ditions were noted. Thus Fe and Cr preferentially populate the larger $Al_{II}$ sites, consistent with size considerations. This result is contrary to the assumption of Vinokurov *et al.* (1960). In explaining the electron paramagnetic resonance (EPR) spectrum of natural chrysoberyl, they hypothesize that Fe occupies only the inversion symmetry sites. Their interpretation of the EPR data has been questioned by Germanier *et al.* (1962).

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# NOTES ON WESTERN MINERAL OCCURRENCES[1]

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## 3. THULITE FROM CAMP CREEK, RUBY MOUNTAINS, MONTANA

Unusually fine specimens of thulite occur at the Camp Creek corundum deposit in the NE $\frac{1}{4}$, sec. 36, T. 8 S., R. 8 W., about $\frac{1}{3}$ mile southwest of the Crystal Graphite mine and about 11 miles southeast of Dillon in southwestern Montana. The occurrence is at an elevation of about 7000 feet near the southwestern corner of the southern Ruby Range. The thulite occurs in a lens of impure marble, 280 feet long and as much as 100 feet thick, which is enclosed in a northeast-trending layer of biotite schist, both forming part of the Prebeltian Cherry Creek Group (Heinrich, 1950; Heinrich and Rabbitt, 1960).

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[1] Contribution No. 260 from The Mineralogical Laboratory, Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan.

The banded carbonate rock ranges from a nearly pure dolomitic marble to a Ca-Mg silicate gneiss consisting chiefly of various proportions of: diopside, tremolite, phlogopite, epidote-group minerals and calcite. Some varieties consist almost entirely of tremolite, blades of which reach 6 inches in length; another type is made up almost exclusively of granular diopside. In the diopsidic rocks, pyroxene bands alternate with bands of plagioclase.

Accessory species include calcic plagioclase, sphene and zircon. Replacing the Ca-Mg silicates is a very fine-grained, porcelanoid aggregate of sericite-chlorite ± talc, calcite and magnetite.

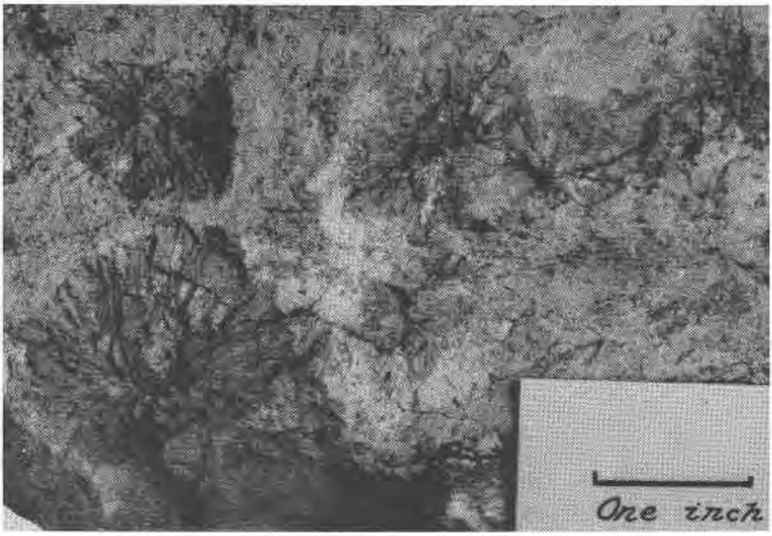

FIG. 1. Rosettes of thulite in diopside-plagioclase marble, Camp Creek, southern Ruby Mountains, Montana.

The epidote minerals occur as individual porphyroblasts or, less commonly, as striking porphyroblastic radial aggregates (Figs. 1 and 2), some of which are 2–3 inches across. They occur within the plagioclase layers, cutting across their fabric and replacing the feldspar. Microscopically, individual blades display conspicuous twinning and show zoning in two ways:

1. Color zoning. The aggregates are distinctly pleochroic in shades of pink near their centers, becoming paler outward along each blade to the colorless extremities.
2. Zoning revealed by variations in birefringence.

Within the marble occur three lenses of corundum gneiss (Heinrich,

1950) which range from 20–130 feet in length and 4–20 feet in thickness. The metamorphic layers are cut, at nearly right angles, by two post-metamorphic diabase dikes that are steeply dipping to vertical and average only a few feet in thickness. These intrusives are part of a prominent swarm of large diabase dikes that represent the youngest Prebeltian unit in southwestern Montana (Heinrich and Rabbitt, 1960).

The corundum gneiss consists of grains and crystals of corundum (5–35%), some beautifully zoned, and variable amounts of biotite, thulite, epidote, calcic plagioclase and diopside; accessory rutile, zircon, tourmaline and apatite; and a fine-grained aggregate of intimately mixed sericite, chlorite, margarite, calcite and magnetite. This last aggregate corrodes and replaces corundum, thulite-epidote, biotite and plagioclase.

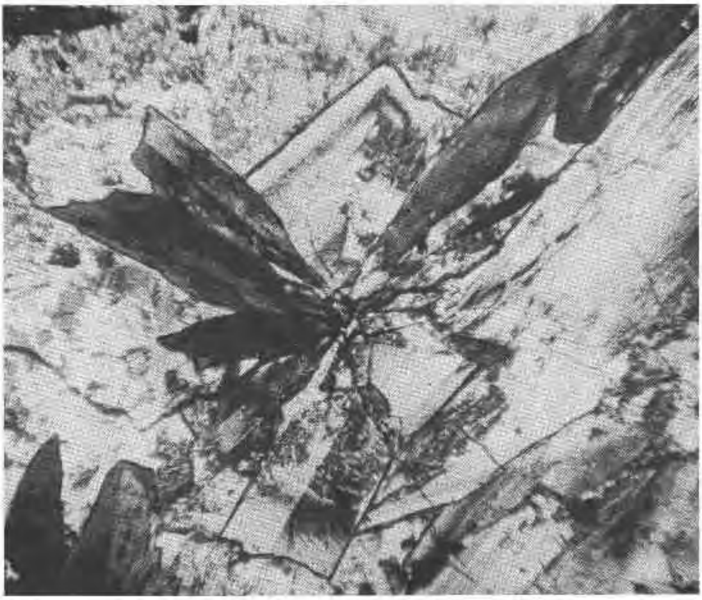

FIG. 2. Complex radial aggregate of thulite (central) passing outward into clinozoisite-epidote, in calcic plagioclase altered to sericite-calcite aggregates. Polars crossed, ×30. Camp Creek corundum deposit, near Dillon, Montana.

The geological history of the thulite marble and the corundum gneiss is outlined in Table 1.

The three stages are part of a single continuous period of metamorphism which moved relatively rapidly to conditions of the amphibolite facies, sillimanite-almandite subfacies, then declined relatively slowly, under decreasing temperatures and negligible stress, to conditions of the

TABLE 1. GEOLOGICAL HISTORY OF THULITE-BEARING ROCKS AT THE CAMP CREEK CORUNDUM DEPOSIT

| | Thulite marble | Corundum gneiss |
|---|---|---|
| Original rock | Argillaceous, dolomitic limestone | High-alumina (bauxitic) clay |
| 1st stage metamorphism (amphibolite facies, sillimanite-almandite subfacies) | Diopside, phlogopite, calcite, calcic plagioclase, sphene, zircon | Corundum, biotite, calcic plagioclase, diopside, rutile, zircon, tourmaline, apatite |
| 2nd stage metamorphism (albite-epidote-amphibolite facies) | Epidote, thulite, tremolite | Thulite, epidote |
| 3rd stage metamorphism (greenschist facies) | Sericite, chlorite, talc, calcite, magnetite | Sericite, chlorite, margarite, calcite, magnetite |

albite-epidote amphibolite facies and finally, rather abruptly, to the environment of the greenschist facies. The intrusion of the diabase dikes has had no discernible effect on the youngest, low-grade metamorphic assemblage.

The analysis of the thulite is presented in Table 2. The writer gratefully acknowledges a grant from the Geological Society of America, a part of which paid for the cost of the analysis.

TABLE 2. COMPOSITION OF THULITE FROM CAMP CREEK, MONTANA

| | 1 | 2 | | 3 |
|---|---|---|---|---|
| $SiO_2$ | 39.27 | .6512 | .6513 | 6 |
| $TiO_2$ | 0.01 | .0001 | | |
| $Al_2O_3$ | 31.51 | .3083 | .3226 | 3 |
| $Fe_2O_3$ | 1.83 | .0114 | | |
| $Mn_2O_3$ | 0.45 | .0029 | | |
| FeO | 0.08 | .0011 | .4427 | 4 |
| MgO | 0.56 | .0138 | | |
| CaO | 23.95 | .4269 | | |
| $Na_2O$ | 0.02 | .0003 | | |
| $K_2O$ | 0.06 | .0006 | | |
| $H_2O^+$ | 2.02 | .1120 | .1120 | 1 |
| $H_2O^-$ | 0.00 | | | |
| Total | 99.76 | | | |

Analyst, John A. Maxwell.

Formula: $(Ca_{1.92}Mg_{0.06}Fe_{0.02})_2(Al_{2.86}Fe_{0.10}^{3+}Mn_{0.04}^{3+})_3Si_3O_{12}(OH)$.

The amount of manganese is small, although not surprisingly so, in view of results obtained by other investigators of thulite (see, for example, Schaller and Glass, 1942; Neumann and Svinndal, 1955; Deer *et al.*, 1962, p. 188), and in view of the fact that, although the entire rosettes are pink megascopically, in thin section only their centers show discernible color and pleochroism.

The high local variability of the epidote minerals is typical of many of their occurrences and emphasizes the fact that small changes in their chemical compositions (especially $Fe^{3+}$ and $Mn^{3+}$) produce disproportionately large changes in their optical properties.

## 4. HYPERSTHENE VEINLETS, TIMBER GULCH, RUBY MOUNTAINS, MONTANA

Both ortho- and para-amphibolites and hornblende gneisses form important and conspicuous units in the Prebeltian Cherry Creek Group in southwestern Montana (Heinrich and Rabbitt, 1960). In Timber Gulch, a southwestward-trending tributary of Blacktail Creek on the southern flank of the Ruby Mountains, southeast of Dillon, Montana (sec. 1, T. 9 S., R. 8 W.), a discontinuous lensoid body of hornblende gneiss, 1500 feet long, trends northeast and dips northwest. The lenses are completely enclosed in granitoid gneiss. As in many such bands the hornblende is partly altered to anthophyllite to form local anthophyllite-hornblende gneiss. At the top of one of the lenses is a band of anthophyllite-garnet gneiss, 5–10 feet across and 200 feet long. Within it occur remnants of fine-grained banded hornblende gneiss in which hornblende-plagioclase-quartz bands alternate with garnetiferous hornblende-rich bands. Cutting across the banding at slight angles are pegmatoid veinlets that contain calcic plagioclase, quartz and crystals of hypersthene, the largest of which measures 1×2 cm. The veinlets themselves are as much as 4 cm thick.

The anthophyllite-bearing amphibolite lenses occur entirely within intrusive granitoid gneisses of syntectonic character (Dillon granite gneiss). Within the lenses three stages of mineral formation are recognizable:

1. Hornblende, calcic plagioclase, garnet, quartz
2. Anthophyllite, replacing hornblende
3. Hypersthene veinlets

The last may be correlated with enclosure of the disrupted amphibolite band within the intruding Dillon granite. A somewhat similar example has been described by Wilson (1952) from the Kulgera Hills, Alice Springs, central Australia, where a rheomorphic granitic dikelet has produced metasomatic aluminous hypersthene replacing the clinopyroxene of an olivine diabase that the dikelet intrudes. It is also noteworthy that the thermal disintegration of ferrous anthophyllite results in the formation of aluminous hypersthene, cristobalite and water (Wittels, 1952).

These studies have been supported by a grant from the Horace H. Rackham School of Graduate Studies (N.S.F.-I.G. 39), of The University of Michigan.

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# DISCUSSION OF "CLEAVAGE IN QUARTZ" BY F. D. BLOSS AND G. V. GIBBS

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There are two points in connection with the paper by Bloss and Gibbs (1963) which, in my opinion, require comment. The first concerns the relatively large number of measurements carried out by the authors which is likely to impress the uninitiated reader. It should be pointed out that the yield of *additional* statistical information per measurement diminishes quite rapidly as the number of measurements increases. Had the experiment been properly designed (from a statistical point of view) a total of three hundred measurements should have been more than adequate to give rise to practically identical results. The effort in carrying out the remainder of the 2269 measurements seems to be wasted, which is especially deplorable in view of the laborious nature of the measurements involved.

The second point concerns the conclusions of the authors which represent another attempt to perpetuate the myth of the existence of cleavages parallel to $r$ and $z$ in quartz. Their conclusions as to the cleavage directions do not follow logically from the result of their experiment and are no more justified than the conclusions arrived at in Bloss' earlier paper