Provenance of olivine in volcanic rocks

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Mike O'Hara's 1968 paper in Nature [1] was important because it demonstrated that ocean floor basalts (MORB) could not be primary magmas of mantle peridotite, a minority view of one at the time. His preferred model was that such basalts formed from more picritic primary magmas after olivine fractionation, in agreement with solutions to the primary magma problem [2] [3]. This is supported by the existence of large olivine grains in olivine-phyric magmas, often called "phenocrysts". High precision electron microprobe analyses were obtained on large millimeter-sized olivine grains hosted by basalts from the Siqueiros Fracture Zone of the East Pacific Rise. Results show no significant core-rim changes in Ni, Ca, Mn, and high Mg numbers. These olivine grains have compositions that are similar to model olivines in equilibrium with anhydrous partial melts of mantle peridotite [4]. It is concluded that these olivine grains are accidental crystals that were plucked from the residual peridotite melting region below the East Pacific Rise. We call them "pyrocrysts" to convey that they originated from the hottest part of the magmatic system, the partial melting region. They differ from phenocrysts which are large grains that form by partial crystallization, and which typically display normal core-rim zoning in Mg number, Ni, Ca, and M. These are also observed in Siqueiros MORB, but phenocrysts that mix with new batches of magma can transform to antecrysts with reverse core-rim zoning. Pyrocrysts form by partial melting, and phenocrysts form by partial crystallization. Olivine pyrocrysts were also found in subduction zone volcanoes from the Kamchatka and Central American arcs, and they reveal in their Ca contents the introduction of water from the slab to the mantle wedge. Pyrocrysts can display reverse zoning owing to slab melt-wedge rock reaction. In general, the study of olivine pyrocrysts offers new opportunities to study direct samples of melting regions below all tectonic environments.

[1] O'Hara, M.J. (1968), *Nature*, **220**, 683-686. [2] Herzberg, C. & O'Hara, M.J. (2002), *J. Petrol.*, **43**, 1857-1883. [3] Herzberg, C. & Asimow (2015), *G Cubed*, 10.1022/2014GC005631 [4] Herzberg, C. (2011), *J. Petrol.*, **52**, 113-146.