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Catchment-scale metal retention revealed from natural bacterial sulfate reduction (BSR)

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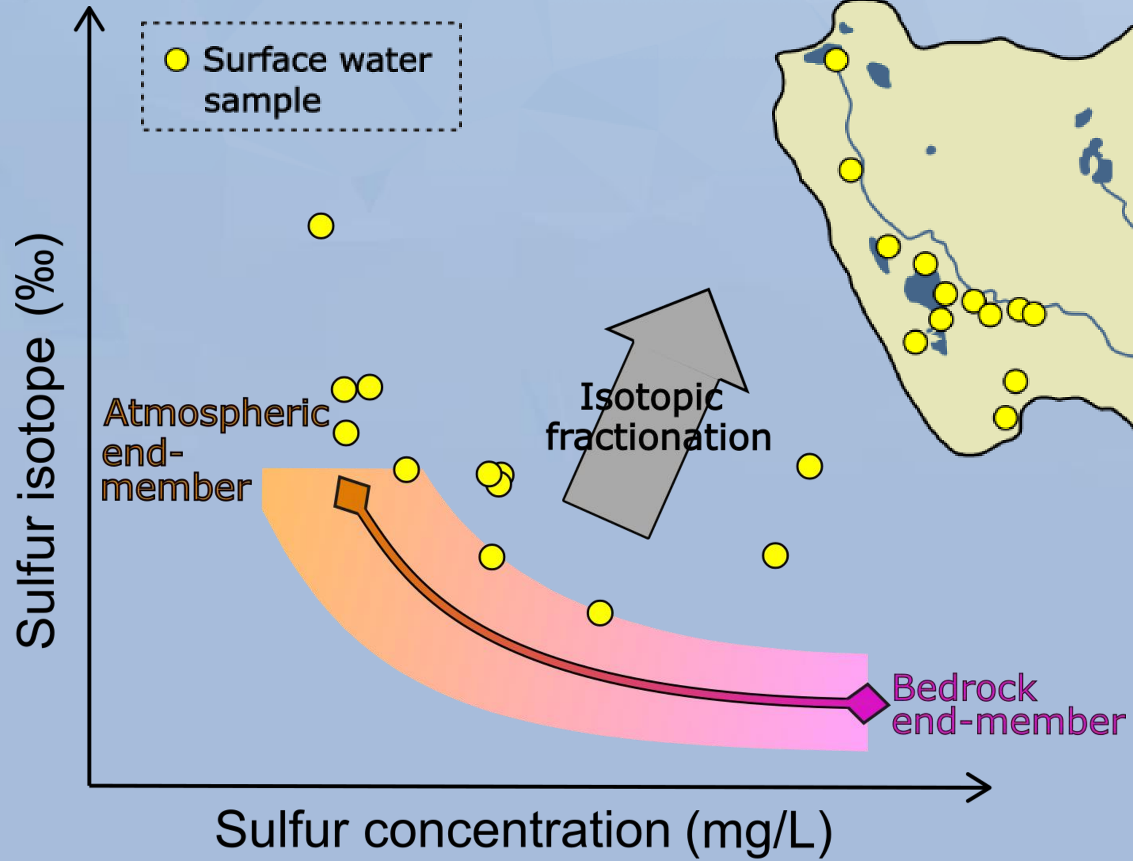

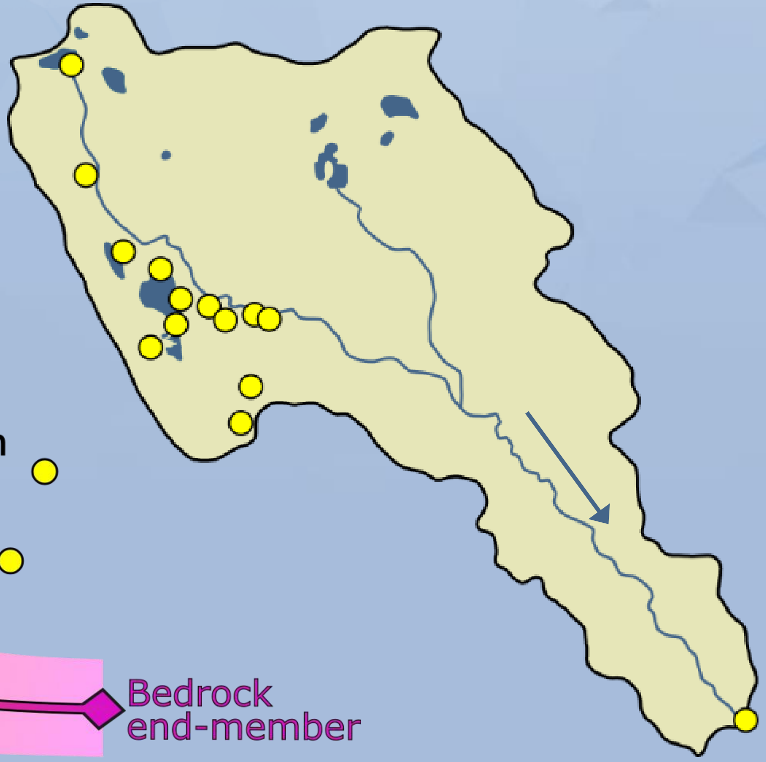

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Bacterial sulfate reduction (BSR):

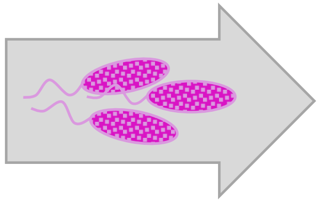
A process that can counteract spreading of acid mine drainage is *bacterial sulfate reduction*:

AQUEOUS PHASE

Sulfate

SO_4^{2-}

Sulfur-reducing bacteria



SOLID PHASE

Hydrogen sulfide

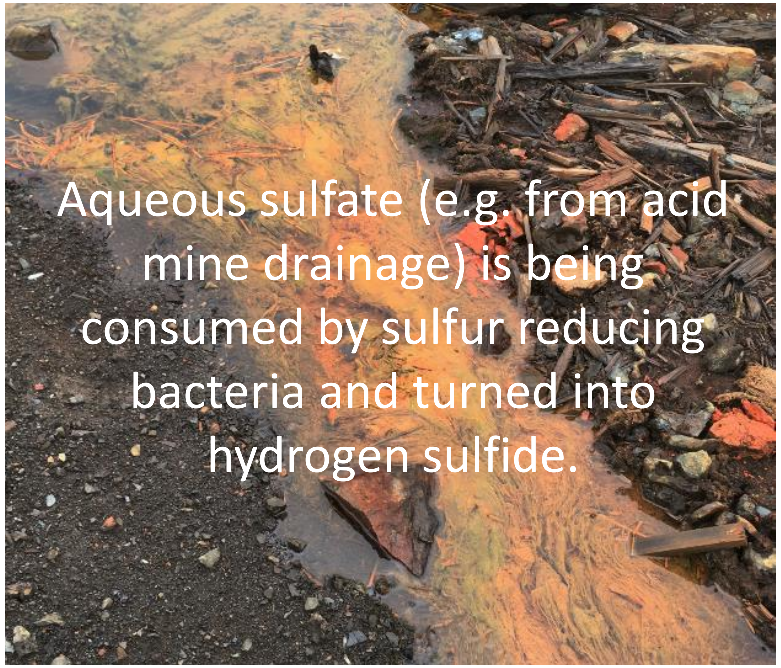
H_2S

↓

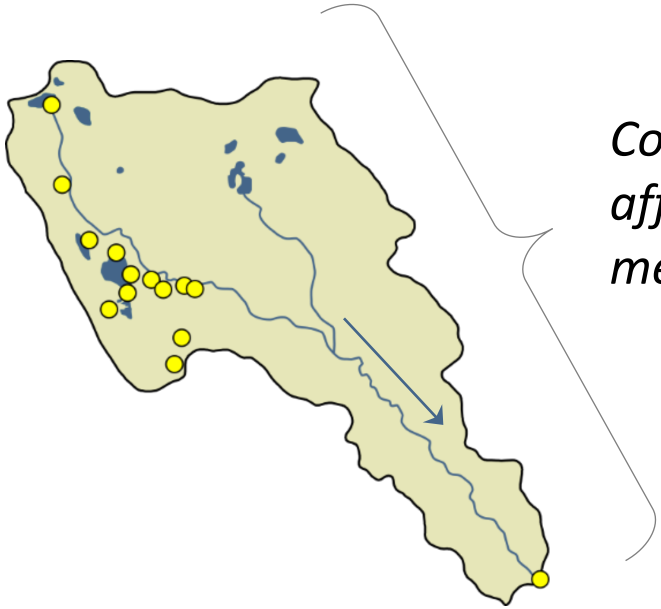
Bind to metal ions

↓

Metal sulfide immobilized in bed sediments



This process has previously only been investigated at smaller scale, but can natural bacterial sulfate reduction occur at multiple locations within a drainage basin?

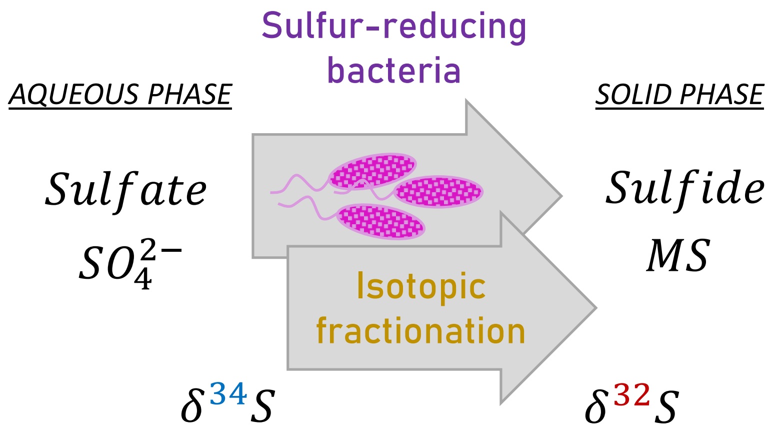


Could natural BSR affect basin-scale metal retention?

AIMS:

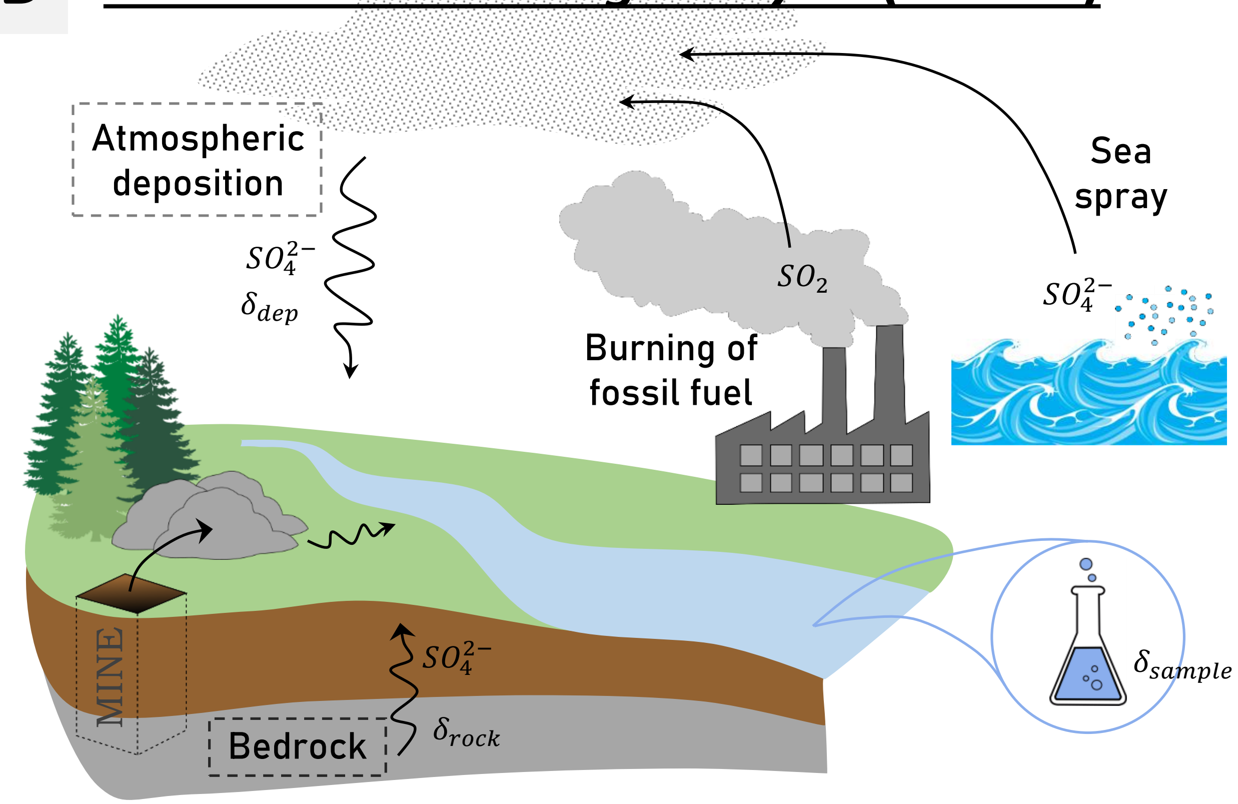
i. Develop a method where basin-scale BSR can be estimated
ii. Investigate the magnitude and spatial variability of BSR across a drainage basin

A Sulfur isotopes: fractionation



Sulfur-reducing bacteria preferentially consume the $\delta^{32}S$, which over time leads to isotopic fractionation.

B *End-member mixing analysis* (EMMA)



C EMMA + Rayleigh equation

Isotopic value from theoretical mixing (δ_{calc}) of end-members can be compared to the measured isotopic value (δ_{sample}), where the difference could indicate bacterial sulfate reduction (BSR).

EMMA: Theoretical mixing:

$$\delta_{calc} = \delta_{dep} f_{dep} + \delta_{rock} f_{rock}$$

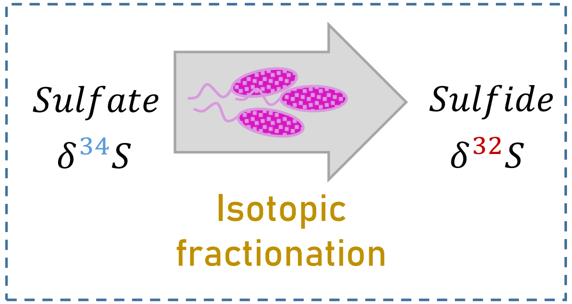
$$1 = f_{dep} + f_{rock}$$

Rayleigh equation:

$$\underbrace{\delta_{sample}}_{\text{Measured sample}} - \underbrace{\delta_{calc}}_{\text{Theoretical mixing}} = \underbrace{\varepsilon \ln(f_{reduced})}_{\text{Bacterial sulfate reduction}}$$

ε = Enrichment factor

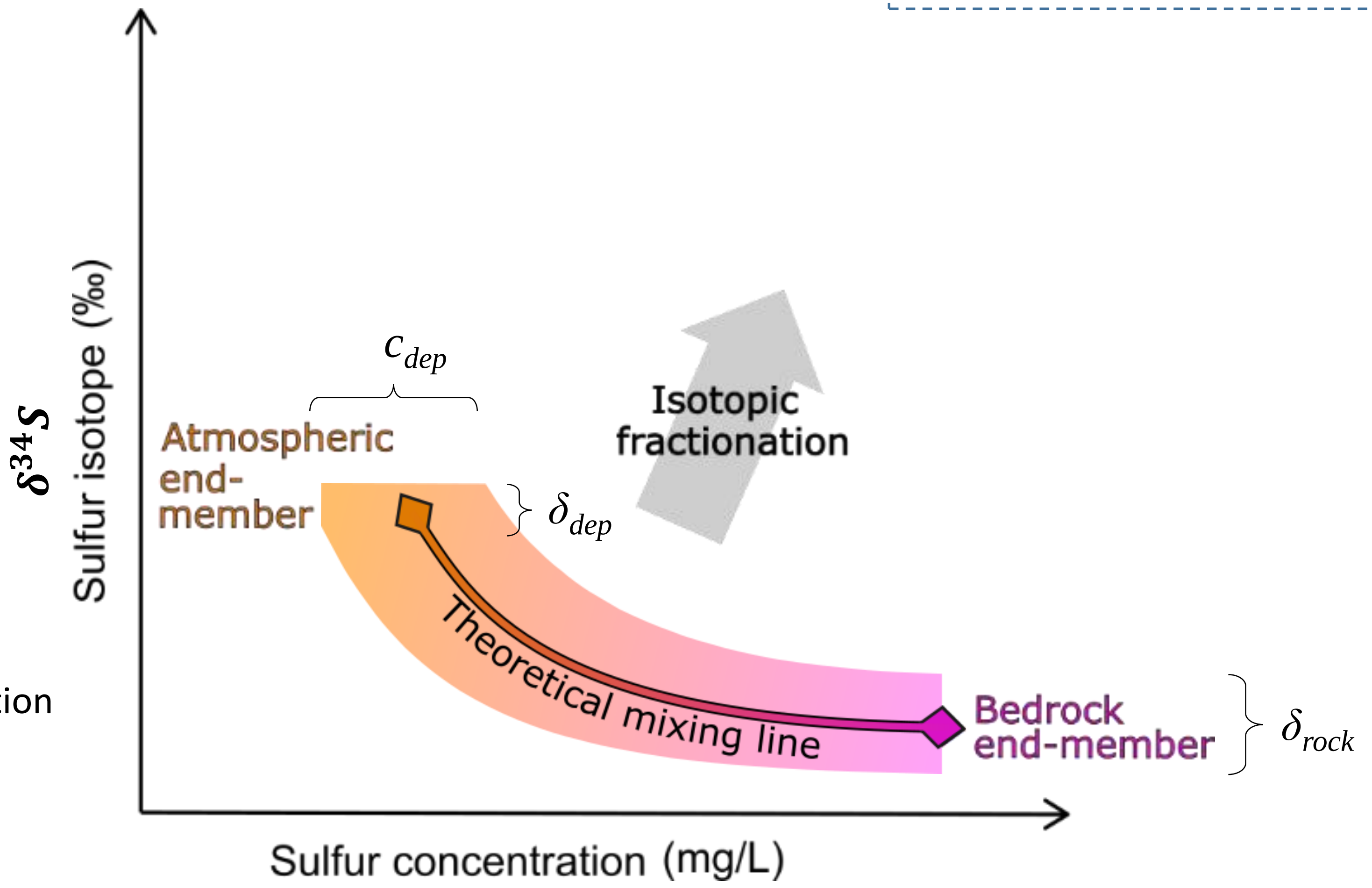
f_{red} = Fraction of reduced concentration



Theoretical mixing:

Measured isotopic value in surface water samples should align to the theoretical mixing line. Deviation from the line could indicate isotopic fractionation and bacterial sulfate reduction (BSR).

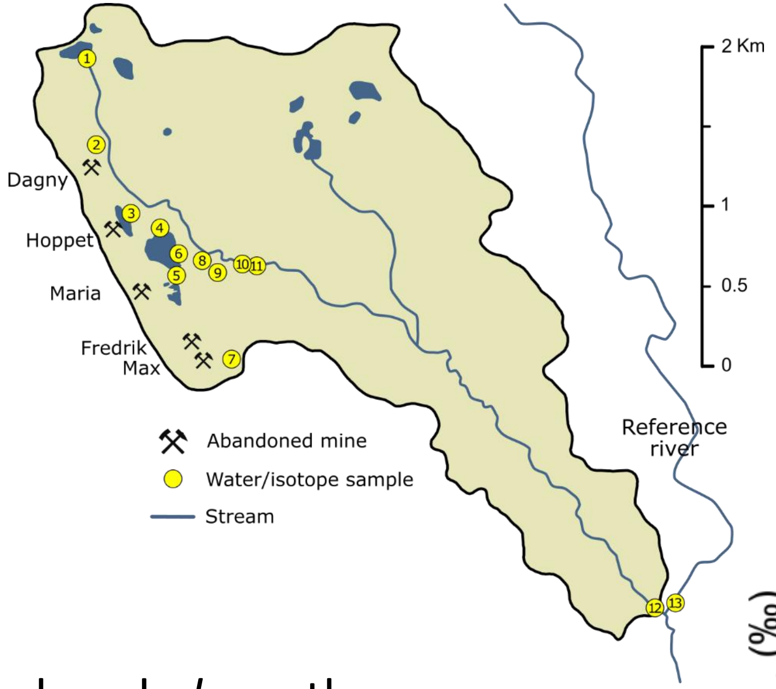
Uncertainty in end-member parameterization was evaluated through a scenario analysis.



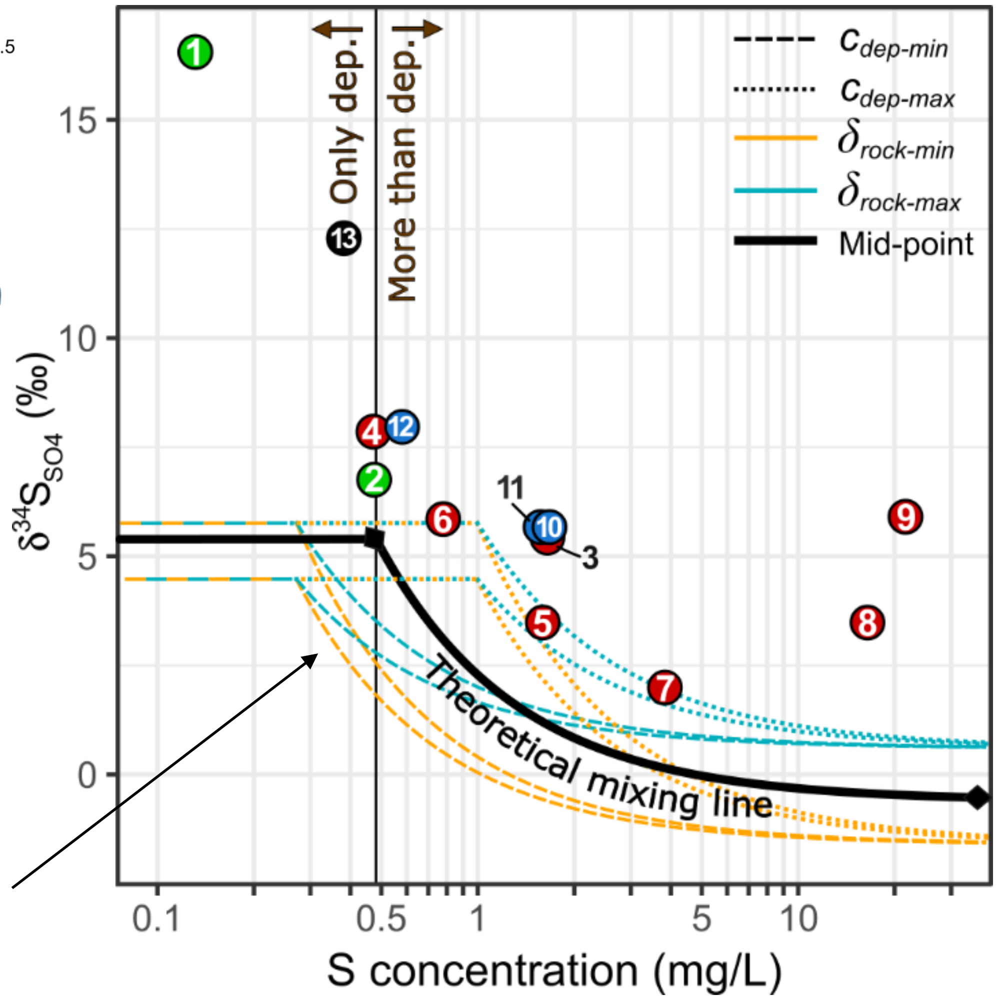
Uncertainty ranges:

- c_{dep} = S concentration from atmospheric deposition
- δ_{dep} = Isotopic value of atmospheric deposition
- δ_{rock} = Isotopic value of bedrock

Results:



← Test case in the Imetjoki catchment ($6.6\ km^2$) in northern Sweden.

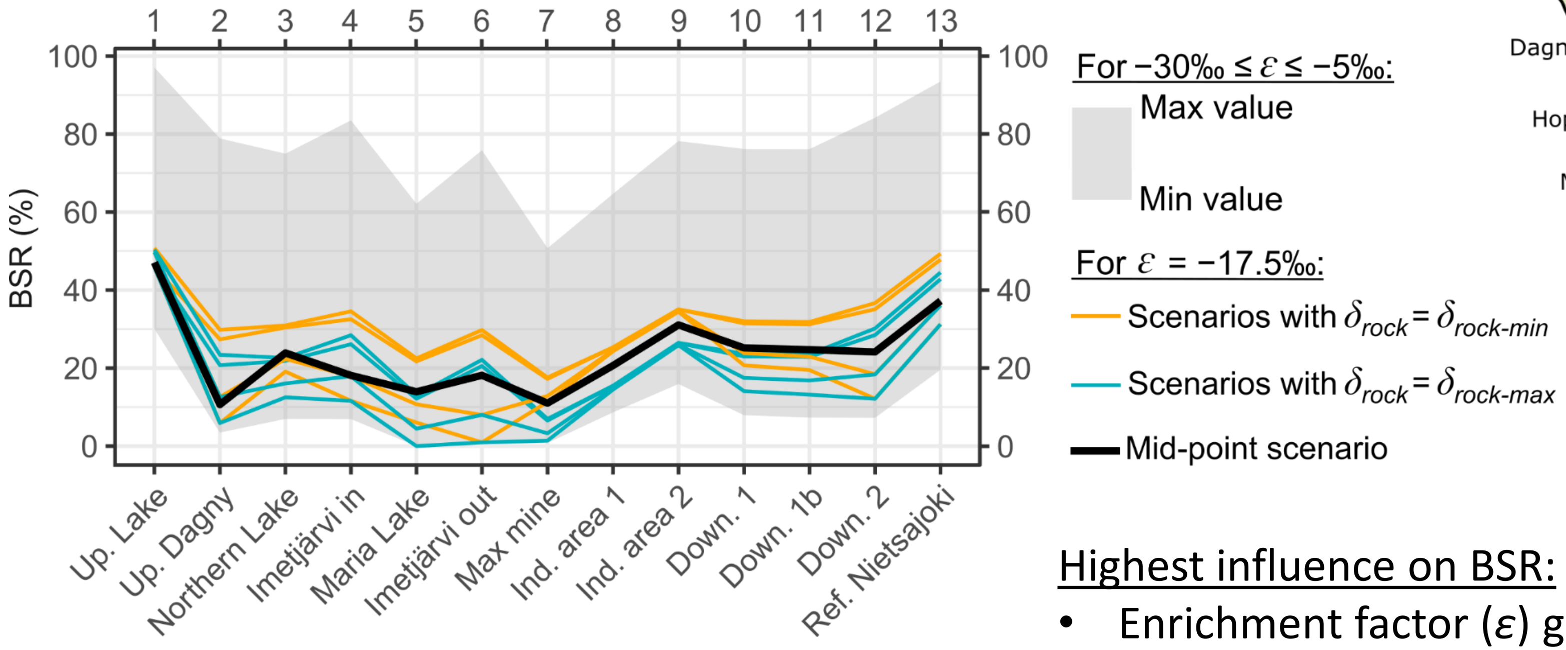


Most measured samples placed *above* the theoretical mixing line

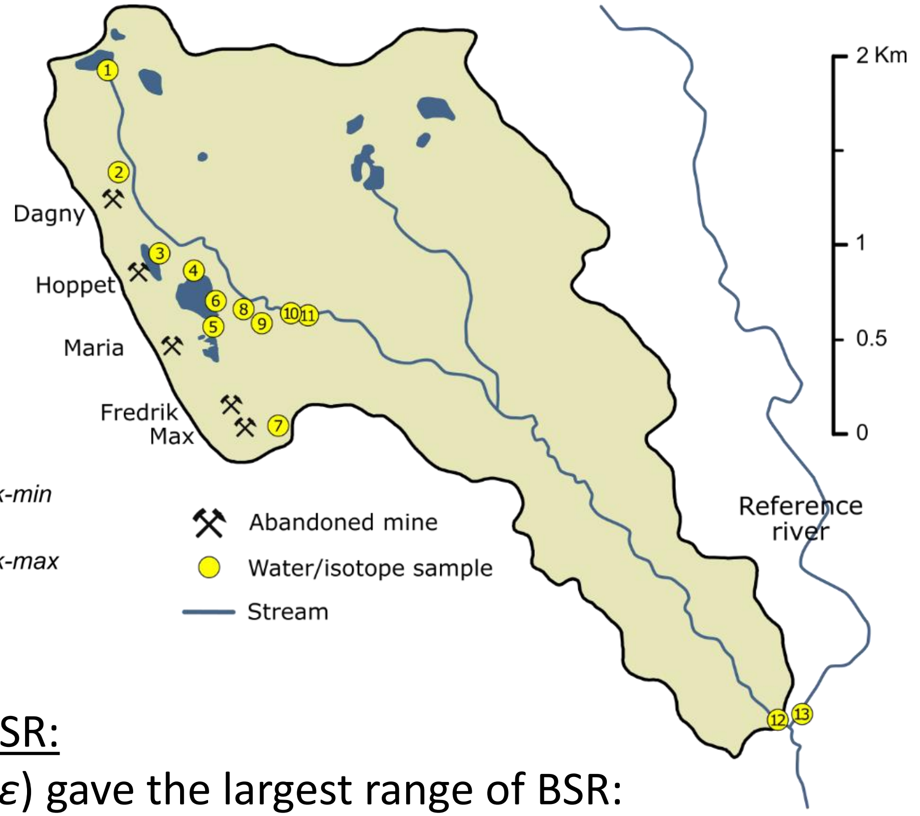
= their isotopic value cannot be explained only by mixing

Scenario analysis of end-member parameterization: maximum and minimum bounds shown here

Results: scenario analysis



ε	Enrichment factor (‰)
δ_{rock}	Isotopic value of bedrock (‰)
BSR	Bacterial sulfate reduction (%)



Highest influence on BSR:

- Enrichment factor (ε) gave the largest range of BSR: 50-75 units
- Isotopic value of bedrock (δ_{rock}) gave BSR-range of 30 units

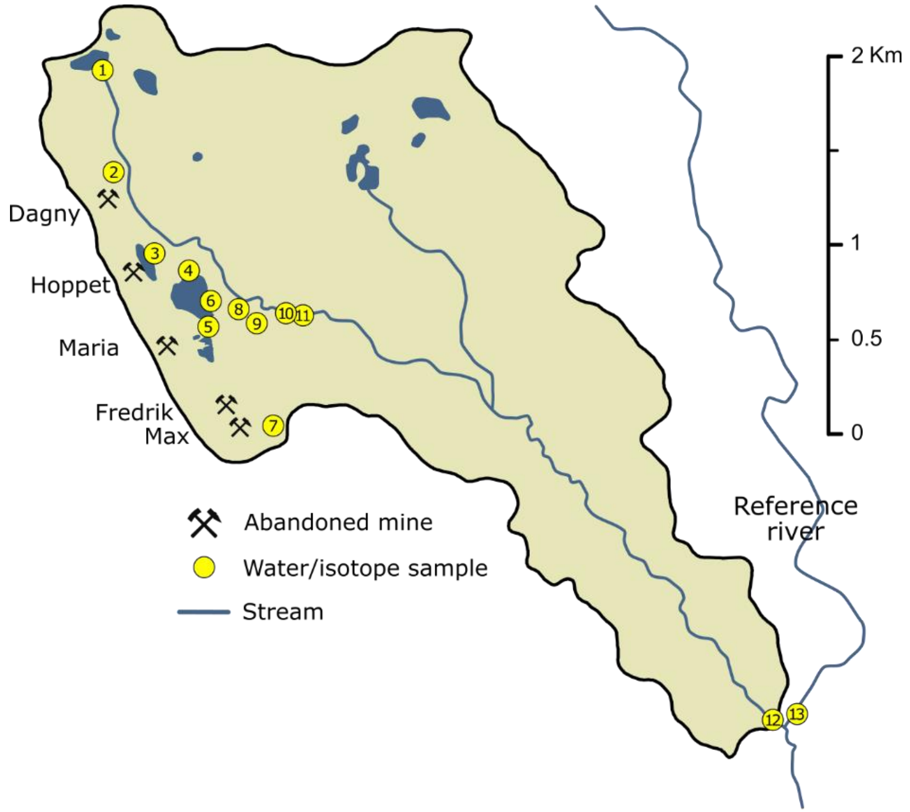
Basin-wide BSR:

- Mid-point scenario gave (for all sampling points) 24% BSR
- Ensemble mean (all scenarios and sampling points) gave 33% BSR

BSR = reduction in SO_4 concentration
Ex. 50% reduction: from 1 mg SO_4/L to 0.5 mg SO_4/L

Conclusions:

- This method is a simple tool to detect and map bacterial sulfate reduction (BSR) in the landscape
- There is a 30% basin-wide BSR present in the test basin
- There are probably multiple locations for BSR within the catchment (i.e. “hot spots”)
- Strategies for remediating acid mine drainage can take advantage of natural BSR → *nature based solution* for acid mine drainage (e.g. re-routing of flow to areas of higher natural BSR)
- BSR as a basin-scale retention process needs to be considered in landscape element cycling analyses



THANK YOU!
If any questions, please contact me at:
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