Chondritic Xenon in the Earth’s mantle: new constraints on a mantle plume feeding magmatism in Europe

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Noble gases are powerful tracers of the origin of terrestrial volatile elements and of the processes that controlled their distribution between the Earth's interior and the terrestrial atmosphere over geological ages. The compositions of magmatic gases provide insights into the evolution of the Earth’s mantle and atmosphere. Despite recent analytical progress in the study of planetary materials and mantle-derived gases, the possible dual origin of the planetary gases in the mantle and atmosphere remains unconstrained.
Xenon deserves particular attention because its isotope systematic can be linked to specific processes during terrestrial accretion (e.g., Marty, 1989; Mukhopadhyay, 2012). The origin of heavy noble gases in the Earth's mantle is still debated, and might not be solar (Holland et al., 2009).
Here, we report high precision xenon isotopic measurements in gases from a CO_2 well in the Eifel volcanic region (Germany), where volcanic activity occurred between 700 ka and 11 ka years ago.
Our Xe isotope data (normalized to ^{130}Xe) show deviations at all masses compared to the Xe isotope composition of the modern atmosphere. The improved analytical precision of the present study, and the nature of the sample, constrains the primordial Xe end-member as being “chondritic”, and not solar, in the Eifel mantle source. The evidence of this primordial component is consistent with an asteroidal origin for the volatile elements in Earth's mantle. It also implies that volatiles in the atmosphere and in the mantle originated from distinct cosmochemical sources. Despite a significant fraction of recycled atmospheric xenon in the mantle, primordial Xe signatures still survive in the mantle.
Our data also show that the reservoir below this volcanic system (Eifel) contains heavy-radiogenic/fissiogenic xenon isotopes, whose ratios are typical of plume-derived reservoirs. The Xe contribution, coming from the spontaneous fission of ^{244}Pu, is 2.26±0.28 %. The Xe contribution from spontaneous fission of ^{238}U is always negligible, the remainder being atmospheric plus primordial. Our data support the notion that the fraction of plutonium-derived Xe in plume sources (oceanic as well as continental) is higher than in the MORB source reservoir. Hence, the MORB—type reservoirs appear to be well distinguished from and more degassed than the plume sources (oceanic as well as continental) supporting the heterogeneity of Earth’s mantle.
Finally, this study highlights that xenon isotopes in the Eifel gas have preserved a chemical signature that is characteristic of other mantle plume sources. This is very intriguing because the presence of a mantle plume in this sector of Central Europe was already inferred from geophysical and geochemical studies (Buikin et al., 2005; Goes et al., 1999). Notably, tomographic images show a low-velocity structure down to 2000 km depth, representing deep mantle upwelling under central Europe, that may feed smaller upper-mantle plumes (Eifel volcanic district-Germany).

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