The nature of the depleted mantle

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The depleted mantle (DM) is defined as "the part of Earth's mantle from which basaltic melt has been extracted" in one or multiple melting events, predominantly at mid-ocean ridges [1]. As such, it is an assembly of variably depleted, and thus compositionally stratified peridotites resulting from relatively high degrees of melting under the ridge axis and lower degrees of melting off-axis. One consequence of this innate compositional heterogeneity of the DM is that its average composition is difficult to estimate, and that there is no unique, compositionally uniform DM reservoir.

For increasingly more incompatible elements, the average composition in any given volume of a heterogeneous DM is increasingly biased towards its least depleted parts, that is, those that have experienced the smallest degree of melting. This bias is enhanced during partial melting and transposed to its derivative melts (i.e., MORB). Incompatible element abundances and ratios in aggregate melts from a heterogeneous DM (i.e., MORB) are therefore dominated by melts from its least depleted parts. Hence although highly depleted materials must volumetrically constitute a significant portion of the DM, they contribute only small amounts of incompatible elements to its partial melts (i.e., MORB).

As a consequence, the average trace element chemistry of a heterogeneously depleted mantle and its derivative melts (i.e., MORB) does not reflect any one section of that depleted reservoir nor a typical or median part of the DM, nor does it accurately reflect the average degree of partial melting the DM has experienced. Hence, estimating the extent of depletion of the DM from incompatible element abundances and ratios in MORB such as Nb/U, or the isotope ratios of incompatible elements (e.g., Sr, Nd, Pb, Hf), will underestimate its extent of depletion and extent of melt extraction. The latter presents an obstacle for estimates of DM composition from incompatible element and isotope ratios in MORB [(cf. 2, 3], but also for inferring the correct extent of depletion and mass of the DM from geochemical and isotopic mass balance [cf. 4].

[1] Stracke, A., 2016. Encyclopedia of Marine Geosciences, [2] Salters, V.J.M. and Stracke, A., 2004, Geochem. Geophys, Geosys. 5, Q05B07, doi.10.1029/2003GC000597, [3] Workman, R.K., Hart, S.R., 2005. Earth Planet. Sci. Lett. 231, 53-72. [4] Allègre, C.J., Hart, S.R., Minster, J.F., 1983. Earth Planet. Sci. Lett. 66, 177-190.