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Xe isotopes in Hadean zircons: constraining the Pu/U ratio of the early Earth

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Models of the origin and evolution of Earth, volatile transport in the mantle and development of the atmosphere require knowledge of noble gas compositions in the past. One important parameter for determining this is the initial Pu/U ratio. ^{244}Pu ($t_{1/2}$ = 82 Ma) is now effectively extinct in the solar system. Both ^{244}Pu and ^{238}U decay through spontaneous fission to ^{131,132,134,136}Xe. Modelling of the evolution of fissiogenic Xe ratios with time shows that plutogenic Xe will dominate at timescales >4.4 Ga, and uranogenic Xe from 3.8 Ga to the present. In theory the Pu/U ratio can be directly determined from measurement of xenon isotopes in samples from this era.

Detrital Hadean Jack Hills zircons have Pb-Pb ages up to 4.4 Ga and provide a potential window to the geochemistry of the very early Earth. Measurement of Xe isotopes in these minute zircons requires a very sensitive technique and we have recently shown evidence for in situ decay of ^{244}Pu in individual zircons (1). Variations in the inferred $(Pu/U)_0$ of specific grains are expected to occur either as a result of degassing of Xe, or igneous fractionation of Pu and U. We have neutron-irradiated a suite of zircons, allowing the simultaneous determination of the apparent Pu/U ratio and U-Xe age of each sample. Quantification of any degassing event experienced by the zircon is therefore possible. We show that the apparent $(Pu/U)_0$ varies up to a maximum of 0.011 in grains with concordant Pb-Pb ages, but that some have suffered significant Xe loss. Igneous fractionation may have played a role in the recorded Pu/U value of specific grains and we intend to investigate this by examining the REE patterns of each grain.

References: (1) Turner et al. (2004) Science, 306, 89-91.