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Introduction: Much of our knowledge about the history and evolution of the Moon stems from orbital and laboratory analyses of volcanic materials [e.g., 1,2]. Pyroclastics are our best source of information about lunar mantle composition and mineralogy, P/T conditions, and volatiles in the interior [e.g., 3,4]. The volatiles in pyroclastic glasses are also relevant for in situ resource utilization (ISRU) [e.g., 5]. Together with mare basalts that originate from comparatively shallower mantle sources, they provide complementary insights into the three-dimensional structure of the lunar interior. Other magmatic deposits bear clues to the crystallization of the magma ocean (e.g., Mg-suite rocks), relating to the formation and global distribution of KREEP [e.g., 6]. Ages of volcanic deposits, determined via crater size-frequency distributions (CSFD) and/or radiometric and exposure ages, allow reconstruction of the thermal evolution of the Moon [e.g., 7,8]. Other important questions address the ascent and eruption of magmas and the dichotomy of volcanic deposits between the nearside and farside [e.g., 9]. Evidence for evolved magmas, i.e., domes and silicic pyroclastic deposits is also present on the Moon, providing added key information on the geochemical, mineralogical, and thermal evolution of the Moon [e.g., 10]

Framework: Our mission concept is based on a lander and a rover, which will have similar technical capabilities as other current landers/rovers in terms of surface clearing, slopes, traverse length, etc. For operational simplicity, we restricted our landing site search to areas with continuous visibility of the Earth for direct communication. We favor spatially extensive and geologically diverse landing sites to fully exploit the capabilities of a rover. We envision a 100-200 kg-class rover that can carry a comprehensive suite of instruments and travel several tens of kilometers to return samples to the lander for further in situ studies or sample-return to Earth. The lander could perform ISRU technology demonstrations as well as geophysical measurements (heat flow, seismic, magnetization) and geochemical analyses of samples (e.g., in situ radiometric age determination with a laser ablation resonance ionization mass spectrometer [11]). The rover could carry sampling tools and a suite of instruments (e.g., LIBS, Raman, IR-spectrometer, multispectral stereo camera) to characterize and pre-select interesting samples. A ground-penetrating radar that operates continuously while the rover moves would yield information on the sub-surface regolith structure [12].

Surviving lunar night would enable more in-depth investigations, a larger spatial coverage by the rover, and the opportunity to perform long-term measurements, for example of heat flow or seismic activity. Thus, we envision that both lander and rover are able to survive the lunar night.

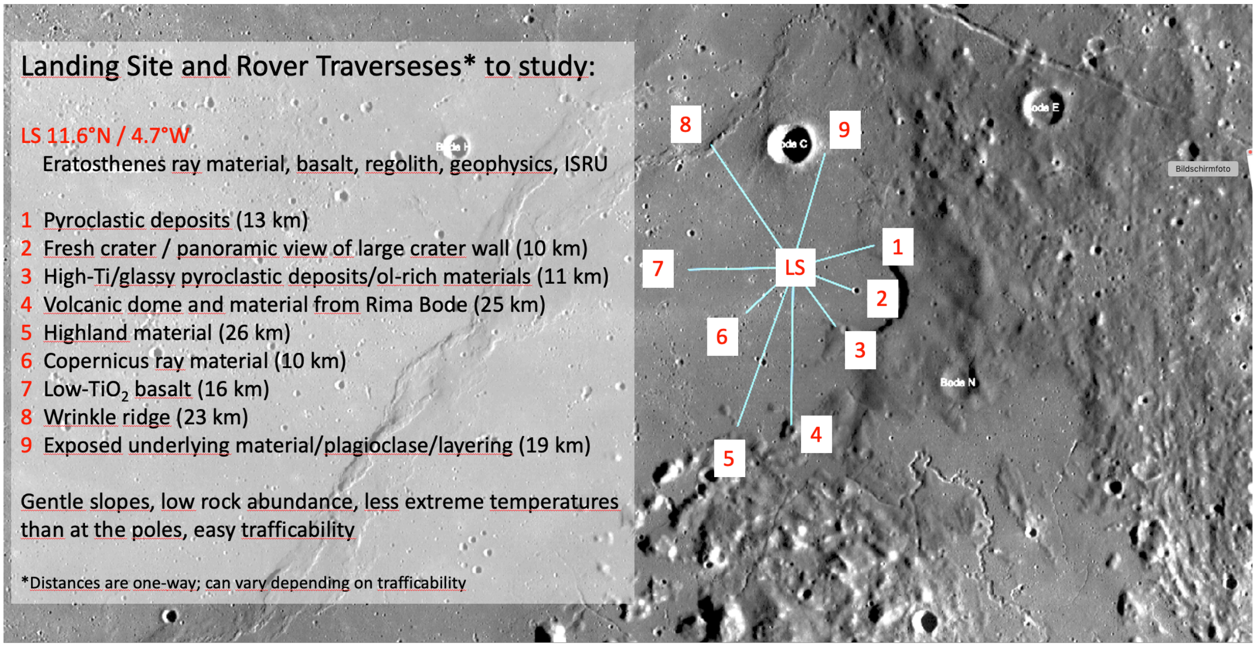
Objectives: With our mission concept, we aim to comprehensively study lunar volcanism with respect to timing, spatial distribution, composition, mineralogy, eruption style, volumes, and ISRU potential. Mission goals include deployment of a geophysics package and testing of ISRU technologies. Table 1 summarizes some aspects of our mission concept and also includes a list of potential instruments to achieve goals and objectives.

Landing Site: We present a candidate landing site south of crater Bode C (Fig. 1), which is low risk in terms of rock abundance and slopes. Compared to previous mission proposals to this general area [e.g., 13], we propose a landing site further to the south (11.6°N / 4.7°W) in order to study pyroclastics, mare basalts, and the local regolith, in addition to Eratosthenes and Copernicus ray materials as well as highland material. Along several traverses, the rover could access: 1) pyroclastic deposits (within 13 km distance of the landing site), 2) a fresh crater and a panoramic view of a large crater wall (10 km), 3) high-TiO_2 or glass-rich pyroclastic deposits and olivine-rich materials (11 km), 4) a volcanic dome and material from Rima Bode (25 km), 5) highland material (26 km), 6) Copernicus ray material (10 km), 7) low-TiO_2 mare basalts (16 km), 8.) a wrinkle ridge (23 km), and 9) exposed underlying plagioclase-rich material and potential layering in a crater wall (19 km).

We estimate that during 1 year of operations, we can travel tens of kilometers and collect tens of kilograms of rock samples either for return to Earth or for in situ analyses on the lander. After landing, we would immediately sample the site vicinity and store a contingency sample in the return canister or feed the analytical instruments on the lander before the rover embarks on its traverses. Although some in situ analyses will be performed, we prefer that the larger part of the samples will be returned to Earth. We consider 1 year of operationality as minimum because our geophysical package (e.g., heat flow, seismometer, magnetometer) will benefit tremendously from longer-period observations.

Table 1. Some of the science objectives, functional requirements, and instruments of our mission concept

SCIENCE OBJECTIVES	FUNCTIONAL REQUIREMENTS	INSTRUMENT
Study the geological context	Stereo, multispectral imagery of landing site, traverses, and sampling stations	Multispectral stereo camera (MSC), IR spectrometer
Identify samples for sampling and characterize their context	Stereo, multispectral images; compositional information	MSC, IR spectrometer, LIBS, Raman, Micro imager
Sample volcanic material	Arm with a sieve to collect 1-2 cm sized pebbles from at least 5 stops along each traverse; storage and sealing in sample container	Flexible robotic arm with a sieve; Storage container
Return samples to Earth for detailed analyses	Store samples in return container; delivery to Gateway or Earth	Ascent stage, sample container, arm to manipulate samples, camera
Derive information on sample ages	Isotopic measurements to derive radiometric ages	Mass spectrometer
Perform in situ geochemical and mineralogical analyses	Stereo, multispectral images and compositional information from beneath the rover, continuous operation when rover is moving	MSC, IR spectrometer, LIBS, Raman, Micro imager
Study the subsurface along the traverses	Produce radar profiles along the traverses to provide information on the regolith structure	GPR
Determine geophysical properties at the landing site	Measure heat flow, remanent magnetization, and seismic activity	Heat flow probe, magnetometer, seismometer
Determine physical properties of regolith	Measure how deep the rover sinks into the regolith by monitoring at least one wheel while driving	Camera
Test ISRU potential	Measure the abundances of O_2 and H_2 that can be produced from regolith samples	ISRU plant, rover arm for sample manipulation


Landing Site and Rover Traverseses* to study:

LS 11.6°N / 4.7°W
Eratosthenes ray material, basalt, regolith, geophysics, ISRU

1 Pyroclastic deposits (13 km)
2 Fresh crater / panoramic view of large crater wall (10 km)
3 High-Ti/glassy pyroclastic deposits/ol-rich materials (11 km)
4 Volcanic dome and material from Rima Bode (25 km)
5 Highland material (26 km)
6 Copernicus ray material (10 km)
7 Low-TiO_2 basalt (16 km)
8 Wrinkle ridge (23 km)
9 Exposed underlying material/plagioclase/layering (19 km)

Gentle slopes, low rock abundance, less extreme temperatures than at the poles, easy trafficability

*Distances are one-way; can vary depending on trafficability

Fig. 1 Location of the proposed landing site and schematic traverses south of crater Bode C

Conclusions: On the basis of our preliminary landing site assessment, we find the region south of crater Bode C to be safe and scientifically of high interest in order to better understand volcanic activity on the Moon. With the capabilities of modern lander/rover (e.g., EL3, VIPER, LUNA, Chang'e), major scientific advancement could be achieved and various techniques of ISRU could be tested in preparation of a human lunar outpost at the Moon. Knowledge gained in both fields, science and exploration, would feed forward into human exploration beyond the Earth/Moon system.

References: [1] Jaumann et al. (2012), Planet. Space Sci. 74; [2] Spudis (2015), Encycl. Volcanoes; [3] Saal et al. (2008) Nature 454; [4] Shearer and Papike (1993), GCA 57; [5] van der Bogert et al. (2020) ELS; [6] Shearer et al. (2006), Rev. Min. Geochem. 60; [7] Wieczorek et al. (2006) Rev. Min. Geochem. 60; [8] Ziethe et al. (2009), Planet. Space Sci. 57; [9] Head and Wilson (2017), Icarus 283; [10] Jolliff et al. (2011) Nature Geosci. 4; [11] Anderson et al. (2015), Rapid Comm. Mass Spectrom. 29; [12] Head and Wilson (2020) Geophys. Res. Lett. 47; [13] Spudis and Richards (2018) LLW2018-21.