SELECTION OF POINTS FOR THE DEVELOPMENT OF A FUNDAMENTAL CONTROL SYSTEM ON THE LUNAR SURFACE

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The fundamental astrometry has accumulated wide practical experience on the development of the inertial co-ordinate system in space, which confirms in particular that rational selection of objects for this purpose is an important stage in investigations and requires urgent attention from the very initial steps. In this respect the problem of the development of a fundamental control system on the Moon is similar to those of the fundamental astrometry (Hopmann, 1967).

Up to the present different catalogues used as reference points for selenodetic datums different kinds of relief features: craters (mainly with diameters from 3 to 20 km), separate mountain peaks or central peaks of great craters, light spots, groups of hills or small craters. However it is well known that conditions for observations of mountain peaks vary considerably according to the changing of azimuth and altitude of the Sun, and are considerably dependent on the relief of neighbouring regions also. The appearance of the light spots depends greatly on the albedo of surrounding areas, their forms and sizes being unequal. Groups of hills or small craters look different on photographs of different scale. Naturally various effects of such kind decrease the precision of measurements.

In this connection a tendency appeared in the last decade to use as reference points only small craters of regular circular form (Kopal, 1960; Kopal and Finlay, 1960). This point of view is based on the following important ideas:

(1) The number of craters on the lunar surface is large enough and their distribution is sufficiently even for the establishment of a homogeneous control system of the required density without using any other relief features as reference points. Thus, according to (Arthur *et al.*, 1963, 1964, 1965, 1966) there are more than 17000 craters on the visible hemisphere of the Moon with diameters not less than 3.5 km. The distribution of craters according to their diameters in four quadrants of the near side of the Moon is presented in Table I*.

We can see from Table I, for example, that quadrants I and II, in which craters are least numerous contain respectively 1229 and 1487 craters with the diameters from 3.5 to 14.9 km – a quantity quite sufficient for providing any catalogues necessary for practical requirements of selenodesy.

* The table is compiled by N. G. Merkulova.

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TABLE I

The number of craters of different sizes on the visible side of the Moon

Diameter km	I quadrant	II quadrant	III quadrant	IV quadrant	The whole visible hemisphere
3.5– 4.9	344	545	1144	1800	3833
5.0– 9.9	586	758	2036	3136	6516
10.0–14.9	299	184	684	1159	2326
15.0–19.9	190	82	370	538	1180
20.0–24.9	135	41	197	359	732
25.0–29.9	95	42	136	194	467
30.0–49.9	167	99	275	379	920
50.0–99.9	92	67	146	189	494
100.0 and more	15	21	45	37	118
Total:	1923	1839	5033	7791	16586

(2) The majority of craters with small diameters have regular forms and thus represent relief features most favourable for astrometric measurements aimed for most pricise determination of the position of their centres.

(3) The character of crater images does not depend on the slope and albedo of the surrounding area and on the scale of photographs; in addition due to comparatively small relative depth ($\sim\frac{1}{10}$ for craters with diameters 1–100 km (Baldwin, 1965)), the errors in measurement resulting from different altitude of the Sun (phase errors) are minimized.

Unfortunately, not one of the existing papers presents a consistent method for the selection of relief details used as reference points. The present paper, taking into consideration the pressing necessity for the creation of a unique lunar fundamental control system proposes a general principle for approach to the selection of features for the development of such system.

The problem of establishing a selenographic co-ordinate system, that is the determination of the position of reference points relative to the lunar equator and to the central meridian, is inseparably linked with the problem of the study of the lunar figure, its orbital elements and libration constants (Koziel, 1962). To make orbital elements and libration constants deduced from the ground based observations more accurate, precise three-axis co-ordinates of a rather limited number of points on the lunar surface are sufficient. For further study of the lunar figure and solving different cartographic problems, much more numerous reference points are needed. Therefore, from the point of view of the expediency of the practical solution of the problem of a lunar fundamental system, its creation may be divided into several stages (Kopal and Finlay, 1960) resulting in the construction of control systems of the first, second and subsequent orders.

Many of the catalogues of lunar features used at present are based on the Franz system (Franz, 1899), consisting of nine points, eight of them having been measured by differential method relative to the ninth one – crater Mösting A. Therefore, generally speaking, the control selenodetic systems of such a kind are systems of the third order at least. Almost every recently published paper on selenodesy emphasizes the necessity of the creation of a new lunar absolute control system free of the Franz catalogue inaccuracies (or of inaccuracies of Schrutka-Rechtenstamm catalogue (Schrutka-Rechtenstamm, 1958) based on it). It is evident that the new fundamental system of the first order should be given by absolute three-axis co-ordinates of a comparatively small number of points measured with the highest possible accuracy. However their number should be sufficient not only to realize the lunar control system and to make the character of the motion of the Moon in space more exact, but also for further study of the lunar figure and construction of the base for lunar charts of high accuracy.

General methods for the development of works on lunar cartography are considered in detail in the paper by Florensky *et al.* (1971). In accordance with the suggestions proposed in this paper the scale 1:1000000 widely used now should remain the base scale for future lunar charts also. The fundamental control system of the first order should ensure the reliability of the cartographic works of scale 1:1000000. This is based on the fact that maps of that scale for the visible hemisphere may be compiled using mainly Earth-based observations and should serve as a main link between large-scaled maps compiled on the basis of extraterrestrial pictures and general small-scale maps compiled by terrestrial methods. An average density of 4 points for each nomenclature sheet of the map should be taken as the necessary minimum density of control system for ensuring the reliability of the cartographic works. This requires that the first order points be distributed evenly on the lunar surface with the density approximately 1 point per $10° \times 10°$ square transferred to the lunar equator. The same requirements have been already substantiated earlier (Kopal and Goudas, 1967; Marchant, 1963) proceeding from some other ideas.

Since the area of the lunar surface is amounts to $\sim$41000 square degrees there should be altogether $\sim$410 of the first order reference points on the Moon and about 250 of these on the visible side (the libration zones included). If we exclude marginal zones which are not clearly observable on the ground-based pictures then $\sim$200 points will be sufficient.

In accordance with the nomenclature division suggested by Florensky *et al.* (1971) for the maps of 1:1000000 scale and coinciding on the whole with the nomenclature division of American aeronautical charts LAC (ACIC, 1967) the whole lunar surface is covered with 140 sheets of the map, 48 full sheets covering the area of $\pm 70°$ along the longitude and latitude. If there are 200 reference points in this area, then every chart sheet of 1:1000000 scale really contains on the average 4 first order reference points.

However as it was mentioned above, the number of points with precise co-ordinate values used for obtaining more accurate parameters of lunar motion in space (which is connected with long and systematic observations) need not be numerous (but not less than three), thus it will be unnecessary in future to use for this purpose the whole complex of the first order points. Moreover, observations for the aims stated above will be carried out in future both with the help of the laser location of cube-corner retro-reflector and with direct astronomical observations carried out from surface of the Moon. Neither method requires a very large number of observational points and therefore it is rational to select a certain sub-group of craters from 200 fundamental first order points evenly distributed on the visible hemisphere of the Moon. The craters will serve like Mösting A as the fundamental points for obtainig with special methods of high precision more accurate parameters of the motion of the Moon and initial geodetic dates. The number of such points should need not be more than twenty.

Thus the first order fundamental control system consisting of 200 points can provide simultaneously the solution of three problems:

(1) Obtaining more accurate values of the libration constants, the Moon's orientation in space and its orbital elements. Since the whole period of libration (optical and physical) covers several decades, the solution of this problem requires long and systematic observations of $\sim$20 points.

(2) Obtaining more precise figure of the Moon, for which the whole first order system ($\sim$200 points) should be observed for a short period of time.

(3) Realization both of the control system for cartographic works of 1:1000000 scale and the basis for development of the second and further order systems which will serve as a basis for the compilation of larger-scale maps. Observations pointed out in Section 2 are sufficient.

The next stage consists of building the second order system of reference points, whose co-ordinates are determined with the differential method. Such a point system should serve as a basis for linking ground and space observations of the Moon. For this one needs at least 10 points for $10° \times 10°$ (Gavrilov, 1969), which means that the second order system should contain about 4100 reference points over the whole lunar surface or about 2000 in the area $\pm 70°$ along the longitude and the latitude (of course, all the first order points should be included in that number). Such a number of second order points ensures in the first approach cartographic works of 1:250000 scale, because at least two second order reference points fall on each sheet of the map according to the nomenclature division (Florensky *et al.*, 1971). Besides, they can be widely applied for astronautical aims.

The next stage is the creation of a wide third order control system permitting us to pass to a detailed mapping of the lunar surface and providing the solution of any cartographic problems. This probably requires about 20000 points on the near side of the Moon. During the Bagnères Conference 10000–40000 third order reference points were suggested (Kopal and Finlay, 1960).

So, the following harmonious scheme for the development of different orders control systems on the visible side of the Moon can be traced:

– about 20 points serving for solving scientific problems on the basis of ground astrometric observations and the subsequent installation of cube-corner retro-reflectors and devices for observations from the lunar surface in the same points;

– about 200 first order fundamental points serving for the study of the figure of the Moon and for small scale mapping up to 1:1000000 scale;

– about 2000 second order points serving mainly for linking ground and space pictures of the lunar surface as well as for applied astronautical problems;

– about 20000 third order points providing large scale cartographic works.

It is evident that different requirements in the number of points and the accuracy of their co-ordinates while constructing control systems of I–III orders involve different methods for observations and for the reduction of the initial data. Undoubtedly in future photogrammetric methods will find wide application in selenodesy.

At present the principal methods for building control systems on the lunar surface remain those of photographic astrometry and the best way for determining the first order point co-ordinates remains taking photographs of the Moon together with the stellar background. In this case the size and quality of the lunar image is limited by the possibilities of modern instruments. To obtain accurate measurement it is obviously reasonable to take, as the first order points, craters with a diameter about 10–12 km (that corresponds to $\sim 6''$ geocentric or to the Mösting A crater sizes). Craters of such sizes are easily visible on the illuminated lunar surface, irrespective of the angle of the Sun, and in particular – on ground pictures taken near the full Moon.

While estimating the quality of the selected craters images one should follow the requirements suggested by Franz (1901), which are valid up to the present time:

(1) The diameter of craters as small as possible.

(2) The contrast against the background as large as possible.

(3) The shapes as clear as possible.

(4) The form as near to a circle as possible.

All these requirements remain valid when constructing the second order system. As the second order craters will be used for linking ground and space pictures of the Moon (i.e. they should be clearly distinguished on the ground photographs), their diameter should amount to 3–5 km. But it is necessary to remember that the visibility of small craters depends on the angle of the Sun and they can be measured in many cases at a distance of some degrees from the terminator only.

Thus, the following scheme of crater selection is suggested for constructing a new lunar fundamental system:

(1) The first order fundamental system including about 200 craters of as regular circular form as possible evenly distributed through the lunar surface, the diameter being about 10–12 km (approximately from 7 to 15 km with the approach to the marginal zones).

Co-ordinates of these points are determined simultaneously by the absolute method from Earth-based pictures of the Moon against a stellar background. The co-ordinates for approximately one tenth of these points are constantly made more accurate during many years both with ground methods and – in the future – with the aid of the laser location of cube-corner retro-reflectors as well as with derect observations from the Moon.

(2) The second order system including about 2000 craters with diameters of 3–5 km. Their co-ordinates are determined by differential methods relating to the first order points using ground and space pictures.

(3) The third order system including about 20000 small craters the co-ordinates of which will be determined by the differential method relatively to the second order points on space pictures by the use of photogrammetry.

Appendix I contains the list proposed by the authors of 192 craters which in general meet the demands formulated in the present paper in conformity with the first order fundamental control system.

Crater distribution according to their diameters in four quadrants of the lunar disc (between the limits $\pm 70°$ along the latitude and longitude) is presented in Table II.

TABLE II
The distribution of craters proposed for the first order fundamental system realization according to their diameters in different quadrants

Diameter km	I	II	III	IV	The whole visible hemisphere
7.1– 7.9	4	5	–	1	10
8.0– 8.9	6	5	3	4	18
9.0– 9.9	8	9	4	2	23
10.0–10.9	5	11	15	10	41
11.0–11.9	8	3	10	8	29
12.0–12.9	8	10	5	17	40
13.0–13.9	6	4	10	7	27
14.0–14.7	2	–	1	1	4
Total:	47	47	48	50	192

Table III shows the number of points common to the proposed system and each of the following systems: Schrutka-Rechtenstamm, 1958; Meyer and Ruffin, 1965; Marchant *et al.*, 1967; Gavrilov *et al.*, 1967; Arthur and Bates, 1968; Moutsoulas, 1970.

TABLE III
The number of points common to the proposed list and some other systems used at present

Catalogue	The number of common points
Schrutka-Rechtenstamm (1958)	26
Meyer and Ruffin (1965)	45
Marchant *et al.* (1967)	120
Gavrilov *et al.* (1967)	83
Arthur and Bates (1968)	154
Moutsoulas (1970)	18

To have the distribution of the chosen fundamental points on the lunar surface sufficiently even, 13 craters absent in all indicated catalogues are also included in the system. The distribution of craters from the proposed list along the visible hemisphere of the Moon is illustrated by the Figure 1.

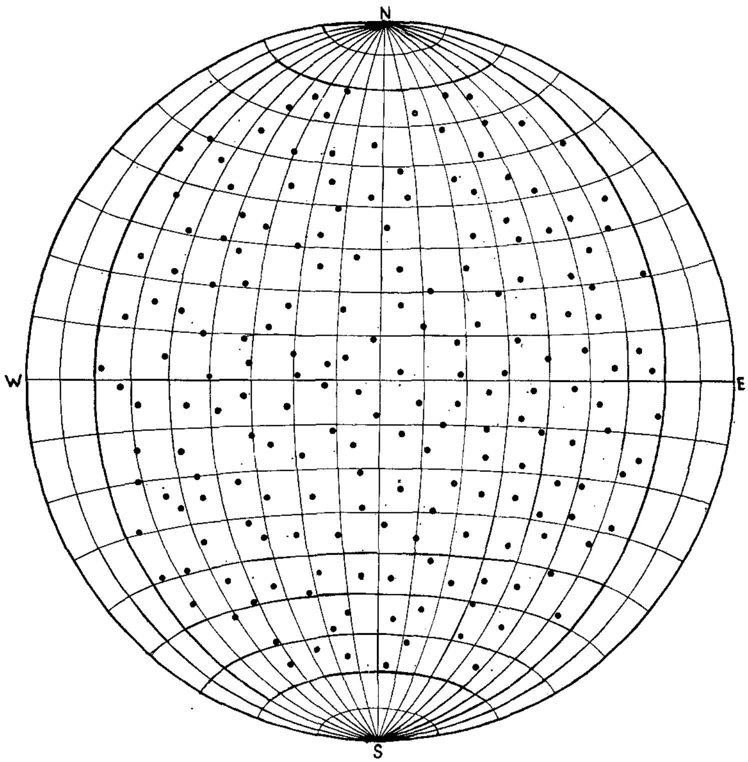

Fig. 1. Distribution of the craters from the proposed list on the near side of the Moon.

Of course the proposed list of points for a fundamental control system is of a preliminary character since the final version can be prepared as a result of thorough discussion only.

Acknowledgement

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Appendix I. List of craters

proposed for the development of a first order fundamental selenodetic system

The appendix contains the following data:

Column 1 – ordinal number;

Column 2 – crater designation according to Arthur *et al.* (1963, 1964, 1965, 1966);

Column 3 – crater number according to the nomenclature of the IAU (Blagg and Müller, 1935) and to the system of lunar craters by Arthur *et al.* (1963, 1964, 1965, 1966);

Column 4–5 – approximate selenographic co-ordinates λ, β according to Arthur *et al.* (1963, 1964, 1965, 1966);

Column 6 – crater diameter according to Arthur *et al.* (1963, 1964, 1965, 1966);

Column 7–8 – data concerning the presence of a certain object in the catalogues listed in Table III. The following abbreviations were accepted:
Schrutka 58 (Schrutka-Rechtenstamm, 1958)
Meyer 65 (Meyer and Ruffin, 1965)
Marchant 66 (Marchant *et al.*, 1967)
Gavrilov 67 (Gavrilov *et al.*, 1967)
Arthur 68 (Arthur and Bates, 1968)
Moutsoulas 70 (Moutsoulas, 1970)
The craters number according to these catalogues are also included; since Rechtenstamn (1958) and Marchand *et al.*, (1967) have no their own numbering the crater numbers according to the IAU nomenclature and to the system of lunar craters (Arthur; 1963, 1964, 1965, 1966) respectively are repeated in Column 8;

Column 9 – number of the corresponding sheet of the Lunar Aeronautical Chart (ACIC, 1967);

Column 10 – notes.

No.	Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates		D km	Presence in catalogues		LAC No.	Notes
			λ	β		Catalogue	No.		
1	2	3	4	5	6	7	8	9	10
1.	Hevelius A	1959	−68.1	+2.8	13.6	Marchant 66	29024	56	
		29024				Arthur 68	538		
2.	Dechem	1728	−67.7	+46.0	11.8	Marchant 66	26741	22	
		26741							
3.	Piazzi A	2230	−66.6	−39.4	13.3			109	
		37603							
4.	Lagrange H	2222B	−66.3	−29.5	10.6	Gavrilov 67	381	92	
		37499				Arthur 68	864		
5.	Galilei A	1844	−62.9	+11.7	11.2	Meyer 65	132	56	
		28270				Marchant 66	28270		
						Gavrilov 67	251		
						Arthur 68	536		
6.	Lohrmann A	1977	−62.6	−0.7	12.0	Meyer 65	138	74	
		38081				Marchant 66	38081		
						Gavrilov 67	387		
						Arthur 68	869		
7.	De Vico C	2062	−62.3	−20.0	11.7	Arthur 68	874	92	
		38325							
8.	Schiaparelli A	1812	−62.0	+23.0	7.2	Moutsoulas 70	42	38	
		28319				Arthur 68	537		
9.	Wargentin C	–	−61.2	−47.4	11.7			110	
		35793							
10.	Naumann B	1877	−60.4	+37.4	10.4	Gavrilov 67	233	23	
		26690				Arthur 68	514		
11.	Sirsalis F	2088	−60.1	−13.6	12.2	Schrutka 58	2088	74	
		38243				Gavrilov 67	389		
						Arthur 68	871		
12.	Marcow E	1725	−59.9	+50.5	11.9			10	
		25747							
13.	Damoiseau E	1992	−58.3	−5.2	13.5	Schrutka 58	1992	74	
		38049				Meyer 65	139		
						Marchant 66	38049		
						Gavrilov 67	385		
						Arthur 68	867		
14.	Lacroix H	2325A	−57.7	−38.7	12.5	Gavrilov 67	373	110	

	36662				Arthur 68	850	
15. Marius L	–	–55.6	+15.8	7.6			56
	27297						
16. Cavendish B	–	–55.1	–23.3	10.1	Arthur 68	861	92
	37359						
17. De Gasparis B	–	–52.6	–27.1	10.6	Meyer 65	158	92
	37405				Marchant 66	37405	
					Arthur 68	863	
					Moutsoulas 70	96	
18. Herodotus A	1806	–52.1	+21.5	9.8	Meyer 65	130	38
	27336				Marchant 66	27336	
					Gavrilov 67	241	
					Arthur 68	528	
19. Wollaston C	1739	–51.7	+31.7	9.7	Marchant 66	26562	38
	26562				Gavrilov 67	231	
					Arthur 68	512	
20. Liouville DA	–	–51.6	+46.6	10.5			23
	25732A						
21. Reiner A	1833	–51.4	+ 5.1	10.1	Schrutka 58	1833	56
	27078				Meyer 65	1	
					Marchant 66	27078	
					Gavrilov 67	235	
					Arthur 68	521	
22. Phocylides G	2277A	–50.7	–51.2	13.6	Gavrilov 67	332	124
	34787						
23. Palmiery J	–	–49.3	–33.6	10.4			110
	36535						
24. Billy D	2138A	–48.3	–14.8	10.3	Arthur 68	857	75
	37225						
25. Marius C	1816	–47.5	+13.9	12.1	Arthur 68	525	57
	27214						
26. Noggerath M	–	–46.6	–44.0	11.3	Moutsoulas 70	127	110
	35629						
27. Flamsteed C	2446	–46.2	– 5.5	9.4	Marchant 66	37019	75
	37019				Gavrilov 67	374	
					Arthur 68	853	
28. Mersenius C	2151	–45.9	–19.8	14.0	Schrutka 58	2151	93
	36373				Gavrilov 67	362	
					Arthur 68	841	
29. Liebig F	2154	–45.7	–24.6	8.9	Gavrilov 67	366	93
	36451				Arthur 68	843	
30. Mairan D	1613	–45.4	+40.9	10.1	Arthur 68	501	23

No.	Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates λ	β	D km	Presence in catalogues: Catalogue	No.	LAC No.	Notes
1	2	3	4	5	6	7	8	9	10
		25635							
31.	Harpalus C	1666 24802	−45.1	+55.5	10.4	Moutsoulas 70 Arthur 68	139 484	11	
32.	Kircher B	2677 32980	−42.9	−65.0	11.4	Arthur 68	747	136	
33.	Kepler C	1557 26157	−41.8	+10.0	12.2	Meyer 65 Marchant 66 Gavrilov 67 Arthur 68	135 26157 223 506	57	
34.	Bessarion D	1576 26323	−41.7	+19.8	9.1	Gavrilov 67 Arthur 68	226 510	39	
35.	Weigel C	2629 33836	−41.6	−59.4	10.0	Arthur 68	783	125	
36.	Angström	1737 25479	−41.6	+29.9	9.8	Gavrilov 67 Arthur 68	213 498	39	
37.	Schiller M	– 34734	−41.0	−48.2	8.7	Moutsoulas 70	162	125	
38.	Encke E	1540 26040	−40.2	+ 0.3	8.6	Meyer 65 Marchant 66 Gavrilov 67 Arthur 68	142 26040 220 503	57	
39.	J. Herschel C	1679 22898	−39.8	+62.3	12.2	Arthur 68	436	11	
40.	Gruithuisen B	1606 25508	−38.7	+35.6	9.9	Arthur 68	499	23	
41.	Wichmann	2457 36113	−38.0	− 7.5	10.6	Marchant 66 Gavrilov 67 Arthur 68	36113 353 830	75	
42.	Gassendi J.	2419 35356	−37.0	−21.6	9.0	Schrutka 58 Meyer 65 Marchant 66 Gavrilov 67 Arthur 68	2419 25 35356 340 816	93	
43.	Diophantus A	1590 25426	−36.6	+27.6	8.6	Arthur 68	497	39	

44. Vitello B	2355	−35.4	−31.2	10.7	Arthur 68	803	93
	34591						
45. Brayley B	1579	−34.3	+20.7	10.2	Marchant 66	25325	39
	25325				Gavrilov 67	211	
					Arthur 68	493	
46. Bayer L	2614A	−33.6	−47.5	13.6	Gavrilov 67	310	111
	33773				Arthur 68	780	
47. Milichius A	1530	−32.0	+ 9.3	9.1	Marchant 66	25126	57
	25126				Gavrilov 67	208	
					Arthur 68	489	
48. Ramsden G	2566	−31.6	−35.3	11.0	Gavrilov 67	323	111
	34527				Arthur 68	800	
49. Anaximenes E	1359C	−31.4	+66.5	9.5	Marchant 66	22901	3
	22901				Arthur 68	438	
50. C. Herschel	1602	−31.2	+34.5	13.4	Marchant 66	24526	24
	24526				Arthur 68	478	
51. Hortensius A	1520	−30.7	+ 4.4	10.2	Meyer 65	145	57
	25007				Marchant 66	25007	
					Gavrilov 67	204	
					Arthur 68	485	
52. Lansberg D	2483	−30.6	− 3.0	11.4	Marchant 66	35005	75
	35005				Arthur 68	810	
53. Euclides B	2462	−30.3	−11.8	10.3	Marchant 66	34290	75
	34290				Gavrilov 67	320	
					Arthur 68	792	
54. La Condamine C	1368B	−30.2	+52.4	10.6	Arthur 68	458	11
	23709						
55. Campanus A	2526	−28.6	−26.0	11.4	Arthur 68	796	94
	34433						
56. Scheiner G	2699A	−28.3	−62.6	13.6	Meyer 65	163	125
	32818				Marchant 66	32818	
					Arthur 68	744	
57. Laplace A	1315	−26.9	+43.7	8.7	Meyer 65	120	24
	23629				Marchant 66	23629	
					Gavrilov 67	185	
					Arthur 68	456	
58. Tobias Mayer D	1419	−26.8	+12.2	8.6	Marchant 66	24241	58
	24241				Arthur 68	470	
59. Darney C	2832	−26.0	−14.1	13.3	Gavrilov 67	318	76
	34224						
60. Longomontanus M	2716A	−23.1	−48.4	10.3	Arthur 68	739	125
	32764						

No.	Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates		D km	Presence in catalogues		LAC No.	Notes
			λ	β		Catalogue	No.		
1	2	3	4	5	6	7	8	9	10
61.	Fontenelle B	1326	−22.9	+61.8	13.7	Marchant 66	21888	11	
		21888				Moutsoulas 70	284		
62.	Cichus C	2763	−21.8	−33.6	11.1	Meyer 65	165	111	
		33505				Marchant 66	33505		
						Gavrilov 67	305		
						Arthur 68	766		
63.	Draper C	1412	−21.5	+17.0	7.8	Meyer 65	128	40	
		23249				Marchant 66	23249		
						Moutsoulas 70	294		
						Arthur 68	446		
64.	Fra Mauro A	2898	−21.0	− 5.5	9.9	Marchant 66	33059	76	
		33059				Gavrilov 67	298		
						Arthur 68	750		
65.	Carlini B	1392	−20.8	+30.3	7.6	Marchant 66	23500	40	
		23500				Arthur 68	453		
66.	Fauth	1482	−20.1	+ 6.3	12.1	Arthur 68	442	58	
		23140							
67.	Gambart A	1498	−18.7	+ 1.0	12.0	Meyer 65	4	58	
		23021				Marchant 66	23021		
						Gavrilov 67	176		
						Arthur 68	439		
68.	Philolaus E	1346	−18.7	+69.6	12.3	Marchant 66	21913	3	
		21913							
69.	Wilhelm E	2726	−18.0	−44.2	13.8	Marchant 66	32629	111	
		32629				Arthur 68	727		
70.	Clavius J	3237	−17.9	−57.9	12.2	Marchant 66	31864	126	
		31864				Arthur 68	679		
71.	Opelt E	2818	−17.8	−17.0	8.0	Meyer 65	168	94	
		32299				Marchant 66	32299		
						Gavrilov 67	288		
						Arthur 68	709		
72.	Hesiodus B	2778	−17.5	−27.1	10.3	Marchant 66	32465	94	
		32465				Gavrilov 67	291		
						Arthur 68	716		
73.	Plato B	1066	−17.2	+53.0	12.6	Marchant 66	21779	12	

	21779				Arthur 68	386	
74. Carlini D	1394	−16.0	+33.0	9.3	Marchant 66	22534	24
	22534				Gavrilov 67	169	
					Arthur 68	415	
75. Gruemberger C	3263A	−15.3	−65.8	13.0	Marchant 66	31901	137
	31901				Arthur 68	683	
76. Timocharis A	1297	−15.3	+24.8	7.4	Meyer 65	116	40
	22441				Marchant 66	22441	
					Gavrilov 67	167	
					Arthur 68	412	
77. Pico B	1121	−15.3	+46.4	11.5	Marchant 66	21782	24
	21782				Arthur 68	387	
78. Turner	2922	−13.2	− 1.4	11.9	Schrutka 58	2922	76
	32022				Marchant 66	32022	
					Gavrilov 67	280	
					Arthur 68	687	
79. Le Verrier D	1302	−12.3	+39.7	9.1	Marchant 66	21663	25
	21663				Gavrilov 67	158	
					Arthur 68	377	
80. Gambart C	1500	−11.8	+ 3.3	12.2	Marchant 66	22005	58
	22005				Gavrilov 67	164	
					Arthur 68	399	
81. Guericke C	2856	−11.5	−11.5	10.9	Schrutka 58	2856	76
	31290				Meyer 65	23	
					Marchant 66	31290	
					Gavrilov 67	276	
					Arthur 68	642	
82. Gauricus D	2748	−11.4	−35.2	13.2	Marchant 66	31567	112
	31567				Arthur 68	653	
83. Clavius MC	3251D	−10.4	−54.8	11.7	Marchant 66	31801	126
	31801				Arthur 68	673	
84. Wolf B	1284B	− 8.7	+16.0	9.4	Marchant 66	21247	41
	21247						
85. Schröter A	1250	− 7.7	+ 4.8	10.1	Arthur 68	353	59
	21038						
86. Alpetragius B	3028	− 6.8	−15.1	10.1	Meyer 65	191	77
	31216				Marchant 66	31216	
					Gavrilov 67	273	
					Arthur 68	638	
87. Archimedes A	1145	− 6.4	+28.0	13.1	Schrutka 58	1145	41
	20497				Meyer 65	11	
					Marchant 66	20497	

No.	Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates λ	β	D km	Presence in catalogues: Catalogue	No.	LAC No.	Notes
1	2	3	4	5	6	7	8	9	10
						Gavrilov 67	141		
						Arthur 68	324		
88.	Proctor D	3213D	− 6.0	−46.1	12.1	Arthur 68	609	112	
		30771							
89.	Thebit L	3074	− 5.4	−21.5	10.4	Marchant 66	30386	95	
		30386							
90.	Mösting A	2933	− 5.2	− 3.2	13.1	Schrutka 58	2933	77	
		30095				Meyer 65	5		
						Marchant 66	30095		
						Gavrilov 67	259		
						Arthur 68	551		
91.	Regiomontanus B	3102	− 3.7	−29.1	10.0	Arthur 68	583	95	
		30458							
92.	Piazzi Smyth	1125	− 3.2	+41.8	12.8	Marchant 66	20646	25	
		20646				Gavrilov 67	144		
						Arthur 68	332		
93.	Plato H	1073	− 2.0	+55.1	10.8	Meyer 65	105	12	
		20822				Marchant 66	20822		
						Gavrilov 67	146		
						Arthur 68	346		
94.	Aristillus B	1146	− 1.9	+34.8	8.2	Marchant 66	20527	25	
		20527				Arthur 68	326		
95.	Bode A	1214	− 1.2	+ 9.0	12.3	Schrutka 58	1214	59	
		20115				Marchant 66	20115		
						Gavrilov 67	130		
						Arthur 68	308		
96.	Ptolemaeus A	2963	− 0.8	− 8.5	9.4	Schrutka 58	2963	77	
		30114				Meyer 65	6		
						Marchant 66	30114		
						Gavrilov 67	260		
						Arthur 68	555		
97.	Walter A	3467	+ 0.8	−32.3	11.5	Arthur 68	927	112	
		40513							
98.	Curtius A	3356	+ 2.7	−68.4	12.3	Marchant 66	40913	137	
		40913				Arthur 68	967		

99. Licetus H	3421	+ 3.1	−45.9	10.4	Meyer 65	86	112
	40731				Marchant 66	40731	
					Arthur 68	943	
100. Aratus	895	+ 4.5	+23.5	10.6	Schrutka 58	895	41
	10470				Meyer 65	10	
					Marchant 66	10470	
					Gavrilov 67	14	
					Arthur 68	24	
101. Hadley B	897A	+ 4.7	+27.7	8.7	Marchant 66	10476	41
	10476				Arthur 68	25	
102. Zach J	3386B	+ 4.8	−57.2	10.8	Meyer 65	85	126
	40844				Marchant 66	40844	
					Moutsoulas 70	465	
					Arthur 68	958	
103. Blanchinus K	(3532A)	+ 5.1	−24.8	8.9	Meyer 65	89	95
	40471				Marchant 66	40471	
					Moutsoulas 70	467	
					Arthur 68	924	
104. Rhaeticus A	834	+ 5.2	+ 1.7	11.3	Shrutka 58	834	59
	10093				Marchant 66	10093	
					Gavrilov 67	4	
					Arthur 68	8	
105. Trouvelot	968	+ 5.8	+49.2	9.0	Marchant 66	10765	12
	10765				Arthur 68	41	
106. Albategnius E	3582	+ 6.4	−12.9	13.7	Marchant 66	41202	77
	41202				Arthur 68	996	
107. Cassini C	932	+ 7.7	+41.6	13.7	Shrutka 58	932	25
	11606				Gavrilov 67	30	
					Arthur 68	88	
108. Hipparchus L	3613	+ 9.0	− 6.8	13.5	Marchant 66	41151	77
	41151				Arthur 68	989	
109. Kaiser C	3463	+ 9.7	−36.6	12.4	Marchant 66	41539	112
	41539				Gavrilov 67	422	
					Arthur 68	1031	
110. Manilius C	797	+10.3	+12.0	7.1	Marchant 66	11270	60
	11270				Arthur 68	72	
111. Abulfeda A	3736	+10.8	−16.4	13.9	Shrutka 58	3736	96
	41278				Marchant 66	41278	
					Gavrilov 67	418	
					Arthur 68	1005	
112. Pentland F	3366A	+11.3	−62.0	12.4	Marchant 66	40898	127
	40898				Arthur 68	966	

No.	Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates λ	Selenographic co-ordinates β	D km	Presence in catalogues: Catalogue	Presence in catalogues: No.	LAC No.	Notes
1	2	3	4	5	6	7	8	9	10
113.	Sulpicius Gallus	606	+11.7	+19.6	12.2	Marchant 66	11393	42	
		11393				Arthur 68	79		
114.	Pontanus J	3809A	+13.2	−30.1	8.9	Marchant 66	41590	96	
		41590				Arthur 68	1035		
115.	Archytas DA	48	+13.5	+63.8	8.5	Marchant 66	11809	13	
		11809							
116.	Jacobi B	3377	+13.9	−54.5	13.8	Marchant 66	41841	127	
		41841				Arthur 68	1062		
117.	Maurolycus J	3852	+13.9	−42.4	9.1	Marchant 66	41677	113	
		41677				Arthur 68	1043		
118.	Dollond	3722	+14.5	−10.5	11.1	Marchant 66	42148	78	
		42148				Gavrilov 67	429		
						Arthur 68	1096		
119.	Alfraganus C	3683	+18.1	− 6.1	10.8	Schrutka 58	3683	78	
		43100				Meyer 65	20		
						Marchant 66	43100		
						Gavrilov 67	443		
						Arthur 68	1182		
120.	Sosigenes A	573	+18.4	+ 7.7	11.9	Schrutka 58	573	60	
		13113				Gavrilov 67	53		
						Arthur 68	164		
121.	Sacrobosco HA	–	+18.5	−23.3	10.3	Gavrilov 67	434	96	
		42399							
122.	Schmidt	552	+18.7	+ 0.9	11.4	Marchant 66	13021	60	
		13021				Arthur 68	158		
123.	Bessel A	622	+20.9	+24.7	7.6	Schrutka 58	622	42	
		13421				Meyer 65	17		
						Marchant 66	13421		
						Gavrilov 67	61		
						Arthur 68	181		
124.	Mitchell E	723	+21.6	+47.6	8.3	Marchant 66	12743	26	
		12743				Moutsoulas 70	586		
						Arthur 68	144		
125.	Barocius EB	3865B	+21.7	−46.6	10.8	Meyer 65	83	113	
		42752				Marchant 66	42752		

					Arthur 68	1152	
126. Rabbi Levi L	4033A	+23.1	−34.7	12.6	Arthur 68	1212	113
	43526						
127. Ross D	534A	+23.2	+12.5	9.1	Marchant 66	13281	60
	13281				Arthur 68	176	
128. Luther	491	+24.1	+33.1	9.5	Marchant 66	13544	26
	13544				Gavrilov 67	63	
					Arthur 68	184	
129. Galle C	722	+24.4	+57.6	11.4	Gavrilov 67	48	13
	12824				Arthur 68	148	
130. Theophilus B	4220	+25.2	−10.6	8.7	Gavrilov 67	458	78
	44118						
131. Polybius B	4109	+25.6	−25.5	12.8	Schrutka 58	4109	96
	43483				Gavrilov 67	449	
					Arthur 68	1204	
132. Torricelli C	4227	+26.0	− 2.7	11.1	Marchant 66	44034	78
	44034				Gavrilov 67	456	
					Arthur 68	1248	
133. Beaumont D	4158	+26.2	−17.1	11.4	Schrutka 58	4158	96
	44229				Gavrilov 67	461	
					Arthur 68	1254	
134. Plana C	645	+27.1	+42.7	13.8	Marchant 66	13637	26
	13637				Gavrilov 67	66	
					Arthur 68	192	
135. Maskelyne B	244A	+28.9	+ 2.0	9.2	Marchant 66	14083	60
	14083				Gavrilov 67	71	
					Arthur 68	205	
136. Vitruvius E	270A	+29.2	+18.6	11.1	Arthur 68	218	42
	14361						
137. Pitiscus A	3992	+30.8	−50.2	10.3	Arthur 68	1231	127
	43726A						
138. Hommel E	3986F	+31.1	−59.0	13.8	Moutsoulas 70	644	127
	42865				Arthur 68	1170	
139. Arnold G	689A	+31.4	+67.3	10.7	Gavrilov 67	50	4
	12902				Arthur 68	154	
140. Sinas	260	+31.6	+ 8.8	12.4	Marchant 66	15115	61
	15115				Gavrilov 67	90	
					Arthur 68	250	
141. Lockyer HA	(4480)	+32.2	−45.0	12.8	Meyer 65	80	113
	43770				Marchant 66	43770	
					Arthur 68	1235	
142. Isidorus A	4292	+33.2	− 8.0	11.7	Meyer 65	65	79

No. Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates λ	β	D km	Presence in catalogues Catalogue	No.	LAC No.	Notes
1 2	3	4	5	6	7	8	9	10
	45143				Marchant 66	45143		
					Arthur 68	1301		
143. Piccolomini L	4083B	+33.8	−26.1	12.2	Schrutka 58	4083B	97	
	44494				Meyer 65	29		
					Marchant 66	44494		
					Gavrilov 67	466		
					Arthur 68	1269		
144. Hall K	(498)	+34.2	+35.5	8.1	Meyer 65	42	27	
	14558				Marchant 66	14558		
					Arthur 68	229		
145. Rosse	4143	+34.9	−17.9	12.1	Schrutka 58	4143	97	
	45340				Marchant 66	45340		
					Gavrilov 67	473		
					Arthur 68	1315		
146. Baily B	661	+35.0	+50.8	7.3	Moutsoulas 70	681	13	
	13767				Arthur 68	198		
147. Römer K	308	+35.5	+22.5	12.1	Marchant 66	15338	43	
	15338				Arthur 68	259		
148. Stiborius G	4060E	+35.9	−37.3	9.5	Meyer 65	79	114	
	44660A				Marchant 66	44660A		
					Arthur 68	1288		
149. Maraldi B	275A	+36.7	+14.3	7.4	Meyer 65	48	61	
	15284				Marchant 66	15284		
					Gavrilov 67	92		
					Arthur 68	256		
150. G. Bond A	495A	+36.8	+31.6	9.3	Moutsoulas 70	685	43	
	15512				Arthur 68	266		
151. Censorinus F	4241	+37.4	− 3.2	12.9	Marchant 66	46005	79	
	46005				Arthur 68	1335		
152. Gaudibert J	4320	+39.2	−11.2	10.1	Marchant 66	46119	79	
	46119				Arthur 68	1339		
153. Hercules D	457	+39.7	+44.7	8.5	Meyer 65	36	27	
	14750				Marchant 66	14750		
					Gavrilov 67	85		
					Arthur 68	243		

154. Taruntius E	219	+40.2	+ 5.5	11.3	Marchant 66	16049	61	
	16049				Gavrilov 67	101		
					Arthur 68	273		
155. Thales A	429	+40.7	+58.4	12.3	Marchant 66	13845	14	
	13845				Arthur 68	201		
156. Schwabe G	681	+42.1	+65.5	14.7	Marchant 66	12970	4	
	12970				Gavrilov 67	51		
					Arthur 68	157		
157. Reichenbach K	4417A	+42.5	−28.9	11.1	Meyer 65	76	97	
	45498				Marchant 66	45498		
					Arthur 68	1323		
158. Janssen L	–	+43.4	−45.9	11.9			114	
	44771							
159. Santbech E	4387A	+44.8	−22.3	11.0	Meyer 65	70	97	
	46357				Marchant 66	46357		
160. Proclus F	206	+45.9	+14.2	9.2	Meyer 65	47	61	
	16294				Marchant 66	16294		
					Arthur 68	277		
161. Berzelius F	312	+46.0	+32.8	12.2	Meyer 65	35	27	
	16504				Marchant 66	16504		
					Arthur 68	284		
162. Cepheus A	391	+46.4	+40.9	12.6	Schrutka 58	391	27	
	15645A				Meyer 65	16		
					Marchant 66	15645A		
					Gavrilov 67	98		
					Arthur 68	270		
163. Rosenberger H	3965B	+46.5	−54.9	12.1	Arthur 68	1286	128	
	44811							
164. Reichenbach M	4417	+46.5	−33.0	12.8	Gavrilov 67	484	114	
	46504							
165. Messier A	(4255)	+46.9	− 2.0	13.0	Schrutka 58	4255	79	W. H. Pickering
	47023				Meyer 65	30		
					Marchant 66	47023		
					Gavrilov 67	488		W. H. Pickering
					Arthur 68	1345		
166. Bellot A	–	+47.7	−13.2	7.8			79	
	47222							
167. Macrobius F	187	+48.4	+22.4	11.4			43	
	16398							
168. Boussingault R	3936B	+48.7	−64.3	12.4	Marchant 66	43920	138	
	43920				Arthur 68	1243		
169. Taruntius A	216	+49.8	+ 7.2	12.2	Schrutka 58	216	61	

No.	Designation	IAU Nrs. and Arthur 1966 No.	Selenographic co-ordinates		D km	Presence in catalogues		LAC No.	Notes
			λ	β		Catalogue	No.		
1	2	3	4	5	6	7	8	9	10
		17152				Meyer 65	31		
						Marchant 66	17152		
						Gavrilov 67	114		
						Arthur 68	289		
170	Young A	–	+51.1	−41.1	12.8			114	
		45685							
171.	Biot	4396	+51.1	−22.6	12.9	Marchant 66	47318	98	
		47318				Gavrilov 67	493		
						Moutsoulas 70	788		
172.	Shellius E	–	+51.5	−28.0	12.0	Moutsoulas 70	792	98	
		46496							
173.	Geminus B	323	+52.2	+34.1	9.9			27	
		16556							
174.	Lick D	112	+52.7	+13.1	13.8	Marchant 66	17272	62	
		17272							
175.	Messier G	4258A	+52.9	− 5.4	12.9	Schrutka 58	4258A	80	
		47099				Marchant 66	47099		
						Gavrilov 67	490		
176.	Peirce B	116	+53.3	+19.3	10.5	Moutsoulas 70	808	44	
		17353							
177.	Endymion G	409	+55.5	+56.4	14.5	Marchant 66	14853	14	
		14853				Arthur 68	245		
178.	Cleomedes B	122	+55.7	+27.1	10.7	Gavrilov 67	119	44	
		17435				Arthur 68	294		
179.	Langrenus D	4691	+55.8	−10.4	8.3	Marchant 66	48118	80	
		48118							
180.	Apollonius C	69	+57.0	+ 3.3	8.7	Marchant 66	18035	62	
		18035				Gavrilov 67	123		
						Arthur 68	298		
181.	Furnerius A	4576	+59.2	−33.5	12.3	Marchant 66	47515	115	
		47515				Arthur 68	1349		
182.	Reimarus H	4503A	+62.0	−49.2	10.3	Arthur 68	1333	128	
		45775							
183.	Holden V	–	+62.1	−18.5	10.1	Meyer 65	69	98	
		48331				Marchant 66	48331		

					Arthur 68	1354		
184. Cleomedes DC	–	+62.4	+30.3	13.8	Moutsoulas 70	864	44	
	17560							
185. Hase A	4623	+62.8	−29.0	14.0			98	
	47478							
186. Mercurius H	397F	+63.5	+49.2	9.8	Gavrilov 67	99	14	
	15785				Arthur 68	271		
187. Firmicus D	56A	+64.3	+ 5.9	10.6	Marchant 66	18190	62	
	18190							
188. Bernouilli D	165	+66.5	+35.8	12.1	Gavrilov 67	122	28	
	17548							
189. Lamé M	(4699B)	+66.6	−15.8	13.0	Marchant 66	48287	80	
	48287				Gavrilov 67	498		Vendelinus M
					Arthur 68	1353		
190. Dubiago Q	65C	+67.0	+ 2.2	13.4			62	
	19013							
191. Eimmart K	–	+67.6	+20.1	13.2	Moutsoulas 70	886	44	
	18364							
192. Maclaurin D	4663	+69.9	− 7.1	10.0	Marchant 66	49132	80	
	49132							

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