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Magma mixing and the origin of layered cumulates: evidence from the Oman ophiolite (Bahla and Wuqbah massifs)

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Ultramafic cumulates, essentially wehrlitic, are an important component of the crustal section of the Oman ophiolite. They cannot be related to the most common gabbroic cumulates through simple fractional crystallization processes in anhydrous conditions. They occur frequently as intrusions post-dating the crystallization of the gabbros and, in such cases, are interpreted as "late intrusive" attributed to subduction or obduction related processes. Many authors have generalized this conclusion to all kinds of ultramafic cumulates, whatever their mode of occurrence, including those that are interlayered with the gabbros and that are supposed to be injected as sills between pre-existing gabbroic layers.

In order to better constrain the origin of the ultramafic cumulates interlayered with gabbros, we have conducted a field, petrographic, and geochemical study of the lower crustal section of Bahla and Wuqbah massifs (westernmost part of the Oman ophiolite) where gabbroic and ultramafic cumulates occur in roughly equal proportions. We have performed detailed geochemical profiles with the SEM and with the LA-ICP-MS across the boundaries between gabbroic and ultramafic layers. In terms of modal composition, individual layers are quite homogeneous and the boundaries between layers are clear-cut down to the microscopic scale. In spite of the sharp nature of the lithological boundaries, the chemical composition in both major and trace elements defines progressive evolutions as they are approached. The thickness of these "cryptic transition zones" varies considerably according to the element and to the mineral considered. It ranges typically from a few mm to a few cm. By the same way, the shape of the geochemical profiles is curved (close to hyperbolic) for some elements (mostly major elements), but is almost linear for many other elements, especially some trace elements. These characteristics are inconsistent with solid-state intra-crystalline diffusion but call for diffusion in a liquid phase and/or for magma mixing. Mixing between either the parent melts of each cumulate suite or between intercumulus liquids percolating in the crystal mush may be envisioned. Whatever the details of the processes, our observations show that the crystallization of interlayered ultramafic and gabbroic cumulates are contemporary events.

Both gabbroic and ultramafic rocks from these massifs are characterized by early crystallization of orthopyroxene, implying that their parent melts were significantly richer in SiO2 than MORB. Moreover, for a same degree of differentiation, their plagioclases are richer in An% and their Cpx are poorer in Al2O3 than MOR gabbros. These characteristics are reminiscent of boninitic-andesitic parent melts. However, Bahla and Wuqbah ultramafic and gabbroic cumulates do not present the extreme depletion in HFSE typical of supra subduction zone boninites. Their trace element signature implies that a MORB source was actually an important ingredient of their parent melts. The simplest way to account for these observations is to invoke mixing between N-MORB extracted from an asthenospheric upwelling and silica enriched melts produced by hydrated re-melting of the lithosphere in response to the deep penetration of hydrothermal fluids.

Magma mixing may account for the coexistence of clear-cut mineralogical boundaries and of progressive geochemical transitions, the change in the nature of the cotectic assemblage occurring suddenly after a certain amount of mixing. We conclude that interlayered ultramafic and gabbroic cumulates characteristic of some cumulate sections in the Oman ophiolite bear witness of complex hybridization processes related to interaction between anhydrous and hydrous magmas.