

## Irish osumilite

G. A. CHINNER and P. D. DIXON

Department of Mineralogy and Petrology, Cambridge University

**SUMMARY.** Osumilite of composition closely approaching that of the K,Mg end-member occurs as a significant constituent of tridymite–enstatite–feldspar–cordierite–hematite–magnetite buchites at the contact of the Tertiary dolerite plug of Tieveragh, Co. Antrim; it is proposed that the mineral be known as osumilite-(K,Mg). Despite laboratory demonstration of the metastability of osumilite-(K,Mg) over a wide pressure–temperature range, the unaltered character and apparently constant composition of the Tieveragh osumilites raises the possibility of an osumilite stability field within the system  $K_2O$ – $MgO$ – $FeO$ – $Al_2O_3$ – $SiO_2$ .

SINCE its first recognition and description by Miyashiro (1956), the cordierite-like mineral osumilite has been recorded from a number of localities, the common mode of occurrence being as crystals in vugs or in the groundmass of rhyolitic or dacitic lavas. The volcanic osumilites show little variation in composition (Olsen and Bunch, 1970) from that of Miyashiro's original, viz.  $(Ca_{0.005}Na_{0.31}K_{0.78})(Mg_{0.92}Fe_{0.92}Mn_{0.16})(Si_{10.22}Al_{4.41}Fe_{0.37}^{3+})O_{30} \cdot H_2O$  (Brown and Gibbs, 1969). Bunch and Fuchs (1969), examining silicate inclusions within the Colomera meteorite, identified an osumilite rich in sodium and magnesium, which they called yagiite. We have recently recognized, in a fused sandstone at the contact of a Tertiary dolerite at Tieveragh, Co. Antrim, an osumilite mineral with a composition close to that of the K,Mg end-member of the series.

The olivine-dolerite plug of Tieveragh (Tomkeieff, 1940) intrudes ashy Old Red Sandstone, producing, in the vicinity of the contact, fused rocks (vitric buchites) and, at a distance, fine-grained hornfelses. The fused rocks show great variation in constitution, depending on their vicinity to refractory lumps of quartz, or to ferromagnesian matter, and to the degree of mingling between the melted ash and the melting magma. Volumes virtually vitric about those in which glass is subordinate to pyrogenetic minerals, or to residual aggregates. Osumilite occurs as a common if irregularly distributed constituent, usually as masses or trails of euhedral and anhedral crystals, set in colourless glass. Cordierite, Na-rich plagioclase, sanidine, and hypersthene are associated, as is tridymite in the form of marginal inversion needles bordering relict quartz grains. The osumilites are usually crowded with inclusions of magnetite, hematite, and glass. Basal sections are isotropic and uniaxial positive in contrast to the birefringent, complexly twinned (001) sections of accompanying cordierite, which however, also show hexagonal morphology. The complex twinning (rather than simple cyclic trilling) suggests these to be not the result of low-cordierite growth on inverted seeds (Zeck, 1972), but direct inversion products from high-cordierite. In our

experience, the osumilite crystals are generally larger than those of cordierite; typical dimensions are shown in fig. 1, with osumilite plates some  $100\ \mu\text{m}$  across and cordierites  $15\ \mu\text{m}$  average dimension. Even in those cases in which osumilite and cordierite are intimately associated, or actually are in contact, no sign can be seen of transformation of one to the other.

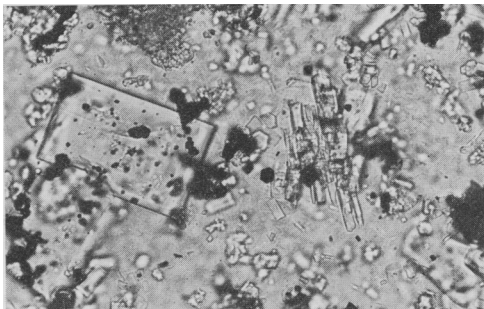


FIG. 1. Photomicrograph of osumilite-bearing Buchite, Tieveragh. The larger transparent crystal to the left of the photograph is a tabular (i.e.  $c$  axis parallel to the shorter dimension) plate of osumilite. The smaller crystals are cordierite, with the exception of the elongate clump to the right of centre, which is of albite-rich plagioclase. Opaques are magnetite and hematite.

Where osumilite crystals occupy the whole thickness of a thin-section, a faint pleochroism,  $\omega$  colourless,  $\epsilon$  pale blue, is just perceptible; refractive indices ( $\pm 0.002$ ) are  $\omega$  1.540,  $\epsilon$  1.546.

The most refined separate obtained had a density range  $2.58\text{--}2.68\ \text{gms/cm}^3$ , and was heavily contaminated with cordierite, glass, and oxide minerals. Osumilite peaks on a diffractometer trace of this separate could be indexed on a hexagonal cell of  $a = 10.08$ ,  $c = 14.35\ \text{\AA}$  (cf.  $a = 10.08$ ,  $c = 14.32$  for pure osumilite-(K,Mg) synthesised by Schreyer and Seifert, 1967).

*Chemistry.* Chemical analyses of osumilites were made with a Geoscan electron probe using the method of Sweatman and Long (1969). In these we encountered the usual analytical problems found in working with fused materials, resulting from the fine grain, the inclusion-rich character, and the occasionally indiscernible thin film of glass over many crystals. The sums of 10 analyses range from 99.4 to 102.5 w %. None the less each individual analysis, when scaled to 30 oxygens, gives a reasonable approximation to the K,Mg end-member of the osumilite series,  $\text{K}^{12}\text{Mg}_2^{61}\text{Al}_3^{41}(\text{Al}_2\text{Si}_{10})^{41}\text{O}_{30}$ .

In table I we have presented an analysis of osumilite with oxide summation closely approaching 100 % (column I) together with the compositional ranges found for each individual component (column II). Column III shows the cations of column I scaled to 30 oxygens. Analysing this in terms of Miyashiro's milarite-type structure (Brown and Gibbs, 1969), occupancy of the 12-coordinated site is close to unity. Divalent ions (Mg, Mn, Fe) show an excess over the two that should occupy the octahedral sites, but if this excess is transferred to the T<sub>2</sub> tetrahedral sites (the vertical tetrahedra, which link the horizontal double ring T<sub>1</sub> tetrahedra) the T<sub>2</sub> occupancy ( $\text{Al} + \text{Ti} + R^{2+}$ ) approaches 3. Miyashiro (1956) postulated, and Khan *et al.* (1971) have demonstrated, this rather unusual 4-coordination of divalent cations in the osumilite-merrillite series. The proportion of 4-coordinated  $R^{2+}$  ions could of course be reduced by assuming that all Fe is  $\text{Fe}^{3+}$ ; recalculation on this basis makes no significant difference to the cell contents. The amount of silicon in the double-ring T<sub>1</sub> tetrahedral sites, 10.6, is slightly in excess of that for ideal osumilite, to which the present mineral is clearly related by the substitution  $0.6 R^{2+} \rightarrow 0.6 \text{Si} \rightarrow 1.2 \text{Al}$ . Solid

solution towards roedderite/merrillite is lacking; this particular osumilite does not appear to contain essential water.

With the 12-coordinated site occupancy close to unity per 30 oxygens, the Tieveragh osumilite does not conform to the  $\sum (K+Na+Ca)$  vs  $K/(K+Na+Ca)$  plot of Olsen and Bunch (1970) and of Forbes *et al.* (1972). In this our osumilite is in the company of the pure K,Mg end-member synthesised by Schreyer and Seifert (1967); the Olsen-Bunch linear relationships may thus be fortuitous.

TABLE I. *Chemical analyses of osumilites*

	I	II	Cations to 30 oxygens for column I	
			III	
SiO <sub>2</sub>	64.35	(63.43-65.98)	Si	10.60
TiO <sub>2</sub>	0.06	(0.04-0.10)	Al	1.40
Al <sub>2</sub> O <sub>3</sub>	19.38	(19.32-20.06)	Al <sup>[iv]</sup>	2.36
FeO	2.16	(2.05-2.25)	Ti	0.01
MnO	0.24	(0.16-0.27)	Fe	0.30
MgO	9.46	(9.25-9.91)	Mn	0.03
CaO	0.13	(0.12-0.17)	Mg	2.32
Na <sub>2</sub> O	0.27	(0.65-0.27)	Ca	0.02
K <sub>2</sub> O	3.98	(3.98-4.08)	Na	0.09
			K	0.84
	100.03			

I. Analysis of osumilite from specimen 61037, Tieveragh.

II. Range of composition of 10 samples.

III. Scaling to 30 oxygens of analysis I.

The mineral yagiite was defined by Bunch and Fuchs (1969) as that part of the osumilite solid solution region with  $Na > K$ ,  $Mg > Fe$ , and  $Si/Al < 7$ ; the name osumilite being reserved for that part with  $K > Na$ ,  $Fe > Mg$ , and  $Si/Al < 7$ . On this basis the Tieveragh osumilite, with  $K > Na$ ,  $Mg > Fe$ ,  $Si/Al < 7$ , would qualify as a new mineral. It seems, however, an unnecessary complication to assign new names to only slightly disparate members of relatively obscure solid solution series not readily differentiated by ordinary petrographic methods. We therefore propose that the Tieveragh osumilite be known simply as osumilite-(K,Mg).

*The stability of osumilite.* With the exception of the meteoritic 'yagiite' all known occurrences of osumilite were formed under low-pressure, high-temperature conditions accompanying near-surface volcanic eruption. The Tieveragh conditions were also relatively oxidizing, close to those of the magnetite-hematite buffer. In their study of osumilite stability, Schreyer and Seifert pointed out that osumilite compositions can be represented by aggregates of common minerals normally considered to be stable under such conditions, and showed, by experiment, that at 1 kbar and 650-700°C, the  $KMg_2Al_3(Si_{10}Al_2)O_{30}$  end member, although nucleating readily, breaks down to other phases—at higher temperatures cordierite + K feldspar + quartz—on prolonged exposure to the conditions of its formation. Osumilite under these conditions is clearly

a metastable phase. The Tieveragh osumilite has a molecular normative constitution of cordierite, 11·3; tridymite, 52·1; potash feldspar, 13·8; plagioclase, 1·8; Ca-free pyroxene 20·7%. All five phases are present within small volumes of the osumilite-bearing buchites and if we assume that they were themselves stable, the only likely possibility for divariant stable existence of osumilite would be afforded by the diadochy of Fe and Mg. We may presume, under the probable low-pressure conditions of formation, the pure magnesian end-members cordierite and enstatite to have been stable with K feldspar, Na feldspar, and tridymite; hence the *stable* occurrence of osumilite would require that osumilite to be more iron rich than the accompanying ferro-magnesian minerals. The coexistence, in systems saturated with quartz and K feldspar, of iron-rich cordierites and orthopyroxenes would thus be precluded. The presence of liquid (glass) in the Tieveragh assemblages again reduces the degrees of freedom to one, but the not unreasonable postulation of water undersaturation of the melt allows us to avoid invocation of the unlikely special univariant condition.

One must none the less recognize the ease with which osumilite-type structures nucleate in the presence of liquid over a wide range of chemical compositions (Schreyer and Shairer, 1962), under experimental conditions (low pressure and brief time) not dissimilar to those which must have obtained in the volcanic environment. The presumption of metastability must remain strong, but in our exploratory probe examination we found no great variation in the composition of the Tieveragh osumilites, such that one might expect from rapid nucleation of an 'accommodating' structure in a variety of silicate liquid compositions. Furthermore, osumilites showing no sign of alteration occur in intimate association with cordierites whose hexagonal morphology and complex trilling about [001] attest to their origin by inversion (rather than by growth of low-cordierite on inverted seeds) from the high-temperature form. While the kinetics of the high-low cordierite inversion are not well delineated, it is analogous to many of the feldspar inversions and presumably requires a reasonable time for the attainment of a state of maximum order. Despite, therefore, extensive experience of osumilite minerals as metastable phases, there seem to be reasonable grounds for assuming initially that the Tieveragh osumilite was a stable phase in the environment of its formation. The vastness of the unexplored low-pressure volume in the system  $K_2O-Na_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O$  certainly gives ample possibility for the accommodation of a small osumilite stability range.

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