

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

ALF OLAV LARSEN, GUNNAR RAADE & PER CHRISTIAN SÆBØ

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Lorenzenite, $\text{Na}_2\text{Ti}_2\text{Si}_2\text{O}_9$, 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): $a = 14.488(2)/14.480(1)$ Å, $b = 8.7061(11)/8.6995(8)$ Å, $c = 5.2308(8)/5.2277(3)$ Å. D_{meas} for coarsely crystalline lorenzenite is $3.436(1)$ g/cm³. Coarsely crystalline lorenzenite is brown, while fibrous lorenzenite is colourless to pale yellow. It is nonpleochroic, and strongly birefringent. The axial dispersion is distinct $r > v$. Biaxial negative, $2V = 42^\circ \pm 4^\circ$, $n > 1.80$. The mineral shows yellow fluorescence in short wave UV light. A cathodoluminescence spectrum of coarsely crystalline lorenzenite shows an intrinsic type of luminescence with a maximum at 500 nm. The average of seven electron microprobe analyses gave the following results for coarsely crystalline/fibrous lorenzenite: Na₂O 17.13/17.74, SiO₂ 34.20/35.03, TiO₂ 44.39/45.13, FeO 0.83/0.34, Nb₂O₅ 2.71/1.40, total 99.26/99.64. The average Fe:Nb ratios are 1:1.80/1:2.25, indicating substitution according to the scheme $\text{Fe}^{2+} + 2\text{Nb}^{5+} \leftrightarrow 3\text{Ti}^{4+}$.

A. O. Larsen, Norsk Hydro a.s., Research Centre Porsgrunn, N-3901 Porsgrunn, Norway; G. Raade and P. Chr. Sæbø, Mineralogisk-Geologisk Museum, Sars Gate 1, N-0562 Oslo 5, Norway.

The mineral lorenzenite was described by Flink (1901) from Narssarsuk, Greenland. The chemical formula was given as $\text{Na}_2\text{Ti}_2\text{Si}_2\text{O}_9$ with 11.92% ZrO₂ substituting for TiO₂. Ramsayite was described as a new mineral with the same formula by Kostyleva (1923) from several localities on the Kola Peninsula. She suggested that the two minerals lorenzenite and ramsayite represent varieties of the same species. Barth & Berman (1930), Kraus & Mussgnug (1941) and Sahama (1947) reexamined the minerals and found them to be practically identical. Because of the rule of priority, lorenzenite has been widely accepted as the name of the mineral (Fleischer & Mandarino 1991). The crystal structure of lorenzenite was solved by Sundberg et al. (1987), and is described as pyroxene-type $[\text{Si}_2\text{O}_6]_\infty$ chains running in the direction of the b -axis. The TiO₆ octahedra lie in two adjacent layers, alternating in each layer with chains of NaO₇ polyhedra. The space group was found to be $Pbcn$ 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 the Narssarsuk pegmatite and Ilimaussaq alkaline complex, South Greenland (Flink 1901; Karup-Møller 1986), the Khibina and Lovozero massifs on the Kola Peninsula, USSR (Vlasov et al. 1966; Semenov 1972; Kostyleva-Labuntsova et al. 1978), the Konderskii massif, Yakutia, USSR (Andreev 1961) and Mont Saint-Hilaire, Quebec, Canada (Mandarino & Anderson 1989). A general review of mainly the Russian lorenzenites has 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-nephelinite 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 miarolitic 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 *canad. 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

southeast 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, pyrrhotite, fluorite, chrysoberyl, magnetite, hematite, ilmenite, pyrophanite, loparite-(Ce), gibbsite, nordstrandite, böhmite, diaspore, calcite, ancylite-(Ce), anglesite, monazite-(Ce), fluorapatite, zircon, thorite, titanite, lorenzenite, datolite, gadolinite-(Ce), meliphanite, leucophanite, barylite, keldyshite, parakeldyshite, catapleiite, hilairite, rosenbuschite, astrophyllite, eudialite, aegirine, hornblende, muscovite, biotite, polythionite, chlorite, stilpnomelane, montmorillonite, nepheline, albite, microcline, eudymite, genthelvite, sodalite, cancrinite, natrolite, thomsonite, gonnardite, 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),

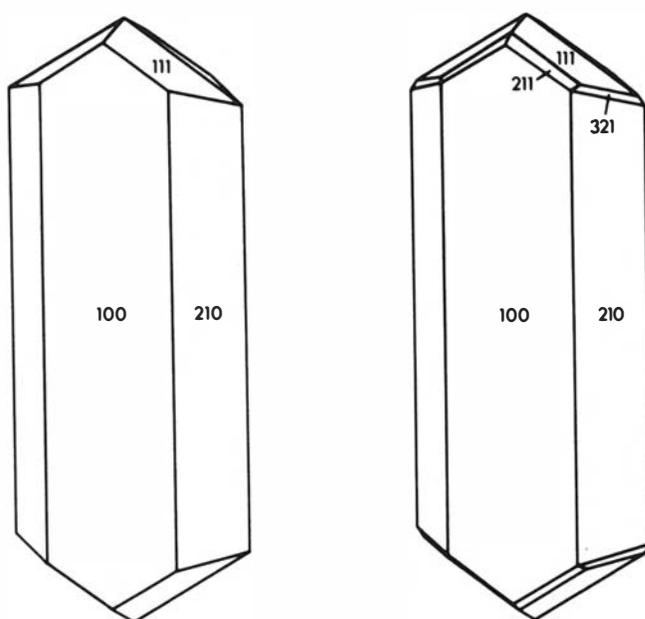


Fig. 1. Lorenzenite crystals from the Bratthagen nepheline syenite pegmatite.

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 lustre. 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

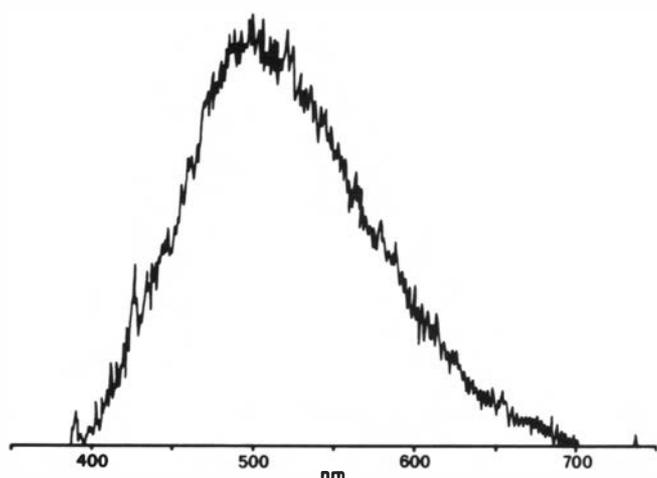


Fig. 2. Cathodoluminescence spectrum for coarsely crystalline Bratthagen lorenzenite.

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 SiO_4 or TiO_6 groups. Lorenzenite from the Kola Peninsula gives an identical CL spectrum (A. N. Mariano, pers. comm. 1991).

X-ray crystallography

Coarsely crystalline lorenzenite and fibrous lorenzenite were run in a Philips APD1700 diffractometer using

$\text{CuK}\alpha_1$ radiation ($\lambda = 1.54059 \text{ \AA}$), 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 (Appleman & 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.

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. x %, but because of a complex line interference (third order $\text{TiK}\alpha_1$ on first order $\text{AlK}\alpha_1$), 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:



and



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

Table 1. Cell parameters and space groups reported for lorenzenite.

Locality	a (Å)	b (Å)	c (Å)	Space group	References
(Synthetic)	14.492(9)	8.699(4)	5.233(2)	<i>Pnca</i>	Glasser & Marr (1979) [PDF 33-1298 (1983)]
Ilimaussaq, S. Greenland	14.6460(110)	8.6763(55)	5.2338(39)		Karup-Møller (1986)
Lovozero, USSR	8.707(3)	5.234(4)	14.492(3)	<i>Pbcn</i>	Sundberg et al. (1987) ¹
Lovozero, USSR	8.7128(10)	5.2327(5)	14.487(2)	<i>Pbcn</i>	Sundberg et al. (1987) ²
Mont Saint-Hilaire, Canada	14.441(6)	8.703(2)	5.231(1)	<i>Pcnb</i>	Mandarino & Anderson (1989)
Bratthagen, Norway*	14.488(2)	8.7061(11)	5.2303(8)		This work
Bratthagen, Norway**	14.480(1)	8.6995(8)	5.2277(3)		This work

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

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

	Coarsely crystalline		Fibrous	
	\bar{x} (n = 7)	Range	\bar{x} (n = 7)	Range
Na ₂ O	17.13	16.85–17.42	17.74	17.47–17.98
SiO ₂	34.20	33.98–34.50	35.03	34.75–35.43
TiO ₂	44.39	43.98–44.68	45.13	43.88–46.25
FeO	0.83	0.71–0.94	0.34	0.17–0.48
Nb ₂ O ₅	2.71	2.33–2.98	1.40	0.88–2.19
Total	99.26		99.64	
Na	1.940		1.979	
Si	1.998		2.016	
Ti	1.950		1.953	
Fe	0.040		0.016	
Nb	0.072		0.036	

to the scheme $\text{Fe}^{2+} + 2\text{Nb}^{5+} \Leftrightarrow 3\text{Ti}^{4+}$, in contrast to $\text{Fe}^{3+} + \text{Nb}^{5+} \Leftrightarrow 2\text{Ti}^{4+}$.

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References

- Andreev, G. V. 1961: Ramsayite from the alkaline pegmatites of the Konderskii massif. In Ginzburg, A. I. (ed.): *Geologiya mestorozhdenii redkikh elementov* 9, 91–98 (in Russian).
- Appleman, D. E. & Evans, H. T., Jr. 1973: Job 9214: Indexing and least-squares refinement of powder diffraction data. *U.S. Geological Survey, Computer Contribution 20, U.S. National Technical Information Service, Document PB 216 188*.
- Barth, T. F. W. & Berman, H. 1930: Neue optische Daten wenig bekannter Minerale. *Chemie der Erde* 5, 22–40.
- Benoit, P. H. 1987: Adaption to microcomputer of the Appleman-Evans program for indexing and least squares refinement of powder-diffraction data for unit-cell dimensions. *American Mineralogist* 72, 1018–1019.
- Borutskii, B. E., Shlyukova, Z. V., Sokolova, M. N., Rudnitskaya, E. S., Lomeiko, E. I., Tsareva, L. P. & Burova, T. A. 1971: Uniformity of the chemical composition of some Khibiny titanosilicates (aenigmatite, ramsayite). In Borneman-Starynkevich, I. D. (ed.): *Metody khimicheskogo analiza i sostav mineralov*, 39–56 (in Russian). Nauka, Moskva.
- Chukhrov, F. V. 1981: *Minerals Vol. 3, Part 2*, 613 pp. (in Russian). Nauka, Moskva.
- DeMark, R. S. 1984: Minerals of point of rocks, New Mexico. *Mineralogical Record* 15, 150–156.
- Dorfman, M. D., Belova, E. N. & Zabavnikova, N. I. (1966): New data on ramsayite. *Trudy Mineralogiceskii Muzeya, Akademii Nauk SSSR* 17, 45–59 (in Russian).
- Ferguson, A. K. 1978a: The occurrence of ramsayite, titanlavenite and a fluorine-rich euclolite in a nepheline syenite inclusion from Tenerife, Canary Islands. *Contributions to Mineralogy and Petrology* 66, 15–20.
- Ferguson, A. K. 1978b: A ramsayite-bearing pegmatoidal clots in a mela-nephelinite from the older volcanics near Bacchus Marsh, Victoria (Australia). *Journal of the Geological Society of Australia* 24, 491–494.
- Fleischer, M. & Mandarino, J. A. 1991: *Glossary of Mineral Species 1991*. Mineralogical Record Inc., Tucson.
- Flink, G. 1901: On the minerals from Narsarsuk on the Firth of Tunugdliarfik in Southern Greenland. *Meddelelser om Grønland* 24, 9–180.
- Glasser, F. & Marr, J. 1979: Phase relations in the system sodium oxide–titanium dioxide–silicon dioxide. *Journal of the American Ceramic Society* 62, 42–47.
- Karup-Møller, S. 1986: Murmanite from the Ilimaussaq alkaline complex, South Greenland. *Neues Jahrbuch für Mineralogie Abhandlungen* 155, 67–88.
- Kostyleva, E. E. 1923: A new mineral, ramsayite, from the Khibinskii and Lovozerkii tundras. *Comptes Rendus Academie des Sciences de l'USSR* 1923, 55–58.
- Kostyleva-Labuntsova, E. E., Borutskii, B. E., Sokolova, M. N., Shlyukova, Z. V., Dorfman, M. D., Dudkin, O. B. & Kozyreva, L. V. 1978: *Mineralogy of the Khibina Massif, vol. 2*, 586 pp. (in Russian). Nauka, Moskva.
- Kraus, O. & Musgnug, F. 1941: Identität von Lorenzenit und Ramsayit. *Naturwissenschaften* 29, 182.
- Mandarino, J. A. & Anderson, V. 1989: *Monteregian Treasures: the Minerals of Mont Saint-Hilaire, Quebec*, 281 pp. Cambridge University Press, Cambridge/New York/New Rochelle/Melbourne/Sydney.
- Mason, R. A. & Mariano, A. N. 1990: Cathodoluminescence activation in manganese-bearing and rare earth-bearing synthetic calcites. *Chemical Geology* 88, 191–206.
- Miljøverndepartementet 1983: *Utkast til verneplan for mineralforekomster i Sør-Norge, Rapport T-546*, 67 pp. Miljøverndepartementet, Oslo.
- Raade, G. 1967: Ramsayite as an alteration product of mosandrite. *Norsk Geologisk Tidsskrift* 47, 249–250.
- Raade, G. 1972: Mineralogy of the miarolitic cavities in the plutonic rocks of the Oslo Region, Norway. *Mineralogical Record* 3, 7–11.
- Raade, G. & Haug, J. 1982; Gjerdingen. Fundstelle seltener Mineralien in Norwegen. *Lapis* 7, 9–15 (+ p. 42).
- Raade, G. & Mladeck, M. H. 1977: Parakeldyshite from Norway. *Canadian Mineralogist* 15, 102–107.
- Sæbø, P. Chr. 1965: Contributions to the mineralogy of Norway. 1. The first occurrence of the rare mineral barylite, Be₂BaSi₂O₇, in Norway. 2. Note on a new occurrence of chrysoberyl in Norway. 3. The first occurrence of ramsayite, Na₂Ti₂Si₂O₉, in Norway. Unpublished thesis, University of Oslo, 38 pp.
- Sæbø, P. Chr. 1966a: A short comment on some Norwegian mineral deposits within the Igneous Rock Complex of the Oslo Region. *Norsk Geologisk Tidsskrift* 46, 260–261.
- Sæbø, P. Chr. 1966b: Contributions to the mineralogy of Norway, No. 35. The first occurrences of the rare mineral barylite, Be₂BaSi₂O₇, in Norway. *Norsk Geologisk Tidsskrift* 46, 335–348.
- Sahama, Th. G. 1947: Analysis of ramsayite and lorenzenite. *American Mineralogist* 32, 59–63.
- Semenov, E. I. 1972: *Mineralogy of the Lovozero Alkaline Massif*, 307 pp. (in Russian). Nauka, Moskva.
- Sundberg, M. R., Lehtinen, M. & Kivekäs, R. 1987: Refinement of the crystal structure of ramsayite (lorenzenite). *American Mineralogist* 71, 173–177.
- Vlasov, K. A., Kuzmenko, M. V. & Eskova, E. M. 1966: *The Lovozero Alkaline Massif*, 627 pp. Oliver & Boyd, Edinburgh/London.