A CHEMICAL AND OPTICAL STUDY OF PIEDMONTITE FROM SHADOW LAKE, MADERA COUNTY, CALIFORNIA

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INTRODUCTION

The purpose of this paper is to present some chemical and optical data on piedmontite recently collected near Shadow Lake, Madera County, California, and to discuss these in relation to the properties recorded from other occurrences.

Abundant material from the Shadow Lake area, collected by Dr. E. B. Mayo, and specimens in the Cornell Mineralogy Collection from Shikoku, Japan; South Mountain, Pennsylvania; and Saint Marcel, Italy, were generously furnished for this study.

NATURE OF THE MATERIAL

The specimens from the Californian occurrence, containing well crystallized piedmontite were taken from a shear zone in schistose volcanic rocks about three hundred yards east of the outlet of Shadow Lake.

Since this zone served as a line of weakness along which mineralizing solutions could rise, the materials in it differ from those of the adjacent, previously described country rock (16),* in being more coarsely crystalline and containing a greater abundance of minerals that might have been formed from introduced substances (Fig. 1). The usual mineral association is piedmontite, tremolite and vein quartz, which were deposited in the order given. In addition some cavities in the rock are lined with small, orange-colored crystals of a garnet that gives the usual bead test for manganese.

The microscopic study has confirmed the order of deposition determined in the hand specimen. In thin section tremolite, itself enclosed in later quartz, can be seen replacing piedmontite. Near the replacement boundaries, the tremolite was darkened by minute inclusions of manganese oxide, doubtless derived from the epidote mineral. Sections parallel and perpendicular to the rock cleavage show that the majority of the piedmontite crystals have their *a* and *b* axes in the plane of schistosity.

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* Numbers in parentheses refer to the bibliography at the end of this paper.

CHEMICAL STUDY

As a preliminary to the complete quantitative analysis of the piedmontite, a spectroscopic comparison was made with material from other occurrences. The spectrograms obtained (Fig. 2), show the compositions to be almost identical. In all, the essential elements, silicon, aluminium, calcium, manganese and iron, together with some magnesium and traces of titanium, cerium, copper and lead were present; the last three being highest in the South Mountain sample, in agreement with the original analysis (8).

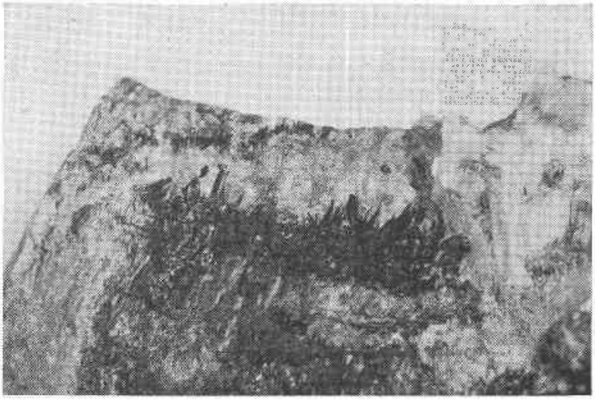

FIG. 1. Specimen ($\frac{3}{4}$X) from the shear zone of Shadow Lake, Madera County, California. Dark blades and needles of piedmontite, embedded in quartz and associated with white, fibrous tremolite.

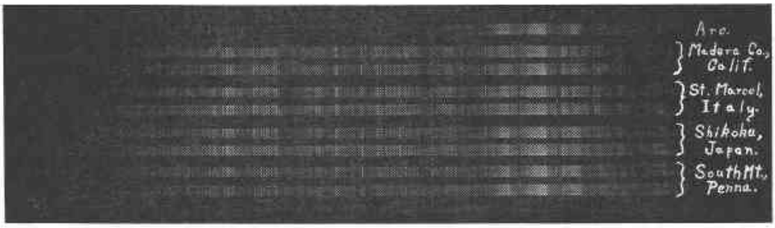

FIG. 2. Spectroscopic Comparison of Piedmontite from Four Occurrences.

In the sample for quantitative analysis and specific gravity determination, it was impossible to eliminate quartz as an impurity, but garnet and tremolite were easily avoided, as they were more or less localized. The sample was prepared, first by crushing and separating in bromoform to remove most of the quartz, then in Klein's solution (Sp. Gr. 3.33), and a final sorting under the binocular.

The specific gravity of this selected product, as obtained by the pycnometer method, was 3.44 at 22°C. or (D_4^{22} 3.43).

To compute the quartz impurity still in the piedmontite, a few pure, well crystallized fragments were selected and run for silica alone, which was found to be 35.26%. The silica in the complete analysis was then corrected to 35.26% and the whole analysis recalculated.

The specific gravity of the pure piedmontite was calculated from a sample (Sp. Gr. = D_4^{22} 3.43) having a quartz impurity (Sp. Gr. 2.654) of 2.79%. The true specific gravity was therefore (D_4^{22} 3.46).

ANALYSIS OF PIEDMONTITE FROM SHADOW LAKE, MADERA COUNTY, CALIFORNIA

T. Kameda, Analyst

	Original	Recalculated
SiO_2	38.05%	35.26%
Al_2O_3	22.49	23.50
Fe_2O_3	4.45	4.65
MgO	0.20	0.21
CaO	21.75	22.73
H_2O	1.31	1.37
TiO_2	0.11	0.12
Mn_2O_3	11.61	12.13
Total	99.97	99.97

This analysis shows no MnO and the analyst states that if any is present, it is only a trace.

The published analyses of piedmontite are represented graphically (Fig. 3) in order of increasing Mn_2O_3 and some interesting, if not accurate, conclusions can be drawn. With the increase of Mn_2O_3 there is also an increase of MnO, in those analyses reporting this oxide, and a ratio of Mn_2O_3:MnO = 4:1 is almost constant. The Saint Marcel mineral, analyzed by Hartwell, and that from California report no MnO but show a slight rise in the Mn_2O_3 curve, which doubtless indicates that the lower oxide was really present but has been included as manganic oxide. With increase of Mn_2O_3 there is a general decline of Al_2O_3, showing a replacement of Al_2O_3 by Mn_2O_3. Also there is a pronounced reciprocal relation between Fe_2O_3 and Al_2O_3. No FeO was reported in any of the analyses. The silica, as expected, varies between well defined limits, 35% to 38.5%. The CaO varies within a range of 5%, except in the analysis of the Saint Marcel piedmontite by Soboero. The relations between the amounts of CaO and MnO are not clear, although one would expect MnO and MgO to replace CaO. However, this series of analyses emphasizes the association of the R_2O_3 oxides and shows a possible relation between Mn_2O_3 and MnO.

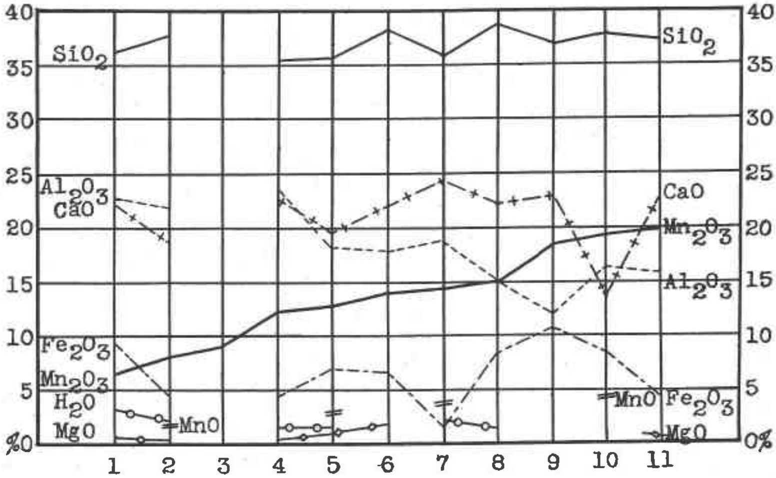

FIG. 3. Variations in the Composition of Piedmontite.

1. Island of Shikoku, Japan. (12)
2. South Mountain, Pennsylvania. (19)
3. Sulphur Springs Valley, Arizona. (15)
4. Madera County, California.
5. Kajlidongri, Jhabua State, Central India. (10)
6. Saint Marcel, Italy. Hartwell analyst. (9)
7. Saint Marcel, Italy. Laspeyres analyst. (13)
8. Saint Marcel, Italy. Rammelsberg analyst. (18)
9. Saint Marcel, Italy. Geffken analyst. (9)
10. Saint Marcel, Italy. Soboero analyst. (9)
11. Saint Marcel, Italy. Deville analyst. (9)

In general the above relationships support the accepted formula for piedmontite, but since the sesquioxides of aluminium, iron and manganese appear to mutually replace one another, and since MnO and small amounts of MgO are present, probably replacing

CaO, it appears that the formula, $H(Ca, Mn, Mg)_2(Al, Mn, Fe)_3Si_3O_{13}$, expresses these relations more accurately.

OPTICAL STUDY

The optical properties of analyzed piedmontite, as recorded in the literature, are very incomplete, and evidently have not been studied as fully as have the chemical properties. Its pleochroism, which is most diagnostic, has been reported for all occurrences and evidently increases in intensity with the increase of manganic oxide (13, 19). In general the pleochroism for the various optical directions is (6, 7, 15, 19, 20):

X = shades of lemon yellow to orange and brownish orange.
Y = red to reddish violet and amethystine.
Z = light rose to carmine and blood red.

The Madera County piedmontite has the following pleochroism (16):

X = lemon yellow to orange.
Y = amethyst to amethystine red.
Z = carmine.

The indices of refraction were determined by immersion in liquids made up of solutions of $AsBr_3$ and AsS in methylene iodide (2). It was found that all the crystals and fragments did not have the same indices in corresponding directions and that they differed as much as ±.005, although there was no visible difference in the color or pleochroism. Similar variations have been observed in epidote from Telemarken, Norway (1). For this reason the means of the values obtained by this method were chosen as representative: $N_g = 1.7985$, $N_m = 1.7649$, $N_p = 1.7385$.

The optic axial angle $2V$ as calculated (11) from the indices was 76° 22′ and as measured on the universal stage varied from 64° to 75°.

The recorded numerical optical characteristics (12, 13, 14, 15) and data on specific gravity (18), although meagre, are shown graphically in order of increasing Mn_2O_3 content (Fig. 4). The lowest value shown for $2V$ (56°) was obtained from material representing the South Mountain occurrence (14), but it is not certain that this material had the composition indicated by Williams' analysis (19). This value however, fits the general trend of the optic axial angle curve very well.

The varying proportions of Mn_2O_3 and Fe_2O_3 produce interesting effects on the optical properties. When these two substances are present in approximately equal quantities, the resulting mineral is optically positive, and has $2V$ between 50° and 60°. The South Mountain mineral approaches this composition and has an optic axial angle of 56°. If the manganese is in excess, the optic axial angle increases, as in the piedmontite from Saint Marcel, analyzed by Laspeyres, in which Fe_2O_3 is to Mn_2O_3 as one to ten, and the optic angle is 82° to 90°. From this it is quite conclusive that a piedmontite without iron should be optically negative and have $2V$ close to 90°.

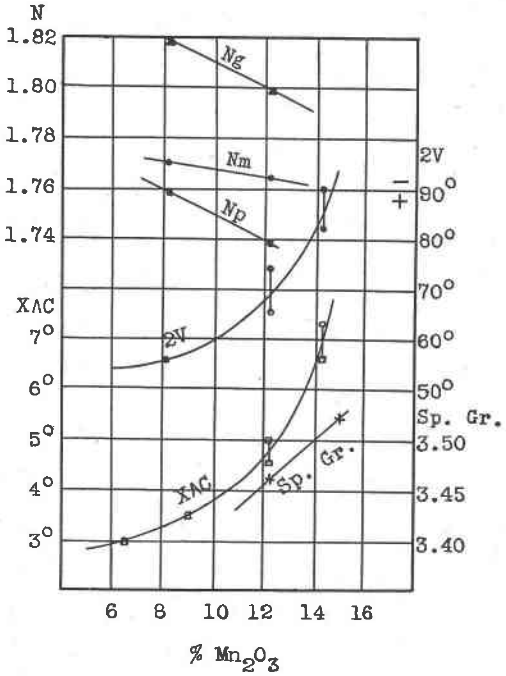

FIG. 4. Relation of Optical Properties and Specific Gravity to Mn_2O_3 Content of Piedmontite.

As Mn_2O_3 in piedmontite decreases in proportion to Fe_2O_3, as in withamite (4), it is highly probable that the $2V$ curve would rise sharply, becoming negative at about two or three percent Mn_2O_3 and with decreasing optic angle pass into ordinary epidote.

The increase of Mn_2O_3 also increases $X \wedge c$ and the specific gravity, and decreases the indices of refraction. From data recorded by Larsen (14) and from Andersen's conclusions (1), it is very probable that the N_g and N_p curves converge with increase of Mn_2O_3 but not enough data are available to justify a definite statement.

In reviewing the literature it was found that little optical research has been done on material represented by chemical analyses, and correlation between the various data can not be made with accuracy. Since this manganese-bearing epidote, although rare, is becoming better known as a rock-forming mineral, further optical study of analyzed material would seem desirable. The possible relations indicated in this paper require confirmation and merit considerable further investigation.

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