Geophysical Research Abstracts
Vol. 20, EGU2018-11263, 2018
EGU General Assembly 2018

Production of nitrous oxide by bolide impacts in a hydrogen rich atmosphere during the Hesperian

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Hydrogen (H_2) from volcanic emissions was required in the atmosphere to keep the Martian surface from freezing during the Hesperian period when the carbon dioxide (CO_2) levels dropped below 1 bar [1]. In addition it played a key role in the chemistry of the atmosphere; for instance, it would have enhanced the conversion of molecular nitrogen (N_2) into nitric oxide (NO) by bolide impacts by a factor of 3 or 4 in the presence of 10% or 20% H_2 in the atmosphere [2]. NO was therefore converted into nitrates and deposited in the martian surface [2]. Nitrates are essential ingredients to support a biosphere [3]. Curiosity has recently discovered the presence of nitrates in Hesperian lacustrine sediments at Gale crater [4]. The presence of H_2 during the Hesperian is required to explain the nitrate levels detected by the Curiosity rover [2]. Here we present experimental data and theoretical calculations that examine the efficiency of bolide impacts for production of nitrous oxide (N_2O) in atmospheres containing different CO_2/N_2 ratios with or without H_2. N_2O was produced with an energy yield of $1.9x10^{14}$ molecules J^{-1} in an atmosphere composed of CO_2/N_2=0.5 and 0% H_2; surprisingly, its yield was enhanced by a factor of 4 and 10 in the presence of 10% and 20% H_2, respectively. Thermodynamical calculations for the energy yield of N_2O based on a similar freeze-out temperature (2300 K) for NO and N_2O underestimates its production by about 3 orders of magnitude. N_2O is a powerful greenhouse gas that may have contributed to the warming of the early Martian atmosphere.

We acknowledge the National Autonomous University of Mexico (UNAM) grant No. IN109416, the National Council of Science and Technology of Mexico (CONACyT) grant number 220626, and the University of Paris 7 (Diderot) and 12 (Est Créteil) for their support. Some of the experiments described here were part of a lab course and were supported by a teaching grant from UNAM (PAPIME PE103216).

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