## NOTES AND NEWS

### EFFECTS OF GAMMA IRRADIATION ON PHYSICAL PROPERTIES OF MINERALS

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In connection with studies of radiation damage in zircons it became of interest to know the effects of various types of radiation on crystals. The present study sought to determine the effects of intense gamma irradiation on a number of minerals.

Homogeneous-appearing mineral samples were selected and examined under the binocular and petrographic microscope in the search for pure specimens. Inclusions and bubbles could not be entirely avoided, especially in quartz, fluorite and halite. Of the materials finally selected, a portion was powdered or otherwise prepared for measurement of physical properties. Parts of both bulk samples and powders were packed with glass wool in glass vials, corked and sent to Brookhaven National Laboratory. There they received $1.5\times10^8$ Roentgens of $Co^{60}$ gamma irradiation. Density of irradiated and non-irradiated portions of all minerals tested and refractive index of most of them were measured. In addition, the 2V's of the micas and the $d_{001}$ dimension of lepidolite were measured.

Densities were measured by a flotation method. After flotation of an 80- 120-mesh powder of a mineral in a $CCl_4$–$C_2H_2Br_4$ mixture or Clerici solution, the density of the liquid was measured with a Christian Becker liquid-density balance which gives direct density measurements to 0.0001 gm./cc.

Refractive indices were measured in immersion liquids using a temperature-variation and a half-shadow method. Illumination was supplied by a sodium vapor lamp. The 2V's of the micas were measured on a universal stage, and the $d_{001}$ dimension of lepidolite was measured with a North American Philips high-angle spectrometer using Fe $K\alpha$ radiation.

Experimental conditions were kept as constant as possible throughout all measurements in order to minimize systematic differences between measurements on irradiated and non-irradiated materials.

Except for difference in color, no significant differences were detected between irradiated and non-irradiated samples (see Tables 1–4).

Precision measurements by Frondel and Hurlbut (1955, p. 1216) showed that decolorization of smoky quartz by heating at 350° was attended by an increase in the indices of refraction. They (1955, p. 1217)

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stated that density changes attendant on decolorization of smoky quartz were unknown, but that Frondel had found earlier that the elastic constants of a particular sample had changed appreciably upon decolorization. The color of all glass specimens and all except one quartz specimen (amethyst) in the present study changed to brown or smoky (smoky quartz became smokier) as a result of gamma irradiation. These results suggest that changes in the physical properties of the samples used in the present study may have been induced by the irradiation, but that these changes were too small to detect with the techniques used.

For each type of fluorite the apparent change of density was within the assigned experimental uncertainty, but in each case the density decreased slightly between 0.001 and 0.003 gm./cc.

Muscovite showed an apparent increase in density and the overlap of the ranges of error of the two measurements was very small. The results on biotite and lepidolite suggest that the result on muscovite was not significant.

Lepidolite showed a significant apparent increase in density (questioned value in Table 1). However, after remeasurement of densities of irradiated and non-irradiated lepidolite, the two values on non-irradiated material and the second on irradiated material lay within a range of

TABLE 1. DENSITY AND REFRACTIVE INDEX MEASUREMENTS

| Mineral | Non-irradiated | | Irradiated | |
|---|---|---|---|---|
| | Density | Refractive index (±0.0003) | Density | Refractive index (±0.0003) |
| Colorless fluorite | 3.187±0.005 | 1.4337 | 3.183±0.0035 | 1.4337 |
| Blue fluorite | 3.185±0.003 | 1.4336 | 3.184±0.002 | 1.4337 |
| Blue-green fluorite | 3.186±0.003 | 1.4339 | 3.183±0.0035 | 1.4336 |
| Pink fluorite | 3.187±0.0005 | 1.4336<br>1.4337 | 3.184±0.002 | 1.4338 |
| Halite | 2.164±0.004 | 1.5439 | 2.162±0.001 | 1.5440 |
| Colorless quartz | 2.655±0.0055 | 1.5440* | 2.650±0.0035 | 1.5442* |
| Amethyst | 2.651±0.0035 | 1.5441* | 2.651±0.002 | 1.5441* |
| Rose quartz | 2.650±0.002 | 1.5441* | 2.650±0.003 | 1.5442* |
| Epidote | 3.467±0.005 | | 3.465±0.004 | |
| Allanite | 3.618±0.013 | | 3.606±0.007 | |
| Muscovite | 2.847±0.005 | ca. 1.596 | 2.854±0.003 | |
| Biotite | 2.884±0.0035 | ca. 1.600 | 2.884±0.002 | |
| Lepidolite | 2.846±0.006<br>2.844±0.004 | ca. 1.560 | 2.860±0.001?<br>2.845±0.004 | ca. 1.5595 |

* Omega index.

TABLE 2. 2V MEASUREMENTS

| Mineral | Non-irradiated | Irradiated |
|---|---|---|
| Muscovite | 43.1°±0.4° | 43.6°±0.4° |
| Biotite | ca. 5° | 8.8°±0.5°<br>7.3°±0.6° |
| Lepidolite | 47.2°±0.1°<br>44.9°±0.4°<br>43.4°±0.1°<br>32.2°±0.4° | 44.3°±0.2°<br>44.4°±0.1°<br>44.5°±0.2° |

0.002 gm./cc. As a further check, 2V's of several specimens of irradiated and non-irradiated lepidolite were measured (Table 2). Those of irradiated specimens were consistently about 44°; the non-irradiated lepidolite exhibited 2V's ranging generally from 43° to 47°, but one flake showed a quite different 2V of about 32° (in some portions the flake showed a 2V of more than 43°). The $d_{001}$ spacing of three specimens each of irradiated and non-irradiated lepidolite was measured on the assumption that a change in density would likely be reflected in this lattice dimension. All values lay in the range 9.93 to 9.94 Å (see Table 3; note that, among non-irradiated specimens, that with a 2V of 32° showed the most anomalous value). It was concluded that no significant change occurred in the lepidolite.

Observed color changes in those minerals in which it was discernible are presented in Table 4. Only the micas and the initially deeply colored allanite and epidote failed to show a noticeable change.

## CONCLUSION

$1.5\times10^8$ Roentgens of $Co^{60}$ gamma irradiation are insufficient to induce, within the limits of experimental error of the present study, significant changes in the density and refractive index of halite, fluorite,

TABLE 3. LEPIDOLITE, $d_{001}$ (Å)

| | |
|---|---|
| Non-irradiated | 9.930<br>9.939 (2V ca. 32°)<br>9.934 |
| Irradiated | 9.936<br>9.936<br>9.941 |

TABLE 4. COLOR CHANGES UPON IRRADIATION

| Mineral | Non-irradiated | Irradiated (bulk) | Irradiated (powder) |
|---|---|---|---|
| Colorless fluorite | colorless | "pure" blue, moderate intensity | very light blue |
| Blue fluorite | light purplish blue | bluish purple, moderate intensity | very lightly colored |
| Blue-green fluorite | light blue-green | deep blue-green | deep blue-green |
| Pink fluorite | very light pink | purple with patches of blue like that of irradiated colorless fluorite; moderate intensity | (powder lost) |
| Halite | colorless | deep brown | brownish gray |
| Colorless quartz* | colorless | brown (between irradiation smoky and irradiated rose in intensity) | smoky (between irradiated smoky and irradiated rose in intensity) |
| Amethyst | purple, somewhat variegated, light intensity | purple, variegated, moderate intensity | no visible change |
| Rose quartz* | light pink | brown (smoky), very intense | gray-brown (smoky), intense |
| Smoky quartz* | light gray-brown | no change | intensification of smoky color |
| Epidote | moderate to dark green | no change | no change |
| Allanite | dark brown or black | no change | no change |
| Muscovite | colorless | no change | ——— |
| Biotite | dark brown to black | no change | ——— |
| Lepidolite | pink | no change | ——— |
| Vial glass | colorless | deep brown | ——— |
| Glass slide | colorless | deep brown | ——— |
| Pyrex(?) tubing | colorless | moderate brown | ——— |
| Cover glass | colorless | light brown | ——— |

* Relative intensities of brown color or smokiness in those quartzes showing it, from most to least intense: irradiated rose, irradiated colorless, irradiated smoky, non-irradiated smoky.

quartz, epidote, allanite, muscovite, biotite and lepidolite; in the 2V's of the three micas; and in the $d_{001}$ spacing of lepidolite. Color changes are quite striking in many colorless and light-colored minerals and glasses.

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REFERENCE

FRONDEL, C., AND HURLBUT, C. S., JR. (1955), Determination of the atomic weight of silicon by physical measurements on quartz: *Jour. Chem. Phys.*, **23**, 1215–1219.

## URANOTHORITE NEAR FOREST HOME, SAN BERNARDINO COUNTY, CALIFORNIA*

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The intensive search for uranium in southern California during recent years is yielding discoveries of some uncommon uranium and thorium minerals, some of which occur under unusual or unique geologic environments. The presence of uranium minerals near Forest Home, San Bernardino County, was brought to the attention of D. F. Hewett early in 1955 by Pierre George, an amateur collector of minerals, of San Gabriel. After some preliminary tests of the materials collected by Mr. George, the area was visited by D. F. Hewett in April. Laboratory work by Jerome Stone and others of the U. S. Geological Survey has confirmed the presence of uranothorite and several other thorium-bearing minerals at several localities near Forest Home.

Forest Home P. O. is on the south side of Mill Creek, due south of San Bernardino Mountain, in the principal valley that drains the south slopes of San Bernardino Mountain (Fig. 1). Eastward from Forest Home, the successive tributaries of Mill Creek from the north are Lost Creek, Alger Creek, and Falls Creek. The uranothorite locality is an opencut on the east slope of Alger Creek valley about 300 feet above the creek and about 3,000 feet north of the point where Alger Creek joins Mill Creek. A rough road follows Alger Creek to an ore bin, and a chute extends up the slope to the opencut. The opencut is about 30 feet long and it is limited by a vertical wall about 15 feet high. During 1954, a few tons of material, probably less than 10 tons, were sorted and shipped for its content of uranium. The names of the owners or shippers are not known.

At another locality, higher on the ridge west of Alger Creek, several

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