Table 7

Device	Vertical		South		North	
	before	after	before	after	before	after
T_0	1.1	1.1	1.0	1.1	0.8	0.8
T_7	1.1	1.4	1.0	1.4	0.7	1.2
T_{20}	1.3	1.7	1.4	1.8	1.2	2.0
T_{60}	2.0	2.0	...	...	...	...

of cosmic rays are explained basically by the temperature effect (dotted-line curves), and, second, the intensity of cosmic rays apparently undergoes noncyclical secular variations. At the same time, the intensity of cosmic rays increased by about 2.5% at the surface and by about 0.5% at 20 m.w.e. depth from the beginning to the end of the year. Within the bounds of experimental errors, this increase is not noticed at depths of 7 and 60 m.w.e. It must be noted that the noncyclical part of variations at a depth of 7 m.w.e. either was accidentally excluded, due to the insufficiently justified method of combining the observations (an interruption in registration occurred due to changing of counters) or had a very small amplitude. At the same time, the effect of intensity increase apparently occurred at 20 m.w.e. Here, the interpretation of data was conducted with the aid of the reading of two independent devices, and for this reason these data may be considered more reliable. Therefore, if we assume that the effect at 20 m.w.e. exists in reality and has an amplitude of several tenths of a percent, it may be asserted that the spectrum of the 11-year variations extends through to energies of several tens of Bev. This fact alone is in immediate contradiction to the results of Parker's computations (17). At the same time, this result agrees well with the computations (18) in which the influence of large scale vortices in the solar wind of interplanetary medium was taken into account.

—Submitted April 10, 1961

References

1 Dorman, L. I., *Cosmic Ray Variations* (State Technical Press, Moscow, 1957).
2 Kuz'min, A. I., Skripin, G. V., and Yarygin, A. V., Contributions of Yakutsk Subsidiary of the Academy of Sciences USSR, Physics Series **2**, 34 (1958).
3 Kuz'min, A. I. and Yarygin, A. V., Contributions of Yakutsk Subsidiary of the Academy of Sciences USSR, Physics Series **2**, 37 (1958).
4 Kuz'min, A. I., Dissertation, Moscow University (1960).
5 Dorman, L. I. and Feynberg, E. L., *Cosmic Ray Variations Underground, at Sea Level and in the Stratosphere* (Academy of Sciences Press, USSR, Moscow, 1959), p. 49.
6 Kuz'min, A. I., *Proceedings of an International Conference on Cosmic Rays* (Academy of Sciences Press, USSR, Moscow, 1960), Vol. 4, p. 48.
7 Dorman, L. I., *Results of International Geophysical Year, Cosmic Rays* (Academy of Sciences Press, USSR, Moscow, 1961), No. 3, p. 198.
8 Kuz'min A. I., *Proceedings of an International Conference on Cosmic Rays* (Academy of Sciences Press, USSR, Moscow, 1960), Vol. 4, p. 252.
9 Kuz'min, A. I. and Skripin, G. V., Contributions of Yakutsk Subsidiary of the Academy of Sciences USSR, Physics Series **3**, 129 (1960).
10 Blokh, Ya. L., Dorman, L. I., and Kaminer, N. S., *Proceedings of an International Conference on Cosmic Rays* (Academy of Sciences Press, USSR, Moscow, 1960), Vol. 4, p. 155.
11 Blokh, Ya. L., Dorman, L. I., and Kaminer, N. S., *Proceedings of an International Conference on Cosmic Rays* (Academy of Sciences Press, USSR Moscow, 1960), Vol. 4, p. 178.
12 Roka, E. G., Z. Naturforsch **A**, 517 (1950).
13 Dorman, L. I., *Results of International Geophysical Year, Cosmic Rays* (Academy of Sciences Press, USSR, Moscow, 1960), No. 3, p. 198.
14 Brunberg, E. A. and Dattner, A., Tellus **6**, 73 (1954).
15 Regener, V. H. and Kenney, J. F., *Proceedings of Moscow Cosmic Ray Conference* (Academy of Sciences Press, USSR, Moscow, 1960), Vol. 4, p. 216.
16 Sekido, I. and Ioshida, S., Rel. Ionosphere Res. (Japan) **4**, 37 (1950).
17 Parker, E. N., Phys. Rev. **110**, No. 6 (1958).
18 Dorman, L. I., *Proceedings of an International Conference on Cosmic Rays* (Academy of Sciences Press, USSR, Moscow, 1960), Vol. 4, p. 328.

Editor's Note

This paper was reviewed by Dr. E. N. Parker, The Enrico Fermi Institute for Nuclear Studies, The University of Chicago, who notes that it is a straightforward discussion of the analysis of cosmic ray variations for the purpose of deducing conditions in interplanetary space, based on Dorman's concept of interplanetary field behavior. A number of people in this country have undertaken similar investigations, e.g., Simpson (1), Gold (2), and many others, based on other concepts of interplanetary fields.

—IGOR JURKEVICH

1 Simpson, J. A., Astrophys. J. Suppl. **4**, 378.
2 Gold, T., Astrophys J. Suppl. **4**, 406.

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Structure of the Moon's Surface and Investigation of the First Photographs of Its Far Side

N. P. BARABASHOV

THE productive study of the lunar surface began after the telescope was invented in 1609. As is well known, at present, the part of the moon visible from the earth is rather well studied. Telescopic investigations revealed many cirques and craters, enormous plains called lunar seas, mountain ranges, isolated elevations, and clear bands (bright rays) spreading radially from certain craters. The nature of these rays has not yet been clarified. Also, numerous fissures (some of them very broad and deep[1]) are noted on the moon's surface. However, even now there is no unique opinion about the state in which the surface layers of the moon are found and what sort of rocks compose them.

A number of astronomers believe that the lunar surface consists of rocks different from those forming the surface of the earth. However, such assumptions are difficult to accept, for the close kinship and similar formation conditions of the

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[1] Lunar fissures, properly termed rilles, are not particularly deep; their depth is never more than one-fifth their breadth.—Reviewer.

earth and the moon make the absence of terrestrial-like rocks on the moon and the presence of kinds unknown on earth quite improbable.

Other investigators hold the opinion that rocks forming the lunar surface are mainly volcanic rocks known on earth but that the surface of these rocks has been modified considerably by meteoritic impacts and other cosmic factors such as cosmic, ultraviolet, and x rays. One must agree with the fact that the effect of such factors on the moon, a body almost devoid of atmosphere, must play a considerable part in reworking the material constituting the lunar surface.

L. N. Radlova (1)[2] maintained that the lunar surface is completely mantled by a layer of material of meteoritic origin. She considered the dust mantle of the moon to be semi-transparent or not quite continuous, so that the underlying surface may be visible through it as if it were translucent.

A. Dollfus (2) assumes that the entire moon is covered by volcanic ashes of varying luminosity, consisting of many-sized grains. This difference in luminosity and grain size is also the cause of difference in the luminosity of lunar formations. The possibility of such a continuous covering of plains as well as of slopes of lunar mountains by ashes meets with substantial difficulties.[3]

N. N. Sytinskaya (3) considers that the entire visible lunar surface is covered with a layer that formed through the disintegration of rock formations composing the moon. The basic factor of such metamorphosis is the impact on the lunar surface by meteoritic bodies of various sizes. We assume that the mantle so obtained is not dust but a porous, spongy sintered slag (of volcanic type), which formed under the effect of high temperature developing from meteoritic impacts.

The low reflection capacity and the small difference in color of the various surface regions constitute the fundamental and the most perceptible characteristic of the lunar surface. It appears that the greatest gradation of reflecting capability (ratio of reflecting capability of lunar surface's darkest spots to those of the brightest region during a full moon) constitutes only 1:3.46, with the brightest regions having a 0.180 luminosity and the darkest, 0.052. As for the coloring, if, in the first approximation, one takes the standard color index to express it, i.e., the difference between the photographic and visual stellar magnitude, it is found that it falls within the 0.92 to 1.12 range. If we plot the minimum and maximum luminosity of lunar details on the x axis and the maximum and minimum color index on the y axis, we obtain a rectangular region in which all lunar objects are included according to luminosity as well as to color index. Here, it is appropriate to note that the area of the rectangle obtained is small compared with the area in which terrestrial rocks may be located and that certain of the rocks occurring within the rectangle may not correspond to the lunar types, for they may have a different energy distribution in various regions of the spectrum, and they may differ also in other characteristics (e.g., polarization, light reflection law, density, etc.). The simultaneous comparison method according to luminosity and color was applied by N. N. Sytinskaya (3), who concluded that not one of the rock types may be recognized as conformable with the lunar surface.

Based on studies adduced in Ref. 4, it was found that the following rocks get into the forementioned "lunar" rectangle: tufaceous lava, liparite, quartz-keratophyre, bestonite, and tuffs. The other types of rocks subjected to measurements did not appear in the rectangle.

As already noted, not all rocks occurring in the "lunar" rectangle may be considered to be components of the lunar surface (because of their polarization properties, laws of reflection, etc.). Based on the study of polarization properties of the lunar surface and terrestrial rocks and also of energy distribution in the 3600 to 7500 Å spectral region, we may conclude that only tuff-like rocks and volcanic ash may be compared with rocks that form the lunar surface.

Our research shows that rocks undergoing fusion either in vacuum or under atmospheric pressure cannot resemble lunar objects; they become almost colorless and have a polarization considerably exceeding that of lunar surface rocks. The fused and subsequently carved rock surfaces are also characterized by an excessive polarization. The porosity of the lunar surface is about 0.80.

Observations that were made in 1918 have shown that the law of light reflection from the lunar surface differs sharply from the Lambert law, approximately valid for ideally mat surfaces. It was shown that the brightness maximum of any arbitrarily located lunar sea sector is reached near the full moon phase, when $\alpha \approx 0$ and $i \approx \epsilon$ (i and ϵ being the angles of incidence and reflection, respectively), i.e., when the ray incident to a lunar sea sector and the ray reflected from it run along almost the same direction. It was later shown by A. V. Markov (5) that mountain regions also have this peculiarity, which thus is not limited to lunar seas. It seemed that if the lunar surface part lies near the western edge of the lunar disk, its brightness increases slowly, reaches the maximum at full moon, and then decreases rapidly. As for the part near the eastern edge of the lunar disk, the opposite phenomenon takes place: brightness quickly increases, reaches a maximum at full moon, and then decreases slowly. For the lunar disk's central meridian, the ascending and descending branches of the curve are symmetrical. Also, it resulted that during the full moon all the regions of the lunar surface with an identical albedo had an identical brightness. Hence it follows that, if the whole of the lunar surface had the same albedo, the moon when full would appear to be a uniformly illuminated disk.

Based on a study of light reflection from rough, porous surfaces covered with many-sized grains, all the forementioned peculiarities of the law of light reflection from the lunar surface were explained by the author as a result of extreme porosity, scarring, and roughness of the lunar surface. It turned out that scarring (microrelief) of the lunar surface was so great that the standard terrestrial rocks, excluding spongy tuffs, which correspond somewhat to the microrelief of the moon, do not resemble the lunar surface rocks. Indicators constructed for the "intensity equator" of the moon by N. S. Orlova (6) as well as by N. P. Barabashov and V. I. Garazha (7) also attested to the same condition. According to Orlova, indicators of continents and seas nearly coincide, whereas those of Barabashov and Garazha are more elongated for the continents than for the seas, which result points to greater scarring in the continental regions.

Further studies by N. P. Barabashov, A. T. Chekirda (8), V. A. Fedorets (9), V. V. Sharonov (10), N. N. Sytinskaya (11), and others agree with the conclusions made at the Khar'kov Astronomical Observatory concerning the intensive scarring of the entire lunar surface.

Research on various artificial surfaces covered with varying irregularities led us to conclude that the best agreement with lunar observations is yielded by surfaces covered with sharp-ended rough spots and parallel fissures.[4]

It was further clarified that fine dust uniformly covering a smooth surface cannot yield the light reflection effects observed on the moon, since the law of reflection from a frag-

[2] Numbers in parentheses indicate References at end of paper.

[3] The recently discovered phenomenon of cold welding for sintering of powders under high vacuum conditions disposes of these difficulties. See R. A. Roche, "The importance of high vacuum in space environment simulation," *Vistas in Astronautics* (Pergamon Press, New York, 1959), Vol. 2, pp. 22–27.—Reviewer.

[4] Recent investigations by van Diggelen ("Photometric properties of lunar crater floors," Recherches Astronomiques de l'Observatoire d'Utrecht **XIV**, no. 2, 1959) show that this model does not agree too well with the observation—the best agreement was obtained with "reindeer moss," i.e., a material possessing holes in all directions, so that it is, in a sense, transparent.—Reviewer.

mented substance approaches the Lambert law as the coarseness of the grains diminishes.

Barabashov, Yezerskaya, Yezerskii, and Ishutina (12) completed a study of the photometric homogeneity of lunar regions, encompassing various types of lunar objects as well as various parts of the lunar disk. The Helmholtz principle of optical reciprocity was used for this purpose. The correlation that must be satisfied by the brightness of two areas of the moon when their surfaces have identical reflecting capabilities was arrived at by Minnaert (13). Eighty-four comparisons were made, and, in the final presentation of the results, the details of each sector were divided into three groups: 1) seas, swamps, and gulfs; 2) continents and craters; and 3) bright rays.

When comparing the objects belonging to one group of lunar formations, the mean deviation is small and notably smaller than when comparing objects belonging to different groups. Thus the greatest deviations are revealed in the photometric comparison of seas and continents with one another. On an average, the seas and continents show a difference in scattering properties, as does the photometric structure of bright rays where they pass over these different regions. The impression is created that bright rays adopt the photometric structure of the regions along which they fall. We thus can conclude that, on an average, the lunar surface is photometrically homogeneous, although seas and continents differ slightly from each other. In some cases, this difference is relatively small. Hence, the conclusion follows that the lunar surface is, on an average, endowed with a single degree of porosity.

The photometric structure of the lunar surface results from the action of internal forces, determining macro- and microrelief, as well as from that of external forces provided with greater action isotropy, and able to exert a substantial influence on microstructure. The photometric uniformity that was revealed gives evidence of this. Consequently, it may be said that in the presence of a general uniformity, lunar seas and continents are still endowed with notable differences: 1) continents are, on an average, more reddish than seas; and 2) the porosity of the continents is, on an average, greater than that of the seas.

Photometric investigations of crushed tuff carried out at the Khar'kov Astronomical Observatory, in which the reflected light was measured while the angles of incidence, reflection, and azimuth between the incident and the reflected ray were all varied independently, have further corroborated the opinion that the lunar surface is covered with irregularly arranged grains, the dimensions of which range from 1 to 6 mm. Investigation of the moon with the help of decimeter waves, for which the moon still appears smooth (14,15), leads to the same results. N. N. Sytinskaya (11) assumes that the irregularities conditioning the lunar microrelief are within the 1 to 10 mm range.

All that has been stated in the foregoing refers to the side of the moon visible from the earth. What the structure of the other side may be and what peculiarities characterize that part of its surface were unknown until recently, although many astronomers advanced various assumptions about it. They considered that the areas occupied by seas on the far side of the moon are as broad as those on its visible side and that craters and cirques are just as numerous. The inference is that the visible and far sides scarcely differ. Others expressed the opinion that the invisible side of the moon, always facing away from the earth, must differ from the visible side. But all these assumptions could not pretend to be at all reliable, for they were based on quite tenuous foundations. At the same time, an understanding of the structure of the moon's far side and the peculiarities of its relief is of substantial interest. That is why the direct photographing of the far side of the moon, carried out with the aid of the automatic interplanetary station (AIS) on October 7, 1959, has great significance for a comprehensive study of our natural satellite and is a historical feat of utmost importance.

Let us recall that photographing the reverse side of the moon aboard the AIS began on October 7, 1959 at 0630 hr Moscow time and lasted 40 min. The selenographic coordinates of the AIS and its distance from the center of the earth for the moments of the beginning and the end of photographing were, respectively, $\beta_1 = +16°.9$; $\lambda_1 = +117°.9$; $R_1 =$ 65,200 km and $\beta_2 = +17°.3$; $\lambda_2 = 117°.1$; $R_2 = 68{,}400$ km. The photographing was carried out with the help of two objectives with focal lengths of 200 and 500 mm. The pictures were transmitted to the earth with the aid of television devices and photographed again on the ground.

From a preliminary study, we could ascertain that mountain regions predominate on the far side of the moon. Seas similar to those located on its visible part are scarce. A fairly large crater sea about 300 km in diameter and situated between the latitudes $\beta = +20°$, $\beta = +30°$ and longitudes $\lambda = \pm 140°$, $\lambda = \pm 160°$ was detected here and designated as the "Moscow Sea." This sea has a gulf, called "Astronauts' Gulf."[5] All the region of the far side of the moon contiguous to its western edge has an albedo intermediate between that of mountainous regions and that of sea regions of its visible side (16).

It should be noted that craters (except those near the terminator), have very smooth, eroded outlines. This is explained by the fact that, at the time of photographing, the moon was almost at the full phase (in relation to the AIS). Moreover, we know that, during the full moon phase, craters are seen by a ground observer as weak, bright rings, only weakly outlined, showing at times darker bottoms. This circumstance, i.e., the lack of relief, has hindered considerably the identification of details and the determination of their character. However, in the southern hemisphere of the moon, a large crater with a diameter of more than 100 km is clearly and sharply outlined in the region with the coordinates $\beta = -20°$ to $-30°$ and $\lambda = -30°$. This crater has been named "Tsiolkovskiy." It merits special attention because it has a particularly dark bottom and an exclusively bright central hill; the brightness of the central hill is quite great, and one is led to wonder whether or not it might be self-luminescent.[6]

A bright line, consisting of a band of craters and hills, extends southeast (cartographic or astronautical directions) of Humboldt Sea. This band is interrupted in places by darker intervals. It has the form of a range extending for almost 2000 km. A bright band resembling a light beam also extends in the same direction.[7]

The results of processing the photographic material at the Khar'kov Observatory were as follows. All the details revealed during the first stage of the processing were quite clearly defined and thus did not cause any doubts. Also, new craters were found, sharply outlined at the terminator, and boundaries of certain seas were made more precise. The final results of the combined processing by the Shternberg State Astronomical Institute in Moscow, the Principal Astronomical Observatory in Pulkovo, and the Khar'kov Astronomical Observatory have led to the revelation of more than 400 details and were presented in the *Atlas of the Far Side of the Moon* (17).

From the examination and subsequent processing of the photographs at Khar'kov University Astronomical Observatory (18,19), we can conclude that:

[5] Not definitely confirmed. See E. A. Whittaker, "Evaluation of the Soviet photographs of the moon's far side," Communications, Lunar and Planetary Laboratory Rept. 13, University of Arizona (to be published).—Reviewer.

[6] Very unlikely. The photographs given in Ref. 17 show that there are many regions brighter than this central object; it might be equally a bright crater (cf., the crater Hercules).—Reviewer.

[7] This bright line consists of ordinary bright rays, three ray centers, and their surrounding nimbi (see reference cited in footnote 5).—Reviewer.

1) The invisible part of the moon photographed with the AIS differs from the visible part directed toward the earth; the former is covered by a great number of craters, and the seas are very few.

2) The albedo of many regions of the far side of the moon is quite high.

3) The bottoms of many craters are very dark, and they compare in degree of darkness with the darkest regions of the visible part of the moon.

4) There extends over the far side of the moon, to the south-southeast of the Humboldt Sea, an enormous and very bright ray originating from a crater surrounded by a bright glow.[8]

5) The central hill of certain craters has so great a degree of brightness that the possibility of luminescence is suggested.[9]

6) Preliminary investigations suggest that the porosity (microrelief) of the surface of the moon's far side is the same as, if not greater than, that of the visible side, and the distribution of brightness over the surface of the full moon visible from the AIS is represented by an almost straight line.

—Submitted September 15, 1960

[8] Actually three ray centers (see footnote 7).—Reviewer.
[9] See footnote 6.—Reviewer.

References

1 Radlova, L. N., Pirioda, No. 8, 23 (1939).
2 Dollfus, A., Ann. Astrophys. **19**, 114 (1956).
3 Sytinskaya, N. N., Astron. Zh. **36**, 315 (1959).
4 Barabashov, N. P. and Chekirda, A. T., Izv. Kommis. Fiz. Planet, Akad. Nauk SSSR (Bull. Commission on Physics of the Planets, Academy of Sciences USSR, Khar'kov Univ.) **1**, (1959).
5 Markov, A. V., Astron. Nachr. **221**, no. 52, 85 (1924).
6 Orlova, N. S., Astron. Tsirkuliar, no. 156, 19 (1955).
7 Barabashov, N. P. and Garazha, V. I., Tsircular KhAO, Khar'kov University Observatory, No. 21 (1960).
8 Barabashov, N. P. and Chekirda, A. T., Publ. KhAO, Khar'kov University Observatory, No. 8, 25 (1948).
9 Fedorets, V. A., Trudy KhAO (Transactions, Khar'kov University Observatory), **2**, No. 10, 49 (1952).
10 Sharonov, V. V., Uch. Zap., Leningr. Gos. Univ. (Scientific Reports, Leningrad State Univ.), No. 31, 28 (1939).
11 Sytinskaya, N. N., Izv. Plan. Kom. (Khar'kov University) **1**, 81 (1960).
12 Barabashov, N. P., Yezerskaya, V. A., Yezerskii, V. I., and Ishutina, T. A., Izv. Plan. Kom. (Khar'kov Univ.) **1**, 67 (1960).
13 Minnaert, M., Astrophys. J. **93**, 403 (1941).
14 Trexler, J. H., Proc. Inst. Radio Engrs. **46**, 286 (1958).
15 Evans, J. V., Proc. Phys. Soc. **B70**, 1105 (1957).
16 *First Photographs of the Far Side of the Moon* (Publishing House of the Academy of Sciences USSR, 1959).
17 *Atlas of the Far Side of the Moon* (Publishing House of the Academy of Sciences USSR, 1960).
18 Barabashov, N. P. and Lipskii, Yu. N., Doklady Akad. Nauk. SSSR (Proceedings of the Academy of Sciences USSR).
19 Barabashov, N. P. and Lipskii, Yu. N., Astron. Tsirkuliar, No. 206, 1 (1959).

Reviewer's Comment

Russian scientists have specialized in physical studies of the moon for many years; measurements of reflectivity, color, photometric properties, etc. have been made independently at various centers in the USSR, and this article gives the more important conclusions reached as a result of these studies. Similar researches, conducted mainly in Europe, have led to similar conclusions.

With the imminence of lunar landings, the most important result, and one that is of immediate concern, is that the lunar surface is porous in the extreme. The first hint of this unusual condition was obtained from temperature measurements of the lunar surface during the progress of an eclipse of the moon, carried out by Pettit and Nicholson at Mt. Wilson Observatory in 1927 (1,2). These measurements indicated that the surface material had very little heat capacity and, more important, that it was an extremely poor conductor of heat, suggesting a very porous condition. The photometric results confirm this conclusion, and the recent extension of the Russian work by van Diggelen at Utrecht* shows that a porosity exemplified by reindeer moss (i.e., interwoven, dendritic types of structures) fits the observations better than a porosity exemplified by coarse pumice or vesiculated lava.

The polarization data obtained by Dollfus (2), namely, that all regions of the moon behave as though covered with dust, can be reconciled with the reindeer moss type of model if we assume that cold welding phenomena take place readily on the moon; in fact, it is the reviewer's opinion that the dendritic or coralline accretions, whatever they may resemble, actually may have been built up from small fragments and dust particles projected through the primary agency of the impact of micrometeorites.

The actual depth of this highly porous surface layer and the average dimensions and separations of the individual elements are not known, since the results of thermal and microwave experiments, which gave indications of these quantities, are usually expressed in terms of a dust layer overlaying a pumice-like layer, which in turn rests on a more solid stratum. Typical figures for these quantities are 5 mm of dust overlaying several centimeters of "pumice" (3). The presence of this porous layer of all parts of the lunar surface (this includes the steepest slopes) should be reckoned with when considering soft lunar landings and subsequent operations.

The other important result of the Russian work is the fact that the far side of the moon, or at least that portion of the far side photographed by Lunik III, contains no major maria at all. Since the moon permanently turns one face earthward because of a maximum distribution of mass along an axis directed toward the center of the earth, the fact that all the major maria are located on the earthward hemisphere strongly suggests a connection between distribution of mass and distribution of maria. However, what this connection is remains to be discovered.

—Ewen A. Whitaker
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* See footnote 4 to N. P. Barabashov's present paper.

1 Pettit, E. and Nicholson, S. B., Astrophys. J. **68**, 279.
2 Dollfus, A., in *Planets and Satellites*, edited by G. P. Kuiper and B. M. Middlehurst (University of Chicago Press, Chicago, Ill., 1961); also Ref. 2 to article by N. P. Barabashov.
3 Gibson, I. E., Astrophys. J. **33**, no. 3.