

## TWO DIOPSIDES FROM SOUTHERN CALIFORNIA\*

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### ABSTRACT

Exceptionally pure diopsides occur in the limestone contact zones at Crestmore near Riverside, and at Cascade Canyon near Upland, California. Chemical analyses and optical properties of both samples, especially that from Cascade Canyon, are close to published values for artificial diopside.

### INTRODUCTION

The Crestmore quarries are located about two miles northwest of Riverside, California, on the west bank of the Santa Ana River, near the San Bernardino County line (Fig. 1). The locality has long been known for the large number of minerals which occur in a restricted area. The geology of the quarries has been described recently by Daly.<sup>1</sup>

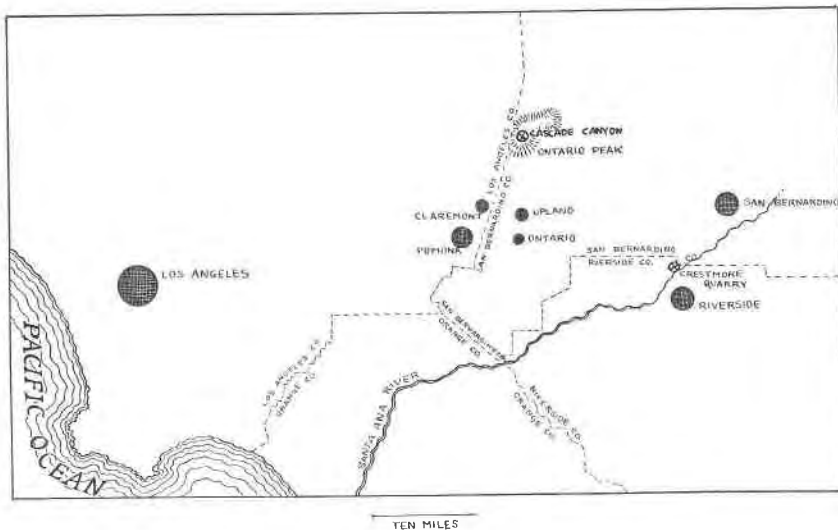


FIG. 1

The diopside was found on the south side of the Wet Weather quarry, in the limestone side of the contact zone which seems to have developed about quartz monzonite porphyry dikes. The diopside is pale green (lumiere green<sup>2</sup>, 29' GGY-b), and commonly occurs in masses of interfering

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<sup>1</sup> Daly, John W., *Am. Mineral.*, vol. 20, pp. 638-659, 1933.

<sup>2</sup> Ridgway, Robert, *Color Standards and Color Nomenclature*, 43 pp. and 53 pls., Washington, 1912.

crystals ranging up to two centimeters in length, and associated with vesuvianite, crestmoreite and interstitial calcite. Isolated well formed crystals of pale diopside are also found in a matrix of sky-blue calcite. These crystals are sometimes elongated parallel to the  $a$ -axis.

Cascade Canyon, the source of our second sample, is located on the northwest slope of Ontario Peak (Fig. 1). This locality also is remarkable for the large number of minerals to be found in a zone of varied metamorphic rocks, which extends up and down the canyon for a mile or more. Noteworthy minerals, in addition to the diopside, are lapis lazuli (perhaps sodalite or haüyne), corundum in barrel shaped crystals, glaucophane(?), fuchsite, and a black iron sulphide having many of the properties of hydrotroilite.

The diopside is found near the mouth of Cascade Canyon where it is crossed by the U. S. Forest Service fire control road, in the SE.  $\frac{1}{4}$  of sec. 36, T. 2 N., R. 8 W., San Bernardino base and meridian. The material is snow white and fine grained. A fibrous, pale blue mineral which optical and chemical examination has shown to be soda tremolite occurs on the cleavage planes of the rock. Some samples also show much intermixed white tremolite, visible with a lens. Other samples consist of diopside nearly free from contamination.

#### OPTICAL PROPERTIES

Optical and crystallographic constants of both occurrences correspond closely to those of the artificial mineral. The indices of refraction were determined by the immersion method in monochromatic light, using a sodium vapor lamp and variable temperature apparatus, with an accuracy of  $\pm .001$  or better. The values for the Crestmore material are slightly higher than those for either the artificial or the Cascade Canyon material. This is probably due to the higher percentage of iron in that from Crestmore. Table 1 gives the optical and crystallographic constants.

TABLE 1. OPTICAL AND CRYSTALLOGRAPHIC CONSTANTS OF DIOPSIDES

|                       | <i>Artificial*</i> | <i>Crestmore</i> | <i>Cascade Canyon</i> |
|-----------------------|--------------------|------------------|-----------------------|
| $N_\gamma$            | 1.694              | 1.695            | 1.693                 |
| $N_\beta$             | 1.6715             | 1.675            | 1.671                 |
| $N_\alpha$            | 1.664              | 1.666            | 1.663                 |
| $N_\gamma - N_\alpha$ | 0.030              | 0.029            | 0.030                 |
| $Z \wedge c$          | 38°30'             | 39°10'           | .....                 |
| 2V                    | 59.3°              | 59°              | .....                 |
| $a \wedge c$          | 74°9'              | 74°45'           | .....                 |

\* Wright, F. E., and Larsen, E. S., *Am. Jour. Sci.*, vol. 27, p. 1, 1909.

2V, extinction on 010( $Z \wedge c$ ) and the angle  $a \wedge c$  were determined for the Crestmore mineral. However, the Cascade Canyon material lacks

crystal form and is too finely granular to make possible any measurements other than indices of refraction. The results, as shown in the table, agree fairly well with those for the artificial substance.

Unusual cleavage is shown by both samples. The usual diopside cleavage is prismatic, with (100) and (001) less common. The Crestmore mineral has good (100) and (001) cleavages, but prismatic cleavage develops only on thin sections which have been roughly ground. The Cascade Canyon diopside has very good basal cleavage or parting but none other of importance. Its flaky and almost micaceous character is suggestive of the variety of diopside sometimes called malacolite.

X-RAY EXAMINATION

X-ray powder photographs by W. H. Dore of the University of California, at Berkeley, indicate that both minerals are of identical structure. Spacings calculated from these patterns check closely with values calculated from data given by Wyckoff,<sup>3</sup> thus positively identifying both our samples as diopside.

CHEMICAL COMPOSITION

Preliminary to the final quantitative analysis, both minerals were examined spectrographically by Dr. T. G. Kennard of the Claremont Colleges. The results are shown in Table 2.

TABLE 2. SPECTROGRAPHIC ANALYSIS OF DIOPSIDES

| <i>Element</i> | <i>Crestmore</i> | <i>Cascade Canyon</i> |
|----------------|------------------|-----------------------|
| calcium        | large            | large                 |
| magnesium      | large            | large                 |
| silicon        | large            | large                 |
| iron           | medium to small  | small                 |
| aluminum       | small            | small                 |
| sodium         | ....             | very small            |
| manganese      | trace            | trace                 |
| silver         | minute trace     | ....                  |
| copper         | minute trace     | minute trace          |
| lead           | minute trace     | ....                  |
| titanium       | minute trace     | trace                 |
| lithium        | ....             | trace                 |
| strontium      | ....             | trace                 |
| vanadium       | ....             | minute trace          |
| lanthanum      | trace?           | ....                  |

The analyses of both minerals show that they are essentially of the composition  $\text{CaMg}(\text{SiO}_3)_2$ . The first column of Table 3 gives the analysis of an artificial diopside prepared by F. E. Wright and E. S. Larsen.<sup>4</sup>

<sup>3</sup> Wyckoff, Ralph, W. G., *The Structure of Crystals*, p. 418, 1924.

<sup>4</sup> *Loc. cit.*

It is this mineral which Winchell<sup>5</sup> uses as the end member for the diopside-hedenbergite series. The figures for the Cascade Canyon diopside are the actual analysis but the Crestmore values have been recalculated omitting 1.47% calcite matrix, which was an impurity in the sample taken for analysis. The Cascade Canyon mineral is essentially the purer of the two minerals and has but very small amounts of iron and aluminum.

TABLE 3. CHEMICAL ANALYSES OF DIOPSIDES

|                                | A      | B      | C      | CaMg(SiO <sub>3</sub> ) <sub>2</sub><br>(theoretical) |
|--------------------------------|--------|--------|--------|---|
| SiO <sub>2</sub>               | 55.59% | 56.50% | 54.54% | 55.48%  |
| CaO                            | 25.73  | 25.56  | 24.76  | 25.90   |
| MgO                            | 18.61  | 17.80  | 17.23  | 18.62   |
| FeO                            | .....  | .....  | 0.30   | .....   |
| Fe <sub>2</sub> O <sub>3</sub> | 0.18   | 0.24   | 0.93   | .....   |
| Al <sub>2</sub> O <sub>3</sub> | .....  | 0.12   | 1.28   | .....   |
| H <sub>2</sub> O+              | .....  | 0.58   | 0.64   | .....   |
| H <sub>2</sub> O-              | .....  | 0.22   | 0.32   | .....   |
| Cl                             | trace  | .....  | .....  | .....   |
| Total                          | 100.11 | 101.02 | 100.00 | 100.00  |

A—Artificial diopside prepared by F. E. Wright and E. S. Larsen.

B—White diopside, Cascade Canyon, Calif. J. D. Laudermilk, analyst.

C—Diopside, Crestmore, Calif. Richard Merriam, analyst.

The other relatively pure diopsides which have been described also occur in limestone contact zones. A notable example is that used by Warren and Bragg<sup>6</sup> in *x*-ray analysis. This diopside, from De Kalb, New York, has optical properties<sup>7</sup> and composition rather close to those of our Crestmore mineral. Another case is that described recently by M. A. Peacock<sup>8</sup> from xenoliths in a New Mexican quartz monzonite. In this case FeO is 0.97%, Al<sub>2</sub>O<sub>3</sub> 2.55%. Indices run about .010 above those of our Cascade Canyon sample. So far as we know the Cascade Canyon material is the purest natural diopside for which both chemical and optical properties have been determined.

<sup>5</sup> Winchell, A. N., Studies in the pyroxene group: *Am. Jour. Sci.*, 5th series, vol. 6, p. 504, 1923.

<sup>6</sup> Warren, B., and Bragg, W. L. *Zeit. Krist.*, vol. 69, pp. 168-193, 1929.

<sup>7</sup> Zimanyi, K., *Zeit. Krist.*, vol. 22, p. 343, 1893.

<sup>8</sup> Peacock, M. A., *Am. Mineral.*, vol. 21, pp. 318-320, 1936.