Supplementary Information for: **Identification of mantle peridotite and a possible Iapetan ophiolite sliver in south Shetland, Scottish Caledonides**

**Supplementary Methods**

Major element compositions were measured by X-ray fluorescence (XRF) at Franklin and Marshall College using a *PW 2404 PANalytical XRF* vacuum spectrometer following the procedures outlined in Boyd & Mertzman (1987). Precision and accuracy for the average of 13 runs of BHVO-2 relative to USGS accepted values is estimated at <0.2% for SiO2 and TiO2, <1% for Al2O3, MgO, Fe2O3T, CaO, Na2O, P2O5, and <3% for K2O. Trace-element abundances were determined at the *Scripps Isotope Geochemistry Laboratory (SIGL)*, with a *Thermo Scientific* *iCAPq* quadrupole inductively coupled plasma mass spectrometer, using methods described previously in Day et al. (2014). Samples were prepared with international and internal rock standards (BHVO-2, BIR-1, BCR-2, AGV-2, DTS-2b, GP-13). Reproducibility of the basaltic reference materials was generally better than 5% (RSD), and 10% (RSD) for peridotite standards.

Osmium isotope and HSE abundance analyses were performed at the *SIGL*. Homogenised powder aliquots were prepared along with total analytical blanks and were digested in sealed borosilicate Carius tubes, with isotopically enriched multi-element spikes (99Ru, 106Pd, 185Re, 190Os, 191Ir, 194Pt), and 11 mL of a 1:2 mixture of Teflon-distilled HCl and HNO3 that was purged of Os by reaction with H2O2. Samples were digested to a maximum temperature of 270˚C in an oven for 72 hours. Osmium was triply extracted from the acid using CCl4 and then back-extracted into HBr (Cohen & Waters, 1996), prior to purification by micro-distillation (Birck et al., 1997). Rhenium and the other HSE were recovered and purified from the residual solutions using standard anion exchange separation techniques. Measurement protocols were identical to those described previously (e.g., Day et al., 2016). Isotopic compositions of Os were measured in negative-ion mode on a *ThermoScientific* *Triton* thermal ionisation mass spectrometer at the *SIGL*. Rhenium, Pd, Pt, Ru and Ir were measured using an *Cetac* *Aridus II* desolvating nebuliser coupled to a *ThermoScientific* *iCAPq* ICP-MS. Offline corrections for Os involved an oxide correction, an iterative fractionation correction using 192Os/188Os = 3.08271, a 190Os spike subtraction, and finally, an Os blank subtraction. Precision for 187Os/188Os, determined by repeated measurement of the UMCP Johnson-Matthey standard was better than ±0.2% (2 St. Dev.; 0.11390 ±20; n = 5). Measured Re, Ir, Pt, Pd and Ru isotopic ratios for sample solutions were corrected for mass fractionation using the deviation of the standard average run on the day over the natural ratio for the element. External reproducibility on HSE analyses using the *iCAPq* was better than 0.5% for 0.5 ppb solutions and all reported values are blank-corrected. The total analytical blanks (*n* = 3) run with the samples had 187Os/188Os = 0.401 ± 0.010, with quantities (in picograms) of 4.2 ±1.3 [Re], 2.8 ±0.3 [Pd], 2.0 ±0.9 [Pt], 13.3 ±1.3 [Ru], 0.3 ±0.2 [Ir] and 0.2 ±0.1 [Os]. These blanks resulted in negligible corrections to samples (<1%).

**Supplementary Discussion**

Steatized rocks in the DSS have been recognized for some time, and were exploited by the Norse during their occupation of Shetland, for the manufacture of utensils (e.g., Jones et al., 2007). The anhydrous bulk-composition of the DSS talc-magnesite samples is similar to that of peridotite that has otherwise experienced extensive serpentinization and metasomatism. The bulk composition of the sample in this study, which has been steatitized and serpentinized, is broadly similar to that of the sample reported in Flinn & Moffat (1985), which was reportedly not steatitized. One principal difference is that the steatitized sample analysed in this study has much lower Mg. We suggest that this difference is due to Mg-loss or Si-gain (Malvoisin, 2015) during localized steatitization within the DSS ultramafic rocks. In the case of the DSS, alteration probably occurred in two distinct episodes. First, by serpentinisation of olivine in the reaction of forsterite → serpentine + brucite, idealized as:

2Mg2SiO4 + 3H2O → Mg3Si2O5(OH)4 + Mg(OH)2

Or through Si metasomatism in the reaction:

3Mg2SiO4 + 4H2O + SiO2 aq → 2Mg3Si2O5(OH)4

Followed by the carbonation of serpentine to form talc-magnesite, in the reaction:

2Mg3Si2O5(OH)4 + 3CO2 → Mg3Si4O10(OH)2 + 3MgCO3 + 3H2O

Relative reduction in the Mg/Si and Al/Si ratios of peridotites has previously been demonstrated to occur during Si metasomatism (Paulick et al., 2006), although in the Dunrossness examples the low Mg in steatitized samples also leads to the possibility that loss of Mg occurred during carbonate metasomatism. The bulk compositions of our sample and that of Flinn & Moffat (1985) are therefore consistent with a peridotite protolith, an observation that is supported by the similarity in bulk composition observed between the DSS ultramafic rocks, and ultramafic rocks preserved in the SOC on Unst and Fetlar. Enrichments in Sr, Ba, Pb, U and Cs, the light REE and Eu all indicate extensive seafloor alteration of the talc-magnesite samples. The REE patterns measured in the talc-magnesite samples are similar to some serpentinized peridotites measured at the Mid-Atlantic Ridge. It has been demonstrated that vent fluids enriched in the LREE and Eu pervasively altered serpentinized peridotites at the Mid-Atlantic Ridge, 15°20′N, ODP Leg 209 (Paulick et al., 2006). In this circumstance, alteration began with serpentinization at 100-200°C under seawater-like pH values, followed by higher-temperature interactions at 300-400°C, with low pH (4-5) (e.g., Paulick et al., 2006).

The results strongly imply that the protolith to the talc-magnesite samples and, therefore, the sample measured by Flinn & Moffat (1985) - as the same outcrops were sampled - were peridotites that experienced variable degrees of serpentinization and/or steatitization in an oceanic environment. Based on prior studies of modern abyssal peridotites, most of the alteration experienced by the protoliths in the DSS could have occurred at a paleo- ridge setting, with no particular requirement for later alteration. Due to the extreme degrees of alteration of samples, it is difficult to ascertain if the protoliths were harburgite or dunite. The current data are permissive of dunitic protoliths, similar to those that make up variably thick (up to 10 m) channels and lenses in the harzburgitic mantle and the bulk of the lower crustal cumulate section in the SOC (e.g., Prichard, 1985; Flinn & Oglethorpe, 2005). Accessory Cr-spinel, usually relatively resistant to low-temperature modification, exhibits widespread alteration to more brightly reflective ferroan Cr-spinel. The ferroan Cr-spinel occurs as ragged rims on primary grains and within intra-grain microfractures. These complex alteration textures indicate there is comparatively little primary Cr-spinel remaining in the DSS samples.

In *Table S1* we report present-day Os values (-2.5 to -3.8) and rhenium depletion (TRD) ages (or minimum melt depletion ages) of 0.7 to 1 Ga, assuming chondritic mantle evolution (after Shirey & Walker, 1998). These are similar to Os values and TRD ages reported for some SOC harzburgites and dunites (O’Driscoll et al., 2012). Assuming a similar Iapetus-aged heritage for the talc-magnesite samples from south Shetland, to the SOC, we also report Os values at 495 Ma – the reported age of the SOC (Spray & Dunning, 1991). The Os values at 495 Ma range from -1.9 to -13.6. The low Os values likely reflect addition of Re after formation of the talc-magnesite samples as harzburgites or dunites, with addition of Re occurring during hydrothermal alteration.

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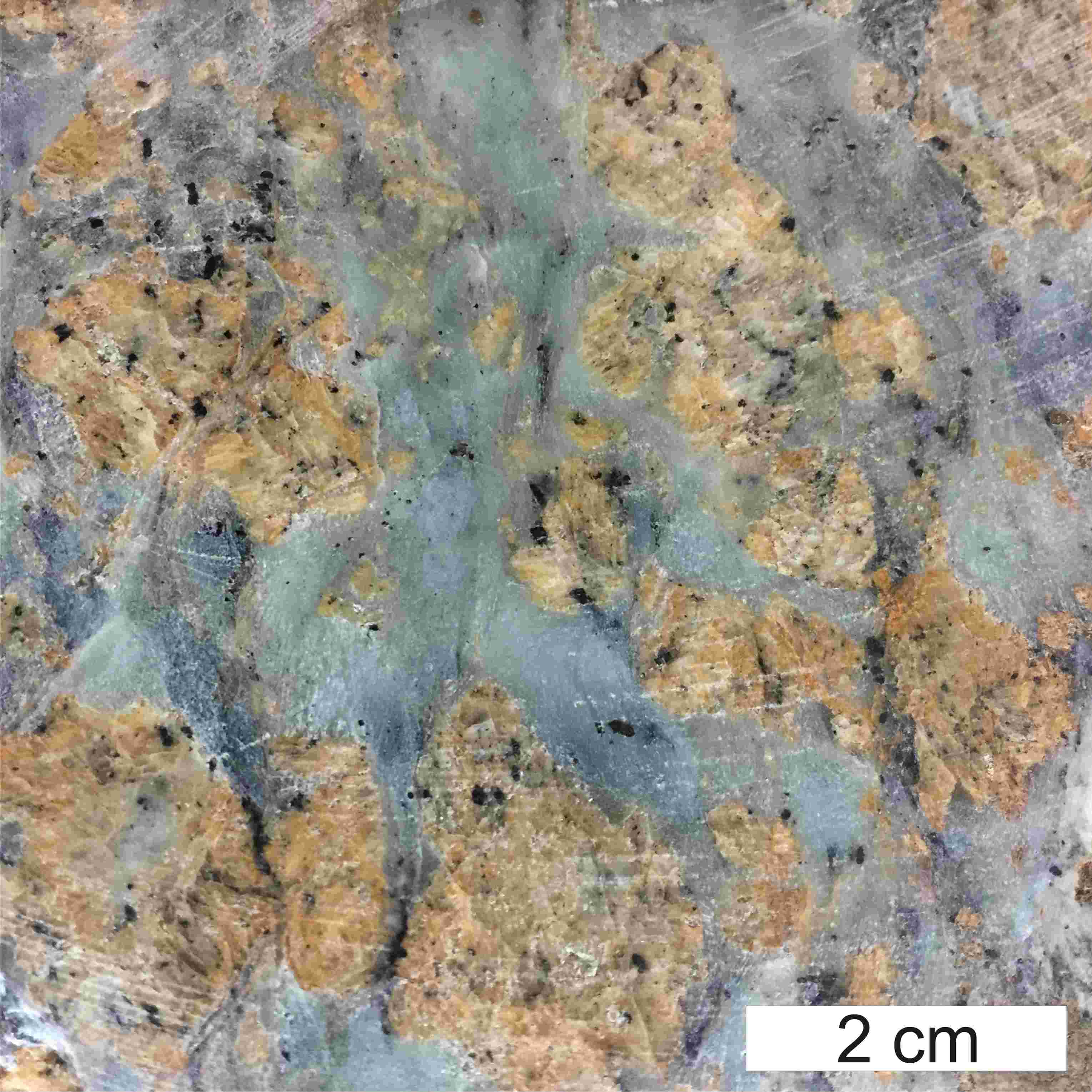
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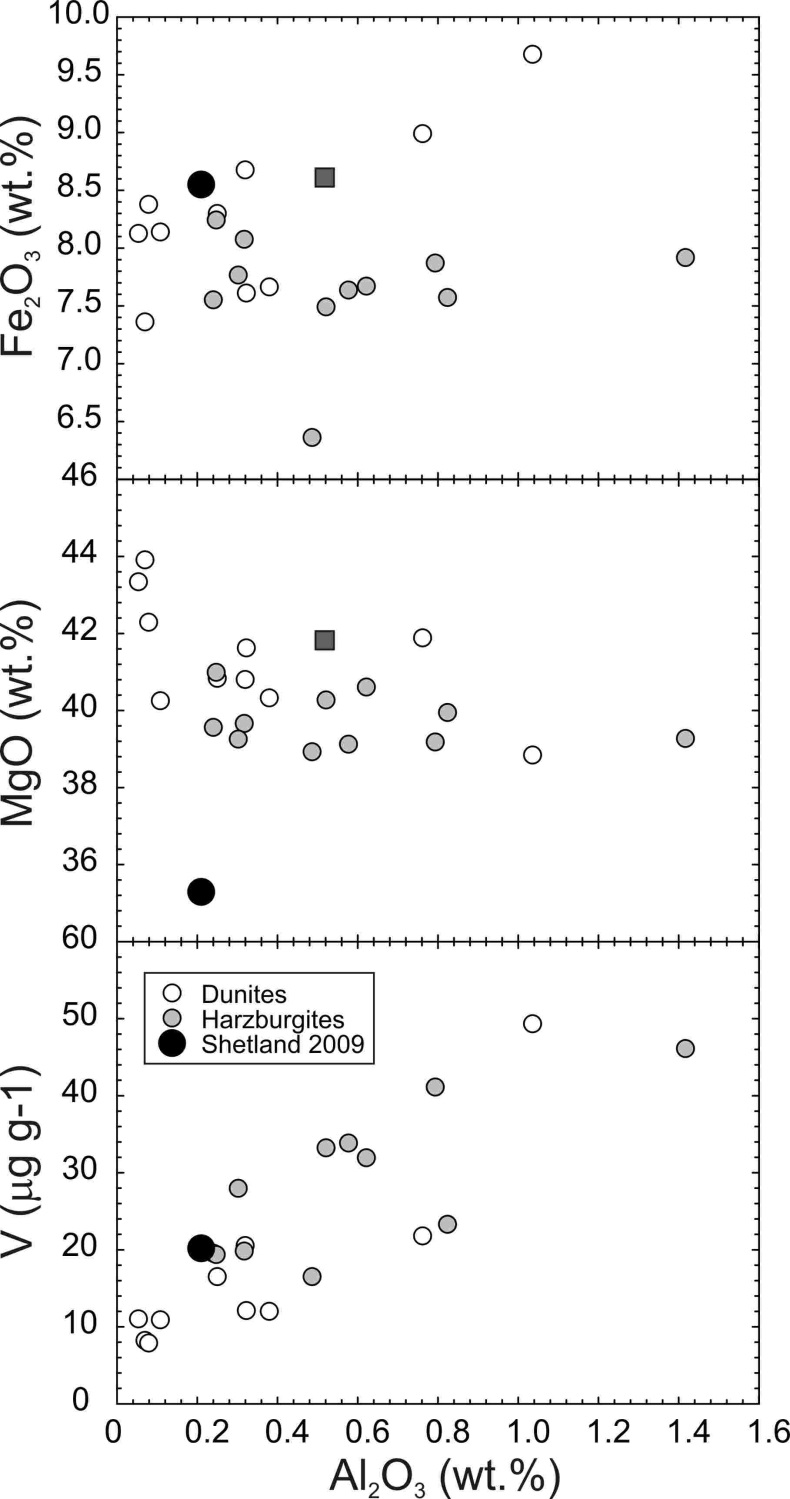
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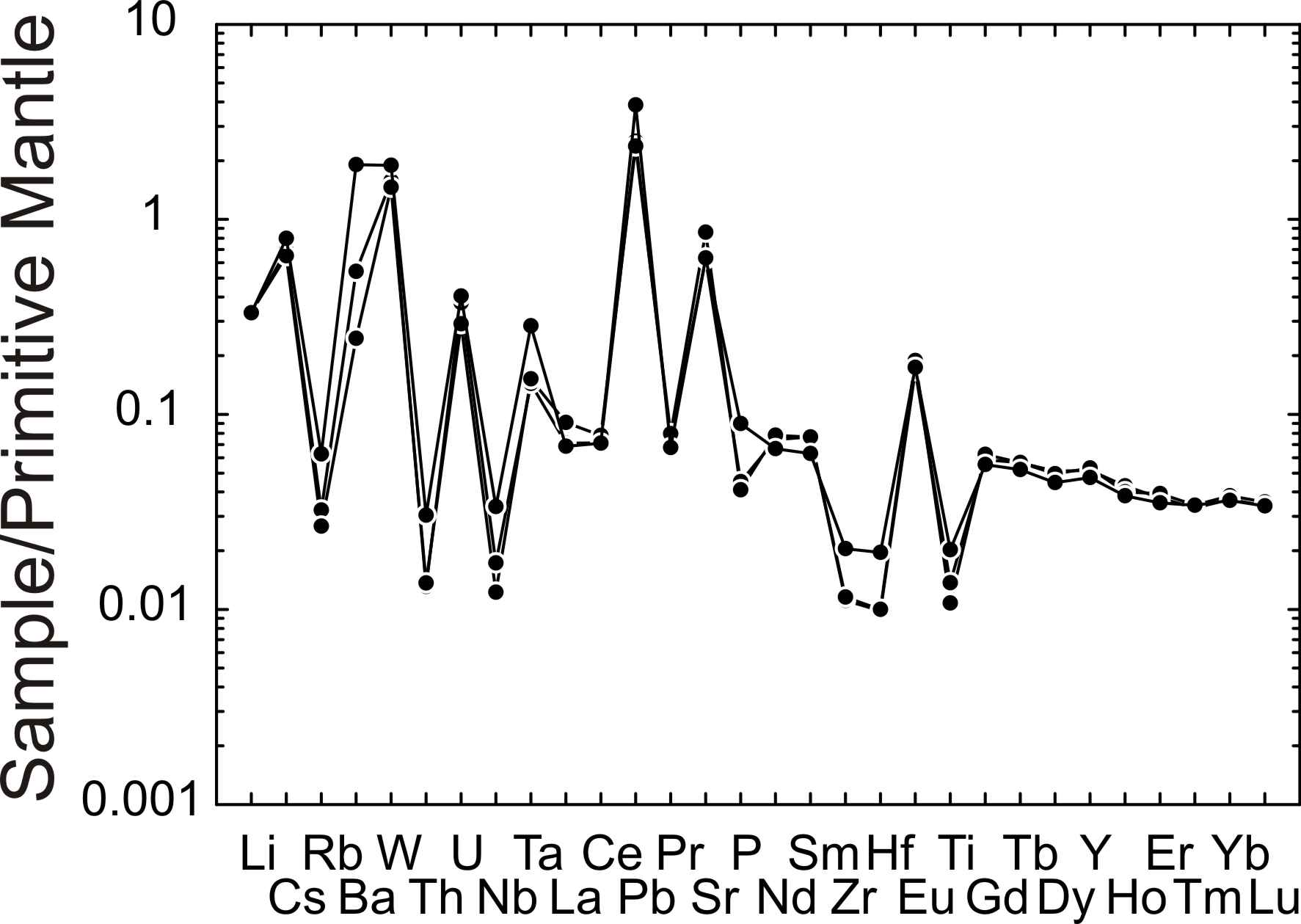
**Supplementary Figures**



**Figure S1** - Photograph of a slab-cut of one of the samples analysed in this study. The sample is a talc-magnesite metamorphic assemblage, representing the reaction of forsterite → serpentine + brucite, followed by carbonation of serpentine to form talc-magnesite. Magnesites are large orange-brown multi-crystalline masses within blue-green talc. Black grains are Cr-spinel, or alteration minerals after Cr-Spinel. Secondary pyrite is also visible in some portions of the samples.

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**Figure S2** - Plots of Al2O3 versus Fe2O3, MgO and V for talc-magnesite samples from south Shetland (Shetland 2009), versus dunite and harzburgite compositions measured for the SOC, on Unst and Fetlar, from O’Driscoll et al. (2012). Also shown is the composition of the ‘Dalradian komatiite’ composition (filled square) from Flinn & Moffat (1985).

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**Figure S3** - Incompatible trace element patterns for talc-magnesite samples from South Shetland, normalized to a primitive mantle composition (Sun & McDonough, 1989), with increasing compatibility to the right.

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