Submitted to Neues Jahrb. Mineral. Monatsh. (6.3.87)

Jahresbericht

N. Jahrb. Mineral. Monats

MRF/371

An evaluation of fluid inclusion decrepitometry using quartz from the Kingsgate molybdenite-bismuth deposits, New South Wales, Australia

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With 5 figures and 2 tables in the text

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Abstract: A study has been made of the relationship between heating-freezing stage and decrepitation data for fluid inclusions in three growth zones of a large quartz crystal from Kingsgate, New South Wales, Australia. It was found that the mean homogenization temperatures can be estimated from the decrepitation data either by specific corrections related to the known inclusion salinity (more precise) or by a general correction which is independent of salinity (less precise). Discrepancies of up to 30-40°C exist between the actual and estimated homogenization temperatures. Of the several possible reasons for these discrepancies the most likely is that the inclusion size affects the temperature of decrepitation.

Key words: Fluid inclusions, decrepitometry, quartz, mineralization, molybdenite, bismuth.

Introduction

Decrepitometry is a method of characterizing mineral samples by the discrete acoustic emissions they produce on heating. These emissions originate in the fracturing and leaking of fluid inclusions. The method can rapidly provide a large quantity of semi-quantitative fluid inclusion data in a survey which can be used in such applications as distinguishing mineralized and barren quartz veins (BURLINSON et al., 1983). As part of a program of testing a new approach to the theory and practice of decrepitometry (HLADKY and WILKINS, 1987; WILKINS et al., 1987), we have examined a well characterized quartz crystal from a quartz-molybdenite-bismuth deposit from Kingsgate, New South Wales, Australia. This study provides a clear example of the relationship between acoustic emissions and fluid inclusion content and enables a detailed evaluation of a number of complexities inherent in the technique.

Materials and methods

The sample studied is part of a large crystal 150 mm in length with corroded prismatic and unequally-developed rhombohedral faces. It was cut into two pieces parallel to one of the larger rhombohedral faces in such a way that three growth zones were intersected. A 7 mm thick slice from one of the cut surfaces was sufficient to provide material both for a polished thin section and crushed samples for decrepitometry. Fig. 1 indicates the location of the samples from the three zones selected for study.

The blocks for decrepitometry were crushed in a small roller mill and sieved into 1000-600, 600-425, 425-212, 212-106 and 106-53 μm fractions. The samples (0.5 g) were run in a newly-designed microprocessor-controlled decrepitometer, constructed by Burlinson Geochemical Services Pty. Ltd., at a heating rate of 20°C/min over the range 100-600°C. The results, which are displayed by the instrument in the form of a histogram of the number of counts per 10°C interval over this temperature range, were then treated on a PDP 11 computer using GAUSS, a curve fitting program which utilizes the subprogram MINIM by D.E. Shaw of the CSIRO Division of Mathematics and Statistics, Sydney, Australia. With this program the curves are resolved into a selected number of Gaussian peaks and the number of counts, mean temperature and standard deviation are tabulated for each peak. The results were then plotted with a Hewlett Packard 7221C plotter.

The thin sections were examined for indications of origin of the inclusions. To determine size distributions, 200 inclusions were selected from each zone using random simultaneous x and y translations of the section on a moving microscope stage. At each position the inclusion closest to the crosswires of the microscope was measured for length and width.

Portions of the thin sections were then cut out for homogenization temperature and salinity determinations using a SGE heating-freezing stage. The stage was calibrated at the triple point of CO_2 (-56.6°C) using a CO_2 inclusion standard, and at the melting points of pure water, $NaNO_3$ (306.8°C) and $K_2Cr_2O_7$ (398°C). At 0°C and below the errors are believed to be ± 0.2°C and in the region of most of the homogenization temperature measurements (200-400°C) the error should be within ± 5°C.

Results

Fluid inclusion distribution

In the section of the outer zone of the crystal a substantial proportion of the inclusions are roughly arranged parallel to a rhombohedral crystal face (Fig. 1) and are primary in origin. Other inclusions not zonally arranged but lying along non-intersecting curved surfaces could also be primary inclusions of the lineage boundary type. Inclusions in the intermediate zone are not zonally arranged but again are mainly to be found along well-defined curved surfaces, very few of which actually intersect one another within the thickness of the section. The inclusions in the core are distributed both irregularly and along well-defined intersecting healed fracture surfaces. It is probable that both primary and pseudosecondary inclusions are present in this zone but because the origin of many inclusions was not clear they were not classified at the time of data collection. The inclusions in this crystal show very little evidence of necking-down. Low density fluids such as may have originated by boiling are absent.

Size frequency distribution data for inclusions from the three zones are presented in Fig. 2.

Heating-freezing stage

The results of the freezing stage examination of the fluid inclusions from the three zones of the crystal (Fig. 3) show that all inclusions are of relatively low salinity. Two groups of inclusions are nevertheless distinguishable from the rim zone of the crystal, one with a salinity < 1.5 wt.% NaCl equiv. (Tm ice 0.0 to -0.7°C) and the other with a salinity in the range 4 to 6 wt.% NaCl equiv. (Tm ice -2.5 to -3.5°C). At least some inclusions in the latter group have appreciable gas contents because in these the freezing occurs in two steps and, when all the ice is melted on warming, the bubble still remains deformed until the invisible clathrate melts at approximately +1°C. Inclusions from the intermediate zone of the crystal all have a salinity of less than 1 wt.% NaCl equiv. and there is no evidence of clathrate formation. Inclusions from the core zone fall into two groups on the basis of whether a clathrate is present or not. A clathrate was found in all inclusions with Tm ice -3.6 to -4.5°C. Although the clathrate is invisible, evidence of melting at approximately +9 to +10°C was obtained by observing bubble movement during cycles of freezing and warming to successively higher temperatures. The gas could not be condensed at -130°C and there was no evidence of any phase change in the bubble in the region of the CO_2 triple point (-56.6°C).

Homogenization temperatures obtained from 100 inclusions in each zone are plotted in Fig. 4. Heating and freezing stage results were obtained from different suites of inclusions except for the core sample from which there was an overlap of 25 inclusions for which both heating and freezing data were obtained.

Decrepitation data

Representative decrepigrams for the three zones are compared with the corresponding homogenization temperature histograms in Fig. 4. An attempt to fit the decrepitometric data by two Gaussian curves was successful for the intermediate and rim zones but unsuccessful for the core samples. These, however, were satisfactorily fitted by three Gaussians. The parameters of the component curves for the five samples from each of the three zones are listed in Table 1.

The effect of particle size of a sample on its decrepitation response is illustrated in Fig. 5 for the different size fractions of the sample from the core of the crystal.

Discussion

Occurrence of crystal

The geology and mineralogy of the Kingsgate quartz-molybdenite-bismuth deposit have been discussed by ANDREWS (1916), GARRETY (1953) and LAWRENCE and MARKHAM (1962). The deposit consists of a number of small irregular pipe-like bodies in the Red Range Granite of Permian age, in proximity to the roof of the intrusion and near the contact with surrounding Carboniferous sediments. The pipes have no brecciation features, but they have a rough zonal structure consisting of a margin of compact granular quartz and bismuth, an intermediate zone consisting of porous granular quartz with disseminated molybdenite and a central zone containing massive molybdenite and coarse granular and well-formed crystals of quartz commonly up to 10-20 cm in size. The crystal selected for the present study was collected from a spoil heap but probably derived from the latter zone.

EADINGTON (1977), in a study of the fluid inclusions of the quartz from the different zones of the pipes, recorded salinities in the range 0- ~10 wt.% NaCl equiv. and homogenization temperatures in the range 210-375°C. Significant variations in the temperature and salinity of