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Pyroxenites – Melting or Migration?: Evidence from the Balmuccia massif

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The recognition of pyroxenites in the mantle, combined with their lower solidus temperatures than peridotite, have been proposed as contributors to melting (Pertermann and Hirschmann, 2003; Sobolev et al, 2005; 2007). Geochemical fingerprints of this process invoke an unspecified 'pyroxenite' as the putative source. In reality, mantle pyroxenites are diverse (Downes, 2007), requiring that their mode of origin and compositional variability be addressed.

Due to the excellent preservation and exposure of the Balmuccia massif, it has become an archetype for orogenic peridotites, providing information on their composition, field relationships and metamorphic history (Shervais and Mukasa, 1991; Hartmann and Wedepohl, 1993; Rivalenti et al., 1995; Mazzucchelli et al., 2009). The Balmuccia massif consists of fertile lherzolite with subordinate harzburgite and dunite and is riddled with pyroxenite bands, which fall into two suites – Chrome-Diopside (Cr-Di) and Aluminous-Augite (Al-Aug), a pairing present in most massif peridotites. Two-pyroxene thermometry gives temperatures of 850±25°C at 1-1.5 GPa, 500°C lower than asthenospheric mantle at that pressure, meaning they do not preserve their original, high temperature mineralogy.

Decimetre-sized Cr-Di bands ($\approx$75% CPX, 25% OPX) occur as initially Ol-free and bound by refractory dunite, but, as the bands are rotated into the plane of foliation, they mechanically incorporate olivine. Al-Aug veins (60% CPX, 25% OPX, 15% Sp) discordantly cut the body, intruding lherzolites which show enrichments in Fe, Al and Ti adjacent to the dykes. Both the Cr-Di suite and the Al-Aug series have indistinguishable Sr-, Nd-isotopic compositions to the host peridotite (Mukasa and Shervais, 1999).

The major element compositions of pyroxenes in the Cr-Di bands and those in the surrounding peridotites are identical. Together with isotopic evidence, this suggests a local source, not only chemically but spatially, where a very low degree melt ($\leq$2%) acts as a transport medium for the pyroxenes and segregates them into dyke-like structures (melt/rock = 0.05-0.1), analogous to 'pressure-solution' creep (Dick and Sinton, 1979). The presence of a melt is required by their REE contents, with moderate La/SmN (0.3 – 0.4) with near-flat HREE (1 < Gd/YbN < 1.1), in contrast to the lherzolites, which preserve highly fractionated La/SmN (0.03 – 0.3) and positively-sloping HREE (0.6 < Gd/YbN < 0.8). Models for their formation as cumulates from a melt are untenable, as, upon decompression, olivine is invariably the first phase to crystallise, thereby drastically reducing Mg# and Cr# to values lower than those in the Cr-Di bands.

The Al-Aug veins have lower Mg# (85-87) than the peridotites and Cr-Di series ($\approx$90). However, CPXs in both the Al-Aug and the lherzolite preserve REE patterns which are subparallel to, but twice as enriched as those in the normal lherzolites. This characteristic can be explained by focusing of a small, (4%) locally-sourced melt similar to that which transported the Cr-Di pyroxenes. This melt was focused to a melt/rock ratio of 0.6 – 0.7, and crystallised to form the cumulus rocks of the Al-Augite suite. The extreme, heavy δ57Fe values observed in both the pyroxenite and adjacent lherzolite (+ 0.75 per mille) also point to a low-degree melt.