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Mass independently fractionated sulfur isotopes reveal recycling of Archean lithosphere in modern oceanic hotspot lavas

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Oceanic crust and sediments are introduced to the mantle at subduction zones, but
the fate of this subducted material within the mantle, as well as the antiquity of this process, is unknown. The mantle is compositionally and isotopically heterogeneous, and it is thought that much of this heterogeneity derives from incorporation of diverse subducted components—both crustal and oceanic lithosphere—over geologic time. Basaltic lavas erupted at some oceanic hotspot volcanoes have long been considered to be melts of ancient subducted lithosphere. However, compelling evidence for the return of subducted materials in mantle plumes is lacking. We report mass independently fractionated (MIF) S-isotope signatures in olivine-hosted sulfides from 20-million-year-old ocean island basalts (OIBs) from Mangaia, Cook Islands (Polynesia). Terrestrial MIF S-isotope signatures were generated exclusively through atmospheric photochemical reactions until $\sim$2.45 billion years ago. Therefore, the discovery of MIF-S in young OIBs indicates that sulfur—likely derived from hydrothermally-altered oceanic crust—was subducted into the mantle before 2.45 Ga and recycled into the mantle source of Mangaia lavas. These new data provide evidence for ancient materials, with MIF 33S depletions, in the mantle source for Mangaia lavas. An Archean age for recycled oceanic crust provides key constraints on the length of time that subducted crustal material can survive in the mantle and on the timescales of mantle convection from subduction to melting and eruption at plume-fed hotspots. The new S-isotope measurements confirm inferences about the cycling of sulfur between the major reservoirs from the Archean to the Phanerozoic, extending from the atmosphere and oceans to the crust and mantle, and ultimately through a return cycle to the surface that, here, is completed in Mangaia lavas. It remains to be seen whether hotspots lavas sampling different compositional mantle endmembers (e.g., EM1, EM2, DMM) will exhibit evidence for recycling of Archean protoliths.