

in oligoclase. They, however, continue to appear after the beginning of quartz crystallization and the larger and better developed chrysoberyls especially are found embedded in quartz. Quartz, enormously the most abundant constituent of the dike, closed the period of crystallization leaving no cavities and forming, alone of all the minerals present, no free crystals.

## CLINOZOISITE FROM LOWER CALIFORNIA<sup>a</sup>

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The locality for the specimens described in this article is the Juarez District, Lower California, Mexico, about 65 miles south of the international boundary. The specimens were obtained from R. M. Wilke, mineral dealer of Palo Alto, California. The mineral is said to occur at the contact between a limestone and an igneous rock. It is probably the same locality that furnished the zoisite described by Farrington.<sup>1</sup>

The material at my disposal consists of five specimens including minerals associated with the clinozoisite. Two of them are pure clinozoisite, one of which is a rough euhedral crystal. Another specimen consists of pink and colorless zoisite ( $n$  about 1.710) in prismatic aggregates with an interior of gray clinozoisite, the two minerals apparently being in parallel position. This specimen resembles the material described by Farrington,<sup>2</sup> but the clinozoisite was evidently overlooked by him. The clinozoisite and zoisite may be distinguished by peculiarities in the interference colors as will be shown later.

In this specimen, and another somewhat similar one, the zoisite is embedded in a matrix of colorless prehnite. Farrington has suggested that the prehnite is the mineral analyzed by Schaller.<sup>3</sup>

The fifth specimen consists of slightly tapering and somewhat flattened prismatic aggregates of zoisite ( $n = 1.707 \pm 003$ ). This is distinguished from the clinozoisite by both the index of refraction and interference colors.

<sup>a</sup> Since this article has gone to press there has appeared in the *Am. Min.*, 9, p. 199, a paper by E. L. Bruce and C. W. Greenland on "A low iron epidote from Porcupine." It is quite likely that this is another occurrence of clinozoisite although no mention is made of anomalous interference colors.—EDITOR.

<sup>1</sup> FIELD COLUMBIAN MUSEUM. *Publication* 112, *Geol. Series*, III, 55-57, (1906).

<sup>2</sup> *Loc. cit.*

<sup>3</sup> *Bull.* 262, *U. S. Geol. Surv.*, p. 128 (1905).

CRYSTAL MORPHOLOGY. One of the specimens examined is a rather large ( $5 \times 3 \times 2$  cm.) rough crystal of greenish gray color somewhat elongated in the direction of the  $b$ -axis as is usual with epidote. The forms present are  $a\{100\}$ ,  $c\{001\}$  and  $f\{\bar{3}01\}$ ; the crystal is broken off where terminal faces might show. Measurements made with a contact goniometer gave the following:  $ac$  ( $100:001$ ) =  $63^\circ 40'$  (calc. for epidote =  $64^\circ 37'$ );  $cc$  ( $001:001$ ) =  $52^\circ 0'$  (calc. =  $50^\circ 46'$ ). The average of three measurements of the angle  $af$  ( $100:\bar{3}01$ ) made on a simple reflection goniometer<sup>3a</sup> gave  $17^\circ 0'$ ; the theoretical (for epidote) is  $16^\circ 46'$ . As shown in ideal cross-section in Fig. 1 this crystal is a penetration-twin with  $a\{100\}$  as twin-plane. Crushed fragments of the specimen used in the optical work examined between crossed nicols often show polysynthetic twinning.

There is perfect cleavage parallel to  $c\{001\}$  as indicated in the drawing.

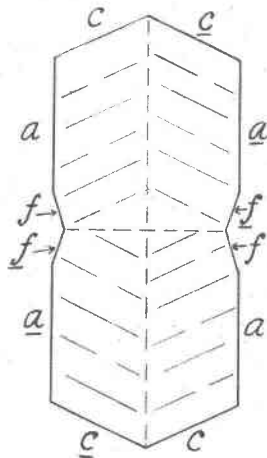


Fig. 1. Ideal cross-section of penetration twin of a clinozoisite crystal.

$a\{100\}$ ;  $c\{001\}$ ;  $f\{\bar{3}01\}$ . Twin-plane =  $\{100\}$ .

OPTICAL PROPERTIES. The three principal indices of refraction of the clinozoisite as determined by the indirect immersion method are as follows:  $n_a = 1.715 \pm .001$ ;  $n_b = 1.717 \pm .001$ ;  $n_\gamma = 1.721 \pm .001$ ;  $n_\gamma - n_a = 0.006 \pm .002$ . In these determinations a Wratten

<sup>3a</sup> Described by the writer. *Science* (n.s.) 27, 929, (1908).

E filter No. 22<sup>4</sup> was used to furnish an approximation to sodium light. Cleavage flakes (parallel to 001) in convergent light give a somewhat eccentric and slightly curved axial bar which means that the axial angle  $2V$  is not far from  $90^\circ$ .

One of the prominent features of clinozoisite is the anomalous character of the interference colors as has been emphasized by Weinschenk.<sup>5</sup> In the specimen of clinozoisite from Lower California, the succession of interference colors observed in wedge-shaped fragments between crossed nicols is as follows: prussian blue, pale blue-gray, greenish yellow, pale red, red, violet, blue, etc. The white of the first order is lacking. Another striking feature is that greenish yellow appears in place of bright yellow of the first order. These anomalous interference colors are somewhat different from those of zoisite. In zoisite there is a change in hue of interference color on rotation of the stage which is not true of the clinozoisite under examination.

**SPECIFIC GRAVITY.** The specific gravity of the analyzed clinozoisite determined on about 2 g. of carefully selected material by means of a pycnometer is 3.212.

**CHEMICAL COMPOSITION.** One of the specimens, a large rough mass free from associated minerals, was used for the chemical analysis. The color of this specimen is gray; in thin fragments it is almost colorless. It was the same specimen that was used for the optical determinations given above. The analysis was made by Mr. W. R. Waelyt, one of my former students, with the following results:

ANALYSIS OF CLINOZOISITE BY W. R. WAELYT

	I	II	Av. I & II	Ratios
SiO <sub>2</sub>	37.85	37.77	37.81	630 = 6 × .105
Al <sub>2</sub> O <sub>3</sub>	31.87	31.82	31.85	312 } = 3 × .110
Fe <sub>2</sub> O <sub>3</sub>	3.02	2.96	2.99	.019 } = 4 × .111
FeO	0.76	0.76	0.76	.010 } = 4 × .111
CaO	24.27	24.44	24.36	.436 } = 1 × .128
MnO	tr.	tr.	tr.	
H <sub>2</sub> O	2.29	2.21	2.25	.128 = 1 × .128
Total	100.06	99.96	100.02	

This is an iron-poor member of the epidote group with 6.8 per cent of the Ca<sub>2</sub>Fe<sub>3</sub>(OH)(SiO<sub>4</sub>)<sub>3</sub> molecule.

<sup>4</sup> Supplied by the Eastman Kodak Co.

<sup>5</sup> *Die gesteinsbildenden Mineralien*, p. 83, Freiburg, (1901).

The preceding analysis proves that the mineral is either clinozoisite or zoisite, which are dimorphous. The crystal form and optical properties taken together prove conclusively that the mineral is clinozoisite (Monoclinic). Zoisite is orthorhombic and has lower indices of refraction.

GENERAL REMARKS ON CLINOZOISITE. The only previously recorded clinozoisite from the North American continent, I believe, is the Huntington, Mass., mineral described by Forbes<sup>6</sup> as epidote ( $\text{Fe}_2\text{O}_3 = 5.67$  per cent). In the same year Weinschenk<sup>7</sup> described minerals of the epidote group from Tyrol with still lower iron content and proposed the name *clinozoisite* for the iron-poor members of the group. Clinozoisite is dimorphous with zoisite. It is possible that clinozoisite is identical with the fouquéite from Ceylon and India described by Lacroix,<sup>8</sup> but until this is definitely proved the name clinozoisite may be retained.<sup>9</sup>

As has been shown by Forbes, Weinschenk, Thomas,<sup>10</sup> Goldschlag<sup>11</sup> and others, there is a continuous gradation between iron-free clinozoisite and iron-rich epidote (pistazite) with a corresponding variation in the optical properties. The correlation between the chemical composition and the various optical properties is not, however, very exact, probably on account of errors in some of the determinations.

It seems probable that clinozoisite is not such a very rare mineral; in thin sections I have frequently found a nearly colorless mineral resembling epidote but with lower birefringence which must be clinozoisite. It is a mineral which has probably been overlooked many times.

<sup>6</sup> *Amer. Jour. Sci.*, 51, 26, (1896).

<sup>7</sup> *Zeit. f. Kryst.*, 26, 156-177, (1896).

<sup>8</sup> *Bull. soc. franc. min.* 12, 330, (1899).

<sup>9</sup> Lacroix in his *Mineralogie de la France* uses the name clinozoisite and not fouquéite.

<sup>10</sup> *Mineral. Mag.*, 14 109-114, (1905).

<sup>11</sup> *Min. u. petr. Mitth.*, 34, 23-60, (1917).