

Chemical composition of acmite/aegirine intergrowths from Rundemyr, Eiker

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Introduction

The two names acmite and aegirine have been applied to the pyroxene mineral with nominal composition $\text{NaFe}^{3+}\text{Si}_2\text{O}_6$. Rundemyr is the type locality of acmite, described by Ström (1821) and named by Berzelius (1821). The Låven island in Langesundsfjord is regarded as the type locality of aegirine, named by Berzelius (1835) after a find by H.M.T. Esmark in 1834. Although the name acmite has priority, it was abandoned in favour of aegirine by the Commission on New Minerals and Mineral Names of the International Mineralogical Association (Morimoto 1988), in order to preserve the commonly used term aegirine-augite. The most conspicuous difference between the two minerals is related to their colour: acmite is brown whereas aegirine is green.

The acmite crystals from Rundemyr were thoroughly described by Brøgger (1890). Pointed and tapering crystal terminations are typical for the mineral (Fig. 1), and its name was fittingly derived from Greek $\alpha\chi\mu\eta$, a spear-point. Twinning on {100} is occasionally present. Typically, the centre of the crystals consists of green aegirine with strong pleochroism. Brown acmite with weak pleochroism forms thick plates mainly coating the pinacoids {100} and {010}, and the terminal faces; it is only rarely present on the vertical prism {110}. It is important to notice that this is not a gradual zonation or alteration but a sharply defined overgrowth. The middle drawing (Fig. 6) on Fig. 1 below shows a cross section of an extreme case where platy acmite is embedded in an aegirine crystal.

Acmite at Rundemyr occurs in a small granitic pegmatite that cuts through Silurian sediments. The pegmatite is probably genetically connected with the soda granite (ekerite) that occurs in the vicinity. The acmite/aegirine crystals may reach a length of several dm when embedded in quartz from the core of the pegmatite, but is also present as smaller prismatic crystals close to the contact with the bedrock. The crystals from the quartz core are often bent or broken.

The results of duplicate analyses of coexisting acmite and aegirine from Rundemyr (analyses R2-1 to R2-4 in Table 1 below) were reported by Raade (1996), and the qualitative difference in chemistry between the two phases was mentioned by Neumann (1985, p. 184), based on personal communication with Raade. Neumann (1961) observed a Sc content of 20 ppm in acmite from Rundemyr. The purpose of the present paper is to present and discuss the complete series of analytical data and to document the analytical procedure. The occasional replacement of pyroxene crystals by quartz, hematite and pyrophanite is also described.

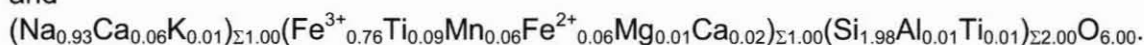
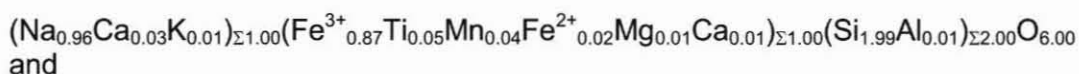
Analytical details

Energy-dispersive analyses were performed in September and November 1978 with an ARL-EMX electron microprobe at Sentralinstituttet for industriell forskning (Oslo). The operating voltage was 15 kV and the probe current 0.35 nA. The probe standards were diopside for Si, Mg and Ca, jadeite for Al and Na, rutile for Ti, fayalite with 2.5 wt% Mn for Fe and Mn, and K-feldspar for K. A rhodonite standard was used for Mn in analyzing pyrophanite and hematite. Pure oxides were the standards for Nb and Ta in the analyses of pyrophanite. The counting data were converted to weight-percent oxides by a procedure described by Bence & Albee (1968), using the program

PROBECOR developed by Kari Thoresen. Ferric iron in the pyroxenes was calculated with the program PYROX, based on a charge-balance method (Neumann 1976); structural formulae are calculated on the basis of the number of cations rather than oxygen atoms.

Pyroxene chemical data

The analytical results, obtained on thin-section preparations, are displayed in Table 1. In sample R2, a pyroxene cross section was analysed: two points of the overgrowth on the {100} faces (brown, fresh acmite) and two points of the interior (remnants of green aegirine in a quartz-rich matrix with opaque phases). The aegirine has a higher content of Ti, Fe²⁺, Mn and Ca, and a lower content of Fe³⁺, compared to the acmite. The empirical formulae of acmite and aegirine in sample R2 (mean of two point analyses) are, respectively:



This relatively small change in composition has a tremendous influence on the pleochroism, probably involving a change in charge-transfer conditions between Fe and Ti. Acmite is closest to the end-member formula NaFe³⁺Si₂O₆.

Sample R1 is a longitudinal section of a steeply terminated acmite crystal. A weak zonation occurs along the elongation. It was analysed in step-scan mode (20 μm steps) in a traverse perpendicular to the elongation, half across the section at a short distance from the terminal faces. The three sets of analytical data in Table 1 are mean values of 6, 10 and 15 points, starting at the edge of the crystal. The 10-point part (R1-2) is slightly depleted in Ti and Mn and has a correspondingly higher Fe³⁺ content. Interestingly, this crystal seems to be devoid of Fe²⁺.

Sample 5 contains crystal cross sections with shells of acmite surrounding cores of unaltered aegirine. The results of two point analyses of aegirine are shown in Table 1.

Sample R4/II is a thin section of the relatively fine-grained border zone of the pegmatite, occurring close to the contact with the metamorphosed sediments. It contains a multitude of small, zoned acmite crystal cross-sections with varying pleochroism in brown and greenish brown. Three point analyses are tabulated in Table 1. Point nos. 1 and 3 are from acmite displaying greenish brown pleochroism, whereas point no 2 has a pale brown pleochroism. The corresponding difference in composition is evident: points 1 and 3 have around 2 wt% FeO and point 2 has nil. There is also a difference in the CaO content.

Sample R3/II shows a cross section of a composite acmite/aegirine crystal with a knife-sharp border between the two components. A step-scan was made across the acmite border (10 μm steps, 10 points). This acmite rim is relatively rich in TiO₂ (Table 1).

Pseudomorphosed pyroxenes

During the evolution of the pegmatite, some of the acmite/aegirine crystals became instable and were replaced by a mixture of quartz and an intimate, scaly intergrowth of two opaque minerals, hematite and pyrophanite. It can also be observed that the central aegirine parts of the crystals may be more or less altered, whereas the acmite rims are still fresh.

Electron-microprobe analytical data on hematite and pyrophanite from a completely pseudomorphosed crystal (sample R4, which is different from sample R4/II in Table 1) are shown in Table 2. The hematite is seen to be rather "impure" with appreciable contents of Si, Al, Ti and Mn. The low analytical totals may indicate that the mineral is slightly hydrated. The pyrophanite is a niobian variety with 6-8 wt% Nb₂O₅. Formula calculation based on a cation sum of 2 and all iron as divalent gives a cation charge of 6.11, which is higher than the ideal charge of 6. If the analytical results can be trusted, this indicates that Fe³⁺ cannot be present in the mineral, and that the expected substitution scheme (Nb,Ta)⁵⁺ + Fe³⁺ ↔ 2Ti⁴⁺ is not operating. To incorporate Nb⁵⁺ for Ti⁴⁺, minor vacancies at both cation sites may be assumed. The mean of the two pyrophanite analyses in Table 2 gives the following empirical formula, based on three O atoms:



The similar cation sums for the two structure sites should be noticed.

Acknowledgements

I am indebted to W.L. Griffin for introducing me to electron-microprobe analytical work.

References

- BENCE, A.E. & ALBEE, A.L. (1968): Empirical correction factors for the electron microanalysis of silicates and oxides. *Journal of Geology* **76**, 382-403.
- BERZELIUS, J. (1821): Tillägg till föregående Afhandling [P. Ström: Undersökning af ett nytt Fossil]. *Kongliga Vetenskaps-Academiens Handlingar*, 163-166.
- BERZELIUS, J. (1835): [Aegirin (Esmark)]. *Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde*, 184-185.
- BRØGGER, W.C. (1890): Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite. *Zeitschrift für Krystallographie und Mineralogie* **16**, 235 + 663 pp. (with 29 separate plates).
- MORIMOTO, N. (1988): Nomenclature of pyroxenes. *American Mineralogist* **73**, 1123-1133 [also in *Mineralogical Magazine* **52**, 535-550 (1988) and in *The Canadian Mineralogist* **27**, 143-156 (1989)].
- NEUMANN, E.-R. (1976): Two refinements for the calculation of structural formulae for pyroxenes and amphiboles. *Norsk Geologisk Tidsskrift* **56**, 1-6.
- NEUMANN, H. (1961): The scandium content of some Norwegian minerals and the formation of thortveitite, a reconnaissance survey. *Norsk Geologisk Tidsskrift* **41**, 197-210.
- NEUMANN, H. (1985): Norges Mineraler. *Norges Geologiske Undersøkelse Skrifter* **68**, 278 pp.
- RAADE, G. (1996): Minerals originally described from Norway. Including notes on type material. *Norsk Bergverksmuseum Skrifter* **11**, 107 pp. (with 7 separate plates).
- STRÖM, P. (1821): Undersökning af ett nytt Fossil. *Kongliga Vetenskaps-Academiens Handlingar*, 160-163.

Table 1. Electron-microprobe analytical data (wt%) for acmite and aegirine from Rundemyr.

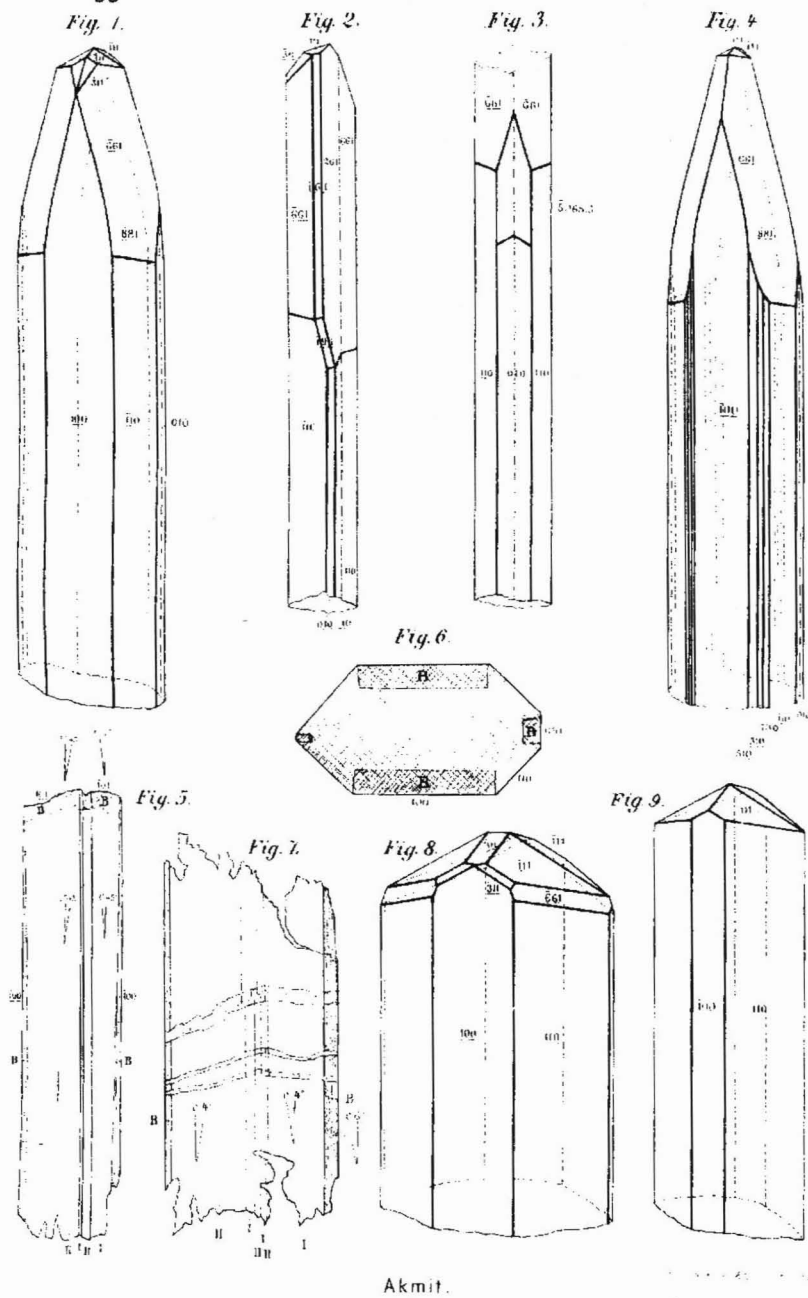
	Acmite		Aegirine		Acmite			Aegirine		Acmite			Acmite
	R2-1	R2-2	R2-3	R2-4	R1-1	R1-2	R1-3	R5-1	R5-2	R4/II-1	R4/II-2	R4/II-3	R3/II
SiO ₂	51.99	52.16	51.48	51.48	51.25	50.78	50.82	51.37	51.21	52.11	52.11	52.02	52.43
Al ₂ O ₃	0.30	0.24	0.20	0.31	0.29	0.27	0.29	0.18	0.17	0.23	0.17	0.28	0.18
TiO ₂	1.83	1.86	3.52	3.65	2.19	1.54	2.19	2.85	2.86	1.50	1.61	1.45	2.73
Fe ₂ O ₃	30.40	29.77	25.41	26.88	30.68	32.60	31.51	27.42	25.99	28.91	31.18	28.76	29.85
MgO	0.20	0.18	0.26	0.24	0.35	0.07	0.04	0.31	0.39	0.12	0.31	0.12	0.09
FeO	0.36	0.78	2.46	1.52	0.00	0.00	0.00	2.80	2.50	1.90	0.00	2.22	0.00
MnO	1.10	1.16	1.83	1.55	0.84	0.67	0.94	1.80	1.79	1.12	0.78	1.03	1.67
CaO	1.13	1.08	2.31	1.59	0.32	0.16	0.08	3.01	2.95	2.04	0.49	2.04	0.51
Na ₂ O	12.95	12.93	12.21	12.68	13.45	13.28	13.29	11.76	11.78	12.38	13.40	12.29	13.47
K ₂ O	0.16	0.14	0.12	0.16	0.18	0.20	0.20	0.14	0.13	0.13	0.11	0.14	0.12
Total	100.42	100.30	99.80	100.06	99.55	99.57	99.36	101.64	99.77	100.44	100.16	100.35	101.05
Si	1.987	1.996	1.984	1.975	1.967	1.960	1.964	1.959	1.980	1.998	1.990	1.997	1.987
Al	0.013	0.004	0.009	0.014	0.013	0.012	0.013	0.008	0.008	0.002	0.008	0.003	0.008
Ti	0.000	0.000	0.007	0.011	0.020	0.028	0.022	0.033	0.013	0.000	0.003	0.000	0.005
Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Al	0.001	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.010	0.000
Ti	0.053	0.054	0.095	0.094	0.043	0.017	0.041	0.049	0.070	0.043	0.044	0.042	0.073
Fe ³⁺	0.874	0.857	0.737	0.776	0.886	0.947	0.916	0.787	0.756	0.834	0.896	0.831	0.851
Mg	0.011	0.010	0.015	0.014	0.020	0.004	0.002	0.018	0.022	0.007	0.018	0.007	0.005
Fe ²⁺	0.011	0.025	0.079	0.049	0.000	0.000	0.000	0.089	0.081	0.061	0.000	0.071	0.000
Mn	0.036	0.038	0.060	0.050	0.027	0.022	0.031	0.058	0.059	0.036	0.025	0.033	0.054
Ca	0.046	0.044	0.095	0.065	0.013	0.007	0.003	0.123	0.122	0.084	0.020	0.084	0.021
Na	0.960	0.959	0.912	0.943	1.001	0.994	0.996	0.870	0.883	0.920	0.992	0.915	0.990
K	0.008	0.007	0.006	0.008	0.009	0.010	0.010	0.007	0.006	0.006	0.005	0.007	0.006
Sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000

Table 2. Electron-microprobe analytical data (wt%) for hematite and niobian pyrophanite from Rundemyr.

	Hematite ¹			Pyrophanite ²	
	R4-H1	R4-H2	R4-H3	R4-P1	R4-P2
SiO ₂	1.13	1.19	1.92	0.18	0.33
Al ₂ O ₃	0.73	0.56	0.70	---	---
TiO ₂	0.47	1.03	0.62	46.31	47.11
Fe ₂ O ₃	92.90	91.31	89.96	---	---
FeO	1.37	1.82	2.37	8.46	9.33
MnO	0.40	0.52	0.48	37.05	36.42
Nb ₂ O ₅	---	---	---	8.15	6.34
Ta ₂ O ₅	---	---	---	0.43	0.14
Total	97.00	96.43	96.05	100.58	99.67
Si	0.031	0.032	0.052	0.005	0.008
Al	0.023	0.018	0.023	---	---
Ti	0.010	0.021	0.013	0.886	0.905
Fe ³⁺	1.896	1.875	1.847	---	---
Fe ²⁺	0.031	0.042	0.054	0.180	0.199
Mn	0.009	0.012	0.011	0.798	0.788
Nb	---	---	---	0.094	0.073
Ta	---	---	---	0.003	0.001
Sum	2.000	2.000	2.000	1.966	1.974

¹ Fe³⁺/Fe²⁺ calculation is based on a charge-balance method (Neumann 1976), assuming a cation sum of 2.

² Structural formulae are based on O = 3.



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Fig. 1. Drawings of acmite crystals from Rundemyr. Reproduced from Plate XIV in Brögger (1890).