Constraining the degassing rate of the mantle since 3 Ga using the deficit of xenon-129 in the ancient atmosphere

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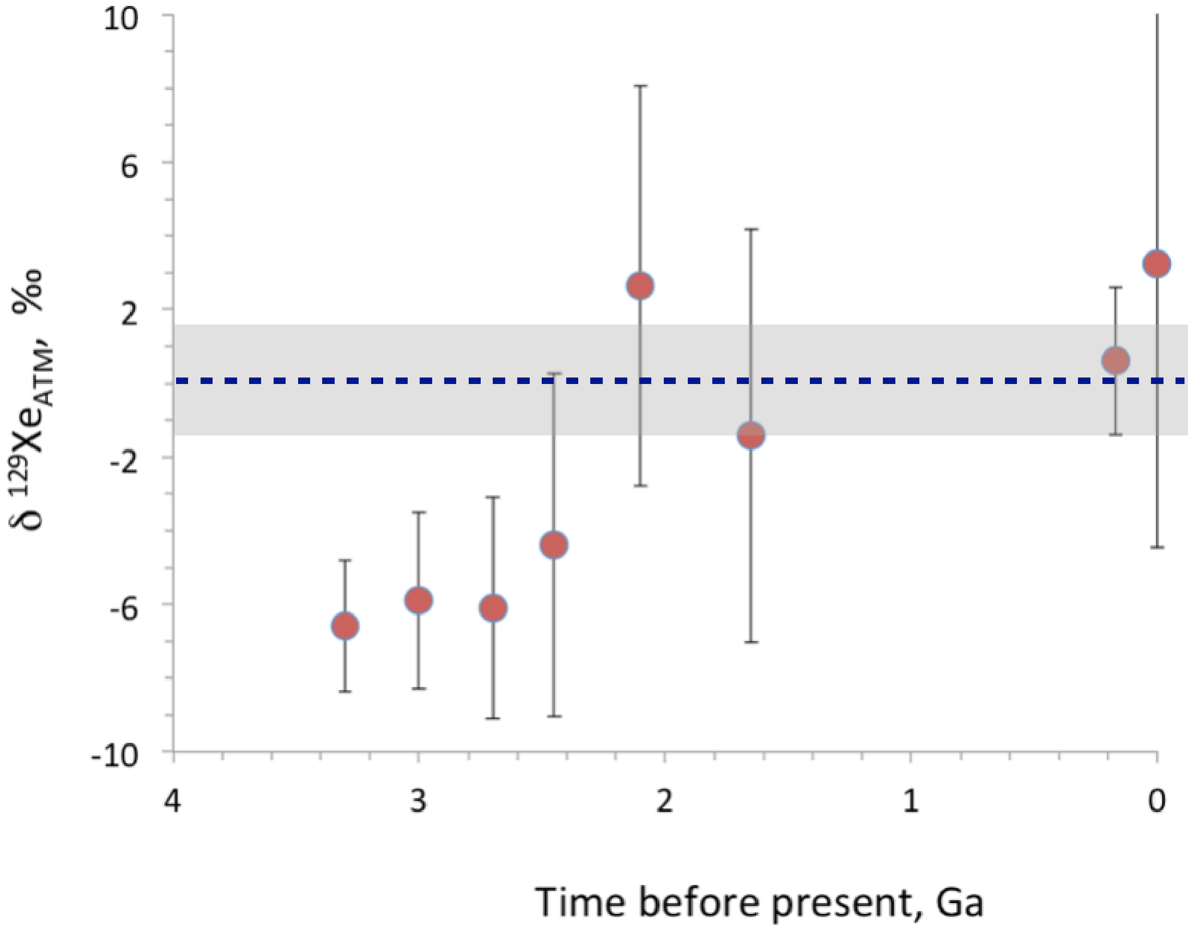
Degassing of volatile elements from the mantle to the atmosphere requires decompression melting, magma generation and degassing, and is therefore linked to mantle convection. Mantle convection is a physical process that tends to minimize temperature contrasts between the Earth's surface and the deep regions of the mantle. Hence its strength was variable through geological periods of time as it depended on heat generation within the Earth as well as heat dissipation to space. Convection of planetary mantles is a key driver of the evolution of planets and on Earth has been modulating the generation and stabilization of the continental crust. Still the thermal regime of the Earth, and notably the radiogenic/total heat production ratio (the Urey number) are not precisely known. It is related to the distribution of radioactive isotopes (mainly $^{238,235}U$, ^{232}Th, ^{40}K) among Earth's reservoirs which varied through time, on the latent heat of core crystallization, on the residual energy of accretion, and on the heat dissipation from the Earth's interior, which depends on mantle convection, a self-regulating process. Geological and geochemical observations have the potential to set constraints on variations of mantle convection in the distant time. Atmospheric xenon presents excesses in ^{129}Xe, an isotope contributed by the decay of extinct iodine-129 ($T_{1/2}$ = 16 Ma). Part of this excess resulted from early degassing of the mantle and, possibily from contributions of comet to early Earth. Mantle degassing also contributed ^{129}Xe to the atmosphere through time since the solid Earth is rich in ^{129}Xe compared to the atmosphere. In agreement with this possibility, remnants of the Archean atmosphere trapped in fluid inclusions (Avice et al *Nature Comm*, 2017, GCA 2018) and in organic matter (Bekaert et al Science Adv 2018) show that xenon in Archean air was depleted in ^{129}Xe compared to the modern composition (see Figure; error bars at 2 s; the grey area represents the reproducibility of air standards at the 2 slevel). However, this deficit cannot be accounted for by the modern degassing rate (as estimated from noble gas fluxes from the mantle), and requires degassing rates two orders of magnitude larger in the distant past than at present. This discrepancy implies a more vigorously convecting Archean-Proterozoic Earth, and suggests a potential impact on the composition of the Archean atmosphere. It also leads credence to models advocating a magmatic origin for drastic environmental changes like the great oxidation event.

Keywords: mantle degassing, Archean, noble gases


10
6
2
-2
-6
-10
4
3
2
1
0
δ 129XeATM, ‰
Time before present, Ga

