RECENT COMET IMPACTS ON THE MOON? J.F. Bell and B.R. Hawke, Planetary Geosciences Division, Hawaii Institute of Geophysics, Univ. of Hawaii, Honolulu, HI 96822.

INTRODUCTION: The Reiner Gamma Formation, an albedo and magnetic anomaly in western Oceanus Procellarum, is the only easily observable nearside example of the enigmatic lunar swirl belts. Swirls are much more abundant on the farside where concentrations exist north and east of Mare Marginis, in and near Mare Ingenii, near Gerasimovich crater, and northwest of the Apollo basin[1,2]. Early interest in lunar swirls centered around the unusual geometry of the albedo patterns which is markedly different from common crater rays[2,3]. Renewed interest in these unusual features has followed the determination that Reiner Gamma and other swirl concentrations are associated with major lunar magnetic anomalies[2,4,5]. Recently, major controversies have developed concerning the origin of swirls and their associated magnetic anomalies. Hood and co-workers[4,5,6] have proposed that the Reiner Gamma Fm. consists of unusually magnetic secondary crater ejecta associated with the nearby crater, Cavalerius, or much less likely, with Olbers A. According to this model, the formation's magnetism was created when shocked and/or heated ejecta fragments with abundant Fe° cooled in the presence of a strong magnetic field. Reiner Gamma's high albedo was attributed to the deflection of the solar wind by the magnetic anomaly[6].

An alternative hypothesis suggests that Reiner Gamma and other swirls are the imprints of one or more recent cometary impacts[1,7]. According to this model, streamers of gas and/or dust in the inner coma struck the lunar surface at high velocity and produced major changes in the upper regolith. Schutz and co-workers[1,7,8] proposed that swirls are relatively young and that the magnetism of Reiner Gamma was induced by the cometary field during impact.

In a recent paper[9], we presented the results of analyses of near-infrared spectra obtained for various portions of Reiner Gamma and surrounding units. It was determined that spectra for bright portions could be matched by mixtures of 90-95% fresh mare basalt and 5-10% fresh highlands material. These spectra are very different from those obtained for the mature highlands material exposed in the Cavalarius ejecta blanket and fresh highlands material on the interior of Olbers A. No evidence was found for the presence of "exotic" components such as magnetite, free iron, or cometary material.

Although these results placed major constraints on the dominant hypothesis for the origin of Reiner Gamma, it was clear that additional spectra data were necessary. The needed data were recently obtained and the results of their analysis are presented here.

METHOD: Higher-resolution vidicon images of the Reiner Gamma region were obtained using a silicon vidicon camera and processed using the procedure and techniques described by McCord et al[10]. Multispectral ratio images and spectral units maps were prepared[10,11]. New near-infrared spectra (0.6-2.5μm) were acquired for very small areas associated with Reiner Gamma using the UH 2.2m telescope at the Mauna Kea Observatory. All spectra were processed using the techniques presented by McCord et al[12].

RESULTS AND DISCUSSION: The new high-resolution multispectral images are generally very similar to the lower resolution 0.45/0.56μm and 0.95/0.56μm images previously presented[9]. Hence none of the features discussed are due to instrumental or processing artifacts. Of particular interest is the "red halo" which surrounds Reiner Gamma and is clearly seen in the 0.40/0.56μm image. The region exhibits low 0.40/0.56μm values and has an intermediate albedo. Since this "red halo" appears to correlate closely with the magnetic anomaly presented by Hood et al[4,5,13], it is possible that the halo, rather than the bright swirls, may contain magnetized material.

Near-infrared spectra were obtained for two portions of the halo. One area was north of the swirl and the other was to the south. Analysis of these spectra indicate that the halo material is very similar to local, mature mare deposits. Abundant agglutinitic glass is present. No "exotic" material was indicated but may be present in amounts to less than those which we can detect by reflection spectroscopy.

High spatial resolution spectra were obtained for the brightest portions of the Reiner Gamma Fm. These spectra are for areas <3km in diameter whereas our previous spectra were for areas about 5 by 10km in extent. Inclusion of small patches of darker terrain in the areas for which the previous spectra were obtained was a major concern. Analysis of the new spectra fully confirm our previous results. The brightest portion of Reiner Gamma consists of major amounts of fresh mare basalt fragments similar to those excavated by the nearby crater Reiner K. Very minor amounts of highlands material (∿5%) are present. The presence of small amounts of highlands debris is not surprising since even larger proportions of highlands material were reported for regolith samples returned from the Apollo 11 and 12 sites[14]. All of the materials in the bright areas are extremely fresh. No agglutinate-rich surface layer is present, hence Reiner Gamma must have been formed in relatively recent times.

Previous suggestions that Reiner Gamma was somehow related to Cavalarius[4,5] prompted us to collect additional spectra for this crater. Spectra obtained for the interior of Cavalerius are almost identical to those of exterior ejecta deposits. Apparently Cavalarius excavated and deposited highlands material which has weathered to maturity. Since the

composition and maturity level of Cavalarius--related deposits are quite different from those of the bright portion of the Reiner Gamma Fm., (mature highlands vs. fresh mare) a related origin seems unlikely.

The similarity in albedo of Olbers A ray deposits to that of Reiner Gamma has been noted[5] and an association between Olbers A crater and Reiner Gamma has been suggested[3]. Olbers A is a very fresh, bright-rayed, late Copernican impact crater which is located in the highlands about 400km west-northwest of Reiner Gamma.

To further investigate this question, spectra were obtained for several areas along the well-developed NE-trending Olbers A ray system in western Oceanus Procellarum as well as for nearby fresh mare craters and mature mare surfaces. The ray spectra are different from those of both the parent crater and the Reiner Gamma Fm. This result suggests that Reiner Gamma is not a product of the Olbers A impact event.

A previously undescribed swirl-like feature in the central highlands was pointed out to us by Dr. P. Schultz. This feature is located just west of Airy crater at 3°E, 18°S and exhibits bright areas as well as a dark lane. Spectra were obtained for the brightest portion of the swirl-like feature and the nearby crater Argelander D. The spectra are identical and their characteristics indicate that immature, feldspar-rich highlands material are present in each area.

CONCLUSIONS: The results of analyses of near-infrared reflectance spectra are inconsistent with numerous previous interpretations of the Reiner Gamma Fm. These include: 1) nué ardente or volcanic ash deposits[16], 2) volcanically derived sublimated[15,17], 3) high albedo volcanic deposits[15], and 4) highlands debris emplaced as impact ejecta. These results, as well as those of Schultz and co-workers[1,7,8], strongly suggest that the selective preservation of high albedo features (formed by secondaries) by a local magnetic field enhancement is not a viable hypothesis. Our results are generally consistent with but place constraints on, the cometary impact hypothesis of Schultz and co-workers[1,7,8]. While the presence of a magnetized component was not detected in either the bright or dark portions of the Reiner Gamma Fm., this material may be present in amounts under our current detection limits.

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