Canadian Mineralogist
Vol. 19, pp. 311-314 (1981)

PEHRMANITE, A NEW BERYLLIUM MINERAL FROM ROSENDAL PEGMATITE, KEMIÖ ISLAND, SOUTHWESTERN FINLAND

E.A.J. BURKE

Institute of Earth Sciences, Free University, De Boelelaan 1085,
1081 HV Amsterdam, The Netherlands

W.J. LUSTENHOUWER

Netherlands Organization for the Advancement of Pure Research (Z.WO.),
De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands

ABSTRACT

Pehrmanite $(Be,Zn,Mg)Fe^{2+}Al_4O_8$ is a new mineral from the Rosendal pegmatite, Kemiö Island, southwestern Finland. It is rhombohedral, polytype $9R$, $R\bar{3}m$, with a 5.70, c 41.16 Å, and $Z = 9$, for which the calculated density is 4.07 g/cm³. The strongest lines of the X-ray powder-diffraction pattern are: 2.856 Å (I = 8)$(11\bar{2}0)$, 2.666(4)$(1.0.\bar{1}.13)$, 2.422(10)$(11\bar{2}9)$, 2.063(4)$(2.0.\bar{2}.11)$, 1.426(5)$(22\bar{4}0)$. It occurs as small, subhedral, hexagonal tablets with green color and vitreous lustre. The Mohs hardness is 8–8½ (calc.), $VHN_{100} = 1700$, and there is no cleavage. Optically, it is uniaxial (–), with mean index of refraction 1.79; parallel extinction, positive elongation. Reflectance (nm, %): 470, 8.34; 546, 8.11; 589, 8.01; 650, 7.86. The composition, as determined by electron microprobe (and qualitatively for Be by ion microprobe), is Al_2O_3 64.4, FeO 23.3, MnO 0.3, MgO 1.9, ZnO 5.2, BeO (by difference) 4.9, total 100.0 weight percent, which yields the empirical formula $(Be_{0.62}Zn_{0.20}Mg_{0.15})_{\Sigma=0.97}(Fe^{2+}_{1.03}Mn_{0.01})_{\Sigma=1.04}Al_{3.99}O_8$. This is the iron analogue of taaffeite and a new member of the högbomite group. The mineral is named for Gunnar Pehrman.

Keywords: pehrmanite, new mineral, beryllium, ion microprobe mass analyzer (IMMA), pegmatite, Rosendal, Kemiö, Finland.

SOMMAIRE

La pehrmanite, $(Be,Zn,Mg)Fe^{2+}Al_4O_8$, espèce minérale nouvelle, provient de la pegmatite Rosendal, île de Kemiö (Sud-Ouest de la Finlande). Elle est rhomboédrique, $R\bar{3}m$, forme polytypique $9R$, a 5.70, c 41.16 Å; pour $Z = 9$, la densité calculée est de 4.07. Les cinq raies les plus intenses du cliché de poudre [d_{hkl} en Å (I)(hkl)] sont: 2.856(8)$(11\bar{2}0)$, 2.666(4)$(1.0.\bar{1}.13)$, 2.422(10)$(11\bar{2}9)$, 2.063(4)$(2.0.\bar{2}.11)$, 1.426(5)$(22\bar{4}0)$. On trouve la pehrmanite en petits cristaux subidiomorphes, hexagonaux, tabulaires, verts, à éclat vitreux et sans clivage. La dureté Mohs est de 8 à 8½ (calc), $VHN_{100} = 1700$. Optiquement elle est uniaxe négative, d'indice de réfraction moyen 1.79, à extinction parallèle et allongement positif. Réflectance: 8.34% à 470 nm, 8.11% à 546 nm, 8.01% à 589 nm et 7.86% à 650 nm. D'après les données de la microsonde électronique (et une détermination qualitative du Be par microsonde ionique), elle contient: Al_2O_3 64.4, FeO 23.3, MnO 0.3, MgO 1.9, ZnO 5.2, BeO (par différence) 4.9, total 100.0% en poids, ce qui mène à la formule empirique $(Be_{0.62}Zn_{0.20}Mg_{0.15})_{\Sigma=0.97}(Fe^{2+}_{1.03}Mn_{0.01})_{\Sigma=1.04}Al_{3.99}O_8$. La pehrmanite, dédiée à *M*. Gunnar Pehrman, est un nouveau membre du groupe de la högbomite et l'analogue ferrifère de la taafféite.

(Traduit par la Rédaction)

Mots-clés: pehrmanite, espèce minérale nouvelle, beryllium, analyse de masse par microsonde ionique (IMMA), pegmatite, Rosendal, Kemiö, Finlande.

INTRODUCTION

The new mineral pehrmanite was found in the course of an investigation of a number of granitic pegmatites on the island of Kemiö, southwestern Finland. The mineral is named after Gunnar Pehrman (born 1895), Emeritus Professor of mineralogy and geology at the university "Åbo Akademi" in Turku (Finland), in recognition of his mineralogical description of the Kemiö pegmatites (Pehrman 1945). The mineral and the name have been approved by the IMA Commission on New Minerals and Mineral Names. Type specimen material is preserved in the Free University collection under numbers HL–6 and HL–12.

OCCURRENCE

The Rosendal pegmatite is located about 2 km north of the village of Rosendal. The pegmatite has been described by Eskola (1914), Pehrman (1945, as Rosendal No. 12) and Volborth (1952). An inventory of recorded minerals has been published by Laitakari (1967, pp. 218–221). The pegmatite and the regional geology have been described in some detail by Burke *et al.* (1977). The pegmatite was quarried in the first half of this century, mainly for potassium feldspar and quartz; Ta-bearing minerals and beryl were important by-products.

The pegmatite is a regular vertically dipping dyke in hornblende gabbro. It is exposed along its east–west strike for about 150 m; its width is 6–10 m, and the body extends vertically to a depth of at least 20 m. Pehrmanite occurs in the wall zone, which has a thickness of about 60 cm. This zone consists mainly of quartz, plagioclase (An 5–27), sillimanite, muscovite and spessartine–almandine garnet, with minor amounts of chlorite, biotite, epidote, allanite and calcite. The mineral assemblage in this zone corresponds to that in Al-rich zones, as defined by Heinrich & Buchi (1969); these commonly contain sillimanite, garnet, hercynite, chrysoberyl, tourmaline, apatite, corundum, staurolite (with up to 1.9 wt. % ZnO) and nigerite (Burke *et al.* 1977).

PHYSICAL AND OPTICAL PROPERTIES

Pehrmanite occurs as small, subhedral hexagonal tabular crystals up to 250 μm across and 40 μm thick, and as oriented overgrowths on nigerite. The crystals have a light green color and a vitreous lustre. No cleavage has been observed. Micro-indentation hardness measurements yielded a VHN_{100} of 1700; the indentations are slightly fractured to perfect. The mineral is very brittle and has a Mohs hardness (calculated from the micro-indentation hardness) of 8–8½. The density, calculated using the empirical formula and unit-cell dimensions, is 4.07 g/cm³. Under the microscope, in transmitted light, pehrmanite is uniaxial negative and weakly to distinctly dichroic, with ω pale greenish and ϵ pale greyish brown. The birefringence is distinctly higher than for nigerite. The sign of elongation is positive. In reflected light, pehrmanite is grey, with a slightly higher reflectance than for hercynite. Reflection pleochroism and internal reflections have not been observed; the anisotropy is very weak. The reflectance in air has been measured with a Leitz MPV microscope photometer using black glass as a standard: 470 nm, 8.34%; 546, 8.11; 589, 8.01; 650, 7.86. The mean index of refraction is 1.79 (calculated from reflectance data).

CHEMISTRY

Electron-microprobe analyses were performed with a Cambridge Instruments Geoscan and Microscan 9. Olivine (for Mg), rhodonite (for Mn), corundum (for Al) and Fe and Zn metals were used as standards. Apparent concentrations were ZAF-corrected with a modified Springer (1967) program and with the Microscan 9 on-line ZAF program. These analyses yielded totals of only about 95 weight %. Energy- and wavelength-dispersion scans indicated the absence of all other elements with atomic number greater than nine. A sample was prepared for experiments with the ARL ion-microprobe mass analyzer of the Metal Research Institute TNO at Apeldoorn, The Netherlands. Primary negatively charged NO_2^- ions (mass 46), accelerated to an energy of 20 kV with a beam current of 1 nA, bombarded the surface of the sample with a probe diameter of 5 μm. The secondary ions showed that the mineral contains Be; no water or hydroxyl could be detected. The combined results of the analyses of pehrmanite (BeO by difference) are presented in Table 1 and are

TABLE 1. RESULTS OF CHEMICAL ANALYSES OF PEHRMANITE AND TAAFFEITE

	1 PEHRMANITE	2 TAAFFEITE	3 TAAFFEITE	4 TAAFFEITE
SiO_2 (weight %)	-	-	0.30	-
TiO_2	-	-	0.02	-
Al_2O_3	64.40	72.11	71.44	70.0
Fe_2O_3	-	0.60	0.40	5.9
FeO	23.30	2.80	6.78	-
MnO	0.30	-	0.02	-
MgO	1.875	20.12	15.76	13.4
ZnO	5.225	-	-	-
BeO	4.9	4.32	5.50	11.0
P_2O_5	-	-	0.02	-
Total	100.00	99.95	100.24	100.3
Number of cations based on 8 oxygen atoms				
Si^{4+}	-	-	0.014	-
Ti^{4+}	-	-	0.001	-
Al^{3+}	3.997	3.979	3.967	3.74
Fe^{3+}	-	0.021	0.014	0.19
Fe^{2+}	1.025	0.110	0.267	-
Mn	0.013	-	0.001	-
Mg	0.145	1.404	1.106	0.91
Zn	0.202	-	-	-
Be	0.620	0.486	0.623	1.20
P^{5+}	-	-	0.001	-
R^{3+}	3.997	4.000	3.996	3.93
R^{2+}	2.005	2.000	1.998	2.11
ΣR	6.002	6.000	5.994	6.04
$100\ Mg/(Mg+Fe_{tot})$	12.39	91.47	79.74	82.73

1. Pehrmanite, Rosendal pegmatite, Finland; mean value of 2 electron-microprobe analyses, BeO by difference.
2. Taaffeite, Mount Painter, Australia; mean value of 4 electron-microprobe analyses, BeO and Fe_2O_3 calculated assuming perfect stoichiometry; Teale (1980).
3. Taaffeite, Musgrave Ranges, Australia; wet-chemical analysis; Hudson et al. (1967).
4. Taaffeite, cut gemstone, Sri Lanka (?); wet-chemical analysis; Anderson et al. (1951).

compared with analyses of taaffeite. Calculation of the number of cations on the basis of 8 oxygen atoms (Table 1) shows that all iron can be taken as divalent and that iron is the dominant cation instead of magnesium, as is the case in taaffeite. The analysis of pehrmanite leads to an empirical formula $(Be_{0.62}Zn_{0.20}Mg_{0.15})_{\Sigma=0.97}(Fe^{2+}_{1.03}Mn_{0.01})_{\Sigma=1.04}Al_{3.99}O_8$.

CRYSTALLOGRAPHY

X-ray-diffraction data for pehrmanite were obtained on powders drilled out under the microscope and taken into rubber solution. A Straumanis-type 114-mm-diameter Debye–Scherrer camera was used with Mn-filtered Fe $K\alpha$ radiation. The X-ray powder-diffraction pattern of pehrmanite (Table 2) is compared with that of taaffeite–9*R* (Hudson *et al.* 1967). Pehrmanite is rhombohedral, $R\bar{3}m$, with *a* 5.70, *c* 41.16 Å. It should be noted that the Be content of pehrmanite is in the same range as that for the taaffeites reported by Teale (1980) and by Hudson *et al.* (1967), but only about half that in the original taaffeite of Anderson *et al.* (1951). All minerals in the högbomite group have a layered structure; they form a series of polytypes designated *nH* or *nR* (McKie 1963). Pehrmanite and taaffeite of Hudson *et al.* (1967) are 9*R* polytypes in McKie's nomenclature or 18*R* polytypes in the nomenclature of Peacor (1967), whereas the taaffeite of Anderson *et al.* (1951) is either the 4*H* or 8*H* polytype. Grey & Gatehouse (1979) have demonstrated that in nigerite (belonging to the högbomite group), the polytype is dependent on the Sn content. One may speak of compositional polytypes: the stacking sequence adopted in the layered structure depends on the Sn content, or the mineral adopts the sequence that allows all the Sn atoms to fully occupy certain sites in the structure. It seems that a similar mechanism is working in the Be minerals taaffeite and pehrmanite. No information is available on the polytype of taaffeite described by Teale (1980); no chemical analyses were published of the 4*H* polytypes of taaffeite reported from China (Vlasov 1966) and Eastern Siberia (Kozhevnikov *et al.* 1977).

TABLE 2. X-RAY POWDER-DIFFRACTION DATA FOR PEHRMANITE

	PEHRMANITE-9R			TAAFFEITE-9R		
	Rosendal pegmatite Finland			Musgrave Ranges Australia Hudson et al. (1967)		
hkil	$d_{calc.}$	$d_{obs.}$	I/I_{10}	$d_{calc.}$	$d_{obs.}$	I/I_{100}
0003	13.7	13.7	1	13.698	13.7	25
$10\bar{1}1$				4.880	4.89	5
0009	4.57	4.56	2	4.566	4.57	40
$01\bar{1}5$	4.24	4.22	2	4.218	4.21	30
$10\bar{1}7$				3.769	3.77	3
$01\bar{1}8$	3.56	3.57	2	3.551	3.55	10
$1.0.\bar{1}.10$	3.16	3.15	3	3.153	3.15	20
$0.1.\bar{1}.11$				2.974	2.975	20
$11\bar{2}0$	2.852	2.856	8	2.838	2.836	30
$11\bar{2}3$				2.779	2.776	3
$1.0.\bar{1}.13$	2.666	2.666	4	2.659	2.658	55
$0.1.\bar{1}.14$	2.527	2.529	3	2.520	2.520	25
$20\bar{2}2$	2.452	2.446	2	2.440	2.438	15
$11\bar{2}9$	2.420	2.422	10	2.410	2.408	100
$02\bar{2}4$				2.390	2.390	5
$20\bar{2}5$	2.366	2.365	1	2.354	2.353	20
$1.0.\bar{1}.16$	2.282	2.279	2	2.276	2.271	35b
$0.2.\bar{2}.10$				2.109	2.108	15
$2.0.\bar{2}.11$	2.061	2.063	4	2.053	2.052	70
$0.2.\bar{2}.13$				1.940	1.939	5
$2.0.\bar{2}.14$	1.891	1.892	1	1.884	1.884	20
$12\bar{3}2$				1.850	1.855	1
$0.2.\bar{2}.16$				1.776	1.776	10
$12\bar{3}8$				1.747	1.747	8
$0.2.\bar{2}.17$				1.723	1.723	13
$03\bar{3}0$				1.638	1.638	5
$0.2.\bar{2}.19$				1.624	1.623	8
$2.1.\bar{3}.13$	1.608	1.609	2	1.601	1.601	25
$1.2.\bar{3}.14$	1.576	1.577	1	1.570	1.569	15
$03\bar{3}9$	1.549	1.548	2	1.542	1.542	20
$0.0.0.27$				1.522	1.523	3
$0.1.\bar{1}.26$				1.505	1.504	10
$0.2.\bar{2}.22$	1.491	1.492	3	1.487	1.487	40
$1.2.\bar{3}.17$				1.473	1.474	1
$2.0.\bar{2}.23$	1.449	1.451	1	1.445	1.445	20
$22\bar{4}0$	1.426	1.426	5	1.419	1.419	80

a_H = 5.70 Å
c_H = 41.16 Å
a_R = 14.11 Å
α_R = 23.32°

a_H = 5.675 Å
c_H = 41.096 Å
a_R = 14.085 Å
α_R = 23.24°

ORIGIN

Several possibilities have been outlined on the subject of the occurrence of Al-rich minerals in pegmatites, among them the desilication of the pegmatite system and the contamination with or the assimilation of Al-rich rocks during the emplacement. In the case of the Kemiö pegmatites, which occur in a gabbro, it is more likely that they were subjected to interaction with a late aluminous hydrothermal fluid. Ginzburg *et al.* (1974) pointed out that rare-metal pegmatites are formed at such depths that the separation of hydrothermal solutions from residual melts becomes impossible. These solutions would then interact with minerals formed earlier in the pegmatites, and the reactions would take place along the outer margins of the pegmatites.

Heinrich & Buchi (1969) reported that chrysoberyl and sillimanite in the Brokärr pegmatite (1 km away from the Rosendal pegmatite) are products of the reaction of aluminous solutions with beryl. In Rosendal, these solution also contained iron and zinc, because of the formation of hercynite and zincian staurolite in the wall zone. Nigerite forms overgrowths on hercynite and gradually replaces hercynite: all stages from initial to complete replacement can be observed. The chemical composition of nigerite in different intergrowths with hercynite in the same specimen is controlled by the chemical composition of the hercynite from which it was formed, as expressed in the Fe/(Fe+Zn) ratio in both minerals (Burke *et al.* 1977). Pehrmanite in turn occurs as overgrowths on nigerite and also gradually replaces nigerite. Late-stage Sn- and Be-bearing solutions reacting with hercynite seem to be the cause of the formation of nigerite and pehrmanite in the Rosendal pegmatite.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. P. Maaskant and Mr. M.H. Maarschalkerweerd for their work on the optical properties, and to Dr. L. Westra for his advice on the regional geology. We are grateful to Drs. D.J. Gras and A.P. von Rosenstiel for the IMMA analyses, which were made possible by a special grant from the Free University. Electron-microprobe facilities were provided by the Free University and the WACOM, a working group for analytical geochemistry subsidized by The Netherlands Organization for the Advancement of Pure Research (ZWO).

REFERENCES

ANDERSON, B.W., PAYNE, C.J. & CLARINGBULL, G.F. (1951): Taaffeite, a new beryllium mineral, found as a cut gemstone. *Mineral. Mag.* **29**, 765-772.

BURKE, E.A.J., LOF, P. & HAZEBROEK, H.P. (1977): Nigerite from the Rosendal pegmatite and aplites, Kemiö island, southwestern Finland. *Geol. Soc. Finland Bull.* **49**, 151-157.

ESKOLA, P. (1914): On the petrology of the Orijärvi region in southwestern Finland. *Comm. Géol. Finlande Bull.* **40**.

GINZBURG, A.I., KUPRIYANOVA, I.I. & FELDMAN, L.G. (1974): A model for the geological–geochemical system "granite intrusive – rare metal ore mineralization". *In* Metallization Associated with Acid Magmatism (M. Štemprok, ed.). *Geol. Surv. Czech.* **1**, 95-98.

GREY, I.E. & GATEHOUSE, B.M. (1979): The crystal structure of nigerite–24R. *Amer. Mineral.* **64**, 1255-1264.

HEINRICH, E.W. & BUCHI, S.H. (1969): Beryl–chrysoberyl–sillimanite paragenesis in pegmatites. *Ind. Mineral.* **10**, 1-7.

HUDSON, D.R., WILSON, A.F. & THREADGOLD, I.M. (1967): A new polytype of taaffeite – a rare beryllium mineral from the granulites of central Australia. *Mineral. Mag.* **36**, 305-310.

KOZHEVNIKOV, O.K., DASHKEVICH, L.M., ZAKHAROV, A.A., KASHAYEV, A.A., KUKHRINKOVA, N.V. & SINKEVICH, T.P. (1977): First taaffeite find in the USSR. *Dokl. Acad. Sci. USSR, Earth Sci. Sect.* **224**, 120-121.

LAITAKARI, A., ed. (1967): Suomen mineraalien hakemisto; index of Finnish minerals with bibliography. *Comm. Géol. Finlande Bull.* **230**.

McKIE, D. (1963): The högbomite polytypes. *Mineral. Mag.* **33**, 563-580.

PEACOR, D.R. (1967): New data on nigerite. *Amer. Mineral.* **52**, 864-866.

PEHRMAN, G. (1945): Die Granitpegmatite von Kimito (S.W.–Finnland) und Ihre Minerale. *Acta Acad. Aboensis, Math. Phys.* **XV.2**, 1-84.

SPRINGER, G. (1967): Die Berechnung von Korrekturen für die quantitative Elektronenstrahl-Mikroanalyse. *Fortschr. Mineral.* **45**, 103-124.

TEALE, G.S. (1980): The occurrence of högbomite and taaffeite in a spinel–phlogopite schist from the Mount Painter province of South Australia. *Mineral. Mag.* **43**, 575-577.

VLASOV, K.A., ed. (1966): *Geochemistry and Mineralogy of Rare Elements and Genetic Types of Their Deposits. 2. Mineralogy of Rare Elements.* Israel Progr. Sci. Transl., Jerusalem.

VOLBORTH, A. (1952): Kemiön pegmatiitit. *Int. Rep., Geol. Surv. Finland.*

Received November 1980, revised manuscript accepted January 1981.