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MULTISTAGE CRYSTALLIZATION OF VEIN QUARTZ IN A FISSURE OF VARIABLE WIDTH

Abstract: Vein quartz from gneiss from Gierałtówek in Izera Upland formed at temperatures 210–270ºC under pressure 0.66 to 0.84 kbar. Parent aqueous solutions contained mainly NaCl in concentrations from 5 to 11 wt %; carbon dioxide is present, as indicated by fluid inclusion studies. The conditions changed within the indicated P and T ranges many times, probably due to increasing width of the fissure hosting the vein.

Keywords: fluid inclusion, quartz, vein, pressure, temperature, carbon dioxide, Sudetes

INTRODUCTION

The vein quartz sample for investigation was taken in the western part of Izera Upland near the village of Gierałtówek, NW of Czerniawa Spa (Fig. 1). This area is built of the Izera gneiss-schist metamorphic complex (Smulikowski 1972) of the age of ca. 500 Ma (Borkowska et al. 1980). The sample came from a 15 to 20 cm thick quartz vein located in metasomatically albitized and muscovitized gneiss. The vein formed as a result of the hydrothermal activity, which was common in the Izera area, and resulted in various veins and several types of metasomatic rocks (albitites, greisens etc., *see* Kozłowski 1978).

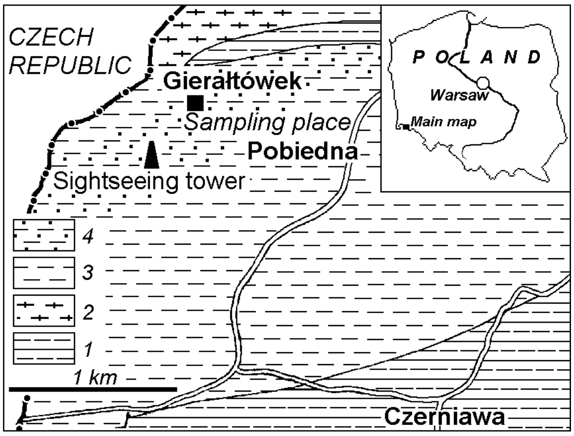

Fig. 1. Location of the sampled quartz vein; 1 – mica-chlorite-quartz schist, 2 – granite-gneiss, 3 – gneiss, 4 – metasomatized gneiss.

SAMPLE AND METHODS

Sample. The investigated quartz consisted of compact cluster of subparallel milky crystals which grew on the walls of an open fissure. The crystals have many gray quartz growth zones from less than 1 mm to 2 mm thick and one amethyst zone of the thickness of 4 mm (Fig. 2).

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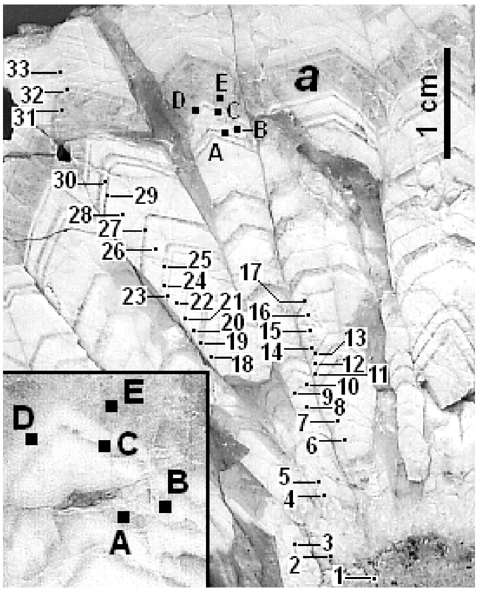

Fig. 2. The investigated vein quartz specimen, ***a*** – amethyst zone, the dots indicate the points, where fluid inclusions were studied, A – E are places of occurrence of fluid inclusions interpreted in Fig. 3 (for the data see Table 1).

Methods. Fluid inclusions were investigated by routine microscope heating and freezing methods (see e. g. Roedder 1984) in double-side-polished 0.5 mm thick slices of quartz. The accuracy of measurements of the homogenisation temperatures (Th) of aqueous inclusions was ±1ºC and the accuracy of Th values of carbon dioxide inclusions was about ±0.05ºC; the *Fluid Co.* microscope cooling-heating stage was applied. For this study 126 fluid inclusions were investigated. NaCl was identified in solution by eutectic point and salt concentration was determined by use of the Bodnar's (1978) data, the aqueous solution isochores were drawn according to the Potter's and Brown's (1977) tables and the isochores of CO_2 – on the basis of the Bulakh's and Bulakh's (1978) data. Pressure during quartz crystallization was determined by the crossed isochores method.

FLUID INCLUSIONS

The investigated fluid inclusions (7–30 µm in length) contained aqueous solutions, aqueous solutions and liquid carbon dioxide or liquid carbon dioxide, all with contraction bubbles. Though both the primary and secondary inclusions were found in the studied sample, here the data from primary inclusions are used. The studied inclusions in the sample formed the sequence from the wall rock gneiss (point 1, Fig. 2) to the central part of the vein (point 33, Fig. 2) with 2–5 inclusions in each point, however, the most complete data were obtained in the points A – E (Table 1, Fig. 3).

Table 1. Fluid inclusion data in the points A – E of the studied sample, 31 inclusions

Point	Inclusions of CO_2		Inclusions of aqueous solution			T cr[a], ºC	P cr[b], kb
	Th, ºC	d, g/cm³	Th, ºC	S, wt %	d, g/cm³		
A	27.2	0.68	185	5.3	0.920	254	0.84
B	28.8	0.65	174	5.3	0.935	229	0.68
C	30.0	0.60	211	5.2	0.890	268	0.69
D	–	–	210	5.3 (L)	0.890 (L)	210	0.02
E	30.5	0.56	221	11.2	0.920	289	0.66

[a] Temperature during crystallization of quartz; [b] pressure during crystallization of quartz; d – density, S – total salinity of the aqueous solution as the NaCl equivalent; L – liquid phase

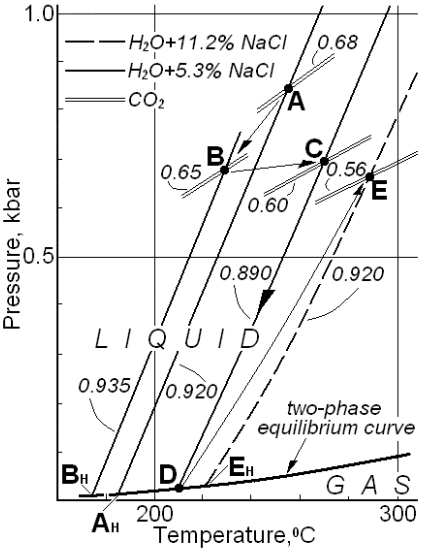

Fig. 3. Isochores of carbon dioxide and aqueous solutions for the points A – E, A_H, B_H, and E_H, indicate the respective homogenization temperatures of aqueous inclusions, for the point C the Th value coincides with the value D. The arrows indicate the sequence of formation of the primary inclusions.

In this part of the quartz sample fluid inclusions in the point A (gray quartz zone) were filled with 1) aqueous solution of the density 0.920 g/cm^3, 2) liquid CO_2 of the density 0.68 g/cm^3, 3) liquid CO_2–aqueous solution inclusions of various proportions of the liquid phases. The calculated temperature of crystallization was 254ºC and pressure – 0.84 kb (crossing isochores method was used). The liquid CO_2 plus aqueous solution inclusions could be theoretically applied to determine the P and T parameters of quartz crystallization with use of the appropriate experimental data (Gehrig 1980, Gehrig et al. 1986), however, the shapes of the inclusions did not allow to calculate the phase proportions precisely enough. The next zone of milky quartz formed at lower temperature and pressure (point B, 229ºC and 0.68 kb), what may be connected with slightly expanding host fissure of the vein. Subsequently temperature increased to 268ºC under the same pressure (0.69 kb; point C in gray quartz zone), what may suggest stabilization of the quartz formation conditions. Next point (D in milky quartz zone) yielded inclusions homogenizing either in gas or liquid phase at the same temperature of 210ºC. This indicates the two-phase state of the mineral-forming solution (in the P–T plot located on the two-phase equilibrium curve, Fig. 3), thus homogenization temperature is the crystallization temperature for quartz surrounding these inclusions; pressure decreased rapidly to ca 0.02 kb, what caused the observed heterogenization (boiling) of the mineral-forming solution. This could be caused by quick increase of the host fissure, in which the quartz vein formed. The liquid aqueous solutions had total salt concentrations almost constant (5.2–5.3 wt %). After the boiling event temperature and pressure increased again to 289ºC and 0.66 kb (point E in the amethyst zone), however, the salinity of aqueous solution became higher (11.2 wt %). Later salinity decreased again to ca. 6 wt % (points 31–33).

Other investigated points (1–30) did not yield such complete sets of fluid inclusion data as the points A–E, especially due to frequent absence of the inclusions containing liquid CO_2. Nevertheless, the total salt concentrations varied in very narrow ranges from 4.9 to 5.5 wt %, homogenization temperatures were from 180 to 215ºC for the gray quartz zones and from 163 to 175ºC for milky quartz zones, and few calculated pressure values were close to 0.7 kb. This suggests that crystallization temperature oscillated during the crystallization of this vein quartz, probably from ca. 210ºC for milky quartz up to 270ºC for gray quartz zones. Other boiling events were not detected.

CONCLUSIONS

The complex pattern of crystallization of quartz in the vein at Gierałtówek, including rapid changes of temperature and pressure of the mineral-forming solution, was probably caused by gradual and discontinuous opening of the host fissure. One event of significant increase of the fissure volume caused boiling and increase of salt concentration of the solution. The liquid flowing into the fissure had variable composition: from pure aqueous solution to apparently pure liquid carbon dioxide, and with various intermediate proportions of these two components. Probably cracks in the wall rock opened periodically conduits to reservoirs of various fluids – either the aqueous one, or liquid carbon dioxide.

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