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Noble gases in Archean hydrothermal quartz: probing mantle geodynamics and xenon atmospheric escape

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The composition of the Earth's atmosphere is an archive of the geological history of our planet, shaped by processes for which noble gases are excellent tracers [1]. The atmospheric $^{20}Ne/^{22}Ne$ ratio evolved through mantle degassing of solar neon into an initially chondritic atmosphere [2-4], with model predicting a ratio between 9.6 and 9.8 during the Archean [2]. Measuring the isotopic composition of paleo-atmospheric Ne therefore constrains mantle degassing history. Xenon also presents striking features: the modern atmosphere is strongly depleted in xenon relative to chondrites [5], and the Archean atmosphere was mass-dependently fractionated relative to the present day [6-8]. A model has been proposed in which xenon escape into space as an ion in an ionized hydrogen flux [9], implying a decrease of the xenon content over time and therefore a higher Xe/Kr ratio in the past [10]. Tracking this ratio may reveal the history of hydrogen escape and the oxidation of Earth's surface reservoirs.

In this study, we measured noble gases contained in fluid inclusions trapped in Archean hydrothermal quartz (3.3-2.7 Ga). After correcting for crustal contributions, we show that the $^{20}Ne/^{22}Ne$ ratio of the Archean atmosphere was slightly lower than today, consistent with a previous model [2]. It implies strong degassing event during the first billion years of the Earth's history [11]. We also show that the Archean atmosphere was up to 2 times more enriched in Xe than today, consistent with the escape model [9,11].

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