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Editorial: Terrestrial analogues of extraterrestrial environments: Assessing habitability and biosignatures preservation

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Editorial on the Research Topic
Terrestrial analogues of extraterrestrial environments: Assessing habitability and biosignatures preservation

Understanding the beginnings of life and searching for it in elsewhere in the Universe include comparative studies of natural Earth-based environments that mimic relevant conditions in other parts of the Solar System. The Earth offers many places where geological, hydrological, climatic, and other environmental features exhibit environmental conditions similar to other planets or moons in the Solar System. It is increasingly evident that few lifeless places on the Earth's surface and in shallow subsurface exist, other than those at extremely high temperature, however extreme that environment may seem from a human perspective. These environments can help scientists study biological processes and their signatures at extremes of temperature, pressure, salinity, oxygen, water activity, acidity, alkalinity, and radiation. Such research is multi-disciplinary, requiring input from biology, planetary science and astronomy, as well as physical sciences. The six papers submitted under this inaugural article Research Topic to Frontiers in Astronomy and Space Sciences cover the latest research contributing towards our understanding of the habitability and biosignature preservation in these environments. One covers laboratory studies of potential diagenesis of organic material that might occur on Mars. The other five are based on field sites spread across five continents—North and South America, Europe, Asia, and Antarctica. Some of these sites, such as Rio Tinto, are well known from previous work. Others, such as Lonar Crater, have received only limited prior attention. The contribution "*Controls on Reactive Oxygen Species Cycles in Yellowstone Hot Springs: Implications for Biosignature Preservation on Mars*" of Hinman et al. is about controls on the cycling of reactive oxygen species, such as hydrogen peroxide, in Yellowstone hot springs and their implications for biosignature preservation on Mars. This study provides insights into iron mineralisation of microbial features in the surface geothermal environment of Yellowstone that may be relevant to searching for biosignatures in equivalent iron-depositing systems on Mars and Earth. The second contribution "*Microbial Metabolism of Amino Acids—Biologically Induced Removal of Glycine and the Resulting Fingerprint as a Potential Biosignature*" of Schwendner et al. examines the microbial metabolism of aminoacids, a key process in their diagenesis impacting the long-term preservation in the geological record on a planet with an active biosphere. The authors observed the biologically induced removal of glycine in microbial populations cultured from two sulfide karst springs in Germany.

The article of Lau et al. "*Microbial Metabolism of Amino Acids—Biologically Induced Removal of Glycine and the Resulting Fingerprint as a Potential Biosignature*" describes sulfur- and iron-rich mineralogical features preserved in permafrost of Ellesmere Island in the Canadian high Arctic. These, they argue, are possible analogues for the type of potential astrobiological targets that might be found on Mars. The sulfides are found in the bedrock carbonates and have been physically weathered to form an ice-cemented colluvium. Weathering of the sulfides is typical of gossan processes and forms a unique mineral assemblage of oxidised and reduced species that may host unique ecological niches. The contribution of Sklute et al. "*A Multi-Technique Analysis of Surface Materials From Blood Falls, Antarctica*" presents the results of a suite of spectroscopic and other analyses of surface samples from Blood Falls at the terminus of the Taylor Glacier, Antarctica. The brines of the subglacial spring contain dissolved ferrous iron, which rapidly oxidises to ferric species, giving the Falls their name. This temperature, hydrological, and chemical environment has been proposed as one of the closest terrestrial analogues to the Martian surface. The studies of the sediments show that the colour is due to the presence of amorphous Fe-rich nanospheres, not iron (hydr)oxides or iron-bearing carbonates as was previously thought.

The review "*Remote and in-Situ Characterization of Mars Analogs: Coupling Scales to Improve the Search for Microbial Signatures on Mars*," led by Harris et al., describes remote sensing and *in situ* characterization of five sites that are potential analogues for features in Gale and Jezero craters on Mars which, at the time of writing, were being explored by the Curiosity and Perseverance Mars rover teams, respectively. The analogue sites were in the Atacama Desert, Devon Island, Rio Tinto, Antarctic Dry Valleys, and Lonar impact crater. They found that the geochemical processes and signatures at the Atacama and Devon Island analogues appeared to be the most similar to those found in the Late Noachian to Early Hesperian rocks characterized by the Curiosity mission at Gale crater on Mars.

The last paper in this Research Topic is "*Diagnostic biosignature transformation under simulated Martian radiation in organic-rich sedimentary rocks*" by Roussel et al. This research report studies the diagenesis of organic matter occurring under high levels of simulated cosmic radiation. Organic-rich terrestrial shales were subjected to a gamma ray dose of 0.9 MGy, equivalent of 15 million years of radiation exposure on Martian surface. The study found that total organic carbon, carbon isotopes, and abundance of some molecular biomarkers did not significantly change as a result of the bombardment. However, the majority of key biosignatures was significantly degraded, with potential implications for the Research Topic and analysis of Martian organic material.

These articles provide a sample of the excellent Frontiers research activities across astrophysics, planetology, and the broader discipline of astrobiology. The Editors sincerely hope that everyone will enjoy this Research Topic.

Author contributions

JC wrote the Editorial. All other authors have made a substantial intellectual contribution to the work, and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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