Methane Release, Regulation of Hydrogen Escape by Crustal Oxidation, Water and Carbonate Evolutions : a Mars'climate Chronology

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Methane has been observed at the 10 ppb level in Mars' atmosphere. We suggest that the present redox imbalance between the H and O escape fluxes is solved by taking into account the sink of oxygen through CH_4 oxidation. The present H escape rate is shown to be mainly driven by the oxidation rate of the crust, not by O escape. Assuming that CH_4 is produced by serpentinization in crustal hydrothermal systems, and that the hydrothermal activity is proportional to the volcanic extrusion rate, we reconstruct the past evolution of the hydrothermal release of hydrogen. It is shown that, since the late Noachian, the major driving mechanism for H escape has been the oxidation of the crust, not oxygen escape. During serpentinization, the oxidation of iron is accompanied by hydration of mafic rocks. From the known relationship between the water amounts involved in oxidation and hydration during serpentinization, we calculate the minimum initial inventory of water compatible with the present Martian D/H ratio. It represents a water Global Equivalent Layer of ≈500 m depth, whose ≈2% are lost to space, ≈4% consumed in crustal iron oxidation, 80% sequestered in crustal hydrated minerals, and ≈14% remain in the present hydrosphere (20 m GEL). Assuming that, like in terrestrial ultramafic rock-hosted hydrothermal systems, hydrothermal fluids result in carbonate precipitation when mixing with cold water, we suggest that substantial amounts of CO_2 have been removed from the atmosphere and converted into carbonates in crustal liquid water pools. The onset of volcanism at late Noachian or early Hesperian, generating high hydrothermal activity, would have resulted, together with crust alteration, in a net loss of CO_2, further converted into carbonates, with the irreversible disappearance of liquid water from the surface ≈3 Gyr ago. By analogy with present Earth, some microbial life could be hosted by Martian deep hydrothermal systems, and the present production rate of cellular matter could be as high as 3 kt yr^{-1}, with a total cumulated production rate of cellular matter of ≈60 g cm^{-2}. A significant fraction of the present Martian atmospheric methane could therefore be biogenic [1].

Keywords: Atmospheres, evolution ; Mars, climate ; Mars, interior ; Mineralogy ; Photochemistry.

References

[1] E. Chassefière and F. Leblanc, Icarus, submitted, 2009.