ART. VII.—*Piedmontite and Scheelite from the Ancient Rhyolite of South Mountain, Pennsylvania;* by GEORGE H. WILLIAMS.

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IN a recent paper on the Ancient Volcanic Rocks of South Mountain in Pennsylvania and Maryland, the identification of the manganese epidote, piedmontite, in the acid lavas was incidentally mentioned.* Several points of interest regarding the occurrence, association and chemical composition of this mineral, which deserve a special notice, have been brought out by its subsequent study.

The acid or rhyolite lavas so extensively developed in South Mountain possess a wide range of color, within which varying shades of pink, maroon and purple are conspicuous. These reddish varieties show many signs of being rich in manganese. Aside from their color, clefts in the rock are often stained black by the oxides of this element, while ordinary weathering not infrequently brings about a similar result. In the basic and more highly ferruginous lavas, conditions favorable to the formation of epidote have at some time obtained to an extent rarely surpassed. Amygdules are filled with this mineral, while in some localities the rock itself is fairly changed to a mass of epidote. Throughout their entire extent the basic lavas have been "epidotized" to a remarkable degree. The tendency to epidote formation is likewise apparent in the acid rocks, especially when they are examined under the microscope. According to the supply of manganese present, however, the common epidote shows every graduation from the faintest rose tinge, through the more pronounced pinks of withamite, to the rich deep carmine of typical piedmontite. All of these varieties frequently occur within the limits of a single thin section, or even as an irregular coloring of a single crystal or group of crystals. In such cases, the deepest color is at the center, as though the

* This Journal, III, vol. xliv, p. 495, Dec. 1892.

growth of epidote had continued, even after the available manganese supply had become exhausted.

The deeply colored, typical piedmontite is irregularly distributed as a microscopic constituent, being most abundant in the reddest rhyolites, and in them, most developed in the feldspar phenocrysts, where it is evidently secondary. At some points a considerable thickness of radiating piedmontite needles occupy cavities and seams in this rock. It is the occurrence of such macroscopic masses of the pure mineral which makes this region an important piedmontite locality; for, while this substance is becoming constantly more widely known as a microscopic rock constituent, the places where it occurs in specimens of macroscopic size and beauty are still very few. In one case piedmontite was found replacing old spherulites and projecting from the sides of ovoid cavities into a mass of enclosing scheelite.

These three types of occurrence will now be described in the inverse order of that in which they have just been mentioned.

1. *Minute crystals in scheelite.*—In the area of rhyolite breccia mentioned in the writer's former paper as occurring in the Buchanan valley, two miles north of the Chambersburg turnpike,* a large block of the acid lava was found behind Musser's store, in which fairly well crystallized piedmontite was abundant. The manganese epidote here occurred wholly or partly filling ovoid areas which resemble old spherulites. The rock itself is banded with lines of flow-structure and has a deep red color from the piedmontite disseminated through it. Associated minerals are quartz and rarely hematite, but the center of the cavity is usually occupied by a white vitreous mineral, into which the terminations of the minute piedmontite needles project, and which, quite contrary to expectation, proved to be *scheelite.*

The projecting ends of these radiating needles, in spite of their minute size, offer the best material yet found for the study of the crystallographic and optical properties of the South Mountain piedmontite. When a little of the white friable matrix is gently pulverized and mounted in balsam for the microscope a very beautiful result is secured. An abundance of sharply defined crystals are seen bounded by the characteristic planes of epidote, but on account of their intense pleochroism exhibiting, when viewed with one Nicol, many tints of yellow, orange, carmine and amethyst. These little crystals, although very sharp and brilliant under the microscope, are rarely over $0{\cdot}2^{mm}$ in length and $0{\cdot}05^{mm}$ in breadth. They are therefore too small to measure, although some of

* Loc. cit. p. 492, and map on p. 483.

their characteristic forms, as seen under the microscope are shown in fig. 1. Their elongation, as is usual for all epidotic minerals, is invariably parallel to the orthodiagonal axis.

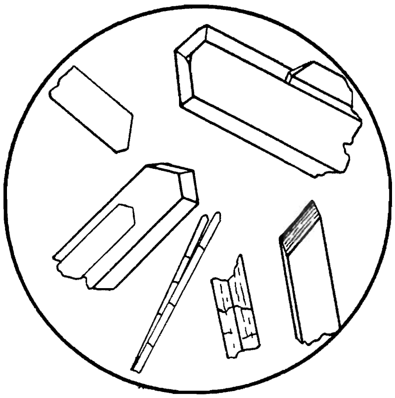

Fig. 1.—Piedmontite needles from scheelite, Buchanan valley, Pa. Magnified × 150.

Crystals which lie upon their orthopinacoid, as in the figure, are straw-yellow to orange, according to their thickness, when their long direction is transverse to the vibrating plane of the Nicol, and some shade of amethyst when these two directions are parallel. In converged polarized light such sections show an acute positive bisectrix with large optical angle, and optical plane normal to their direction of elongation. Crystals lying on the positive orthodome show the same amethyst shades parallel to their longest direction and deep carmine transverse thereto. The pleochroism is therefore 𝔞, yellow; 𝔟, amethyst; 𝔠, carmine, and the absorption: 𝔠 > 𝔟 > 𝔞, or 𝔠 > 𝔟 = 𝔞. In terms of Radde's international color scale the tints of the rays vibrating in these three directions were fixed, as nearly as possible, as 𝔞 = 7, *s*; 𝔟 = 23, *l*; 𝔠 = 25, *m*. This pleochroism agrees, except for differences due to variation in the amount of manganese, with that of all other red epidotes as may be seen from the following table:

Locality.	*Author.*	𝔞	𝔟	𝔠
St. Marcel	Laspeyres	clear orange	amethyst	blood-red
Sweden	Flink	orange	violet	carmine
Japan	Koto	deep reddish violet	light violet	brownish red
Groix	Lacroix	yellow	very clear rose	bright rose
Glencoe	Lacroix	lemon-yellow	clear rose	light rose
South Mt.	Williams	yellow to orange	amethyst	carmine

The exception in the case of the Japanese piedmontite as given by Koto,* does not agree with my own determination upon a number of specimens from Japan received from him. My examinations of the Japanese piedmontite show it to be quite normal, and give: 𝔞, yellow; 𝔟, pale violet; 𝔠, magenta. I also find the absorption not as Koto gives it, 𝔞 > 𝔠 > 𝔟, but 𝔠 > 𝔟 > 𝔞.

* Journal of the College of Science, Imperial University, vol. i, p. 306, 1887.

The determination of the colorless mineral associated with the piedmontite at this locality as *scheelite* was so unexpected that a few words may be devoted to its properties. It is quite brittle and has a vitreous to resinous luster and fairly good pyramidal cleavage. No trace of crystal form was observed, but the cleavage angle measured approximately 100°. In converged polarized light the pyramidal cleavage flakes show a uniaxial figure of positive character and strong double refraction. Moistened with hydrochloric acid the fragments became yellow and then, as the solution dries it becomes a deep blue. Fused with Na_2CO_3 on charcoal and dissolved in water the solution is a deep blue. The phosphor-salt bead is green when hot in the reduction flame, but it remains a deep emerald tint on becoming cold, instead of turning blue as the scheelite bead usually does. The specific gravity determined by a pycnometer with the little material at hand gave 5·61, which, though somewhat low for scheelite, is as good a result as could be expected with the somewhat porous substance.

2. *Radiating aggregates filling veins in the rhyolite.*—The locality which has furnished the greatest abundance of South Mountain piedmontite is on the west flank of Pine Mountain about one mile north of Monterey station. The mineral has here a deep carmine color and forms spherulitic aggregates of needles upon which no trace of crystal form is visible. They are crowded closely together and fill irregular veins which vary in width from 5 or 6^{cm} to the finest possible threads. The average diameter of the radiating aggregates is from 5 to 7^{mm}, although occasional needles have been observed measuring as much as 10^{mm} in length.

In microscopic section these aggregates present a brilliant appearance. The piedmontite needles have the same optical properties as the more perfect crystals already described; but, since there is no parallelism of their $\grave{a}$ and $\grave{c}$ axes, the fibers all show an amethystine color in the direction of their elongation, but various shades of carmine, yellow and orange in transverse directions. Some of the needles show in their pleochroism a complex twinning structure like that figured by Laspeyres.* The microscope shows further that the needles of these radiating aggregates are minutely intergrown with clear limpid quartz. This mixture is so extremely intimate as to render the obtaining of pure material for analysis very difficult. A powder obtained with the Thoulet solution was carefully analyzed by Mr. W. F. Hillebrand, of the U. S. Geological Survey, with the following result:

* Zeitschrift für Kryst., vol. iv, Pl. XI, fig. 8. 1880.

SiO_2	47·37
Al_2O_3	18·55
{ Ce_2O_3	0·75
{ R_2O_3 (other rare earths)	1·28
Fe_2O_3	4·02
Mn_2O_3	6·85
MnO	1·92
CaO	15·82
MgO	0·25
K_2O	0·68
Na_2O	0·23
H_2O	2·08
CuO	0·11
PbO	0·14
Total	100·05

The silica is here 10 per cent too high for epidote, but as the microscope showed that the only impurity was pure quartz, it seemed quite justifiable to recalculate the analysis after deducting 10 per cent of this substance. To substantiate this conclusion another separation was attempted with greater care. The piedmontite was very finely pulverized and only that portion used which fell in a solution of methelyne iodide having a specific gravity of 3·32. The microscope showed that there was still a small quantity quartz admixed, although much less than in the preceding instance. A determination of the silica of this powder by Mr. Hillebrand gave 40·08 per cent. It seems therefore certain that the recalculation of the analysis given above on a basis of 37·37 per cent silica would give very nearly the composition of our piedmontite. The result thus secured is as follows:

SiO_2	37·37
Al_2O_3	22·07
{ Ce_2O_3	0·89
{ R_2O_3 (other rare earths)	1·52
Fe_2O_3	4·78
Mn_2O_3	8·15
MnO	2·285
CaO	18·825
MgO	0·30
K_2O	0·81
Na_2O	0·27
H_2O	2·48
CuO	0·13
PbO	0·17
Total	100·05

This analysis is of especial interest in showing that the South Mountain piedmontite is a connecting link between three recognized members of the epidote group. In the first place, the amount of cerium and other rare earths which it contains indicates a considerable admixture of the allanite or orthite molecule; while the presence of both manganous and manganic oxides gives this mineral a position intermediate between true piedmontite and the mangan-epidote of Flink. Copper occurs extensively in the rocks which carry the piedmontite.

Another locality for piedmontite filling veins in the rhyolite was found near the head of Miney Run below the Clermont Hotel. While similar to that on Pine Mountain, the mineral is here less abundant.

3. *Piedmontite as a microscopic constituent of the rhyolite.* —Although piedmontite has as yet been observed in macroscopic quantities in the South Mountain rhyolite only at the three localities above mentioned, it is quite generally disseminated as a microscopic constituent. Other occurrences like those already described will doubtless come to light as the detailed examination of the rhyolite area proceeds.

The reddest rhyolites contain microscopic piedmontite most abundantly and this color, as in the case of the well-known "porfido rosso antico," seems to be due to the mineral. The most representative specimens of this variety are from the small area of rather coarse and porphyritic rhyolite occurring just at Monterey station, Pa. This rock, which may be regarded as a type of all the others of this region like it, has a micropoikilitic* groundmass enclosing good-sized phenocrysts of checkered anorthoclase and smaller ones of rounded quartz. It shows no particular evidence of dynamic action, though there is some secondary quartz and sericite present. The groundmass is full of black specks, probably manganese oxide resulting from the alteration of piedmontite, while there is every indication that the latter mineral, along with its associated rose and common epidote, is itself always of secondary origin. It occurs in veins or cracks in the feldspar phenocrysts and groundmass or in isolated patches, usually in association with secondary quartz, epidote and black manganese oxide. The piedmontite is not infrequently surrounded by a zone of pale rose or colorless epidote, which, however, seems to be rather granular than of continuous crystalline structure with the deep red mineral in the center (fig. 2).

As the microscopic piedmontite agrees in all its physical properties with the macroscopic, except for its greater tendency to mix in all proportions with the epidote molecule, no

* G. H. Williams: "On the use of the terms poikilitic and micropoikilitic in petrography;" Journal of Geology, vol. i. p. 176, 1893.

attempt was made to isolate it. There is no reason to believe that it is not the same mineral as that concentrated in the veins.

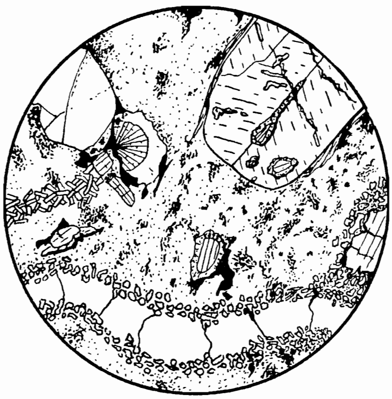

Fig. 2.
Occurrence of microscopic piedmontite in minute veins with secondary quartz and surrounded by rims of epidote. Magnified × 25.

As piedmontite is constantly increasing in importance as a rock constituent, it has appeared to the writer worth while to record all occurrences heretofore published. As far as possible he has made a comparative study of these occurrences.*

We notice in epidote a tendency to form red varieties, just as, in the case of hornblende, there is a tendency to form blue ones (glaucophane, riebeckite, gastaldite, crocidolite). Thulite is red zoisite. The red epidote of Rotherkopf in the Tyrol† and the withamite of Glencoe in Scotland contain very little manganese, and are comparable with the rose epidotes associated with the microscopic piedmontite of South Mountain and Japan.‡ The recorded piedmontite occurrences which the writer has been able to find are as follows:§

1. *With manganese ore deposits.*—San Marcel,* Viù, and Mezzenile, Italy‖ (piedmontite); Jakobsberg,* Sweden¶ (mangan-epidote, with MnO only).

2. *Spherulitic aggregates as veins in eruptive rocks.*—Glencoe,* Scotland** (withamite); South Mountain,* Penn.

3. *Secondary constituent of eruptive rocks.*—"Porfido rosso antico," Djebel Dokhan,* Egypt††; Quartz porphyries of Missouri;*‡‡ granulite of Haute-Loire, France;§§ South Mountain,* Penn.

* For assistance in gathering material for this study the writer would express his gratitude to Mr. C. S. Bement of Philadelphia; Mr. J. S. Diller of Washington; Prof. L. V. Pirsson of New Haven; Prof. B. Koto of Tokyo; Prof. G. Flink of Stockholm and Prof. A. Lacroix of Paris.

† H. Bücking: Zeitschr. f. Kryst., vol. ii, p. 384, 1878.

‡ B. Koto: Jour. Coll. Sci., Imp. Univ. Japan, vol. i, p. 310, 1887.

§ Asterisk denotes specimens studied by this writer.

‖ Laspeyres: Zeitschr. f. Kryst., vol. iv, p. 435, 1880; Jervis, quoted by Hintze: Handb. Min., p. 255, 1890.

¶ G. Flink: Zeitschr. f. Kryst., vol. xv, p. 88, 1889.

** D. Brewster: New Edinb. Journ. Sci., vol. ii, p. 218, 1825; Heddle: Min. Mag., vol. v, p. 15, 1882; Lacroix: Bull. Soc Min. de Fr., vol. vi, p. 75, 1886.

†† H. Rosenbusch: Die mass. Gest., 1st ed., p. 290, 1877; 2d ed., p. 472, 1887; Th. Liebisch: Zeitschr. d. geol. Ges., vol. xxix, p. 717, 1877.

‡‡ E. Haworth: Inaug. Dissertation, Am. Geologist, vol. i, p. 365, 1888.

§§ Lacroix: Minéralogie de la France, vol. i, p. 155, 1893.

4. *In crystalline-schists.*—Chlorite-sericite gneiss and glaucophane schist, Japan;* on ilmenite from mica-schist, Island Groix, France;† in gabbro-diorite (alteration product of hornblende), Chichibu, Japan.‡

The writer is indebted to Messrs. Diller and Pirsson for two occurrences of piedmontite in quartz-porphyry which have not as yet been described. The first is in the porphyries and felsites of the Boston basin. Although Mr. Diller does not mention this mineral in his paper on these rocks, it occurs in at least six sections which were kindly loaned the writer for examination. From Mr. Pirsson the writer has a section of a porphyry almost identical with the common South Mountain type, which comes from the "Archæan area of Georgia near Tennessee." It has a finely developed micropoikilitic groundmass, considerable rather pale piedmontite (perhaps withamite), and is especially interesting as showing the persistence of the rhyolite to the southern end of the Appalachian region.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, March 24, 1893.