STRATIGRAPHY OF THE MARE FLOWS IN SOUTHERN OCEANUS PROCELLARUM.

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Introduction: Southern Oceanus Procellarum is host to some areas which are believed to be representative of basalts that have yet to be sampled (e.g. Flamsteed [1]). As such, the area is interesting for compositional studies to compare with areas from which we have samples. Southern Oceanus Procellarum is complex, containing several flooded craters and many flow units distinguishable by their spectral properties [2]. The purpose of this work is to identify flow boundaries based on compositional variations across the southern Oceanus Procellarum region, and measure flow lengths and, where possible, flow thickness. Ultimately, the total volume of mare basalts in Oceanus Procellarum will be estimated, using impact craters as sub-surface probes to locate the depth of the mare/highland boundary. To date we have studied the Flamsteed, Damoiseau, Cavaleris/Reiner and Marius Hills areas with the intention of extending our study to cover the whole of Oceanus Procellarum.

Data Reduction: Clementine data from the UVVIS camera, covering wavelengths from 415nm to 1000nm, were reduced using the ISIS software and the procedure outlined by the US Geological Survey [3]. Those interested in the details of the reduction techniques used (i.e. photometric coefficients etc.) are invited to contact the first author for more information. A standard multispectral cube was produced for each of the areas studied, with the red channel controlled by the 750nm/415nm ratio, the green by the 750nm/950nm ratio and the blue channel by the 415nm/750nm ratio. Using these ratios, mature low-Ti mare appear red, mature high-Ti mare appear blue, and yellow/green pixels indicate the presence of a freshly exposed mafic component such as an immature basalt. Mature/immature highland materials are represented by red/blue respectively, and we have found that cyan can indicate either the presence of highland material or a freshly excavated mafic unit. To distinguish between the two, five-point spectra must be analysed. In addition to the multispectral image, we constructed FeO and TiO_2 maps based on the algorithms of [4] and [5]. These aid the differentiation of a mafic and highland signature. Photographic images from Lunar Orbiter IV were also used during this work.

Mare flows: The multispectral images reveal a variety of flow units across the surface of the mare, identified by red and blue as described in the previous section. The continuum slope between 415nm and 750nm is controlled by both compositional variation (in this case TiO_2) and maturity effects, both of which are necessary to identify flows physically separated in time and composition. While there are a large number of individual flow boundaries across the region (>30), this does not necessarily imply that there have been >30 discrete eruptions. It is of course quite possible that a young flow has partially covered an older flow leaving two separate areas of the older flow still exposed at the surface. This possibility is highlighted by analysis of the five-point spectra, showing many of the flows to be spectrally indistinguishable in the Clementine data. If it is assumed that all flows with the same five-point spectral signature are the same flow, then the number of individual units decreases significantly to <15.

The highest concentration of individual flow units occurs in the Marius Hills area. These flows also have the smallest areas of all those studied, suggesting that they may have originated from some of the domes and cones in the Marius Hills, rather than from a larger fissure eruption, which is the likely origin of the more extensive flows.

Impact craters as probe to stratigraphy: Impact craters expose subsurface material in their ejecta blankets and in their central peaks, making them ideal for probing a region's stratigraphy. As part of this research, we have looked at impact craters of varying size in order to determine the composition of subsurface materials, and in particular to search for highland materials [6]. If highland material can be identified in the ejecta of an impact crater, this implies that the cratering event has penetrated the mare-highland boundary and we can then infer a depth of that boundary using the well known excavation depth:diameter relationship of [7]. The easiest way to look for highland contamination in mare craters is to study an FeO map; highland material will generally have little FeO compared to mare basalts. In combination with analyses of five-point spectra, the FeO map allows us to discriminate between highland material and fresh mafic ejecta.

Craters with highland materials in their ejecta: There are several instances where highland material can be found in the walls and ejecta of impact craters across southern Oceanus Procellarum. As would be expected, the farther a crater is from the edge of the mare, the deeper it must excavate to expose highland units. This is shown in Table 1 with details of some of these craters. All had a simple form, and hence we used the excavation depth:diameter ratio of 1:10 [7] in our calculations.

Craters with no highland materials in their ejecta: The majority of craters on the mare in the study areas show no evidence of highland material in their ejecta or walls. These craters still provide a lower limit for the thickness of mare basalts and hence a lower limit on the volume of material erupted. The largest of these craters are shown in Table 2 and include Reiner (6.92°N, 305.25°E) with a diameter of 28km. The lower limit to the mare depth quoted in Table 2 is calculated from Equation 8.3.3 of [7], which refers to the depth of stratigraphic uplift at a crater centre. It should be noted that this equation is derived from terrestrial examples, and may well require adjustment for use on lunar craters. Assuming the values in Table 2 to be representative of the real situation, it is apparent that the mare thickness around Reiner is at least twice that of areas due south.

Flooded Craters: There are a number of instances where just the rim of a crater is visible above the surface of the mare flows. These rims, which appear to be of highland composition from their FeO content and five-point spectra, give us an indication of the diameter of the crater. From the equations in table 8.1 of [**7**], it is then possible to calculate a depth to the floor of the crater, and hence a thickness of mare material. Details of these craters are given in Table 3, and it can been seen that the thickness implied for each of these is much greater than those calculated by the crater excavation method in Table 1. This is expected for two reasons. Firstly, the flooded craters are generally farther from the mare edges and secondly, the craters themselves will have created a hole deeper than the surrounding ground level when they formed. By calculating instead the rim height (the height of the rim above the surrounding ground level, table 8.1 [7]) we find a value much closer to the largest mare depth values in Table 1. This is shown in the final column of Table 3.

Summary: These results will be used to produce an isopach map and an estimate of the volume of mare erupted in the southern part of Oceanus Procellarum. Future work will centre around the expansion of the study area to include the northern regions, and given enough data points, a contour map of the mare depth across the whole region will be constructed

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Table 1: Craters which have excavated highland material in their ejecta

Latitude	Longitude	Mare Depth (m)
14.97°S	310.40°E	250
12.93°S	311.38°E	410
9.40°S	313.61°E	60
9.28°S	313.60°E	60
9.23°S	314.09°E	750
6.64°S	310.90°E	510
5.49°S	313.88°E	860
5.19°S	301.86°E	1360
3.71°S	307.23°E	440
3.59°S	309.92°E	430
2.62°S	298.70°E	940
0.73°S	297.52°E	1210
9.24°N	293.60°E	470

Table 2: Largest craters with no highland material in their ejecta or walls.

Latitude	Longitude	Lower limit to mare depth (m)
0.84°S	302.80°E	1180
6.92°N	305.25°E	2340

Table 3: Flooded craters

Latitude	Longitude	Depth to floor (m)	Depth to ground (m)
13.76°S	310.02°E	3280	1080
4.00°S	308.74°E	4020	1410
3.03°S	315.95°E	4300	1540
3.80°N	304.58°E	3170	1030