

GADOLINITE FROM HUNDHOLMEN, TYSFJORD, NORTH NORWAY

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Nilssen, Borghild: Gadolinite from Hundholmen, Tysfjord, north Norway. Contribution to the mineralogy of Norway, No. 55. *Norsk Geologisk Tidsskrift*, Vol. 53, pp. 343–348. Oslo 1973.

Non-metamict gadolinite from Hundholmen, north Norway was described optically by Vogt (1922). Chemical data reveal no significant differences from isotropic gadolinites, except for a very low Th content. X-ray diffraction study indicates a slightly larger unit cell than usual for metamict gadolinites.

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Gadolinite from Hundholmen, Tysfjord, north Norway was first reported by Vogt (1922), who stated that the mineral was uncommonly fresh and free from alteration products. When first reported it was probably the least altered of all known gadolinites. Other minerals which usually occur in a metamict amorphous state such as orthite and even fergusonite were also reported to be partly birefringent at this locality. Vogt explained this as being due to a lack of radioactive elements like thorium and uranium in the pegmatite although he had no chemical analyses to support this statement. Uraninite has since been found at the same locality (H. Neumann & B. Nilssen, unpublished) and the present gadolinite is here shown to contain small amounts of both uranium and thorium. Vogt made detailed optical studies of the mineral, but no chemical analysis was carried out.

The mineral is found in a dark dyke which cuts the Hundholmen pegmatite. This dyke consists of gadolinite, orthite, a mineral described by Vogt as epidote-orthite, which may be identical with lomgaardite, some fergusonite and uraninite in a groundmass of fluorite. Quartz and feldspar occur only in minor amounts. Separation of the minerals (with heavy liquids and magnetic separation) gave a concentrate of clear green slightly rounded crystals of gadolinite. The fraction was further purified and finally handpicked. The crystals are anisotropic, with a high refractive index, weak pleochroism – olive to green, axial angle $\sim 85^\circ$, optically positive, $r < v$.

The optical data given by Vogt (1922):

$$\alpha = 1.801 \quad \beta = 1.812 \quad \gamma = 1.824$$

are in excellent agreement with determinations on the present material. The crystals give good X-ray diffraction films. The pure fraction was analysed by a combination of conventional wet chemical methods and X-ray fluorescence spectrometry. RE, Fe, Mn, U, Th were determined by X-ray fluorescence

analysis of a combined oxide precipitate. The chemical data are converted to cation proportions. Fluorine is subtracted as CaF_2 with the corresponding amount of Ca, and alkalis as feldspar with Al and Si. The need for such a correction is confirmed by microscopic studies which reveal a number of small inclusions of fluorite and feldspars in the gadolinite crystals. H_2O is disregarded. The 0.50 % H_2O^+ may indicate a slight incipient metamictization, but the water certainly does not enter the crystal lattice. The corrected cation proportions are given in column 3, Table 1. These data are recalculated to oxygen = 10 and grouped according to the theoretical formula $\text{Y}_2\text{FeBe}_2\text{Si}_2\text{O}_{10}$ as follows: $(\text{Y, RE, Ca, U, Th})_{1.98}(\text{Fe, Mg})_{0.96}(\text{Be, Al})_{1.81}\text{Si}_{2.05}\text{O}_{10.00}$. This indicates a deficiency in the Be positions, which was originally thought to indicate unfilled positions in the crystal lattice.

According to Oftedal (1964), however, boron is usually present in gadolinites. It has not been determined in this sample, but has been found by Oftedal (using optical spectrography) in another part of the specimen from

Table 1. Chemical composition.

	Wt. %	Cat. prop.	Cat. prop. (corrected)
SiO_2	24.49	40.77	38.57
Al_2O_3	0.70	1.37	0.97
FeO	13.14	18.29	18.29
BeO	8.50	33.99	33.99
B_2O_3	n.d.		—
MgO	0.10	0.25	0.25
CaO	2.16	3.85	0.96
Na_2O	0.11	0.35	—
K_2O	0.07	0.15	—
Y_2O_3	31.67	28.05	28.05
La_2O_3	0.05	0.03	0.03
Ce_2O_3	0.22	0.13	0.13
Pr_2O_3	0.06	0.04	0.04
Nd_2O_3	0.39	0.23	0.23
Sm_2O_3	0.52	0.30	0.30
Eu_2O_3	0.03	0.02	0.02
Gd_2O_3	1.97	1.09	1.09
Tb_2O_3	0.40	0.22	0.22
Dy_2O_3	3.74	2.00	2.00
Ho_2O_3	0.85	0.45	0.45
Er_2O_3	3.78	1.98	1.98
Tm_2O_3	0.70	0.36	0.36
Yb_2O_3	3.30	1.67	1.67
Lu_2O_3	0.98	0.49	0.49
UO_2	0.34	0.12	0.12
ThO_2	0.10	0.04	0.04
H_2O —	0.13		
H_2O^+	0.50		
F	1.1	5.79	—
Total	99.11		
B_2O_3	1.2		3.45

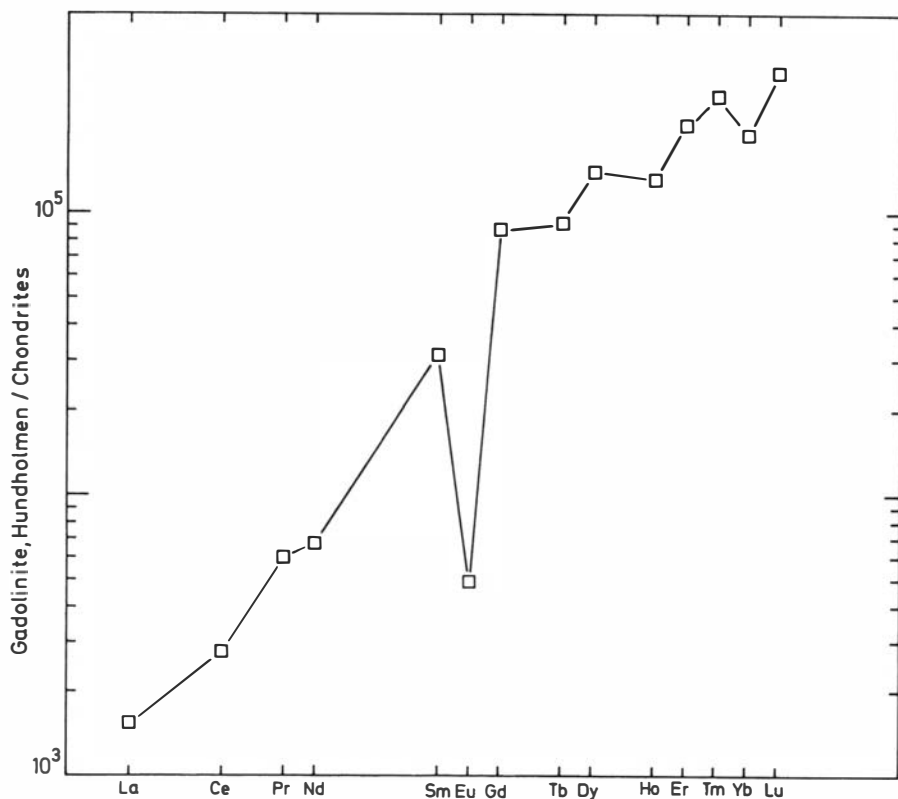


Fig. 1. Distribution of REE in gadolinite.

which our sample was taken. He gives the value as 12000 ppm (pers. comm.). The analysis has been recalculated on the assumption that our analysed material contains the same amount of boron, with the following result:



A substitution of B for Be is not unexpected considering the similarities of the datolite and the gadolinite crystal structures.

The rare earth analysis reveals a predominance of the smaller heavier elements. Ratioing to chondrites and plotting against ionic radius (Haskins et al. 1968) (Fig. 1) gives a relatively smooth curve emphasizing this trend, and at the same time revealing a pronounced Eu depletion. Available data from the literature show that Eu depletion is a common feature in pegmatite minerals containing rare earth elements as major constituents. This suggests that either pegmatite minerals commonly crystallize from a medium depleted in Eu relative to the other REE, or else that such a structure discriminates against the take up of Eu during the incorporation of REE in its lattice.

In fact both processes are probably operating. Studies indicate that quite a high proportion of terrestrial Eu occurs in the divalent state. The ionic radius of Eu^{2+} is close to that of Ca. It is thus readily taken up in early formed Ca bearing rock forming minerals (hence the strong Eu enrichment commonly seen in plagioclase and corresponding Eu depletion of the residuum).

Minerals showing a strong preference for trivalent ions (such as the RE minerals) will reject the divalent Eu.

The specific gravity of the analysed fraction was determined by pycnometre, filled with toluene, and found to be 4.33. The specific gravity calculated from the corrected chemical formula and the X-ray data was 4.86. Since the analysed material was contaminated by lighter substances such as fluorite, feldspar and water it is not surprising that the measured value is lower than the calculated value.

X-ray studies

As mentioned above the gadolinite from Hundholmen is very fresh and unaltered in contrast to most gadolinites which are known from the literature. X-ray diffraction films taken with 9 cm cameras, using Mn filtered Fe radia-

Table 2. X-ray data for gadolinites.

Hundholmen				Otomé			Siberia	
d obs.	I	d obs. (1000 °C)	hkl	d calc.	d obs.	I	d obs.	I
6.06	w		011	5.98			5.98	2
			002	4.94				
4.80	s	4.74	100	4.72	4.72	w	4.69	5
4.19	vw	4.13	012	4.12			4.11	3
			110	3.98				
3.85	w		020	3.76			3.74	3
3.78	w	3.71	111,11 $\bar{1}$	3.70	3.73	vw		
		3.51	021	3.52	3.57	w	3.51	3
		3.43	102,10 $\bar{2}$	3.41			3.43	5
3.15	m	3.11	112,11 $\bar{2}$	3.10	3.11	s	3.13	10
3.07	m	3.03	013	3.02	3.02	w	3.03	2
2.99	mb		022	2.99			2.94	3
		2.94	120	2.94				
2.86	s	2.82	121,12 $\bar{1}$	2.82	2.80	s	2.83	10
2.60	b	2.56	113,11 $\bar{3}$	2.54	2.54	s	2.56	9
2.58	s	2.54	122,12 $\bar{2}$	2.53				
2.56	diff. s	2.47	004	2.48			2.47	1
		2.42	031	2.43	2.43	vw		
2.40	w	2.37	200	2.36	2.35	m	2.37	3
		2.36	014	2.35				

I—intensities visually estimated.
Hundholmen, present paper;
Otomé Japan, Ito & Mori 1953;
Siberia, Petrova et al. 1963.

Table 3. Cell dimensions for gadolinite.

Hundholmen (unheated)		Otomé (Ito & Mori 1953)
a	4.80	4.71
b	7.60	7.52
c	10.07	9.89
β	90°46'	90°33'

tion is in very good agreement with published data. D-values have been calculated from powder diffraction diagrams taken with a Guinier Quadruple Focussing Camera, using Fe radiation, a quartz monochromator and lead nitrate as internal standard (Table 2). The cell dimensions calculated from these data reveal a slightly larger cell size than that published by Ito & Mori (1953) (Table 3) and also by other authors (Petrova et al. 1963, Lima de Faria 1964). Heating of the mineral to 1000 °C in air reduces the difference. This fact is not easily explained. The H₂O content (ca. 0.5 %) is too low to cause a significant swelling of the crystal lattice. As Fe²⁺ has a larger ionic radius than Fe³⁺ it is possible that the loss of water and a simultaneous oxidation of iron may be the reason for the contraction of the lattice on heating in air. There is no indication of any significant difference in chemical composition between the gadolinite from Hundholmen and other gadolinites for which chemical data are available. On the other hand published cell dimensions are determined on heated material in most cases since most known gadolinites are metamict amorphous.

Vogt's theory that the extremely low level of metamictization of the RE minerals from Hundholmen is due to lack of radioactive elements in the pegmatite is no longer tenable since uraninite has been found even in the same handspecimen as the gadolinite. The content of U and specially of Th in the gadolinite itself is very low compared to altered gadolinites where Th content varies from 0.5 to more than 4 % ThO₂. An extremely fresh gadolinite from Siberia described by Kudima et al. (1963) is reported to be free from both U and Th. It therefore seems likely that the very low content of Th (0.1 %) in the Hundholmen gadolinite is the reason for its unaltered condition.

Acknowledgements. – I wish to thank Professor H. Neumann for critically reading the manuscript, and amanuensis B. Jensen for discussions and for correcting the language. B. Bruun and S. Bergstøl performed the chemical analyses.

September 1972

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