Platinum-Group Element Mineralisation Within Two Mafic/Ultramafic Intrusions of the British Palaeogene Igneous Province

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Recent work on Eastern Greenland (e.g. Andersen et al. 1998; Bird et al. 1995), Iceland (Andersen et al. 2002) and North West Scotland (e.g. Butcher et al. 1999; Pirrie et al. 2000) has shown that the PGE-enriched magmatism is a ubiquitous and long-lived feature of the North Atlantic Igneous Province (NAIP). The British Palaeogene Igneous Province (well-exposed along the north western seaboard of the British Isles) forms the south western expression of the NAIP and is characterised by voluminous flood basalts, extensive dyke swarms and several central intrusive complexes (Figure 1a). Chromitite-hosted PGE mineralisation is present in association with mafic and ultramafic intrusions within at least three of these central complexes. Of these, the notable example is the Rum intrusion where well-documented PGE mineralisation occurs throughout the central intrusive complex (Butcher et al. 1999; Power et al. 2000; Power and Andersen, 2001). This study presents detailed mineralogical and geochemical analyses of the PGE-bearing mafic – ultramafic intrusions on Mull (the Ben Buie intrusion) and on Skye (the Peridotite Series of the Cuillin Complex) (Pirrie et al. 2000).

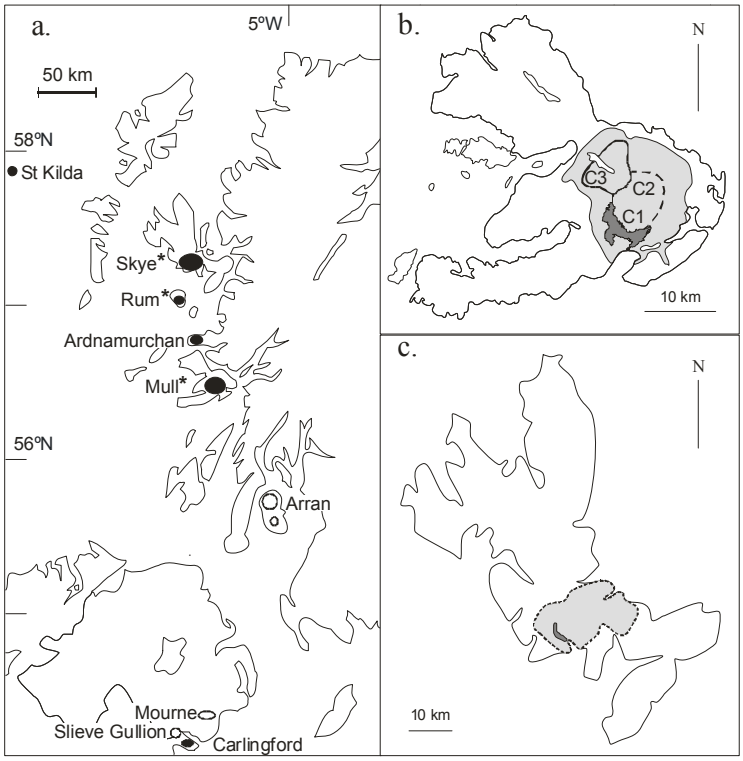

Figure 1. *a: Location of central intrusive complexes within the British Palaeogene Igneous Province. Filled circles: mafic-ultramafic dominated, open circles: acid dominated. * PGE mineralisation present. b: Simplified map of the Mull central intrusive complex (light shading) showing the location of the Ben Buie intrusion (dark shading) relative to the 3 intrusive centres (C1, C2, C3). c: Simplified map of Skye central intrusive complex (light shading) showing location of the Peridotite Series (dark shading).*

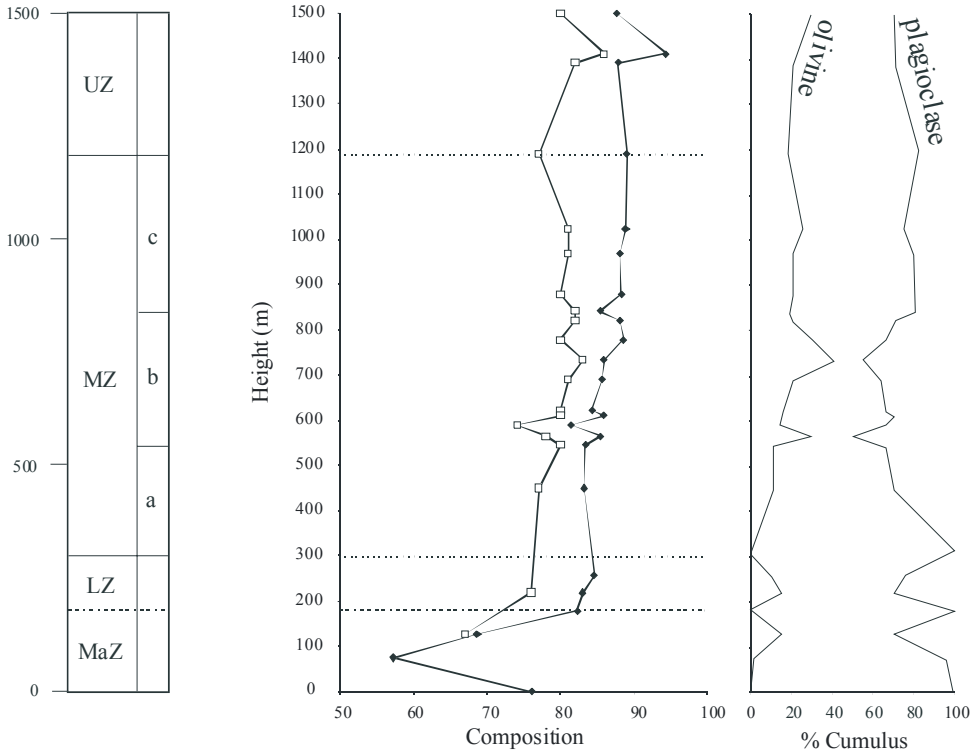

Figure 2. *Schematic log through the Ben Buie intrusion showing variations in cumulus phase chemistry and mineralogy. Filled diamonds: anorthite component of plagioclase, open squares: forsterite component of olivine. UZ: upper zone, MZ: middle zone: LZ lower zone, MaZ: marginal zone.*

The Ben Buie Intrusion, Mull

The Ben Buie intrusion is located on the south-western periphery of the Mull intrusive centre (Figure 1b) and was emplaced during the later stages of Centre 1 activity at about 58 Ma (e.g. Skelhorn et al. 1969; Emeleus and Gyopari, 1992). It comprises layered Ca-rich gabbroic cumulates with sporadic exposures of olivine cumulates (Lobjoit, 1959). The gabbroic cumulates are subdivided into four discrete stratigraphic units on the basis of mineralogy and geochemistry. A thin clinopyroxene and plagioclase-rich marginal zone occurs at the base of the intrusion above which lies the Layered Series which comprises three discrete zones (lower, middle and upper) each of which has a distinct cumulus texture and mineralogy (Figure 2). Mineral compositions through the Layered Series show little variation although there are some distinct reversals in compositional trend indicating that the primary magma was either compositionally inhomogeneous (stratified) or that the magma chamber experienced repeated influxes of magma. Small, laterally discontinuous (typically < 100 m long) bodies of olivine cumulates (predominantly troctolites and peridotites) crop out sporadically throughout the intrusion but marginal relationships are obscured and they may be either inclusions or plugs. Planar, laterally persistent chromitite laminae and convoluted and discontinuous chromitite seams are present within at least two of the olivine cumulate bodies.

Areas of potential PGE enrichment were identified on the basis of mineralogy (typically presence of sulphides and/or chromite) at different stratigraphic levels within the Layered Series and from the olivine cumulates and analysed for bulk total PGE+Au by Ni sulphide fire assay with an INAA finish. Total PGE+Au contents for the gabbroic and olivine cumulates do not exceed 50 ppb indicating that these lithologies are slightly depleted relative to primitive mantle. In contrast, the chromitite layers are mildly enriched with respect to primitive mantle with bulk PGE+Au concentrations up to 189 ppb. The flat chondrite normalised profiles (Figure 3) of the gabbroic and olivine cumulates show no evidence of PGE fractionation. Conversely, the chromitite samples have a slightly fractionated profile with Rh enrichment with respect to the other PGE. Similar profiles have been reported from chromitite layers

of the Critical Zone of the Bushveld Complex (von Gruenewaldt & Merkle, 1995) and chromitite layers within the Akanvaara intrusion in Finland (Mutanen, 1996). This distinct PGE profile has been attributed to PGE concentration through chromite precipitation (von Gruenewaldt & Merkle, 1995).

Individual PGM grains have only been identified within the chromitites. The mineralogy largely reflects the PGE concentrations with an assemblage dominated by laurite, irarsite, sperrylite, hollingworthite and rare michenerite. Most of the PGM are either included within, or at the margin of silicates and chromite grains; sulphide-hosted PGM are rare.

Peridotite Series, Skye

Ultramafic cumulates of the Peridotite Series crop out in an elongate zone at the south western margin of the Outer Layered Series of the Cuillin Complex (Figure 1c). Claydon and Bell (1992) delineated six discrete stratigraphic units. The lower three units are dominated by olivine cumulates (dunites and mela-troctolites) whilst the upper two are plagioclase-dominant (leuco-troctolite and rare anorthosite). Unit 4 is composed of hetrogeneous breccias with clasts ranging from dunite through to anorthosite (Claydon & Bell, 1992). Younger gabbros intrude and truncate the northern margin and contain numerous large (up to 20 m) xenoliths and unrotated blocks of Peridotite Series lithologies (Weedon, 1961). Chromitites are abundant throughout the three lowermost units and display a variety of morphologies from thin planar (10 mm), laterally persistent laminae through to highly convoluted and irregular seams that locally exceed 10 cm in thickness. The planar chromitites can be traced for several tens of metres and exceptionally in excess of 100 m (Bell & Claydon, 1992). In addition, chromitites occur within many of the included blocks and rare chromitite clasts are present within the Unit 4 breccias.

PGM are present within chromitites throughout the Peridotite Series including those from within included blocks and the Unit 4 breccias. A moderately diverse PGM assemblage is present, dominated by laurite and sperrylite. Less common phases include ruarsite, Pt-Rh-Fe alloys, Pd arsenides and Pd bismuthotellurides. In common with the Ben Buie intrusion, the PGM typically occur enclosed within, or at the margin of, silicates and chromite grains although sulphide-hosted PGM are also present. Bulk rock PGE concentrations within the chromitites are enriched with respect to primitive mantle with total PGE+Au values up to 508 ppb. Most samples have flat chondrite normalised profiles (Figure 4) indicating that PGE fractionation is not a significant process. However, two samples (both from chromitites within included blocks) have slightly negative slopes indicative of IPGE enrichment through chromite crystallisation or PPGE depletion possibly through later hydromagmatic or hydrothermal processes.

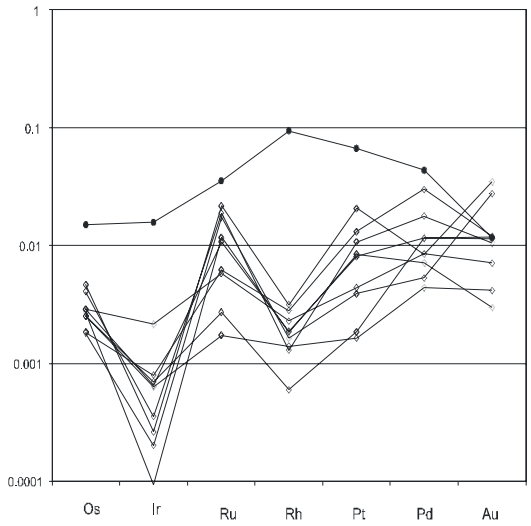

Figure 3. *Chondrite normalised data for the Ben Buie intrusion. Open diamonds: gabbroic cumulates, filled circles: chromitite lamina.*

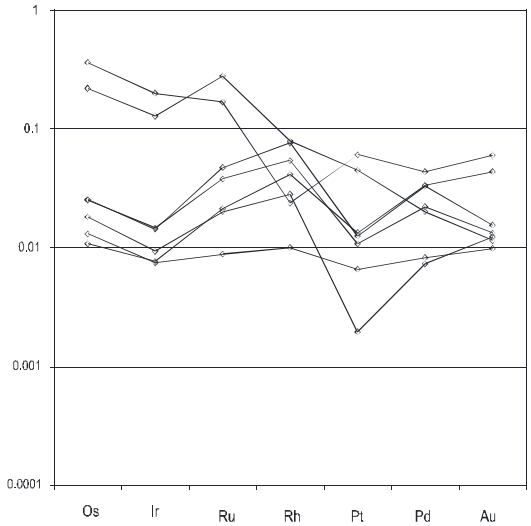

Figure 4. *Chondrite normalised data for the Peridotite Series, Skye. All data from chromitites.*

Conclusions

PGE are locally enriched within the Ben Buie intrusion of Mull and the Peridotite Series of Skye but only within chromitite laminae and seams. The mineralisation is largely sulphide-poor although this may be due to later hydrothermal/hydromagmatic processes. This work confirms that the basic magmatism associated with British Palaeogene Igneous Province was PGE enriched and indicates that other mafic-ultramafic complexes such as the Ardnamurchan Complex and the Carlingford Complex may also host significant PGE mineralisation.

Acknowledgements

SJP is funded through NERC Studentship GT04/99/ES90. MRP is funded through ESF grant 011019SW1.

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