Chemical Fingerprint of Quartz Crystals Sampled Across the Lepontine Zone in the Swiss Alps

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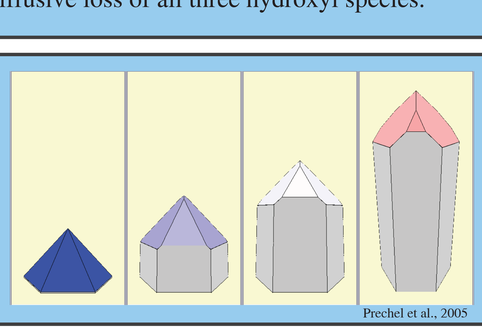
Abstract

Quartz crystals record the evolution of hydrothermal fluid systems that accompanied the uplift of the Swiss Alps. Crystals from twenty localities were collected along a geologic traverse across four distinct temperature regimes that define the Alpine Mountain Range. Spectroscopic measurements reveal the changing fluid compositions, crystal growth timescales, and post-crystallization thermal histories characteristic of each regime. We present results on crystals extracted from the high temperature hydrothermal veins of the Lepontine Zone, representing the southern portion of the Alpine traverse. Individual crystals were sectioned into 1 mm thick wafers cut perpendicular to the c-axis for micro-infrared spectroscopic study. Initial investigations demonstrate relatively high trace hydroxyl concentrations compared to hydrothermal quartz elsewhere in the Alpine traverse, with AlOH abundances generally twice as large as LiOH and molecular water. Concentration profiles are observed near the edges of crystals and show diffusive loss of all three hydroxyl species.

Why Study Hydrothermal Quartz Crystals?

- Characterizing the origin and evolution of hydrothermal fluids is critical for understanding the nature of continent-continent collisions and the processes involved in constructing large mountain belts such as the Alps and Himalayas. The large fluid systems accompanying metamorphic processes in these mountain building events represent the major means of chemical and thermal transport in the Earth's upper crust.
- Quartz crystals growing on the walls of fractures capture the thermal and chemical characteristics of their host hydrothermal fluids.

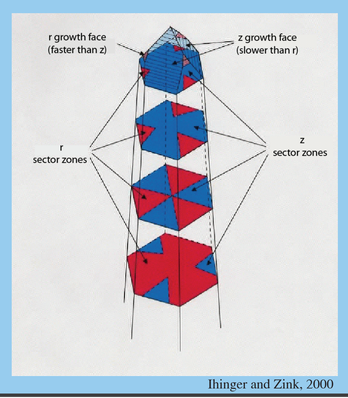
Impurity Absorbances Provide Clues to Crystal Evolution



Prechel et al., 2005

Rapid growth of r facies (forefront) compared to z facies leads to higher concentrations of trapped impurities.

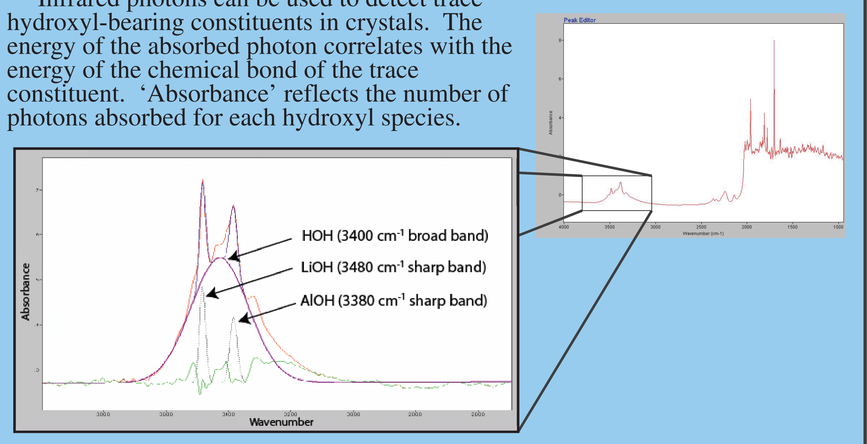
Crystals found in hydrothermal veins contain independent sector zones, wherein orders-of-magnitude variations in impurity concentrations are preserved.

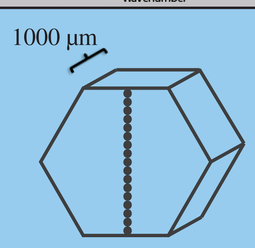


Ihinger and Zink, 2000

The Infrared Technique

Infrared photons can be used to detect trace hydroxyl-bearing constituents in crystals. The energy of the absorbed photon correlates with the energy of the chemical bond of the trace constituent. 'Absorbance' reflects the number of photons absorbed for each hydroxyl species.



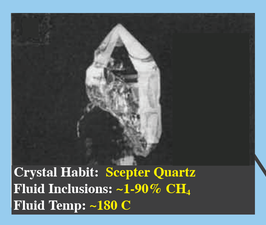


Crystal traverses across a sample show variations in impurity concentrations on length scales of ~100 microns.

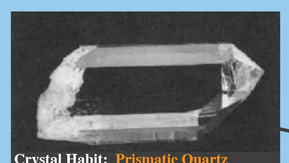
Variations Across Alpine Metamorphic Zones

Zone Characteristics
(from Mullis et al., 1994)

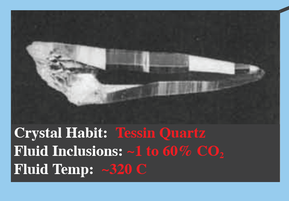
Crystal Habit: Steep Rhombohedral Quartz
Fluid Inclusions: ~1 to 80% Heavy Hydrocarbarbons
Fluid Temp: ~150 C



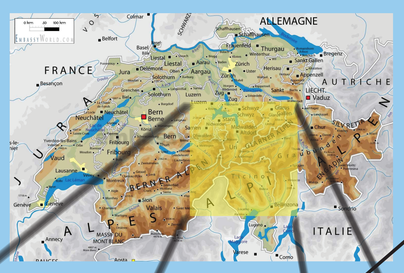
Crystal Habit: Scepter Quartz
Fluid Inclusions: ~1-90% CH_4
Fluid Temp: ~180 C

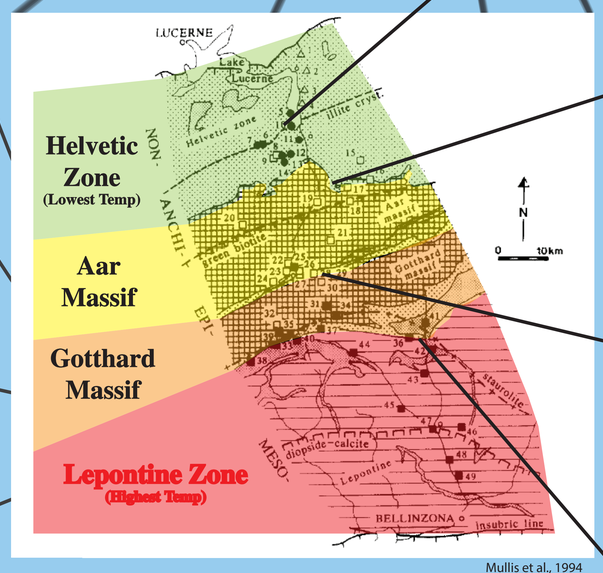


Crystal Habit: Prismatic Quartz
Fluid Inclusions: ~80 to 99 % CH_4
Fluid Temp: ~260 C



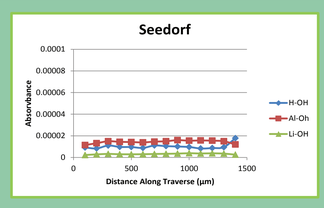
Crystal Habit: Tessin Quartz
Fluid Inclusions: ~1 to 60% CO_2
Fluid Temp: ~320 C

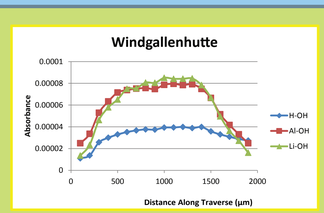


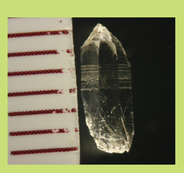


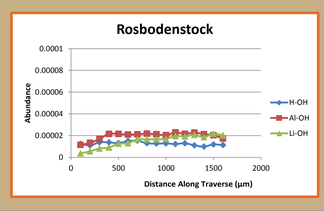
Mullis et al., 1994

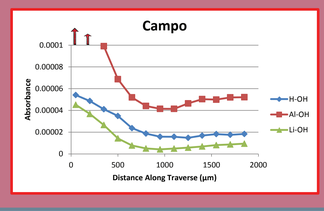
Zone Localities
(this work)

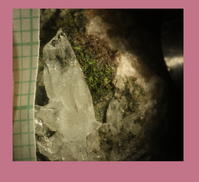






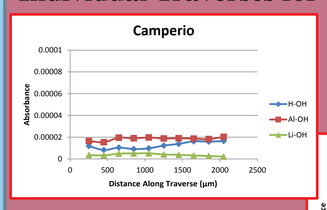


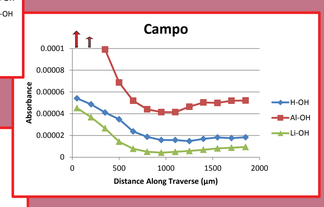


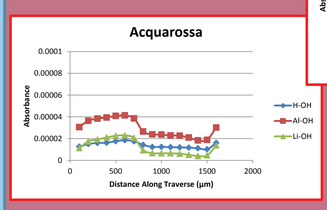


Variations Within Lepontine Zone

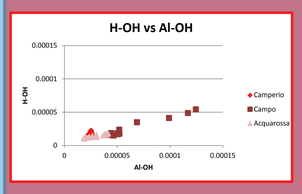
Individual Traverses for 3 Lepontine Localities

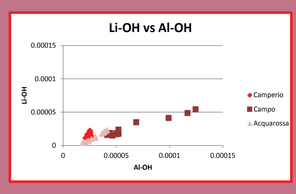




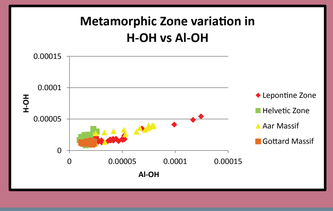


Species Variations: Results from 3 Lepontine Localities





Species Variations: Results from each Metamorphic Zone



Comparison of HOH vs AlOH across the different metamorphic zones. Ratio of HOH to AlOH (slope) is similar across zones.

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http://www.embassyworld.com/maps/Maps_Of_Switzerland/

What's Next?

We are going to study the spatial variation of other impurities, including hydrocarbon species, in relation to temperature and known Al-OH, HOH, and Li-OH concentrations. Emphasis will be placed on the Helvetic Zone, a known area of heavy hydrocarbon concentrations formed at low temperatures. We will also investigate the relationship between growth rate, the diffusion of impurities, and the temperature of formation across the four Alpine metamorphic zones.

Findings

- **Absolute concentrations of hydroxyl impurities vary by more than a factor of five in Lepontine quartz crystals.**
- **Al-OH, HOH, and Li-OH concentrations track one another in Lepontine quartz crystals.**
- **Al-OH concentrations are approximately double H-OH concentrations.**
- **Ratios of hydroxyl species (slope) are similar for different localities within the same Alpine metamorphic zone.**
- **Alpine Metamorphic zones generally show similar ratios of H-OH and Al-OH.**