HOW TO SAMPLE AN ALIEN WORLD? LESSONS FOR EUROPA FROM APOLLO 16. D. M. Persaud[1] and C. B. Phillips[2], [1]University of Glasgow, UK, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (divya.persaud@glasgow.ac.uk).

Introduction: In planetary exploration, once a landing site has been selected and a mission has successfully landed, one of the next decisions will be sampling location. Stationary missions that do not have the benefit of mobility, such as pathfinding landers to ocean worlds like Europa, and those limited by surface lifetime, will require some degree of autonomy in the selection of sampling locations within a reachable workspace [1].

In this work, we investigate the sampling sites of Apollo 16, treating the Moon as our best Europa analogue. We use archival data and imagery of four Apollo 16 sites and their respective core samples to constrain how the surface appearance of sampling sites couples with subsurface geology.

Case study: Our case study comprises the Apollo 16 drive tube core samples and the four sites at which they were taken: 60010/09 and 60014/13 at Station 1; 64002/01 at Station 4; and 68002/01 at Station 8. Each of these cores is a double core, consisting of two vertical segments for a total depth of 60–65 cm.

First, we annotated the 70 mm Hasselblad images of the core locations using the annotations in various Apollo 16 reports, with further annotations using known sizes of objects in-scene (e.g., boot-prints, the width of the core tubes, tire tracks) (Fig. 1a).

Next, we used the sample site descriptions in the Apollo interagency reports and catalogs to define first-order "bins" that could define the geology of these sampling locations. We focused on two categories, grain size and shape, based on the description overlap with the Apollo 16 sample core documentation. Using these bins, we classified each of the four locations, calculating first-order percentages within each core. For two of the cores (60010/09 and 60014/13), the textual descriptions were poor. To address this, we used the annotated imagery at the sample site of 60010/09 to calculate the percentage of rocks > 1 cm to adjust the bin assignments, and used this calibration of textual description to numerical value to assign bins to 60014/13.

We then repeated the process with the cores using the X-ray stratigraphic columns and unit descriptions (Fig. 1b). We used the X-ray columns due to the availability of these columns in the Apollo 16 reports, and lack of consistent, post-dissection sedimentological descriptions in the literature, although this is a subject for future work. We first identified generalized units based on similar grain sizes and other characteristics, due to the high granularity of the stratigraphic descriptions, and then classified each unit per the pre-defined bins to calculate percent distribution of size/shape for each core.

Finally, we graphed these size/shape bins vs. percent fraction for these four datasets for comparison.

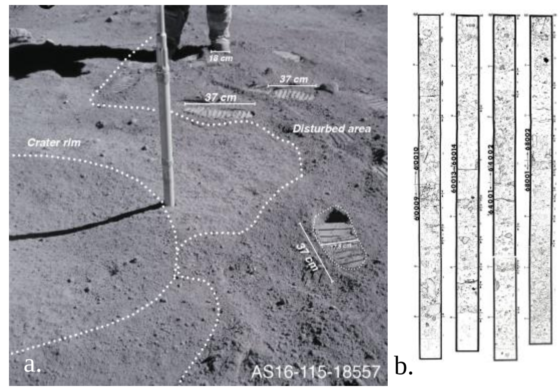

Fig. 1. *(a) Apollo 16 image AS16-115-18557 showing the sampling site for core 60010/09, overlaid with annotations from known measurements and notes from the Apollo 16 documentation. (b) X-ray images of 4 core samples from Apollo 16, aligned and scaled to each other for comparison.*

Results: Fig. 2 shows the resulting plots of size and shape distributions at each of the four sites for the surface and the core sample.

For size, < 1 cm is dominant in all of the cores as well as most of the surface areas, although more dominant for three of the cores. The surfaces at the sites also show a wider distribution of sizes. We interpret this as partly having to do with the mechanics of the drive core, as the core tube is 4 cm in diameter; the sampling process necessarily precludes rocks bigger than a few centimeters from becoming entrained by the core tube, which will bias the size distribution in the column.

Core 68002/01 is characterized by grain sizes 1–4 cm dominantly, and < 1 cm secondarily. This is interpreted as ejecta deposits in the upper surface from the local, 10–15 m-diameter impact crater two meters away [2]. Archival reports also describe potential impact horizons at depth indicating other impacts. Contrast this with 64002/01, which sampled the South Ray ejecta blanket, showing, as with 60010/09 and 60014/13, larger grain sizes at the surface and dominantly < 1 cm grains in the core.

For shape, 60010/09 and 60014/13 are similar in both the core and surface data, showing a mix of subrounded/subangular grains, with some angular fraction in the surface material at 60014/13. Core 64002/01 is 100% subangular while the surface material ranges from well-rounded to subrounded and angular, once again more uniform in the subsurface than the surface.

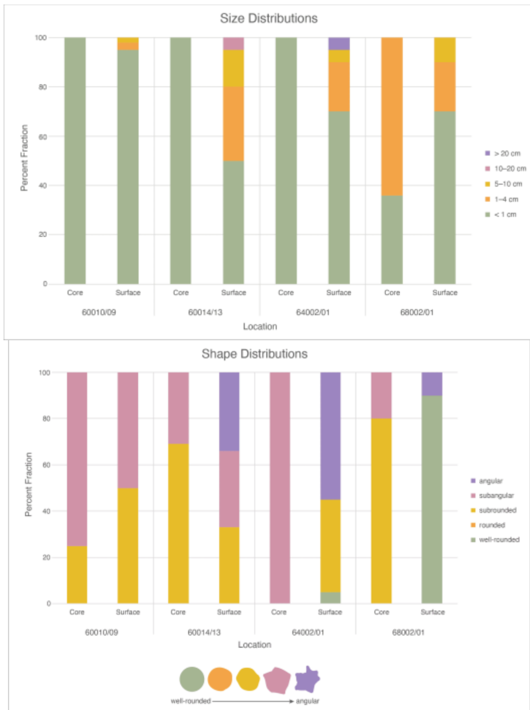

Fig. 2. *Size and shape distributions for the four core samples and their respective surface sites, with the size/shape bins indicated by color.*

Similarly, core 68002/01 is dominated by subrounded grains (with a small fraction of subangular, the delineation of which traditionally being subjective), while the surface material is dominated by well-rounded grains with an angular portion, and nothing of the intermediary classifications. (We note that the size distribution of 68002/01 appears to be different from the size distribution reported in [2]. We attribute this discrepancy to visual inspection from a dissected core vs. X-rays of the intact core.)

The proximity of 68002/01 to a process that distributed material at depth therefore influenced the size and shape distribution vertically. This is where the Moon may diverge as an analog from Europa: which geological processes modify Europa at this scale, and how do they work?

Conclusions: Preliminary analysis of these four locations on the Moon indicates that the appearance alone of the surface at the location where a core sample is taken, without consideration of geologic context, is not a clear indication of what we will find below the surface. In some cases, the surface can give an indication of the subsurface grain sizes and shapes; however, this is not the case where more complex geology occurs, as in the case of 64002/01 and 68002/01. 64002/01 in particular shows a decently wide range of grain size and shape at the surface but is uniform in the core sample, and we may better understand and contextualize this from understanding the sample site's location relative to the South Ray ejecta blanket.

While our approach is necessarily simplistic and abstract, it illustrates the power of choice and familiarity with geological processes; as 68002/01 shows, there is something more to gain from geological context which is not captured by these numbers, and its interpretation can help us understand the strata at depth.

For Europa, these results point to geologic context and possibly age as important factors for understanding the relationship between the surface and the subsurface, especially given the alien nature of Europa's geologic processes. Better constraining the interplay between different surface processes—e.g., sintering, sputtering, radiolysis, and impact gardening at the small scale; secondary cratering; and formation of ridges and bands—and how they are expressed in the upper centimeters of Europa will be important for understanding the sampling environment and forming a sampling strategy. Understanding the local and regional geologic context at any potential landing region will be essential to choosing sampling locations and interpreting sample results.

Future work: We plan to integrate other bins, incorporate other Apollo core samples and existing post-dissection studies, and study the sampling decision-making processes to better understand how and why sampling occurred. Mars and terrestrial analogs may also offer more detailed information for case studies, as well as control of data collection, in the case of fieldwork, to help eliminate biases and generalizations we have made using the lunar data.

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