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Johnsomervilleite, a new transition-metal phosphate mineral from the Loch Quoich area, Scotland

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SUMMARY. Johnsomervilleite, $Na_{10}Ca_6Mg_{18}(Fe, Mn)_{25}(PO_4)_{36}$ has Z = 3, *a* 15.00 Å, *c* 42.75 Å and cell volume 8330 $Å^3$ and is a new rhombohedral species occurring in two metamorphic segregation pods in Moine gneiss of kyanite-sillimanite grade. Associated minerals are apatite, jahnsite, graftonite, mineral A, phosphosiderite, rockbridgeite, mitridatite, and vivianite. It is dark brown, brittle, and glassy, H = 4½, D = 3.35 (calc. 3.41) with a perfect basal (?) cleavage. Eight electron probe analyses are given and *d* spacings for 50 lines. The mineral, which is a Mg-Fe analogue of fillowite, is named after the late Mr J. M. Somerville who presented a specimen of garnet-quartz rock, which contained the new species, to the Royal Scottish Museum.

JOHNSOMERVILLEITE has been found in two small metamorphic segregation pods, 15 and 30 cm long, occurring in striped kyanite-sillimanite-bearing Moine gneiss at the entrance of Glen Cosaidh (OS 1-inch sheet no. 35, 967013) at Loch Quoich. Within the segregation pods an interesting transition-metal phosphate assemblage occurs and some of the minerals identified have not been previously recorded from the UK. Throughout the Loch Quoich area are numerous muscovite-bearing simple pegmatites which occasionally carry green, anhedral apatite; however, johnsomervilleite and the other transition-metal phosphates do not occur in the pegmatites.

Assemblage and paragenesis. The segregation pods consist of quartz, muscovite, plagioclase, almandine-spessartine garnet, and anhedral green apatite together with rare, very small clusters of graftonite, jahnsite, phosphosiderite, rockbridgeite, mitridatite, vivianite, and the new mineral johnsomervilleite. An X-ray powder diffraction photograph of grey to flesh pink greasy grains, up to 4 mm, with a good cleavage identified the mineral as a member of the graftonite-beusite solid-solution series whereas an electron probe analysis characterized the mineral as graftonite. (Three spot analyses on the same grain showed the following compositional range FeO 34.2-34.4, MnO 8.2-9.7, MgO 4.6-5.9, CaO 9.5-9.7, P_2O_5 42.2-44.6 wt%). Within the graftonite are located numerous, minute, colourless inclusions, mainly rod-like to irregularly shaped with the rods elongated on cleavage planes of a phase (mineral A) which is not yet positively identified. Six individual inclusions were analysed, one analysis per inclusion, and the results, which suggest a constant composition, are as follows: FeO 41.1-42.0, MnO 3.1-3.7, MgO 11.9-13.1, CaO 0.1-0.2, P_2O_5 42.7-44.6 wt%. The analyses are remarkably close to the ideal formula of $Mg\,Fe_2^{2+}(PO_4)_2$ for which the author has been unable to find, up to date, a comparable composition in the mineralogical literature. Anhedral jahnsite, measuring up to 1 mm, is nut-brown with a greasy lustre which contrasts markedly with glassy brown johnsomervilleite. A single spot analysis of jahnsite yielded the following composition Fe_2O_3 30.4, MnO 4.2, CaO 4.3, MgO 6.5, P_2O_5 34.6 wt%. Pink to white phosphosiderite is the rarest of all the transition-metal phosphates in the assemblage and occurs as a minute single patch. Johnsomervilleite usually occurs in close association with graftonite or vivianite, and in the former case either occurs as included blebs or more usually rims the host. Isolated pools of johnsomervilleite remain in vivianite and where the two are in contact a porcellanous brownish-white rim separates the two phases. A single analysis of this rim gives the same composition as johnsomervilleite (see Table I). It is convenient to group graftonite, mineral A, johnsomervilleite, and apatite as the primary phosphates in the assemblage, for the remaining phosphates with their high water contents are clearly secondary in origin. Mitridatite occurs as yellowish khaki-green crusts or more compact masses in the phosphate clusters whereas dark olive-green rockbridgeite has only been observed in loose material.

Jahnsite was first reported by Moore (1974) from the Tip Top pegmatite, near Custer, South Dakota, and this type of occurrence is typical for many complex pegmatite phosphate minerals. The second type of occurrence of phosphates is in sedimentary environments. It would thus seem that the high-grade metamorphic environment of the Loch Quoich assemblage has had a totally different geological history from the above well-established igneous and sedimentary environments. The Moine metasediments have attained kyanite-sillimanite grade and rare kyanite is present in one of the segregation pods. It is not unreasonable to assume that fairly high temperatures and pressures were operative during the formation of the primary phosphate assemblage. The style and distribution of the unidentified inclusions in the graftonite also suggests that these may well be either a low-melting or exsolution product from the graftonite. The only other possible explanation is that the primary phosphates formed in a sedimentary environment similar to that of satterlyite (Mandarino *et al*., 1978) and have persisted 'metastably' over a large range of PT conditions during loading and unloading. Thin calc-silicate horizons are present in the area and it is not unreasonable to assume that phosphate-rich nodules could have been present also. These sedimentary nodules, with an appreciable manganese content, would be the starting material for the transitional metal phosphate minerals which have attained kyanite-sillimanite grade.

Physical properties. Johnsomervilleite occurs as anhedral grains or pools, the largest area measuring about 1.5 mm across and is very dark brown with a sub-conchoidal fracture and vitreous lustre. Only one cleavage, which is perfect, has been observed and from the preferred orientation effects noted on one faint line of the X-ray powder diffraction photographs the cleavage is most probably parallel to $\{001\}$. Using the 'sink-float' method with diluted Clerici solution three grains yielded a specific gravity result of 3.35. The hardness (Mohs) of johnsomervilleite, which is brittle, is $4\frac{1}{2}$ and it is soluble in 20% *v/v* HCl, H_2SO_4, and HNO_3 acids. No fluorescence was observed under long- and short-wave ultraviolet light. The streak is light brown.

Optical properties. In transmitted light the mineral is brown, non-pleochroic and optically positive. In spite of rhombohedral symmetry being suggested from the X-ray data johnsomervilleite is anomalously biaxial with an estimated $2V$ of 10°, a feature shown also by the related species fillowite. The mineral has a very low birefringence and due to an acute shortage of grains, combined with a high preferred orientation, the full optical characterization was not possible. Most grains produced optic axis figures and thus only $\alpha (\simeq \beta)$ could be measured and a value of 1.655 was obtained.

Chemistry. Eight analyses of johnsomervilleite, together with one of the brownish white porcellanous rim are tabulated in Table I. The analyses were undertaken by electron probe microanalysis using a jadeite standard for sodium, wollastonite for calcium, synthetic MgO, iron, and manganese metals, and apatite for phosphorus. The analyses were performed on separate areas of a small, polished mount which contained most of the transitional metal phosphates and also on separate grains which had all been previously X-rayed to check that they matched material from the block. Using the average composition (column A) of the

TABLE I. *Electron probe microanalyses of johnsomervilleite*

	1	2	3	4	5	6	7	8	A	B
FeO	25.6	26.9	26.7	26.8	25.9	26.0	25.5	26.1	26.2	26.1
MnO	5.1	5.1	4.9	5.2	5.5	5.3	5.5	5.2	5.2	5.3
MgO	13.2	12.7	13.3	12.7	12.8	12.7	13.2	12.7	12.9	13.4
CaO	6.0	6.4	6.2	6.1	6.3	6.3	6.3	6.2	6.2	6.4
Na_2O	5.3	5.4	4.8	4.3	4.7	4.8	3.7	4.4	4.7	4.7
P_2O_5	44.8	44.9	44.8	44.8	44.8	44.3	44.7	45.0	44.7	44.8
Total	100.0	101.4	100.7	99.9	100.0	99.4	98.9	99.6	99.9	100.7

A. Average of 1–8.

B. Brownish white, porcellanous rim between johnsomervilleite and vivianite.

TABLE II. *X-ray powder data for johnsomervilleite*

d_{obs}	I_{est}	*hkl*	d_{calc}
14.50	5	003	14.25
11.20	50	102	11.10
8.19	5	104	8.25
7.20	1	105 006	7.14 7.12
6.75	5	113	6.63
6.22	2	201	6.42
5.60	2	204	5.55
5.16	2	116	5.16
4.91	5	108	4.94
4.48	10	207	4.45
4.30	10	300	4.33
4.12	10	303	4.14
3.70	70	10.11 306	3.72 3.70
3.55	70	20.10 00.12	3.57 3.56
3.480	5	314	3.41
3.326	5	226	3.318
3.209	5	402 309	3.211 3.200
3.109	5	317	3.103
2.965	70	10.14	2.973
2.764	100	31.10	2.755
2.637	2	416	2.634
2.595	2	501 21.14	2.593 2.593
2.501	40	330	2.500
2.443	10	421	2.451
2.355	10	336	2.359
2.310	5	512	2.319
2.269	2	22.15 11.18	2.269 2.264
2.221	2	50.10 41.12	2.220 2.218
2.129	10	32.14 42.10 20.19	2.133 2.129 2.126
2.085	2	30.18 520	2.082 2.080
2.045	2	33.12	2.046
2.008	2	22.18 51.11	2.006 2.000
1.971	2	609 42.13	1.970 1.967
1.918	2*b*	32.17	1.922
1.852	20	531 51.14 60.12	1.854 1.854 1.850
1.824	10		
1.796	10		
1.713	5		
1.675	5*b*		
1.656	5		
1.645	5		
1.616	5		
1.586	5		
1.568	5		
1.549	5		
1.496	5		
1.490	5		
1.460	2		
1.442	8		
1.418	2*b*		

b = broad line.

first eight analyses, and on the basis of 144 oxygen atoms per unit cell, the following empirical formula is obtained

$$Na_{8.58}Ca_{6.29}Mg_{18.3}(Fe_{20.82}Mn_{4.17})_{\Sigma=24.99}P_{36.04}O_{144}$$

The above is very close to the ideal formula of $Na_{10}Ca_6Mg_{18}(FeMn)_{25}(PO_4)_{36}$ which shows affinities to the very rare mineral fillowite. In johnsomervilleite all the iron is reported as FeO whereas microchemical tests suggest a small amount of ferric iron is present. Very little data exists for fillowite and it would thus seem that johnsomervilleite corresponds to a Mg- and Fe-dominant analogue of that species.

X-ray data. Powder diffraction data are given in Table II for fifty lines and was obtained using Fe-$K\alpha$ radiation and an 114.6 mm diameter camera. The scarcity of material, combined with the perfect cleavage, made if difficult to add a suitable internal standard without producing spotty lines and the powder data have been produced without reference to an internal standard.

A preliminary examination of the data, combined with the optical biaxiality, suggested orthorhombic symmetry and indeed three possible orthorhombic cells could be deduced, together with an hexagonal solution. Electron diffraction studies, however, showed the material to be hexagonal with a 15.00 Å and c 42.75 Å, the cell volume is 8330 Å^3, $c/a = 2.85$. These parameters are very similar to those of fillowite and the d spacings are somewhat shifted to smaller values than those of fillowite. Nevertheless a very close structural resemblance is apparent between the two minerals though the structure of fillowite has not yet been determined. The number of formula units, Z is 3 and using the empirical formula the calculated density is 3.41. From the indexing rhombohedral symmetry is suspected due to the limitations imposed upon h, k, and l according to h-k+l = 3 (one line at d 8.19 Å does not fit this ruling).

The new species, and name, was approved by the International Mineralogical Association Commission on New Minerals and Mineral Names and type material is deposited in the Scottish Mineral Collection of the Royal Scottish Museum, Edinburgh.

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