

Hydroxyapophyllite from the Mofjellet mine, Mo i Rana, northern Norway. Contributions to the mineralogy of Norway, No. 66

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Hydroxyapophyllite occurs as a coating of multiply twinned crystals in the Mofjellet mine near Mo i Rana, northern Norway. The composition corresponds to $(K_{0.94}Na_{0.06})Ca_{4.10}(Si_{7.98}Al_{0.02})O_{20}(OH)_{1.18} \cdot 7.89H_2O$. It is white to nearly colourless, nonfluorescent. $H = 4\frac{1}{2}$. The measured density is $2.375(5) \text{ g/cm}^3$, the calculated density 2.385 g/cm^3 . The unit cell dimensions are $a = 8.968(0) \text{ \AA}$, $c = 15.869(13) \text{ \AA}$ and $V = 1276.5 \text{ \AA}^3$. DTA and TG curves are given. Dehydration occurs in two steps, at 285°C and 410°C with respectively 2.5 percent and 14.4 percent weight loss. It is assumed that recrystallization occurs between the two weight loss steps. Recrystallization and formation of $CaSiO_3$ (wollastonite) occurs at 915°C .

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Apophyllite, $KCa_4Si_8O_{20}(F,OH) \cdot 8H_2O$, is a rather common mineral in a variety of rock types, usually occurring as well developed crystals in vugs and cracks. Fluorine has traditionally been considered as an essential constituent of apophyllite. Dunn et al. (1978) investigated a large number of apophyllites from different localities throughout the world, and found a few low-fluorine and fluorine-free apophyllites. This resulted in a revision of the nomenclature; *fluorapophyllite* and *hydroxyapophyllite* are used for apophyllites with fluorine and hydroxyl dominating, and *apophyllite* when the composition is not known (Dunn et al. 1978, Dunn & Wilson 1978). During a recent investigation of 21 Norwegian apophyllites, one 'pure' hydroxyapophyllite was found (Larsen 1980). The others varied from 46.8 to 97.0 molecular percent fluorapophyllite. The one hydroxyapophyllite comes from the Mofjellet mine near Mo i Rana, Nordland county. The present article describes this relatively uncommon mineral.

Occurrence

Saager (1966) reported apophyllite occurring in a tectonic zone in the Mofjellet mine. The zone, which may be up to 20 cm wide, strikes N-S and

dips 80°W . It is situated within ore lens II, approximately 70 to 80 m below sea level (Burman, personal communication). In vugs and cracks within this zone, hydroxyapophyllite was found as an up to 2 cm thick coarsely crystalline crust on a sulphide-impregnated greyish mica gneiss. Fibrous white thaumasite often covers the hydroxyapophyllite, which again overgrows rhombohedral calcite crystals.

Physical properties, morphology

Hydroxyapophyllite from the Mofjellet mine is translucent white to nearly colourless with a white streak. The Moh's hardness is $4\frac{1}{2}$. No fluorescence was noted either in long- or short-wavelength ultraviolet light. The hydroxyapophyllite has an excellent {001} cleavage and good {011} cleavage. The density was determined on carefully selected cleavage fragments to be $2.375(5) \text{ g/cm}^3$ at 20°C using a pycnometer filled with toluol.

The mineral is optically (+). The refractive indices, determined by the immersion method for NaD, are $\omega = 1.543(1)$ and $\epsilon = 1.541(1)$.

The Mofjellet hydroxyapophyllite forms aggregates of multiple twinned crystals. The crystal faces may reach 2 cm across, and the crystals

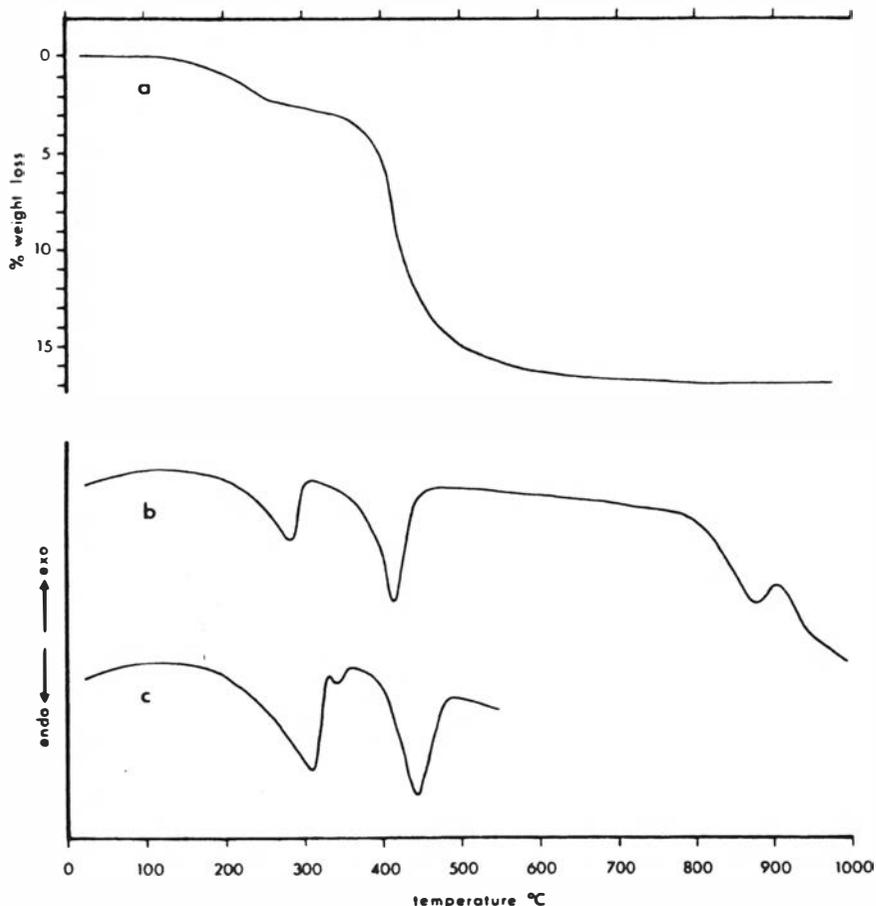


Fig. 1. TG curve (a) and DTA curve (b) for hydroxyapophyllite from the Mofjellet mine and DTA curve (c) for fluorapophyllite from the Gottes Hülfe mine, Kongsberg.

display a nearly cube-like appearance with well developed prism $a\{100\}$ and pinacoid $a\{001\}$ and very small dipyrmaid $p\{111\}$. The prism faces are striated parallel to c .

X-ray crystallography

Least squares refinement of the cell parameters based on an X-ray powder pattern obtained using $\text{CuK}\alpha_1$ radiation, graphite monochromator and $\text{Pb}(\text{NO}_3)_2$ as internal standard, gave $a = 8.968(0) \text{ \AA}$, $c = 15.869(13) \text{ \AA}$ and $V = 1276.5 \text{ \AA}^3$. This gives a calculated density of 2.385 g/cm^3 , which is in good agreement with the measured value of 2.375 g/cm^3 .

Chemistry. Thermal properties

Material for chemical analysis was carefully handpicked. The hydroxyapophyllite was analyzed by means of X-ray fluorescence spectrometry (Si, Al, Ca, Fe, K, Rb), atomic absorption spectrometry (Mg, Na) and ion-selective electrode (F).

$\text{H}_2\text{O} +$ was determined as loss on ignition. The results are shown in Table 1. The Mofjellet hydroxyapophyllite is close to the theoretical composition for $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{OH}) \cdot 8\text{H}_2\text{O}$. The formula is $(\text{K}_{0.94}\text{Na}_{0.06})\text{Ca}_{4.10}(\text{Si}_{7.98}\text{Al}_{0.02})\text{O}_{20}(\text{OH})_{1.18} \cdot 7.89\text{H}_2\text{O}$, assuming the hydroxyl group acts as charge balance.

The thermal properties were obtained using a

Perkin-Elmer TGS-2 thermobalance, run at a heating rate of 25°C per minute and a DuPont 900 DTA at a heating rate of 10°C per minute. The thermogravimetry curve shows that the water is lost in two steps of 2.5 and 14.4 weight percent respectively (Fig. 1 a). According to Rouse et al. (1978), there is no structural difference in the site of the water molecules. Nor is the amount of hydroxyl alone sufficient to account for any of the weight loss steps. Therefore one may assume that a recrystallization takes place after the mineral has lost about 15 percent of its total water content. This has been demonstrated by Chao (1971) and reproduced for a fluorapophyllite from the Gottes Hülfe Mine at Kongsberg, Norway (Fig. 1 c). The energy of crystallization is shown on the DTA curve as an exothermal peak at 340°C, while the two endothermal dehydration peaks occur at 310°C and 440°C. The corresponding dehydration peaks for hydroxyapophyllite occur at 285°C and 410°C (Fig. 1 b). The exothermal recrystallization peak is not visible for this mineral. Another difference between hydroxyapophyllite and fluorapophyllite is that while the former loses 2.5 weight percent in the first dehydration step and 14.4 weight percent in the second step, fluorapophyllite loses about half its water at each step (Colville et al. 1971). This may explain why the recrystallization peak is not visible on the hydroxyapophyllite DTA curve; only minor ordering of the water molecules is necessary to establish the new compound, a partially dehydrated apophyllite.

At about 800°C the dehydrated hydroxyapophyllite begins to sinter, and at about 880°C a broad, low endothermal peak occurs, followed by an exotherm at 915°C. These peaks are probably due to the crystallization of CaSiO₃ (wollastonite) and subsequent transformation from β to α modification.

The transformation is reversible, but sluggish in the α→β direction (Welsh 1964). Other phases are identified in the annealed product by X-ray powder diffraction.

Discussion

Dunn et al. (1978) pointed out that both fluorapophyllite and hydroxyapophyllite are often present in the same locality, even within the same specimen. Only rarely is hydroxyapophyllite found alone in a locality, and in those cases the

Table 1. Chemical composition of hydroxyapophyllite

	Weight percent of oxides		Number of atoms based on 8 (Si,Al)	
	1	2	1	2
SiO ₂	52.99	53.11	Si 7.983	} 8.000
Al ₂ O ₃	0.19		Al 0.017	
CaO	25.42	24.79	Ca 4.103	} 4.109
MgO	0.01		Mg 0.002	
FeO	0.03		Fe 0.004	} 1.000
Na ₂ O	0.20		Na 0.058	
K ₂ O	4.89	0.50	K 0.940	} 1.000
Rb ₂ O	0.02		Rb 0.002	
F	0.01		F 0.005	
H ₂ O+	16.87	16.90	H 16.952	17.000
	100.63	100.00		

1. Hydroxyapophyllite, Mofjellet mine.
2. Theoretical composition for KCa₄Si₈O₂₀(OH)·8H₂O

occurrences are normally connected with sulphide ore deposits (Dunn et al. 1978). Because of the restricted amount of data on hydroxyapophyllite and its paragenesis it is difficult to say whether this is of any relevance. However, the Mofjellet hydroxyapophyllite material closely resembles the type material from Ore Knob Mine, Jefferson, Ashe county, Virginia. It is clear that it is the amount of fluorine present at any time during formation that decides how much fluorine enters the apophyllite molecule. Fluorine has a tendency to be preferred instead of hydroxyl.

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