Water in Hydrothermal Feldspar

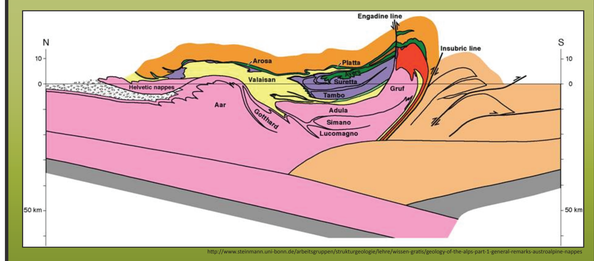
Steven C. Brost Faculty Mentor: Phillip D. Ihinger
Department of Geology, University of Wisconsin-Eau Claire, Eau Claire, WI 54702

Abstract

We present new results on the abundance and distribution of hydrous impurities in crustal feldspar. Feldspar is the most common mineral in the Earth's crust, and although water is present in only trace amounts (~ hundreds of ppm), this quantity is sufficient to make crustal feldspar one of, if not the, largest reservoir for water on our planet. Here we report on measurements of water contained in feldspar grown in hydrothermal veins of the Swiss Alps. Gemmy specimens of adularia (K-feldspar), albite (Na-feldspar), and quartz have been analyzed using infrared spectroscopy at high spatial resolution (100-µm spot sizes). We note the presence of distinctive absorption bands associated with each type of mineral. We characterize the 3-dimensional variation within single crystals and compare and contrast their variations with other minerals that grew contemporaneously in the same host vein. Our results show potential for discerning variations in fluid conditions present during and subsequent to crystal growth.

Hydrothermal Mineralization in the Swiss Alps

Our samples were formed during the mountain building event known as the Alpine Orogeny. This event put extreme pressure and temperature on sedimentary rock at depth. The water-rich minerals experienced dehydration and released hydrothermal fluids into the surrounding rock. These fluids took advantage of weak points in the overlying rock to generate fluid-filled fractures. Upon ascent through the decreasing thermal gradient, the fluids cooled and reached saturation in quartz and feldspar. These minerals incorporated contaminant species that reflect the composition of the fluids from which they crystallized.

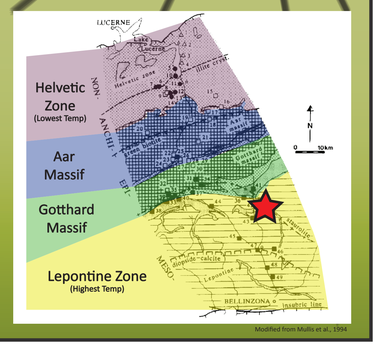


http://www.steinmann.uni-bonn.de/arbeitsgruppen/strukturgeologie/lehre/wissen-gratis/geology-of-the-alps-part-1-general-remarks-austroalpine-nappes


http://en.wikipedia.org/wiki/Matterhorn#mediaviewer/File:

Area of Study

- The general location of our samples derive from southeastern Switzerland in the beautiful ranges north of Bellinzona, Switzerland.
- All our samples were collected within the Adula Massif of the high-temperature Lepontine Zone of metamorphism, as defined by Mullis et al. (1994).
- The fluids active in this area were some of the hottest fluids of the Alpine Orogeny. (>300°C; Mullis et al., 1994).



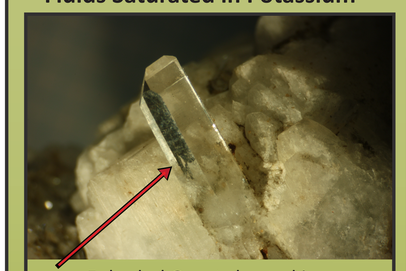
Modified from Mullis et al., 1994

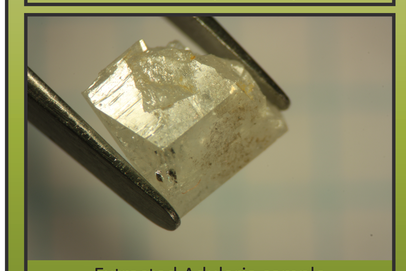
Motivation for Study

Understanding the nature of water incorporated in quartz and feldspar is of fundamental importance to geologists for several reasons:

1) ppm levels of dissolved water in a mineral significantly changes its rheologic behavior (see *Water in Feldspar* panel);
2) The impurities incorporated into hydrothermal minerals reflect the composition of their host fluids, and thus provide the only direct evidence for understanding the chemical evolution of the hydrothermal systems operating during mountain-building events;
3) The distribution of hydrous impurities within single crystals offer insights into the nature and time-scales of growth evolution and post-crystallization thermal soaking (Ihinger and Zink, 2000).

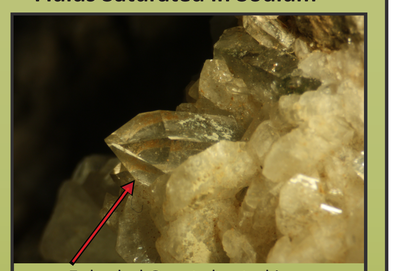
Fluids Saturated in Potassium


Euhedral Quartz hosted in a K-rich feldspar (Adularia) host


Extracted Adularia sample


Peter Baumann, Swiss strahler extraordinaire, extracted both feldspar-quartz specimen pairs used in this study.

Fluids Saturated in Sodium


Euhedral Quartz hosted in a Na-rich feldspar (Albite) host

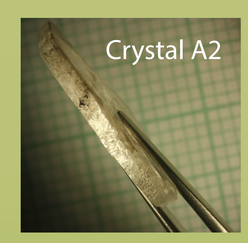

Extracted Albite sample

The Infrared Technique

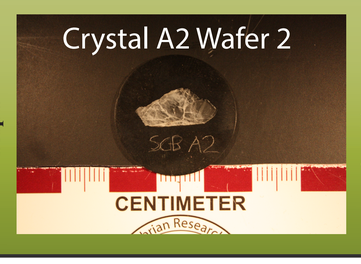
- Infrared photons can be used to detect trace hydroxyl-bearing constituents in crystals. The energy of the absorbed photon correlates with the energy of the chemical bond of the trace constituent, with each constituent associated with a unique absorption band.
- Feldspar and quartz samples were prepared for FTIR analysis using equipment housed in the Materials Science Center at UW-Eau Claire. Single crystals were oriented and mounted in graphite pucks. Pucks were cut into wafers and doubly-polished to ~1.0 mm. High-resolution (100 µm spot sizes) FTIR traverses were conducted across individual crystal wafers.

Step 1

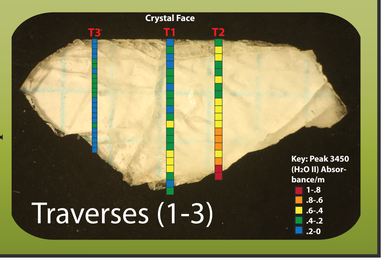
Step 2



Step 3

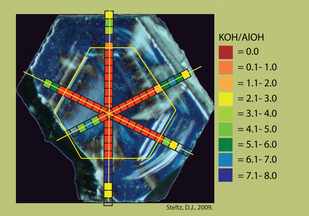


Step 4

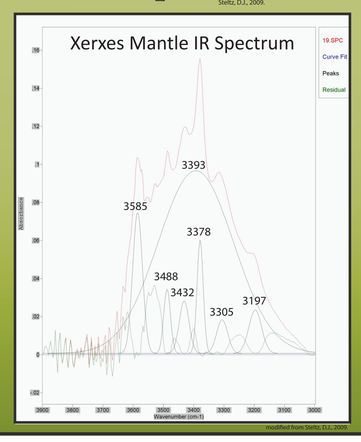


Water in Quartz

The study of water in quartz crystals coexisting with feldspar provides additional important insights into the nature of their host hydrothermal fluid systems. Previous studies by UW-Eau Claire students have discovered that some quartz crystals contain a mantle enriched in K-OH species (Steltz, 2009). Our study examines the presence and magnitude of individual hydroxyl peaks of quartz growing from contrasting fluids saturated in potassium and sodium, respectively. We hope to determine whether the companion quartz crystals contain distinguishing absorption bands.

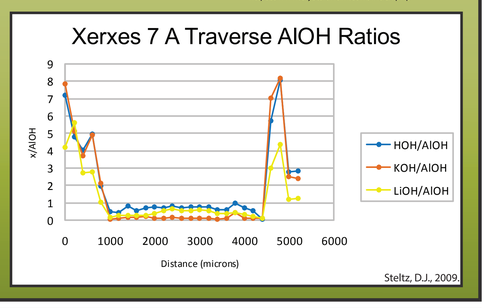


Steltz, D.J., 2009.



modified from Steltz, D.J., 2009.

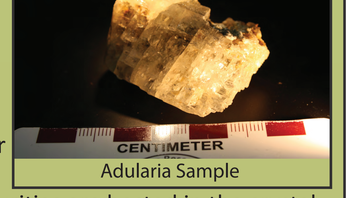

https://www.crystalarium.com/index.php



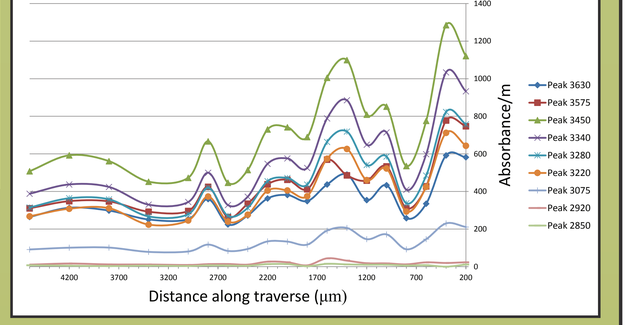
Steltz, D.J., 2009.

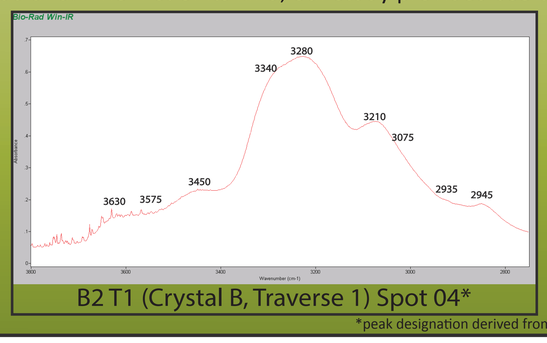
Water in Feldspar

Feldspar is the most abundant mineral in the continental crust, and collectively represents one of the largest reservoirs for water on Earth. Understanding the behavior of these crystals and the nature of how hydrous impurities are hosted in the crystal is valuable. The small amounts of water incorporated into the crystal lattice dramatically affect the physical properties of the mineral: ppm levels of water alter a mineral's viscosity (and thus its ability to deform) by orders of magnitude and lowers its melting temperature by hundreds of degrees. Thus, the presence of water in feldspar largely controls the deformation behavior of the crust. In previous studies we focused on FTIR analysis of Adularia. The first of its kind, our study provided useful data examining internal variations of hydrous impurities in single crystals. Continuing the characterization of Adularia and extending our studies to plagioclase feldspar will benefit our understanding the role of water in Earth evolution.

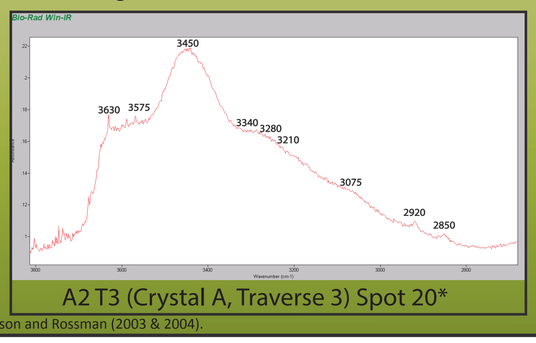


Adularia Sample





B2 T1 (Crystal B, Traverse 1) Spot 04*



A2 T3 (Crystal A, Traverse 3) Spot 20*

*peak designation derived from work of Johnson and Rossman (2003 & 2004).

Future Research

- Continue characterization of different Adularia localities.
- Expand on characterization of other hydrous impurities in plagioclase feldspar.
- Compile data on 3D hydrous impurities within feldspar and quartz to understand growth history.
- Explore for trends in hydrous impurities between coexisting crystals in the same vein.

Observations & Conclusions

- We have sampled and prepared feldspar-quartz specimen pairs.
- There are internal variations of hydrous impurities within hydrothermal K-feldspar.
- We observe identical absorption bands in K-feldspar crystals sampled from different veins, and hydroxyl assignments can be made according to the literature.
- Variations in the abundance of hydrous impurities fluctuate on microscopic length scales (100 µm), and create distinct peaks and valleys along analytical traverses.
- Differences in concentrations along profiles in crystals sampled from different veins suggest unique growth histories within individual hydrothermal systems.

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.
Johnson, E.A., and Rossman, G.R., 2003, The concentration and speciation of hydrogen in feldspars using FTIR and H MAS NMR spectroscopy: American Mineralogist, v.88, p.901-911.
Johnson, E.A., and Rossman, G.R., 2004, A survey of hydrous species and concentrations in igneous feldspar: American Mineralogist, v.89, p.586-600.
Johnson, E.A., 2006, Water in Nominally Anhydrous Crustal Minerals: Speciation, Concentration, and Geologic Significance: Reviews in Mineralogy & Geochemistry, v.62, p.117-154.
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.

Acknowledgements

We acknowledge Peter Baumann of Altdorf, Switzerland, for his help in acquiring the feldspar & quartz specimen pairs. We also thank the UW-Eau Claire International Fellows Program and Office of Research and Sponsored Programs for funding our field studies. The Materials Science Center at UW-Eau Claire (and in particular, Dr. Matthew Jewell) provided valuable access to sample preparation facilities. We also appreciate the assistance of Anthony Wagner for his sample prepration advice, and general assistance in the material science lab.