Competing Diffusion Pathways in High-Temperature Metamorphic Quartz

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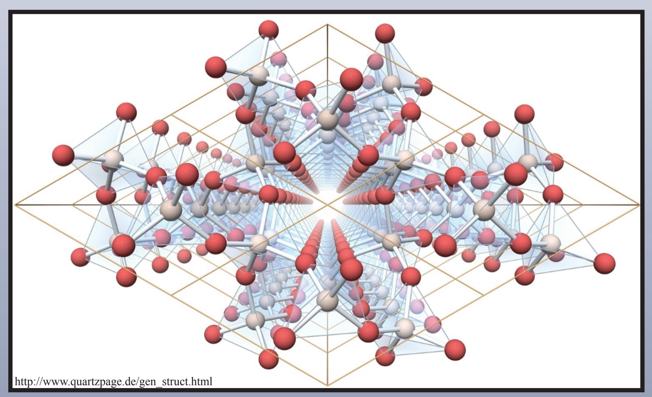
The Power of AND

Abstract

We present spectroscopic analyses that characterize the distribution and abundance of hydroxyl-bearing impurities within a single quartz crystal grown in hydrothermal fluid. We focus on a gemmy quartz crystal collected in a vein from the high-temperature Lepontine Zone of the Swiss Alps. We utilize high-resolution (200µm spot size) infrared spectroscopic analyses conducted on traverses across thin (~750µm) wafers cut perpendicular to the c-axis of the crystal. IR-spectra record characteristic peaks associated with HOH, LiOH and AlOH contaminant species. Species concentrations vary vertically and horizontally through the crystal both as a function of uptake during growth and diffusion following growth. We show that all concentration profiles reveal relative diffusion competing migratory pathways exist within hydrothermal quartz crystals, and that each pathway, as well as their aggregate, can provide valuable information for discerning the post-crystallization thermal histories of their host crystal. Our goal interact to produce the observed impurity gradients within the crystal.

Motivation for Study

- Hydrothermal fluids released during metamorphism contain large amounts of dissolved chemicals that precipitate quartz crystals under favorable conditions
- The crystal structure of quartz can accommodate hydrous impurities during growth
- Thus, quartz crystals can serve as a recorder of their host transient fluids
- A number of potential factors govern the abundance and distribution of hydrous impurities in quartz:

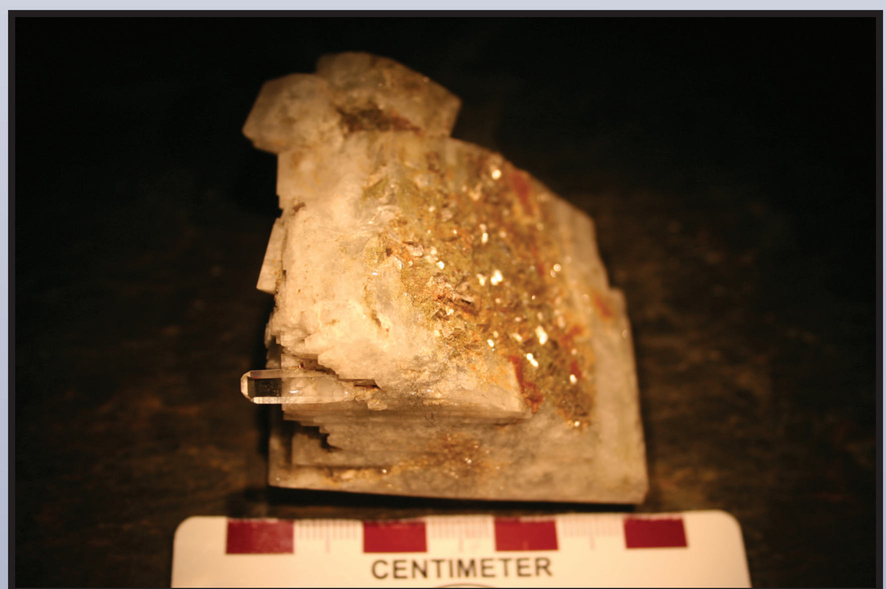


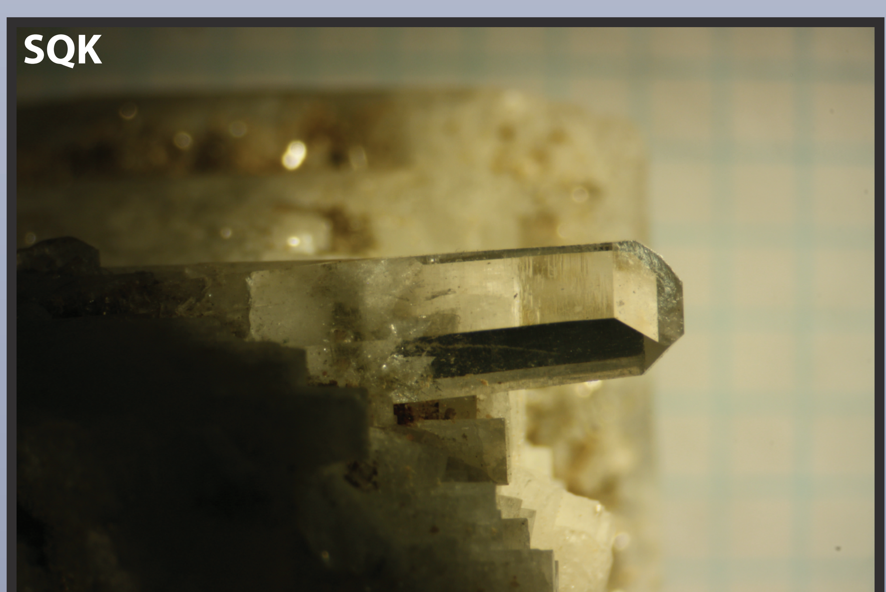
1. Original fluid composition: Fluctuating levels of trace constituents in hydrothermal fluids can lead to corresponding variations in precipitated quartz
2. Growth rate: Faster growth rates trap contaminant species on active growth faces
3. **Post-Growth Diffusion: Multiple pathways including the terminus, base and sides of quartz crystals allow for impurity migration during thermal soaking after growth.**

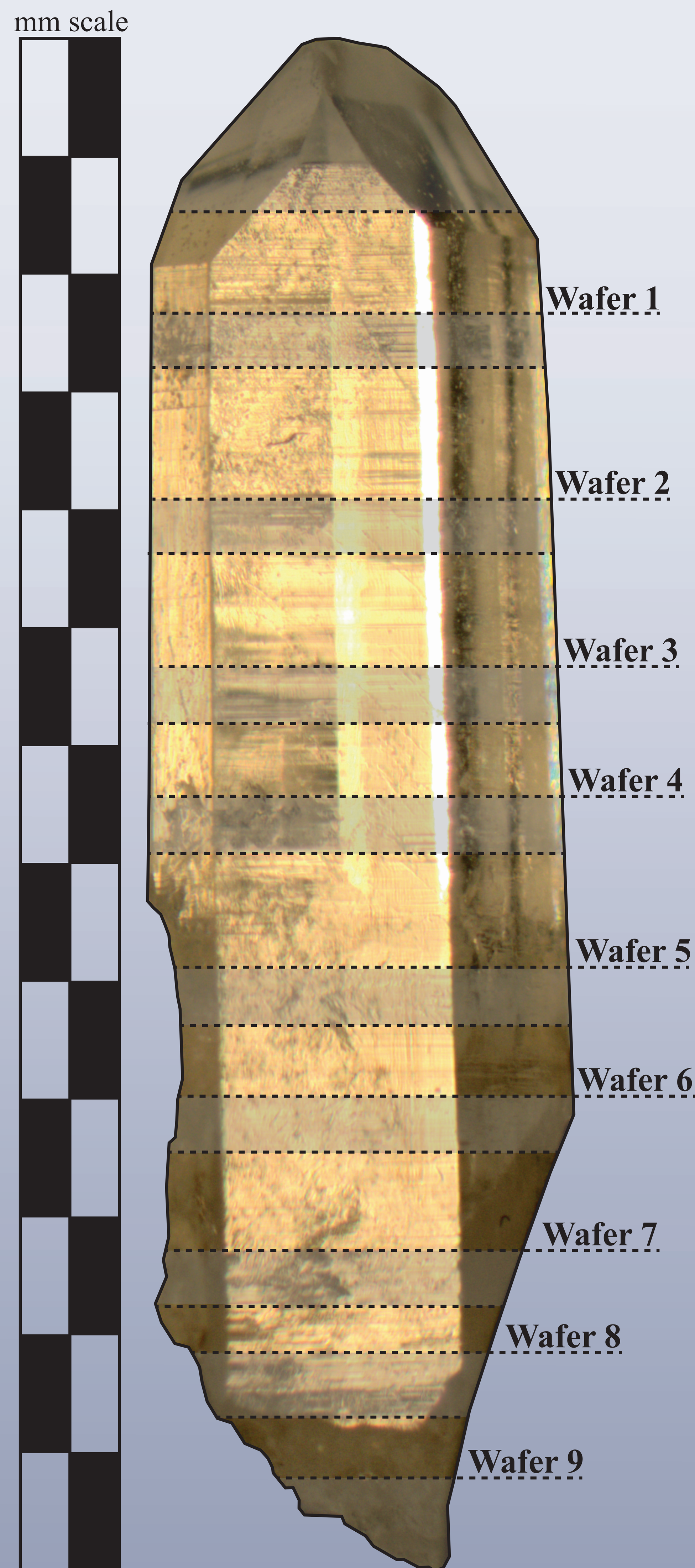
- **Identification and quantification of these factors will allow impurity abundance and distribution within hydrothermal quartz to function as a powerful tool in reconstructing the chemical and thermal evolution of metamorphic processes.**

Our Crystal

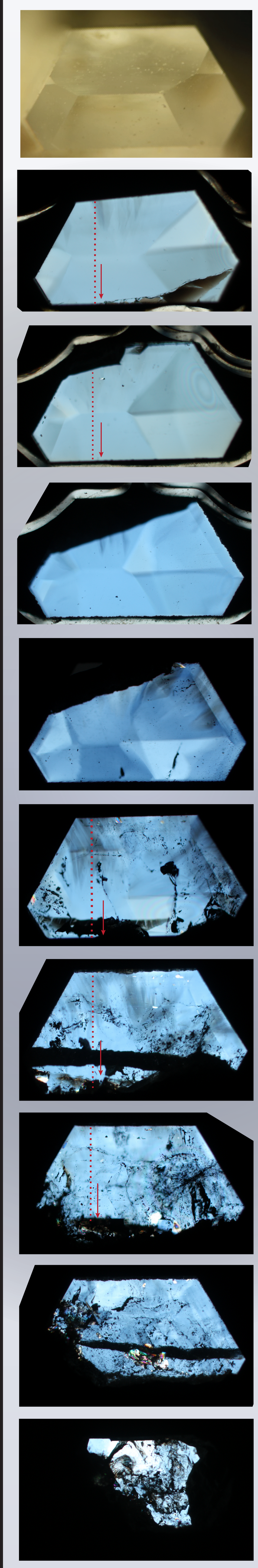
- Gemmy quartz crystal collected from a high temperature, high pressure metamorphic vein in the Swiss alps
- Co-precipitated with K-feldspar (adularia)

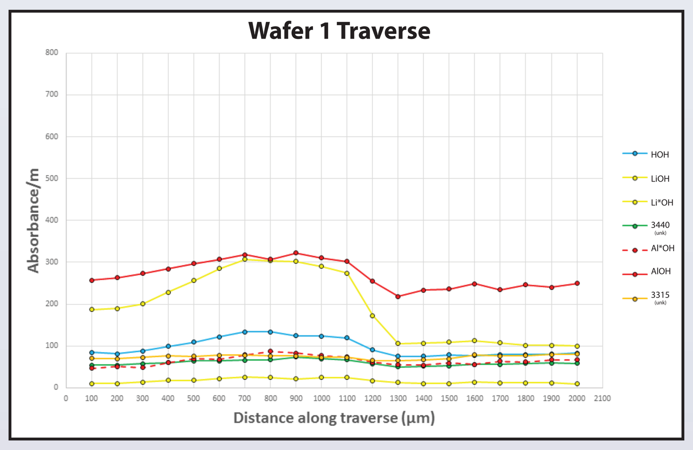


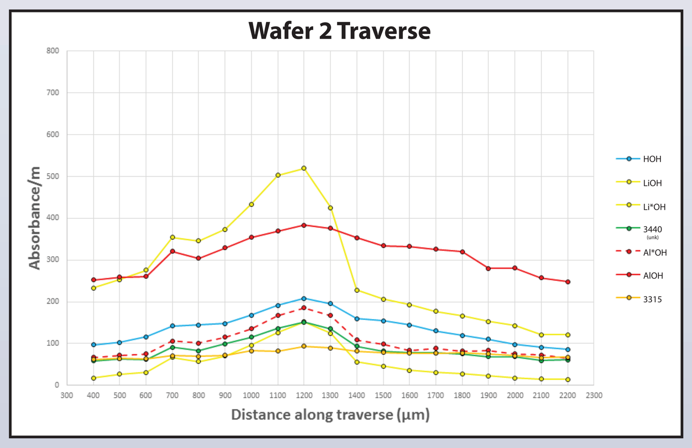


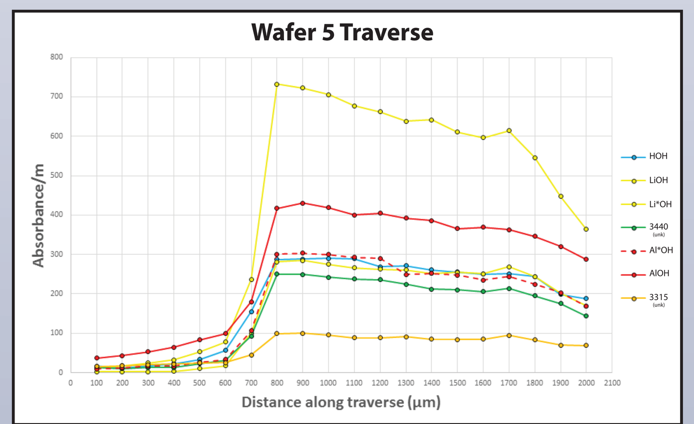


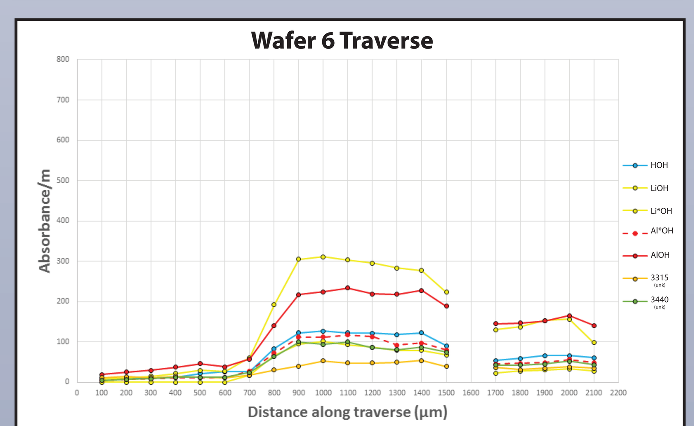
Wafers

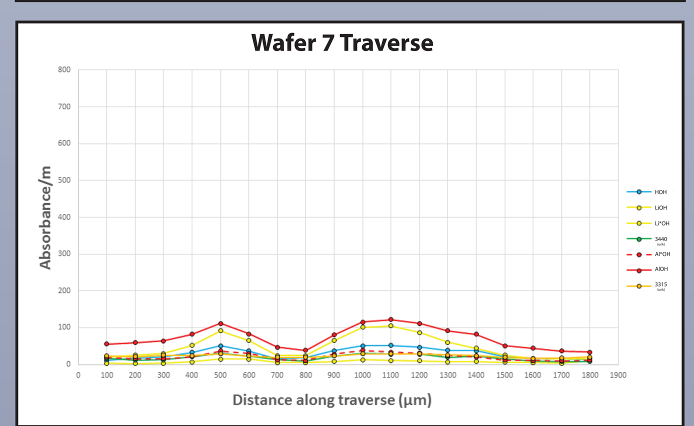




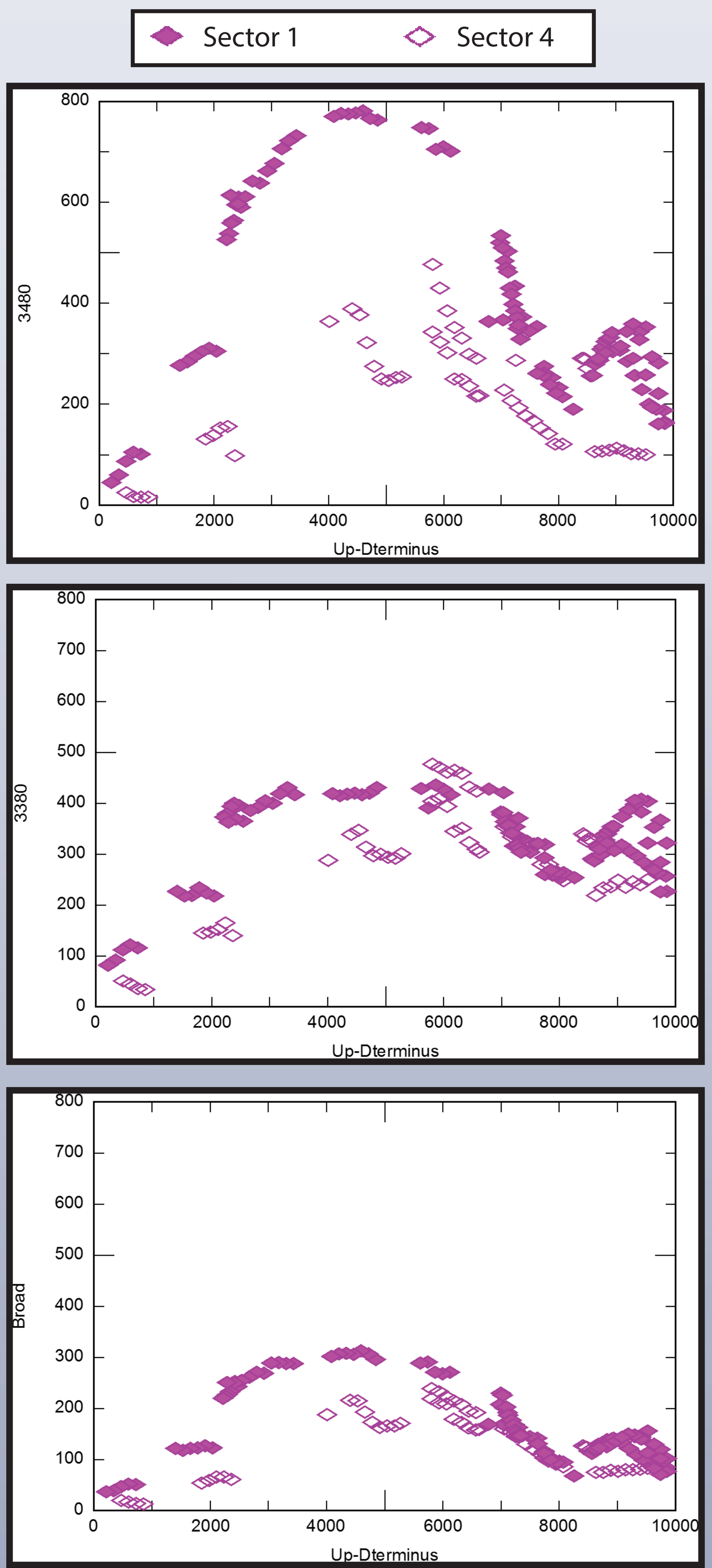


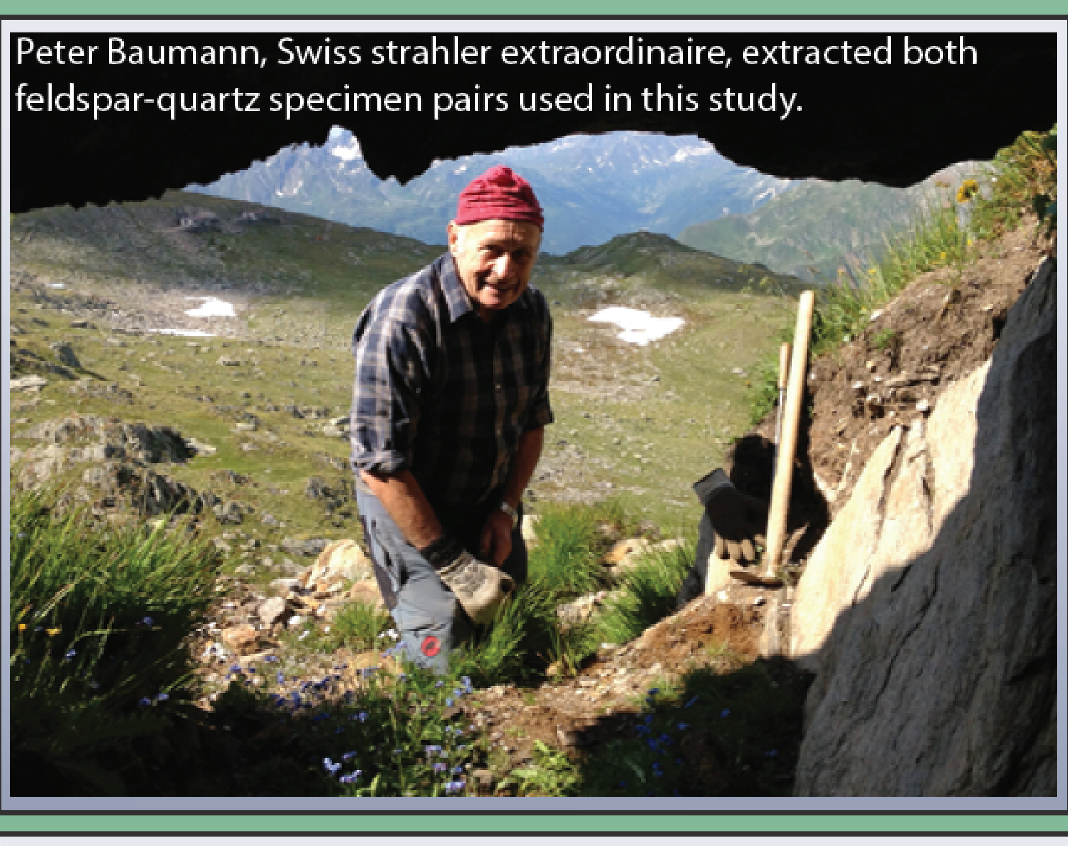






Comparison of the Distribution of Impurities with height in crystal





Results and Conclusions

- Optically and structurally distinguishable sector zones within the crystal faithfully record where growth occurred on respective rhombohedral and prism faces.
- Sizes and shapes of sector zones document the morphologic evolution throughout the growth history of the crystal.
- Variations in the abundance and distribution of hydrous impurities within sector zones may result from several potential factors:
  1. ***Rate of growth***: Impurity uptake is a function of growth kinetics; 'r' rhombohedral crystal faces grow faster than 'z' rhombohedral faces; both grow faster than 'm' prism faces.
  2. ***Armoring effect***: Concurrent growth on 'm' prism faces serve to prevent radial diffusion of hydrous species during growth, limiting horizontal diffusion out of the crystal.
  3. ***Post-crystallization diffusion along c-axis channels***:
     - For each sector, impurity abundances define vertical profiles consistent with diffusion both toward the terminus and toward the base of the crystal.
     - Within and between sectors, small differences in crystal structure affect the diffusive behavior of hydrous impurities.
- Abundance profiles from the base to the terminus indicate two distinct phases of growth, as documented by two regions with elevated concentrations in hydrous impurities.

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References

Ihinger, P.D., Zink, S.I., 2000, Determination of relative growth rates of natural quartz crystals, Nature, v. 404, no. 6780, p. 865-9.
Mullis, J., Dubessy, J., Poty, B., and O'Neil, J., 1994, Fluid regimes during late stages of a continental collision: Physical, chemical, and stable isotope measurements of fluid inclusions in fissure quartz from a geotraverse through the Central Alps, Switzerland: Geochemica et Cosmochimica Acta, v.58, no.10, p.2239-2267.
Steltz, D.J., 2009, Two Stage Growth Evolution of Hydrothermal Quartz: Impurities Tell the Story, CERCA presentation poster.