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Constraints on the neon isotopic composition of the lower mantle by single vesicle analyses in Icelandic glasses

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The origin of volatile elements on Earth is still debated. Noble gases, due to their chemical inertness, can serve as powerful proxies to study planetary formation processes and mantle evolution. Neon is particularly relevant for tracing the source of volatile elements of our planet as its isotopic composition varies greatly between reservoirs in the Solar System. The existence of a preserved (over 4.45 Ga), relatively undegassed, reservoir in the mantle has been inferred from noble gas isotopic systematics[1]. This reservoir is tapped by deeply rooted mantle plumes, namely Galapagos, Hawaii and Iceland plumes. Analysis of quenched glass, preserving magmatic gases, from these locations, revealed that the neon isotopic composition of the lower mantle is different to that of the upper mantle (source of the MORBs), particularly for the $^{21}Ne/^{22}Ne$ ratio. In both cases however, neon has a $^{20}Ne/^{22}Ne$ ratio over 12, akin to a solar, primitive source, distinct from the atmospheric ratio of 9.8. Two models may explain Earth's mantle neon isotopic compositions: (1) the capture and dissolution of a primordial atmosphere in an early magma ocean, or (2) solar wind irradiation of pre-planetary dust yielding different $^{20}Ne/^{22}Ne$ ratios in a preserved reservoir. The exact neon isotopic compositions of the lower mantle is still unclear, however. Indeed, the step-heating or step-crushing analytical techniques leads to a mixing curve for neon isotopic ratios between air contained in cracks and open vesicles ($^{20}Ne/^{22}Ne$ = 9.8) and the mantellic value, contained in closed vesicles. To address this, we analyzed single vesicles from undegassed Icelandic subglacial lavas and developed a statistical approach to determine the $^{20}Ne/^{22}Ne$ of the Icelandic source. This technic has been shown to be efficient to obtain the neon isotopic composition devoid of shallow atmospheric contamination Our findings support solar wind irradiation of protoplanetary disk dust as the mechanism for Earth's light volatile accretion, aligning with Péron et al.[2] for the Galapagos mantle source.

[1] Allègre et al., 1983. Nature 303, 762-766.

[2] Péron et al., 2017. GPL v3 n2 151-159.