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Aeolian abrasion of rocks as a mechanism to produce methane in the Martian atmosphere

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Abstract

Seasonal changes in methane background levels and methane spikes have been detected in situ a meter above the Martian surface, and larger methane plumes detected via ground-based remote sensing, however their origin have not yet been adequately explained. Here we quantify for the first time the potential importance of aeolian abrasion as a mechanism for releasing trapped methane from within rocks.

1. Introduction

The Curiosity rover has measured background levels of atmospheric methane a meter above the Martian surface of 0.41 ± 0.16 ppb/sol with spikes of up to 7 ppb [8]. Ground-based observations suggest larger methane spikes (plumes) with an average peak of 33 ppb and a maximum value of 45 ppb [7]. The UV irradiation of meteoric-derived organic matter within surface sediments appears to be one of the most plausible mechanisms for producing low background levels of methane [5]. It has also been suggested that the release of methane from fluid inclusions in basalt during aeolian erosion could release detectable methane to the Martian atmosphere [5], yet to date, there has been no quantitative estimate of this flux. Further, the potential for the aeolian abrasion of sedimentary rocks to produce the methane concentrations detected by Curiosity and ground-based observations is completely unexplored, despite the presence of abundant sedimentary rocks on the Martian surface, including Gale Crater [3].

The average erosion rate on Mars between the Hesperian and present are of the range 1×10^{-5} - 0.01 μm yr^{-1} [6] while inter-dune field abrasion rates of local basaltic bedrock are in the range of 0.1-50 μm yr^{-1} [2]. Importantly, many terrestrial minerals and rocks contain gases trapped in discrete inclusions, fractures or within the grains themselves [5]. This includes not only igneous rocks, such as basalts, but evaporites and mudstones, all of which are exposed on the Martian surface [3]. A recent analysis of a range of Martian meteorites has confirmed the presence of methane gas trapped within Martian basalt inclusions, with coincident concentrations of other gases indicating a Martian origin rather than later terrestrial contamination [1].

2. Results

Fig. 1a), d) and g) and Fig. 2a), d) and g) show the methane flux from basalt and Martian meteorite samples over a period of 1 hour and 30 sols respectively. Over a time period of 30 sols, abrasion rates of 1×10^{-5} μm yr^{-1} and 0.75 μm yr^{-1} are unable to produce sufficient methane to compete with estimates generated from the breakdown of meteoritic material by UV irradiation [5]. Our results show the aeolian abrasion of terrestrial analogue sedimentary rocks have the potential to produce higher methane fluxes compared to basalt. However, the relatively high methane fluxes from the aeolian abrasion of sedimentary rocks are obtained by the use of terrestrial rock analogues that include organic-rich biogenic/thermogenic deposits.

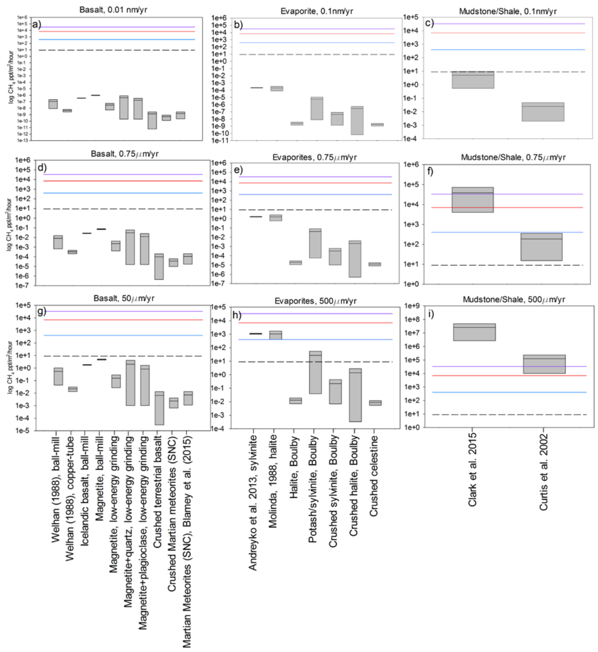

Figure 1. Estimated methane fluxes via aeolian abrasion in a one hour time period. Abrasion rates are from literature. Purple line: average (33ppb) methane flux of plume measured by ground-based observations [7], red and blue lines: peak (700ppb) and average (400ppb) values of methane measured by the Curiosity rover respectively [2], dashed line: methane flux from organic breakdown [5].

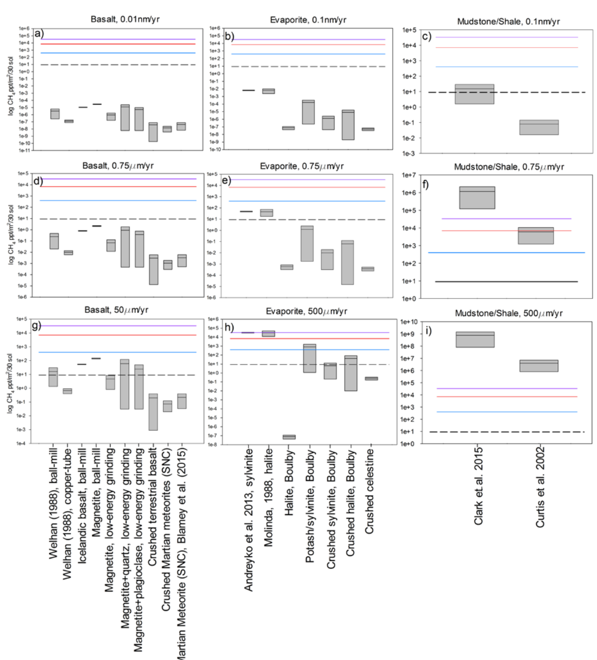

Figure 2. Estimated methane fluxes from the aeolian abrasion of analogue Martian rock samples using a period of 30 sols and assuming vertical mixing over the entire Martian atmospheric column. Abrasion rates and lines are as per Fig. 2.

3. Conclusions

It is concluded that aeolian abrasion of basaltic or sedimentary rocks on the Martian surface is an unlikely mechanism to produce methane concentrations detected by in situ observations from the MSL Curiosity rover and remote ground-based sensing observations. Hence, we suggest that other sources of methane gas must be inferred to explain both the seasonal variations in background atmospheric methane and higher concentration plumes detected on Mars.

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