

A re-examination of tobermorite.

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TOBERMORITE, a hydrated silicate of calcium, was described by M. F. Heddle in 1880¹ from three Scottish localities: two near Tobermory in the island of Mull, and the third a quarry near the pier at Dunvegan in Skye. Further localities for the mineral are Sgùrr nam Boc, Loch Eynort in Skye,² and Ardtornish Bay in Morven (Morvern), Argyllshire.³

Because of marked similarity in chemical composition it has been suggested that tobermorite might be identical with gyrolite.⁴ In view of this and of the current interest in hydrated calcium silicates in cement chemistry the species has been re-examined. Three specimens, all originally in the Heddle collection of the Royal Scottish Museum, have been studied. They represent the two Mull localities (S.M. 435 A1 and A2) and Loch Eynort in Skye (B.M. 1937,1490) and agree closely with the Heddle descriptions. In two cases, north of Tobermory pier and Loch Eynort, the amygdale in which the mineral occurs is lined as noted by Heddle with a colourless zeolite now found from X-ray rotation photographs about the needle axis in each case to be thomsonite. The mass of pinkish tobermorite in all cases consists of a very compact, fine-grained aggregate of minute birefringent units (average size of crystals about 0.002 cm. diameter) with a mean refractive index of 1.558 ± 0.003 .

X-ray powder photographs from small fragments of each specimen gave a consistent pattern (table I) which could not be matched with that of any available data for natural material. They differed in particular from gyrolite. A comparison with data for crestmöreite showed some resemblance. This led to comparison with 'calcium silicate

¹ M. F. Heddle, *Min. Mag.*, 1880, vol. 4, p. 119.

² M. F. Heddle, *Trans. Geol. Soc. Glasgow*, 1893, vol. 9, p. 254.

³ J. Currie, *Min. Mag.*, 1905, vol. 14, p. 93.

⁴ E. S. Dana, *System of mineralogy*, 6th edit., 1892, p. 570; M. H. Hey, *Chemical index of minerals*, 1950, p. 91.

hydrate (I)¹. The latest data for the latter, kindly supplied by Dr. H. F. W. Taylor, are given in table I and show a close match.

TABLE I. X-ray powder data for tobermorite in Å.

Tobermorite						Calcium silicate hydrate (I) ¹ .	
Tobermory pier, Mull.		Bloody Bay, Mull.		Loch Eynort, Skye.		I.	d.
I.	d.	I.	d.	I.	d.	I.	d.
vvs	11.4	s	11.3	vvs	11.2	s	11
mw	5.47	m	5.44	m	5.46	ms	5.6
—	—	—	—	vw	4.23	—	—
mw	3.50	vw	3.52	mw	3.54	vw	3.55
vw	3.34	w	3.37	vw	3.31	vw	3.28
s	3.10	ms	3.08	vs	3.10	vvs	3.07
m	2.99	m	2.96	ms	2.98	s	2.97
ms	2.82	mb	2.82	ms	2.82	s	2.80
vw	2.74	vw	2.71	vw	2.72	—	—
vw	2.52	vw	2.50	wb	2.52	vw	2.52
vw	2.45	vw	2.43	vw	2.44	vw	2.48
wb	2.30	wb	2.29	mwb	2.29	ms	2.28
—	—	vw	2.18	—	—	—	—
w	2.15	vw	2.14	w	2.14	m	2.15
vw	2.09	vw	2.08	w	2.09	m	2.07
mw	2.01	mw	2.00	mw	2.00	m	2.00
—	—	vw	1.95	—	—	vw	1.93
m	1.847	mb	1.836	ms	1.844	vs	1.83
—	—	—	—	—	—	vw	1.81
—	—	vw	1.731	vw	1.768	vw	1.76
mw	1.673	mw	1.667	vw	1.731	vw	1.71
vw	1.622	—	—	mw	1.670	s	1.67
—	—	vw	1.565	w	1.624	vw	1.61
w	1.550	w	1.540	—	—	vw	1.59
vw	1.503	—	—	w	1.545	m	1.53
vw	1.442	—	—	vw	1.508	—	—
vw	1.402	—	—	vw	1.440	vw	1.43
vw	1.380	—	—	vw	1.401	w	1.405
vw	1.290	—	—	vw	1.380	w	1.395
vw	1.268	—	—	—	—	vw	1.370
vw	1.258	—	—	—	—	—	—
vw	1.220	—	—	—	—	vw	1.260
vw	1.185	—	—	—	—	vw	1.225
vw	1.170	—	—	—	—	vw	1.185
vw	1.117	—	—	—	—	vw	1.160
—	—	—	—	—	—	w	1.110
—	—	—	—	—	—	vw	1.075

Order of decreasing intensities: vvs, vs, s, ms, m, mw, w, vw, vw, b = broad. All photographs with Cu-K α radiation.

¹ Synthetic CaSiO₃.aq.-Ca₃Si₂O₇.aq. H. F. W. Taylor, Journ. Chem. Soc. London, 1950, p. 3682; L. Heller and H. F. W. Taylor, *ibid.*, 1951, p. 2397; 1952, p. 1018. [M.A. 11-314, 471.]

It was decided to make a new analysis of the mineral and the Loch Eynort specimen was chosen. The result is shown in table II (column 3) compared with the two original analyses of Heddle.

TABLE II. Chemical analyses of tobermorite.

	1.	2.	3.		1a.	2a.	3a.
SiO ₂ ...	46.508	46.62	46.17	Si ...	1.011	1.004	1.001
Al ₂ O ₃ ...	2.402	3.895	4.26	Al ...	0.061	0.098	0.109
Fe ₂ O ₃ ...	1.139	0.664	—	Fe''' ...	0.018	0.010	—
FeO ...	1.853	1.080	0.15	Fe'' ...	0.034	0.019	0.003
MgO ...	0.474	—	trace	Mg ...	0.016	—	—
CaO ...	33.404	33.978	35.15	Ca ...	0.779	0.784	0.817
Na ₂ O ...	0.356	0.891	0.56	Na ...	0.014	0.038	0.007
K ₂ O ...	1.445	0.572	0.25	K ...	0.041	0.015	0.023
H ₂ O ...	12.606	12.109	13.47	H ₂ O ...	0.914	0.869	0.974
				ΣR ...	0.963	0.964	0.959
	100.187	99.81	100.01				

1. North of the pier, Tobermory, Isle of Mull. M. F. Heddle (1880).

2. Bloody Bay, Tobermory, Isle of Mull. Sp. gr. 2.423. M. F. Heddle (1880).

3. Loch Eynort, Skye. Sp. gr. 2.458 ± 0.005 . Analyst, D. I. Bothwell, on 1 gram of material.

1a, 2a, 3a. Analyses 1, 2, 3 recalculated to basis of O = 3.

The material used for this analysis shows on microscopic examination slight differences in appearance and refractive index which are related to small variations in macroscopic opacity, but otherwise shows no signs of the presence of a second phase. X-ray photographs of the different parts are identical. It appears then that the alumina and alkalis reported in all the analyses may be regarded not as due to impurities but as belonging to the tobermorite. But in view of the identity of the powder photographs of tobermorite and 'calcium silicate hydrate (I)' it would appear that neither the alumina nor alkali is an essential constituent of tobermorite, which may be formulated $\text{CaSiO}_3 \cdot \text{H}_2\text{O}$ with some replacement of 3Ca by 2Al and of Ca by (Na,K)₂. The 'calcium silicate hydrate (I)' of H. F. W. Taylor may therefore be regarded as synthetic tobermorite.

Note added in proof. Additional specimens have been examined from the Currie collection in the Grant Institute of Geology, University of Edinburgh, by kind permission of Prof. A. H. Holmes. Those from Bloody Bay and Loch Eynort are closely comparable with the material described above. Five small specimens from Sundelaget, Strömö, Faeroes, doubtfully referred to tobermorite (J. Currie, Trans. Edinburgh Geol. Soc., 1907, vol. 9, p. 37), were found to be gismondine.