AN UPDATE ON THE MOON DIVER MISSION: FIELD TESTS AND INSTRUMENT REQUIREMENTS.

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Introduction: The Moon's lavas provide a rare window into planetary differentiation processes. However, lunar lavas are difficult to access because they are covered by a thick layer of regolith almost everywhere on the lunar surface. Moon Diver is a planetary mission concept aiming to use an extreme terrain rappelling rover called Axel to descend into a 125-m-deep pit in Mare Tranquillitatis [1,2] to study the lava layers exposed in cross-section [3]. The instrument suite includes two rover-mounted camera types: a "FarCam" designed to image the far side of the pit, a set of "CloseCams" to image the near-side of the pit. Axel also carries a Multispectral Microimager (MMI) [4] to observe the mineralogy of the near-side wall, an Alpha Particle X-ray Spectrometer [5] to observe the elemental chemistry of the wall, and a "Surface Preparation Tool" (SPT). On the lander are three lander cameras: one to observe the egress of the rover from the lander, and two cameras to capture the topography of the pit as the lander descends. In order to prepare for this potential mission, the Moon Diver team has fielded several versions of the Axel rover at terrestrial analog terrains and studied the payload instruments in order to produce instrument requirements that meet the objectives of the mission. In this work, we will discuss what can be learned about the lunar interior from observations of a lava stratigraphy, experiments done to understand the effects of measurement error on petrological analyses, synergies between X-ray spectroscopy and VIS/NIR spectroscopy, and the lessons learned from deploying various instantiations of the Axel Rover over steep basaltic cliffs at multiple field sites.

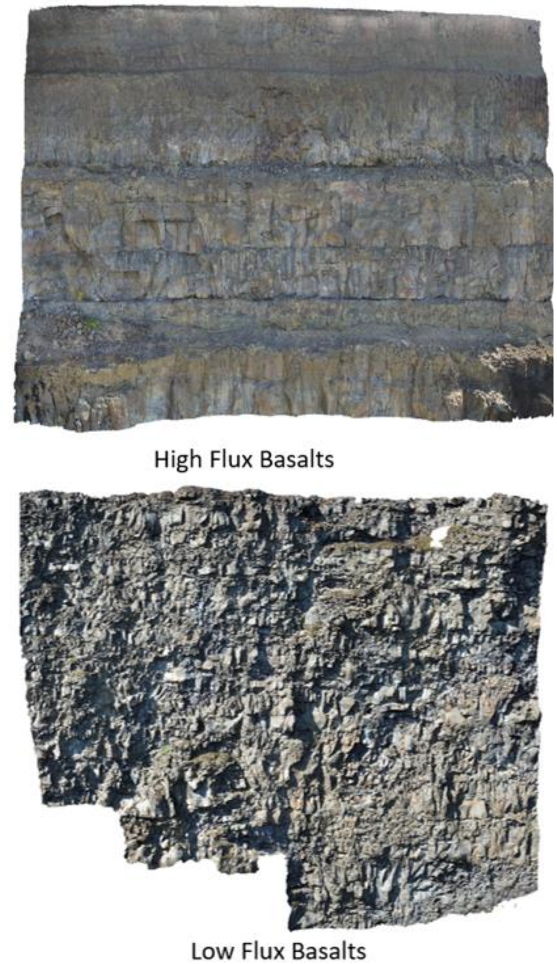

Figure 1. Examples of low flux and high flux basalts from the Columbia River Basalts (top) and a complex flow-field at Ásbyrgi, Iceland. Both walls are approximately 60 m tall.

Observations of lava stratigraphy: The lunar maria are mostly flat, featureless plains of basalt, with the few well-defined lava flows extending for hundreds of kilometers [6]. Previous authors have suggested that the lunar maria flows are thick because they have a high volume flux. Lunar magmas, which should be negatively buoyant in the low-density lunar crust, would accumulate near the bottom of the crust until overpressure caused a dike to propagate to the surface, after which they would emerge at a high flux [7]. Shallow magma chambers which feed typical low-flux eruptions should be rare, as the lavas will generally not be neutrally buoyant within the crust. Melts that stall in the crust are not likely to be erupted. However, meter-scale layers are visible in the walls of lunar pits, and the thickness proposed for mare basalt lava flows has ranged significantly, from sub-meter to 455 m [1,8]. High-flux lavas from the mantle would be more likely to deliver mantle-derived magmas (more representative of their source region), while low-flux lavas from shallow reservoirs would be more likely to come from a complex mush system with increased probability for magma mixing and complex phenocrysts. The type of data derived from the FarCam instrument (**Figure 1**) would be suitable for distinguishing between these two end-members. The Moon Diver team collected imagery and topography of about 10 lava walls in order to determine the camera resolution that is needed for this task from a distance of ~100 m (the diameter of the pit). Meanwhile, the MMI and APXS can be used to assess the origins of the lavas through petrographic analysis. For example, if the lava is glassy, or if the mineralogy of the lavas matches what is expected by crystallizing a melt with its APXS-derived bulk composition, then the lava is more likely to be a "liquid composition", more representative of the source. However, if these instruments reveal complex phenocrysts or a bulk composition suggestive of magma mixing or assimilation, it is not likely to represent a liquid composition.

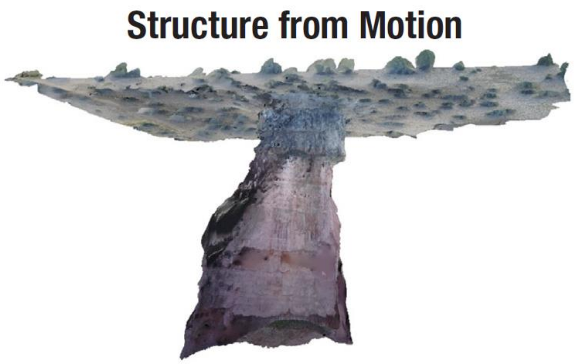

Figure 2. 3-D reconstruction of a terrestrial pit.

Errors and Synergies Between Rover Contact Instruments:

The APXS instrument is more accurate when it is measuring a homogeneous sample, especially a powder or a glass [9]. In this mission, it would be measuring potentially in-situ rock compositions, whose heterogeneity can introduce error. However, if the compositions and locations of the minerals within the sample rock are known, the accuracy of the APXS measurements can be improved. MMI provides a map of mineral phases so that Moon Diver can learn from a gamut of samples all the way from homogenous glass to coarse crystalline or porphyritic samples.

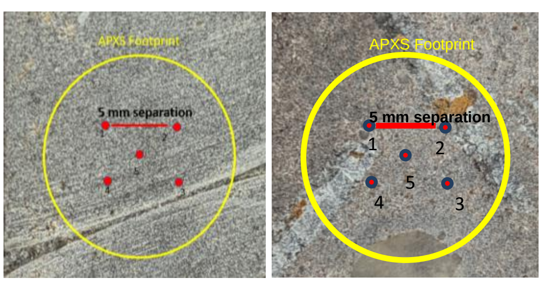

Figure 3. Two example samples analyzed with MMI and with an APXS analog instrument. (Left) A homogeneous sample. If the central measurement point is moved around by 5 mm, it doesn't make a significant different in the bulk composition. On the other hand, a very heterogeneous sample with large phenocrysts (Right) changes significantly with instrument placement.

Lessons Learned from Rover Deployment:

Various Axel Rover prototypes were lowered down lava layer walls. The reconstruction of the wall is easiest for FarCam images, because of the distance from the target and gradual change of perspective with descent. In order to get good image alignment and 3-D reconstruction for the near wall, images should be taken at a time of day to avoid both the shadow of the rover and lens flares. The rover should be lowered very slowly, so that there is plenty of overlap of images. Even so, image continuity can be lost if the rover goes over a lip or crosses bland terrain without significant visual landmarks. Such patches need to be aligned manually. The team continues to improve the process for reconstructing descent topography.

Future Plans: The team is currently working on a project to study how the rover would be operated by the mission team and the decision-making structure that would be needed to navigate these unusual vertical terrains under the time-constrained scenario of a mission lasting only one lunar day.

References:

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Additional Information: Parts of this work were completed at the Jet Propulsion Laboratory, California Institute of Technology.