THE LUNAR FAR SIDE SWIRLS: DISTRIBUTION AND POSSIBLE ORIGINS;
L. L. Hood and C. R. Williams, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721.

Introduction: The lunar Reiner γ swirls consist of swirl-like medium albedo units located mostly on the far side and eastern limb (1). These albedo markings correlate closely with magnetic anomalies detected with the Apollo subsatellite magnetometers in two established cases, including that of the prototypical swirl, Reiner γ on western Oceanus procellarum (2,3). Two primary models for the origin of the swirls have been suggested since the magnetics data became available. The first considers that the swirls represent surficial scouring and/or residues resulting from one or more recent impacts of cometary comae on the lunar surface (4). The associated magnetic anomalies are hypothesized to result from transient enhancements of the interplanetary magnetic field due to interaction of the cometary atmosphere with the Moon. The second model considers that the swirls represent albedo contrasts due to deflection of the solar wind ion bombardment by the associated strong magnetic anomalies (5). This model supposes that solar wind hydrogen is at least a partial catalyst for the production of Fe and Ti-rich agglutinates that are dominantly responsible for the darkening and reddening of lunar surface materials with time (6). Analyses of telescopic near-infrared reflectance spectra for the near side swirl, Reiner γ, have been interpreted as indicating that this feature represents an alteration or disruption of pre-existing mare regolith, thereby favoring the cometary impact hypothesis (7). In this paper, as a further test of the cometary impact hypothesis, we examine the distribution of the more numerous far side swirls relative to major surface geologic units and relative to electron reflection maxima measured with instruments on the Apollo subsatellites.

Mapping and Correlative Studies: Apollo 15, 16, and 17 metric camera photographs, selected Apollo 17 Hasselblad photographs, Lunar Orbiter I, III, IV, and V photographs, and Zond 8 photographs were reexamined for the presence of Reiner γ-type swirls, i.e. medium to high albedo markings with a curvilinear or sinuous shape. Despite some limitations, the existing photographic coverage shows that extensive groups of Reiner γ swirls are concentrated in four main zones on the far side: [i] north and east of Mare Marginis on the eastern limb; [ii] within Mare Ingenii and Van de Graaff crater on the south-central far side; [iii] northwest of the Apollo basin on the southern far side; and [iv] west of the Orientale basin, centered on the crater Gerasimovich. Regional maps were constructed to record this distribution as well as major surface units obtained from standard geologic maps. A comparison of these maps with those of ref. 5 shows general agreement although there are significant differences in detail. We attribute these differences mainly to the use of wide-angle photographs at nearly constant solar phase angle in order to better assess the relative brightness and size of individual swirls over a large region. In addition to the swirl maps, we have constructed more detailed maps of the Apollo 15 and 16 subsatellite electron reflection measurements covering the same regions for correlative purposes.

The only apparent correlation of swirl locations with surface geology is a tendency for swirls to occur near units of furrowed and pitted terrain that has been interpreted to be the result of antipodal seismic modification associated with large basin-forming events (8). Units of this type are shown on standard maps in the Mare Marginis zone (Orientale antipode) and in the Ingenii–Van de Graaff zone (Imbrium antipode). In the zone northwest of the Apollo basin (Serenitatis antipode), units of the same class are visible (Lunar Orbiter I frame 38M) and have been added to our maps though they are not explicitly shown on standard maps (9). The remaining zone (centered on Gerasimovich, west of Orientale) exhibits no such terrain although it is located within 5° of the Crisium antipode. This may be attributable to masking by Orientale ejecta as suggested in ref. 8. The concentrations of swirls northwest of the Apollo basin and centered on Gerasimovich are closely correlated with low-resolution electron reflection maxima. (The Gerasimovich swirls were previously found to be correlated with an anomaly maximum in Apollo 15 subsatellite magnetometer data (3).) Large and broad ER maxima occur over the Mare Marginis swirl belt and the nearby furrowed and pitted terrain; no clear preference for one or the other appears to be shown by the ER data in this zone. Finally, the Ingenii swirls occur mainly at southern latitudes that are too large for useful coverage by the available ER data set.

Conclusions: The present maps of far side swirl distributions show a strong tendency for occurrence in the antipodal zones of relatively young large impact basins (Imbrium, Orientale, Serenitatis, and Crisium) where unusual terrain interpreted to be the result of seismic modification is also found in most cases. Since cometary impacts would be expected to occur in random surface locations, the observed preference for basin antipodal zones is inconsistent with a cometary impact hypothesis. The largest concentrations of lunar magnetic anomalies ('magcons') have previously been found to occur in these same antipodal zones (10). Origins for the lunar swirls must therefore be sought that are consistent with a basin-related formation of the magcons (e.g. 11) but compatible also with a relatively young apparent age as deduced from photogeology (4).

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