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Editorial: Advances in Mars research and exploration

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Editorial on the Research Topic
Advances in Mars research and exploration

The pursuit of finding habitable conditions or life outside our planet has always been fascinating. In terms of habitability, Mars is the most Earth-like planet within our solar system as it displays comparable physical determinants such as radius, mass, and temperature, and physicochemical markers such as available energy, substrate stability, suitable chemistry, and past liquid stability. In addition, the Martian regolith and subsurface contain water in frozen and possibly in liquid or transient liquid states; Mars has moderate surface gravity to enable future colonization; and the Martian climate, although harsh, can still theoretically support life forms analogous to terrestrial extremophiles. Thus, Mars research and exploration holds a significant place in planetary sciences, advancing our knowledge beyond the Earth.

The interest towards Mars research and exploration has gained significant momentum in the past three decades owing to the advances in computing, hardware, remote sensors, public data availability, and outreach. The next stages of this exploration demand more multidisciplinary efforts to effectively use the vast planetary data being gathered using various missions, platforms, and techniques. With this overview, our Research Topic aimed to bring together research and reviews from the Mars community covering topics on geomorphology, atmosphere, geochemistry, and future exploration. The editorial team consisted of academics from early, mid, and advanced career stages, offering valuable perspectives and feedbacks throughout the editorial process. After thorough review, all the accepted papers in the present Research Topic were novel, comprehensive, and informative with emphasis on the systematic and recent advances in our knowledge, tools, techniques, and methods for Mars research and exploration.

Within Martian geomorphology and geochemistry disciplines, two papers were accepted for publication. The first such paper by Howari et al. investigates certain aspects of recurring slope lineae (RSL), the dark albedo features which are often interpreted as possible transiently flowing water on Martian surface. Using multisensory datasets from High Resolution Imaging Science Experiment (HiRISE), Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), Context Camera (CTX), and Mars Orbiter Laser Altimeter (MOLA), Howari et al. start with providing an updated global distribution map of RSL sites, and they further go on to perform a geomorphological and compositional analysis of Asimov and Hale craters, two confirmed RSL sites. Howari et al. also investigate the possibility of RSL activity due to deliquescence mediated by favourable temperature and humidity conditions, concluding that the local temperatures in Asimov Crater are high enough to allow deliquescence during the months of RSL activity with a water vapor column nearly five times higher than those measured before RSL appearance. The second paper addressing Martian geomorphology, authored by Chao and Zhibao, investigates the distribution characteristics and patterns of dune landforms. This study also took a multisensory approach, taking key inputs from CTX, Thermal Radiation Imaging System (THEMIS), HiRISE, and MOLA. The results from Chao and Zhibao indicate that the Martian dunefields are spatially distinct, scattered, and mainly concentrated in high-latitude and polar regions. Similar to their terrestrial counterparts, Martian dunes are mainly located in low-lying geomorphic units which favour sand accumulation. Based on these results, Chao and Zhibao conclude the limited sand supply as an important feature of the Martian dune development conditions, and their spatially scattered nature can provide important clues to understanding the Martian aeolian environment and evolutionary history.

The other published papers explored various aspects of the Martian electromagnetic and radiation environment. For example, Gonçalves et al. validate a model which is used to predict the radiation environment expected at different locations on the Martian orbit, atmosphere and surface, as a function of epoch, latitude and longitude. The model is called the detailed Martian Energetic Radiation Environment Model (dMEREM), developed for the European Space Agency, and it takes into account the specific atmospheric and soil composition, based on different particle propagation codes for primary Galactic Cosmic Rays or Solar Particle Events. Gonçalves et al. validate dMEREM with differential proton fluxes measured with the NASA Curiosity rover Radiation Assessment Detector (RAD) at the Gale Crater, at the surface of Mars. The authors report a good agreement between the proton fluxes measured at the surface with RAD and the corresponding dMEREM predictions, thus proving the usefulness of dMEREM in the assessment of the expected ionising radiation field on the surface of Mars. The only review article in this Research Topic, authored by Mittelholz and Johnson discusses the Martian crustal magnetic field, discussing its presence, magnitude, and significance from the Martian subsurface to its upper atmosphere. Research on Mars' crustal magnetic field can offer vital clues about the planet's interior evolution and surface crustal modification. While available datasets have provided useful information on the acquisition and modification of magnetization in the crust, the authors highlight several research gaps regarding the nature and origin of crustal magnetization, and the past of Martian magnetism. Mittelholz and Johnson also discuss the ways in which all these research questions can be addressed through laboratory analysis, modelling and new datasets.

Finally, two of the published papers aimed at future Mars exploration. The paper by Poian et al. argues in favour of the concept of science autonomy to reduce data redundancy. As a pioneering work in this domain, the authors develop a proof-of-concept for Mars Organic Molecule Analyzer (MOMA) instrument onboard the planned ExoMars rover, where MOMA will be able to perform selected onboard science data analyses and then act upon those analyses through self-adjustment and tuning of instrument parameters. Poian et al. also discuss the challenges and limitations of this implementation for future missions. Another paper by Abel et al. covers all the more important topic of *in-situ* resource utilisation (ISRU) for future Mars missions. The authors integrated climate data into a radiative transfer model to show the usefulness of photovoltaics-based power systems as an adequate and practical solution to sustain a crewed mission for an extended period and that too over a large fraction of the Martian surface. Thus, all the published studies in this Research Topic demonstrate the importance of different research and exploration activities aimed at improving our understanding of the Red Planet. Many progresses are expected in relation with the forthcoming exciting Mars missions which are supposed to target the current four goals, prioritised by the Mars Exploration Program Analysis Group (MEPAG), pertaining to Martian habitability, climate, geology, and preparation for human exploration.

Author contributions

AB and LS organised this Research Topic with valuable support from MB and AG. AB and LS initiated the first draft of the editorial with subsequent edits and inputs from MB and AG.

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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