Ruthenium stable isotopes and the late accretion history of the Earth

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Elevated abundances of highly siderophile elements in Earth's mantle are thought to reflect the late accretion of broadly chondritic material (the late veneer) after cessation of core formation. However, Ru/Ir and Pd/Ir in the Earth's mantle are suprachondritic, suggesting that the late veneer did not consist of meteorites or was a mixture of chondrites and iron meteorites [e.g. 1, 2]. Alternatively, Ru and Pd were less siderophile during the late stages of Earth's core formation, in which case some Ru (and Pd) would have been retained in Earth's mantle during metal segregation [3]. To distinguish between these different processes and ultimately constrain the nature and composition of the late veneer, we initiated a systematic study of mass-dependent Ru isotope variations in meteorites and terrestrial samples. Ruthenium stable isotope fractionations may occur during processes in the solar nebula as well as during formation and crystallization of metallic cores in differentiated planetary bodies, including the Earth. As such Ru stable isotopes provide a promising new tool to link the late veneer to specific types of meteorites and to identify fractionation processes that might have affected highly siderophile elements in Earth's mantle during the late stages of core formation.

We obtained Ru stable isotopic data for a comprehensive set of iron meteorites and chondrites using double spike MC-ICPMS [4]. Iron meteorites reveal large Ru isotope variations induced during fractional crystallization of their parental cores. By contrast, all chondrites have indistinguishable Ru isotopic compositions, indicating that solar nebula processes did not result in significant Ru stable isotope variations. Thus, by comparing the Ru stable isotopic composition of the Earth's mantle to those of chondrites and iron meteorites it will be possible to assess whether iron meteorites contributed to the late veneer, and whether Ru in the Earth's mantle became isotopically fractionated due late-stage sulfide segregation during formation of the Earth's core [3]. This comparison will require measurements on primitive mantle rocks to determine the Ru stable isotope composition of Earth's mantle; these analyses are currently under way.

[1] Becker H. et al (2006) GCA 70, 4528-4550. [2] Fischer-Gödde M. and Becker H. (2012) GCA 77, 135-156. [3] Rubie D. et al. (2016) Science 353, 1141-1144. [4] Hopp T. et al. (2016) JAAS 31, 1515-1526.