

SWIRL DISTRIBUTION ON THE LUNAR SURFACE: LOCATIONS ANTIPODAL TO THE YOUNG BASINS?

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The nature of diffuse albedo anomalies on the lunar surface that look like swirls is one of most interesting mystery in current lunar studies. There are two main classes of hypotheses of the swirl origin: formation of the swirls in the regions antipodal to large impact basins (1), and formation of the swirls in result of cometary impacts (2).

Unusual, light-colored surface markings were observed in Mare Marginis in results of the analysis of Apollo-8 photography and visual observation (Whitaker, 1969). Identical markings were distinguished by El-Baz (1971) in Mare Ingenii on the lunar far side and were associated with those in Mare Marginis. It was noted that the positioning of these two regions on the lunar globe was striking: the swirls of Mare Marginis location was diametrically opposed to the Mare Orientale, and the swirls of Mare Ingenii lied on opposite side of the Mare Imbrium (El-Baz and Worden, 1972). According to the opinion of the authors these markings are perhaps due to chemical alteration of the surface material, and the alteration may have been caused by the release of gases from the lunar interior. The release of gases, in turn, may have been triggered by seismic-wave attenuations at the antipodal areas of the impacts that created basin Imbrium and basin Orientale.

Later, Hood and Schubert (1980) proposed that swirls represent regions whose higher albedo have been preserved due to deflection of the solar wind ion bombardment by strong crustal fields. The most likely magnetization mechanism was proposed by Hood (1987), in which the ionized vapor cloud produced in a hypervelocity basin-forming impact expands around the Moon and concentrates the pre-existing ambient magnetic field at the basin antipode. The analysis of the swirl distribution carried out by Lin et al. (1988) confirms that the swirl-like albedo markings of the Reiner Gamma class on the far side of the Moon are located near the antipodes of the young impact basins, Imbrium, Orientale, Serenitatis, and Crisium. The most recent data obtained by the Lunar Prospector show that swirl features are associated with magnetic anomalies and they lie on regions antipodal to the Imbrium, Serenitatis, and Crisium basins (Hood et al., 1999).

Gold and Soter (1976) suggested a mechanism of a local magnetic field origin on the Moon in result of cometary impact. The local shock produced by collision of the main mass of a comet nucleus with the Moon will indeed occur just when the ambient solar wind fields have been strongly enhanced, as the large partially ionized cometary coma is compressed against the lunar surface. Schultz and Srnka (1980), Bell and Hawke (1987), Shevchenko (1993) considered that swirl patterns on the lunar surface could be related to the imprint of recent cometary impacts. This hypothesis does not suggest correlation between the swirl locations and the regions antipodal to basins.

In order to investigate the features of the swirl distribution along lunar surface there were identified and mapped swirl locations within regions where they were observed. The areas of all identified swirl fragments were measured and statistical analysis of the distribution was performed (Shevchenko, 1994, 1996). In Figure 1 modified sketch map of the distribution of swirl markings on the lunar surface is shown. Contours indicate the total area occupied by swirl fragments inside each frame $10^{\circ} \times 10^{\circ}$. Contour interval is $2.5 \times 10^3 \text{ km}^2$.

All swirl markings (with the only one exception – Reiner Gamma formation) lie on the far side of the Moon. Reiner Gamma swirl is relatively small formation. Its area is $3.3 \times 10^3 \text{ km}^2$. Swirl region in Mare Ingenii extends on the area equal to $50.2 \times 10^3 \text{ km}^2$. The swirl area in Mare Marginis achieves $73.9 \times 10^3 \text{ km}^2$.

Locations of the regions antipodal to young and large (diameter of the main rim is more than 500 km) basins are shown in the sketch map too (letter “A” means “antipode” of the corresponding basin). Relative ages and diameters of the basins were identified by Wilhelms (1984). The Orientale basin is youngest. It is related to the younger Imbrian Period (3.2 – 3.8 b.y.). The formation of the Imbrium basin is related to the Imbrian Period too. According to Wilhelms’ classification the Imbrium basin is relatively older than Orientale one. Others basins shown in the sketch map are related to the younger Nectarian Period (3.8 – 3.9 b.y.). They have nearly the same age.

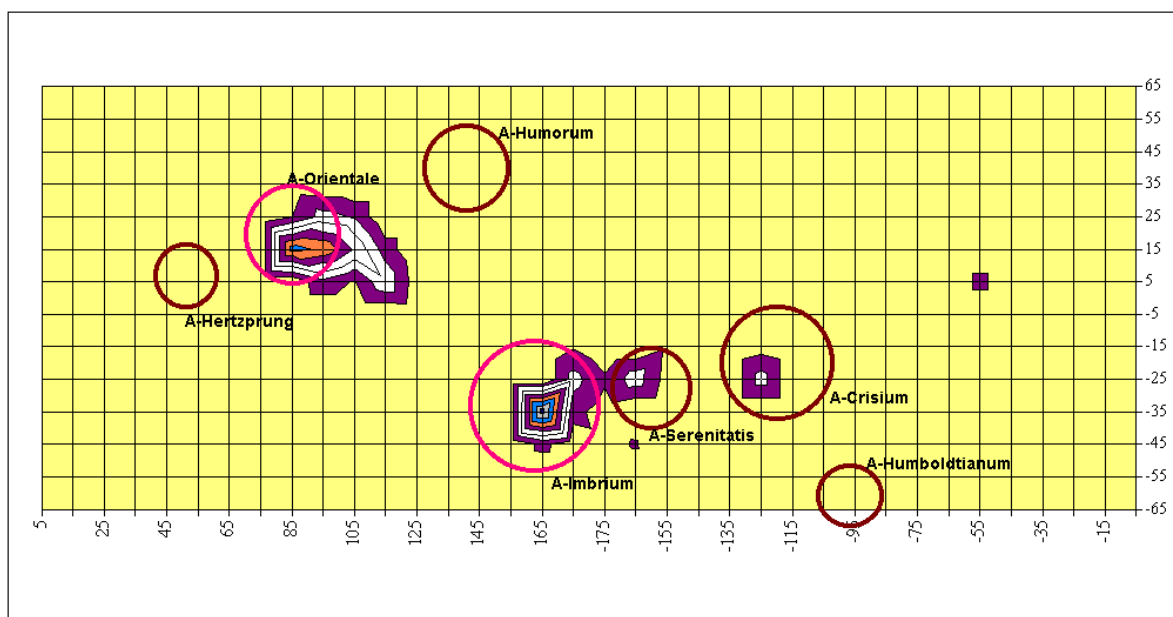


Fig. 1

The more strong correlation is observed for youngest large basins: Orientale and Imbrium. The swirls are absent in region antipodal to youngest (second age group, more younger than Imbrium basin) but small (320 km) Schrodinger basin. This antipodal region locates on the near side of the Moon. The swirl area is observed on region antipodal to Serenitatis basin, but any swirl markings are absent on regions antipodal to Humorum, Hertzprung, and Humboldtianum basins in spite of similar age and diameter of them.

On the other hand, there are two cases of absence of correlation between swirl areas and regions antipodal to impact basins (for small swirl formations). The Reiner Gamma formation is most obvious example of that the correlation mentioned above is not statistically strong and do not exclude the swirl origin associated with external reason, such as cometary impact (Pinet et al., in press). Of great interest is to compare the typical morphological features of the different swirl markings. The available Clementine images (Clementine DIM, 1997) allows one to compare, for example, albedo features of the Reiner Gamma formation with albedo features of the swirl markings located in the area antipodal to the Crisium basin. The area includes a fragment that is located in the crater Gerasimovich itself and some small albedo formation to the North of the main structure.

Fig. 2a shows a bright “loop” - typical detail of the Reiner Gamma. In Fig. 2b it is shown the analogous detail of swirl located into crater Gerasimovich. The linear scale of the both images is the same. Other type of characteristic detail – “close loop” is shown in Fig. 3a (Reiner Gamma swirl) and in Fig. 3b (crater Gerasimovich swirl). The linear scale of the both images is the same.

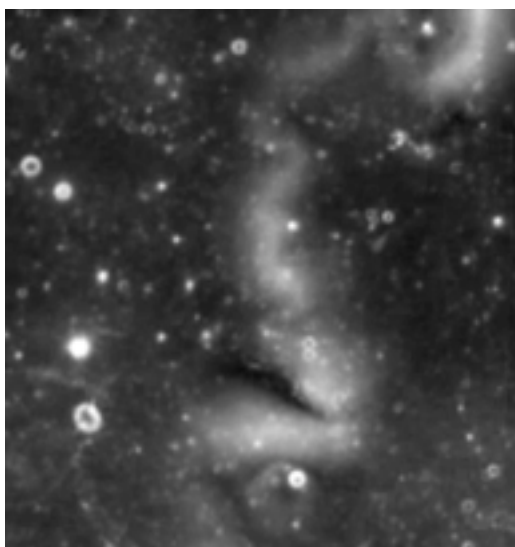


Fig. 2a

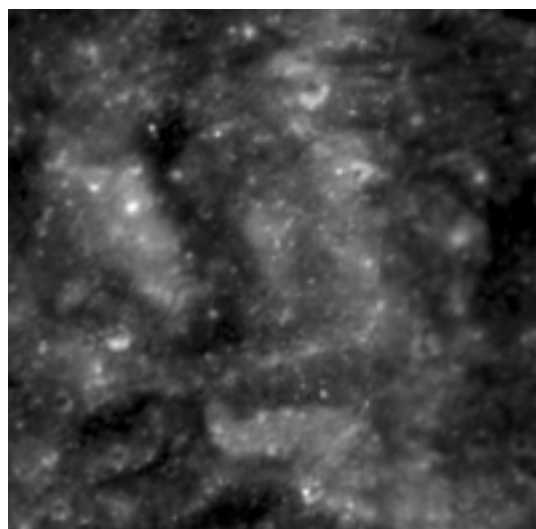


Fig. 2b

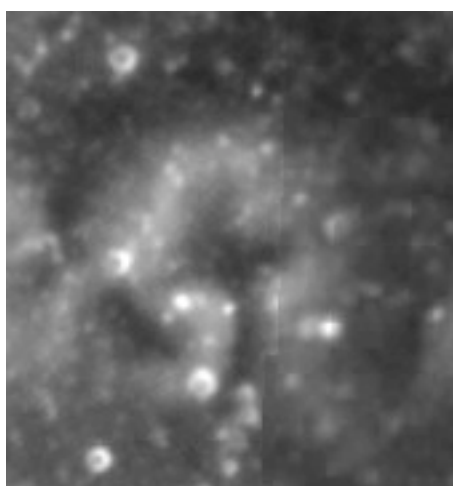


Fig. 3a

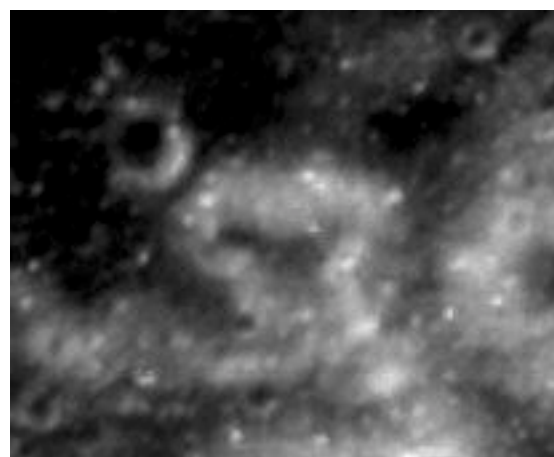


Fig. 3b

The presence of the characteristic details in the form of complex loops inside crater Gerasimovich swirl allows unambiguous classification of this albedo anomaly as a swirl of the same type as Reiner Gamma.

References. Bell, J.F., Hawke, B.R. *Publ. Astr. Soc. Pac.*, 99, 1987, 862-967. *Clementine Digital Image Model*, U.S.G.S.-NASA CD, 1999. El-Baz, F. In: *Trans. American Geophys. Union, Fall Meeting*, 1971. El-Baz, F., Worden, A.M. In: *Apollo 15 Preliminary Science report. NASA SP-289*, 1972, 25.1-25.27. Gold, T., Soter, S. *Planet. Space Sci.*, 24, 1976, 45-54. Hood, L.L., Schubert, G. *Science*, 208, 1980, 49-51. Hood, L.L., *Geophys. Res. Lett.* 14, 1987, 844-847. Hood, L.L., Yingst, A., Mitchell, D.L., Lin, R.P., Acuna, M., Binder, A. In: LPI contribution № 980, 1999, 28-29. Lin, R.P., Anderson, R.A., Hood, L.L. *Icarus*, 74, 1988, 529-541. Pinet, P.C., Shevchenko, V.V., Chevrel, S.D., Daydou, Y., Rosemberg, C. *J. Geophys. Res.* (in press). Schultz, P.H., Srnka, I.J. *Nature*, 284, 1980, 22-26. Shevchenko, V.V. *Astron. Zh.*, 70, № 3, 1993, 623-634. Shevchenko, V.V. *Astronomy Reports*, 38, № 6, 1994, 831-838. Shevchenko, V.V. *Solar System Research*, 30, № 1, 1996, 51-63. Whitaker, E.A. In: *NASA SP-201*, 1969, 34-35. Wilhelms, D.E. In: *The Geology of the Terrestrial Planets, NASA SP-469*, 1984, 107-205.