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Thermoluminescence in Quartz Irradiated by Gamma Rays —A Mineralogical and Geological Application—

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Thermoluminescence was applied to quartz from various geological origins. And the difference of geological occurrences of quartz was detectable from their glow peaks.

When irradiated by gamma rays, three kinds of glow peak (A, B and C peak) appeared. In this paper, the nature of B and C peak in quartz from various rocks was discussed, mainly the heights and the positions of C peaks after gamma irradiation of 10^7 roentgen were examined. Then it was clarified that the height and the position of C peak are closely related to the geological origin.

Many works regarding thermoluminescence in quartz are well known.[1~7] The nature of glow peaks appeared at various temperatures has been discussed and recently the nature of glow peaks in quartz irradiated by x-rays or gamma rays has considerably clarified by using various methods. Until now, none of the study of thermoluminescence in quartz has been studied from geological point of view.

Quartz grains (100-200 mesh) from various rocks were separated by hand picking, heavy solution and magnetic method. Separated quartz samples were irradiated with the gamma rays of Cobalt 60 (about 1.18×10^5 roentgen per hour).

For a preliminary test, the quartz samples from various geological origins were irradiated with gamma rays of the dosages of 10^5, 10^6, 5×10^6, 10^7 and 2×10^7 roentgen and their thermoluminescence were measured.

The apparatus used for the measurements consists of a furnance with a silver hot plate, a photomultiplier, a D.C amplifer and two-pen recorder. The hot plate (15 mm in diameter) on which the powdered quartz sample (80 mg) was spread evenly was equipped with a chromel-alumel thermocouple. The heating rate was 90°C/min until the temperature reached 450°C.

The emission of the non-irradiated natural quartz samples was feeble and almost neglisible in comparison with that of the artificial gamma irradiated one of high dosage level. It seems to be reasonable that the natural samples were annealed in the earth crust repeatedly. And also the difference of the dose rate between the artificial gamma irradiation and natural radioactivity in the rock may be related.

Each gamma irradiated sample showed the three kinds of glow peak which are classified from their peak range, that is at about 100-120°C (A peak), 185°C (B peak) and 230-290°C (C peak). The glow curves for various dosages in two

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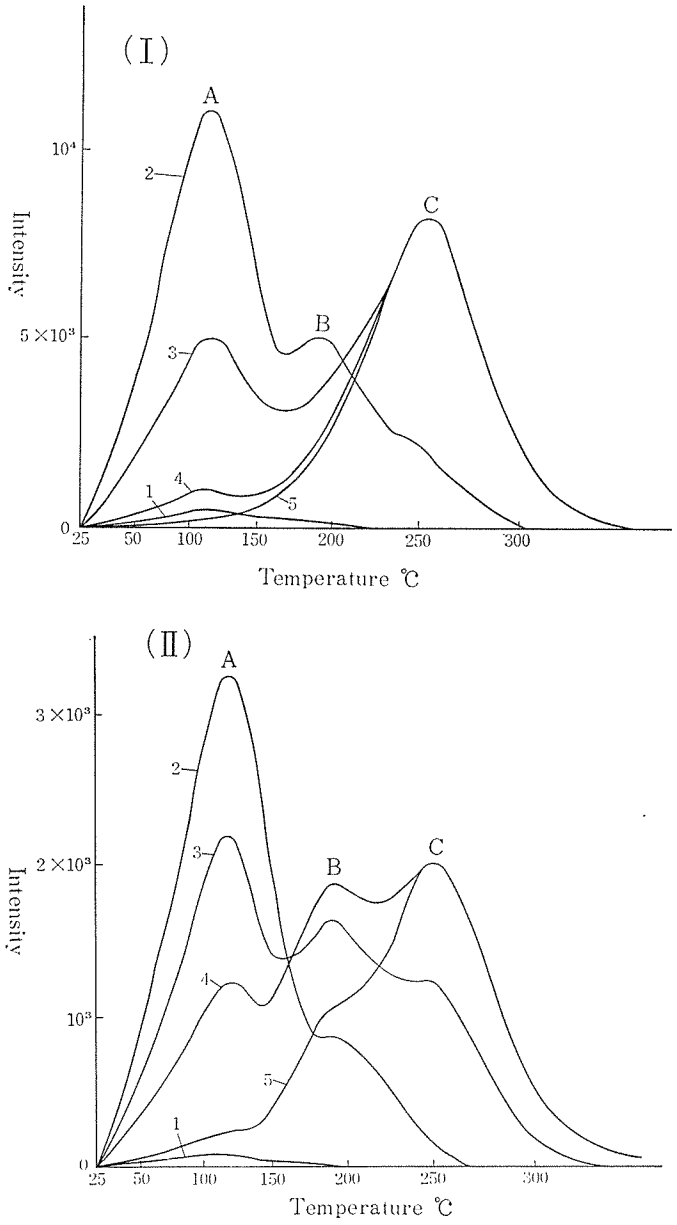

Fig. 1. The glow curves for various dosages (1. 10^5 r, 2. 10^6 r, 3. 5×10^6 r, 4. 10^7 r, 5. 2×10^7 r) in two quartz samples blackened (I) and faintly blackened (II) after gamma irradiation.
(I) high quartz from quartz porphyry (from Yamane, Yamaguchi prefecture)
(II) quartz from pegmatite (from Okugano, Mie prefecture)

quartz samples (blackened and faintly blackened sample after gamma irradiation) are shown in Fig. 1 and the heights of the three kinds of their glow peaks for various dosages are shown in Fig. 2.

Intensity of A peak is attained to the maximum with the dosage of 1×10^6–

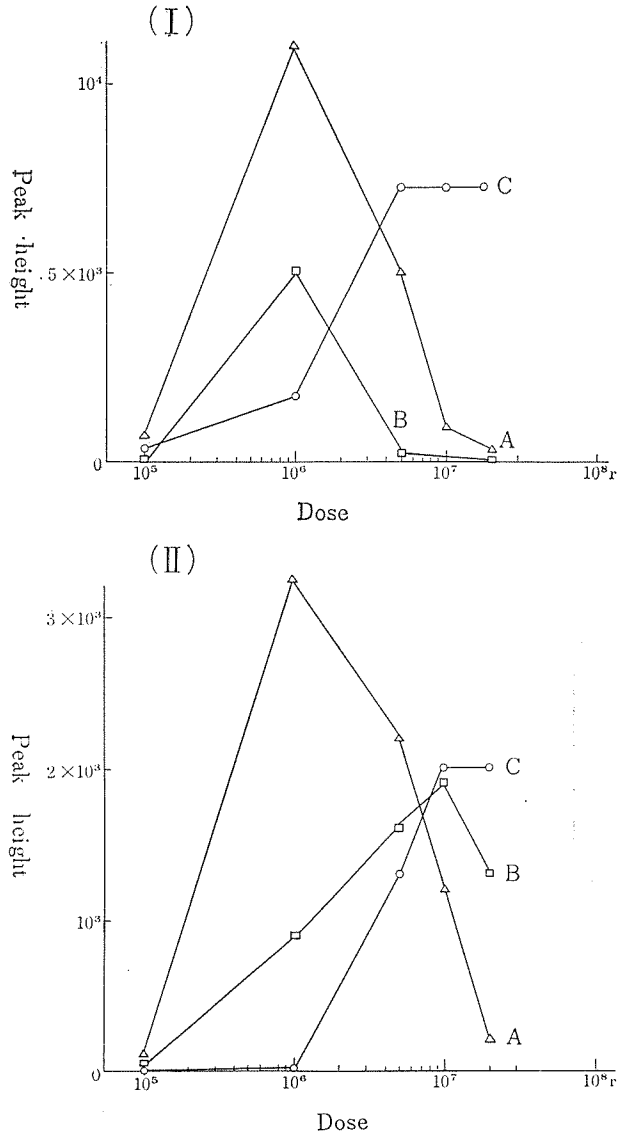

Fig. 2. The heights of the three kinds of glow peak (A, B and C peak) in two quartz samples shown in Fig. 1 for various dosages.

5×10^6 r and gradually decayed with high dosage level. The nature of this peak was studied in detail by Ichikawa (1968),[7] so the nature of this peak is not mentioned in this paper.

The dosage which the intensity of B peak is attained to the maximum is considerably different in each sample. In the samples easily blackened by gamma irradiation, intensity of B peak is attained to the maximum with low dosage level (below 1×10^6 r) (Fig. 2-I), but in the faintly or non-blackened samples which occur in hydrothermal vein or pegmatite, intensity of B peak is attained to the maximum with high dosage level (about 10^7 r) (Fig. 2-II). Ichikawa

(1968)[7] mentioned that this peak might be associated with the alumium center, which consists of hole trapped in the vicinity of the substitutional aluminum and of the interstitial positive ion having trapped an electron, and the center is responsible for the color of smoky quartz. But in the present work, the origin of this peak was not determinable.

Intensity of C peak is saturated with about the dosage of 5×10^6 r in most samples (Fig. 2-I), and with about the dosage of 10^7 r in some samples (Fig. 2-II). In a quartz sample, the intensity of this peak is in proportion to the degree of blackening in quartz. C peak is very stable one in contrast with A and B peak, and the intensity of this peak is not decayed after gamma irradiation of 2×10^7 r (Fig. 2). So quartz samples from various geological origins were irradiated with the dosage of 10^7 r (about the saturation dosage of intensity of C peak for various quartz samples) and were measured on the height (intensity) and the poition (temperature) of C peak. First, relation between the height of C peak and the degree of blackening was examined, but any relation was not found. From the result of measurements, quartz from druse in pegmatite generally showed highest intensity and one from shist or hydrothermal vein with pyrite showed the lowest intensity. The intensity of the former is about 10^4

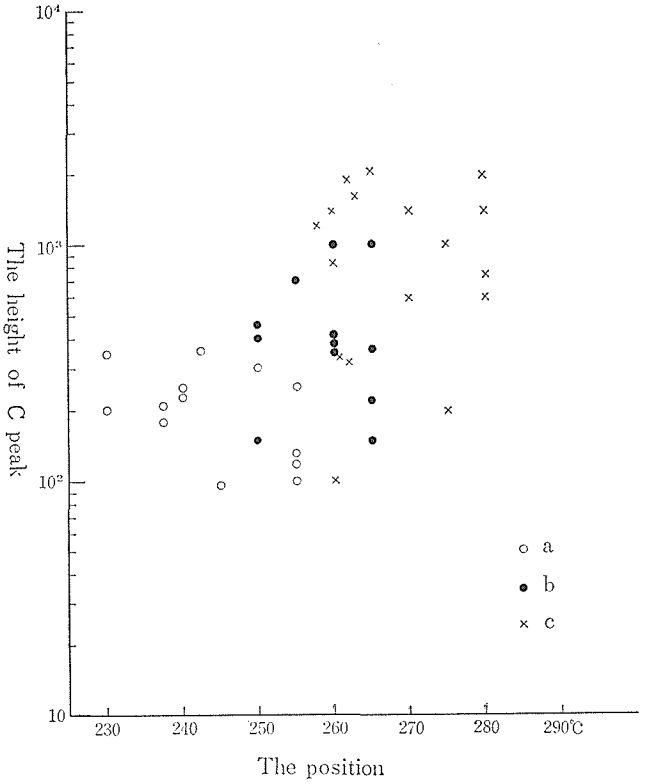

Fig. 3. Variation of the height and the position of C peak in quartz from various rocks after 10^7 r irradiation.
a: high quartz from volcanic rock, b: high quartz from quartz porphyry or granite porphyry, c: quartz from granite

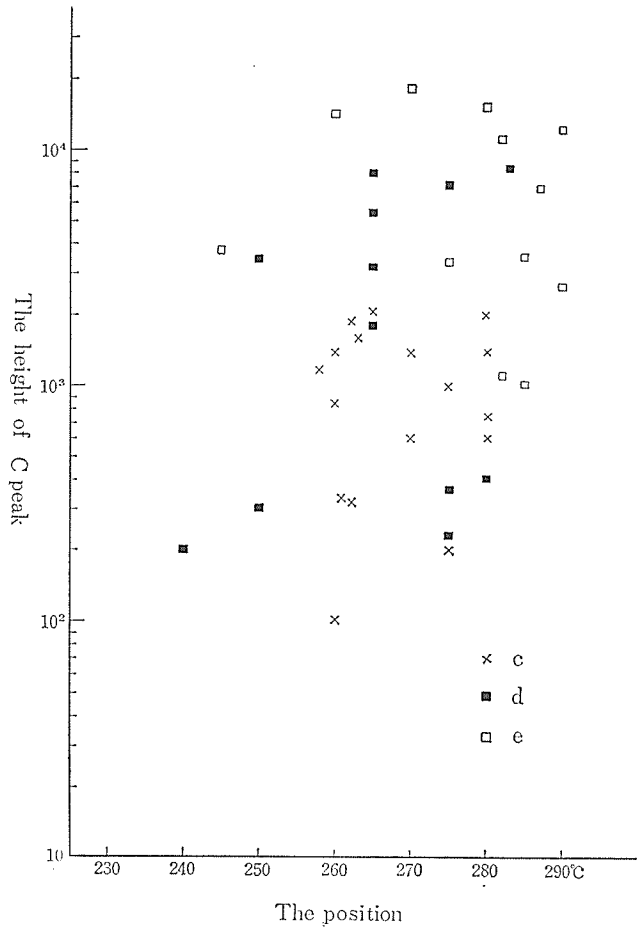

Fig. 4. Variation of the height and the position of C peak in quartz from various rocks after 10^7 r irradiation.
c : quartz from granite, d : quartz from pegmatite, e : quartz from druse in pegmatite.

magnitude of the latter.

The variation of the heights and the positions of C peak for quartz samples from igneous rocks after gamma irradiation of 10^7 r is shown in Fig. 3 and 4. In Fig. 3, granitic quartz and volcanic quartz are grouped into separate areas, and quartz from quartz porphyry or granite porphyry falls into a intermediate area of the two. This phenomenon resembles the result shown in The α-β inversion of quartz from granites and rhyolites after Keith and Tuttle (1952).[8]

As shown in Figs. 3, 4, on the upper limit in the height of C peak for various rock groups, the writer's samples were as follows ; volcanic rock<quartz porphyry or granite porphyry<granite<pegmatite<druse in pegmatite. And also the same relation was detectable on the upper limit in the position of C peak. In volcanic rocks from same volcanic areas, quartz from tuff showed lower temperature (position) than that from lava in the position of C peak.

Quartz samples plotted in the vicinity of the lower limit in the height or in the position of C peak in some rock groups seem to have been formed in specific circumstances. For example, two granitic samples plotted in the vicinity of the lower limit in the height of C peak (Fig. 3) occur in tertiary granite which seem to be of magmatic origin. Five pegmatitic samples showed in the vicinity of the lower limit in the height (Fig. 4) are faintly blackened after gamma irradiation of 10^7 r in contrast with the other pegmatitic samples considerably blackened, so these were formed at lower temperatures than the others and seem to belong to the hydrothermal origin. And three pegmatitic samples plotted in the vicinity of the lower limit in the position (Fig. 4) are coexistent with specific minerals, such as lepidolite, andalusite and corundum. Quartz of of the parallel growth from druse in pegmatite falls into the lower limit of the position (Fig. 4).

In the case of hydrothermal vein, quartz associated with pegmatite showed considerably higher intensity in C peak than that from vein with pyrite. Even in the same quartz vein, quartz from the part of druse showed considerably higher intensity and higher temperature than that from overall in the vein.

In metamorphic rocks, quartz from gneiss generally showed higher intensity than that from shist, but showed slightly lower intensity than that from granite.

In conclusion, B peak is related to the geological occurrence of quartz. The gamma irradiation dosage which attains to the maximum height of B peak, of quartz formed at high temperature is generally lower than that of quartz formed at low temperature.

C peak is closely related to the geological occurrence of quartz. From the data ragarding C peak and occurrences of various rocks, it is clear that quartz grown at the pneumatolitic condition shows generally high in the height and the position of C peak.

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