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Tracking Earth's geodynamical evolution with the isotopic composition of atmospheric argon: new constraints from post-impact hydrothermal quartz

GUILLAUME AVICE[1], FELIX VAYRAC[1], FANNY CATTANI[2], RAY BURGESS[3], MICHAEL W. BROADLEY[3], LUDOVIC FERRIÈRE[4], AARON J. CAVOSIE[5], NICK E. TIMMS[6] AND CHRISTOPHER L. KIRKLAND[7]

[1]Université Paris Cité, IPGP, CNRS

[2]Université Paris Cité, IPGP

[3]University of Manchester

[4]Natural History Museum Abu Dhabi, Abu Dhabi, United Arab Emirates

[5]Space Science and Technology Centre (SSTC), School of Earth and Planetary Sciences, Curtin University

[6]School of Earth and Planetary Sciences, Curtin University

[7]Timescales of Mineral Systems Group, Curtin University

The Earth's atmosphere records 4.5 Gyr of geodynamical evolution. Noble gases track this evolution because atmospheric isotopic ratios like $^{20}Ne/^{22}Ne$ and $^{40}Ar/^{36}Ar$ track physical processes such as volatile exchanges between the Earth's interior (mantle and crust) and its atmosphere [1-4]. However, a significant lack of data exists for the period between 3.0 Ga and 0.5 Ga, making it difficult to tune existing compositional models and test whether mantle outgassing or continental crust growth had the greatest impact on the atmospheric composition of argon. Recent studies revealed that post-impact hydrothermal minerals are reliable records of the composition of the ancient atmosphere [5]. The present study focuses on two new impact sites: Yarrabubba in Australia (2.2 Ga, [6]) and Dhala in India (2 Ga, [7]).

Analyses were performed by crushing experiments conducted on irradiated and non-irradiated quartz samples and laser step-heating experiments on irradiated samples. Crushing experiments on Dhala samples revealed a mixture between crustal and paleo-atmospheric gases with a derived $^{40}Ar/^{36}Ar$ ratio of 254±8 for paleo-atmospheric argon. Step-heating data define an isochron with an age of 2049±22 Ma and a trapped initial $^{40}Ar/^{36}Ar$ ratio of 260±2. We propose that at 2 Ga, the atmospheric $^{40}Ar/^{36}Ar$ ratio was 257±3. This result provides a new precise anchoring point on the argon evolution curve and is broadly in line with predictions from recent models [2,3]. Yarrabubba samples contain paleo-atmospheric gases but extrapolation to a chlorine-poor paleo-atmospheric end-member yields relatively imprecise $^{40}Ar/^{36}Ar$ ratios. An Ar-Ar age of 1.18 Ga obtained on a pseudotachylite sample suggests that the system might have been reset by fluid circulation event(s) during late Mesoproterozoic events as present throughout the Pinjarra orogen [8,9].

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