

# CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

## No. 21. On the occurrence of Mn-poor Piemontite and Withamite in Norway.

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**Abstract.** New occurrences of piemontite and withamite are recorded, together with a reconsideration of certain 'piedmontites' described by O. ANDERSEN (1911). Partial chemical analyses and semi-quantitative spectrographic analyses of these minerals are presented together with some optical data. It is concluded that the 'piedmontite' recorded by O. ANDERSEN (1911) from Notodden and material recently found at Tinnsjø should be classified as withamite. Material from Furenes is identified as true piemontite. With the exception of one occurrence of withamite, the piemontites and withamites in Norway have unusually low manganese contents.

The piemontites and withamites in Norway appear to have originated either in fairly low-grade regional metamorphic environments or as late crystallization or replacement products associated with pegmatites and quartz veins within rocks which have undergone higher grades of metamorphism. This is in agreement with the observations of previous workers.

### Introduction

Piemontite<sup>1</sup> and withamite are monoclinic manganese-rich minerals of the epidote group. They are easily distinguished from their manga-

<sup>1</sup> Piemontite is synonymous with "piedmontite", the term commonly used in the English literature. However, the term piemontite is preferred as that name was first proposed for the manganese-rich epidote at the original locality by Kengott in 1853 (in HINTZE, 1897). The alteration of this term to "piedmontite" (by DANA in 1854, according to DEER *et al.*, 1962) appears to have been a translation from Italian to English and is therefore in error.

nese-poor analogues-clinozoisite and epidote (pistacite) by their reddish colour and their strong pleochroism in thin-section ( $\alpha$  = yellow,  $\beta$  = amethyst,  $\gamma$  = red). Withamite is similar to piemontite in many respects, but it differs both in its low content of manganese ( $\text{Mn}_2\text{O}_3 + \text{MnO} = 0.83 - 0.96$  wt. per cent) and in its optically negative character.

The original locality for piemontite is near the village of St. Marcel in the Piemonte province in northwestern Italy where it is associated with manganese ore. According to HINTZE (1897), piemontite was first discovered there in 1758 by Cronstedt. Piemontite, although relatively rare among the epidotes, has since been found in many parts of the world in fairly low-grade metamorphic rocks, pegmatites, manganese ores and associated with acidic and intermediate volcanic rocks.

Withamite was first described by BREWSTER (1825) and later in detail by C. O. HUTTON (1938). The original locality for withamite is in Glen Coe, Argyllshire, Scotland, where it is associated with milky white epidote, green epidote, calcite and quartz in vesicles and veinlets in altered andesitic lavas. Withamite has also been observed as a major component of the groundmass in the intermediate dike known as the 'Porfido rosso antico' at Djebet Dokhan in Egypt (DEER *et al.*, 1962)

A recent discovery of manganese epidote in the Telemark province, Norway (CARTER, 1962) stimulated this study of the occurrence and properties of piemontite and withamite in Norway. To date, manganese epidotes have been discovered at seven localities scattered throughout Southern Norway (Fig. 1). Descriptions of their occurrence and paragenesis (so far as it is known), together with partial chemical analyses, semi-quantitative spectrographic analyses and some optical data are presented below.

### Occurrences in Norway

1. "Piedmontite" was first observed in Norway, at a locality near Notodden, by W. WERENSKIOLD (1909, p. 27). Subsequently O. ANDERSEN (1911) completed a comprehensive study of the minerals from that area: locality 1, Fig. 1. The "piedmontite" occurs within small pegmatite lenses in muscovite-quartz-microcline schist. Microcline and quartz, the principal components of these pegmatites, are accom-

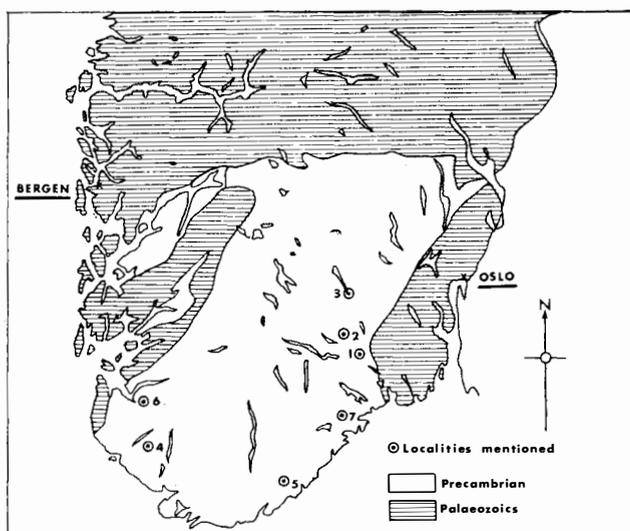


Fig. 1.

panied by abundant epidote, "piedmontite" and hematite, together with some oligoclase, muscovite, titanite, biotite, apatite and calcite. The "piedmontite" and epidote appear to have formed prior to the crystallization of the titanite, hematite, apatite and feldspar. The muscovite, biotite and most of the calcite were interpreted as being of secondary nature.

Andersen presented optical, crystallographic and chemical data on the red "piedmontite", a green epidote and a brown epidote which showed all transitions into the red and green varieties. He quoted distinct optical and chemical differences between the green epidote and the red "piedmontite", but drew attention to the constancy of crystal morphology in all three varieties. The optical differences comprised increasing  $2V$ , accompanied by a decrease in birefringence from the green to the red end members, together with differences in pleochroism and axial angle. These optical differences were paralleled by a difference in chemical composition, e.g. the Mn: Fe ratio of the "piedmontite" was greater than that of the green epidote, which contained only a trace of Mn.

2. H. NEUMANN and S. SVINNDAL (1955, p. 148) recorded "piedmontite" from Kleppen in E. Telemark: (Fig. 1, locality 2). There the

“piedmontite” was intimately associated with cyprine (blue vesuvianite) and thulite within a quartz vein which ran parallel to a quartz-porphry associated with amphibolite sills. The quartz vein, contained, in order of decreasing abundance, thulite, clinozoisite, “piedmontite”, grossularite, cyprine, diopside, oligoclase, scapolite and desmine. Neumann and Svinndal observed that the minerals of this deposit did not represent a ‘true equilibrium’ state.

3. T. F. W. Barth has noted piemontite as occurring at Askekor, northeast of Heskestad in Rogaland: (Fig. 1, locality 4). The piemontite was found in a quartz-monzonite lens situated within a migmatitic gneiss. The migmatite is composed of a mixture of light-coloured quartz-monzonitic gneiss and darker quartz-clinoenstatite — (chlorite) — andesine gneiss. Epidote and piemontite occurred as small grains and granular aggregates in parts of the quartz monzonite. The relationship of the epidote and piemontite is not clear, although it appears to be of a retrograde nature.

4. In 1958, piemontite was collected by T. F. W. Barth, W. Elders and B. Nilssen from a pegmatite within the Birkeland granite near Herefoss, Sørlandet: (Fig. 1, locality 5). This pegmatite is situated at the contact between the granite and an amphibolitic inclusion. The pegmatite consists of predominant microcline and quartz associated with oligoclase, muscovite, biotite, chlorite, fluorite, epidote, piemontite, pyrite, magnetite, molybdenite, ilmenite, fergusonite and orthite. The mineral paragenesis of this body has not been studied in detail.

5. In 1955 specimens containing piemontite, from Furenes in Høyland, near Stavanger: (Fig. 1, locality 6) were brought to the Mineralogisk Museum in Oslo by Mr. S. Gundersen. The accurate locality of this occurrence is not known. The specimens show small zoned crystals of piemontite occurring within veins in highly altered rocks which are composed of tremolitic amphibole, sercitedised feldspar and calcite. In one specimen a large vein cutting the rock was filled with quartz, calcite and piemontite.

6. In 1959, J. P. Schaer found grains of piemontite in a mylonite situated on the north shore of Lake 207 near Gjerstad: (Fig. 1, locality 7). The mylonite occurs within the gigantic breccia-zone which roughly separates the Telemark formation from the Kongsberg—Bamble formation. The piemontite, and associated green epidote, appears to have

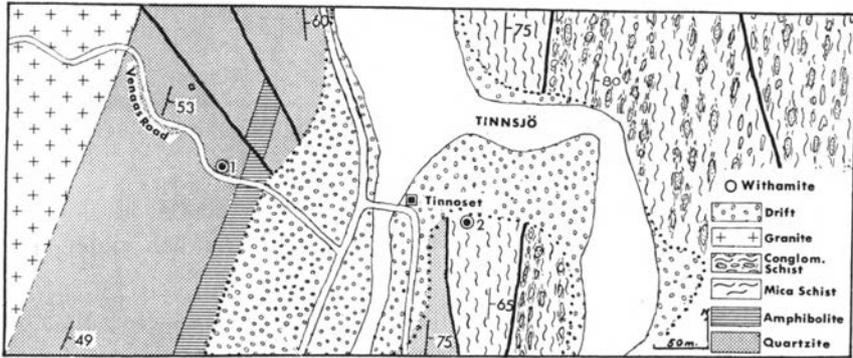


Fig. 2.

partially replaced the matrix and porphyroclasts of the mylonite subsequent to the main period of mylonitisation.

7. Finally, withamite was recently found by one of the authors (CARTER 1962) at two localities near the southern part of Lake Tinnsjø in Telemark: (Fig. 1, locality 3). Withamite, as disseminated and corroded crystals, was found within a rose-coloured quartzite (the colour of the quartzite being chiefly due to hematite) and also in an almost pure, white quartzite (Fig. 2, locality 1). The quartzite is well foliated owing to the presence of sericite-rich planes and most of the withamite crystals are localized along these divisional planes. This relationship suggests a secondary origin of the withamite rather than a primary detrital origin.

Abundant minute crystals of withamite were also found within quartz veinlets in a muscovite-microcline-quartz schist: (Fig. 2, locality 2). The withamite of this second occurrence is closely associated with a quartz vein. Veinlets of withamite apparently selectively replaced muscovite and feldspar along the schistosity.

### Partial chemical compositions and optical data

#### 1. The "Piedmontite" from Notodden.

In his paper on the Notodden "piedmontite", O. ANDERSEN (1911) gives a detailed description of the various epidotes and "piedmontites" found there. He states that all the epidotes and "piedmontites"

examined were optically negative. The optical properties given by him are recorded as:

Green Epidote:  $a : c = 4^\circ 11'$ ;  $-2V = 73^\circ 39'$ ;  $Nm = 1.7542 \pm 0.0005$ ; biref. 0.019 to 0.035;  $\alpha =$  straw yellow,  $\gamma =$  yellow-green.

Brown Epidote:  $-2V = 74^\circ 1'$ ;  $Nm = 1.7594 \pm 0.0005$ ; biref. 0.022 to 0.034;  $\alpha =$  straw yellow,  $\gamma =$  reddish violet.

"Piedmontite":  $a : c = 2^\circ 57'$ ;  $-2V = 75^\circ 20'$ ;  $Nm = 1.7561 \pm 0.0005$ ; biref. 0.014 to 0.027;  $\alpha =$  greenish yellow,  $\gamma =$  violet red.

There is a close similarity between the optical properties of the so-called "piedmontite" from Notodden and those of the original withamite as described by HUTTON (1938). The optical properties of the original withamite are:

$a : c = 1^\circ$ ;  $-2V = 78^\circ \pm 1$ ;  $\alpha$  1.733,  $\beta$  1.750,  $\gamma$  1.762, all  $\pm 0.002$ ; biref. 0.029;  $\alpha =$  clear yellow,  $\beta =$  pale amethyst,  $\gamma =$  purplish red. There is also a strong similarity between the chemical composition of the Notodden "piedmontite" and that of the original withamite; see Table 1. On the basis of this similarity in optical and chemical properties between the "piedmontite" of Notodden and the mineral withamite, the "piedmontite" from Notodden is herein reclassified as withamite. This is the first occurrence of withamite to be recognized in Norway.

## 2. Recent finds of withamite and piemontite.

Partial chemical analyses ( $Fe_2O_3$  and  $Mn_2O_3 + MnO$ ) and certain optical data for the various epidotes, withamites and piemontites are presented in Table 2. Owing to both a paucity of material and the fine-grained nature of the minerals from most of the localities, the data are unfortunately limited. Neither optical nor chemical data could be obtained from localities 3 (Askekor) and 6 (Gjerstad).

The manganese epidote from Furenes (loc. 5) appears to be a true piemontite (biref. 0.028) which has a remarkably low manganese content. Much of the material examined from this locality showed well-defined, though irregular, zoning. The more deeply coloured portions of the crystals always possessed a lower  $2V$  than the paler sectors. In one typical crystal, for example, the deeply-coloured sectors had

Table 1. Partial Chemical Analyses of Withamite (wt. per cent).

	I	II
SiO <sub>2</sub> .....	37.90	37.57
Al <sub>2</sub> O <sub>3</sub> .....	25.70	24.70
Fe <sub>2</sub> O <sub>3</sub> .....	11.21	11.31
Mn <sub>2</sub> O <sub>3</sub> .....	0.58	0.96
FeO .....	—	—
CaO .....	22.37	23.32
H <sub>2</sub> O + .....	2.24	1.83
	100.00%	99.69%

I = The Notodden "piemontite" (= withamite); O. Andersen (1911); + 0.5 % Sr.

II = Withamite, Glen Coe; C. O. Hutton (1938); + 0.09 % SrO.

2V = 59° to 68°, the moderately coloured portions had 2V = 73° to 76° and the palest areas had 2V = 76° to 80°.

The red epidote from Tinnsjø (loc. 7), being optically negative, is identified as withamite. This withamite has a significantly higher content of manganese oxide than any withamite recorded; 3.17 wt. per cent as compared with 0.83, 0.96 (Glen Coe) and 0.58 (Notodden). It has even a higher manganese content than the piemontite from Furenes although the MnO + Mn<sub>2</sub>O<sub>3</sub> : Fe<sub>2</sub>O<sub>3</sub> ratios are approximately the same for the two minerals.

Optic axial angle determinations could not be made on the red epidotes from Kleppen (loc. 2) and Herefoss (loc. 4). The "piemontite" from Kleppen was identified by its brownish-red colour and X-ray powder pattern (NEUMANN and SVINNDAL, 1955); the powder pattern of piemontite is similar to that of epidote but the *d*-spacings are somewhat different (NEUMANN *et al.*, 1957). However, a distinction between piemontite and withamite cannot, as yet, be made by this method. On the basis of the very low content of manganese oxide in the red epidote from Kleppen (0.21 wt. per cent), the writers suggest that this mineral may be withamite. On a similar basis, we suggest that the red epidote from Herefoss (0.50 wt. per cent MnO + Mn<sub>2</sub>O<sub>3</sub>) may be withamite.

One of the outstanding characteristics of the piemontites and withamites from Norway (with the exception of the withamite from Tinnsjø) is their very low manganese contents, particularly those of the

Table 2. Partial Chemical Analyses (wt. per cent) and Optical Data for Withamites, Piemontites and Epidotes mentioned in the publication. Anal. Ing. B. Bruun 1959.

Locality	Mineral	Fe <sub>2</sub> O <sub>3</sub>	MnO + Mn <sub>2</sub> O <sub>3</sub>	Nm	2V
Furenes	Piemontite	7.57	2.76	1.730	+ 73° av.
Herefoss	Withamite (?)	3.25	0.50	1.700	n.d.
Kleppen	Withamite (?)	4.57	0.21	n.d.	n.d.
Kleppen	Green epidote	1.75	0.54	n.d.	n.d.
Notodden	Withamite*	11.21	0.58	1.756	— 75°
Notodden	Green epidote*	12.06	tr.	1.754	— 73°
Notodden	Brown epidote*	n.d.	n.d.	1.759	— 74°
Tinnsjø	Withamite	11.17	3.17	1.749	— 76° av.

\* Anal. O. Andersen 1911.

withamite from Notodden and the withamites (?) from Kleppen and Herefoss. It is notable that these minerals exhibit such strong red colours and strong pleochroism with such minute quantities of manganese oxide (the original withamite, which has only 0.58 Mn<sup>+3</sup> atoms per formula unit, possesses a strong pleochroism comparable with that of piemontite). Moreover, the green epidote from Kleppen contains more manganese oxide than the withamite (?). For these reasons, it was decided to make semi-quantitative spectrographic analyses of the samples in order to determine whether some element other than manganese was present in sufficiently large quantities to account, at least partially, for these optical effects. The results of these analyses are shown in Table 3.

The colour of such allochromatic minerals as epidotes will be dependent upon a combination of various factors. Firstly, with regard to actual composition, the relative concentrations and valence states of those elements occupying the B sub-groups of the periodic table (V, Cr, Mn, Fe, Co, Ni, Cu) would be deciding factors. Secondly, the

Table 3. Semi-quantitative Spectrographic Analyses in ppm. Anal. I. Oftedal.  
tr = trace detected; n.d. = not detected.

Locality	Mineral	Ba	Be	Na	Se	Sr	Ti	V	Y	Yb
Furenes	Piemontite	3,000	n.d.	tr	tr	5,000	tr	tr	tr	n.d.
Herefoss	Withamite (?)	3,000	n.d.	tr	tr	10,000	tr	tr	tr	n.d.
Kleppen	Withamite (?)	10	n.d.	tr	tr	10,000	tr	1,000	tr	n.d.
Kleppen	Green Epidote	100	tr	tr	tr	10,000	tr	100	tr	n.d.
Notodden	Withamite	10	n.d.	tr	tr	3,000	tr	tr	tr	tr
Notodden	Green Epidote	300	n.d.	tr	tr	10,000	tr	tr	tr	tr
Notodden	Brown Epidote	10	n.d.	tr	tr	10,000	tr	tr	tr	n.d.
Tinnsjø	Withamite	1,000	n.d.	tr	10	10,000	tr	tr	100	tr

possibility of structural defects combined with the influence of certain ions should also be considered.

The partial analyses of Tables 2 and 3 provide no consistent chemical evidence which might account for the colouration — pleochroism phenomena observed in all the specimens described here. However, the two epidotes of Kleppen are worthy of further mention. As the green epidote from Kleppen contains more  $\text{MnO} + \text{Mn}_2\text{O}_3$  than the red epidote of that locality, the strong red colouration in the latter cannot be due entirely to the total Mn content. It is therefore possible that the red colouration of the relatively Mn — deficient epidote might in this case be due to a chromophoric effect of its noticeably higher vanadium content or perhaps due to a higher ratio of  $\text{Mn}^{+3} : \text{Mn}^{+2}$  compared with that of the green variety.

### Discussion and Conclusions

The piemontites and withamites in Norway appear to have originated either during fairly low-grade metamorphic conditions or as late crystallization or replacement products associated with pegmatites and quartz veins in rocks of higher grades of metamorphism.

These associations are in accordance with the commonest occurrences of piemontites and withamites in other localities (HUTTON, 1938, 1942; MYASHIRO and SEKI, 1958; and, SUZUKI, 1942).

It should be emphasized that the piemontites and withamites in Norway (with the exception of the withamite at Tinnsjø) have unusually low Mn contents. MYASHIRO and SEKI (1958) studied the relationship between the composition of piemontites and the apparent temperature of their formation (as indicated by their occurrence) for 17 localities in many parts of the world. They found that, in general, piemontites which crystallized at low temperatures (in glaucophane-schists and green-schists; their group *a*) contained less Mn than those which apparently formed at higher temperatures (in higher-grade schists and associated with volcanic rocks). The Mn contents of piemontites and withamites from Norway are, on the average, considerably lower than in those considered by MYASHIRO and SEKI (1958) to have formed at the lowest temperature. But most of the occurrences in Norway suggest that the manganese epidotes formed at higher temperatures, equivalent to group *b* of MYASHIRO and SEKI (1958). The writers feel, therefore, that such conclusions should be considered with reserve. These authors did not study the influence of Mn-content of the host rocks on that of the piemontite and, to our knowledge, there is no experimental evidence to support their hypothesis.

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