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RE-EQUILIBRATION EXPERIMENTS ON NATURAL FLUID INCLUSIONS IN METAMORPHIC GARNET

KAINDL, R.[1], BAKKER, R. J.[2], DIAMOND, L. W.[3]
[1] Institute of Mineralogy and Petrology, Universitätsplatz 2, A-8010 Graz, Austria.
[2] Institute of Geosciences, Department of Mineralogy and Petrology, Peter Tunner-Str. 5, A-8700 Leoben, Austria.
[3] Institute of Geology, University Bern, Baltzerstr. 1-3, CH-3012 Bern, Switzerland.
E-mail: reinhard.kaindl@uni-graz.at

Introduction

Fluid inclusions in minerals provide direct evidence of the fluid phase present in most geologically significant processes in the earth's crust and mantle. Garnet is particularly useful for reconstructing crustal processes because it is common and due to its high strength and low diffusion coefficients, it tends to retain a chemical record of events associated with its growth. Garnet has been shown to preserve primary high-grade fluid inclusions (e.g. Touret, 1981), and fluid inclusions in garnet are generally assumed to be less sensitive to retrograde metamorphic processes than those in quartz. Recently, however, Kaindl et al. (1999) and Kaindl, Abart (2002) proposed retrograde re-equilibration as an explanation of an observed mis-match between *P–V–T* properties of primary inclusions in garnet and the *P-T* properties of the peak metamorphic mineralogy in the same samples. The recognition of post-entrapment modifications, which contradict the basic assumption of classical fluid inclusion research, namely isochoric – isoplethic behaviour after trapping, is obviously highly important.

Experimental work on fluid inclusions in different types of salts and quartz (e.g. Bodnar, Sterner, 1987) has enormously increased knowledge of the processes involved in fluid inclusion trapping and post-trapping modifications. Re-equilibration experiments with fluid inclusions in quartz are numerous but still controversial (e.g. Bakker, Diamond, 1998). The aim of this study is to identify and characterise post-entrapment modifications of natural fluid inclusions in garnets under high *P–T* experimental conditions. Here we present preliminary results of re-equilibration experiments using natural material from one of the metamorphic rocks studied by Kaindl et al. (1999).

Geologic setting and sample description

The samples are from the Kaunertal, western Austria, which is part of the Austroalpine basement nappe pile in the Eastern Alps. It consists of various metaigneous and metasedimentary rocks and it experienced a long-lived, complex metamorphic history including three metamorphic events of Caledonian, Hercynian and Createaceous age. The Caledonian event is poorly preserved; the dominant Hercynian amphibolite-facies metamorphism is overprinted by a high-pressure – low-temperature Cretaceous metamorphism of greenschist-facies grade. In the Kaunertal area, metapelites and paragneisses dominate over amphibolites and large orthogneiss stocks. The samples were collected from a biotite-muscovite-gneiss, which is crosscut by fine-grained aplitic veins composed of mainly quartz and plagioclase and garnet in the centre of the veins. The garnet is predominantly almandine in solid solution with spessartine and other components; its chemical composition is slightly variable (all values in mol%): Almandine 72-77; spessartine 17-22; grossular 1-5; andradite 0-4; pyrope 0-1. This vein garnet has been used for experimentation.

Original inclusions prior to re-equilibration experiments

Many parts of the garnet host are very dark to almost opaque. Its birefringence is around 1.8. To improve microscopic observation comparatively thin double-polished sections of about 100μm were prepared. Parts of the garnet still remain dark at this thickness but others are transparent and inclusions well observable. The high abundance of fluid inclusions in the garnet ensured that sufficient inclusions remained in the thin-section for observation. Individual fluid inclusions were characterised by microthermometry and micro-Raman spectroscopy before experimentation. Fluid inclusions occur in intragranular clusters concentrated in the rims of more or less idiomorphic, highly poikiloblastic garnet porphyroblasts within the aplitic veins. They are commonly idiomorphic, with negative rhombo-dodecahedral shapes, and they range in size between 3 and 20 μm. The number of inclusions within individual clusters is highly variable. Many inclusions contain a liquid and a vapour at room temperature. The relatively constant volume fraction of the vapour phase between 0.8 and 0.9 indicates a homogenous fluid during trapping. Unknown captive crystals (transparent to grey and partly weakly birefringent) are present in some inclusions. Almost opaque inclusions are coated by thin, relatively well crystallized graphite films (identified by micro-Raman spectroscopy).

Two types of aqueous fluids were observed in the inclusions: (1) Highly saline, with initial melting temperatures between -70 and -50 °C and final ice-melting temperatures around -20 °C; (2) Weakly saline, with initial melting temperatures around -20 °C and final ice-melting temperatures between -8 and -2 °C. All the inclusions homogenise to the liquid phase between 162 and 234 °C. Bulk molar volumes range between 19.2 and 21 cm^3/mol.

Experimental method

A fragment of the studied thin-section was placed in a gold capsule with an inner diameter of approx. 3 mm. To prevent breakage of the sample, two quartz rods with an appropriate diameter were loaded below and above the sample within the capsule. The open capsule was inserted into a cold-seal autoclave and pressurized to 382 MPa with argon and heated to 500 °C. At these conditions the fluid inclusions experienced internal overpressure. The experiment lasted for 21 days. Following the experiment the same fluid inclusions in the sample were re-examined.

Inclusion properties following experimentation

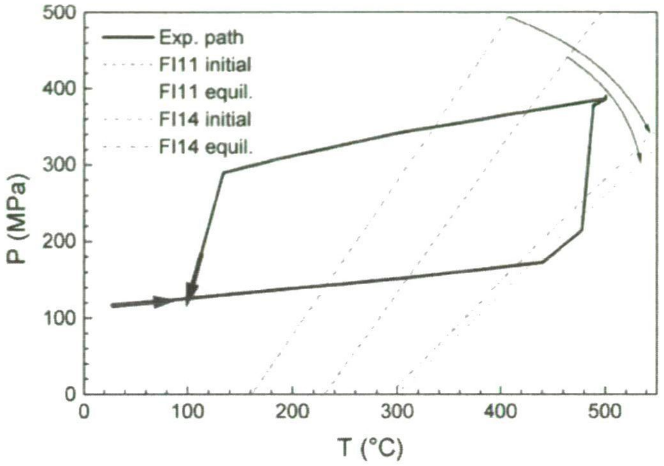

Figure 1: P-T-diagram showing the experimental path and isochores of two selected inclusions in garnet prior (initial) and following (equil.) experimentation. Arrows mark isochore rotation indicating density loss of the inclusions.

Parts of the host garnet reacted chemically during the experiment, as evidenced by a change from an initially dark appearance before experimentation, to opaque after the experiment. Cracks were observed to have formed at the corners of some larger inclusions and in the inclusions which changed from transparent to opaque. These features indicate decrepitation and leakage. The volume fraction of the vapour phase generally increased. New crystalline phases formed in some inclusions, such as hematite (identified by Raman spectroscopy). Initial melting temperatures did not change significantly; final ice-melting was slightly lower or remained almost unchanged. The homogenisation temperatures of some of the inclusions significantly increased to 370 °C, but in other inclusions the values decreased. The molar volumes remained almost unchanged or increased to 25.9 cm^3/mol.

Discussion and Conclusion

The experiment illustrates that fluid inclusions in garnets may indeed undergo post-entrapment modifications. Similarly to experimental results in quartz, the bulk density of fluid inclusions may change via decrepitation (classical leakage), whereas the bulk composition remains approximately unchanged. Furthermore, the experiments indicate that chemical reactions can be provoked between the garnet and the enclosed fluid. Further experimentation is needed for a systematic characterisation of post-entrapment alteration of fluid inclusions, as induced by factors such as pressure gradients and chemical potential gradients with respect to the surroundings of the host crystal, in addition to chemical reactions within the inclusions.

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