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Practical application of synthetic fluid inclusions: production of calibration standards

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Synthesis of fluid inclusions in natural materials, mainly quartz is an experimental technique that was refined and widely applied by Bodnar & Sterner (1987). The method is based on the relatively fast healing process of microcracks in minerals at high temperature and pressure. The distorted crystals do not heal perfectly (Fig. 1), and a huge amount of fluid inclusions is synthesized. The fluid that is present at experimental conditions is trapped accidentally, and it is completely isolated from the system around the crystal. The generated fluid inclusion trails mark the position of the former crack.

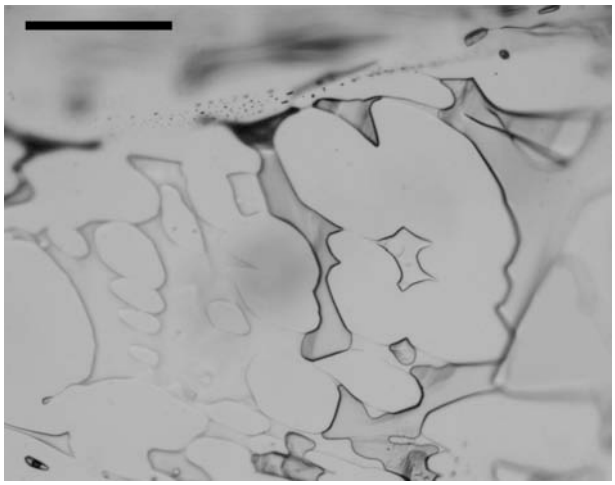

Fig. 1. Quartz growth within crack, the clear spots mark the positions where top and bottom of the crack are connected with new crystals, fluid inclusions form in between these crystals. Scale bar is 100 µm.

The hydrothermal laboratory of the University of Leoben has been optimized for the generation of synthetic fluid inclusions. The method of Bodnar & Sterner (1987) has been further refined in this laboratory, with e.g. internal thermocouples to be able to control the starting and ending conditions of a specific experiment. The experiment set-up allows well-defined T-P-t paths and can be adapted to calculated isochoric paths of specific fluids. The hydrothermal laboratory is equipped with 10 externally heated cold-seal pressure vessels, and maximum experimental conditions are 800 ˚C and 1000 MPa.

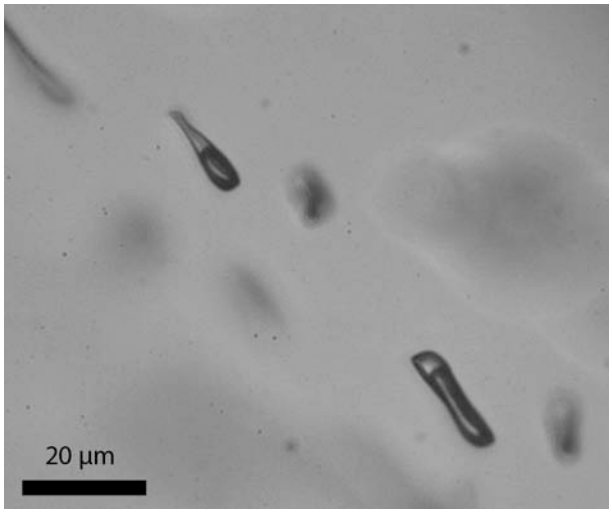

Fig. 2. Elongated synthetic H_2O fluid inclusions with critical density.

A large variety of fluids can be used in these experiments, consequently, many different types of standard fluid inclusions with well-defined compositions and densities can be produced. Thermodynamic properties of these fluid systems can be used to calibrate numerous analytical instruments (microthermometry, Raman spectroscopy, laser-ablation methods). The most common fluid systems for the calibration of microthermometry are **a**. pure H_2O fluid with a critical density (Fig. 2), T_m(SV→LV) = 0.0 ± 0.1 ˚C (melting of ice) and T_h(LV→L) = 374.0 ± 0.5 ˚C (critical homogenization); **b**. CO_2-H_2O fluids (Fig. 3), T_m(SSV→SLV) = -56.6 ± 0.2 ˚C (melting of CO_2) and T_m(SLV→LLV) = 9.9 ± 0.1 ˚C (melting of clathrate); **c**. H_2O salt (e.g. NaCl) fluid with an

eutectic composition (Fig. 4), T_m(SSV→SLV) = -21.2 ± 0.2 ˚C (eutectic melting).

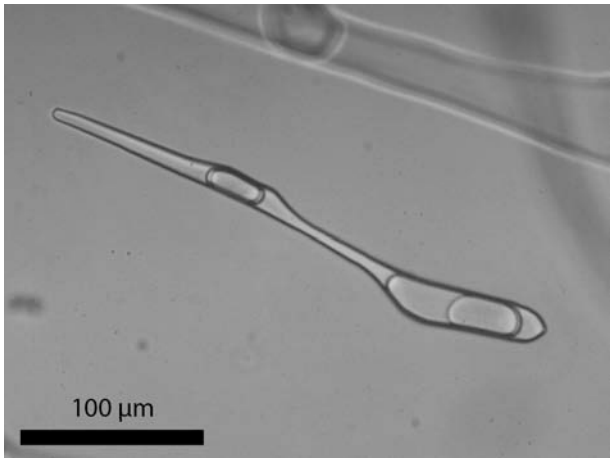

Fig. 3. Elongated synthetic H_2O-CO_2 fluid inclusion with three phases, two CO_2 bubbles (L+V) separated by an aqueous liquid solution.

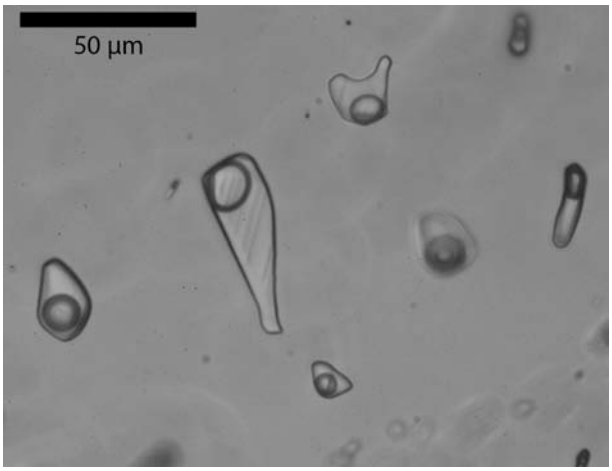

Fig. 4. Synthetic H_2O-NaCl fluid inclusions of variable sizes and shapes with an eutectic composition (23.3 mass% NaCl)

The uncertainties of thermodynamically fixed temperatures of phase changes in fluid systems are defined by the precision of the stage that is used in microthermometry. The production of mixed H_2O-gas fluids is based on the use of solid silver-oxalate for CO_2 (explosive decomposition at 140 ˚C) and solid silver-azide for N_2 (explosive decomposition at 250 ˚C). The fluid inclusions in Figure 2, 3 and 4 were synthesized at 550 ˚C - 72 MPa, 600 ˚C - 400 MPa and 600 ˚C - 220 MPa, respectively.

REFERENCES

Bodnar RJ, Sterner SM (1987) In: *Hydrothermal Experimental Techniques (ed. GC Ulmer & HL Barnes),* 423-457.