Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.16449

The influence of crustal recycling on the molybdenum isotope composition of the Earth's mantle

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Several studies suggested that the Mo isotope composition of Earth's mantle may be subtly sub-chondritic [1,2]. This observation cannot be reconciled with a likely barely detectable enrichment in heavy Mo isotopes in Earth's mantle following core-mantle differentiation [3]. A study of the Mo isotope composition of Earth's crust suggested it may be super-chondritic [4]. Complementarity between Mo isotopes in Earth's crust and mantle implies that Mo isotopes can provide valuable insights into the evolution of Earth's mantle-crust system.

However, a sub-chondritic Mo isotope composition of the accessible mantle is debated. Given the incompatibility of Mo, mid-ocean ridge basalts (MORB) are arguably the most obvious type of rocks to study the Mo isotope composition of the mantle. Two previous studies yielded variably sub-chondritic to super-chondritic Mo isotope compositions in MORB [1,2], with no obvious systematics to explain the variability. More recently, a study focussed on enriched MORB, i.e. $(La/Sm)_N > 1$, suggested they obtained higher Mo isotope ratios following metasomatism of mantle lithosphere caused by low degree partial melts derived from the mantle [5], thus explaining some of the variability in MORB.

We analysed depleted MORB, i.e. $(La/Sm)_N < 1$, from the Pacific, Indian and Atlantic oceans to determine their Mo isotope compositions and estimate a value for the bulk mantle. Our samples are characterised by sub-chondritic Mo isotope compositions on average, and none of the individual depleted MORB display super-chondritic values. Combined with literature data, we find that the bulk, accessible mantle is on average slightly sub-chondritic. Modelling suggests that >1 billion years of plate tectonic cycling of dehydrated, subducted oceanic crust into the mantle can explain the evolution of the mantle Mo isotope and Ce/Pb ratios in tandem, which is not the case for extraction of mantle partial melts. Our results thus add to the notion that the depleted mantle has been extensively modified by subduction-processed, oceanic crust.

[1] Bezard et al. (2016), EPSL 453, 171-181; [2] Liang et al. (2017), GCA 199, 91-111; [3] Hin et al. (2019), Chem. Geol. 504, 177-189; [4] Yang et al. (2017), GCA 205, 168-186; [5] Chen et al. (2022), EPSL 578, 117283.