A note on the occurrence of chevkinite, allanite, and zirkelite on St. Kilda, Scotland

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ABSTRACT. The occurrence of three accessory minerals with significant rare earth contents in Tertiary acid rocks of St. Kilda is described. Allanite, zirkelite, and chevkinite were identified by electron probe analysis (with energy-dispersive attachment) and the chevkinite confirmed by X-ray diffraction. Brief comparison is made with other Tertiary occurrences of *RE* minerals. This is the first recorded occurrence of chevkinite in Great Britain.

THREE minerals with significant *RE* concentrations have been found in the acid rocks of St. Kilda. These rocks are generally fine- to medium-grained granites with local coarser patches and drusy cavities (Cockburn, 1935; Harding, 1966a). Over 85% of each granite consists of quartz, alkali feldspar, and sodic plagioclase in variable proportions and in textures ranging from granitic to granophyric. Other minerals present are opaques, chlorite, amphibole, and accessory minerals in the Conachair Granite, or pyroxene, amphibole, biotite, chlorite, opaque oxides, and accessories in the Glen Bay Granite, Na h-Eagan granite, and Glen Bay Gabbro pegmatite. The three minerals containing rare earth elements (*REE*) account for considerably less than 1% of their respective host rocks but occur in quantities comparable with zircon, apatite and other accessory minerals.

The commonest of the three is chevkinite, $Fe_2(Ca,REE,Y)_8Ti_8Si_8O_{44}$, which occurs in the granites of Glen Bay, Na h-Eagan, and Conachair (fig. 1). Typical habits are elongate needles and stumpy prisms up to 200 μm long which in thin section are markedly pleochroic from red-brown to opaque. Chevkinite is generally found in quartz or alkali feldspar but some grains are enclosed by amphibole or magnetite. Chevkinite occurs in some but not all specimens of the granites collected and appears to have a patchy distribution, particularly in the Conachair Granite where it is commoner at the margins of the intrusion than in the interior.

The mineral was identified by electron microprobe using X-ray energy dispersive analysis and a Link Systems data handling programme, and results of the analyses are given in Table I, columns
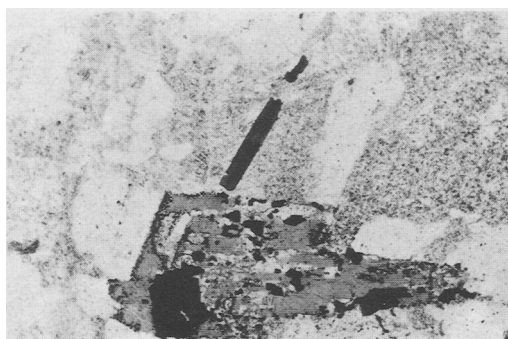

FIG. 1. Acicular grain of chevkinite (0.2 mm long) rests in turbid alkali feldspar next to a subhedral amphibole (ferro-hornblende) with inclusions of magnetite. (Glen Bay Granite, slide S 67633, plane polarized light.)

1, 2, and 3. By themselves the results are not sufficient to distinguish between chevkinite and perrierite which are polymorphs (Ito and Arem, 1971), so analysed grains were picked out of polished thin sections and put in a Gandolfi camera. The X-ray powder patterns obtained confirmed that chevkinite is present in the Conachair and Glen Bay granites (X-ray films X 8257 and X 8385, held in the Petrology Unit, IGS) and pending further work the mineral of similar composition in the granite of Na h-Eagan is provisionally considered to be the same.

Chevkinites from other parts of the world such as the USA (e.g. Jaffe *et al.*, 1956) and Greenland (e.g. Brooks and Rucklidge, 1976) have a range of compositions but the occurrences on St. Kilda consistently show major Si, Ti, Fe, Ca, La, Ce, and Nd, with variable amounts of Y, Nb, Th, P, Zr, Al, and Mg. An exceptional grain in the Conachair Granite has 6.3% NbO_2 and this is associated with relatively high Fe, Al, and Th and relatively low Si, Ca, Ti, and Y in the mineral. Considering the range of elements present the proportions are surprisingly consistent throughout the three granites. Each granite represents a different phase of intrusion, has a slightly different composition

TABLE 1. *Energy-dispersive electron probe analyses of chevkinite, allanite, and zirkelite from St. Kilda*

	Chevkinite				Allanite			Zirkelite
	1	2	3		4	5	6	7
SiO_2	20.13	20.27	19.31		31.30	34.61	31.07	0.55
TiO_2	18.24	18.22	18.18		1.27	—	2.24	28.44
Al_2O_3	0.59	0.48	0.30		13.29	18.78	10.96	0.31
FeO^*	11.19	10.51	10.93		16.64	12.72	17.68	8.26
MgO	0.10	—	—		0.35	—	0.29	0.20
CaO	2.72	2.93	2.69		11.21	15.24	9.33	3.59
La_2O_3	12.72	11.25	11.48		6.05	3.92	6.19	—
Ce_2O_3	21.75	20.83	21.02		11.24	7.32	11.95	2.26
Nd_2O_3	6.34	6.06	5.54		3.10	2.11	3.71	3.23
Sm_2O_3	—	—	—		0.43	—	0.34	0.88
Y_2O_3	0.76	—	0.91		0.23	1.86	0.97	9.59
Nb_2O_5	0.77	0.56	1.02		—	—	—	1.47
ZrO_2	—	—	—		—	—	—	32.04
ThO_2	0.40	0.62	0.40		0.20	—	0.43	—
P_2O_5	—	0.43	—		—	—	—	—
Total	95.71	92.16	91.78		95.31	96.56	95.16	90.82

Atomic proportions†

Si	8.45	8.63	8.40	Si	3.24	3.23	3.28	Si	0.04
Ti	5.76	5.83	5.94	Al	1.62	2.06	1.36	Ti	1.50
Fe	1.93	1.74	1.97	Fe	0.38	—	0.64	Al	0.03
Al	0.29	0.24	0.15	Ti	0.10	—	0.18	Nb	0.05
Nb	0.15	0.11	0.20	Fe	1.06	0.99	0.99	Ca	0.27
Fe	2.00	2.00	2.00	Mg	0.06	—	0.05	Mg	0.02
Ca	1.22	1.34	1.25	Ca	1.24	1.52	1.06	Fe	0.49
La	1.97	1.77	1.84	La	0.23	0.14	0.24	Y	0.36
Ce	3.34	3.25	3.35	Ce	0.43	0.25	0.46	Ce	0.06
Nd	0.95	0.92	0.86	Nd	0.11	0.07	0.14	Nd	0.08
Y	0.17	—	0.21	Others	0.01	0.09	0.08	Sm	0.02
Th	0.04	0.06	0.04					Zr	1.10

* Total iron listed as FeO.   † Atomic proportions are based on 44(O) for chevkinite, 13(O) for allanite, and 7(O) for zirkelite.

1. Glen Bay Granite S 67633; mean of 4 analyses.
2. Granite sheet on Na h-Eagan S 67651; mean of 3 analyses.
3. Conachair Granite S 67654; mean of 5 analyses and excluding one with unusually high Nb.
4. Granite vein, Abhainn Mhor S 64877; mean of 6 analyses of red-brown core of grain.
5. Analysis of pale green rim of grain detailed in 4.
6. Pegmatite, Glen Bay Gabbro, S 65207; mean of 3 analyses.
7. Pegmatite, Glen Bay Gabbro, S 65207; mean of 3 analyses.

Notes: S numbers refer to slides held in the Petrology Unit, IGS, Exhibition Road, London SW7 2DE. The energy-dispersive analytical technique is unsuitable for the determination of elements of high atomic number in amounts less than about 0.5 wt. %. The low totals reported could therefore be due to the presence of other *REE*, Ta, Hf, and other elements in amounts less than this detection limit.

and a different suite of accessory minerals. Sphene, apatite, and ferropigeonite occur in the Glen Bay Granite but not in the Conachair Granite, ferro-augite occurs in the granite sheets of Na h-Eagan, and thorite (ThO_2) has so far been found only in the Conachair Granite.

The second red-brown *RE* mineral, allanite, is similar to chevkinite and has the general formula $(Ca,REE)_2(Fe,Ti)Al_2Si_3O_{12}(OH)$. It has not been found in the three granites that contain chevkinite but occurs at a height of 750 ft in Abhainn Mhor in a granite vein that at first sight resembles the

Conachair Granite but in detail has a different mineralogy. Allanite also occurs in a gabbro pegmatite vein or elongate pod in the gabbro on the eastern rock shelves of Glen Bay. The analyses set out in Table I, columns 4, 5, and 6, show that in detail the allanite in the granite vein contains higher Al, Ca, and Y than that in the pegmatite; this difference is further emphasized in the zoning pattern of a crystal in the granite vein where the pale green rim has considerably more Ca and Al than the brown core. The rim is correspondingly poor in Ti and Fe contents and this may be the reason for the colour change. Late epidotes with REE contents of less than 0.5 % (see notes to Table I) exist as discrete crystals in this rock, but the RE are found in quantities up to 2.0 % in associated grains of sphene.

In the gabbro pegmatite the allanite is associated with the third rare-earth mineral, zirkelite. It again is red-brown in thin section and is essentially an oxide of Ti, Zr, Fe, Y and Ca. The mean of analyses of three grains is given in Table I, column 7, with atomic proportions based on 7 oxygen atoms. The order of the elements is such as to facilitate comparison with other zirkelites from the British Tertiary Province described by Williams (1978). He found tiny zirconolites in the Rhum ultrabasic layered rocks with a composition largely of Ca, Fe, Ti, and Zr oxides with only 2.06 % yttrium oxide, a composition significantly different from that of the St. Kilda grains. Despite its discovery last century the chemistry and structure of the mineral are still not well known and its range in composition has given rise to different names. However, following Fleischer (1975) and Embrey and Fuller (1980) it appears that only one mineral species is involved and the name zirkelite is preferred. Numerous attempts were made to obtain X-ray patterns from analysed zirkelites extracted from polished sections of the pegmatite. In each case the grain analysed was 30–50 μm long and adhering to quartz or feldspar. Distinct lines attributable to quartz or feldspar were obtained but none corresponding to the strong lines of zirkelite or of any other mineral were seen, and it is probable that the mineral is metamict.

On St. Kilda the zirkelite grains occur in an elongate pegmatite pod oriented at an oblique angle to the margin and the banding of the Glen Bay Gabbro (Harding, 1966b). The pegmatite consists of ferroaugite, amphibole (ferroedenite), chlorite (diabantite), magnetite, ilmenite (with Mn), quartz, oligoclase, orthoclase, biotite, epidote, allanite, sphene, apatite, zircon, and zirkelite. This mineralogy is consistent with the pegmatite having formed from the last residues of a basaltic (tholeiitic) liquid which had precipitated the major Fe-

Mg minerals and felspars to form the Glen Bay Gabbro and thereby concentrated elements such as Zr, Nb, Y, and the REs. Zirkelite forms anhedral or acicular grains up to 1.0 mm long and is similar in size to the other accessory minerals (fig. 2). It is red-brown to dark brown and faintly pleochroic, a feature that in the St. Kilda rocks is used to distinguish it from allanite (strongly pleochroic red-brown to almost colourless) and chevkinite (moderately pleochroic red-brown to black). Some grains are composed of elongate prisms in parallel growth and in thin section the different thicknesses give a striped effect parallel to the length.
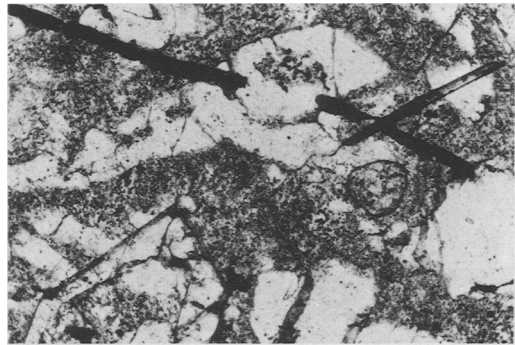

FIG. 2. Acicular zirkelite, 0.5 mm long and nearly opaque, lies in turbid alkali feldspar and quartz and is associated with translucent acicular zircon and skeletal apatite. (Pegmatite in Glen Bay Gabbro, slide S 69748A, plane polarized light.)

The RE content of the Glen Bay Granite was reported by Meighan (1979) and together with the obsidian from Sandy Braes (Co. Antrim) and the Mourne Granite G1 (Co. Down), it shows high concentrations compared with other acid rocks in the British Tertiary Province. The proportions of the REE throughout the province are broadly consistent, with Ce, La, and Nd the most abundant. In the Glen Bay Granite the ratios of Ce:La:Nd:Sm have been calculated relative to an arbitrary Nd abundance of 1 and they are compared with similar ratios calculated for the minerals in Table II.

The ratios in chevkinite from the Glen Bay Granite show a significant difference from those in the whole rock and this indicates that other minerals containing REE must be present. Zircon, apatite and sphene are possible hosts but analysis of these minerals by electron probe energy-dispersive techniques has not revealed any concentration above 0.5 wt. % level.

The ratios of La:Ce:Nd:Sm in allanite and chevkinite are very similar but in contrast to this

TABLE II. *REE ratios in St. Kilda minerals*

	1	2	3	4	5	6	7	8	9
La	1	2.07	1.92	2.14	2.03	1.93	1.72	0.0	1.5
Ce	1.71	3.52	3.53	3.90	3.74	3.57	3.30	0.72	1.0
Nd	1	1	1	1	1	1	1	1	1
Sm	0.22	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.10	0.26	0.3

1. Glen Bay Granite, whole rock, QUB73, Meighan, 1979.
2. Chevkinite, Glen Bay Granite, S 67633.
3. Chevkinite, Na h-Eagan, S 67651.
4. Chevkinite, Conachair Gr. S 67654.
5, 6. Allanite, granite vein, S 64877.
7. Allanite, pegmatite, S 65207.
8. Zirkelite, pegmatite, S 65207.
9. Sphene, granite vein, S 64877.

consistency, the *REE* content of the zirkelite in the gabbro pegmatite is significantly different. Nd replaces Ce as the most abundant *RE* and Sm is a significant constituent while La is entirely absent. Other minerals in the rock have very low contents of *REE* so it is likely that the proportions of zirkelite and allanite will largely determine the content and proportions of *REE* in the whole rock. And it follows that if the two minerals are not evenly distributed, the *REE* pattern will vary for different parts of the rock. La is the most abundant *REE* in sphene which occurs with allanite in the granite vein (Table II, column 9). Total *REE* content of the sphene is low and less than 2% of each oxide is present so in these terms it is of minor importance when compared with allanite (with for example 11% Ce_2O_3). Nevertheless the proportions of *REE* are different and again could affect whole-rock proportions if the distribution of sphene and allanite were not homogeneous. Similarly, variations could arise in a rock series if for instance allanite crystallized at a different time and was separated from sphene or zirkelite.

It is difficult to distinguish and identify the three *RE* minerals in thin section by optical means because they are all red-brown and generally very small, and it is likely that both chevkinite and zirkelite have been overlooked in other rocks of the Tertiary Igneous Province. Williams (1978) has expressed similar feelings on the problems of detection. Exley (1980) has described sphenes with 46% *RE* oxides from Skye granites and he comments that they are petrographically similar to allanite. Their composition is similar to the chevkinites reported here and further studies are desirable (Exley, pers. comm.) to investigate their X-ray crystallography. In the slightly different context of extrusive acid rocks Brooks *et al.* (1981) have analysed the distribution of *REE* between minerals and glass in the Sandy Braes obsidian. They found that allanites, zircons, and apatites contain different

proportions of *REE* and they emphasize the effects these differences may have on magma evolution. In the context of intrusive rocks the present work indicates considerable variation in the *REE* contents of various minerals and supports the conclusions of Brooks *et al.* (1981) concerning their effect on magma evolution.

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