

# Polyolithionite from syenite pegmatite at Vøra, Sandefjord, Oslo Region, Norway. Contributions to the mineralogy of Norway, No. 65

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Polyolithionite from Vøra has a chemical composition close to the ideal end-member formula  $\text{KLi}_2\text{AlSi}_4\text{O}_{10}\text{F}_2$ . It has the 1M polytype structure with  $a = 5.196(4)$ ,  $b = 8.960(4)$ ,  $c = 10.051(4)$  Å,  $\beta = 100.29(5)^\circ$ . The measured density is  $2.82(1)$  g/cm<sup>3</sup>, the calculated density  $2.84$  g/cm<sup>3</sup>. Optical measurements gave  $\beta = 1.556(1)$ ,  $\gamma = 1.559(1)$ ,  $2V\alpha = 43(3)^\circ$  on one sample and  $\beta = 1.551(1)$ ,  $\gamma = 1.555(1)$  on another. DTA/TGA curves and infrared spectrum are given. The mineral paragenesis of the Vøra syenite pegmatite is reported, and data are given that indicate enrichment of Li in the dark mineral constituents.

The Gladstone-Dale relationship applied to micas is shown to give better agreement between calculated and measured mean refractive index using  $k$ -values from Larsen & Berman (1934) than using the values of Mandarino (1976).

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The name polyolithionite was introduced by Lorenzen (1884) for a lithium-rich mica from syenite pegmatites at Kangerdluarssuk, Greenland. Brøgger (1890:195) described a lithium mica occurring as a rarity in syenite pegmatite on the island Lille Arøy in the Langesundsfjorden area. He was aware of the possible identity with polyolithionite, but lack of material prevented further investigations. A semiquantitative spectrographic analysis of the mineral by Oftedal (1940) showed a lithium content similar to that of polyolithionite from the original locality.

A small specimen containing light-coloured mica plates 1 cm across, associated with K-feldspar, albite and aegirine, was collected by G. Raade from a pegmatite on the east side of Lille Arøy. It gives an X-ray powder pattern of the 1M lepidolite structure type, typical for polyolithionites (Levinson 1953, Munoz 1968). Very small amounts of a similar mica, associated with analcime and aegirine, were X-ray identified from the island Låven in Langesundsfjorden. The occurrence of polyolithionite as a rare constituent of the syenite pegmatites in the Langesundsfjorden area can thus be regarded as fairly well established.

In 1976 a light mica was found in some quantity in a syenite pegmatite near Sandefjord. Preliminary investigations indicated an appreciable lithium content, and it was subsequently

identified as polyolithionite, with a composition close to  $\text{KLi}_2\text{AlSi}_4\text{O}_{10}\text{F}_2$ . Such micas are relatively uncommon, occurring in some syenite pegmatites as a late-stage formation. Apart from the Norwegian occurrences it is known only from Greenland (Bøggild 1953, Semenov 1969), the Kola peninsula (Vlasov et al. 1966, Semenov 1972), Siberia (Semenov et al. 1974, Sveshnikova et al. 1976:34–35), and Mont St. Hilaire, Quebec, Canada (Perrault 1966).

Because of its rarity and since no complete data have been recorded on material from a single locality, the Vøra polyolithionite is described in some detail in this paper, and an account of the mineral paragenesis of the pegmatite is presented.

## Occurrence

The polyolithionite locality is situated at Vøra, Vesterøya, some 8 km SSE of Sandefjord, in the southern part of the Oslo Region. Two very coarse-grained syenite pegmatites are exposed in larvikite cliffs. The lower pegmatite forms a steeply dipping, irregular dyke, less than 1 m wide, which can be followed for a distance of 30–40 m. The upper pegmatite is exposed for a shorter distance and it may possibly have been connected with the lower one. There is a distinct

difference in mineralogy between the upper and lower pegmatites. Polyolithionite, quartz, arfvedsonite, catapleiite, and monazite have only been found in the upper dyke, whereas astrophyllite, biotite (rare), eudidymite, and thorite seem to be confined to the lower dyke.

The main mineral is a greyish to brownish K-feldspar, occurring in individuals up to 20 cm. Aegirine and barkevikite are widespread, the latter especially in the northern part of the lower pegmatite. Aenigmatite is also common, in irregular masses up to 20 cm across. Small amounts of anatase were identified as a secondary product after aenigmatite. Euhedral apatite crystals are often met with, and may show alteration to bastnäsite. Fibrous masses of elpidite, frequently somewhat altered, are relatively abundant, especially in the upper pegmatite. Other minerals occasionally met with are albite, zircon, pyrochlore, and magnetite. In addition, epididymite, calcite, chlorite, and montmorillonite are sparingly present.

Aegirine, barkevikite, zircon, and apatite belong to the early formed minerals in the pegmatites, whereas aenigmatite, polyolithionite, elpidite, and quartz have crystallized later. Epididymite, albite, and calcite are among the youngest formations. Brøgger (1890) also observed that his lithium mica was younger than aegirine and K-feldspar.

The presence of larger amounts of aenigmatite is a feature of considerable interest, since this mineral has never been identified with certainty in the syenite pegmatites of the larvikite area, although Brøgger (1890:432) claimed its probable existence in the Langesundsfjorden pegmatites. Quartz and arfvedsonite are very rare constituents of the pegmatites in Langesundsfjorden (Brøgger 1890:12, 410), and elpidite is reported for the first time from Norwegian syenite pegmatites.

Information on the mineralogy of the Vøra occurrence was given by R. Hansen and S.-A. Berge (pers. comm. 1976), who first observed these and other interesting pegmatites in the vicinity of Sandefjord.

## X-ray crystallography

X-ray powder diffraction data for polyolithionite from Vøra (grain-size < 0.063 mm) are given in Table 1. Care was taken to avoid preferential orientation. The powder pattern is in close

Table 1. X-ray powder diffraction data for polyolithionite from Vøra, Sandefjord.

$hkl$	$d_{\text{obs}}(\text{Å})$	$d_{\text{calc}}(\text{Å})$	$I/I_1$
$\alpha = 5.196(4) \text{ Å}$		$b = 8.960(4) \text{ Å}$	
$c = 10.051(4) \text{ Å}$		$\beta = 100.29(5)^\circ$	
001	9.93	9.89	45
002	4.95	4.94	100
020	4.482	4.480	25
$\bar{1}10, \bar{1}10$	4.446	4.440	15
$\bar{1}11$	4.318	4.308	15
021	4.083	4.081	15
$\bar{1}11$	3.829	3.835	15
$\bar{1}12$	3.594	3.593	40
022	3.324	3.320	50
003	3.296	3.297	85
$\bar{1}12$	3.073	3.075	50
$\bar{1}13$	2.870	2.868	25
023	2.656	2.655	20
$\bar{2}01$		2.589	
130, $\bar{1}30$	2.581	2.579	20
032		2.557	
200, $\bar{2}00$	2.553	2.556	15
$\bar{1}31$		2.552	
004		2.472	
113	2.473	2.470	5
210, $\bar{2}10$	2.460	2.458	5
$\bar{2}02$		2.457	
$\bar{1}31$	2.443	2.442	5
$\bar{1}32$		2.376	
201	2.375	2.374	10
$\bar{1}14$	2.318	2.318	<5
221		2.242	
040	2.241	2.240	5
$\bar{2}03$		2.221	
220, $\bar{2}20$	2.217	2.220	<5
033		2.213	
041	2.185	2.185	<5
$\bar{2}22$	2.154	2.154	<5
$\bar{1}33$		2.126	
202	2.123	2.121	5
005	1.978	1.978	30

Philips diffractometer, graphite monochromator,  $\text{CuK}\alpha_1$  ( $\lambda = 1.54051 \text{ Å}$ ).  $\text{Pb}(\text{NO}_3)_2$  was used as internal standard. Intensities were measured from peak heights. Indexing based on Munoz (1968). 20 reflections were used for least-squares refinement of cell parameters.

agreement with that of synthetic 1M polyolithionite with space group  $C2/m$ , as reported by Munoz (1968). Thus the Vøra polyolithionite is definitely the 1M polytype, the other possible polytypes (2M<sub>2</sub> and 3T) being distinguishable from their X-ray powder data (Munoz 1968) or optical properties.

The refined cell parameters for the Vøra polyolithionite are  $a = 5.196(4)$ ,  $b = 8.960(4)$ ,  $c = 10.051(4)$  Å,  $\beta = 100.29(5)^\circ$ ,  $V = 460.4(6)$  Å<sup>3</sup>. For comparison, the cell dimensions for polyolithionite from Kangerdluarssuk (Munoz 1968: 1495) are  $a = 5.189$ ,  $b = 8.974$ ,  $c = 10.067$  Å,  $\beta = 100^\circ 27'$ , which give  $V = 461.0$  Å<sup>3</sup>.

## Physical and optical properties

The Vøra polyolithionite occurs as thick, irregular crystal books and aggregates with a very pale yellowish green colour, occasionally stained brownish by iron compounds. The individual mica plates may reach 5–6 cm across. The density was determined to 2.82(1) g/cm<sup>3</sup> by the sink/float method, using di-iodomethane diluted with acetone. The calculated density is 2.84 g/cm<sup>3</sup>.

The mineral is biaxial negative. The refractive indices  $\beta = 1.556(1)$  and  $\gamma = 1.559(1)$  were measured in white light, the refraction liquids being checked on an Abbe refractometer. Orthoscopic U-stage measurements gave  $2V_\alpha = 43(3)^\circ$ , with very little variation between three different cleavage flakes from the same specimen, the large error being assigned because of difficult adjustment of the instrument. From this, the lower refractive index  $\alpha$  is calculated to 1.537, giving a birefringence of 0.022, but it should be noted that an error of  $\pm 0.001$  in  $\beta$  and  $\gamma$  will influence the calculated  $\alpha$ -value to a considerable degree. To check the variability in refractive indices, two cleavage flakes from another specimen were measured, and these gave  $\beta = 1.551(1)$  and  $\gamma = 1.555(1)$ . A similar variation in the refractive indices of lithium micas, even within a single sample, was noted by Winchell (1942) and Levinson (1953).

## Discussion

The very careful optical measurements reported by Winchell (1942) for polyolithionite from Kangerdluarssuk are within the following ranges:

$\alpha$  (meas.) = 1.540–1.554,  $\alpha$  (calc.) = 1.525–1.563,  
 $\beta$  (meas.) = 1.560–1.569,  $\gamma$  (meas.) = 1.562–1.574,  
 $2V_\alpha$  (meas.) = 36–46°.

The mean values of the four determinations (by J. J. Marais) for which all three indices were measured are:

$\bar{\alpha} = 1.546$ ,  $\bar{\beta} = 1.564$ ,  $\bar{\gamma} = 1.566$ .

It is evident that these figures are significantly higher than those for the Vøra polyolithionite, but they are nevertheless consistent with earlier measurements on the Kangerdluarssuk material by Larsen & Berman (1934:161) reporting  $\alpha = 1.544$ ,  $\beta = 1.565$ ,  $\gamma = 1.566$ ,  $2V_\alpha = 40^\circ$ , and from Hendricks & Jefferson (1939:758)  $\gamma = 1.569$  and  $2V_\alpha = 40^\circ$ .

As is shown later, the chemical compositions of the Vøra and Kangerdluarssuk polyolithionites are almost identical (Table 2) and their cell volumes and densities are very close. It is therefore reasonable to expect that their refractive indices would be similar – in fact, the specific refractive energies of the Vøra and Kangerdluarssuk minerals are  $K = 0.2026$  and  $K = 0.2028$ , respectively, using the  $k$ -values of Mandarino (1976) or  $K = 0.1998$  and  $K = 0.2001$  using the older  $k$ -values from Larsen & Berman (1934). This discrepancy in optical properties needs an explanation.

Levinson (1953) concluded that the lepidolite polytypes are not distinguishable on the basis of optical properties. Since he demonstrated a certain correlation between Li<sub>2</sub>O content and polytypic form, it follows that the general chemistry of lithium micas cannot easily be deduced from optical data (cf. Munoz 1968:1507). Attempts at correlating chemical and optical properties of lithium micas have not been very successful, partly because the chemical variation is not fully accounted for in a binary or ternary diagram. Winchell & Winchell (1951:371) gave the following extrapolated values for the polyolithionite end member:

$\alpha = 1.543$ ,  $\beta = 1.555$ ,  $\gamma = 1.558$ ,  $2V_\alpha = 45^\circ$ .

In his comprehensive study based on four molecular components, Tröger (1962:428) has given these extrapolated data for polyolithionite (iron-free and with F<sub>0.70</sub>OH<sub>0.30</sub>):

$\alpha = 1.524$ ,  $\beta = 1.542$ ,  $\gamma = 1.545$ ,  $2V_\alpha = 43^\circ$ .

For synthetic 1 M polyolithionite the following values are given by Munoz (1968:1495):

$\alpha = 1.529$ ,  $\beta = 1.552$ ,  $\gamma = 1.555$ ,  $2V_\alpha = \text{ca. } 30^\circ$ .

Moreover, a lepidolite from Antsongombato, Madagascar, with a composition close to polyolithionite (Li<sub>2</sub>O = 6.84 wt%; Stevens 1938, No. 16) has these mean values (Winchell 1942, table 4, No. 16):

$\bar{\alpha} = 1.534$ ,  $\bar{\beta} = 1.553$ ,  $\bar{\gamma} = 1.556$ ,  $2V_\alpha = 47.9^\circ$ .

Table 2. Chemical composition of polyolithionite.

Weight percent of oxides		Number of atoms based on 12(O,OH,F)				
1	2	1	2			
SiO <sub>2</sub>	60.20	59.56	Si 3.991	3.991	3.966	3.966
Al <sub>2</sub> O <sub>3</sub>	11.73	12.04	Al 0.917	} 2.922	0.945	} 3.024
Nb <sub>2</sub> O <sub>5</sub>	0.08	1.52	Nb 0.002		0.046	
TiO <sub>2</sub>	1.10	0.48	Ti 0.055		0.024	
Fe <sub>2</sub> O <sub>3</sub>	0.88	0.13	Fe <sup>3+</sup> 0.044		0.006	
FeO	trace	0.42	Fe <sup>2+</sup>		0.023	
MgO	0.15	0.34	Mg 0.015		0.034	
MnO	0.07	0.03	Mn 0.004		0.002	
Li <sub>2</sub> O	7.07	7.26	Li 1.885	} 1.033	1.944	} 1.056
CaO	0.04	trace	Ca 0.003		0.068	
Na <sub>2</sub> O	0.41	0.53	Na 0.053	} 1.964	0.939	} 1.837
K <sub>2</sub> O	11.15	11.05	K 0.943		0.049	
Rb <sub>2</sub> O	0.80	1.14	Rb 0.034	1.761	1.628	
F	8.40	7.73	F 1.761	0.203	0.209	
H <sub>2</sub> O <sup>+</sup>	0.46	0.47	H 0.203			
H <sub>2</sub> O <sup>-</sup>	0.81	0.73				
	103.35	103.43				
-O≡F <sub>2</sub>	3.54	3.26				
	99.81	100.17				

1. Vøra, Sandefjord. Analyst: A. O. Larsen.

2. Kangerdluarsuk?, Greenland (Stevens, 1938).

It is thus quite clear that the Vøra polyolithionite has optical properties close to those cited above, and that the Kangerdluarsuk polyolithionite deviates considerably from this. Obviously, the simplest explanation is that the analyzed sample from Greenland must have been different from that available for optical determinations (cf. Winchell 1942:130). This problem is discussed further in the chapter on chemical composition.

## Chemical composition

Material for chemical analysis was carefully handpicked and crushed in an agate mortar. The elements Si, Al, Nb, Ti, Fe total, Mg, Mn, Ca, K, Rb, Cs, and V were analyzed by X-ray fluorescence spectrometry, using synthetic and inter-

national rock standards. Li was determined by flame emission spectrophotometry and Na by atomic absorption spectrometry. Wet chemical methods were used for the determination of Fe<sup>2+</sup> and F (Grimaldi et al. 1955), and the Penfield method for H<sub>2</sub>O<sup>+</sup>. The result is presented in Table 2 (the Cs and V contents were below the detection limits). The empirical formula for the Vøra polyolithionite, based on 12(O, OH, F), is (K<sub>0.94</sub>Na<sub>0.05</sub>Rb<sub>0.03</sub>)(Li<sub>1.89</sub>Al<sub>0.92</sub>Ti<sub>0.06</sub>Fe<sup>3+</sup><sub>0.04</sub>Mg<sub>0.02</sub>)Si<sub>3.99</sub>O<sub>10.00</sub>(F<sub>1.76</sub>OH<sub>0.20</sub>O<sub>0.04</sub>), which is close to the ideal end-member composition KLi<sub>2</sub>AlSi<sub>4</sub>O<sub>10</sub>F<sub>2</sub>.

Some trace element contents were determined by optical emission spectrographic analysis: B 58 ppm, Ni 18 ppm, Ga 10 ppm. Traces of Cr, Cu, Sn were detected, but no Be, Sc, V, Sr, Ba, Pb were found by this method.

## Discussion

The chemical analysis of polyolithionite from Greenland (? Kangerdluarssuk) (Stevens 1938) is shown for comparison in Table 2. The two analyses are nearly identical, the main difference being in the minor constituents  $\text{Nb}_2\text{O}_5$ ,  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{FeO}$ . High contents of Nb seem to be typical for polyolithionites; Semenov (1969) has reported up to 2.55 wt%  $\text{Nb}_2\text{O}_5$  in polyolithionite from Ilímaussaq, Greenland, and suggests a coupled substitution of the type  $(\text{Nb},\text{O}_2) \Leftrightarrow (\text{Al},\text{F}_2)$ .

The  $\text{TiO}_2$  and  $\text{Fe}_2\text{O}_3$  contents of the Vøra polyolithionite are higher than for most lithium-rich micas (Stevens 1938, Foster 1960), and it may be questioned whether the major part of these, and  $\text{Nb}_2\text{O}_5$ , really enter the mica structure or not. It was shown that the Vøra polyolithionite contains a thin film of iron-rich compounds along cleavage planes. Inclusions of prismatic crystals with double pyramidal terminations, mostly around 0.05 mm long and often occurring in dense clusters, were shown to be quartz from microprobe investigations. A few tiny inclusions of zircon were also detected with the microprobe, but no inclusions containing Ti were found. We have no indications that the Greenland material analyzed by Stevens did contain any inclusions, as it is stated to be pure by optical examination (Stevens 1938:614).

In order to resolve this question, polyolithionites from Vøra, Kangerdluarssuk, and Ilímaussaq were analyzed for  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Nb}_2\text{O}_5$ , and  $\text{Ta}_2\text{O}_5$  with the microprobe, and refractive indices were measured for two of the micas from Greenland (contents in wt%; probe data corrected for dead-time and background):

	$\text{TiO}_2$	$\text{Fe}_2\text{O}_3$	$\text{Nb}_2\text{O}_5$	$\text{Ta}_2\text{O}_5$	$\beta$	$\gamma$
Vøra 1	0.8	0.4	nil	nil		
Vøra 2	1.2	0.4	nil	nil		
Ilímaussaq 1	0.7	0.1	1.1	nil	1.562(1)	1.564(1)
Ilímaussaq 2	1.0	0.2	0.8	nil		
Kangerdluarssuk	0.4	0.3	1.7	nil	1.562(1)	1.564(1)

The high contents of  $\text{TiO}_2$  and  $\text{Nb}_2\text{O}_5$  in the Vøra and Kangerdluarssuk micas, respectively, are thus confirmed (cf. Table 2). The  $\text{Fe}_2\text{O}_3$  contents are, however, somewhat lower than in the bulk analysis. Again, the high refractive indices of the Greenland polyolithionites are substantiated.

The most reasonable solution to the problem of the anomalously high refractive indices of the Greenland polyolithionites must be that these are somehow caused by the high contents of  $\text{Nb}_2\text{O}_5$ ,

which has an unusually high specific refractive energy (0.295 in Larsen & Berman 1934, 0.268 in Mandarino 1976). It is even possible that the  $k$ -value for  $\text{Nb}_2\text{O}_5$  should be still higher for the mica structure.

The mean refractive index  $n = (\alpha + \beta + \gamma)/3$  as calculated from the Gladstone-Dale relationship using  $k$ -values from Larsen & Berman (1934) is 1.563 and 1.564 for the Vøra and Kangerdluarssuk polyolithionites, respectively (with a  $k$ -value of 0.193 for  $\text{Al}_2\text{O}_3$  and a density of 2.82 g/cm<sup>3</sup>). These figures are in satisfactory agreement with the measured values, that is, the difference is around 1.0% for the Vøra mica and 0.3% for the Kangerdluarssuk material.

Jaffe (1956) has shown that the Gladstone-Dale relationship usually holds very well for various minerals, also for complex silicates like the micas. The same result was obtained by Müller (1966) in his study of co-existing micas and chlorites. We have made a brief survey of some literature data for lepidolites, also using  $k$ -values from Larsen & Berman (1934), and have obtained deviations between calculated and measured  $n$ 's of around 1%. In general, it can be stated that the Gladstone-Dale relationship with the 'old'  $k$ -values seems to give 'errors' only just greater than 1% for mica minerals, and in most cases lower than 0.5%. However, Mandarino's (1976)  $k$ -values, which were mainly based on Tutton's salts, give much poorer agreement for micas, between 1 and 2%. It seems reasonable to expect that the  $k$ -values of Larsen & Berman (1934) will give better results for micas than values based on sulphates, chromates, and selenates. Moreover, Mandarino's test for his  $k$ -values was circular – he used Tutton's salts to derive  $k$ 's and then the same salts to check the results.

## Thermal properties

DTA and TGA curves were obtained simultaneously in nitrogen atmosphere with a Mettler thermo-analytical equipment (Fig. 1). The DTA curve shows a broad endothermal deflection in the region 50–700°C with a maximum around 350°C. A sharp endothermal decomposition peak with large  $\Delta T$  occurs at 910°C. There is apparently also a small endothermal effect at 950°C. This curve is similar to that for polyolithionite from Lovozero published by Vlasov et al. (1966:427), and reproduced in Vlasov (1966:27).

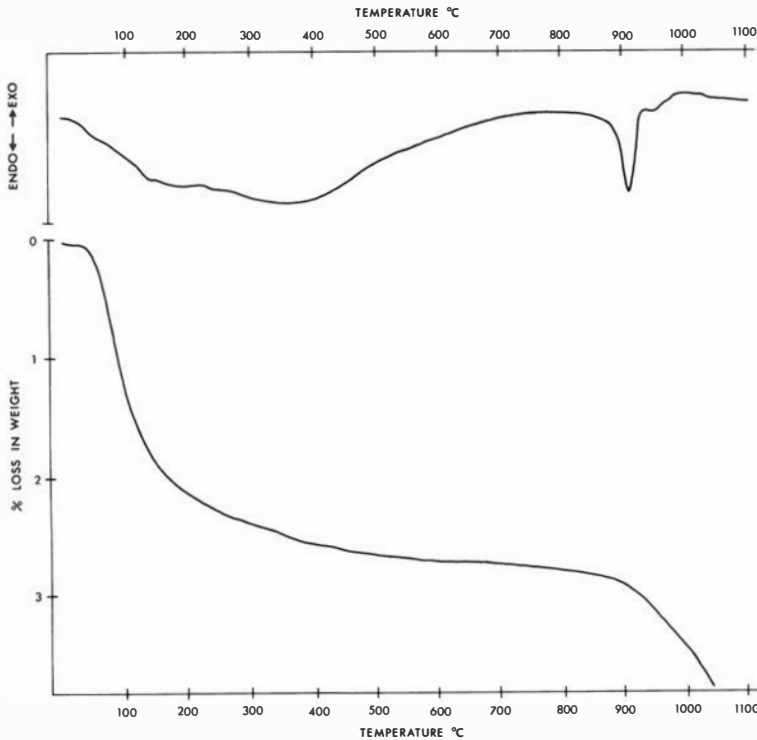


Fig. 1. DTA curve (top) and TGA curve (bottom) for polyolithionite from Vøra, Sandefjord. Sample weight 50.71 mg. Rate of heating 4 deg/min, in nitrogen. Reference material  $\text{Al}_2\text{O}_3$ .

A pronounced endothermal peak around 890–920°C seems to be typical for lithium micas (van der Marel 1956:235, Smykatz-Kloss 1974: 73–74).

The weight loss is rapid between 50 and ca. 200°C where mainly the absorbed water escapes, then the TGA curve flattens out until the temperature reaches about 900°C, where the weight loss is again rapid due to dehydroxylation and escape of fluorine. This last step on the TGA curve corresponds with the strong endothermal effect on the DTA curve. However, the amount of expelled water is 2 wt% at 160°C according to the TGA curve, and this is far more than the amount of  $\text{H}_2\text{O}^-$  reported in the analysis (0.81 wt% below 110°C and 0.87 wt% below 160°C). This can be explained by the fact that the material used for the thermal run was the fraction <0.063 mm, which was sieved from a portion similar to that used for chemical analysis. This fraction constitutes only a smaller part of the bulk analytical substance, and because of its large surface area it is presumably enriched in absorbed water compared to the bulk material. Mackenzie & Milne (1953) studied the effect of variation in the time of dry grinding of musco-

vite, and found that it had a pronounced effect on the shape of the DTA and TGA curves. They ascribed this to a partial breakdown of the muscovite structure on prolonged grinding, but did not discuss the increased capability of water absorbance by the finely ground mica material.

### Infrared spectrum

Absorbed water in the Vøra polyolithionite is responsible for the broad infrared absorption bands at about 3500 and 1650  $\text{cm}^{-1}$  which are due to O-H stretching and bending vibrations, respectively (Fig. 2). Any sharp absorption bands in the region 3500–3700  $\text{cm}^{-1}$  attributable to minor hydroxyl substitution for fluorine in the structure are masked by the first of these broad bands. The sharpness of the other absorption bands is a good indication of the ordered structure of polyolithionite (Farmer 1974: 357), with Li and Al being practically uniquely distributed among the octahedral sites and with virtually no Al substitution in the tetrahedral sites.

Infrared absorption bands occur at the following frequencies (Fig. 2): 1135, 1095, 985, 960, 870, 785, 710, 580, 520, 470, 445, 415, 360, 340,

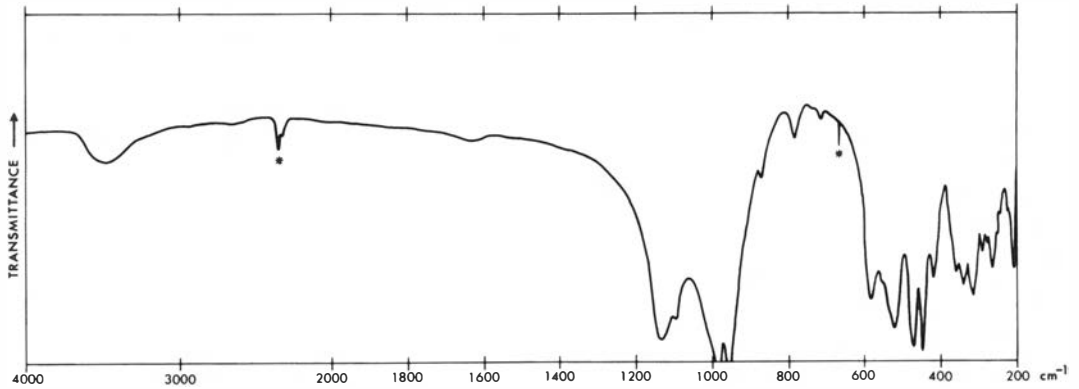


Fig. 2. Infrared spectrum of polyolithionite from Vøra, Sandefjord; 1.5 mg in 200 mg KI disc. Note change in scale at 2000  $\text{cm}^{-1}$ . The two absorption bands marked with asterisks (2350 and 665  $\text{cm}^{-1}$ ) are due to atmospheric  $\text{CO}_2$ , caused by slightly unbalanced beams.

315, 290, 265, and 205  $\text{cm}^{-1}$ . The assignment of observed infrared absorption bands to lattice vibrations for lithium micas is discussed e.g. by Farmer & Russell (1964), Ishii et al. (1969), and Farmer (1974).

## General discussion

The existence of silica-oversaturated, Li-rich pegmatites in the southern larvikite area of the Oslo Region has some interesting petrochemical implications. It was shown by Raade (1973) that the larvikite of this massif is, broadly stated, nepheline-bearing in the western part, contains neither free nepheline nor quartz in the middle part, and is quartz-bearing in the eastern part. This is in accordance with the structural investigations of Petersen (1978), indicating that the larvikite complex consists of a number of circular structures, arranged in a manner that suggests a general shift of igneous activity towards the west with a concomitant increase in modal nepheline content. The Vøra pegmatite is situated within an area of quartz/nepheline-free to slightly undersaturated larvikite. It will be the subject of future investigations to relate the occurrence of mineralogically different types of syenite pegmatites in this area to the petrographic and structural variations of the larvikite complex.

Although polyolithionite is the only specific Li mineral in the syenite pegmatites of the Oslo Region, they nevertheless do contain appreciable amounts of Li, which is e.g. found in the widespread mineral lepidomelane (biotite) in

concentrations up to 0.7 wt%  $\text{Li}_2\text{O}$  (Strock 1936, Oftedal 1940). A so-called ditroite from the Langesunds fjorden area was shown to contain 0.11 wt%  $\text{Li}_2\text{O}$ , the Li being strongly concentrated in the dark minerals (mica 0.5 wt%  $\text{Li}_2\text{O}$ , pyroxene + amphibole 0.35 wt%  $\text{Li}_2\text{O}$ ) (Strock 1936: 192). Similarly, the dark minerals from the Vøra pegmatite show high contents of Li:

Arfvedsonite (upper dyke)	1.35 wt% $\text{Li}_2\text{O}$
Barkevikite (upper dyke)	0.49
Lepidomelane (lower dyke)	0.37
Aegirine (upper dyke)	0.25
Astrophyllite (lower dyke)	0.14
Aenigmatite (upper dyke)	0.05
Aegirine (lower dyke)	0.02

The large difference in Li content between aegirine from the upper and lower dykes should be noted.

It is evident that the Vøra type of syenite pegmatite is unique among the pegmatites associated with larvikite, both mineralogically and geochemically.

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