Lorenzenite from the Bratthagen nepheline syenite pegmatites, Lågendalen, Oslo Region, Norway

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Lorenzenite, Na4Ti2Si2O9, from nepheline syenite pegmatites at Bratthagen, Lågendalen, Vestfold county, Norway occurs in two morphologically different habits: as well-defined orthorhombic crystals or more rarely as fibrous aggregates. Crystal forms observed: {100}, {210}, {111}, {211}, {321}. The unit cell dimensions for Bratthagen lorenzenites are (coarsely crystalline/fibrous):

\[ a = 14.488(2)/14.480(1) \text{Å}, \quad b = 8.7061(11)/8.6995(8) \text{Å}, \quad c = 5.2308(8)/5.2277(3) \text{Å}. \]

For coarsely crystalline lorenzenite, the space group is \( \text{Pbcn} \) and the axial choice was \( a > b > c \). The TiO6 octahedra lie in two adjacent layers, alternating in each layer with chains of NaO polyhedra. The space group was found to be \( \text{Pbcn} \) and the axial choice was \( c > a > b \). However, the most frequently used setting for lorenzenite is \( a > b > c \), which is maintained throughout this paper.

Lorenzenite is a mineral typically occurring in alkaline rocks, notably syenite pegmatites. Major and important localities are: a nepheline syenite inclusion localities for lorenzenite are: a nepheline syenite inclusion been given by Chukhrov (1981, pp. 471-477). Other localities for lorenzenite are: a nepheline syenite inclusion in an ignimbritic sequence from Tenerife, Canary Islands (Ferguson 1978a); a pegmatite in mela-nepheline from near Bacchus Marsh, Victoria, Australia (Ferguson 1978b); in small vugs in phonolite sill at Point of Rocks, New Mexico, USA (DeMark 1984). In Norway, lorenzenite has been found in miorolitic cavities in an alkali granite at Gjerdingen, Nordmarka, Oslo (Sæbø 1966a; Raade 1972; Raade & Haug 1982). Lorenzenite has also been found together with fluorite, aegirine and titanite as alteration products after mosandrite in nepheline syenite pegmatite on Låven island in the Langesundsfjord district (Raade 1967). Lorenzenite has been found in nepheline syenite pegmatite in the Bjørndalen quarry in the Tvedalen area, Larvik (S. A. Berge, pers. comm. 1991). The mineral occurs as crystals up to a few millimetre in length together with kainosite-(Y) and pyrophanite embedded in calcite. Associated minerals include fluorite, mosandrite, pyrochlore, nepheline, aegirine, microcline and molybdenite. During investigation of the nepheline syenite pegmatites at Bratthagen in Lågendalen, Oslo Region, lorenzenite was found and identified by one of the authors (PChrS) and a preliminary description of this mineral was part of his cand. real. thesis (Sæbø 1965). A new investigation including X-ray crystallography, chemical analysis, crystal morphology and a cathodoluminescence spectrum, in addition to the unpublished work by Sæbø (1965), has resulted in the present description of lorenzenite from the Bratthagen locality.

Occurrence

The Bratthagen nepheline syenite pegmatite locality is situated in a road cut on main road \( RV 8, 200 \) m
setheast of Bratthagen farm in Lågendalen, Vestfold county. Because of its complex and scientifically interesting mineralogy, the locality has since November 1984 been protected by law. Mineral collecting is not permitted at the site (Miljøverndepartementet 1983).

Several steeply dipping nepheline syenite pegmatite dikes, between 10–30 cm wide, transect a trachytoidal foyaite. The locality is described in more detail by Sæbø (1966b). In the pegmatite dikes, lorenzenite is one of the first minerals to crystallize together with aegirine and zircon, somewhat earlier than the matrix of feldspars and nepheline. Some of the large lorenzenite crystals are intimately associated with aegirine. The crystals are always idiomorphic against zircon; in one sample, a crystal of lorenzenite is nearly completely embedded in a crystal of zircon. This indicates that lorenzenite crystallized slightly earlier than zircon and probably simultaneously with aegirine. Lorenzenite is most frequently found in the border zones of the pegmatite. Accessory minerals from the first (magmatic) stage of the pegmatite formation include pyrophanite, pyrochlore, loparite-(Ce), monazite-(Ce), catapleiite, parakeldyshite and analcime. After the magmatic stage of the pegmatite formation, tectonic movements and intensive hydrothermal processes acted upon the pegmatites and resulted in the crystallization of a large number of minerals, mainly confined to the central parts of the pegmatite dikes. The accessory minerals and their paragenetic relationships were treated by Sæbø (1965, 1966b). Since then, several new minerals for the locality have been found. Here is an updated list of the minerals from the Bratthagen locality (including those already mentioned): sphalerite, galena, pyrohotite, fluorite, chrysoberyl, magnetite, hematite, ilmenite, pyrophanite, loparite-(Ce), gibbsite, nordstrandite, böhmite, diaspor, calcite, ancyrite-(Ce), anglesite, monazite-(Ce), fluorapatite, zircon, thorite, titanate, lorenzenite, datolite, gadolinite-(Ce), melaphanite, leucopanite, barylite, keldyshite, parakeldyshite, catapleiite, hilairite, rosenbuschite, astrophyllite, eudialite, aegirine, hornblende, muscovite, biotite, polythionite, chloride, stilpnomelane, montmorillonite, nepheline, albite, microcline, eudidymite, genthelvite, sodalite, cancrinite, natrolite, thorsonite, jonnardite, analcime. Barylite and parakeldyshite were described by Sæbø (1966b) and Raade & Mladeck (1977), respectively.

Very rarely, colourless to pale yellow, fibrous lorenzenite has been found in the Bratthagen locality, either as radially, star-shaped clusters of needles up to 2 mm in diameter or as fine-acicular aggregates filling voids and cracks in analcime masses. This indicates that fibrous lorenzenite has crystallized quite late and probably belongs to the hydrothermal stage of the pegmatite formation. Two distinctly different morphological varieties of lorenzenite have also been described from the Khibina massif by Dorfman et al. (1966) and Borutskii et al. (1971). There, fibrous lorenzenite is related to recrystallization as a result of hydrothermal alteration of Ti-containing minerals (titanite, lamprophyllite, ilmenite), while well developed lorenzenite crystals are of primary origin.

**Morphology. Physical properties**

Lorenzenite crystals from the Bratthagen locality are very often fractured and broken and the fragments may or may not exhibit traces of crystal faces. The crystals are generally millimetre-sized, although individual crystals up to 10 mm in length and 3–5 mm wide have been observed. A cleavage parallel to (100) is rather imperfectly present. Crystals of the Bratthagen lorenzenite show a well developed orthorhombic prism \{210\}, bipyramid \{111\} and pinacoid \{100\} as the main forms. Small \{211\} and \{321\} pyramids are present on some crystals. The crystals are elongated in the direction of the c-axis (Fig. 1). The Bratthagen crystals are quite similar to lorenzenite crystals from other localities, as shown by Flink (1901) and Chukhrov (1981).

The density of coarsely crystalline lorenzenite from Bratthagen is 3.436(1) g/cm³ determined at 22°C by the sink/float method using Clerici’s liquid diluted with water. The calculated density, based on the cell parameters and the mean value of the chemical analyses, is 3.474 g/cm³.

**Optical properties**

Well-developed crystals of Bratthagen lorenzenite are brown in colour, translucent to transparent, with vitreous to adamantine luster. The Bratthagen lorenzenite is nonpleochroic with refractive indices much higher than 1.80. Refractive indices of lorenzenites are in the range 1.89–2.04 (Chukhrov 1981). The birefringence is rather
strong. The axial dispersion is distinct \( r > v \). The mineral is biaxial negative with \( 2V = 42^\circ \pm 4^\circ \). This is in good agreement with most of the values reported earlier (Chukhrov 1981). The optical axial plane is parallel to (010). The optic orientation is \( Y = c, X = b, Z = a \).

The mineral shows a medium strong response to short wave UV light (254 nm) with yellow fluorescence. This is also observed on lorenzenite from Lovozero, the Kola Peninsula, USSR. Dull green fluorescence has been reported for lorenzenite from Mont Saint-Hilaire, Quebec, Canada (Mandarino & Anderson 1989). The Bratthagen lorenzenite shows a dull creamy white cathodoluminescence (CL), which slowly decays with time of exposure to the electron beam. The CL emission of coarsely crystalline Bratthagen lorenzenite has been scanned from 350 nm to 750 nm at CL conditions of 4 kV and 80 mA using the same equipment as described by Mason & Mariano (1990). The spectrum shows a broad band with maximum at 500 nm (Fig. 2). This spectrum is an intrinsic type of CL that probably arises from defects in the \( \text{SiO}_4 \) or \( \text{TiO}_6 \) groups.

Lorenzenite from the Kola Peninsula gives an identical CL spectrum (A. N. Mariano, pers. comm. 1991).

### Chemical composition

The electron microprobe analyses were done using a Cameca Camebax Microbeam wavelength dispersive microprobe at 15 kV and 10 nA, employing Cameca’s PAP corrections. The following standards were used: Omphacite (Na), pyrophanite (Ti), wollastonite (Si), fayalite (Fe) and pure metal (Nb). Ca and Sr were sought, but not found. Al is present in the lorenzenite in a concentration of \( 0. \times \% \), but because of a complex line interference (third order TiK\(_\alpha\) on first order AlK\(_\alpha\)), it was not possible to analyse for Al. The results are shown in Table 2 as average values and compositional range of seven arbitrary spots on both coarsely crystalline lorenzenite and fibrous lorenzenite, and the chemical formulas are:

\[
\text{Na}_{1.94}(\text{Ti}_{1.95}\text{Fe}_{0.04}\text{Nb}_{0.07})\text{Si}_{2.06}\text{O}_{9}
\]

and

\[
\text{Na}_{1.98}(\text{Ti}_{1.95}\text{Fe}_{0.02}\text{Nb}_{0.04})\text{Si}_{2.01}\text{O}_{9},
\]

respectively.

The coarsely crystalline lorenzenite is fairly homogeneous in composition, while the fibrous lorenzenite shows somewhat varying chemistry, especially for the substituting elements Fe and Nb. From the average analytical values the calculated Fe:Nb ratios are 1:1.80 and 1:2.25 for coarsely crystalline lorenzenite and fibrous lorenzenite, respectively. Thus, the coupled substitution of Fe and Nb for Ti occurs mainly according to CuK\(_\alpha\) radiation (\( \lambda = 1.54059 \) Å), graphite monochromator and Si (NBS 640a) as internal standard. The X-ray powder diffraction patterns are practically identical with that reported by Glasser & Marr (1979) (International Centre for Diffraction Data PDF 33-1298). The unit cell dimensions were calculated from the powder diffraction patterns by least squares refinement (Applemann & Evans 1973; Benoit 1987). The results are shown in Table 1 and compared with data for lorenzenites reported during the last decade. The Bratthagen lorenzenite is virtually identical with most other lorenzenites. There are very small variations in the cell parameters among lorenzenites, which reflect the limited chemical substitutions found in this mineral.

### X-ray crystallography

Coarsely crystalline lorenzenite and fibrous lorenzenite were run in a Philips APD1700 diffractometer using \( \text{CuK}_{\alpha} \) radiation (\( \lambda = 1.54059 \) Å), graphite monochromator and Si (NBS 640a) as internal standard. The X-ray powder diffraction patterns are practically identical with that reported by Glasser & Marr (1979) (International Centre for Diffraction Data PDF 33-1298). The unit cell dimensions were calculated from the powder diffraction patterns by least squares refinement (Applemann & Evans 1973; Benoit 1987). The results are shown in Table 1 and compared with data for lorenzenites reported during the last decade. The Bratthagen lorenzenite is virtually identical with most other lorenzenites. There are very small variations in the cell parameters among lorenzenites, which reflect the limited chemical substitutions found in this mineral.

<table>
<thead>
<tr>
<th>Locality</th>
<th>( a (\text{Å}) )</th>
<th>( b (\text{Å}) )</th>
<th>( c (\text{Å}) )</th>
<th>Space group</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Synthetic)</td>
<td>14.492(9)</td>
<td>8.699(4)</td>
<td>5.233(2)</td>
<td>( \text{Pnca} )</td>
<td>Glasser &amp; Marr (1979) [PDF 33-1298 (1983)]</td>
</tr>
<tr>
<td>Ilmaaussaq, S. Greenland</td>
<td>14.660(110)</td>
<td>8.6763(55)</td>
<td>5.2338(39)</td>
<td>( \text{Pnca} )</td>
<td>Karup-Møller (1986)</td>
</tr>
<tr>
<td>Lovozero, USSR</td>
<td>8.707(3)</td>
<td>5.234(4)</td>
<td>14.492(3)</td>
<td>( \text{Pnca} )</td>
<td>Sundberg et al. (1987)</td>
</tr>
<tr>
<td>Lovozero, USSR</td>
<td>8.7128(10)</td>
<td>5.2327(5)</td>
<td>14.487(2)</td>
<td>( \text{Pnca} )</td>
<td>Sundberg et al. (1987)</td>
</tr>
<tr>
<td>Mont Saint-Hilaire, Canada</td>
<td>14.441(6)</td>
<td>8.703(2)</td>
<td>5.231(1)</td>
<td>( \text{Pnca} )</td>
<td>Mandarino &amp; Anderson (1989)</td>
</tr>
<tr>
<td>Bratthagen, Norway*</td>
<td>14.488(2)</td>
<td>8.7061(11)</td>
<td>5.2303(8)</td>
<td>( \text{Pnca} )</td>
<td>This work</td>
</tr>
<tr>
<td>Bratthagen, Norway**</td>
<td>14.480(1)</td>
<td>8.6995(8)</td>
<td>5.2277(3)</td>
<td>( \text{Pnca} )</td>
<td>This work</td>
</tr>
</tbody>
</table>

1 Powder diffraction method. 2 Single crystal method. * Coarsely crystalline lorenzenite. ** Fibrous lorenzenite.
References


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Table 2. Chemical composition (wt%) for Bratthagen lorenzenite. Atomic proportions calculated on the basis of six cations.

<table>
<thead>
<tr>
<th></th>
<th>Coarsely crystalline</th>
<th>Fibrous</th>
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<tr>
<td></td>
<td>$\bar{x}$ (n = 7)</td>
<td>Range</td>
</tr>
<tr>
<td>Na2O</td>
<td>17.13</td>
<td>16.85–17.42</td>
</tr>
<tr>
<td>SiO2</td>
<td>34.20</td>
<td>33.98–34.50</td>
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<tr>
<td>TiO2</td>
<td>44.39</td>
<td>43.98–44.68</td>
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<tr>
<td>FeO</td>
<td>0.83</td>
<td>0.71–0.94</td>
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<tr>
<td>Nb2O5</td>
<td>2.71</td>
<td>2.33–2.98</td>
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<tr>
<td>Total</td>
<td>99.26</td>
<td></td>
</tr>
</tbody>
</table>

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