

# Gaidonnayite from nepheline syenite pegmatite on Siktesøya in the southern part of the Oslo Region, Norway

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Gaidonnayite,  $\text{Na}_2\text{ZrSi}_3\text{O}_9 \cdot 2\text{H}_2\text{O}$ , the orthorhombic dimorph of catapleiite, has been found in small vugs in a nepheline syenite pegmatite dike on Siktesøya, Oslo Region, Norway. The mineral occurs as transparent, colourless to very pale green crystals in aggregates up to 1 mm across. Gaidonnayite probably formed as the result of hydrothermal alteration of eudialite. The crystals display the forms {001}, {010}, {101} and {120}. The average of 18 electron microprobe analyses gives the following empirical formula:  $(\text{Na}_{1.52}\text{K}_{0.40})_{\Sigma 1.92}(\text{Zr}_{0.97}\text{Ti}_{0.07}\text{Nb}_{0.02})_{\Sigma 1.01}\text{Si}_{3.00}\text{O}_9 \cdot 2\text{H}_2\text{O}$ . The unit cell dimensions are  $a = 11.761(8) \text{ \AA}$ ,  $b = 12.830(6) \text{ \AA}$ ,  $c = 6.693(4) \text{ \AA}$ ,  $V = 1009.9(8) \text{ \AA}^3$ . The cell parameters of gaidonnayite show a linear correlation with the potassium content. Gaidonnayite from Siktesøya shows a vivid green fluorescence in short-wave UV light (254 nm). The UV excited fluorescence spectrum is typical of uranyl-activated minerals.

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Gaidonnayite ( $\text{Na}_2\text{ZrSi}_3\text{O}_9 \cdot 2\text{H}_2\text{O}$ ) was first described from miarolitic cavities in nepheline syenite at Mont Saint-Hilaire, Quebec, Canada (Chao & Watkinson 1974). So-called  $\alpha$ -catapleiite from the Narssarssuk pegmatite, South Greenland (Gordon 1924) was shown to be identical with gaidonnayite by Mandarinò & Sturman (1978). Some of the  $\alpha$ -catapleiite material has been shown to be georgechaoite, an Na-K ordered mineral species isostructural with gaidonnayite (Boggs & Ghose 1985). Gaidonnayite has been found in the Lovozero alkaline massif (Khomjakov & Semenov 1979) and from a carbonatite at Vuoriyarvi (Voloshin et al. 1989), both on the Kola Peninsula, USSR. A potassian gaidonnayite was described from the Kipawa agpaite syenite complex, Quebec, Canada by Roberts & Bonardi (1983), and excellent crystals of gaidonnayite have been found in an igneous sill in a limestone quarry at Montreal, Quebec, Canada (Horwath & Gault 1990).

In the autumn of 1987, samples rich in vugs were collected from a nepheline syenite pegmatite dike exposed in a construction site for a summer house at Brønnebukta on the northeastern part of Siktesøya in the Langesundsfjord, Oslo Region, Norway. Some samples contained a transparent, colourless to very pale green mineral showing a vivid green fluorescence in short-wave UV light. The mineral was subsequently identified by X-ray diffraction as gaidonnayite, and is thus a new species that can be added to the extensive list of minerals from the nepheline syenite pegmatites in the Oslo Region, which became known through the work of Brøgger (1890). The mineral list was updated by Raade et al. (1980). It is interesting to note that catapleiite, the dimorph of gaidonnayite, was originally described by

Weibye (1849) from Låven island, 4.5 km southeast of the gaidonnayite locality.

## Occurrence

Gaidonnayite occurs locally in abundance in vugs in a hydrothermally altered nepheline syenite pegmatite dike as crystal aggregates intergrown with and partly covered by small crystals of zircon. Accessory minerals in the vugs include microcline, albite, aegirine, analcime, natrolite and more rarely eudidymite, hilairite and polyolithionite. With the exception of the zeolites, eudidymite, gaidonnayite and zircon are the latest minerals to crystallize in the vugs. The late-stage zirconium minerals are the result of hydrothermal alteration of a primary zirconium mineral, probably eudialite, as this mineral is found relatively abundantly in less altered parts of the pegmatite. Gaidonnayite has also been found in small amounts unevenly distributed along cracks and joints in the pegmatite dike. Other minerals found in the pegmatite are nepheline, biotite, hornblende, magnetite, sodalite, astrophyllite, fluorite, wöhlerite, leucophanite, berberite, epididymite, nordstrandite, molybdenite, galena, sphalerite, löllingite, pyrite, chalcopyrite and calcite. Because of blasting, it was not possible to study the pegmatite dike *in situ*, but from the material available it seems as if the gaidonnayite-bearing part of the pegmatite was of limited extent.

## Morphology

Gaidonnayite aggregates may reach 1 mm across (Fig. 1). They are strongly fractured and fragile. Individual

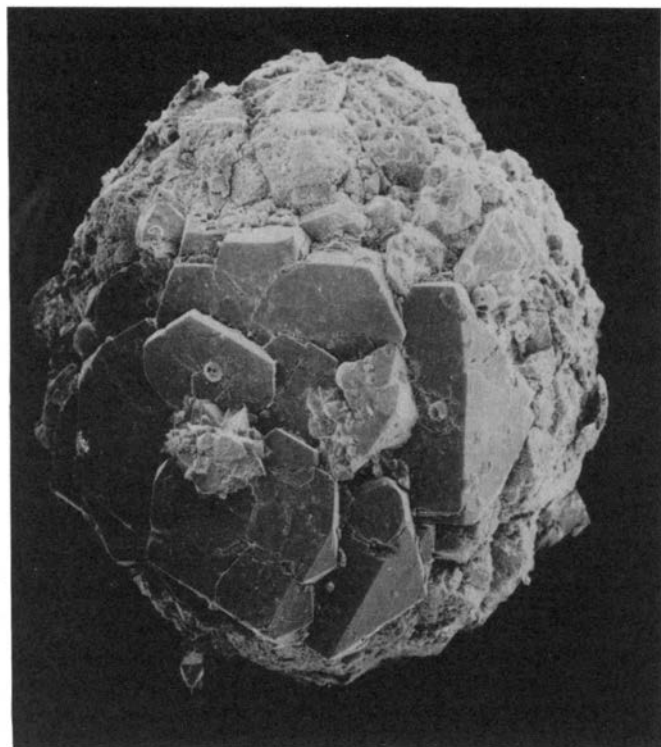


Fig. 1. SEM photomicrograph showing a crystal aggregate (approximately 1 mm across) of gaidonnayite partly overgrown by zircon from Siktesøya.

orthorhombic crystals display the {001} and {010} pinacoids as well as {101} and {120} prisms (Fig. 2). Indices were found by measuring interfacial angles from oriented crystals on SEM photomicrographs. The {001} pinacoid is a new form not previously reported for gaidonnayite.

### Chemical composition

Several crystals of gaidonnayite from Siktesøya were analysed with a CAMEBAX MICROBEAM wavelength dis-

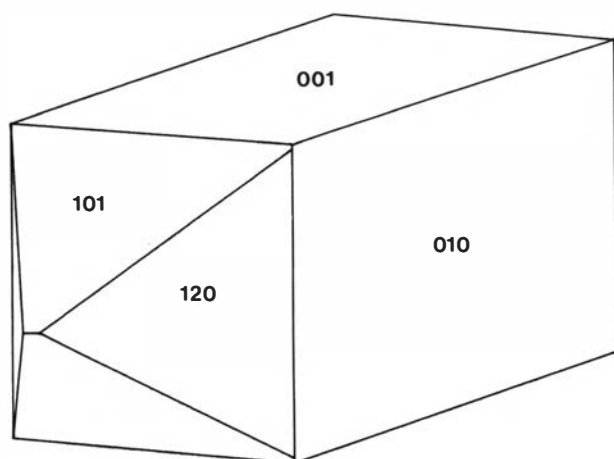


Fig. 2. Crystal drawing of gaidonnayite from Siktesøya.

Table 1. Electron microprobe analyses (in wt. %) of gaidonnayite from Siktesøya.

	Range	Average (n = 18)	Number of atoms based on 9 oxygens*	
SiO <sub>2</sub>	42.28–45.76	43.95	Si	3.00
TiO <sub>2</sub>	0.35–1.84	1.36	Ti	0.07
ZrO <sub>2</sub>	26.07–29.33	27.82	Zr	0.92
Nb <sub>2</sub> O <sub>5</sub>	0.25–2.20	0.68	Nb	0.02
FeO	0.00–0.24	0.06	Fe	<0.01
ZnO	0.00–0.29	0.10	Zn	<0.01
Na <sub>2</sub> O		11.50**	Na	1.52
K <sub>2</sub> O	3.94–5.30	4.56	K	0.40
H <sub>2</sub> O		8.80***	H <sub>2</sub> O	2.00
Total		98.83		

\* Not including oxygens in H<sub>2</sub>O.

\*\* Maximum value increased by 15% (see text).

\*\*\* H<sub>2</sub>O by stoichiometry.

persive electron microprobe, employing Cameca's PAP corrections. The following standards were used: wollastonite (Si), rutile (Ti), pure metals (Zr and Nb), fayalite (Fe), pure ZnS (Zn), omphacite (Na) and orthoclase (K). Calcium and aluminium were not detected.

Loss of sodium under the electron beam turned out to be a serious problem, while loss of potassium occurred to a much lesser degree. A series of ten analyses was performed at 15 kV and 10 nA while moving the sample under a defocused beam (up to 30 μm in diameter). In another series of six analyses, sodium was analysed at 10 kV and 5 nA and the other elements at 15 kV, 10 nA. In a final series of six analyses, the experimental conditions were 10 kV, 3.5 nA for sodium and 15 kV, 5 nA for the other elements. A defocused beam was also used in the latter two series. The Na<sub>2</sub>O concentrations are fairly erratic in all three series, and lowering the voltage and beam current did not significantly improve the results for sodium. The K<sub>2</sub>O values show only a limited variation. The rate of sodium loss was tested during counting periods of 10 s and it was concluded that the maximum Na<sub>2</sub>O value obtained (9.99 wt.%) increased by 15% would give an approximately correct value of 11.5 wt.% for Na<sub>2</sub>O.

The average of 18 selected electron microprobe analyses (Table 1) gives the following empirical formula, based on nine oxygens in the anhydrous part:



### Luminescence spectroscopy

The Siktesøya gaidonnayite shows a bright green fluorescence in short-wave UV light. This is also reported for gaidonnayite from Mont Saint-Hilaire, Quebec, Canada, although non-fluorescent gaidonnayite has also been found (Horwath & Gault 1990). Gaidonnayite shows no cathodoluminescence.

The emission spectrum for the Siktesøya gaidonnayite using a short-wave UV lamp (254 nm) was scanned from 350 nm to 750 nm. The resulting spectrum shows several

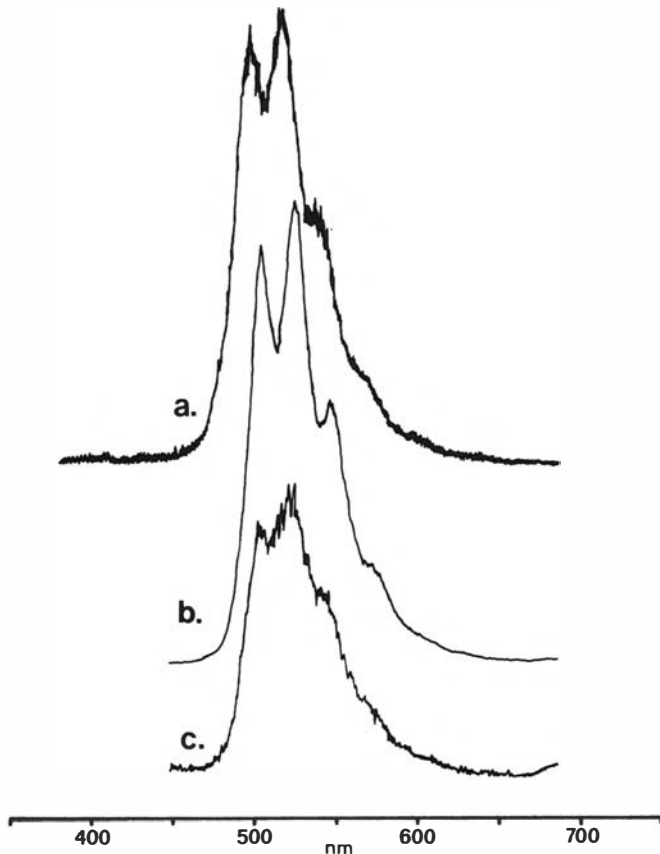


Fig. 3. Emission spectra using short-wave UV light for gaidonnayite from Siktesøya (a), opal from Maracas, Bahia, Brazil (b), and hydrous thorite from the Kipawa agpaitic complex, Quebec, Canada (c).

peaks in the green region of the visible range (Fig. 3a). Emissions from the UV lamp, mainly yielding a strong peak at 400 nm and several peaks in the region 690–750 nm, are subtracted from the spectra in Fig. 3.

A complex spectrum like the one obtained for gaidonnayite is typical of uranyl-activated minerals. This is exemplified by the spectrum of opal from Maracas, Bahia, Brazil (Fig. 3b). Fluorescent opals and chalcodites containing 15–3000 ppm U are well-known (UO<sub>2</sub>)<sup>2+</sup>-activated minerals (deNeufville et al. 1981). Uraniferous hydrous thorite from the Kipawa agpaitic complex, Quebec, Canada also shows an emission spectrum very similar to that of gaidonnayite (Fig. 3c). The slight wavelength shifts observed in the three spectra may be the result of crystal field effects for the different hosts.

### X-ray crystallography

Gaidonnayite is orthorhombic, space group *P2<sub>1</sub>nb*, *Z* = 4 (Chao & Watkinson 1974). The crystal structure was solved by Chao (1985) and consists of sinusoidal single silicate chains of tetrahedra. They repeat at every six tetrahedra along [101] and [10 $\bar{1}$ ] and are cross-linked by one Zr–O octahedron and two distorted Na–O octahedra.

Gaidonnayite from Siktesøya was run in a Philips APD

1700 diffractometer using a step scan with a sampling interval 0.01° 2 $\Theta$ , an integration time of 2 s, CuK $\alpha$ <sub>1</sub> radiation ( $\lambda$  = 1.54059 Å) and a graphite monochromator. Si (NBS 640A) was used as an internal standard. Forty-two reflections in the *d*-value interval 6.43 Å to 1.77 Å were used for calculating the cell parameters by least squares refinement using the program of Appleman & Evans (1973), modified by Benoit (1987). The cell parameters found for the Siktesøya gaidonnayite are

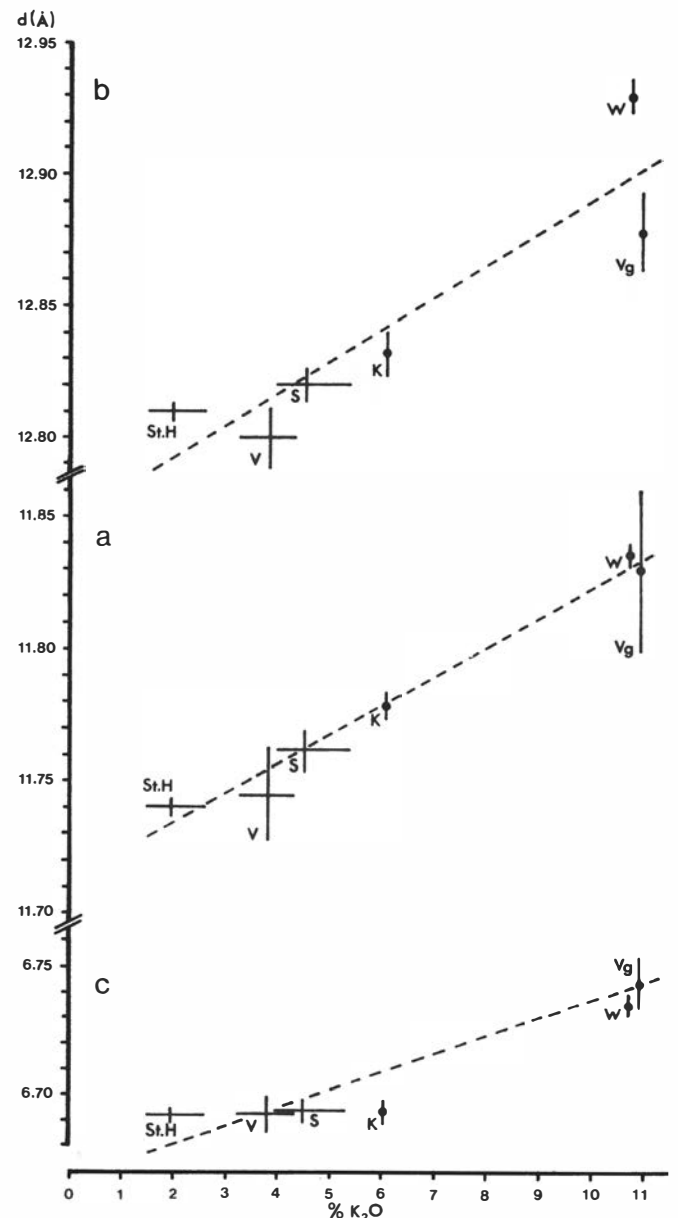


Fig. 4. Cell parameters versus potassium content for gaidonnayite and georgechaoite. Vertical and horizontal bars indicate standard deviation and range in chemical composition, respectively. Filled circle indicates a single value. The stippled lines are found by linear regression. St.H is gaidonnayite from Mont Saint-Hilaire, Quebec, Canada (Mandarino & Sturman 1978). K is gaidonnayite from Kipawa, Quebec, Canada (Roberts & Bonardi 1983). S is gaidonnayite from Siktesøya (this work). V and V<sub>g</sub> are gaidonnayite and georgechaoite, respectively, from Vuoriyarvi, Kola Peninsula, USSR [The cell parameters were calculated from powder diffraction data given by Voloshin et al. (1989)]. W is georgechaoite from Wind Mountain, New Mexico, USA (Boggs & Ghose 1985).

$a = 11.761(8) \text{ \AA}$ ,  $b = 12.830(6) \text{ \AA}$ ,  $c = 6.693(4) \text{ \AA}$  and  $V = 1009.9(8) \text{ \AA}^3$ . The X-ray powder pattern is similar to that reported by Chao & Watkinson (1974) and is therefore not given here.

## Discussion

Potassium is the major substituent in gaidonnayite, and concentrations up to 7.0% K<sub>2</sub>O have been reported (Mandarino & Sturman 1978). Roberts & Bonardi (1983) pointed out that there is a correlation between the cell parameters of gaidonnayite and the potassium content. Georgechaoite, the Na-K ordered mineral isostructural with gaidonnayite, has ideally 11.28% K<sub>2</sub>O and cell parameters considerably larger than those of gaidonnayite. Fig. 4 indicates that there is a linear correlation between the cell parameters and the potassium content, using data from the literature in addition to data for the Siktesøya gaidonnayite. Some of the data are encumbered with quite large statistical errors which may be attributed to several factors, among which inhomogeneity due to strong variation in the potassium content and the presence of other substituents (Zn, Fe, Nb, Ti for Zr) are the most important.

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