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# Chiavennite from syenite pegmatites in the Oslo Region, Norway

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## Abstract

Chiavennite occurs as reddish orange spherulites in vugs of syenite pegmatite at four different localities in the southern Oslo Region of Norway. Chemical analysis and TGA give a formula very close to $CaMnBe_2Si_5O_{13}(OH)_2{\cdot}2H_2O$. The mineral is orthorhombic, $a$ 8.866(7), $b$ 31.34(2), $c$ 4.787(3)Å, Z = 4. The strongest reflections ($d$ in Å, ($I/I_1$), ($hkl$)) of the powder pattern (diffractometer data with preferred orientation) are: 15.7(55)(020), 7.84(25)(040), 5.84(15)(140), 3.917(100)(080), 3.260(15)(201), 2.889(15)(251). Chiavennite crystals have the following properties: hemimorphic, spear-shaped, flattened on {010} with pyramid {161}; good to perfect cleavages on {100}, {010}, and {001}; D (meas.) 2.56 g/cm$^3$, D (calc.) 2.65 g/cm$^3$ for the ideal formula; optically biaxial positive, $\alpha$ 1.596(2), $\beta$ 1.600(2), $\gamma$ 1.618(2) in white light; $2V_Z$ (calc.) 50°; weak pleochroism in pale yellowish brown, $X < Z$; and optical orientation $X = a$, $Y = b$, $Z = c$.

## Introduction

The mineral that is described here under the name of chiavennite (Bondi *et al.*, 1983), was originally observed from a Norwegian syenite pegmatite as early as 1970. One of the present authors (R. Å.) started to work on the mineral at that time, but the description was not completed due to lack of suitable material for single-crystal work. The mineral was established to be a new species, a Ca-Mn-Be-silicate. The finding of far better material from another pegmatite in the same area in 1974 initiated a new investigation of the mineral. An abstract of the complete data was submitted to the Commission on New Minerals and Mineral Names of the I.M.A. on March 4, 1981. A description of the same mineral from an Italian occurrence was received by the chairman of the Commission only a few days prior to our proposal. The new mineral was approved after a joint submission of the data from the Italian and Norwegian groups, and was named chiaven-

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nite from the Italian locality (Bondi *et al.*, 1983). As the two occurrences are quite different, the descriptions are being published separately. Type material from Norway is deposited with the Mineralogical-Geological Museum, University of Oslo.

## Occurrences and parageneses

The syenite pegmatites of the Oslo Region, Norway, became famous through the classic monograph of Brøgger (1890). An updated list of the minerals of these pegmatites was recently published by Raade *et al.* (1980).

Chiavennite was first discovered in one of the syenite pegmatites of the Heia larvikite quarry, Tvedalen, 10 km W of Larvik, southern Oslo Region. The pegmatites of this quarry are sheet-like, 10–50 cm thick, and occur with different orientations along joints in the larvikite. Chiavennite crystallized as one of the latest minerals in vugs, forming spherulites on analcime and natrolite. The following additional minerals occur in the chiavennite-bearing pegmatite: K-feldspar, albite, biotite (lepidomelane), acmite (aegirine), zircon, thorite, thomsonite, chlorite, hambergite, arsenopyrite, löllingite, galena, apatite, fluorite, and the late-formed or secondary minerals wulfenite, wickmanite, leadhillite, and hydrocerussite (Åmli and Griffin, 1972). Where the chiavennite occurs, the feldspar is somewhat altered and nepheline, which is present in other parts of the pegmatite, is absent.

The second Norwegian occurrence of chiavennite is a syenite pegmatite that was exposed during road work (route E18) at Blåfjell, Langangen, some 8 km NW of the first locality in Tvedalen. This pegmatite is very irregular, approximately 10 m long, and the mineralogy varies somewhat from place to place. The most common minerals are K-feldspar, nepheline, hastingsitic hornblende (so-called barkevikite), biotite (lepidomelane), magnetite, analcime, and natrolite. Zircon, thorite, wöhlerite, fluorite, and chlorite are minor phases which occur locally. Sulfides (galena, sphalerite, molybdenite, arsenopyrite) and löllingite are rare. Chiavennite has been found in a restricted part of the pegmatite, where it occurs in druses as the latest mineral of the sequence analcime, acmite (aegirine), helvite, eudidymite, natrolite, chiavennite. It is also found along cracks in K-feldspar and analcime. Epididymite has also been identified from this part of the pegmatite, but is not associated with chiavennite. Small amounts of hambergite are encountered in association with analcime. Another Be mineral is leucophanite, which occurs in some of the zeolitized parts of the pegmatite, but always in a very altered condition. Finally, a completely metamict gadolinite-(Ce) has been found in material from the debris derived from this or possibly a near-by pegmatite. It recrystallizes essentially to a $CeO_2$ phase when heated in air and to a gadolinite phase when heated in nitrogen (Segalstad and Larsen, 1978). The list of minerals given here is not complete; there are still some unidentified phases to be studied from this locality.

A third Norwegian occurrence of chiavennite was established very recently (1981), from a syenite pegmatite at Bakkane, Brunlanes, along route 302, about 3 km SW of Larvik. It is here associated with epididymite, growing on analcime and natrolite in druses of the pegmatite. A fourth locality in the vicinity (Vevja, also called Bakken, a larvikite quarry of the Tvedalen district) was reported during the revision of this manuscript. Chiavennite was found as small spherulites on analcime crystals.

It seems safe to assume that chiavennite may be rather wide-spread as a late crystallization product in the syenite pegmatites of the larvikite area. The description that follows is based on material from the second (Langangen) locality.

## Chemical composition

One complete and one partial chemical analysis of two different batches of hand-picked material assembled from several vugs are given in Table 1. The analytical methods for the first analysis are as follows: $SiO_2$—colorimetric (molybdenum blue), F—pyrohydrolytic separation and ion selective electrode, $CO_2$ and $H_2O$—Perkin-Elmer PE240 elemental analyzer, remainder—atomic absorption spectrophotometry after $HF/H_2SO_4$ dissolution. For the second analysis, $Na_2O$ and $K_2O$ were determined by flame emission spectroscopy, the remainder by atomic absorption, after fusion with $Li_2CO_3/H_3BO_3$ and leaching with 6M HCl.

Table 1. Chemical analyses of chiavennite from Langangen, Norway

| Oxide | Weight per cent | | Elem. | No. of atoms * | |
|---|---|---|---|---|---|
| | 1 | 2 | | 1 | 2 |
| $SiO_2$ | 50.0 | 52.8 | Si | 4.432 | 4.796 |
| $Al_2O_3$ | 6.76 | 4.99 | Al | 0.706 | 0.535 |
| BeO | 8.72 | 7.91 | Be | 1.857 | 1.726 |
| FeO | 2.01 | 1.03 | Fe | 0.149 | 0.078 |
| MnO | 10.6 | 10.58 | Mn | 0.796 | 0.814 |
| ZnO | n.a. | 0.02 | Zn | | 0.001 |
| MgO | 0.14 | 0.16 | Mg | 0.019 | 0.022 |
| CaO | 9.69 | 9.46 | Ca | 0.920 | 0.921 |
| $Na_2O$ | 0.68 | 0.59 | Na | 0.117 | 0.104 |
| $K_2O$ | 0.04 | 0.04 | K | 0.004 | 0.004 |
| $H_2O$ | 10.4 | n.a. | H | 6.150 | |
| $CO_2$ | 0.83 | n.a. | | | |
| F | 0.21 | n.a. | F | 0.059 | |
| | 100.08 | | O | 16.769 | |
| $-O{\equiv}F_2$ | 0.09 | | | | |
| | 99.99 | | | | |

1. Analyst: V.K. Din. BM(NH) Lab. No. 7823.
2. Analyst: A. Åsheim (partial analysis).
   Below detection limit: SrO, BaO, $TiO_2$, $ZrO_2$.

For analytical details, see text.

n.a. = not analyzed.

* based on Σ cations = 9 (excluding H); $CO_2$ is not considered.

Table 2. X-ray powder diffraction data for chiavennite from Langangen, Norway

| *hkl* | $d_{calc}$(Å) | $d_{obs}$(Å) | $I/I_1$ | *hkl* | $d_{calc}$(Å) | $d_{obs}$(Å) | $I/I_1$ |
|---|---|---|---|---|---|---|---|
| 020 | 15.669 | 15.7 | 55 | 0.12.0 | 2.611 | 2.613 | <5 |
| 040 | 7.834 | 7.84 | 25 | 1.10.1* | 2.514 | 2.526 | <5b |
| 120 | 7.716 | 7.65 | <5 | 281 | 2.502 | 2.499 | <5b |
| 140 | 5.871 | 5.84 | 15b | 331 | 2.445 | 2.440 | <5 |
| 200 * | 4.433 | 4.379 | <5 | 012 | 2.387 | 2.386 | <5b |
| 031 | 4.352 | 4.343 | <5 | 351 * | 2.334 | | |
| 041 * | 4.085 | 4.126 | 10 | 032 | 2.333 | 2.336 | <5 |
| 080 | 3.917 | 3.917 | 100 | 2.10.1* | 2.257 | | |
| 051 | 3.804 | 3.818 | 10b | 132 | 2.256 | 2.255 | <5b |
| 260 * | 3.380 | 3.405 | 5 | 1.12.1* | 2.220 | | |
| 161 * | 3.279 | 3.303 | <5b | 400 * | 2.216 | | |
| 201 | 3.253 | 3.260 | 15 | 142 | 2.216 | 2.218 | <5 |
| 221 | 3.185 | 3.192 | 5 | 420 * | 2.195 | | |
| 231 | 3.106 | 3.116 | 5b | 371 | 2.193 | 2.190 | <5 |
| 241 | 3.004 | 3.004 | <5b | 152 | 2.168 | 2.164 | 5 |
| 1.10.0 | 2.955 | 2.951 | 5b | 431 * | 1.975 | | |
| 251 | 2.887 | 2.889 | 15 | 092 | 1.972 | 1.973 | <5 |
| 181 | 2.869 | 2.863 | 5 | 0.16.0 | 1.959 | 1.960 | <5b |
| 091 * | 2.816 | 2.840 | 5 | 480 | 1.929 | 1.931 | <5b |
| 191 * | 2.684 | 2.700 | <5b | 461 | 1.877 | 1.878 | <5 |
| 271 | 2.631 | 2.630 | 5 | 1.15.1 | 1.872 | 1.872 | <5 |

Diffractometer, Cu$K\alpha_1$ radiation, graphite monochromator. Internal standard: quartz. Intensities equal peak heights (preferred orientation). Indexing based on space group $P2_1ab$. Refined cell parameters (from 29 reflections): *a* 8.866(7), *b* 31.34(2), *c* 4.787(3) Å. * not used for calculation of cell parameters. b = broad peak.

The differences between the two analyses seem to reflect a real variation in the Si, Al, Be, and Fe contents between the two batches; the sums of the atomic proportions of Si, Al, Be are very close for the two sets of data (*cf.* also analytical data of Bondi *et al.*, 1983). Based on the assumption that there are 9 cations (excluding H) per formula unit, and the sum of O + (OH) + F equals 15, the empirical formula from the first analysis is $(Ca_{0.92}Na_{0.12})_{\Sigma 1.04}$ $(Mn_{0.80}Fe_{0.15}Mg_{0.02})_{\Sigma 0.97}$ $(Be_{1.86}Al_{0.14})_{\Sigma 2.00}$ $(Si_{4.43}Al_{0.57})_{\Sigma 5.00}O_{12.45}(OH)_{2.49}F_{0.06}\cdot 1.83H_2O$. The minor amount of $CO_2$ is not considered, because its role in the structure is not known. The idealized formula is $CaMnBe_2Si_5O_{13}(OH)_2\cdot 2H_2O$. According to the empirical formula, Al probably substitutes for both Si and Be, and there seems to be a variable amount of O and (OH). Perhaps the substitution schemes are $(Si_{5-x}Al_x)O_{13-x}(OH)_{2+x}$ and $(Ca_{1-y}Na_y)(Be_{1-y}Al_y)$.

The infrared spectrum shows the presence of both $(OH)^-$ and $H_2O$. It is very close to that presented by Bondi *et al.* (1983), only with some minor differences: no shoulder at 3410 $cm^{-1}$, no absorbance at 680 $cm^{-1}$, and an extra absorbance at 1130 $cm^{-1}$. Hydroxyl ions are probably present in two different structural sites (splitting of the OH stretching frequency).

A thermogravimetric run on 6.22 mg gave a steady loss of weight up to 575°C (7.5%, corresponding to *ca.* $2H_2O$), then a distinct weight loss occurs at 600°C (hydroxyl groups), the total weight loss up to 950°C being 12.5%. The curves obtained are very similar to those of Bondi *et al.* (1983), except that the net percentage weight loss of our sample is somewhat higher and the peak on the DTG curve is shifted from 640 to 600°C. The rate of heating was 25°C/min, as compared to 20°C/min for the Italian mineral.

## X-ray crystallography

Single-crystal study by the Weissenberg and precession methods showed the chiavennite to be orthorhombic. Due to the small grains and the thin-platy habit of the mineral, the single-crystal photographs were very weak, and the extinction rules could not be ascertained, except that the lattice is primitive and reflections of the type *h*00 and 0*k*0 are restricted to $h = 2n$ and $k = 2n$. This is consistent with the space group $P2_1ab$ reported by Bondi *et al.* (1983), which we have adopted for indexing the powder pattern (Table 2). The refined cell parameters are *a* 8.866(7), *b* 31.34(2), *c* 4.787(3)Å; *V* 1330(3)Å$^3$, $Z = 4$. The powder data obtained with a diffractometer display a pronounced preferred orientation of the thin-platy crystals, reflections of the type 0*k*0 being strongly enhanced. The exact position of the numerous small peaks with intensities 5 or <5 may be difficult to locate, hence the larger than normal differences between *d* (calc.) and *d* (obs.) for some reflections (Table 2). The strongest reflection on a Guinier film was that at 3.260Å, which only has an intensity of 15 on the diffractometer tracing. The variation in intensities because of preferred orientation is discussed by Bondi *et al.* (1983). The two strongest lines in their Gandolfi pattern ($I = 100$) are at 15.7 and 2.903Å.

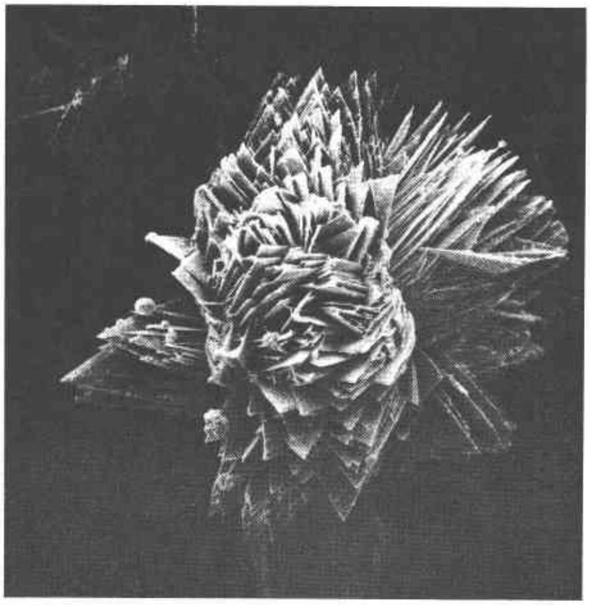

Fig. 1. Aggregate of chiavennite crystals (0.4 mm across), growing on an acmite (aegirine) needle. SEM photomicrograph.

## Physical properties

Chiavennite forms aggregates (mostly spherulites) up to 2 mm across, consisting of platy, spear-shaped crystals of orthorhombic symmetry, flattened on {010} and elongated along [100] (Figs. 1 and 2). The largest individual crystal plates are about 10 μm thick. The hemimorphic appearance of the crystals suggests the non-centrosymmetrical point group *mm*2, which is confirmed by the space-group determination (Bondi *et al.*, 1983); thus the space group *Pmab* which has the same diffraction criteria as $P2_1ab$ is eliminated. The interfacial angle between two adjacent pyramidal faces was measured on SEM photomicrographs, and the top angle of the platelets was measured under the petrographic microscope. From simple geometrical calculations, knowing the orientation of the crystal, the pyramidal form was identified as {161}. The calculated angle $(161)\Delta(1\bar{6}1)$ is 102.25°, the SEM measurements gave 101.5–103°. The idealized crystal habit is shown in Figure 3.

The color is reddish orange, the streak (or rather color of the powdered mineral) is pale ocher, and the luster vitreous to pearly. Chiavennite is non-fluorescent in ultraviolet light. The centers of some chiavennite spherulites are colored black or dark brown by an unknown phase, possibly a Mn oxide. Care was taken to avoid contamination with this impurity when preparing the material for chemical analysis. Good to perfect cleavages along {100}, {010}, and {001} were observed on SEM photomicrographs (Fig. 4), as well as under the microscope. A density of 2.56(5) g/cm$^3$ was determined by the sink/float method in diiodomethane diluted with acetone. This value is certainly somewhat low because of the porous nature of the crystal aggregates. The calculated density is 2.65 g/cm$^3$ for the ideal formula, 2.64 g/cm$^3$ for the empirical formula. The Mohs' hardness could not be measured.

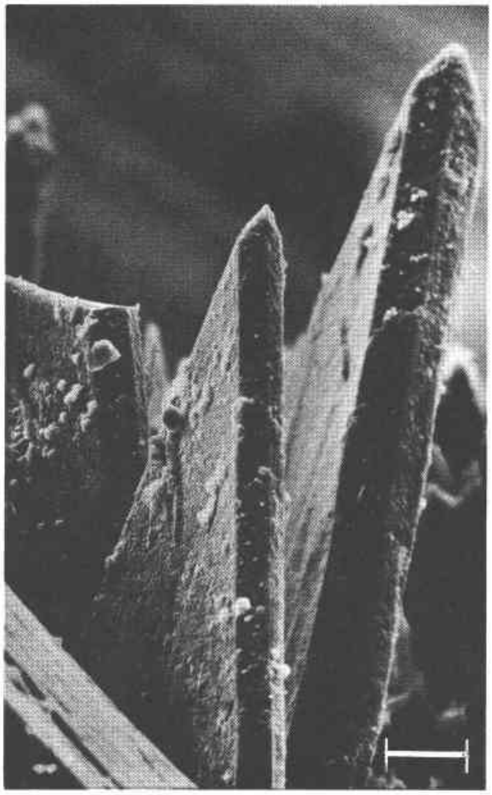

Fig. 2. Chiavennite crystals showing pinacoid {010} and orthorhombic pyramid {161}. SEM photomicrograph; scale bar is 10 μm.

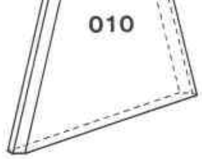

Fig. 3. Clinographic projection of a chiavennite crystal with forms {010} and {161}, compare Fig. 2 (drawn with the computer program of Dowty, 1980). Note that this crystal projection is correctly oriented for the setting $a < c < b$, which was that originally chosen. In the present paper a different axial designation such that $c < a < b$ has been adopted.

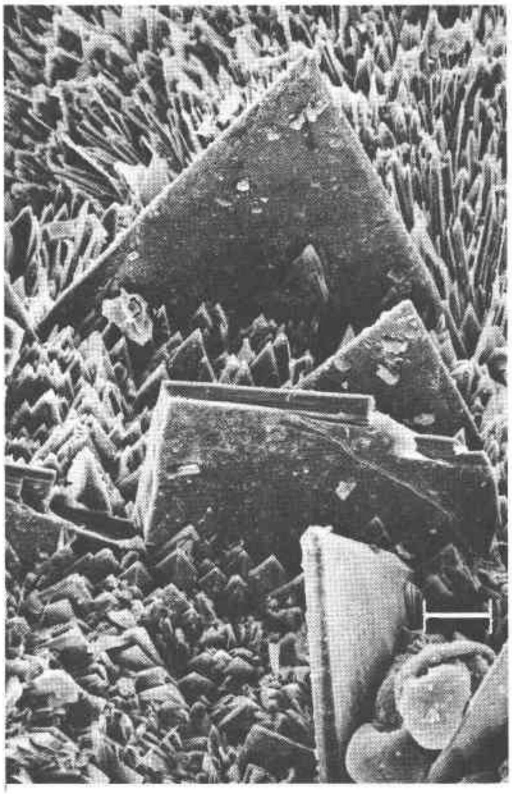

Fig. 4. The broken chiavennite crystal in the middle clearly displays the three cleavages along {100}, {010}, and {001}. SEM photomicrograph; scale bar is 20 $\mu$m.

The mineral is optically biaxial positive. Refractive indices of $\alpha$ 1.596(2), $\beta$ 1.600(2), and $\gamma$ 1.618(2) were measured in white light by the immersion method. The optic angle $2V_Z$ is calculated to be 50°. These indices are somewhat higher than for the Italian mineral, which is most likely due to a higher OH/F ratio in the Norwegian mineral (F was not analyzed for by Bondi *et al.*, 1983). Weak pleochroism in pale yellowish brown with absorption $X < Z$ was noted. The optical orientation is $X = a$, $Y = b$, $Z = c$, OAP (010); most fragments show negative elongation. Refractive indices measured in Na light on material from Tvedalen are $\alpha$ 1.594(5), $\gamma$ 1.613(5); $2V_Z$ medium, $r \gg v$.

The Gladstone–Dale relationship gives $K_c = 0.2226$ (refractive energy from chemical data; *k*-values from Mandarino, 1976), whereas $K_p = 0.2283$ (refractive energy from calculated density 2.65 g/cm$^3$ and mean refractive index). According to Mandarino (1979), this is an excellent agreement [compatibility index $1-(K_p/K_c) = -0.026$]. Using the measured density, $K_p = 0.2363$ and $1-(K_p/K_c) = -0.062$; still a fair agreement.

## Discussion

Chiavennite is a hydrated phase that forms at low temperatures, but the mode of occurrence is distinctly different for the Italian and Norwegian localities. Whereas first bavenite and then chiavennite were formed as secondary minerals after beryl in the Italian Alpine granitic pegmatite (Bondi *et al.*, 1983), the Norwegian mineral is the last one to crystallize in a sequence of other beryllium minerals in vugs of syenite pegmatites. It is conceivable that the late formation of chiavennite and the other associated Be minerals might be the result of a complete break-down of primary leucophanite, at least at the Langangen locality. The interesting suite of Be minerals in the syenite pegmatites of the larvikite area (including also meliphanite and chrysoberyl as well as late-formed berborite and behoite) is currently under investigation. A more detailed discussion of the conditions of formation of the various minerals is better postponed until that study has been completed. Local variations in the chemical composition of the late-stage fluids is probably one of the main reasons for the diversity in low-temperature Be minerals of these syenite pegmatites.

Two other Ca–Mn–Be–silicates are known in nature. These are trimerite, $CaMn_2Be_3(SiO_4)_3$, and harstigite, $Ca_6MnBe_4(Si_3O_{10})_2O_2(OH)_2$, both of which are anhydrous, although the latter is hydroxyl-bearing. The temperature of formation for these phases is most probably higher than for chiavennite, but the $H_2O$ fugacity of the environment is of course also of importance.

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## References

Åmli, R. and Griffin, W. L. (1972) Contribution to the mineralogy of Norway, No. 47. Three minerals new to Norway: wickmannite, leadhillite and hydrocerussite. Norsk Geologisk Tidsskrift, 52, 193–196.

Bondi, M., Griffin, W. L., Mattioli, V., and Mottana, A. (1983) Chiavennite, $CaMnBe_2Si_5O_{13}(OH)_2 \cdot 2H_2O$, a new mineral from Chiavenna (Italy). American Mineralogist, 68, 623–627.

Brøgger, W. C. (1890) Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite. Zeitschrift für Krystallographie, 16, 1–235 + 1–663.

Dowty, E. (1980) Computing and drawing crystal shapes. American Mineralogist, 65, 465–471.

Mandarino, J. A. (1976) The Gladstone–Dale relationship—Part I: Derivation of new constants. Canadian Mineralogist, 14, 498–502.

Mandarino, J. A. (1979) The Gladstone–Dale relationship. Part III: Some general applications. Canadian Mineralogist, 17, 71–76.

Raade, G., Haug, J., Kristiansen, R., and Larsen, A. O. (1980) Langesundsfjord. Lapis, 5(10), 22–28 (+ p. 44).

Segalstad, T. V. and Larsen, A. O. (1978) Gadolinite-(Ce) from Skien, southwestern Oslo region, Norway. American Mineralogist, 63, 188–195.

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