Crystallography

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1962

SovietRxiv

Abstract

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On the Conditions of Mineral Formation in Pegmatites According to Data from the Study of Primary Inclusions in Topaz

(Presented by Academician A. V. Shubnikov, 8 VII 1961)

We were able to find unquestionably primary inclusions in topaz crystals from the pegmatites of Volhynia. These inclusions, which have the form of negative crystals (0.01-0.3 mm), are located along the planes of former faces in the root part of the crystals. It is generally known that the study specifically of primary inclusions of the mother medium gives the most valuable information about the genesis of the host crystal. We therefore devoted special attention to them.

About 70% of the total volume of the inclusions is occupied by solid phases, alongside which liquid and gas are necessarily present (Fig. 1a). Without dwelling on the description of the extremely laborious operations for extracting the substance of the inclusion, we shall point out that determination of the solid phases was carried out by crystal-optical methods. Refraction was measured in immersion by the method of chromatic variation (accuracy not less than $\pm$0.003).

As a final result, we established the following phases in the inclusions in topaz (in order of decreasing relative content): 1) low-temperature quartz, $N_m = 1.544$, $N'_g = 1.552$—abundant; 2) muscovite, $N'_p = 1.552$, $N'_g = 1.588$—abundant; 3) cryolite, $N = 1.342$—medium content; 4) an undetermined mineral having the form of pseudohexagonal flakes, $N \simeq 1.51$—little; 5) fluorite (?) and, in general, various fluorides and chlorides of K, Na, Ca—very little; 6) aqueous solution; 7) gas phase.

Each of the inclusions contains one and the same set of minerals, apparently with identical quantitative proportions and identical ratios between the volumes of the solid phases and the sum of the liquid and gas phases.

Judging from the impressions of crystals of quartz, mica, and cryolite on the walls of the cavity in the topaz, deposition of the substance of the topaz itself continued even after isolation of the inclusion. The amount of topaz thus separated apparently amounts to no less than 1% (of the total volume of the inclusion), judging from the depth of the impressions.

A series of experiments was carried out on heating preparations of topaz with primary inclusions. Using an ordinary heating stage on a microscope, we were able to verify that upon heating to 500° the gas bubble gradually decreased in size and finally disappeared completely. At the same time the solid phases changed little: only the smallest crystals dissolved or melted during prolonged heating. Upon heating above 500° the inclusions invariably burst. Higher temperatures were reached in a bomb, in which the furnace together with the specimen was under an inert-gas pressure of about 3000 kg/cm^2. Unfortunately, visual observations of the preparation during heating are impossible in this apparatus.

The very first experiments showed that upon heating to 1000° the contents of the inclusions become completely homogeneous. On cooling, in each of the inclusions we obtained a brownish silicate glass, inactive in polarized light, in which bubbles separated out, containing liquid and gas phases at room temperature. In cracked inclusions,

···having lost their volatiles, no melting of the crystals contained in the inclusions took place.

Experiments involving short-term heating (3–5 h) of specimens to 700° showed that the contents of small inclusions (0.01 mm along the long axis) dissolved completely. The contents of larger inclusions dissolved only partly (remnants of quartz crystals remained). In inclusions 0.1 mm in size, however, the crystalline phases remained unmelted. In one of the inclusions it was possible to observe a shift in the boundary between a quartz grain and muscovite; this is evidence that at 700° each of these grains was noticeably melted, and that upon cooling the growth of quartz and muscovite proceeded differently than during the initial crystallization. One of the experiments lasted 24 h. Such a duration of the experiment at a temperature of 740° was already sufficient for dissolution to occur in the overwhelming majority of inclusions, and only in inclusions exceeding 0.2 mm were strongly melted quartz crystals preserved (Fig. 1). Repeated heating of the same specimen showed that the silicate glass of the inclusions melted again, as indicated by the change in the position and number of bubbles in the inclusions (Fig. 1). The quartz grains preserved in large inclusions after the first experiment noticeably decreased in volume upon repeated heating. This also indicates that the silicate glass surrounding the remnants of quartz crystals in the inclusions after the experiment was again capable of dissolving quartz upon reheating.

Of particular interest in this connection was the interaction at 700–740° of the liquid contents of the inclusions with the walls of the enclosing mineral, topaz. Figure 2 shows two photographs of one primary inclusion, taken at room temperature before the experiment and after heating to 700°. Comparison of the photographs shows that after melting and subsequent cooling the configuration of the inclusion boundaries changed noticeably. In place of the smooth faces of the negative crystal, after the experiment there appeared uneven boundaries covered with a large number of teeth ([1]).

On the basis of the change in the configuration of the boundaries, we determine that the amount of topaz that passed into solution during heating was about 10-15 vol.%.

As was noted after experiments with melting, or even incomplete dissolution, of the contents, the solid contents formed a silicate glass upon cooling. The aqueous solution and gases dissolved completely in the silicate melt. Upon cooling, however, part of the aqueous solution and gases separate as one or several bubbles. The spherical shape of the bubbles made it possible to determine the ratio between the gas and liquid phases in them. It may be assumed that the specific volume of the aqueous medium in a liquid-gas inclusion in glass is 1.7 cm^3/g. This means that (if it were pure water) upon heating to 700° a pressure of up to 2600 atm would have to develop in the inclusions.

Summarizing the above, on the basis of the study carried out on primary inclusions, the following may be asserted:

Fig. 1. Series of photographs of a group of primary inclusions in a topaz crystal from the pegmatites of Volhynia at room temperature. 350×.

a—before heating experiments. In each of the inclusions a gas bubble, a small amount of liquid, and a large number of crystals are visible, of which the two largest are quartz (in the center) and muscovite (on the right).

—the same group after heating at 700° for 3.5 h. In the small inclusions glass with bubbles is visible. In the largest inclusion (0.2 mm), part of the quartz crystal remained unmelted.

—the same group after repeated heating; the quartz crystal in the largest inclusion became still more strongly melted.

Fig. 2. Primary inclusions in topaz at room temperature. 600×. **a**—before heating, —after heating to 700°. A strong change in the configuration of the inclusions is clearly visible, from which it follows that about 10% of the topaz must have passed into the liquid phase at 700°.

Figure plate with subfigures labeled , , , .

1. The density and concentration of the pegmatite mother medium were very high; it contained more than 50% SiO_2. The solubility of topaz in this medium proved to be about 10-15% of the total volume.

2. The fact that gas-liquid bubbles existed in the inclusions of silicate glass after heating indicates that the melt was almost saturated with respect to water at the experimental temperature (700°) and contained more than 10% water.

3. On the basis of the temperature at which substantial dissolution of the included minerals and of the walls of the enclosing topaz occurred, it may be assumed that in nature, in pegmatites, the crystallization of topaz, quartz,

muscovite, cryolite, and other minerals took place at approximately 700° and at several thousand atmospheres.

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Received
27 VI 1961

CITED LITERATURE

[1] G. G. Lemmlein, DAN, 72, No. 4, 775 (1950); G. G. Lemmlein, M. O. Kliya, AN, 82, No. 5, 765 (1952).

Note: Figure translations are in progress. See original paper for figures.