

# Minerals of the låvenite group from South Greenland and Norway

Henrik Friis, Tonči Balić-Žunić, Terry Williams & Ole V. Petersen

## Introduction

Låvenite is a sorosilicate with the ideal formula  $Zr(Fe,Mn)Na_2Si_2O_7F$ , which was first described as a new mineral from the island Låven in the Langesundsford, Norway (Brögger 1884, 1890). It occurs as dark brown tabular to prismatic crystals. The crystal structure of låvenite was solved by Mellini (1981) showing that the cations, apart from Si, are distributed between four distinctive octahedral sites (called M1-M4). The låvenite group also contains the minerals burpalite, ideally  $ZrCaNa_2Si_2O_7F_2$  (Merlino et al. 1990) and normandite ideally  $Ti(Fe,Mn)Na_2Si_2O_8F$  (Chao & Gault 1997). The members of the group are all monoclinic apart from burpalite which is orthorhombic.

During a visit to the Nanna pegmatite in 2001 HF found a yellow elongated mineral resembling låvenite. The Nanna pegmatite is situated close to the famous Narssârssuk pegmatite, South Greenland, and is formed as part of the many alkaline complexes in the region known as the Gardar province. Initial studies showed a higher content of Na than in normal låvenite and a detailed study of the låvenite group was therefore initiated.

## Samples studied

**L1** is up to 5 mm brown, elongated låvenite crystals from the eudialyte and thorite rich pegmatite on Natrolittodden on the eastern part of Vesle Arøya. Note this island was previously called Lille Arøya and provided the material used for the chemical study by Cleve in Brögger (1890).

**L2** forms brown, slight elongated to rounded patches in fine grained albite. The material is from the huge pegmatite in the Sagåsen larvikite quarry in Tvedalen, Norway.

**N1** forms up to 20 mm elongated, yellow crystals that sometimes form larger aggregates and is from the Nanna pegmatite, South Greenland.

**N2** is from a pegmatite 8 m from the pegmatite where L1 was found on Natrolittodden on the eastern part of the island Vesle Arøya. The yellow crystals form groups of parallel orientated crystals with the groups being several cm in diameter and the individual crystals up to a few mm. This pegmatite is already type locality for the two species cappelenite-(Y) (Brögger 1884, 1890) and grenmarite (Bellezza et al. 2004).

The Nanna pegmatite has been believed to be found for the first time in 1963 and intensively collected in 1968 and 1970 (Petersen et al. 1999). However, in a study of leucophanites from the collection of the Geological Museum in Copenhagen a sample from 1907 labelled *Leucophan med astrophyllit fra Narsarsuk?* was found. Interestingly, the mineral identified as astrophyllite was not astrophyllite, but in fact nafertisite, which, in Greenland, has only been found in the Nanna pegmatite showing that already in the early 20<sup>th</sup> century material was collected from this pegmatite. In spite of this it took almost 100 years before the first mineral descriptions of the pegmatite was published.

The Nanna pegmatite differs in composition and structure from other pegmatites in the Gardar province of South Greenland. It consists of an outer zone dominated by sodalite, nepheline and feldspar and a hydrothermally altered core. The main minerals found in the core are natrolite, analcime, nafertisite and calcioancylite-(Ce). This type of zoned pegmatite is well-known from the Langesundsfjord, Norway, but not in the Gardar province. In the Langesundsfjord *lâvenite* is mostly associated with the primary unaltered parts of the pegmatite making it one of the primary Zr-minerals, which is also how the yellow mineral occurs in the Nanna pegmatite.

### Chemical composition

Initial analyses of the mineral from the Nanna pegmatite indicated a composition similar to that of burpalite, but structural analyses showed the mineral to have a unit cell like that of *lâvenite*, *i.e.* monoclinic rather than orthorhombic. Brögger (1890) mention that at Lâven a light yellow mineral with similar morphology as *lâvenite* is often found associated with *lâvenite*. However, the composition of the yellow mineral could not be determined due to small amount and intergrowth with *lâvenite* (Brögger 1890). But, Brögger (1890) mentioned that the yellow mineral seemed to have similar chemistry to *lâvenite*, but with a higher Na and lower Mn and Fe content.

Table 1 compares the chemical composition of the four *lâvenite* samples of this study based on electron probe micro analyses (EPMA) with data from the literature. It shows that the yellow members of the group all have a higher Na and F content and lower Fe + Mn than the brown minerals of the *lâvenite* group, as suggested Brögger (1890). Furthermore Figure 1 shows the intergrowth between *lâvenite* and the new phase.

The chemical data shows that the yellow mineral from the Nanna pegmatite and Vesle Arøya (N2) are identical. The results by combining the chemical and crystal structural analyses show the mineral is monoclinic with a *lâvenite* structure and hence not identical to burpalite (Friis et al., in prep). The crystal structure analysis shows that the distributions of cations in the yellow mineral is the same as in burpalite (see Table 2), but because the *lâvenite* structure is a polytype of burpalite the yellow mineral is not a new species. The reduced positive charge caused by Na substituting for Mn + Fe in the new phase results in F substituting and dominating one oxygen site, as in burpalite.

Table 2 also shows that *lâvenite* and the new phase differs on the M3 site which is dominated by Na in the former and Ca in the latter and in burpalite. However, normandite is also dominated by Ca on this site and differs from *lâvenite*. The sample from Sagåsen (L2) is close to a typical *lâvenite* in all but the M3 site, where it is not clearly dominated by Na but contains an equal amount of Ca.

### Conclusions

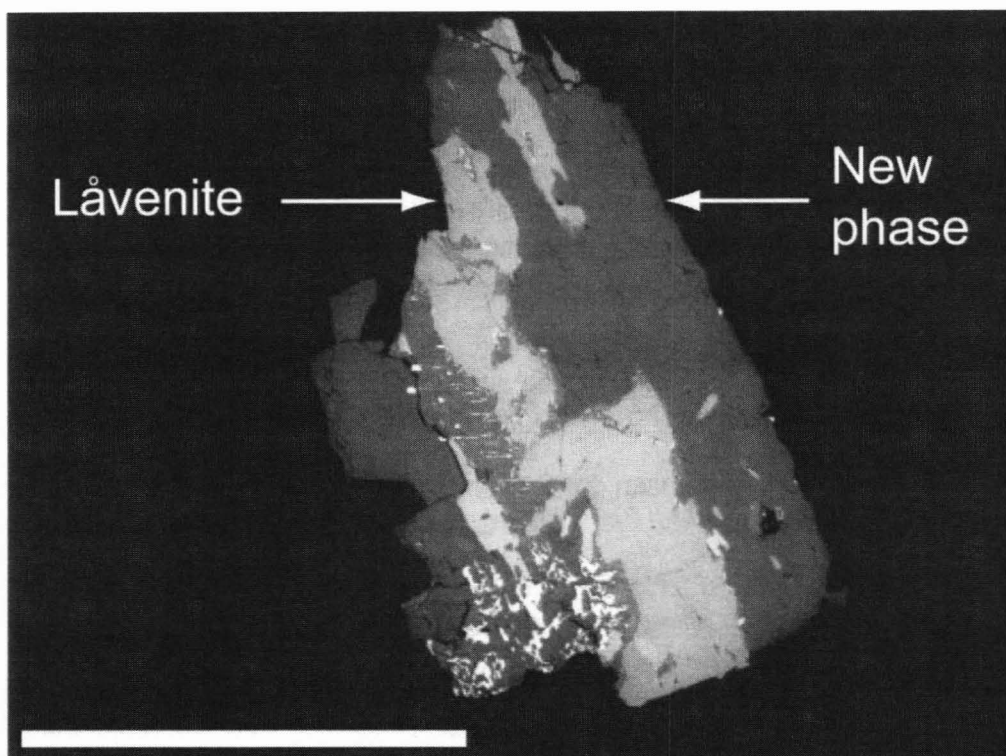
The yellow mineral found at the Nanna pegmatite is a new phase with the same cation distribution as burpalite but the structure of *lâvenite*, making it a polytype of burpalite. The sample from Vesle Arøya (N2) is identical to the Greenlandic material. The *lâvenite* sample from Sagåsen differs from normal *lâvenite* by having a higher Ca content, and is close to be a new species. This study has shown that the potential substitution mechanisms in the *lâvenite* group is vast as three of the four octahedral sites can be dominated by different cations, but the M4 site is always dominated by Na. The flexibility of the structure to incorporate different cations means that the potential for finding new mineral species belonging to the *lâvenite* group is immense.

## Acknowledgements

Alf Olav Larsen is thanked for making samples from the Langesundsfjord available for this study and for guiding HF to the localities of the Langesundsfjord.

## References

- BELLEZZA, M., FRANZINI, M., LARSEN, A.O., MERLINO, S. & PERCHIAZZI, N. (2004): Grenmarite, a new member of the götzenite-seidozerite-rosenbuschite group from the Langesundsfjord district, Norway: definition and crystal structure. *European Journal of Mineralogy* **16**, 971-978.
- BRÖGGER, W.C. (1884): Foreløbig meddelelse om to nye norske mineraler, Låvenit og Cappelenit. *Geologiska Föreningens i Stockholm Förhandlingar* **7**, 598-600
- BRÖGGER, W.C. (1890): Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite. *Zeitschrift für Kristallographie und Mineralogie* **16**, 1-663.
- CHAO, G.Y. & GAULT, R.A. (1997): Normandite, the Ti-analogue of låvenite from Mont Saint-Hilaire, Quebec. *Canadian Mineralogist* **35**, 1035-1039.
- FRIIS, H., BALIĆ-ŽUNIĆ, T., WILLIAMS, C.T. & PETERSEN, O.V.: Characterisation of a dimorph of burpalite with the låvenite structure and the question of nomenclature and classification of låvenite-group minerals. *In prep.*
- MCDONALD, A.M., PETERSEN, O.V., GAULT, R.A., JOHNSEN, O., NIEDERMAYR, G., BRANDSTÄTTER, F. & GIESTER, G. (2001): Micheelsenite,  $(Ca, Y)_3Al(PO_3, OH, CO_3)(CO_3)(OH)_6 \cdot 12H_2O$ , a new mineral from Mont Saint-Hilaire, Quebec, Canada and the Nanna pegmatite, Narsaarsuup Qaava, South Greenland. *Neues Jahrbuch für Mineralogie Monatshefte* **8**, 337-351.
- MELLINI, M. (1981): Refinement of the crystal structure of låvenite. *Tschermaks Mineralogische und Petrographische Mitteilungen* **28**, 99-112.
- MERLINO, S., PERCHIAZZI, N., KHOMYAKOV, A.P., PUSHCHAROVSKY, D.Y., KULIKOVA, I.M. & KUZMIN, V.I. (1990): Burpalite, a new mineral from the Burpalinskii massif, North Transbaikal, USSR: its crystal structure and OD character. *European Journal of Mineralogy* **2**, 177-185.
- PERCHIAZZI, N., MCDONALD, A.M., GAULT, R.A., JOHNSEN, O. & MERLINO, S. (2000): The crystal structure of normandite and its crystal-chemical relationships with låvenite. *Canadian Mineralogist* **38**, 641-648.
- PETERSEN, O.V., JOHNSEN, O., CHRISTIANSEN, C.C., ROBINSON, G.W. & NIEDERMAYR, G. (1999): Nafertisite -  $Na_3Fe_{10}Ti_2Si_{12}(O, OH, F)_{43}$  - from the Nanna pegmatite, Narsaarsuup Qaava, South Greenland. *Neues Jahrbuch für Mineralogie-Monatshefte* **7**, 303-310.



**Figure 1.** Back-scatter image of a grain from Vesle Arøya (N2) showing the intimate intergrowth between lāvenite and the new phase. The scale bar is 400  $\mu\text{m}$ .

**Table 2.** Dominant cations in the four octahedral sites of the lāvenite group minerals.

	L1	L2	N1	N2	Burpalite <sup>1</sup>	Lāvenite <sup>2</sup>	Normandite <sup>3</sup>
<b>M1</b>	Zr	Zr	Zr	Zr	Zr	Zr	Ti
<b>M2</b>	Mn, Fe	Mn, Fe	Na	Na	Na	Mn, Fe	Mn, Fe
<b>M3</b>	Na	Na, Ca	Ca	Ca	Ca	Na	Ca
<b>M4</b>	Na	Na	Na	Na	Na	Na	Na

<sup>1</sup> Merlino et al. (1990); <sup>2</sup> Mellini (1981); <sup>3</sup> Perchiazzi et al. (2000)

**Table 1.** Chemical composition of analysed samples from EPMA and literature data. Formulae are calculated based on six cations.

<i>n</i>	New phase, N1, South Greenland		New phase, N2, Vesle Arøya, Norway		Låvenite, L1, Vesle Arøya, Norway		Låvenite, L2, Sagåsen, Norway		Låvenite, Langesundsfjord, Norway <sup>1</sup>		Burpalite, Burpala, Russia <sup>2</sup>		"Orthorhombic låvenite", Burpala, Russia <sup>1</sup>	
	Wt.%	<i>apfu</i>	Wt.%	<i>apfu</i>	Wt.%	<i>apfu</i>	Wt.%	<i>apfu</i>	Wt%	<i>apfu</i>	Wt%	<i>apfu</i>	Wt%	<i>apfu</i>
Na <sub>2</sub> O	<b>13.8(3)</b>	1.78	<b>14.1(2)</b>	1.79	<b>11.9(2)</b>	1.58	<b>10.68(8)</b>	1.40	<b>12.44</b>	1.63	<b>13.86</b>	1.69	<b>10.89</b>	1.38
CaO	<b>11.7(4)</b>	0.84	<b>11.9(4)</b>	0.84	<b>8.2(2)</b>	0.60	<b>13.1(1)</b>	0.95	<b>8.32</b>	0.60	<b>14.52</b>	0.98	<b>15.39</b>	1.08
MnO	<b>3.0(1)</b>	0.17	<b>3.6(1)</b>	0.20	<b>5.3(1)</b>	0.31	<b>6.8(1)</b>	0.39	<b>5.54</b>	0.32	<b>0.60</b>	0.03	<b>1.58</b>	0.09
FeO	<b>1.6(1)</b>	0.09	<b>2.0(3)</b>	0.11	<b>3.6(3)</b>	0.21	<b>2.8(2)</b>	0.16	<b>3.86</b>	0.22	<b>0.43</b>	0.02	<b>0.37</b>	0.02
Fe <sub>2</sub> O <sub>3</sub>									-		-		<b>0.95</b>	0.05
TiO <sub>2</sub>	<b>0.8(1)</b>	0.04	<b>1.2(1)</b>	0.06	<b>3.2(2)</b>	0.16	<b>2.3(2)</b>	0.12	<b>0.12</b>	0.02	<b>1.06</b>	0.05	<b>1.95</b>	0.10
MgO	<b>0.03(1)</b>	0.00	<b>0.10(1)</b>	0.01	<b>0.11(1)</b>	0.01	<b>0.08(1)</b>	0.01	<b>0.12</b>	0.01	-		-	0.00
SiO <sub>2</sub>	<b>29.9(1)</b>	1.99	<b>30.1(1)</b>	1.97	<b>28.9(1)</b>	1.97	<b>29.2(2)</b>	1.97	<b>29.72</b>	2.00	<b>31.82</b>	2.00	<b>30.67</b>	2.00
Al <sub>2</sub> O <sub>3</sub>	-	-	<b>0.02(1)</b>	0	<b>0.02(2)</b>	0	<b>0.04(4)</b>	0.00	-		-		-	0.00
ZrO <sub>2</sub>	<b>27.9(3)</b>	0.91	<b>24.5(3)</b>	0.78	<b>27.2(4)</b>	0.91	<b>25.0(5)</b>	0.82	<b>27.40</b>	0.90	<b>31.11</b>	0.96	<b>30.20</b>	0.96
Nb <sub>2</sub> O <sub>5</sub>	<b>3.2(3)</b>	0.10	<b>4.7(2)</b>	0.14	<b>6.0(4)</b>	0.19	<b>3.7(1)</b>	0.11	<b>4.73</b>	0.15	<b>0.22</b>	0.01	<b>0.70<sup>#</sup></b>	0.02
HfO <sub>2</sub>	<b>0.30(7)</b>	0.01	<b>0.57(8)</b>	0.01	<b>0.7(2)</b>	0.01	<b>0.5(1)</b>	0.01	-		-		-	0.00
Ta <sub>2</sub> O <sub>5</sub>	<b>0.1(1)</b>	0	<b>0.1(1)</b>	0	<b>0.2(2)</b>	0	<b>0.2(2)</b>	0	-		-		-	0.00
Y <sub>2</sub> O <sub>3</sub>	<b>1.41*</b>	0.05	<b>1.66*</b>	0.04	<b>0.83*</b>	0.03	<b>1.06*</b>	0.04	<b>0.23</b>	0.01	<b>0.32</b>	0.01	<b>n.d.</b>	0.00
REE <sub>2</sub> O <sub>3</sub>	<b>0.82*</b>	0.02	<b>0.89*</b>	0.02	<b>0.47*</b>	0.01	<b>0.52*</b>	0.01	<b>n.d.</b>		-		<b>1.26</b>	0.00
F	<b>7.9(2)</b>	1.66	<b>7.4(2)</b>	1.54	<b>3.44(5)</b>	0.75	<b>4.7(1)</b>	1.02	<b>4.68</b>	1.00	<b>8.1</b>	1.61	<b>6.24</b>	1.29
H <sub>2</sub> O									-		<b>1.23</b>	0.13	<b>1.34</b>	0.29
OH									-			0.26	-	
O=F	<b>3.33</b>		<b>3.14</b>		<b>1.45</b>		<b>2.02</b>		<b>1.97</b>		<b>3.41</b>		<b>2.58</b>	
Total	<b>99.13</b>		<b>99.70</b>		<b>98.62</b>		<b>98.66</b>		<b>98.29</b>		<b>99.86</b>		<b>98.96</b>	

*n* is number of analytical points. <sup>1</sup> Mellini (1981). <sup>2</sup> Merllino et al. (1990). <sup>#</sup> is sum of Nb and Ta. \* ICPMS data