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METHODS OF INVESTIGATION OF MELT INCLUSIONS

INTRODUCTION

Investigations of melt inclusions have specific features, different than those typical of gaseous-liquid inclusions. This report presents the most important advices for studies of this special type of inclusions in minerals.

PHASES IN MELT INCLUSIONS

Inclusions, which formed due to trapping of small homogeneous portions of melt, at room temperature may appear as: a) glassy one-phase inclusions, b) glassy inclusions with shrinkage bubble, c) glassy inclusions with shrinkage bubble and daughter crystal phases, d) glassy inclusions with daughter crystal phases without shrinkage bubble, e) completely crystallised inclusions containing shrinkage bubble. The shrinkage bubble may be filled with a gas of various density – from very low to very dense, and by liquid phase of water solution, carbon dioxide etc. Soluble salts like NaCl or KCl may crystallise in melt inclusions either directly from melt, or from the aqueous solution separated from melt on cooling of the inclusion, depending on the water and the respective salt contents in parent melt. The inclusions may form due to heterogeneous trapping as well – the vacuole may trap melt and bubble of gas, melt and droplet of liquid water solution or melt and tiny crystal. The distinguishing of the melt inclusions of the homogeneous trapping and those of the heterogeneous trapping is not trivial, because the appearance of the phases in melt inclusions on cooling very frequently depends on the metastability phenomena. A thorough analysis of the occurrence and sizes of the phases in inclusions of various dimensions usually helps to solve this problem.

The analysis of chemical composition of melt (glass) or crystal phases in inclusions requires the use of an electron, ion or laser microprobe. The essential problems of this analysis will be discussed on the example of the electron microprobe. If the total composition of melt should be determined, first the inclusion must be homogenised, i.e. the crystal phases and glass must be molten and gas (shrinkage) bubble should disappear on heating. The hot preparation should be rapidly cooled (quenched) to obtain homogeneous overcooled melt (glass) in inclusions. The preparation with open inclusion is made by very thorough

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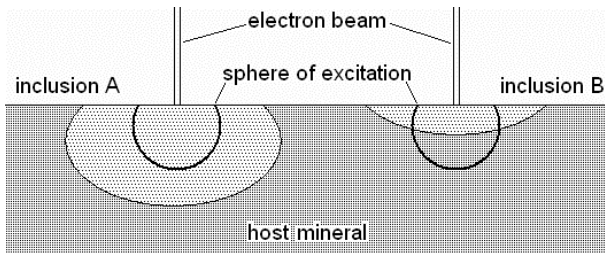


Fig. 1. Scheme of the correct (inclusion A) and incorrect (inclusion B) electron microprobe analysis of melt inclusions.

excitation by electron beam reaches the underlying host mineral and the results are contaminated by influence of the foreign substance.

HOMOGENISATION

The preparations for the studies of homogenisation of melt inclusions are either single not polished grains, or two-side polished slices of rock. The grains are used for the quenching method, polished preparations for the high-temperature microscope stage or for both.

The high-temperature microscope stage techniques are described elsewhere (*e.g.* Roedder 1984). However, they require several-hours-long microscope observations at elevated temperatures and use of special cooling units for the microscope optics. The more convenient quenching technique (Kozłowski 1981) needs special microfurnace (Fig. 2), in which the preparation is heated several times for one or two hours and after each such period is quenched on hollow copper block with dry ice in it. The quenched inclusions in the preparation are checked under microscope, if necessary in immersion. The heating is repeated till homogenisation of the inclusion is achieved (Fig. 3). The time of heating must be long enough to get the homogeneous melt at each temperature, otherwise the overheating of the inclusion is possible, with the escape of hydrogen from inclusion water (Kozłowski 1985).

Homogenisation runs at temperatures close to 1000°C are not difficult for minerals not sensitive to these conditions like quartz or apatite. If the mineral contains iron (especially Fe²⁺) or manganese, oxidation may cause decomposition of the mineral and its alteration to an opaque substance. Thus special protection

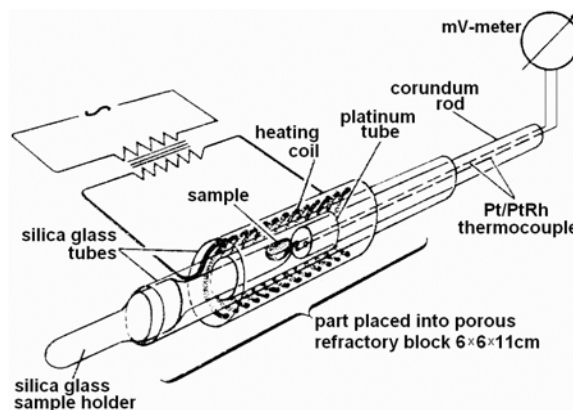


Fig. 2. Scheme of microfurnace for the quenching method of homogenisation of melt inclusions.

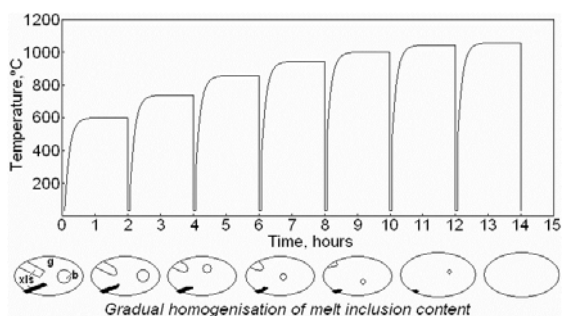


Fig. 3. Plot of quenching run; xls – crystals, g – glass, b – bubble.

against oxygen and oxygen-bearing substances (water, CO₂) must be foreseen, when ferrous olivine, pyroxene or amphibole is studied. Even nitrogen may cause decomposition of such minerals at temperatures exceeding 1000°C. For short runs at 800–1000°C graphite or iron powders may be used to eliminate oxygen. However, placing preparation in these powders makes difficult the proper quenching, thus it is not recommended. The good method of elimination of oxidants from the microfurnace is to supply it with slow flow of nitrogen-free argon or helium, earlier purified by passing through saturated KOH solution (absorption of CO₂), pyrogallol (O₂), PdCl₂ solution (H₂) and cold trap filled loosely with mineral wool, or a tube filled by solid CaO or askarite to eliminate water. Finally, dust should be stopped – it may be a small box with clean mineral wool. Quenching must be in oxygen-free atmosphere as well.

One should remember that the host mineral substance might have precipitated on the walls of inclusion vacuole, thus on the homogenisation run it must be dissolved (Fig. 4). The layer of this substance may be recognised from the early daughter minerals partly “immersed” in it, or due to a little different refractive index, when compared to the host mineral.

Quenching does not produce perfect glass in melt inclusions, if phosphate, carbonate or halide components are abundant. They exsolve from silicate melt and form minute crystal segregations. Thus, in such cases the microscope heating stage technique is recommended.

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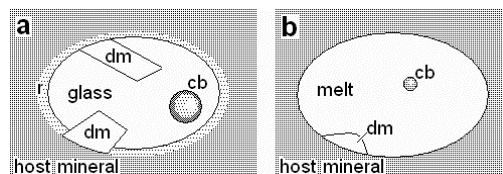


Fig. 4. Host-mineral substance (a) precipitated in vacuole (r) and dissolved in melt (b); dm – daughter mineral, cb – contraction bubble.