ROTATION OF THE MOON AND LUNAR COORDINATE SYSTEMS*

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To the memory of
Geoffrey Mills, (1937–1970)
colleague and friend.

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Abstract. The need for precise definition of lunar reference systems is stressed and the principles on which systems of lunar coordinates could be based are established. Differences between coordinate systems defined by the dynamical properties of the lunar configuration and the rotational motion of the lunar globe about its centre of gravity are outlined, and rigorous mathematical formulae relating those systems have been developed. The principles of reduction of measurements are outlined and in the Appendix the absolute coordinates obtained for 700 lunar features are presented.

Lunar exploration has made necessary the knowledge of the position of features on the surface of the Moon and the definition of their coordinates with an accuracy much higher than that provided by the fundamental selenographic theories developed in the past. To mention only one example, in order to be able to aim at a laser reflector positioned on the Moon, we must know its situation with an accuracy better than 2 km, which in selenographic coordinates corresponds to 3′. Otherwise the transmitted laser beam, having at the distance of the Moon a diameter of about 4 km, will miss the target. And by now, when a number of reflectors have been placed there by various missions, we should be in a position to adopt a precise and uniquely defined net of lunar coordinates.

How the situation stands at present can be seen on the first two figures which give a comparison between Lipskii's map of the Moon and the map prepared for NASA by ACIC.

Figure 1, in which the area of Oceanus Procellarum around crater Marius as mapped by ACIC (top) and Lipskii (bottom) can be seen together for comparison, demonstrates the considerable difference in longitude between the two coordinate systems. In the first, the 50° W meridian passes several minutes of arc away from the edge of the crater, while in the second the same meridian intersects the crater. Comparison of the mapping of the northern part of Mare Imbrium (Figure 2) shows the difference in latitude between the two coordinate systems. The apparent position of the 40° N parallel with respect to the edge of the craters Helicon and Le Verrier as seen in Lipskii's map (left) and that of ACIC (right) makes the same point obvious. Moreover, these differences are not the largest. In the far side of the Moon the situation is much worse. However, since there the problem of lack of precise orientation of lunar photography

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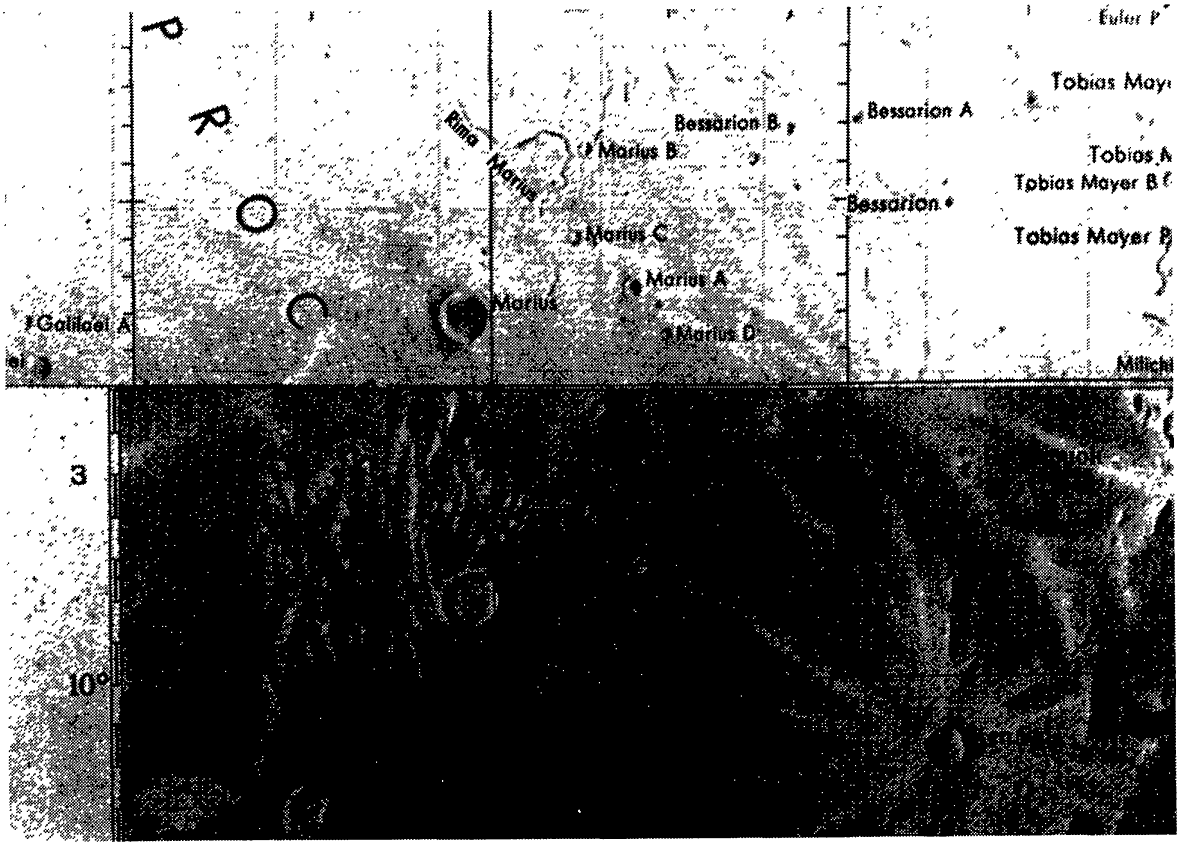

Fig. 1. Coordinate grid in the area of Marius crater of Oceanus Procellarum, as mapped by ACIC (top) and Lipskii (bottom). The position of the 50° W meridian with respect to crater Marius makes obvious the amount of disagreement in longitude, which exists between the two systems.

is encountered, which makes a certain degree of disagreement excusable, we present here the case of the near side of the Moon, where mapping differences indicate that our knowledge about the lunar configuration still needs to be improved, while an agreement in the definition of the basic coordinate axes is an essential requirement.

In order to be able to estimate the magnitude of the differences which exist amongst the various maps of the Moon and catalogues of coordinates of lunar points, and to discover whether they follow any systematic pattern, we have to study the principles on which the development of a coordinate system is based.

There are two main requirements for the choice of any grid:

(i) accuracy of definition, and

(ii) simplicity in expression.

Therefore if for example a body possesses spheroidal symmetry, it is reasonable to adopt a spherical polar coordinate system. And that is the case with stellar configurations, the rotation axis of which, coinciding with their axis of symmetry, provides us with a unique point of reference for the measurement of latitudes. Of course, we are left free to choose any point on the equator for the measurement of longitudes. And the criteria in that choice can be as human and arbitrary as the choice of the meridian passing through the place where the Romans decided to build Londinium as the refer-

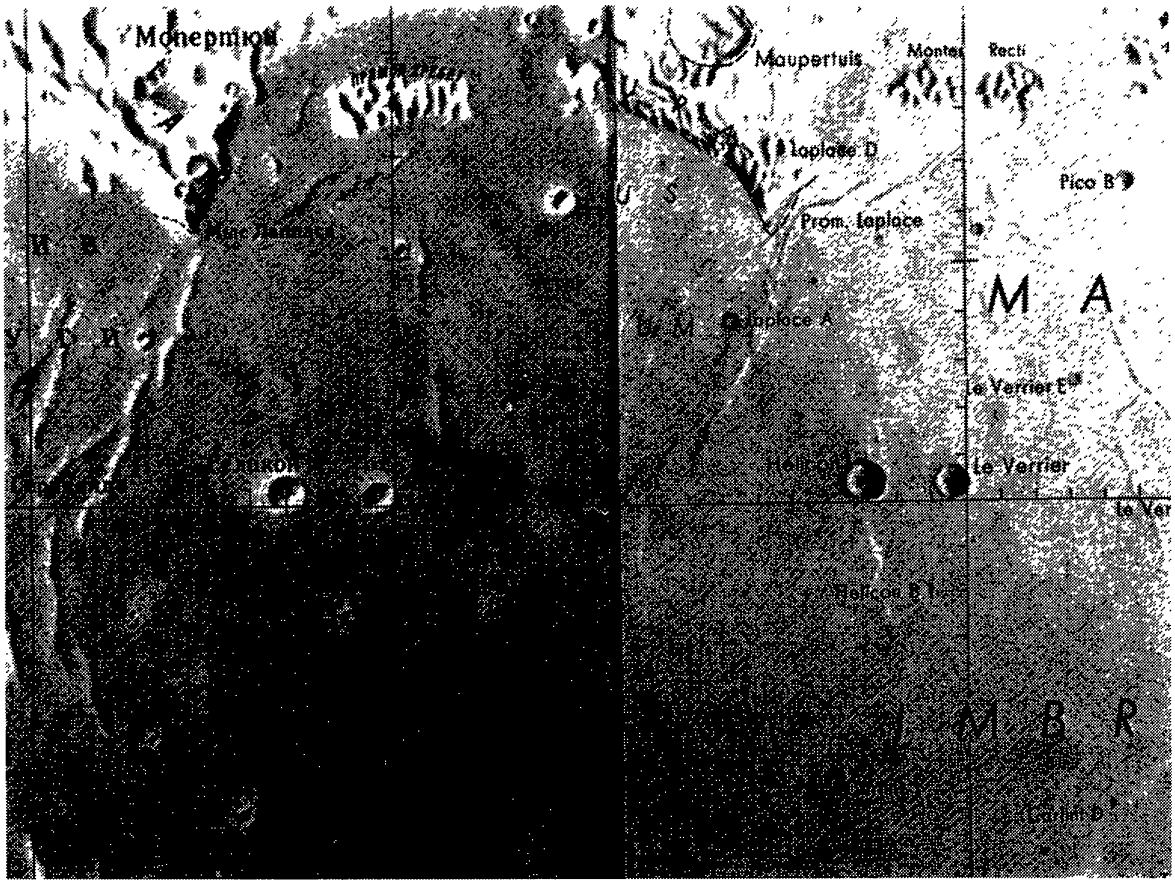

Fig. 2. The mare Imbrium area in the vicinity of crater Helicon, as mapped by Lipskii (left) and ACIC (right). Comparison of the position of the 40°N parallel with respect to the craters Helicon and Le Verrier gives a good estimation of the magnitude of differences in latitude between the two systems of coordinates.

ence plane for the measurement of longitudes on Earth. In the case of an ellipsoid even that freedom ceases to exist, since for these, longitudes are generally referred to the direction of the major axis.

However, when we come to the point of choosing an appropriate system of selenographic coordinates, we are left with more than one possibility. We can decide which our principal axes should be by considering the geometrical shape of the Moon, its dynamical configuration, or its rotational motion. And those three systems do not coincide with each other.

If the Moon were homogeneous and possessed quite low viscosity, thus allowing the forces of isostasy to give it at some stage of its evolution the regular hydrostatic equilibrium shape, then its geometrical figure would be considered as a very simple choice. But it has been proved that the Moon is not homogeneous. There are considerable variations in density inside the Moon, so large that they can be detected by orbiting spacecraft. And the fact that those density anomalies still exist there, so close to the surface, proves that the viscosity coefficient within the Moon must be very high. That explains why the lunar surface lacks any geometrical symmetry. There is no part of the surface of the Moon smooth and uniform enough to give by extrapolation a reference shape, in the way the surface of oceans defines the geoid. Of course, we can always select a number of lunar points and try to generate some geometrical figure which would house them. Nevertheless, that does not meet our original requirements, that the system should be accurate by definition and simple in expression.

The principal axes of inertia seem to be a more appropriate system of coordinate axes, since their definition is unique and unmistakable. As they are rigidly fixed in the lunar globe, the coordinates of any point on the surface of the Moon in that reference system will remain unchanged with time. It is our opinion that all lunar maps should be readjusted, in order to agree with this system. It must be pointed out that so far, in the preparation of various catalogues and maps, no precise definition of their basic axes has been given. From the reduction techniques used, one can realize in most cases that they refer to the axis of rotation of the Moon, which was erroneously assumed to be fixed in the Moon (otherwise the coordinates of lunar features would have been presented as functions of time).

We do not want to altogether abandon the idea of using the axis of lunar rotation, since a reference to that simplifies the work of astronomical observations from the surface of the Moon, as well as velocity studies at various parts of the lunar surface, which are essential in some experiments. Part of our task will be to examine the displacement of the rotation axis within the lunar globe. But, as its position is time dependent, to use it as the basic reference axis in a system of coordinates needed for identification purposes, is most inconvenient. We propose, therefore, that positions on the Moon should be referred to and identified with respect to the principal axes of inertia, while an ephemeris of the relative position of the instantaneous axis of rotation of the lunar globe will make possible transformation of the constant selenographic coordinates into the system with zero velocity component in latitude, whenever that is required.

Moreover, we have to contend with the algebra of additional coordinate systems.

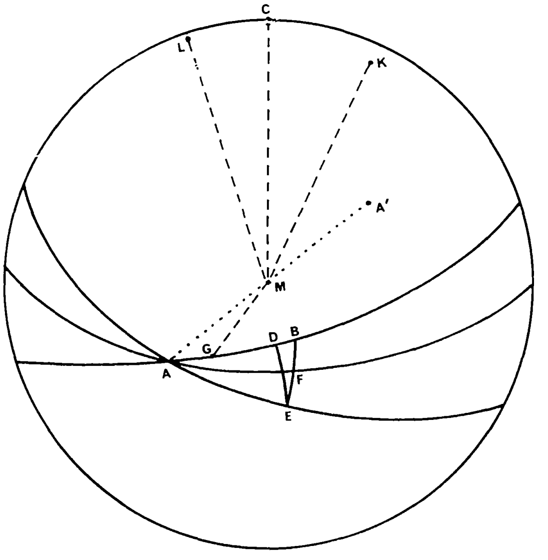

Fig. 3. Projection of the optical librations on the selenocentric celestial sphere.

The 'mean equator' of the Moon, mentioned in the literature, corresponds to the equator of a globe obeying precisely Cassini's laws of motion. Besides, when we measure in our laboratories the position of lunar formations on photographic plates, we deal with a system of rectangular coordinates on the plane. These are usually chosen parallel to the equatorial or the ecliptic system of stellar coordinates, and then the study of the optical libration, the apparent rotation of the lunar globe, governed by the geometry of the Earth-Moon system becomes necessary. A rigorous mathematical formulation of the relations between those different systems is an essential requirement before we attempt any selenodetic reductions.

On the selenocentric sphere (Figure 3), the circle ADB, with axis ML, represents the lunar equator, the circle AF, with axis MC, is parallel to the ecliptic, and the circle AE, with axis MK, the plane of the lunar orbit, where E is the sub-Earth/point and the arcs ED and EF are perpendicular to the circles AD and AF respectively. If MG is the first radius of the Moon, according to Cassini's laws of motion, it rotates at a rate equal to the mean orbital motion of the Moon, and since at the time when the Moon was at the node, the G was at point A we have

$$AG = l_{☾} - \Omega \tag{1}$$

where $l_{☾}$ stands for the mean longitude of the Moon and Ω for the longitude of the mean ascending node.

For an observer on the Earth E is the apparent centre of the lunar disc, which is noticeably different from the adopted origin of selenographic coordinates G. The components GD and DE of that displacement, along the lunar equator and the meridian, constitute the optical libration in longitude, l, and latitude, b, respectively. Therefore we have

$$l = AD - AG\,. \tag{2}$$

The argument AD is calculated from the spherical triangle ADE, where

$$\sin \widehat{EAD} \cdot \cot \widehat{ADE} = \sin AD \cdot \cot AE - \cos AD \cdot \cos \widehat{EAD}\,. \tag{3}$$

The angle $\widehat{EAD}$ is equal to the sum of the inclination of the lunar orbital plane to the ecliptic and the inclination of the lunar equator to the ecliptic:

$$EAD = i + I\,; \tag{4}$$

the currently adopted values for i and I are:

$$i = 5°8'43''.4 \pm 0''.1 \tag{5}$$

and

$$I = 1°32'1''.0 \pm 7''.0\,. \tag{6}$$

Moreover

$$ADE = \pi/2\,. \tag{7}$$

Therefore, the relation (3) becomes

$$\tan AD = \tan AE \cdot \cos(i + I)\,. \tag{8}$$

However, if we consider the plane *EFB*, which is perpendicular to the ecliptic, we notice that the angular distance *AF* is equal to the difference of the ecliptic longitude of the Moon, λ, and the longitude of the mean ascending node, Ω, while *EF* equals the ecliptic latitude of the Moon, β. The elements of the triangle *AFE* are connected with the relation:

$$\sin \widehat{FAE} \cdot \cot \widehat{EFA} = \sin AF \cdot \cot AE - \cos AF \cdot \cos \widehat{FAE} \tag{9}$$

which gives

$$\sin i \cot (\pi/2) = \sin (\lambda - \Omega) \cdot \cot AE - \cos (\lambda - \Omega) \cdot \cos i \tag{10}$$

and finally

$$\tan AE = \frac{\tan (\lambda - \Omega)}{\cos i}. \tag{11}$$

Introducing the expression for *AE* given by Equation (11) into Equation (8) we obtain

$$AD = \tan^{-1} \left[\frac{\tan (\lambda - \Omega)}{\cos i} \cos (i + I) \right] \tag{12}$$

which, combined with Equations (1) and (2), gives

$$l = \tan^{-1} \left[\frac{\tan (\lambda - \Omega)}{\cos i} \cos (i + I) \right] - (l_{☾} - \Omega). \tag{13}$$

The displacement of the centre of the lunar disc in latitude, b, can also be calculated with the use of relations connecting elements of the spherical triangle *ADE*. We have

$$\sin (\pi/2) \cdot \cot (i + I) = \sin (l_{☾} - \Omega + l) \cdot \cot b \tag{14}$$

and therefore

$$b = \tan^{-1} [\sin (l_{☾} - \Omega + l) \cdot \tan (i + I)]. \tag{15}$$

At this stage of our analysis, we ought to give some explanation about the way in which the approximate expression for the optical libration in latitude, which appears in the literature, was derived. It might be recalled that it possesses the form

$$b = B - \beta \tag{16}$$

where

$$\tan B = - \sin (\lambda - \Omega) \cdot \tan I. \tag{17}$$

This comes with the assumption that

$$DE \simeq BE. \tag{18}$$

We can obtain *BE* as the sum of *BF* and *FE*. The angular distance *FE* is equal to the ecliptic latitude of the Moon, β, with opposite sign, while *BF* can be expressed in terms of other elements of the triangle *ABF*, where

$$\sin (\pi/2) \cdot \cot I = \sin (\lambda - \Omega) \cdot \cot BF - \cos (\pi/2) \cdot \cos (\lambda - \Omega). \tag{19}$$

That gives

$$BF = \tan^{-1}[\sin(\lambda - \Omega)\cdot\tan I] \tag{20}$$

and therefore

$$b \simeq BE = \tan^{-1}[\sin(\lambda - \Omega)\cdot\tan I] - \beta\,. \tag{21}$$

That approximation introduces an error of the order of $0^0.001$, which we can now avoid, since modern computing facilities make easy the precise and fast computation of trigonometric functions.

There is an additional apparent displacement of the selenographic coordinates we have to take into account at the reduction of lunar measurements. It is caused by the fact that the terrestrial observer is not situated on the line joining the centres of the Earth and the Moon. Moreover, as he follows the Earth's rotation, he observes a diurnal motion of the lunar features.

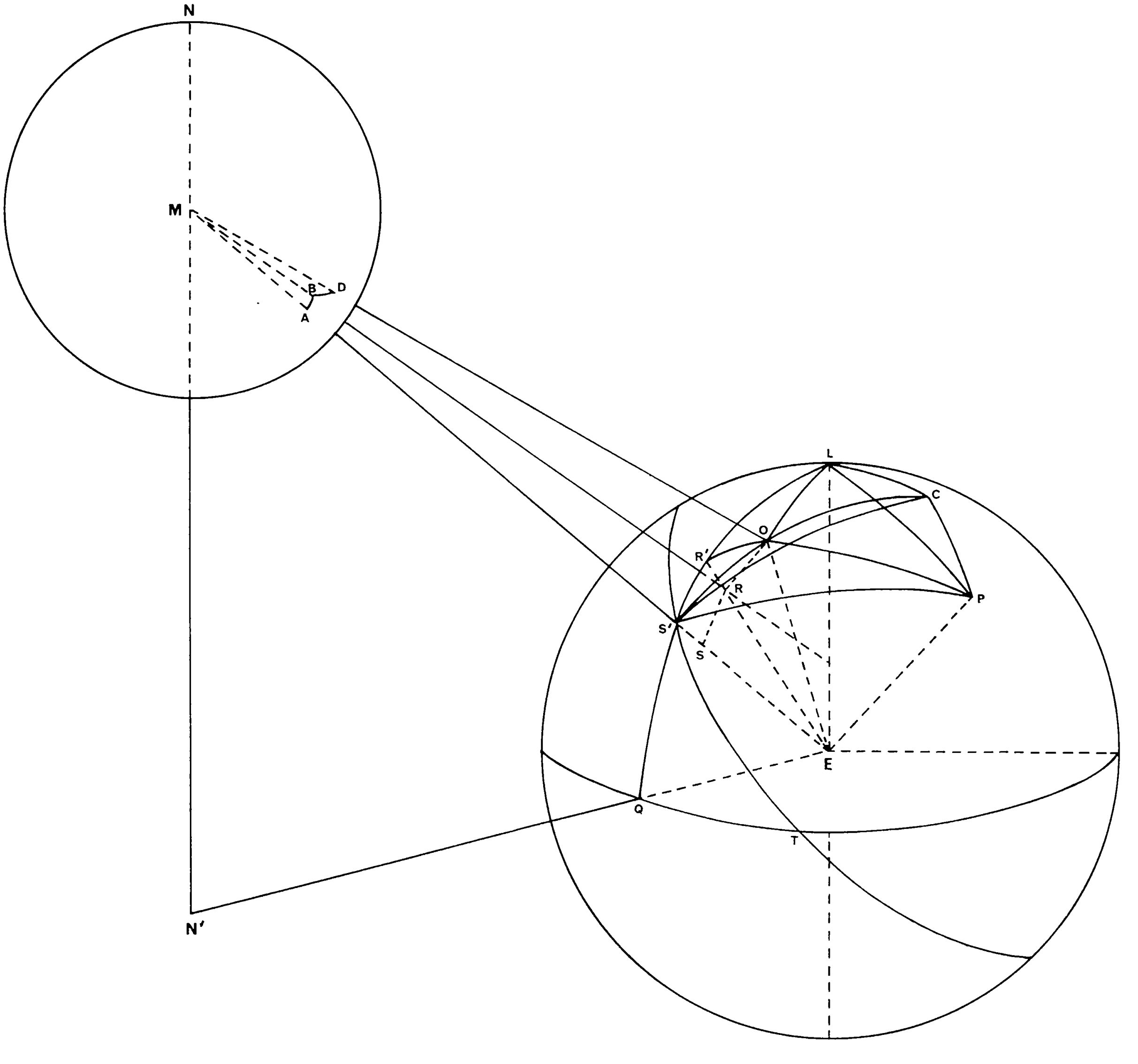

Fig. 4. Geocentric system (right) demonstrating the geometry of the observer's position and its relation to the topocentric libration projected on the selenocentric sphere (left).

It has been customary, since the time of the desk calculators and logarithmic tables, to apply certain approximate differential corrections, like those derived by Atkinson (1951) and adopted by the Astronomical Ephemeris and the Nautical Almanac. They are based on the assumption that the magnitude of parallactic displacements on the lunar surface remains within the limits of the Moon's horizontal parallax which is valid only in the case of Earth-based observations. However, today we can include into our computer programmes the exact mathematical description of the phenomenon.

Suppose that in Figure 4 E is the centre of the Earth, M the centre of the Moon, O the position of the observer and the axis LE is parallel to the polar axis of the Moon MN, while EN' is the perpendicular from E to the lunar axis, EP is the polar axis of the Earth, and the path of the lunar orbit is projected on the circle TS'. If A is the apparent centre of the lunar disc as seen from the Earth, the position of which we have so far computed with respect to the point E, and D the centre of the lunar disc as seen from O, the angle $\widehat{BMA} = \delta b$ measured on the lunar meridian defines the diurnal libration in latitude; the diurnal libration in longitude, δl, is equal to $\widehat{BMD}/\cos b$, where $b = -\widehat{N'EM}$ is the optical libration of the Moon in latitude.

Assuming that OR is the perpendicular from O to the plane MEL, and RS the perpendicular from R to the line EM which joins the centres of the Earth and the Moon, we have

$$\sin(\delta l \cdot \cos b) = \frac{OR}{OM} \tag{22}$$

and

$$\delta b = \frac{RS}{SM}. \tag{23}$$

The distances OR, OM, RS, and SM can be expressed in terms of the distance R of the centre of the Earth from the centre of the Moon and the distance r of the observer from the centre of the Earth, as follows,

$$OR = r \cdot \sin \widehat{REO}, \tag{24}$$

$$OM = \sqrt{R^2 + r^2 - 2Rr \cdot \cos \widehat{MEO}}, \tag{25}$$

$$RS = r \cdot \cos \widehat{REO} \cdot \sin \widehat{REM}, \tag{26}$$

$$SM = r - r \cdot \cos \widehat{REO} \cdot \cos \widehat{REM}. \tag{27}$$

Therefore our problem is to compute the angles REO, MEO and REM, all of which are subtended to the centre of the Earth and can be represented by the angular distances $R'O$, $S'O$ and $R'S'$ on the geocentric sphere.

The relations

$$\frac{\sin R'O}{\sin R'LO} = \frac{\sin LR'}{\sin LOR'} \tag{28}$$

and

$$\sin R'L \cdot \cot OR' = \sin \widehat{LR'O} \cdot \cot \widehat{R'LO} + \cos R'L \cdot \cos \widehat{LR'O} \tag{29}$$

which connect the elements of the spherical triangle $LR'O$ and give,

$$\sin R'O = \sin LO \cdot \sin \widehat{R'LO} \tag{30}$$

and

$$\cos (R'S' - b) = \frac{\tan OR'}{\tan R'LO} \tag{31}$$

respectively.

Since, as we have already mentioned, the angular distance $S'Q$ is equal to the optical libration in latitude, b, with opposite sign, we have

$$S'L = \pi/2 + b \tag{32}$$

and therefore the angle $R'LO$ can be expressed in terms of elements of the triangle $S'LO$ with use of the relation

$$\cos \widehat{R'LO} = \frac{\cos OS' + \cos LO \cdot \sin b}{\cos b \cdot \sin LO}, \tag{33}$$

while from the triangle POS' we have

$$\cos OS' = \cos PO \cdot \cos PS' + \sin PO \cdot \sin PS' \cdot \cos \widehat{OPS'}. \tag{34}$$

Since $PO = \pi/2 - \varphi_0$, where φ_0 is the latitude of the observer, $PS' = \pi/2 - \delta$, where δ is the declination of the Moon, and the angle OPS' is the hour angle of the Moon, H, Equation (34) becomes

$$\cos OS' = \sin \varphi_0 \cdot \sin \delta + \cos \varphi_0 \cdot \cos \delta \cdot \cos H. \tag{35}$$

The argument LO can be found from the relation

$$\cos LO = \cos I \cdot \cos CO + \sin I \cdot \sin CO \cdot \cos \widehat{LCO} \tag{36}$$

in the triangle OCL, where $I = LC$ is the inclination of the lunar equator to the ecliptic.

The angle $\widehat{LCO}$ is equal to the difference of the angles $\widehat{LCP}$ and $\widehat{PCO}$, the first of which is equal to the longitude of the ascending lunar node ,Ω, while the second can be computed from the relation

$$\cos \widehat{PCO} = \frac{\sin \varphi_0 - \cos CO \cdot \cos \varepsilon}{\sin CO \cdot \sin \varepsilon} \tag{37}$$

which links the elements of the triangle PCO, where $\varepsilon = \kappa$ is the inclination of the Earth's equator to the ecliptic. From the same triangle we find finally that

$$\cos CO = \cos \varepsilon \cdot \sin \varphi_0 + \cos \varphi_0 \cdot \sin \varepsilon \cdot \cos \widehat{OPC} \tag{38}$$

and since

$$\widehat{OPC} = \pi/2 + ST \tag{39}$$

where ST stands for the local sidereal time which is equivalent to the hour angle of γ, we find finally that

$$\cos CO = \cos\varepsilon \cdot \sin\varphi_0 - \cos\varphi_0 \cdot \sin\varepsilon \cdot \sin ST\,. \tag{40}$$

The great advantage of the above analysis, in comparison to others appearing in the literature, is that at no stage of our discussion have we imposed the restriction that the observer must be on the surface of the Earth. We have not simplified any formula with the assumption that some quantity was small and negligible. The distance from the centre of the Earth, r, the geocentric latitude, φ_0, and the longitude, which enters into our formulae through the sidereal time, could belong to any point in space. Therefore, we have developed a method, with which we can calculate precisely at any time the apparent displacement of points on the surface of the Moon, as seen from a moving spacecraft.

Detection of the rotation of the Moon is based on the measurement of the residual displacement of features on the observed lunar disc after the elimination of the components of apparent rotation which we described. Whilst the theoretical study of the phenomenon and results accomplished so far are accounted elsewhere (Moutsoulas, 1971) and the technical details of a new photographic method, which secures more accurate observational material have also been presented (Moutsoulas, 1970), we shall present here the principles of the reduction of measurements.

Let us consider m measurable points on n photographic plates of the Moon. The coordinates of the ith point on the jth plate can be calculated in terms of its selenographic coordinates. This can be done by transformation of the spherical-polar system of selenographic coordinates into a selenocentric rectangular coordinate system x, y, z, rotating with the Moon, the x-axis of which coincides with the mean direction of the Earth, the z-axis is directed towards the lunar north pole, and the y-axis, forming with the other two axes a right-handed system, is directed towards the completed part of the lunar orbit. The relation between these two coordinate systems can be expressed by the following system of equations:

$$x_i = (R + h_i) \cdot \cos\lambda_i \cdot \cos\beta_i \tag{41}$$

$$y_i = (R + h_i) \cdot \sin\lambda_i \cdot \cos\beta_i \tag{42}$$

$$z_i = (R + h_i) \cdot \sin\beta_i \tag{43}$$

where R stands for the mean radius of the Moon, and h_i is the altitude of the ith point relative to the mean radius, the selenographic longitude and latitude of which are λ_i and β_i respectively.

If p, q and r are the rotational components of the physical libration referred to the x, y, z axes, they will cause displacements of points on the lunar surface amounting to:

$$\delta x_i = qz_i - ry_i \tag{44}$$

$$\delta y_i = rx_i - pz_i\,, \tag{45}$$

$$\delta z_i = py_i - qx_i\,. \tag{46}$$

Comparison between the effect of the rotation p, q, r and that of an identical rotation expressed in terms of the physical libration in inclination, node and longitude on the value of the direction cosines, give at a first order approximation:

$$-qI\sin\psi - r\sin(\varphi+\psi) = -\tau\sin(\varphi+\psi) \tag{47}$$

$$pI\sin\psi - r\cos(\varphi+\psi) = -\tau\cos(\varphi+\psi) \tag{48}$$

$$p\sin(\varphi+\psi) + q\cos(\varphi+\psi) = \varrho\sin\psi + \sigma I\cos\psi \tag{49}$$

$$qI\cos\psi + r\cos(\varphi+\psi) = \tau\cos(\varphi+\psi) \tag{50}$$

$$-pI\cos\psi - r\sin(\varphi+\psi) = -\tau\sin(\varphi+\psi) \tag{51}$$

$$-p\cos(\varphi+\psi) + q\sin(\varphi+\psi) = -\varrho\cos\psi + \sigma I\sin\psi \tag{52}$$

$$-q + rI\cos\varphi = \varrho\sin\varphi - \sigma I\cos\varphi + \tau I\cos\varphi \tag{53}$$

$$p - rI\sin\varphi = \varrho\cos\varphi + \sigma I\sin\varphi - \tau I\sin\varphi \tag{54}$$

$$-pI\cos\varphi + qI\sin\varphi = 0 \tag{55}$$

where the Eulerian angles θ, φ, ψ and the components ϱ, σ, τ of physical libration in inclination node and longitude respectively are related by means of the system of equations:

$$\theta = I + \varrho \tag{56}$$

$$\psi = \Omega + \sigma \tag{57}$$

$$\varphi = 180^\circ - l_☾ - \psi + \tau\,, \tag{58}$$

From the system of Equations (47)–(55) and within the degree of approximation considered so far, the following expressions for the rotation components p, q and r can be easily found

$$p = \varrho\cos\varphi + \sigma I\sin\varphi \tag{59}$$

$$q = -\varrho\sin\varphi + \sigma I\cos\varphi \tag{60}$$

$$r = \tau\,. \tag{61}$$

If X_C and Y_C denote the coordinates of a point on the photographic plate, as calculated from its adopted selenographic position, and X_0, Y_0 the measured coordinates of that point on the plate, the differences between the two pairs can be interpreted in terms of the values adopted for the calculation. We therefore have

$$(X_0 - X_c)_{i,j} = \frac{\partial X}{\partial x}\Delta x_{i,j} + \frac{\partial X}{\partial y}\Delta y_{i,j} + \frac{\partial X}{\partial z}\Delta z_{i,j} \tag{62}$$

$$(Y_0 - Y_c)_{i,j} = \frac{\partial Y}{\partial x}\Delta x_{i,j} + \frac{\partial Y}{\partial y}\Delta y_{i,j} + \frac{\partial Y}{\partial z}\Delta z_{i,j} \tag{63}$$

where

$$\Delta x_i = \frac{\partial x}{\partial R}\Delta R_i + \frac{\partial x}{\partial \lambda}\Delta\lambda_i + \frac{\partial x}{\partial \beta}\Delta\beta_i \tag{64}$$

$$\Delta y_i = \frac{\partial y}{\partial R}\Delta R_i + \frac{\partial y}{\partial \lambda}\Delta\lambda_i + \frac{\partial y}{\partial \beta}\Delta\beta_i \tag{65}$$

$$\Delta z_i = \frac{\partial z}{\partial R}\Delta R_i + \frac{\partial z}{\partial \lambda}\Delta\lambda_i + \frac{\partial z}{\partial \beta}\Delta\beta_i . \tag{66}$$

Combination of the differences caused by the physical libration and those due to erroneous determination of coordinates, gives, finally,

$$\begin{aligned}(X_0 - X_c)_{i,j} = {} & \frac{\partial X}{\partial x}\left[\frac{\partial x}{\partial R}\Delta R_i + \frac{\partial x}{\partial \lambda}\Delta\lambda_i + \frac{\partial x}{\partial \beta}\Delta\beta_i + r_j y_i - q_j z_i\right] + \\ & + \frac{\partial X}{\partial y}\left[\frac{\partial y}{\partial R}\Delta R_i + \frac{\partial y}{\partial \lambda}\Delta\lambda_i + \frac{\partial y}{\partial \beta}\Delta\beta_i + p_j z_i - r_j x_i\right] + \\ & + \frac{\partial X}{\partial z}\left[\frac{\partial z}{\partial R}\Delta R_i + \frac{\partial z}{\partial \lambda}\Delta\lambda_i + \frac{\partial z}{\partial \beta}\Delta\beta_i + q_j x_i - p_j y_i\right]\end{aligned} \tag{67}$$

and

$$\begin{aligned}(Y_0 - Y_c)_{i,j} = {} & \frac{\partial Y}{\partial x}\left[\frac{\partial x}{\partial R}\Delta R_i + \frac{\partial x}{\partial \lambda}\Delta\lambda_i + \frac{\partial x}{\partial \beta}\Delta\beta_i + r_j y_i - q_j z_i\right] + \\ & + \frac{\partial Y}{\partial y}\left[\frac{\partial y}{\partial R}\Delta R_i + \frac{\partial y}{\partial \lambda}\Delta\lambda_i + \frac{\partial y}{\partial \beta}\Delta\beta_i + p_j z_i - r_j x_i\right] + \\ & + \frac{\partial Y}{\partial z}\left[\frac{\partial z}{\partial R}\Delta R_i + \frac{\partial z}{\partial \lambda}\Delta\lambda_i + \frac{\partial z}{\partial \beta}\Delta\beta_i + q_j x_i - p_j y_i\right].\end{aligned} \tag{68}$$

In a first approximation values of the physical libration predicted from calculation have been adopted and the list of coordinates of lunar features presented in the Appendix (Table I) has been developed, in continuation of work which the late G. A. Mills started in Manchester. Their distribution over the lunar surface appears in Table II.

Acknowledgments

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Appendix

TABLE I

Coordinates of 700 lunar reference points

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
1	71.42	0.10	−28.13	0.02	1.26	0.36	3.9	
2	71.21	0.05	36.07	0.01	−1.42	0.12	6.5	
3	70.81	0.05	− 9.19	0.01	−1.24	0.14	6.6	
4	69.80	0.04	15.92	0.01	−1.19	0.14	6.4	
5	69.66	0.04	− 3.38	0.01	−1.20	0.22	4.3	MacLaurin Mc
6	69.12	0.05	17.69	0.01	−2.53	0.23	4.1	
7	68.52	0.07	16.10	0.00	−0.84	0.29	5.1	
8	68.34	0.06	−32.77	0.01	−0.85	0.33	4.1	
9	68.26	0.05	4.29	0.01	−0.49	0.20	4.1	Dubiago Y
10	68.25	0.06	33.21	0.02	−0.65	0.22	5.5	Berosus A
11	68.17	0.06	20.28	0.01	−2.25	0.23	4.7	Eimmart K
12	67.92	0.06	− 0.26	0.01	−1.22	0.24	3.7	MacLaurin O
13	67.71	0.04	33.84	0.01	−2.06	0.19	6.7	
14	67.57	0.04	19.19	0.01	−3.24	0.20	4.6	Eimmart Ka
15	67.39	0.03	35.60	0.02	−1.09	0.09	8.3	
16	66.88	0.03	−13.15	0.01	−1.15	0.20	6.7	
17	66.81	0.06	−23.21	0.01	−0.22	0.20	4.6	
18	66.70	0.04	38.15	0.01	−1.24	0.08	7.6	
19	65.97	0.04	45.52	0.01	0.99	0.13	5.5	
20	65.65	0.14	27.64	0.02	−1.26	0.64	7.4	
21	65.47	0.03	2.87	0.01	−1.79	0.08	3.4	
22	64.61	0.02	−40.52	0.02	−0.92	0.14	9.5	
23	64.22	0.04	17.14	0.01	−2.99	0.14	5.6	
24	64.03	0.04	53.91	0.01	0.41	0.08	3.2	
25	63.51	0.04	35.70	0.01	−0.16	0.22	4.3	
26	63.31	0.03	−17.81	0.01	−0.22	0.08	4.4	
27	62.84	0.04	− 0.04	0.01	−0.71	0.28	3.2	
28	62.81	0.03	−13.46	0.01	−0.19	0.10	5.2	Vendelinus T
29	62.72	0.03	30.37	0.01	−1.11	0.15	3.7	Cleomedes Dc
30	62.72	0.04	− 7.61	0.01	−0.42	0.21	4.3	Webb L
31	62.61	0.06	−17.18	0.01	−2.67	0.34	4.4	Vendelinus Z
32	62.58	0.03	52.15	0.01	−0.48	0.05	5.9	
33	62.46	0.03	−22.84	0.01	−0.36	0.29	4.1	
34	62.39	0.04	−35.30	0.01	−0.65	0.08	6.1	
35	62.21	0.01	−13.75	0.01	0.31	0.16	4.3	Vendelinus K
36	62.17	0.03	−18.48	0.01	−1.35	0.10	4.0	Holden V
37	61.88	0.03	13.12	0.01	−3.29	0.14	4.1	
38	61.66	0.04	−15.25	0.02	−2.51	0.18	3.9	Vendelinus H
39	61.60	0.04	6.24	0.01	−0.24	0.17	4.7	
40	60.56	0.03	8.84	0.01	0.75	0.19	3.0	
41	60.41	0.03	13.18	0.01	−3.01	0.16	2.8	Picard Y
42	60.39	0.04	30.05	0.01	−1.52	0.09	3.1	Burckhardt B

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Diameter	Name
43	60.31	0.07	7.50	0.01	−1.08	0.56	2.2	Firmicus H
44	60.11	0.06	−17.94	0.01	−0.54	0.47	3.3	
45	60.08	0.08	−27.68	0.02	−1.12	0.42	6.4	Petavius C
46	59.64	0.09	− 2.12	0.01	−2.41	0.76	5.1	Webb H
47	59.55	0.04	41.82	0.02	−0.56	0.18	3.3	
48	59.19	0.03	10.81	0.01	−2.61	0.19	4.1	
49	59.07	0.09	57.68	0.02	−1.28	0.24	4.5	
50	59.04	0.04	29.48	0.01	−0.48	0.21	4.1	Cleomedes S
51	58.88	0.06	3.83	0.01	−1.41	0.55	5.1	Apollonius H
52	58.49	0.06	− 0.82	0.01	−2.21	0.51	5.3	Webb B
53	58.40	0.03	− 6.64	0.01	−2.10	0.12	3.0	Langrenus Ka
54	57.85	0.06	22.42	0.01	−3.17	0.43	3.8	Cleomedes Fa
55	57.22	0.05	44.07	0.01	−1.58	0.24	5.7	Shuckburgh E
56	57.21	0.08	46.67	0.02	−1.31	0.44	4.0	
57	57.14	0.04	26.88	0.02	−2.50	0.22	6.5	Cleomedes J
58	56.83	0.13	47.04	0.03	−1.17	0.60	3.7	
59	56.54	0.03	−23.73	0.01	−1.51	0.17	3.8	Wrottesley (Cent Mt)
60	56.39	0.07	48.47	0.01	−1.82	0.21	6.9	
61	56.14	0.03	−51.45	0.00	−1.91	0.15	4.5	
62	55.84	0.05	5.84	0.01	−0.55	0.45	4.4	
63	55.82	0.04	− 1.23	0.01	−1.81	0.44	4.0	
64	55.74	0.03	11.77	0.01	−2.43	0.37	4.6	
65	55.57	0.03	−42.46	0.02	−0.73	0.25	5.3	
66	55.41	0.02	25.29	0.01	−0.94	0.07	4.3	
67	55.13	0.03	−43.74	0.01	−0.12	0.03	5.0	
68	55.07	0.06	−18.40	0.01	−0.35	0.41	4.4	
69	55.06	0.02	37.01	0.01	0.12	0.18	2.9	
70	54.55	0.04	−44.97	0.01	−3.03	0.14	5.0	
71	54.44	0.04	2.24	0.01	−2.34	0.34	4.0	Taruntius O
72	54.42	0.04	− 2.81	0.01	−1.80	0.31	2.9	
73	54.32	0.06	41.63	0.02	−0.06	0.34	5.3	
74	54.04	0.05	− 5.87	0.01	−1.50	0.43	3.6	Langrenus Fe
75	53.96	0.06	59.68	0.02	−1.48	0.17	7.2	
76	53.74	0.02	2.40	0.01	−2.11	0.13	4.1	Taruntius N
77	53.72	0.02	19.39	0.01	−4.06	0.04	4.6	Pierce B
78	53.71	0.01	−15.36	0.01	−0.03	0.08	5.1	McClure
79	53.58	0.04	49.64	0.02	−0.75	0.17	4.1	
80	53.43	0.04	8.41	0.01	0.17	0.15	3.9	
81	53.37	0.05	−20.07	0.02	−0.05	0.46	5.6	
82	53.30	0.08	46.61	0.02	−1.26	0.46	6.1	
83	53.25	0.05	38.14	0.02	−1.53	0.29	3.8	
84	52.81	0.05	−44.58	0.02	−0.18	0.13	3.1	
85	52.42	0.04	13.77	0.01	−2.23	0.27	3.8	
86	52.36	0.04	51.20	0.01	−0.94	0.14	7.1	
87	51.91	0.02	11.53	0.01	1.47	0.26	3.7	Lick C
88	51.67	0.03	−39.76	0.01	−0.96	0.21	4.1	Rheita B

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
89	51.63	0.03	0.67	0.02	−1.72	0.36	4.8	Taruntius K
90	51.56	0.06	−27.96	0.01	−0.71	0.42	5.9	
91	51.53	0.08	−28.95	0.02	−1.32	0.61	4.7	Snellius C
92	51.44	0.04	− 8.78	0.01	−1.81	0.47	4.4	Goclenius Ua
93	51.16	0.04	−22.64	0.01	−0.98	0.39	8.3	Biot
94	50.99	0.06	43.52	0.01	−1.62	0.36	4.2	
95	50.97	0.07	−30.33	0.02	0.26	0.56	2.6	
96	50.84	0.08	−24.71	0.01	0.36	0.57	7.4	Biot E
97	50.76	0.01	− 8.52	0.01	−0.92	0.20	3.7	Goclenius Ub
98	50.72	0.05	10.64	0.02	−1.47	0.50	4.3	Lick E
99	50.17	0.10	−55.06	0.01	−2.21	0.41	3.5	
100	49.52	0.04	27.85	0.01	−1.55	0.31	5.2	Tralles C
101	49.48	0.08	33.34	0.02	−0.31	0.64	4.1	
102	49.24	0.08	41.80	0.02	−1.51	0.54	2.9	
103	49.16	0.04	−44.12	0.01	−1.09	0.25	4.0	
104	48.65	0.02	45.46	0.01	−1.14	0.04	4.2	
105	48.64	0.02	−18.91	0.02	−0.06	0.14	7.3	Cook G
106	48.35	0.06	−50.15	0.02	−2.25	0.39	5.1	
107	48.31	0.11	60.36	0.02	−1.14	0.31	6.2	Thales H
108	48.27	0.04	−21.77	0.01	0.24	0.33	4.5	
109	48.01	0.04	50.04	0.01	−1.54	0.21	4.9	
110	47.84	0.02	−10.45	0.02	−0.22	0.15	3.4	
111	47.75	0.03	22.97	0.01	0.07	0.23	4.2	
112	47.69	0.02	−13.51	0.01	0.09	0.17	4.0	Bellot B
113	47.65	0.07	20.45	0.01	1.17	0.68	4.5	Macrobius Q
114	47.18	0.05	31.24	0.02	0.40	0.32	4.0	
115	46.71	0.06	12.85	0.01	1.56	0.71	3.3	
116	46.39	0.03	− 3.57	0.01	−1.52	0.43	4.6	Messier D
117	46.36	0.04	−50.28	0.01	−0.43	0.19	4.5	Watt A
118	46.02	0.06	−15.06	0.02	−0.41	0.76	2.9	Colombo (Cent Mt)
119	46.00	0.05	29.80	0.02	0.32	0.36	4.1	
120	45.56	0.02	−19.73	0.01	0.10	0.12	4.2	Santbech θ
121	45.50	0.02	−11.76	0.01	−0.03	0.09	2.9	
122	45.46	0.07	− 3.31	0.01	−0.95	0.84	3.4	Messier E
123	45.28	0.08	52.42	0.02	−1.26	0.37	3.6	
124	45.17	0.05	−15.07	0.01	−0.97	0.61	3.6	
125	45.15	0.03	16.33	0.01	1.39	0.42	4.8	Proclus R
126	45.15	0.03	−39.52	0.01	1.20	0.24	4.2	
127	45.14	0.06	20.83	0.02	−0.82	0.71	4.3	Macrobius C
128	44.97	0.08	−42.49	0.02	0.13	0.70	4.0	
129	44.91	0.16	64.46	0.03	0.22	0.45	5.4	
130	44.46	0.02	11.81	0.01	−0.55	0.21	3.3	
131	44.16	0.05	−20.78	0.02	−1.72	0.41	5.7	Santbech (Cent Mt)
132	44.05	0.36	70.53	0.06	−1.44	0.56	4.4	
133	43.79	0.04	48.64	0.02	−1.16	0.25	4.9	
134	43.67	0.05	− 0.76	0.01	−0.47	0.52	3.3	Secchi X

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
135	43.46	0.03	− 7.91	0.01	−0.60	0.50	4.4	Gutenberg Ea
136	43.34	0.02	10.82	0.02	0.14	0.38	3.4	
137	43.02	0.05	−30.84	0.01	−0.12	0.31	2.7	
138	42.77	0.04	−28.46	0.01	3.35	0.27	3.0	
139	42.41	0.01	29.10	0.01	1.14	0.04	4.8	Newcomb H
140	42.37	0.03	4.86	0.01	−0.45	0.35	2.9	Taruntius Ea
141	42.16	0.12	70.08	0.02	0.05	0.26	5.0	
142	41.91	0.02	−42.73	0.01	−1.47	0.22	3.8	
143	41.82	0.03	41.06	0.01	−0.91	0.16	4.1	
144	41.53	0.04	3.69	0.00	−0.49	0.55	3.6	Secchi B
145	41.49	0.05	3.30	0.01	−0.59	0.74	3.7	Secchi A
146	41.21	0.04	51.32	0.02	−2.04	0.15	3.2	Hercules H
147	41.13	0.04	−18.14	0.01	−0.56	0.37	4.5	Bohnenberger W
148	40.92	0.08	63.08	0.02	−0.92	0.29	4.0	
149	40.56	0.03	−55.95	0.01	−1.09	0.17	3.9	
150	40.42	0.03	30.66	0.02	−0.10	0.38	4.2	
151	40.13	0.05	58.58	0.02	−1.50	0.26	4.3	Thales W
152	40.13	0.04	39.03	0.01	−0.52	0.24	4.9	
153	40.10	0.08	−30.50	0.03	4.34	0.86	4.6	
154	39.57	0.03	−30.46	0.01	4.63	0.37	4.4	
155	39.55	0.03	−19.41	0.01	0.29	0.31	4.1	Bohnenberger λ
156	39.45	0.05	−20.40	0.01	−0.67	0.62	6.7	Santbech M
157	38.91	0.04	−42.67	0.02	−0.65	0.37	3.6	
158	38.66	0.06	−54.81	0.02	−0.42	0.40	9.3	
159	38.50	0.02	8.84	0.01	0.86	0.22	3.3	Cauchy E
160	38.44	0.02	14.38	0.01	0.03	0.36	3.6	Lyell B
161	38.35	0.03	22.96	0.01	−0.31	0.27	4.9	
162	38.13	0.05	−34.56	0.01	0.50	0.61	4.3	Neander Y
163	38.04	0.03	−22.92	0.02	1.37	0.44	3.7	
164	37.87	0.06	34.86	0.02	0.38	0.75	3.6	
165	37.73	0.02	−32.97	0.01	1.56	0.13	5.1	Neander X
166	37.51	0.13	52.80	0.04	−0.85	0.96	4.7	
167	37.38	0.02	−19.52	0.01	−0.59	0.21	5.2	
168	37.28	0.02	9.51	0.02	0.67	0.31	2.9	
169	37.23	0.03	69.96	0.02	0.24	0.10	12.2	
170	37.07	0.02	44.23	0.01	−1.30	0.18	5.6	
171	36.96	0.03	36.34	0.01	−1.10	0.18	5.0	
172	36.93	0.02	31.62	0.02	−0.67	0.18	5.5	G Bond A
173	36.67	0.03	−47.43	0.01	−0.37	0.20	7.8	
174	35.82	0.02	9.71	0.01	0.22	0.43	3.4	Cauchy B
175	35.36	0.04	50.98	0.02	−2.24	0.25	5.0	
176	34.92	0.04	4.81	0.01	0.86	0.61	3.7	
177	34.80	0.03	−24.79	0.00	1.71	0.52	3.1	
178	34.41	0.02	−19.81	0.01	−0.56	0.42	3.2	
179	34.18	0.02	58.50	0.01	−2.12	0.14	6.0	
180	34.14	0.02	−19.33	0.01	−0.11	0.12	2.4	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
181	34.12	0.03	−48.66	0.01	−0.26	0.27	3.5	
182	33.91	0.14	−61.40	0.04	0.42	0.78	4.9	
183	33.71	0.01	−10.76	0.02	−0.81	0.11	4.4	Daguerre B
184	33.68	0.02	10.34	0.02	0.56	0.26	3.0	
185	33.61	0.05	−45.41	0.03	−0.22	0.43	7.5	
186	33.36	0.02	− 8.89	0.01	−0.17	0.34	6.1	Isidorus K
187	33.26	0.03	29.97	0.02	0.60	0.37	4.2	
188	33.25	0.07	75.44	0.02	−0.17	0.15	5.1	
189	33.22	0.05	42.66	0.01	−1.17	0.41	5.1	
190	33.21	0.03	44.91	0.02	−1.21	0.25	4.7	
191	33.07	0.03	3.53	0.01	0.76	0.45	3.0	Maskelyne Ja
192	33.06	0.02	6.85	0.01	0.49	0.14	3.3	Sinas K
193	32.77	0.03	4.17	0.01	1.21	0.53	3.5	Maskelyne N
194	32.34	0.06	−35.68	0.02	2.34	0.96	5.9	Stiborius F
195	32.22	0.03	18.46	0.01	−0.90	0.38	3.4	
196	32.10	0.06	50.70	0.03	−2.03	0.53	5.5	
197	32.04	0.05	57.85	0.02	−1.42	0.31	5.2	
198	31.95	0.08	59.41	0.04	−1.83	0.48	4.1	
199	31.76	0.03	67.44	0.01	−1.50	0.13	7.9	
200	31.52	0.03	16.14	0.01	0.01	0.56	3.5	Vitruvius M
201	31.30	0.02	−32.21	0.02	2.64	0.36	4.5	
202	31.22	0.02	24.25	0.01	−0.14	0.29	3.2	
203	31.11	0.06	−58.98	0.01	−1.25	0.37	5.5	
204	30.91	0.02	− 6.51	0.01	−0.94	0.61	3.3	
205	30.64	0.04	51.47	0.03	−2.17	0.43	4.2	
206	30.62	0.05	−51.99	0.04	−0.56	0.36	4.2	Hommel Ha
207	30.60	0.01	−41.36	0.01	0.65	0.10	4.5	Riccius R
208	30.39	0.05	−59.81	0.01	−0.53	0.39	10.4	Hommel Z
209	30.34	0.03	5.36	0.01	0.41	0.56	3.2	Maskelyne N
210	29.73	0.02	39.48	0.01	−1.43	0.12	4.7	
211	29.71	0.03	3.26	0.00	−0.32	0.67	3.6	Maskelyne K
212	29.46	0.16	66.03	0.05	−1.85	0.76	3.5	
213	29.19	0.03	− 2.58	0.01	−1.03	0.41	4.8	Torricelli B
214	29.16	0.03	23.23	0.02	−1.67	0.39	2.4	Le Monnier La
215	29.07	0.06	−35.75	0.03	2.22	0.98	5.5	Riccius Y
216	28.80	0.05	− 2.22	0.01	0.10	1.30	3.5	
217	28.42	0.02	8.11	0.01	0.47	0.27	2.2	
218	28.41	0.02	27.25	0.02	−1.51	0.23	3.4	
219	28.24	0.02	− 4.00	0.00	−0.15	0.56	3.5	
220	28.16	0.01	42.24	0.01	−0.64	0.19	4.5	
221	28.06	0.05	−55.97	0.02	−0.62	0.28	3.0	
222	27.81	0.02	−47.02	0.03	0.45	0.13	5.0	Pitiscus T
223	27.76	0.04	28.35	0.02	−1.21	0.46	3.2	Le Monnier Ka
224	27.71	0.05	50.30	0.02	−0.98	0.54	5.6	
225	27.37	0.04	1.31	0.01	0.06	0.67	3.7	Maskelyne X
226	26.96	0.02	6.49	0.00	−0.31	0.39	4.2	Maskelyne Ma

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Diameter	Name
227	26.86	0.01	52.86	0.01	−1.07	0.04	3.5	
228	26.78	0.03	50.10	0.01	−1.61	0.12	5.0	
229	26.69	0.02	2.34	0.01	−0.53	0.56	3.9	Maskelyne G
230	26.50	0.07	70.08	0.03	0.37	0.27	3.1	
231	26.46	0.02	−19.90	0.02	1.61	0.35	4.0	Beamont J
232	26.45	0.02	−31.58	0.02	1.47	0.44	5.5	Lindenau E
233	25.51	0.03	−41.65	0.02	1.45	0.52	5.6	Nicholai D
234	25.33	0.02	−47.51	0.01	0.17	0.14	5.6	Pitiscus G
235	24.67	0.04	−63.52	0.03	−0.71	0.34	3.0	
236	24.56	0.03	65.37	0.02	−1.17	0.13	5.2	
237	24.27	0.03	−28.77	0.01	3.18	0.66	4.0	Rothmann K
238	23.95	0.03	−10.18	0.01	0.21	0.89	2.9	
239	23.10	0.02	−37.48	0.02	1.36	0.26	4.5	
240	23.03	0.03	33.64	0.02	−1.53	0.50	3.7	
241	22.75	0.02	3.11	0.01	−0.07	0.72	3.0	Arago Ca
242	22.71	0.02	8.54	0.01	−0.75	0.26	4.0	Arago E
243	22.67	0.03	−63.42	0.02	−0.07	0.25	6.3	Manzinus M
244	22.56	0.02	19.67	0.02	−1.26	0.37	3.9	
245	22.54	0.04	−33.30	0.02	4.62	0.73	3.9	Zagut S
246	22.40	0.03	6.94	0.01	−0.56	0.25	2.8	Arago D
247	21.84	0.02	47.72	0.01	−2.21	0.14	4.8	Mitchell E
248	21.56	0.02	−48.24	0.01	−0.44	0.23	3.0	
249	21.06	0.02	29.70	0.02	−1.26	0.44	4.1	Posidonius N
250	21.04	0.01	−11.10	0.01	0.67	0.08	3.4	Kant X
251	21.00	0.02	−52.59	0.02	−1.10	0.37	5.3	
252	20.83	0.03	35.57	0.02	−1.22	0.51	4.6	
253	20.79	0.02	−19.67	0.01	3.51	0.22	4.0	
254	20.46	0.03	−38.28	0.02	−0.07	0.62	4.6	Busching A
255	20.14	0.03	31.64	0.02	−1.43	0.57	3.2	Posidonius W
256	19.75	0.04	62.10	0.02	−1.61	0.16	6.5	
257	19.72	0.01	30.54	0.01	−1.26	0.19	3.1	Posidonius E
258	19.21	0.03	40.03	0.02	−0.03	0.37	4.3	
259	19.14	0.10	67.00	0.05	0.45	0.61	4.7	
260	19.08	0.03	60.01	0.02	−2.26	0.25	5.3	
261	19.07	0.02	−60.91	0.03	−1.28	0.18	4.1	
262	18.91	0.02	11.63	0.01	0.51	0.25	3.7	Ross C
263	18.73	0.02	3.71	0.01	0.47	0.54	3.3	Ritter D
264	18.72	0.05	−59.17	0.02	−0.21	0.47	4.0	Kinau L
265	18.71	0.03	55.94	0.02	−2.61	0.36	3.2	
266	18.60	0.03	−14.39	0.02	3.72	0.73	3.4	
267	18.59	0.04	−43.73	0.02	−0.82	0.80	4.6	
268	18.57	0.03	−51.06	0.01	−2.60	0.32	3.4	
269	18.22	0.05	−43.21	0.03	1.34	1.20	3.3	
270	18.01	0.01	11.35	0.01	0.42	0.17	4.0	Maclear A
271	17.76	0.02	53.77	0.03	−0.83	0.43	7.9	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
272	17.58	0.03	27.25	0.02	−1.11	0.73	5.1	Linné Ed
273	17.41	0.01	35.94	0.01	−1.34	0.02	4.0	
274	17.39	0.02	45.65	0.02	−0.58	0.43	4.4	Eudoxus B
275	17.38	0.02	−20.90	0.02	3.65	0.49	3.2	Sacrabosco P
276	17.32	0.04	−43.51	0.04	1.74	0.92	3.3	
277	17.26	0.02	−24.31	0.02	0.95	0.59	3.8	Sacrabosco W
278	17.14	0.02	28.71	0.01	−1.22	0.39	4.2	Linné D
279	16.93	0.03	−37.83	0.02	2.12	0.52	4.3	Buch B
280	16.84	0.01	−43.15	0.02	0.05	0.51	3.3	Barocius C
281	16.44	0.02	26.57	0.01	−0.97	0.52	4.3	Linné E
282	16.42	0.03	55.01	0.02	−2.07	0.45	7.4	
283	16.31	0.04	42.31	0.03	0.61	0.99	3.8	
284	16.16	0.14	71.46	0.07	−0.27	0.61	3.0	
285	16.04	0.03	−44.56	0.02	−1.50	0.78	3.4	
286	15.50	0.02	− 8.78	0.01	2.13	0.98	2.7	
287	15.39	0.01	− 0.18	0.01	1.07	0.83	3.2	Theon Senior A
288	15.38	0.02	− 9.10	0.01	1.94	1.16	2.9	Dollond T
289	15.35	0.01	7.36	0.01	0.58	0.19	3.4	Julius Caesar B
290	14.74	0.01	21.14	0.01	−1.51	0.24	4.0	Bessel G
291	14.42	0.01	28.96	0.02	−1.17	0.59	3.2	Linné A
292	14.27	0.02	−58.89	0.00	0.46	0.22	4.5	
293	14.11	0.02	0.21	0.01	1.57	0.48	4.4	Theon Senior B
294	14.07	0.06	−54.42	0.02	−1.06	0.73	6.7	
295	14.03	0.03	−55.68	0.03	−0.57	0.44	4.0	
296	13.86	0.01	21.26	0.01	−1.16	0.28	5.2	Bessel F
297	13.02	0.02	− 4.41	0.01	1.42	0.76	3.3	
298	13.01	0.02	50.16	0.03	−1.63	0.43	4.3	
299	12.67	0.01	9.47	0.01	1.40	0.12	3.7	Boscovich A
300	12.47	0.01	− 2.34	0.01	1.55	0.73	1.9	
301	12.36	0.01	19.06	0.01	−0.56	0.19	3.1	
302	12.24	0.01	−19.05	0.02	2.05	0.54	2.6	Geber D
303	12.22	0.01	−12.80	0.00	2.42	0.60	3.0	Abulfeda Q
304	12.14	0.02	−36.51	0.02	1.06	0.71	3.3	
305	11.68	0.01	−40.33	0.01	1.06	0.19	4.3	Maurolycus B
306	11.49	0.02	−30.96	0.02	1.77	0.97	3.4	
307	11.32	0.01	53.90	0.02	−2.08	0.32	4.8	
308	11.16	0.02	8.63	0.01	1.46	0.81	2.2	
309	10.95	0.01	−37.41	0.02	0.41	0.37	5.4	Gemma Frisius K
310	10.82	0.02	−29.02	0.01	2.77	0.09	4.8	Apianus L
311	10.79	0.01	30.42	0.02	−0.56	0.57	2.8	Linné B
312	10.77	0.01	−18.06	0.01	2.11	0.43	3.0	
313	10.74	0.02	16.93	0.02	1.02	0.77	3.4	
314	10.37	0.02	− 3.97	0.01	2.04	0.78	3.4	Saunder T
315	10.03	0.02	−31.83	0.02	2.23	0.82	4.2	
316	9.39	0.01	−17.22	0.01	2.17	0.33	3.6	Airy S
317	9.37	0.03	62.90	0.03	−1.96	0.48	5.6	Archytas U

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
318	9.14	0.02	61.55	0.03	−0.54	0.40	4.5	
319	8.91	0.01	−21.73	0.01	1.89	0.42	5.2	Playfair E
320	8.65	0.01	17.81	0.01	0.59	0.12	2.8	Manilius H
321	8.11	0.02	− 3.12	0.01	1.95	1.34	2.6	
322	7.84	0.01	9.10	0.01	1.86	0.17	3.3	
323	7.81	0.01	0.51	0.01	2.52	0.31	3.1	
324	7.78	0.01	21.80	0.01	1.57	0.24	3.5	
325	7.39	0.01	37.25	0.02	0.81	0.53	3.4	
326	7.03	0.01	28.58	0.00	−0.22	0.21	4.5	
327	7.01	0.01	13.26	0.01	0.64	0.67	5.5	Manilius D
328	6.85	0.02	60.08	0.02	−1.06	0.28	4.9	
329	6.42	0.01	52.36	0.01	−1.14	0.32	3.6	
330	6.39	0.02	−14.64	0.01	2.32	0.97	3.8	
331	6.37	0.02	58.61	0.02	−0.67	0.41	5.4	
332	6.34	0.01	19.77	0.02	0.79	0.24	4.3	Sulpicus Gallus G
333	6.12	0.03	−52.62	0.06	0.03	1.28	5.2	
334	5.97	0.01	3.50	0.01	1.59	0.09	4.5	Triesnecker D
335	5.74	0.01	56.42	0.02	−1.97	0.45	4.4	Protagoras B
336	5.70	0.01	−18.02	0.01	1.86	0.97	4.6	Airy (Cent Mt)
337	5.49	0.03	62.43	0.03	−0.97	0.38	4.9	
338	5.28	0.01	61.30	0.03	−1.96	0.32	4.5	Archytas W
339	5.28	0.01	44.34	0.02	−0.25	0.58	5.0	
340	5.10	0.01	7.62	0.01	0.90	0.71	3.9	Hyginus B
341	5.04	0.01	−24.76	0.02	0.02	0.32	6.2	Blanchinus K
342	4.71	0.02	−57.32	0.03	−0.67	0.74	4.5	
343	4.57	0.02	−21.65	0.01	3.82	0.39	3.8	
344	4.42	0.02	43.97	0.02	−1.06	0.69	4.2	Cassini L
345	4.36	0.01	11.42	0.02	0.91	1.01	3.0	Hyginus D
346	4.04	0.02	−19.79	0.01	2.10	0.66	2.3	
347	4.02	0.00	16.48	0.11	0.90	0.24	3.6	
348	4.01	0.05	−59.82	0.13	0.86	2.35	5.1	
349	3.96	0.02	40.05	0.02	−2.30	0.62	4.6	Cassini B
350	3.81	0.01	41.32	0.01	−1.71	0.25	6.5	Cassini M
351	3.46	0.01	24.04	0.01	2.47	0.21	5.0	
352	3.32	0.02	14.09	0.01	0.46	0.39	3.8	
353	3.16	0.01	−21.14	0.02	1.31	0.64	3.4	Faye A
354	3.11	0.01	48.75	0.02	−2.31	0.26	5.7	
355	2.84	0.01	−26.31	0.02	2.39	0.27	4.2	
356	2.35	0.01	71.61	0.03	0.90	0.29	2.5	
357	1.51	0.01	−52.63	0.02	−0.61	0.53	6.7	
358	1.51	0.01	1.24	0.01	0.92	0.82	4.0	Blagg
359	1.08	0.02	−47.18	0.02	0.41	0.45	4.7	Licetus L
360	0.82	0.02	−24.72	0.02	3.73	0.21	5.3	La Caille H
361	0.71	0.01	− 9.34	0.01	1.84	1.06	3.6	Ptolemaeus Y
362	0.41	0.01	14.04	0.01	1.62	0.24	2.1	
363	0.35	0.01	−41.01	0.01	−1.03	0.13	5.4	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Diameter	Name
364	0.01	0.01	52.25	0.03	−0.81	0.73	6.4	Alpes Ab
365	−0.05	0.01	54.57	0.04	−1.78	0.72	7.2	
366	−0.14	0.02	39.33	0.01	−1.53	0.34	3.9	Piton B
367	−0.21	0.01	7.84	0.02	2.36	0.95	2.4	
368	−0.33	0.01	27.81	0.01	−0.54	0.71	5.1	
369	−0.62	0.01	−2.85	0.02	1.91	1.16	4.7	Reaumur X
370	−0.76	0.02	−52.94	0.02	1.41	0.55	3.4	
371	−0.79	0.01	−12.75	0.01	3.64	0.45	3.5	
372	−1.12	0.02	−4.57	0.02	2.34	1.14	2.5	
373	−1.14	0.01	−56.01	0.03	0.06	0.21	2.9	
374	−1.22	0.01	−17.14	0.02	0.14	0.72	3.0	
375	−1.64	0.01	−20.32	0.01	2.78	0.37	3.1	
376	−1.81	0.01	42.47	0.01	−1.18	0.26	4.8	
377	−2.17	0.02	32.76	0.02	−0.04	0.87	4.5	
378	−2.56	0.01	25.02	0.02	0.25	0.59	4.0	Archimedes L
379	−2.64	0.01	32.18	0.01	−0.64	0.36	3.8	Archimedes D
380	−2.85	0.01	−46.32	0.02	1.25	0.21	3.1	
381	−2.96	0.02	54.64	0.02	−0.56	0.25	5.6	
382	−3.36	0.01	40.50	0.01	−1.35	0.43	4.9	Piazzi Smyth B
383	−3.47	0.00	10.21	0.01	1.92	0.56	2.8	
384	−3.52	0.01	6.35	0.01	1.68	0.42	3.8	Bode G
385	−3.91	0.02	13.02	0.02	1.70	0.26	4.0	
386	−4.14	0.02	13.50	0.01	2.25	0.34	3.1	
387	−4.50	0.01	22.82	0.01	0.41	0.87	2.1	
388	−4.51	0.01	−4.01	0.01	1.82	0.48	4.3	Flammarion B
389	−4.81	0.01	−1.28	0.00	2.37	0.41	3.9	
390	−5.14	0.01	10.04	0.01	1.79	0.36	3.3	
391	−5.51	0.02	−52.07	0 04	0.26	0.71	5.1	
392	−5.60	0.02	22.90	0.02	0.26	1.11	3.3	
393	−6.01	0.02	−24.43	0.01	1.08	0.56	3.2	
394	−6.04	0.02	−17.94	0.02	0.93	0.55	3.6	Alpetragius H
395	−6.12	0.01	−13.68	0.02	0.99	0.78	4.1	Alpetragius C
396	−6.20	0.01	−28.17	0.01	1.24	0.33	4.1	Regiomontanus E
397	−6.21	0.03	−52.84	0.03	2.61	0.34	3.6	
398	−6.21	0.02	52.16	0.04	−0.72	0.43	5.4	Plato G
399	−6.28	0.02	−36.76	0.02	0.91	1.14	3.4	
400	−6.29	0.01	15.24	0.01	0.71	0.21	3.3	
401	−6.65	0.02	47.24	0.03	−2.24	0.64	5.5	Pico C
402	−6.90	0.02	36.48	0.01	−1.12	0.34	4.9	Kirch E
403	−7.02	0.02	−52.25	0.02	0.68	0.34	3.8	Maginus T
404	−7.33	0.01	3.60	0.01	2.27	0.82	2.5	Schröter Kb
405	−7.34	0.02	−2.69	0.01	0.73	0.98	4.4	Mösting B
406	−7.38	0.01	49.57	0.03	−1.74	0.78	3.4	Plato U
407	−7.55	0.02	44.67	0.02	−2.11	0.59	3.6	Pico K
408	−7.78	0.02	−54.03	0.01	1.21	0.29	5.4	
409	−7.97	0.01	31.03	0.01	−0.83	0.12	5.3	Archimedes X

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
410	− 8.06	0.04	67.05	0.04	−0.81	0.44	3.7	Epigenes F
411	− 8.12	0.02	58.37	0.00	−2.08	0.15	5.4	
412	− 8.64	0.01	5.63	0.02	1.45	0.51	2.5	
413	− 9.00	0.00	56.92	0.01	−2.18	0.12	5.1	Plato Va
414	− 9.41	0.02	−10.12	0.01	1.58	0.52	3.2	Davy K
415	− 9.92	0.02	39.56	0.02	−1.24	0.41	3.8	Kirch M
416	−10.10	0.01	−26.61	0.01	0.36	0.20	4.6	Lippershey R
417	−10.53	0.02	3.22	0.01	0.61	0.71	3.1	Gambart C
418	−10.64	0.01	−50.28	0.02	0.73	0.43	4.8	
419	−10.83	0.02	−24.21	0.01	0.06	0.48	3.8	Lippershey M
420	−11.18	0.03	−39.47	0.02	0.75	0.59	3.7	Sasserides B
421	−11.20	0.01	−14.47	0.02	0.18	0.79	3.8	Lassell H
422	−11.27	0.04	54.58	0.03	−2.06	0.55	3.7	Plato T
423	−11.62	0.01	6.95	0.01	0.35	0.54	3.4	Schröter M
424	−11.68	0.03	46.86	0.03	−0.62	0.49	6.4	
425	−11.94	0.02	− 7.37	0.01	1.77	0.85	2.9	Parry τ
426	−11.96	0.02	29.84	0.02	−0.21	0.31	3.9	
427	−12.15	0.03	−47.05	0.04	1.79	0.58	3.7	
428	−12.21	0.03	60.81	0.02	−1.43	0.32	5.8	
429	−12.74	0.03	−46.21	0.03	1.45	0.88	4.5	
430	−12.85	0.02	40.18	0.02	−1.74	0.56	4.0	Le Verrier B
431	−12.98	0.02	− 8.90	0.01	0.52	0.41	3.4	Parry B
432	−13.49	0.02	−26.44	0.02	0.38	0.28	4.2	Pitatus J
433	−13.94	0.02	39.38	0.02	−1.86	0.34	4.4	Le Verrier W
434	−14.15	0.02	24.74	0.02	−0.34	0.68	3.2	Timocharis C
435	−14.15	0.03	46.85	0.02	−1.82	0.71	2.9	Pico Ba
436	−14.34	0.02	14.74	0.01	2.17	0.37	3.0	
437	−14.35	0.02	−29.02	0.02	0.83	0.54	5.2	
438	−14.63	0.03	−15.01	0.02	0.14	0.62	2.7	Guericke P
439	−14.84	0.02	− 0.51	0.00	1.50	0.29	3.0	Gambart N
440	−14.96	0.02	−50.42	0.01	1.51	0.39	4.8	
441	−15.24	0.02	2.24	0.01	1.66	0.40	3.5	
442	−15.31	0.03	−53.16	0.01	0.70	0.37	2.9	Clavius R
443	−15.84	0.02	−45.22	0.02	0.54	0.50	3.5	Tycho H
444	−15.92	0.02	4.61	0.01	1.45	0.58	3.3	
445	−16.11	0.02	− 2.56	0.01	1.31	0.41	3.3	
446	−16.41	0.01	−36.12	0.02	2.82	0.27	3.5	
447	−16.48	0.02	35.76	0.02	−1.57	0.38	3.5	
448	−16.96	0.02	−19.18	0.02	0.31	0.52	3.1	Gould A
449	−17.00	0.01	−13.57	0.01	0.88	0.19	3.9	Opelt K
450	−17.07	0.03	27.26	0.02	0.19	1.05	3.8	
451	−17.29	0.02	38.21	0.01	−1.31	0.36	5.8	Le Verrier A
452	−17.34	0.02	−16.42	0.03	1.22	0.51	3.2	
453	−18.21	0.03	6.92	0.02	1.18	0.56	2.6	Copernicus H
454	−18.42	0.02	−22.21	0.02	0.08	0.45	4.0	Wolf A

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Diameter	Name
455	−18.48	0.01	−37.42	0.01	1.14	0.23	5.1	Heinsius H
456	−18.49	0.01	−24.86	0.02	−0.42	0.42	3.6	Keiss D
457	−18.57	0.04	− 2.61	0.01	0.34	0.84	3.3	Fra Mauro J
458	−18.66	0.03	60.27	0.01	−2.61	0.05	7.4	
459	−18.81	0.02	27.41	0.02	−0.33	0.71	3.3	
460	−19.08	0.02	−18.50	0.03	0.44	0.56	4.4	Bullialdus Y
461	−19.56	0.02	14.01	0.02	1.03	0.56	4.0	Gay Lussac F
462	−19.92	0.01	− 0.51	0.01	0.96	0.22	2.7	Gambart τ
463	−20.08	0.04	44.21	0.02	−1.61	0.56	2.1	La Place Fa
464	−20.21	0.02	2.54	0.03	1.02	0.17	3.1	Gambart Ac
465	−20.33	0.01	−37.35	0.04	1.74	0.50	3.5	
466	−20.63	0.03	38.91	0.02	−1.16	0.21	3.2	Le Verrier S
467	−20.80	0.02	36.54	0.02	−1.45	0.26	4.0	Helicon BA
468	−20.80	0.05	−53.36	0.04	2.21	0.76	4.6	
469	−20.85	0.02	16.23	0.01	0.08	0.53	3.8	Gay Lussac B
470	−21.12	0.00	16.24	0.02	0.42	0.04	2.4	
471	−21.13	0.03	54.35	0.01	−1.76	0.28	3.1	
472	−21.45	0.02	−10.90	0.01	0.84	0.46	2.8	Bonpland P
473	−21.46	0.02	17.06	0.02	−0.55	0.37	5.1	Draper C
474	−21.61	0.02	−21.72	0.02	1.51	0.56	3.8	
475	−21.68	0.02	20.46	0.01	0.07	0.29	3.0	Pytheas A
476	−21.69	0.05	−49.78	0.03	−1.38	0.91	6.5	
477	−22.85	0.02	35.07	0.02	−1.21	0.15	3.4	Carlini C
478	−23.29	0.04	−47.19	0.03	2.02	0.75	3.6	
479	−23.30	0.03	61.86	0.02	−2.46	0.29	6.8	Fontenelle B
480	−23.31	0.04	−60.40	0.03	0.84	0.38	3.9	
481	−23.40	0.03	28.51	0.02	−0.55	0.50	4.0	La Hire A
482	−23.63	0.03	21.74	0.02	0.02	0.68	3.3	Pytheas W
483	−23.65	0.02	31.06	0.02	−0.66	0.37	3.3	Carlini K
484	−23.71	0.02	−37.59	0.02	1.74	0.15	3.4	
485	−23.90	0.01	−21.65	0.01	0.75	0.21	3.6	Bullialdus E
486	−24.13	0.04	40.44	0.03	−1.77	0.41	3.8	Helicon E
487	−24.76	0.04	31.31	0.02	−1.02	0.65	3.0	Carlini L
488	−25.34	0.02	−12.38	0.01	0.52	0.58	4.8	Darney E
489	−25.71	0.03	− 9.35	0.01	0.67	0.57	4.2	Euclides D
490	−25.71	0.03	−41.65	0.02	0.51	0.41	3.6	
491	−25.74	0.04	−48.31	0.01	1.85	0.56	5.6	
492	−25.75	0.03	55.18	0.03	−2.38	0.31	6.1	La Condamine O
493	−26.21	0.04	−52.35	0.01	−0.32	0.35	4.5	Longomontanus R
494	−26.35	0.02	− 1.88	0.01	0.51	0.47	3.4	Lansberg N
495	−26.35	0.03	−13.26	0.02	0.21	1.08	2.0	Darney F
496	−26.63	0.02	26.57	0.02	0.15	0.27	3.2	
497	−26.64	0.05	5.93	0.02	0.31	1.12	3.3	Hortensius C
498	−26.66	0.02	−48.68	0.01	0.45	0.26	5.5	
499	−26.96	0.03	−23.57	0.01	1.03	0.64	4.2	Agatharchides ϕ
500	−27.06	0.02	8.24	0.02	2.07	0.35	3.5	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
501	−27.56	0.17	64.57	0.06	−2.61	0.85	5.6	Fontenelle C
502	−27.74	0.08	−27.93	0.02	−0.63	0.78	3.9	
503	−27.86	0.09	60.52	0.05	−1.56	0.54	3.9	Fontenelle X
504	−28.14	0.04	54.11	0.02	−1.17	0.28	5.0	
505	−28.42	0.02	27.14	0.02	0.73	0.26	2.5	
506	−28.46	0.03	25.31	0.01	0.06	0.20	3.5	Euler H
507	−28.52	0.14	64.46	0.06	−2.67	0.69	5.6	Fontenelle C
508	−28.70	0.02	−41.57	0.01	1.06	0.32	4.8	
509	−28.71	0.05	43.56	0.02	−1.71	0.50	4.0	
510	−28.79	0.01	10.07	0.01	1.94	0.17	3.7	Milichius BA
511	−28.86	0.06	21.38	0.02	0.73	1.08	3.5	Euler L
512	−29.14	0.04	18.47	0.02	1.36	0.66	3.9	
513	−29.25	0.10	63.21	0.04	−3.61	0.49	4.8	Fontenelle M
514	−29.34	0.01	51.33	0.02	−2.27	0.08	6.8	Maupertuis L
515	−29.61	0.02	−10.51	0.01	0.36	0.39	2.9	
516	−29.63	0.01	−36.87	0.02	2.16	0.22	3.8	
517	−30.15	0.05	−20.81	0.02	1.02	0.96	3.9	
518	−30.56	0.03	−30.97	0.02	1.16	0.45	4.4	
519	−30.77	0.02	39.26	0.01	−1.73	0.31	2.9	
520	−30.77	0.03	19.62	0.02	1.29	0.44	3.5	
521	−30.78	0.04	−27.30	0.02	1.39	0.66	3.9	
522	−30.91	0.07	−25.91	0.03	0.66	0.75	3.8	
523	−31.02	0.08	62.56	0.02	−3.02	0.37	6.7	J Herschel R
524	−31.82	0.04	−52.76	0.01	0.26	0.29	7.3	
525	−32.08	0.07	66.63	0.03	−3.16	0.26	4.3	
526	−32.11	0.02	5.71	0.01	0.61	0.31	3.8	Hortensius D
527	−32.17	0.02	− 0.58	0.02	1.43	0.34	4.0	Kunowsky CA
528	−32.28	0.06	− 0.21	0.01	0.85	0.38	3.8	Kunowsky C
529	−32.37	0.05	−15.23	0.01	0.26	0.72	4.2	Herigonius EB
530	−32.86	0.06	−45.31	0.02	0.98	0.57	6.6	Hainzel D
531	−33.13	0.02	4.98	0.01	−0.16	0.28	4.1	Kunowsky
532	−33.14	0.05	−17.05	0.02	−0.31	0.64	3.2	Herigonius Ee
533	−33.22	0.04	60.12	0.01	−2.08	0.18	5.0	J Herschel N
534	−33.23	0.08	63.65	0.03	−2.46	0.27	2.1	J Herschel P
535	−33.46	0.05	36.41	0.02	−1.18	0.54	3.4	C Herschel V
536	−33.65	0.04	− 6.34	0.02	−0.60	0.42	3.4	Euclides F
537	−33.96	0.06	21.11	0.03	0.07	0.77	4.1	Brayley F
538	−34.02	0.10	−50.03	0.03	1.15	0.76	9.5	
539	−34.70	0.04	55.96	0.02	−2.46	0.12	6.3	
540	−34.71	0.02	34.22	0.01	−2.26	0.14	4.7	C Herschel E
541	−34.86	0.04	15.08	0.02	0.31	0.57	2.9	Bessarion V
542	−35.10	0.03	− 4.91	0.01	−0.16	0.36	3.3	Euclides JF
543	−35.48	0.14	−54.71	0.06	1.32	0.92	9.6	
544	−35.62	0.05	−43.56	0.02	−1.21	0.53	3.8	
545	−35.66	0.02	3.23	0.01	0.38	0.16	4.1	
546	−35.73	0.02	4.63	0.01	0.36	0.20	4.3	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
547	−35.77	0.03	1.74	0.01	0.61	0.46	4.3	
548	−35.86	0.01	−20.66	0.01	−0.16	0.05	3.2	
549	−35.85	0.04	−32.07	0.01	1.92	0.35	3.5	
550	−36.20	0.04	−17.94	0.02	−0.27	0.64	3.1	
551	−36.67	0.03	−24.21	0.02	−0.61	0.39	2.7	
552	−36.68	0.04	− 2.68	0.02	−0.18	0.68	3.6	Wichmann CA
553	−36.84	0.03	− 7.34	0.01	0.06	0.40	3.2	Wichmann A
554	−37.32	0.02	− 4.66	0.01	0.06	0.46	4.1	Wichmann C
555	−37.51	0.03	−13.75	0.00	0.61	0.37	3.7	
556	−37.54	0.04	−22.66	0.00	0.15	0.34	4.3	
557	−37.86	0.07	30.83	0.03	−0.06	0.92	4.9	
558	−38.06	0.04	46.97	0.01	−0.56	0.36	3.6	
559	−38.21	0.08	52.26	0.03	−2.48	0.45	4.0	
560	−38.34	0.03	−10.64	0.01	0.19	0.12	4.2	Letronne A α
561	−38.36	0.02	32.88	0.00	−0.88	0.28	2.8	
562	−38.48	0.06	60.46	0.02	−2.83	0.36	5.3	J Herschel D
563	−39.04	0.04	−43.62	0.00	0.28	0.14	3.5	
564	−39.52	0.03	5.24	0.01	0.36	0.32	3.2	Encke J
565	−39.70	0.02	−26.45	0.01	−0.71	0.27	4.2	
566	−39.71	0.02	21.27	0.01	−0.37	0.16	5.0	Brayley E
567	−39.93	0.02	4.44	0.02	0.13	0.42	2.4	
568	−40.02	0.04	39.27	0.01	−0.76	0.34	5.4	Mairan B
569	−40.30	0.02	26.62	0.01	0.40	0.17	2.9	
570	−40.48	0.04	−23.57	0.00	−0.02	0.36	6.0	Doppelmayer L
571	−41.01	0.06	−32.91	0.01	0.50	0.44	6.0	
572	−41.10	0.02	40.86	0.02	−1.14	0.27	5.3	
573	−41.12	0.05	30.91	0.01	−1.05	0.56	3.6	Angström A
574	−41.21	0.09	−48.12	0.02	−0.61	0.76	3.4	
575	−41.68	0.02	−20.36	0.01	−0.95	0.28	4.1	Gassendi L
576	−42.06	0.03	2.02	0.02	0.46	0.62	3.9	Maestlin G
577	−42.45	0.05	7.16	0.01	−0.04	0.49	4.6	
578	−42.54	0.04	10.58	0.01	−0.02	0.72	4.5	
579	−42.56	0.05	2.092	0.02	−0.42	0.65	3.9	Brayley L
580	−43.35	0.05	−46.93	0.02	0.62	0.37	4.8	
581	−43.41	0.06	35.60	0.02	−1.10	0.42	3.1	
582	−43.50	0.05	14.59	0.01	0.04	0.56	3.3	
583	−43.62	0.03	− 3.09	0.00	−0.55	0.49	3.2	Flamsteed K
584	−43.91	0.14	56.24	0.03	−2.03	0.67	5.1	
585	−43.99	0.03	19.56	0.01	0.22	0.43	3.6	
586	−44.14	0.06	31.76	0.01	−1.32	0.65	4.5	Angström B
587	−44.25	0.07	−37.91	0.01	1.42	0.64	4.2	
588	−45.24	0.04	12.16	0.02	−0.48	0.43	4.2	
589	−45.39	0.06	10.54	0.01	0.05	0.74	2.9	
590	−45.58	0.02	0.23	0.00	−0.15	0.19	4.1	Suess FB
591	−45.67	0.06	39.14	0.02	−2.06	0.55	3.2	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
592	−45.86	0.04	− 6.86	0.01	−0.35	0.26	3.2	Flamsteed CD
593	−45.86	0.02	−15.23	0.01	−0.24	0.28	4.5	Gassendi F α
594	−46.01	0.06	−30.76	0.01	2.06	0.57	3.2	
595	−46.01	0.04	− 3.68	0.00	−0.87	0.56	2.6	Flamsteed E
596	−46.24	0.05	15.14	0.01	−0.96	0.39	4.3	
597	−46.26	0.02	11.71	0.00	−0.31	0.12	4.3	
598	−46.27	0.05	19.28	0.01	−1.40	0.45	3.5	Aristarchus T
599	−46.65	0.04	−39.46	0.01	0.78	0.34	3.7	
600	−46.66	0.04	−43.99	0.02	−0.60	0.28	3.6	
601	−46.81	0.07	10.46	0.01	−0.37	0.76	4.2	
602	−47.75	0.02	−26.82	0.01	0.24	0.18	4.0	
603	−48.06	0.09	53.45	0.02	−1.28	0.46	5.1	Harpalus Y
604	−48.78	0.06	33.16	0.01	−1.69	0.43	1.8	
605	−48.94	0.14	60.97	0.03	−1.04	0.46	3.9	
606	−49.17	0.02	−25.62	0.01	0.65	0.16	3.1	
607	−49.26	0.04	− 5.01	0.01	−0.32	0.47	3.6	Flamsteed GD
608	−49.52	0.05	−51.14	0.00	−1.36	0.28	2.3	
609	−49.65	0.04	9.41	0.01	−0.69	0.57	3.4	
610	−49.81	0.04	25.35	0.02	−0.13	0.28	3.0	
611	−49.86	0.07	29.26	0.02	−0.61	0.57	2.2	Aristarchus P
612	−50.41	0.06	−33.03	0.01	1.45	0.42	5.3	
613	−50.46	0.02	6.09	0.00	−0.52	0.07	3.7	Suess L
614	−50.61	0.02	−19.64	0.01	0.48	0.09	3.6	
615	−50.72	0.06	2.28	0.01	−0.66	0.61	2.3	Reiner S
616	−50.77	0.12	46.05	0.02	−2.71	0.66	2.1	
617	−50.98	0.04	40.91	0.02	−2.83	0.27	5.0	Mairan G
618	−51.26	0.08	17.86	0.01	−0.70	0.81	4.7	Marius P
619	−51.62	0.05	−20.93	0.02	0.36	0.38	4.3	Mersenius B
620	−51.96	0.02	0.21	0.00	−0.96	0.21	4.5	Hermann E
621	−52.08	0.03	−32.84	0.01	1.90	0.16	3.4	
622	−52.21	0.06	− 5.58	0.00	−1.04	0.61	3.4	Flamsteed H α
623	−52.51	0.02	−27.01	0.02	−0.03	0.02	4.6	De Gasparis B
624	−52.88	0.09	−44.46	0.01	−0.83	0.52	3.0	
625	−53.22	0.03	−33.89	0.00	0.75	0.25	4.2	
626	−53.44	0.02	−17.18	0.00	−0.01	0.18	4.3	Zupus A
627	−53.48	0.04	−21.68	0.02	0.65	0.28	6.7	Cavendish L
628	−53.70	0.08	53.82	0.01	−2.97	0.31	4.7	Harpalus H
629	−53.92	0.04	30.89	0.01	−1.36	0.22	3.8	Wollaston V
630	−53.97	0.06	17.28	0.01	−1.33	0.42	2.8	
631	−54.16	0.02	−42.45	0.00	−1.49	0.12	7.8	
632	−55.02	0.06	21.93	0.01	−1.86	0.77	3.9	Herodotus C
633	−55.25	0.04	−16.11	0.00	0.08	0.39	4.0	
634	−55.32	0.07	46.78	0.02	−2.25	0.36	2.3	
635	−55.48	0.08	−42.07	0.01	−1.54	0.35	7.9	
636	−55.68	0.03	− 2.49	0.00	−1.20	0.21	4.7	Damoiseau G
637	−55.85	0.04	− 5.10	0.00	−1.38	0.40	3.5	Damoiseau G α

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Dia-meter	Name
638	−56.06	0.03	−31.85	0.00	−0.13	0.13	7.5	
639	−56.20	0.05	16.53	0.02	−1.24	0.55	3.8	Marius LA
640	−56.64	0.11	30.69	0.02	−2.06	0.82	4.2	Lichtenberg G
641	−56.85	0.09	13.29	0.00	1.11	0.69	3.0	Galilei M
642	−57.07	0.04	−24.47	0.01	0.36	0.21	5.0	Paul Henry A
643	−57.12	0.02	− 0.32	0.01	−0.84	0.12	3.1	Hermann B
644	−57.13	0.08	19.18	0.01	−1.67	0.77	5.4	
645	−57.30	0.04	38.67	0.02	−2.89	0.11	5.1	Rümker E
646	−57.34	0.04	−13.19	0.00	−0.41	0.42	3.8	
647	−57.40	0.05	37.27	0.02	−2.52	0.32	4.3	
648	−57.41	0.02	−10.35	0.00	−1.31	0.11	4.9	Siralis K
649	−57.42	0.01	2.64	0.01	−0.94	0.04	2.1	Hermann J
650	−57.51	0.02	5.38	0.00	−1.28	0.20	2.7	Reiner N
651	−57.73	0.03	−18.06	0.01	0.04	0.19	3.8	
652	−57.85	0.08	24.67	0.02	−1.60	0.47	3.6	
653	−57.90	0.06	− 3.19	0.00	−1.42	0.43	3.3	Damoiseau Gb
654	−58.16	0.04	−18.48	0.01	1.02	0.36	4.7	
655	−58.17	0.02	0.42	0.00	−1.12	0.08	5.3	Hermann A
656	−58.40	0.04	−17.21	0.01	−1.02	0.28	3.4	Fontana W
657	−58.62	0.04	−25.68	0.00	2.91	0.17	6.3	Paul Henry P
658	−58.64	0.14	53.63	0.02	−1.83	0.46	3.6	
659	−58.86	0.07	26.65	0.02	−2.23	0.51	4.2	Schiaparelli B
660	−60.02	0.01	27.80	0.01	−2.41	0.08	2.8	Schiaparelli D
661	−60.28	0.09	17.10	0.01	−1.18	0.76	3.6	
662	−60.50	0.02	4.25	0.00	−1.51	0.16	4.9	
663	−60.95	0.04	11.08	0.00	−1.24	0.38	3.5	
664	−61.40	0.10	16.16	0.02	−1.31	0.77	4.1	Galilei T
665	−62.01	0.10	13.94	0.01	−2.05	0.75	5.8	Galilei E
666	−62.08	0.01	− 4.01	0.01	−1.02	0.17	4.6	
667	−62.14	0.03	27.12	0.01	−2.24	0.25	3.4	Schiaparelli E
668	−62.24	0.01	22.98	0.00	−2.56	0.14	4.3	Schiaparelli A
669	−62.25	0.02	29.73	0.01	−1.81	0.16	4.9	
670	−62.61	0.03	8.78	0.01	−1.30	0.26	4.5	
671	−63.56	0.03	31.35	0.00	−2.24	0.25	5.1	
672	−64.10	0.03	2.68	0.01	−0.76	0.24	4.1	
673	−64.51	0.05	18.48	0.01	−1.70	0.38	3.8	
674	−64.70	0.06	40.76	0.01	−2.82	0.27	4.3	
675	−64.76	0.07	17.25	0.01	−2.06	0.57	2.7	Krafft U
676	−64.87	0.03	− 0.93	0.01	−1.13	0.22	1.8	
677	−65.40	0.06	8.12	0.00	−1.68	0.42	5.1	Cavalerius F
678	−66.02	0.03	−27.73	0.01	1.17	0.25	3.7	
679	−66.08	0.05	26.37	0.00	−1.75	0.34	3.7	
680	−66.31	0.11	−37.44	0.01	−0.65	0.47	6.1	Piazzi B
681	−66.54	0.13	52.68	0.02	−3.06	0.37	4.2	
682	−66.60	0.08	39.73	0.01	−2.22	0.38	2.9	

Table I (Continued)

No.	Longitude	Δlong.	Latitude	Δlat.	Height over datum	Δh	Diameter	Name
683	−66.63	0.03	9.23	0.00	−1.40	0.18	4.3	Cavalerius X
684	−67.16	0.06	12.68	0.01	−1.24	0.38	4.1	Galilei G
685	−67.85	0.04	−26.03	0.00	−0.56	0.26	5.8	Byrgius D
686	−67.91	0.28	54.86	0.02	−1.63	0.67	7.9	
687	−67.98	0.08	42.88	0.02	−2.92	0.29	3.8	Harding D
688	−68.01	0.01	−10.67	0.01	0.17	0.08	4.5	
689	−68.04	0.04	−17.83	0.00	−1.24	0.20	6.2	Krüger G
690	−68.64	0.10	8.18	0.01	0.38	0.66	4.2	
691	−69.24	0.06	− 1.35	0.01	−0.55	0.36	5.5	Lohrmann Bα
692	−69.68	0.08	4.68	0.01	−0.82	0.39	3.9	
693	−70.52	0.28	54.37	0.02	−2.41	0.57	4.6	
694	−70.75	0.05	−38.80	0.01	−2.38	0.10	3.1	
695	−70.83	0.08	−31.76	0.09	−1.26	0.32	6.5	
696	−71.52	0.04	− 4.85	0.01	−0.81	0.17	4.0	Grimaldi H
697	−71.85	0.05	−17.08	0.01	−1.60	0.14	4.2	Krüger B
698	−71.90	0.04	15.96	0.01	−1.52	0.08	3.7	Krafft E
699	−72.96	0.05	− 9.59	0.01	−0.21	0.22	11.8	Casatus B
700	−75.19	0.08	−12.26	0.01	0.96	0.28	2.0	Wilson F

TABLE II

Distribution of reference points over the lunar surface

Lat. \ Long.	(−75°)–(−50°)	(−50°)–(−25°)	(−25°)–0°	0°–25°	25°–50°	50°–75°
(−75°)–(−50°)		493 524 538 543 608	370 373 391 397 403 408 418 440 442 468 480	235 243 251 261 264 268 292 294 295 333 342 348 357	106 117 149 158 182 203 206 208 221	61 99
(−50°)–(−25°)	612 621 623 624 625 631 635 638 657 678 680 685 694 695	490 491 498 502 508 516 518 521 522 530 544 549 563 565 571 574 580 587 594 599 600 602 606	380 396 399 416 420 427 429 432 437 443 446 455 465 476 478 484	237 239 245 248 254 267 269 276 279 280 285 304 305 306 309 310 315 355 359 363	103 126 128 137 138 142 153 154 157 162 165 173 181 185 194 201 207 215 222 232 233 234	1 8 22 34 45 65 67 70 84 88 90 91 95
(−25°)–0°	614 619 622 626 627 633 636 637 642 643 646 648 651 653 654 656 666 676 688 689 691 696 697 699 700	488 489 494 495 499 515 517 527 528 529 532 536 542 548 550 551 552 553 554 555 556 560 570 575 583 592 593 595 607	369 371 372 374 375 388 389 393 394 395 405 414 419 421 425 431 438 439 445 448 449 452 454 456 457 460 462 472 474 485	238 250 253 266 275 277 286 287 288 297 300 302 303 312 314 316 319 321 330 336 341 343 346 353 360 361	105 108 110 112 116 118 120 121 122 124 131 134 135 147 155 156 163 167 177 178 180 183 186 195 204 213 216 219 231	3 5 12 16 17 26 27 28 30 31 33 35 36 38 44 46 52 53 59 63 68 72 74 78 81 92 93 96 97
0°–25°	613 615 618 620 630 632 639 641 644 649 650 652 655 661 662 663 664 665 668 670 672 673 675 677 683 684 690 692 698	497 500 510 511 512 520 526 531 537 541 545 546 547 564 566 567 576 577 578 579 582 585 588 589 590 596 597 598 601 609	367 383 384 385 386 387 390 392 400 404 412 417 423 434 436 441 444 453 461 464 469 470 473 475 482	241 242 244 246 262 263 270 289 290 293 296 299 301 308 313 320 322 323 324 327 332 334 340 345 347 351 352 358 362	111 113 115 125 127 130 136 140 144 145 159 160 161 168 174 176 184 191 192 193 200 202 209 211 214 217 225 226 229	4 6 7 9 11 14 21 23 37 39 40 41 43 48 51 54 62 64 71 76 77 80 85 87 89 98
25°–50°	616 617 629 634 640 645 647 659 660 667 669 671 674 679 682 687	496 505 506 509 519 535 540 557 558 561 568 569 572 573 581 586 591 604 610 611	366 368 376 377 378 379 382 401 402 406 407 409 415 424 426 430 433 435 447 450 451 459 463 466 467 477 481 483 486 487	240 247 249 252 255 257 258 272 273 274 278 281 283 291 311 325 326 339 344 349 350 354	100 101 102 104 114 119 133 139 143 150 152 164 170 171 172 187 189 190 210 218 220 223	2 10 13 15 18 19 20 25 29 42 47 50 55 56 57 58 60 66 69 73 79 82 83 94
50°–75°	628 658 681 686 693	492 501 503 504 507 513 514 523 525 533 534 539 559 562 584 603 605	365 381 398 410 411 413 422 428 458 471 479	236 256 259 260 265 271 282 284 298 307 317 318 328 329 331 335 337 338 356 364	107 109 123 129 132 141 146 148 151 166 169 175 179 188 196 197 198 199 205 212 224 227 228 230	24 32 49 75 86