REASSESSMENT OF LUNAR CENTRAL PEAK MINERALOGY AND IRON CONTENT USING THE KAGUYA MULTIBAND IMAGER.

M. Lemelin[1], P.G. Lucey[1], and E. Song [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 1680 East-West Rd, Honolulu, HI, USA, 96822, mlemelin@hawaii.edu.

Introduction:

The Multiband Imager (MI), a multispectral sensor onboard Kaguya, provides high spatial resolution data (~20 m/pixel in the UVVIS, 60 m/pixel in the NIR) in 9 spectral bands (415-1550 nm). These bands are very similar to those acquired by Clementine UVVIS camera (~100 m/pixel, 415-1000 nm) in 1994, and are well suited to map the abundance of olivine, pyroxenes, and plagioclase on the Moon. Recently, the Kaguya team released a version of their high spatial resolution data corrected for the shading effects of topography, drastically reducing the error associated with mineral and elemental mapping algorithms using reflectance data. In this paper we use this new data with FeO and mineral mapping algorithms to gain new insights regarding the lunar crust from inspection of central peaks.

Central peaks provide among the best insight to the lunar crust composition since they expose rocks from depths (the lower crust, perhaps mantle) and are less weathered than the average lunar terrane; looking at central peaks allows us to understand better the lateral and vertical composition of the lunar crust and mantle [1,2]. Many studies have looked at central peak mineralogy using Clementine data. For example, Tompkins and Pieters (1999) [3] looked at the mineralogy of 109 central peaks using Clementine UVVIS (415-1000 nm) data and spectral parameters correlated to mineral abundances. They found that the lunar crust is compositionally diverse, both globally and locally within central peaks, and found a more anorthositic crust than generally assumed with a bulk plagioclase content of ~81 %, ranging from "pure" anorthosite near the surface towards a more mafic composition with depth. They also found evidence of mafic intrusions in both highlands and basins, and suggest that the lower crust is more compositionally diverse than the uppermost crust. Cahill *et al.* (2009) [4] modeled the mineralogy of 55 central peaks using a Hapke radiative transfer model and Clementine UVVIS/NIR data (415-2000 nm). They combined their results with modeled crustal thickness [5,6] and the depth of origin of these central peaks to characterize the lunar crustal composition with depth. They found (1) strong compositional similarities to Mg-suite material in all lunar terranes, (2) that central peak mineralogy becomes more rich in plagioclase as the crust thickens, and (3) that the depth of origin of dominantly mafic mineralogy are confined to the lower crust, primarily within the South Pole-Aitken basin (SPA) and the Procellarum Kreep Terrane (PKT). Recently, studies have looked at central peak mineralogy using MI data; Ohtake *et al.* (2009) [7] have found exposures of pure anorthosite (~98 vol.% Fe-bearing crystalline plagioclase) and bits of anorthosite in many central peaks (*e.g.*, Jackson, Tycho) [7].

In this study we compute the mineralogy for 34 of the 55 central peaks studied by [4] using (1) MI UVVIS/NIR data corrected for topographic shading, (2) an improved version of Hapke's radiative transfer model validated with LSCC data [8,9], and (3) new crustal thickness models from GRAIL data [10].

Data and Methods:

We use MI UVVIS/NIR data at full spatial resolution and downsample it to ~80 m/pixel. We acquire data for the 34 central peaks studied by [4] that have latitude within ±50° to minimize any residual shadowing effect caused by low sun angles. We select the pixels within these central peaks and analyze them with a modified version of Hapke's radiative transfer model. We build a spectral library for mixtures of olivine, pyroxenes and plagioclase, 7 values of SMFe (0.05 to 0.7 wt%), Mg# 65, and grain size of 17 µm, which gives us 46,207 spectra. We build a second library having the same values, but a grain size of 200 µm for plagioclase, as done by [7], for a total of 92,414 spectra. We use a gradient descent algorithm to refine the mineral abundances. Because spectra of different composition can be similar, we use their FeO content as a constraint. We recalibrate the FeO algorithm using MI data of resolved sampling sites, and find a new optimized origin of x_{0Fe}=0.04 and y_{0Fe}=1.39. We plot the measured FeO content (wt%) of Apollo samples versus their Fe parameter (θ_{Fe}) derived from their MI reflectance as in [11], over plot θ_{Fe} for 55 pixels that have been reported has pure anorthosites in Jackson (assuming a FeO content of 0.5 wt%), and find that the relationship between FeO and θ_{Fe} is exponential rather than linear [11]; we derive a new FeO algorithm:

$$\text{FeO (wt\%)} = (1.0708 * \theta_{Fe2}) - 0.3986$$

$$\theta_{Fe2} = 0.0656e^{(3.6681*\theta Fe1)}$$

$$\theta_{Fe1} = -\arctan(((R_{950}/R_{750})-y_{0Fe})/(R_{750}- x_{0Fe}))$$

Finally, we use the modeled crustal thickness (T_1) derived from GRAIL data [10] to find the proximity (P_1) to the crust/mantle boundary for each crater as:

$P_1 = T_1 - D_{exc}$

D_{exc} is the maximum depth of excavation from [2].

Initial Results: We find that there is a weak tendency for the crust to become more mafic, and therefore less anorthositic with depth (Fig. 1) only if the FHT and SPA are treated together. We also find that there are compositional similarities to Mg-suite material (possibly mafic instrusions) in all lunar terranes that excavated material between ~5-25 km from the crust/mantle boundary (Fig. 1), which support what has been found by [4].

We also find that the plagioclase histogram for Jackson crater (Fig. 1) has a bimodal distribution, with a global maximum 92 wt% plagioclase, and a local maximum at 98 wt% plagioclase. Exposures of pure anorthosite (~98 vol.% plagioclase) was also found by [7] in some MI spectra.

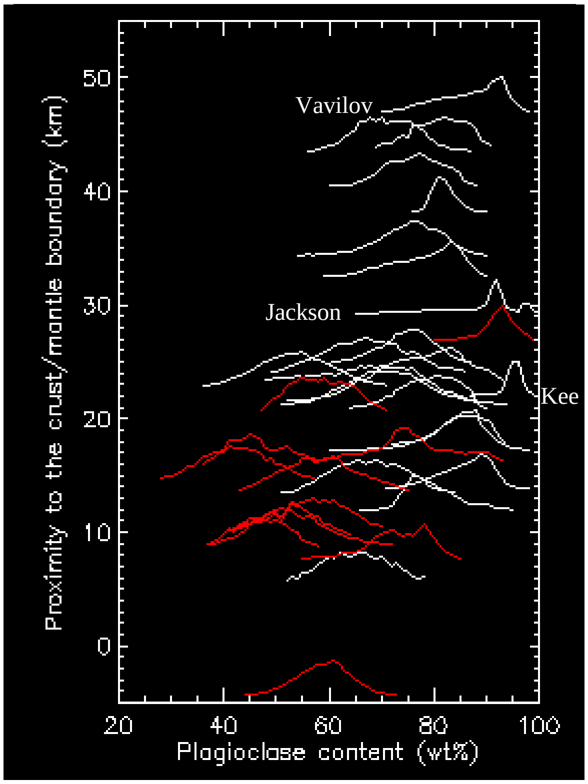

Figure 1. Histograms of plagioclase content (wt%) for 34 central peaks and their proximity to the crust/mantle boundary [2,6]. Red data are craters in SPA, white data are in the FHT, Kee = Keeler.

Copernicus has the highest average olivine content (11.01 wt%) of the central peaks analysed, which corresponds to an olivine/mafic minerals of 72.71 % (Fig. 2), followed by Keeler (3.22 wt% and 67.27 %). Aitken crater is compositionally similar to the FHT; it has higher olivine/mafic minerals and lower orthopyroxene/mafic minerals than most of the craters in SPA. Its proximity to the crust/mantle boundary is 26.93 km, which is similar to the FHT craters.

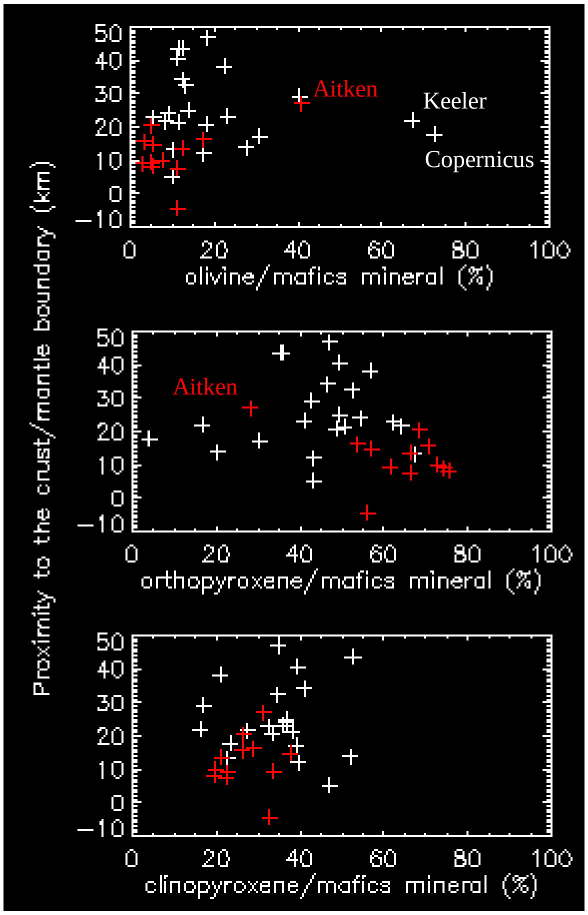

Figure 2. Average mineral abundances normalized by the total abundance of mafic minerals for the 34 central peaks analysed and their proximity to the crust/mantle boundary [2,6]. Red data are craters in SPA, white data are in the FHT.

Conclusion: We find that there is no strong increase in mafic character with depth within the FHT or SPA; if they are treated together there is a weak decrease in plagioclase content with proximity to the mantle. Furthermore, while isolated exposures of anorthosite are common, the average composition of central peaks is more mafic than anorthosites, requiring a substantial component other than anorthosite within the entire crustal column.

References: [1] Pieters, C.M. (1982) *Science, 215*, 59-61. [2] Pieters, C.M. (1986*)Reviews of Geophysics, 24*, 557-578. [3] Tompkins, S. and Pieters, C.M. (1999) *Meteor. & Planet. Science, 34*, 25-41. [4] Cahill, J.T.S. et al. (2009*) JGR., 114*, E09001. [5] Wieczorek, M.A. and Phillips, R.J. (1998) *JGR, 103*, 1715-1724. [6] Wieczorek, M.A. et al. (2006) *Rev. Mineral. Geochem., 60*, 221-364. [7] Ohtake, M. et al. (2009) *Nature, 461*, 236-241. [8] Taylor, L.A. et al. (2001) *JGR, 106(E11)*, 27985-27999. [9] Taylor, L.A. et al. (2010) *JGR, 115*, E02002. [10] Wieczorek, M.A. et al. (2012) *Science, 8*, 671-675. [11] Lucey, P.G. et al. (2000) *JGR, 105*, 20,297-20,305.