Past and present acid production in high-alpine catchments

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Introduction

In recent years, the production of acid has been observed in the Eastern Alps [1) 2) 3)]. The acid production is manifested by Al-precipitates visible in the streambeds and in high alpine lake sediments. The acid originates from microcrystalline pyrite embedded in the gneisses and micashists (Fig. 1). Elements are being leached out of the host rock during the acidification in concentrations above drinking water limit. The occurrence always presents in combination with thawing permafrost bodies.

Since global warming will further speed up permafrost thawing, we aim to assess the future mobilization of toxic elements through (i) a sediment-based paleoapproach and (ii) by an experimental modern approach. For (i) we have collected Lago Vago sediment cores to obtain information about how often and how far back in the past acidifications have occurred. Regarding (ii), we have conducted column experiments to identify drivers of the current acidification.

$$4\,FeS_2 + 15\,O_2 + 14\,H_2O \rightarrow 4\,Fe(OH)_3 + 8\,H_2SO_4$$

Fig. 1: Pyrite weathering reaction

Study Site

Fig 2: Lago Vago with permafrost body and precipitates in lakebed and sediment core showing white precipitates

The rock samples used for the column experiments are from Lago Vago and Val Lavirun. For Val Lavirun, the Al-precipitates marking the acid production are observed in the stream percolating out of the permafrost body. At the Lago Vago site, the permafrost body sits right above a lake as shown in Fig. 2. The study sites both lie in the basement of the austroalpine nappes which consist of gneisses and micashists (Fig. 3). White streambeds are visible in Fig. 4.

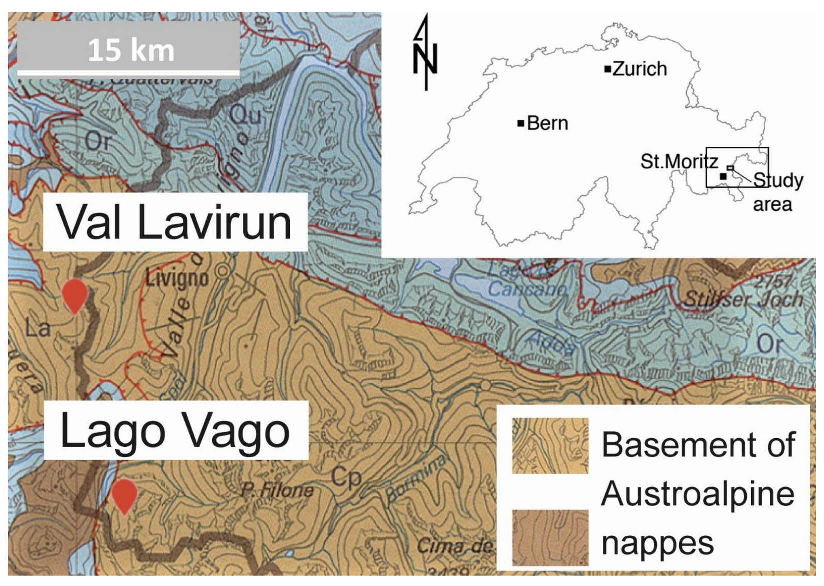

Fig. 3: Study sites in the Eastern Alps

Fig. 4: Lago Vago streambed

Methods

- Column experiment (Fig. 5)
- Element analyses with Inductively Coupled Plasma – Optical Emission Spectrum and Ion Chromatography of sampled column water
- Sediment cores measured with Computed Tomography and X-Ray-Fluorescence Spectroscopy

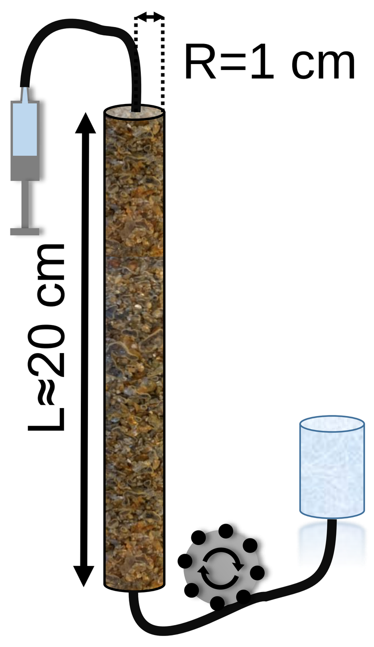

Fig. 5: Column experiment setup

Column-experiment samples from Val Lavirun and Lago Vago were crushed and milled receiving coarser grain-size fractions (0.25 - 2 mm) and coarse including finer grain-size fractions (0 – 2 mm). The Lago Vago (2680 m.a.s.l.) lakebed was mapped with a sonar and two sediment cores of around 12 cm each were obtained.

Results I and Discussion: CT & XRF measurements of sediment cores and Bathymetry of Lago Vago

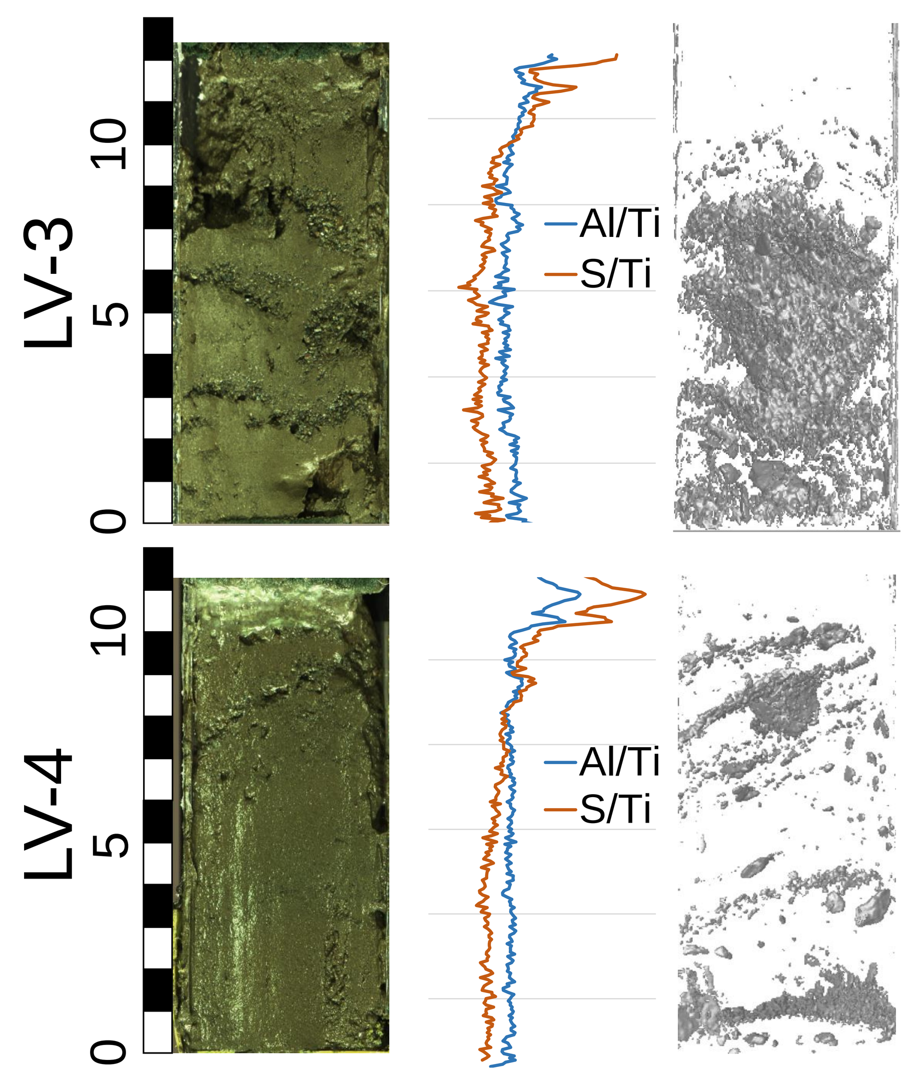

Fig. 6: Lago Vago sediment cores with normalised Al and S signals (in cps) and CT density model

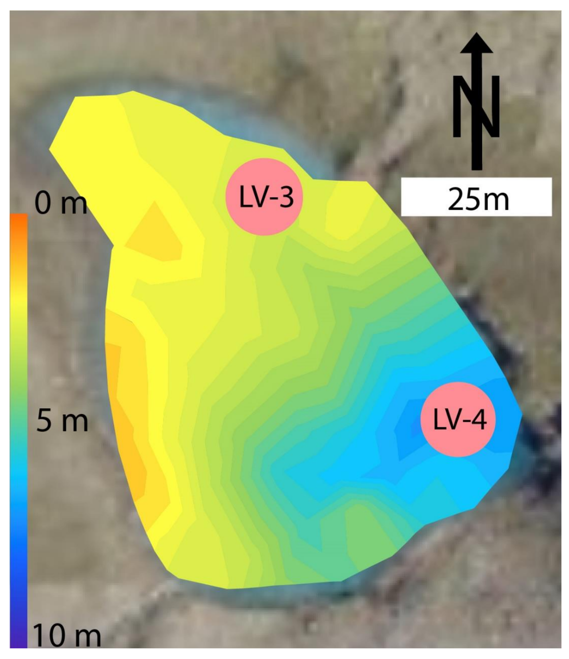

Fig. 7: Lago Vago bathymetry

- Al and S are elevated towards the top (Fig. 6)
- No peaks in older, lower parts
- More coarse sediments in LV-3
- Fine sediments with intermittent coarse layers in deeper LV-4 (Fig. 7)

Results II and Discussion: Column experiments

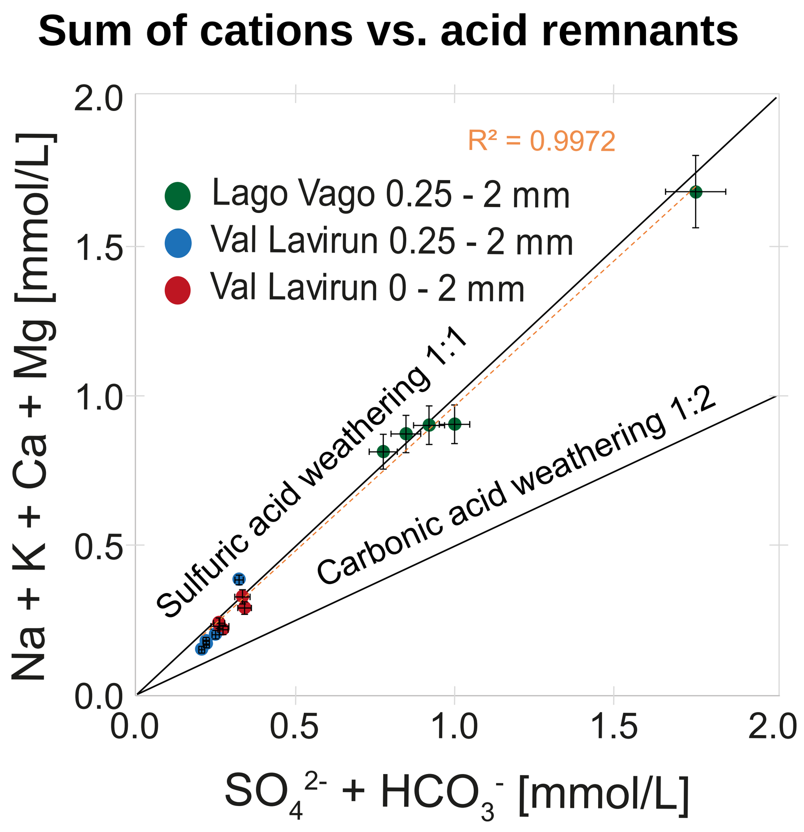

Fig. 8: Sum of cations vs. acid remnants

The plot in Fig. 8 shows the concentrations of the cations stemming from silicate weathering vs. the acid remnants, representing the acid having weathered the silicate minerals.

- Measured concentrations plot close to 1:1 → characteristic for sulfuric acid weathering → pyrite weathering

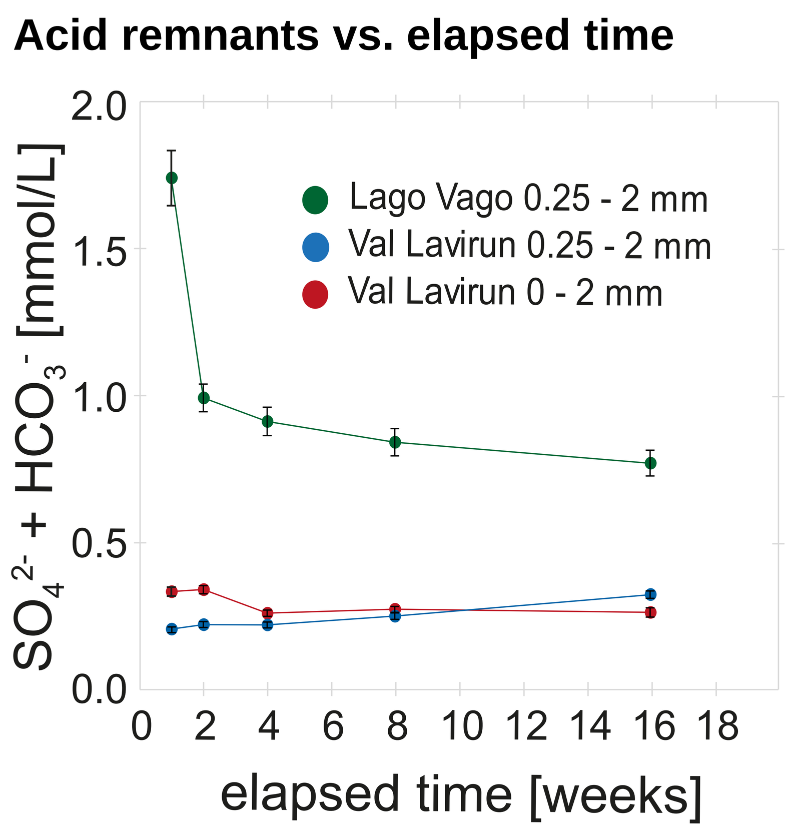

Fig. 9: Acid remnants vs. elapsed time

How the acid production evolves over time is shown in Fig. 9.

- Concentration increases over time for Val Lavirun 0.25 – 2 mm
- Concentration decreases over time for Val Lavirun 0 - 2 mm and Lago Vago 0.25 – 2 mm
- After sixteen weeks, the concentrations of the decreasing and increasing trends cross over.

Conclusion

- Pyrite is the driver of acid production and thus toxic element mobilisation
- The higher the pyrite content and the higher the water flux through permafrost systems, the higher the mobilized solute fluxes
- Process is a recent phenomenon, core shows no precedence
- More permafrost melting → higher water flux through system → more pyrite exposed → increased solute mobilisation
  - ➢ Process will intensify in the future

Outlook: ^{14}C-Dating of core to assess the onset of the Lago Vago acidification, geochemical modelling, smear slides diatoms mapping

References

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