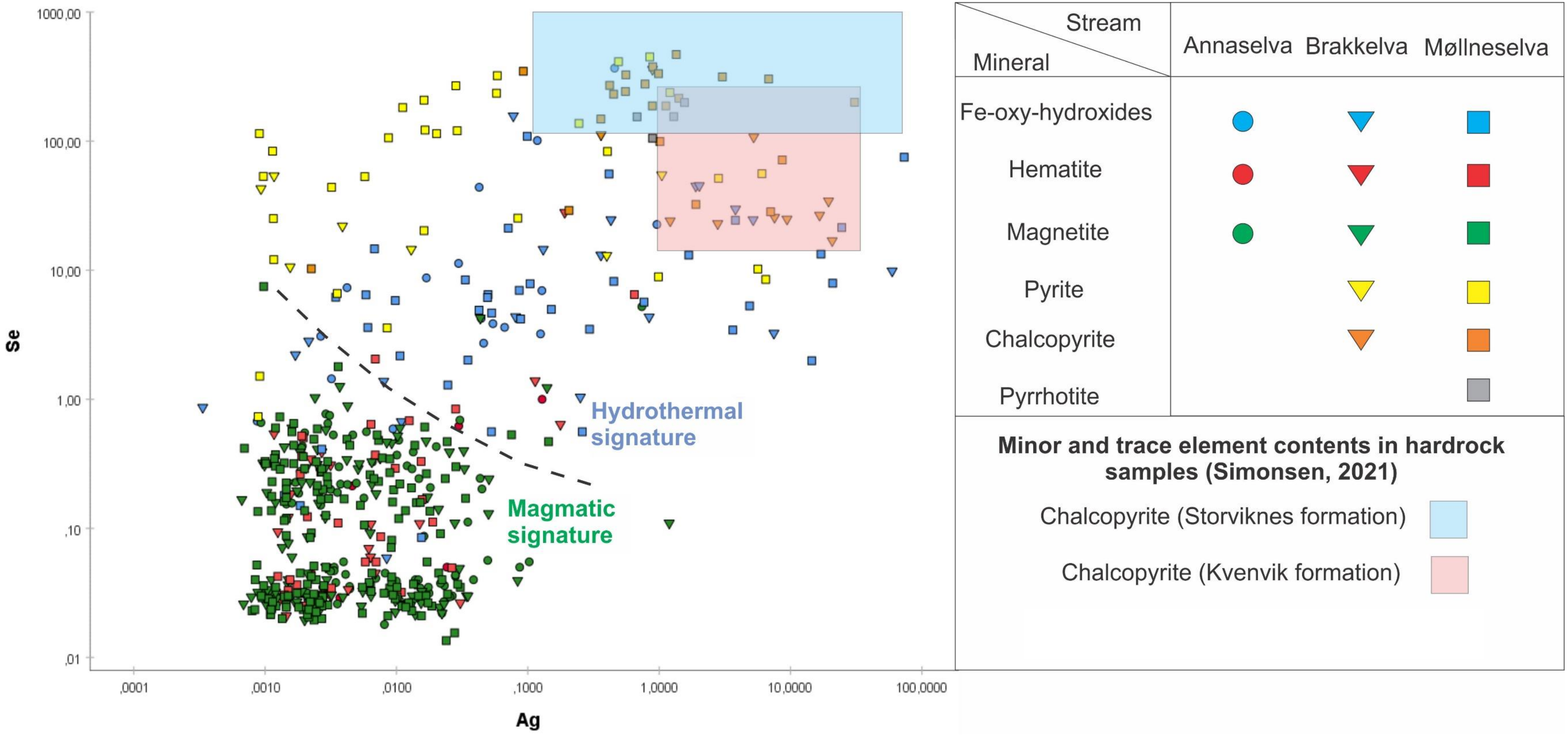
- Composition of minerals can differ with respect to the environment in which they are formed in.
  - Example: Magnetite of magmatic/hydrothermal origin.
- Magnetite does not seem to be a reliable indicator mineral in AKTW.

Møllneselva stream



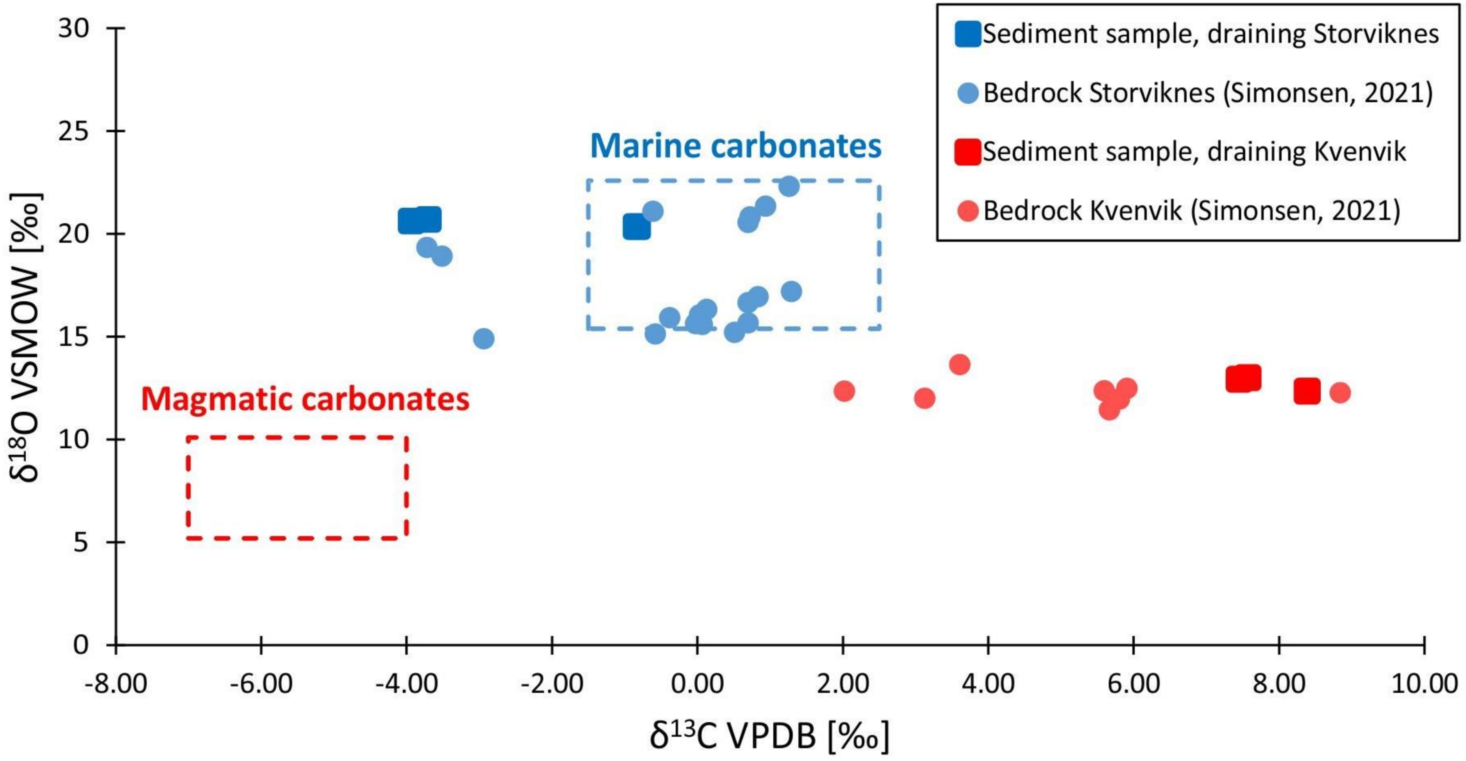
Ni/Cr in magnetite

Indicator minerals, LA-ICP-MS of heavy minerals



Carbonate stable isotopes

- Two groupings:
  - Storviknes: high positive δ18O, δ13C ~ 0 ‰.
  - Kvenvik: Lower, but positive δ18O and δ13C typically +3 to +10 ‰.



Reference isotopic compositions of magmatic carbonates: Stakes & O'Neil (1982) and marine carbonates: Veizer & Hoefs (1976).

Conclusions

- The <63 µm fraction is enriched in most of analysed elements.
- A different bulk chemical signature is displayed in sediments from each of the streams.
  - Chalcophile elements (hydrothermal signature).
  - Divalent cations (carbonate-rich lithologies).
  - Siderophile elements (mafic rocks hosting the Cu mineralization).
- Magnetic separation + hand picking of heavy minerals is efficient.
- Hydrothermal Cu mineralisation: high Ag and Se.
  - Signature of Fe-oxy-hydroxides resembles the hydrothermal signature of sulphides. Indicator mineral?
- Isotopic signature of carbonates is preserved in stream sediments.

Thank you!