Antipodes on the Moon

Yu. N. Lipskiy and Zh. F. Rodionova
Shternberg State Astronomical Institute, Moscow, U.S.S.R.

Cartographic methods are presently used to study not only the Earth, but also the Moon and Mars, and will soon be used for Mercury and other planets. These methods will remain for some time the only possible methods for determination of many quantitative characteristics of surface formations such as coordinates of objects in various systems, linear dimenions of formations, areas of flat surfaces and higher order surfaces, volumes of various objects, and relative indices and characteristics.

In the department of physics of the Moon and planets of the Shternberg State Astronomical Institute (GAISH), cartometric work was done in order to determine the areas of the lunar maria and large craters. The areas of the maria were determined twice in 1968 using a photomap of the visible hemisphere at a scale of 1:5 million (ref. 1) and segments of a lunar globe (ref. 2), and in 1971 using a full map of the Moon (ref. 3). The results of the measurements of areas of the maria are presented in table 1, together with the data of Westfall (ref. 4) and Shoemaker and Hackmann (ref. 5). Table 2 presents the areas of circular maria, measured from the peaks of the surrounding ridges, and their mean diameters calculated from the area.

The lunar surface is characterized by asymmetry in the locations of maria. On the visible hemisphere, lava flows occupy an area of 5937 million km² or 31.2 percent; on the back side, 474 000 km² or 2.5 percent. The northern hemisphere contains 4351 million km² or 22.9 percent; the southern hemisphere 2060 million km² or 10.8 percent. In the western hemisphere are 3891 million km² or 20.0 percent, and in the eastern hemisphere 2521 million km² or 13.3 percent. Over the entire surface of the moon, maria-type formations occupy 6411 million km² or 16.9 percent of the surface area. Figure 1a presents a diagram of the placement of maria-type formations within 10-degree bands of latitude by quadrants. Some 65 percent of all maria formations are concentrated within latitudes of $+40°$ to $-10°$.

Thalassoids and large craters over 100 km in diameter occupy the same amount of area as all of the maria taken together—16.5 percent. In the northern hemisphere, large craters cover an area of 2371 million km², and in the southern hemisphere 3870 million km². The visible hemisphere contains 1906 million km² of these formations; the back hemisphere contains 4344 million km². Table 3 presents the distribution of large craters by hemispheres. Based on measurements of the areas of large craters, a histogram has been constructed of the dependence of the number of craters on diameter (see fig. 2a). This distribution can be approximated by a curve generated by $y = A\,e^{-Bx}$. The coefficients $A = +138$, $B = +0.45$ were found by the method of least squares. This curve agrees well with the empirical distribution of craters with diameters of 100 to 300 km according to the criterion of Kolmogorov. Craters over 300 km in diameter predominate on the reverse side, where there are 12 in this range. Figure 2b shows that thalassoids have the same dimensions as do the circular maria and form a special group of formations, which has already been noted (refs. 6 and 7). The 11

Table 1.—*Areas of Maria Formations Measured by Various Authors (in thousands of km²)*

Area	Shoemaker Hackmann 1961	Rodionova 1968	Westfall 1970	Rodionova 1971
	Visible Side			
Oceanus Procellarum	—	2102	2147	2102
Mare Imbrium	864	830	835	829
Mare Frigoris	439	347	433	436
Mare Tranquillitatis	402	430	408	421
Mare Fecunditatis	311	311	334	326
Mare Serenitatis	318	305	312	303
Mare Nubium	261	253	240	254
Mare Crisium	165	180	197	176
Mare Humorum	107	113	115	113
Mare Smythii	—	109	77	104
Sinus Roris	—	107	291	—
Mare Nectaris	96	96	99	101
Mare Cognitum	—	73	—	—
Lacus Somniorum	65	66	66	72
Mare Marginis	—	64	82	62
Mare Vaporum	—	51	53	55
Sinus Medii	33	48	49	52
Sinus Aestuum	36	—	43	40
Sinus Iridum	—	—	—	39
Palus Epidemiarum	29	40	29	27
Mare Humboldtianum	99	23	28	22
Mare Undarum	—	13	19	21
Palus Putredinis	—	—	14	12
Mare Spumans	—	14	14	16
Mare Veris	—	20	16	12
Lacus Mortis	41	—	14	12
Mare Anguis	—	8	—	10
Mare Struve	—	—	—	4
Mare Autumni	—	—	4	3
Mare Aestatis	—	4	4	1
	Far Side			
Mare Australe	—	147	148	151
Mare Orientale	—	65	60	54
Mare Moscoviense	—	67	49	50
Mare Ingenii	—	—	27	15
Mare Pacificus	—	20	—	13

Table 2.—*Areas of Circular Seas Measured From Surrounding Ridges*

Area	Area Thousands of km²	Diameter, km	Note
Mare Imbrium	958	1104	
Mare Orientale	725	961	From Cordillera
	356	642	From Rook Mountains
Mare Nectaris	417	729	From Rupes Altai
	134	413	From Pyrenaeus
Mare Serenitatis	356	641	
Mare Crisium	209	516	
Mare Moscoviense	166	460	
Mare Humorum	153	442	
Mare Smythii	147	433	
Mare Ingenii	93	344	
Sinus Iridium	52	258	
Mare Humboldtianum	51	254	
Lacus Mortis	25	180	

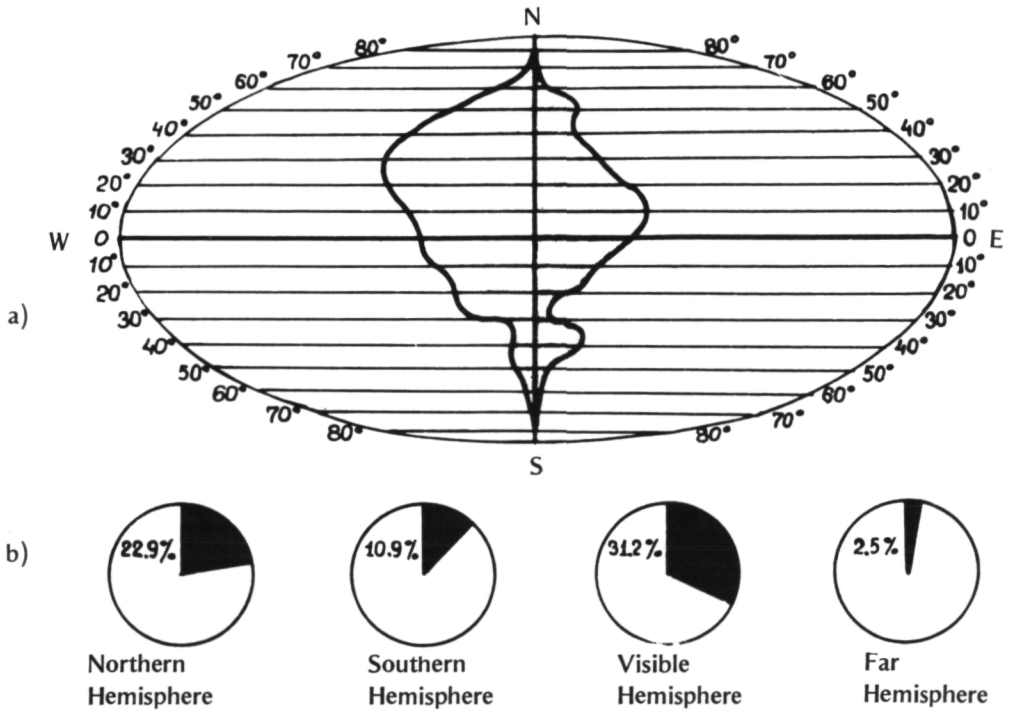

Figure 1.—*Distribution of maria areas.*

Table 3.—*Distribution of Craters Over 100 km in Diameter by Hemispheres*

Diameter, km	On Visible Hemisphere	Number of Craters		In Southern Hemisphere	Entire Surface
		On Far Hemisphere	In Northern Hemisphere		
100–120	37	46	31	52	83
120–140	26	26	20	32	52
140–160	16	15	12	19	31
160–180	5	11	7	9	16
180–200	5	10	7	8	15
200–220	5	4	4	5	9
220–240	1	4	3	2	5
240–260	2	4	3	3	6
260–280	—	2	—	2	2
280–300	2	—	—	2	2
300–320	—	—	—	—	—
320–340	—	4	1	3	4
340–360	—	3	2	1	3
360–380	1	—	—	1	1
380–400	—	1	1	—	1
400–420	—	—	—	—	—
420–440	—	—	—	—	—
440–460	—	2	1	1	2
460–480	—	—	—	—	—
480–500	—	—	—	—	—
500–520	—	1	—	1	1
520–540	—	—	—	—	—
540–560	—	—	—	—	—
560–580	—	—	—	—	—
580–600	—	1	1	—	1

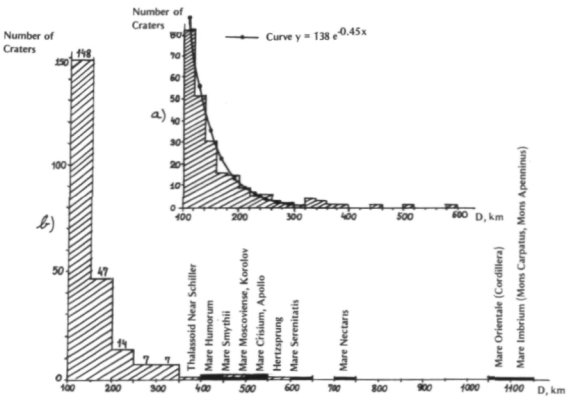

Figure 2.—*Histogram of the number of craters, according to their diameters.*

formations on the back side over 300 km in diameter correspond to maria formations diametrically opposite on the visible side. Figure 3 shows a diagram of the antipodes, listed in table 4. This diagram shows the contours of the maria on the visible side between the $\pm 60°$ parallels and their antipodes on the opposite side, arbitrarily shown in the areas diametrically opposite. The roman numerals on the map and in the table represent formations on the visible side; the arabic numerals, the far side. Only Birkhoff crater (342 km diameter) fails to fall within this group. It is on a common diameter with a continental area and the area of highest elevation on the visible side.

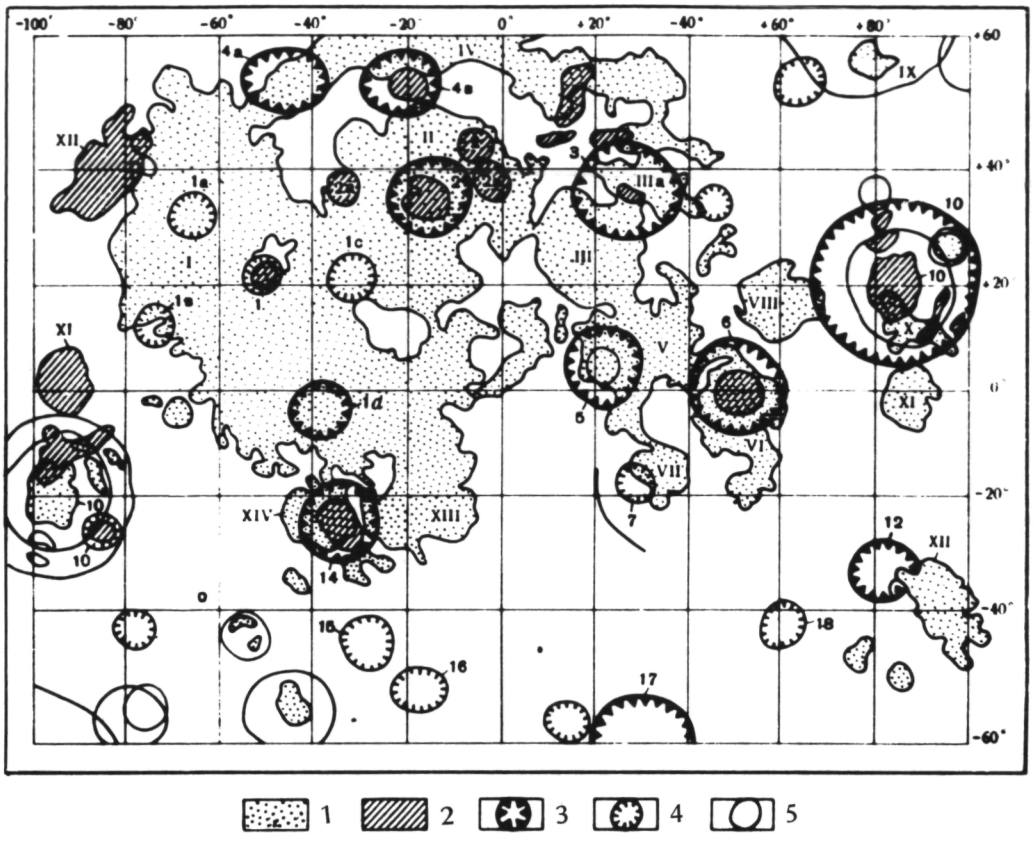

Figure 3.—*Map of the antipodes on the Moon. Maria features: 1—on the nearside; 2— on the farside; 3,4—thalassoides and craters on the farside (D > 300 km, 200 < D < 300 km, accordingly; 5—on the nearside.*

Of the 11 craters 200 to 300 km in diameter on the far side, eight are antipodes of maria formations on the visible side, and three fall in the same continental areas as does Birkhoff.

Yet another pecularity has been noted in the distribution of thalassoids and large craters (over 200 km diameter) on the surface of the Moon: most of them are located within the limits of 2 mutually perpendicular circles. The first circle has an inclination to the equator, $i = +37°16'$ and intersects the equator at point $\Omega = -81°45'$. It passes through the following formations (see fig. 4):

1. Oppenheimer—207 km diameter
2. Apollo—502 km
3. Mare Orientale—961 km
4. Oceanus Procellarum
5. Mare Imbrium—1104 km
6. Mare Serenitatis—641 km
7. Lacus Somniorum
8. Mare Crisium—516 km
9. Mare Marginis
10. Mare Smythii—433 km
11. Pasteur—251 km
12. Fermi—206 km
13. Tsiolkovskiy—189 km
14. Gagarin—269 km
15. Mare Ingenii—344 km
16. Leibnitz—247 km
17. Kármàn—198 km
18. Poincaré—339 km

The primary mascons are also located along this circle in Mare Imbrium, Mare Serenitatis, Mare Crisium, and Mare Smythii.

The second circle has an inclination $i =$

Table 4.—*Table of Antipodes on the Moon*

Visible Hemisphere		Far Hemisphere
I	Oceanus Procellarium	1 Tsiolkovskiy (1)—189 km,(2) 1a Milne—250 km, 1b Pasteur—251 km, 1c Gagarin (1)—269 km, 1d Mendeleev—345 km
II	Mare Imbrium	2a Mare Ingenii (1)—344 km, 2b Leibnitz (1)—247 km 2c Kármàn (1)—198 km
III	Mare Serenitatis	3 Apollo (1)—502 km
IIIa	Lacus Somniorum	
IV	Mare Frigoris	4 Planck—332 km, Poincaré (1)—339 km
V	Mare Tranquillitatis	5 Korolev—450 km
VI	Mare Fecunditatis	6 Hertzspring (1)—586 km
VII	Mare Nectaris	7 Mach—196 km
VIII	Mare Crisium	
X	Mare Marginis	10 Mare Orientale (1)
XI	Mare Smythii	
XII	Mare Australe	12 Lorentz—340 km
XIV	Mare Humorum	14 Mare Moscoviense (1)—460 km
	Bailly	Swartzschild—214 km
	Unnamed Maria Surface North of Hershel	Schrödinger (1)—324 km

NOTES: (1) Basins with bottom partially covered by lava.
(2) Diameter of basins in kilometers based on outer edge.

$-52°44'$ and $\Omega = 124°50'$ and passes through:

1. Birkhoff—342 km
2. Landau—226 km
3. Lorentz—340 km
4. Gerard Q—217 km
5. Oceanus Procellarum
6. Mare Humorum—442 km
7. Palus Epidemiarum
8. Mare Nubium
9. Deslandres—218 km
10. Mare Australe
11. Humboldt—205 km
12. Mare Moscoviense—460 km
13. Campbell—228 km
14. D'Alembert—227 km.

This circle passes through the mascon in Mare Humorum.

Large formations not included in the two main circles include: Planck—332 km, Schrödinger—342 km. Bailly—295 km, the thalassoid near Schiller on the visible side (coordinates at center 56°S, 46°W)—367 km, Schickard—206 km, Swartzchild—214 km, located on the third circle, passing along meridians $-46°$, 134° and perpendicular to the contemporary equator, on which are located such large formations as: Korolev—450 km, Hertzsprung—586 km, Oceanus Procellarum, Sinus Medii, Mare Tranquillitatis, Mare Fecunditatis, and Al-Khwarizmi discovered by Farouk El-Baz (ref. 8). We should also note the meridional placement (along $\pm$ 90°) of such formations as: the Mare Humboldtianum, Mare Marginis, Mare Smythii, Mare Australe, Mare Orientale, and Lorentz.

This distribution of large formations indicates the great importance of continued study of various characteristics along these belts (determination of crustal thickness, tectonic, age, and other peculiarities).

References

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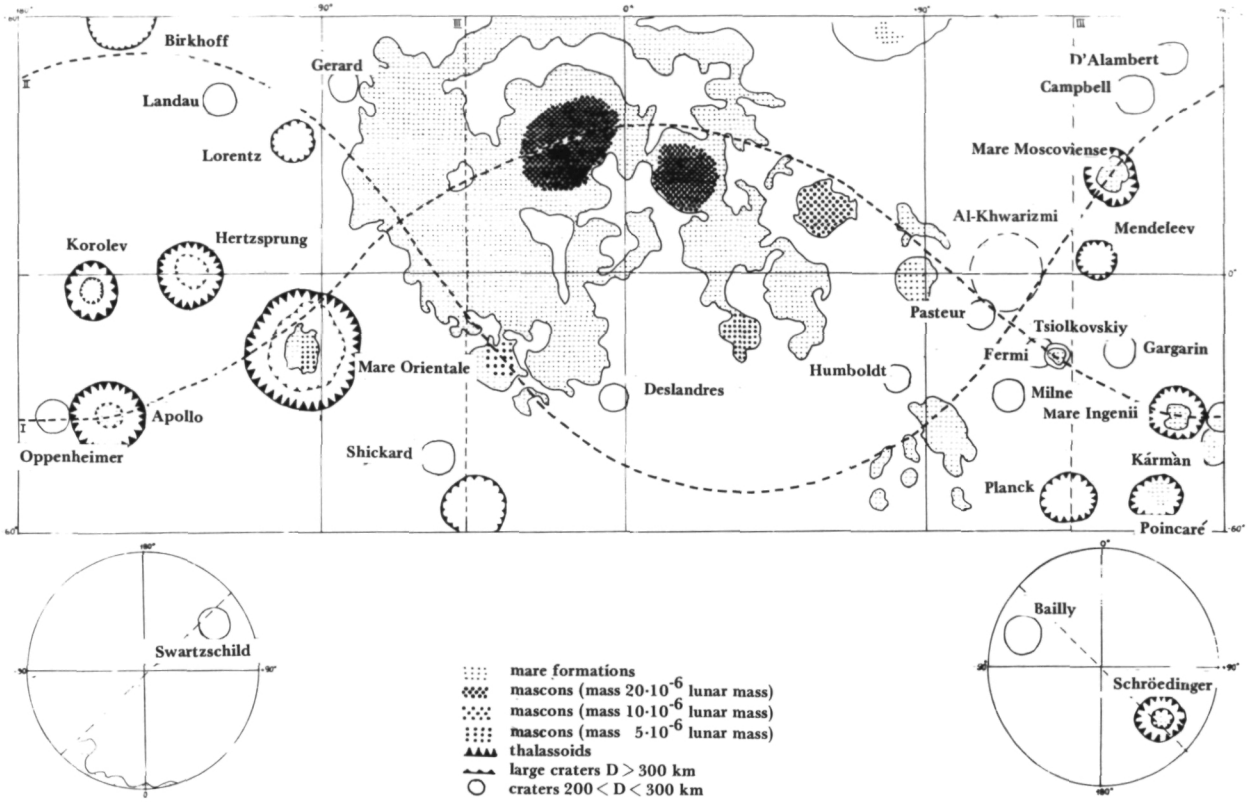

Figure 4.—*Diagram of maria, thalassoides, and craters* (D > *200 km).*

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