COMPOSITIONAL HETEROGENEITY WITHIN LUNAR CENTRAL PEAKS. D. P. Moriarty[1], C. M. Pieters[1], N. Petro[2], and P. J. Isaacson[3], [1]Dept. Geological Sciences, Brown Univ., Providence RI, 02912 [Daniel_Moriarty@Brown.edu], [2]NASA GSFC, [3]HIGP, Univ. of Hawaii, Manoa.

Introduction: The purpose of this study is to characterize the compositional heterogeneity across lunar central peaks in order to determine properties of the source region. We take advantage of the high spatial and spectral resolution of data returned by the Moon Mineralogy Mapper (M^3) mission, using spectra and spectral parameter maps to study the distribution of compositions within individual peaks.

Background: Most compositional remote sensing techniques are sensitive to the near-surface of a body. Impact craters expose material from depth and therefore are an important window into the interior of a body. For central peak craters, peak material must originate from depths greater than the maximum depth of impact melting [e.g., 1]. Since depth of melting can be related to crater diameter, the minimum depth of origin of central peak material can be estimated. Typical values for these depths range from ~1 to ~22 km for craters ~20 to ~140 km in diameter [1].

Previous studies have reported varying degrees of compositional heterogeneity within central peaks. In general, central peaks in highlands regions display less heterogeneity than central peaks within basins [2]. Spectra from Bullialdus in the Nubium Basin suggest a central peak of multiple compositions [3]. An exception to the general rule occurs within the South Pole - Aitken Basin (SPA), where central peak spectra indicate a homogenous, noritic composition [2]. Previous analyses have argued that the low degree of heterogeneity between [4] and within [2] SPA central peaks might indicate the presence of a thick, homogenous impact melt sheet underlying the basin.

Data and Methods: As a mapping spectrometer with high spatial and spectral resolution, M^3 produces data well-suited to characterize the compositional heterogeneity of a region. The instrument is sensitive from 460 to 3000 nm with a spectral resolution split between 20 and 40 nm (the higher resolution corresponding to the wavelengths of mafic absorption bands) [5]. The instrument operated in two different optical periods. The first (OP1) had a pixel size of 140 m x 140 m, while the second (OP2) had a pixel size of 280 m in the cross-track dimension [6].

We begin with Level 2 M^3 data, publicly available through NASA's PDS archive. To reduce the slope imparted by space weathering processes, we divide each datastrip by a bland highlands spectrum taken from within the image. In the resulting relative reflectance image cube, we mask shadowed regions and select only pixels from the peak elevated above the crater floor. These areas are sloped, reducing the accumulation of regolith and mixing with surrounding materials.

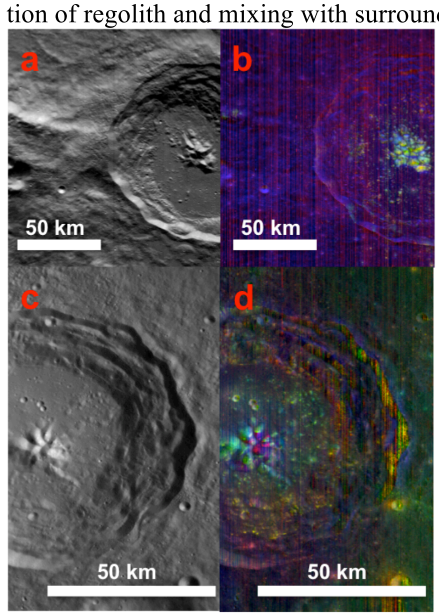

Fig. 1: (a) Finsen, radiance at 2936 nm, (b) standard color composite, (c) Bullialdus, radiance at 2936 nm, (d) standard color composite

Since the central peaks we are studying display prominent mafic compositions, we calculate spectral parameters relevant to the 1- and 2 µm mafic absorption bands. Integrated band depth (IBD) and estimated band center (EBC) are calculated using both tools developed for validation efforts by the M^3 team and new tools developed for this study. Integrated band depth is calculated by summing over relevant wavelengths the quantity one minus the ratio between reflectance and an estimated continuum. Band minimum is estimated by fitting a quadratic curve to each absorption band. Band minima are only calculated for pixels with a positive integrated band depth. While the specific parameter values obtained cannot be considered to be accurate in an absolute sense due to the relative reflectance procedure, studying the distribution of parameter values can provide insights into the compositional heterogeneity of a region. For this study, IBD for both bands and the 2 µm EBC are considered (low signal data quality issues lead to physically unrealistic results for Bullialdus's 1 µm EBC).

Parameter maps and color composites provide an overview of the heterogeneity of a region. The standard M^3 color composite shown in Fig 1b,d (red = 1 µm IBD, green = 2 µm IBD, blue = reflectance at

1489 nm) is a good indicator of spatial variations in mafic materials. Further insight is gained by studying the statistics of spectra and individual parameters.

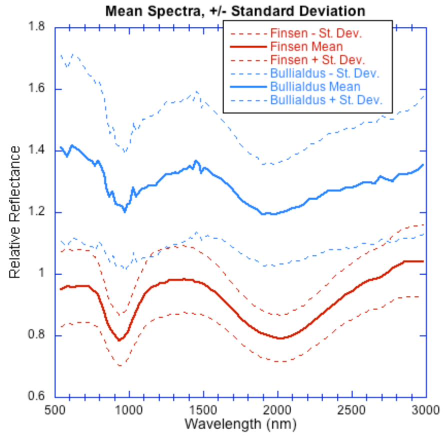

Fig. 2: Central peak spectral statistics: Finsen (red), Bullialdus (blue)

Results:

Finsen. Finsen (42.38° S, 177.96° W, D=73 km [7], Fig. 1a-b) is located within SPA. The mean spectrum is plotted in Fig. 2, along with the mean +/- the standard deviation calculated for each band. Mean values and coefficients of variation (standard deviation divided by the mean) for each parameter are given in Table 1. Finsen's central peak exhibits absorptions at ~910 and ~2010 nm, consistent with a noritic composition (Fig. 2).

Bullialdus. Bullialdus (20.74° S, 22.36 ° W, D=61 km [7], Fib. 1c-d) is located within the Nubium basin on the nearside of the Moon. Compared to Finsen, a higher degree of spectral heterogeneity is apparent in Bullialdus's color composite (Fig. 1d). This is supported by the larger spectral standard deviation (Fig. 2), and parameter coefficients of variation (Table 1).

Discussion: While the mean parameter values are not strictly accurate, the coefficients of variation can give a sense of the spread of values. For each parameter calculated, Bullialdus has a higher coefficient of variation than Finsen. This indicates a wider spread of values and could imply greater compositional heterogeneity. This appears to be in agreement with other measures. Finsen's spectral standard deviation is smaller (Fig. 2) and its color composite displays a smaller range in colors (Fig. 1b,c),. Although this could be due to Finsen sampling a thick, homogenous impact melt sheet as discussed in [2] and [3], there are other possibilities. The nearside lower crust may be more heterogeneous than the farside lower crust due to the observed higher degree of mare volcanism and potentially associated magmatic intrusions [8]. Alternatively, Finsen may be exposing homogenous orthopyroxenitic mantle material consistent with seismic velocity studies [9, 10]. Finally, Bullialdus's apparent heterogeneity may be derived from impact melt remaining in the central peak [3]. Further worker is required to constrain the observed variation to composition and limit contribution from other effects.

Table 1: mean and coefficient of variation for spectral parameters

	Finsen	Bullialdus
1 µm IBD (mean)	1.61	1.47
1 µm IBD (coeff. of variation)	0.289	0.33
2 µm IBD (mean)	2.31	1.041
2 µm IBD (coeff. of variation)	0.197	0.473
2 µm EBC (mean)	2106 nm	2070
2 µm EBC (coeff. of variation)	0.0120	0.0227

Limitations: Although the approach outlined here has proven to be useful, it is not yet quantitative. In addition to composition, a number of other factors effect the spectra. Although the Level 2 M^3 data is photometrically corrected, the correction is at a topographic spatial resolution too low to account for the actual topography of the central peaks. Slight bands in our chosen "featureless" spectra could shift or weaken bands in the resulting relative reflectance spectra. Residual slopes and noise significantly effect the estimated band centers and depths. Space weathering, regolith accumulation, grain size, noise, thermal effects, photometry, and the presence of impact melt can all introduce changes in spectra and parameters that are unrelated to heterogeneity in the source region.

Future Work: To place constraints on the source regions of central peak material, global and regional trends in heterogeneity must be established through the study of more craters. Care must be taken to consider comparable pixel distributions in each central peak so that the regions are directly comparable. Proper steps must be taken to reduce the contribution of noise and other non-compositional effects to spectra. This will allow us to constrain the compositional heterogeneity of stratigraphic layers sampled by central peaks.

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