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Unlocking Earth's Atmospheric Past: Noble gases in paleo-atmospheric archives

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The Earth's atmosphere exerts a strong control on the habitability of Earth's uppermost layers. The atmosphere is also an integrated archive of the evolution of the entire planet. The history of the atmosphere remains largely unknown due to the lack of samples carrying a reliable record of the composition of ancient Earth's atmosphere [1]. Pioneering works by Pr. Grenville Turner and cie [2-4], as well as recent studies, have demonstrated that the elemental and isotopic compositions of atmospheric noble gases evolved under the influence of processes such as atmospheric escape, magmatic outgassing and subduction. I will: i) review the current state of knowledge on the evolution of the composition of the Earth's atmosphere, ii) what makes some geological samples reliable paleo-atmospheric archives [5,6], and iii) present new results on the evolution of the atmosphere. Isotopic evolution of atmospheric xenon is a potential tracer of hydrogen escape [7,8]. Analyses of 3.5 Ga-old barites suggest a stepwise evolution of the isotopic composition of atmospheric xenon. The overabundance of xenon [9] in the ancient atmosphere remains poorly determined. Post-impact hydrothermal minerals from the Dhala impact crater (2049±22 Ma) contain paleo-atmospheric argon with a $^{40}Ar/^{36}Ar$ value of 254±8. The evolution of atmospheric argon, due to mantle outgassing [10], could have slowed or even paused between 2.7 and 2 Ga, potentially reflecting a period of reduced geodynamic activity. [1] Avice, G., & Marty, B. 2020, Space Sci Rev, 216, 36. [2] Cadogan, P. H. 1977, Nature, 268, 38. [3] Rice, C. M., et al. 1995, Journal of the Geological Society, London, 152, 229. [4] Kelley, S., Turner, G., et al. 1986, EPSL, 79, 303. [5] Avice, G., et al. 2023, EPSL, 620, 118351. [6] Cattani, F., Avice, G., Ferrière, L., & Alwmark, S. 2024, Chemical Geology, 670, 122440. [7] Avice, G., Marty, B., Burgess, R., et al. 2018, GCA, 232, 82. [8] Zahnle, K. J., Gacesa, M., & Catling, D. C. 2019, GCA, 244, 56. [9] Broadley, M. W., et al. 2022, EPSL, 588, 117577. [10] Zhang, X. J., et al., 2023, EPSL, 609, 118083