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Picritic basalts from the Palaeocene lava field of west-central Skye, Scotland: evidence for parental magma compositions

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Abstract

Mineral chemistry and whole-rock compositional data are reported for two lavas of picritic basalt from the Palaeocene lava field of west-central Skye, Scotland. Whole-rock compositions for both flows plot on Thompson's (1982) 9 kbar cotectic for olivine + plagioclase + clinopyroxene + liquid. Both flows contain highly forsteritic olivine phenocrysts (*c.* Fo_{89}), which enclose early-precipitated crystals of chrome-spinel (Al_2O_3: *c.* 25 wt.%; Cr_2O_3: *c.* 36 wt.%; FeO + Fe_2O_3: *c.* 20 wt.%; MgO: *c.* 15 wt.%). The olivine compositions indicate equilibrium with picritic basalt magma compositions, as represented by the whole-rock compositions of both lavas. A high-pressure origin for the chrome-spinels is suspected on the basis of their textural association and aluminous composition. Compositional comparisons between the whole-rock and mineral chemistry characteristics of both flows and a picritic basalt chill facies of the temporally- and spatially-associated Rum Igneous Complex suggests that similar parental magmas were involved.

KEYWORDS: basalt, picrite, magma composition, Skye, Scotland.

Introduction

THE compositions of primary magmas involved in the formation of the Palaeocene lavas of the British Tertiary Volcanic Province (BTVP) have been the subject of intense investigation over the last thirty years (for example, Thompson, 1974, 1982; Thompson *et al.*, 1972, 1980; Thirlwall and Jones, 1983; Dickin *et al.*, 1984, 1987). The main focus of these investigations has involved the whole-rock geochemical characteristics of a significant number of lava flows, whereas little attention has been paid to their mineral chemistry. This study is concerned with the mineral chemistry and whole-rock compositions of two flows of picritic basalt within the lava field in west-central Skye and addresses the following questions:
(i) What can the textural features and compositions of olivine and spinel phenocrysts within the

two flows tell us about the composition of the parental magma(s) involved in the formation of the lava field;

(ii) What links exist between the magmas of the lava field and the intrusive centres of the BTVP; in particular, the layered, spinel-bearing peridotites [for example, on Skye (Bell and Claydon, 1992) and on Rum (Henderson, 1975; Henderson and Wood, 1981; Dunham and Wilkinson, 1985)].

Geochemical evolution of magmas of the British Tertiary Volcanic Province

Detailed whole-rock geochemical studies of a significant number of flows from the Skye Lava Supergroup by Thompson and his co-workers led them to present an evolutionary model whereby variable-percentage, mantle-derived, alkali olivine basalt magmas underwent polybaric fractional crystallization and were selectively contaminated by crustal lithologies during their ascent. Similar interpretations have been made on lavas from other remnants of the Palaeocene lava field of NW Scotland, for example, on Mull (Morrison *et al.*, 1985; Thompson *et al.*, 1986) and on the islands of Rum, Eigg, Canna and Muck (Ridley, 1971, 1973, 1977; Emeleus, 1985).

Thompson *et al.* (1972, 1980) recognised two main evolutionary magmatic trends during the formation of the Skye lava field: (i) alkali olivine basalt–hawaiite (Si- and K-poor, Fe- and Ti-rich)–mugearite–benmoreite; and, (ii) hypersthene-normative basalt–Si- and K-rich, Fe- and Ti-poor intermediates–trachyte. They concluded that the most primitive magmas involved in each of these lineages were generated at high pressures in a compositionally-heterogeneous (garnet lherzolite, ± phlogopite) mantle undergoing variable amounts of partial melting. Subsequently, magma evolution involved crystal–liquid fractio-

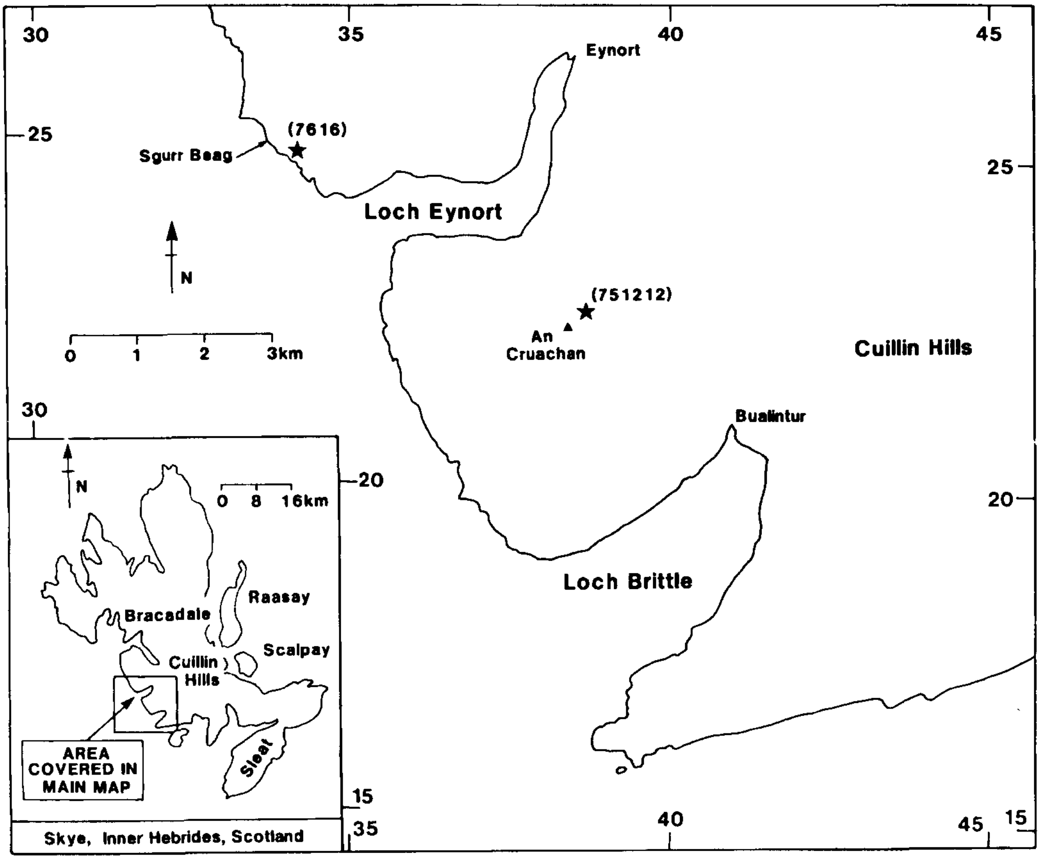

FIG. 1. Location map of the picritic basalt lavas of west-central Skye.

nation at pressures between that pertaining within the upper mantle source region and the Earth's surface, involving, at high pressures, an aluminous sub-calcic clinopyroxene (Thompson, 1974; Thompson *et al.*, 1980) and, at low pressures, various assemblages from the group: olivine, plagioclase, clinopyroxene, titaniferous magnetite, apatite, amphibole, Fe-Mg mica and alkali feldspar.

A compositionally-unique flow of olivine tholeiite basalt, with MORB-like characteristics, constitutes a third magma type within the lava field (Esson *et al.*, 1975: Williamson and Bell, 1994).

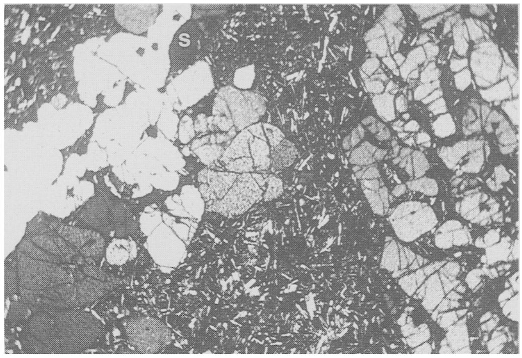

FIG. 2. Photomicrograph of the An Cruachan picritic basalt lava [751212] showing chrome-spinel (S) phenocrysts partially enclosed by large skeletal olivine phenocrysts (all other large crystals). Field of view *c.* 3 mm × 2 mm. Plane-polarized light.

Geologic setting and field characteristics

The flows which comprise the lava field of west-central Skye have been subdivided into a number of groups and formations based upon the presence of intercalated fluviatile, lacustrine and volcaniclastic deposits (Williamson and Bell, 1994). The two flows of picritic basalt are as follows: (i) 751212, within the Glen Brittle Formation of the Cruachan Lava Group, on the NE side of An Cruachan at [NG 384 225]; and, (ii) 7616, within the Tusdale Formation of the Glen Caladale Lava Group, in the cliff section east of Sgurr Beag at [NG 339 248] (Fig. 1). Both form relatively restricted flows, with distinctive reddish weathering characteristics, typical of olivine-rich lithologies within the BTVP. In hand-specimen they are dark, compact aphanites with obvious lime green to yellow phenocrysts of olivine. Spinel can be identified with a hand-lens. Plagioclase and clinopyroxene do not occur as phenocryst phases.

Mineral textures and mineral chemistry data

All mineral analyses were determined on a Cambridge Instruments Geoscan, in either the University of Durham or the University of Glasgow, using wavelength-dispersive techniques. Standard operating conditions were, typically 20 kV accelerating voltage, 30 nA beam current, and an integrated counting time of 40 s. The beam diameter was in the region of 2.5 μm, or better. Standards comprised well-characterised natural silicates and pure metals. ZAF and dead-time corrections were applied. Total iron was determined as FeO, and for spinel analyses was subsequently partitioned between ferrous (Fe^{2+}) and ferric (Fe^{3+}) by the method of Finger (1972).

Olivine occurs as the dominant phenocryst, constituting 8–17 vol.% of the mode (Fig. 2). These crystals occasionally have embayed subhedral or skeletal forms, are up to 5 mm in length, and have core compositions of *c.* Fo_{89} (Table 1). Glomeroporphyritic aggregates of olivine are common. More rarely, olivine phenocrysts up to 10 mm occur within 751212. Zoning, towards more iron-rich rims of composition *c.* Fo_{83} is present, especially within the smaller crystals. NiO contents are comparatively high and in the range 0.30–0.34 wt.%. Alteration of olivine to secondary products is not significant; where seen, the alteration consists of saponite ± yellow-green chlorite ± Fe-oxides.

The other phenocryst phase is a red to deep brown translucent spinel (*s.l.*), which is commonly enclosed within olivine phenocrysts. Typically the spinels (*s.l.*) range in size from 0.1 to 0.5 mm and vary from euhedral forms through to relatively corroded or embayed forms with faint, thin rims of opaque material. Representative analyses of the spinels (*s.l.*) are presented in Table 2.

Three associations of spinels (*s.l.*) occur in the Skye picritic basalt lavas: (i) as inclusions completely enclosed by olivines; (ii) partially enclosed by olivines, but protruding into the groundmass; and, (iii) within the groundmass. Crystal form tends towards euhedral in (i), whereas in (ii) and (iii) crystals exhibit corroded or embayed margins and tend towards anhedral shapes. In associations (ii) and (iii) there is the almost ubiquitous development of a very thin rim or mantle of titaniferous magnetite, suggesting some form of late-stage crystal–melt reaction. Such rims are absent within the spinels enclosed by olivines. The secondary phase 'ferritchromit' (Haggerty, 1976) was not detected.

TABLE 1. Representative analyses of olivines from Skye picritic basalt lavas (751212 and 7616)

Sample No.	751212	751212	751212	751212	751212	7616	7616	7616
Association	1	2	3	4	5	6	7	8
SiO_2	39.54	39.62	40.33	39.94	40.57	40.93	39.97	38.62
TiO_2	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Al_2O_3	0.07	0.07	0.13	0.08	0.10	0.08	0.01	0.02
Cr_2O_3	0.03	0.03	0.06	0.04	0.02	0.02	0.02	0.01
FeO	10.17	10.46	10.53	10.80	10.81	11.17	11.12	16.57
MgO	48.92	48.69	48.74	48.50	48.37	48.36	48.20	43.88
NiO	0.35	0.34	0.45	0.33	0.32	0.25	0.35	0.24
MnO	0.05	0.06	0.13	0.13	0.05	0.05	0.17	0.21
CaO	0.20	0.28	0.31	0.31	0.24	0.22	0.24	0.27
Total	99.35	99.55	100.68	100.13	100.48	101.08	100.10	99.84
Atomic %								
Fo	89.52	89.25	89.12	88.89	88.85	88.50	88.44	82.93
Fa	10.48	10.75	10.78	11.11	11.15	11.50	11.56	17.07
Formula (on the basis of 4 oxygens)								
Si	0.9816	0.9824	0.9884	0.9857	0.9954	0.9882	0.9873	0.9779
Ti	0.0006	0.0000	0.0000	0.0001	0.0000	0.0000	0.0006	0.0006
Al	0.0020	0.0020	0.0038	0.0022	0.0029	0.0022	0.0004	0.0007
Cr	0.0008	0.0006	0.0012	0.0008	0.0004	0.0004	0.0004	0.0001
Fe	0.2116	0.2168	0.2158	0.2229	0.2219	0.2319	0.2318	0.3517
Mg	1.8055	1.7991	1.7800	1.7838	1.7687	1.7679	1.7744	1.6549
Ni	0.0071	0.0068	0.0089	0.0065	0.0062	0.0041	0.0075	0.0050
Mn	0.0011	0.0013	0.0026	0.0027	0.0010	0.0010	0.0036	0.0045
Ca	0.0071	0.0074	0.0084	0.0081	0.0064	0.0060	0.0066	0.0104
Total	3.0174	3.0164	3.0091	3.0128	3.0029	3.0017	3.0126	3.0058

Association: 1–3: core to rim traverse in phenocryst; 4–5: core and rim of phenocryst; 6: core of phenocryst; 7–8: core and rim of phenocryst.

Compositional variation within and between the spinels is very limited and is illustrated in the plots of Fig. 3, together with compositional trends established for spinels from the intrusive complex on Rum (Henderson, 1975), *c.* 20 km south of Skye. The significance of these additional data will be discussed later. The Rum Intrusive Complex is of similar age to the lava field of west-central Skye, but slightly older (Williamson, 1979; Williamson and Bell, 1994).

All of the spinels analysed (other than the titaniferous magnetite rims) plot within the interior of a multicomponent spinel (or modified Johnson) prism (Stevens, 1944; Haggerty, 1976) and may be precisely referred to as chrome-spinels (*s.s.*). The euhedral spinels mantled by olivines are the most depleted in Fe^{3+} and Cr^{3+}, and have relatively high concentrations of TiO_2 (0.93 wt.%). Cr_2O_3, and Al_2O_3 contents of *c.* 35 wt.% and *c.* 25 wt.% are typical. Based upon their included association and lack of compositional zonation, it may reasonably be concluded that these spinels are closest to any original, magmatic composition and have not been subjected to significant mineral–melt or subsolidus reaction. No localised compositional modification of the mantling olivines has been identified and therefore no cation exchange involving the spinel and olivine is suspected.

Analyses of spinels which are partially enclosed by olivines, but which have been in contact with a groundmass (liquid) phase, have slightly higher inferred Fe_2O_3 contents (and are similar to spinels within the groundmass, see Table 2). In all other compositional respects, these spinels are identical to the spinels enclosed within olivines (see above). Such spinels may have become exposed to the groundmass liquid due to mechanical fragmentation of the olivines during eruption.

Spinels within the groundmass of the lavas show a minor amount of compositional zoning, with cores richer in Cr_2O_3 and MgO, and poorer in Al_2O_3 and TiO_2 (Table 2). However, this zonation is not strongly developed, especially

TABLE 2. Representative analyses of spinels from Skye picritic basalt lavas (751212 and 7616)

Sample No.	751212	751212	751212	7616	7616	7616	7616
Association	1	2	3	4	5	6	7
SiO_2	1.87	0.33	0.27	0.37	0.40	0.43	1.36
TiO_2	0.93	0.93	0.82	0.77	0.82	0.89	1.01
Al_2O_3	25.81	26.14	23.84	22.84	21.28	22.44	23.62
Cr_2O_3	35.86	35.15	38.78	39.12	40.51	38.22	34.82
Fe_2O_3	4.06	8.14	8.02	8.07	8.16	9.11	8.44
FeO	15.71	11.93	11.13	12.23	12.81	11.96	14.60
MgO	15.02	16.01	16.04	15.41	14.96	15.59	14.43
NiO	0.33	0.30	0.20	0.40	0.39	0.52	0.46
MnO	0.27	0.33	0.39	0.35	0.37	0.33	0.39
Total	98.86	99.26	99.49	99.56	99.70	99.49	99.13
Formula (on the basis of 32 oxygens)							
Si	0.447	0.080	0.065	0.089	0.097	0.105	0.329
Ti	0.167	0.166	0.148	0.140	0.151	0.163	0.184
Al	7.269	7.381	6.734	6.543	6.148	6.437	6.747
Cr	6.771	6.655	7.341	7.514	2.846	7.349	6.669
Fe^{3+}	0.729	1.468	1.446	1.476	1.504	1.668	1.539
Fe^{2+}	3.138	2.388	2.229	2.486	2.623	2.433	2.957
Mg	5.345	5.713	5.726	5.579	5.463	5.211	5.211
Ni	0.063	0.056	0.039	0.078	0.077	0.089	0.089
Mn	0.054	0.067	0.080	0.071	0.076	0.068	0.050
Total	23.983	23.974	23.808	23.976	23.985	23.523	23.775

Association:1: within olivine phenocryst; 2: in embayment near olivine; 3: in groundmass; 4–7: core (4) to rim (7) traverse in groundmass crystal.

when compared to spinels from other volcanic suites (for example Thompson, 1973; Ridley, 1977; Scowen *et al.*, 1991). Relative to the spinels enclosed within olivines, the groundmass spinels are richer in Cr_2O_3 and poorer in Al_2O_3.

The groundmass of the picritic basalts consists of small (< 0.25 mm), rounded olivines (*c.* Fo_{60}) in a granular arrangement with a weakly pleochroic titaniferous augite (1.5 mm) of composition *c.* $Wo_{44}En_{36}Fs_{20}$, thin plagioclase laths (c. An_{70}), and interstitial Fe-Ti oxides. Secondary minerals include: biotite chlorite and amphibole. Rare, interstitial analcite, most likely of secondary origin, is also present.

Whole-rock compositions

Major-element whole-rock analyses of the two picritic basalt lavas are presented in Table 3, together with analyses of comparable lavas from the Svartenhuk Peninsula, west Greenland (Clarke, 1970; see also Holm *et al.*, 1993), the Deccan Traps of India (Krishnamurthy and Cox, 1977), and proposed ultrabasic magma compositions from the BTVP. The Skye lavas were analysed for major-elements by XRFS using glass discs in the Department of Geology & Applied Geology, University of Glasgow. In terms of normative components, both lavas plot on the undersaturated portion of the 9 kbar cotectic estimated by Thompson (1982) from experimental data for the system di–hy–ol–ne–Q.

Although the modal abundance of olivine within the Skye picritic basalt lavas may suggest olivine accumulation, certain compositional characteristics indicate that they are not of predominantly cumulus origin. First, olivine of composition Fo_{89} would be in equilibrium with a magma with a molecular ratio of MgO/FeO of *c.* 2.6–2.8 (Roeder and Emslie, 1970). The value of this ratio for the two Skye lavas is in the range 2–3, but is, however, dependent upon the assumed value of FeO/Fe_2O_3 in the magma. Second, the experimental data of Roeder and Emslie (1970) indicate that olivine precipitated from a basaltic magma will be relatively enriched in both magnesium and iron. Consequently, whole-rock compositions of olivine-rich cumulates differ from picritic lavas (i.e. magmas) in that the former show an absolute iron enrichment (i.e. Fe_2O_3*, = FeO + Fe_2O_3) relative to the parent magma. The Skye picritic basalt lavas have values of Fe_2O_3* which

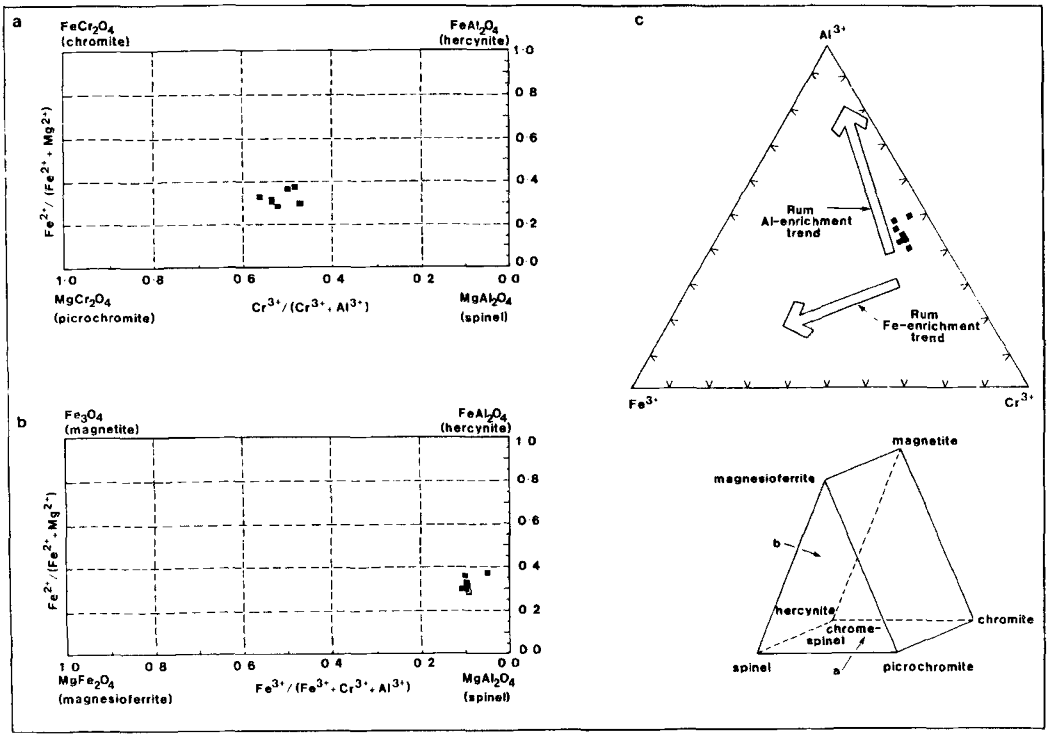

FIG. 3. Plots of: (*a*) $Fe^{2+}/(Fe^{2+} + Mg^{2+})$ *vs.* $Cr^{3+}/(Cr^{3+} + Al^{3+})$; (*b*) $Fe^{2+}/(Fe^{2+} + Mg^{2+})$ *vs.* $Fe^{3+}/(Fe^{3+} + Cr^{3+} + Al^{3+})$; and (*c*) Al^{3+}–Fe^{3+}–Cr^{3+}; for chrome-spinels from Skye picritic basalt lavas (solid squares), plus Rum Al- and Fe-enrichment trends from Henderson (1975). See main text and Table 2 for details.

are within the range of typical aphyric magnesian (8–10 wt.% MgO) basalts which are common within the Skye Lava Supergroup (Thompson *et al.*, 1972), and do not show any significant Fe-enrichment of the type identified in olivine-rich accumulative rocks where plagioclase fractionation has most likely occurred (for example, McBirney, 1989). Therefore, on variation diagrams involving $Fe_2O_3^*$ and some form of differentiation index (for example, Fe# (= $Fe_2O_3^*/(MgO + Fe_2O_3^*)$), see Thompson *et al.*, 1972), there is no significant change in $Fe_2O_3^*$ with fractionation in the picritic basalt to basalt compositional range.

Relative to other identified or proposed picritic (or peridotitic) magmas recognised within the BTVP (for example, 6, 7, and 8 in Table 3; see also Gibb, 1976, and Claydon and Bell, 1992), the picritic basalt lavas of Skye are very similar, but typically less aluminous. However, an almost identical major-element composition has been determined by Greenwood *et al.* (1990) for a chill facies from the SE portion of the Eastern Layered Series of the Rum Igneous Complex (5 in Table 3). This picrite contains *c.* 19 vol.% of olivine phenocrysts ($Fo_{72.1-87.3}$) with skeletal-hopper forms, which typically enclose, or partially enclose, microphenocrysts of chrome-spinel (of unspecified composition). In the groundmass are variolitic intergrowths of plagioclase ($An_{53.4-67.3}$) and clinopyroxene ($Wo_{47.5-42.0}En_{41.0-43.0}Fs_{11.5-15.0}$), which are within the compositional range of these two minerals in the Skye picritic basalt lavas.

Based upon the bulk-rock composition of the Rum picrite chill, Greenwood *et al.* (1990) calculated an equilibrium olivine composition of $Fo_{91.1}$ using the data of Roeder and Emslie (1970) and an assumed value of K_D = 0.30 (= $[Fe/Mg]^{olivine}/[Fe/Mg]^{liquid}$). Because of the discrepancy in olivine composition ($Fo_{72.1-87.3}$ measured, relative to $Fo_{91.1}$ calculated), Greenwood *et al.* (1990) calculated the composition of the liquid fraction in equilibrium with olivines of composition $Fo_{87.3}$. This was achieved by removal of 15 wt.% of olivine, an amount close to the measured 19 vol.% of olivine phenocrysts. The calculated residual liquid is an olivine tholeiite comparable to other postulated parental magmas involved in the formation of picritic dykes and layered peridotites and troctolites of the Rum and Skye intrusive complexes (Table 3; Gibb, 1976; Greenwood *et al.*, 1990; Claydon and Bell, 1992).

Interpretation and discussion

The olivine phenocrysts within the picritic basalt lavas (Table 1) are of almost constant composition (*c.* Fo_{89} and are within the compositional range of olivines which are thought to be typical of mantle peridotites (for example, Dick and Bullen, 1984). Melts in equilibrium with olivines of composition

TABLE 3. Whole-rock analyses of Skye picritic basalt lavas, together with other picritic basalt lavas and proposed ultrabasic magma compositions in the British Tertiary Volcanic Province

	1	2	3	4	5	6	7	8
SiO_2	44.30	44.51	44.40	46.44	46.05	46.24	46.54	46.74
TiO_2	1.10	1.18	1.18	1.99	0.76	0.96	1.17	0.73
Al_2O_3	10.93	12.30	10.20	9.28	13.39	15.84	14.77	16.04
Fe_2O_3	1.25	1.25	3.80	4.80	11.03	1.62	3.75	3.41
FeO	9.81	10.11	7.50	6.37	n.d	8.95	6.85	8.53
MnO	0.17	0.18	0.17	0.17	0.18	0.23	0.19	0.29
MgO	18.66	17.17	18.60	15.23	15.38	9.83	9.86	12.23
CaO	9.87	9.37	9.70	11.11	9.11	11.74	12.06	10.38
Na_2O	1.71	1.98	1.37	1.75	1.64	1.64	1.53	1.47
K_2O	0.14	0.19	0.13	0.67	0.44	0.07	0.14	0.15
P_2O_5	0.19	0.21	0.14	0.29	0.11	0.03	0.07	0.03
H_2O^+	1.31	1.22	2.33	2.34	1.60	2.62	2.83	-
Total	99.44	99.67	99.52	100.44	99.69	99.77	99.76	100.00
ClPW (Wt.) Norms								
Ap	0.4429	0.4895	0.3264	0.6763	0.2564	0.7000	0.1633	0.7000
Il	2.09	2.25	2.25	3.79	1.45	1.83	2.23	1.39
Mt	1.82	1.82	5.52	6.98	1.82	2.35	5.45	4.96
Or	0.8268	1.1200	0.7679	3.96	2.60	0.4135	0.8273	0.8862
Ab	11.36	13.75	11.59	14.81	13.87	13.88	12.95	12.44
An	21.73	24.10	21.30	15.49	27.87	35.66	33.03	36.73
Di	20.79	16.84	20.52	29.71	13.36	18.18	21.08	11.72
Hy	-	-	8.42	8.04	8.25	11.98	18.27	18.41
Ol	37.39	36.46	26.50	14.65	28.61	12.79	2.93	13.40
Ne	1.68	1.62	-	-	-	-	-	-

1. 751212, north-east side of An Cruachan, west-central Skye [NG 384 225].
2. 7616, cliff section east of Sgurr Beag, west-central Skye [NG 339 248].
3. Average of seven olivine basalt lavas, Svartenhuk Peninsula, west Greenland (Clarke, 1970, Table 1, analysis 4).
4. Picrite basalt, western Deccan Traps, India (Krishnamurthy and Cox, 1977, Table 1, Specimen number 252, flow number D-11).
5. Picrite chill, north face of Beinn nan Stac, SE Rum (Greenwood *et al.*,, 1990, Table 1, analysis 1).
6. 45cm thick aphyric dyke cutting picrite dyke, Coire a' Ghreadaidh, Cuillin Hills (Drever and Johnston, 1966, Table 1, analysis 6).
7. Chilled margin of dyke 29, west spur of Sgurr Dearg, Cuillin Hills (quoted in Gibb, 1976, Table 1, analysis A, from Gibb, 1968).
8. Calculated liquid composition of dyke E_2, free from megacrysts, of an anorthite-bearing gabbroic anorthosite dyke, between River Ose and Loch Beag, Bracadale, NW Skye (Donaldson, 1977, Table 4, analysis 44L).

Fo_{89} will contain *c.* 15 wt.% MgO, similar to the whole-rock compositions reported here for both lavas (Table 3) and picrites from other continental flood basalt provinces (for example, 3 and 4 in Table 3).

The euhedral nature of the chrome-spinels within the Skye picritic basalt lavas, together with their lack of compositional zoning, may be used as evidence of their primary nature. The early paragenetic association of these chrome-spinels make them especially significant in terms of elucidating likely fractional crystallization mineral assemblages for the suite of lava compositions on Skye (Thompson *et al.*, 1972, 1980; Thompson, 1982).

Thompson (1974) reported high-pressure phase equilibria data for a number of lavas from Skye, including one which was relatively magnesian (sample 66018, with MgO = 11.08 wt.%). Of importance, olivines precipitated during high-pressure experiments (14 kbar) were almost identical in composition to those of phenocryst cores from 66018. Thompson (1974) argued that this pointed towards the whole-rock composition of 66018 being that of a liquid, and not a liquid plus accumulated olivine crystals. Furthermore, Thompson (1974) recorded brown aluminous spinels within early-precipitated olivines in 66018, with: Al_2O_3 26 wt.%; Cr_2O_3 24 wt.%; and MgO: 8 wt.%. Ridley (1977) reported compositional data from zoned spinel crystals from a Palaeocene lava from Muck, Inner Hebrides, with core compositions: Al_2O_3 *c.* 33 wt.%; Cr_2O_3 *c.* 21 wt.%; and MgO *c.* 18 wt.%, zoned to rims depleted in Al_2O_3, MgO and Fe_2O_3 and enriched in FeO. Ridley (1977) interpreted this compositional variation in terms of crystal–melt reactions involving Mg–Fe, Cr–Al, Fe^{3+}–M^{3+} and Fe^{2+}–Ti–M^{3+}.

Simple relationships linking spinel composition and pressure during crystallization have not, as yet, been established (for example, see Roeder and Reynolds, 1991). However, it is noteworthy that the spinel data reported by Thompson (1974) for high-pressure equilibria match with the Al_2O_3 contents of the spinels reported here. Roeder and Reynolds (1991) argued that the suppression of plagioclase as a liquidus phase at high pressures would lead to increases in the alumina content of both the melt and coexisting spinels. Thompson's experimental data on 66018 suggests that at high pressures this is the case and thus explains the aluminous nature of the spinels.

The compositional similarity between the Skye picritic basalt lavas and a picrite chill from the margin of the Rum Intrusive Complex has already been noted (see Whole-rock compositions). However, the chrome-spinels within the peridotite cumulates of the intrusive complexes of Rum and Skye show reaction relationships, indicative of spinel + melt reactions, with consequent compositional variations (Henderson and Suddaby, 1971; Henderson, 1975; Henderson and Wood, 1981; Dunham and Wilkinson, 1985; Bell and Claydon, 1992). Henderson (1975) recognised Al- and Fe-enrichment trends from the original chromian chrome-spinels on Rum. The Al-enrichment trend was attributed to reaction between the chrome-spinel and olivine + a melt rich in plagioclase components, whereas the Fe-enrichment trend was attributed to reaction with intercumulus melt. Both of these trends are shown on Fig. 3. Significantly, the chrome-spinels enclosed in olivines in the Skye picritic basalt lavas have low calculated concentrations of Fe_2O_3 (Table 2), confirming that they have not undergone any significant post-crystallization reaction with a melt phase. Henderson and Wood (1981) recorded an example of a chrome-spinel crystal which is zoned from an Al-rich and Cr-poor core, to a Cr-rich and Al-poor rim. The core composition recorded by Henderson and Wood (1981) (Al_2O_3 23.8 wt.%, Cr_2O_3 35.8 wt.%) is almost identical to that reported here for the unzoned chrome-spinel phenocrysts in the Skye picritic basalt lavas. Therefore, taken along with the whole-rock compositional data reported by Greenwood *et al.* (1990) for the Rum picrite chill, this suggests that the magma from which the Rum peridotite cumulates were precipitated was similar to that represented by the picritic basalt flows of Skye, but that in the subvolcanic environment of Rum the chrome-spinels were able to partially re-equilibrate (i.e. produce compositional zonation) by reaction with intercumulus plagioclase (Henderson and Wood, 1981). The compositions of the cumulus olivines within the Rum peridotites (Henderson and Wood 1981; Dunham and Wilkinson, 1985) are within the same range as those of the Skye picritic basalt lavas (Table 1) and the picrite chill on Rum (see earlier).

The compositional similarities identified here lead us to conclude that the magma type(s) involved in the intrusive complex on Rum were also involved in the construction of the lava field of west-central Skye (Table 3). Consequently, certain of the mineral chemistry trends identified within the lava field might be applicable in the elucidation of the magmatic evolution of the ultrabasic and basic rocks of the Rum Igneous Complex. Further evidence for this type of compositional relationship between extrusive and intrusive units in the BTVP is provided by Mattey *et al.* (1977) and Bell *et al.* (1994), who have shown clear links between the geochemical evolution of members of the Skye Main Dyke Swarm and the suite of cone-sheets which invade the Cuillin Igneous Complex on Skye, respectively, and the olivine tholeiite basalt lava of Preshal More on Skye (Thompson *et al.*, 1972; Esson *et al.*, 1975).

Conclusions

Within the Palaeocene lava field of west-central Skye, two occurrences of picritic basalt have been identified. These unevolved lava compositions have not been reported before from the BTVP and carry phenocrysts of olivine (*c.* Fo_{89}) and chrome-spinel. The paragenetic association and composition of the chrome-spinels are indicative of high-pressure crystallization and are similar to core compositions recognised by Henderson and Wood (1981) from spinel layers within peridotite cumulates of the nearby and slightly older Rum Igneous Complex, and suggests that similar parental magma types were involved.

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