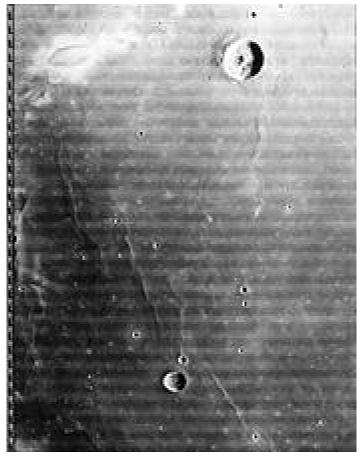

LUNAR SWIRLS, MAGNETIC ANOMALIES, AND THE REINER GAMMA FORMATION

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ABSTRACT

Reiner Gamma is the only near side example of the elusive Lunar Swirl features. There exist only three other known examples, two on the moons far side, and another on Mercury. The origin of these surface deposits and their related magnetic anomalies are a matter of debate, which most likely will not be settled until future lunar missions. We shall here consider their nature and possible origins.

Over a period of 20 or so years, this writer has enjoyed observing many different forms of Lunar features. But One of the most intriguing questions about lunar features I have encountered has been the nature of the lunar ray systems. This interest led me to the feature known as Reiner Gamma, centered at the selenographic coordinates Xi= -.851 Eta= +.129, or -59.11 Deg. Longitude, +7.41 Deg. Latitude. At first glance, one gets the distinct impression that this object is nothing more than a curious Ray feature, but upon more detailed investigation, obviously this is not so.

One strange aspect I find concerning this object is its neglect in most of the popular lunar literature. Only when one begins to actively investigate such an object does this become obvious, as happens with Reiner Gamma. It is all but ignored in the popular Lunar works, with only recent exceptions. It has been drawn on many lunar charts, photographed by the Lunar Orbiter and Apollo missions, and many earth based telescopes. Descriptions of objects in its vicinity abound, but it is seldom mentioned outside professional texts. Even such prolific lunar students as Patrick Moore have paid little attention to this feature.

One prominent aspect of this deposit differentiates it from the lunar ray systems. Unlike the major ray features associated with major impact craters such as Tycho, Copernicus, and Kepler, for instance, Reiner Gamma becomes easily visible soon after lunar sunrise and shortly before lunar sunset.

Apparently, Reiner Gamma is a ray-type surficial deposit, possibly composed of substrate material such as powdered rock. Its appearance is that of a swirl-like pattern composed of high and low albedo units (figure _____, Inez Beck). It is the only nearside example of the rare lunar "swirls." Two additional examples of these features are found on the far side, near Mare Marginis and Mare Ingenii. Based on the most accepted theories of swirl genesis, we might conclude that the only probable correlation between swirl features and the lunar rays to be in the composition of the high albedo units.

This writer's early hypothesis identified Reiner Gamma with the ray extending from Kepler to approximently XI = -.810 ETA = +.130. On any good lunar photograph of the Reiner Gamma/Kepler region, one will note an uncanny alignment between the Swirl deposit and this western Kepler ray. Others have proposed similar ray-crater candidates, such as the ejecta blanket and diffuse ray system of Cavalerious, also the bright rayed crater Olbers A (8). It must be noted that Reiner Gamma exhibits a higher albedo than the Cavalerious rays, while in contrast the albedo units of both Reiner Gamma and Olbers A exhibit definite similarities.

Reiner Gamma exhibits a total lack of elevation and other forms of relief. For example, I find no association with sub-telescopic secondary impact craters. This writer has conducted a search of Lunar Orbiter photographs showing no conclusive evidence of higher cratering within the boundary of the deposit than in the surrounding terrain. Lunar Ray systems, on the other hand, exhibit an increase in crater counts within their higher albedo units as compared with surrounding terrain. (4).

D.W. Arthur noted that mare ridges similar to those transecting Reiner Gamma to possess slopes 20-50 meters high as measured in other areas. Ridges transecting the deposit cast shadows on telescope photos of the region when taken at low solar illumination. But the deposit itself show no signs of shadows. Thus, the maximum thickness of the deposit is suggested as approx. < 10 meters ( ).

This brings us to the question of origin. Unfortunately, we have no mineralogical samples from these locations. Owing to the lack of physical data besides the significant discovery of a magnetic anomaly associated with this feature (6), we must learn the origin of such rare features from indirect methods, such as telescopic observation, photography and other imagery, photometric, and indirect data from the Apollo, Lunar Orbiter, and Galileo Missions.

There are several leading theories as to the origin of Reiner Gamma and the other swirl features. These include cometary impact, antipodal effects of major basin formation (seismic wave effects), unusual lunar ray systems controlled by the high magnetic fields located at these locations, solar magnetic storm phenomena, and the gaseous alteration from lunar volcanism, to name a few. (5).

We shall here primarily consider the most accepted, that of cometary impact and antipodal effects of major basin formation impact events.

Due to the heavily cratered nature of the surface of the moon and Mercury, it is a natural assumption (assuming impact as the mechanism of most lunar cratering) that at least some of these craters are due to the impact of cometary bodies, especially in light of mass extinction theories, in which major "showers" of comets from the Ort cloud caused extinctions such as that of the dinosaurs.

It has been suggested that the Swirl features indigenous to the Moon and Mercury are of such cometary origin (6). The problem exists as to how to distinguish cratering resulting from cometary impact from that produced as the result of meteoroid impact.

In the cometary impact view of the origin of the lunar swirl features, it was proposed that Reiner Gamma, and those swirls found on the lunar far side, are the result of the impact of a split nucleus comet, with at least two impact points identified: the far side crater Goddard A marking the point of impact of one of these nucleuses, whereas a smaller crater on the rim of O'Day would mark the second point of impact. (6).

Thus, these swirl patterns could be the result of high-velocity imprinting of cometary dust and the fine structure of the coma. The age of these patterns has been suggested as 10 years (6), making these patterns relatively young lunar features.

The idea of fragmented cometary structures orbiting within the inner solar system is nothing new. In recent months this has become especially apparent considering the forthcoming encounter between comet Shoemaker-Levy 9 and the planet Jupiter. Additional examples of such fragmented (split nucleus) comets can be cited, such as comet West (1976). Comet Brooks 2 (1886) may also be an example fragmented from the gravitational forces of Jupiter. Evidence of such multiple nucleus comets impacting solar system bodies may be cited. For example, Ganymede exhibits "lined up" craters that suggest the impacting body to have been that of such a multiple or split nucleus object (14). Callisto boasts 13 similar examples, including Gipul Catena, a 620 km impact crater chain (17).

Lunar counterparts for such alignments are not unusual. One choice example lies east of Walter (near Long. 6.45, Lat. -42.41, see IV-107-H3), consisting of an alignment of 6 craters (figure-----) closely matching the Gipul Catena feature on Callisto. While many of these probably resulted from secondary impact of major crater ejecta, it is logical to assume that multiple nucleus cometary impacts are responsible for others. This brings forth the possibility of a new observational program for the identification and cataloging of aligned craters.

It is important to note that besides the swirl pattern at Reiner Gamma, a relatively strong field of magnetization has also been discovered, and other magnetic anomalies in other regions that include those containing the far side swirl features (Hood, 1979). This association could be explained by the cometary-impact model, in which the impacting coma and tail have caused deposits and possibly altered the physical properties of the upper regolith in these locations. Shultz and Srnka suggested the impacting coma gases could have produced concentrations of magnetite in the dark areas of these swirls. (6).

The absence of a global magnetic field on the Moon is a well

established fact, dating from the early days of lunar probes. These strong localized magnetic fields found in association with the swirl features, in addition to lunar samples displaying strong, stable components of natural remanent magnetization (NRM) add credence to both the cometary impact and the antipodal magnetization theories discussed below, and are cited as possible evidence to support each model. Strangway (1973) proposed the hypothesis that lunar magnetic anomalies were the result of meteoroid impacts (18).

The second view considered here on the origin of the Swirl patterns suggests quite a different scenario from that proposed in the cometary impact model. It has been suggested that major Mare formation (i.e., the Imbrium impact event) lead to antipodal effects, such as subdued pits, hillocks, fractures, and chaotic textures (9), besides the swirl features.

In this hypothesis, the swirl markings on both the Moon and Mercury are attributed to be the result of major impacts diametrically opposed (antipodal) to the swirl's positions. It is noted that the swirl features found at Mare Inginii, Mare Marginis, and on Mercury are located directly antipodal to Mare Imbrium, Mare Orientale, and the Mercurian Caloris Basin, respectively.

While Reiner Gamma is typical of the lunar swirls, it must be noted that it is not located at the antipode of a major basin, although some argument can be made as to its antipodal source being the far side feature Tsiolkovsky.

Hood (et al., 1979) noted magnetic signatures at the antipodes of 26 ringed impact basins, the strongest of which were at the antipodes of young ringed basins. All the Lunar Swirl features are correlated with such strong magnetic anomalies, with the Reiner Gamma feature marking the position of the strongest of these. Also, it was noted in the same work that even the older basins reflected fields at their antipodes, although these fields were relatively weak. All these observations seem to strengthen the antipodal basin point of view.

In closing there is another possibility that I will address briefly, the possibility that lunar and Mercurian swirl features might be the result of impact ejecta acted upon by localized fields of magnetism, independent of the impact event producing the anomalies themselves. Thus, both these theories might be necessary to explain these swirl patterns. In both cases, it has been suggested that these magnetic anomalies and the swirl patterns themselves resulted in some way from the impact of another body with the surface of the moon.

Both models attempt to explain the magnetic anomalies described above, and either could explain the swirl patterns as the result of ejecta having been acted upon by these fields of magnetism.

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