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Destabilization of methane clathrate hydrate by meteorite impacts on present-day Mars

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The series of methane detection and non-detection in the atmosphere of Mars over the last two decades has raised numerous questions about methane generation and destruction mechanisms, which still remain unexplained. It has been suggested that Martian methane could have a biological origin and be generated by organisms living in the subsurface where conditions are more hospitable [1]. Methane could also be produced through several abiologic processes, including Fischer-Tropsch Type (FTT) reactions where H_2 reacts with CO_2 in the presence of a metal catalyst [2]. The H_2 necessary for the FTT reactions can be produced by several processes and notably by serpentinization [3]. Many of the proposed generation mechanisms for methane would take place hundreds of meters to several kilometers deep in the crust of Mars. Once produced, methane can migrate upwards and be either directly released at the surface or trapped in subsurface reservoirs, such as clathrate hydrates, where it could accumulate over long time before being episodically liberated during destabilizing events. These phenomena leading to surface degassing imply a change in temperature/pressure conditions of the methane reservoirs and are multiple: faulting and landslide generated by seismicity, impact, climatic changes...

In this study, we investigate the capacity of small-sized (a few tens to a few hundred meters diameter) impact craters to thermally penetrate the Martian ground and release methane through the dissociation of subsurface clathrate reservoirs. The impacts of small meteorite are more frequent on present-day Mars and could represent a likely process that would sporadically destabilize shallow gas reservoirs, inducing the degassing of methane in the atmosphere of the planet. We use a one-dimensional finite difference thermal model of the subsurface to calculate the depth of stable methane clathrate hydrates. The impact-induced heat, calculated using the Murnaghan equation of state, is then added to geothermal temperatures to obtain the post-impact temperature distributions similarly to [4]. We apply our model to different case studies in order to constrain the impactor radius, velocity and impact angle required to destabilize a subsurface clathrate layer that would discharge methane amounts corresponding to the observations.

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