

and magnesium, and the ferric iron by aluminum. The amount of combined water may be variable.

Although these analyses do not correspond in every detail, they nevertheless indicate a general composition which may be represented by the formula:  $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot 4\text{SO}_3 \cdot 12$  to  $15 \text{H}_2\text{O}$ . The mineral is exceptionally soluble in water, with an acid reaction. It has an astringent taste. It alters to a yellowish white ferric salt, probably coquimbite. Its high solubility, and the ease with which the mineral loses water with the simultaneous oxidation of the ferrous iron, account for its rarity.

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### PIEDMONTITE FROM THE SULPHUR SPRING VALLEY, ARIZONA.<sup>1</sup>

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A specimen of piedmontite was sent to the Arizona Bureau of Mines for identification, and the locality was visited by the writer and additional material collected for study. The locality is on the southeast slope of the Pat Hills, in the Sulphur Spring Valley, southeastern Arizona. More exactly, it is near the northern edge of T.27 E., R.17 S., Gila and Salt River Base and Meridian.

The volcanic rocks in this region consist of a series of andesitic flows, dark gray in color, and with a porphyritic texture. Both hornblende and plagioclase feldspar occur as phenocrysts in a fine-grained groundmass. In a thin section of the fresh rock the hornblende is of a brownish color, strongly pleochroic, and with a small extinction angle. This is probably a variety of basaltic hornblende. Grains of magnetite are commonly associated with it, especially where the hornblende shows a resorption border. The plagioclase feldspar is present in the slide as rather stout laths which are considerably smaller in size than the crystals of hornblende, and show a more or less parallel arrangement. Polysynthetic twinning is common, and the maximum extinction angle in the symmetrical zone shows them to be basic andesine, near  $\text{Ab}_1\text{An}_1$ . The groundmass is microcrystalline, and appears to consist largely of minute feldspar laths together with scattered grains of magnetite and a little apatite. The texture is porphyritic.

As the amphibole in this rock is a variety known as basaltic hornblende, a mineral sometimes found in basalt and the more

<sup>1</sup>Published by permission of the Director, Arizona Bureau of Mines.

basic andesites, some petrographers would probably classify the rock as an olivine-free basalt; but the plagioclase is basic andesine, near  $Ab_1An_1$ , and the rock should be placed with the andesites.

Piedmontite occurs at this locality as narrow veinlets, usually less than one millimeter in thickness, and filling fractures in the andesite. It also occurs, to a certain extent, as single crystals, or an aggregate of crystals replacing feldspar and hornblende throughout the mass of the rock. On a fracture surface the rock is coated with a thin layer of the mineral, commonly as small rosettes of minute crystals seldom over one millimeter in length. Where the piedmontite has replaced either feldspar or hornblende, radiating clusters of the mineral are less common, and the single crystals or grains have no particular orientation. In some cases clusters have been found to occupy cavities in the rock, and the longer crystals when examined with a microscope show terminal faces, but the individual crystals are too small to be mounted and measured on the goniometer.

Associated with the piedmontite is considerable quartz and some kaolin. This silicification of the andesite appears to have accompanied the formation of the piedmontite, while the kaolin is probably the result of surface waters altering unreplaced feldspar or perhaps sericite. Cutting the andesite in all directions are numerous veinlets of calcite carrying small amounts of malachite and chrysocolla. These calcite veins with associated copper minerals are not related in origin to the piedmontite, but are much later.

At this locality the piedmontite is of a cherry-red color, and corresponds rather closely to 71"-i, in Ridgway's Color Standards and Nomenclature. However, where the individual crystals are very minute the aggregate has an earthy appearance, and is then the color of old rose. A rather unusual feature of some of the rosettes is shown in Fig. 1. Here, the central portion of the rosette is piedmontite of a dark, reddish color, and surrounding this there is a light-colored portion of a pale yellow color, and the line of demarkation between the two is rather sharp. Very likely the light-colored portion of the rosette is a variety of epidote low in iron. The red and pale yellow portions of each crystal have the same optical orientation. This would suggest that the supply of manganese suddenly ceased, and the crystal continued to grow as a variety of common epidote. An examination of crystals of piedmontite in thin sections with both upper and lower nicols out

shows a greater intensity of color near the center of the crystal. This concentration of color applied both to the red and yellow tints. Occasionally the central portion of a grain is red while the border on each side is pale yellow.

The mineral is remarkably fresh and unaltered even within a few feet of the surface. On some of the fracture planes there is a thin, black film of manganese oxide; and a close examination of some of the rosettes as well as cavities in the rock show a pulverulent black substance that may be pyrolusite.

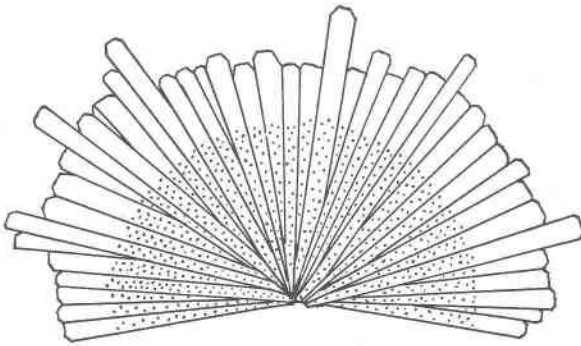


Fig. 1. Rosette of piedmontite. Center red, surrounded by light-colored variety of epidote. Enlarged drawing of a small rosette.

Piedmontite, like epidote, is monoclinic in crystallization, and is elongated parallel to the ortho-axis. The plane of the optic axes is parallel to (010); perpendicular to the basal cleavage. The mineral is optically positive. Refraction and double refraction high. Extinction  $X \wedge c$  axis is  $-3^{\circ}30''$  (av. of several determinations). Pleochroism strong, X = amethystine red; Y = light rose; Z = deep, lemon yellow.

Chemically, piedmontite is a basic orthosilicate of calcium, aluminum, iron, and manganese, and belongs to the epidote group. The  $Mn_2O_3$  varies from 5 to 15 per cent.<sup>2</sup> A determination of the manganese in the piedmontite from the Pat Hills was made by Dr. Buehrer of the Department of Chemistry, University of Arizona. He found the mineral to contain 8.91 per cent. manganese oxide calculated as  $Mn_2O_3$ . It would be interesting to know if those portions of the crystal which are of a deeper color contain a higher percentage of manganese, but the small size of the crystals makes this determination impossible.

<sup>2</sup> Dana's Textbook of Mineralogy, 3rd edition by W. E. Ford: p. 532 (1922).

The piedmontite was deposited by hydrothermal solutions reacting with the silicates in the andesite, chiefly feldspar and hornblende. In addition to manganese, the solutions carried considerable silica. It is possible that these solutions as well as the manganese may have had their origin in the andesite flows, and the manganese abstracted from the ferromagnesian silicates.

OTHER OCCURRENCES OF PIEDMONTITE. At St. Marcel,<sup>3</sup> in the Valley of Aosta, in Piedmont, this mineral occurs in braunite, and is associated with quartz, greenovite, violan, and tremolite. It is also common in the glaucophane and chlorite schists of Japan.<sup>4</sup> Here, it is associated with garnet, rutile, orthoclase, and hematite in schists. A manganese epidote occurs in the crystalline limestone at Jakobsberg,<sup>5</sup> Nordmark, Sweden. Piedmontite from Annapolis, Missouri, was described by E. Harworth,<sup>6</sup> and occurs in a quartz porphyry. This mineral has also been found in the mica schists of the Island of Groix,<sup>7</sup> and in the Central Plateau at Haute-Loire as microscopic crystals in granulite. At South Mountain, Pennsylvania,<sup>8</sup> the mineral occurs in aporhyolite associated with scheelite. The mineral appears to have replaced old spherulites. Piedmontite has been found in red granite at Djebel Dokhan, Egypt.<sup>9</sup> Piedmontite crystals from Jothvād in Nárukat, India, have been described by Fermor.<sup>10</sup> Rogers<sup>11</sup> found piedmontite as a microscopic constituent in a thin section of quartz porphyry from a boulder in Pliocene or Pleistocene gravels at Pacific Beach, San Diego Co., California. The location of the igneous mass from which this boulder was derived is, however, unknown. The mineral appears to have replaced some ferromagnesian constituent, probably biotite. Associated with the piedmontite is common epidote and black grains of manganese oxide.

<sup>3</sup> Dana, E. S.; *A System of Mineralogy*: pp. 521-522 (1898).

<sup>4</sup> Koto, B.; *Jour. Coll. of Sci., Imp. Univ. Tokyo*, 1, p. 303 (1887).

<sup>5</sup> Laspeyres; *Zeitsch. f. Kryst.*, 4, p. 435 (1880).

<sup>6</sup> Harworth, E.; *Am. Geologist*, 1, p. 365 (1888).

<sup>7</sup> Lacroix, A.; *Minéralogie de la France et des ses colonies*: 1, pp. 153-155, (1893-95).

<sup>8</sup> Williams, G. H.; Piedmontite and scheelite from the ancient rhyolite of South Mountain, Pennsylvania: *Am. J. Sci.*, 36, 3rd series, pp. 50-57 (1893).

<sup>9</sup> Liebisch, Th.; *Zeitschr. d. geol. Ges.*, 29, 717 (1877).

<sup>10</sup> Fermor; *Mem. Geol. Sur. India*, 37 (1909).

<sup>11</sup> Rogers, A. F.; Notes on rare minerals from California: *School of Mines Quarterly*, 33, p. 373-381 (1912).

Many of the original papers quoted above were not available to the writer, and the references were obtained in part from that excellent paper by Williams in the *American Journal of Science*, to which the reader is referred for additional information.

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### VOLTAITE FROM JEROME, ARIZONA

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The Department of Geological Sciences, University of California, has received some very good specimens of the rare mineral voltaite from Jerome, Arizona, sent by Mr. George L. McIntyre of Eureka, Utah. He reported that the specimens were formed in brecciated quartz immediately above burning sulphide ore on the upper levels of the United Verde Mine. It is his opinion that the voltaite has been formed by the ascending sulphur vapors. The ore of the mine has been burning for a number of years; it was first set on fire when the back of a stope collapsed and the friction ignited the sulphur present in the sulphides. Reber<sup>1</sup> reported the burning sulphide ore in his report on the region, but he made no mention of the voltaite. This article was prepared under the direction of Professor Arthur S. Eakle and the writer wishes to gratefully acknowledge his aid and helpful criticism.

The mineral when fresh occurs in small, black, opaque, resinous crystals varying in size from 1 mm. to 5 mm. Crystals of the 1 to 2 mm. size predominate; only in one specimen were the larger crystals obtained. The hardness is about 3 and the mineral gives a greenish gray streak. The specific gravity as determined with a Jolly balance is 2.75. The fracture is conchoidal with no apparent cleavage. It is difficultly soluble in water but goes into solution readily with dilute acid. A strong potassium flame is obtained before that blow-pipe and the assay turns to a brick-red powder.

Several of the crystals were measured on a Fuess reflecting goniometer and good reflections were obtained from the faces of the fresh crystals. The crystals are isometric with the majority showing simple cubes, but the combination of cube and octahedron was found on several crystals, and one crystal is a combination of the octahedron and dodecahedron.

Under the microscope, the voltaite is transparent, having a pale green color. The mineral is isotropic and the index of refraction.

<sup>1</sup> Reber: *Am. Inst. Min. Met. Eng.*, 66 (1922).