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Synergies between geological laboratory analyses on the Moon and Mars

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Abstract

Human spaceflight opens up vast possibilities of scientific research on planetary bodies, such as the moon and Mars. While there is some debate as to which should be the first goal, the consensus is that both will be visited in the mid-term future. To ensure that manned missions to either Moon or Mars will yield a maximum scientific outcome, it is necessary to start the debate about what the scientific community would like to achieve on the moon and Mars, and what equipment would be required to meet these goals. Here, we will look at the most pressing open questions in the field of lunar and Martian geology and how to address them.

1. Introduction

Significant progress has recently been made in launch systems that could bring humans to the moon and to Mars in the not-so-distant future, and several institutes work on systems and system components to support human life on the surface of either planetary body. One of these activities is project MaMBA (short for Moon and Mars Base Analog) which is located at the ZARM in Bremen and dedicated to creating a full-scale, functioning habitat. One core element of MaMBA is the lab supporting geological analyses, among others.

Some analyses are best performed in-situ, during a surface EVA, and others require a sample return to Earth. Nevertheless, it is expected that the first surface habitats will contain a geology laboratory, which could be used for sample analyses, including for the purpose of improving sample quality, and the classification of which samples should be sent to Earth for more in-depth analysis. Previous sampling of lunar materials during the Apollo missions has been with the view of making all analyses back on the Earth.

Including a geology laboratory at a lunar or Martian base would face certain limiting factors such as weight of equipment, energy supply, need of consumables (e.g., gases, liquids), and qualification of the staff. However, the objective of this study is to give a general overview of what can be considered minimum requirement of instrumentation to achieve the necessary first order results.

The laboratory can be compared with what would be considered a well-equipped geology laboratory at a university or research institute with the difference that we will apply some limits concerning equipment size and staff requirements. We will focus on equipment that already has reached some minimization, for instance for robotic missions, and does not require whole teams of trained personnel.

2. Lunar Geology

The Moon is one of the most studied planetary objects; however there are still several major open questions about its formation, evolution, and geology [1]. In situ and continuous investigation of the moon interior structure, volcanic material, and regolith physical and chemical characteristics would help us answer those questions. The moon surface offers a prime analysis possibility of its own impact cratering history and consequently other inner planetary objects. Lunar regolith offers a record of a few Ga of space weathering which would not only increase our knowledge about regolith formation, but also about the sun and cosmic rays variation since the formation of the moon. A geology laboratory, would, in addition, allow a close study on the past volcanic activities.

3. Martian Geology

After four decades of orbital exploration of Mars surface, we have now clear evidence of the past presence of liquid water on the Martian surface [2]. In addition to the observation of fluvial valleys and crater lakes, aqueous minerals and evaporites have, as well, been widely detected on the surface. The presence of these minerals reveals that the climate and surface conditions at the time of their formation must have been different from the current one. In situ investigation of the surface and near surface material

would be crucial for increasing our understanding of the history of liquid water on Mars, which has direct implication on the search for life on the red planet.
Understanding the stratigraphical relation between various geological units, their chemical composition and mineralogy, the formation environment of the aqueous minerals and evaporites in addition to the chronology of surface events, and the interior structure of Mars are our main study goals for a laboratory situated on the Martian surface.

4. Lab Equipment for Moon and Mars

Given the aforementioned broader science questions for the moon and Mars, and bearing in mind the concept of the lab as a place for swift determinations before more detailed analysis of selected samples can be made on Earth, here we suggest the lab to be equipped with, at least, the following:

- First, for selection outside:

1. Visual inspection: high resolution portable camera in order to document the morphology and texture of areas of interest in close-up as well as landscapes. This would enable the possibility of further investigating the ROI in the lab. Tools for sampling, e.g., hammers, chisels, hand-operated core drillers, and lens, as well as sample bags and containers.
2. Cartography equipment such as mapping camera and GPS equivalent which would allow a wide geological investigation in combination to the orbital data.
3. Hand-held petrophysical tools such as susceptimeters.
4. IR spectrometer: for mineralogy characterization and identification of the igneous, hydrated, and evaporite minerals, in addition to comparison with remote sensing results.
5. GPR: to investigate the subsurface layers and potentially composition of material, in higher resolution than already obtained by remotely sensed data.

- Secondly, inside the lab:

6. Visual analysis: binocular magnifiers, with tools such as fluorescent light etc.
7. Capacity to cut and polish rocks of up to hand specimen dimensions (i.e., a cubic dm).
8. Equipment for semi-automated thin section production; for the analysis of thin sections and cut-and-polished rock slabs optical microscopes for both translucent and reflected light.
9. Mineralogy and microstructures: Scanning Electron Microscope coupled with an Energy Dispersive X-Ray (SEM-EDX).
10. VIS+IR imaging spectrometer: to examine crushed samples, their composition and grain size.
11. Raman laser spectrometer: To identify mineral phases at a small scale in a prepared sample.

5. Field equipment

The above mentioned list of instruments would serve as a generic “base lab” for answering a variety of geologic questions. In addition, some of the objectives above would require more specialized equipment installed outside of the habitat:

- Seismometer, heat measurement instrument.

As the moon and Mars have significant differences in term of exogenic surface processes, following separates field equipment between the moon and Mars.

- First, in case of the Moon:
  - Space Weathering: Small particle counter to quantify the micrometeorite flux on the lunar surface over time; portable ASD-type.
  - Lunar volatile content: To monitor the local volatile quantity and avoid contamination in a terrestrial lab, volatile abundances could be measured directly on the Moon, using Secondary Ion Mass Spectrometers (SIMS).
- Second, in case of Mars:
  - A weather station including measurement of wind, pressure, atmospheric composition, and composition variation.
  - Dust collector for later lab experiments on the composition and grain size.

6. Summary

We suggested a list of equipment that could help future astronauts perform geological analyses on the surfaces of the moon and Mars. Much of the equipment is very similar, with only minor differences between the two planetary bodies, meaning that instrumentation developed for the moon could be re-used on a mission to Mars.

References

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