Sulphur and carbon signatures of metamorphic processes in the Nepal Himalayas

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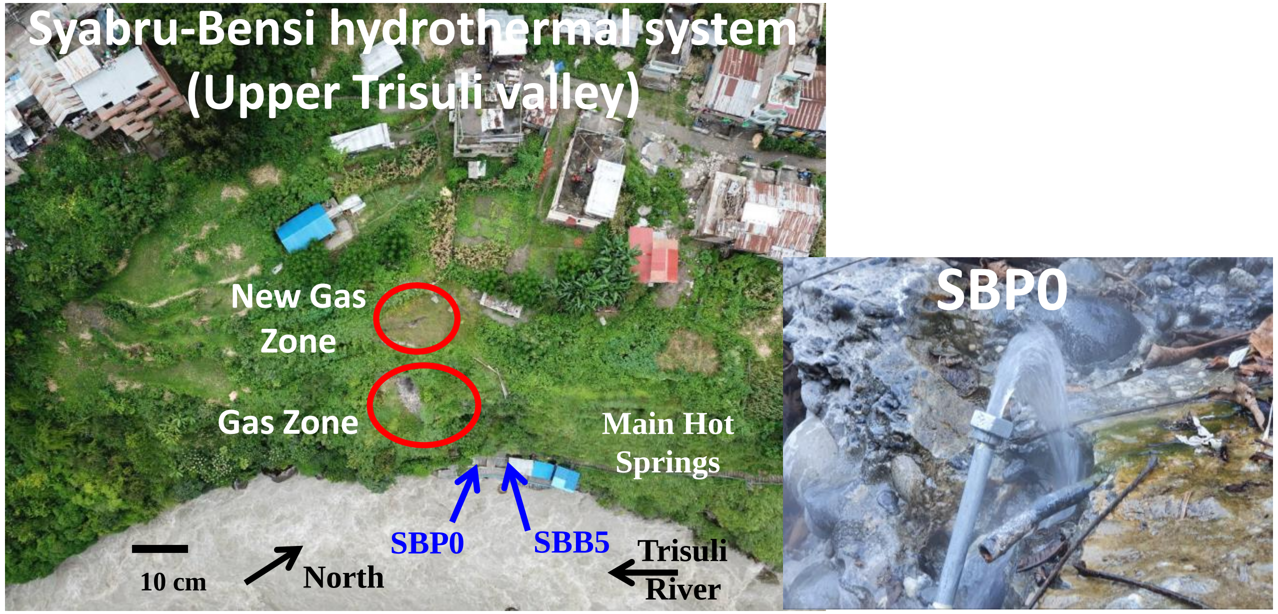
The highly conductive zones in the Nepal Himalaya: occurrences of graphite and/or fluids?

Mid-crustal conductive zones imaged by MT survey in the vicinity of the Main Central Thrust zone (Unsworth et. al., 2005).

Graphite-bearing metamorphic rocks

High electrical conductivity and polarizability of black schists (Börner et al., 2018).

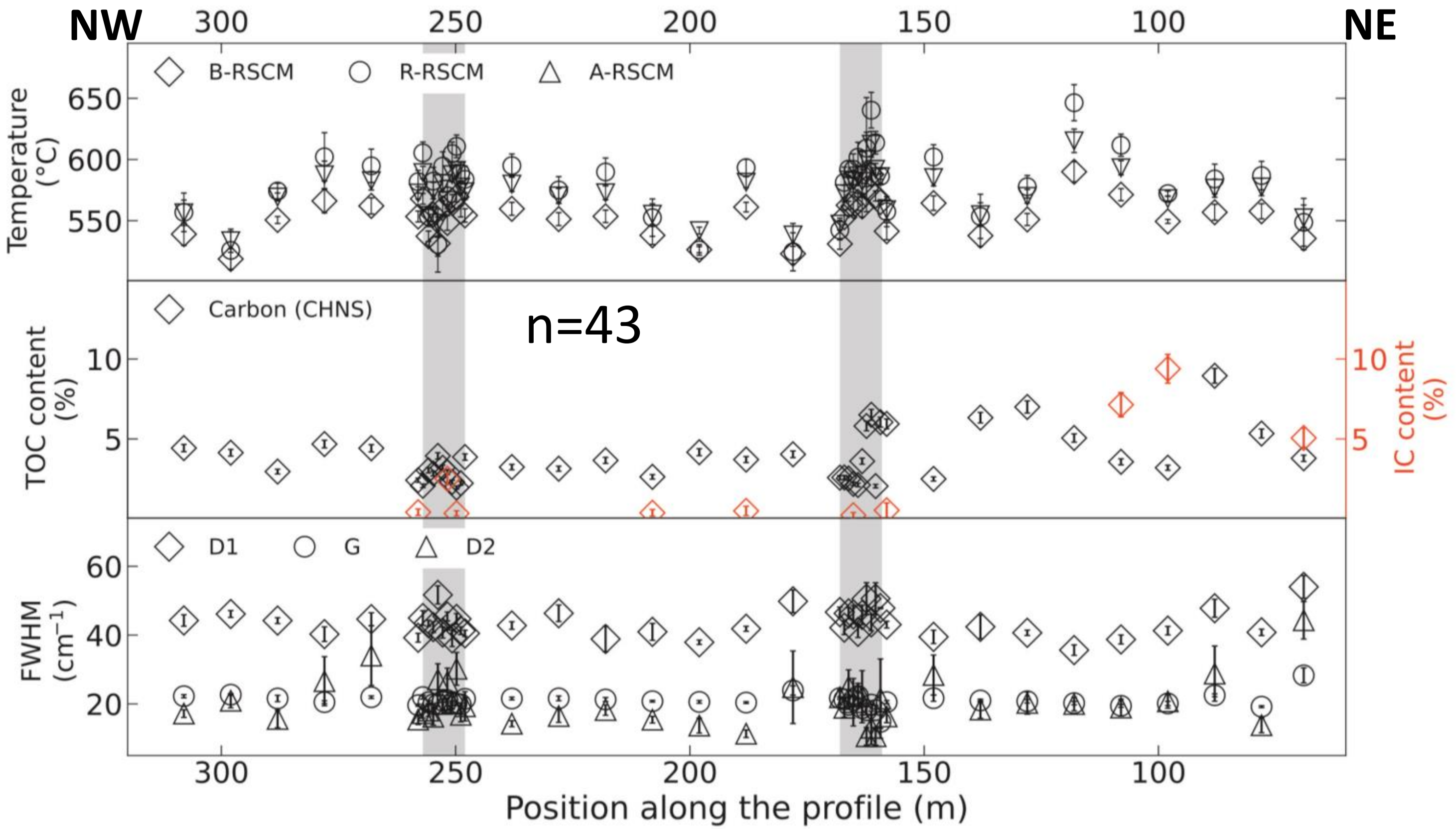
CO_2-rich metamorphic fluids



Hydrothermal systems releasing CO_2 marked with H_2S sensitive to large earthquakes (Girault et al., 2018).

What are the sulphur and carbon signatures in the MCT zone in the Nepal Himalayas?

Results: Characterization of Black Schist in the Upper Trisuli Valley



Total samples analyzed: 137

Mean TOC content: **3.8±0.2** % Mean peak-T: **554.6±2.5** °C

- Thermal metamorphic evolution in the Upper LHS
- Distribution of graphite along the Himalayan range

Black Schist

Temperature: Raman Spectroscopy

Beyssac et al 2002 [T(°C)=−445 R2+641]

$$R2 = \left(\frac{D1}{G + D1 + D2}\right)_A$$

Carbon%: CHNS Analyzer

TOC: Decarbonation- Rinsing method

Carbon Isotope

Pyrolysis (≈1400°C)

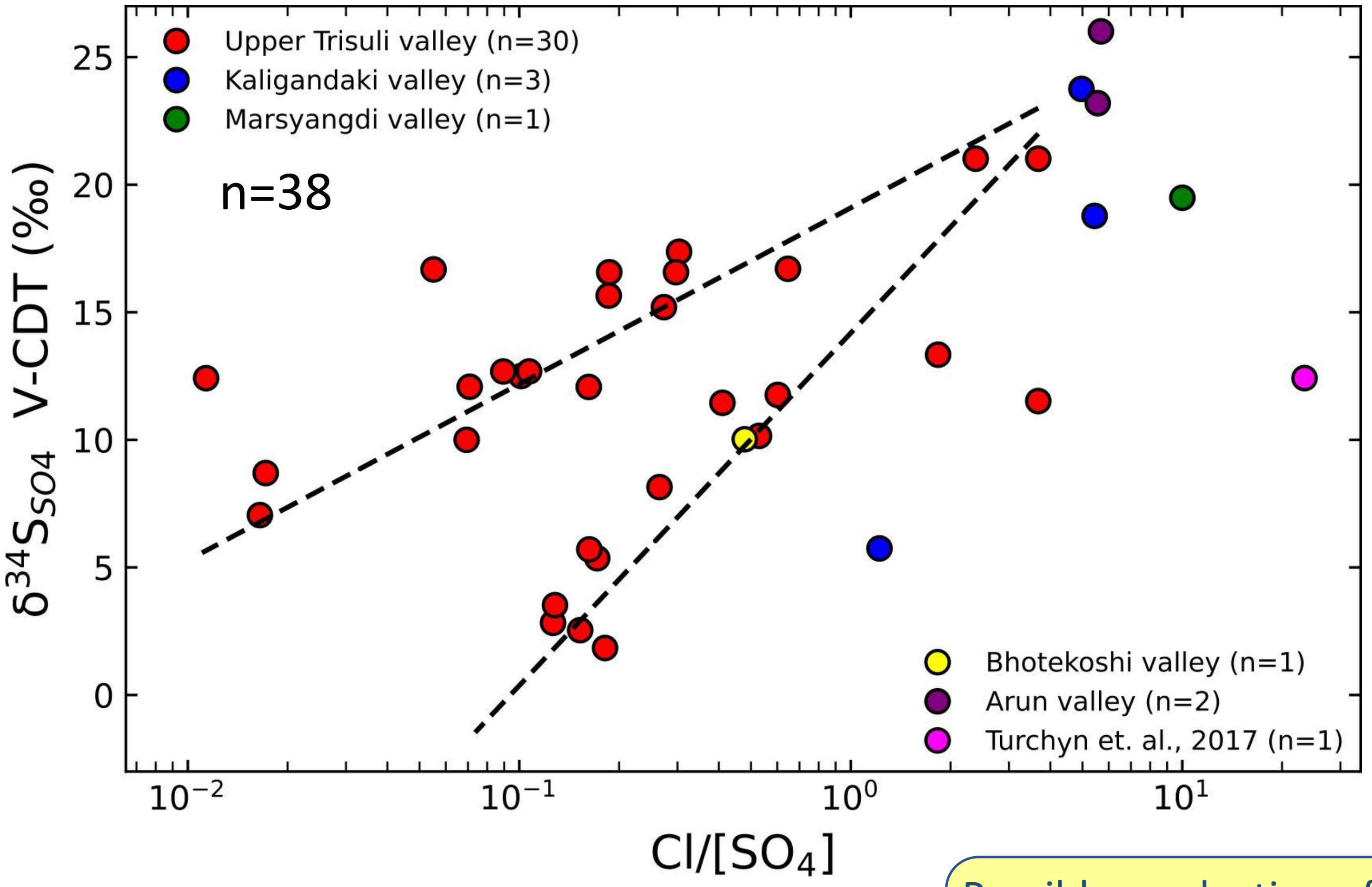
⇩

Delta V™ Isotope Ratio Mass Spectrometer

Organic content represented by mean δ^{13}C: **−21.6±0.5 ‰** (n=20)

2)

Results: Sulphate signature in hot springs at hydrothermal systems



Sulfur Isotope

CHEMISTRY

- 3 ml $AgNO_3$ + 7 ml distilled water
- 20 ml $CrCl_2$ and 5 ml HCl

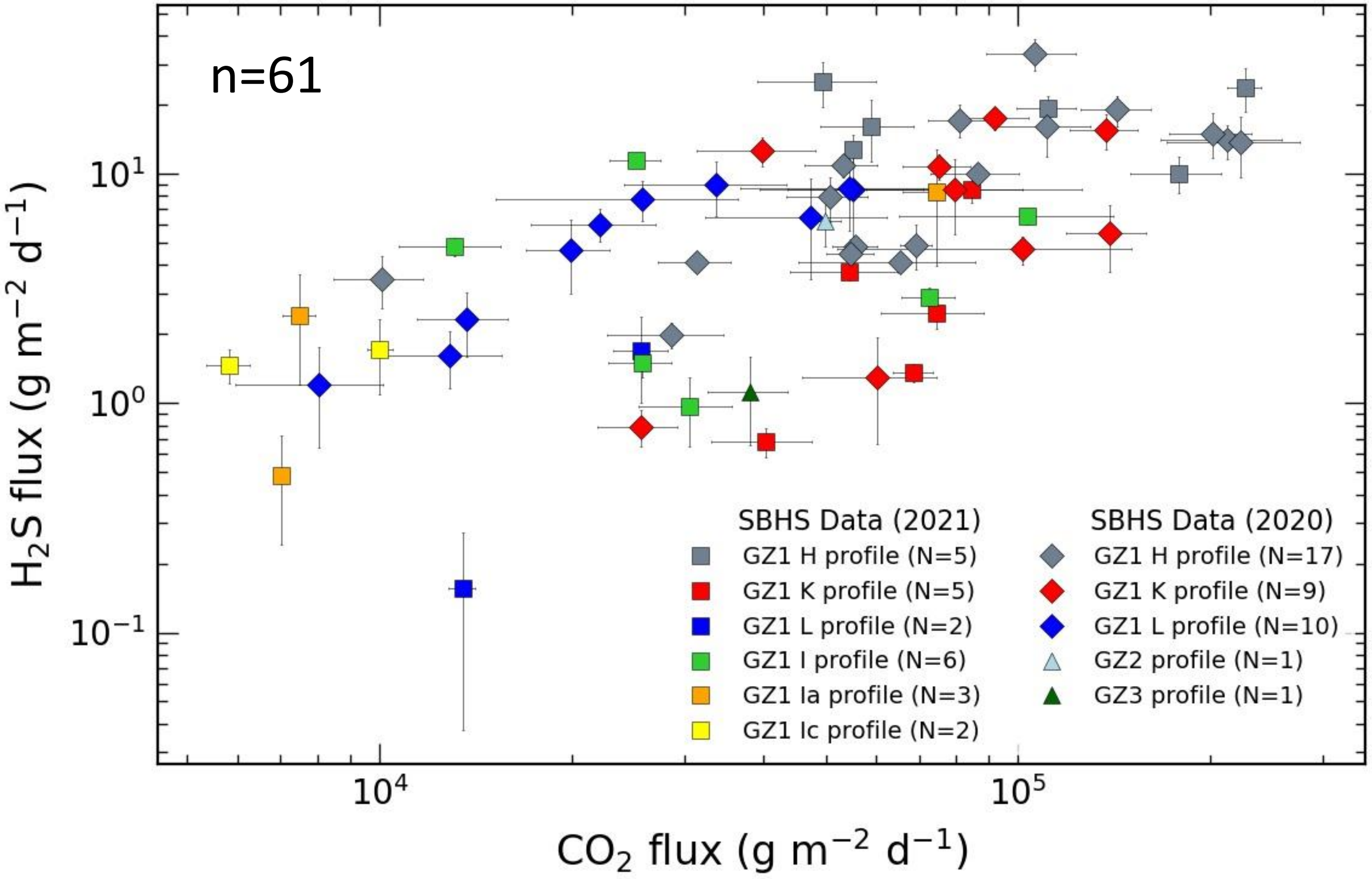
Mass Spectrometer

Considerable S isotope variation across Himalayan springs

Two different fractionation mechanisms ?

Possible production of sulphur by:
- low-T bacterial sulphate reduction ?
- high-T abiotic sulphate reduction ?

Results: CO_2- and H_2S-rich diffuse degassing structures at hydrothermal systems



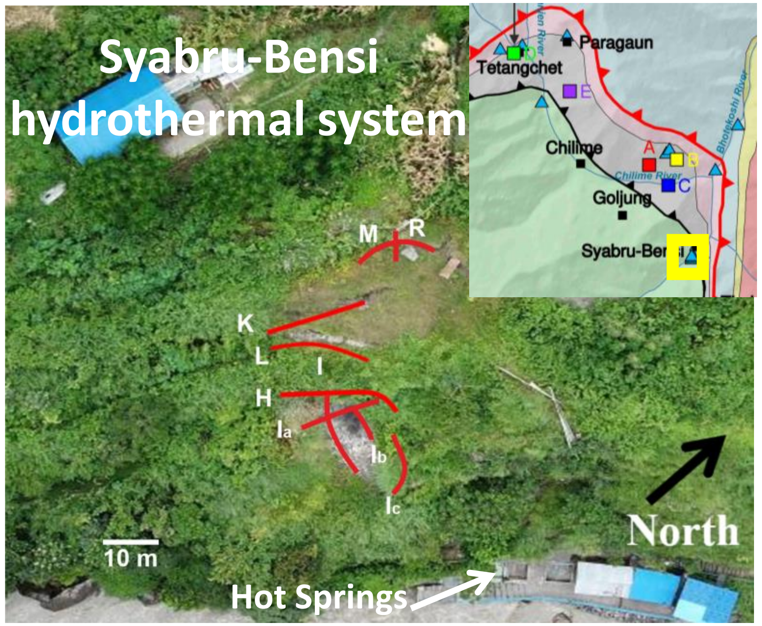
CO_2 and H_2S fluxes are correlated

CO_2 likely is the carrier gas of H_2S

Accumulation Chamber method

$$\Phi_a = \frac{P_{atm} M_a}{RT} \frac{V}{S} \frac{dC}{dt}\bigg|_{t=0}$$

where a is the H_2S/CO_2 concentration, P_{atm} mean atmospheric pressure, M is the molar mass , R is the ideal gas constant, T is the ambient temperature, and V and S are chamber volume and footprint area, respectively.



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Conclusions

1. Black schists with high carbon content all along the MCT, constraining thermal metamorphic evolution of upper LHS.

2. Possible source(s) of sulphur: pyrite oxidation and Bacterial Sulphate Reduction mechanism.

3. Gaseous CO_2 carrier of H_2S towards the surface, suggesting advection mechanism and deep H_2S source.

Carbon and sulphur sequestration versus release helps to characterize the carbon source-to-sink duality of large orogens and the carbon and sulphur geochemical cycles.