

Emeleusite: a new $\text{LiNaFe}^{\text{III}}$ silicate from south Greenland

B. G. J. UPTON, P. G. HILL, O. JOHNSEN,* AND O. V. PETERSEN*

Department of Geology, Edinburgh EH9 3JW

* Geological Museum, University of Copenhagen, DK-1350 Copenhagen K

SUMMARY. Emeleusite ($\text{Li}_2\text{Na}_4\text{Fe}_2^{\text{III}}\text{Si}_{12}\text{O}_{30}$) is an orthorhombic (pseudohexagonal) mineral occurring as euhedra within a facies of a peralkaline trachyte dyke. The composition is: SiO_2 70.75; TiO_2 0.55; ZrO_2 0.10; Al_2O_3 1.34; Fe_2O_3 12.13; MgO 0.10; MnO 0.03; Na_2O 11.98; Li_2O 2.78; 99.76. The density is 2.775 g/cm^3 (calculated) and 2.76(7) g/cm^3 (determined); hardness 5-6. It is colourless, transparent, and has a glassy lustre. Emeleusite is biaxial negative with $2V_z$ varying from near-zero to $c. 30^\circ$, $r \gg v$. The refractive indices are: α 1.596; β 1.597; γ 1.597; with $\alpha \parallel b$; $\beta \parallel a$; $\gamma \parallel c$. Emeleusite can occur as interpenetration triplets with {110} as twin planes. The space group is *Acam* or *Abaz* with $a = 10.073 \pm 0.002$ Å; $b = 17.350 \pm 0.005$ Å and $c = 14.010 \pm 0.005$ Å. $Z = 4$. Prominent powder diffraction lines are 7.001(5) 002, 4.352(10) 220, 040, 3.501(7) 004, 3.209(8) 311, and 3.090(7) 124. While the structure is as yet unknown it is suggested that it is an orthorhombic associate of the milarite group.

EMELEUSITE is the name proposed for a new mineral, $\text{Li}_2\text{Na}_4\text{Fe}_2^{\text{III}}\text{Si}_{12}\text{O}_{30}$, occurring as a minor constituent of a peralkaline trachyte dyke on the island of Igdlutalik in the Julianehåb district of south Greenland. The field-relations and petrology of the dyke have been described by Upton *et al.* (1976). The dyke rocks are typically fine-grained (50-100 μm); they are notably heterogeneous with the component minerals concentrated in lenses, schlieren, and contrasted layers that display what appears to be flow-folding. The principal constituents are albite and aegirine, often with trachytoid laminar orientation. Accessory minerals include quartz, riebeckite, micas, zircon, pectolite, apatite, calcite, and opaque oxides. Also, the rarer minerals (titanian-) narsarsukite and (zinc-) nordite occur, together with (hydrated?) thorite and an, as yet, unidentified CaREE silicate.

Because of extensive frost-shattering, the internal relationships of the dyke-rocks are generally indeterminable. During collection of materials from this locality in 1974, one sample (G.G.U. 181903), weighing *c.* 1 kg, was collected that on investigation proved to be largely composed of the new mineral emeleusite.

The mineral was named in honour of Dr. C. H. Emeleus, Department of Geological Sciences, University of Durham. The mineral and the name have been approved by the I.M.A. Commission on New Minerals and Mineral Names. The type material is deposited in the Geological Museum, Copenhagen University, and in the Department of Geology, Edinburgh University.

Petrography of sample G.G.U. 181903. The sample shows a pale-cream to pink lenticular core (*c.* 10 × 30 cm) enveloped in flow-banded green (aegirine-rich) and white (albite-rich) layers (fig. 1). The lenticular core is composed almost wholly (> 90%) of emeleusite as roughly equidimensional crystals of up to 2 mm in length. The remainder of this sample core consists of very fine-grained albite, interstitial to the emeleusite.

Separation and analytical techniques. A portion of the sample was crushed and washed. Material containing aegirine inclusions was separated using an electromagnetic separator. The remaining

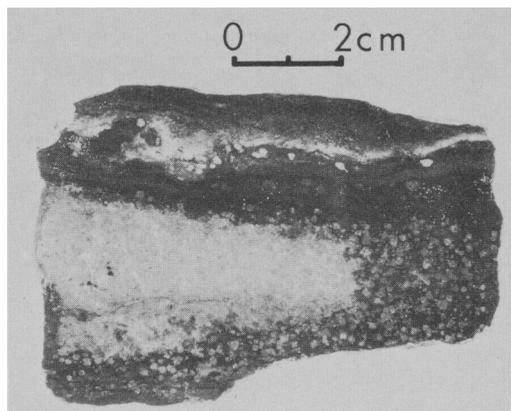


FIG. 1. Photograph of a cut and polished surface through sample G.G.U. 181903 showing the leucocratic core composed of emeleusite and accessory albite. Emeleusite euhedra (white) can also be seen in the surrounding darker bands.

albite-emeleusite concentrate was separated by means of a centrifuge, with tetrabromoethane and acetone. Li_2O was determined flame-photometrically on this separate, which was optically homogeneous and which showed no X.R.D. peaks for either albite or aegirine.

Since the sample core is composed solely of emeleusite and (accessory) albite, the $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio determined on this should be representative of the emeleusite itself since the iron-content of the albite is negligible (Table I).

Microprobe analysis of the three mineral constituents of 181903 were made using a Cambridge Instrument Microscan 5, operating at 20 kV and a probe-current of 30 nA. The elements were measured against well-established standards of simple composition: wollastonite containing 24.00 wt % Si; jadeite, 11.34 Na; corundum, 52.92 Al, periclase, 60.32 Mg; speccure Fe; speccure Ti; 99% pure Zr; and speccure Mn.

Corrections for dead-time counting losses, atomic number, absorption, and characteristic fluorescence differences between standard and unknown were made and are essentially those described by Sweatman and Long (1969).

General description. The emeleusite is transparent, colourless or creamy-pinkish, and has a glassy lustre. The specific gravity was determined as 2.76(7) g/cm^3 and calculated as 2.775 g/cm^3 . The hardness, difficult to determine on account of the small size of the crystals, is between 5 and 6. There appears to be no distinct cleavage.

The mineral is orthorhombic (pseudo-hexagonal) and the euhedral crystals display the forms: $\{100\}$, $\{010\}$, $\{001\}$, $\{110\}$, $\{101\}$, and $\{011\}$. The crystals

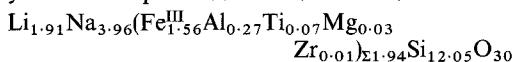
TABLE I. *Average probe-analyses of mineral species in 181903. No. of analyses of each mineral in parentheses*

	Emeleusite (10)	Aegirine (6)	Albite (2)
SiO_2	70.75	52.51	68.75
TiO_2	0.55	0.39	0.01
Al_2O_3	1.34	0.62	19.25
Fe_2O_3	12.13	31.43	0.44
MgO	0.10	0.12	0.01
MnO	0.03	0.17	0.02
CaO	0.00	0.12	0.00
K_2O	0.00	0.00	0.02
Na_2O	11.98	13.79	11.35
Li_2O^*	2.78	—	—
ZrO_2	0.10	0.03	0.00
	99.76	99.18	99.85

* Determined flame-photometrically (M. J. Saunders).

are tabular parallel $\{010\}$ as is shown in the drawing of an idealized crystal, fig. 2a.

Composition. Emeleusite is highly siliceous; the other major components Fe (inferred to be almost wholly ferric), Na, and Li are accompanied by lesser amounts of Al, Ti, Mg, Mn, and Zr. Otherwise the mineral is remarkably free of minor and trace constituents. The composition shown in Table I yields the empirical formula:



on the basis of O = 30.

Optical properties. Universal Stage investigation shows emeleusite to be biaxial negative with α parallel to the b -axis, β parallel to the a -axis, and γ parallel to the c -axis, i.e. the optical axial plane is the b - c plane.

The principal refractive indices were determined by means of the λ - T variation method using optical glass as internal standard (Micheelsen, 1957). The principal indices of refraction for $\lambda = 589$ nm are: α 1.596 \pm 0.001, β 1.597 \pm 0.001, and γ 1.597 \pm 0.001.

$2V_\alpha$ varies from nearly zero to $c. 30^\circ$ (white light); emeleusite shows very strong axial-angle dispersion with $2V_\alpha$ red light \gg $2V_\alpha$ violet light. The $2V_\alpha$ for violet light is almost 0° .

Emeleusite forms pseudo-hexagonal, interpenetration, normal triplets, with $\{110\}$ as the twin planes. The single individuals are tabular parallel to $\{010\}$ and strongly elongated after $[100]$. The c -axis forms the pseudo sixfold axis of these triplets. Fig. 3a shows a photomicrograph of a triplet and fig. 2b, a drawing of an idealized triplet. In many of the triplets each of the three orientations is represented by several parallel individuals; fig. 2c shows a drawing of an idealized triplet of this type seen along the pseudo sixfold axis. Fig. 3b is a photomicrograph showing a section (nearly) parallel to the pseudo sixfold axis of the type of triplet referred to above; compare fig. 2d.

X-ray data. Weissenberg studies on single crystals show that emeleusite is orthorhombic. Systematic extinctions observed on single crystal X-ray photographs are consistent with those required for space groups *Acam* and *Aba2*. The preliminary cell parameters obtained from single crystal studies were refined by a least-squares programme (REFBASE-2, written by E. S. Leonardsen) using powder diffraction data (Table II) obtained with a Guinier-Hägg camera and Cu- $K\alpha$ radiation. Quartz was used as an internal standard. The refined values are:

$$\begin{aligned} a &= 10.073 \pm 0.002 \text{ \AA}, \\ b &= 17.350 \pm 0.005 \text{ \AA}, \\ \text{and } c &= 14.010 \pm 0.005 \text{ \AA}. \end{aligned}$$

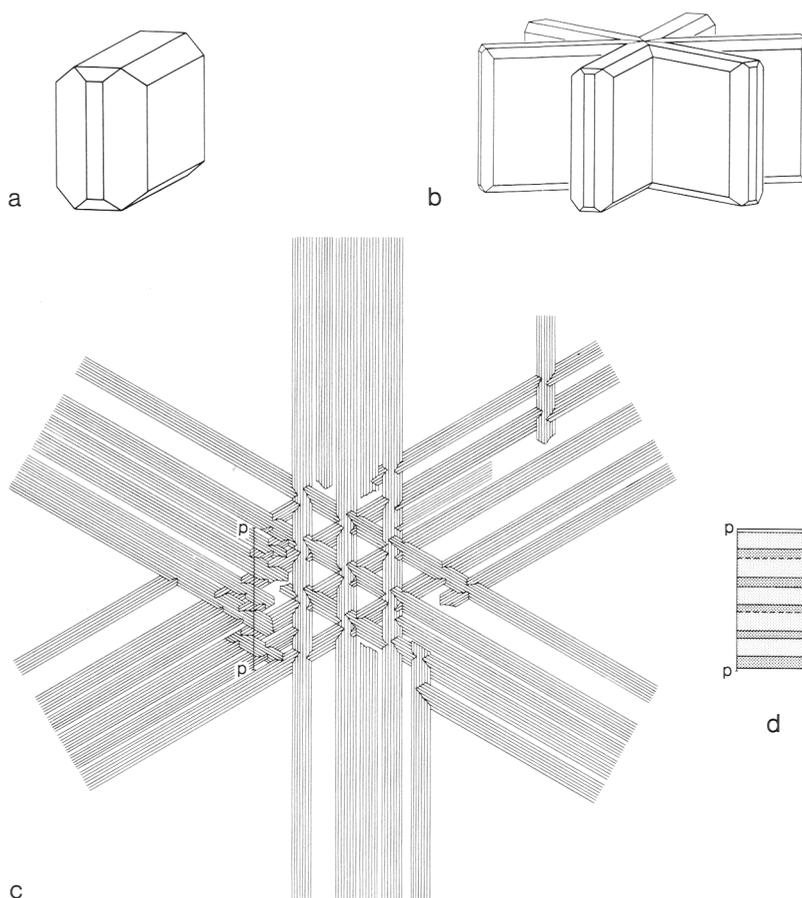
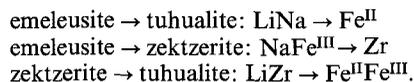


FIG. 2. *a*, drawing of an idealized crystal of emeleusite; clinographic projection. *b*, drawing of an idealized pseudohexagonal interpretation triplet of emeleusite. Twin planes $\{110\}$; clinographic projection. *c*, as for *b*, but with each of the three orientations represented by several parallel individuals; orthographic projection along the pseudo sixfold axis. *d*, drawing of an idealized section through the triplet shown on *c*, along $p-p$; compare fig. 3*b*.

The axial setting was chosen to illustrate the pseudohexagonal symmetry ($b \sim 2a \sin 60^\circ$) and to stress the close relationship between emeleusite and minerals of the milarite group. The latter are all hexagonal with $a \sim 10 \text{ \AA}$ and $c \sim 14 \text{ \AA}$, and their structure is characterized by paired hexagonal rings, $\text{Si}_{12}\text{O}_{30}$. While no structural information about emeleusite is yet available, the chemical and X-ray data suggest that emeleusite is an orthorhombic associate of the milarite group.

Two other minerals, tuhualite ($\text{Na}_2\text{Fe}_2^{\text{II}}\text{Fe}_2^{\text{III}}\text{Si}_{12}\text{O}_{30} \cdot \text{H}_2\text{O}$) (Merlino, 1969) and zektzerite ($\text{LiNaZrSi}_6\text{O}_{15}$) (Dunn *et al.*, 1977) share the same relationship with the milarite group, and may, together with emeleusite, form an orthorhombic

subgroup. The unit cell parameters of tuhualite are $a = 14.31 \text{ \AA}$, $b = 17.28 \text{ \AA}$, and $c = 10.11 \text{ \AA}$ (Hutton, 1956), while those of zektzerite are $a = 14.306 \text{ \AA}$, $b = 17.330 \text{ \AA}$, and $c = 10.140 \text{ \AA}$; thus (apart from different setting of axes) these values are very close to those of emeleusite. The chemistry differs in the following way:



Thermal analyses. Thermal gravimetric analyses showed no loss in weight between 25°C and 600°C , and differential thermal analysis showed no reaction until the mineral melted at 890°C .

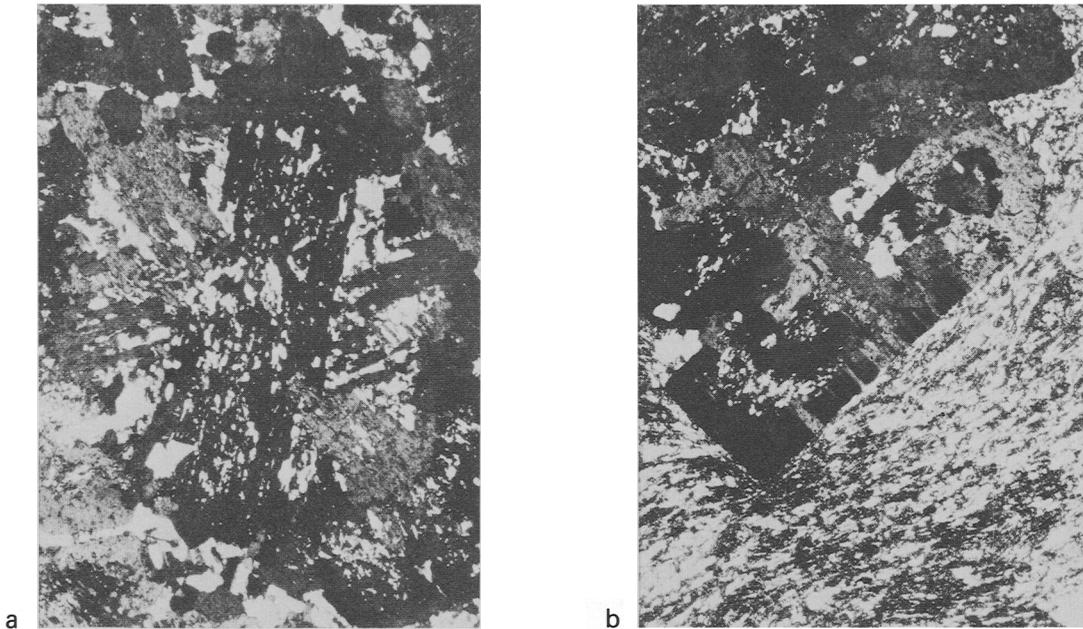


FIG. 3. *a*, photomicrograph, $60\times$, $\lambda = 546$ nm, crossed nicols, of pseudo-hexagonal penetration triplet in emeleusite, as seen parallel to the pseudo sixfold axis. Twin plane $\{110\}$, photo, H. Micheelsen. *b*, photomicrograph, $60\times$, $\lambda = 546$ nm, crossed nicols, of pseudo-hexagonal penetration triplet of emeleusite as seen in section parallel, or slightly oblique, to the pseudo sixfold axis, compare fig. 2*d*, photo, H. Micheelsen.

TABLE II. X-ray powder data for emeleusite

<i>I</i>	d_{obs}	d_{calc}	<i>hkl</i>	<i>I</i>	d_{obs}	d_{calc}	<i>hkl</i>
5	7.001	7.005	002	1	2.232	2.230	064
5	4.792	4.793	122	2	2.195	2.196	271
2	4.578	4.572	211	2	2.178	{ 2.178	440
10	4.352	{ 4.356	220	2	2.142	{ 2.177	164
6	4.087	{ 4.338	040	2	2.117	{ 2.144	353
3	3.697	{ 4.089	202	3	1.990	{ 2.118	206
5	3.666	{ 3.699	222	3	1.963	{ 2.116	344
7	3.501	{ 3.688	042	3	1.920	{ 1.992	280
5	3.463	3.666	231	3	1.900	{ 1.990	424
8	3.209	3.501	004	3	1.963	{ 1.962	520
6	3.192	3.463	142	4	1.885	{ 1.885	531
7	3.090	3.209	311	1	1.875	{ 1.876	191
6	2.875	3.192	151	1	1.862	{ 1.862	415
4	2.801	3.090	124	1	1.827	{ 1.828	355
5	2.728	2.875	204	4	1.827	{ 1.827	540
2	2.687	2.801	251	1	1.768	{ 1.826	175
1	2.655	{ 2.730	224	1	1.752	{ 1.768	542
5	2.629	{ 2.725	044	5	1.709	{ 1.753	346
5	2.520	2.687	153	5	1.709	{ 1.753	471
4	2.507	2.655	340	5	1.709	{ 1.751	008
3	2.418	2.629	144	5	1.620	{ 1.710	1.10.0
3	2.333	2.520	400	5	1.514	{ 1.709	266
		2.507	260	4	1.514	{ 1.709	157
		2.418	420	1	1.620	{ 1.620	544
		{ 2.335	006	1	1.514	{ 1.515	295
		2.334	324	4	1.514	{ 1.514	604

Cu- K_{α} radiation, Guinier-Hagg camera. Intensities estimated visually.

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