FUTURE ROBOTIC STUDY OF LUNAR BASINS: GOALS FOR GEOCHEMISTRY AND GEOPHYSICS.

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Geology and geochemistry of lunar basins: Various proposals have been made during the past decade for lunar landers and rovers. We present a summary of the scientific goals for geochemistry and geophysics and related technical requirements for future lunar lander missions, focused on the lunar maria, in order to contribute to the previous made and new proposals. Important questions that remain unresolved from our existing data are related to the origin and age of mare basalts, the solidification of the magma ocean, global variation in chemistry of mare basalts, and the positive gravity anomalies (mascons) and isostatic state of the basins.

Compositional studies: The chemistry and mineralogy of mare basalts represent those of the lunar mantle and are therefore of high interest to deduce the internal structure and evolution of the Moon. It has become clear from previous missions that strong lateral variations in chemistry of the mare basalts exist [1]. Radiometric dating will be useful to study the inhomogeneous distribution of elements in relation to time. Stable isotope analysis and radiometric dating will contribute to understanding of chemical evolution and global variation of the magma ocean, magma mixing processes, and thermal evolution. Detailed radiometric dating of impact melt and mare basalts for various basins will clarify the timescale of mare volcanism and the time gap between basin forming impact and volcanic activity (±500Myr [2]). Heat flow measurements are required to determine the role of radiogenic heat in mare volcanism at the Procellarum KREEP terrane and will provide information on the evolution and thermal state of the Moon as well.

Gravity and internal structure: Most circular basins coincide with regions of large positive gravity anomalies or mascons [3]. The current consensus is that mascons result from a mantle plug caused by isostatic adjustment after the basin forming impact and basin infill of dense mare basalts. Thickness of the mare basalts and depth of the crust-mantle boundary are significant inputs in the current models and have been determined only indirectly from combining gravity with topography and basin morphology. New subsurface images are required to complete our existing models.

Instruments for future missions: We now propose four types of instruments to make the investigations that are mentioned above.

Element analysis: We argued that spectroscopy of the surface is necessary for further understanding of lunar geochemistry. In situ robotic analysis however faces technical challenges. Most spectroscopic instruments that are currently used (e.g. XRF, XPS, electron microprobe) are large and significantly too heavy to serve as payload on a planetary mission. Recently however, spectrometer design has made major progression with the Raman/LIBS instrument that is currently developed for ESA's ExoMars mission.

Isotope analysis: Previous work on samples of lunar basalts has been done with Sm/Nd, Rb/Sr, U/Pb and tungsten isotopes. These methods provide a good coverage of isotope systems, but the number of sample locations is limited. In situ isotope analysis and radiometric dating for different basins is favorable, but faces technical difficulties. Current mass spectrometers are too heavy for payload on planetary missions and hence sample return followed by isotope analysis on Earth seems currently more realistic.

Subsurface imaging: Current subsurface images of the Moon result from the Apollo lunar sounder experiment (ALSE) and were made using ground penetrating radar. The depth range of this instrument type is however limited (2 km) and in order to investigate moho depth (below basins >20 km [4]), other techniques are thus required. Reflection seismology forms a good alternative. We propose a rover that places geophones around a basin and collect the signal that they record from moonquakes. In order to record active seismometry, the rover can place a seismic source as well, for example vibroseis instruments. It has been argued by Lognonné [5] that the meteorites may produce a sufficient amount of energy to function as a seismic source.

Heat flow measurements: We explained that heat flow measurements would contribute to the study of the thermal state of the Moon. Furthermore this will record geophysical properties of the regolith like electrical conductivity and permittivity. A package for heat flow measurement includes a penetrator that places the recording instruments at a depth of few meters within the regolith. A certain package is currently being developed for the ExoMars mission (i.e. HP^3). We suggest this package as a model for development of future lunar robotic instrumentation.

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