# A MINERALOGIC INVESTIGATION OF SOME GARNETS FROM THE CATALINA MOUNTAINS, PIMA COUNTY, ARIZONA

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## INTRODUCTION

The rocks exposed in the Front Range and crestal portions of the Catalina Mountains contain abundant garnet. A mineralogic investigation was undertaken to determine the nature of the garnets in representative rock types. Thirty specimens were selected for this study from the rocks exposed along the crest of the Catalina Mountains in the general vicinity of Palisades Ranger Station (Fig. 1).

The rocks sampled include various members of the Mesozoic(?) gneiss and granite complex (DuBois, 1959) including banded augen gneiss, augen gneiss, granitic gneiss, gneissic granite, and aplitic to pegmatitic materials; as well as metasediments of the Apache group of Younger Precambrian age. The generalized geologic features and sample locations are shown in Figure 1. The mineralogic investigations included (1) refractive index determinations, (2) density determinations, (3) qualitative chemical tests, (4) unit cell edge determinations, and (5) determination of chemical composition.

## MINERALOGIC INVESTIGATIONS

### Refractive Index

The index of refraction was determined by matching the index of crushed fragments with that of calibrated oil immersion liquids. Preliminary investigations were made in white light by the oblique illumination method. The dispersive properties of the immersion media gave distinct color fringes when the index of the fragment matched the index of the liquid for yellow light. The match was then checked using sodium light. The accuracy of the determinations is believed to be good to $\pm 0.002$.

The refractive indices for the end members of the garnet group have been calculated by Ford (1915) and measured by Skinner (1956). The results are compared in Table 1. The refractive indices determined in the present work indicates that the garnets are not pure end members, but consist of mixtures of two or more components (Table 3).

### Specific Gravity

The specific gravity of the garnets was determined on the Berman

TABLE 1
REFRACTIVE INDEX OF GARNETS IN SODIUM LIGHT

| End Member | Ford | Skinner |
|---|---|---|
| Grossularite | 1.735 | 1.734 ±0.002 |
| Andradite | 1.895 | 1.887 ±0.002 |
| Almandite | 1.830 | 1.830 ±0.002 |
| Spessartite | 1.800 | 1.800 ±0.002 |
| Pyrope | 1.705 | 1.714 ±0.002 |

Microbalance with toluene as the immersion media. The larger samples were weighed in the double pan attachment. The results of successive readings on the same sample agreed within ±0.001 for most samples 10 mg or larger. The density value presented represents the average of three measurements. For samples where the individual grains weighed less than 10 mg, and whose diameter was too small to stay in the helical basket of the double pan attachment, the powder basket was used. The results obtained with the powder basket were subject to much more variation, ±0.005, for successive measurements on the same sample. The most reproducible results were obtained when the garnets were placed into the basket after wetting it with toluene and immersing it immediately. The specific gravity value represents the average of six successive measurements.

Some published values of specific gravity for the end members of the garnet group are shown in Table 2. The values by Fleischer (1937) are calculated from measurements made upon natural compound garnets. Those by Skinner (1956) are calculated from the volume of the unit cell. The density determinations (Table 3) indicate that the garnets under investigation are mixtures of two or more end members of the garnet group.

TABLE 2
MEASURED AND CALCULATED DENSITIES OF GARNETS

| End Member | Fleischer Measured Sp. G. | Skinner Calculated Sp. G. |
|---|---|---|
| Grossularite | 3.530 | 3.594 |
| Andradite | 3.835 | 3.859 |
| Almandite | 4.325 | 4.318 |
| Spessartite | 4.180 | 4.190 |
| Pyrope | 3.510 | 3.582 |

Unit Cell Edge Determinations

X-ray powder photographs of 15 garnet samples were taken with a Philips 114.58 mm diameter powder camera having the Straumanis film mounting. The samples were prepared as rolled spindles using Duco cement as the

TABLE 3
PHYSICAL PROPERTIES OF THE CATALINA GARNETS

| Sample Number | Rock Type | Refractive Index | Density | Cell Edge (Å) | Composition |
|---|---|---|---|---|---|
| Sc 109 | Aplite to pegmatite | 1.813 | 4.100* | | |
| Sc 119 | Gneissic granite | 1.817 | 4.104 | 11.630 | $alm_{46}$ $sp_{16}$ $pyr_{20}$ $and_{18}$ |
| Sc 123 | Aplitic dike | 1.813 | 4.102* | 11.629 | $alm_{40}$ $sp_{32}$ $pyr_{16}$ $and_{14}$ |
| Sc 144 | Gneissic granite | 1.815 | 4.094 | 11.629 | $alm_{50}$ $sp_{24}$ $pyr_{12}$ $and_{14}$ |
| Sc 146 | Gneissic granite | 1.827 | 4.190* | 11.623 | $alm_{58}$ $sp_{23}$ $pyr_{4}$ $and_{15}$ |
| Sc 167 | Granitic gneiss | 1.823 | 4.171 | 11.627 | $alm_{45}$ $sp_{31}$ $pyr_{6}$ $and_{14}$ |
| Sc 205 | Augen gneiss | 1.817 | 4.145 | 11.630 | $alm_{47}$ $sp_{28}$ $pyr_{12}$ $and_{13}$ |
| Sc 226 | Pegmatite | 1.820 | 4.169* | 11.625 | $alm_{46}$ $sp_{36}$ $pyr_{6}$ $and_{12}$ |
| Sc 242 | Gneissic granite | 1.823 | 4.190 | 11.626 | $alm_{52}$ $sp_{27}$ $pyr_{6}$ $and_{15}$ |
| Sc 276 | Gneissic granite | 1.816 | 4.094 | 11.625 | $alm_{48}$ $sp_{21}$ $pyr_{16}$ $and_{15}$ |
| Sc 278 | Pegmatitic gneiss | 1.814 | 4.103* | 11.629 | $alm_{46}$ $sp_{24}$ $pyr_{14}$ $and_{16}$ |
| Sc 280 | Pegmatite | 1.820 | 4.133* | 11.628 | $alm_{52}$ $sp_{21}$ $pyr_{11}$ $and_{16}$ |
| Sc 285 | Banded augen gneiss | 1.813 | 4.144 | 11.632 | $alm_{34}$ $sp_{49}$ $pyr_{8}$ $and_{9}$ |
| Sc 286 | Mica schist | 1.817 | 4.113 | 11.628 | $alm_{52}$ $sp_{23}$ $pyr_{13}$ $and_{12}$ |
| Sc 292 | Gneissic granite | 1.815 | 4.150 | 11.628 | $alm_{38}$ $sp_{44}$ $pyr_{7}$ $and_{11}$ |
| Sc 305 | Gneissic granite | 1.814 | 4.123 | 11.628 | $alm_{42}$ $sp_{32}$ $pyr_{11}$ $and_{14}$ |
| Sc 318 | Pegmatite | 1.819 | 4.168 | | |
| Sc 322 | Granitic augen gneiss | 1.819 | 4.157 | | |
| Sc 323 | Aplite dike | 1.825 | 4.176* | | |
| Sc 326 | Gneissic granite | 1.817 | 4.148* | | |
| Sc 331 | Gneissic granite | 1.823 | 3.986*** | | |
| Sc 338 | Massive granite | 1.817 | 4.113 | | |
| Sc 342 | Gneissic granite | 1.821 | 4.193 | | |
| Sc 344 | Gneissic granite | 1.822 | 4.182 | | |
| Sc 362 | Massive granite | 1.813 | 4.129 | | |
| Sc 379 | Gneissic granite | 1.815 | 4.131 | | |
| Sc 382 | Gneissic granite | 1.820 | 4.192 | | |
| Sc 387 | Gneissic granite | 1.821 | 4.166 | | |
| Sc 425 | Gneissic granite | 1.822 | 3.827*** | | |
| Sc 436 | Mica schist** | 1.815 | 4.140 | | |

* Density determinations with powder basket.

** Mica schist from Rincon Mountains.

*** Doubtful values—garnets highly fractured.

binding agent. Nickel filtered Copper $K_{\alpha}$ radiation was used and the X-ray unit was run at 40 KV and 20 ma. Good resolution in the back reflection region was obtained with exposures of 5 to 6 hours.

TABLE 4
CELL SIZES OF GARNETS, $a_0$(Å)

| | |
|---|---|
| Grossularite | 11.851 |
| Andradite | 12.048 |
| Almandite | 11.526 |
| Spessartite | 11.621 |
| Pyrope | 11.459 |

The values for the unit cell sizes were determined by taking the average cell edge for the six highest 2θ angles. The probable accuracy of the $a_0$ value is $\pm$0.001 (Table 3). The cell sizes of the pure end members of the garnet group were determined by Skinner (1956) and are shown in Table 4.

## Chemical Composition

Inasmuch as the determination of chemical composition of garnets based upon their physical properties necessitates some knowledge of the elements present certain qualitative tests were employed. Manganese, the most critical element, was determined by the sodium carbonate bead test (Brush and Penfield, 1898) and also by the sodium bismuthate test (Short, 1940). Positive results were obtained for each of the garnets for which the cell edge had been determined.

The chemical composition was determined from the physical properties previously investigated by reference to Figure 2 of a paper by Winchell (1958). The most significant properties, the cell edge and refractive index (N), are used as the abscissa and ordinate respectively. Winchell then plotted each of the end members described by Skinner (1956) and connected each by a straight line. The third variable, specific gravity, was then plotted as contour lines on the tetrahedra thus formed. An unknown garnet can be located with respect to two faces of the tetrahedron by plotting $a_0$ and N, and then can be located within the tetrahedron by a contour representing its density. The chemical composition of the garnet can then be expressed in terms of four end members. The data for the Catalina garnets is summarized in Table 3.

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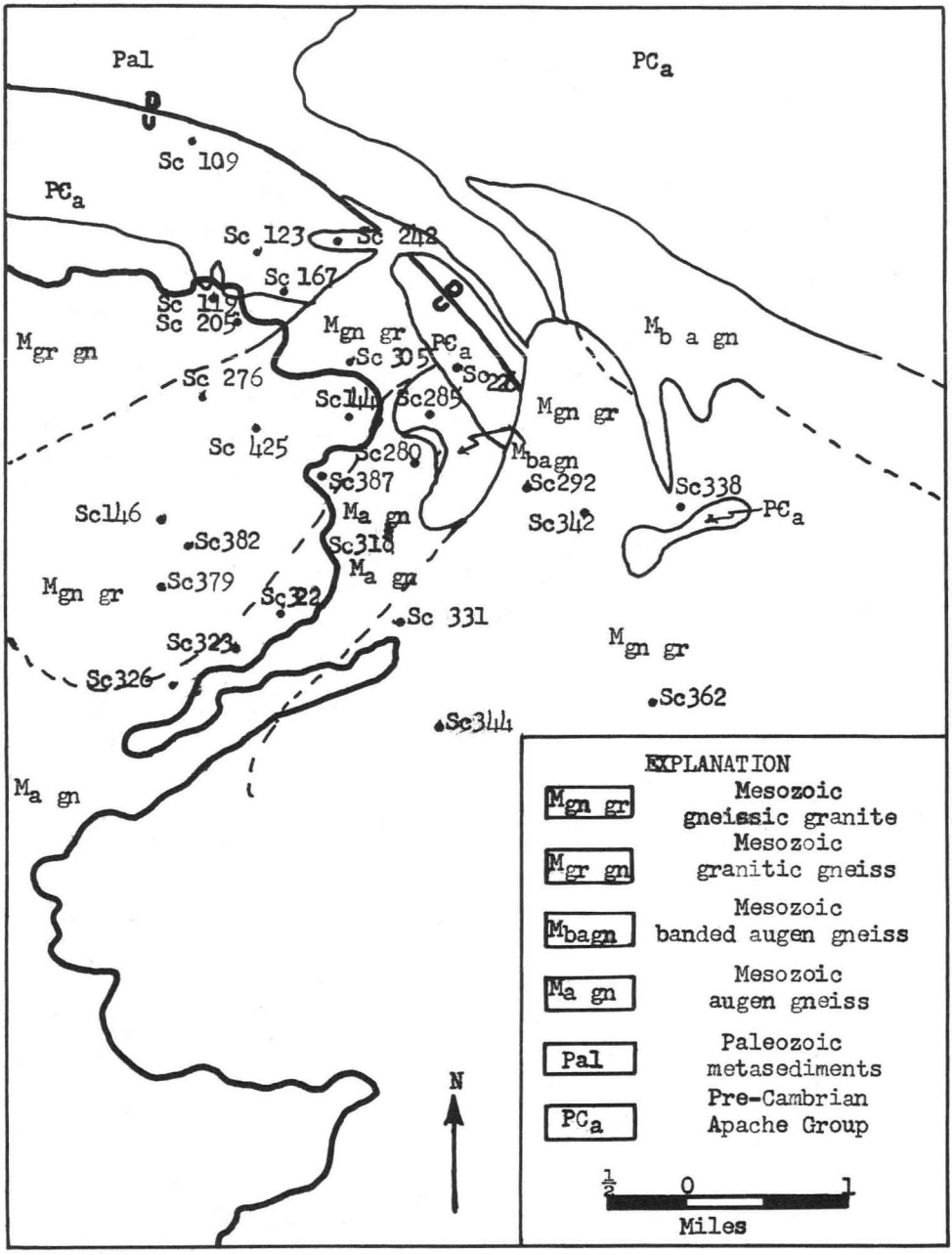


Figure 1. --Sketch map of the general geologic features and sample locations.