

**Contrasting Mg isotopic compositions between Fe-Mn nodules and surrounding soils: Accumulation of light Mg isotopes by Mg-depleted clay minerals and Fe oxides**

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Magnesium isotopic systematics has been increasingly used to trace the biogeochemical cycle of Mg in soil systems and Fe oxides are the critical soil components that affecting the geochemical behaviors of elements in soils. The role of Fe oxides in fractionating Mg isotopes, however, still remains unclear. Here, Mg isotopic compositions are reported for Fe-Mn nodules (FMNs), surrounding soils, and soil waters for a paddy soil profile to improve the understanding of processes controlling Mg isotopic compositions of soil systems. Our results indicate that FMNs are isotopically lighter than surrounding soils but heavier than soil water, and surrounding soils are isotopically lighter than parent granite. The extremely distinguishing isotopic compositions between FMNs and soils reflect different Mg sources in mineral crystal structure. Structural Mg in surrounding soils is mainly from granite weathering, whereas that in FMNs is from soil waters due to the frequently repeated dissolution and precipitation of Fe oxides. The enrichment of heavy Mg isotopes relative to soil waters in FMNs is resulted from the preferential incorporation of <sup>26</sup>Mg when Mg<sup>2+</sup> substitutes for Fe<sup>3+</sup> in goethite. The lighter Mg isotopic compositions relative to the parent granite can be explained by the retention of light Mg isotopes in exchangeable sites of Mg-depleted mineral. Moreover, we suggest that ion-exchange process preferentially removes heavy Mg isotopes from soil minerals, leaving soil exchange fractions hosting light Mg isotopes. Our study demonstrates that Mg-depleted clay minerals and Fe oxides can considerably lower the soil  $\delta^{26}\text{Mg}$  values, highlighting the major roles of these two soil minerals in controlling soil Mg isotopic compositions.