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Detection of organic matter on Mars, results from various Mars missions, challenges, and future strategy: A review

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This review paper summarizes the literature on the organic matter detection by various Mars lander/rover missions, in order to understand the progress towards dealing with methodological challenges in the analysis of the Martian regolith and drilled mudstone samples. This paper shows that Martian missions are so far successful in detecting simple and some complex organic molecules, but their origin i.e., whether sourced by cosmic dust, meteoric bombardment, geochemical reduction of inorganic carbon during hydrothermal or igneous activity, or produced biologically in the ancient habitable Martian deposition environment, remains unknown. The preservation of organic matter in the Martian depositional realm has also been found as one of the biggest hurdles in its search. Therefore, upcoming ExoMars mission has been equipped with the instruments that would be able to drill and retrieve 2 m subsurface cores for organic matter analysis, with the assumption that the subsurface samples would have better chances of preserving original organic matter from the disintegration by ultraviolet (UV) radiation, galactic cosmic rays, and solar energetic particles. In addition to the method used for organic matter detection in previous missions [simple pyrolysis-GCMS and the use of combination of thermal combustion and derivatization (thermochemolysis)-GCMS], other alternative organic matter detection methodologies i.e., Raman spectroscopy (laser 523) plus deep resonant Raman and fluorescence spectroscopy are used in Mars 2020 Perseverance rover and will be used in ExoMars mission as well. Learning from the past and upcoming Mars missions will help in developing strategies and tools for the future Martian missions with goal to better understand it is ancient habitability.

KEYWORDS

Mars, organic matter detection, Vikings, Phoenix, Curiosity, ExoMars, extraterrestrial life, Perseverance

Introduction

There is compelling evidence that during the first half-billion years (4 to 3.5 Ga), Mars was wetter i.e., its surface and shallow subsurface hosted liquid water (Nisbet and Sleep, 2001; Baker, 2006; Greenwood et al., 2008). As a result, Mars has become the most promising target for astrobiological studies. However, the major question is how long this water must persist for life to evolve. Based on the Earth's geological record the estimated upper limit for the origins of life is considered 500 million years (Davis and McKay, 1996). Using a simple climate model, Davis and McKay (1996) determined that liquid water habitats on Mars could have survived for up to 500 million years under relatively thin ice covers with an atmospheric temperature below freezing point. Thus, the timeframe for liquid water on early Mars appears