Can volcanism build hydrogen-rich early atmospheres?

P.K. LIGGINS[1*], O. SHORTTLE[12] AND P.B. RIMMER[134]

[1]University of Cambridge, Department of Earth Sciences
(*correspondence: pkl28@cam.ac.uk)
(os258@cam.ac.uk, pbr27@cam.ac.uk)
[2] University of Cambridge, Institute of Astronomy
[3] University of Cambridge, Cavandish Astrophysics
[4]MRC Laboratory of Molecular Biology, Cambridge

Hydrogen in rocky planet atmospheres has been invoked in arguments for extending the habitable zone via N_2-H_2 and CO_2-H_2 greenhouse warming[1], and providing atmospheric conditions suitable for efficient production of prebiotic molecules[2]. On these planets, volcanic outgassing can act as a hydrogen source, provided it balances the hydrogen loss rate from the top of the atmosphere. Here, we show that both Earth-like (Figure 1) and Mars-like planets can sustain atmospheric H_2 fractions of several percent across relevant magmatic fO_2 ranges, provided hydrogen escape operates somewhat less efficiently than the diffusion limit in some cases. We use a thermodynamic model of magma degassing to determine which combinations of magma oxidation state, volcanic flux and hydrogen escape efficiency can build up appreciable levels of hydrogen in a planet's secondary atmosphere.

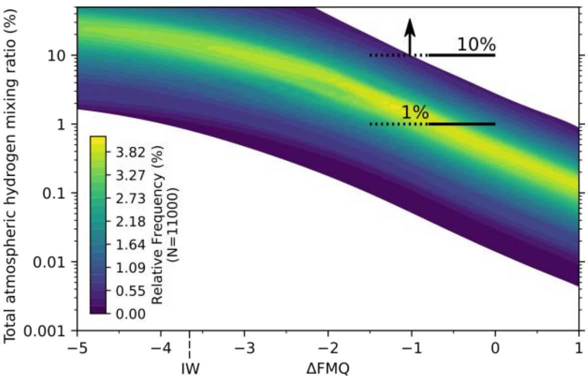

Figure 1: Relative frequency of volcanically sourced H_2 mixing ratios in a planetary atmosphere, as a function of magmatic fO2.

We suggest that an early Mars-like planet with magmas reduced compared to Earth (around IW) could sustain an atmospheric H_2 mixing ratio of ~5-10%, an amount sufficient to raise the mean surface temperature above 273 K.

[1] Ramirez & Kaltenegger (2017), *ApJ* 837, L4. [2] Miller & Urey (1959), *Science* 130, 245-251.