Münster, 31 March 2019

Dear Editor,

We are pleased to hereby submit our manuscript entitled “Primordial and recycled helium isotope signatures in the mantle transition zone” to *Science.*

Helium isotopes have been one of the key tools used to construct dynamic models of the Earth's mantle in which the deeper parts in particular are viewed as primitive, un-degassed reservoirs that have maintained a more pristine chemical composition than the well-mixed upper mantle that has been thoroughly processed by subduction. The picture offered by He isotopes and other noble gases has been questioned numerous times, on the basis that it is difficult to attribute, in an objective way, a depth to geochemical signals portrayed by these tracers. Here we offer a unique view on this problem, provided by the first He isotope measurements of super-deep diamonds whose depth of origin is constrained by the mineral inclusions that they contain.

The fluid inclusions in super-deep diamonds from Brazil provide the most direct evidence of the deep mantle helium isotope signatures, not affected by degassing and shallow crustal contamination like those from ocean island basalts. The helium isotope data are combined with the first trace element data and unique Pb-Sr isotope data measured on picograms of material, and carbon isotope compositions of the diamond hosts. The trace element and C-Pb-Sr data in this manuscript show the involvement of subducted material deep in the mantle. The 3He/4He ratios, 3He and 4He concentrations, and δ13C values indicate mixing between a plume component and degassed subducted pelagic sediments. Deep mixing can create the geochemical compositions found in ocean island basalts, as evidenced by a comparable range in Pb and He isotope signatures recorded in the fluid inclusions in these super-deep diamonds.

This study is considered of high interest to the diverse readers of *Science* because of the importance of the presented results for our understanding of the inner Earth geochemistry and structure. No prior discussions have taken place with an editor of *Science* about the work described in this manuscript. The manuscript or related materials is not under consideration elsewhere, only a general abstract for the Goldschmidt conference has been submitted. We have provided suggestions for reviewers below. We hope that you will consider our manuscript for publication in *Science.*

On behalf of all the authors,

Yours sincerely,

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