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YTTROFLUORITE–YTTROCERITE–CERFLUORITE IN NORWEGIAN PEGMATITES

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Yttrofluorite has been identified in a pegmatite from Eivolden, Drag in Tysfjord, Nordland county, the second locality of this mineral in Norway. Following brief notes on the Norwegian occurrences of yttrofluorite, chemical analyses and X-ray data are presented on the fluoritic material from Eivolden and from the original locality at Hundholmen in Tysfjord. *It has been found that the Hundholmen material corresponds to cerfluorite—yttrocerite, rather than yttrofluorite.* In conclusion it is suggested that rare earths in fluorite can vary in type and amount within any one pegmatite body. Two other localities of yttrofluorite in Norway are also described.

INTRODUCTION

On examining material collected during the mapping of quartzfeldspar deposits in the Drag district of Tysfjord, Nordland county, the mineral yttrofluorite was identified in pegmatite specimens from Eivolden. The identification was made in 1962, and this is the second locality of this mineral in Norway. It is earlier known from Hundholmen in Nordland, a pegmatite genetically related to the Tysfjord granite, and was described by Th. Vogt (1911, 1914, 1923) and later by Goldschmidt & Thomassen (1923).

More recently, while working with the mineral tysonite (Sverdrup, Sæbø & Bryn 1965), yttrofluorite has been identified from two other localities: Jennyhaugen in the Drag district, and Höydalen, Tördal, Telemark county.

Yttrofluorite has the general formula $(Ca,Y)F_{2-2.33}$; the cell size $a_0 = 55.0$ (Strunz 1958).

According to Vogt (1911), yttrofluorite has a higher specific gravity and a poorer cleavage than fluorite. The colour is usually yellow to yellow-brown, but can also be brown or yellow-green. The mineral is brittle and has a glassy lustre on its cleavages. Yttrofluorite is cubic; hardness 4.5, specific gravity 3.55 and refractive index approximately 1.455. Vogt also mentioned that the chemistry can vary. One analysis was given:

	Per cent
CaO	54.89
Y-earths	17.35
Ce-earths	1.68
Alkali	0.15
F (calculated)	45.54
Loss of ignition	0.67
H_2O^- (100°)	0.22
	120.50
– O	19.17
	101.33

In addition, one spectroscopic analysis was given:

Most	Y
Dull	Ce and Er
Medium	Dy, Gd, La, Nd, Sa
Weak	Ad and Cp (=Yb), Nd, Tu
Traces	Tb, Pr, Eu
Missing	Th and Sc

Analyst: Herrn Hofrat F. Exner.

Th. Vogt (1914) has dealt with the YF_3-CaF_2 problem and also discussed the system CeF_3-CaF_2. The discussion is based on synthetic minerals. (The system CeF_3-CaF_2 was actually investigated by Professor Tammann in Göttingen, Germany, but the results were reported by Vogt.)

The results of the investigation were:

A mixture of the elements	Ca-Y-F	= Yttrofluorite.
" " " " "	Ca-Ce-F	= Cerfluorite.
" " " " "	Ca-Ce-Y-F	= Yttrocerite.

CaF_2-YF_3 forms a completely solid solution up to approximately 40% YF_3.

CaF_2-CeF_3 forms a completely solid solution up to approximately 55.8% CeF_3. Within the range of isotropism this system has been called the fluorite-yttrofluorite group.

Later, Vogt (1923) published two new analyses of yttrofluorite:

	Th. Vogt	Zambonini
Calciumfluoride	76.43%	89.07%
Fluorides of Y-group	21.90%	10.59%
Fluorides of Ce-group	2.12%	0.95%

With regard to the yttrofluorite occurring on Hundholmen, Vogt maintained that there is no doubt about its identification, since the Y content is much larger than that of Ce.

Goldschmidt & Thomassen (1923) investigated the crystal structure of yttrofluorite. They stated that the mineral was homogeneous and well crystallized, $a = 5.49 \times 10^{-8}$ cm. Furthermore, they maintained that its structure is almost identical to that of fluorite and that yttrium took the place of Ca in the lattice.

Strunz (1957) gave the following constants:

Fluorite; CaF_2	$a_0 = 5.46$ Å
Yttrofluorite; $(Ca,Y)F_{2-2.33}$	$a_0 = 5.50$ Å
Cerfluorite $(Ca,Ce)F_{2-2.33}$	$a_0 = 5.47$ Å

'YTTROFLUORITE' FROM HUNDHOLMEN IN TYSFJORD

This locality is indicated on the map, Fig. 1. The mineral in question has a yellow-brown colour and generally occurs together with microcline, quartz and some plagioclase. In thin-section, bastnäsite ($CeFCO_3$) can be observed as small grains occurring within the fluoritic material. A metamict mineral which is present has been identified as euxenite.

YTTROFLUORITE FROM THE EIVOLDEN QUARTZ-FELDSPAR DEPOSIT, DRAG IN TYSFJORD, NORDLAND

The locality is marked on the map, Fig. 1.

Geology: The Eivolden quartz-feldspar deposit together with those from Jennyhaugen and Lapplegret (Sverdrup & Sæbø 1958) is one of the largest pegmatites in the neighbourhood of Drag. This pegmatite is a large, somewhat irregular lense-shaped body situated within the Tysfjord granite (Foslie 1941). A quarry in the pegmatite was opened in 1910, production of feldspar continuing intermittently for more than 50 years. Production was stopped in 1962, however, because of the increasingly unsafe working conditions.

Yttrofluorite appears together with quartz, microcline, plagioclase, kainosite and a mineral which is possibly lombardite. With regard to the kainosite this is the second reported occurrence of the mineral in Norway (Norges Geologiske Undersøkelse, Yearbook 1962, p. 383). If the identification of lombardite is correct, this would also be the second locality of this particular mineral in Norway. The plagioclase in the pegmatite is usually An_{10}, but in contact with the yttrofluorite is much more basic, An_{30}. This is not unexpected because, as well as kainosite, yttrofluorite and lombardite are both calcium-rich minerals.

The yttrofluorite from this locality is white to colourless. Indices of refraction are given in Table 1.

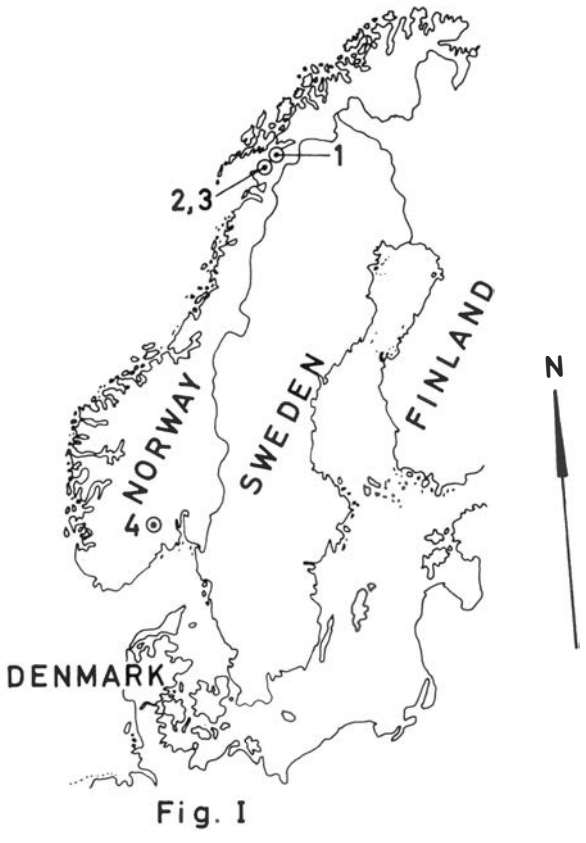

Fig. 1. Map (ca. 1:16 mill.) showing the localities of the yttrofluorite - yttrocerite - cerfluorite deposits in Norway (all quartz-feldspar deposits). 1) Hundholmen, 2) Eivolden, 3) Jennyhaugen, 4) Høydalen.

For determination of the cell sizes a 9 cm X-ray Debye and Scherrer camera with Fe-radiation and Mn-filtration was used. The X-ray powder pattern is identical to that of the yttrofluorite from Hundholmen, and the mineral has a much larger cell size than ordinary fluorite.

The chemical data are presented in Tables 2, 3 and 4.

The cell size of the yttrofluorite from Hundholmen has also been determined by the present author and was found to be $a_0 \approx 5.50$.

Table 1. Cell size and indices of refraction of 'Yttrofluorite'

Locality	a_0	n
Yttrofluorite, Hundholmen	[1] 5,50	[2] 1,457
Yttrofluorite, Eivolden	$\approx 5{,}51_8$	$\approx$ 1.460
Yttrofluorite, Jennyhaugen	$\approx 5{,}48_9$	
Yttrofluorite, Tørdal	$\approx 5{,}48_2$	
Fluorite	[1] 5,46	[2] 1,434

[1] Strunz (1957).
[2] Larsen & Berman (1934).

YTTROFLUORITE FROM JENNYHAUGEN, DRAG IN TYSFJORD, NORDLAND

Notes on the general geology of this area have been given in an earlier publication (Sverdrup, Sæbø & Bryn 1965).

Yttrofluorite here appears together with bastnäsite and tysonite. The mineral is completely intergrown with tysonite, so much so that it is impossible to isolate these two minerals by heavy liquid or magnetic separation methods. In thin-section the mineral appears as small isotropic crystals inside and together with tysonite. X-ray powder photographs have assisted in distinguishing between tysonite and yttrofluorite (Sverdrup, Sæbø & Bryn 1965).

The cell size of the yttrofluorite is given in Table 1.

YTTROFLUORITE FROM HØYDALEN, TØRDAL, TELEMARK

The geological situation as well as the material has been described in a previous paper (Sverdrup et al. 1965).

The type of material is closely related to that found at Jennyhaugen. Yttrofluorite from this locality is also intergrown with tysonite, and it is again impossible to isolate the two minerals. Under the microscope the yttrofluorite is present as small isotropic grains, and on an X-ray powder photograph structures both of this mineral and of tysonite are well developed.

The measured cell sizes are presented in Table 1.

CHEMICAL DATA

The intergrowth between yttrofluorite and tysonite in the pegmatites from Jennyhaugen and Høydalen has made it impossible to carry out any chemical

Table 2. Analyses of 'Yttrofluorite'

	Hundholmen Wt %	Eivolden Wt %
F	33.1	39.0
CO_2	2.9	1.0
SiO_2	0.4	2.6
P_2O_5	0.06	0.004
CaO	35.1	44.5
Na_2O	0.16	0.25
K_2O	0.05	0.05
Oxides of the Ce-group + La_2O_3	24.4	4.1
Oxides of the Y-group + possible ThO_2	15.9	18.0
X-ray spectrographic analyses:		
Th	a little	traces
U	no	no

Analysers: lab. eng. Andreassen and constructor Solem, Department of Chemistry, Norges Geologiske Undersøkelse.

Table 3. Spectrographic determination of rare earth elements in 'Yttrofluorite'

	Hundvolden Wt %	Eivolden Wt %
Y_2O_3	16.1	63.3
La_2O_3	15.8	2.1
CeO	36.5	6.9
Pr_2O_3	3.0	0.9
Nd_2O_3	14.1	5.4
Sm_2O_3	3.3	2.6
Eu_2O_3	–	–
Gd_2O_3	3.2	5.4
Tb_2O_3	0.4	–
Dy_2O_3	3.0	5.9
Ho_2O_3	0.5	–
Er_2O_3	1.9	4.3
Tm_2O_3	0.3	–
Yb_2O_3	1.7	3.3
Lu_2O_3	–	–
	99.8	100.1

The near-complete analyses of the yttrofluorite from Hundholmen and Eivolden after recalculation are listed in Table 4.

Analyst: lab. eng. Faye, Dept. of Chemistry, Norges Geologiske Undersøkelse.

analyses. However, the material from the Eivolden and Hundholmen localities in Tysfjord has been analysed (Table 2).

To obtain the quantitative determination of the rare earths the oxides of the Ce and Y groups were mixed together and a new spectrographic determination of the different elements then made.

The data are given in Table 3.

In order to make a calculation of the analyses as correctly as possible, it has been necessary to make a correction for contaminating minerals such as microcline, albite, small amounts of apatite, and also bastnäsite. Both analyses have some deficiency of fluorine. Concerning the material from Hundholmen, it can be noted that the fluorite after recalculation contains approximately 30 per cent of rare earth fluoride. Most of the rare earths in this fluorite occur as cerium. The fluorite from Eivolden has approximately 23 per cent of rare earth fluoride. In this case, however, the rare earths belong to the yttrium group.

CONCLUDING REMARKS

From the analyses and calculations it is apparent that the fluorite from Hundholmen has a high content of rare earths, and confirmatory evidence of this is seen in the cell size determination. The investigated material is not an yttrofluorite, however, as stated by Vogt (1923), but rather an yttrocerite or even

Table 4. Total analyses of Cerfluorite-yttrocerite from Hundholmen and yttrofluorite from Eivolden

	As oxides			As elements	
	Hundholmen Wt %	Eivolden Wt %		Hundholmen Wt %	Eivolden Wt %
F	33.1	39.0	F	33.1	39.0
CO_2	2.9	1.0	CO_2	2.9	1.0
SiO_2	0.4	2.6	Si	0.19	1.21
P_2O_5	0.06	0.04	P	0.03	0.02
CaO	35.1	44.50	Ca	25.09	31.80
Na_2O	0.16	0.25	Na	0.12	0.19
K_2O	0.05	0.05	K	0.04	0.04
Y_2O_3	6.49	13.99	Y	5.11	11.02
La_2O_3	6.37	0.46	La	5.43	0.40
CeO	14.71	1.52	Ce	11.97	1.24
Pr_2O_3	1.21	0.20	Pr	1.03	0.17
Nd_2O_3	5.68	1.19	Nd	4.87	1.02
Sm_2O_3	1.33	0.57	Sm	1.15	0.50
Eu_2O_3	–	–	Eu	–	–
Gd_2O_3	1.29	1.19	Gd	1.12	1.04
Tb_2O_3	0.16	–	Tb	0.14	–
Dy_2O_3	1.21	1.30	Dy	1.05	1.14
Ho_2O_3	0.20	–	Ho	0.18	–
Er_2O_3	0.77	0.95	Er	0.67	0.83
Tm_2O_3	0.12	–	Tm	0.11	–
Yb_2O_3	0.69	0.73	Yb	0.60	0.64
Lu_2O_3	–	–	Lu	–	–
Th	a little	traces	Th	a little	traces
U	no	no	U	no	no

possibly cerfluorite. Deer, Howie & Zussman (1962) say that: '... the chief substitutions which can take place (in fluorite) are Y and Ce for Ca, and in the variety yttrofluorite $(Ca,Y)F_{2-3}$ the YF_3 molecule may amount to 10-20 per cent, ..., with minor amounts of CeF_3. The natural occurrence of the variety yttrocerite must be considered doubtful. ...' The present investigation, however, has clearly established the existence of natural yttrocerite. It is of interest here to note that a small amount of Y in yttrofluorite from Hundholmen has also been observed by Tschirwinsky (1922). Moreover, Vogt's material clearly shows an enrichment in Y relative to Ce.

In the present author's opinion, this would seem to indicate that the rare earth in the fluorite of Hundholmen varies in type from place to place within the pegmatite body. This means that it should be possible, at Hundholmen, to collect specimens of yttrofluorite as well as yttrocerite and cerfluorite.

The material collected and examined from Eivolden, however, is definitely representative of yttrofluorite.

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