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Ruthenium isotope constraints on the nature of Earth's late-stage building blocks

MARIO FISCHER-GÖDDE[1], CARSTEN MÜNKER[1], HARRY BECKER[2], WOLFGANG MAIER[3], KRISTOFFER SZILAS[4], CARINA GERRITZEN[5], MARTIN VAN KRANENDONK[6] AND HUGH SMITHIES[7]

[1]Universität zu Köln
[2]Freie Universität Berlin
[3]School of Earth and Ocean Sciences, Cardiff University
[4]University of Copenhagen
[5]Institut für Geologie und Mineralogie, University of Cologne
[6]Australian Center for Astrobiology, University of New South Wales
[7]Geological Survey of Western Australia

Presenting Author: mfisch48@uni-koeln.de

Ruthenium belongs to the group of highly siderophile elements (HSE:Re-Os-Ir-Ru-Rh-Pt-Pd-Au), which are key elements for studying core formation and late-stage accretion processes on Earth and other planetary bodies. Owing to their iron loving character, it would be expected that HSE would be almost quantitatively extracted to the core during metal-silicate differentiation. Hence, Ru and other HSE abundances in the mantle today are interpreted to derive from late accretion of a 'late veneer' consisting of meteoritic materials that were added to the Earth after core formation had ceased.

However, experimental studies revealed that the tendency of some HSE to bond with iron decreases significantly under high pressure and temperature conditions of core formation and that it would also be feasible to, at least partially, explain the mantle composition by incomplete extraction of HSE during late-stage core formation processes [1]. Thus, the Ru isotope inventory of the modern mantle may consist of a mixture of two different fractions: one deriving from the late veneer and the other fraction predating the late veneer. The pre-late veneer fraction has been identified in Archean mantle-derived rocks from SW Greenland (3.8-3.0 Ga) and komatiites from the Pilbara (3.5-3.2 Ga) and Yilgarn (2.7 Ga) cratons as it is distinct from the composition of the modern mantle (by +20 ppm) [2,3]. The presence of such pre-late veneer Ru on Earth opens a unique new perspective not only for assessing the nature of Earth's building blocks towards the end of its main accretion and before modification of the mantle composition by the late veneer, but also for constraining the nature and origin of the late veneer material.

The preserved Ru isotope vestige of the pre-late veneer mantle is best explained by late mixing of carbonaceous chondrite-like late veneer fraction into Earth's mantle. Towards the end of the Archean eon, the transition from a stagnant lid mode to a plate tectonic regime with deep reaching subduction caused efficient mixing of the late veneer component, resulting in a homogeneous modern mantle composition.

[1] Rubie et al. (2016) Science. [2] Fischer-Gödde et al. (2020) Nature. [3] Fischer-Gödde et al. (2020) Goldschmidt.