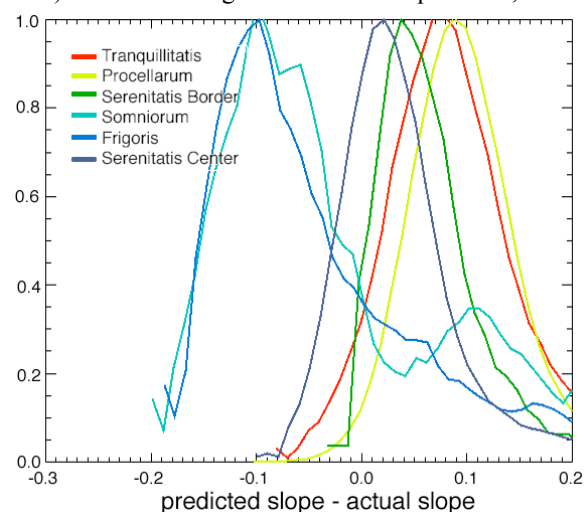


**COLOR REFLECTANCE TRENDS IN THE MARE: IMPLICATIONS FOR MAPPING IRON WITH MULTISPECTRAL IMAGES.** B. B. Wilcox<sup>1,2</sup> P. G. Lucey<sup>1</sup> and J. J. Gillis<sup>1</sup>, <sup>1</sup>Hawaii Institute of Geophysics and Planetology, University of Hawaii, 2525 Correa Road, Honolulu, HI 96822, <sup>2</sup>email: bbwilcox@higp.hawaii.edu.

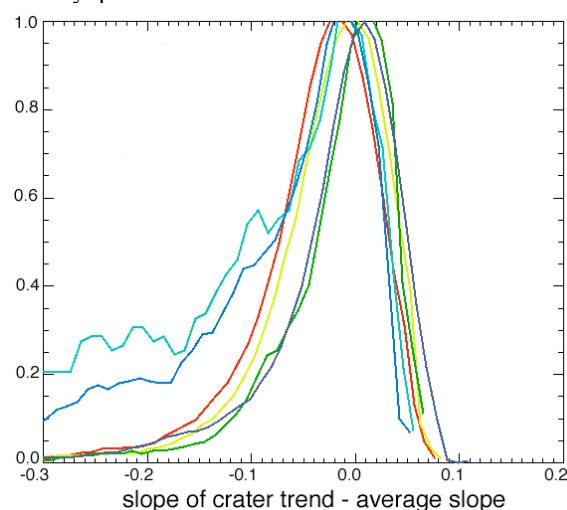
**Introduction.** Remotely mapping iron on the lunar surface requires the separation of the spectral effects of iron and maturity. Increasing iron causes a darkening and reduced reddening of soil between 950 and 750 nm, while increasing maturity causes a darkening and reddening of soil [1]. The Lucey iron method [2] was designed to enable the mapping of iron at the full resolution of Clementine (100 m/pixel) after separating out the effects of maturity. The Lucey method was based on an observation that trends of uniform composition but varying maturity form radial patterns on a plot of reflectance at 750 nm versus the ratio of reflectance at 950/750 nm. However, Staid and Pieters [3] noted that in the mare trends were more parallel than radial. This suggests that the Lucey method might not be optimally compensating for maturity. Also, various calibrations of that technique [2,4,5] give inconsistent results in terms of suppressing maturity anomalies. Both of these problems limit the usefulness of the Lucey method for mapping small-scale iron anomalies, which might be used for mapping vertical stratigraphy in the mare. Here we test whether the reflectance trends are more radial or more parallel in the mare and present a new method for separating the spectral effects of iron and maturity in lunar mare regions.

**Methods and Results.** Using plots of 750 nm reflectance versus 950/750 nm ratio we examined the spectral trends of nearly 10,000 fresh craters (OMAT >0.3) in six mare regions: Mare Tranquillitatis, Mare

Serenitatis center and border, Lacus Somniorum, Mare Frigoris, and Oceanus Procellarum. A region of interest was manually chosen around each crater that included the crater and its ejecta blanket, and these points were used to examine the spectral trends. Most craters exhibited highly correlated trends. Those with poor correlation were examined and it was determined that the scatter was due to topographic shading, mostly found in data with large phase angles. To assess whether the crater trends were radial to each other we compared the slopes predicted by the Lucey method to the observed slopes of the trends (Fig. 1). The predicted slope was found by taking the average reflectance at 750 nm and the average ratio of 950/750 nm reflectance of each crater and applying the Lucey method algorithm [2]. Fig.1 shows that there is significant deviation between the predicted and observed slopes, suggesting that the trends are not best fit by a radial parameter. To test whether the slopes are more parallel to each other, we compared the observed slopes of the crater trends to the average slope (Fig. 2). The average was found by taking the mode of the histogram of slopes from each of our six mare study areas and averaging these six modes. The slopes of the crater trends in all of our study areas are similar, except for a number of outliers in Frigoris and Somniorum. These outliers are due to the large phase angles in these data, where the effects of topographic shading are the most pronounced. The otherwise closely parallel trends confirm the observation of



**Fig.1.** Histograms of the slope predicted by the Lucey method minus the actual slope of crater trends for each mare.



**Fig. 2.** Actual slopes of crater trends for each mare area minus the average slope. Histograms cluster at zero, suggesting closely parallel trends.

Staid and Pieters [3] and suggest that an improved method could be developed for separating the spectral effects of iron and maturity based on this observation.

To define a new parameter that is correlated to iron and better compensates for maturity, we performed a coordinate rotation on the plots of reflectance at 750 nm versus the ratio 950/750 nm reflectance. This new parameter

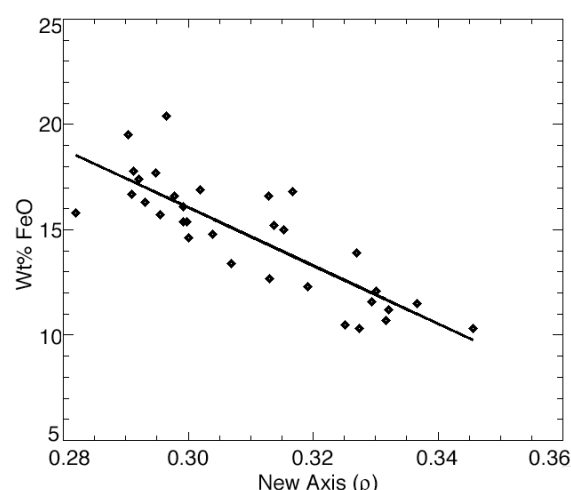
$$\square = R_{750} \sin(\phi) + (R_{950}/R_{750}) \cos(\phi)$$

where  $\phi = 1.3885$  radians, the average mare slope, is then compared to Apollo and Luna site reflectances and known iron values (Fig. 3) to give

$$\text{Wt\% FeO} = -137.97\square + 57.46.$$

This method better suppresses maturity anomalies than the previous calibrations of the Lucey method. To test what level of an iron anomaly can be trusted, iron was calculated for each point in craters not showing anomalies due to topographic shading. The standard deviation of iron per crater was calculated, and in all of the mare study areas the standard deviations are generally less than 0.5 wt% FeO.

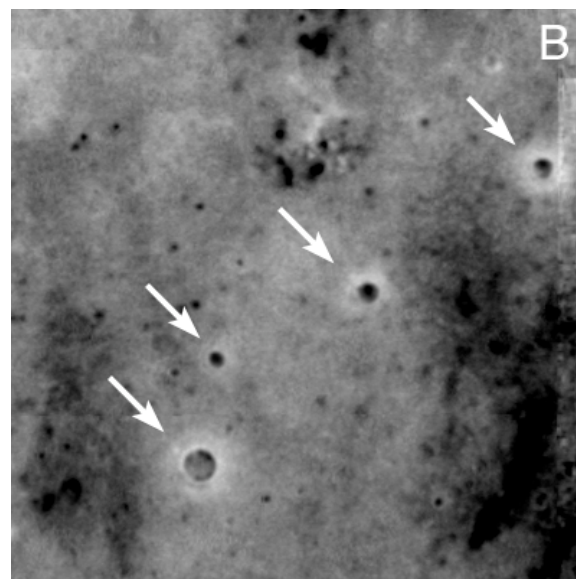
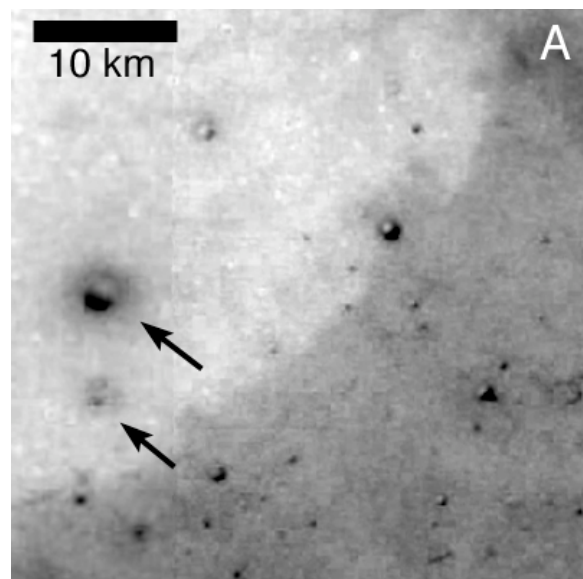
**Discussion.** The method developed here to map iron in the mare more completely separates the spectral effects of iron and maturity. This enables the detection of small-scale iron anomalies that differ by as little as 0.5 wt% FeO from their surroundings. Small craters that perhaps excavated an underlying mare unit of differing composition can be detected (Fig. 4), whereas with the Lucey method they might have been mistaken for maturity anomalies, or not



**Fig. 3.** Known iron values for Apollo and Luna samples versus the new parameter  $\square$  determined from the site Clementine reflectance values. Data from [4].

detected above the noise. Thus vertical stratigraphy can be mapped. Anomalies due to topographic shading remain in data with large phase angles, but these are readily detected and not easily mistaken for true iron anomalies.

**References.** [1] Fischer E. M. and Pieters C. M. (1994) *Icarus*, 111, 475-488. [2] Lucey P. G. et al. (1995) *Science*, 268, 1150-1153. [3] Staid M. I. and Pieters C. M. (2000) *Icarus*, 145, 122-139. [4] Blewett D. T. et al. (1997) *JGR*, 102, 16319-16325. [5] Lawrence D. J. et al. (2002) *JGR*, 107, 5130.



**Fig. 4.** Examples of craters that have excavated units of differing iron content. Craters in Fig. 4A have excavated material  $\sim 2$  wt% lower in iron, showing that the mare unit on the left of the image is overlying the unit on the right. Large craters in Fig. 4B have excavated a unit  $\sim 1$  wt% higher in iron. 4A located in Mare Humorum at (-25, 328), 4B in Mare Tranquillitatis at (7, 24).