# FLUID INCLUSIONS AND THEIR SIGNIFICANCE FOR THE METAMORPHIC EVOLUTION OF THE AUSTROALPINE BASEMENT

by

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The pressure-temperature-time-fluid evolution of the Radenthein Complex (RC) west and the Schneeberg Complex (SC) east of the Tauern window can be compared applying petrological methods and fluid inclusion data. Both units contain fluid inclusions in the metamorphic index mineral garnet beside quarts, which enables direct investigation of the metamorphic fluid phase, their preservation in fluid inclusions and post-trapping re-equilibration processes during metamorphism. Peak metamorphic temperatures of both units are within the error range identical between 550 and 600°C whereas lower maximum pressures in the RC (5.5–7.5 kbar) compared to the SC (8–10 kbar) may reflect the different tectonic position of the investigated samples. The high $CO_2$ content ($X_{CO2}$ ~ 0.5) of the peak metamorphic fluid in the RC is uncommon for metapelitic rocks. Extensive fluid exchange between carbonate-bearing rocks diluted the initially $CO_2$-poor aqueous fluid and may be the reason for the widespread large crystal growth in the RC. Estimations of the physico-chemical conditions (pressure, temperature and composition) of the peak-metamorphic fluid phase in the RC and fluid inclusions in peak-metamorphic grown garnet and kyanite yielded inconsistencies, which can be explained by metamorphic reactions between fluid inclusion and host mineral or re-equilibration of the inclusions via preferential water loss.

Within basal units of the predominantly eo-Alpine metamorphic SC fluid inclusions in pre-Alpine grown garnet cores occur, which were trapped during the Variscan or Permo-Triassic metamorphic event and did not re-equilibrate during the high-pressure eo-Alpine overprint. $CO_2$-$H_2O$ inclusion assemblages of variable $X_{CO2}$ which occur in quartz from the RC are absent in the SC. Carbonic assemblages of the RC contain additional gas components beside $CO_2$ in contrast to the SC. Textures, densities and dissolved salt components of aqueous inclusion assemblages are more or less similar in both areas. The differences may be explained by a different number of samples, tectonic position or salt contents. Re-equilibration processes affecting all investigated fluid inclusion assemblages like preferential water diffusion, leakage or necking down cannot be excluded but are not always necessary to explain the observed inclusion systematics.

## Radenthein Complex

Amphibolite facies metapelites of the Radenthein Complex (eastern Austroalpine basement contain fluid inclusions in the metamorphic index minerals garnet and kyanite and in quartz. The metamorphic sequence of the Radenthein Complex is well suitable to study the metamorphic fluid phase, its temporal evolution and preservation within inclusions. Geothermobarometry, stable isotope data and fluid inclusion studies revealed inconsistencies between peak metamorphic pressure-temperature conditions on one hand and observed fluid composition and density of fluid inclusions trapped within the peak metamorphic minerals garnet and kyanite on the other hand. Oxygen isotope thermometry on several mineral pairs yielded concordant peak metamorphic temperatures in the range of 560 to 590°C. Combining these temperature estimates with the analysis of phase relations suggests that the pressure was between 5.5 and 7.5 kbars and that $X_{H2O}$ was between 0.4 and 05 during peak metamorphism. The fluid inclusion assemblages within garnet and kyanite are dominantly $CO_2$-$N_2$, and $CO_2$-$H_2O$ respectively. The generally low $CH_2O$, (< 0.26) of the fluid and the high fluid molar volumes of 42 to 70 $cm^3$/mole are inconsistent with the estimated peak metamorphic conditions.
Scanning electron images, Raman and infrared spectra of solid phases within fluid inclusions indicate retrograde closed system reactions that produced chlorite within garnet and aluminum sheet silicates in kyanite hosted inclusions. This mechanism is corroborated by fluid modeling. A virtual fluid inclusion that trapped the presumed peak metamorphic fluid ($X_{H2O}$ = 0.46, molar volume = 33 $cm^3$/mole) changes its composition and density by producing chlorite and quartz on the expense of garnet and the water fraction of the fluid. The final density of such an inclusion is consistent with the observed density range of the fluid inclusion assemblage entrapped in garnet. The fluid compositions and densities of a supposedly syn-peak metamorphic generation of garnet and kyanite hosted fluid inclusions from the medium grade metamorphic Radenthein Crystalline basement are inconsistent with the peak metamorphic conditions estimated from oxygen isotope thermometry and mineral parageneses. The garnet and kyanite hosted fluids are generally significantly lower in water content and density than predicted for peak metamorphic conditions. The observed discrepancy is ascribed to retrograde closed system hydration reactions that produced chlorite within garnet and an undetermined aluminous sheet silicate within kyanite-hosted inclusions. The net effect of such hydration reactions is to decrease the water content and the density of the originally entrapped fluid. The effect of the supposed hydration reactions is qualitatively and quantitatively sufficient to explain the observed characteristics of the water-poor low density garnet and kyanite hosted fluid inclusions. Alternative re-equilibration mechanisms such as water leakage may have occurred in garnet, kyanite and quartz, but are not necessary to explain the observed composition and density of inclusion assemblages in garnet and kyanite.

## Schneeberg Complex

The unique tectonic position of the Schneeberg Complex (SC) in the Austroalpine basement nappe pile and its characteristic lithologic features make it a key area for the understanding of pre-and eo-Alpine metamorphic evolution in this area of the Eastern Alps. Numerous studies dealing with structural geology, petrology, geochemistry and metamorphic evolution of the SC have been carried out.

This thesis focuses mainly on the transition zones, where both metamorphic events are well preserved. Petrographic descriptions of the rocks and mineral phases with the aim of light microscopy and scanning electron microscopy; fluid inclusion studies of mineral phases grown during peak metamorphism, i.e. garnets, and age dating of monazites were combined with geothermobarometric data from this study and the literature.

The sedimentary rocks of the Schneeberg were metamorphosed at amphibolite facies conditions during the eo-Alpine orogeny. Although the eo-Alpine metamorphism dominates the lithologies of the Schneeberg Complex relics of an older metamorphism are preserved within a transition zone to the underlying polymetamorphic unit of the Ötztal-Stubai Complex. Phase petrology and conventional geothermobarometry yielded temperatures between 550 and 600°C and pressures from 8 to 10 kbar for the peak conditions of the eo-Alpine metamorphic event. The age of monazite inclusions in the rims of garnet and the matrix of mica schist from the transition zone of 93 ± 11 Ma is consistent with former age estimations within the Schneeberg Complex and supports the predominantly eo-Alpine rnetamorphism. Few older monazite grains in the matrix may indicate a high-temperature/low pressure event affecting large areas of the Eastern Alps in Permo-Triassic times. Low density, low salinity primary aqueous fluid inclusions in garnet cores from the transition zone record either a Variscan metamorphic fluid and re-equilibrated or were trapped during this Permo-Triassic event. Fluid inclusions in quartz are related to the dominating eo-Alpine metamorphism with the exception of presumably pre-Alpine aqueous low density inclusions in quartz protected by garnet against re-equilibration. Low densities and high resistivity of garnet against deformation and stretching favored the preservation of pre-Alpine trapped fluid inclusions. The present water rich compositions and reduced water activities for Variscan metamorphic metapelites suggest $CO_2$-loss from former mixed aqueous-carbonic fluid inclusion in garnet, presumably in Permo-Triassic times. Inconsistencies between the calculated eo-Alpine metamorphic fluid and fluid inclusions in quartz indicate gas reactions changing fluid compositions from $H_2O$-$CH_4$ dominated to $CO_2$- and $H_2O$ rich.