**VARIETIES OF LUNAR SWIRLS.** David T. Blewett[1], C. G. Hughes[2], B. Ray Hawke[3], and Nicola C. Richmond[4]. [1]NOVASOL, 733 Bishop St., 28th Floor, Honolulu, HI 96813 (dave.blewett@nova-sol.com); [2]Dept. of Geology and Planetary Science, Univ. of Pittsburgh, Pittsburgh, PA 15260; [3]Hawaii Inst. of Geophysics and Planetology, Univ. of Hawaii, Honolulu, HI 96822; [4]Lunar and Planetary Laboratory, Univ. of Arizona, Tucson, AZ 85721.

**Introduction:** Lunar swirls are unusual bright markings found in both the maria and the highlands [1, 2]. These sinuous high albedo patches sometimes exhibit dark lanes between bright segments. Swirls have no apparent topographic expression and appear to overprint the surfaces on which they lie. Several origins for lunar swirls have been proposed. The association between swirls and magnetic anomalies has led to the hypothesis that the magnetic anomaly protects the surface from the solar wind [e.g., 3]. Lacking solar wind sputtering and implantation, the swirl has not undergone the normal soil-darkening process to which unshielded areas are subjected. Thus it may be that the presence of a magnetic anomaly specially preserves a high albedo, even though a magnetically shielded surface would still experience micrometeorite bombardment. Melting, agglutinate formation, and vapor deposition among regolith grains as a result of micrometeorite impact are thought to play a major role in space weathering [e.g., 4, 5]. A number of magnetic anomalies are correlated with terranes antipodal to the major impact basins [e.g., 6, 7]. This implies that the shielding has been operating since the time of basin formation (>~3.8 billion years), and hence that the swirls are very old features. However, over time crater-forming impacts could contribute new ejecta material to a magnetically shielded area, occasionally "refreshing" the swirl.

Alternate formation mechanisms for lunar swirls involve surface effects produced during the recent impact of meteor swarms [8], a comet coma and nucleus [2], or disrupted comet fragments [9]. The goals of the present work are to investigate the optical properties of lunar swirls, to compare the optical properties of bright swirl and dark lane material to nearby normal fresh and mature surfaces, to examine the relationship between optical properties and magnetic field strength at various locations in and around swirls, and to determine if these findings are consistent with the predictions of the various hypotheses of swirl origin.

**Data Sets:** We have been conducting a integrated study of lunar swirls [10, 11] using data from a variety of sources. The Clementine mission provided multispectral images in the UV-Vis portion of the spectrum. Images calibrated to reflectance can be used to produce a number of spectral parameter maps, including relative color (415-nm/750-nm or "UV/Vis" ratio), optical maturity (OMAT) [12], iron and titanium content [13], abundance of pyroxene and agglutinates [14], and the maturity parameter Is/FeO [14]. Data from the Lunar Prospector magnetometer experiment has been continued to a common altitude of 35.5 km for selected areas [7]. These maps of total magnetic field strength may be superimposed on the Clementine image products to facilitate comparison.

**A Continuum of Swirl Types:** The Reiner Gamma formation (RGF, Fig. 1), owing to its nearside location in Oceanus Procellarum at 7.5° N, 302.5° E, is the most famous lunar swirl and is considered to be the type example. The RGF is not antipodal to any major basin, but a magnetic anomaly of ~7 nT maximum strength at 35.5 km is present. The RGF exhibits a complex looping structure extending over hundreds of kilometers. However, not all locations with strong magnetic anomalies have similar complex swirl morphology. For example, an anomaly in the Descartes region of the central nearside highlands is much stronger in magnitude than that at the RGF [15]. A diffuse bright patch is present at the Descartes location (Fig. 2), though apart from high albedo it does not show other swirl characteristics. However, it has been argued that the unusual albedo could be a result of overlapping ejecta from two nearby craters [16]. A magnetic anomaly of approximately the same peak strength as the RGF is found in the highlands near Airy crater [10], though the anomaly covers a much smaller area. A small bright feature with a possible dark lane is present – perhaps an incipient swirl. The antipode to Crisium basin, found in the farside highlands in the vicinity of the crater Gerasimovich, is the site of a magnetic anomaly with strength ~2× that of the RGF. Present here are bright patches with some simple looped structure and dark lanes (Fig. 3).

**Mare – Highland Differences:** The bright portions of the swirls all have high UV/Vis ratios, corresponding to "blue" color relative to the surroundings, and high OMAT values suggesting the presence of fresh unweathered material. From the examples investigated in this work, it appears that a strong magnetic anomaly at a mare location is likely to correlate with the complex swirl morphology characteristic of the RGF. Strong magnetic anomalies in the highlands are associated with high albedo features that display less well-developed swirl structure.

**Future Work:** A number of high-quality Earth-based telescopic spectra for locations in and around the RGF have been collected [17]. These near-infrared reflectance spectra (~0.6-2.5 μm) can provide information on the mineralogy and state of maturity of the surface. We plan to conduct modeling of the spectra using modern radiative transfer methods [e.g., 18] in an attempt to further constrain the abundance of SMFe and agglutinates in swirl material.

**References:** [1] F. El-Baz (1972), *Apollo 16 Prelim. Sci. Rep. NASA SP-315*, 29-93. [2] P. Schultz and L. Srnka (1980), *Nature 284*, 22. [3] L. Hood and C. Williams (1989), *Proc. LPSC 19th*, 99; L. Hood et al. (2001), *JGR 106*, 27825-27839. [4] B. Hapke (2001), *JGR 106*, 10039. [5] S. Noble and C. Pieters (2003), *Sol. Syst. Res. 37*, 31. [6] R. Lin et al. (1988), *Icarus 74*, 529-541. [7] N. Richmond et al. (2005), *JGR 110*, E05011. [8] L. Starukhina and Y. Shkuratov (2004), *Icarus 167*, 136. [9] P. Pinet et al. (2000), *JGR 105*, no. E4, 9457-9475. [10] C. Hughes et al. (2006), *LPS XXXVII*, abstract no. 1230; C. Hughes et al. (2007), *GRL*, in preparation. [11] N. C. Richmond and L. L. Hood (2006), abstract, AGU Fall meeting. [12] P. Lucey et al. (2000), *JGR 105*, 20,377. [13] P. Lucey et al. (2000), *JGR 105*, 20,297. [14] C. Pieters et al. (2006), *Icarus 184*, 83-101. [15] N. Richmond et al. (2003), *GRL 30*, 1395. [16] D. Blewett et al. (2005), *JGR. 110*, E04015. [17] J. Bell and B. Hawke (1981), *Proc. LPSC 12th*, 679-694; J. Bell and B. Hawke (1987), *Publ. ASP 99*, 862-867. [18] B. B. Wilcox et al. (2006), *JGR 111*, doi:10.1029/ 2006JE002686.

**Figures:** Clementine "natural color" mosaics, with contours of Lunar Prospector total magnetic field strength at 35.5 km altitude. Contour lines are labeled in nT. Sinusoidal projection with north to the top.

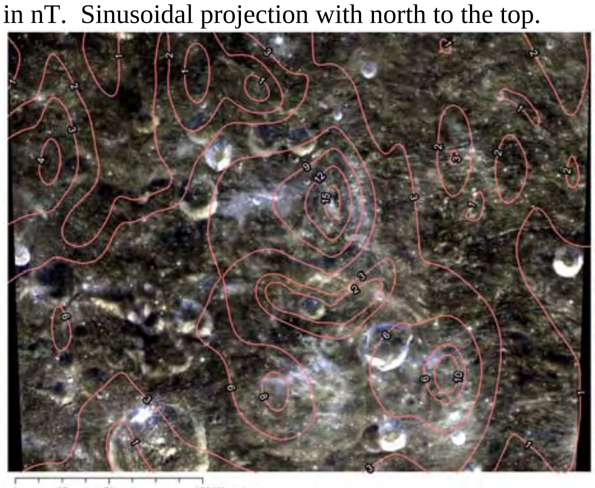


Figure 3 (above). The region antipodal to the Crisium basin. The crater directly above the "75 km" tick mark is Gerasimovich R, ~55 km diameter.

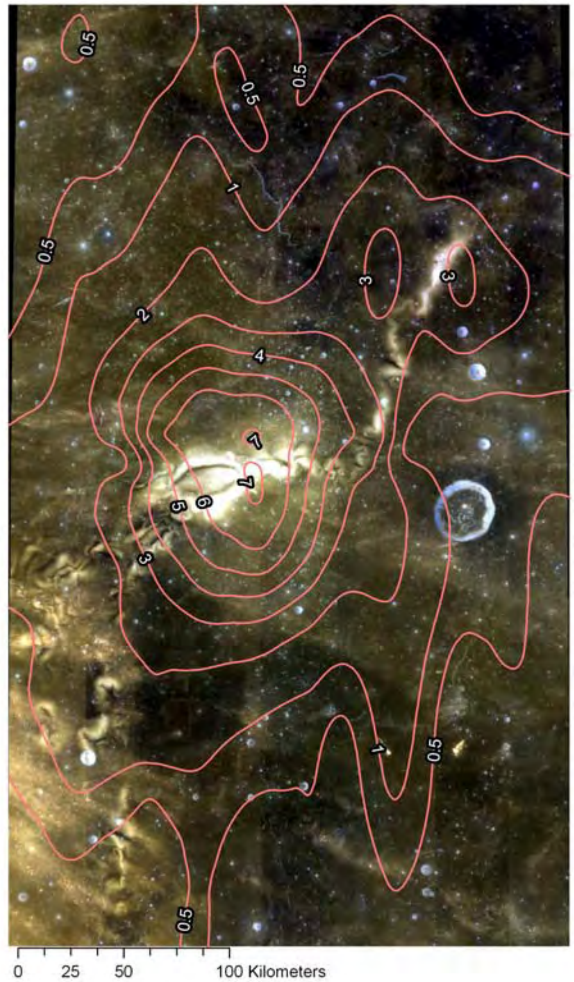


Figure 1. Reiner Gamma Formation.

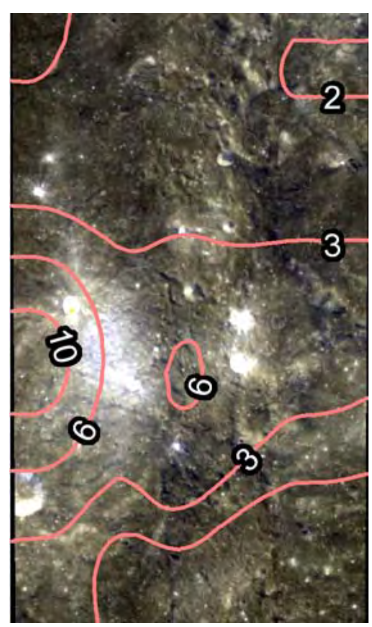


Figure 2 (right). Central nearside highlands. An anomalous bright patch is located to the right of the contour label "10". Width of image ~100 km.