

Ferrokentbrooksite (Brøgger's *xanthopite*) from Skutesundskjær in the Langesundsfjord district, Norway

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Introduction

Eudialyte (*senso lato*) is a common constituent of the agpaitic pegmatites in the Langesundsfjord district in the western part of the Larvik plutonic complex. The mineral has rarely been found in the Sandefjord district (Andersen et al. 1996). Brøgger (1890) summarised the literature on eudialyte (*eucolite*) and gave a thorough description of the mineral from the Langesundsfjord district. He mentioned (p. 499) that in 1888 he discovered a pale orange, eudialyte-like mineral on the Skutesundskjær island in the Langesundsfjord. The mineral occurred as granular masses partly showing crystalline outlines. A provisional analysis performed by P. T. Cleve, shown in Table 1, indicated that the mineral contains a significant content of niobium, and a higher content of manganese, but lower content of silicon and chlorine compared to normal *eucolite* from the Langesundsfjord district. However, due to the inadequately developed crystals and the small amounts of material, it was impossible to present a complete description of the mineral. Brøgger concluded that until more material became available, it must remain an open question whether this would be a new species. The "type" material of the mineral is housed at the Naturhistoriska Riksmuseet (NRM, Swedish Museum of Natural History) in Stockholm. Brøgger's labels read (Fig. 1): *Eukolit, var. Xanthopit*. The latter is the working name given by Brøgger, referring to the yellowish colour of the mineral. The name, however, never left Brøgger's working desk, and the mineral has never been properly investigated. The present work includes new analyses on Brøgger's "type" material, and an interpretation of the results in view of the new species of the eudialyte group, which have been defined by Johnsen et al. (2003b).

Occurrence

Skutesundskjær is actually two neighbouring islets, almost connected at ebb. The main pegmatite dike on the northern Skutesundskjær is approximately 2 m thick. The main minerals are greyish white microcline, nepheline, *spreustein* (natrolite), cancrinite, albite, biotite, ferro-edenite and aegirine. Accessory minerals include rosenbuschite, wöhlerite, hiortdahlite, mosandrite, eudialyte (*s. l.*), tadhikite, catapleiite, zircon, thorite, pyrochlore, astrophyllite, fluorite, leucophanite, molybdenite, sphalerite, galena, analcime, thomsonite, gibbsite and diaspore. The other small pegmatite dikes on the islet are partly apophysis from the main dike, partly separate pegmatite dikes. The small dikes contain the same minerals, but may in some places show considerable concentrations of certain species. The pegmatites on the southern Skutesundskjær contain more or less the same minerals as on the northern islet. Skutesundskjær is the type locality for rosenbuschite. Extensive mineral collecting, including blasting, from the late 19th century until the 1930's, have almost completely destroyed the main pegmatite dikes. Both islets, however, were protected by law in 1973 because of the diversity of minerals at the localities.

Samples

Brøgger's type material at NRM comprises 6 catalogue numbers: #530923 is a 3x2x1 cm sample plus three very small pieces; #530924, #530925, #530927 and #530928 are mounted crystals of poor quality, contained in sealed glass vials; #530926 is a test tube with "gravel" of the material. Brøgger (1890) mentioned that the eudialyte

mineral was discovered in a sample containing rosenbuschite, and that poorly developed crystals, up to a couple of millimetres in length, were embedded in fluorite or zeolites. Examination of the type material showed that the following minerals are present: microcline, biotite, aegirine, nepheline, pyrochlore, wöhlerite, rosenbuschite, tadzhikite, *xanthopite*, fluorite, analcime and molybdenite. It is worth mentioning that the tadzhikite is well displayed at one end of the main sample #530923, and it is strange that Brøgger made no notice of this rather conspicuous mineral, which was described as a new species about 80 years later (Efimov et al. 1970).

Xanthopite occurs as irregular masses, and crystal faces are developed where the mineral is embedded in analcime or fluorite. *Xanthopite* is yellowish orange and translucent.

Chemical composition

The analyses on the main and minor elements, except Ti, Al, Fe and the rare earth elements were done in wavelength-dispersive mode on a JEOL 733 electron microprobe using the same analytical conditions and calibration standards as reported in the description of ferrokentbrooksit (Johnsen et al. 2003a). Carefully handpicked material was decomposed by nitric and sulphuric acids, and the concentrations of Ti, Al and the REE were determined by PerkinElmer Elan DRC-II ICP-MS, while Fe was determined by AAS. The results are shown in Table 1, compared to the analytical data from Brøgger (1890).

An infrared spectrum was obtained on ground material pressed into a KBr pellet and recorded using a PerkinElmer S-2000 FT-IR spectrometer in the range 4000 - 450 cm^{-1} (Fig. 2). The broad absorption bands at approximately 3480 and 1640 cm^{-1} are assigned to the [OH] stretching mode and the [H₂O] bending mode, respectively. The bands between 1100 and 450 cm^{-1} are due to the stretching and bending vibrations of the [SiO₄] group. The two bands at 1425 and 1506 cm^{-1} are attributed to the stretching mode of a [CO₃] group. The infrared spectrum is practically identical to that reported by Johnsen et al. (2003a), except for stronger absorption bands for the [CO₃] group in *xanthopite*. The presence of carbonate appears to be common in the eudialyte group of minerals, and has been discussed by Johnsen et al. (1999). Two members of the eudialyte group containing carbonate as an essential constituent, zirsilite-(Ce) and carbokentbrooksit, have recently been described by Khomyakov et al. (2003). Due to the scarcity of *xanthopite*, the amount of CO₂ has not been quantified. However, the IR absorption bands of the carbonate group are rather strong. In fact, even stronger than the same bands of the Sagåsen zirsilite-(Ce), which contains 0.77 wt.% CO₂ or 0.77 apfu (CO₃) (Larsen et al. 2005). Therefore, the empirical formula has been calculated assuming 1 apfu (CO₃) in *xanthopite*. Brøgger (1890) reported a loss on ignition of 2.11 wt.%, probably mainly due to liberation of CO₂. The rather high content of Ce₂O₃ reported by Brøgger is likely due to co-precipitation of the rare earth elements during the old-fashioned analytical procedure. Co-precipitations of Zr, Ca and Nb with Hf, Sr and Ta, respectively, are probably also the case in the analysis by Brøgger (1890), who reported higher concentrations of ZrO₂, CaO and Nb₂O₅ than found by the present EMP analysis.

X-ray crystallography

X-ray powder diffraction data on *xanthopite* were obtained using a Philips X'pert diffractometer (CuK α_1 radiation, $\lambda = 1.54056 \text{ \AA}$). Si (NBS 640a) was used as internal standard. Indexing and least squares refinement were done by the program CELREF, and the unit cell dimensions found are $a = 14.1716(40) \text{ \AA}$, $c = 30.1215(1) \text{ \AA}$, and $V = 5236(1) \text{ \AA}^3$.

Kat. No No 530923-930 Min. XVe. 13
27 Eukalit, var. Xanthopit, Br.
analysert af Clive.
Skudsundersøgar
v. Burkenik, N.
Stockh. högsk. min. inst. N. C. Br. lys. 88.

Fig. 1. Brøgger's original label of xanthopite.

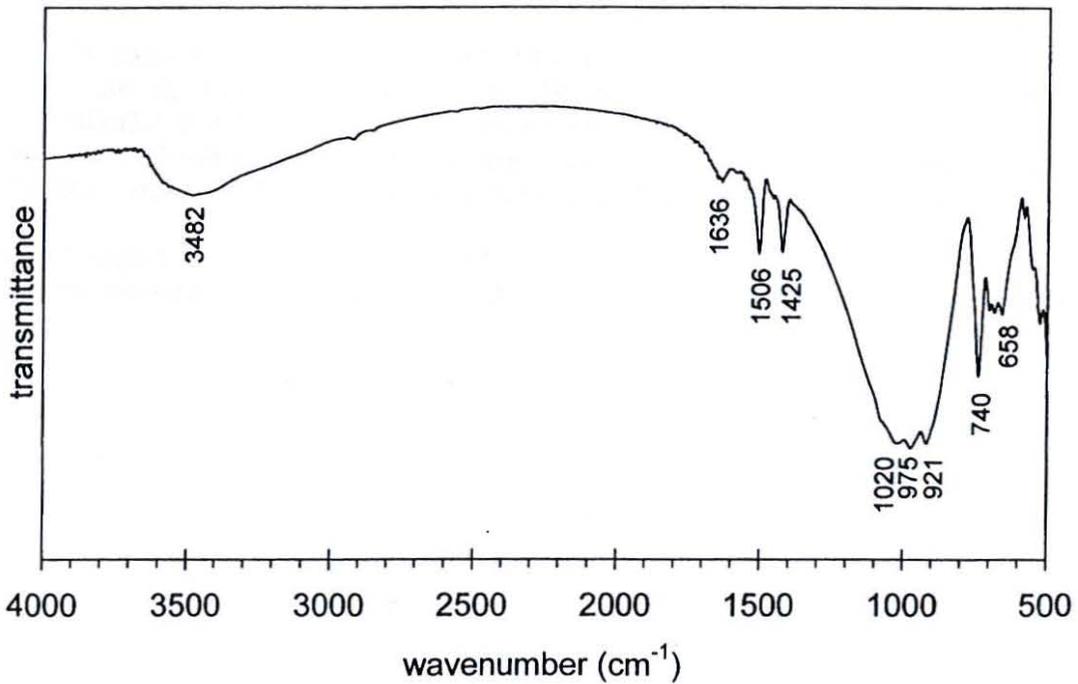


Fig. 2. Infrared spectrum of Brøgger's xanthopite.
The principal absorption bands are indicated.

Conclusion

The present chemical analysis is in relatively good agreement with the result reported by Brøgger (1890), and confirms the fact that W. C. Brøgger found a mineral which he was close to describing as a new species 115 years before it was described as ferrokentbrooksit by Johnsen et al. (2003a).

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Table 1. Chemical composition (in oxide weight- %) of ferrokentbrooksit (*xanthopite*) from Skutesundskjær, and corresponding number of atoms per formula unit based on 29(Si+Al+Zr+Ti+Hf+Nb+Ta). The EMP result is the mean of three analysis points.

Brøgger (1890)		This work			
SiO ₂	45.15	SiO ₂	44.66	Si	24.403
TiO ₂	-	TiO ₂	0.60	Ti	0.247
ZrO ₂	12.51	ZrO ₂	11.26	Zr	3.000
HfO ₂	-	HfO ₂	0.46	Hf	0.072
Al ₂ O ₃	-	Al ₂ O ₃	0.80	Al	0.515
Y ₂ O ₃	0.32	Y ₂ O ₃	0.24	Y	0.070
La ₂ O ₃	-	La ₂ O ₃	1.65	La	0.333
Ce ₂ O ₃	4.80	Ce ₂ O ₃	2.05	Ce	0.410
Pr ₂ O ₃	-	Pr ₂ O ₃	0.13	Pr	0.026
Nd ₂ O ₃	-	Nd ₂ O ₃	0.28	Nd	0.055
Sm ₂ O ₃	-	Sm ₂ O ₃	0.02	Sm	0.004
Eu ₂ O ₃	-	Eu ₂ O ₃	0.00	Eu	0.000
Gd ₂ O ₃	-	Gd ₂ O ₃	0.03	Gd	0.005
Tb ₂ O ₃	-	Tb ₂ O ₃	0.00	Tb	0.000
Dy ₂ O ₃	-	Dy ₂ O ₃	0.03	Dy	0.005
Ho ₂ O ₃	-	Ho ₂ O ₃	0.01	Ho	0.000
Er ₂ O ₃	-	Er ₂ O ₃	0.03	Er	0.005
Tm ₂ O ₃	-	Tm ₂ O ₃	0.00	Tm	0.000
Yb ₂ O ₃	-	Yb ₂ O ₃	0.04	Yb	0.007
Lu ₂ O ₃	-	Lu ₂ O ₃	0.00	Lu	0.000
Nb ₂ O ₅	3.52	Nb ₂ O ₅	2.98	Nb	0.736
Ta ₂ O ₅	-	Ta ₂ O ₅	0.18	Ta	0.027
WO ₃	-	WO ₃	0.00	W	0.000
FeO	3.90	FeO	4.28	Fe	1.956
MnO	3.60	MnO	3.09	Mn	1.430
MgO	-	MgO	0.00	Mg	0.000
CaO	12.11	CaO	11.17	Ca	6.540
SrO	-	SrO	0.80	Sr	0.253
Na ₂ O	11.17	Na ₂ O	10.89	Na	11.537
K ₂ O	0.11	K ₂ O	0.55	K	0.383
F	-	F	0.00	F	0.000
Cl	0.55	Cl	0.58	Cl	0.537
CO ₂	(2.11*)	CO ₂	1.34**	C	1.000
H ₂ O	-	H ₂ O	0.39**	H	3.463
-O≡F	-	-O≡F	0.00		
-O≡Cl	0.12	-O≡Cl	0.13		
Total	99.73	Total	98.97		

* Reported as loss on ignition.

** Determined by stoichiometry, calculated assuming 1(CO₃) and 2(OH+Cl).

Empirical formula for ferrokentbrooksit (*xanthopite*):

