Helium isotope signatures of the mantle transition zone

S. TIMMERMAN1*, M. HONDA1, A.D. BURNHAM1, Y. AMELIN1, S. WOODLAND2, D.G. PEARSON2, A.L. JAQUES1, C. LELOSQ1, V.C. BENNETT1, G.P. BULANOVA3, C.B. SMITH1, J.W. HARRIS4, E. TOHVER5

1RSES, Australian National University, Australia
(*correspondence: suzette.timmerman@anu.edu.au)
2University of Alberta, Canada
3University of Bristol, United Kingdom
4University of Glasgow, United Kingdom
5University of Sao Paolo, Brazil

Helium isotope compositions of basalts play a critical role in defining models of Earth’s chemical structure. The higher 3He/4He ratios of plume-related basalts relative to mid-oceanic ridge basalts (MORB) are taken as key evidence of a primordial undegassed reservoir with high 3He/4He ratios present in the Earth’s lower mantle. However, the preservation of such a reservoir over the Earth’s history has been questioned based on geophysical evidence of slab subduction into the lower mantle. Further, He isotopes in basalts are affected by plume entrainment, degassing, and crustal contamination. We studied twenty-four super-deep, sub-lithospheric diamonds from the Juina area, Brazil, to obtain a new view of the He isotopic composition of the deep mantle, unaffected by the above processes.

Fluid inclusions within these super-deep diamonds, likely from transition zone depths (410-660 km), have 3He/4He ratios correlating with δ13C values from the diamond host. High 3He/4He ratios (>MORB) are associated with higher 3He concentrations and the lowest δ13C values, whereas low 3He/4He ratios are associated with mantle δ13C values. Trace element patterns and Sr and Pb isotopic compositions of these fluid inclusions indicate the presence of subducted pelagic sediments and oceanic crust/lithosphere. The Pb isotopic compositions of the fluid inclusions show a similar variation as OIBs, from the EMII to the HIMU end-member. These features are best explained as the result of differential mass balance, with low [He] in the subduction fluids supplying the organic carbon and trace elements, and high [He] with high 3He/4He ratios in fluids associated with a plume. These new data indicate a high 3He/4He source must at least be present >410 km depth and likely in the lower mantle, and has implications for mantle convection and the preservation of chemical heterogeneities in the mantle.