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KEYWORDS: kalsilite, $KAlSiO_4$, thermal expansion, infrared spectra.

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Reyerite, tobermorite, calcian analcime and bytownite from amygdales in a Skye basalt

A ROAD realignment scheme at the bridge over the Allt Coir' a' Ghobhainn (NG 407322) on the A863, near Drynoch, has cut into two distinctive lava types on the northern side of the road. To the west of the bridge greyish-green, highly amygdaloidal basaltic lavas contain abundant analcime whereas dark, compact lavas with relatively few amygdales form a 30 foot high cliff to the east. Derived from the latter are loose blocks which contain amygdales infilled predominantly by a pearly, gyrolite-like mineral together with tobermorite and a greyish, extremely hard, porcellaneous phase. The latter, which frequently lines larger amygdales or fills smaller amygdales, is an intergrowth of calcian analcime and bytownite. X-ray powder diffraction and infrared methods identify the gyrolite-like phase as the rare species reyerite cf. closely related truscottite.

A number of hydrated calcium silicates—gyrolite, okenite, reyerite, tacharanite, tobermorite, and xonotlite—have been previously reported by Walker (1971) in olivine basalts of Mull and Morven. Sweet (1961) discovered tacharanite, gyrolite and tobermorite in an olivine dolerite outcropping just north of Portree, Skye, and Cann (1965) noted reyerite filling slightly metamorphosed amygdales at 'S Airde Beinn, 5 km west of Tobermory, Mull.

Olivine basalt

Thin section examination of this dark, compact rock reveals a groundmass with microporphyritic olivine and pyroxene, the former exhibiting varying degrees of serpentinization. An electron probe analysis of groundmass olivine yielded the following composition: SiO_2 37.8, Al_2O_3 0.1, FeO 23.9, MnO 0.4, CaO 0.4, and MgO 37.7 wt. % indicating Fo 73.7 mol. %. A groundmass plagioclase analysis reduces to $Or_{1.1}Ab_{30.7}An_{68.2}$. From these compositions it is deduced that in a dry system, at one atmosphere, liquidus plagioclase forms at 1220 °C and olivine at 1150 °C (Russell, pers. comm.). An X-ray fluorescence analysis (EDS) of the basalt gave the following results: SiO_2 48.45, TiO_2 1.61, Al_2O_3 16.31, FeO 10.68 (total Fe as FeO), MnO 0.14, MgO 7.71, CaO 10.47, Na_2O 1.73, K_2O 0.37 and loss on ignition 2.86 wt. % [total 100.33].

Reyerite and tobermorite

Reyerite is micaceous and infills central zones within the amygdales. Tobermorite occurs as the 11 Å phase. It forms highly fibrous, radiating sheaves or rosettes, the latter up to 0.4 cm radius. Minor associated minerals in these reyerite-bearing amygdales are chlorite, calcite, pectolite and thomsonite.

Electron probe analyses of reyerite and tobermorite are presented in Table 1. It is noteworthy that when reyerite analyses are normalized to 24 (Si+Al) atoms per formula unit close to 10% of the tetrahedral sites are filled with Al. The same degree of site occupancy was reported by Clement and Ribbe (1973) in Virginian reyerite and, additionally, by Cann (1965). Analyses 1 and 4

TABLE 1. Electronprobe - microanalyses of reyerite and tobermorite from Skye

	1	2	3	4	5	6	7	8	9	10
SiO_2	47.63	52.93	52.91	51.08	49.80	50.34	49.90	48.08	46.88	46.33
Al_2O_3	4.01	4.13	4.29	3.82	4.14	4.10	4.01	3.96	4.04	4.20
FeO	nd	0.01	0.01	0.02	0.04	0.01	0.01	0.01	0.01	nd
MgO	0.08	0.18	0.07	0.49	0.01	0.01	nd	0.03	0.03	0.03
CaO	29.81	31.82	31.47	31.20	31.18	30.72	30.71	35.24	34.60	35.03
Na_2O	0.54	0.49	0.52	0.42	0.41	2.12	1.62	0.03	0.02	0.04
K_2O	9.07	8.35	6.59	5.22	8.84	5.16	4.28	0.03	0.03	0.02
	91.14	97.91	95.86	92.25	94.42	92.46	90.53	87.38	85.61	85.65
Atoms to 24 (Si + Al)										
Si	21.83	21.97	21.90	22.05	21.86	21.90	21.91	21.88	21.78	21.67
Al	2.17	2.03	2.10	1.95	2.14	2.10	2.09	2.12	2.22	2.33
Fe	-	0.06	-	0.01	0.02	-	0.03	-	-	-
Mg	0.06	0.12	0.04	0.32	0.01	-	-	0.02	0.02	0.02
Ca	14.66	14.15	13.96	14.43	14.66	14.32	14.45	17.18	17.20	17.57
Na	0.48	0.04	0.42	0.36	0.36	1.78	1.38	0.02	0.02	0.02
K	5.31	4.42	3.48	2.87	4.95	2.86	2.40	0.02	0.02	0.01

Analyses 1-7, reyerite, separate flakes, single spot analysis per flake.
Analyses 8-10, tobermorite, separate fibrous sheaves, single spot analyses per sheaf, n.d. = not detected
(Analyses performed on a Cambridge Instruments Microscan V, using the following standards - corundum, periclase, orthoclase, jadeite, wollastonite and iron).

(Table 1) which exhibit maximum and minimum alkali content respectively calculate to the empirical formulae below based on 58 oxygen atoms following the Merlino (1972, 1988) structural models [H_2O and OH idealised].

Anal. 1 $(K_{4.76}Na_{0.39})_{\Sigma 5.15}Ca_{13.17}$
$(Si_{19.65}Al_{1.95})_{\Sigma 21.60}O_{58}(OH)_8 . 6H_2O$

Anal. 4 $(K_{2.60}Na_{0.33})_{\Sigma 2.93}Ca_{13.19}$
$(Si_{20.16}Al_{1.76})_{\Sigma 21.92}O_{58}(OH)_8 . 6H_2O$

Loss on ignition values for hand-picked reyerite show considerable variation from 8.8 to 13.1 wt. %. Cann (1965) reported 10.4 wt. % H_2O (total) in Mull reyerite in contrast to Chalmers *et al.* (1964) who found 6.8 wt. % H_2O in type locality reyerite. Merlino (1972) ascertained that within the crystal structure of reyerite from the type locality two aluminium cations in the unit cell are ordered on a particular site; alkali ions and water molecules are located, with partial occupancies, in wide voids. Merlino's formula for reyerite is $(Na,K)_2Ca_{14}Si_{22}Al_2O_{58}(OH)_8 . 6H_2O$ which is sodium dominant compared with potassium dominant reyerites from localities detailed in this paper. The wide range in alkali and/or water, contents is at variance with Merlino's formula although plausible from the structure.

Calcian-analcime-bytownite intergrowth

Back scattered electron imaging of this intergrowth reveals ragged plagioclase laths approximately 3 × 10 μm randomly orientated and displaying 'resorbtion-solution features'. Analcime intergrown with plagioclase is calcian, with considerable Ca-Na variation, in contrast to the constant composition of bytownite (An_{77}). The latter is appreciably more basic than groundmass plagioclase (An_{68}) of the host rock. A second generation analcime, forming veinlets and patches, pervades the intergrowth. Further investigation of this intergrowth is under way and will form the subject of a forthcoming short paper.

Paragenesis

Walker (1971) discovered that the calcium silicate hydrates occurred outside the central aureole in Mull. For the Mull reyerite Cann (1965) invoked slight thermal metamorphism of gyrolite, whereas Clement and Ribbe (1973) ascribed reyerite genesis to low-grade regional metamorphism. Heddle (1893) reported tobermorite [confirmed by Claringbull and Hey (1952)] from Loch Eynort, Skye. Tobermorite is not exclusive to amygdales near Portree, as Sweet (1961) found augite crystals surrounded by tobermorite and mesolite.

The olivine basalt which hosts the reyerite, tobermorite, calcian-analcime-bytownite assemblage is quite fresh apart from serpentinization and no signs of thermal metamorphism have been detected. From the mineralogy it is implicit that a Ca- and Si-rich fluid may have been mobile within the deepest (hottest) zones of the lava pile during zeolitization. This would be in line with the views of Bell (1984) who found evidence for a hydrothermal system during the later subvolcanic period of igneous activity in Skye.

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Szaibelyite and fluoborite from the St Dizier Sn-borate skarn deposit, NW Tasmania, Australia

THE rare borate minerals szaibelyite ($MgBO_2OH$) and fluoborite ($Mg_3BO_3(F,OH)_3$) occur abundantly in a proximal magnesian ore skarn deposit in NW Tasmania, Australia. They have not been reported from Australia before, probably both because the set of geological circumstances necessary for their genesis are rarely met and their identification is difficult. In other areas outside Australia the minerals typically occur where dolomite marbles have been replaced by ore skarn assemblages, or where dolomite-silicate assemblages have been metamorphosed. They have been reported with such minerals as clinohumite (e.g. Minakawa, 1977); vonsenite, nordenskioldine harkerite, pyroxene, monticellite, etc. (Wang, 1983; Tilley, 1951) and commonly in proximal magnesian Sn skarns (e.g. Alexandrov, 1974, 1975; Wang, 1983; Zhao, 1984; Zhiji, 1984; Shufeng, 1984; Kwak, 1987).

In NW Tasmania the minerals occur within a relatively large ore skarn deposit, the St Dizier deposit, which represents a possible resource of 1.75 million tons of Sn ore averaging 0.75 wt. % SnO_2. Additional economic elements include minor amounts of Cu, Zn, W, and rare Be. The deposit occurs within an indented keel-shaped block of country rock marginal to the northern contact of the Devonian Heemskirk granite batholith, 20 km NW of the town of Zeehan. The keel consists mainly of Precambrian Oonah formation quartzite and dolomite, with minor limestone and graphitic shale. These dip almost vertically and strike normal to the granite's contact. The dolomite, shale, and (to a lesser extent) the limestone have been first altered by contact metamorphism yielding various types of rocks including predazzitic marble, andalusite–phengitic hornfels and calc–silicate-bearing marble. Later Fe–Si–Sn–B–Mn–Zn(–etc.)-bearing ore solutions, superimposed upon some of the above marbles, have yielded a complex ore skarn deposit consisting of at least 43 minerals with a large variation of skarn assemblages (Nicholson, 1985, for full descriptions of the deposit).

As in most proximal (near-to-contact) magnesian skarns, there is an early, largely anhydrous assemblage of forsterite–diopsidic pyroxene + magnetite ± cassiterite assemblage with superimposed (*a*) early F-bearing silicate phases (humite-group minerals) followed by (*b*) a magnetite–borate phase [magnetite + hulsite + szaibelyite + fluoborite ± Sn-bearing ludwigite ± warwickite(?)], (*c*) a hydrous 'retrograde' skarn phase (e.g. serpentine + talc + greenalite + tremolite), (*d*) a