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Martian methane and stability of clathrates in the crust of Mars

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Abstract

In recent years, methane was detected in the Martian atmosphere [4, 5, 6, 7, 9]. However, its origin is still unknown at present time and several mechanisms have been suggested to explain its presence on the red planet such as volcanic activity, contribution from meteorites and comets, photolysis of water in presence of carbon monoxide, hydrogeochemical processes or biological activity [1, 2]. Whatever the process of methane formation, past or present CH_4 can be stored in clathrates. These chemical compounds formed by water and gas are stable in the Martian crust and could serve as methane reservoirs. A change in temperature or pressure can lead to the dissociation of clathrates and thus the release of the trapped gas. The stability zone of clathrates approach the Martian surface with increasing latitude. Seasonal and interannual thermal oscillations could therfore destabilize clathrates at high latitude and cause the release of methane.

1. Introduction

Methane, observed at a level of 10 ppbv in Martian atmosphere, has a non-uniform distribution involving a lifetime of 200 days, smaller than the 300 years calculated by photochemical models [8]. Another interesting characteristic about methane is the correlation between the mixing ratios of water vapor and methane [6] that strengthens the existence probability of methane clathrates on Mars. Indeed, CH_4 concentration is higher where the water vapor is more abundant. In order to explain this phenomenon, the existence of metastable clathrates decomposing in the atmosphere and releasing methane has been suggested [3]. In this work, we focused on the stability of clathrates in the Martian crust. Current conditions of the red planet do not allow them to be stable on the surface but they can remain stable in the crust if they were formed below a certain depth depending on the surface temperature conditions. With the change in temperature inside the crust it is possible to obtain destabilization of clathrates.

2. Stability of clathrates

The region of the crust that meets the criteria for thermodynamic stability of clathrates is called clathrate stability zone. We calculated this stability zone in the present conditions of Mars for methane and carbon dioxide clathrates. We used the software CSMHYD [10] to obtain the phase diagrams of clathrates.

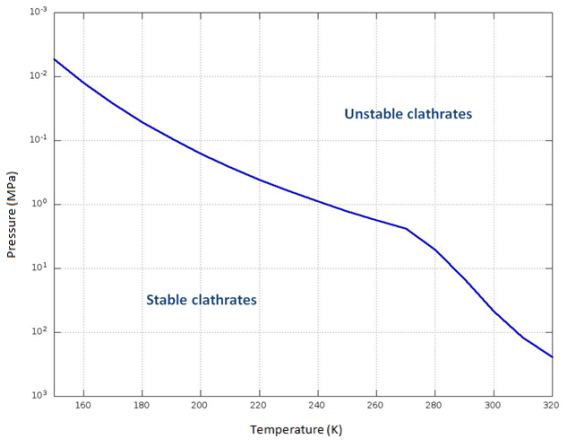

Figure 1: Phase diagram of methane clathrate obtained using the software CSMHYD [10].

We calculated the temperature and pressure variations in the crust of Mars by assuming that the latter was constituted of basalt with pores filled with ice. By comparing the phase diagrams with temperature profiles obtained, we were able to determine the depths of the start and the end of the methane and carbon dioxide clathrate stability zone in the crust for different latitudes. The results showed that the clathrate stability zone approaches the surface with increasing latitude (therefore increasing the possibility to have methane degassing near the poles) and that CO_2 clathrates were

formed at shallower depth than methane clathrates (therefore increasing the possibility to have methane if methane is mixed with CO_2).

3. Destabilization of clathrates

The temperature changes within the crust due to surface temperature variations can cause the destabilization of clathrates and release the trapped gas. We studied the destabilization due to seasonal surface temperature variations as well as changes in the planet's obliquity. The thermal oscillations caused by the variation of the obliquity could have destabilized clathrates at all latitudes while the seasonal or interannual thermal oscillations destabilize clathrates at high latitudes only.

4. Conclusion

Current conditions in the crust of Mars are favorable to the presence of clathrates. These chemical structures can serve as methane reservoirs and their dissociation could release CH_4 in the atmosphere of Mars.
Observed spatial and temporal variations of methane on Mars is not inconsistent with presence of clathrates whose stability zone varies as a function of surface temperature in seasonal and longer time scales.
In the present study, we considered a homogeneous soil. The composition and thermo-physical properties of soil vary spatially and the geothermal flux is likely not constant over the surface of Mars. We are currently investigating the changes in clathrate stability zone due to spatial variation of crustal temperature profiles and other effects such as the salinity of water.

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