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Editorial: Terrestrial field analogues for planetary exploration

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Editorial on the Research Topic
Terrestrial field analogues for planetary exploration

Field analogues for planetary exploration are terrestrial environments and/or associated geomaterials that share physical, chemical and/or geological similarities with modern or ancient extraterrestrial environments or with conditions or features that approximate those found on other planetary bodies. Field analogue sites are used to train astronauts, test instruments and/or assist the interpretation of observations made during space missions and as such are of crucial support for planetary exploration (Foucher et al., 2021). Some of these terrestrial analogues are characterised by extreme physical and chemical conditions (very high or low temperature, very high or low pH, etc.) and as such considered extreme environments as they are generally considered inhospitable for most (known) lifeforms (e.g. Cavalazzi et al., 2019; Cavalazzi and Filippidou, 2021). Such environments are inhabited by organisms known as extremophiles, which are mostly bacteria that can survive the extreme conditions and develop special metabolic pathways of great interest when searching for extraterrestrial life. Planetary scientists and astrobiologists use these extreme terrestrial environments as natural laboratories to explore the limits of microbial life as we know it, and as analogues for the study of similarly harsh environments on other celestial bodies, e.g. the Moon, Mars, asteroids and also exoplanets. The aim is to focus our search on where we can potentially find evidence of life and, if possible, how to unambiguously recognise it. This database of biosignatures is essential as a baseline comparison for information we obtain from past and future planetary missions (Westall et al., 2021).

Detailed characterization and understanding of terrestrial analogues are essential to prepare for upcoming and ongoing missions, including testing and improving technologies, developing workflows, protocols and space mission concepts, understanding human factors in space exploration, and understanding bio-geochemical processes and how microbiological activity is preserved as *biosignatures* in the rock record.

Foucher et al. (2021) identified the following categories of planetary analogues: 1) sites used for their planetary analogy; 2) sites used for analogies in their mechanical and chemical processes; 3) sites used for their petrological and mineralogical analogy; 4) analogue sites of astrobiological interest; 5) engineering analogue sites.

In this Research Topic, we present several analogues falling in the above-mentioned categories. Sites used for their petrological and mineralogical analogy with Martian environments, such as the basalts presented by Cogliati et al. In their work the authors used a basalt regolith simulant to test our ability to identify inorganic bio-signatures for life detection on early Mars. As mentioned before, terrestrial analogues might improve our ability to model physical and chemical processes occurring on other celestial bodies as they are used for analogies in their mechanical and chemical processes. This is the case of the new model for the ablation waves formed by ice sublimation presented by Carpy et al. Ablation waves are transverse linear bedforms that can be identified on several planets such as Mars (North Polar Cap) and Pluto.

The work by Schmidt et al., hinges on the terrestrial analogue as a scenario for testing hypothesis on geological and hydrogeological processes active on Mars. This work presents a model of groundwater circulation in a setting that is considered an analogue of the playa deposits on Mars, the Makgadikgadi Pans of Botswana. This environment has several analogies with Martian evaporitic deposits, and in this paper the authors deal with the interaction between geological structures, i.e. faults, with the upwelling of groundwater. The same site revealed a high potential as an engineering analogue site, as outlined in the work by Toledo et al. The authors tested a Radiation and Dust Sensor (RDS), which is part of the Mars Environmental Dynamics Analyzer instrument on board NASA's Mars 2020 Perseverance rover, in the extreme and dusty environment of the Makgadikgadi Pans. This paper highlights the importance of terrestrial field analogues in order to fully appreciate the data we are receiving from space missions and, in this particular case, helps understanding fascinating atmospheric phenomena such as the dust devils on Mars. Similarly, Ferrari et al. tested the Mars Multispectral Imager for Subsurface Studies (Ma_MISS) instrument in the Río Tinto (Spain), a river draining the largest acid province in the world. Ma_MISS is a miniaturized visible and near-infrared (VIS-NIR) spectrometer integrated into the drilling system of the ESA Rosalind Franklin rover mission that aims at the exploration of the Martian subsurface. This is an example of how field analogues can assist engineers improve instruments for planetary exploration and at the same time improve our understanding of biological communities living in extreme environments.

This Research Topic includes a review paper on impact craters, offering a new perspective to the study and exploitation of these well-known planetary analogues. Impact craters present morphologies and processes as well as high-pressure minerals that are common across the Solar System, but they also present a unique opportunity for training scientists and astronauts. The paper from Lambert and Reimold offers a new method for the assessment of the suitability of different terrestrial impact craters as geological and planetary training sites.

The goal of this Research Topic is to advance our knowledge of how terrestrial analogues can efficiently be exploited for the production of valuable benchmarking data for ongoing and future planetary missions and for testing instruments and techniques. The study of these extreme terrestrial environments has the potential to expand our knowledge of the processes to be expected on other planets and the type of evidence expected from the presence of extant or fossil water activity and associated microbial life. It is also our job to protect and preserve these analogue systems, to make a rationale use of them is critical (Marino et al., 2023) since we rely on planetary analogues to obtain a better understanding our own Planet and other planetary bodies.

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